"FUNCTIONAL EVALUATION OF HILLY RURAL ROADS"

A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

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To

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HIMACHAL PRADESH, INDIA

May-2018

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"FUNCTIONAL EVALUATION OF HILLY RURAL ROADS"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Munish Kumar (141661), Sahil Chaudhary (141665) & Akhil Kumar (141694)** during a period from August 2017 to March 2018 under the supervision of **Dr. Rajiv Ganguly**, (Associate Professor) & **Mr. Aakash Gupta,** (Assistant Professor) and Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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TABLE OF CONTENTS

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ABSTRACT

Roughness is important parameter as a measure of functional condition of a pavement. It constitutes the smoothness and frictional properties of the pavement surface and in turn is related to the safety, and the pavement distress is related to the comfort and serviceability. Roughness is determined using the international roughness index (IRI), which also depends on other functional distresses present on the pavement surface. The present study focuses on developing a relationship between the roughness and other surface distresses of rural roads. Accordingly, twelve rural roads were selected in Shimla and Solan districts of Himachal Pradesh, India. Various parameter data will be collected for every 50m separately. Roughness data was collected using MERLIN. An equation will be developed with the IRI value and the visible distresses based on the data collected in the field.

ABBREVIATIONS

IRI	International Roughness Index
MTD	Mean Texture Depth
PSI	Present Serviceability Index
RRL	Road Research Laboratory
TRL	Transport Research Laboratory
RR	Rural Road
ANN	Artificial Neural Network
MLR	Multiple Linear Regression
MSE	Mean Square Error
RMSE	Root Mean Square Error
MAE	Mean Absolute Error
SRV	Skid Resistance Value

LIST OF FIGURES

Description	Page no.

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Any structure that is built will deteriorate with time. Thus it is necessary that these structures, in our case flexible pavements, are evaluated occasionally, periodically to assess their current condition and also to check the remaining life of the pavement and how much more time the pavement can serve the users satisfactorily. So, for that one must have appropriate tools to evaluate existing pavements condition, collect some suitable information and must be able to interpret the data which is obtained and make appropriate decisions in terms that its condition is improved and increase its durability.

1.1.2 Factors influencing the performance of a pavement are:

i. Traffic

Traffic is one of the important factors which impact pavement performance. The performance of pavement is mostly influenced by the configuration, number of load repetitions and magnitude of load from vehicles.

ii. Moisture (Water)

Moisture can significantly weaken the support strength of subgrade soil. Moisture enters the pavement structure through holes and cracks present on the surface, laterally through the subgrade and through capillary action from the underlying water table. The result of the entrance of moisture is the loss of particle interlock, lubrication of particles and particle displacement.

iii. Subgrade

The subgrade is the underlying soil which supports the applied loads form wheel. If the subgrade is too fragile to support the loads, the pavement will deform extremly which finally causes failure of pavement.

iv. Quality of Construction

Failing to obtain proper compaction, quality of materials, accurate layer thickness all directly and improper moisture conditions during construction affects the pavement performance.

v. Maintenance

Performance of pavement also depends on when and what method maintenance is used.

These factors degrade the health of pavements leading to decrement in their service lives. Thus it becomes crucial to check the condition of existing pavement (both structural and functional) in order to address their maintenance requirements.

1.2 Functional Evaluation

Functional evaluation of highways is mainly concerned with the ride quality or surface texture and safety of a highway section

The functional evaluation of pavement is carried out for following purposes:

i. To assess the surface quality of pavement.
ii. To determine surface condition of pavement in terms of different forms of riding quality by which the urgency for maintenance is evaluated.
iii. To measure performance of newly laid road by its roughness value.
iv. To propose a suitable maintenance method, based on roughness data.
v. For evaluating safety of pavement surface in terms of skid resistance provided.
vi. For recording pavement performance with help of roughness data accumulated over a period of time.

1.3 Types of Functional Evaluation

Surface characteristics which affect pavement riding quality related to safety, comfort and serviceability are main the concern of functional evaluation of pavement. Attribute of surface condition decide surface characteristics of interest as:

a. Serviceability

   Roughness of road can be measured by several equipment's and can be evaluated by different tools. Typical examples of indicators are Present Serviceability Index (PSI), International Roughness Index (IRI), Bump Integrator value.

b. Safety

   Safety depends on the surface texture in terms of frictional resistance or skid resistance offered by the surface of pavement.

c. Surface Distress

   Usually surface defects are expressed as condition related to cracking, raveling, potholes and many other such surface failures.

1.4 Functional Evaluation Parameters

a) Roughness

Roughness is an undesirable deviation of the pavement surface compared to its planar surface as shown in fig 1.1. It causes vibrations in vehicles, thus promoting discomfort while riding. The International Roughness Index (IRI) is the most widely used parameter for roughness measurement. It is generally expressed in terms of m/Km.

Fig. 1. 1 Flexible pavement having roughness

b) Rut Depth

Rut is a surface depression on road along the wheel path as shown in fig. 1.2. Ruts generally appear due to the wear and weak load bearing capacity of the road structure.

Fig. 1. 2 Rutting

c) Skid Resistance

Skid resistance is the force developed when a tire that is prevented from rotating and slides along the pavement surface (Highway Research Board, 1972). It is an important pavement evaluation parameter because if skid resistance is inadequate, it will lead to increase in number of skid related accidents. Skid resistance relies upon pavement surface texture. Skid resistance changes over time depending upon the age and road tire interaction.

d) Macro-Texture

Road surface textures are deviations from the planar and smooth surface affecting the vehicle and tire interaction.

e) Pot Holes

Potholes are bowl-shaped holes as shown in fig.1.3. These are progressive failure. Firstly, small fragments from the top layer are dislodged. Then over time, the distress progress downward into the underlying layers. Potholes are generally formed when the pavement disintegrates under load of traffic, due to insufficient strength in one or more layers of the pavement.

Fig. 1. 3 Pothole

f) Raveling

Raveling is the loss of material from the surface of pavement as shown in fig.1.4. It occurs due to inadequate adhesion between the bitumen and the aggregate. Initially, fine aggregate disintegrates and leaves small and rough patches in the pavement surface. As the disintegration continues, larger aggregate breaks loose, leaving rougher surfaces.

Fig. 1. 4 Raveling

g) Patching

A patch is defined as a portion of the pavement that has been removed and replaced as shown in fig.1.5. Patches are usually used to repair defects in a pavement.

Fig. 1. 5 Patching

CHAPTER 2

LITERATURE REVIEW

2.1 General

Hamdi et al (2017) [19]

The study conducted a research on 'Prediction of Surface Distress Using Neural Networks'. In this paper, the aim of this research to predict Surface Distress Index (SDI) values following a data-driven approach. Later this model will be accordingly applied by using data obtained from the Integrated Road Management System (IRMS) database. Artificial Neural Networks (ANNs) are used to predict SDI index using input variables related to the surface of distresses, i.e. crack area and width, pothole, rutting, patching and depression.

Kumar, P. et al (2017) [13]

In this paper a research on 'Functional and Structural evaluation of pavement'. The research evaluated the condition of a selected section of a pavement from Budalur to Pudupatti on State Highway 99. Based on the analysis of distress data, the pavement was rated using IRC: 82 - 2015.

Hermawan (2017) [4]

The research on the 'Use of International Roughness Index and Structural Number' for Rehabilitation and Maintenance Policy of Local Highways was conducted. The data collection of roughness and structure value with the help of Road Roid app and Web based GIS. The research also predicted the future value of roughness value by using formula given by Patreson (1987).

Abdelfaraj, R. et al (2016) [1]

The study included a research on the ‘Pavement Surface Unevenness Evaluation’. They developed the design and construction activities as well as to plan and accomplished the most appropriate pavement management and evaluation program when the infrastructures are subjected to the wear due to traffic and environmental actions. Pavement evaluation is a technique of assessing the condition of a pavement, both structurally and from the point of view of surface characteristics relatives and their economic evaluation.

Karim, M.A. et al (2016) [20]

In this study a research on the ‘Road Pavement Condition Index (PCI) Evaluation and Maintenance’. In this research, the pavement condition was evaluated in terms of the surface distresses existing at the time of the field evaluation. The PCI procedure was used in this study ,so it was easy to deals with the subject of pavement distresses identification most comprehensively and is based on a sound statistical technique of pavement sampling.

Muhammad, M. (2016) [12]

The study conducted a research on ‘Highway subsurface assessment using pavement surface distress and roughness data’. A relationship between International Roughness Index (IRI) and pavement damage was obtained. The results of the analysis indicated that a significant relationship exists between IRI and cracking, and IRI and raveling. The results of this research also showed that the rutting did not show a significant relationship to IRI values. At last it can be concluded from the results that cracking and raveling may possibly be described as ride quality distresses, whereas the rutting distress may be described as non-ride quality distress.

Mustafa, A. (2015)

The study gave a relationship between 'Manual and Function Pavement condition'. The aim of this paper was to study and investigate the possibility of correlating manual Pavement condition index represented by Urban Distress Index (UDI) which are calculated. Based on pavement distress type, severity and quantity to the Function evaluation Index like International Roughness Index (IRI) and Skid resistance factor for a sample of pavement sections and recommendation to use the new technology for pavement evaluation to save money, valuable time and safety for PMMS staff.

Darter, I., Michael (2014) [10]

The study included a research on 'Effect of Pavement Deterioration Types on IRI and Rehabilitation'. A relationship between the Present Serviceability Rating (PSR), International Roughness Index (IRI), and selected pavement distress types was obtained. A predictive model was developed between PSR and the IRI. It is recommended by this research that the Highway Performance Monitoring System used both the IRI and selected pavement distress types as trigger values for more consistent and accurate results in predicting future rehabilitation needs on the nation's highways.

Abiola, O. S., Kupolati, W. K. and Odunfa, S. O. (2014) [2]

This study predicted Visual Pavement Score from International Roughness Index. They collected data for four consecutive years and obtained relationship between IRI and Distress using regression model.

Wang, H. et al (2013) [25]

The study included a research on 'Pavement Roughness Evaluation For Urban Road Management'. In this paper there was a calculation of IRI to evaluate the road condition. For calculation of IRI a small section of urban road was selected. In this paper, IRI data detection by auto device was analyzed.

Adu-Gyamfi, Y. O et al (2013) [24]

The study was conducted on 'Functional Evaluation of Pavement Condition Using a Complete Vision System'. The study includes a complete vision system and combine its output into geographical information system i.e. GIS for automated pavement management and monitoring.

A novel model method i.e. active contour model was used for edge detection and also shows the pavement distresses and necessary for accurate crack location and shape detection.

Shah. U. Yogesh et al (2013) [9]

The study included a research on 'Development of Pavement Condition Index for Urban Road Network'. The methodology included identification of urban road sections, pavement distress data collection smethods, development of individual distress index and finally developing a combined OPCI for the network. The four performance indices viz. Pavement Condition Distress Index (PCI Distress), Pavement Condition Roughness Index (PCI Roughness), Pavement Condition Structural Capacity Index (PCI Structure) and Pavement Condition Skid Resistance Index (PCI Skid) are developed individually.

Prasad, J.R. et al (2013) [6]

This study was conducted on 'Development of Relationship between Roughness (IRI) and Visible Surface Distresses on PMGSY Roads'. Roughness value was obtained using Bump Integrator which was calibrated by MERLIN. A regression equation between visual surface distress and IRI value developed based on the collected data.

Chandra, R. et al (2013) [2]

The research proposed a relationship between 'Pavement Roughness and Distress Parameters for Indian Highways'. An empirical, linear and nonlinear model was developed between road roughness and patching, potholes, rut depth, raveling, and cracking. Artificial Neural Network (ANN) was used to model pavement roughness with distress parameters. The study showed that the Artificial Neural Network model gives a more suitable forecast of road roughness for a given set of distress parameters rather than empirical nonlinear & linear models.

Tukaram, D. (2012) [18]

The study included a research on Artificial Neural Network (ANN) based 'Pavement Deterioration Models for Low Volume Roads' in India. This study summarized the implementation of pavement condition prediction method by using the Artificial Neural Network (ANN) to predict distresses (cracking, raveling, rutting) and roughness for Low Volume Roads (LVR) in India.

Gupta, A. et al (2011) [17]

The research was conducted on 'Pavement Deterioration and Maintenance Model for Low Volume Roads'. The research established structural and functional response measurement models of 18 sections of low volume pavements, which were carried out for consecutive two years in Uttrakhand and Uttar Pradesh states of India. The Statistical analysis and Artificial Neural Network (ANN) was used to develop these models.

Mgangira, M. et al (2008) [22]

The study was conducted on 'Characterization of Pavement Distress from Test Pit Observation'. In this paper there is a discussion on forms of distress within pavement layers. The focus of this study was on the observed orientation of crack propagation within the pavement layers. It was shown that the crack propagation is not always in the vertical plane.

Sun, L et al (2001) [23]

The research was conducted on 'Modeling Indirect Statistics of Surface Roughness'. This research includes the analysis of pavement roughness by Quarter-car model-based indirect statistics .They establish the relationship between the international roughness index (*IRI*) statistic of a quarter-car response and the power spectral density (PSD) of road random excitation using stochastic process theory.

Chua, M.et al (1994) [21]

The research was conducted on 'Identifying Pavement Distresses from Video Images'. In this research they capture the pavement images by video camera mounted on moving vehicle. This research uses an 8mm cam recorder, an image-digitizing board, and 486 microcomputers and images captured at a vehicle speed of 24 km/h (15 mph)

CHAPTER 3

OBJECTIVES

Objective of Project

a) To evaluate rural roads on the basis of Roughness value, skid resistance, macro-texture and surface distress.

b) Propose a quantitative relation of International Roughness Index (IRI) value upon rut depth, pot holes, raveling, cracking and patching.

CHAPTER 4

METHODOLOGY

4.1 Selection of Rural Roads

Twelve roads are selected for their functional evaluation. Criteria for selection of road were:

i. All roads must be rural roads.
ii. Length of road stretch is about 2-2.5 km.
iii. At least one surface distress must be present.

Each road stretch is divided in segments of about 50m. Values of all distress parameters discussed earlier are obtained for each stretch.

Following table 4.1 and fig 4.1 & 4.2 shows selected rural roads for evaluation of pavement in our project

Table 4. 1 Selected rural roads

Road ID	Road Name	Width	Road ID	Road Name	Width
RR-1	Domehar-Waknaghat Road	3.5	RR-7	Shoghi Lagroo Road	3.35
RR-2	Salogra Ashwini Khad Road	3.35	RR-8	Wakna link Road	3.25
RR-3	Kyari Bangla Road	3.35	RR-9	Saij Road	3.35
RR-4	Basha Road	3.35	RR-10	Chail Road	3.4
RR-5	Industrial Road	3.5	RR-11	Nain-Basal Road	3.35
RR-6	Salana Road	3.3	RR-12	Dadhog Road	3.3

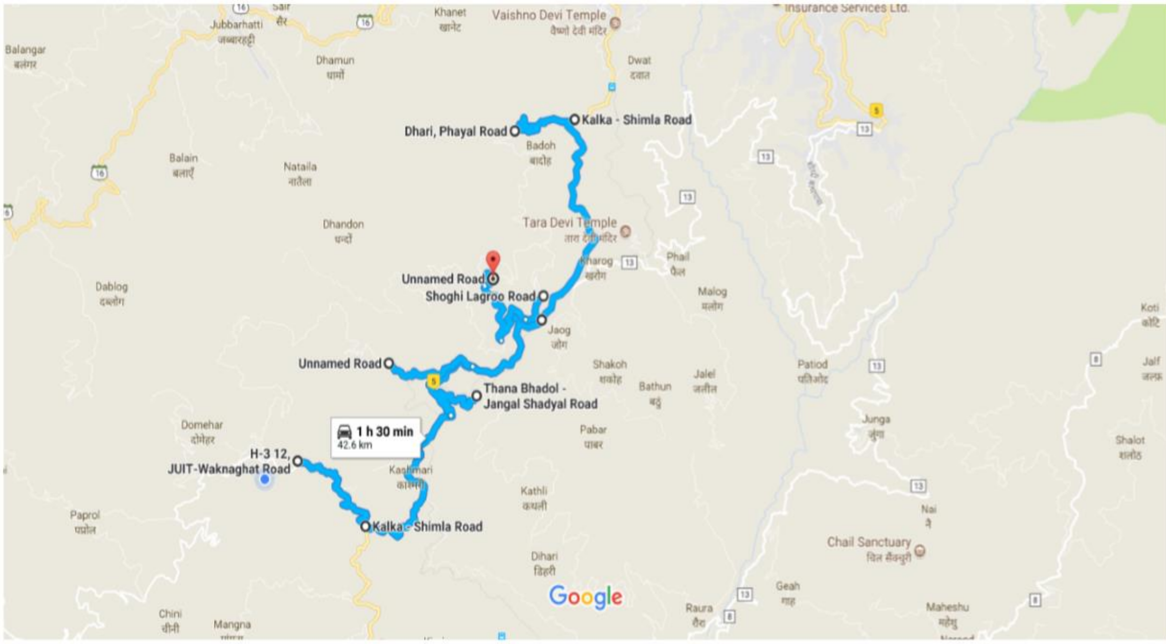

Fig. 4. 1 Selected rural roads [16]

Fig. 4. 2 Selected rural roads

4.2 Measurement of Pavement Distress

The visible signs of pavement deterioration, called pavement distresses, include all types of surface deformation such as cracks, patches, potholes and others. In our project we opted to measure rut depth, cracks, patches, raveling and potholes. The reason for selecting these distresses is that these distresses are most common and occur more frequently.

4.2.1 Measurement of Rut depth

Rut depth shows maximum value of lateral unevenness of traffic lane, within two parts of the passing wheel. For its measurement commonly used equipment is Straightedge.

Fig.4.3 shows the definition of rut depth.

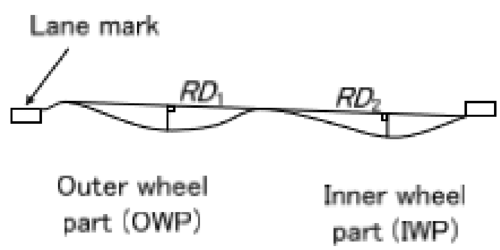

Fig. 4. 3 Definition of rut depth

Fig. 4. 4 Measurement of rut depth

4.2.2 Measurement of Potholes

Pothole volume is calculated by filling the pothole using Grade-2 sand. Area is calculated visually.

Fig. 4. 5 Measurement of pothole

4.2.3 Measurement of Raveling

The area of raveling is calculated by using simple measuring equipment like tape or scale. The raveled area is measured, in each segment, by enclosing the area in square or rectangular shape as shown in fig. 4.5.

Fig. 4. 6 Raveling in Basha Road (RR-4)

4.2.4 Measurement of Patches

The area of patching is calculated by using simple measuring equipment like inch tape or scale. The patch area is measured in each segment by enclosing the area in rectangular or square shape as as shown in fig. 4.6.

