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ELUCIDATION OF SOIL PROPERTIES FOR RURAL AREA ROAD CONSTRUCTION USING POLYMERIZED SOIL STABILIZATION TECHNIQUES

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***Abstract* - The soil stabilization begins once the polymer has been chosen. Following this procedure, a road of 100 metres (or whatever length is possible) have been designed. Standard road construction equipment was also utilized to build the roads. Soil evaluation for road construction at rural area is still challenges due to several factors. Here, the study design focused on the soil stabilization techniques and the main objectives of the study was to elucidate the rural soil properties for the road construction**

Index Terms – Rural, Soil, Polymerized, Stabilization, Construction.

INTRODUCTION

The soil sample for this research was taken from a rural location at a depth of Xm to Ym utilizing the disturbed sampling technique. Changes in soil characteristics such as Maximum dry density (MDD), Optimum moisture content (OMC), California bearing ratio (CBR), unconfined compressive strength (UCS), and other related tests are observed [1-3].

Footsteps, automobiles, trucks, and rain compress the soil at first [4]. The polymer is then sprayed to a depth of 0.75 inch and crushed by the vehicles. Sand will be added up to 0.25 inch and compressed further. The polymer slab will then be inserted and compressed for 3 inches [5].

Finally, a fourth layer of polymer slab will be applied up to four inches thick, followed by a standard blacktop seal [6]. However, once the road is built, the road's uniformity and dust management will be evaluated.

Polyacrylamide (PAM) was chosen as the soil conditioner for this research because it is a well-known anionic polymer that helps to stabilise the soil surface structure and porosity [7].In comparison to water applications, the proposed building would significantly assist in dust management and further decrease water consumption and emissions as a consequence of daily truck operations for water applications [8]. The main flaw in this research is that, although it helps with the building of new roads, using the same approach to repair old roads is laborious [9].It also contains the usual method for performing Benkelman Beam Deflections, which reflect the pavement's structural behaviour. The current research additionally gathered data on pavement temperature, type of subgrade soil, plasticity index of soil, moisture content of subgrade soil, and yearly rainfall data in order to make adjustments in the Benkelman Beam Deflection values [10-14]. On the subgrade soil samples collected from chosen rural road portions, the California Bearing Ratio (CBR) test was also performed, showing both wet and unsoaked CBR. The K-value, or modulus of subgrade response, was calculated using the IRC: 58-2015 correlation table between soaking CBR and K-value [15-16].The categorized traffic volume survey was carried out manually in the area throughout both the lean and peak seasons, and the Average Annual Daily Traffic was calculated using the IRC standard code SP:72-201.

RESEARCH METHODOLOGY

In this research, 12 rural stretches in Maharashtra , India, each measuring 2.5 km in length and averaging 3 metres in width were chosen for gathering pavement distress, pavement roughness, and pavement structural data. The 12 rural road sections in the area of Nagpur Districts in Maharashtra, India, were chosen. Each chosen country road length is 3.5 metres wide. The following sections provide the field data gathered in terms of Pavement Inventory, Functional Condition of Roads, Structural Condition of Roads, CBR of Roads, K-value, and categorized traffic volume of chosen rural road sections. A list of all data parameters, as well as the equipment utilized, the amount of data points gathered, and the method employed, has been provided.

Table 1: Selected Rural Road Stretches:

Road ID	**Road Name (Village Names)**	**Road ID**	**Road Name (Village names)**
NRR-1	Bokhara-Lonara	NRR-7	Sawarmendha -Brahmanwada
NRR-2	Lonara - Gumthala	NRR-8	Brahmanwada - Khandala
NRR-3	Gumthala - Gumthi	NRR-9	Khandala -Walni
NRR-4	Gumthala - bailwada	NRR-10	Sawarmendha - Champa
NRR-5	Gumthala-Chakkikhapa	NRR-11	Champa - Babulkheda
NRR-6	Gumthi - Sawarmendha	NRR-12	Babulkheda - Tandulwani

Pavement Inventory Data:

Pavement inventory details include Name of the road, Category of the road viz. rural road, NH or SH, number of lanes, carriageway width of the road, and surface type, maintenance and construction history of the roads

Table 2: Inventory Data of Pavement for selected Rural Road Sections

Rural Road ID	**Name of road**	**Category of Road**	**No.of Lanes**	**width**	**Surface Type**	**Age of pavement from last overlay In years**
NRR1	Bokhara-Lonara	Rural	One	3.5metre	Premix Carpet	7
NRR2	Lonara - Gumthala	Rural	One	3.5metre	Premix Carpet	5
NRR3	Gumthala - Gumthi	Rural	One	3.5metre	Premix Carpet	7
NRR4	Gumthala - bailwada	Rural	One	3.5metre	PremixCarpet	6
NRR5	Gumthala-Chakkikhapa	Rural	One	3.5metre	Premix Carpet	6
NRR6	Gumthi - Sawarmendha	Rural	One	3.5metre	Premix Carpet	7
NRR7	Sawarmendha -Brahmanwada	Rural	One	3.5metre	Premix Carpet	5
NRR8	Brahmanwada - Khandala	Rural	One	3.5metre	Premix Carpet	6
NRR9	Khandala -Walni	Rural	One	3.5metre	Premix Carpet	7
NRR10	Sawarmendha - Champa	Rural	One	3.5metre	Premix Carpet	7
NRR11	Champa - Babulkheda	Rural	One	3.5metre	Premix Carpet	6
NRR12	Babulkheda - Tandulwani	Rural	One	3.5metre	Premix Carpet	7

Functional Evaluation Data

Pavement distresses (cracking, raveling, potholes, patching, rutting) which are predominantly prevailing on the selected rural road sections in Maharashtra region, pavement roughness in terms of IRI, Mean Texture Depth (MTD), and Skid Resistance were all collected as part of the functional evaluation. The data for all functional parameters was gathered over the course of a year.

Distressed Pavement

The pavement distress data was gathered on 12 rural road sections in Nagpur, Maharashtra. Pavement cracking, raveling, potholes, patching, and rutting are some of the most common pavement problems in the area. Pavement distresses such as cracking, raveling, and patching were assessed using basic measuring tools such as tape and scale, which were then translated into percentages represented as the total area of the surface. The cracking has been classified as longitudinal cracking, transverse cracking, and alligator cracking, with low, medium, and high severity levels.

Summary of Equipment used, data points collected and procedure followed for various pavement parameters

Table3:Summary of Equipment used, data points collected and procedure followed for various pavement parameters

Parameter	**Equipment Used**	**Number of Data Points Collected**	**Procedure Followed**
Cracking	Simple measuring equipment	Length, Width and Area of All Cracked surface (with severity)	IRC-82:2015
Ravelling	Simple measuring equipment	All raveled area (with severity)	IRC-82:2015
Patching	Simple measuring equipment	All patched area (withseverity)	IRC-82:2015
Rutting	3 m Straight Edge	All rut depth data prevailing in 2.5km section	IRC-82:2015
Potholes	Simple measuring equipment and sand replacement method to determine volume of pothole	All pothole data (with severity)	IRC-82:2015
Road Roughness	MERLIN	Four passes of MERLIN in each 500 m section	IRC-82:2015& TRL MERLIN Report 229
Skid Resistance	Skid Resistance Pendulum Tester	Three Skid resistance values (wet & dry) at every50minterval	IRC-82:2015 &ASTM-274[28]
Mean Texture Depth	Sand Patch Apparatus	Mean texture depth at Every 50 m interval	BS 598Part105& ASTME965
PavementDeflection	BenkelmanBeam	25deflectionpointson each2.5kmroadsection	IRC:81-1997
BRvalue	CBRApparatus	Threesamplesfrom eachroadsection	IRC:36-2010 and IS2720
K-value	--	One value for each road using average CBRvalue	IRC:58-2015
TrafficVolume	Manually	7days traffic count	IRC:SP:72-2015

