"STUDY OF MAINTENANCE STRATEGY PROVISIONS BASED ON FUNCTIONAL EVALUATION OF PAVEMENTS"

A THESIS

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

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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HIMACHAL PRADESH, INDIA

May 2019

STUDENT'S DECLARATION

I hereby declare that the work that has been presented in the Project report entitled "STUDY OF MAINTENANCE STRATEGY PROVISIONS BASED ON FUNCTIONAL EVALUATION OF PAVEMENTS**"** submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Aakash Gupta**. This work has not been submitted elsewhere for the reward of any other degree. I am truly responsible for the contents and data in this report.

Signature of Student

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Date: May, 2019

CERTIFICATE

This is to certify that the work presented in the project report titled **“**STUDY OF MAINTENANCE STRATEGY PROVISIONS BASED ON FUNCTIONAL EVALUATION OF PAVEMENTS**”** 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 **Nakshatra Gautam (151671)** during a period from August 2018 to March 2019 under the supervision of **Mr. Aakash Gupta, Assistant Professor**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: May, 2019

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ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my project guide Mr. Aakash Gupta, Assistant Professor for the continuous support in my B.Tech project. I thank him for his efforts and guidance which was very necessary for the completion of my work. Without his guidance and the right suggestions this work would not have been possible.

I would also like to express my gratitude towards Mr.Jaswinder Deswal, Lab Technician, Civil Engineering department and Mr.Akhilesh Singh for their cooperation and help.

Last but not the least, I whole heartedly thank every single individual who has directly or indirectly helped and encouraged me in gaining a better approach of doing things and in making this task a success.

ABSTRACT

Certain parameters play a very important role while considering the safety and the maintenance of the pavements. The pavement can be rated on the basis of different types of parameters which can be measured and worked upon to get the desired results. The factors constitute the smoothness and surface properties of the pavement surface which are related to the safety, and the roads distress is related to the comfortability of the ride.

Roughness along with skid resistance values is determined along with the various surface distresses including potholes, patching, cracking and macro structure. The data collected is then compared with the standard values to define a rating and thus develop a maintenance strategy. The hilly village roads are selected from the districts of Shimla and Solan, Himachal Pradesh, India. The data is recorded for 2.5km stretch.

The study also aims at developing a relationship between the volume of potholes and the mean dimensions and depth of the pothole which will help the team to work out the quantity of the maintenance work with a comparatively reduced time and labour. The team could input the data in the derived equation to get the volume of the pothole and carry out the desired work.

ABBREVIATIONS

IRI	International Roughness Index
MTD	Mean Texture Depth
PSI	Present Serviceability Index
RRL	Road Research Laboratory
TRL	Transport Research Laboratory
SRV	Skid Resistance Value

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

Every structure that has been constructed deteriorates with passing time. Therefore it is important that these built structures, like in this case flexible pavements, are assessed periodically to evaluate their present condition and furthermore to assess the rest of the life of the roads and the amount of additional time the road can be used by the people effectively. Thus, for that we must have some devices to assess preexisting condition of the pavements, gather some reasonable data and to use the information which is acquired with a motive to increase the durability and improve the condition of pavements.

1.1.1 FACTORS AFFECTING PAVEMENT'S PERFORMANCE

1. **Traffic**: It is of the most impactful factor affecting the performance of the pavement. The pavement performance depends on the configuration, type of load, load repetitions and the amount of load from traffic.
2. **Moisture**: Moisture affects the support strength of the subgrade to a large extent. It enters the layers through cracks and distresses on the surface, reaching onto the subgrade, also, the capillary action leads to the moisture reaching the layer. The presence of moisture decreases particle interlocking and leads to particle displacement in the form of uneven settlement and various other distresses.
3. **Subgrade**: The subgrade is the lower most layer of the pavement that takes up the loads from the traffic. If the subgrade is too weak, the pavement will lead to deformation which finally leads to the failure of the structure.
4. **Quality of construction**: The quality with which the construction has been done plays a major role in durability and service life of pavements. There has to be accurate thickness with well compacted layers.
5. **Maintenance**: If the pavement is maintained at regular intervals followed by surveys, then it could lead to the increment in the durability of the pavement. The growth and the reasons for the various distresses deteriorating the pavement can be minimized and removed by maintenance.

1.2 FUNCTIONAL EVALUATION

Functional analysis of roads involves the ride quality, texture and safety of a road. This, functional evaluation of pavements is carried out due to following reasons:

- To judge the present surface quality of road.
- To obtain the roughness value of roads and to measure performance.
- To propose an acceptable maintenance methodology, supported by roughness information.
- For the evaluation of the safety of pavement on the basis of skid values.
- For recording pavement performance using roughness data being accumulated.

1.3 TYPES OF FUNCTIONAL EVALUATION

Surface properties that have an effect on the riding quality of the pavement associated with safety, comfortability and serviceability are the major concerns behind evaluating pavement based on functional parameters.
Surface conditions of any pavement can be judged based on the following.

1. **Serviceability**
   Roughness of the road surface is measured by several equipments and tools. Some of the indicators that depicts roughness and hence serviceability are IRI and Bump Integrator value.

2. **Safety**
   Safety depends upon the surface in terms of friction offered by the roads preventing the skidding of the vehicle. Skid resistance value on both the dry and wet surfaces is determined to judge safety.

3. **Surface Distress**
   Usually defects on the surface are explained as conditions associated with cracking, raveling, potholes etc.

1.4 FUNCTIONAL EVALUATION: PARAMETERS

1. **Roughness**

Roughness is defined as an unwanted deviation of the surface of the pavement compared to its smooth surface. It causes the vehicles to vibrate leading to reduce in the comfortability while riding. The I.Resistance Index is the most generally used factor for measuring roughness. The values are in units meter per kilometer (m/km).

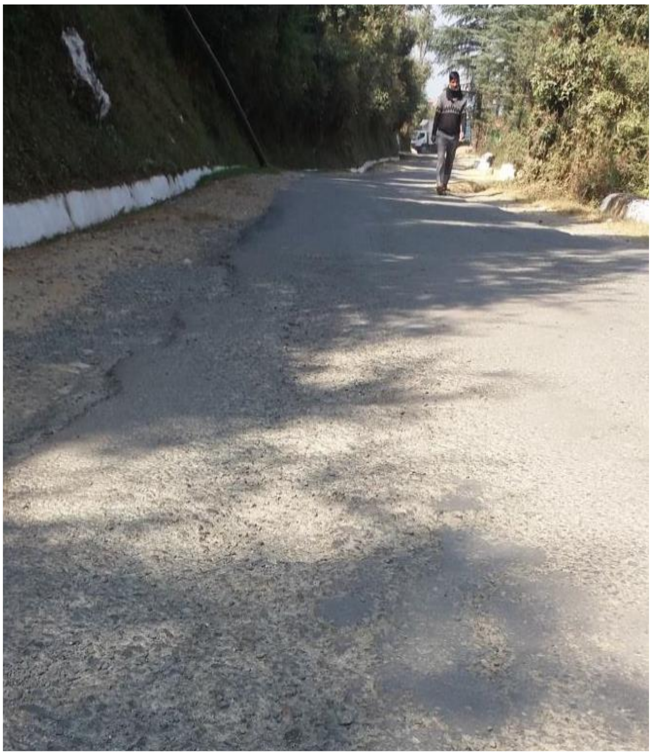

Fig.1.1: Roughness on flexible pavement

2. **Rut Depth**

Rut can be described as a depression in the surface of the pavement on the wheel path as shown in fig.1.2. Ruts usually occur because of the damaged and weakened load transferring capacity of the pavement.

Fig.1.2:Rutting on the road surface

3. **Skid Resistance**

When breaks are applied and the tire is prevented from rotating, then it slides on the surface of the pavement, so, skid resistance is the force of friction developed while the sliding of the tire on the surface. It is a crucial pavement analysis parameter as if skid resistance is insufficient, it'll cause increment of skid reported accidents. SR depends upon surface texture of roads.

4. **Macro-Texture**

Road texture are the results of changes from the smooth and planar surface between the surface of the pavement and the point of contact with the tyre of the vehicle.

5. **Pot Holes**

Potholes are concave holes. These holes are the type of failure that increases with time. Firstly, tiny fragments from the topmost layer get popped out. Then with time, the distress moves into the lower layers. These are usually seen once the pavement disintegrates under traffic load, because of weakened strength in the layers.

Fig.1.3: Depression due to pothole

6**. Patching**

A patch is explained as the portion of the pavement that is removed and repaired. Patches indicates the repair work done on the pavement.

Fig.1.4: Patching at RR-1

CHAPTER 2

LITERATURE REVIEW

Chandra, R. (2013)

This study gave a relationship between Roughness and the various Distress Parameters. The roughness and visual distress data was collected by using Network Survey Vehicle. The various models was obtained indicating the road irregularities and functional evaluation parameters including potholes, patches. An AN model was also tried to find the relation between the roughness and distresses. The study indicated that the ANN model yields a better forecast of road roughness for a provided set of distress parameters as compared to empirical equations and non linear curves.

