Evaluation of Rural Road Pavement Performance After Monsoon: A case Study of Surat District

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Abstract
Road transport particular provides door to door service, thus ensures accessibility to nooks and corners of the country. It has been realized that the absence of all weather road connectivity is a major impediment in the development of rural areas. The Government of India, having realized that providing rural accessibility serves as a means for poverty alleviation, launched Pradhan Mantri Gram Sadak Yojana (PMGSY). Pavement evaluation is implying the assessment of residual or available structural strength of the pavement. To determine the current condition of pavements and their historical trends so as to use that information in formulating management plan of action. we select some roads of Surat district as a study area. We collect the data and samples from field like traffic data, soil data, structural data of pavement and DCP-CBR relationship to know the performance of the roads which are constructed under the PMGSY scheme and based on the results the roads are classified in different categories as the Good, Average or Fair and Poor condition. The study recommended for categorized roads that need improvements.

Keywords: Pavement evaluation, Dynamic cone penetration (DCP), Rural Road Pavement Performance Study (RRPPS).

Introduction

Road network is vital to the economic development, trade and social integration. It facilitates smooth conveyance of both people and goods. Size of the road network, its quality and access have a bearing on transport costs. Besides, road network promote specialization, extend markets and thereby enable exploitation of the economies of scale. Global competition has made the existence of efficient road transport and logistics systems in delivery chain an absolute imperative.

Rural Road connectivity is a key component of rural development by promoting access to economic and social services and thereby generating increased agricultural incomes and productive employment opportunities. Providing good road network in rural areas is very essential for the development of the country.

A well-connected rural road network is a basic requirement for the development of rural areas. The government of India has launched a major rural road programme, called as

Pradhan Mantri Gram Sadak Yojana (PMGSY) in year 2000, which focuses directly to the rural road connectivity with respect to the population served by the connectivity.

The basic objective of PMGSY is to provide all weather roads. The standards of road construction are maintained at desirable level. Even after maintaining desirable standards in construction, certain factors such as rainfall, soil characteristics, temperatures etc leads to deterioration of pavement. National Rural Road development Agency (NRRDA) has undertaken the project Rural Road Pavement Performance Study (RRPPS) in 2006 which will be carried out by Principal Technical Agency's and State Technical Agency's. Due to all these aspects the Rural Roads Pavement Performance are required to get the useful feedback for the project management and for formulating suggestions for better solutions for the design specification and construction practice which are useful for the cost effectiveness and the socio-economic upliftment of the rural area.

OBJECTIVE

The main objectives of present study are:

(i) To assess the deterioration of pavement after monsoon under different field conditions and find out the degradation in pavement performance with respect to the pavement performance data.

(ii) To evaluate the pavement performance of rural roads and to identify roads that needs improvement and categories the roads according to their condition.

LITERATURE REVIEW

In literature found the evaluation of pavements by different methods. B M Kiggundu, U. Bagampadde and D Kalumba have presented the study on pavement performance of Kampala city roads. The findings in this study were appearance of early pavement defects, which were attributed among others to absence of steady maintenance programme and uncontrolled traffic growth on the study roads. The study recommended that authorities should implement a steady maintenance programme, balanced traffic management and encouragement of larger passenger carrying units in order to avert early growth of pavement defects. The purpose of this study is to define and identify factors causing premature failures on Kampala city roads. To establish a relationship between the design and actual lives of Kampala city roads and to propose a remedial plan.

Deepika Chukka, Chakravarthi V have tried to understand the performance of pavements which depends to a large extent on the strength and stiffness of the subgrades. Subgrade strength (CBR) plays a major role in pavement design. Since determination of CBR value in field requires need of equipment and is also time consuming alternatively one can be predict CBR value of subgrade in field from other soil support tests namely Dynamic Cone Penetrometer Index (DCPI) which has evolved as the most versatile rapid, in situ evaluation device currently available for use in determining sub grade properties. Correlations of DCPT index to CBR and its use in performance evaluation of pavement layers make it an attractive alternative to more expensive and time-consuming procedures. In this study an attempt has been made to develop relationship equations between DCPT index to Index and engineering properties of few subgrades with low plasticity characteristics. The tests include determination of DCP index in field and engineering properties in the lab. Studies are extended for both pre monsoon and post monsoon periods to know the effect of moisture on all properties. The main objective of this study is to determine the penetration index using Dynamic Cone Penetrometer and to explore the feasibility of employing DCP testing for subgrade soil characterization. From the experimental study, it was concluded that Atterberg limits of subgrade are influenced due to fines (%). As fines (%) is more liquid limit and plastic limit are more It is observed that % fines have effect on void ratio for all subgrades. Void ratio is affected by fines (%) for all subgrades. Void ratio decreases due to increase in fines (%). Moisture effect on DCPI is significant. DCPI increases with moisture. DCPI value decreases with the increasing CBR. The DCPI can be used to determine average CBR and the relation can be expressed as Log (CBR) = 0.441-0.296 log (DCPI).