Fig. 4. 7 Patching in Salana Road (RR-6)

4.3.5 Measurement of Cracking

The cracking measured are of 3 types: i) Longitudinal ii) Transverse iii) Mapped/Alligator. The length and width of longitudinal and transverse crack is measured using tape and scale respectively as shown in 4.7, 4.8 & 4.9.

Fig. 4. 8 Mapped cracking

Fig. 4. 9 Transverse cracking

Fig. 4. 10 Longitudinal cracking

4.3 Rating of Pavement on Basis of Distress Data

The rating of pavement is done as per criteria given in following table of IRC 82-2015. The distress data namely raveling, cracking, potholes and patching data for each 500m length of road is converted into percentage by dividing it by the area of 500m road surface. Then rating to each parameter is given in reference of following table:

Table 4. 2 Pavement distress based rating for rural roads according to IRC 82-2015

Distress (%)	**Range of Distress**		
Raveling	>20	10-20	<10
Cracking	>20	10-20	<10
Pothole	>1	0.5-1	<0.5
Patching	>20	5-20	<5
Rating	1	1.1-2	2.1-3
Condition	**Poor**	**Fair**	**Good**

After assigning rating number to each distress parameter, weightage is given to obtained rating value, for calculation of Weighted Rating Value of each parameter.

Table 4. 3 Weighted Rating Value for each parameter in IRC 82-2015

Parameter	**Weightage (Multiplier Factor)**
Raveling	0.75
Cracking	1
Pothole	0.5
Patching	0.75

The **Final Rating Value** is calculated by taking average of Weighted Rating Values of all distress parameters.

4.4 Measurement of Roughness

Several types of instruments are available for measuring road roughness producing variety of indices. The different indices obtained are correlated to a standard common scale IRI (International Roughness Index). In our project we used MERLIN to find out road roughness value.The device is called MERLIN is an acronym for a Machine for Evaluating Roughness using Low-cost INstrumentation.

4.4.1 Principle of Operation of MERLIN

The device has two feet and a probe which rest on the road surface whose roughness is to be measured. The two feet are 1.8m away and the probe lies at the center. The device measures the vertical displacement between the road surface under the probe and the center point of a virtual line joining the two points where the road surface is in contact with the 2 feet as shown in 4.10. This displacement is known as the 'mid-chord deviation'.

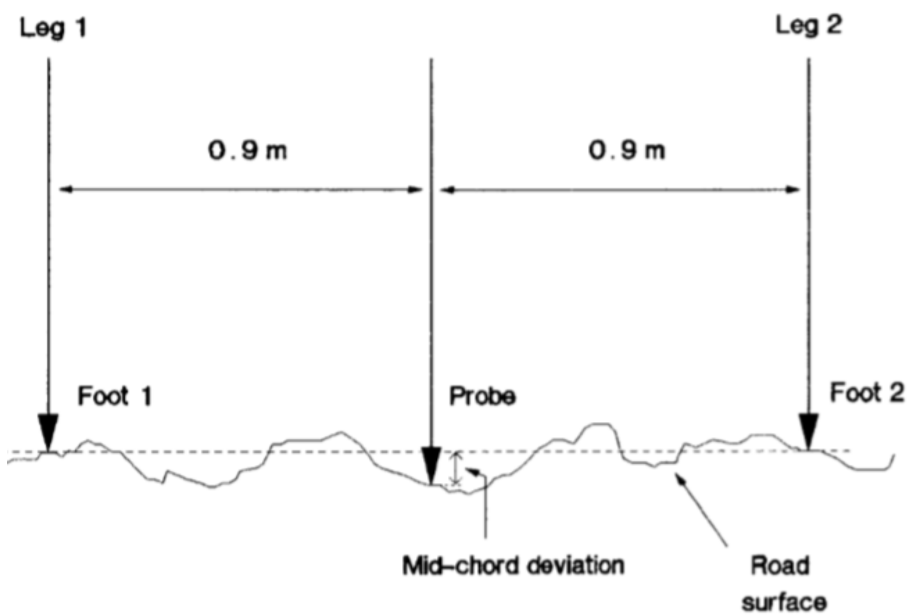

Fig. 4. 11 Working Principle [14]

When measurements are taken at successive intervals along the road, then rougher the road surface, greater will be the variability of the displacements.

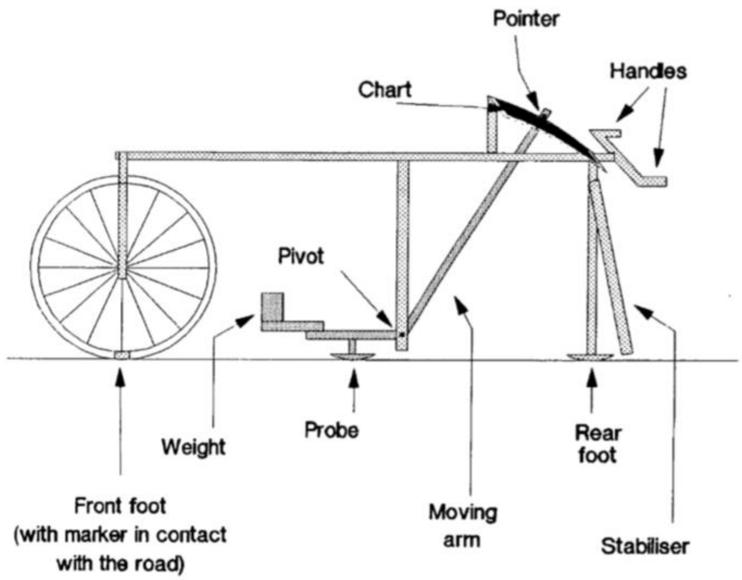

Fig. 4. 12 Component parts of MERLIN [14]

4.4.2 Procedure

200 measurements are taken at regular intervals, once every wheel revolution. At each measuring point, the instrument is rested on the road with the wheel in its normal position and the probe, rear foot and stabilizer in contact with the surface of road as shown in . The operant then records the position of the pointer on the chart/graph with a cross in the appropriate column.

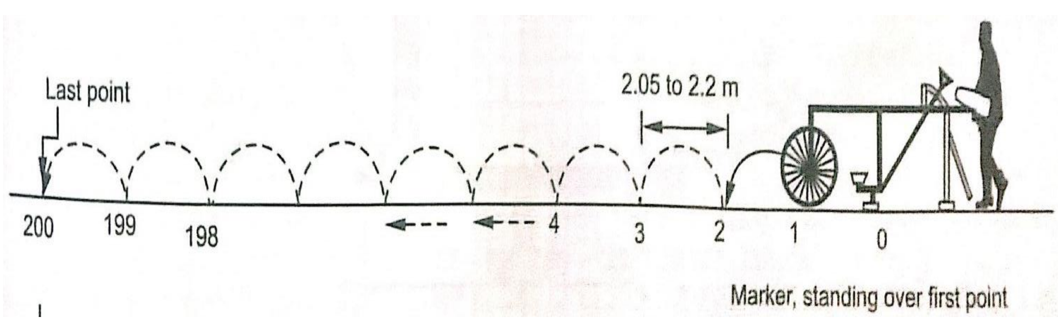

Fig. 4. 13 MERLIN test section [14]

Fig. 4. 14 MERLIN test at RR-6

Total length for one segment =200*circumference of wheel (approximately 410 – 440 m).

Then D value of MERLIN roughness is obtained

The International Roughness Value (IRI) can be determined from D value using Transport Research Laboratory (TRL) recommended equation:

$$\mathbf{IRI = 0.593 + 0.0471 * D}$$

The above procedure is carried out on each road. We have assumed that the roughness value obtained of a segment is of about 500m. And on each segment 4 times the same procedure is carried out, thus obtaining four D values of each segment. IRI value is calculated by taking the average of the obtained D values.

4.4.3 Pavement Evaluation on Basis of IRI Value

The roads are evaluated on the basis of obtained IRI value in reference to following table:

Table 4. 4 Approximate relationship between IRI and condition of pavement (based on Sayers and Karamihas, 1998; Sayers et al. 1986) [5]

Range of IRI (m/km)	Condition Of Pavement
Up to 2.5	Excellent Profile
2.5 - 4.0	Very good surface profile
4.0 - 6.0	Good surface profile
6.0 - 8.5	Fair surface profile
8.5 - 13.5	Frequent transverse undulations
13.5 - 16.5	Rough surface
16.5 - 20.5	Very rough surface and unsatisfactory ride

4.5 Skid Resistance Measurement

TRL portable Skid Resistance Tester has been used for measuring skid resistance. This is one of the easiest, cheapest and widely accepted instruments used for the measuring friction characteristics of road surfaces.

Procedure

The instrument is placed on the surface along the longitudinal direction of road. Then the instrument is leveled by adjusting the legs of instrument as shown in fig. 4.14. The pendulum is lowered and adjusted such that the rubber disk touches the road surface for 12.7cm (+/- 2mm) in a swing. Water is applied the test surface. Then swing is executed and reading is noted down. The same procedure is carried out after every 50m on the selected roads.

Fig. 4. 15 Portable Skid Resistance Tester at Domehar Road (RR-1)

Table 4. 5 TRL suggested minimum value of skid resistance measured

Category	Type of site	Minimum value of resistance of wet-surface
A (Critical Stretches)	Roundabouts, approaches to traffic signals on unrestricted roads	65
B (High speed lanes)	National highways, State highways	55
C (Normal speed lanes)	All other sites of pavement surfaces, village roads	45

4.6 Measurement of Macro-Texture

The skid resistance of pavement also depends on the surface macro-texture. Surface macro texture is measured by means of Mean Texture Depth (MTD). MTD is the output determined from Sand Patch Test belonging to volumetric technique of texture measurement method.

Sand Patch Test Procedure

This test is described in British Standard (BS 598 Part 105, 1990) and ASTM E 965. A metal cylinder, with a volume of approximately 50ml, is filled to the top with the natural silica sand (grade2). Sand is poured on the road surface and spread it with the rubber disc spreading tool (a 63.5 mm diameter flat wooden disc with a 16 mm thick hard rubber disc) into a circular patch with the surface depressions filled to the level of the peaks as shown in. Diameter of circular patch is obtained by taking the average diameter of circular patch in four different directions. The Mean Textural Depth (MTD) value is obtained by the following formula:

$$MTD = (\text{Volume of sand}) / (\text{Area of patch})$$

The same procedure is carried out after every 50m on the selected roads.

Fig. 4. 16 Sand Patch Test in Domehar road (RR-1)

4.7 Relation between Pavement Distress Data and Roughness

In our project, we attempted to develop mathematical relations between distress parameters and roughness of pavement. The models include conventional linear regression equations and advanced model such as the neural network model. These equations are developed by using the data for RR-1, RR-2, RR-3, RR-4, RR-5, RR-6, RR-7 and RR-9. The parameters and their units used are as follows:

Table 4. 6 Parameters used with their units

Parameter		**Units**
Roughness	IRI value in each segment (each segment 500m)	m/km
Raveling	Cumulative area in each segment	m^2
Patching	Cumulative area in each segment	m^2
Cracking	Cumulative area in each segment	m^2
Rut	Cumulative depth in each segment	mm
Potholes	Cumulative area in each segment	m^2

4.7.1 Multiple Linear Regression Modeling

Multiple Linear Regression (MLR) analysis is carried out using Python, for the data of the 8 rural roads to determine the relationship between roughness and distress parameters. The following form of relation is assumed:

$$\mathbf{IRI = a_0 + a_1*Raveling + a_2*Patching + a_3*Cracking + a_4*Rut + a_5*Potholes}$$

Where a_0 = model constant and a_1, a_2, a_3, a_4 and a_5 are coefficients of Raveling, Patching, Cracking, Rut and Potholes respectively.

4.7.2 Artificial Neural Network (ANN) Modeling

Artificial neural networks (ANNs) are biologically inspired computer programs designed to simulate the way in which the human brain processes information. ANNs gather their knowledge by detecting the patterns and relationships in data and learn (or are trained) through experience. ANNs have three layers that are interconnected. The first layer consists of input neurons. These neurons send data on to the second layer, which in turn sends the output neurons to the third layer. Fig. 4.16 shows a simple example of an artificial neuron. Mathematically, if $I_1 \ldots I_i \ldots I_n$ are the input values and $W_{lj} \ldots W_{ij} \ldots W_{nj}$ are synaptic weight values, then net_j is the summation of the product of the incoming neuron's activation and the synaptic weight of the connection at the typical j^{th} neurone expressed as $\sum I_i W_{ij}$. Thus the resultant net_j as presented in Eq. is obtained, where n is the number of incoming neurons, i is the vector of incoming neurons, W is the vector of the synaptic weights, and α is node threshold.

$$net_j = \sum I_i W_{ij} + \alpha_i$$

The output at jth neurode is Oj as expressed in following Eq., where f(net) is an activation function:

$$O_j = f(net_j)$$

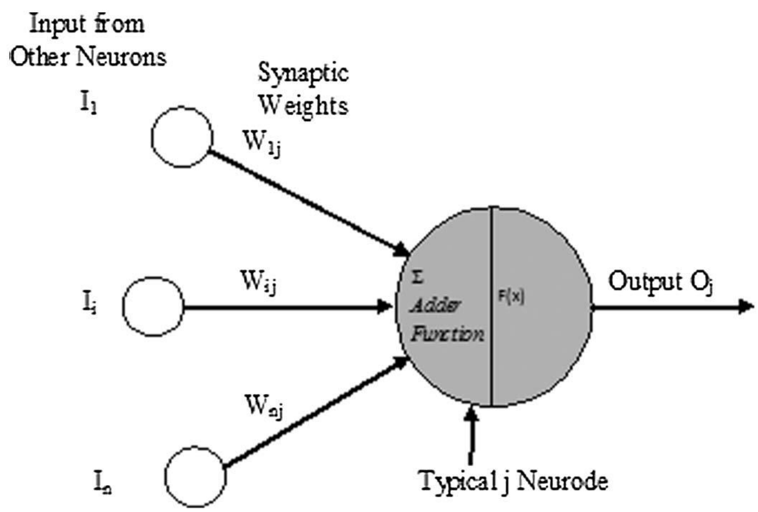

Fig. 4. 16 Function of artificial neuron

The activation function we used is **ADAM** function. The Adam algorithm is a broader adoption for deep learning applications in computer vision and natural language processing. The ANN modeling is done using Python.

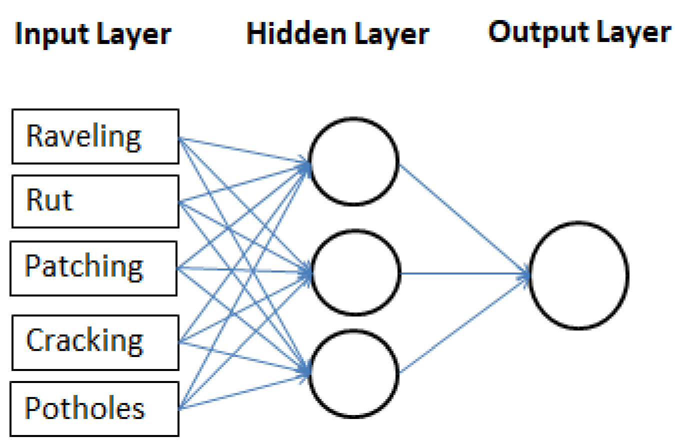

Fig. 4. 17 Structure of ANN model

4.8Evaluation of Linear Regression Model ANN Model

Linear Regression Model and Neural network model both are evaluated for the remaining data of 4 roads. For more objective evaluation, a range of conventional measures such as Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Relative Error (MARE) are estimated for remaining data. These terms are calculated as follows:

$$MAE = \frac{\sum|X - X'|}{n}$$

$$RMSE = \sqrt{\frac{\sum|X - X'|}{n}}$$

$$MARE = \frac{1}{n}\sum\frac{|X - X'|}{X}$$

CHAPTER 5
RESULT

5.1 Distress Based Rating of Rural Roads According To IRC 82- 2015

Table 5. 1 Distress based rating of Domehar road (RR-1)

Table 3.6				
Distress Type	**Input (%)**	**Rating**	**Weightage**	**Weighted Rating Value**
Cracking (%)	3.714	2.666	1	2.665
Raveling (%)	1.416	2.873	0.75	2.154
Patching (%)	1.734	2.688	0.75	2.016
Pothole (%)	0.008	2.990	0.500	1.495
Final Rating Value				**2.215**
Condition				**Good**

Table 5. 2 Distress based rating of Askwanikhad Road (RR2)

Distress Type	**Input (%)**	**Rating**	**Weightage**	**Weighted Rating Value**
Cracking (%)	1.227	2.890	1	2.889525535
Ravelling (%)	1.714	2.846	0.75	2.134286948
Patching (%)	0.000	3.000	0.75	2.25
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				2.193
Condition				

Table 5. 3 Distress based rating of Kyaribangla Road (RR-3)

Distress Type	**Input (%)**	**Rating**	**Weightage**	**Weighted Rating Value**
Cracking (%)	0.638	2.943	1	2.943
Raveling (%)	1.870	2.832	0.75	2.124
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				**2.204**
Condition				**Good**

Table 5. 4 Distress based rating of Basha Road (RR-4)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.003	3.000	1	3.000
Raveling (%)	0.305	2.973	0.75	2.229
Patching (%)	0.061	2.989	0.75	2.242
Pothole (%)	0.019	2.920	0.500	1.460
Final Rating Value				**2.233**
Condition				**Good**

Table 5. 5 Distress based rating of Industrail Road Road (RR-5)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.014	2.999	1	2.999
Raveling (%)	27.677	1.000	0.75	0.750
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.070	2.945	0.500	1.473
Final Rating Value				**1.868**
Condition				**Fair**

Table 5. 6 Distress based rating of Salana Road (RR-6)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	2.046	2.816	1	2.816
Raveling (%)	8.351	2.248	0.75	1.686
Patching (%)	1.991	2.642	0.75	1.981
Pothole (%)	0.042	2.930	0.500	1.465
Final Rating Value				**1.987**
Condition				**Fair**

Table 5. 7 Distress based rating of Lagroo Road (RR-7)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.320	2.971	1	2.971
Raveling (%)	15.586	1.497	0.75	1.123
Patching (%)	0.133	2.976	0.75	2.232
Pothole (%)	0.064	2.944	0.500	1.472
Final Rating Value				**1.950**
Condition				**Fair**

Table 5. 8 Distress based rating of Wakna Road (RR-8)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.007	2.999	1	2.999
Raveling (%)	0.551	2.950	0.75	2.213
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				**2.241**
Condition				**Good**

Table 5. 9 Distress based rating of Saij Road (RR-9)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.008	2.999	1	2.999
Raveling (%)	0.000	3.000	0.75	2.250
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				**2.250**
Condition				**Good**

Table 5. 10 Distress based rating of Chail Road (RR-10)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.845	3.000	1	2.924
Ravelling (%)	0.000	3.000	0.75	2.250
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				**2.231**
Condition				**Good**

Table 5. 11 Distress based rating of Nain Basal (RR-11)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	1.532	2.862	1	2.862
Raveling (%)	1.306	2.882	0.75	2.162
Patching (%)	0.595	2.893	0.75	2.170
Pothole (%)	0.026	2.970	0.500	1.485
Final Rating Value				**2.170**
Condition				**Good**

Table 5. 12 Distress based rating of Dadhog (RR-12)

Distress Type	Input (%)	Rating	Weightage	Weighted Rating Value
Cracking (%)	0.000	3.000	1	3.000
Raveling (%)	0.000	3.000	0.75	2.250
Patching (%)	0.000	3.000	0.75	2.250
Pothole (%)	0.000	3.000	0.500	1.500
Final Rating Value				**2.250**
Condition				**Good**

5.2 Pavement Evaluation on Basis of Roughness Value

Obtained IRI values and condition of road based on IRI values of 12 roads for segment of 500 m.