J.R. Prasad

This study was also based on Development of Relationship amongst IRI and Visual Surface Distresses. Bump integrator was used to get the desired data. An equation amongst visual surface distresses and IR Index values was developed.

S. U. Yogesh

The study includes a look on analysing of overall surface indexes. The method includes determination of road surface portions, collection of road distresses, development of distresses index for a particular parameter and in the end developing a combined report. The four performance indices i.e. PCI Distress, PCI Roughness and PCI Skid are developed on an individual basis.

Jay N. Meegoda and Shengyangao (2014)

This paper evaluated the time-sequence information of roughness to GPS info so to develop a model to predict the progression of pavement roughness over pavement age. The developed deterioration curve was developed and normalized. The present calculated condition state was then used to develop cost-effective treatment techniques for maintenance of pavement.

Amer Abdulaziz Mustafa (2015)

This research gave relation amongst Function and Manual condition of pavement. The study aimed at evaluation of the outcome of relating pavement condition index represented by UDI. Based on the type of distress, a relation was to set between the function evaluation like IRI and SR factor for a particular section of a pavement or recommendation to use the strategies so as to minimize the expenditure of money and precious time.

Mubaraki Muhammad

The study carried out a research on the information of roughness. A relationship between pavement damage and IRI and also between other distresses. The results indicate that a significant relationship exists between the factors with confidence level: 95. Also their was not any major relation between rutting and values of IRI. It can be deduced from the results that raveling and cracking can be taken up as ride quality, while rutting can be represented as non-riding distress.

Francisco Dalla Rosa1 and Nasir G. Gharaibeh

The research worked on the development of IRI prediction model along with the validation process especially for low to medium traffic loading conditions. The traffic conditions was majorly focused upon as compared to other distress parameters.

A I Setianingsih et (2017)

The results showed that by providing the importance to the road maintenance at comparatively better conditions are economical. Recommendation of maintaining the road with good conditions were setup.

Hermawan

The use of IR Index and SN for repairment along with the maintenance was conducted. Roughness along with the SN value data was collected using Road Roid app and internet dependent Geography Information System. This study predicted roughness value too.

Prasanna Kumar R et al (2017)

The paper is based on total evaluation of pavement including functional and structural parameters. The research studied the preexisting portion of a selected road from Budalur to Pudupatti. The analysis of various types of undulations data.

CHAPTER 3

OBJECTIVES

1. To evaluate hilly village roads on the basis of IRI value, skid resistance values, macro-texture and other surface distress.
2. To rate the pavement and discuss the maintenance strategy.
3. Propose a quantitative relation of volume of potholes with its depth and mean diameter.

CHAPTER 4

METHODOLOGY

4.1 ROADS SELECTION

Six roads were selected for the functional evaluation.

The following things were kept in mind while selecting the roads.

1. All roads must be rural roads.
2. The available length of road stretch should be around 2 to 2.5 kms.
3. Surface distresses must be present.

Each road stretch of 2.5 kms is divided into segments of about 50m and the values of distress parameters including skid resistance, roughness, potholes, cracking, patching, raveling and surface texture were recorded.

The Table 4.1 below along with the figures 4.1 and 4.2 shows the hilly village pavements selected for the evaluating pavements.

ID of Road	Name of the road
RR-1	Domehar-Wakna Road
RR-2	Kyari Bangla Road
RR-3	Industrial Road
RR-4	Salana Road
RR-5	Shoghi Lagroo Road
RR-6	Nain Basal Road

Table 4.1: Selected rural roads

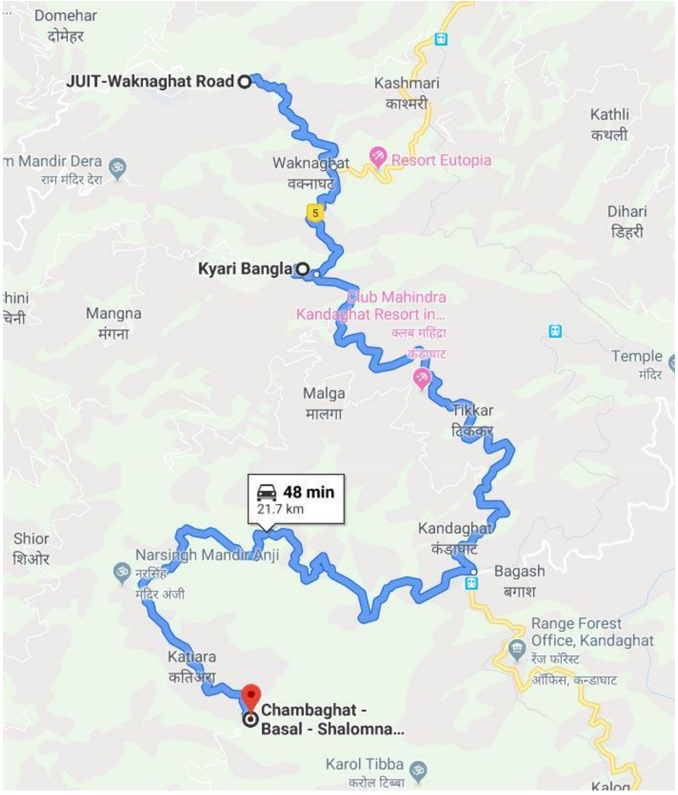

Fig.4.1: Some of the village roads selected

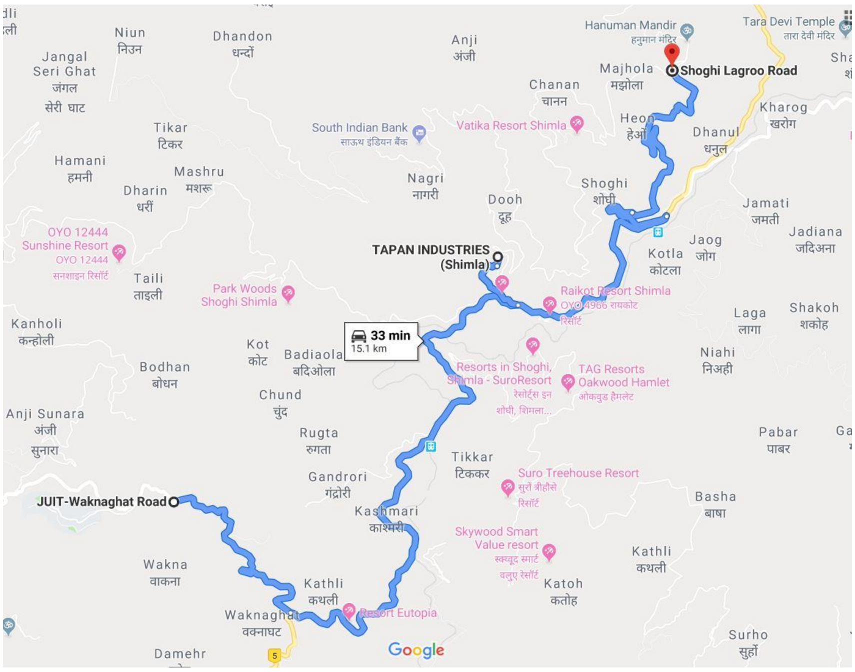

Fig.4.2: Some of the village roads selected-2

4.2 <u>MEASUREMENT OF ROAD DISTRESSES</u>

The factors of deterioration of road which are visually visible are known as the pavement distresses and includes patches, potholes, cracking, rutting etc. In the project we measured rut depth, cracking, patching, potholes.

These distresses are most common and occur frequently and are so selected.

4.2.1 Measurement of Rut depth

This shows lateral unevenness on the wheel paths. Straightedge is commonly used to measure rut depth.

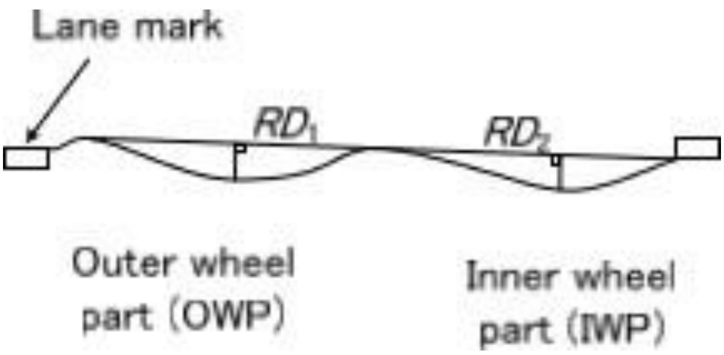

Fig.4.3: Rut depth explained

Fig.4.4: Rut depth on pavement

4.2.2 Measurement of dimensions of potholes

The mean diameter of the pothole is calculated by finding out the mean of the four readings taken at different axes. The volume however is evaluated by completely filling it with sand. Area of the pothole is evaluated by the help of mean diameter.

Fig.4.5: Determining volume of pothole at RR-5

4.2.3 Patching measurement

The area of patching is evaluated by the use of instruments such as inch tape. The patched area is enclosed in rectangular or square shaped area and then the segment is measured.

