Influence of Unbounded Materials Properties on Routing Potential of Low Volume Roads

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Abstract- *Rural roads are the tertiary road system in total road network which provides accessibility for the rural habitations to market and other facility centres. In India it consistutes about 85% of the total road network. However, merely creating the road assets is not enough and it has to be maintained periodically and preserved carefully. Majority of these roads are provided with flexible pavement. But the rate of deterioration of flexible pavement is much higher than the rate of deterioration of a rigid pavement and hence maintenance cost involved is higher. The Government of India lunched the Pradhanamantri Gram Sadak Yojana (PMGSY) in December – 2000 with an aim to provide all weather roads to rural areas. It was proposed to take up 173,000 unconnected habitations of population above 500 (250 in case of hilly, desert and tribal areas) under PMGSY programme. With this background in the present study, fifteen low volume roads were identified in Warangal, Guntur and Kurnool districts in Andhra Pradesh to carry out the pavement performance study. The main objective of this study is to evaluate the influence of unbound material properties such as Water Bound Macadam (WBM) base course gradation (grading II and grading III) granular sub-base gradation, sub-base and subgrade field densities and subgrade moisture content on the rutting potential of low volume roads. The detailed analysis was carried out using the SPSS stastical tool and permanent deformation (rutting) model has been developed.*

I. INTRODUCTION

GENERAL

More than 80% of roadway mileage in the world carries less than 200 vehicles per day and would therefore be classified as low volume roads. Roads located in the rural areas make up a large fraction of the low volume roads simply because of the lower population in rural areas. Low volume roads make up a substantial proportion of network of most developing countries. Unfortunately, the poor condition of these roads hindered the economic developments and has suppressed poverty alleviation effort in many countries and one among them is India. India is a vast country having an area of more than 3 million kilometres of roads network, making it the largest in the world. Low Volume Roads (LVRs) consist of 2.65 million km. These roads form a critical link to the nation for better transportation system, and to provide mobility to the rural areas. Vast rural road network in the country has been developed recently which not only measure the agricultural production and the size of the markets but also provide better prices, reduction in transport cost and the creation of better health, employment and educational opportunities to rural population in India

STATUS OF RURAL ROADS IN INDIA

In Indian context, low volume roads or rural roads commonly referred to as the constitute of Other District Roads (ODR) and Village roads (VR). ODRs are feeder roads connected to district/block head quarters, VRs connects the cluster of villages where the producer must find some way to transport goods from one place to the other. Many of these roads have an earth or gravel surface and have low volumes of motorized traffic, which is sometimes exceeded by pedestrian, cycle and animal traffic flows.

LOW VOLUME ROAD

According to Transportation Research Board (TRB, 1999) "a low volume road is considered a road that has relatively low use (an average daily traffic of less than 400 vehicles per day), low design speeds (typically less than 80 kmph), and corresponding geometry".

The main characteristics of low volume rural roads that set them apart from more conventional highways are as follows:

The development of the road has a high potential to influence economic development through supply side effects,

There will generally be periods during a year with disrupted possibility.

Improvements in rural access typically give rise to benefits that arise from four sources:

(i) Lower transport costs to existing traffic due to smoother and sometimes shorter routes,
(ii) Savings in time due to faster travel,

(iii) Economic development benefits resulting in generated (new) traffic, and
(iv) Social benefits due to improved access to schools, hospitals, etc.

FACTORS AFFECTING PAVEMENT PERFORMANCE

In general, pavement performance depends on several factors. These factors can be grouped into the following categories
(i) Traffic factors,
(ii) Material properties and composition,
(iii) Environmental factors,
(iv) Distresses and
(v) Others factors

Traffic Factors These include traffic volumes, axle load, and number of ESAL, tyre pressure, truck type axles, configuration, load application time and mechanism.

Material Properties and Composition These include the main engineering properties of the materials used in pavement construction such as strength or bearing capacity, gradation, mix properties, elastic and resilient modulus and Poisson's ratio in addition to the type of the construction material used.

Environmental Factors Environmental factors include temperature, freeze and thaw, humidity and precipitation, and ground water.

Distresses The different types of distress such as longitudinal cracking, transverse cracking, rutting, edge cracking, roughness, reflection cracking, alligator cracking etc. affects the pavement performance.

Other Factors Other factors include geometric features (longitudinal and cross slopes, provision of drainage facilities), design and construction factors such as pavement structure thickness, maintenance level, surface characteristics (micro and macro texture) and the quality of construction works including initial roughness level, and construction joints.

NEED FOR THE STUDY

Rural road traffic conditions in India are distinctly different from other roads. A variety of vehicles are used for the transportation of goods on rural roads, they range from animal drawn bullock-carts to the fast moving commercial vehicles. Dawson et al.,(2007) concluded that many of the rural roads are distressed due to some over loaded local trucks and other commercial vehicles and environmental factors (temperature, precipitation etc.). Rutting, ravelling, roughness and cracking are also the main contributing factors of pavement failure.

II. LITERATURE REVIEW

GENERAL

In this chapter, an attempt has been made to review the literature on rutting and various rutting models developed across the world by various research agencies and researchers.

RUTTING

Rutting is one of the major structural distress mechanisms in flexible pavements. Because of the increase in tyre pressure and axle loads in recent years, rutting has become the dominant mode of failure of flexible pavement in many countries. There are various reasons for rutting depending on configuration and structural capacity of various layers and environmental conditions.

Rutting is a longitudinal depression in the wheel paths of flexible pavements with or without transverse displacement. It can be measured with 3 m straight edge or with profiler at regular intervels. Rut is a physical distortion of surface and it also prevents the cross drainage of water during the rains, leading to accumulation of water in rut and causing the potential of hydroplaning related problems. The hydroplaning phenomenon consists of the buildup of a thin layer of water between the pavement and tyre and results in the tyre losing contact with the surface, with the consequent loss of steering control.

