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Research Article

Roughness Prediction Modelling for Flexible Pavement in Low Volume Roads in State of Tamil Nadu in India

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Abstract: In this research paper, prediction model is developed for the progression of roughness, which is the most important performance indicator of flexible pavements. Since many stretches of flexible pavements in village roads in India are not exposed to routine maintenance for years together due to the paucity of the funds and models are not available for predicting the performance of the pavements under such conditions, this research is focused to develop prediction model for the roughness of flexible pavements exposed to least or nil routine maintenance. Roughness data were collected from the selected in- service pavements (171 stretches in Tamil Nadu state in India) and model is developed using stepwise regression analysis. The model has been validated with independent field data. The versatile roughness prediction model developed in this study will be useful for practicing engineers in managing the flexible pavements in low volume roads exposed to least or nil routine maintenance.

Keywords: Roughness, Pavement strength, stepwise regression analysis, Low volume roads, Structural number.

INTRODUCTION

Road transportation sector plays a crucial role in accessing the growth of any country. India has very good road connectivity with nearly 3.4 million km length of road networks [1]. Though enormous types of roads are available in India, low volume village road connecting small villages with each other and also with other category of roads plays a vital role towards the economic growth of the country as it has direct linkage with agricultural and production sectors. Presently, the total length of low volume village roads in India is around 26, 50,000 km [2]. All these roads are constructed with flexible pavements with poor pavement composition due to paucity of funds. The Government of India is investing lot of money on constructing such roads every year. Even though huge investment is made for the construction of such roads, maintenance has become a difficult task due to the non availability of scientific maintenance norms. Hence, scientific maintenance procedures are to be evolved on the basis of actual performance of low volume flexible pavements. Even though, many scientific models are available for assessing the performance of flexible pavements, these cannot be applied to village roads having very low traffic volume and poor pavement composition. Several models are available for assessing the performance of flexible pavements, but these are having the following limitations [3-9]

- Many performance models have been developed mainly in Europe and North America for planning, design, construction and maintenance of pavements. Hence these models have some inbuilt limitations and are not necessarily directly transferable for global applications.
- Global models have a number of explanatory variables and the models are complex in nature.
- In India, low volume village roads have very low traffic volume with less than 25 commercial vehicles per day (CVPD) [10-11] and poor pavement composition. Currently available models are not effective for these conditions.

In India, due to paucity of funds, several village roads are not exposed to routine maintenance continuously for about four to six years.

Therefore, an attempt is made in this study to develop roughness prediction model for the flexible pavements in village roads (with very less traffic volume and least maintenance care) in Indian conditions which would have direct application without any correction factors and with less number of input data. Since roughness is accepted as a good indicator for indicating the overall condition of the pavement, roughness modeling has been taken in this study.

Keeping the view of the necessity, the main objectives of this study have been evolved as follows:-

- To develop roughness prediction model for flexible pavements in village roads with very less traffic volume and very little maintenance in Indian conditions.
- To develop most versatile model to facilitate the field engineers to use it without any difficulty
- Validation of the developed model

STUDY METHODOLOGY

The entire research work was divided into the following steps. (i) The locations of test sections on in service pavements were identified with different age group. (ii) The roughness measurements and traffic surveys were made on selected test sections. The sub grade strength was assessed by conducting California Bearing Ratio (CBR) tests on samples collected from test sections. The pavement composition details were obtained from the road agencies and same were confirmed while making pits for CBR tests. Rainfall particulars for the test sections were collected from metrological department of India. (iii) Roughness prediction model was developed using regression analysis. (iv) Validation and sensitivity analysis of model were carried out.

IDENTIFICATION OF SITES FOR TEST SECTIONS

The district of Thiruvallur in Tamil Nadu State in India has been chosen as the study area. The availability and ease of acquisition of data and equipment prompted the researcher to choose the study area in Tamilnadu State specifically in Thiruvallur district. In consultation with Rural Road and Panjayat Raj Department Officials, 171 test sections of 200m length each were initially identified with different age group. The following criteria were adopted for the identification of test section.

- Selection of village roads with traffic less than 150 CVPD.
- Sections on straight reaches and plain terrains
- Sections without cross roads, cross drainage works and habitations.
- Sections with uniformity in longitudinal and transverse directions with regard to crust composition, sub grade, drainage and surface conditions to the extent possible.

PERFORMANCE EVALUATION

Roughness measurement

Roughness was measured using Merlin equipment for a total number of 171 sections [12]

Traffic volume survey

The traffic surveys were conducted for seven consecutive days round the clock, by engaging adequate number of enumerators. From the survey data, commercial vehicle per day (CVPD) was calculated for each section.