Fig.4.6: Patching at RR-6

4.2.4 Measurement of Cracking

There are three types of cracking that has been measured.

- Longitudinal cracking
- Transverse cracking
- Alligator cracking

The cracked portion on the road is enclosed in a rectangle and then the length and width is measured by using simple measuring tape.

The figures (Fig.4.7, 4.8, 4.9) below shows the cracking.

Fig.4.7: Longitudinal cracking at RR-1

Fig.4.8: Transverse cracking at RR-2

Fig.4.9: Alligator cracking at RR-1

4.3 PAVEMENT RATING ON THE BASIS GUIDELINES

After collecting distress data, the road is rated based on IRC82:2015.The distress data of patching, cracking and potholes for each segment of road is converted into percentage by finding the ratio of the distress and the total area of the 500m of segment.

The rating range of parameters is as shown in the Table4.2.

Distress (%)	**Range of Distress**		
Cracking	Greater than 20	10 to 20	Less than 10
Potholes	Greater than 1	0.5 to 1	Less than 0.5
Patching	Greater than 20	5 to 20	Less than 5
Rating	1	1.1 to 2	2.1 to 3
Condition	**Poor**	**Fair**	**Good**

Table 4.2: Pavement distress based rating.

Parameter	**Weightage**
Cracking	1
Pothole	0.5
Patching	0.75

Table 4.3: Multiplier factor of each parameter.

The final rating of the pavement is evaluated by finding up the average value of individual parameters.

4.4 ROUGHNESS MEASUREMENT

A number of simple tools can be used to measure the value of roughness on a particular stretch of road. The different factors obtained are related to a standard common scale of IRI. In this project we have used a device called MERLIN which is the short form of Machine for Evaluating Roughness with Low-cost INstrumentation.

Principle on which MERLIN works

This device consists of 2 feet along with a probe that rests on the ground of which the roughness is to measured. The distance of 1.8m is there between the two feet. The probe is present in the centre. This device takes up the displacement in the vertical position between the surface of the road lying below the probe and the middle point of a line that virtually joins the 2 point of contact of feet with the road. Fig.4.11 shows the working principle of MERLIN.

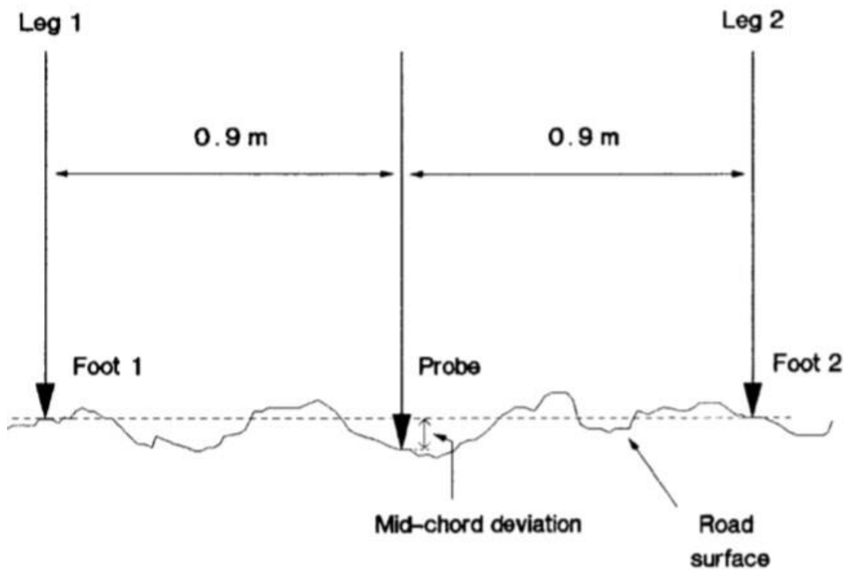

Fig. 4.10: Working Principle

The rougher the surface, the more variability would be seen in the displacements.

The following fig.4.12 shows the component parts of MERLIN

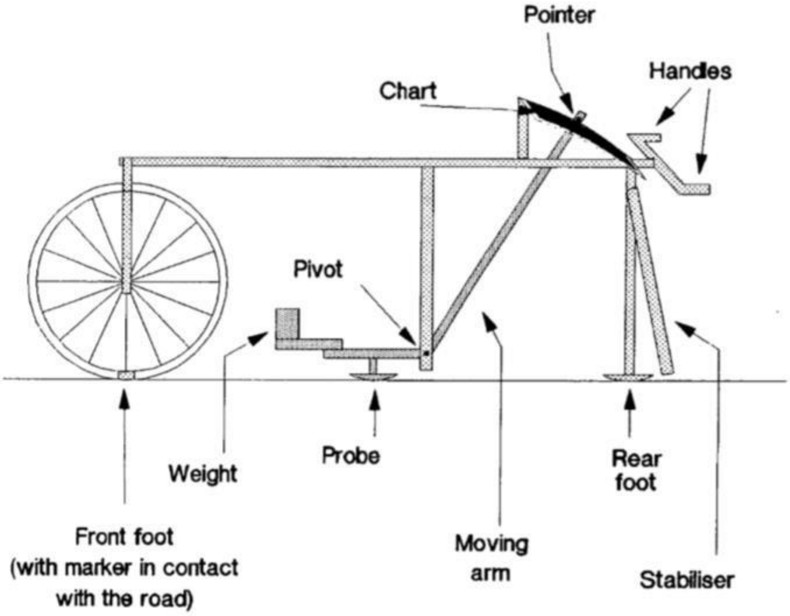

Fig.4.11: Component parts of MERLIN

Procedure for taking markings

On every revolution of the wheel, a reading showing the displacement in noted taking around 200 measurements. At each resting point, probe, rear foot and stabilizer should be in the contact with the road surface and the wheel should be in normal position. The operator marks the tip of the pointer on the graph representing a cross.

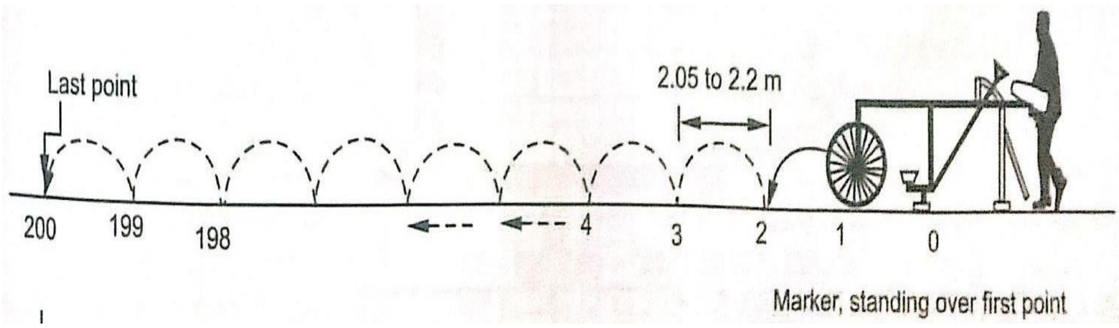

Fig.4.12: Test section of MERLIN

Total length of one segment = number of readings*circumferenceof the tyre.
Then D value is calculated from the graph.

The IRI value can be found out using the D value using relation recommended by the TRL:

$$IRI = 0.593+0.0471*D$$

The above mentioned steps are done for each road. On each segment 5-6 times the similar steps are performed, thus getting 5-6 D-value. IRI values are then calculated putting the average of the D value into the above mentioned relation.

4.4.1 EVALUATION OF PAVEMENT ON THE BASIS OF IRI-VALUE

The pavements are judged according to the IRC code.

IRI range (m/km)	Pavement's condition
Upto 2.5	Excellent
2.5 to 4	Very good surface
4 to 6	Good surface
6 to 8.5	Fair surface
8.5 to 13.5	Frequent undulations
13.5 to 16.5	Rough surface
16.5 to 2.5	Very rough surface and unsatisfactory ride

Table 4.4: Relationship between IRI and condition of the pavement

4.5 MEASUREMENT OF SKID RESISTANCE

Skid Resistance Tester is used for determining the skid resistance on the surface of roads. This is very easy and cheap that is used for obtaining the of frictional properties of the pavements.

Steps involved

The tester is placed and leveled on the road by adjusting legs of the instrument. The pendulum arm needs to be lowered and adjusted in such a way that the rubber stoppers just touches the surface of the road. The surface is made wet. Then the pendulum is allowed to swing and the corresponding highest value is considered. The same steps are performed for every 100m on the roads selected.

Fig. 4.13: Skid Resistance Testing at RR-6

Category	Type of stretch	Min value on wet-surface
A (Critical Stretches)	Roundabouts	65
B (High speed lanes)	National and State highways	55
C	All pavement surfaces, rural roads	45

Table 4.5: Minimum resistance value suggested by TRL

4.6 MEASUREMENT OF MACRO-TEXTURE

Surface macro-texture also affects the skid resistance. MTD is the obtained by Sand Patch Test.

Procedure

The test is taken up from British Standard and ASTM E965.