ORIGINS OF RUTTING

Garba (2002) reported that there are two basic origins of rutting (i) deep structural problems and (ii) asphalt mixture rutting near the surface. Deep structural rutting occurs in the unbound layers, aggregate base and subgrade below the Hot Mix Asphalt. Typically only thin pavement sections, less than 200 mm, exhibit subgrade rutting. This thickness will depend on the pavement materials, subgrade strength and traffic loads

TYPES OF PAVEMENT RUTTING

Rutting throughout the asphalt pavement structure is caused by over-stressing the underlying base or subgrade layers. This overstressed condition can be the result of inadequate thickness design for the applied traffic or for the strength properties of the underlying materials.

CAUSES OF RUTTING

Generally there are three causes of rutting in asphalt pavements: accumulation of permanent deformation in the asphalt surfacing layer, permanent deformation of subgrade, and wear of pavements caused by studded tyres. In the past, subgrade deformation was considered to be the primary cause of rutting and many pavement design methods applied a limiting criterion on the vertical strain at the subgrade level. These three causes of rutting can act in combination, i.e., the rutting could be the sum of permanent deformation in all layers and wear from studded tyres.

Rutting Caused by Weak Asphalt Mixture

Rutting resulting from accumulation of permanent deformation in the asphalt layer is now considered to be the principal component of flexible pavement. This is because of the increase in truck tyre pressures and axle loads, which puts asphalt mixtures nearest the pavement surface under increasingly high stresses. Rutting caused by the weak asphalt layer can be seen from the Figure.

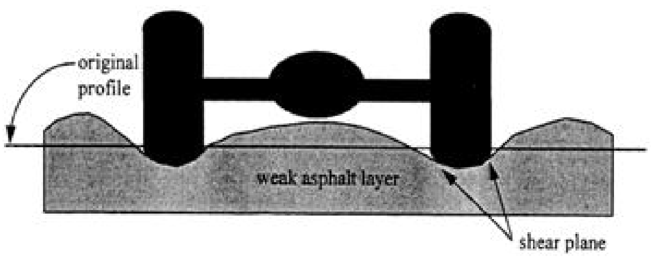

Figure Rutting caused by weak asphalt layer

Rutting Caused by Weak Subgrade Rutting can be caused by too much repeated load applied to subgrade, subbase or base below the asphalt layer (Garba, 2002). In many cases this is due to insufficient depth of cover on the subgrade resulting from too thin asphalt section to reduce the stress from applied loads to tolerable level. Thus this type of rutting is considered to be more of a structural problem than a material problem and is often referred to as structural rutting. Intrusion of moisture can also be the cause for weakening of the subgrade. In this type of rutting, the accumulated permanent deformation occurs in the subgrade. Rutting caused by the weak subgrade can be seen from the Figure

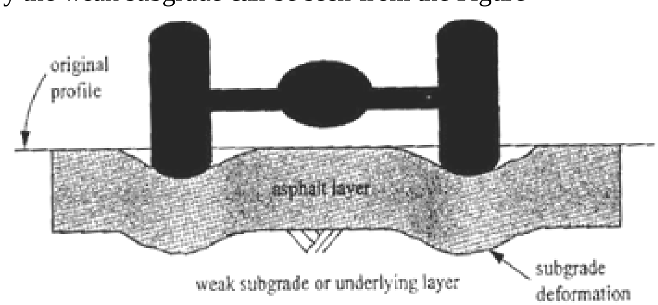

Figure Rutting from weak subgrade

FACTORS AFFECTING RUTTING

Rutting is strongly influenced by traffic loading, pavement thickness, subgrade strength and moisture content, and gradation. Climate can also have a large influence especially when the pavement subgrade undergoes seasonal variations in bearing capacity, or when bituminous courses are subjected to high temperatures.

Tarefder et al. (2003) discussed about the significant factors that affect rut potential of HMA. The factors are mainly of three types: mix factors, load factors and environmental factors. To predict the rutting of HMA an Asphalt Pavement Analyzer (APA) can be used. This measures rut potential at selected points along the wheel path as a function of number of loading cycles. The main objective of their study was to develop factors for which rut is high and low value which lies within a certain range. All these factors are divided into three sets such as set A, B, and C. Set A consists of seven parameters in eight different sets each at two levels. Set B consists of six factors namely wheel load, hose pressure, test temperature, test condition and gradation. Set C consists of five factors namely wheel load, hose pressure, test temperature, moisture and gradation. The results obtained by these factors were analysed statistically. The analysis showed that in set A the factors such as binder's Performance Grade (PG), specimen type, test temperature and moisture are the most significant factors and in set B the factors such as aggregate gradation, temperature, bitumen content and moisture are found to be significant. The rut ranges for different sets are determined. The authors concluded that out of all the sets considered, the most significant factors contributed to rutting were binder grade, temperature, gradation, subgrade moisture and binder content.

AGGREGATE GRADATION

Aggregate gradation is the distribution of particle sizes expressed as a percentage of the total weight. The gradation as a percent of the total volume is of most importance, but expressing gradation as a percent by weight is much easier and is a standard practice. Gradation is determined by sieve analysis, sieves are stacked from the largest openings on the top to the smallest opening on the bottom, and a pan is placed at the bottom of the stack, by passing the material through a series of sieves and weighing the material retained on each sieve, gradation can be determined. The gradation of an aggregate is normally expressed as total percent passing various sieve sizes.

