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A STUDY ON THE PERFORMANCE OF FLEXIBLE PAVEMENTS

[1]PANCHADI MANOJ KUMAR [2]B.PRAVEEN BABU

[1]M. Tech, Department of Civil Engineering, MVR College Of Engineering and Technology, Paritala,

Krishna District, Vijayawada, Andhra Pradesh, India.

[2] Assistant Professor, Department of Civil Engineering, MVR College Of Engineering and Technology, Paritala, Krishna District, Vijayawada, Andhra Pradesh, India.

ABSTRACT: ***The country has witnessed tremendous increase in the vehicle population and increased axle loading pattern during the last decade, leaving its road network overstressed and leading to premature failure. The type of deterioration present in the pavement should be considered for determining whether it has a functional or structural deficiency, so that appropriate overlay type and design can be developed. Structural failure arises from the conditions that adversely affect the load carrying capability of the pavement structure. Inadequate thickness, cracking, distortion and disintegration cause structural deficiency.***

Functional deficiency arises when the pavement does not provide a smooth riding surface and comfort to the user. This can be due to poor surface friction and texture, hydro planning and splash from wheel path, rutting and excess surface distortion such as potholes, corrugation, faulting, blow up, settlement, heaves etc. Functional condition determines the level of service provided by the facility to its users at a particular time and also the Vehicle Operating Costs (VOC), thus influencing the national economy.

This study attempts to identify the parameters that affect the performance of roads and to develop performance models suitable to Vijayawada conditions. A critical review of the various factors that contribute to the pavement performance has been presented based on the data collected from selected road stretches of Vijayawada. These roads represent the urban conditions as well as National Highways, State Highways and Major District Roads in the sub urban and rural conditions.

I.INTRODUCTION

The increasing traffic intensity, high tire pressure, increasing axle loads etc are causing early signs of distress to bituminous pavements throughout the world. The deterioration of the paved roads in tropical and subtropical countries differs from those in the more temperate regions of the world. This can be due to the harsh climatic conditions and sometimes due to the lack of good pavement materials and construction practices.

Pavement performance can be defined as the ability of the road to meet the demands of traffic and environment during its design life. The reduction in the performance level of the pavement with time is termed as deterioration. Flexible pavements deteriorate due to many factors, predominantly traffic, climate, material, construction quality and time. These multiple parameters make the process very complex. The condition of the road at any time can be predicted approximately using performance models.

For managing the transport infrastructure system, prediction and modelling of their performance are the main inputs as well as major challenges. The predicted deterioration play major roles at both network level and project level. The overall facilities can be planned for justifying the budget and resources with help of deterioration models. The planning and scheduling of the maintenance work for individual project is dependent on the time at which the section becomes deficient in service. This can be predicted through accurate deterioration models. Development of appropriate transportation policy and evaluation of the economic impacts also depend on the performance and interplay between the infrastructure facility and its user (traffic). One such example is the imposition of axle load limits, which is responsible for the damage of the pavement at exponential rates.

Lack of necessary maintenance results in deterioration of the pavement, which in turn cause damage to the vehicles and higher fuel consumption, thereby increasing the vehicle operating (VOC) and user costs. To ensure an acceptable level of service, comfort and safety on these roads, road maintenance activities are very essential. Also, for increasing the life of the pavement, timely and appropriate maintenance is very essential. In this context, by understanding the performance of the pavement accurately has great significance. Performance prediction of flexible pavements is an essential activity in the design of flexible pavement overlays, can be used to develop appropriate strategies, and improved design methodologies. Also a developing country like India is now facing the challenge of preserving and enhancing its transportation system infrastructure within limited budget allocation. So, prioritization of roads is required for planning optimum Maintenance and Rehabilitation (M&R) strategies.

Efficient management of the road infrastructure can be achieved by predicting their performance accurately. Since the deterioration and performance of the pavements depend on multiple factors like traffic, climate, environment, construction quality, age, etc., the process is very complex. Many researchers all over the world have developed performance prediction models applicable for particular set of conditions. But these models require more generalization to have accurate and comprehensive predictive ability.

