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Permanent Deformation on Flexible Pavement; Rutting Effect on Bituminous Concrete Pavement



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ABSTRACT

Pavements represent an important infrastructure to all countries. In India, huge investments have been made in constructing a large network. The network requires great care through conducting periodic evaluation and timely maintenance to keep the network operating under acceptable level of service. Pavement distress prediction and pavement condition prediction models can greatly enhance the capabilities of pavement management system. These models allow pavement authorities to predict the deterioration of the pavements and consequently determine needs and activities, predicting the timing of maintenance or rehabilitation, and estimating the long range funding requirements for preserving the performance of the network.

In this study, historical data of pavement distress forming five parameters of data is collected in low volume rural roads of three districts namely Guntur, Kurnool, and Warangal in the period of seven months. pavement condition ,pavement evaluation, and predict parameters for the pavement deterioration is the mathematical description that can be used to predict future pavement deterioration based on present pavement condition and deterioration factors .These data were categorized, processed, and analyzed..These data have been employed to generate prediction of pavement distress and condition models for the low volume rural roads of 15 stretches. Through the study, the most severely affected pavement distress type stretch is on HASANPARTHY TO NAGARAM (W13) having been identified. The behavior of these distress types has been investigated. A linear regression function was found to be an excellent representation of the data. Five for rural main pavement distress models have been developed. However, more comprehensive pavement condition models have also been developed, for rural main condition .the developed models provide a reasonable prediction of pavements condition. The models were assessed by standard error and residual analysis. By taking the soil tests, rut, raveling, cracking, pothole, edge failures are measured with the help of load man or vertical measurements steel rod to find outing the deformation of flexible pavement based on traffic data and substituting this all requires equations to find out Root Man Square error value. Comparing the RMS value to actual values obtain in the field in validation to conclude the percentage of error where is heavy by above comparisons due to this to knowing the serviceability of road.

Keywords: Low volume road, granular pavement, pavement evaluation, Pavement deterioration.

INTRODUCTION

India has more than 3.3 million kilometres of road network out of which Low Volume Roads (LVRs) accounts for 2.7 million kilometres which includes Other District Roads (ODRs) and Village Roads (VRs). LVRs are the tertiary road system in total road network which provides accessibility for the rural habitations to market and other facility centres. In India, during the last five decades, LVRs are being planned and programmed in the context of overall rural development, and tried to provide “all weather connectivity” with some level of achievement.

More than 80 percent of roadway mileage in the world carries less than 200 vehicles per day and would therefore be classified as LVRs (Gourley and Greening 1999). Traffic conditions in rural area are distinctly different from major roads. A variety of vehicles are used for transportation of goods on rural roads, ranging from animal drawn bullock-carts to the fast moving commercial vehicles. LVRs form a critical link to the nation for better transportation system, and to provide mobility to the rural areas. The development of rural infrastructure is crucial for the sustainable development of rural economic as well as the welfare of the poor people in rural areas. Inadequate rural connectivity and lack of mobility creates serious constraint to accelerated rural development. The critical role played by roads in economy development is being realized now.

NEED FOR THE STUDY

The application of pavement management techniques in India have been recognized recently as versatile tools for tackling road maintenance and rehabilitation problems. To establish these strategies, pavement performance data over a period of time is required for the development of appropriate deterioration models. Without adequate data, the road needs cannot be quantified or evaluated accurately, and planning decisions tend to become short-term. It is important, therefore, to identify which parameters are essential and relevant as predictive models. A number of studies have been conducted in general for high volume roads, but very few studies have been conducted on low volume roads. Most of the studies, such as the AASHTO, Kenyan and Brazilian studies were performed considering only the prevailing conditions of the respective regions.

Traffic conditions on low volume roads are distinctly different from other roads. Dawson et al. (2007) observed that many of the low volume roads are distressed due to over loaded local trucks, commercial vehicles, environmental factors such as temperature and precipitation etc. In addition to these factors, rutting, ravelling, roughness and cracking are also the main contributing factors of pavement failure. With this back ground, in the present study, an attempt has been made to identify the factors influencing performance of low volume roads. Pavement deterioration models have been developed for low volume roads considering three years in-service flexible pavement data. Following pavement deterioration models have been developed in this dissertation work: rutting model, cracking model, pothole model, ravelling model, and edge drop model.