Table 5. 13 Obtained Roughness Data

Segment	**D value (mm)**	**Average D value (mm)**	**IRI (m/km)**	**Condition of Road**
RR-1				
1	119.7, 120.1, 122.9, 12.62	122.08	6.34	Fair surface profile
2	111.2, 109.4, 105.4, 114	110	5.77	Good surface profile
3	60.1, 62.5, 59.7, 65.2	61.875	3.5	Very Good surface profile
4	95.7, 105.6, 108.4, 110.3	105	5.53	Good surface profile
5	117.08, 107.7, 110, 114.82	112.4	5.88	Good surface profile
RR-2				
1	135.8,141.15,144.125,138.925	140	7.18	Fair surface profile
2	126.75, 120, 122.08, 126.17	123.75	6.42	Fair surface profile
3	150, 144.75, 146.75, 145.5	146.75	7.5	Fair surface profile
4	144.8, 147.5, 141.25, 143.95	144.375	7.39	Fair surface profile
5	156.25,156.66,158.455,154.455	156.455	7.96	Fair surface profile
RR-3				
1	117, 122.15, 122.08, 118.77	120	6.245	Fair surface profile
2	156.4, 154.2, 157.15, 156.85	156.15	7.94	Fair surface profile
3	120, 117, 114.15, 108.85	115	6	Good surface profile
4	117.5, 117, 120, 114.5	117.25	6.11	Fair surface profile
5	117.3, 122.2, 128.38, 122.88	122.69	6.37	Fair surface profile

Road	D value (mm)	Average D value (mm)	IRI Value (m/km)	Condition of Road
RR-4				
1	95.8, 87.15, 83.8, 84.25	87.75	4.7	Good surface profile
2	75, 79.75, 82.75, 81.7	79.8	4.35	Good surface profile
3	102, 97.75, 101.75, 98.5	100	5.303	Good surface profile
4	105, 110.15, 93.75, 88.6	99.375	5.27	Good surface profile
5	85.4, 94.3, 110.4, 101.5	97.9	5.2	Good surface profile
RR-5				
1	190.15, 195.75, 187.8, 186.3	190	9.542	Frequent Transverse Undulation
2	182, 177.925, 179.15, 180.925	180	9.071	Frequent Transverse Undulation
3	150, 152.9, 161.415, 159.685	156	7.94	Fair surface profile
4	187.5, 181.3, 184.15, 184.65	184.4	9.27	Frequent Transverse Undulation
5	128.8, 130, 135.85, 137.05	132.925	6.85	Fair surface profile
RR-6				
1	158, 164.75, 159.67, 164.9	161.83	8.21	Fair surface profile
2	156.15, 162.7, 158, 161.83	159.67	8.11	Fair surface profile
3	124.125, 129.08, 121.9, 129.395	126.125	6.53	Fair surface profile
4	164.15, 159.08, 160.08, 153.69	159.25	8.09	Fair surface profile
5	172.5, 168.08, 170.67, 170.15	170.35	8.61	Frequent Transverse Undulation

Road	D value (mm)	Average D value (mm)	IRI Value (m/km)	Condition of Road
RR-7				
1	184.75,179.66, 181.08, 181.19	181.67	9.15	Frequent Transverse Undulation
2	156.83, 154, 160.75, 163.42	158.75	8.07	Fair surface profile
3	160.75,166.9,164.925, 158.065	162.66	8.25	Fair surface profile
4	152, 153.415, 157.75, 156.835	155	7.89	Fair surface profile
5	168, 174.92, 170.3, 166.78	170	8.6	Frequent Transverse
RR-8				
1	110.3, 104.655, 108, 103.445	106.6	5.61	Good surface profile
2	112.3, 104.08, 106.5, 117.12	110	5.77	Good surface profile
3	124.3, 128.655, 135.8, 131.445	130.05	6.71	Fair surface profile
4	131.4, 101.66, 120.08, 112.98	116.53	6.08	Good surface profile
RR-9				
1	100.92,105.855,103.08, 105.145	103.75	5.47	Good surface profile
2	120.3, 116.95 123.75, 107.32	117.08	6.1	Fair surface profile
3	119.08, 117.75, 124.95, 126.22	122	6.33	Fair surface profile
4	107.5, 115.75, 120, 111.75	113.75	5.95	Good surface profile
5	98.87, 101.95, 106.25,103.17	102.56	5.42	Good surface profile

Road	D value (mm)	Average D value (mm)	IRI Value (m/km)	Condition of Road
RR-10				
1	167.3, 170.95,174.92, 168.03	170.3	8.6	Frequent Transverse Undulation
2	152, 150.85, 157.3, 157.35	154.375	7.86	Fair surface profile
3	130.3, 132.08, 140.885, 130.055	133.33	6.87	Fair surface profile
4	144, 149.5, 136.07, 141.57	142.785	7.31	Fair surface profile
5	130.3, 134.16, 135.4, 139.23	134.78	6.94	Fair surface profile
RR-11				
1	154.3, 158.885, 160.92, 159.215	158.33	8.05	Fair surface profile
2	156.47, 150, 154.115, 154.415	153.75	7.83	Fair surface profile
3	145.667, 154.08, 143.9,152.033	148.92	7.6	Fair surface profile
4	125.15, 120, 123.9, 118.75	121.95	6.33	Fair surface profile
5	133.5, 131.75, 141.96, 143.7	137.73	7.08	Fair surface profile
RR-12				
1	143.47, 136.3, 139.115, 133.115	138	7.09	Fair surface profile
2	132.3, 136.9, 133.8, 125	132	6.81	Fair surface profile
3	134.7, 140.7, 138.47, 131.33	136.3	7.01	Fair surface profile
4	142.667, 149.5, 143.07, 136.203	142.86	7.321	Fair surface profile
5	133.875, 131.785, 131.07, 133.15	132.47	6.83	Fair surface profile

5.3 Multiple Linear Regression Analysis

After carrying out Multiple Linear Regression Analysis using data of 8 rural roads, in Python, following equation is obtained:

$$\mathbf{IRI = a_0 + a_1*Raveling + a_2*Patching + a_3*Cracking + a_4*Rut + a_5*Potholes}$$

Where $\mathbf{a_0}$ = 6.09957245, $\mathbf{a_1}$ = 5.09554645e-03, $\mathbf{a_2}$ = -4.61350807e-04

$\mathbf{a_3}$ = -6.86132376e-04, $\mathbf{a_4}$ = 2.65750660e-03, $\mathbf{a_5}$ = -5.06181293e-02

The observed IRI value and estimated IRI value through Linear Regression Analysis (for eight roads used for modeling) are depicted in graph .

Mean square error (MSE) came out to be **1.20.**

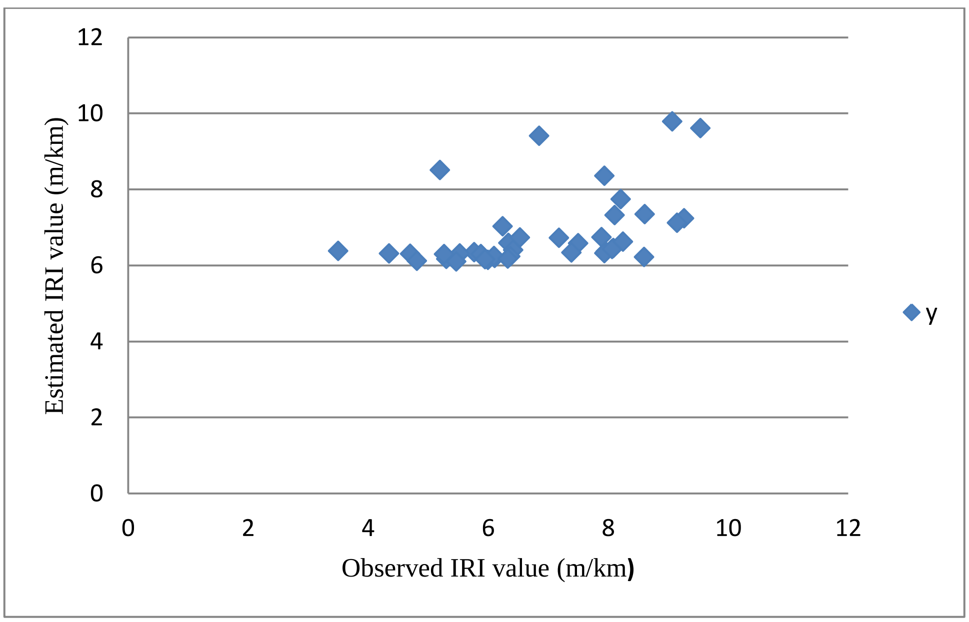

Fig. 5. 1 Observed and Estimated IRI value by Linear regression model

5.4 Artificial Neural Network (ANN) Modeling

Out of 59 observations 40 were considered for modeling. Using python for modeling and after conducting 400 iterations, following matrices are obtained in ANN modeling

$$A = \begin{bmatrix} 0.02041941 & -0.32067513 & -0.07565305 & -0.57067007 \\ -0.01256086 & 0.20340621 & 0.05749074 & 0.01560008 \\ 0.13974294 & 0.13776062 & -0.17453206 & -0.46154943 \\ 0.37533218 & 0.2741423 & -0.46876886 & -0.02928221 \\ -2.11466789 & 1.83537602 & 1.52017021 & -2.01762629 \end{bmatrix}$$

$$B = \begin{bmatrix} 2.43678427 & 2.12153649 & -2.31749678 & -0.02869677 \end{bmatrix}$$

$$C = \begin{bmatrix} 0.04890359 & 0.02579387 & 0.06368469 \\ -0.05745524 & -0.05301028 & -0.08035797 \\ -0.01329415 & -0.04513765 & -0.00348995 \\ -0.00798575 & 0.04496895 & 0.03753651 \end{bmatrix}$$

$$D = \begin{bmatrix} 2.79158378 & 2.83287549 & 2.81367564 \end{bmatrix}$$

$$E = \begin{bmatrix} 0.36862737 \\ 0.48194414 \\ 0.42558071 \end{bmatrix}$$

$$F = \begin{bmatrix} 2.36558318 \end{bmatrix}$$

Using following algorithm, values of IRI are obtained for the eight roads:

IRI = (((((([Raveling Patching Cracking Rut Potholes]*A) +B) * C) + D) * E) + F

The observed IRI value and estimated IRI value through ANN (for eight roads used for modeling) are depicted in graph . Mean square error (MSE) came out to be **0.9227**

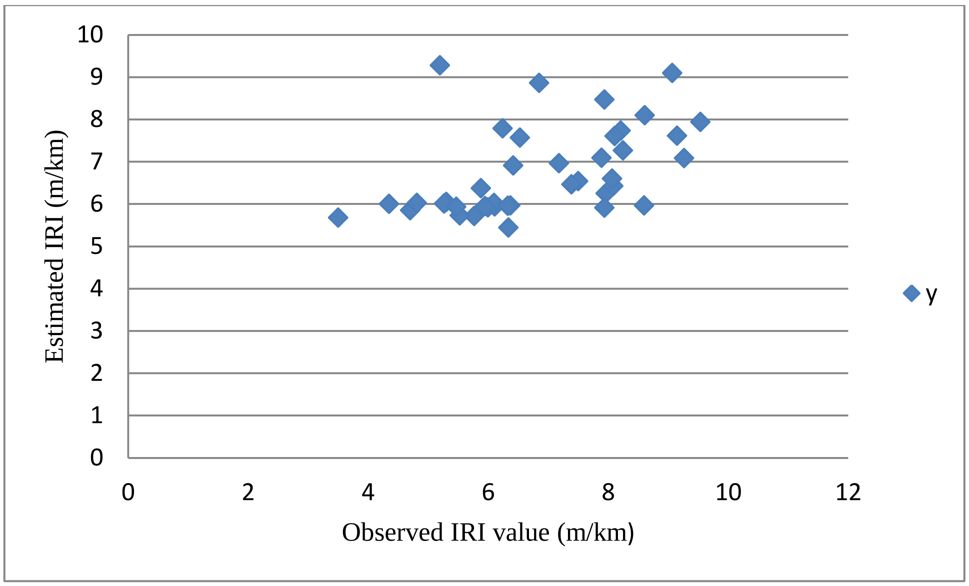

Fig. 5. 2 Observed and Estimated IRI value through ANN

5.4 Evaluation of Linear Regression Model ANN Model

The models are evaluated by comparing the observed and estimated IRI values of roads RR -8, RR-10, RR-11, RR-12. The comparison is shown in Annexure XIV and in following graphs:

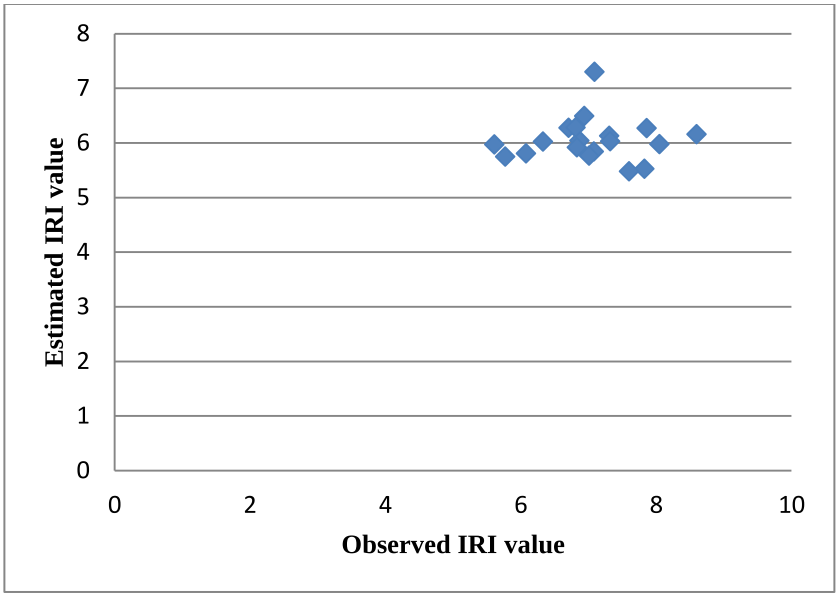

Fig. 5. 3Observed and Estimated IRI value by Linear regression model

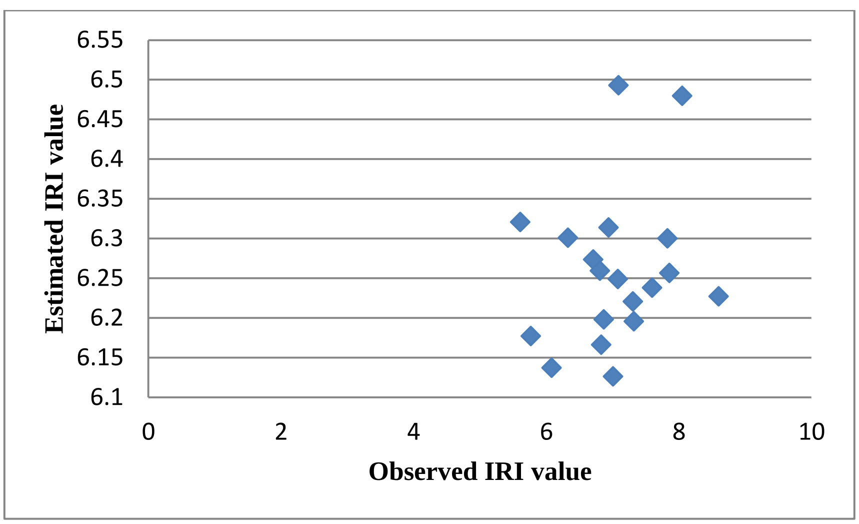

Fig. 5. 4 Observed and Estimated IRI value through ANN

The Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Relative Error (MARE) value is calculated as follows:

Table 5. 14 Model evaluation

Model (sample size 19)	**MAE**	**RMSE**	**MARE (%)**
Multiple Linear Regression	1.05	1.16	14
ANN	0.90117	0.93	12.22

5.4.1 Skid Resistance and MTD

The skid resistance test and Sand patch test was conducted on all 12 roads at an interval of 50m. The S.R. value and MTD value both fall within the recommended values for the rural roads. All the obtained values are shown in Appendix.

CHAPTER 6

CONCLUSION

From our project we can conclude that**:**

1. According to our distress parameters reading from 12 Rural roads only RR-5, RR-6, RR-11 are Fair and rest of the rural roads are good.

2. Out of 12 Rural roads, the observed IRI value of RR-2, RR-3, RR-6, RR-10, RR-11 have Fair surface profile whereas RR-5, RR-7 have frequent transverse undulation profile and rest of the roads have good surface profile.

3. The relationships between pavement roughness and distress parameters were obtained by Multiple Linear Regression and Artificial Neural Network (ANN). After obtaining the equations we found that the Mean Square Error of ANN is 23% less than the linear model. So the mean square error is indicate that the ANN model is a better model.

4. After the evaluation of the models it was found that the Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Relative Error (MARE) value of ANN model are less as compared to Linear model. Thus ANN model yields a better forecast of road roughness for a given set of distress parameters.

5. Significant difference between the obtained IRI value and estimated IRI value can be observed. This can be explained by the fact that the amount of input data is low.

