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S. Shankar C.S.R.K Prasad and B. Bhaskar

Abstract: Pavement management system PMS is a term that relates to a system that utilizes the condition coding of roadways coupled with the identification of strategies to determine maintenance or re-construction activities. A pavement management system contains a series of decision units used to determine how and when to repair the roads surface based on various tests. These tests can be simply visual or employ special software and databases to provide rankings for roads or road. In India, mostly pavements are flexible in nature. Maintenance of flexible pavements is more difficult than rigid one as the surface of flexible pavement is affected by the atmospheric conditions more easily than rigid pavement. In the present paper four rural road test sections are identified in the various division of Warangal district to carry out the rural road pavement performance, detailed data collection has been done on the selected test sections i.e. road inventory survey, pavement condition survey and traffic volume survey and analysis was carried out using Highway Development Management (HDM-4) tool for responsive and schedule maintenance and compression was made among and best alternative was recommended.

1.0. INTRODUCTION

Low-volume roads (LVRs) or rural roads (RR) which are said to make up more than 75% of the world's road network are a critical component of any agency's infrastructure system. India has a rural road network of about 2.7 million km developed with an investment of almost Rs 35,000 crore, estimated to have a replacement value of about Rs 180,000 crore. This constitutes over 80 per cent of the total road network; however, about a million km length of the road does not meet the technical standards required. A study (Fan et al., 1999) carried out by the International Food Policy Research Institute on linkages between government expenditure and poverty in rural india has revealed that an investment of Rs 1 crore in roads lifts 1650 poor persons above the poverty line. They provide links from homes-farms- markets and for raw materials. LVR play a key role in supporting economic growth and alleviating poverty. These roads, which are dominant, introduce major challenges to road planning and management. The economic threshold for paving has traditionally been accepted as 150 to 200 veh/day. The LVR pavements normally consist of natural gravel materials in most layers and thin bituminous surfacing.

For LVR there is no exact definition, but it could be defined primarily as secondary or tertiary roads that have less than400 vehicles per day as the design average annual daily traffic (AADT) Hudson, 1987.)These roads may also have high percentages of heavy loads. According to IRC: SP: 20-2002and SP-72-2007 defines the traffic less than 100 motorized veh/day and it is not likely to grow due to situation, like, dead end, low habitation and difficult terrain conditions is defined as rural road and for low volume rural roads, still carrying sizeable volume of truck and bus traffic the maximum number of ESAL applications considered for flexible pavement is up to 1 million ESALS.LVR may be two-lane asphalt paved roads with up to 2,000 veh/day. A widely recognized LVR definition sets the upper limit at 400 vehicles per day.

1.1. RESEARCH SIGNIFICANCE

Pavement maintenance management system provides (PMMS) a tool to the highway agencies in the road section for maintenance, predicting the pavement performance alternatives in the estimation of costs of pavement maintenance strategies with a view to select an optimal strategy with the least life cycle cost analysis. Rural Road traffic conditions in india are distinctly different from other roads. Thin bituminous surfaces (20 mm) are predominantly provided as wearing courses. Majority of the road length under the state roads (other than national highways) is single lane only. The funds available for maintaining the roads, in traffic worthy conditions, are not adequate and no tools are available for making the inputs in a scientific manner. The extent of overloading on this road is increasing rapidly. Presently Pavement maintenance for rural roads is based on the judgment and experience. It is therefore a pressing need exists to have systematic PMS based on the relevant data. In the present study detailed Functional and Structural condition evaluation were carried for selected stretches in Warangal district. A detailed analysis were carried out using HDM-4 tool for responsive and schedule maintenance and comparison was made among, best alternative was recommended.

