PERFORMANCE OF GRAVEL BASE ROADS IN KARNATAKA UNDER PRADHAN MANTRI GRAM SADAK YOJANA

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ABSTRACT: **In the present work, two rural roads constructed under the Technology Demonstration Project of PMGSY phase IX namely, Jannenahally L Hatty to K C Road (2.5 km) and K T Kapile to T-16 (3.0 km) in Challakere taluk, Chitradurga district, Karnataka State, India, were considered for Pavement Performance Studies. The objective of the work was to conduct Pavement Performance Studies on these roads which include Structural and Functional evaluations. The stretch was further divided into 0.5 km stretch for Roughness Evaluation (using MERLIN) and 100 m sub-sections for pavement condition survey (using Pavement Condition Index) for both the stretches. Detailed surveys were carried out on the above said stretches. Road inventory survey included the findings relating to properties of bitumen and soil, rainfall, temperature, properties of shoulder material, sub-base, base and type of adjoining land etc. In periodic survey, surface drainage rating, roughness value using MERLIN, sub-grade moisture content has been investigated. In Pavement condition survey, rut depth, longitudinal depression, cracking of bituminous layer, percentage of raveling, severity of potholes and area of patching has been measured. In the traffic surveys different types of vehicles including commercial vehicles have been recorded for 24 hours X 3 days for the computation of MSA. In the axle load surveys, type of vehicle, make, number of axles and load on each axle have been recorded to determine the Vehicle damage factor (VDF). In the non-destructive structural evaluation, Deflection studies using Benkelman Beam Deflectometer (BBD test) is being done. In practice, BBD Test is conducted only on wearing courses greater than 40 mm, but in order to assess the rebound deflection of the beneath gravel base layers, BBD test has been conducted.**

The distresses observed on these roads are a few percentages of raveling, road cutting, patching, potholes and roughness. Comparison has been done considering pavement condition index (PCI). Commercial vehicles per day, annual rainfall and sub-grade moisture content will give assessment about performance of pavement with time. From the Benkelman Beam deflection Studies, the average characteristic deflection obtained was well within the permissible limits for the obtained MSA

***Keywords* - Pavement Performance, Structural evaluation, Functional evaluation, Equivalent factor, MERLIN, IRI Value.**

I. INTRODUCTION

In India, rural roads are the part of tertiary road system, which consist of other district roads (ODR) and village roads (VR). Nearly 50% of 6 lakh villages have road access. The Government of India has committed to provide full connectivity under a special major programme known as Pradhan Mantri Gram Sadak Yojana (PMGSY).

Due to the quantum jump in road developments in the country availability of quality aggregates is becoming an area of concern. For the construction of low volume roads it is possible to use locally available marginal materials and soft aggregates by suitably modifying them with addition of lime or cement or any other additive other than lime or cement. In order to promote cost effective and fast construction technologies in the construction of rural roads, it has become imperative to mainstream the technologies already developed through R&D in the past as also to undertake further research and technology initiatives duly taking into account the environment, geographic and scarcity of natural resources. Immediate focus should be on promotion of locally available marginal materials, industrial wastes, new materials and environment friendly cold mix technologies. This would help not only in cost reduction but also in the reduction of carbon footprint in the process or at the time of construction

Performance studies on National Highways and State Highways are being conducted, but a very few studies have been carried out on performance of village roads. The construction practices and traffic characteristics of village roads differ from those of National Highways and State Highways. Pavement performance studies of rural roads constructed under PMGSY phase IX, technology demonstration project are carried out in two cycles per year (i.e., during the harvesting season and non-harvesting seasons) for a period of three years, totally of six cycles to know the performance of these roads.