Gill K S, Jha J N and Choudhary A have tried to estimate CBR value using dynamic cone penetrometer. IRC-37-2001, Indian Standard deals with the design of flexible pavement and recommends the California Bearing Ratio (CBR) as an indicator of subgrade soil strength. The subbase/base thickness of pavement is governed by the CBR value of the subgrade soil along with some other parameters such as traffic intensity, climatic conditions etc. The conventional CBR testing method is expensive, time consuming and its repeatability is low. Additionally, it is very difficult to mould the sample at the desired in-situ density in the laboratory CBR test. Values of in-situ density are under estimated due to local dampness of surface water percolation and stress release while taking out the sample. Dynamic cone penetration test (DCPT) value conducted in the field can be used to estimate the CBR value provided a suitable relationship exists between CBR and DCPT value. In this study, an attempt has been made to establish a relationship between DCPT value and CBR.

Parampreet Kaur, K S Gill and B S Walia have correlated the CBR value obtained by DCP and soaked laboratory CBR. For the design of flexible pavement, the sub-grade soil strength is estimated with California Bearing Ratio test (IRC-37-2001). In 1929, this test was developed by California Division of Highway and is used to evaluate the suitability of sub grade and the materials used in sub base and base course. This test can be done in the laboratory as well as in the field. But this conventional CBR testing has low repeatability. It is an expensive and time-consuming test. Moreover, it is very difficult to mould the sample at desired in situ density in the laboratory. Therefore, to overcome these problems, the other method (Dynamic Cone Penetrometer) is used in this study. This is an instrument used to evaluate in situ strength of pavement base, sub base and sub grade materials. The CBR values are obtained by conventional method and with the help of Dynamic Cone Penetrometer (DCP) and both the values are correlated to find the conventional CBR value by using DCP in the field. So, with the help of this relationship, it will be easy to get information about the strength of sub grade over the length of road. From the experimental study, it was concluded that the soaked CBR values of uniform soils which has similar characteristics can be determined quickly and will have adequate accuracy using DCP test results. For existing conditions, the in situ DCPT can be conducted for determination of field CBR value for in situ density. It may be helpful to control quality and achieving more uniform structural property in enhancing highway construction.

Vaiana R, Capiluppi G F, Gallelli V, Iuele T and Minani V have presented that the pavement surface performances have a great influence on road functionality and can affect user's safety, vehicle operational costs, environmental sustainability. The assessment of evolution of pavement surface performance plays a fundamental role in road pavement management and is useful in order to allocation of maintenance resources. In the light of the above, authors introduced the first results carried out from a two-year monitoring of an experimental road section. Four different dense graded wearing courses were designed with different aggregates: limestone, basalt and expanded clay. Several surface performances were measured by different devices (Skid Tester, Sand Patch Test, Laser Profilometer). The assessment of pavement surface performance evolution plays a key role in road pavement management and maintenance operations. Based on the above-mentioned facts, this study focused on the analysis of the most important factors that affect texture deterioration such as aggregate and binder properties, road geometry and traffic. Several microtexture and macrotexture prediction models were also listed. Surface