S. Shankar, Research Scholar, Transportation Division, Department of Civil Engineering, NIT Warangal, and A.P-India-mail: Email: shreebunty@gmail.com.
C.S.R.K Prasad, Professor and Head, Transportation Division, Department of Civil Engineering, NIT Warangal, A.P-India. Email: csrk_prasad@yahoo.com.
B.Bhaskar M.Tech student, Transportation Division, Department of Civil Engineering, NIT Warangal, A.P-India. Email: bhaskar.nitw@gmail.com

1.2. OBJECTIVES OF THE STUDY

To reveview the comprehensive literature on development of pavement performance system in India and different parts of world, and to identify the various distresses in rural roads and ascertain their causes from detailed distresses survey. To develop the deterioration models using Highway development and management (HDM-4), tool based on the model to suggest the pavement maintenance and management strategies for rural roads and their treatments options for over a period of time.

2.0. LITERATURER REVIEW

The use of pavement performance models to predict future pavement conditions for the highway network is a part of the agency's pavement management activities. Traditionally, pavement performance has referred to the serviceability-performance concepts defined by Carey-Irick (1958), which represents performance as the variation or history of pavement serviceability with time. Since that time, the term performance has been used loosely by individuals in the pavement management field. As a result, it has become common practice among practitioner's and researchers to use terms such as deterioration to represent the change in pavement performance over time. For the purpose of this course, the term performance models will be used to represent the pavement deterioration patterns that are modeled. Pavement performance models vary depending on the type of performance that is being modeled. For example, pavement condition can be defined in terms of measured quantities of distress or a subjective rating based on a visual assessment of the overall condition of a pavement section. Individual distress quantities may be used to drive maintenance or rehabilitation activities, or the information may be combined to calculate a condition index.

3.0. STUDY AREA AND METHODOLOGY

Warangal District in A.P has an area of 12,846 km² and a population of 3,246,004 of which 19.20% was urban as of2001. The district is bounded by Karimnagar District to the north, Khammam District to the east and southeast, Nalgonda District to the southwest, and Medak District to the west. This district has a small airport, Mamnoor, which could accommodate small aircraft like the ATR 42. Warangal is located at 18, 79.58 It has an average elevation of 302 m (990 feet). A STPI (Software technology parks of India) has been set up at National Institute of Technology, Warangal with the intention of taking the benefits of the Information Technology revolution to second tier cities. Warangal makes an excellent location for this because of its proximity to Hyderabad. The following rural road stretches in Warangal district were selected for study based on the selected parameters and criteria i.e. Edupusalapally - Kommugudem (W1), Tarigoppula- Abdulnagaram (W2), Ashwaraopally – Veldhi (W3), Stationghanpur- Sreepathpally (W4) and Fig2 depict the methodology adopted for the study.

4.0 ANALYSIS AND DISCUSSIONS

Generally in HDM-4 a standard is defined by a set of operations or work activities with definite intervention criteria to determine event to carry them out. In general terms, intervention levels define the minimum levels of service that is allowed. A standard is user defined according to the road surface class to which it is applied, the characteristics of traffic on the section, and the general operational practice in the study area based upon engineering, economic and environmental considerations. Standards are grouped in to two types for input purposes i.e. maintenance standards and improvement standards. The maintenance and improvement standards for the road sections taken that, Base alternative is taken as reconstruction of pavement after 5 years. Second one is crack sealing and overlay are considered as maintenance standards for the road sections. . In scheduled criteria maintenance and improvement works are to be carried out at the end of every two years interval, where as in the case of responsive criteria maintenance standards are given when cracking area is more than or equal to 10% of total carriageway area and IRI value is greater than or equal to 4%. The analysis was carried out in responsive criteria for maintenance standards in the year of 2010 and improvement standards for the year of 2013.