A. OBJECTIVES OF THE STUDY

1. Selection of rural roads to evaluate the performance of the roads constructed with new technology. (Gravel Base – Soil Aggregate mix)
2. Collection of periodic performance data viz., unevenness/roughness survey by MERLIN.
3. Conducting pavement condition survey to evaluate the distresses in terms of the Pavement Condition Index rating
4. Conducting Benkelman Beam Deflection studies to know the rebound deflection and to calculate the characteristic deflection value
5. Conducting Axle load survey and classified volume counts for the determination of VDF and MSA

B. SELECTION OF THE STUDY AREA

In this case study, two rural roads were selected in Challakere Taluk, Chitradurga District, Karnataka state, which was constructed under the Technology Demonstration Project of PMGSY Phase IX. The details of the test sections are shown in Table 1 and 2

Table 1: Details of the stretch -1 and crust details

Name of the Road: Jannenahally L Hatty to K. C. Road				
Chainage of Test Section: 0.0 km to 2.0 km				
Description	**Layer Width in (m)**	**Material Used**	**Layer Thickness in (mm)**	**Overall crust thickness (mm)**
Sub Base	7.50	Local GSB	100	**295**
Base Courses	4.05	**Soil - Aggregate Mix**	100	
	3.90	**WBM GRADE - III**	75	
Surface Course	3.75	Premix Chip Carpet	20	
Chainage of Test Section: 2.0 km to 2.5 km				
Sub Base	7.50	Local GSB	100	**295**
Base Courses	4.05	**Soil - Aggregate Mix**	100	
	3.90	**Wet Mix Macadam**	75	
Surface Course	3.75	Premix Chip Carpet	20	

Table 2: Details of the stretch -2 and crust details

Name of the Road: K T kapile to T - 16				
Chainage of Test Section: 1.5 km to 1.8 km				
Description	**Layer Width in (m)**	**Material Used**	**Layer Thickness in (mm)**	**Overall crust thickness (mm)**
Sub Base	7.50	Local GSB	100	**275**
Base Courses	4.05	**Soil - Aggregate Mix**	100	
	3.90	**Soil - Aggregate Mix**	75	
Surface Course	3.75	**Surface Dressing**	NA	
Chainage of Test Section: 1.8 km to 2.3 km				
Sub Base	7.50	Local GSB	100	**295**
Base Courses	4.05	**Soil - Aggregate Mix**	100	
	3.90	**Wet Mix Macadam**	75	
Surface Course	3.75	Premix Chip Carpet	20	
Chainage of Test Section: 2.3 km to 4.5 km				
Sub Base	7.50	Local GSB	100	**295**
Base Courses	4.05	**Soil - Aggregate Mix**	100	
	3.90	**WBM GRADE - III**	75	
Surface Course	3.75	Premix Chip Carpet	20	

II. LITERATURE SURVEY

Nagraj et. al (1995) developed a composite ranking methodology for the prioritization of maintenance of highways.

Intech associates and TRL (2003) with World Bank and DFID has resulted in the implementation of a significant Rural Road Surfacing Research (RRSR) programme. The aim of the RRSR programme is to establish a range of sustainable road surfaces that better use local resources, minimizing Whole-Life-Costs and supporting the Vietnam Government's poverty alleviation and road maintenance policies.

Jain et. al (2006) suggested optimal maintenance measures for low volume roads constructed under PMGSY. Veeraraghavan (2008) explained the appropriate and timely maintenance which will extend the service life of rural roads already constructed.

Gupta et. al (2008) explained that the pavement performance model is an equation that relates some extrinsic "time factor" to a combination of intrinsic factors with performance indicators.

Saranya ullas et. al (2013) developed regression models using SPSS packages for the road stretches where distresses were identified The different parameters affecting the pavement performance were identified. It includes Modified Structural Number (MSN) and Vehicle Damage Factor (VDF). Non-linear regression models were formulated for ravelling initiation, cracking progression, pothole progression and roughness SPSS predicted values are nearer to observed values. Hence these models are suitable for the Performance predictions of selected roads. Their liability of roughness progression models was checked by T-test.

Vandana Tare et. al (2013) developed a pavement deterioration modeling for low volume roads to establish regression equations between various parameters such as pavement condition index, pavement age, commercial vehicles per day, annual rainfall and subgrade moisture content.