OBJECTIVES OF THE STUDY

The main objectives of this study are listed below:

1. To review the concept of pavement deterioration and the factors associated with the performance for low volume roads.
2. To determine the rate of deterioration of low volume roads considering various material, traffic, and climatic conditions through systemic data collection.
3. To develop pavement deterioration models for various distress types prevailing in low volume roads.

Criteria for Selection of Pavement Sections for Evaluation

The pavement sections in the present study have been selected based on the following criteria:

- ❖ The selected test stretch should comprise of flexible pavement on a fairly ground, preferably on low embankment without a steep gradient.

- The length of test section selected is 500 m starting from a land mark in this case, sign board of PMGSY or kilometre stone of the road.
- The road condition should be uniformly good without any undulations, ruts and other distresses. There should not be any water logging conditions, culverts etc. within the test sections.
- Section is selected on straight reaches and not on curved portions. Also, approaches to bridge and culverts were avoided. History of the pavement section should be available i.e., year of construction, crust details and traffic volume counts, etc.

DETAILED DESCRIPTION OF STUDY AREAS

S.No	Name of the test section	Road ID	District	Subgrade Soil type	Rainfall intensity (mm/yr)	Traffic volume Curve	Surface type
1	Chakaraypalem To Davuluru	G1	Guntur	B.C soil	>1000	B	BT
2	Yeletipalem to Dhulupudi	G2		B.C/silt mixed	>1000	C	BT
3	Palem To Kollimerla	G3		B.C soil	>1000	C	BT
4	Loyapally To Zendapetathanda	G4		Silty / Mixed red earth	500-1000	C	BT
5	Midthur To Kazipeta	K5	Kurnool	B.C soil/ HG soil	500-1000	B	BT
6	Aspari To Haligera	K6		B.C soil	500-1000	A	BT
7	Joannagiri To Pendekal	K7		Grave/BC	500-1000	A	BT
8	NH -18 To Gottlur	K8		B.C soil	500-1000	B	BT
9	Tarigoppala To Abdul Nagaram	W9	Warangal	Gravel	500-1000	B	BT
10	Station Ghanpur To Sreepathpally	W10		Gravel	>1000	B	BT
11	Veldhi To Ashwaraopally	W11		Gravel	500-1000	B	BT
12	Edupusalapally to Kommagudem	W12		Gravel	>1000	B	BT
13	Hasanparthy To Nagaram	W13		B.C soil	500-1000	B	BT
14	Somidi To Subbayyapally	W14		B.C soil	500-1000	C	BT
15	PWD road To Singaram	W15		B.C soil	500-1000	B	BT

FIELD AND LABORATORY STUDIES

Figure 1 shows atypical cracking pattern PWD Singaram Stretch

Road ID	Traffic (msa)				
	January 2015	Feb 2015	March 2015	April 2015	May 2015
G1	0.02	0.030	0.06	0.08	0.23
G2	0.014	0.024	0.033	0.05	0.105
G3	0.078	0.090	0.111	0.153	0.28
G4	0.009	0.009	0.017	0.026	0.101
K5	0.029	0.033	0.045	0.079	0.111
K6	0.01	0.019	0.026	0.094	0.359
K7	0.041	0.043	0.045	0.079	0.111
K8	0.01	0.020	0.02	0.07	0.11
W9	0.045	0.047	0.081	0.093	0.126
W10	0.012	0.048	0.05	0.111	0.16
W11	0.038	0.048	0.062	0.101	0.112
W12	0.072	0.072	0.081	0.125	0.245
W13	0.046	0.057	0.08	0.103	0.118
W14	0.056	0.062	0.071	0.084	0.111
W15	0.059	0.072	0.109	0.836	0.925