Table4.Unsoaked CBR and Soaked CBR Values of all soil samples

	Unsoaked CBR				Soaked CBR			
Roads	**CBR-1**	**CBR-2**	**CBR-3**	**Average CBR (%)**	**CBR-1**	**CBR-2**	**CBR-3**	**Average CBR(%)**
NRR1	26.60	28.40	27.90	27.63	18.54	19.01	20.14	19.23
NRR2	24.54	25.01	27.52	25.69	15.24	15.97	18.11	16.44
NRR3	19.89	22.41	20.85	21.05	10.22	11.58	14.41	12.07
NRR4	28.69	29.11	30.85	29.55	18.64	19.41	20	19.35
NRR5	17.68	19.21	18.16	18.35	9.73	11.52	9.26	10.17
NRR6	27.85	26.35	30.49	28.23	18.26	19.71	20.47	19.48
NRR7	26.25	28.95	26.13	27.11	15.65	16.87	21.06	17.86
NRR8	27.36	28.34	31.15	28.95	19.22	20.35	21.21	20.26
NRR9	25.06	27.47	28.2	26.91	15.74	16.46	17.45	16.55
NRR10	19.27	23.18	25.29	22.58	11.84	12.12	14.11	12.69
NRR11	25.88	26.41	26.43	26.24	15.98	16.48	19.32	17.26
NRR12	22.91	24.75	23.95	23.87	14.21	15.49	16.29	15.33

Modulus of Subgrade Reaction(K-value)

The modulus of subgrade reaction(Kvalue) has also been determined approximately corresponding to the soaked CBR value using IRC: 58-2015 "Guidelines for the design of plain jointed Rigid Pavements for highways.

Table5. Selected stretches K-Value

Road ID	NRR1	NRR2	NRR3	NRR4	NRR5	NRR6	NRR7	NR8	NR9	NRR10	NRR11	NRR12
K-Value	6.79	6.40	5.79	6.81	5.52	6.83	6.0	6.96	6.42	5.88	6.52	6.25

Age of Pavement:

The age of pavement i.e. the number of years from last overlay till the year in which the Benkelman Beam study conducted was taken from DPR of the selected road sections available with PWD, Maharshtra.

Table6.Age of Pavement of all selected stretches from last overlay (in years)

Road ID	**NRR1**	**NRR2**	**NRR3**	**NRR4**	**NRR5**	**NRR6**	**NRR7**	**NRR8**	**NRR9**	**NRR10**	**NRR11**	**NRR12**
Age (years)	7	5	7	6	6	7	5	6	7	7	6	7

Traffic Volume Survey

Buses, two-axle trucks, multi-axle trucks, light commercial vehicles, light passenger vehicles, and two-wheelers were all enumerated manually for seven days (12 hours each day) by experienced enumerators, covering all kinds of vehicles.

The traffic volume survey was conducted twice, first during the lean season and again during the high season, for a total of seven days, as shown in Figures

