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Pavement Serviceability Index for Urban Roads in Bengaluru

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Abstract:- In the present study stretches Bangalore were selected, to develop the present serviceability index (PSI) equations for cement concrete roads. To carry out the studies, the test stretches were selected with varying pavement conditions from very bad to good condition. The unevenness of the pavements was determined using field survey, Visual rating, Ride ratting and the unevenness values were expressed in terms of International Roughness Index (IRI). The distresses such as raveling, spalling, faulting, cracking etc were measured and recorded. The rating studies were carried out by constituting three panels with six raters in each panel. The three rating panels constituted were highway, mixed and non-highway panels. The raters were trained for assessing the pavement surface by both visual and ride rating techniques and to rate the test stretches on a scale of 0- 5. The ratings of the three panels from the field observations were subjected to error elimination viz leniency error and central tendency error. The true ratings were obtained after application of corrections to the individual ratings. The distress data and the mean of the corrected ratings of both visual and ride ratings were used and regression analysis were carried out to develop PSI equations for concrete roads based on both visual and ride ratings.

I. INTRODUCTION

Efficient road transportation plays an important role in the economy of any Nation. Road transport in India, occupies a dominant position in the overall transportation system of the country due to its advantages like easy availability, flexibility of operation, door to door service and reliability. India owns the second largest network of roads in the world, next to USA. As per statistics of year 2009, the total road length in the country is over 3.3 million km, which gives the spatial road density of about 1 km/km^2 of area. Out of the total road network of India, village and other roads (Low Traffic Volume Roads) consist of 80% share. Low traffic volume roads are mainly rural roads in India carrying daily traffic less than 450 Commercial Vehicles per Day (CVPD). The thickness of sub-base layer is around 200 mm and the total thickness of each layer of base course varies from 100 – 120 mm. Surface course is usually 20 mm thick premix carpet layer. Low volume roads serve as one of the key infrastructure work, placed for integrated rural development, which has become a matter of growing urgency for considerations of social justice, national integration and economic uplift of the rural areas.

The importance of preserving road network in good condition is widely recognized and therefore, performance evaluation of the existing roads is an absolute necessity. Performance of flexible pavements has long been recognized as an important parameter in their design and maintenance. In order to measure and prepare model for pavement performance, it is necessary to clearly define the pavement performance. The importance of preserving road network in good condition is widely recognized and therefore, performance evaluation of the existing roads is an absolute necessity. Performance of flexible pavements has long been recognized as an important parameter in their design and maintenance. In order to measure and prepare model for pavement performance, it is necessary to clearly define the pavement performance.

According to American Association of State Highway and Transport Officials (AASHTO), pavement performance is defined as–the serviceability trend of pavement over a design period of time, where serviceability indicates the ability of the pavement to serve the demand of the traffic in the existing conditions. In other words, pavement performance can be obtained by observing its structural and functional performance or predicting the serviceability of a pavement from its initial service time to the desired evaluation time. Normally, pavement condition can be evaluated on the basis of four aspects i.e. riding quality, surface distress, structural capacity and skid resistance. Deterioration of pavement can be attributed to various factors like age, traffic, environment, material properties, pavement thickness, strength of pavement as well as subgrade properties which affect the mechanical characteristics of a pavement. These factors affect the performance of the pavement in a complex manner. To understand the mechanism and to forecast the future condition of pavement, these deterioration models are necessary. Pavement deterioration model is a mathematical relationship between the pavement condition and the factors listed above. The pavement deterioration model predicts the future condition of the pavement, which is helpful in development of Maintenance Management Model or Maintenance Priority Index (MPI). This index is a rating used to prioritize the maintenance schedule of pavement based on the severity of distresses and its condition.