50 ml of fine sand with natural silica sand (grade 2) is taken and is pour onto the surface of the road and is spread in a circular manner using a 63mm round disc with a 16mm thick rubber surface touching the road surface. The surface depression gets filled to the peak level. The diameter of the circular patch formed on the surface is measured. The MTD value can be determined by the following equation:

$$MTD = \text{Volume of silica sand} / \text{Area of circular patch}$$

.

Fig.4.14: Sand Patch Test on RR-4

CHAPTER 5

RESULT

5.1 PAVEMENT EVALUATION ON BASIS OF ROUGHNESS VALUE

IRI values for 6 roads for segment of 400m at a time is obtained.

Table 5.1: Obtained Roughness Data

Segment	D-value (mm)	Avg. D-value	IRI (m/km)	Road condition
RR-1: Domehar Road				
1	120.830	106.836	5.624	Good surface profile
2	64.166			
3	113.333			
4	142.250			
5	112.253			
6	88.186			
RR-2: Kyari Bangla Road				
1	82.857	116.66	6.087	Fair surface profile
2	91.153			
3	121.250			
4	138.750			
5	122.360			
6	143.640			
RR-3: Industrial Road				
1	106.110	142.31	7.295	Fair surface profile
2	145.820			
3	123.330			
4	175.670			
5	158.620			
6	144.360			

RR-4: Salana Road				
1	70.830	71.22	3.947	Very good surface profile
2	61.874			
3	64.750			
4	70.420			
5	82.350			
6	77.140			
RR-5: Shoghi Lagroo Road				
1	101.670	116.66	6.087	Fair surface profile
2	115.010			
3	122.920			
4	137.500			
5	94.355			
6	128.540			
RR-6: Nain Basal Road				
1	155.833	153.90	7.841	Fair surface profile
2	154.000			
3	160.000			
4	152.080			
5	146.233			
6	155.200			

5.2 DISTRESS BASED RATING ACCORDING TO IRC 82:2015

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	3.330	2.433	1	2.433
Patching (%)	1.709	2.270	0.75	1.702
Pothole (%)	0.003	2.100	0.50	1.050
Final rating				**1.73**
Pavement condition				**Fair**

Table 5.2: Distress rating: Domehar road (RR-1)

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	0.715	2.172	1	2.172
Patching (%)	0.114	2.110	0.75	1.583
Pothole (%)	0.0005	2.100	0.50	1.050
Final rating				**1.60**
Pavement condition				**Fair**

Table 5.3: Distress rating: Kyari Bangla road (RR-2)

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	0.033	2.103	1	2.103
Patching (%)	0.000	2.100	0.75	1.575
Pothole (%)	0.004	2.100	0.50	1.050
Final rating				1.58
Pavement condition				**Fair**

Table 5.4: Distress rating: Industrial road (RR-3)

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	0.758	2.176	1	2.176
Patching (%)	1.847	2.285	0.75	1.714
Pothole (%)	0.0006	2.100	0.50	1.050
Final rating				**1.65**
Pavement condition				**Fair**

Table 5.5: Distress rating: Shoghi Salana road (RR-4)

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	0.251	2.125	1	2.125
Patching (%)	0.236	2.126	0.75	1.600
Pothole (%)	0.004	2.100	0.50	1.050
Final rating				**1.59**
Pavement condition				**Fair**

Table 5.6: Distress rating: Shoghi-Lagroo road (RR-5)

Type of distress	Input(%)	Rating	Weightage	Weighted rating value
Cracking (%)	1.099	2.210	1	2.210
Patching (%)	0.707	2.170	0.75	1.628
Pothole (%)	0.001	2.100	0.50	1.050
Final rating				**1.63**
Pavement condition				**Fair**

Table 5.7: Distress rating: Nain Basal road (RR-6)

5.3 SKID RESISTANCE AND MEAN TEXTURE DEPTH

The skid resistance test along with the Sand patch method was carried out on all 6 pavements.

The S.R.value and MTD value both satisfy the codes of practise for bituminous pavements and village roads.

The recorded and evaluated values are provided in Appendix.

5.4 RELATION BETWEEN THE VOLUME AND DIMENSIONS INCLUDING DEPTH AND DIAMETER OF POTHOLES

After trying to establish the relation between the parameters taken up. It has been found that the parameters can be put in a linear relation which indicates that the parameters does not satisfy the equation y= mx+c.

So a non linear equation of the form

$$\mathbf{V = a + bx_1^c - dx_2^e}$$

tends to denote a relation between the various dimensions taken

where, V = volume of the pothole

a = 3548.218

b = 15.58179

c = 1.433864

d = 5164.34

e = -0.3951

x_1 = mean diameter of the pothole

and x_2 = depth of the pothole.

Table 5.8: The potholes data along with the observed and estimated values

S.no.	Diameter (cm)	Depth (cm)	Vol. of sand (ml)	
			Observed	Estimated
1	30.5	2.5	2150	2046.121
2	27.5	2.7	1900	1864.958
3	28	3.2	2200	2138.652
4	27	2.2	1600	1524.125
5	30.5	3	2350	2296.033
6	32.5	2.5	2100	2245.739
7	27.5	3.2	2150	2091.416
8	26.5	3.2	1900	1998.061
9	24	2	1350	1105.82
10	32.5	2.5	2500	2245.739
11	24	3.5	2000	1884.841
12	20	3.2	1350	1429.822
13	29.5	2	1750	1616.988
14	29	2.8	2100	2057.525
15	22	2.5	1250	1263.081
16	26.5	3	1800	1913.823
17	26.5	2.8	1650	1821.364
18	27.5	2.7	2350	1864.958
19	24.5	2.5	1350	1481.784
20	27.5	2.6	1800	1812.557
21	30.5	2.6	1900	2101.412
22	28	2.5	1750	1804.502
23	27.5	3	2200	2007.178

24	23	2.5	1500	1349.335
25	28	2.6	1750	1859.793
26	29	3.5	2450	2347.682
27	26.5	3	2000	1913.823
28	28	3	2250	2054.414
29	29.5	2.5	1750	1948.4
30	30.5	3.2	2450	2380.271
31	22	2.5	1350	1263.081
32	21	2	950	847.0995
33	25	3	1600	1776.645
34	27.5	2.5	1800	1757.266
35	30	2	1600	1665.672
36	30.5	2.2	1900	1859.845
37	25.5	3	1700	1821.985
38	27	3.2	2150	2044.551
39	29.5	2.3	1850	1827.968
40	26	3.2	1850	1951.951
41	25	2	1150	1195.32
42	24	3	1800	1687.144
43	26.5	2.8	1750	1821.364
44	23.5	2.8	1500	1550.533
45	22	3	1350	1512.993
46	25	3.6	2200	2009.188
47	29	2.8	2150	2057.525
48	26	3	1700	1867.713
49	30.5	2.5	1900	2046.121

50	24	2.5	1350	1437.232
51	27	3.2	2350	2044.551
52	26	2	1450	1286.388
53	26	3.2	1800	1951.951
54	21.5	3.2	1300	1554.733
55	30.5	2.4	1800	1987.656
56	23.5	3.7	2000	1909.056
57	25	2	1350	1195.32
58	34	2.5	2600	2399.009
59	28.5	2.2	1800	1665.829
60	29.5	2.5	1950	1948.4
61	33	2.8	2550	2453.949
62	25	2.5	1450	1526.732
63	29	3	2250	2149.985
64	31	2.5	2200	2095.508
65	32.5	2	1900	1914.327
66	31	2.8	2250	2252.962
67	24	4	2300	2046.627
68	26.5	2.5	1500	1663.911
69	29	3	2100	2149.985
70	30	2.5	1950	1997.084
71	21	3.8	1550	1726.768
72	24	3.2	1900	1771.382
73	25.5	4	2500	2181.468
74	27.5	4.2	2800	2423.678
75	29	3	225	2149.985

76	30.5	3	2600	2296.033

The estimated and the observed value are close enough.

The difference however is due to the availability of less number of data for the potholes.

R-squared is a measure of how closely the data are is related. It is also known as the coefficient of determination.

The figure below shows the undulations.

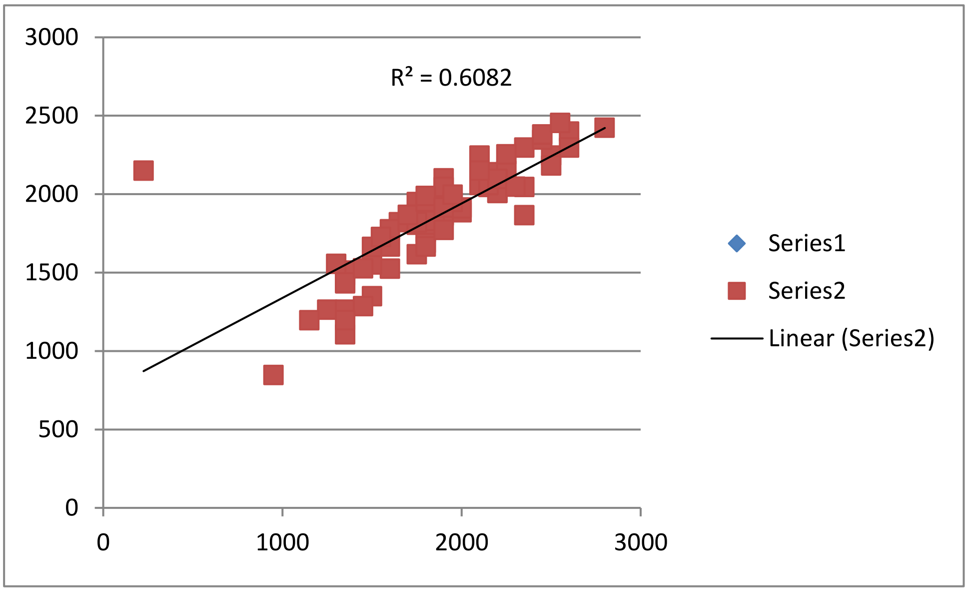

Fig.5.1: Graphical presentation of pothole data with R^2 = 0.608

CHAPTER 6

CONCLUSION

From the project we have concluded that:

1. According to the surface distresses data collected from the six selected rural hilly roads, all the roads are found to be in a fair condition.