III. ENGINEERING SURVEYS AND INVESTIGATIONS

A. Road Inventory Survey

Road Inventory survey is a comprehensive list of details of the road regarding the formation width, carriageway width, and average shoulder width on each side, type of adjoining land along the test stretch, thickness of various layers, binder properties, general details and other general details of the pavement. The road inventory for both the stretches is summarized in the table 3

Table 3: Road Inventory data

Name of the Road	**Jannenahally L hatty to K C Road**		**K T Kapile to T-16**		
Pavement Composition And crust Details					
Description	**0.0 km to 2.0 km**	**2.0 km to 2.5 km**	**1.5 to 1.8 km**	**1.8 to 2.3 km**	**2.3 to 4.5 km**
Sub-Base	100	100	100	100	100
Base course	100	100	100	100	100
Surface course	75	75	75	75	75
Wearing course	20	20	NA	20	20
Overall thickness	295	295	275	295	295
General Details					
Type of adjoining land	AL + BU	AL	AL	AL + BU	AL + BU
New construction or Upgradation	UG	UG	UG	UG	UG
Annual avg. rainfall (mm)	450	450	450	450	450
Avg. min and max temp (∘C)	24- 40	24- 40	24- 40	24- 40	24- 40
Avg. min and max depth of GWT (m)	30-35	30-35	30-35	30-35	30-35
Month and year of opening to traffic	June 2012	June 2012	Sept 2012	Sept 2012	Sept 2012
Binder properties					
Grade of bitumen used	60/70	60/70	60/70	60/70	60/70
Penetration in (mm)	65	65	66	66	66
Softening point (℃)	45	45	45	45	45
Pavement details					
Embankment height (m)	0.15	0.15	0.15	0.15	0.15
Carriageway width (m)	3.75	3.75	3.75	3.75	3.75
Shoulder width (m)	1.875	1.875	1.875	1.875	1.875
Type of surface	BS	BS	BS/SD	BS	BS
Condition of shoulder (Good, Fair ,Poor)	Good	Good	Good	Good	Fair
Effectiveness of surface Drainage (Good, Fair, Poor	Good	Good	Good	Good	Good

AL- Agricultural Land; BU- Built Up; UG- Up gradation; NC- New Construction; NA-Not Applicable; BS- Bituminous Surface; SD- Surface Dressing

B. Functional Evaluation

Functional evaluation is primarily concerned with the ride quality or surface texture of a highway pavement which affects the ride quality/riding comfort of the road user and vehicle operation costs

1) *Roughness/Unevenness Survey by MERLIN*

Roughness/unevenness survey was conducted by MERLIN on the stretches to estimate the roughness of the pavement surface. To determine the roughness of a section of road, 200 measurements should be made at regular intervals at a distance of 0.6 m from the edge of the road. (TRL report 229, cundill). In this case study MERLIN measurements were made w.r.t the technologies adopted viz., the MERLIN sheets were changed as the technology changed to know the unevenness/roughness on each technology adopted. The recording of roughness survey is done on a typical recording chart and IRI is Calculated by eqn. **IRI=0.593+0.0471(D),** where "D" is measured from the histogram and IRI is expressed in terms of (m/km) or (mm/km). IRI values below 3 are usually not important as it has very little effect on the riding quality and Vehicle operating cost. The abstract of the MERLIN roughness value is summarized in the table 4.

2) *Pavement Condition Survey*

Pavement Condition Index (PCI) is a numerical indicator of present condition that is directly to the pavement surface operational condition. The PCI is a function of the type of distress. The pavement may also become inadequate due to general deterioration with age.

Considering the serviceability criteria as per **ASTM D 6433-11** for each distress attributes the following factors was obtained. The pavement condition index values along the stretch of road is calculated using the pavement condition survey data and as tabulated in the table 5