Selection of suitable aggregate gradation is one of the important elements. Angular, rough-textured aggregates provide more resistance than rounded, smooth-textured aggregates. Some of the aggregate gradations commonly adopted in the preparation of bituminous mixtures are: midpoint gradation of Bituminous Concrete as per Ministry of Road Transport and Highways (MORTH) specifications, Strategic Highway Research Programme (SHRP). Superpave project recommended the uses of 0.45 power gradation charts to define a permissible gradation. The maximum density gradation plots as straight line from maximum aggregate size to the origin. According to this specification, any gradation that passes above or below the restricted zone but within the relevant control points is expected to produce a good performing mixture. The gradation requirements of WBM material and granular sub-base material are shown in table 1and 2 respectively.

Table 1 Gradation requirements for WBM layer as per MORTH (2001)

Grading	Size range (mm)	IS sieve designation (mm)	Percent by weight passing
1	90 to 45	125	100
		90	90-100
		63	25-60
		45	0-15
		22.4	0-5
2	63 to 45	90	100
		63	90-100
		53	25-75
		45	0-15
		22.4	0-5
3	53 to 22.4	63	100
		53	95-100
		45	65-90
		22.4	0-10
		11.2	0-5

Table 2. Gradation requirements for granular sub-base course as per MORTH (2001)

IS sieve designation (mm)	Percent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75.0	100	-	-
53.0	-	100	-
26.5	55-75	50-80	100
9.50	-	-	-
4.75	10-30	15-35	25-45
2.36	-	-	-
0.425	-	-	-
0.075	< 10	< 10	< 10

EARLIER STUDIES **Zakaria et al. (1995)** characterised unbound aggregate for rutting or permanent deformation under wheel passes. Artificially produced crushed bricks aggregate and naturally occurring quartzite were compacted in a specially prepared container in order to measure the rut depths. The Transportation Road Research Laboratory (TRRL, 1994) wheel tracking device with modified vertical loads was used to run on the compacted aggregate surface. They considered four factors which influence the rutting i.e. aggregate quality, gradation, moisture content and wheel contact pressure. Analysis of rut depths obtained for different combination showed that initial grading and moisture are the most influencing factors for the development of ruts on compacted aggregate surface, For dense grading and dry conditions, quartzite aggregate undergoes less rutting than brick aggregate, whereas for open grading, performance of brick aggregate undergoes less rutting than brick aggregate. They concluded that among the four factors considered, the aggregate type had the least influence and grading type had the highest influence on the rut depth at particular number of wheel passes.

III. STUDY METHODOLOGY

GENERAL

In the previous chapter, the literature review on various rutting models has been discussed along with the background information on the rutting. In the present chapter details about the proposed methodology for the present study are presented.

For the purpose of Rural Road Pavement Performance Study (RRPPS) three districts namely Warangal, Guntur and Kurnool in Andhra Pradesh were considered. The list of selected test sections is presented in tables. 3.1 to 3.3.

Table1 Different selected test stretches in Warangal district.

Table1 Different selected test stretches in Warangal district

S.No.	Road Name	District	Subgrade	Rainfall intensity (mm)	Traffic intensity	Surface type
W1	Tarigoppala to AbdullaNagaram	WARANGAL	Gravel	500-1000	B	OGPC
W2	Station Ghanpur to Sreepathpally		Gravel	> 1000	B	OGPC
W3	Veldi to Ashwaraopally		Gravel	500-1000	B	OGPC
W4	Edupusalapally to Kommugudem		Gravel	>1000	B	OGPC
W5	Hasnaparthy to Nagaram		BC	500-1000	B	OGPC
W6	Somidi to Subbayapalli		BC	500-1000	B	OGPC
W7	PWD Road to Singaram		BC	500-1000	B	OGPC

Table.2 Different selected test stretches in Guntur district

S.No.	Road Name	District	Subgrade	Rainfall intensity (mm)	Traffic intensity	Surface type
G1	Chekrayapalem to Dhavaluru	GUNTUR	B.C soil	>1000	B	OGPC
G2	Yeletipalem to Dhulpudi		B.C/Silty	> 1000	C	OGPC
G3	Palem to Kolimerla		B.C	>1000	C	OGPC
G4	Loyapalli to Zendapeta thanda		Silty/red earth	500-1000	C	OGPC

Table 3 Different selected test stretches in Kurnool district

S.No.	Road Name	District	Subgrade	Rainfall intensity (mm)	Traffic intensity	Surface type
K1	Midthur to Khazipet	KURNOOL	B.C soil/H.G soil	500-1000	B	OGPC
K2.	Aspari to Heligera		B.C soil	500-1000	A	OGPC
K3	Jonnagiri to Pendyakal		Gravel/B.C	>1000	C	OGPC
K4	NH - 18 to Gotluru		B.C soil	500-1000	B	OGPC

OVERVIEW OF THE METHODOLOGY

The study methodology adopted in this study to evalue the influence of unbound material properties on the rutting potential of low volume roads is shown in Figure.