2. The roads also have fairly good profile with respect to the roughness index. RR4 and RR1 have very good and good surface profile respectively, however the rest of the roads fall under the category of fair surface profile.

3. All the roads are safe according to the skid resistance value and surface texture depth collected and compared with the standard guidelines.

4. The relationship between the volume of the pothole and the mean dimensions as well as depth in not a linear equation. The linear relation cannot be established between the parameters taken up. However a non linear relation is found.

5. There is a difference between the estimated and practically observed values of volume of pothole which can be explained by the point that the data inputted is less in quantity.

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APPENDIX

ANNEXURE I

Table 7.1: Data: Domehar road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	58	42	13.384	0	10.26	0.86
50-100			8.326	0	9.460	
100-150	55	44	4.867	0	17.652	
150-200			15.249	0	10.354	
200-250	59	45	16.233	0	7.365	
250-300			11.325	0	0	
300-350	53	42	3.257	0	1.254	
350-400			6.726	0	0	
400-450	56	48	8.242	0	4.256	
450-500			2.044	0	3.210	
500-550	55	48	9.246	0	0	0.91
550-600			12.259	0	0	
600-650	60	48	1.256	0	3.780	
650-700			8.327	0.08256	2.588	
700-750	58	46	10.289	0	5.085	
750-800			6.078	0	0	
800-850	63	55	0.582	0.07080	0	
850-900			0	0	0	
900-950	61	45	0	0	2.378	
950-1000			2.467	0	4.785	
1000-1050	59	44	4.568	0.01295	0	0.82
1050-1100			0	0	2.375	
1100-1150	61	50	2.180	0	0	
1150-1200			0	0	0	
1200-1250	62	55	0	0	5.67	
1250-1300			0	0	0	
1300-1350	56	42	0.083	0	11.52	
1350-1400			0	0	0	
1400-1450	58	46	0.608	0	0	
1450-1500			14.257	0	0	
1500-1550	60	47	10.258	0	0	0.77
1550-1600			6.665	0	2.440	
1600-1650	64	57	0	0	3.724	

1650-1700			0	0	0	
1700-1750	57	46	4.560	0	2.548	
1750-1800			6.246	0.03550	0	
1800-1850	64	54	2.365	0.05286	0	
1850-1900			8.553	0	0	
1900-1950	55	43	0.420	0	5.214	
1950-2000			12.245	0	4.278	
2000-2050	55	41	8.630	0	0	0.92
2050-2100			3.540	0	3.674	
2100-2150	63	52	0	0	0	
2150-2200			0	0	0	
2200-2250	52	42	4.576	0	0	
2250-2300			2.365	0	0	
2300-2350	55	46	1.854	0	2.45	
2350-2400			0	0	0	
2400-2450	54	41	6.326	0	0	
2450-2500			9.647	0	1.872	

ANNEXURE II

Table 7.2: Data: Kyari Bangla road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	62	54	2.342	0	0	1.12
50-100			0	0	0	
100-150	65	49	1.224	0	0	
150-200			3.784	0	0	
200-250	60	52	0	0	0	
250-300			0	0	0	
300-350	58	46	0	0	0	
350-400			2.542	0	0	
400-450	59	48	3.240	0	0	
450-500			3.550	0	0	
500-550	62	48	0	0	0	0.96
550-600			0	0.009882	0	
600-650	63	51	2.145	0.013806	0	
650-700			0	0	0	
700-750	55	44	4.47	0	1.480	
750-800			0	0	0	
800-850	58	45	0	0	0	
850-900			4.450	0	2.344	
900-950	62	50	0	0	0	
950-1000			6.620	0	0	
1000-1050	59	49	2.215	0	0	1.24
1050-1100			1.250	0	0	
1100-1150	66	54	4.25	0.002456	0	
1150-1200			0	0	0	
1200-1250	58	44	0	0	0	
1250-1300			0.157	0	0	
1300-1350	62	48	0.175	0	3.442	
1350-1400			0	0	0	
1400-1450	63	51	0	0	0	
1450-1500			0	0	0	
1500-1550	60	51	0	0	0	1.08
1550-1600			0	0	0	
1600-1650	58	47	2.265	0	0	

1650-1700			3.840	0	0	
1700-1750	57	49	0.075	0	0	
1750-1800			0	0.005824	0	
1800-1850	61	52	0	0	0	
1850-1900			1.358	0	0	
1900-1950	63	50	0	0	0	
1950-2000			0	0	1.326	
2000-2050	62	50	0	0	0	1.30
2050-2100			0	0	0	
2100-2150	59	47	0	0	0	
2150-2200			0	0	0	
2200-2250	54	45	0	0	0	
2250-2300			0	0	0	
2300-2350	62	50	2.758	0	0	
2350-2400			0	0.012056	0	
2400-2450	65	54	0.975	0	0	
2450-2500			0	0	0	

ANNEXURE III

Table 7.3: Data: Industrial road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	74	62	0	0.017	0	1.27
50-100			0	0	0	
100-150	67	59	0.045	0	0	
150-200			0.02404	0	0	
200-250	65	56	0	0	0	
250-300			0	0	0	
300-350	73	64	0.01653	0.005	0	
350-400			0.0536	0	0	
400-450	75	63	0.036	0	0	
450-500			0	0.063	0	
500-550	71	60	0	0.069	0	1.65
550-600			0	0	0	
600-650	66	55	0	0.017	0	
650-700			0.036	0	0	
700-750	64	52	0	0	0	
750-800			0	0.018	0	
800-850	59	48	0	0	0	
850-900			0.04583	0	0	
900-950	68	56	0	0	0	
950-1000				0	0	
1000-1050	68	55	0.0224	0	0	1.24
1050-1100			0	0	0	
1100-1150	70	60	0	0.054	0	
1150-1200			0.062	0	0	
1200-1250	72	62	0.0492	0	0	
1250-1300			0	0	0	
1300-1350	72	63	0.0145	0	0	
1350-1400			0	0	0	
1400-1450	66	58	0	0.0223	0	
1450-1500			0	0	0	
1500-1550	71	57	0	0	0	1.08
1550-1600			0.985	0	0	
1600-1650	64	52	0.0156	0	0	

1650-1700			0.0948	0	0	
1700-1750	59	48	0	0.075	0	
1750-1800			0	0	0	
1800-1850	68	55	0.245	0	0	
1850-1900			0.65	0	0	
1900-1950	70	59	0.02445	0	0	
1950-2000			0.0350	0	0	
2000-2050	74	61	0	0	0	1.12
2050-2100			0	0	0	
2100-2150	62	52	0	0	0	
2150-2200			0	0	0	
2200-2250	66	58	0	0	0	
2250-2300			0	0	0	
2300-2350	68	60	0	0	0	
2350-2400			0.0256	0	0	
2400-2450	70	61	0	0	0	
2450-2500			0	0	0	

ANNEXURE IV

Table 7.4: Data: Salana road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	66	57	9.0245	0	0	0.95
50-100			2.2450	0	8.554	
100-150	65	58	0	0	10.250	
150-200			0	0	0	
200-250	58	49	0	0	0	
250-300			0.1570	0	9.625	
300-350	65	54	0.0450	0	12.254	
350-400			0.0332	0	0	
400-450	66	58	0	0.003458	28.245	
450-500			0	0.00842	32.784	
500-550	58	47	0	0	0	1.04
550-600			0	0	0	
600-650	70	62	0	0	0	
650-700			0	0	0	
700-750	67	55	0	0	0	
750-800			0	0	0	
800-850	68	57	0	0	3.952	
850-900			0	0	4.254	
900-950	62	51	7.2540	0	2.854	
950-1000			4.3250	0	4.250	
1000-1050	64	54	2.0014	0	1.486	0.84
1050-1100			0	0	9.650	
1100-1150	65	56	0	0	0	
1150-1200			0	0	0	
1200-1250	68	54	0	0.0042	0	
1250-1300			3.2560	0	0	
1300-1350	65	58	0	0	0	
1350-1400			0	0	0	
1400-1450	60	48	0	0.0039	0	
1450-1500			0	0	0	
1500-1550	58	49	8.6540	0	0	0.96
1550-1600			4.2560	0	0	
1600-1650	60	52	0	0	0	