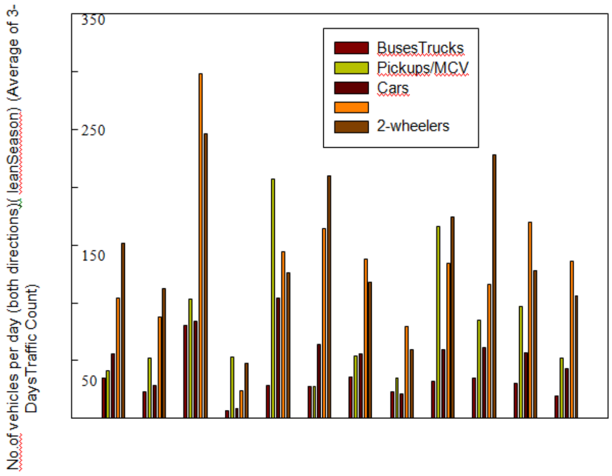

Figure1Traffic Volume Survey for Lean Season

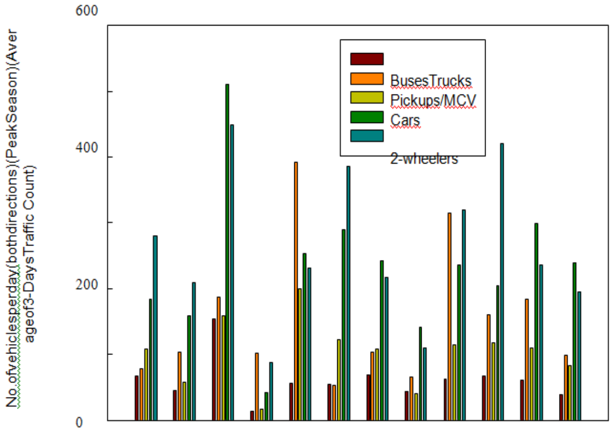

Figure2 Traffic Volume Survey for Peak Season

The traffic volume was calculated using IRC: SP: 72-2015 "Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads" for all of the chosen rural road sections. The categorized traffic volume data for all of the chosen rural road sections has been provided.

RESULTS AND DISCUSSION:

1.The percentage cracking is found to be lowest(0.14%) in NRR9 whereas it is highest in rural road stretch of NRR1with5.36%

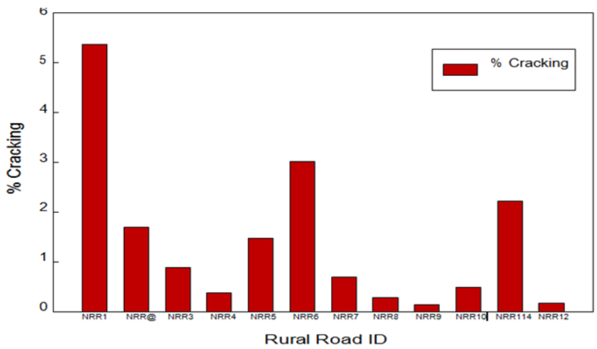

Figure 3. Percentage Cracking of selected road stretches

2. Also, the percentage raveling is found to be lowest in NRR9 with 0.28% and shown a significant effect in NRR5 with 38.74%

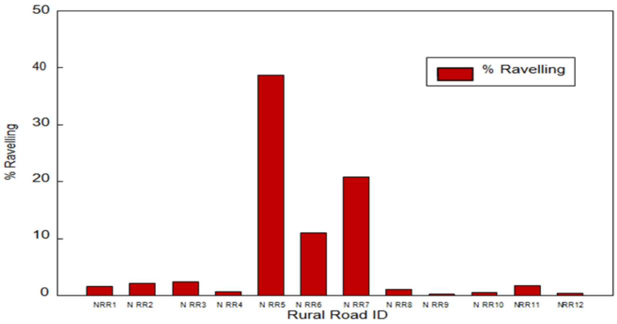

Figure4.Percentage Raveling of selected road stretches

3. The distress patching is found to be very low on all the roads in a range of 0.22%-2.68%.The highest percentage patching is found to be on NRR6.

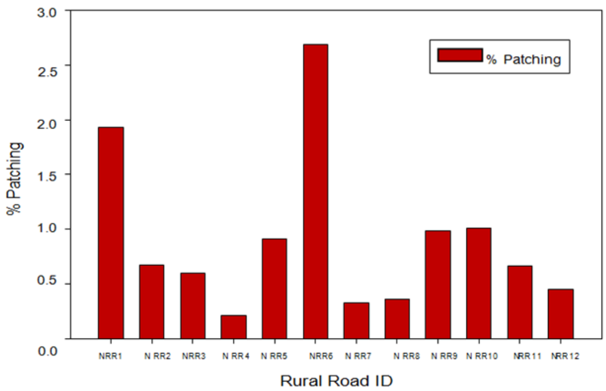

Figure5.Percentage Patching of selected road stretches

4. The total volume of potholes measured throughreplacing a known volume of sandwith the pothole bowl is found to be significant on NRR7 with 0.28 m3 of volume. However, least volume of pothole is found to be on NRR1 with 0.076 m3 ofvolume.