6. All the roads can be considered safe on the basis of skid resistance value and mean textural depth data.

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APPENDIX

ANNEXURE I

Data collected for RR-1 i.e. Domehar - Waknaghat Road

Table 7. 1 Data collected for Domehar road

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	3.74	17.26	0	12.725	0
50-100	2.265	7.657	0	9.39	0
100-150	4.04	25.7503	0.0407	5.64	0
150-200	12.965	15.256	0.0054	14.81	0.01208
200-250	2.838	5.841	0	18.515	0
250-300	9.945	4.255	0	7.62	0
300-350	4.69	0	0.0112	2.835	0.0048
350-400	2.64	0	0.0155	7.2	0
400-450	2.905	6.26	0	4.02	0
450-500	1.605	0	0.0148	2.97	0
500-550	0.96	2.76	0	11.605	0
550-600	0	0	0	11.3	0
600-650	1.011	0	0		0
650-700	1.04	0	0	10.638	0
700-750	0	5.085	0	8.256	0
750-800	0	0	0.0164	6.12	0
800-850	1.519	0	0	0	0
850-900	0	4.76	0	0	0
900-950	0.895	0	0.0348	0	0
950-1000	0	0	0	0	0
1000-1050	0.54	0	0	0	0
1050-1100	0.465	2.375	0	0	0
1100-1150	0	0	0	5.223	0
1150-1200	0	0	0	5.4	0
1200-1250	1.836	5.67	0	0	0
1250-1300	0.93	0	0.0056	0	0
1300-1350	5.224	11.52	0	6.085	0
1350-1400	0.6695	0	0	0	0
1400-1450	1.74	0	0	0	0.0208

1450-1500	1.84	3.645	0	18.254	0.01
1500-1550	4.846	0	0.0022	13.02	0
1550-1600	0	0	0	12.61	0
1600-1650	0	0	0	0	0
1650-1700	0	3.505	0	0	0
1700-1750	1.44	3.24	0	15.01	0
1750-1800	1.338	0	0.084	2.075	0
1800-1850	3.36	3.15	0	6.405	0
1850-1900	6.32	0	0.0328	8.488	0
1900-1950	0	11.58	0	4.9725	0
1950-2000	3.04	0	0	0	0
2000-2050	1.93	0	0	20.297	0
2050-2100	4.245	0	0	0	0
2100-2150	0	0	0.0375	11.3205	0
2150-2200	0	0	0.0045	11.75	0
2200-2250	13.467	0	0	0	0
2250-2300	7.69	0	0.0672	24.005	0.001

Segment (m)	**Pot holes**	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0	16,11,8	61	0.505
50-100	0	18	63	0.603
100-150	0	12,17	60	0.836
150-200	0	0	62	0.618
200-250	0	0	63	0.698
250-300	0	0	60	0.732
300-350	0	15	61	0.806
350-400	0	17,14,21	48	0.907
400-450	0	0	56	0.618
450-500	0	0	52	0.732
500-550	0	0	56	0.809
550-600	0	0	55	0.827
600-650	0	0	62	0.846
650-700	0	0	63	0.865
700-750	0	0	60	0.884
750-800	0	18	54	0.902
800-850	0	19,15	59	0.921
850-900	0	12	59	0.940

900-950	0	16,16	61	0.959
950-1000	0	0	65	0.977
1000-1050	0	0	60	0.996
1050-1100	0	0	62	1.015
1100-1150	0	0	64	1.034
1150-1200	0	18.5,21,22.5	60	1.052
1200-1250	0.015394	0	56	1.071
1250-1300	0	0	61	1.090
1300-1350	0	0	64	1.109
1350-1400	0	0	63	1.128
1400-1450	0	18	60	1.146
1450-1500	0	17	61	1.165
1500-1550	0.000713	19,21	59	1.184
1550-1600	0	0	61	1.203
1600-1650	0	0	63	1.221
1650-1700	0	0	61	1.240
1700-1750	0	0	58	1.259
1750-1800	0	0	62	1.278
1800-1850	0	23	60	1.296
1850-1900	0	18.5	56	1.315
1900-1950	0	14.5,16.5	62	1.334
1950-2000	0	18	64	1.353
2000-2050	0	12	61	1.371
2050-2100	0	13,15.5	58	1.390
2100-2150	0	0	55	1.409
2150-2200	0	0	54	1.428
2200-2250	0	0	55	1.447
2250-2300	0	0	59	1.465

ANNEXURE II

Data collected for RR-2 i.e. Salogra-Ashwini Khad Road

Table 7. 2 Data collected for Ashwinikhad road

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	11.93	0	0	5.23	0
50-100	0.855	0	0	13.04	0
100-150	2.545	0	0.96	0	0
150-200	0.2	0	0	0	0
200-250	5.615	0	0	0	0
250-300	0.05	0	0	2.6	0
300-350	13.26	0	0	1.83	0
350-400	4.34	0	0	17.39	0
400-450	6.78	0	0	11.5	0
450-500	1.74	0	0	12.9	0
500-550	6.505	0	0	6.47	0
550-600	0	0	0	0	0
600-650	4.44	0	0	0	0
650-700	6.25	0	0	4.62	0
700-750	4.235	0	0	2.534	0
750-800	0	0	0	0	0
800-850	3.825	0	0	0	0
850-900	4.04	0	0	0	0
900-950	0	0	0	2.52	0
950-1000	10.715	0	0	0	0
1000-1050	9.54	0	0	0	0
1050-1100	0	0	0	0	0
1100-1150	6.135	0	0	3.63	0
1150-1200	0	0	0	0	0
1200-1250	0	0	0	1.144	0
1250-1300	0	0	0	0	0
1300-1350	5.75	0	0	0	0
1350-1400	0	0	0	0	0
1400-1450	0	0	0	1.026	0
1450-1500	0	0	0	1.53	0

1500-1550	5.67	0	0	0	0
1550-1600	2.83	0	0	0	0
1600-1650	2.696	0	0	0	0
1650-1700	0	0	0	0	0
1700-1750	0	0	0	1.6925	0
1750-1800	0	0	0	0	0
1800-1850	2.92	0	0	2.4375	0
1850-1900	3.1525	0	0	0	0
1900-1950	0	0	0	0.99	0
1950-2000	3.19	0	0	0.96	0
2000-2050	3.56	0	0	0	0
2050-2100	0	0	0	0	0
2100-2150	1.875	0	0	1.1028	0
2150-2200	4.08	0	0	0	0
2200-2250	0	0	0	0	0
2250-2300	0	0	0	1.2475	0
2300-2350	1.975	0	0.002275	1.125	0
2350-2400	0	0	0	2.265	0
2400-2450	0	0	0	0	0

Segment (m)	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
0-50	17	62	1.32
50-100	16,12	61	0.85
100-150	12.5,15	58	1.30
150-200	0	54	0.97
200-250	0	56	0.81
250-300	0	62	0.89
300-350	14,16	58	1.27
350-400	18,19,22	64	1.33
400-450	0	58	0.97
450-500	0	58	0.91
500-550	0	55	0.87
550-600	9,12	57	0.79
600-650	0	55	0.73
650-700	0	64	0.85
700-750	10,12	62	1.19

750-800	0	60	1.06
800-850	0	60	0.70
850-900	0	58	0.65
900-950	0	59	0.79
950-1000	0	55	0.84
1000-1050	0	57	0.91
1050-1100	0	56	0.91
1100-1150	15,18	58	1.05
1150-1200	0	60	1.16
1200-1250	0	65	0.89
1250-1300	16.5	63	0.72
1300-1350	14,16,10	62	0.79
1350-1400	0	63	0.79
1400-1450	21,13	61	0.97
1450-1500	16,18.5	62	1.05
1500-1550	0	55	0.87
1550-1600	0	56	1.05
1600-1650	0	58	1.04
1650-1700	0	62	0.97
1700-1750	0	57	0.80
1750-1800	0	52	0.84
1800-1850	23	56	1.16
1850-1900	16.5,14	59	1.00
1900-1950	0	62	1.07
1950-2000	0	63	0.91
2000-2050	0	57	0.84
2050-2100	0	59	1.01
2100-2150	0	55	0.74
2150-2200	0	54	0.91
2200-2250	16	58	1.16
2250-2300	21,9,8	61	0.98
2300-2350	0	52	1.18
2350-2400	0	53	1.32
2400-2450	15,11	59	0.76

ANNEXURE III

Data collected for RR-3 i.e. Kyari Bangla Road.

No presence of Potholes and Patching in this road.

Table 7. 3 Data collected for Kyari Bangla Road.

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	0	0	0	1.28	0
50-100	0	0	0	0	0
100-150	0	0	0	2.795	0
150-200	0	0	0	3.275	0
200-250	0	0	0	0	0
250-300	0	0	0	0	0
300-350	0	0	0	3.59	0
350-400	0	0	0	3.67	0
400-450	153.18	0	0	0	0
450-500	0	0	0	4.47	0
500-550	0	0	0	0	0
550-600	0	0	0	4.495	0
600-650	0	0	0	0	0
650-700	0	0	0	0	0
700-750	0	0	0.004	6.645	0
750-800	0	0	0	2.295	0
800-850	0	0	0	1.335	0
850-900	0	0	0	4.23	0
900-950	0	0	0	0.715	0
950-1000	0	0	0		0
1000-1050	0	0	0	0.495	0
1050-1100	0	0	0	2.31	0
1100-1150	0	0	0	0.76	0
1150-1200	0	0	0	1.23	0
1200-1250	0	0	0	1.065	0
1250-1300	0	0	0	0	0
1300-1350	0	0	0	0.48	0
1350-1400	0	0	0	0	0
1400-1450	0	0	0	0	0

1450-1500	0	0	0	0	0
1500-1550	0	0	0	1.2925	0
1550-1600	0	0	0	0	0
1600-1650	0	0	0	2.19	0
1650-1700	0	0	0	0	0
1700-1750	0	0	0	0	0
1750-1800	0	0	0	0	0
1800-1850	0	0	0	0.945	0
1850-1900	0	0	0	0	0
1900-1950	0	0	0	0.96	0
1950-2000	0	0	0	0	0
2000-2050	0	0	0	0.845	0
2050-2100	0	0	0	0	0
2100-2150	0	0	0	0	0
2150-2200	0	0	0	0	0
2200-2250	0	0	0	0.99	0
2250-2300	0	0	0	0	0
2300-2350	0	0	0	0	0
2350-2400	0	0	0	0	0
2400-2450	0	0	0	0	0

Segment (m)	**Rut depth(mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
0-50	15	62	1.32
50-100	0	63	1.34
100-150	0	61	1.26
150-200	0	60	1.04
200-250	0	58	1.02
250-300	0	57	0.94
300-350	0	61	1.06
350-400	16	63	1.33
400-450	8,9	62	1.05
450-500	14	59	1.08
500-550	12,13	58	1.02
550-600	0	59	1.11

600-650	0	62	1.32
650-700	0	63	1.44
700-750	0	63	1.19
750-800	0	62	1.06
800-850	18	61	1.26
850-900	16	60	1.00
900-950	17	59	0.94
950-1000	12	58	1.02
1000-1050	11,9	56	0.94
1050-1100	0	57	1.26
1100-1150	0	58	1.20
1150-1200	0	57	1.15
1200-1250	0	61	1.37
1250-1300	0	62	1.06
1300-1350	0	52	1.02
1350-1400	0	61	0.94
1400-1450	0	51	1.23
1450-1500	0	50	1.05
1500-1550	0	63	1.02
1550-1600	0	64	1.05
1600-1650	0	58	1.12
1650-1700	9,7	57	0.97
1700-1750	11,12	59	1.11
1750-1800	0	56	1.32
1800-1850	0	59	1.16
1850-1900	0	53	1.06
1900-1950	0	55	1.07
1950-2000	0	56	0.91
2000-2050	18	58	0.94
2050-2100	0	60	1.01
2100-2150	0	62	1.04
2150-2200	16,12	63	0.91
2200-2250	0	58	1.16
2250-2300	0	54	0.98
2300-2350	8	55	1.26
2350-2400	0	56	1.37
2400-2450	0	53	1.08

ANNEXURE IV

Data collected for RR-4 i.e. Basha Road

No data for Mapped and Transverse cracking was obtained on this road.

Table 7. 4 Data collected for Basha Road

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking Longitudinal Area (sq. m)
0-50	1.05	0.469	0
50-100	4.4361	0	0
100-150	2.1358	0	0
150-200	5.02	0	0
200-250	1.1956	0	0
250-300	0.102	0	0
300-350	0	0	0
350-400	0.22	4.5335	0
400-450	0	0	0
450-500	1.5	0	0
500-550	0.315	0	0
550-600	0	0	0
600-650	0	0	0
650-700	0.35	0	0.0153
700-750	0	0	0
750-800	0	0	0
800-850	0	0	0
850-900	0	0	0
900-950	0	0	0
950-1000	0	0	0
1000-1050	0.95	0	0
1050-1100	0	0	0
1100-1150	0	0	0
1150-1200	0	0	0
1200-1250	0	0	0
1250-1300	2.1325	0	0.0084

1300-1350	0.945	0	0
1350-1400	0	0	0
1400-1450	0	0	0.2135
1450-1500	0	0	0
1500-1550	0	0	0
1550-1600	0	0	0
1600-1650	1.05	0	0
1650-1700	0	0	0
1700-1750	0	0	0
1750-1800	0	0	0
1800-1850	0	0	0
1850-1900	0	0	0
1900-1950	0	0	0
1950-2000	0	0	0
2000-2050	3.1175	0	0
2050-2100	0	0	0
2100-2150	0	0	0
2150-2200	0	0	0
2200-2250	0	0	0
2250-2300	0.48	0	0
2300-2350	0	0	0
2350-2400	0	0	0
2400-2450	0	0	0
2450-2500	0	0	0

Segment (m)	Pot holes	Rut depth (mm)	Skid Resistance Value (SRV)	Mean Texture Depth (mm)
	Volume (cubic m)			
0-50	0	11	57	0.94
50-100	0	0	55	0.81
100-150	0	0	58	0.85
150-200	0	0	56	0.97
200-250	0.0294109	12,14	59	0.87
250-300	0	10,15.5	55	0.91
300-350	0	0	57	1.20
350-400	0	0	53	1.23
400-450	0	0	56	0.94
450-500	0	16	57	0.93
500-550	0	17	59	0.78
550-600	0	12	56	0.91
600-650	0	9,10	54	0.85
650-700	0	9	59	1.00
700-750	0	11,12	59	1.04
750-800	0	0	56	0.78
800-850	0	0	54	0.72
850-900	0	0	58	0.71
900-950	0	0	60	0.76
950-1000	0	0	62	1.00
1000-1050	0	0	56	0.94
1050-1100	0	0	58	1.11
1100-1150	0	0	54	1.02
1150-1200	0	0	51	1.02
1200-1250	0	0	56	0.89
1250-1300	0	0	57	0.98
1300-1350	0	0	63	0.73
1350-1400	0	0	61	0.85
1400-1450	0	11,8	58	0.96
1450-1500	0	0	63	1.05
1500-1550	0	14	60	0.97
1550-1600	0	0	55	0.96

1600-1650	0	0	56	1.07
1650-1700	0	0	58	1.02
1700-1750	0	0	61	0.87
1750-1800	0	0	59	0.94
1800-1850	0	16	58	0.99
1850-1900	0	11,8	53	0.96
1900-1950	0	8	55	1.08
1950-2000	0	15	59	0.78
2000-2050	0	0	60	0.91
2050-2100	0	0	61	0.87
2100-2150	0	0	61	1.02
2150-2200	0	0	58	0.94
2200-2250	0	0	57	0.88
2250-2300	0	0	56	0.91
2300-2350	0	0	60	0.81
2350-2400	0	0	62	1.05
2400-2450	0	0	58	0.97
2450-2500	0	0	59	0.96

ANNEXURE V

Data collected for RR-5 i.e. Industrial Road

No data of patching was obtained for this road

Table 7. 5 Data collected for Industrial Road

Segment (m)	**Raveling (sq. meter)**	**Cracking**		
		Longitudinal	Mapped	Transverse
		Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	16.5315	0	0	0
50-100	62.07	0	0	0
100-150	46.76	0	0	0
150-200	100.43	0	0	0
200-250	28.618	0.02404	0	0
250-300	42.235	0	0	0
300-350	14.36	0	0	0
350-400	37.41	0.01653	0	0
400-450	22.74	0.0536	0	0
450-500	61.24	0.036	0	0
500-550	32.725	0	0	0
550-600	133.26	0	0	0
600-650	47.77	0	0	0
650-700	50.72	0	0	0
700-750	66.155	0	0	0
750-800	78.99	0	0	0
800-850	46.93	0	0	0
850-900	42.85	0	0	0
900-950	41.7	0.04583	0	0
950-1000	140.54	0	0	0
1000-1050	32.348	0.0075	0	0
1050-1100	29.72	0.0224	0	0
1100-1150	28.88	0	0	0
1150-1200	161.96	0	0	0
1200-1250	84.464	0.062	0	0
1250-1300	27.795	0.0492	0	0
1300-1350	166	0	0	0
1350-1400	73.15	0	0	0

1400-1450	52.62	0	0	0
1450-1500	30.312	0	0	0
1500-1550	118.689	0	0	0
1550-1600	13.472	0	0	0
1600-1650	35.545	0	0	0
1650-1700	16.38	0.0324	0	0
1700-1750	56.64	0	0	0
1750-1800	57.01	0	0	0
1800-1850	38.28	0.0276	0	0
1850-1900	24.185	0	0	0
1900-1950	12.97	0	0	0
1950-2000	31.465	0.0398	0	0
2000-2050	0	0.0156	0	0
2050-2100	0	0.0948	0	0.00303
2100-2150	94.735	0	0	0
2150-2200	35.635	0	0	0
2200-2250	52.192	0	0	0
2250-2300	33.24	0	0	0
2300-2350	0	0.0288	0	0.6666
2350-2400	0	0.0044	0	0
2400-2450	0	0	0	0
2450-2500	0	0	0	0

Segment (m)	**Pot holes**	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0.063	0.00	64	1.59
50-100	0.069	0.00	65	1.28
100-150	0	26.00	66	1.39
150-200	0.017	11,14	64	1.27
200-250	0	0.00	63	1.52
250-300	0	0.00	62	1.68
300-350	0	0.00	63	1.39
350-400	0	18.00	60	1.32
400-450	0	16,18	59	1.26
450-500	0.005	11,12,8	62	1.15
500-550	0	0.00	61	1.26
550-600	0	0.00	58	1.44

600-650	0	0.00	64	1.59
650-700	0	0.00	65	1.52
700-750	0	0.00	66	1.19
750-800	0.013	17.5,12	62	1.52
800-850	0.002	0.00	63	1.53
850-900	0	0.00	64	1.37
900-950	0	0.00	57	1.16
950-1000	0	0.00	60	1.32
1000-1050	0	0.00	59	1.44
1050-1100	0	21.00	61	1.34
1100-1150	0	16,15.5	64	1.26
1150-1200	0.018	0.00	63	1.16
1200-1250	0	10,14,7	65	1.11
1250-1300	0	0.00	56	0.98
1300-1350	0	0.00	63	1.00
1350-1400	0	0.00	64	1.25
1400-1450	0	0.00	62	1.18
1450-1500	0	0.00	59	1.25
1500-1550	0	0.00	60	1.12
1550-1600	0	0.00	58	1.08
1600-1650	0	21.00	62	1.24
1650-1700	0	19.00	63	1.37
1700-1750	0	15,9	64	1.02
1750-1800	0	0.00	64	0.80
1800-1850	0	0.00	63	0.87
1850-1900	0	14.00	61	0.84
1900-1950	0	0.00	60	0.76
1950-2000	0.011	0.00	63	0.78
2000-2050	0	0.00	63	0.88
2050-2100	0	0.00	58	0.79
2100-2150	0	12.00	59	0.85
2150-2200	0	0.00	56	0.91
2200-2250	0	0.00	55	0.76
2250-2300	0.048	0.00	58	0.84
2300-2350	0	0.00	57	0.79
2350-2400	0	0.00	59	0.84
2400-2450	0	10,12	57	0.81
2450-2500	0	0.00	60	