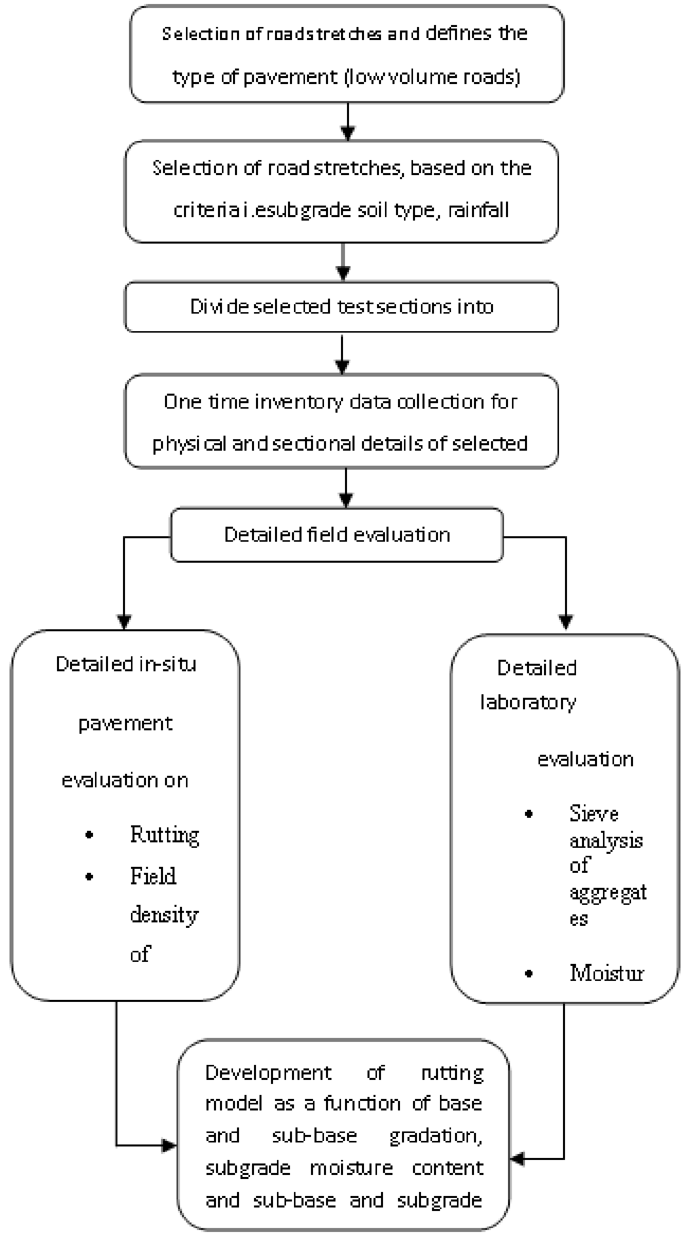

Figure: Study methodology

Selection of Road Stretches

The road stretches were selected based on the criteria adopted i.e., sub-grade soil type, rainfall, traffic volume, pavement condition and surface type.

The following parameters have been considered in this study for selection of the road stretches:

Sub-grade soil:

The subgrade soil of three types was considered, they are:

Gravely and sandy,

Silty,
Clayey soils and their combinations.

Rain fall intensity:

The test sections were classified based on rainfall as:
Less than 50 mm,
500-1000 mm,
Greater than 1000 mm.

Traffic volume:

Classification of test stretches was also done based on the number of commercial vehicles plying on that road at the time of selection. The classification of traffic volume is given as follows
A : 0 to 15 CVPD
B : 16 to 45 CVPD
C : 46 to 150 CVPD
D : 151 to 450 CVPD
E : > 450 CVPD

Surface type:

Open Graded Pre-mix carpet (OGPC)

Selection of test sections

The length of test section selected is 500 m, starting from a land mark item (sign board of PMGSY or kilometer stone of the road).

Normally section is selected on straight portion of roads and not on horizontal curves, approaches to culverts, bridges were avoided while selecting the test section.

The past history of the section should be available i.e., year of construction, traffic and section details.

The test sections are to be selected to cover as far as possible the following two variables.

Subgrade soil type, and Annual rainfall.

The selected stretches were inspected by manual visual inspection method.

Detailed laboratory evaluation

Laboratory test involves the sieve analysis (gradation) on the aggregate samples collected from the base course the soil samples collected from the field were tested for the wet sieve analysis for the sub-base course and moisture content of the subgrade soil samples.

SUMMARY

In this chapter the methodology and the criteria for selection of the stretches are discussed and the guidelines required to select the stretch were presented. Type of data to be collected from the field and the laboratory tests to be conducted is also discussed.

IV. STUDY AREA AND DATA COLLECTION

GENERAL In the previous chapter, the study methodology and criteria for selecting the sections for the study has been discussed.

Warangal is a district in Andhra Pradesh, India. Warangal District has an area of 12,846 km^2, and a population of 28, 18,832 of which 19.20% was urban as 2001. The district is bounded by Karimnagar district o the north, Khammam district to the east and southeast, Nalgonda distinct to the southwest, and Medak district to the west. Warangal is well known for its granite quarries. Hyderabad International Airport is about 3 ½ hours by road from Warangal city. This district has a small airport, Mamnoor, which could accommodate small aircraft like the ATR 42.

The following stretches are selected in Warangal district.

Tarigoppala to Abdulla Nagaram (W_1)

Tarigoppala to Abdulla Nagaram is in Naremetta mandal consisting of 6.3 km length and provides connectivity between above two villages. The agricultural, dairy and vegetable products of these villages have to be transported to the market centers of Warangal i.e. Chinnapendyal, Kazipet and Hanamkonda with short route. The total benefitted populations of about 2170 of these villages are also use of this road for accessing secondary and higher education schools. The subgrade soil is Gravel, the rain fall intensity is between 500-1000mm and the maximum and minimum temperatures are 46^0 and 28^0 C respectively, this road was constructed under phase three. For the purpose of pavement performance the test section was selected for km 2/900 - km 3/400

Station Ghanpur to Sreepathpally (W_2)

This is a through road which connects National Highway 202 at one end and R&B Road (MDR) at other end and makes more accessibility to the rural areas. The length of this road is 5.3 km. The road connects Station Ghanpur, Sreepathpally and Pallagutta with a total population of 20000 and this road falls under Station Ghanpur block. The subgrade soil is Gravel, the rain fall intensity is greater than 1000mm and the maximum and minimum temperatures are 46^0 and 28^0 C respectively, this road was constructed under phase four. For the purpose of pavement performance the test section was selected for km 3/500 **-** km 4/000.