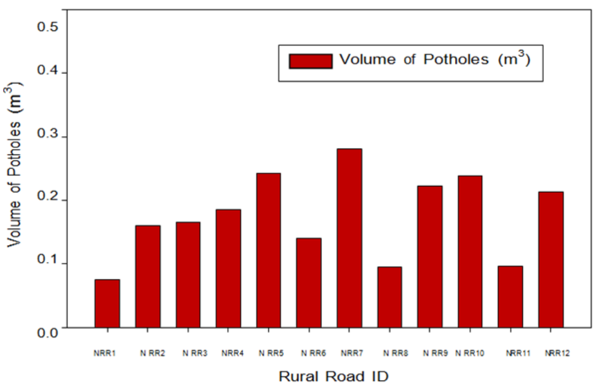

Figure 6. Total Volume of Potholes on selected road stretches

5. Also, the mean rut depth is found to be highest on NRR 1 with a value of 16.8 mm and NRR9 secures lowest 8.26 mm mean rut depth

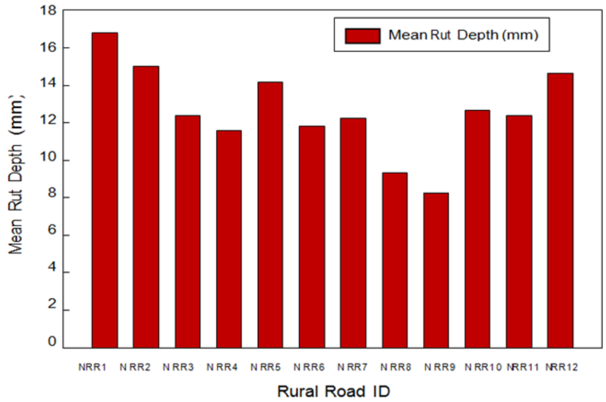

Figure7. Mean Rut Depth on selected road stretches

6. The mean texture depth obtained by sand patch method is found to be significant on NRR5 with 1.16 mm.

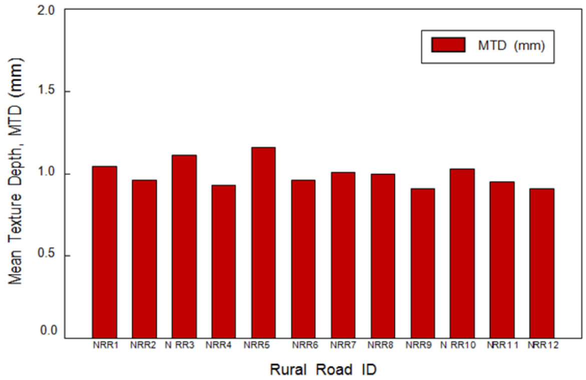

Figure8. Mean Texture Depth on selected road stretches

7. The International Roughness Index derived by MERLIN is obtained by taking theaverage of four reading per 500 m stretch and found to be highest on NRR5 with 8.5mm/km whereas it is lowest on NRR4 with5.9 mm/km.

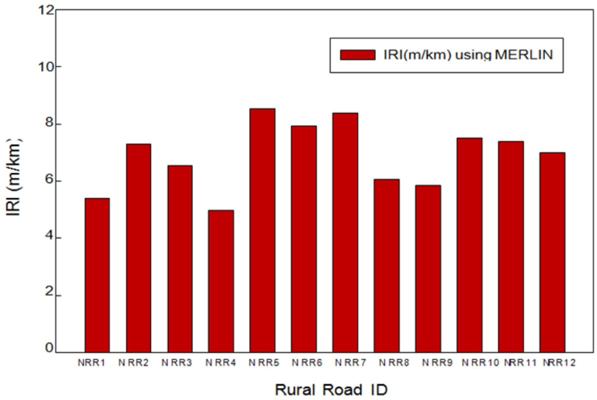

Figure 9. IRI on selected road stretches

8. As the dry skid resistance value for all the selected stretches is more than 65, hence all the roads are in good condition with respect to skid resistance value.