The main input data considered for performance prediction is the structural strength of the pavement. The structural strength of a pavement is determined by measuring the deflection of pavement under the traffic loads. In the case of pavement, which has been well compacted conditioned by the continuously moving traffic, there will be elastic deformation under each wheel load application. When the wheel load is released, the pavement surface will perform an elastic recovery, also termed as rebound deflection. Decisions on strengthening or reconstruction of pavement are made from analysis of structural strength data. This data gives insight to the right cause of deterioration. Pavement engineers should understand the factors, which affect the long-term performance of overlays so as to design and provide long lasting overlays.

Prioritization or ranking or optimization models are used for determining the best maintenance and rehabilitation package for a given road network. The present quality of the pavement is represented some indices with the data on the condition using the prioritization models. The parameters which are commonly used for ranking are traffic volume, category of road, quality index etc. The prioritization and ranking are used to determine the allocation of the M & R resources to the road sections. The basic criteria for the analysis of the optimization models can be the minimization of improvement cost & vehicle operating cost and residual value of the pavements during the period selected as the life span, or maximization of the quality and performance of the entire network within the available annual budgets and minimum quality levels. Budgeting and resource allocation at the network level and activity planning and project prioritization at programming level can be done using the performance prediction models. At project level, an accurate model is helpful for determining and designing the corrective measures including the M & R strategies.

II. LITERATURE REVIEW

Aggarwal et al. (2005) has given an overall picture of the problems of road networks in developing countries, which are rapid traffic growth, inadequate funding for maintenance and upkeep, lack of skilled man power, attitude towards maintenance etc. Thube et al. (2005) critically reviewed the maintenance management strategy for low volume roads in India and stressed the need for development of pavement distress data base, deterioration models, optimal investment and maintenance strategy and highlighted the need for a suitable National level policy regarding paving of unpaved low volume roads in India.

Juang and Amirkhanian et al.,(1992) Documented the findings of a study carried out on the use of Pavement Management System (PMS) in the United States. A model using fuzzy logic for a PMS based on priority ranking was developed. An index called Unified Pavement Distress Index (UPDI) was also developed and this was used to measure the distress condition of the pavement. Guidelines for rating six types of distresses, weights among the different types of distresses, fuzzy set representations, fuzzy mathematics and the definition of UPDI and its use in pavement database were given by this approach.

Collop and Cebon et al., (1995) Reported a whole-life performance model (WLPPM). This model is capable of making deterministic pavement damage predictions resulting from realistic traffic and environmental loading. Realistic predictions of pavement degradation with traffic has been obtained by taking into account most of the primary factors of vehicle/pavement interaction. Simulation by WLPPM shows that short- wave length surface – roughness components can be smoothed out, and traffic loading increases the amplitude of long wave length components.

Gary et al., (2011) He was made a study of the road network condition and pavement management system of the city of Abbotsford and found that the condition of the major road network in 2004, in terms of cracking as a percentage of surface area was on an average of 7.7%. It is also reported that the average International Roughness Index (IRI) was 2.1 mm/m. The GHG reduction due to the application of PMS was significant by adopting $ 3.8 million funding scenario and has now reached 1,300 tons and could total to more than 17,000 tones over 20 years.

III. METHODOLOGY

Selection of Road Stretches:

Based on a preliminary assessment with respect to the road conditions and traffic, 8 roads from five corporations, which represent urban conditions, were selected for the study.

Potholes: Study stretches of length about 200 to 500 m was selected considering identical conditions. The data of potholes on each study stretch were collected and recorded periodically two or more times a year covering different seasons including the periods before and after monsoon season.

Alligator crack

Pothole and Alligator Cracks

Traffic Studies: Traffic studies were conducted on the study road stretches with axle load survey on roads indentified for deterioration modeling.

Axel load survey

Roughness Survey: Roughness or ride quality is a measure of the unevenness of the pavement surface along a linear plane. It represents the ability of the pavement to provide a comfortable ride to the users. Pavement roughness is considered as the most important road feature by the public. Roughness is important on roads with higher speed limits, for those above 70 km per hour.

Roughness survey in progress

Skid Resistance Test:

The basic function of a pavement is to extend smooth and safe surface for the travelling public. The travelling public is primarily interested in this functional condition, which is primarily measured with roughness and surface friction. The engineers and managers are interested in developing the most cost-effective maintenance and rehabilitation program.