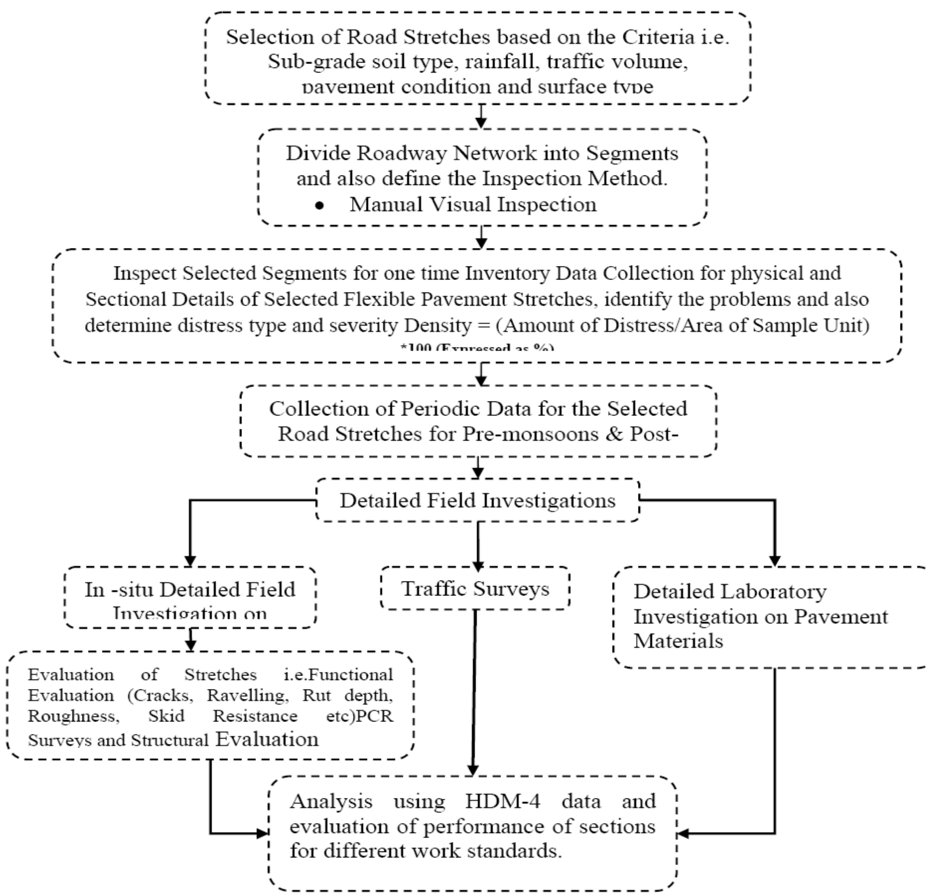


Fig1: Study methodology

4.1 Calibration factors and deterioration models

Bituminous surfacing start developing cracks at some point of their service life under the combined action of traffic loading and the environment. The cracks in the surface are defects of serious nature, which weaken the pavement structure on account of water penetration, and are largely responsible for further deterioration. Cracks once initiated progress in extent and severity, and ultimately lead to spalling and potholes. Average calibration factors were developed for each distress in initiation and progression and presented in tables 1-7.

Table 1: Calibration factor for crack initiation

Road id	ICA (%)	YE4	SNP	CDS	CRT	Kcia
W1	12.09	0.009	4.39	1.25	3	0.802
W2	10.42	0.011	3.40	1.25	3	0.797
W3	11.28	0.018	3.99	1.25	3	0.79
W4	13.02	0.011	4.93	1.25	3	0.817

Average Calibration factor Kcia=.802

Table 2: Calibration factor for crack progression

Road id	dACA	CRP	CDS	ΔTA	SCA	KCPA
W1	1.73	0.64	1.25	1	1.71	0.96
W2	0.811	0.64	1.25	0.88	0.37	0.96
W3	0.811	0.64	1.25	0.88	0.78	0.88
W4	0.811	0.64	1.25	0.88	0.21	1.17

Average calibration Factor K_{cpa} = 0.997

Table 3: Calibration factor for raveling initiation

Road id	IRV(%)	CDS	RRF	YAX	KVI
W1	152.2	1.25	2	0.167	4.76
W2	150.19	1.25	2	0.253	4.76
W3	144.38	1.25	2	0.506	4.76
W4	150.47	1.25	2	0.241	4.76