GUNTUR

Guntur is located at $16^0$12 N 80^0 16 E it has an average elevation of 33 meters and situated on the plains. There are few hills in the surrounding suburban areas. The District is located around 64 km to the north of the Bay of Bengal on the east coast of India. The Krishna River forms the northeastern and eastern boundary of the district, separating Guntur District from Krishna District. The district is bounded on the southeast by the Bay of Bengal, on the south by Prakasam District.

The following stretches are selected in Guntur district.

Chakryapalem to Davuluru (G1) This road is situated 50 km away from Guntur head quarters in Tenali sub division. The subgrade soil type is Black cotton soil. Both side of the road is completely agriculture land with one side field channel. The traffic volume on this road varies from 40**-** 50 CVPD. During the visit the test section is selected in a Chainage from km 4/400 km to 3/900 km straight section with a permanent land mark of bridge and up to 3/900 Chainage bore well near palemela trees. This road stretch started with C.C pavement from village portion about 600 m and than remaining is Black Topped surface.

Yeletipalem to Dhulipudi (G2) This road is providing the connectivity between the Yeletipalem to Dhulipudi and Veeravarankivaripalem having a population more than 2500. Subgrade soil is BC mixed with silt. The total length of the road is about 4.4 km, out of which 0.35 km is C.C pavement. The construction of road is started in the year 2006, completed and opened to traffic in the month of January 2007. The traffic volume on this road is about 150 cvpd. More no of Commercial Vehicles have been flying on this road (Tractors, Trucks) during agricultural season. The Chainage of the test section is km 4/600 to 5/100. The shoulder is compacted with gravel, during the visit it was observed that the pavement condition is good in terms of its riding quality on this test section.

KURNOOL

Kurnool, as a village, has existed for more than 2000 years. Kurnool was a major fort during the reign of the Vijayanagar emperors. There is still a grand citadel, Konda Reddy Buruju which symbolizes the glory which the town enjoyed in Vijayanagar times, but it is not certain how the watchtower got its name. Kurnool city lies on the southern banks of the Tungabhadra River.

Midthurorvakallu to Khazipeta (K1) This road is situated 40 km away from Kurnool head quarters. The subgrade soil is Black cotton soil and red earth soil with an average CBR of 5%. The movement of vehicles for agricultural goods on this road is an about 80%. Three villages namely Midthur, Khazipeta, and Oravakallu benefitted with combined population of 7038. The nature of crops grown in this area paddy, jawar and chilies. Selected pavement test section is from km 2/000 to 2/410. The subgrade soil in this road is combination of BC mixed with silt, shale rock type with hard soil in km 3/400 to km 3/900 Chainage.

Johannagiri to Pendekal (K2) The total length of the road is about 14.00km out of which 8km is existing BT, proposed length of the road is 5.80 km. The rail way line is passing through on this road which resulted in increase in traffic about 80 cvpd. Due to over loading (more trucks) the existing road is badly deteriorated.

DATA COLLECTION

One time road inventory data and other relevant data were collected for Warangal Guntur and Kurnool districts on the selected stretches in the initial stage and recorded in prescribed format. For easy data collection and evaluation the pavement sections were divided into sub-sections i.e., 500 m length and for each 50 m sub section, details were collected as per procedures and recorded in prescribed formats. For this 50 m a detailed functional and structural evaluation studies have been conducted.

Rutting data was recorded for the different stretches of the rural roads. Rutting data was collected by using a 3m straight edge and measuring it across the wheel path. For the aggregate gradation purpose the pavement is disturbed at the shoulder portion and the base material i.e. grade II &III material, and the sub-base material, the soil samples for the determination of subgrade moisture content were collected from the field, and in-situ field density of subbase and subgrade also determined.

SUMMARY

In this chapter the study area and detailed description of all the stretches have been discussed. The detailed procedures of data collection in the field were also discussed.

V. ANALYSIS AND DISCUSSION

GENERAL

In the previous chapter, the description of the study area and detailed description of the test sections and the procedure for data collection has been discussed. This chapter presents the detailed analysis of the test stretches and results obtained were discussed thoroughly.

ANALYSIS OF SELECTED TEST STRETCHES IN WARANGAL DISTRICT

Tarigoppala to Abdulla Nagaram (W1) The detailed analysis of the test stretch Tarigoppala to Abdulla Nagaram has been discussed in the following sections.

Rutting is defined as the longitudinal depression along the wheel path. In the present investigation the rut depth was measured using 3m straight edge. From this the rutting was calculated and is shown in table1.

Table 1 Average rut depth values for the W1 stretch

Chainage (km)	Rut depth (mm)		Average rut depth (mm)
	LWP	RWP	
2/900 - 2/ 950	8	9	9
	7	12	
2/950 - 3/000	6	7	6.5
3/000 - 3/050	10	10	9.25
	10	7	
3/050 - 3/100	1	9	4.5
	1	7	
3/100 - 3/150	9	11	10.25
	11	10	
3/150 - 3/200	9	6	7.5
3/200 - 3/250	7	6	8
	7	12	
3/250 - 3/300	6	6	6
3/300 - 3/350	10	11	9.5
3/350 - 3/400	8	9	6.5
	9	0	

Station Ghanpur to Sreepathpally (W_2)

The detailed analysis of test stretch Station Ghanpur to Sreepathpally has been presented in subsequent sections and results are summarized in Table 1

Table 1 Summary of average rut depth and different factors considered for W2 stretch