Table 4: Average Roughness/Unevenness Values and IRI Values

Sl. No	**Chainage**		**Cycle 1**	**Cycle 2**	**Cycle 3**	**Average IRI value (m/km)**	**Total Average IRI Value**	**Riding Quality**
	From	**To**						
1	0.0	2.0	2.62	2.68	2.71	2.67	**2.75 m/km or 2750 mm/km**	**GOOD**
2	2.0	2.5	2.83	2.83	2.83	2.83		
Sl. No	**Chainage**		**Cycle 1**	**Cycle 2**	**Cycle 3**	**Average IRI value (m/km)**	**Total Average IRI Value**	**Riding Quality**
	From	To						
1	1.5	1.8	3.41	3.53	3.53	3.49	**3.49 m/km**	**FAIR**
2	1.8	2.3	2.71	3.06	3.06	2.94	**2.80 m/km or 2800 mm/km**	**GOOD**
3	2.3	4.5	2.56	2.70	2.73	2.66		

Note: For Earth, gravel, surface dressed or asphaltic concrete roads, roughness can be determined using the equation **IRI=0.593+0.0471(D)**…. ($2.4<IRI<15.9$) where IRI is the roughness in terms of **International Roughness Index in (mm/km)** and "D" is measured from the MERLIN chart in (mm). Measurement of **IRI values Below 3 is not usually important** because at this level roughness has very little effect on Vehicle Operating Costs

Table 5: PCI Value and Rating

Stretch – 1 (Jannenehally L Hatty to K C Road)				
Sl. No	**Chainage**		**Pavement Condition Index**	**Pavement Condition Rating**
	From	**To**		
1	0.0	2.0	99	**GOOD**
2	2.0	2.5	99	**GOOD**

Stretch – 2 (K T Kapile to T - 16)				
Sl. No	**Chainage**		**Pavement Condition Index**	**Pavement Condition Rating**
	From	**To**		
1	1.5	1.8	98	**GOOD**
2	1.8	2.3	99	**GOOD**
3	2.3	4.5	99	**GOOD**

C. Structural Evaluation

Structural adequacy of a pavement is concerned with its load carrying capacity. Measurement of transient deflection under design wheel loads serves as an index of the pavement to carry wheel loads under prevailing conditions.

1) Benkelman Beam Deflection Studies (As per IRC: 81-1997)

The rebound deflection value obtained at each point was calculated making use of the initial, intermediate and final rebound deflection values, after applying correction where ever necessary. The average of the rebound deflection values, at every 50 m staggered interval over the entire stretch given for BBD studies was calculated. From the deflection values of the observation points within each stretch, the standard deviation (d) was calculated. The characteristic deflection value, Dc has been worked out taking **Dc = (m+d),** for Village Roads, where 'm' is the mean deflection values. The average characteristic deflection value for the two stretches is shown in table 6

2) Classified Traffic Volume Counts

Classified traffic volume counts were carried out for the test stretches in accordance with IRC: 9 - 1972. A 24 hour manual count was conducted on hourly basis for three days and the details were recorded. The vehicles are classified as representative vehicles such as two wheelers, three wheelers, buses, 2 and 3 axle trucks, jeeps, cars, vans mini bus, mini trucks, tractors, bicycles, animal drawn carts (pneumatic tyred and iron tyred). The ADT of all class of vehicles were multiplied with their respective PCU factor and PCU and average CVPD were calculated. The abstract of PCU, CVPD and MSA calculated are shown in table 7

Table 6: Average Characteristic Deflection

Stretch – 1 (Jannenehally L Hatty to K C Road)							
Sl. No	**Chainage**		**Cycle 1**	**Cycle 2**	**Cycle 3**	**Average Characteristic Deflection (mm)**	**Total Average Characteristic Deflection (mm)**
	From	**To**					
1	0.0	1.0	0.10	0.46	0.28	0.28	**0.51**
2	1.0	2.0	0.29	0.41	0.33	1.03	
3	2.0	2.5	0.17	0.29	0.24	0.23	

Stretch - 2 (K T Kapile to T-16)							
Sl. No	**Chainage**		**Cycle 1**	**Cycle 2**	**Cycle 3**	**Average Characteristic Deflection (mm)**	**Total Average Characteristic Deflection (mm)**
	From	To					
1	1.5	1.8	0.41	0.38	0.35	0.38	**0.27**
2	1.8	2.3	0.16	0.33	0.08	0.19	
3	2.3	3.0	0.24	0.21	0.20	0.21	
4	3.0	3.5	0.20	0.38	0.30	0.29	
5	3.5	4.0	0.18	0.28	0.29	0.25	
6	4.0	4.5	0.24	0.37	0.30	0.30	