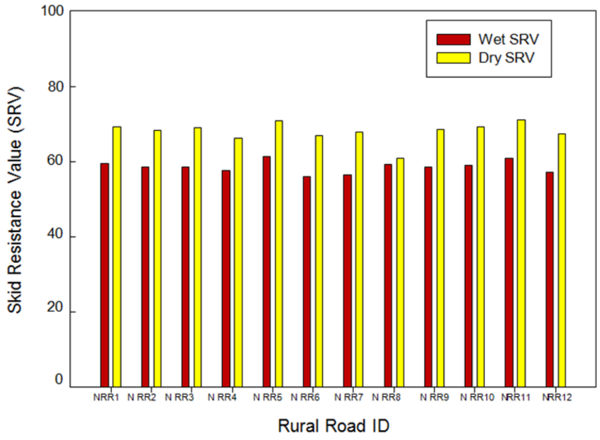

Figure 10. Skid Resistance Value on selected road stretches

9. According to experts, cracking is more essential than other distress indicators, and mean texture depth is the least relevant parameter in pavement performance and maintenance, utilizing Analytical Hierarchy Process.

10. The R2 value for both training and testing data in the linear regression model of road roughness is 0.821 and 0.810, respectively, indicating a strong connection.

11. For training and testing data, the MSE (Mean Squared Error) of the linear regression model is 0.24 and 0.19, respectively, indicating that the predicted values of IRI using this model are extremely similar to the observed values of IRI.

12. The R2 value for both training and testing data in the non-linear regression model of road roughness is 0.844 and 0.837, respectively, indicating a strong connection.

13. For training and testing data, the MSE of the non-linear regression road roughness model is 0.22 and 0.16, respectively, while the MSE of the model built using Artificial Neural Network is 0.371.

14. According to the Benkelman beam research, NRR5 has the most distinctive deflection value of 1.8 mm and NRR4 has the least characteristic deflection value of 0.65 mm for all twelve chosen rural road lengths. As a result, out of the twelve chosen sections related to poor structural strength, NRR5 must be maintained first.

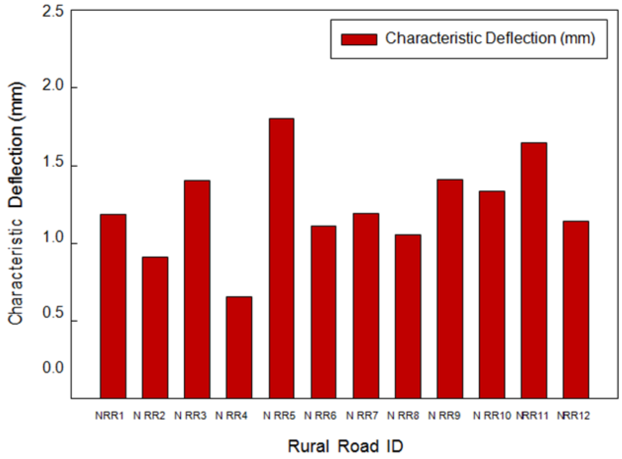

Figure 11. Characteristic Deflection of all selected stretches

15. The average unsoaked and soaked CBR value of NRR5 is 18.35% and10.17% which is least among all the selected roads which show poor sub grade strength.