performance data were carried out from a two-year monitoring of an experimental road section where four different dense graded friction courses, produced with aggregate of different petrographic nature, were laid. Traditional tests to measure in-situ micro and macrotexture were carried out; overall 4 monitoring campaigns were done. It is noted that this project was run in partnership with the Road Network Division of Provincial Administration of Cosenza (Italy). Microtexture results show some differences in the deterioration behavior of the 4 mixes, probably related to the petrographic nature of aggregate and to the binder type, confirming how the combination of aggregate and bitumen has a significant effect on skid resistance, especially during pavement early life. In particular, aggregates with lower PSV values (limestone) have a lower resistance to the stripping phenomenon, becoming immediately more exposed to traffic actions. In the case of mixes with aggregates characterized by higher values of PSV, few months after the surface laying (around 6 months), the binder coatings are smoothed but not removed from the aggregate, determining a lower early life skid resistance. Macrotexture evolution was also investigated; the data analysis shows that the general trend in terms of texture depth is an early life decrease followed by increase and then either gradual decrease or increase, depending on the mix type. The initial decrease is due to the migration phenomenon of the bitumen inside the voids of the mix; after some months (around 6) the migrated bitumen is removed by trafficking and the texture depth begins to increase again. This trend is different for M3 friction course, probably because this mix is characterized by a higher percentage of binder content that contributes to clog the voids for a longer time. In this case, texture depth begins to increase around 13 months after the pavement was laid. The relationship between macrotexture data measured by means of two different devices (Sand Patch Test and Laser Profilometer) was also investigated. A further analysis of the surface profile data will be carried out in order to determine also texture disaggregate indicators.
Kumar P and Patel V have presented that the Pavement deterioration models, which simulate the deterioration process of pavement conditions and provide forecasting of pavement condition over time, play a pivotal role in pavement management systems. To develop pavement deterioration model, deflection and roughness measurements were carried out of 18 sections of PMGSY roads of Uttarakhand and Uttar Pradesh States. Out of these 18 sections, data was collected on 17 sections last year also. Regression analysis and artificial neural network (ANN) were used to develop the models. Best model was chosen based on the coefficient of multiple determination R2 and residual sum of squares (SSE) as well considering logical relationship between input parameters and output parameter. Polynomial relationship fit very well between input parameters, such as, pavement age, CBR of subgrade, traffic, pavement thickness and pavement condition indicators such as deflection, roughness. Parried t-test is carried out for the validation purpose of chosen best models. Maintenance priority index was also developed using three parameters named as deflection, roughness and traffic to decide the priority of road for maintenance work. From the study observed that if pavements are classified on the basis of parameters influencing pavement conditions, such as, pavement age, traffic, CBR of subgrade and pavement thickness then it predicts the pavement condition very well.

Data Collection

1. Site Selection

The Gujarat is located in the Western part of the India. Surat is located in South Gujarat Region. Recently, the district of Surat was bifurcated into two new districts, viz. Surat district with headquarter at Surat and Tapi district with it headquarter at Vyara. The district of Surat is divided into ten revenue talukas. Choryasi, Palsana, Kamrej, Bardoli, Olpad, Mangrol, Mandvi and Surat city are the major developed talukas in the district, out of this we select PMGSY roads in Olpad, Choryasi, Mangrol, Mahuva, Bardoli as study area.
In this study all the data of traffic, soil sample, DCP test, CBR collected from each road on site. Field studies emphasize the observation of real user behavior. For the planning process preparation of database is pre requisite step it is carried through inventory studies and field studies etc. with basic data it is easy to judge the present condition that prevail. Accurate and large database are required to clearly assess the problem and formulate policy and plans for future. The collected, processed, arranged and interpreted data should be free from any bias.

2. Data collection

In order to collect the data at various PMGSY roads as mentioned earlier the following field surveys have been carried out:

- Road Inventory Data
- Traffic Survey
- Soil Survey
- Pavement Condition Survey
- Dynamic Cone Penetrometer

In road inventory data, the temperature data, rainfall data, ground water level, year of opening of traffic and the thickness of the selection of roads, existing condition of the side shoulder and CD works etc. and detailing of sub-base, base course, surfacing course. All the details are as per DPR of PMGSY.
Traffic volume studies have been conducted to know the variation trends in traffic growth with time at all the approaches.