Pavement strength

Pavement strength in this study is measured in terms of structural number. The concept of structural number (SN), a pavement strength indicator, was originally developed during the AASHO Test [13, 14, 5]. The relationship used to obtain the structural number of a pavement is calculated as following Eq. (1).

$$SN = a_1 \times t_1 + a_2 \times t_2 + a_3 \times t_3 + \cdots + a_n \times t_n = \sum a_{n1} t_n \; \ldots\ldots\ldots\ldots > 1$$

Where , a_1, a_2, a_3, ...a_n , are the strength coefficients of materials used in different pavement layers t_1, t_2,t_3,...t_n , are the corresponding thickness in inches.

The strength coefficients suggested by Central Road Research Institute (CRRI), New Delhi, for Indian conditions for different materials are used in this study [13].

The structural number (SN) thus obtained is modified to make into account the sub-grade strength, by the following Eq.(2) developed during the Kenya study [15,16]

$$MSN = SN + 3.51(\log_{10} CBR) - 0.85(\log_{10} CBR)^2 - 1.43 \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots > 2$$

Where, MSN- *modified structural number,* *SN- structural number,* *CBR-California bearing ratio of sub grade soil.*

Rainfall Particulars

Rainfall particulars for the test sections were collected from meteorological department of India and utilized.

DEVELOPMENT OF MODEL AND DISCUSSION

The parameters measured on all the 171 test sections, during the course of the study are analysed to obtain input parameters for the development of model. The response variable considered in this study is roughness. The range of response variable employed in this study for the development of model and validation varies from 3m/km to 9m/km.

Modelling of roughness progression puts together the impact of different distress modes and the relative influence of traffic loading, pavement strength, pavement age and environmental conditions. Hence the explanatory variables considered in this study are (i) commercial vehicle per day (ii) modified structural number (iii) age and (iv) cumulative rainfall. The range of explanatory variables employed in this study for development of model and validation are given Table 1. Out of 171 sections, data collected from 120 test sections are kept as " in-sample" data for model development and remaining are designed as " out-of - sample" data for model validation. The in- sample data and out-of-sample data were obtained by sorting the data randomly.

Table-1: Range of Explanatory Variables Employed in the Development Validation

Description	Notation	Unit	Minimum	Maximum	Mean
Commercial Vehicle Per Day	CVPD	No.	2	9	5.5
Pavement age since last renewal	AGE	Years	0	10.5	5.25
Modified Structural Number	MSN	--	0.91	2.78	1.845
Roughness value	ROU	m/km	3	9	6
Annual Rainfall	RAIN	mm	695	2139	1417

The stepwise multiple linear regression analysis is carried out with all the four explanatory variables using SPSS 19.0 software. In the regression analysis, the explanatory variable "RAIN" do not get any significance. Good correlation exists between roughness and the other three explanatory variables (CVPD, MSN, AGE). The significance of explanatory variables in descending order is observed to be MSN, AGE and CVPD.

The best model obtained is as follows with R^2 value of 0.894

$$\boldsymbol{ROU = 3.823 + 0.549\,AGE - 0.750 MSN + 0.100\,CVPD} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. > 3$$

(SE=0.56, N=120)

In the above model, roughness increases with increase in CVPD and AGE, as they appear with positive coefficients. Roughness decreases with increase in MSN, as it appears with negative coefficient. The negative sign indicates that stronger the pavement, lesser the potential for surface unevenness.

In order to explain the robustness of the model, a plot is made between predicted versus observed roughness values of the out- of-sample data as shown in Fig.ure1. The alignment of plotted points along the line of equality indicates the robustness of the model.

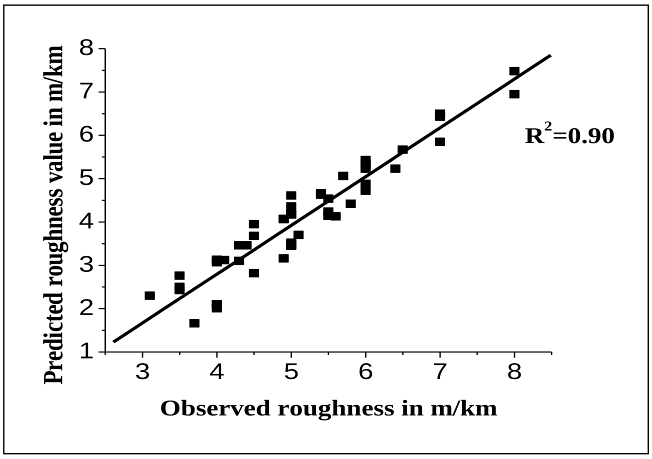

Fig-1: Comparison of predicted and observed roughness values using out of sample data

To explain the sensitivity of roughness to MSN, a plot is made between arbitrary MSN values and corresponding roughness values obtained from the developed model considering mean values of age and CVPD of test sections taken in this study (Figure.2). In this graph, the steepness of the line indicates the sensitiveness of the model even for a small change in MSN value. It is observed that when the MSN value increases by 0.5, the roughness value decreases by 0.375 m/km.