II. METHODOLOGY

A. Test Stretches for Field Study Collection of pavement distress data by field surveys

The pavement distress data is collected from a selected road stretch in Urban roads in Bengaluru city, Karnataka. Data collection is done for analysis from the considered road stretches. The structural evaluation and functional evaluation data is collected and is processed for further studies For the study, totally 13 road stretches in Bengaluru city were selected with different road conditions. Each road stretch is of length 1 km divided in to 10 sections of 100m Length. The following criteria were used for the selection of the test stretches. The test stretches were straight without horizontal curves and steep gradient. The test stretches have fairly uniform riding quality and surface condition throughout the length of stretch. Cross drainage works, over bridge are to be avoided within the selected test stretches. For the study, totally 13 road stretches in Bengaluru city were selected with different road conditions. Each road stretch is of length 1 km divided in to 10 sections of 100m Length. The following criteria were used for the selection of the test stretches.

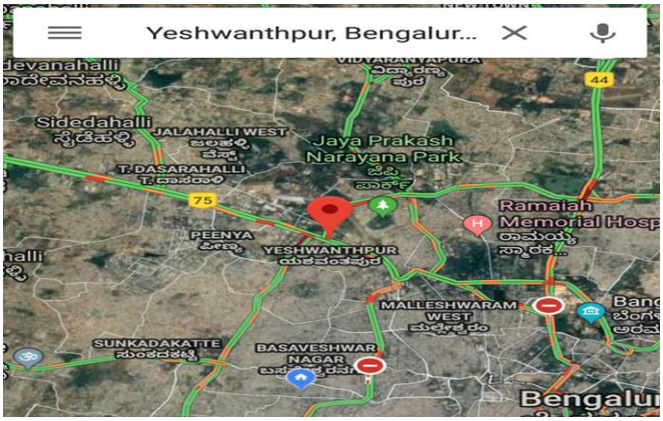


Fig 1:- Location of Bengaluru city Arterial and Sub Arterial roads

Section Number	Name of Test Stretches	Sides
Section 1	M S Ramaiah Road, Mattikere.	LHS & RHS
Section 2	Yashawanthpura Police station to CCD	LHS & RHS
Section 3	YSP(Galianjaneya temple) to Maramma Circle	LHS & RHS
Section 4	Kanteerava studio main road	LHS & RHS
Section 5	Mysore road From R R gate to B U gate	LHS & RHS
Section 6	Rajagopal nagar to SBM stop	LHS & RHS
Section 7	Brindavana to NTTF	LHS & RHS

Table 1:- Selected Test Stretches for the present study

B. Structural Condition Evaluation:

The structural condition evaluation is carried out on all the selected pavement stretches considering 50m length of road section for every measurement.

➢ *Surface Distress Evaluation*

This involves the measurement of rut depth, crack length and width at selected test points and surface defects such as potholing, patching, etc. over the entire pavement surface of the selected stretch.

- *Crack Area Measurements*

Cracks develop due to the repeated application of loads causing excessive tensile strain in the bituminous layers. The cracks are generally measured in unit area. Keeping deflection observation point as center, a square of sides 1mX1m is marked on the surface. Details of cracks in the marked area are recorded.

✓ *Severity Levels:*

L—an area of cracks with no or only a few connecting cracks: cracks are not appalled or sealed: pumping is not evident

M— an area of inter connected cracks forming a Complete pattern: cracks may be slightly spalled: Cracks may be sealed: pumping is not evident.

H— an area of moderately or severely spalled interconnected cracks forming a complete pattern: pieces may move when subjected to traffic: cracks may be sealed: pumping may be evident.

C. Visual Rating Technique

The members of the rating panel were trained to walk along the left and right wheel paths on the selected stretches and condition of the pavements was assessed based on the visual judgment of surface characteristics.

Sl.No.	Description Based on Visual Rating	Numerical Scale
1	Perfectly even surface Without undulation, Cracking Patching.	4-5
2	Slightly uneven Surface with some undulation no pot holes and slight cracking.	3-4
3	Moderately uneven surface, Visible patching and medium cracking.	2-3
4	Uneven surface with improper patched potholes medium to heavy cracking.	1-2
5	Uneven surface with different type undulation badly patched potholes, heavy cracking.	0-1

Table 2:- Effect of Distresses on Visual Rating (VR)Effect of Distresses on Ride Rating (RR)