1650-1700			0	0.0042	0	
1700-1750	64	55	0	0.00395	0	
1750-1800			0	0.00173	4.870	
1800-1850	65	58	0	0	3.642	
1850-1900			9.5520	0	0	
1900-1950	68	60	0	0	0	
1950-2000			0	0	0	
2000-2050	72	61	0	0	0	1.22
2050-2100			0	0	0	
2100-2150	65	57	4.2530	0	0	
2150-2200			0	0	1.885	
2200-2250	57	48	0	0.017	0	
2250-2300			0.0097	0	0	
2300-2350	64	55	0	0	0	
2350-2400			0	0	0	
2400-2450	61	52	1.8452	0	0	
2450-2500			0	0	0	

ANNEXURE V

Table 7.5: Data: Shoghi Lagroo road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	62	54	0	0.054	0	0.86
50-100			0	0.065	0	
100-150	64	52	0	0.021	5.650	
150-200			0	0	0	
200-250	68	59	0	0	0	
250-300			0	0	2.242	
300-350	71	60	0	0	0	
350-400			0	0.0145	0	
400-450	69	57	0	0	0	
450-500			0	0	0	
500-550	64	55	0	0	0	0.98
550-600			0	0.054	0	
600-650	66	55	0	0.042	0	
650-700			0	0	0	
700-750	65	54	0	0	0	
750-800			8.084	0	0	
800-850	65	53	0	0	1.457	
850-900			0	0	0	
900-950	65	57	0	0	0	
950-1000			4.231	0	0	
1000-1050	69	60	0	0	0	1.42
1050-1100			0	0	0	
1100-1150	72	61	0	0	0	
1150-1200			0	0	3.454	
1200-1250	57	48	0	0	0	
1250-1300			0	0	0	
1300-1350	62	52	2.254	0	0	
1350-1400			0	0	0	
1400-1450	62	50	0	0	0	
1450-1500			0	0	0	
1500-1550	68	55	0	0	0	1.15
1550-1600			4.256	0	0	
1600-1650	64	58	0	0	0	

1650-1700			0	0.004	0	
1700-1750	56	48	0	0	0	
1750-1800			0	0	0	
1800-1850	61	53	0.008	0	0	
1850-1900			0	0	0	
1900-1950	58	49	0	0.024	0	
1950-2000			0	0	0	
2000-2050	67	58	0	0	0	0.98
2050-2100			0	0	0	
2100-2150	66	59	0	0	4.245	
2150-2200			0	0.026	0	
2200-2250	72	62	0	0	0	
2250-2300			0	0	0	
2300-2350	62	54	0	0	0	
2350-2400			0	0	0	
2400-2450	68	55	0	0.017	0.680	
2450-2500			0	0	0	

ANNEXURE VI

Table 7.6: Data: Nain Basal road

Segment (m)	Skid resistance value (SRV)		Cracking (m^2)	Potholes (Vol. in m^3)	Patching (m^2)	Mean texture depth (mm)
	Dry	Wet				
0-50	58	45	3.0452	0	6.62	0.90
50-100			6.520	0.00545	5.58	
100-150	60	50	1.854	0.00254	2.24	
150-200			2.654	0	2.88	
200-250	56	48	0	0	3.65	
250-300			0	0	4.58	
300-350	54	45	0	0.00245	0	
350-400			9.654	0	0	
400-450	55	47	3.458	0	0	
450-500			1.245	0	2.36	
500-550	60	49	0	0.04501	0	0.88
550-600			0	0	1.28	
600-650	54	45	0	0	0	
650-700			4.562	0.0085	0	
700-750	55	48	2.547	0.0045	0	
750-800			0	0	0	
800-850	52	42	0	0	3.45	
850-900			3.54	0	0	
900-950	58	46	0	0	0	
950-1000			0	0	0	
1000-1050	56	48	2.47	0	0	0.92
1050-1100			0	0	4.85	
1100-1150	55	44	0	0	0	
1150-1200			0	0	0	
1200-1250	60	52	1.44	0	0	
1250-1300			4.25	0.00450	0	
1300-1350	62	51	0	0	0.24	
1350-1400			0	0	0.98	
1400-1450	56	48	0	0	2.45	
1450-1500			0	0	3.47	
1500-1550	62	50	0	0	0	1.04
1550-1600			5.550	0	0	
1600-1650	65	53	4.653	0	2.75	

1650-1700			6.243	0	0	
1700-1750	58	49	7.250	0	0	
1750-1800			0	0	0	
1800-1850	55	47	0	0	3.65	
1850-1900			0	0	0	
1900-1950	61	49	0	0.0033	0	
1950-2000			0	0	0	
2000-2050	59	45	0	0	1.14	0.84
2050-2100			5.245	0	0	
2100-2150	62	54	0	0	0	
2150-2200			0	0	0	
2200-2250	58	46	0	0	0	
2250-2300			0	0	0	
2300-2350	62	54	0	0	0	
2350-2400			3.50	0.0015	0.875	
2400-2450	55	42	2.75	0	0	
2450-2500			0	0	0	

ANNEXURE VII

Roughness data obtained using MERLIN.