Average calibration Factor K_{vi} = 4.76

Table 4: Calibration factor for raveling progression

Road id	DARV(%)	RRF	CDS	YAX	ΔTV	SRV	Kvp
W1	1.81	2	1.25	0.167	1	0.370	2.25
W2	2.50	2	1.25	0.23	1	3.0	1.98
W3	1.82	2	1.25	0.506	1	19.42	1.97
W4	1.81	2	1.25	0.167	1	3.360	1.98

Average calibration Factor k_{vp} = 2.04

Table 5: Calibration factor for pothole initation

Road id	IPT	CDB	HS	YAX	MMP	KPI
W1	7.57	0.80	150	0.167	15	0.99
W2	7.28	0.80	150	0.353	30	1.13
W3	6.55	0.80	150	0.506	20	0.887
W4	7.32	0.80	150	0.241	15	0.99

Average calibration factor Kpi = 1.00

Table 6: Calibration factor for raveling progression

Road id	DNPT	CDB	YAX	MMP	ADISI	KPP

W1	0.084	0.80	0.167	15	3.0	0.201
W2	0.074	0.80	0.353	30	3.3	0.390
W3	0.126	0.80	0.506	20	0.37	0.405
W4	0.142	0.80	0.241	15	19.47	0.143

Average Calibration factor K_{pp} = 0.285

Table 7: Calibrationvfactor for roughness

Road id	ΔRI	ΔRISs	ΔRIc	ΔRIr	ΔRIt	ΔRIe	Kgp
W1	0.032	0	0.011	0.011	0	0.01	1.0
W2	0.031	0.001	0.005	0.014	0	0.01	1.01
W3	0.029	0.001	0.005	0.013	0	0.01	1.0
W4	0.025	0	0.005	0.009	0	0.01	1.07

Average Calibration factor Kcia=.802

Crack initiation model

$$ICA = K_{cia}\left[CDS^2 * 4.21EXP\left\{0.14 * SNP - 17.1\left(\frac{YE4}{SNP^2}\right)\right\} + CRT\right]$$

Crack progression model

$$dACA = K_{cpa}\left(\frac{CRP}{CDS}\right) * \left[(1.84 * 0.45 * \delta t_A + SCA^{0.45})^{\frac{1}{0.45}} - SCA\right]$$

Ravelling initiation model

$$IRV = K_{vi} * CDS^2 * 10.5 * RRF * EXP(-0.156 * YAX)$$

Ravelling progression model

$$dARV = K_{vp}\left(\frac{1}{RRF}\right)\left(\frac{1}{CDS^2}\right)\left[\left(\left[(0.6 + 3.0YAX) * 0.352 * \delta t_A + SRV^{0.35}\right)\right]^{\frac{1}{0.35}} - SRV\right]$$

Pothole initiation model

$$IPT = K_{pi}2.0\left[\frac{(1 + 0.05 * HS)}{(1 + 1 * CDB)(1 + 0.5 * YAX)(1 + 0.01 * MMP)}\right]$$

Pothole progression model

$$dNPT_i = K_{pp} * ADIS_i\left[(1 + 1 * CDB)(1 + 10 * YAX)(1 + 0.005 * MMP)/(1 + 0.08 * HS))\right]$$

Roughness progression model

$$\Delta RI = 1.02(\Delta RI_S + \Delta RI_C + \Delta RI_r + \Delta RI_r + \Delta RI_t) + \Delta RI_e$$

Where
ICA = time to initiation of all structural cracks (years)
Kcia = calibration factor for initiation of all structural cracking (default = 1)
CDS = construction defects indicator for BT surface (0.5 for brittle, 1.0 for optimum, and 1.5 for soft)
SNP = average annual adjusted structural number of the pavement
YE4 = annual number of equivalent standard axles (millions/lane)
CRT = crack retardation time due to maintenance (years) (3.0)
dACA = incremental change in area of all cracking during year
kcpa = calibration factor for cracking progression (default = 1)
CRP = retardation of cracking progression due to preventive treatment
δta = fraction of analysis year in which all cracking progression applies
SCA = minimum (ACAa, (100 – ACAa))
ACAa = area of cracking at start of analysis year (years
IRV = time to raveling initiation (years)
Kvi = calibration factor for raveling initiation (default = 1)