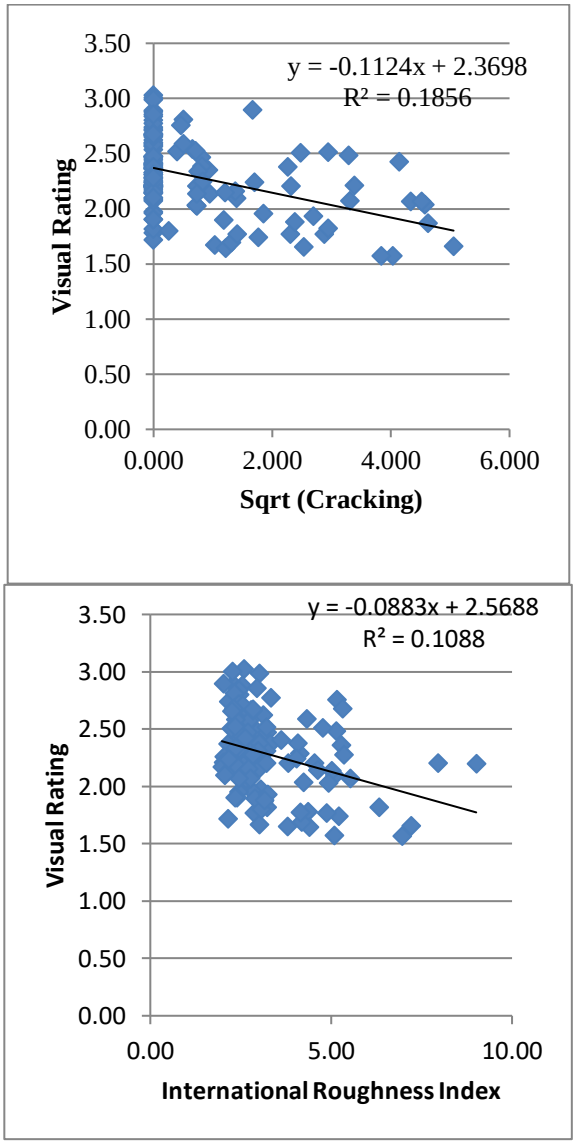
In order to develop a Multiple Linear Regression model for VR, the best suited function of a distress is selected. The choice of the function is done on the basis of higher R2 value provided by the distress function linearly. The following figures show the best suited linear functions of each parameter considered against both Visual and Ride Rating for the development of suitable PSI model.

➢ *Development of PSI Model*

The PSI model was developed along the lines of AASHO road test studies using the field measurements such as Cracking, Rut depth, Raveling, Patching, Pot holes, IRI and Mean PSR values. The PSI equation was developed for both the visual and ride rating using excel analysis tool pack and regression analysis. The PSI models were after selecting the best suited distress function individually and finally a multiple linear regression analysis was carried out to develop models. The best suited distress function here, refers to the distress function which gives highest R2 value when plotted against the dependent variable IRI.

- *Effect of Distresses on Visual Rating (VR)*

In order to develop a Multiple Linear Regression model for RR, the best suited function of a distress is selected. The choice of the function is done on the basis of higher R2 value provided by the distress or deformation function linearly. The following figures show the best suited linear functions of each parameter considered against Ride Rating for the development of suitable PSI model.