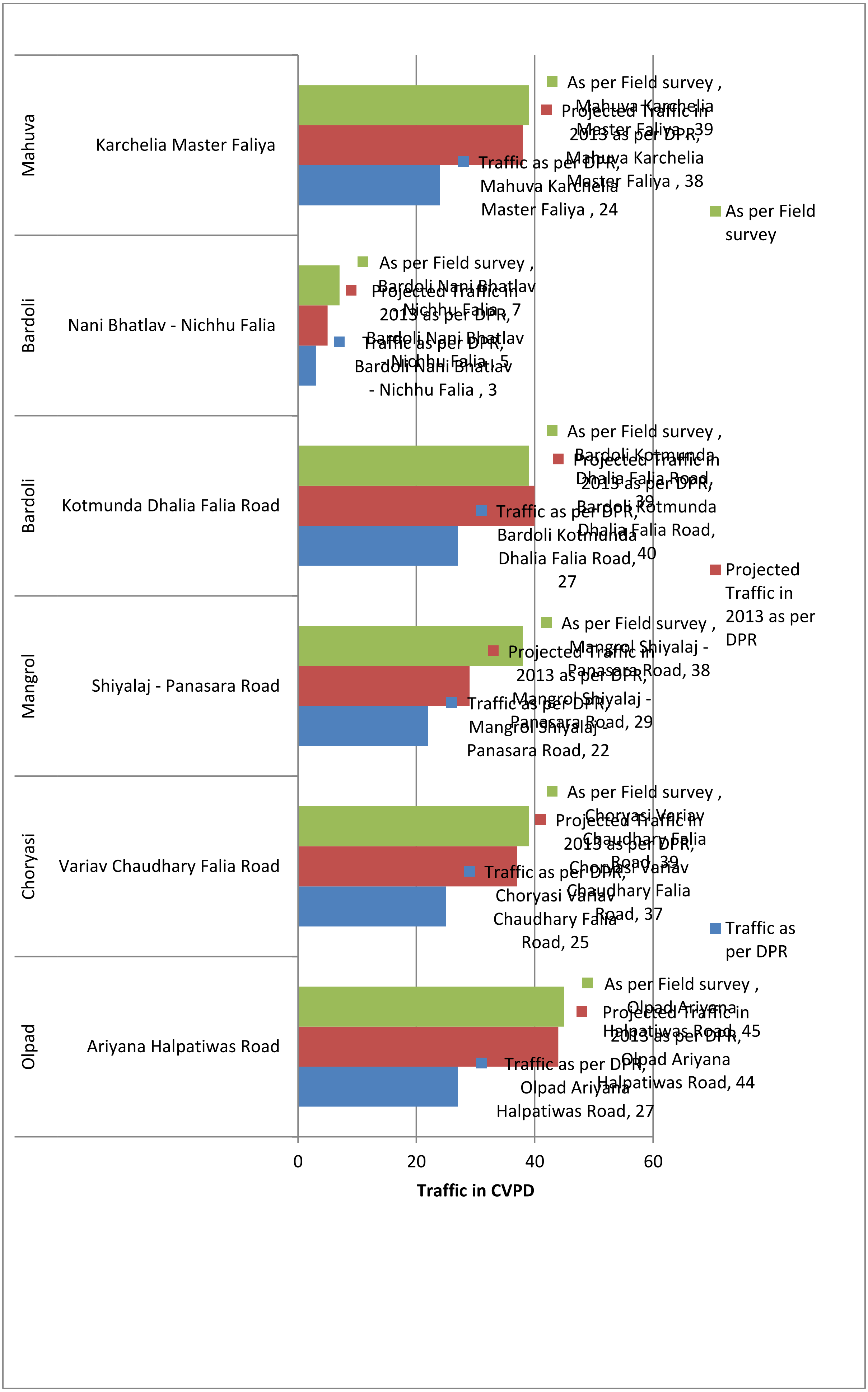

Figure 1: Traffic Comparison of Surat District Roads

From the above analysis, the traffic is comparatively more due to industrialization and other socio-economic development which could not be forecasted in DPR at that time.

3. Pavement Condition Survey

Step 1: Spot observation of Roads.

Spot observation of roads includes measurement of road dimension ie. Length and width of road, observation of Rutting, Raveling, Cracking, Pot holes, Edge drop and Bleeding.

Step 2: Area measurement of above defects

Find out Rutting, Raveling, Cracking and Pot holes by measuring length and width of affected area. Find total area by addition of all defected areas on the road. Find percentage of Alligator cracking, longitudinal cracking, Rutting and Depression.