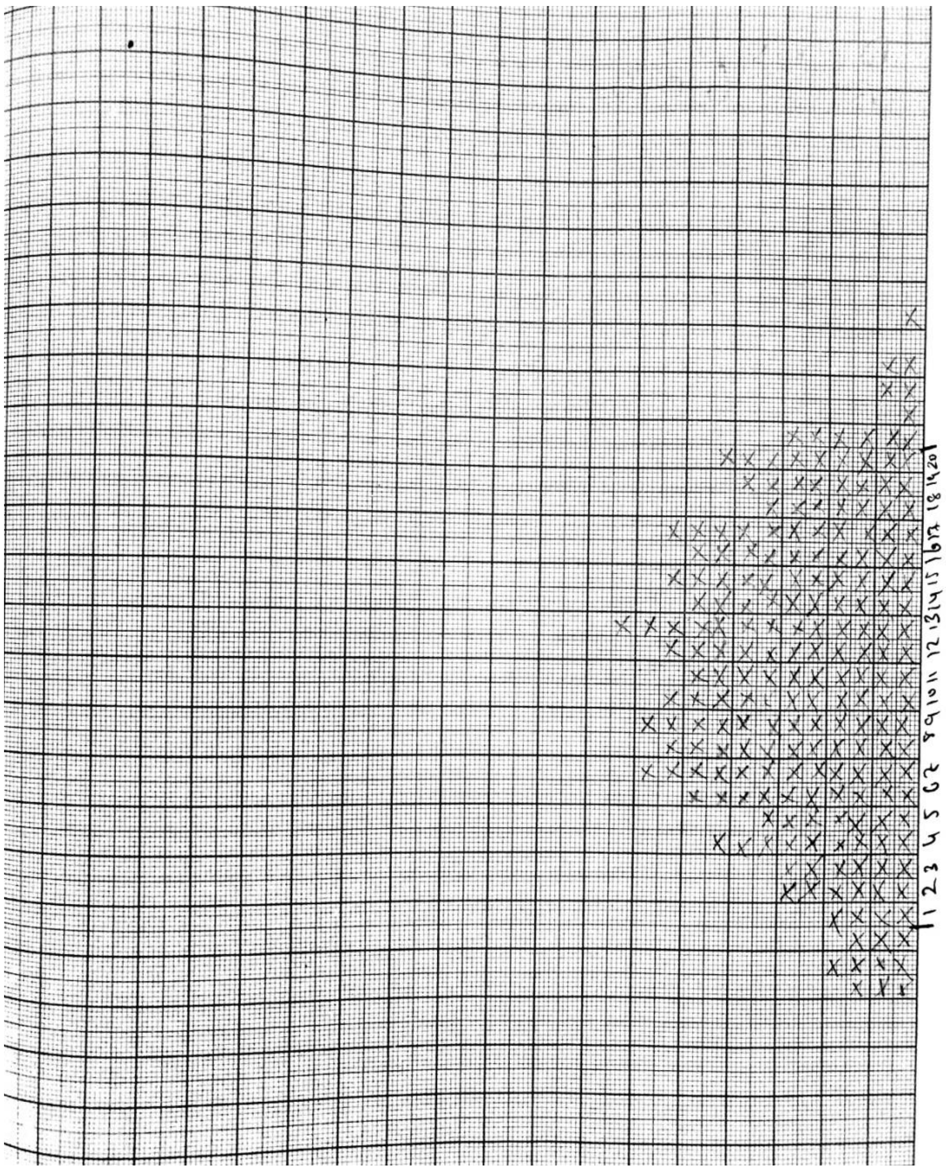

Fig.7.1: Sample graph data: RR-1

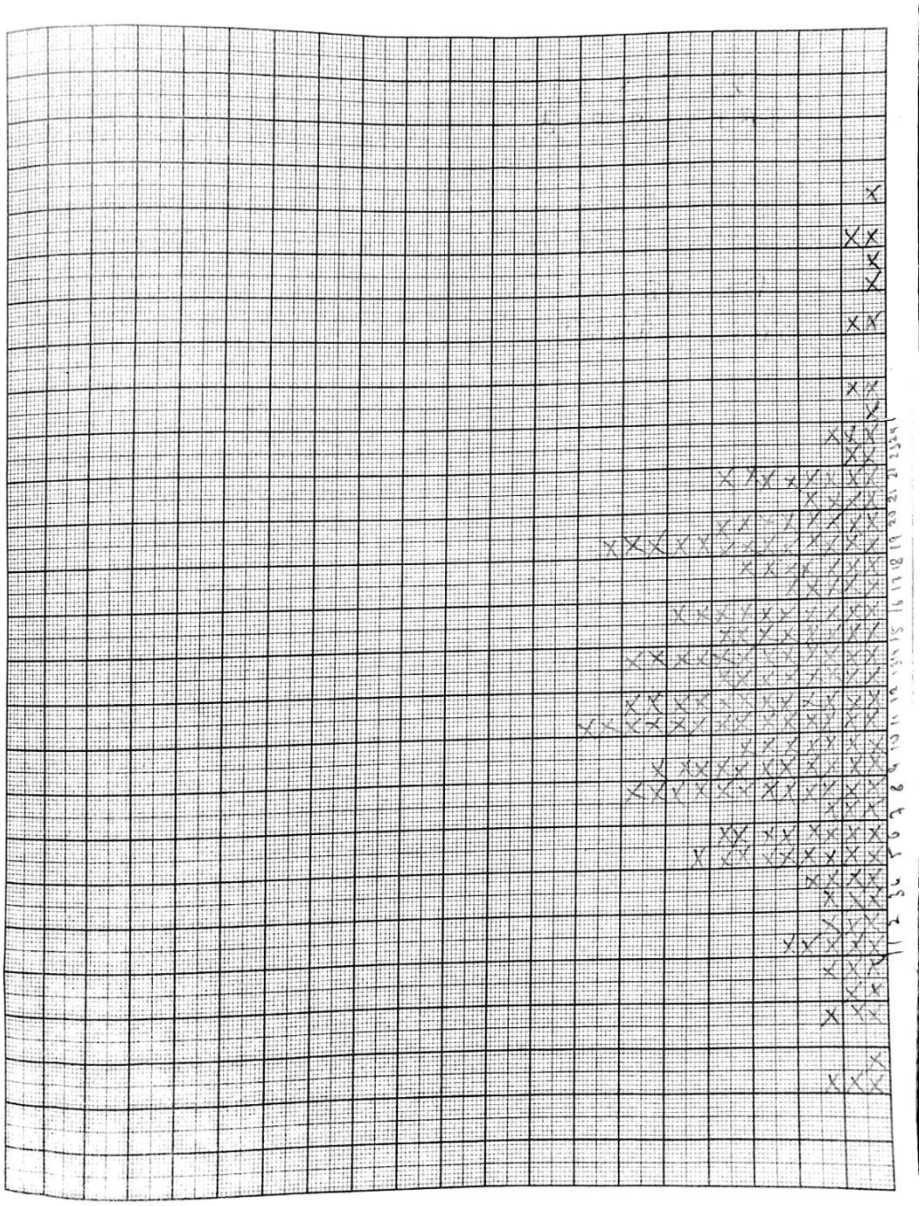

Fig.7.2: Sample graph data: RR-2

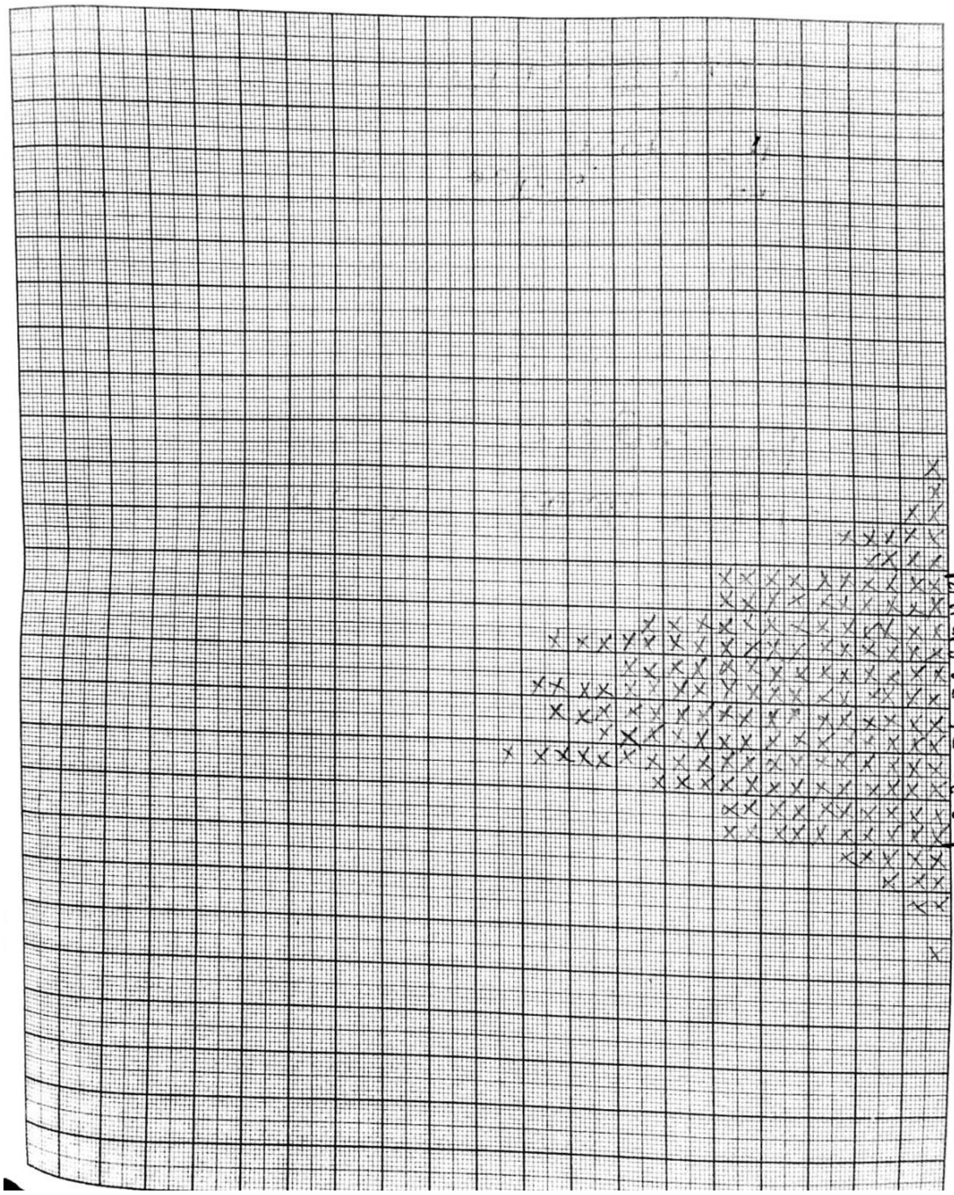

Fig.7.3: Sample graph data: RR-3