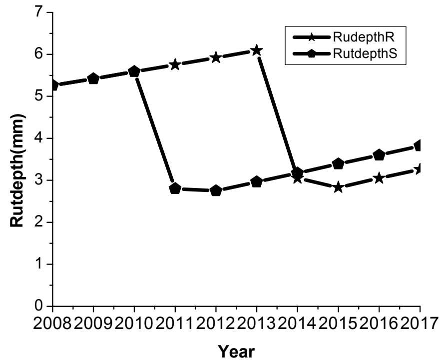
RRF = raveling retardation factor due to maintenance
YAX = annual number of axles of all vehicle classes in analysis year (millions/lane)
dARV = change in area of raveling during analysis year (percent)
kvp = calibration factor for raveling progression (default = 1)
δtv = fraction of analysis year in which raveling progression applies
SRV = minimum (ARVa, (100 – ARVa))
ARVa = area of raveling at start of analysis year (percent)
IPT = time between initiation of wide cracking or raveling and initiation of potholing
Kpi = calibration factor for pothole initiation (default = 1)
HS = total thickness of bituminous surfacing (mm)
CDB = construction defects indicator for the base (0 for no defects, 1 for some defects, and 1.5 for several defects)
MMP = mean monthly precipitation (mm/month)
dNPTi = additional number of potholes per kilometer derived from distress type i
Kpp = calibration factor for pothole progression (default = 1)
ADISi = percent area of wide cracking at start of analysis year, or percent area of raveling at start of analysis year, or number of existing potholes per km at start of analysis year
ΔRI = total incremental change in roughness during the analysis year (IRI m/km)
Kgp = calibration factor for roughness progression (default = 1)
ΔRIs = incremental change in roughness due to structural deterioration during the analysis year (IRI m/km)
ΔRIc = incremental change in roughness due to cracking during the analysis year (IRI m/km)
ΔRIr = incremental change in roughness due to rutting during the analysis year (IRI m/km)

4.2. Detailed analysis using HDM-4 for work standards (Base alternative-Reconstruction)

Table 8 depicts the variation of rut depth for both the scheduled and responsive cases for the (W1) section. The variation of rut depth is shown here for the period of 10 years is obtained from the HDM-4 analysis output. The typical analysis for one test section (W1) is presented here and same analysis was carried for the other stretches taking into consideration of base alternative (reconstruction, crack sealing and overlay for responsive and schedule criteria.

Table 8: Variation of rut depth in responsive and schedule maintenance for base alternative, crack sealing and overlay

year	Rut depth(S)	Rut depth(R)		year	Rut depth(S)	Rut depth(R)		year	Rut depth(S)	Rut depth(R)
2008	5.26	5.26		2008	5.26	5.26		2008	5.26	5.26
2009	5.42	5.42		2009	5.42	5.42		2009	5.42	5.42
2010	5.59	5.59		2010	5.59	6.17		2010	5.59	6.17
2011	5.75	2.80		2011	5.75	6.91		2011	5.75	6.91
2012	5.92	2.75		2012	5.92	6.91		2012	5.92	6.91
2013	6.09	2.96		2013	6.09	6.90		2013	6.09	6.90
2014	3.05	3.17		2014	6.26	6.90		2014	6.26	6.90
2015	2.83	3.39		2015	6.43	6.90		2015	6.43	6.90
2016	3.05	3.60		2016	6.68	6.90		2016	6.60	6.90
2017	3.26	3.82		2017	6.93	6.89		2017	6.78	6.89