Step 3: Find out Total Deduct Value (TDV) for each defect from the Figure 4.4, 4.5 & 4.6 (Graph) shown below. Each graph contains three lines representing High, Medium and Low intensity of defects. Choose the appropriate intensity and percentage of area gives TDV.

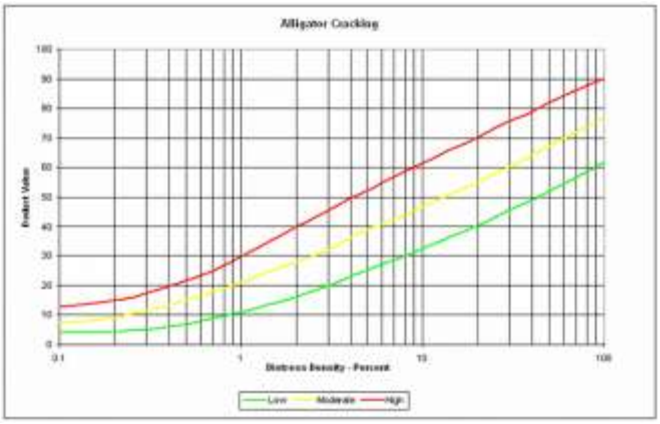

Figure 2: Percentage Area v/s Deduct value for alligator cracking

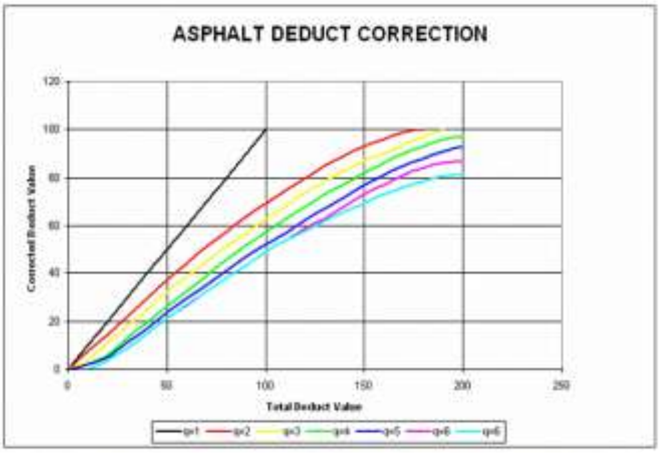

Figure 3: Total Deduct Value v/s Corrected deduct value with respect to no. of defect

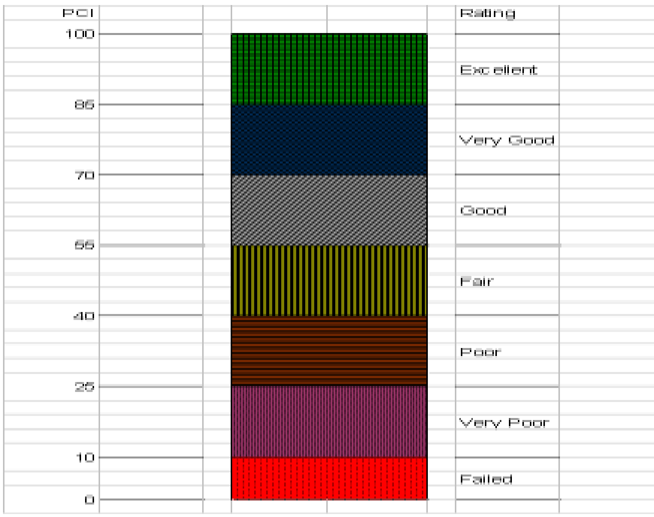

Figure 4: Road Rating with respect to PCI Value

Table 1: Pavement Condition Field Survey Observation

Sr. No	Block	Road Length (km)	Alligator Cracking Area (%)	Longi. Cracking Area (%)	Rutting + Depression Area (%)	CD Work	Side Shoulder
1	Olpad	1.00	12 - M	5 - M	5 - L	Good	Good
2	Choryasi	1.10	14 - M	4 - M	3 - L	Good	Fair
3	Mangrol	3.06	15 - H	8 - H	10 - M	Fair	Fair
4	Mahuva	1.50	5 – L	4 - M	2 - L	Good	Good
5	Bardoli	1.61	6 - L	4 - L	2 - M	Good	Good
6	Bardoli	1.50	5 - L	2 - L	2 - L	Good	Good

4. Dynamic Cone Penetrometer

The dynamic Cone Penetrometer (DCP) is an instrument designed for the rapid in-situ measurement of the structural properties of existing road pavements constructed with bound materials. Continuous measurements can be made down to a depth 800mm or when an extension road is fitted, to a depth of 1200mm.