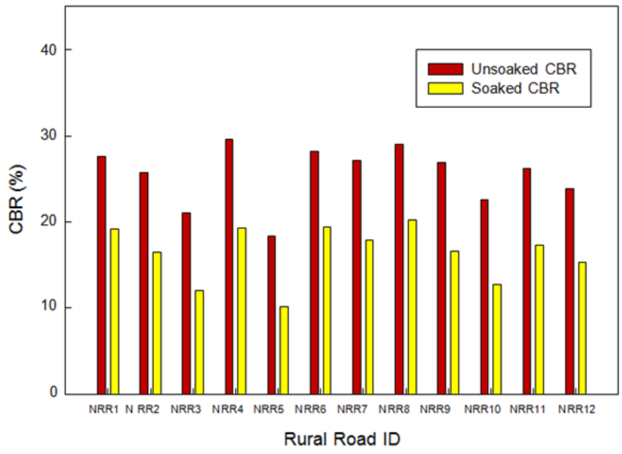

Figure 12. Unsoaked CBR and Soaked CBR Values of selected stretches

16. The average annual daily traffic (AADT) of 940 is maximum on NRR3 followed by NRR5 with an AADT of 713,hence the traffic volume on NRR5 has significant contribution to the pavement deflection value of 1.8mm.

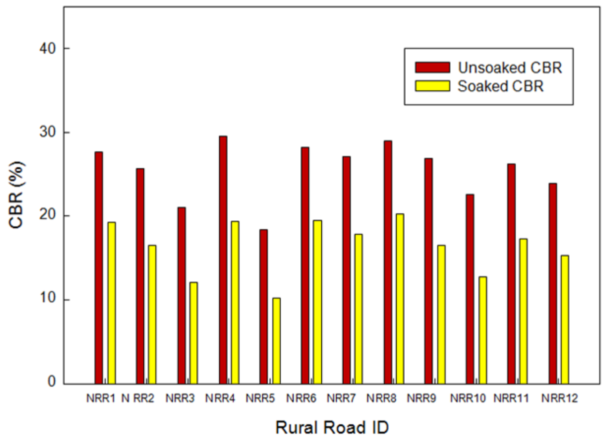

Figure13.Average Annual Daily Traffic of selected stretches

17. The age of pavement from last overlay is in the range of 5-7 years.

18. The two mathematical models of pavement surface deflection prediction models developed are evaluated using statistical parameters such as Mean Absolute Error(MAE), Mean Squared Error (MSE) and Root Mean Squared Error (RMSE) .The model developed is found to be better than model developed depending upon better RMSE value and R2 value of 0.19and0.76 as compared to0.21 and 0.72 respectively.

19. The two models developed for pothole volume prediction suggests that the linear regression model with R2 value of 0.87 provides betterresults as compared to the non-linear regression model with R2 value of 0.85 respectively.

CONCLUSION

The results of the functional and structural assessment of pavements, the creation of a road roughness model and a pavement surface deflection model, and the development of a Rural Road Maintenance Priority Index was a major concern [17,18]. The Rural Road Maintenance Priority Index (RRMPI) has shown to be a strong and useful tool for highway engineers and road authorities, particularly for rural road sections with steep terrain, in prioritizing different pavement portions for their maintenance plans. It also aids in the strategic deployment of road repair funds without causing any financial loss.

The current research looked at rural roads in order to priorities the rural road network for the most effective use of road maintenance money. The current research evaluated the pavement upkeep by conducting functional and structural evaluations of the same rural roads in mountainous terrains. Twelve rural road segments near Nagpur Maharashtra were chosen for the creation of the International Roughness Index prediction model, the Benkelman Beam Pavement Deflection model, the pothole volume prediction model, and the Rural Road Maintenance Priority Index (RRMPI). The following conclusions may be made from the findings of this study:

- The goals were accomplished after extensive data collecting on functional and structural assessment factors, which aided in the development of roughness index models and pavement surface deflection models, which led to the development of RRMPI.