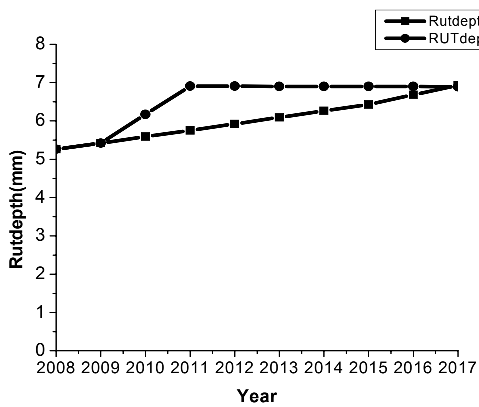


Fig 2: Variation of rut depth for base alternative

Fig 3: Variation of rut depth for crack sealing

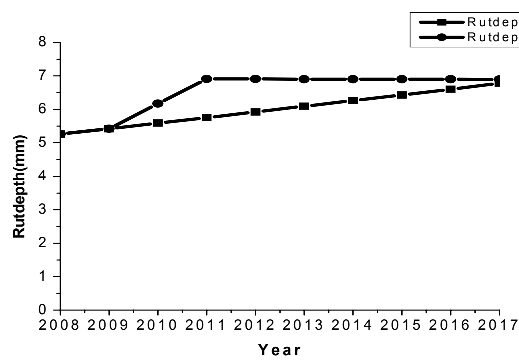


Fig 4: Variation for rut depth for overlay

Table 8 depicts the variation of rut depth for both responsive and scheduled cases for the section. The variation of rut depth is shown for the period of 10 years obtained fromHDM-4 output. Fig 2 clearly shows that scheduled alternative maintenance was required after every two years, and in other hand the base alternative option was reconstruction and is reconstructed in the year of 2014,because the rut depth reaches a maximum value of 6.75mm in that year. In schedule case the maintenance is required after every 2 year in order to maintain the pavement in good condition. The figure 3 depicts that, the maintenance standard for crack sealing was not implanted in responsive case, as in the case of the schedule maintenance crack sealing options was adopted in the year of 2011, where the increase in rut depth decreases shown in figure 3.

Table 9: Variation of SNP in schedule and responsive cases.

Year	SNPK(R)	SNPK(S)	Year	SNPK(R)	SNPK(S)	Year	SNPK(R)	SNPK9(S)
2008	3.99	3.99	2008	3.99	3.99	2008	3.99	3.99
2009	3.98	3.98	2009	3.98	3.98	2009	3.98	3.98
2010	3.97	3.97	2010	3.97	3.97	2010	3.97	3.97
2011	3.96	3.97	2011	3.96	4.17	2011	3.96	4.17
2012	3.93	2.99	2012	3.93	4.17	2012	3.93	4.17
2013	3.9	2.99	2013	3.9	4.37	2013	3.9	4.37
2014	3.9	2.99	2014	3.85	4.37	2014	3.85	4.37
2015	2.99	2.99	2015	3.79	4.56	2015	3.79	4.56
2016	2.99	2.99	2016	3.71	4.56	2016	3.71	4.56
2017	2.99	2.99	2017	3.92	4.76	2017	3.61	4.76

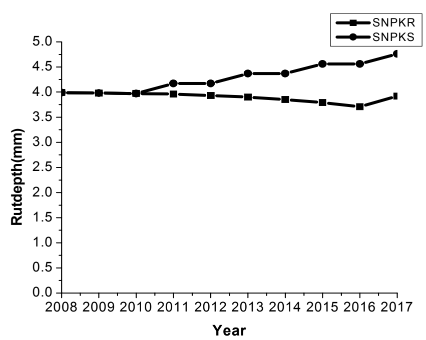


Fig 5: Variation of structural number for base alternative crack sealing

Fig 6: Variation of SN for

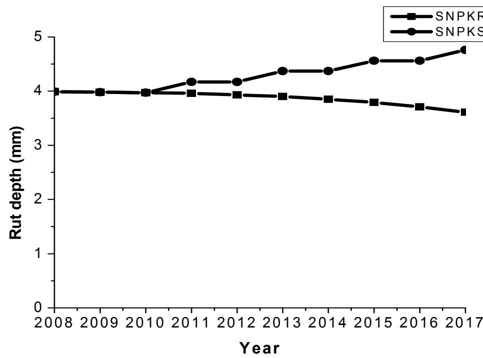
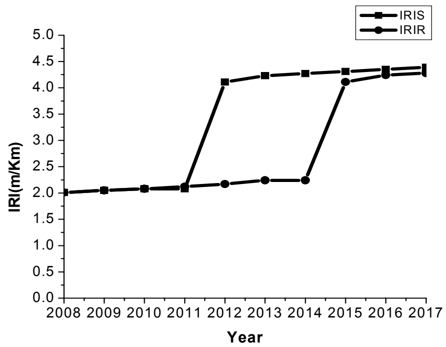