Analysis Methods:

Analysis by Section: In the method of Analysis by Section, each of the road sections selected for the project are analyzed separately. Several alternatives like maintenance and/or improvement standards can be defined for any of the section, with one alternative designated by the user as the base alternative and all other alternatives will be compared with the base alternative. Economic indicators (e.g. NPV, IRR and NPV/C) are calculated for each section alternative.

Analysis by Project: In the method of Analysis by Project, a project is defined as the set of road works to be carried out on one or more road sections that can be grouped together conveniently to be undertaken as one contract or work instruction. Several project alternatives can be analysed to determine the most cost-effective option. Analyses involving new sections and diverted traffic can be performed only using this method.

IV Study area Field investigation and Results

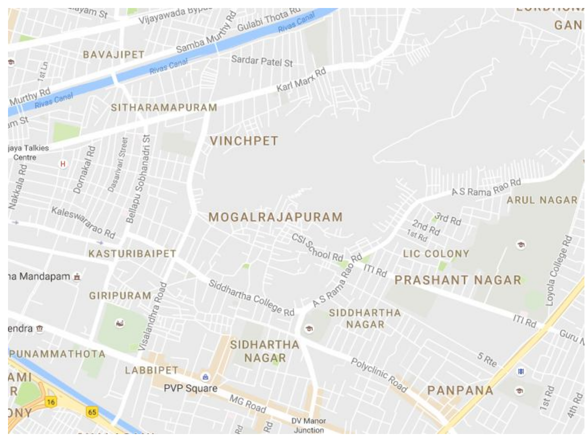
The present research study is divided into two parts.8 in-service urban roads distributed in the five Corporations of the State were selected for the first part of the study. The data on the sub grade soil properties and deflection characteristics of 8 stretches in these urban settings were collected for analysis and development of relationships with pavement condition, soil properties and deflection.

The second part of the study focuses on to develop pavement deterioration models applicable to vijayawada conditions using time series data. Eight road sections representing NH, SH and MDR with variation in traffic composition, soil properties, climate, drainage characteristics and land use were selected. Periodic data were collected from the field.

Urban Roads selected for the study:

List of Urban Roads selected for study

s.no	Road name	Length	Section ID
I	Vijayawada corporation		
1	Sitharamapuram-Governorpet	1.7km	Vw01
2	Bavajipet to Arundalpet	0.7km	Vw02
3	Vinchpeta to islampet	1.6km	Vw03
4	Prashanth nagar to sidharth nagar	1.5km	Vw04
5	Bharathi nagar to panpana	2km	Vw05
6	Giripuram to kasthribaipet	0.4km	Vw06
7	Panama to Siddhartha nagar	1.1km	Vw07
8	Labbipet to sri ram nagar	1.3km	Vw08



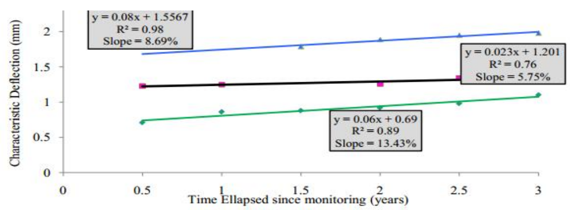
Study Roads in Vijayawada Corporation

V.PAVEMENTS PERFORMANCE MODELS

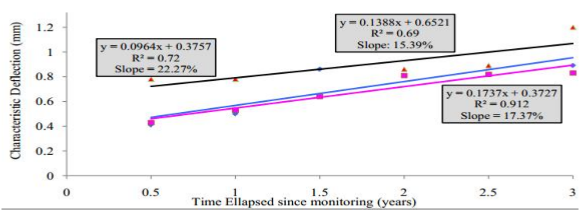
Pavement is a complex physical structure with non-homogeneous composition of bituminous mixture, aggregate and sub grade soil with variation in traffic, climatic conditions, environment and construction quality. Researchers have developed different models for predicting the performance of flexible pavements using the data generated through extensive studies in different geographical regions.