Table 7: Average PCU, CVPD and MSA

Stretch – 1 (Jannenehally L Hatty to K C Road)					Stretch – 2 (K T Kapile to T - 16)				
Sl. No		**PCU**	**CVPD**	**MSA**	**Sl. No**		**PCU**	**CVPD**	**MSA**
1	Cycle 1	222	41	**0.76**	**1**	Cycle 1	360	35	**0.81**
2	Cycle 2	192	36		**2**	Cycle 2	230	36	
3	Cycle 3	161	17		**3**	Cycle 3	196	29	

3) Axle Load Surveys

Axle Load Survey was conducted on the test stretches using a Weigh-in-Static portable weigh bridge by analyzing the dynamic pressure of each tyre separetly. The survey was conducted along with the traffic volume count for 24 hours X 3 days. The axle load survey was conducted in accordance with IRC: SP: 19-2001. Only the axles with weight of 3 tonnes and above are considered to have effect on the pavement performance, hence axles with weight of 3 tonnes and above were considered in the study. The average of vehicle Equivalent Factors and their total average Vehicle Damage Factor (VDF) are shown in the table 8

D. Geo - Technical Investigations

Soil investigations such as the soil classification, Atterberg limits, compaction paramaters (OMC and MDD) CBR, and natural moisture content were conducted in the laboratory in order to determine the soil properties and other engineering properties of soil. The soil samples were collected from the respective chainages shown in the table and tests were conducted in accordance with **IS – 2720** and **MORTH** specifications. The results of these are shown in the table 9

Table 8: Average Equivalent Factor

Stretch – 1 (Jannenehally L Hatty to K C Road)			
Sl. No	**Average Equivalent Factor (E.F)**		**Total average VDF**
1	Cycle 1	0.0463	**0.0467**
2	Cycle 2	0.0434	
3	Cycle 3	0.0506	

Stretch - 2 (K T Kapile to T-16)			
Sl. No	**Average Equivalent Factor (E.F)**		**Total average VDF**
1	Cycle 1	0.0470	**0.0394**
2	Cycle 2	0.0515	
3	Cycle 3	0.0194	

Table 9: Geotechnical Investigations on soil

Sl.no	**Chainage (km)**		**Soil classification**	**Atterberg limits (IS-2720 part 5, 1985)**			**Compaction parameters (IS 2720, part 8 1983)**		**CBR (IS-2720 part 12, 1983)**	**Natural Moisture content (IS-2720 part 2, 1983)**
	From	**To**		**LL (%)**	**PL (%)**	**PI (%)**	**MDD (g/cc)**	**OMC (%)**	**56 blows**	**(%)**
Stretch – 1 (Jannenehally L Hatty to K C Road)										
1	0.0	1.0	SM	30	22	8.0	1.85	1.88	6.0	6.0
2	1.0	2.5	SM	30	22	7.0	12.5	11.5	8.0	6.0
Stretch - 2 (K T Kapile to T-16)										
1	1.5	2.5	SM	34	24	9.5	1.68	13.0	6.0	6.0
2	2.5	3.5	SM	28	22	7.0	1.88	12.0	7.0	6.0
3	3.5	4.5	SM	26	20	6.0	1.91	11.0	8.0	6.0

V. COST OF CONSTRUCTION

Table 10: Cost of Construction per km length

Sl no	**Name of the Road**	**Total length In km**	**Total cost of Road Construction in lakhs**	**Cost per km length**
1	Jannenahally L Hatty to K C Road	2.5	53.96	21.58
2	K T Kapile to T – 16	4.50	93.74	20.83

The cost of construction of conventional asphalt road per km is around 21.57 lakhs. The cost of construction of Gravel Base roads is 21.58 lakhs. Since the locally available and marginal materials are used in the construction of rural roads, the unnecessary hauling of material from other places is eliminated. It also reduces the impact on the environment, and overcomes the scarcity of natural resources and reduces the carbon footprint throughout the construction process