Table 1 Traffic data during the study periods

Road ID	Characteristic Rut depth(mm)						
	January 2015	Feb 2015	March 2015	April 2015	May 2015	June 2015	July 2015
G1	4.9	7.3	9.1	10.1	11.3	19.4	26.1
G2	36.4	43.45	45.3	46.7	47.3	48.8	52.3
G3	3.9	5.4	7.7	9.5	12.3	16.1	22.9
G4	8.1	12.6	13.8	16.3	20.1	26.4	36.8
K5	14.7	26.6	37.4	39.7	39.7	42.6	47.6
K6	17.8	15.05	16.7	18.5	18.5	20.1	31.8
K7	13.4	14.3	15.6	18.1	18.1	21.3	39.3
K8	18.4	24.4	26	27.4	27.4	28.9	37.5
W9	2.64	7.45	8.9	9.7	11.6	13	15.4
W10	1.72	5.83	5.6	7.5	10.5	12	15.4
W11	1.88	6.78	9.1	8.2	10.9	14.3	19
W12	8.42	9.13	12.4	13.9	17.4	24.4	26.3
W13	5.8	12.02	19.5	23.9	26.6	27.5	29.1
W14	8	11.98	22.5	24.4	29.9	35	49.8
W15	10.3	15.41	25	32.7	35.9	43.3	59.8

Table 2 Characteristic rut depth during study period

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Road code	Atterberg Limits (%)		PI (%)	Grain Size Analysis % Passing IS Sieves(mm)							IS Classification,	Heavy Compaction		Field Moisture (%)	Soaked CBR Value,%	Unsoaked CBR (%)
	LL	PL		4.75	2.0	0.6	0.425	0.212	0.075	dust		MDD (gm/cc)	OMC (%)			
G1	30	16	14	76.54	62.44	31.22	22.56	9.47	0.40	0	SP	1.80	16.23	20	3	24
G2	46	23	23	50.67	42.28	19.79	15.44	6.45	0.15	0	SP	1.45	31.34	41	3	24
G3	27	13	14	64.95	39.53	15.31	10.98	4.28	0.23	0	SP	1.92	13.37	8	6	28
G4	48	25	23	75.55	55.59	35.79	32.58	20.72	0.49	0	SP	1.37	24.82	11.8	3	28
K5	30	16	14	96.05	84.04	58.48	43.41	13.81	0.36	0	SP	1.91	14.57	10	4	24
K6	29	15	14	58.50	48.31	31.33	24.44	12.81	0.25	0	SP	1.68	14.70	18	6	13
K7	28	16	12	63.59	28.23	12.99	11.39	7.38	0.16	0	SP	1.94	11.85	9.3	5	24
K8	46	25	21	67.39	52.74	25.36	17.15	6.89	0.13	0	SP	1.75	19.11	14	10	18.
W9	32	16	16	84.9	54.7	26.4	20.8	11.3	3.8	0	SW	1.65	13.33	12	5	21
W10	32	16	16	89.1	65.2	30.4	23.9	10.9	2.2	0	SW	1.62	13	14	5	18
W11	32.5	13.4	18	86.1	67.4	36.5	30.4	15.7	2.6	0	SW	1.71	15.25	10	6	20
W12	30	16	14	86.1	67.4	36.5	30.4	15.7	2.6	0	SP	1.68	14.21	13	5	20