DEFLECTION STUDIES:

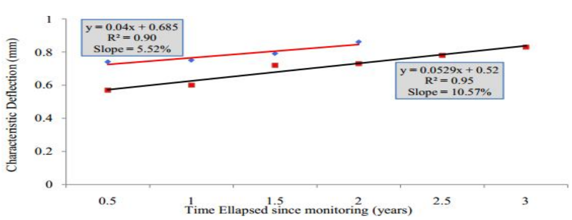
The amount of pavement deflection under a wheel load is the measure of the structural stability of the pavement system. For weaker sections, higher value of deflection is shown. From the data obtained through field investigations conducted with Benkelman Beam as per the procedure given in Chapter 3, the progression of the deflection on the study stretches are plotted as given in figure **.** Slope of the progression line for the homogenous sections, which is a measure of the change in the value of Y corresponding to a unit change in the value of X, were also derived.



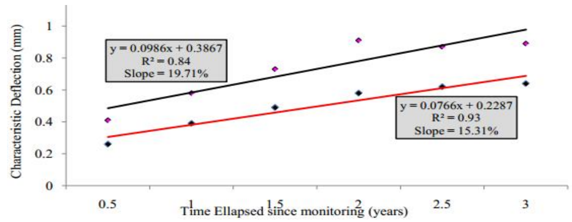
Sitharamapuram to governorpet road



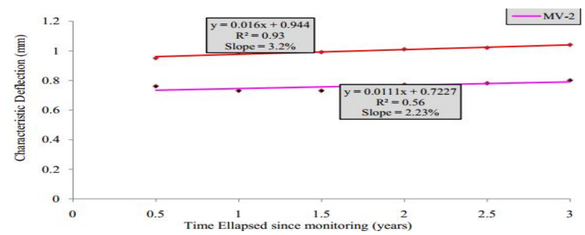
Bavajipet to arundalpet road



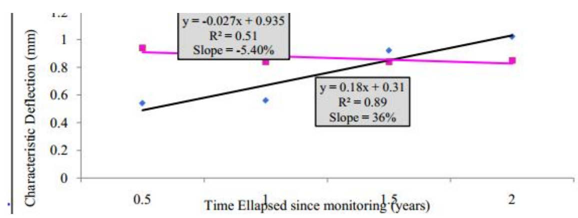
Vinchpeta to islampet road



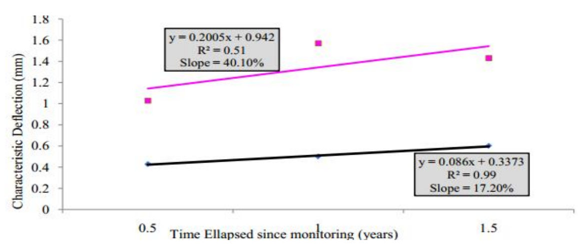
Prashanth nagar to sidharth nagar road



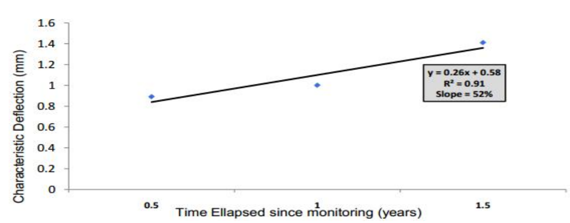
Bharathi nagar to panpana road



Giripuram to kasthribaipet road



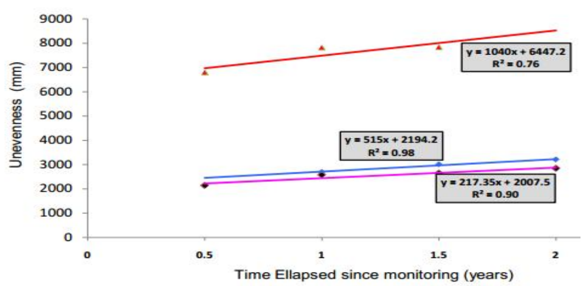
Panana to sidharth nagar road



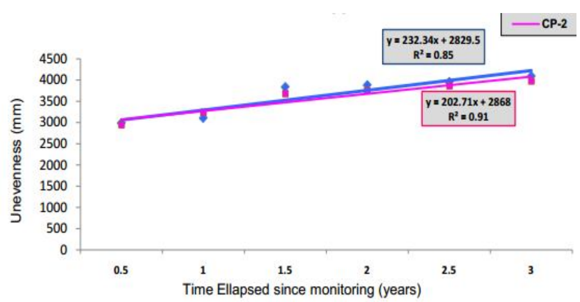
Labbipet to sri ram nagar road

ROUGHNESS STUDIES:

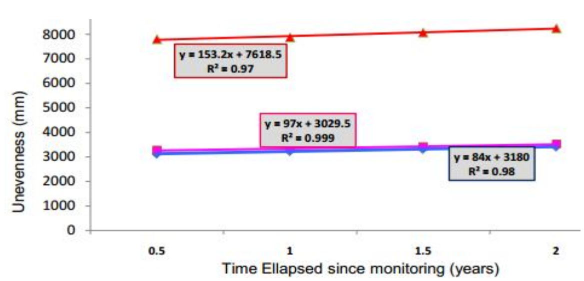
The serviceability of a pavement is largely a function of its unevenness, which is represented as IRI values internationally. This is also represented in terms of mm per kilometer and measured using the Bump Integrator. The roughness values on the study stretches were measured from the field studies as per the procedure discussed in Chapter 3. The progression of unevenness on the study roads are given in figures .



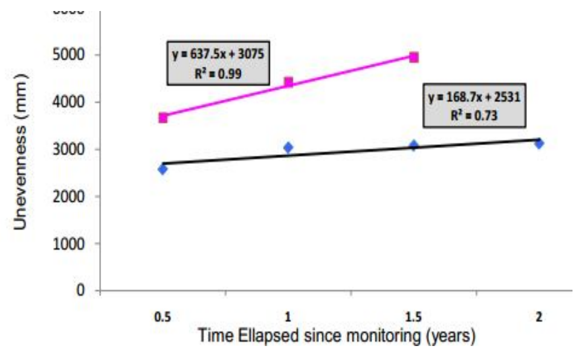
Sitharamapuram to governorpet road



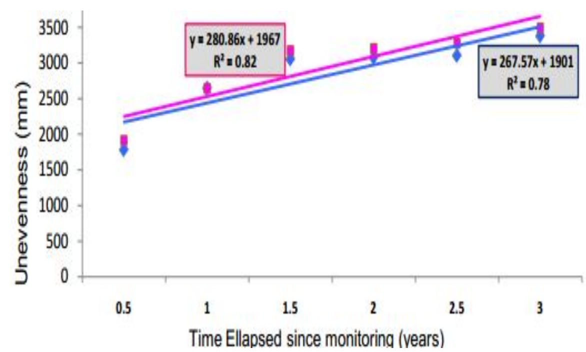
Bavajipet to arundalpet road



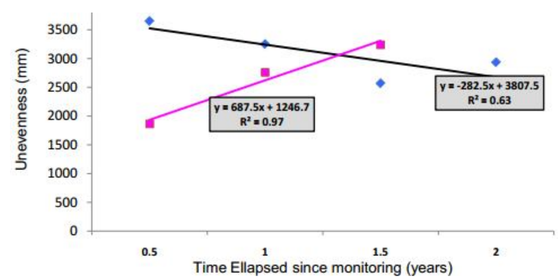
Vinchpeta to islampet road



Prashanth nagar to sidharth nagar road



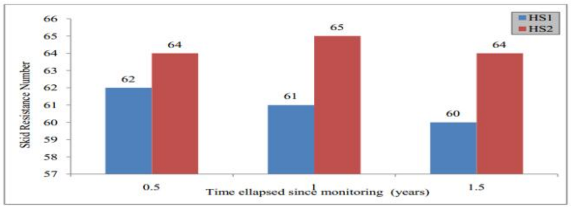
Panana to sidharth nagar road



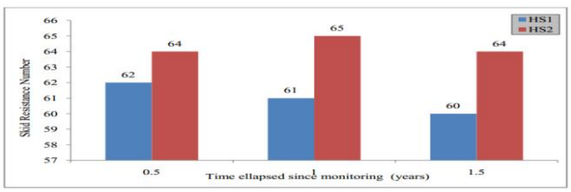
Labbipet to sri ram nagar road

SKID RESISTANCE STUDIES:

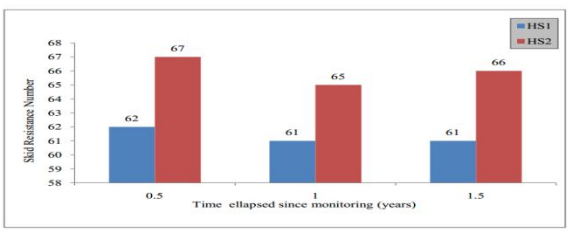
The skid resistance of the study stretches were measured using Portable Skid Resistance Pendulum Tester and the results are represented as bar charts



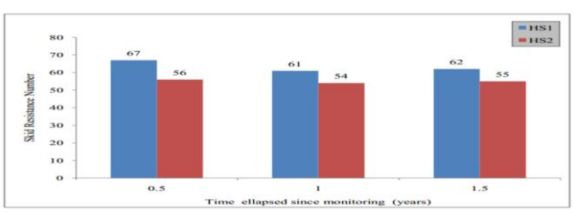
Sitharamapuram to governorpet road



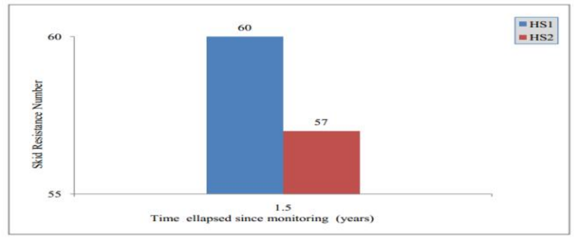
Bavajipet to arundalpet road



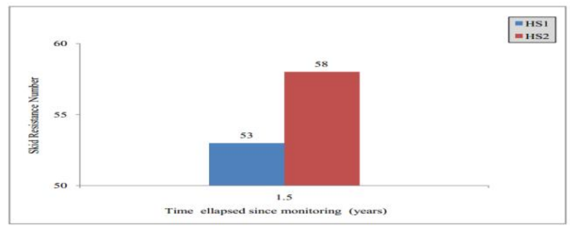
Vinchpeta to islampet road



Prashanth nagar to sidharth nagar road



Panana to sidharth nagar road



Labbipet to sri ram nagar road

Calibration and validation of the progression models:

The parameters of regression models estimated and calibrated were found to be statistically significant by various statistical parameters like R2, t-test, F-test. The internal validation method was adopted for validating the developed regression models. The models developed were used to predict corresponding values and these estimated values are compared with observed values. A paired t- test for means was used to evaluate if there exists any significant difference between observed and estimated values.

Student's t-test for pavement performance models

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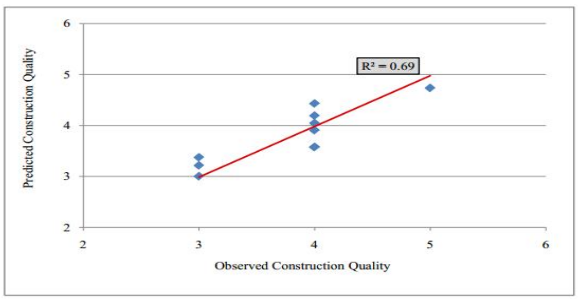
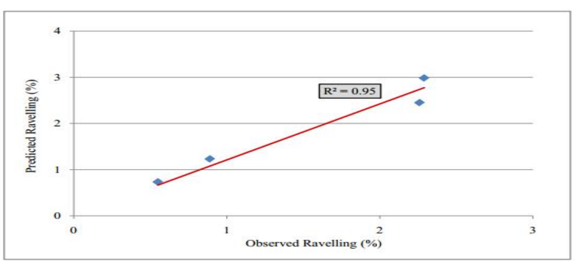
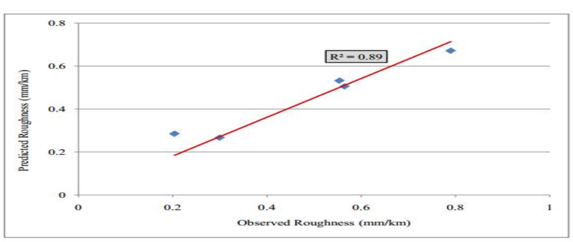
Models	Relationship	Calculated absolute t-test value	Tabular t-test value
Construction Quality	$CQ = (RC)^{0.568} + (MSN)^{0.451} - 10.722$	0.039	2.262
Ravelling Progression	$RVP = (RVi * AGE)^{0.339} + (CQ)^{-0.808} + (VDF)^{0.487} - 0.589$,	2.952	3.182
Roughness Progression	$RGP = (CQ * RVt)^{-0.547} - 2.342\ (MSN)^{-0.952} + 0.0672\ PHi$,	0.949	2.776
Pothole Progression	$PHP = (CQ)^{-26.86} - 0.047 * MSN * AGE + (RVP)^{0.465} + (PHi)^{0.081}$,	0.344	2.776
Alligator Crack Progression	$ACP = (VDF)^{0.155} - 1.735 * (MSN * AGE)^{-0.238}$	0.051	2.776
Deflection Progression	$Def = 0.358 \times DEFi + 0.009 \times e^{vdf} - 0.002 \times e^{msn} + 0.653$	0.452	2.776