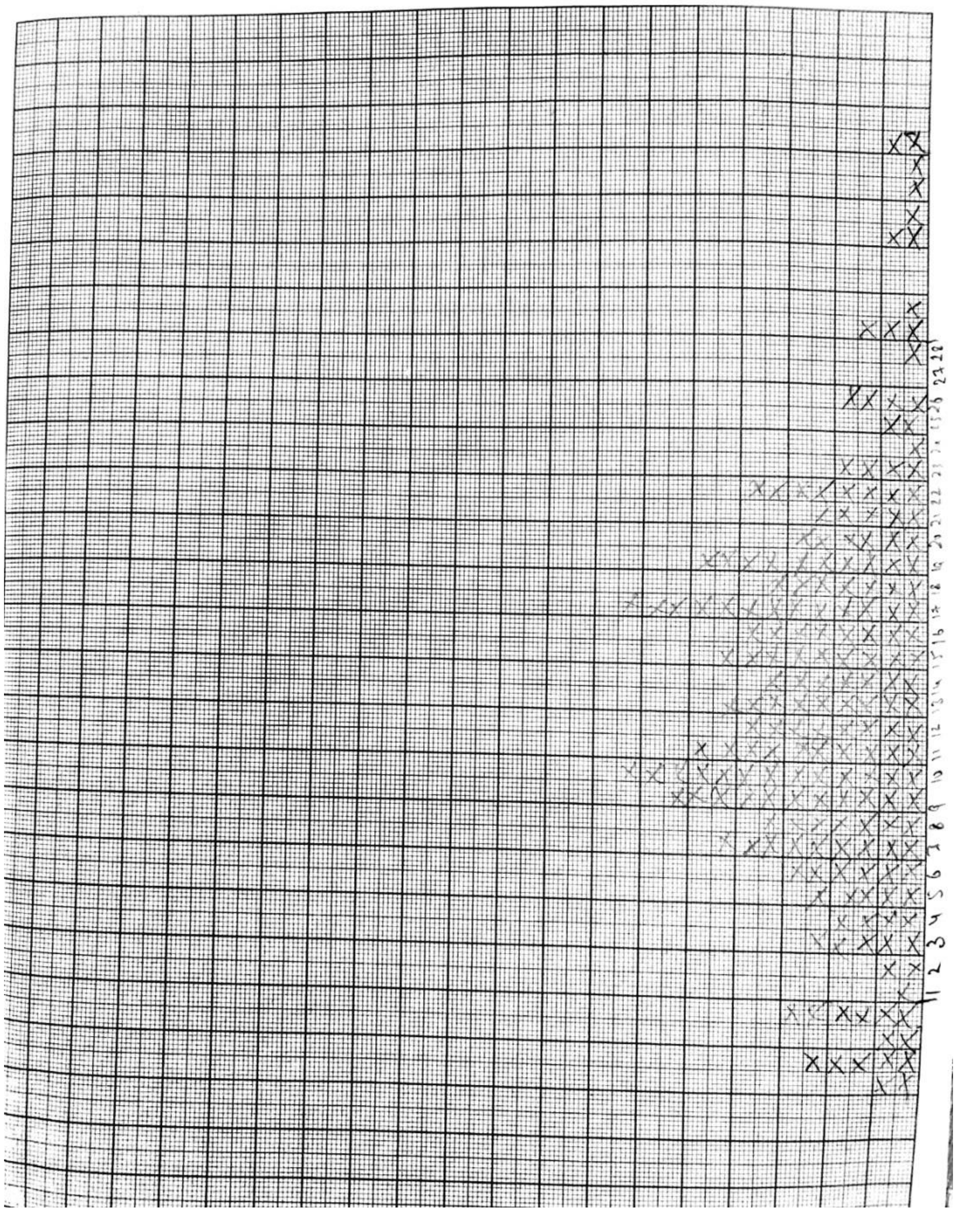

Fig.7.4: Sample graph data: RR-4

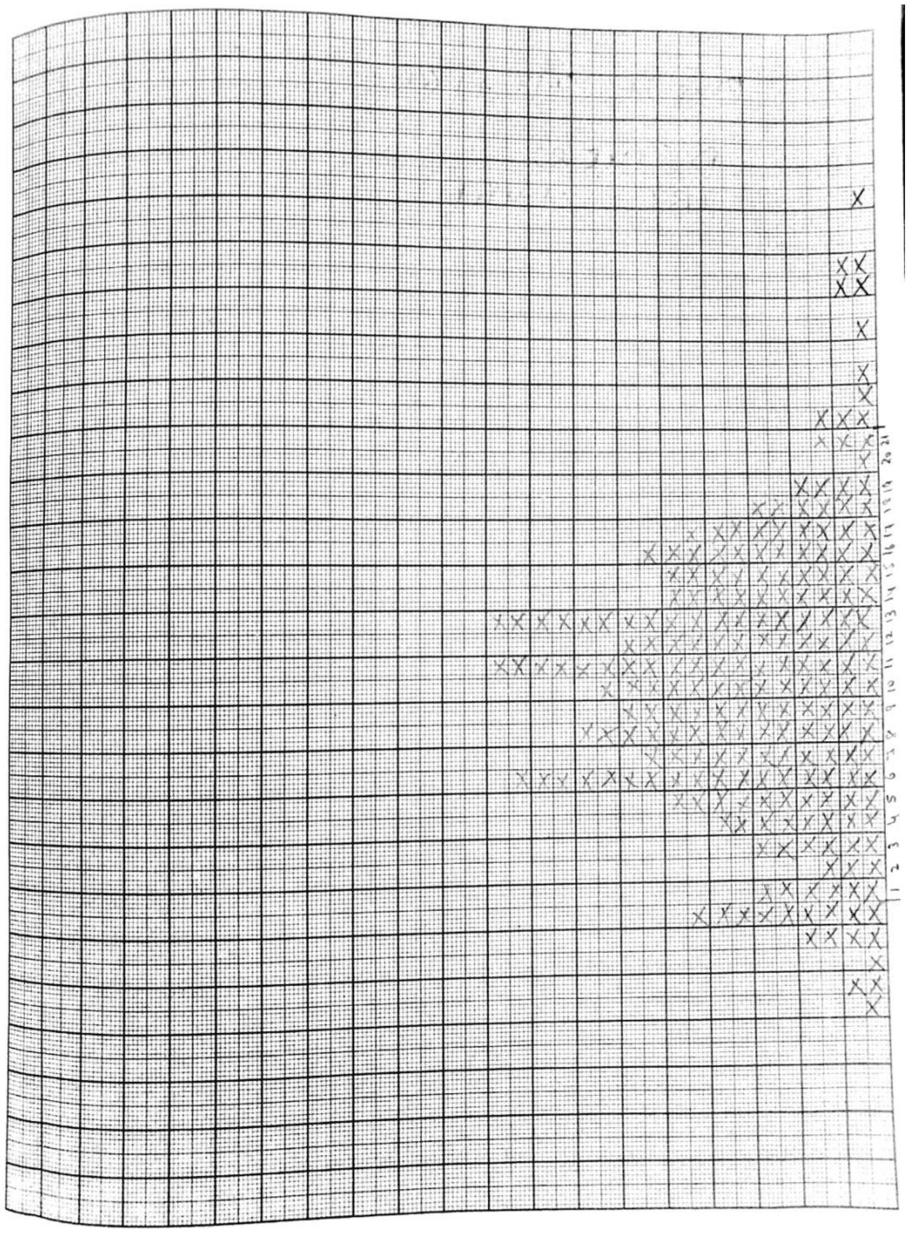

Fig.7.5: Sample graph data: RR-5

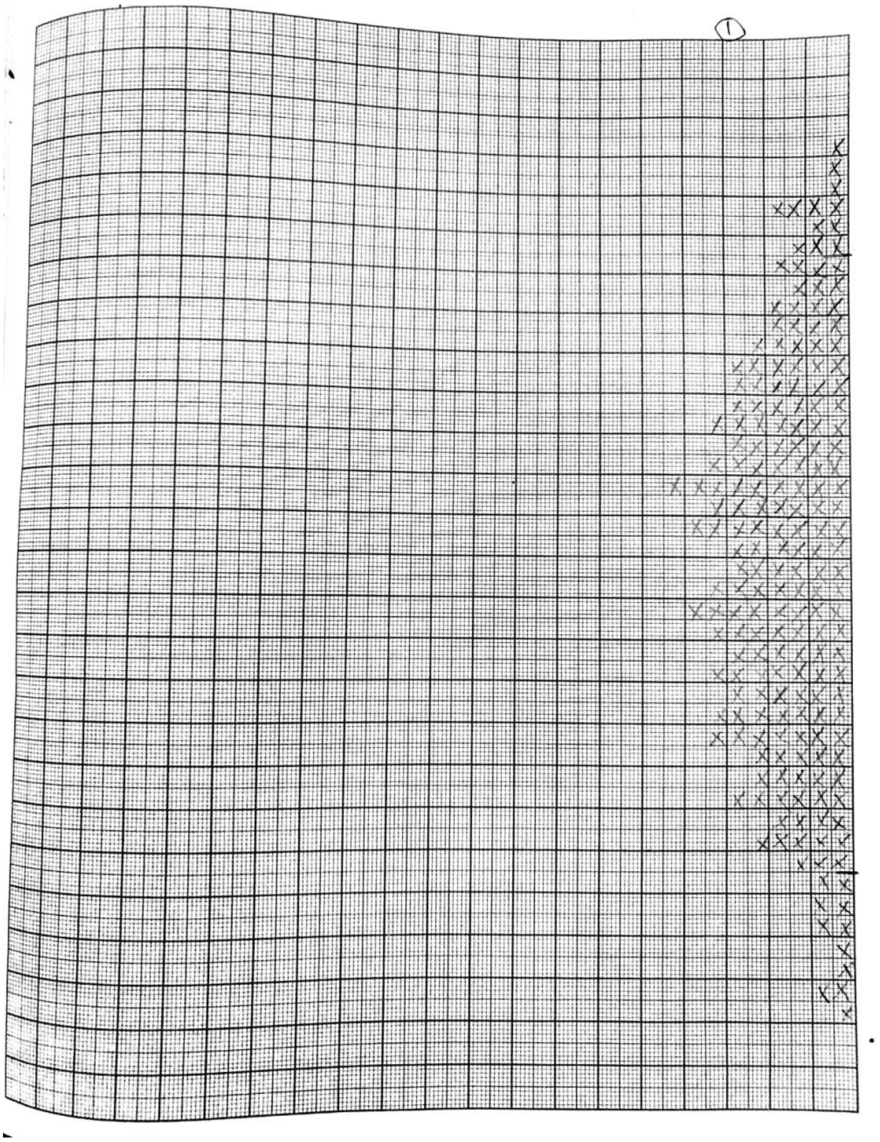

Fig.7.6: Sample graph data: RR-6