Fig 7: Variation for structural number for over lay

The variation of structural number for both the maintenance standard cases is presented in the figure 5-7.The do or nothing criteria has been adopted in responsive criteria in the year of 2015, in the schedule case it is clearly indicates that the reconstruction of pavement will be done in the year of 2012.In the figure 7 the variation n of structural number for both scheduled and responsive cases are shown. In scheduled case the pavement is in good condition because of maintenance after every 2 years. In case the responsive maintenance standards the reconstruction is not required within the 10 years of design period.

Table 10: Variation of roughness in schedule and responsive case

Year	**IRIAvg(m /km(s)**	**IRIAvg(m/ km (R)**	**Year**	**IRIAvg(m /km(s)**	**IRIAvg(m/k m(R)**	**Year**	**IRIAvg(m/km(s)**	**IRIAvg(m/ km(R)**
2008	2.01	2.01	2008	2.01	2.01	2008	2.01	2.01
2009	2.05	2.05	2009	2.05	2.05	2009	2.05	2.05
2010	2.08	2.08	2010	2.08	2.08	2010	2.08	2.08
2011	2.08	2.12	2011	2.01	2.12	2011	2.01	2.12
2012	4.11	2.17	2012	2.03	2.17	2012	2.03	2.17
2013	4.23	2.24	2013	2.01	2.24	2013	2.01	2.24
2014	4.27	2.24	2014	2.03	2.33	2014	2.03	2.33
2015	4.31	4.11	2015	2.01	2.44	2015	2.01	2.44
2016	4.35	4.24	2016	2.03	2.59	2016	2.03	2.59
2017	4.39	4.28	2017	2.01	2.02	2017	2.01	2.75



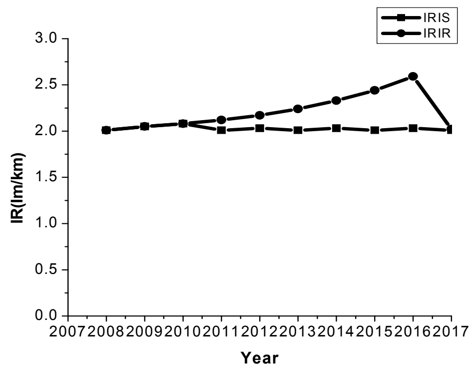


Fig 8: Variation of roughness for base alternative crack sealing

Fig 9: Variation of roughness

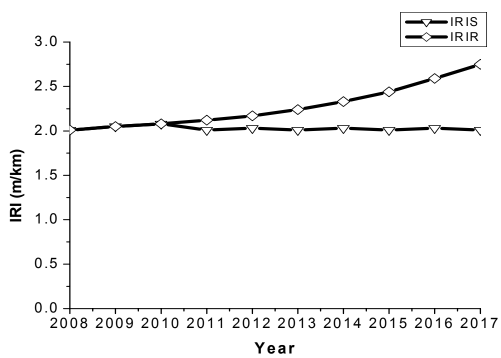
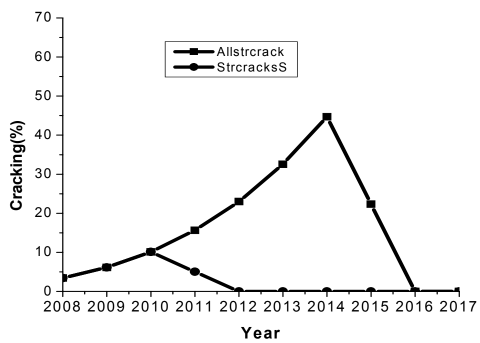


Fig 10: Variation of roughness for overlay

The variation of roughnes index for the section for both scheduled and responsive cases are shown in table 10. From the figure 8 it is observed that the roughness of the pavement is increasing for both the cases based on the do or nothing criteria. In the scheduled case the roughness value attains the maximum value of four in the year 2011 and in responsive case the value attains maximum in the year 2014.From the figure 9 it is clear that in case of responsive criteria the crack sealing option will be implemented in the year 2016, because the total cracking area of pavement increase 10% in that years where as on other case the roughness is within the limits because of periodic maintenance for every 2 years.