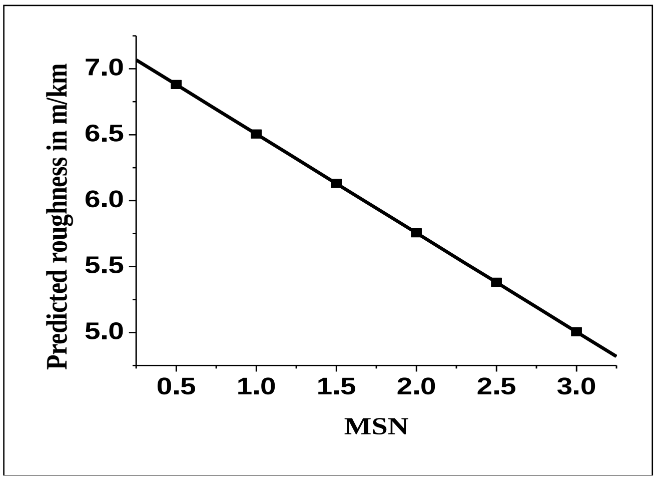

Fig-2: Plot between arbitrary MSN values and corresponding roughness values for sensitivity analysis.

To explain the sensitivity of roughness to age, a plot is made between arbitrary ages and corresponding roughness values obtained from the developed model considering mean values of MSN and CVPD of test sections taken in this study (Figure.3).In this plot, the steepness of the line indicates the sensitiveness of roughness even for a small change in age. It is observed that when the Age increases by 0.5 year, the roughness value increases by 0.275m/km.

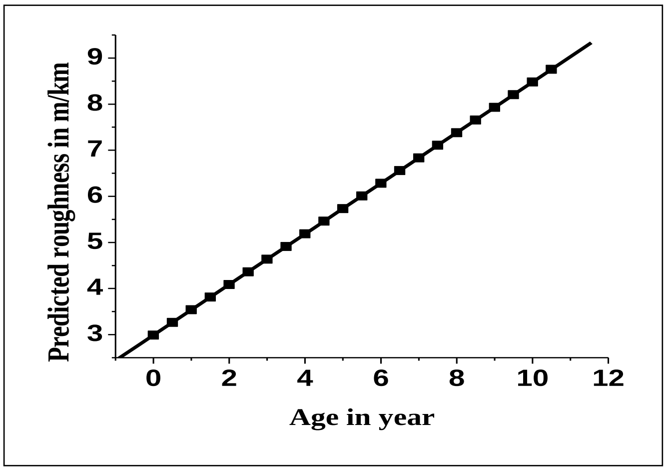

Fig-3: Plot between arbitrary Ages and corresponding roughness values for sensitivity analysis.

To explain the sensitivity of roughness to CVPD, a plot is made between arbitrary CVPD values and corresponding roughness values obtained from the developed model considering mean values of MSN and age of test sections taken in this study Figure.4. In this graph, the steepness of the line indicates the sensitivity of roughness for even a small change in CVPD.

It is observed that when the CVPD increases by 1, the roughness value increases by 0.1 m/km.

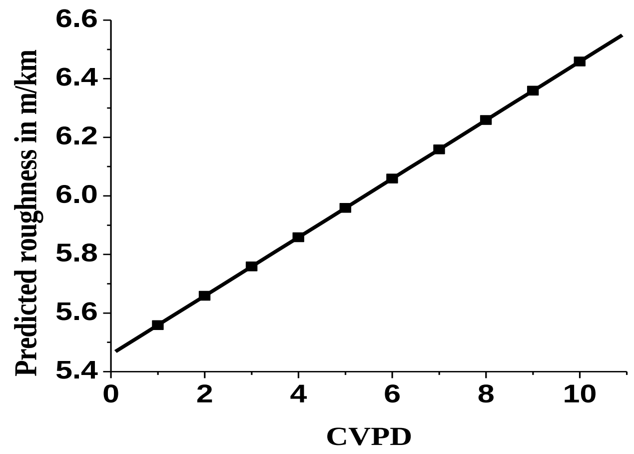

Fig-4: Plot between arbitrary CVPD and corresponding roughness values for sensitivity analysis.

CONCLUSIONS

- The model, as developed in this study in its multiple linear forms, is evaluated and showed to provide adequate prediction capability. Comparison of the predicted values with actual values (out of sample data) demonstrates their accuracy and found to be quite reasonable.
- The significance of explanatory variables in descending order in the model are found to be modified structural number, age and traffic.
- The rainfall factor is found to be insignificant factor as the test sections in this study were not subjected to inundation.
- The model developed in this study can be used as an effective tool in maintenance management of flexible pavements for low volume village roads.

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