- Different mathematical models have been developed to estimate the value of the International Roughness Index based on various distress factors that are accessible and have a significant impact on the roughness of Nagpur rural roads. The models were created using linear regression, non-linear regression, and Artificial Neural Networks, demonstrating that when compared to Artificial Neural Networks, linear regression and non-linear regression provide highly good outcomes.
- For the tested data, the R2 values for linear and non-linear models are 0.810 and 0.837, respectively, indicating a strong connection between observed and projected IRI. Both models are very accurate; however, the non-linear model's R2 value is 3.34 percent higher than that of the linear regression model. As a result, the non-linear model is thought to be more trustworthy than the linear regression model.
- For the tested data, the MSE values of the linear regression model, non-linear regression model, and ANN model are 0.19, 0.16, and 0.67, respectively, indicating that linear regression and non-linear regression models predict much better outcomes than the ANN model. Because the amount of data observations needed for data training in Artificial Neural Network modelling is very low, this is the case. As a consequence, it is recommended that a larger number of data sets be gathered in order to improve the findings of the Artificial Neural Network model for future study on Maharashtra rural roads.
- In this study, structural evaluation data from twelve rural road stretches near Nagpur area were used to develop mathematical models to predict Benkelman beam characteristic deflection using Soaked CBR, Un-soaked CBR, Average Annual Daily Traffic (AADT), Age of pavement from last overlay (in years), and K-value. The models were created using the sklearn package in Python and linear regression analysis. The correlation matrix was created to examine the relationship between the parameters. Because Soaked CBR and Unsoaked CBR are shown to be strongly linked, any of them may be ignored. As a result, unsoaked CBR was left out of the modeling since soaked CBR is a fair representation of pavement subgrade structural strength.
- Traditional statistical metrics such as MAE, MSE, RMSE, and R2 values were used to compare the generated models. When compared to previous models, the model created to predict pavement deflection utilizing soaking CBR, AADT, and pavement age was shown to be more accurate, with R2 values of 0.76 and RMSE values of 0.19. The pavement maintenance management system and structural study of pavements both need the modeling of characteristic deflection. The use of mathematical models to predict characteristic deflection values may provide quick overlay design estimates without the need for a field Benkelman beam survey, which causes traffic interruption on small country roads in steep terrain and raises project costs.
- The two models developed for pothole volume prediction model suggest that the linear regression model, with a better R2 value of 0.87, provides better results than the non-linear regression model and can be proven to be a vital tool for highway engineers to directly calculate the pothole volume without actual measurements.
- According to the Rural Road Maintenance Priority Index (RRMPI) research, NRR1 and NRR4 have RRMPI in the 80-100 range, indicating outstanding pavement, while NRR5, NRR7, NRR10, and NRR11 have RRMPI in the 50-65 range, indicating acceptable pavement. It is evident that prioritization of various criteria is different, as multiple indexes have been calculated on a range of 0-100, which do not provide a clear image of the worst or best state of any road.
- The RRMPI leads to appropriate maintenance money allocation, proving to be an important tool for highway maintenance engineers and transportation authorities. It also contributes to the country's long-term growth.
- It is also apparent that prioritizing cannot be done only on the basis of the International Roughness value or the Benkelman Beam deflection value, since this results in random outcomes and improper utilization of the maintenance budget.
- In terms of IRI, BBD, and RRMPI rankings, it was discovered that NRR5 has the highest priority rating and should be maintained first, while RR4 is the best road and should be maintained last. However, NRR6 is ranked third, ninth, and fifth in terms of maintenance priority, according to IRI, BBD values, and the RRMPI approach. As a result, RRMPI denotes a clear and lucid state of various roadways.
- In future study, the number of rural road lengths chosen in steep terrain for gathering field data functional and structural characteristics may be increased.
- The road category may be changed to National Highway or State Highway, both of which are critical in any mountainous area or terrain.
- The PWD highway authority responsible for the maintenance of rural road network may design and implement a PMS using the approach used in this research.
- Field or highway engineers may be taught to apply the present maintenance approach effectively.
- The road roughness model and pavement characteristic deflection model are predicted using just a few functional and structural factors in this research. To enhance the current established models, future research may incorporate additional structural and functional characteristics, as well as more stretches of greater length in kilometers.
- During the study, some difficulties pertaining to data collection for Benkelman Beam were observed due to traffic congestion because of narrow roads. Hence, rapid technique of Falling Weight Deflecto meter to determine deflection can be used in further study. The Pavement Surface Deflection Model may also be improved by using additional data points

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