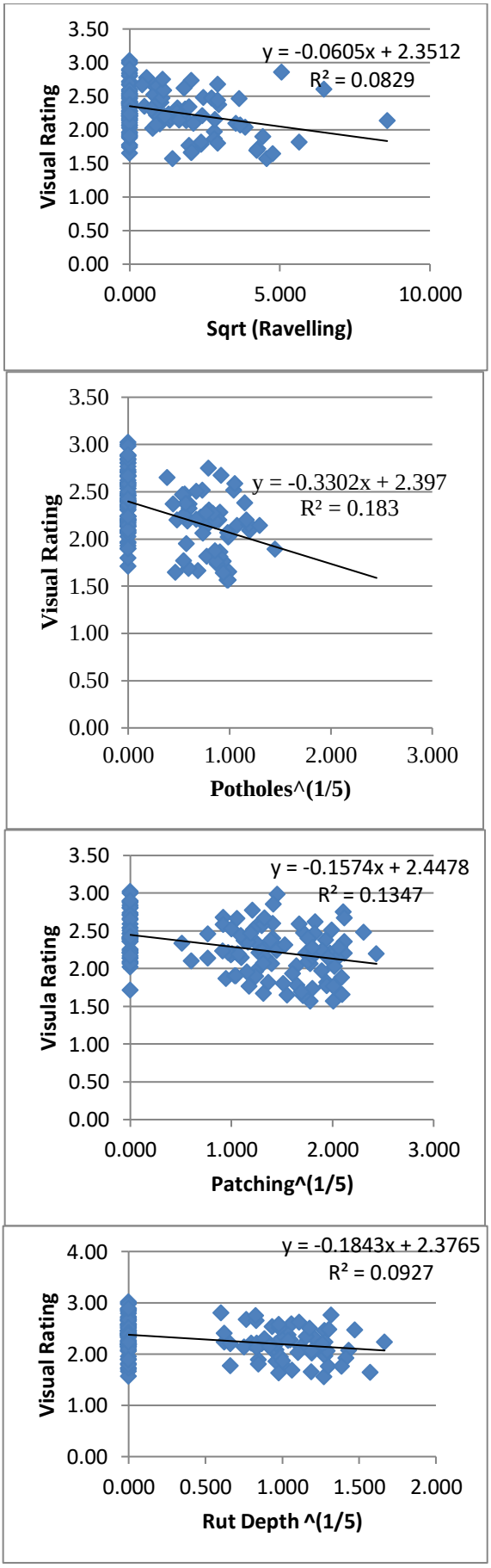


Fig 2:- Variation of VR with respect to IRI

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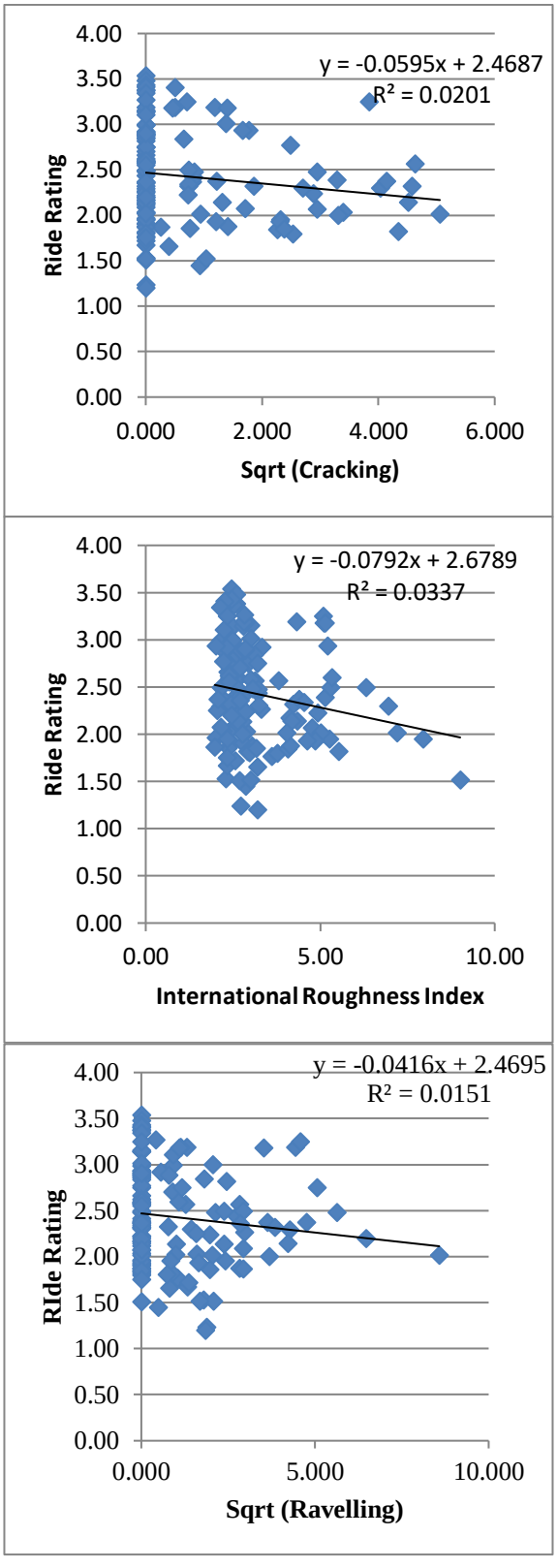
- *Effect of Distresses on Ride Rating (RR)*

In order to develop a Multiple Linear Regression model for RR, the best suited function of a distress is selected. The choice of the function is done on the basis of higher R2 value provided by the distress or deformation function linearly. The following figures show the best suited linear functions of each parameter considered against Ride Rating for the development of suitable PSI model.



