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In-situ performance assessment of low volume roads in three districts of Andhra Pradesh

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ABSTRACT

This study represents the largest of its kind to evaluate the Rural Road Pavement Performance (RRPPS) in Andhra Pradesh in co-operation with the National Rural Roads Development Agency (NRRDA), for sponsoring the research project. Rural roads not only account for a major portion of national road networks, but also play a very vital role in the socio-economic growth of a country. Realizing this fact, in the present study an attempt has been made to assess the condition of rural road under varied climatic and environment conditions to assess their performance. To fulfill the objectives three districts namely Warangal, Guntur and Kurnool were selected for pavement evaluation study purpose. Based on the extensive field study and analysis it is concluded that rutting values over a season increases. This is due to the ingress of moisture content in base sub base and sub-grade layers. A correlation between the allowable number of Load repetitions to limit permanent deformation and compressive vertical strain on the top of the sub-grade was developed. Further it is observed that most of the roads have Pavement Serviceability Index (PSI) values below two indicating the need for immediate maintenance. Finally a model to predict the distress and condition ratings of the pavement was proposed.

Introduction

During the year 1978, a working group was set up at planning commission for providing all weather connectivity to all the villages of India (Planning Commission, PEO, and Report No: 201, 2010). During the 1980s, Indian Road Congress (IRC) conducted studies on the rural roads with the main objective to find out and quantify the possible impact of roads on the socio economic development in rural areas. The survey conducted in remote areas in India by Central Road Research Institute (CRRI 1989) reported that the villages located on the main road are comparatively well developed than those away from the roads. No pavement design procedure was adopted for construction of such roads. During the Eighth Five-year Plan (1992-97) priorities were accorded to link all villages with a population of 1000 and above to accelerate village connectivity.

Low Volume Roads (LVRs) constitute an integral component of the road system in all countries. Their importance extends to all aspects of the social and economic development of rural communities. It is known that on a world-wide basis, the number of low traffic roads far exceeds the mileage of high traffic roads.

In the recent past, Government of India (GoI), with the initiation of the ambitious programme “Pradhan Mantri Gram Sadak Yojana” (PMGSY) gave great importance to low volume roads realizing their role in the economic development of rural areas. The vast expansion of the road network has brought connectivity to the rural areas of the country. Majority of these roads are usually constructed as flexible pavement with a thin bituminous surfacing layer of Open Graded Premix Carpet (OGPC) of 20 mm as per the guidelines given in IRC:SP:20 (2002) and IRC:SP:72 (2007). Current methods that are used for maintenance of these roads are based on the judgment and experience of engineers, without considering the actual pavement performance data. Regular maintenance would minimize not only wastage of financial resources but also other resources such as equipment, manpower and materials. Till the launching of PMGSY, the roads covered only 60 per cent of habitations in the country. Understanding the various direct and indirect functions, the Government of India launched the PMGSY scheme in the year of 2000 to provide connectivity to all villages through good and all weather roads. With this background in the present study an effort has been made to assess the performance of LVRs in the three districts of Andhra Pradesh under Rural Road Pavement Performance Study (RRPPS) sponsored by National Rural Road Development Agency (NRRDA), GoI.

Figure 1. View of Rural Road carrying Load in Jonnagirei – Pendekal (K1) In Kurnool District

Pavement Performance

Road agencies and researchers have dedicated, considerable amount of time and effort to develop a well established field tested procedures for pavement evaluation and decision making process. Those efforts contributed to better understanding and the evaluation of performance and rehabilitation procedures. Poor pavement performance denotes the pavement deterioration over a time under the prevailing traffic and environment conditions. Pavement condition can be controlled mainly by six measures, based on which the overall pavement performance can be evaluated and their life can be extended. From the extensive data and field studies it was indicated that

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predominant distresses in LVRS are rutting, cracking, roughness, pothole and edge failure modes.

Selection of Test stretches and Filed Studies

The test sections were identified in three districts of Andhra Pradesh with the help of local Panchayat Raj (PR) Department Engineers. These roads were constructed under the PMGSY scheme. In the preliminary stage, about fifty eight roads were selected out of which fifteen road stretches were selected based on the scientific assessment considering subgrade soil type, pavement type, traffic intensity, annual average rainfall and surface type criteria. These test sections are located in different geographical and environmental conditions within the state. Subgrade soil is one of the main parameters that will influence the performance of a these roads. Total of about 72 km was considered for the study. The lists of roads selected are presented in Table 1.