Chainage (km)	Average rut depth (mm)	RMSE			Field Density(g/cc)		Subgrade moisture content (%)
		Base Gr.III gradation	Base Gr.II gradation	Sub-base gradation	sub base	Sub grade	
3/500 – 2/550	0	16.583	10.63	13.291	1.754	1.983	2.99
2/550 – 3/600	14	24.212	15.198	25.488	1.619	1.735	6.22
3/600 – 3/650	7	18.049	11.664	16.782	1.501	1.815	5.20
3/650 – 3/700	0	16.118	12.625	15.187	1.85	2.15	3.11
3/700 – 3/750	0	17.922	10.963	16.329	1.712	2.065	3.25
3/750 – 3/800	5	17.871	14.38	15.853	1.516	1.775	3.92
3/800 – 3/850	0	19.58	10.158	12.701	1.85	2.135	3.15
3/850 – 3/900	0	16.34	9.476	13.616	1.784	2.182	3.50
3/900 – 3/950	0	14.73	8.52	12.99	1.65	1.994	3.43
3/950 - 3/1000	0	15.101	9.219	12.626	1.639	1.885	3.86

The variation of the rut depth with various factors considered are shown in Figure 1 to 2

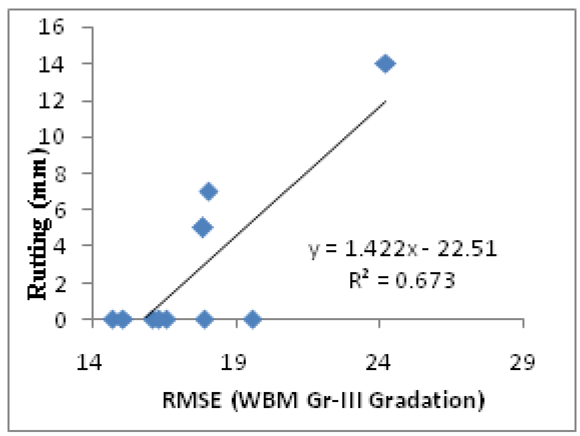

Figure 1: Variation rut depth with WBM (Gr.III WBM Gradation) for W2 stretch

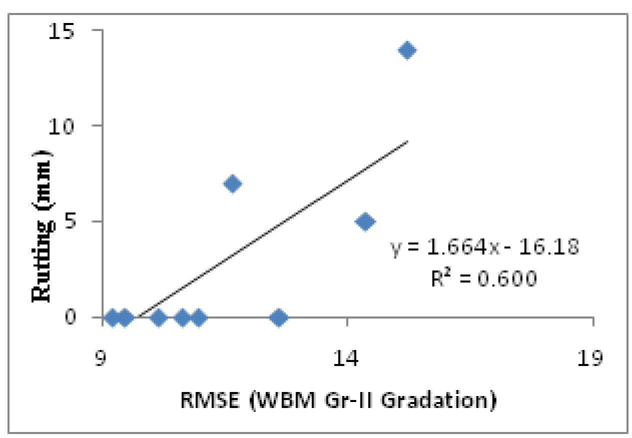

Figure 2 Variation of rut depth with (Gr-II Gradation) for W2 Stretch

ANALYSIS OF SELECTED TEST STRETCHES IN GUNTUR DISTRICT

Chekrayapalem to Dhavaluru (G_1)

The detailed analysis of test stretch Chekrayapalem to Dhavaluru has been presented in subsequent sections and results are summarized in Table 1

Table 1 Summary of average rut depth and different factors considered for G1 stretch

Chainage(km)	Average rut depth (mm)	RMSE			Field Density(g/cc)		Subgrade moisture content (%)
		Base Gr.III gradation	Base Gr.II gradation	Sub-base gradation	sub base	Subgrade	
4/400 – 4/350	12	21.523	15.905	18.526	1.782	1.626	5.83
4/350 – 4/300	6	18.708	13.549	14.433	1.829	1.794	5.21
4/300 – 4/250	0	12.371	9.705	11.604	1.839	1.816	3.12
4/250 – 4/200	4	12.47	12.465	15.947	1.797	1.795	6.01
4/200 – 4/150	4	13.281	10.285	14.52	1.803	1.651	4.77
4/150 – 4/100	16	23.564	18.072	24.158	1.745	1.606	6.93
4/100 – 4/050	24	25.102	24.346	26.538	1.652	1.65	6.66
4/050 – 4/000	0	10.67	7.197	13.291	1.934	1.934	6.18
4/000 – 3/950	6	14.65	9.705	14.256	1.707	1.697	5.24
3/950 – 3/900	0	11.823	13.438	15.612	1.854	2.021	4.12

The variation of the rut depth with various factors considered are shown in Figure 1 to 2

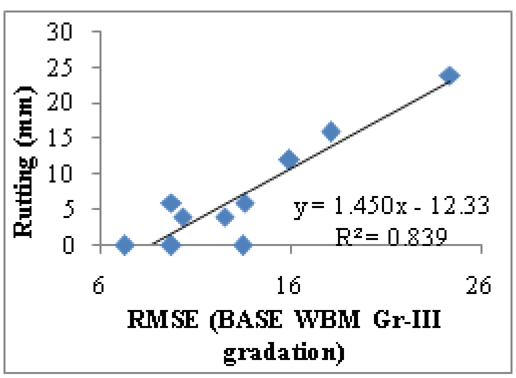

Figure1: Variation of rut depth with RMSE of sub base gradation for G1 stretch

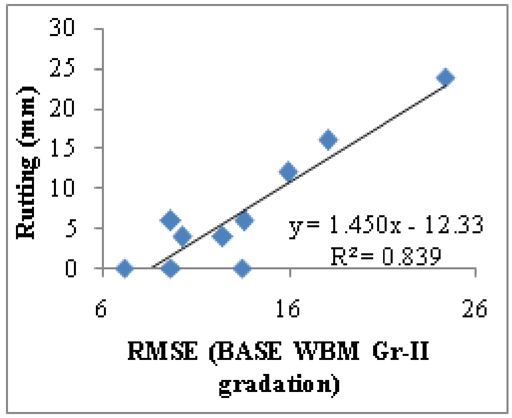

Figure 2: Variation of rut depth with sub-base field density for G1 stretch

Yeletipalem to Dhulpudi (G_2)

The detailed analysis of test stretch Yeletipalem to Dhulpudi **(G_2)** has been presented in subsequent sections and results are summarized in Table1.