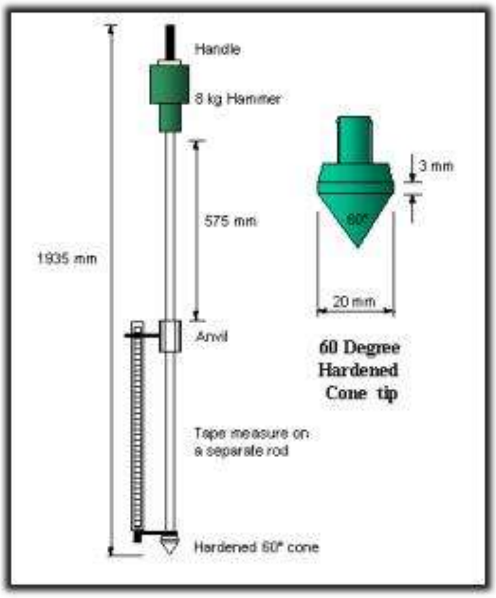

Figure 5: Dynamic Cone Penetrometer Instrument

Figure 6: Dynamic Cone Penetrometer Test Results on Graph

Table 2: Dynamic Cone Penetrometer Test Results

Sr. No	Road	Layer	P-1	CBR	P-2	CBR	P-3	CBR
1	Ariyana - Halpativas Road	Base	2.78	>100				
		Sub-Base	3.11	97.20				
		Sub-Grade	27.4	6.25				
2	Variav Chauthry Faliya Road	Base	1.57	>100				
		Sub-Base	3.13	96.22				
		Sub-Grade	14.1	14.41				

3	Shiyalaj-Pansara Road	Base	0.85	>100	1.03	>100	0.88	>100
		Sub-Base	3.30	90.14	3.08	98.45	3.22	92.9
		Sub-Grade	15.7	12.58	7.19	33.81	10.1	21.8
4	Kotmuda Dhalia Ovara Faliya Road	Base	0.67	>100	0.77	>100		
		Sub-Base	2.43	>100	1.05	>100		
		Sub-Grade	24.5	7.21	10.0	22.3		
5	Nani Bhatlai Nichhlu Faliya Road	Base	0.29	>100	0.62	>100		
		Sub-Base	1.11	>100	2.84	>100		
		Sub-Grade	9.83	22.78	12.4	16.96		
6	Karchelia Master Faliya Road	Base	0.51	>100				
		Sub-Base	1.97	>100				
		Sub-Grade	13.0	16.0				

Data ANALYSIS

In this study the CBR value found by DCP test in unsoaked condition. Compaction by the vehicles after a period of time, the CBR value comes more than the laboratory unsoaked CBR. This is because of the reason that in laboratory, loose samples taken from the site and there is no compaction in loose samples. So, in this study, the CBR value of field is more than the laboratory unsoaked CBR value.

Table 3 shows the DCP results and field CBR value relationship. The value of unsoaked CBR for sub-grade, sub-base and base course directly derived by the DCP value. The CBR value from the DCP test derived from the equation 1.

$$Y = 405.68\ X\ -1.2599 \qquad \text{.........................}\ (1)$$

Where, Y = CBR Value in %

X = DCP Value in mm/blow

The CBR value is also determined by another equation 5.2 by Kelyn (1975),

$$\text{Log (CBR)} = 2.62 - 1.27 * \text{Log (PI)} \text{........}\ (2)$$

Where, PI = Penetration Index or DCP Value in mm/blow

In this study the equation 1 is used.

Here, the results of field unsoaked CBR value obtained from the DCP value and the unsoaked CBR value obtained from the Laboratory tests were compared and analyzed that the CBR value is higher in the field than the laboratory unsoaked CBR.