The length of each test section was 0.5 km. The test sections were so selected as to avoid sharp curves and steep gradients. Each layer had a thickness of 75 mm. The field studies were carried out twice a year at an interval of six months, covering pre -monsoon and post- monsoon seasons to collect the functional and structural pavement condition data. For the purpose of collecting data, the selected road was partitioned into homogeneous sections. Table 1and 2 presents the condition of pavement in terms of PSI index and details of road stretches. It is clear that some of the roads fall below PSI 2.0 within 3-4 years after opening to traffic. Like AASHO model for determining the PSI, pavement serviceability model with the data obtained from the field studies has been generated.

Table 1. PSI values of Selected Roads

ID	Mandal	Length (km)	Opening to Traffic	PSI
G1	Kollipara	5.2	2002	2.6
G2	Anagrams	4.4	2005	1.5
G3	Kakumanu	3.6	2004	2.8
G4	Veldurthy	12.7	2005	1.4
K1	Nandikotukuru	4.2	2004	1.6
K2	Aluru	3.2	2004	2.3
K3	Pathikonda	4.6	2005	2.1
K4	Allagadda	8.4	2004	1.8
W1	Narmetta	6.3	2004	2.3
W2	Station Ghanpur	5.8	2005	3.6
W3	Raghunathpally	2.5	2005	2.2
W4	Mahabubabad	3.9	2006	3.7
W5	Hasanparthy	1.9	2004	2.0
W6	Hanmakonda	1.7	2003	2.0
W7	Wardhannapet	3.0	2005	1.9

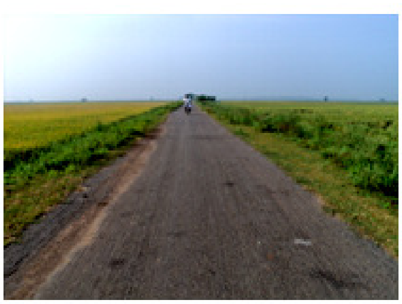

Figure 2. View of Rural Road Surface damged Palem - Kollimerla (G1) in Guntur District.

Figure 3. View of Rural Road measuring roughness with MERLIN (W4)

Estimation of CBR and M_R

Dynamic Cone Penetrometer (DCP) test was conducted on all the test sections during the each visit. From the obtained data the critical analysis was performed. The analysis indicated that a study increase in the penetration index values of the pavement layers. From this it is clear that lower penetration value indicates the layer consists of good quality of material on the top of the surface. Similarly higher penetration index value indicates the lower quality of material. Further with the increase in the age of the pavement Penetration Resistance (PR) values are also increasing. After calculating the PR values an attempt has been made to estimate the CBR and Resilient Modulus (MR) values, from available DCPI data with the help of available relationship between the DCPI and CBR for rural roads. For this the model developed by Heukelom et al. (1962) equations are used in the analysis.

$$\text{Log (CBR)} = 1.896 - 0.708 \text{ Log (DCPI)} \quad (1)$$

$$\text{MR (psi)} = 1500\text{CBR} \quad (2)$$

From the analysis of above it was revealed that the estimated California Bearing Ratio (CBR) and MR values indicated that CBR values of the pavements layers decreases as the DCPI increases. Further the MR values decreases as the DCPI increases. Hence DCPI and MR are inversely proportional to each other.

Estimation of vertical sub-grade strain (εv)

In order to find the vertical subgrade strain, BISAR package is used to get the Subgrade Strain values. Two Load positions are considered i.e., one is at under Wheels position and the other is between Wheels position. Vertical stress 686kPa, spacing between the axles is 315mm; poison ratios for all the pavement layers is 0.35 were considered. The summary of vertical subgrade stain vales obtained using BISAR software is presented in Table 3. The damage analysis was performed for both fatigue cracking and rutting parameters. In the present investigation only Rutting criterion is considered and projected the strains and csa to calculate the strain at csa at 50mm rut depth of all the test sections. The projected srtain value at 50mm rut depth is presented in Table 4.