Table 3 Properties of soils of sub grade

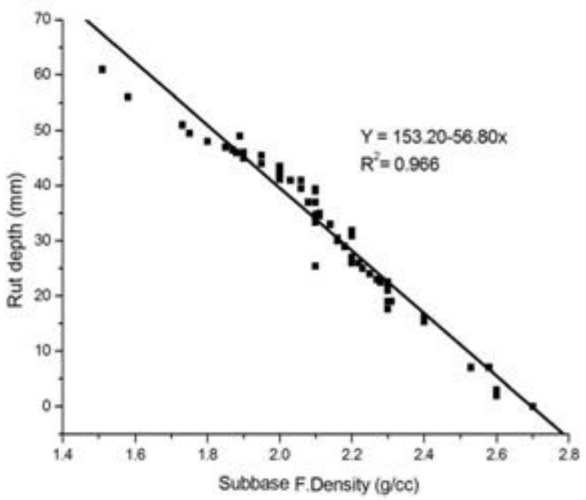

Figure 2 Variation of measured rut depth with

Sub-base field density for G1 stretch

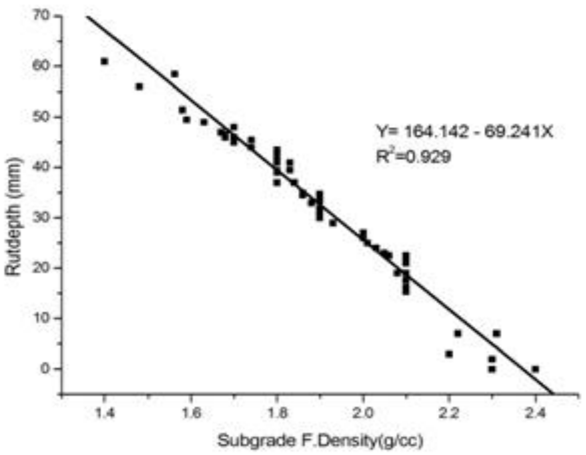

Figure 3 Variation of measured rut depth with

Sub grade field density for G1 stretch

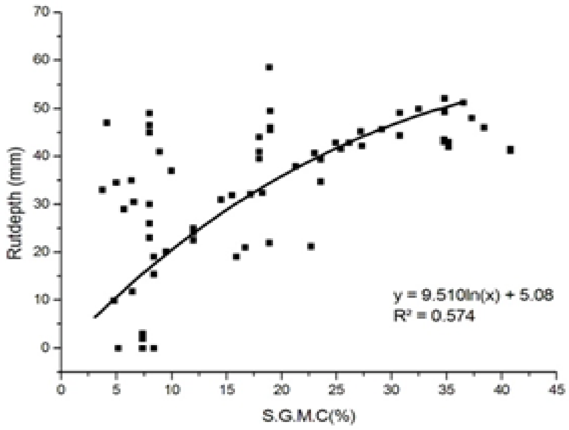

Figure 4 Variation of measured rut depth with

Sub-base moisture content for G1 stretch

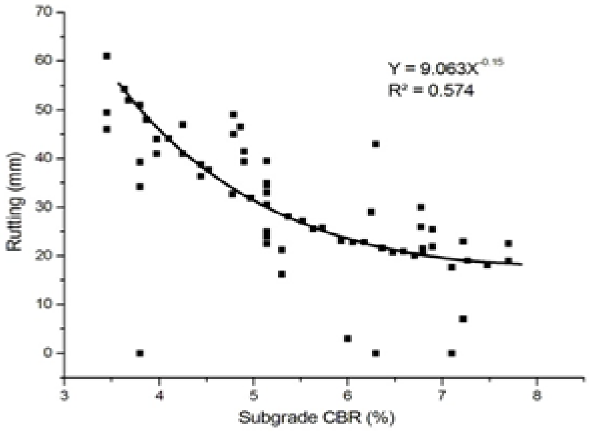

Figure 5 Variation of measured rut depth

with Sub-grade CBR for G1 stretch

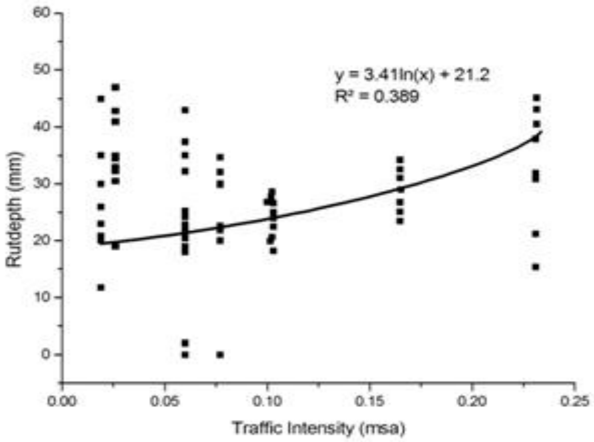

Figure 6 Variation of measured rut depth with Traffic intensity for G1 stretch

Chainage		Rut depth (mm)	Field Density(g/cc)		Subgrade moisture content (%)	Subgrade CBR (%)	Traffic intensity (msa)
From	To		Sub-base	Subgrade			
4/400	4/450	30.9	2.16	1.90	14.5	4.20	0.231
4/450	4/500	0.0	2.70	2.30	8.4	3.80	0.231
4/500	4/550	0.0	2.70	2.30	8.4	3.80	0.231
4/550	4/600	15.4	2.35	2.13	8.4	5.30	0.231
4/600	4/650	39.3	2.06	1.83	39.5	3.80	0.231
4/650	4/700	33.4	2.13	1.87	34.1	3.80	0.231
4/700	4/750	34.2	2.13	1.87	35.8	3.80	0.231
4/750	4/800	16.2	2.35	2.13	22.7	5.30	0.231
4/800	4/850	21.2	2.29	2.07	22.7	5.30	0.231
4/850	4/900	31.9	2.16	1.90	15.5	3.80	0.231
4/400	4/450	34.7	2.13	1.87	23.6	6.87	0.077
4/450	4/500	0.0	2.70	2.30	5.2	7.12	0.077
4/500	4/550	0.0	2.70	2.30	5.2	7.12	0.077
4/550	4/600	17.6	2.33	2.10	18.9	7.12	0.077
4/600	4/650	45.3	1.90	1.70	41.6	4.86	0.077
4/650	4/700	39.4	2.05	1.82	23.6	4.86	0.077
4/700	4/750	41.5	2.03	1.80	40.8	4.86	0.077
4/750	4/800	21.9	2.29	2.07	18.9	6.87	0.077
4/800	4/850	25.4	2.13	1.87	18.9	6.87	0.077
4/850	4/900	41.1	2.03	1.80	40.8	4.86	0.077
4/400	4/450	37.0	2.08	1.84	31.7	6.32	0.060
4/450	4/500	0.0	2.69	2.42	7.4	6.32	0.060
4/500	4/550	0.0	2.69	2.42	7.4	6.32	0.060
4/550	4/600	19.0	2.31	2.08	15.9	7.65	0.060
4/600	4/650	46.0	1.90	1.70	38.4	6.32	0.060