ANNEXURE VI

Data collected for RR-6 i.e. Salana Road

Table 7. 6 Data collected for Salana Road

Segment (m)	Raveling (sq. m)	Patching (sq. m)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	30.464	11.515	0.0028	8.36	0.0012
50-100	9.41	4.06	0.0048	10.21	0
100-150	23.755	10.1445	0	0	0
150-200	38.53	0	0.014	25.695	0
200-250	26.498	0	0	13.655	0.0032
250-300	27.62	10.98	0.0158	5.45	0
300-350	12.105	10.41	0	0	0
350-400	42.295	51.804	0	1.32	0
400-450	14.4	26.5025	0	0	0
450-500	9.51	3.917	0	18.765	0
500-550	16.56	23.51	0.0028	21.23	0
550-600	15.48	3.44	0	9.275	0
600-650	6.12	5.15	0	0	0
650-700	23.11	1.84	0.0032	7.29	0
700-750	21.21	0	0	0	0
750-800	0	0	0	9.895	0
800-850	55.541	0	0.0416	6.615	0
850-900	0	0	0	0	0
900-950	50.16	0	0	0	0
950-1000	0	0	0	0	0
1000-1050	0	0	0.0332	7.875	0
1050-1100	17.34	0	0	0	0
1100-1150	17.58	0	0	0	0
1150-1200	0	0	0	0	0
1200-1250	9.12	0	0	0	0
1250-1300	0	0	0	0	0
1300-1350	4.53	0	0.0084	2.25	0
1350-1400	8.8025	0	0	0	0
1400-1450	0	0	0	0	0

1450-1500	12.58	0	0.0092	4.51	0
1500-1550	3.225	0	0	0	0
1550-1600	16.95	0	0	0	0
1600-1650	8.635	0	0	0	0
1650-1700	8.595	0	0	0	0
1700-1750	3.83	1.02	0	0	0
1750-1800	4.105	0	0	0	0
1800-1850	0	0	0.0048	9.77	0
1850-1900	26.975	0	0	0	0
1900-1950	5.565	0	0	0	0
1950-2000	9.37	0	0	0	0
2000-2050	0	0	0	0	0
2050-2100	15.47	0	0	0	0
2100-2150	3.78	0	0	0	0
2150-2200	10.824	0	0	0	0
2200-2250	0	0	0.006	6.515	0
2250-2300	15.89	0	0	0	0
2300-2350	14.74	0	0	0	0
2350-2400	11.285	0	0	0	0
2400-2450	18.79	0	0	0	0
2450-2500	18.19	0	0	0	0

Segment (m)	**Pot holes**	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0.001	19.0	57	0.887
50-100	0.003	14,12	58	0.855
100-150	0	0.0	59	1.140
150-200	0	0.0	55	1.204
200-250	0	12.0	52	1.144
250-300	0	0.0	63	1.269
300-350	0	0.0	60	0.987
350-400	0	0.0	57	1.225
400-450	0	0.0	55	1.153
450-500	0	11.0	57	0.980
500-550	0	13.0	59	1.061
550-600	0	12.0	54	0.942

600-650	0	0.0	56	0.907
650-700	0	0.0	61	0.987
700-750	0.008	0.0	58	0.887
750-800	0	0.0	55	0.893
800-850	0.033	11,15	58	0.964
850-900	0	0.0	62	1.194
900-950	0.004	0.0	54	0.972
950-1000	0	0.0	55	0.784
1000-1050	0	15,10	57	0.848
1050-1100	0.048	0.0	56	0.907
1100-1150	0	0.0	51	1.061
1150-1200	0	0.0	54	0.914
1200-1250	0.005	0.0	56	0.861
1250-1300	0	0.0	51	1.053
1300-1350	0	0.0	50	1.036
1350-1400	0	0.0	56	0.887
1400-1450	0	0.0	54	0.848
1450-1500	0	0.0	49	0.836
1500-1550	0	0.0	54	0.972
1550-1600	0	9,8.5	52	0.957
1600-1650	0	12.0	56	1.053
1650-1700	0	16.0	59	0.935
1700-1750	0.017	0.0	60	1.027
1750-1800	0.004	0.0	61	0.887
1800-1850	0	0.0	62	0.972
1850-1900	0	0.0	60	0.824
1900-1950	0	0.0	50	0.874
1950-2000	0	8.0	56	0.942
2000-2050	0	0.0	57	0.887
2050-2100	0	5,8,12	52	0.987
2100-2150	0	0.0	54	0.887
2150-2200	0	0.0	51	0.842
2200-2250	0	0.0	53	1.011
2250-2300	0	0.0	58	0.807
2300-2350	0	0.0	56	0.842
2350-2400	0	11.0	59	0.987
2400-2450	0	0.0	61	0.914
2450-2500	0	0.0	56	0.874

ANNEXURE VII

Data collected for RR-7 i.e. Lagroo Road

Table 7. 7 Data collected for Lagroo Road

Segment (m)	Raveling (sq. m)	Patching (sq. m)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	35.154	4.24	0	0	0
50-100	42.98	0	0	0	0
100-150	66.27	0	0	0	0
150-200	56.98	0	0	0	0
200-250	43.14	1.2	0	0	0
250-300	165	0	0	0	0
300-350	122.1	0	0	0	0
350-400	65.13	0	0	0	0
400-450	4.53	0	0	0	0
450-500	31.492	0	0	0	0
500-550	24.19	1.04	0	0	0
550-600	50.18	0	0	0	0
600-650	0	0	0.021	7.51	0
650-700	5.275	0	0.0464	4.505	0
700-750	63.715	0	0	0	0
750-800	46.665	0	0	4.085	0
800-850	17.72	4.62	0	0	0
850-900	34.645	0	0	0	0
900-950	22.25	0	0	0	0
950-1000	31.141	0	0	5.46	0
1000-1050	37.835	0	0	0	0
1050-1100	27.635	0	0	0	0
1100-1150	15.432	0	0	2.325	0
1150-1200	34.32	0	0	0	0
1200-1250	20.592	0	0	0	0
1250-1300	19.28	0	0	0	0
1300-1350	14.56	0	0	0	0
1350-1400	23.42	0	0	0	0
1400-1450	10.01	0	0	0	0

1450-1500	10.91	0	0	0	0
1500-1550	25.84	0	0	0	0
1550-1600	14.775	0	0	0	0
1600-1650	8.9	0	0.0172	0	0
1650-1700	17.175	0		0	0
1700-1750	6.72	0		0	0
1750-1800	6.855	0		0	0
1800-1850	8.72	0		0	0
1850-1900	0	0		0	0
1900-1950	4.27	0		0	0
1950-2000	4.08	0		0	0
2000-2050	13.42	0		0	0
2050-2100	5.15	0		2.79	0
2100-2150	12.525	0		0	0
2150-2200	8.025	0		0	0
2200-2250	6.02	0		0	0
2250-2300	0	0	0.0056		0.0024
2300-2350	0	0	0	0	0
2350-2400	9.075	0	0	0	0
2400-2450	6.39	0	0	0	0
2450-2500	4.8	0	0	0	0

Segment (m)	**Pot holes**	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0.071	16.0	60	1.17
50-100	0.003	14.0	58	0.90
100-150	0.018	0.0	57	1.14
150-200	0.010	0.0	64	1.27
200-250	0.021	0.0	52	0.99
250-300		0.0	54	1.23
300-350		11,10	65	1.15
350-400	0.019	9,7	68	0.98
400-450		15.5,17	56	1.06
450-500		0.0	54	1.28
500-550	0.016	0.0	52	1.06

550-600		0.0	52	0.99
600-650		0.0	48	1.16
650-700		0.0	65	0.89
700-750		21.0	60	0.96
750-800		14.0	62	1.19
800-850	0.009	0.0	56	0.84
850-900		0.0	60	1.33
900-950		16.0	54	0.85
950-1000		0.0	52	1.05
1000-1050		18.0	53	0.89
1050-1100		12.0	55	0.96
1100-1150		13,9	54	1.17
1150-1200		0.0	52	1.05
1200-1250		0.0	54	1.12
1250-1300		0.0	56	0.89
1300-1350		0.0	54	1.10
1350-1400		0.0	58	0.98
1400-1450		0.0	59	0.97
1450-1500		0.0	54	0.87
1500-1550		12,11	56	0.84
1550-1600		9,6,10	59	0.99
1600-1650	0.021	0.0	56	1.03
1650-1700		0.0	58	0.89
1700-1750		0.0	56	1.13
1750-1800		0.0	54	1.05
1800-1850		0.0	55	1.07
1850-1900		0.0	56	1.14
1900-1950	0.010	12.0	57	0.82
1950-2000		9.0	54	0.85
2000-2050		0.0	56	0.94
2050-2100		0.0	56	0.84
2100-2150		0.0	56	1.01
2150-2200		0.0	58	0.70
2200-2250		0.0	59	0.85
2250-2300		9.0	55	0.74
2300-2350	0	0.0	54	1.26
2350-2400	0	0.0	59	0.91
2400-2450	0	0.0	57	1.05
2450-2500	0	0.0	57	0.91

ANNEXURE VIII

Data collected for RR-8 i.e. Wakna link.

No data for patching was obtained.

Table 7. 8 Data collected for Wakna link road

Segment (m)	Raveling (sq. m)	Cracking		
		Longitudinal	Mapped	Transverse
		Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	2.632	0	0	0
50-100	1.0295	0.0024	0.42	0
100-150	4.1425	0	0	0
150-200	3.342	0	0	0
200-250	0	0	0	0
250-300	5.606	0	0	0
300-350	1.807	0	0	0
350-400	0	0	0	0
400-450	1.89	0	0	0
450-500	0	0	0	0
500-550	0.128	0	0	0
550-600	0	0	0	0
600-650	0	0	0	0
650-700	0	0.0064	0	0
700-750	0.741	0	0	0
750-800	0	0	0	0
800-850	0	0	0	0
850-900	0	0	0	0
900-950	0	0	0	0
950-1000	7.025	0	0	0
1000-1050	0.48	0	0	0
1050-1100	2.055	0.0066	0	0
1100-1150	0	0	0	0
1150-1200	0.32	0	0	0
1200-1250	0.285	0	0	0
1250-1300	3.075	0	0	0
1300-1350	0	0	0	0
1350-1400	0.48	0	0	0

1400-1450	0	0.0036	0	0
1450-1500	0	0	0	0
1500-1550	0	0	0	0
1550-1600	0	0	0	0
1600-1650	0	0	0	0
1650-1700	0	0	0	0
1700-1750	0	0.0072	0.05	0
1750-1800	2.31	0	0	0
1800-1850	0	0	0	0
1850-1900	0	0	0	0
1900-1950	0	0	0	0
1950-2000	0	0	0	0
2000-2050	0	0	0	0
2050-2100	0	0	0	0
2100-2150	0	0	0	0

Segment (m)	**Pot holes**	**Rut depth (mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0	**8.00**	60	
50-100	0	9,5	61	1.19
100-150	0	0.00	58	1.05
150-200	0	0.00	57	1.04
200-250	0	0.00	59	0.00
250-300	0	0.00	62	1.26
300-350	0	10,12	64	0.91
350-400	0	0.00	61	1.39
400-450	0	0.00	58	1.40
450-500	0	0.00	53	1.28
500-550	0.001414	6,8	62	1.07
550-600	0	0.00	61	0.83
600-650	0	0.00	59	1.16
650-700	0	0.00	57	0.89
700-750	0	0.00	64	1.14
750-800	0	0.00	55	0.80
800-850	0	0.00	57	1.10

850-900	0	0.00	59	1.14
900-950	0	0.00	59	1.15
950-1000	0	0.00	60	1.18
1000-1050	0	15.00	63	0.90
1050-1100	0	12,9	61	0.84
1100-1150	0	0.00	56	0.81
1150-1200	0	0.00	59	0.87
1200-1250	0	0.00	62	0.96
1250-1300	0	0.00	60	1.16
1300-1350	0	0.00	57	0.84
1350-1400	0	9,10,12	55	0.98
1400-1450	0	0.00	53	0.97
1450-1500	0	0.00	56	0.78
1500-1550	0	15.00	63	0.78
1550-1600	0	0.00	61	0.94
1600-1650	0	0.00	60	1.03
1650-1700	0	09,10	62	0.89
1700-1750	0	0.00	58	0.92
1750-1800	0	0.00	64	1.49
1800-1850	0	0.00	59	1.00
1850-1900	0	12.00	62	0.91
1900-1950	0	8.00	60	0.87
1950-2000	0	14.00	59	0.72
2000-2050	0	0.00	58	1.53
2050-2100	0	0.00	57	1.00
2100-2150	0	8,6	54	0.83

ANNEXURE IX

Data collected for RR-9 i.e.Saij Road.

Table 7. 9 Data collected for Saij Road.

Segment (m)	**Raveling (sq. meter)**	**Patching (sq. meter)**	Longitudinal Area (sq. m)	Mapped Area (sq. m)	Transverse Area (sq. m)
0-50	0	0	0	0	0
50-100	0	0	0	0	0
100-150	0	0	0	0	0
150-200	0	0	0	0	0
200-250	0	0	0	0.2	0
250-300	0	0	0	0	0
300-350	0	0	0	0	0
350-400	0	0	0	0	0
400-450	0	0	0	0.27	0
450-500	0	0	0	0	0
500-550	0	0	0	0	0
550-600	0	0	0	0	0
600-650	0	0	0	0	0
650-700	0	0	0	0	0
700-750	0	0	0	0	0
750-800	0	0	0	0	0
800-850	0	0	0	0	0
850-900	0	0	0	0	0
900-950	0	0	0	0	0
950-1000	0	0	0	0.22	0
1000-1050	0	0	0	0	0
1050-1100	0	0	0	0	0
1100-1150	0	0	0	0	0
1150-1200	0	0	0	0	0
1200-1250	0	0	0	0	0
1250-1300	0	0	0	0	0
1300-1350	0	0	0	0	0
1350-1400	0	0	0	0	0
1400-1450	0	0	0	0	0
1450-1500	0	0	0	0	0

1500-1550	0	0	0	0	0
1550-1600	0	0	0	0	0
1600-1650	0	0	0	0	0
1650-1700	0	0	0	0	0
1700-1750	0	0	0	0	0
1750-1800	0	0	0	0	0
1800-1850	0	0	0	0	0
1850-1900	0	0	0	0	0
1900-1950	0	0	0	0	0
1950-2000	0	0	0	0	0
2000-2050	0	0	0	0	0
2050-2100	0	0	0	0	0
2100-2150	0	0	0.0015	0	0
2150-2200	0	0	0	0	0
2200-2250	0	0	0	0	0
2250-2300	0	0	0	0	0
2300-2350	0	0	0	0	0
2350-2400	0	0	0	0	0
2400-2450	0	0	0	0	0

Segment (m)	**Rut depth(mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
0-50	11.00	58	0.86
50-100	0.00	62	0.84
100-150	0.00	56	0.81
150-200	0.00	60	0.74
200-250	0.00	58	0.80
250-300	10,9,15	54	0.91
300-350	0.00	62	0.92
350-400	0.00	58	0.83
400-450	0.00	56	0.91
450-500	0.00	63	0.74
500-550	0.00	64	0.99
550-600	0.00	58	0.89
600-650	0.00	60	0.97
650-700	0.00	54	0.72
700-750	0.00	58	0.74

750-800	0.00	60	0.84
800-850	0.00	59	1.01
850-900	0.00	57	0.86
900-950	6,8	58	0.72
950-1000	0.00	59	0.97
1000-1050	0.00	54	0.81
1050-1100	0.00	56	0.84
1100-1150	12.00	58	0.81
1150-1200	14.50	60	0.87
1200-1250	11.00	61	0.96
1250-1300	0.00	62	1.16
1300-1350	0.00	55	0.84
1350-1400	0.00	59	0.98
1400-1450	0.00	57	0.97
1450-1500	0.00	63	0.78
1500-1550	0.00	52	0.78
1550-1600	0.00	54	0.95
1600-1650	0.00	59	1.03
1650-1700	0.00	61	0.89
1700-1750	0.00	58	0.92
1750-1800	12.00	56	1.49
1800-1850	0.00	62	1.00
1850-1900	011,8	58	0.91
1900-1950	0.00	54	0.87
1950-2000	0.00	63	0.72
2000-2050	0.00	55	1.53
2050-2100	0.00	64	1.00
2100-2150	0.00	62	0.83
2150-2200	0.00	61	1.08
2200-2250	0.00	54	0.73
2250-2300	0.00	60	0.74
2300-2350	0.00	56	1.26
2350-2400	0.00	59	0.91
2400-2450	14,9	62	1.05

ANNEXURE X

Data collected for RR 10 i.e. Chail road

No data for pothole was found.