Table 11: Showing all structural variations for responsive and schedule criteria

Year	Str cracks(%)R	Str cracks(%)S	Year	Str cracks(%)R	Str cracks(%)S	Year	Str cracks(%)R	Str cracks(%)S
2008	3.44	3.44	2008	3.44	3.44	2008	3.44	3.44
2009	6.15	6.15	2009	6.15	6.15	2009	6.15	6.15
2010	10.12	10.12	2010	10.12	5.06	2010	10.12	5.06
2011	15.63	5.06	2011	15.63	0	2011	15.63	0
2012	23	0	2012	23	0	2012	23	0
2013	32.57	0	2013	32.57	0	2013	32.57	0
2014	44.69	0	2014	44.69	0	2014	44.69	0
2015	22.35	0	2015	28.98	0	2015	57.96	0
2016	0	0	2016	2.87	0	2016	68.96	0
2017	0	0	2017	10.84	0	2017	77.69	0



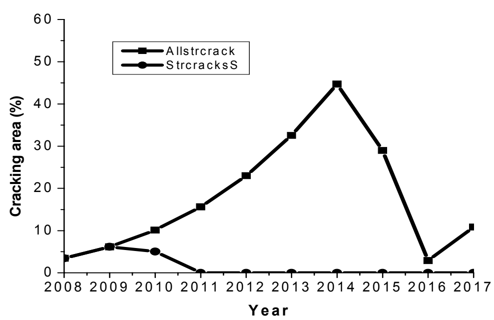


Fig 11: Variation of structural cracks base alternative crack sealing

Fig 12: Variation structural cracks for

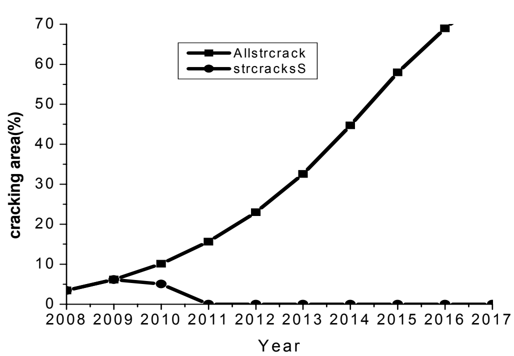


Fig 13: Variation of overlay for structural cracks

6.0 SUMMARY

In this study four rural road stretreches have been identified to carry out the pavement performance studies. The inventory details have been collected in standard formats. The inventory details like type of surface, condition of shoulder, surface drainage, roughness and details of embankment have been collected and used to assess the general condition of the sections.Visula rating survey has been conducted on all the stretches to determine the pavement codition.Trafic volume studies have been conducted on the test sections for 12 hours duration. The number of commercial vehicles has been considered in selecting the maintenance strategies. Detailed analysis was carried out usingHDM-4 for responsive and schedule maintenance and comparison was made among the best alternative was recommended.

7.0 CONCLUSIONS

Based on the field studies and analysis the following conclusions have been drawn.

1. From the road inventory survey details it is inferred that the shoulder condition is poor on all the roads.
2. From the road inventory survey details it is inferred that the surface drainage is poor on all the roads.
3. Deterioration models are developed for the sections with average calibration factors for one time data
   which can be further modified in future with time series data.
4. Comparison has been made for the pavement sections between improvement and maintenance standards to get best pavement maintenance option.
5. Deterioration of the pavement sections are generated using HDM-4 and tabulated for further studies.

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