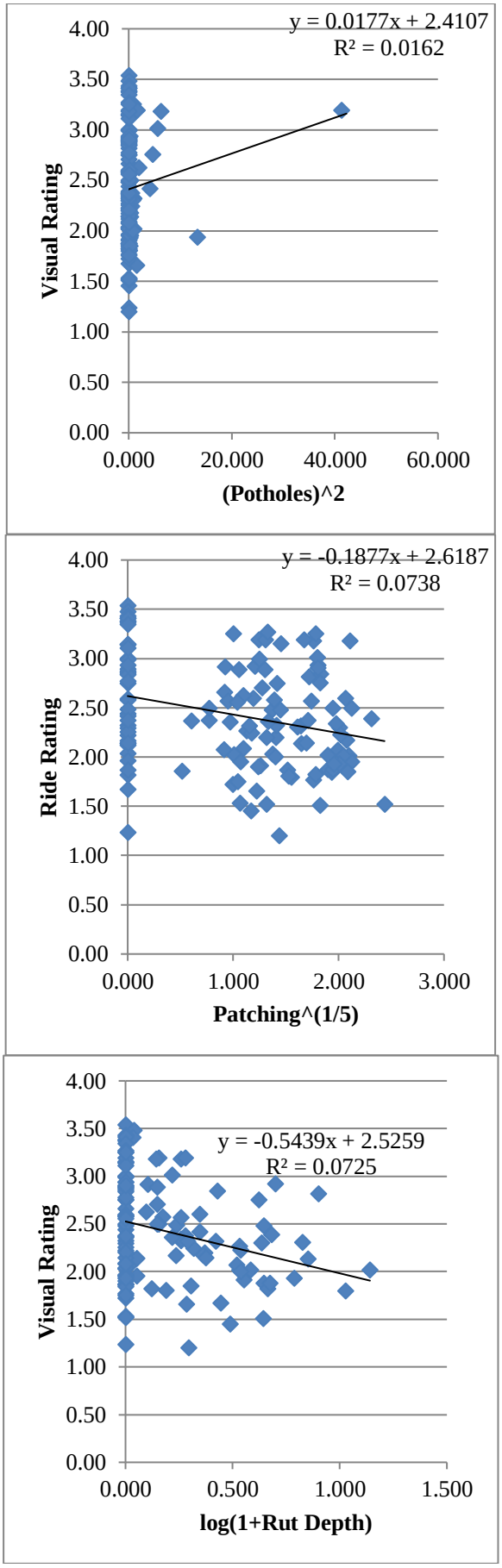


Fig 3:- Variation of RR with respect to IRI

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D. Using the Distress data and the Rating data, arriving at Pavement Condition Index as per IRC 82:2015.

Road Identification	Chainage	Cracking	Patching	Raveling	Potholes	Rut depth	Roughness	PCI
		Density %	Density %	Density %	Density	Density (mm/km)	IRI	
M S Ramaiah Road (L.H.S)	0.000 to 0.100	0.000	0.000	0.000	0.000	0.000	2.47	79
	0.100 to 0.200	0.000	0.000	0.000	0.000	0.000	2.28	79
	0.200 to 0.300	0.000	0.000	4.211	0.000	0.000	2.16	75
	0.300 to 0.400	0.000	0.000	0.000	0.000	0.000	2.56	79
	0.400 to 0.500	0.000	0.000	0.000	0.000	0.095	2.66	78
	0.500 to 0.600	0.000	0.000	0.000	0.000	0.000	2.59	79
	0.600 to 0.700	0.000	0.000	0.000	0.000	0.000	2.53	79
	0.700 to 0.800	0.000	0.000	0.000	0.000	0.095	2.60	78
	0.800 to 0.900	0.000	0.000	0.000	0.000	0.000	2.45	79
	0.900 to 1.000	0.000	0.000	0.000	0.000	0.000	2.44	79