Table 7. 10 Data collected for Chail road

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	0	0	0	0	0
50-100	0	0	0	0	0
100-150	0	0	0	0	0
150-200	0	0	0	0	0
200-250	0	0	0	0.2	0
250-300	0	0	0	0	0
300-350	0	0	0	0	0
350-400	0	0	0	0	0
400-450	0	0	0	0.27	0
450-500	0	0	0	0	0
500-550	0	0	0	0	0
550-600	0	0	0	0	0
600-650	0	0	0	0	0
650-700	0	0	0	0	0
700-750	0	0	0	0	0
750-800	0	0	0	0	0
800-850	0	0	0	0	0
850-900	0	0	0	0	0
900-950	0	0	0	0	0
950-1000	0	0	0	0.22	0
1000-1050	0	0	0	0	0
1050-1100	0	0	0	0	0
1100-1150	0	0	0	0	0
1150-1200	0	0	0	0	0
1200-1250	0	0	0	0	0
1250-1300	0	0	0	0	0
1300-1350	0	0	0	0	0
1350-1400	0	0	0	0	0
1400-1450	0	0	0	0	0
1450-1500	0	0	0	0	0

1500-1550	0	0	0	0	0
1550-1600	0	0	0	0	0
1600-1650	0	0	0	0	0
1650-1700	0	0	0	0	0
1700-1750	0	0	0	0	0
1750-1800	0	0	0	0	0
1800-1850	0	0	0	0	0
1850-1900	0	0	0	0	0
1900-1950	0	0	0	0	0
1950-2000	0	0	0	0	0
2000-2050	0	0	0	0	0
2050-2100	0	0	0	0	0
2100-2150	0	0	0.0015	0	0
2150-2200	0	0	0	0	0
2200-2250	0	0	0	0	0
2250-2300	0	0	0	0	0
2300-2350	0	0	0	0	0
2350-2400	0	0	0	0	0
2400-2450	0	0	0	0	0

Segment (m)	Rut Depth (mm)	Skid Resistance Value (SRV)	Mean Texture Depth (mm)
0-50	0	61	0.76
50-100	0	59	1.06
100-150	0	56	0.97
150-200	12,11,9	58	1.01
200-250	0	57	1.28
250-300	0	65	1.21
300-350	0	60	0.97
350-400	0	69	0.87
400-450	0	65	0.99
450-500	16	54	0.74
500-550	18	56	0.97
550-600	14,12	53	1.05
600-650	0	63	0.89
650-700	0	55	1.28
700-750	15	60	1.24

750-800	0	61	1.16
800-850	0	59	0.90
850-900	0	64	1.15
900-950	0	55	1.37
950-1000	0	63	1.16
1000-1050	0	64	1.04
1050-1100	0	62	0.92
1100-1150	9,12,16	61	1.34
1150-1200	0	60	1.03
1200-1250	0	56	1.16
1250-1300	0	54	0.91
1300-1350	0	57	0.81
1350-1400	0	58	1.00
1400-1450	0	56	1.13
1450-1500	0	54	1.04
1500-1550	0	60	1.42
1550-1600	12	63	1.12
1600-1650	14.5	59	1.08
1650-1700	11,8	52	0.90
1700-1750	0	55	0.79
1750-1800	0	58	0.99
1800-1850	0	56	0.90
1850-1900	0	61	1.14
1900-1950	0	62	0.84
1950-2000	0	63	1.40
2000-2050	18	55	0.78
2050-2100	19	64	0.90
2100-2150	0	62	1.07
2150-2200	0	61	1.30
2200-2250	0	54	0.91
2250-2300	9,8,12	60	0.94
2300-2350	0	56	0.84
2350-2400	0	59	1.10
2400-2450	14.5	62	0.82

ANNEXURE XI

Data collected for RR-11 i.e. Nain road.

Table 7. 11 Data collected for Nain road.

Segment (m)	Raveling (sq. meter)	Patching (sq. meter)	Cracking		
			Longitudinal	Mapped	Transverse
			Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	8.155	5.56	0	2.0725	0
50-100	3.02	6.62	0	4.3	0
100-150	5.01	5.21	0	2.325	0
150-200	3.77	6.295	0	2.945	0
200-250	5.845	2.88	0	11.64	0
250-300	5.57	0	0	6.04	0
300-350	2.7	4.84	0	1.9475	0
350-400	3.12	0	0	0	0
400-450	2.74	2.31	0	0	0
450-500	8.115	0	0	2.62	0
500-550	3.6	1.26	0	2.4	0
550-600	0	0	0	0	0
600-650	4.58	0	0	0	0
650-700	1.64	2.04	0	6.5425	0
700-750	0	0	0	2.4245	0
750-800	0	0	0	0	0
800-850	2.09	0	0	0	0
850-900	2.48	3	0	0	0
900-950	1.47	0	0	2.59	0
950-1000	0	0	0	0	0
1000-1050	2.55	0	0	0	0
1050-1100	2.71	0	0	2.185	0
1100-1150		0	0	0	0
1150-1200	2.28	0	0	4.34	0
1200-1250	3.58	0.27	0	2.88	0
1250-1300	0.56	0.96	0	0	0
1300-1350	1.245	0.48	0	4.685	0
1350-1400	0	0	0	0	0
1400-1450	1.48	3.025	0	2.72	0
1450-1500		0	0	0	0

1500-1550	1.59	0	0	13.0222	0
1550-1600		0	0.0022	7.6528	0
1600-1650	1.24	1.08	0	0	0
1650-1700	1.338	0	0	0	0
1700-1750	4.38	0.855	0	6.56	0
1750-1800	1.94	0	0	0.8125	0
1800-1850	2.88	0.88	0	7.395	0
1850-1900	1.73	0	0	5.378	0
1900-1950	2.91	0.36	0	5.095	0
1950-2000	0	0	0	0	0
2000-2050	0	0	0	3.72	0
2050-2100	3.445	0	0	0	0
2100-2150	4.4	0	0	6.83	0
2150-2200	0	0	0.00485	6.18	0
2200-2250	3.06	0	0	0	0
2250-2300	0.62	1.13	0	0	0
2300-2350	0	0	0	0	0
2350-2400	1.557	0.825	0	0	0
2400-2450	0	0	0	1.02	0
2450-2500	0	0	0	0	0

Segment (m)	**Pot holes**	**Rut depth(mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
	Volume (cubic m)			
0-50	0.000	21,9	63	0.87
50-100	0.00565	11,12	66	0.91
100-150	0.00318	0.0	64	1.40
150-200	0	0.0	68	1.05
200-250	0.00241	0.0	61	0.70
250-300	0	0.0	60	0.97
300-350	0	0.0	56	1.07
350-400	0	9,10	63	1.13
400-450	0	15.0	67	0.77
450-500	0.02055	0.0	60	0.91
500-550	0	18.0	54	1.19
550-600	0.00192	0.0	60	0.82
600-650	0	0.0	57	0.76

650-700	0.000	22.0	58	0.80
700-750	0.00848	14,9	65	1.10
750-800	0.000	0.0	63	0.96
800-850	0	0.0	64	0.90
850-900	0	0.0	56	1.10
900-950	0.00758	0.0	60	1.37
950-1000	0	0.0	65	0.88
1000-1050	0	0.0	64	0.99
1050-1100	0	11,8,15	62	1.12
1100-1150	0	0.0	56	1.01
1150-1200	0	0.0	63	1.12
1200-1250	0	0.0	61	0.97
1250-1300	0	0.0	59	0.82
1300-1350	0	0.0	52	0.91
1350-1400	0	0.0	61	1.09
1400-1450	0	0.0	62	0.91
1450-1500	0	0.0	63	1.04
1500-1550	0	0.0	59	1.12
1550-1600	0	0.0	57	0.87
1600-1650	0	0.0	60	0.91
1650-1700	0	12.0	58	1.09
1700-1750	0	14.0	61	1.01
1750-1800	0	11.0	59	0.99
1800-1850	0	10,9	66	1.00
1850-1900	0	0.0	63	1.14
1900-1950	0.0044	0.0	64	1.05
1950-2000	0.000	0.0	62	0.69
2000-2050	0.000	0.0	59	0.73
2050-2100	0.000	0.0	58	0.61
2100-2150	0.000	0.0	61	0.81
2150-2200	0.000	0.0	62	0.78
2200-2250	0.000	0.0	64	0.97
2250-2300	0.000	16.0	63	0.84
2300-2350	0.000	8,12	58	0.82
2350-2400	0.000	0.0	62	0.87
2400-2450	0.000	0.0	56	0.92
2450-2500	0.000	0.0	58	1.04

ANNEXURE XII

Data collected for RR-12 i.e. Dadhog road.

No data of potholes, raveling and patching was obtained.

Table 7. 12 Data collected for Dadhog road.

Segment (m)	Cracking		
	Longitudinal	Mapped	Transverse
	Area (sq. m)	Area (sq. m)	Area (sq. m)
0-50	0	0	0
50-100	0	0	0
100-150	0	0	0
150-200	0	0	0
200-250	0	0	0
250-300	0	0	0
300-350	0	0	0
350-400	0	0	0
400-450	0	0	0
450-500	0	0	0
500-550	0	0	0
550-600	0	0	0
600-650	0	0	0
650-700	0	0	0
700-750	0	0	0
750-800	0	0	0
800-850	0	0	0
850-900	0	0	0
900-950	0	0	0
950-1000	0	0	0
1000-1050	0	0	0
1050-1100	0.0051	0	0
1100-1150	0	0	0
1150-1200	0	0	0
1200-1250	0	0	0
1250-1300	0	0	0
1300-1350	0	0	0
1350-1400	0	0	0

1400-1450	0	0	0
1450-1500	0	0	0
1500-1550	0	0	0
1550-1600	0	0	0
1600-1650	0	0	0
1650-1700	0	0	0
1700-1750	0	0	0
1750-1800	0	0	0
1800-1850	0	0	0
1850-1900	0	0	0
1900-1950	0.0024	0	0
1950-2000	0	0	0
2000-2050	0	0	0
2050-2100	0	0	0
2100-2150	0	0	0
2150-2200	0	0	0
2200-2250	0	0	0
2250-2300	0	0	0
2300-2350	0	0	0
2350-2400	0	0	0
2400-2450	0	0	0

Segment (m)	**Rut depth(mm)**	**Skid Resistance Value (SRV)**	**Mean Texture Depth (mm)**
0-50	30.0	56	1.06
50-100	21.0	50	0.97
100-150	16,9	52	0.87
150-200	24.0	56	0.65
200-250	21,12	54	0.70
250-300	15.0	53	0.97
300-350	0.0	54	0.97
350-400	0.0	56	0.85
400-450	0.0	61	0.91
450-500	0.0	56	1.06
500-550	0.0	61	1.17
550-600	0.0	56	0.96
600-650	0.0	57	1.10

650-700	0.0	54	0.89
700-750	0.0	58	1.04
750-800	0.0	56	1.26
800-850	14,9	61	0.89
850-900	0.0	58	0.74
900-950	0.0	61	0.97
950-1000	26,11	59	1.07
1000-1050	0.0	59	0.77
1050-1100	0.0	50	0.84
1100-1150	0.0	57	0.89
1150-1200	0.0	61	1.06
1200-1250	0.0	59	0.96
1250-1300	0.0	61	0.92
1300-1350	0.0	63	0.70
1350-1400	0.0	58	0.96
1400-1450	0.0	56	1.08
1450-1500	10.0	59	0.78
1500-1550	8,7	58	0.98
1550-1600	0.0	61	0.92
1600-1650	0.0	55	0.79
1650-1700	0.0	53	0.98
1700-1750	0.0	58	1.05
1750-1800	0.0	57	0.95
1800-1850	0.0	60	1.04
1850-1900	0.0	59	0.92
1900-1950	9.0	52	0.71
1950-2000	12.0	55	0.76
2000-2050	0.0	62	0.73
2050-2100	0.0	58	0.78
2100-2150	0.0	57	0.84
2150-2200	0.0	54	0.87
2200-2250	0.0	61	0.81
2250-2300	0.0	59	0.75
2300-2350	0.0	60	0.87
2350-2400	0.0	59	0.92
2400-2450	11,9	56	0.97

ANNEXURE XIII

Roughness data obtained by MERLIN (one of each road)

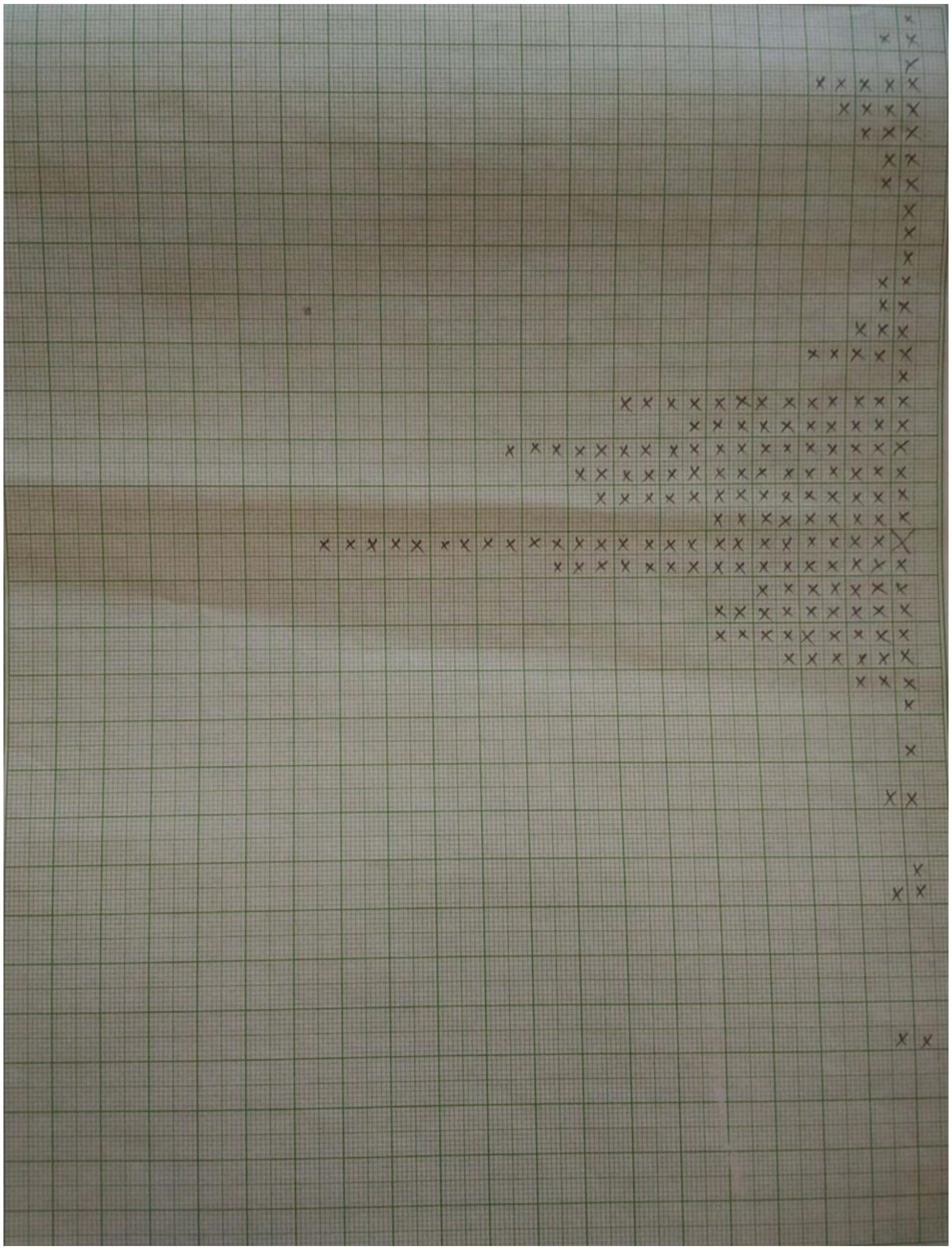

Fig. 7. 1 Roughness data for Domehar road (RR-1)

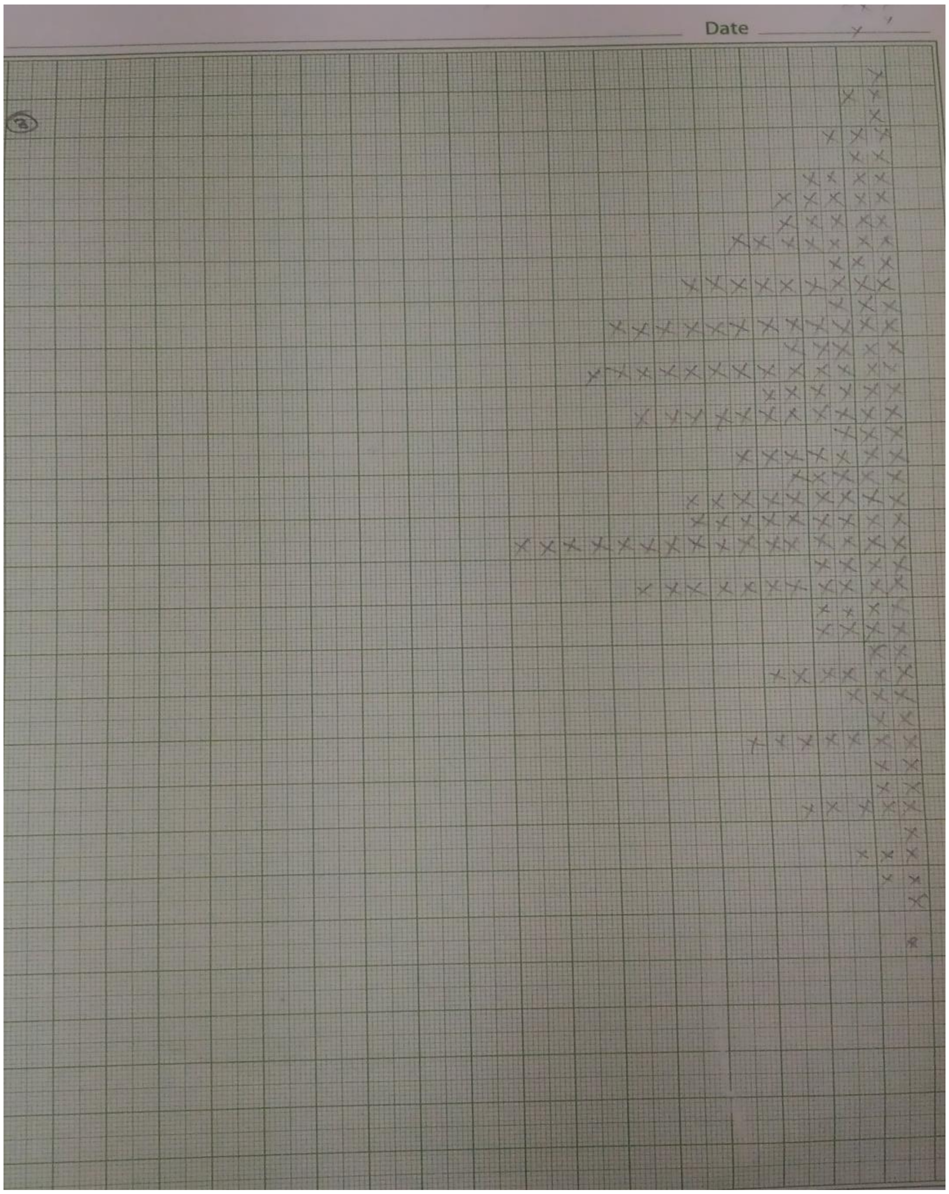

Fig. 7. 2 Roughness data for Ashwinikhad road (RR-2)