4/650	4/700	42.0	2.00	1.78	35.2	6.32	0.060
4/700	4/750	43.0	2.00	1.78	35.2	6.32	0.060
4/750	4/800	22.5	2.29	2.07	27.4	7.65	0.060
4/800	4/850	26.0	2.22	2.00	27.4	7.65	0.060
4/850	4/900	43.0	2.00	1.78	35.2	6.32	0.060
4/400	4/450	39.0	2.07	1.83	29.4	5.97	0.060
4/450	4/500	2.0	2.64	2.28	7.4	5.97	0.060
4/500	4/550	3.0	2.62	2.24	7.4	5.97	0.060
4/550	4/600	21.0	2.30	2.07	16.7	6.78	0.060
4/600	4/650	48.0	1.83	1.65	37.3	5.97	0.060
4/650	4/700	43.0	1.97	1.76	34.8	5.97	0.060
4/700	4/750	43.5	1.96	1.82	34.8	5.97	0.060
4/750	4/800	21.5	2.29	2.09	26.9	6.78	0.060
4/800	4/850	27.0	2.21	1.98	26.9	6.78	0.060
4/850	4/900	46.0	1.87	1.68	34.9	5.97	0.060
4/400	4/450	37.0	2.08	1.84	10.0	6.78	0.019
4/450	4/500	7.0	2.53	2.22	8.3	7.22	0.019
4/500	4/550	7.0	2.58	2.31	8.0	7.22	0.019
4/550	4/600	23.0	2.27	2.05	8.0	7.22	0.019
4/600	4/650	49.0	1.89	1.63	8.0	4.79	0.019
4/650	4/700	45.0	1.90	1.70	8.0	4.79	0.019
4/700	4/750	45.0	1.90	1.70	8.0	4.79	0.019
4/750	4/800	26.0	2.22	2.00	8.0	6.78	0.019
4/800	4/850	30.0	2.16	1.90	8.0	6.78	0.019
4/850	4/900	46.5	1.87	1.68	8.0	4.86	0.019
4/400	4/450	34.5	2.11	1.86	5.0	5.14	0.026
4/450	4/500	56.0	1.58	1.48	10.6	3.80	0.026
4/500	4/550	29.0	2.18	1.93	5.7	6.25	0.026
4/550	4/600	41.0	2.03	1.80	8.9	4.25	0.026
4/600	4/650	30.5	2.16	1.90	6.6	5.14	0.026
4/650	4/700	35.0	2.11	1.86	6.4	5.14	0.026
4/700	4/750	33.0	2.14	1.88	3.8	5.14	0.026
4/750	4/800	47.0	1.85	1.67	4.2	4.25	0.026
4/800	4/850	19.0	2.31	2.08	8.4	4.25	0.026
4/850	4/900	51.0	1.73	1.58	9.8	3.80	0.026
4/400	4/450	22.5	2.28	2.06	12.0	5.14	0.103
4/450	4/500	25.0	2.23	2.01	12.0	5.14	0.103
4/500	4/550	61.0	1.51	1.40	26.0	3.45	0.103
4/550	4/600	44.0	1.95	1.74	18.0	3.97	0.103
4/600	4/650	49.5	1.75	1.59	19.0	3.45	0.103
4/650	4/700	39.5	2.06	1.83	18.0	5.14	0.103
4/700	4/750	24.0	2.25	2.03	12.0	5.14	0.103
4/750	4/800	46.0	1.88	1.68	19.0	3.45	0.103
4/800	4/850	41.0	2.06	1.83	18.0	3.97	0.103
4/850	4/900	45.5	1.95	1.74	19.0	3.45	0.103