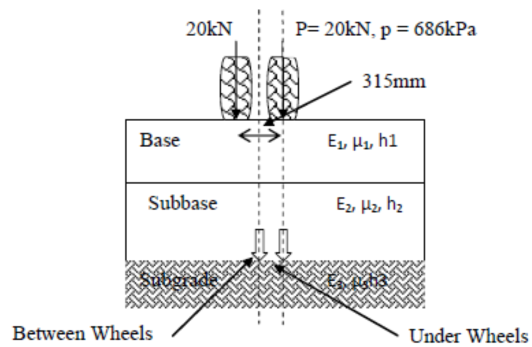

Table 2. Selected Road stretches for performance study in Andhra Pradesh

Road ID	Length (km)	District	Subgrade Soil type	Rainfall Intensity(mm/yr)	Traffic volume Curve
G1	12.78	Guntur	Silty	500-1000	C
G2	5.20		B.C soil	>1000	B
G3	4.40		B.C	>1000	C
G4	3.60		B.C soil	>1000	C
K1	4.60	Kurnool	Gravel/Red	500-1000	A
K2	4.20		B.C soil	500-1000	B
K3	3.20		B.C soil	500-1000	A
K4	8.40		B.C soil	500-1000	B
W1	6.30	Warangal	Gravel	500-1000	B
W2	2.56		Gravel	500-1000	B
W3	5.80		Gravel	>1000	B
W4	3.96		Gravel	>1000	B
W5	3.05		B.C soil	500-1000	B
W6	1.70		B.C soil	500-1000	C
W7	1.93		B.C soil	500-1000	B

Table 3: Summary of Vertical Subgrade Strains Using BISAR Software

Road ID	Strains						
	April 2008	Sept- 2008	Feb - 2009	May - 2009	Jan - 2010	May - 2010	Dec - 2010
	1St Visit	2nd Visit	3rd Visit	4th Visit	5th Visit	6th Visit	7th Visit
G1	2.75E-04	2.91E-04	3.07E-04	3.28E-04	4.98E-04	5.97E-04	6.66E-04
G2	3.76E-04	4.11E-04	5.76E-04	7.39E-04	7.65E-04	9.77E-04	1.69E-03
G3	4.43E-04	4.58E-04	4.92E-04	5.19E-04	5.42E-04	6.17E-04	6.51E-04
G4	2.52E-04	2.80E-04	2.95E-04	4.05E-04	4.19E-04	4.92E-04	5.87E-04
K1	2.41E-04	2.77E-04	3.08E-04	3.24E-04	3.64E-04	4.12E-04	4.55E-04
K2	3.66E-04	3.69E-04	4.47E-04	4.75E-04	5.60E-04	6.01E-04	7.22E-04
K3	2.90E-04	3.75E-04	4.53E-04	4.77E-04	5.26E-04	5.86E-04	7.20E-04
K4	3.08E-04	3.27E-04	3.88E-04	3.94E-04	4.51E-04	4.87E-04	6.73E-04
W1	2.57E-04	3.05E-04	3.58E-04	4.04E-04	5.49E-04	6.34E-04	6.79E-04
W2	2.39E-04	3.77E-04	4.05E-04	4.78E-04	4.95E-04	6.54E-04	5.47E-04
W3	3.49E-04	3.91E-04	4.00E-04	4.22E-04	4.76E-04	4.87E-04	5.70E-04
W4	2.44E-04	3.46E-04	4.26E-04	4.99E-04	5.24E-04	6.01E-04	6.44E-04
W5	2.95E-04	3.74E-04	4.29E-04	4.66E-04	4.96E-04	5.06E-04	6.02E-04
W6	3.72E-04	5.01E-04	5.25E-04	6.00E-04	6.39E-04	6.93E-04	8.12E-04
W7	2.83E-04	3.31E-04	3.38E-04	3.69E-04	4.35E-04	4.86E-04	5.28E-04

Table 4. Projected Strain Values at 50 mm Rutting

Road Id	Strain	N(msa)
G1	0.001484313	0.753574457
G2	0.004154191	0.288095766
G3	0.000183745	0.513170377
G4	0.001324252	0.450647457
K1	0.000190056	0.146399027
K2	0.024993807	24.89427307
K3	0.002077827	0.406334222
K4	0.014278822	4.138062783
W1	0.007354325	1.214023621
W2	0.00135635	0.621271142
W3	0.001029862	0.460193904
W4	0.001116052	0.579596112
W5	0.000607921	0.20145827
W6	0.000986159	0.13526128
W7	0.000243715	0.324499104

Figure 4. Conducting Pavement Evaluation Study on LVR Estimation of Strain & CSA calculated at 50mm.