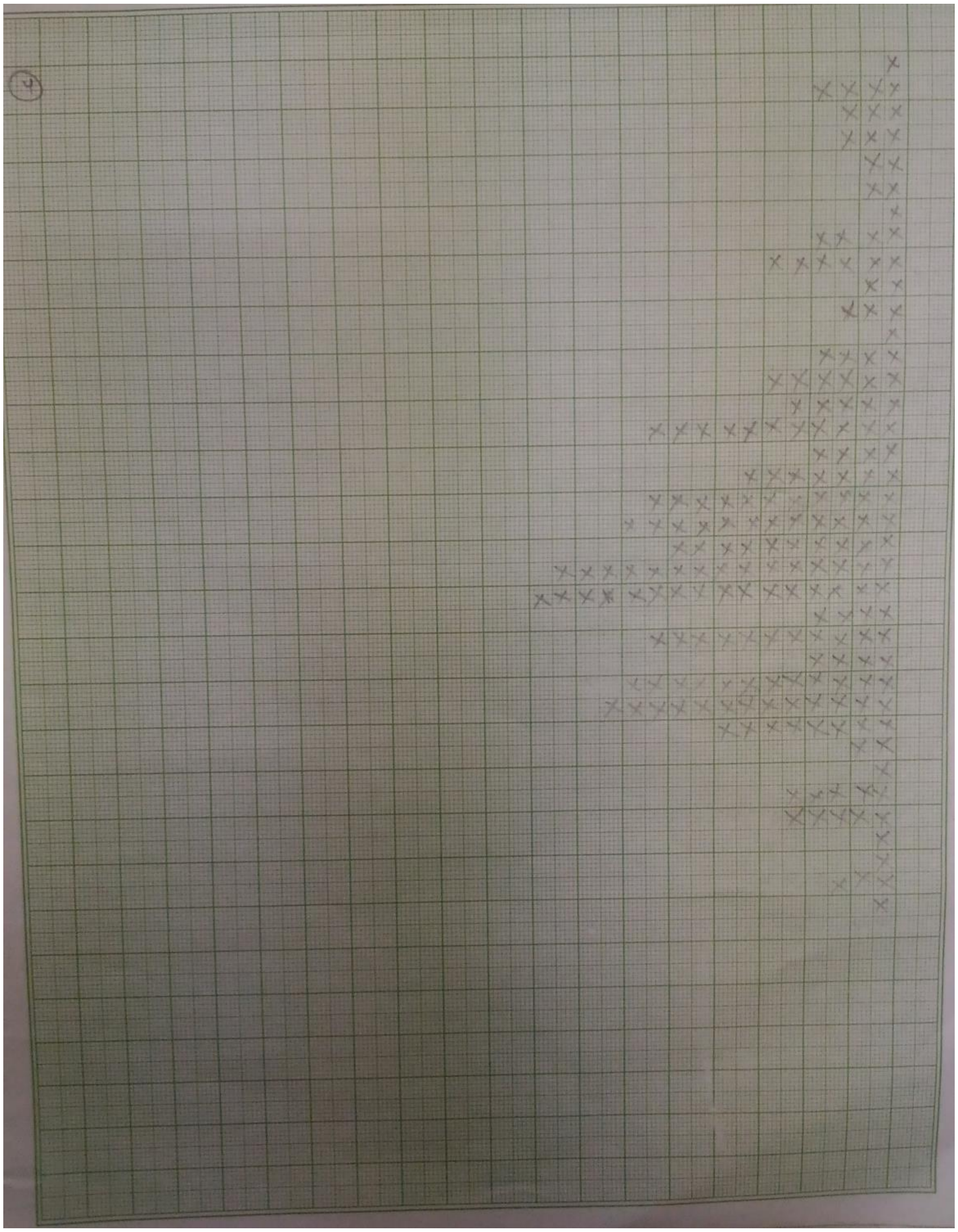

Fig. 7. 3 Roughness data for Kairibangla road (RR-3)

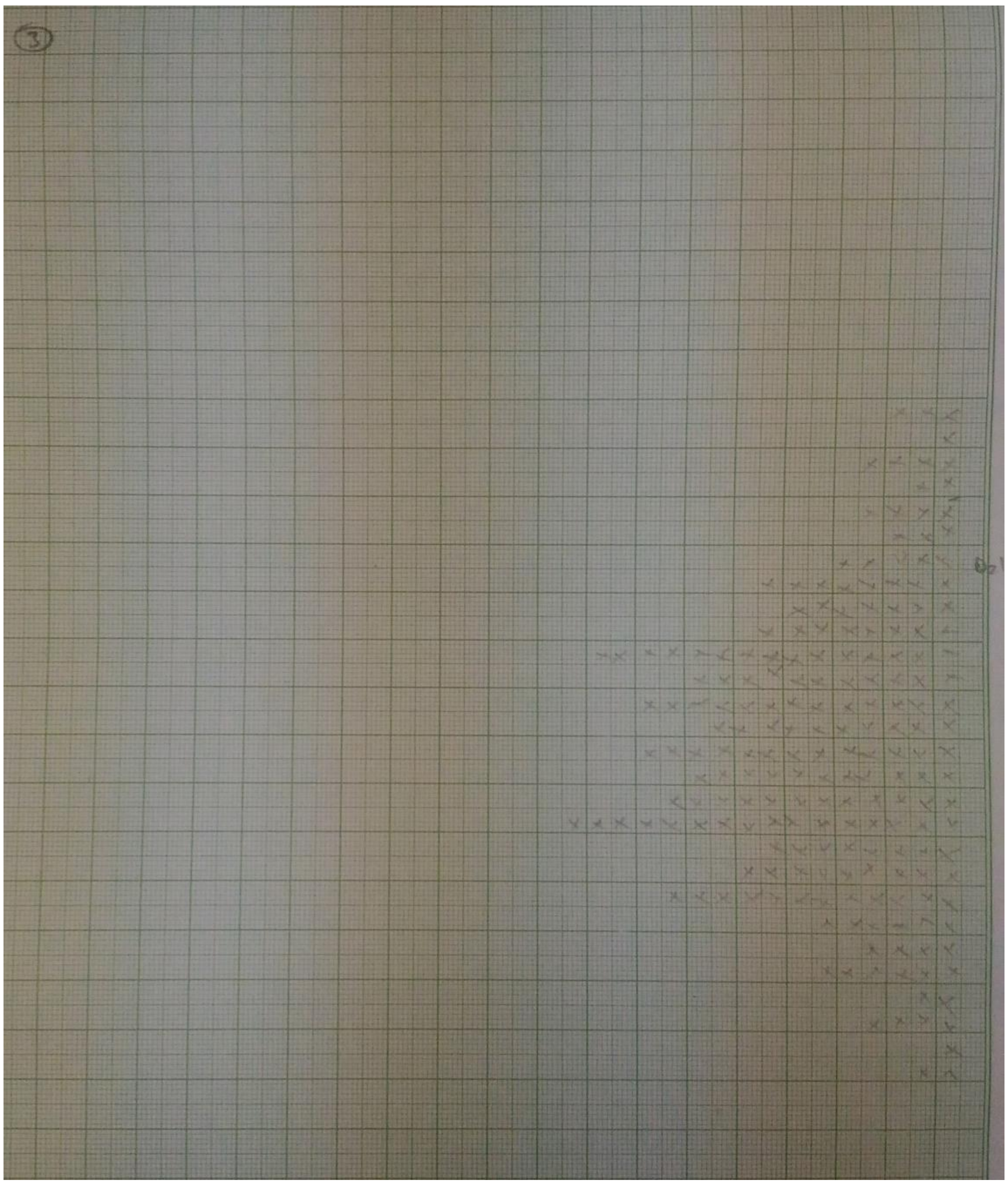

Fig. 7. 4 Roughness data for Basha road (RR-4)

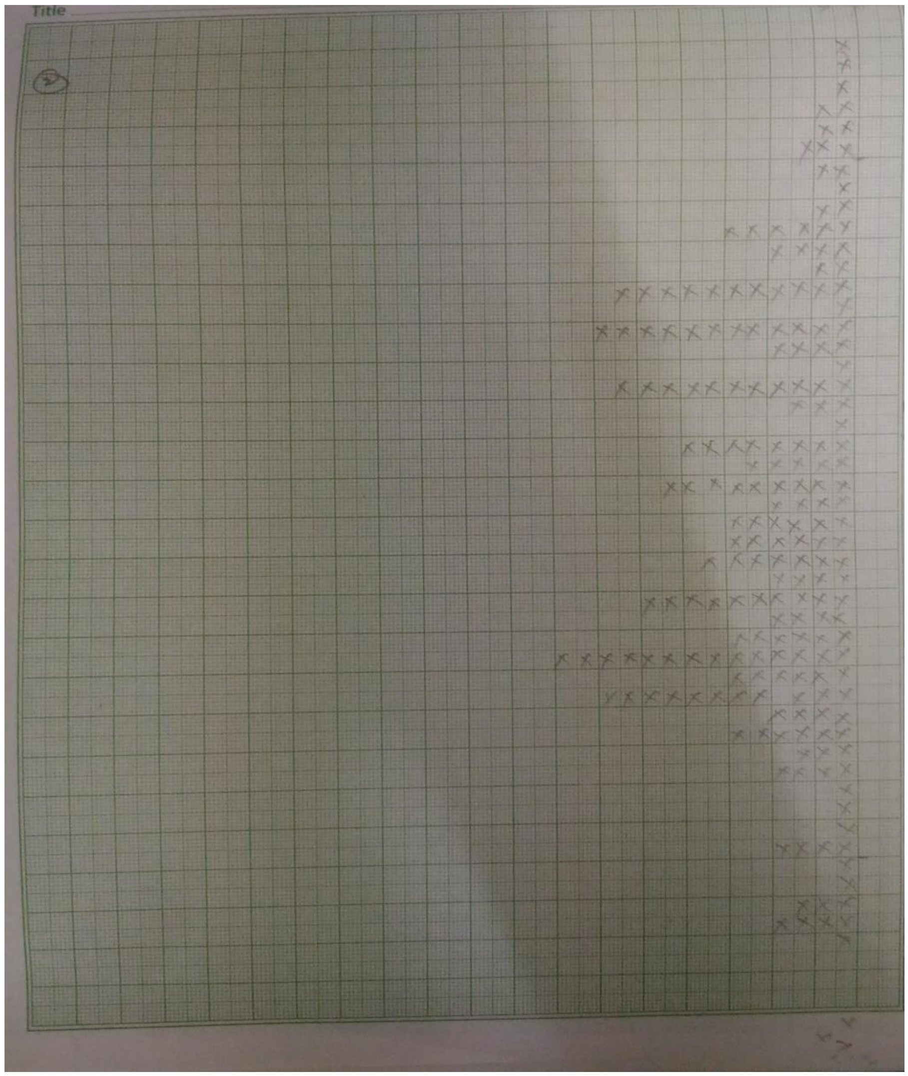

Fig. 7. 5 Roughness data for Industrial road (RR-5)

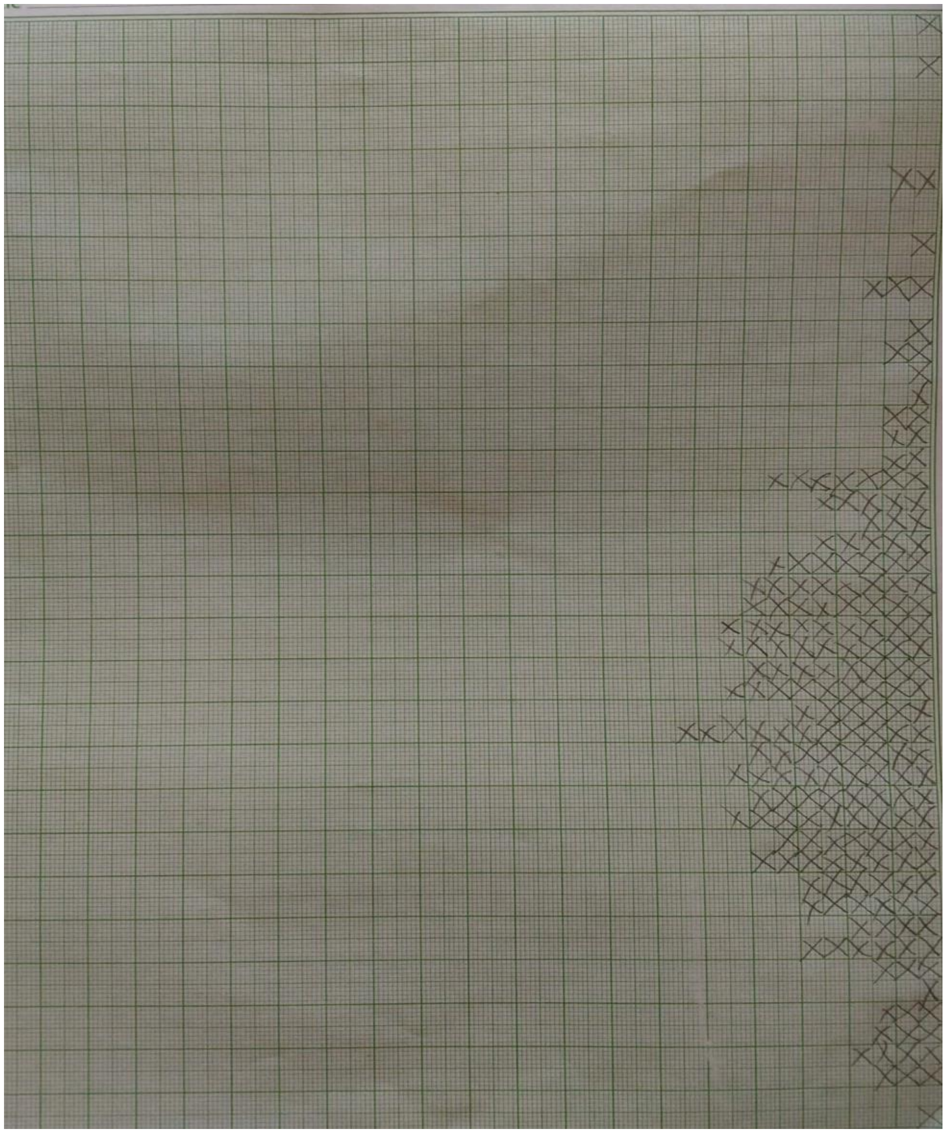

Fig. 7. 6 Roughness data for Salana road (RR-6)

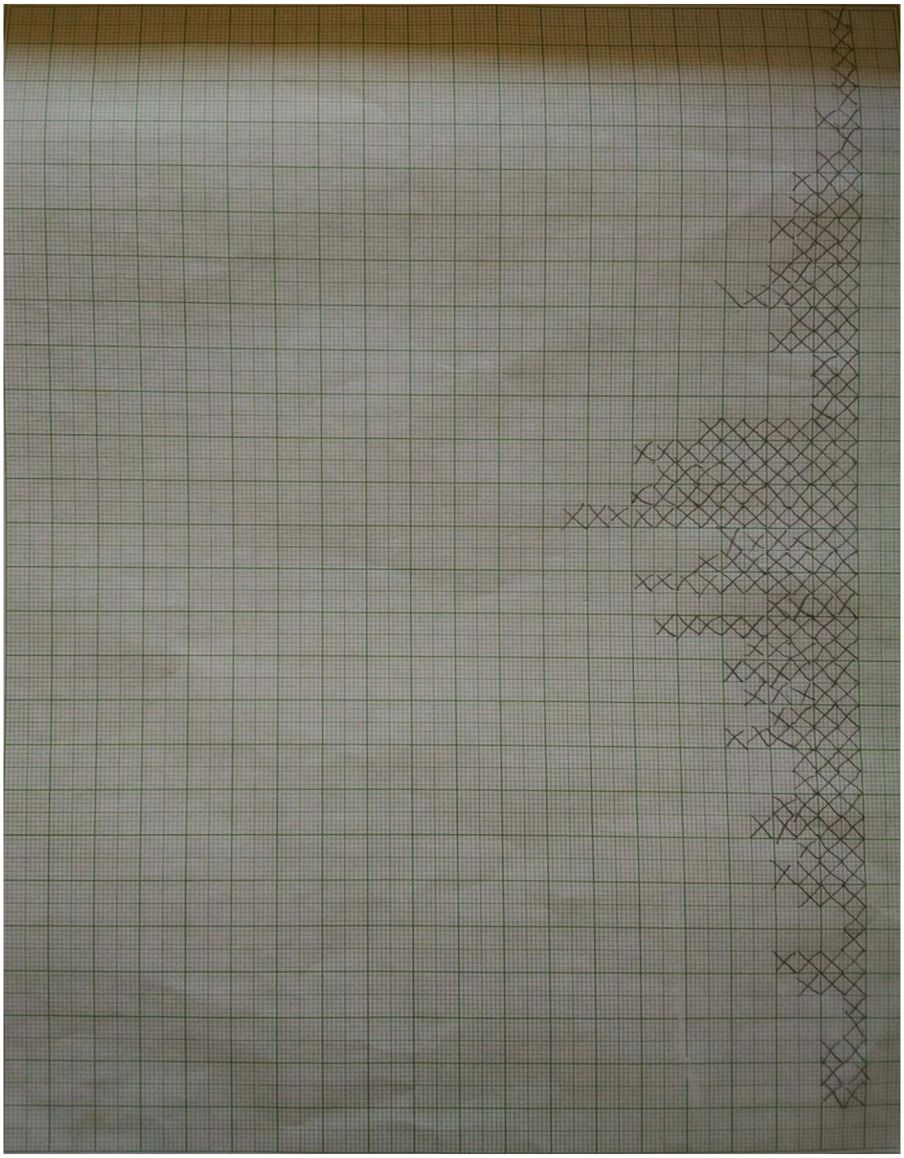

Fig. 7. 7 Roughness data for Lagroo road (RR-8)