Table 1 Summary of average rut depth and different factors considered for G2 stretch

Chainage(km)	Average rut depth (mm)	RMSE			Field Density(g/cc)		subgrade moisture content (%)
		Base Gr.III gradation	Base Gr.II gradation	Sub-base gradation	subbase	subgrade	
4/500 – 4/550	9	25.69	12.68	14.584	1.78	1.742	4.82
4/550 – 4/600	12	19.456	13.549	15.325	1.715	1.725	4.98
4/600 – 4/650	10	16.368	11.98	12.604	1.71	1.721	3.12
4/650 – 4/700	22	28.365	18.82	27.458	1.8	1.652	6.25
4/700 – 4/750	14	15.124	10.285	10.365	1.62	1.651	4.77
4/750 – 4/800	12	19.362	15.22	20.388	1.611	1.606	4.20
4/800 – 4/850	16	25.658	20.1364	21.457	1.796	1.788	5.66
4/850 – 4/900	4	10.67	8.56	11.236	1.934	1.934	6.18
4/900 – 4/950	8	11.254	9.705	8.56	1.808	1.998	4.86
4/950 – 5/000	4	11.823	13.438	10.235	1.961	2.021	4.15

The variation of the rut depth with various factors considered are shown in Figure 1 to 2

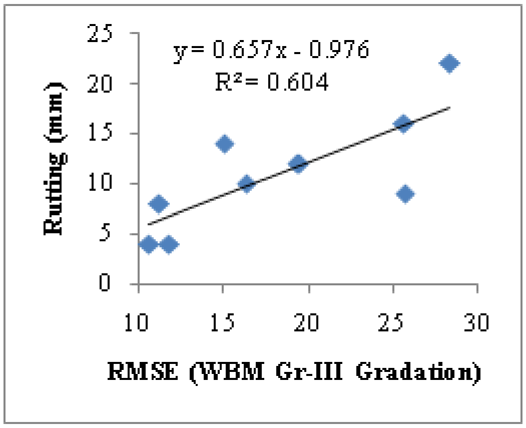

Figure 1: Variation rut depth with WBM (Gr.III Gradation) for G2 stretch

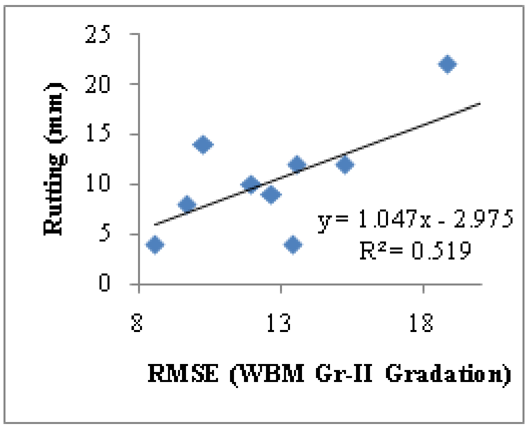

Figure 2: Variation of rut depth with (Gr-II Gradation) for G2 Stretch

ANALYSIS OF SELECTED TEST STRETCHES IN KURNOOL DISTRICT

Midthur to khazipet (K_1)

The detailed analysis of test Midthur to khazipet stretch has been presented in subsequent sections and results are summarized in Table 1

Table 1 Summary of average rut depth and different factors considered for K1 stretch.

Chainage(km)	Average rut depth (mm)	RMSE			Field Density(g/cc)		subgrade moisture content (%)
		Base Gr.III gradation	Base Gr.II gradation	Sub-base gradation	sub base	subgrade	
2/000 – 2/050	23.66	23.658	15.786	10.256	1.815	1.869	6.12
2/050 – 2/100	28.5	28.569	16.334	24.254	1.612	1.843	6.55
2/100 – 2/150	24.166	26.539	16.118	24.55	1.621	2.024	8.54
2/150 – 2/200	34.526	38.526	20.158	27.854	1.571	1.785	5.64
2/200 – 2/250	32.4	30.256	18.569	20.458	1.752	1.785	7.75
2/250 – 2/300	17.0	17.787	9.356	12.0356	2.145	1.895	5.40
2/300 – 2/350	19.333	22.6	12.568	22.125	1.842	1.895	2.98
2/350 – 2/400	22.5	21.895	14.528	22.55	1.895	1.785	4.97
2/400 – 2/450	27.333	24.661	16.254	22.547	1.854	1.788	5.94
2/450 - 2/500	29.33	22.091	18.254	23.584	1.784	1.698	7.66

The variation of the rut depth with various factors considered are shown in Figure 1 to 2.

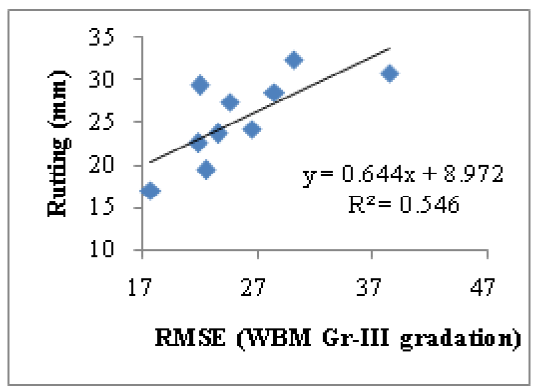

Figure 1: Variation rut depth with WBM (Gr.III Gradation) for K1 stretch

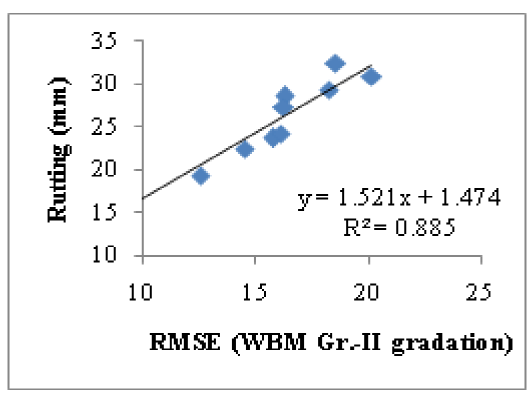

Figure2: Variation of rut depth with (Gr-II Gradation) for K1 Stretch

Aspari to Heligera (K_2)