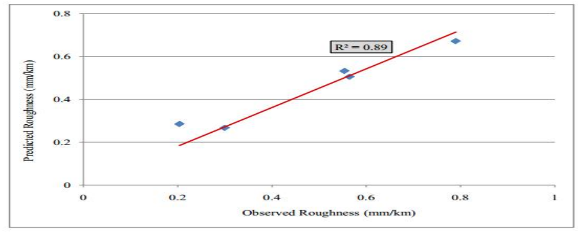
Comparision of observed vs construction quality



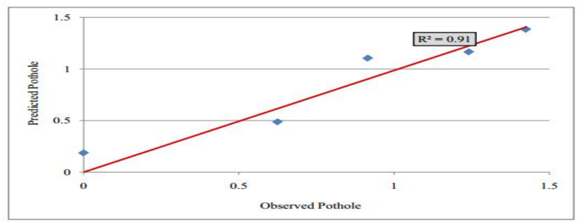
Comparision of observed vs predicted raveling



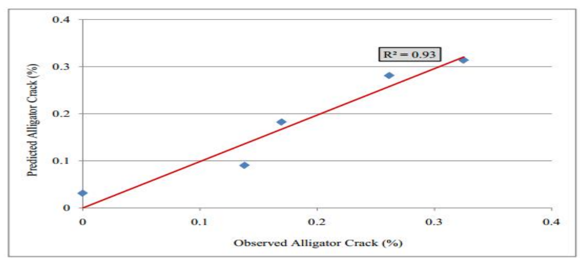
Comparision of observed vs predicted roughness



Comparision of observed vs predicted pothole



Comparision of observed vs alligator crack

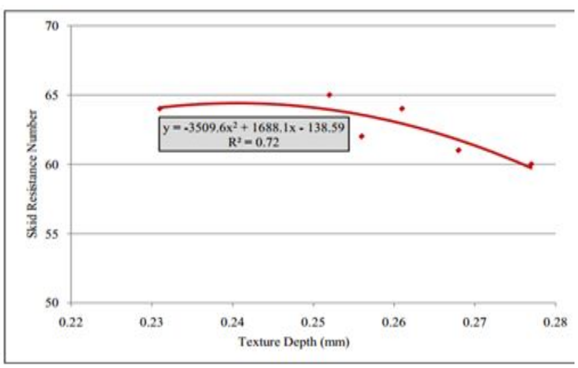


Comparision of observed vs predicted deflection

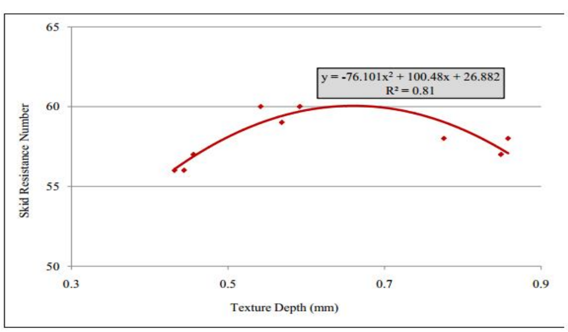
Safety related performance model-relationship between texture depth and skid resistance:

Polynomial relationship between Texture depth (x) and Skid Resistance Number

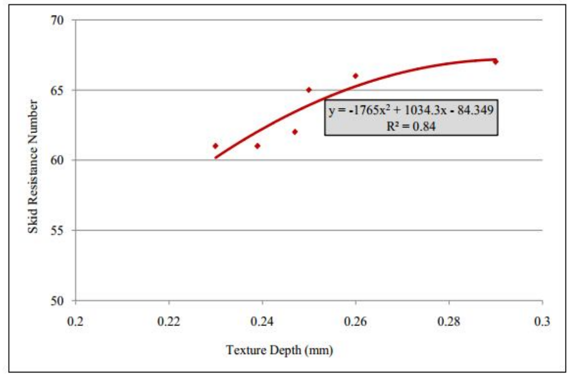
Study stretch	Polynomial relationship between texture depth and skid resistance number	R^2	Skid resistance (mm)		
			Mean	Standard deviation	Standard error
Sitharamapuram to governorpet road	$SN=-3509.6TD^2+1688.1TD-138.59$	0.72	62.67	1.97	0.80
Bavajipet to Arundalpet	$SN=-76.101TD^2+100.48TD+26.882$	0.81	57.89	1.54	0.51
Vinchpeta to islampet	$SN=-1765TD^2+1034.3TD-84.349$	0.84	63.67	2.66	1.09
Prashanth nagar to sidharth nagar	$SN=5x10^{-10}TD^2+121.69TD+7.7421$	0.94	58.00	4.08	2.04



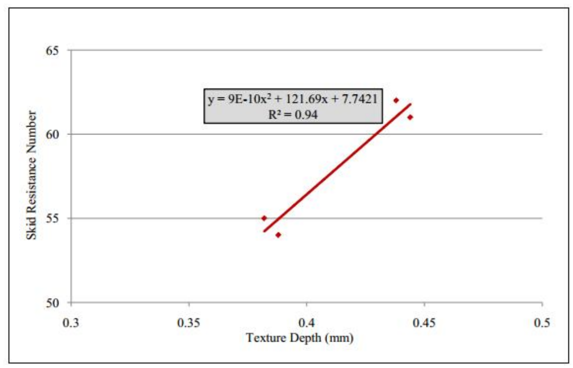
Sitharamapuram to governorpet road



Bavajipet to arundalpet road



Vinchpeta to islampet road



Prashanth nagar to sidharth nagar road

VI CONCLUSIONS

Based on the present study, the conclusions drawn are presented in three sections as given below

Relationship of Pavement Strength and Pavement Composition:

1. The strength of the pavement represented by the measured deflection at the surface on mature soil sub grades is influenced by the sub grade soil properties and layer composition on an in-service pavement in urban conditions.

2. The parameters such as Field Dry Density, Field Moisture Content, Optimum Moisture Content, Maximum Dry Density, Atterberg Limits, CBR, Soil

composition and the fraction of Silt & Clay of the sub grade soil have influence on the strength of the pavement

Pavement Performance Models

1. Rutting is found to be absent on the study road stretches. The reasons that can be attributed for this are the absence of lane segregation and lane discipline

2. The regression models developed for deflection and roughness progression gave promising results for predicted values when validated with the observed values.

3. The developed models are simple and are useful for estimating the structural and functional behavior of flexible pavements with anticipated traffic loading. These models can be used to find the allowable traffic loading at different limiting values of deflection, crack area, RCI and UI. Thus, the phasing of maintenance/rehabilitation activities can be scientifically planned.

Overlay Options

1. From the analysis, it was seen that due to the high increase in vehicular traffic and congestion, Level of Service of the study stretch became very low, thus demanding a Partial Widening in addition to overlay.

2. Ultra Thin White Topping is suggested as an appropriate overlay option for roads similar to the study roads, which reduces the Life Cycle cost of the pavement.

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