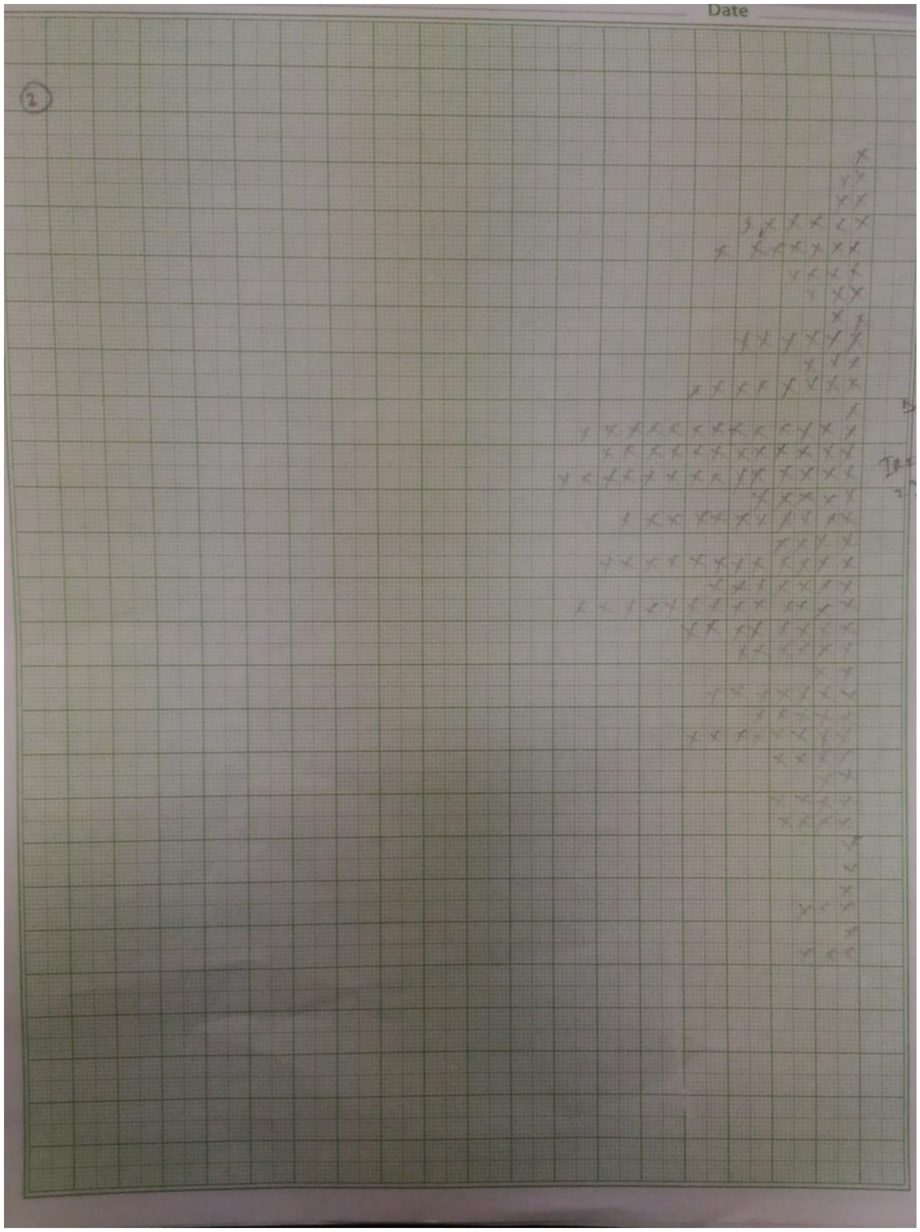

Fig. 7. 8 Roughness data for Wakna road (RR-8)

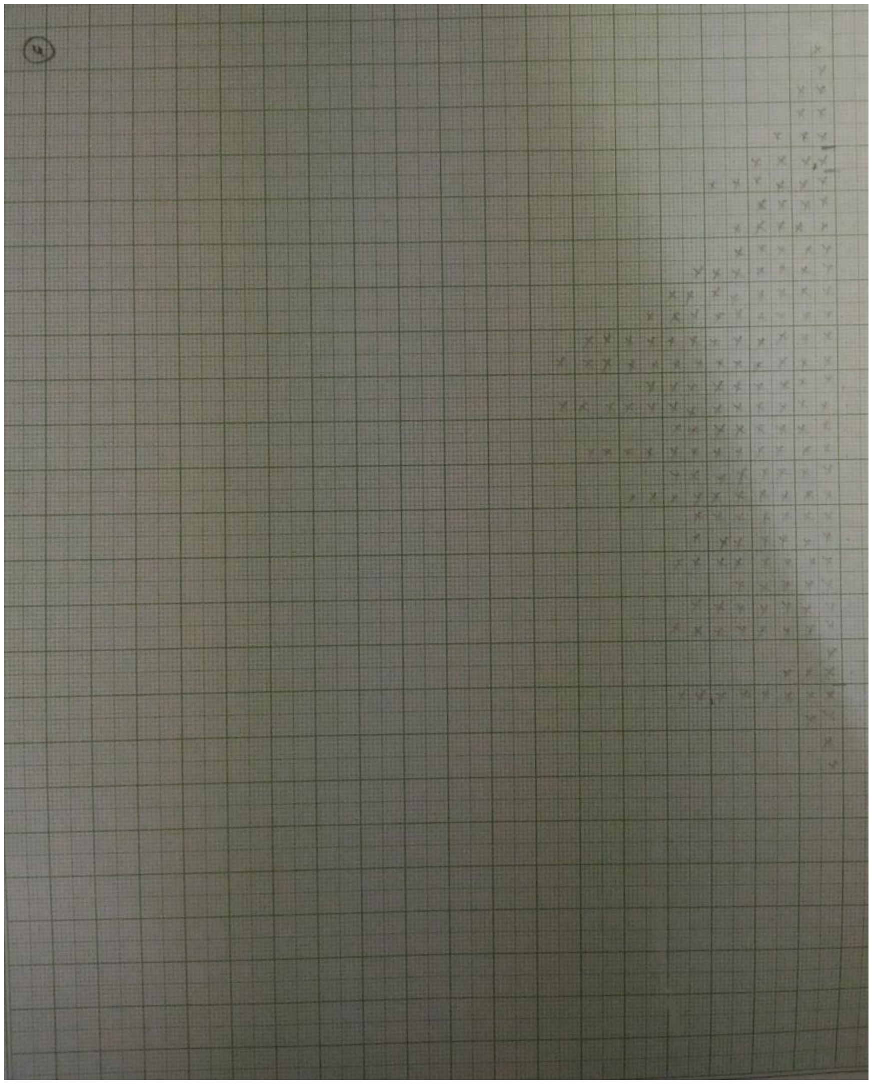

Fig. 7. 9 Roughness data for Saij road (RR-9)

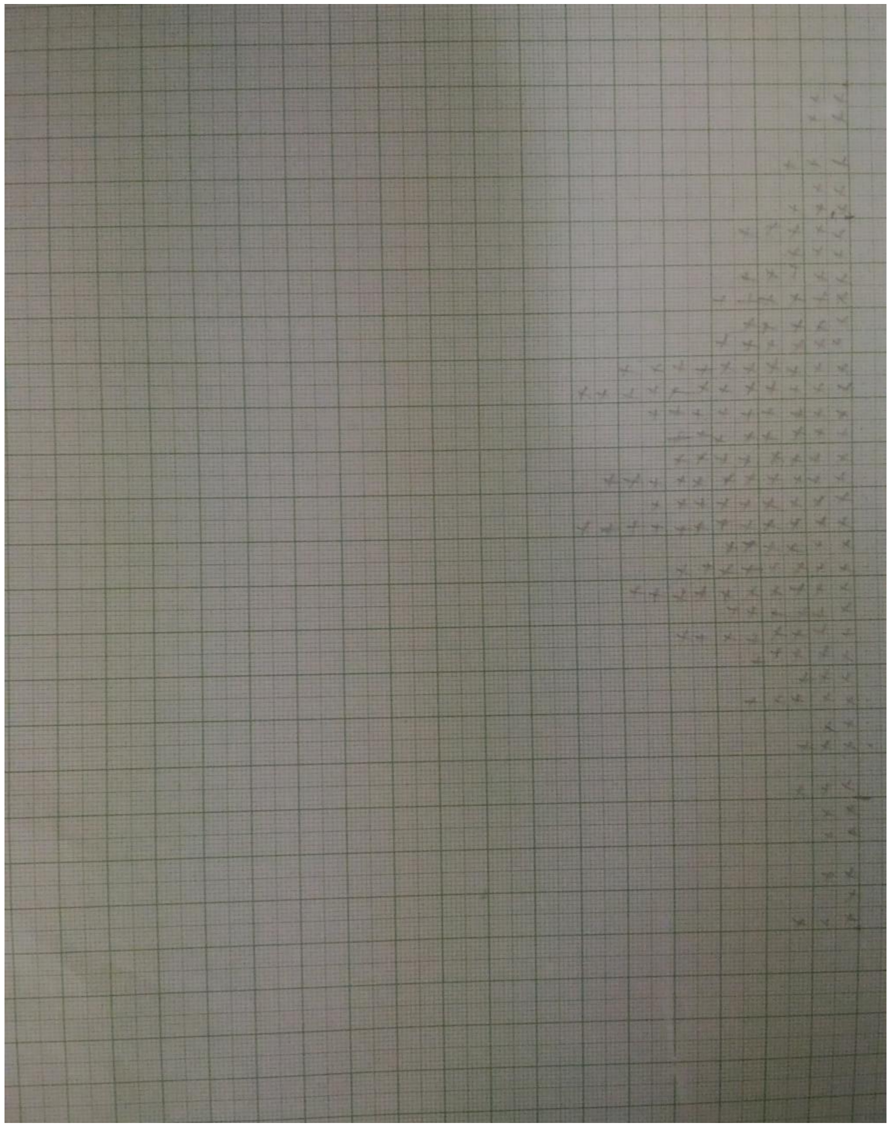

Fig. 7. 10 Roughness data for Chail road (RR-10)

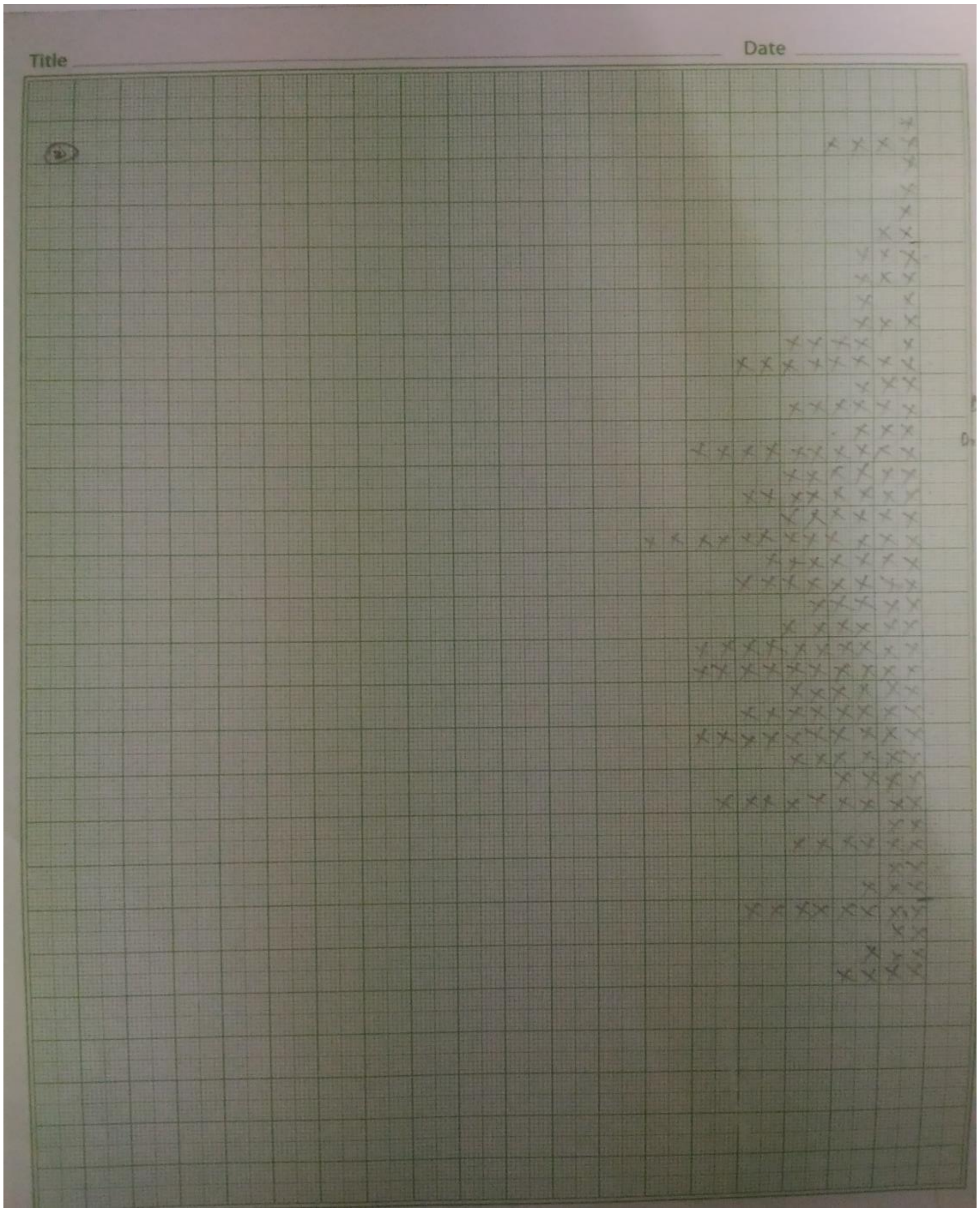

Fig. 7. 11 Roughness data for Nain Basal road (RR-11)

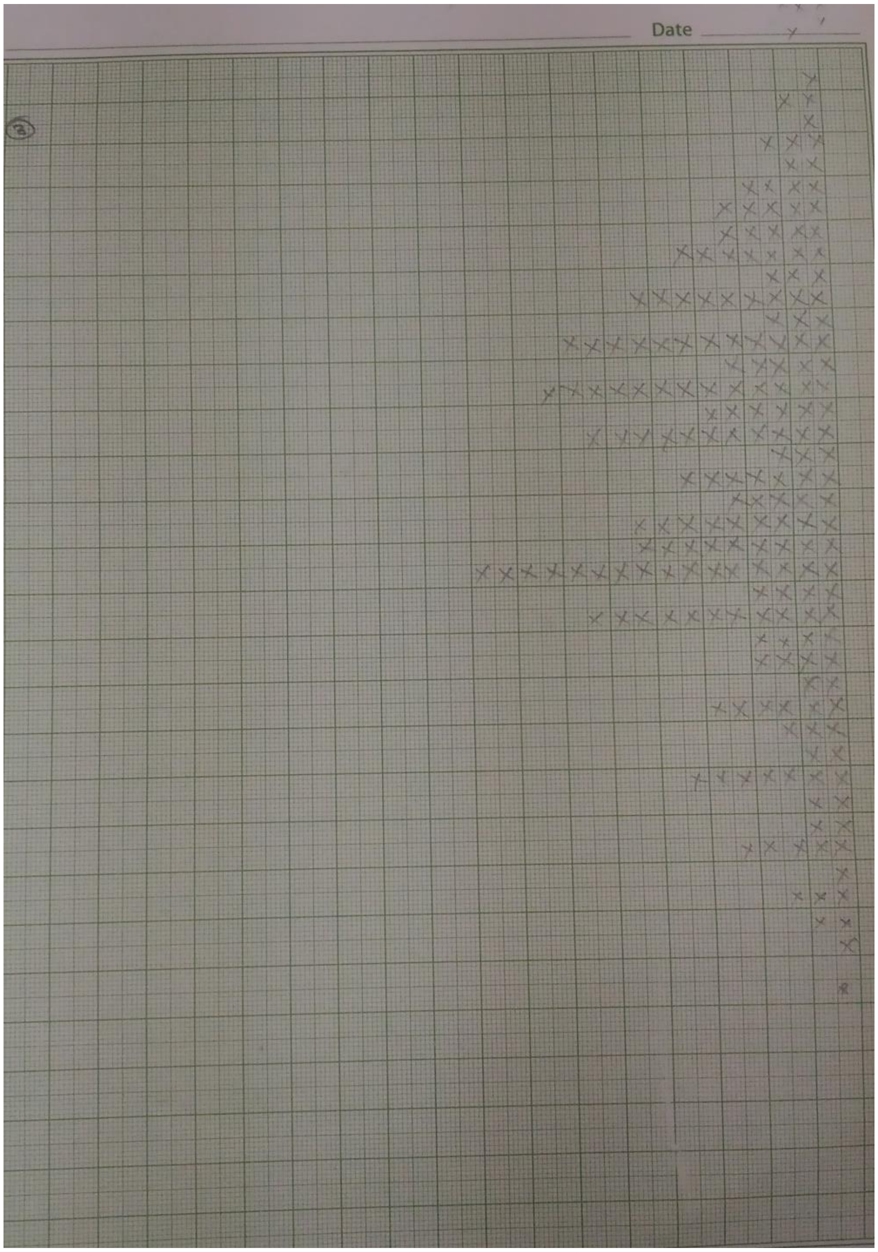

Fig. 7. 12 Roughness data for Dadhog road (RR-12)

ANNEXURE XIV

The observed and estimated IRI values, of the roads whose data is taken as input for the formation of models i.e RR-1, RR-2, RR-3, RR-4, RR-5, RR-6, RR-7, RR-9.

Table 7. 13 Observed and estimated IRI values for 8 rural roads

Observed IRI	Estimated IRI through Linear Regression Model	Estimated IRI through ANN model
6.34	6.59357659	5.43933582
5.77	6.34360963	5.71099091
3.5	6.38260375	5.675704
5.53	6.31520525	5.72406006
5.88	6.30000967	6.36600971
7.18	6.72403256	6.96028328
6.42	6.40710247	6.90860844
7.5	6.58105564	6.53508186
7.39	6.34178129	6.45939827
7.96	6.3667824	6.25049019
6.245	7.03178226	7.78213406
7.94	6.31990936	5.90532303
6	6.1483725	5.91837978
6.11	6.19952381	5.93452549
6.37	6.24181875	5.95902014
4.7	6.30514244	5.84512806
4.35	6.31552574	5.99998569
5.303	6.17043389	6.04566097
5.27	6.29626325	6.00484467
4.812	6.11786546	6.02340794
5.2	8.50851662	9.27544212
9.542	9.60925325	7.93751526
9.071	9.79104772	9.09056854
7.94	8.35431781	8.46314812
9.27	7.2404966	7.08272839
6.85	9.40755984	8.85895443
8.21	7.746109	7.72953224
8.11	7.32610835	7.60020161
6.53	6.73027981	7.56162453
8.09	6.45482444	6.41954613

8.61	7.34929398	8.09595585
9.15	7.12260363	7.61331367
8.07	6.43266651	6.59508896
8.25	6.62906713	7.26550961
7.89	6.74567411	7.08467293
8.6	6.21883776	5.9590435
5.47	6.0994215	5.93144226
6.1	6.246876	6.02342415
6.33	6.18195515	5.95210934
5.95	6.16069407	5.94700909

The observed and estimated IRI values, of the roads whose data is taken as input for the evaluation of models i.e RR-8, RR-10, RR-11, RR12.

Table 7. 14 Observed and estimated IRI values for 8 rural roads

Observed IRI	Estimated IRI through Linear Regression Model	Estimated IRI through ANN model
5.61	5.96447659	6.32062231
5.77	5.74377012	6.17699492
6.71	6.26949644	6.27340989
6.08	5.80086708	6.13677754
8.6	6.15438795	6.22681028
7.86	6.26648808	6.25621439
6.87	6.03821468	6.19790019
7.31	6.12593842	6.22048797
6.94	6.48711109	6.31350173
8.05	5.97525024	6.4795851
7.83	5.51933384	6.29994001
7.6	5.47523212	6.23758883
6.33	6.01991367	6.30082374
7.08	5.83765125	6.24881851
7.09	7.29913521	6.49288342
6.81	6.27556229	6.25902284
7.01	5.75961876	6.12614401
7.321	6.02803135	6.19522622
6.83	5.9143815	6.16601011