The detailed analysis of test stretch Aspari to Heligera has been presented in subsequent sections and results are summarized in Table 1

Table 1 Summary of average rut depth and different factors considered for K2 stretch

Chainage(km)	Average rut depth (mm)	RMSE			Field Density(g/cc)		subgrade moisture content (%)
		Base Gr.III gradation	Base Gr.II gradation	Sub-base gradation	sub base	subgrade	
1/000 – 1/050	0	12.045	8.569	26.575	1.86	1.943	4.47
1/050 – 1/100	20	24.235	10.235	30.692	1.523	1.606	6.46
1/100 – 1/150	20	25.458	12.458	26.355	1.621	1.568	6.14
1/150 – 1/200	0	17.883	5.950	27.526	1.785	1.864	3.72
1/200 – 1/250	0	10.235	3.873	25.230	1.856	1.963	4.15
1/250 – 1/300	0	8.457	5.158	22.356	1.88	1.909	4.64
1/300 – 1/350	0	10.235	8.473	18.546	1.758	1.904	7.25
1/350 – 1 /400	0	15.678	5.495	22.356	1.586	1.937	4.18
1/400 – 1/450	0	11.296	6.309	20.145	1.965	2.044	5.87
1/450 - 1/500	17	12.564	17.568	25.093	1.623	1.854	6.18

The variation of the rut depth with various factors considered are shown in Figure 1 to 2

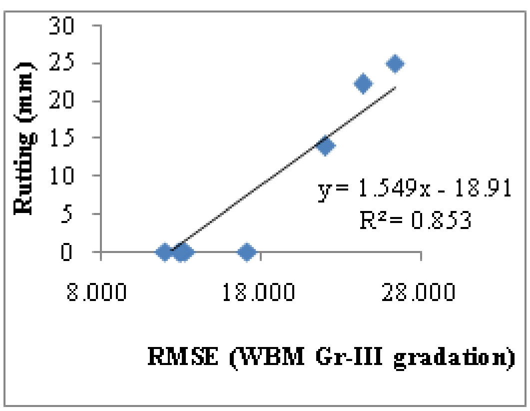

Figure 1: Variation rut depth with WBM (Gr.III Gradation) for K2 stretch

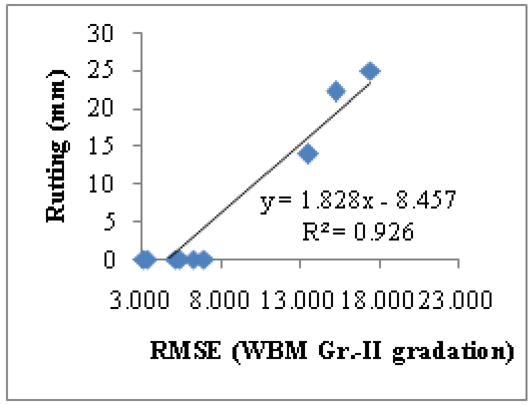

Figure 2: Variation of rut depth with (Gr-II Gradation) for K2 Stretch

SUMMARY

In this chapter the detailed analysis and results of the fifteen tests stretches and the development of models using the SPSS statistical package have been discussed.

VI. SUMMARY AND CONCLUSIONS

SUMMARY

Rutting is one of the major failures in flexible pavements. Because of the increase in tyre pressure and axle loads in recent years, rutting has become the dominant distress in flexible pavements. There are various causes of rutting depending on the configuration and structural capacity of various layers and environmental conditions. An attempt has been made in this study to find influence of various parameters such as WBM (Gr.III & Gr.II) aggregate gradation, subbase gradation, subbase and subgrade field density and subgrade moisture content on the observed rut depth on the selected pavement stretches. In order to achieve this objective fifteen stretches were identified in Warangal, Guntur and Kurnool of Andhra Pradesh state. The data on above mentioned parameters has been collected from all the fifteen stretches. The model has been developed for each stretch and it was observed that there is significant influence of all the parameters on the rut depth.

CONCLUSIONS

Based on the field studies and analysis the following conclusions are

There is a considerable influence of the Base gradation (WBM Gr-III &Gr-II) and Subbase gradation on the rut depth. In this study, the upper limit values of standard gradation have been taken as the datum to find the RMSE Values of Base and subbase layers of all the stretches. It has been assumed that when the base and subbase course layers are constructed with upper limit of the standard gradation, one can expect minimum rut depth. Based on the assumption the RMSE values are calculated for all the selected stretches. After analyzing the data it was observed that even the rut depth is zero, the RMSE value is high for some of the chainages of selected stretches. In most of the cases with the increase in RMSE values, there is a increase in rut depth values in the most of the selected stretches.

The field density of subbase and subgrade are much influencing on the rut depth. 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 very high.

SCOPE FOR FURTHER WORK

One can extend the same work using this data to develop rutting models by considering various other factors like traffic, and pavement age after continuing this work 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. To develop various progression models continuous data base is required. Hence it can be incorporated in further study. Further studies can also be carried out on the effects of gradation on rut depth as discussed in the conclusions.

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