In Pavement Distress Deterioration Analysis

- Ariyana to Halpativas road.
- Length: 1.00 km
- Width: 3.75 mt
- Total Area: 1000 X 3.75 = 3750 sq.mt
- Road Condition:

1) Alligator Cracking observed in field: - 12%

450 sq.mt Area: - Medium cracking

2) Longitudinal Cracking observed in field: -5%

188 Rmt: - Medium cracking

3) Rutting and Depressions observed in field: -5%

117 sq.mt: - Low Depressions

Deduct Value is finding by graph

Distress Density- (Distress/Total Area) %	Deduct Value
450 sq.mt/3750 sq.mt. = 12 %	48 % > 5
188 Rmt. /3750 Rmt. = 5 %	22 % > 5
190 sq.mt. /3750 sq.mt. = 5 %	20 % > 5

So, q=3.

Now TD value = 90 %.

By Graph (See in figure 3): -

Corrected Deduct Value = 60 %

Pavement Condition Index (PCI) = 100-60 = 40 %.
By Category Graph (Refer figure 4)
It is coming in Fair Category.

By this method we analyse the all six roads and will get result.

Conclusion

Evaluation based on the Pavement Condition Survey data and experiment results. The roads are categorized ‘Very Good or Good’, ‘Average or Fair’ and ‘Poor’ which shown in Table 4.

Table 4: Summary of the road evaluation

Sr. No.	Block	Name of road	Category
1	Bardoli	Kotmunda Dhalia Ovara Falia Road	Good
2	Bardoli	Nani Bhatlav Nichalu Falia Road	Very Good
3	Mahuva	Karchelia Master Falia Road	Good
4	Olpad	Ariyana Halpativas Road	Fair
5	Choryasi	Variav chaudhry Falia Road	Fair
6	Mangrol	Shiyalaj to Pansara Road	Very Poor

From the above results of the roads,

- The Very Good and Good category of the roads were constructed in 2004, 2005 and 2008. The Pavement Condition of the road is good. The design and construction of the roads is efficient and acceptable.
- The DCP value can be converted in to the unsoaked CBR values and this value is compared to Laboratory unsoaked CBR value. It is clearly seen that the field CBR value is higher than the Laboratory CBR value in all the layer like Sub-Grade, Sub-Base and Base layer.
- On the basis of test results, it is found that unsoaked CBR value of the hard murrum or quarry spoil used as a sub-base layer, the unsoaked CBR value is average 20% or above. In the design, thickness of each layer in DPR is acceptable
- The Dynamic Cone Penetrometer test is used for the structural evaluation of the roads, which shows that the thickness of each layer can also be verified by DCP test.
- The growth rate adopted in design is 6% and design period is 10 years. Now after concluding the traffic survey analysis, the CVPD comes nearer to the projected CVPD in 2013, so the growth rate adopted in the design is correct.

Recommendations

From the present study, following recommendations are made to get the best Performance of the Rural Roads under PMGSY as per design and as per specifications.

1) The present study related to pavement performance establishes that good category roads are useful as per requirement. Fair and poor category roads shall be given proper treatment to avoid further deterioration.
2) 6% growth is considered in design in poor category of roads. From the results of traffic survey, it is found that this rate is on lower side and therefore the same should be increased as per the traffic survey in all similar cases while giving treatment to these roads. After giving required treatment for improvement of pavement of road there will be further benefits of accommodation of more traffic. The treatment will also upgrade the category of the road from poor to fair and fair to good.
3) Proper storm water drainage is to be provided along road length to collect the rain water from the top of the carriageway through shoulder into the drain in monsoon.

Future Scope

1. In present study, the Pavement Performance Study is done only in Rural Roads in PMGSY; this also can be done in National Highway, State Highway, Major District Roads and Urban Roads to improve their performance and also collect the data to improve their quality at the time of maintenance.
2. The Rural Roads Pavement Performance Study is done twice in a year, before monsoon and after monsoon. After monsoon, to know the changes in behavior of the soil, pavement condition of the road, also the different layer DCP values and related their CBR values to find out the appropriate solution which improve the performance of the rural roads.
3. From the DCP values and CBR values prepare the design catalogue for the different section of the road on the basis of traffic data and CBR data.
4. Pavement deterioration models can be developed so that pavement condition over a period of time can be progressively determined.

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