A model was developed in relation with CSA & Strains projected at 50 mm Rut Depth. In view of the fact that the number of load repetitions required to progress from the onset of cracking to limiting failure conditions is fewer for thin asphalt layers than for thicker layers. It should be noted that the use of compressive strain on the top of the subgrade as a failure criterion is valid only when the permanent deformation is caused by the weak subgrade rather than by the overlying layers. The developed model is presented below. Figure 5 shows the variation of CSA with projected strain values at 50 mm rut depth. It is clearly noticed among all the the K2 test section has Strain values are exceeded are shown in Table 4.The equation 3 has been used to predict the allowable number of load repetitions to limit permanent deformation.

Nd = 0.2916*(e) 178.84(εz) (3)

Where,

Nd = allowable number of load repetitions to limit permanent deformation.

εz = Compressive strain on the top of the subgrade

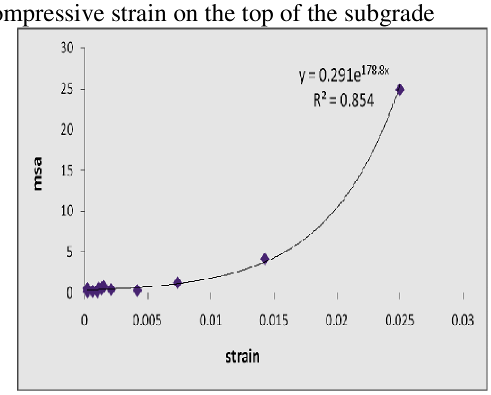

Figure 5.Variation of Strain VS msa

A model to predict the distress level of pavement layers using penetration rate (PR) values of the sub-grade and Aggregate Base Course (ABC) layers is developed based on the coupled contribution of the sub-grade and the ABC materials. The developed distress model is validated using field data from test sites. A procedure was proposed by which the DCP data can be utilized to evaluate the pavement distress state for categorizing the need for rehabilitation measures. Figure 6 shows a plot of the PR-subgrade versus the PR-ABC from data obtained in the field.The ‘‘pt = 2.5’’ line representing the proportional requirement for PR-ABC and PR-subgrade values. If these values are satisfied, the pavement strength meets the criteria for terminal serviceability of 2.5. This line will be referred to as the pt = 2.5 criterion. Data plotted to the right of the pt = 2.5 line were for sites with condition rating index values equal to 2 and 1 and data plotted to the left side were sites with condition rating index values equal to 3 and above.

PR value of ABC and subgrade layers on the right side of the line have an average PR of 6.1 and 11.5 (mm/blow). PR value of ABC and SG layers on the left side of the line have an average PR of 6.6 and 8.46 (mm/blow). It is apparent from the results of the field testing program that the coupled contribution of the subgrade and the ABC layers affects the condition rating of the roads.

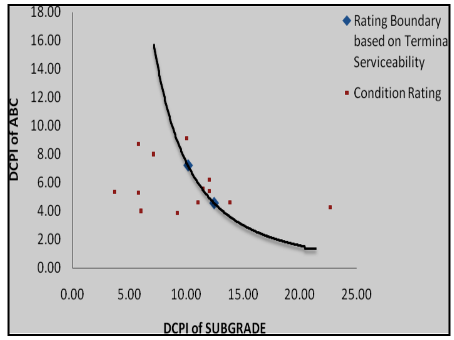

Figure 6. Serviceability line as a function of PR-ABC and PR-subgrade

Conclusions

Rutting values over a season increased this is due to the ingress of moisture content in base, sub base & subgrade layers & also due to the accumulation of permanent deformation on the subgrade layer as the vehicles passes over a season. A correlation between the allowable number of Load repetitions to limit permanent deformation & compressive vertical strain on the top of the Subgrade was developed as Nd = a*(e) b (εz) and the b coefficients are 0.2916 and 178.84. It is also revealed that most of the roads have PSI values below two within 2-3 years of design period which indicating the need for immediate maintenance to restore its condition. A model to predict the distress and condition ratings of the pavement was attempted using the PR-subgrade and the PR-ABC values to construct a terminal serviceability pt = 2.5 line. This line defines the boundary between good and poor road conditions.

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