Table 4 Summary of rut depth and different factors considered for G1 stretch

For the model development using influencing parameters, different forms of equations were tried and the form represented by Equation(1) has been selected. Similar models were developed for individual stretches. For explanatory purpose the following equation of G1 stretch is presented here.

$$RD_{G1} = -32.758 * (SBFD) - 19.485 * (SGFD) + 3.597 * Ln\,(SGMC) - 0.035 * (CBR)^{2.590} + 2.396 * Ln\,(N) + 25.489 \qquad (1)$$

$R^2 = 0.982$, F-test $= 76.22$ and Standard error $= 2.16$

Where,

SBFD = sub-base field density,

SGFD = subgrade field density,

SGMC = subgrade moisture content,

CBR = subgrade CBR (%), and

N = traffic intensity (msa).

The general form of the rutting model for individual stretches and combined district models with coefficients a, b, c, d etc., are represented by Equations (2) and(3).

The complete analysis with the corresponding statistical significance is shown in Table 5.2.

$$RD = a * (SBFD) + b * (SGFD) + c * Ln\,(SGMC) + d * (CBR)^{e} + f * Ln\,(N) + g \qquad (2)$$

$$RD = a * (SBFD) + b * (SGFD) + c * Ln\,(SGMC) + d * (CBR)^{e} + f * Ln(N) + g * (Base\ G.III) + h * (Base\ G.II)^{i} + j * (Sub\ BG)^{k} + l \qquad (3)$$

Coefficients	Road ID													
	G1	G2	G3	G4	**GM**	K5	K6	K7	K8	**KM**	W9	W10	W11	W12
a	-32.758	-42.099	-5.51	-0.25	**-4.58**	-13.129	-1.724	-0.308	-8.467	**-11.606**	-2.891	-3.438	-12.063	-19.555
b	-19.485	-1.513	-5.577	-5.537	**-30.424**	-10.264	-0.078	-0.045	-0.649	**-0.902**	-13.22	-4.873	-9.387	-5.186
c	3.597	1.233	13.993	7.873	**7.763**	2.963	0.446	0.218	6.532	**0.078**	8.962	6.802	5.769	4.17
d	-0.035	-9.914	-40.816	-11.88	**-0.016**	-19.797	-0.348	-0.776	-0.361	**-18.742**	-4.059	-0.328	-2.396	-38.567
e	2.59	-0.358	-0.209	-0.655	**2.627**	-0.41	0.387	0.345	1.872	**-0.474**	-0.113	1.118	11.291	-4.278
f	2.396	0.561	3.592	1.232	**0.656**	1.158	0.04	0.226	0.652	**1.201**	1.642	0.626	0.445	2.522
g	25.489	21.723	23.041	12.208	**20.145**	29.164	-1.133	-0.678	40.165	**21.308**	17.62	14.641	-0.464	93.502
h	---	---	---	---	**0.606**	---	---	---	---	**0.063**	---	---	---	---
i	---	---	---	---	**-8.543**	---	---	---	---	**-0.591**	---	---	---	---
j	---	---	---	---	**1.27**	---	---	---	---	**0.127**	---	---	---	---
k	---	---	---	---	**-16.373**	---	---	---	---	**-3.662**	---	---	---	---
l	---	---	---	---	**0.321**	---	---	---	---	**0.32**	---	---	---	---
R-square	0.982	0.979	0.797	0.765	**0.777**	0.891	0.794	0.73	0.799	**0.821**	0.756	0.757	0.852	0.729
F-test	76.23	83.56	87.97	25.47	**73.18**	184.52	276.47	46.86	19.49	**145.72**	57.89	29.39	61.21	195.55
Standard error	2.16	0.79	4.31	4.25	**8.08**	3.44	1.39	4.11	4.43	**4.53**	1.69	2.62	3.34	1.33

Table 5 Coefficients of Rutting Models for all the stretches

VALIDATION OF THE MODEL

The validation of the model is done by utilizing the field data obtained from the selected test section and the predicted values from the developed models. Figure 5.62 shows the relation between observed rut depth and the predicted rut depth.