IV. SUMMARY AND CONCLUSIONS

A) Functional Evaluation

- The roughness value of stretch - 1 obtained by the average of three cycles in terms of International Roughness Index (IRI) is 2.75 m/km or 2750 mm/km. As the IRI value obtained is below 3, the stretch is said to have GOOD riding quality or riding comfort. The IRI value of stretch - 2 is found to be 3.49 m/km or 3490 mm/km, due to the top layer being surface dressed (1.5-1.8 km) which had more unevenness and the base courses being constructed with 2 layers of Soil-Aggregate Mix and stone grafting. Hence the Surface dressing layer had a very little effect and the riding quality was FAIR.

And for CH: 1.8 to 4.50, the IRI value was found to be 2.80 m/km or 2800 mm/km and the riding quality was GOOD and hence the riding comfort is good and does not have much effect on the vehicle operation costs.

- Based on the various results obtained from pavement distress survey, the PCI value is found to be 98 - 99 for both the stretches viz., stretch-1 and stretch-2. Therefore the overall rating of the pavement is considered as GOOD as per the Standard PCI rating.

B) Structural Evaluation

- Based on the results of BBD studies, (refer Table No. 6) the average characteristic deflection is found to be 0.51 mm for stretch-1 and 0.27 for stretch-2. Therefore the Gravel Base Roads are not showing much deflection and are within the permissible limits, overlay is not required at the present stage.

- Based on the PCU and CVPD values obtained from the calculated values of Cumulative standard axles for the present traffic data, the MSA is found to be 0.76 MSA for stretch-1 and 0.81 MSA for stretch-2. Therefore the present traffic movement has no effect on the performance of the pavement and normal traffic is plying on the stretch.

- Based on the Axle Load Surveys conducted, the VDF obtained from average of three cycles is 0.0467 for stretch-1 and 0.0394 for stretch-2. It was noticed that no over loaded vehicles were plying on the road and there is no damage caused to the road from these vehicles.

REFERENCES

[1] S.K. Khanna and C.E.G. Justo, *Highway Engineering*, Nem Chand & Bros, Roorkee, 7th edition, 1991

[2] Dr. Ebrahim M. Asi, *Pavement Performance Evaluation*, International Journal of Pavement Research and Technology, Vol. 5 No. 2, March 2012

[3] Vandana Tare, H. S. Goliya, Atul Bhatore & Kundan Meshram, *Pavement Deterioration Modeling for Low Volume Roads*, Journal of Indian Roads Congress, Vol. 73- 4, Paper No. 590,April-June 2013

[4] Saranya Ullas, T. Sreelatha& B. G Sreedevi, *Pavement Distresses and Roughness Modeling - A case study*, Proceedings of ICEE-2013, International Journal of Innovative Research in Science Engineering and Technology, Vol-2, Special issue December 2013

[5] M.A Cundill, *The MERLIN Road Roughness Machine: User Guide*, Transportation Research laboratory, TRL Report 229, 1996

[6] American Standards for Testing Materials, *Standard Practice for roads and parking lots, Pavement condition Survey*, ASTM D 6433-11

[7] S.K. Khanna - C.E.G. Justo - A. Veeraraghavan, *Highway materials and Pavement Testing*, Nem Chand & Bros, Roorkee, 5th edition, 2009-2013

[8] Roads Department, Republic of Botswana, *Guidelines for Axle Load Surveys* December 2000

[9] Ministry of Rural Development, *Specifications for Rural Roads*, Indian Roads Congress (first Revision) 2014

[10] Indian Roads Congress, *Guidelines for Strengthening of Flexible road pavements using Benkelman Beam Deflection Technique*, IRC: 81 (First Revision) 1997

[11] Indian Roads Congress, *Guidelines for the Design of Flexible pavements*, IRC: 37 (Third revision) 2012

[12] Indian Roads Congress, *Guidelines for Surface Evenness of Highway Pavements*, IRC: SP: 16 (First Revision) 2004