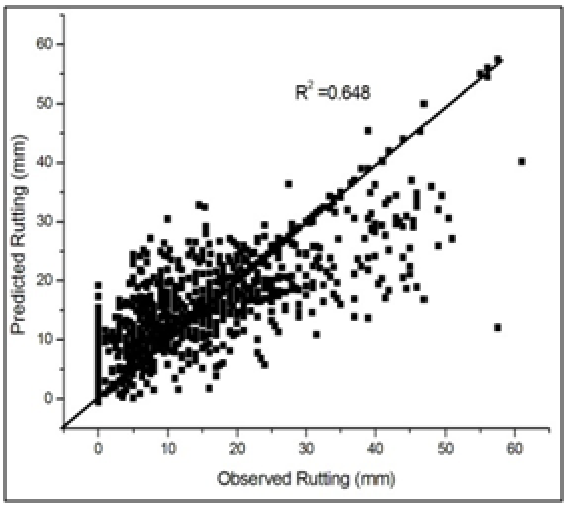

Figure 7 Relation between the observed and predicted rut depth

As the R^2 value is more than 0.6, this indicates a good relation between the observed and predicted rut depth values. Figure 5.63 shows the relation between observed cracking and the predicted cracking. As the R^2 value is more than 0.6, this indicates a good relation between the observed and predicted cracking values.

CONCLUSIONS

Based on the field studies and analysis the following conclusions are

- ➢ The influence of field density of the sub-base and field density of the subgrade materials on the observed rut depth is much higher when compared to other independent variables considered in this study. It was observed in most of the cases of all the selected stretches that with the increase field density, there is a decrease in the rut depth. The coefficient of determination is also found to be significantly high. The decrease in rut depth with increase in field density is due to the fact that the resistance of a material to permanent deformation will increase with increase in the density thus resulting in lower rut depths.
- ➢ The subgrade moisture content showed good correlation with rut depth in all the fifteen stretches of the roads considered in this study i.e. with the increase in subgrade moisture content, there is an increase in the rut depth. Because of increase in the moisture content, the subgrade gets weaker and one can expect an increase in the rut depth.
- ➢ Among all the parameters considered for the development of rutting model, base course (WBM grading III) gradation is found to have least influence on the rut depth.
- ➢ The influence of pavement age, camber and longitudinal gradient on the observed Pothole is much higher when compared to other independent variables considered in this study where as traffic intensity has lower influence on Pothole.
- ➢ By considering all the fifteen stretches of specified variables the ultimate model was developed for Pothole. The coefficient of

determination (R^2) value is 0.792. It is important to note that the CBR, Traffic Intensity, Mean Monthly Precipitation, No. of Potholes, Pavement Age, Stripping Value, Camber and Longitudinal Gradient could not explain 20% of the observed cracking values.

- Stripping Value of aggregate and traffic are found to greatly affect the raveling whereas pavement age has least contribution to raveling. For the raveling model the coefficient of R^2 value is 0.894. It is important to note that the Pavement Age, Mean Monthly Precipitation, Stripping Value, Traffic intensity, Camber and Longitudinal Gradient could not explain 10% of the observed.
- The influence of camber, longitudinal gradient and traffic on the observed Edge failure is much higher when compared to other independent variables considered in this study where as pavement age has lower influence on Edge failure.
- The coefficient of determination (R^2) value is 0.828. It is important to note that the Camber, Longitudinal Gradient, Traffic intensity, CBR and Modulus of elasticity of the shoulder material could not explain 17% of the observed edge failure values.
- During the study period among all the 15 stretches it has been observed that Hasanparthy to Nagaram (W13) stretch is severely affected by the factors considered whereas the least affected stretch is found to be Tarrigopula to Abdul Nagaram (W9).

SCOPE FOR FURTHER WORK

One can extend the same work using this data to develop deterioration models by all these parameters for few more years. To evaluate the performance of the pavements with proper maintenance, continuous study for successive years is required. For that this study is to be continued and historical data has to be generated. In addition to this test track with all the control conditions in the laboratory can also be incorporated in future study.

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