Fig 4:- M S Ramaiah Road (L.H.S)

Road Identification	Chainage	Cracking	Patching	Raveling	Potholes	Rut depth	Roughness	PCI
		Density %	Density %	Density %	Density	Density (mm/km)	IRI	
M S Ramaiah Road (R.H.S)	0.000 to 0.100	0.253	0.000	0.000	0.000	0.079	2.31	78
	0.100 to 0.200	0.000	0.000	0.000	0.000	0.000	2.50	79
	0.200 to 0.300	0.000	0.000	0.000	0.000	0.000	2.79	80
	0.300 to 0.400	0.000	0.000	0.000	0.000	0.000	2.35	79
	0.400 to 0.500	0.000	0.000	0.000	0.000	0.718	2.62	74
	0.500 to 0.600	0.000	0.000	0.000	0.000	0.000	2.45	79
	0.600 to 0.700	0.000	0.000	0.000	0.000	0.000	2.27	79
	0.700 to 0.800	0.000	0.000	0.000	0.000	0.000	2.14	79
	0.800 to 0.900	0.000	0.000	0.000	0.000	0.000	2.55	79
	0.900 to 1.000	0.000	0.000	0.000	0.000	0.000	2.65	79

Fig 5:- M S Ramaiah Road (R.H.S)

E. PCI (Pavement Condition Index) model for the measured distress values on the Selected Pavement Section

➢ *Development of PCI Model*

The PCI model was developed along the lines of ASTM D6433 using the field measurements such as Cracking, Raveling, Patching and Pot holes. The PCI equation was developed using excel analysis tool pack (Regression Analysis) at 95% level of confidence. The PCI model was developed after selecting the best suited distress function individually and finally a multiple linear regression analysis was carried out to develop model. The best suited distress function here refers to the distress function which gives highest R2 value when plotted against the dependent variable PCI.

The Equation to Determine PCI is PCI=73.61-0.8489(Cracking)-0.1853(Patching)-0.318(Ravelling)-4.054(Potholes)-1.410(Rut Depth)

ANOVA					
	df	SS	MS	F	Significance F
Regression	5	10378.26	2075.652	65.79757	3.08E-33
Residual	124	3911.708	31.54603		
Total	129	14289.97			

Fig 6

➢ *Using the Distress data and the Rating data, developing a Present Serviceability Index model*

Visual Rating(VR)=$0.8035\times(IRI)+0.1494\times\sqrt{(5\&RutDepth)}-0.23\times\sqrt{(5\&PotHoles)}+0.0045\times\sqrt{Ravelling}-0.444\times\sqrt{(5\&Patching)}-0.191\times\sqrt{Cracking}$

R2 = 0.84

ANOVA					
	df	SS	MS	F	Significance F
Regression	6	585.668	97.61133	113.2672	1.14E-47
Residual	124	106.8606	0.861779		
Total	130	692.5286			

Fig 7

III. RESULTS AND DISCUSSIONS

➢ From the roughness test result it was observed that IRI value of test stretch varies from 1.98 to 9.01m/Km. based on the IRI values and FHWA guidelines the roughness of test stretches can be classified under good to rough.

➢ Various distress measurements were carried out such as roughness, cracking, rut depth and raveling. IRI value varied from 1.98 to 9.01 m/Km. Density of Various Disterss Viz., cracking varied from 0 to 25.571%, Rut depth varied from 0.00 to 12.838 mm/km, raveling varied from 0.00 to 73.514%, Patching varied from 0.00 to 85.714% and Pot Holes Varied from 0.00 to 6.423%.

➢ The rating studies were carried out by constituting 3 panels. Viz: Technical panel, mixed panel and Non-Highway panel for the Thirteen selected pavement stretches. The mean visual rating values varied from 1.57 to 3.03. The mean ride rating value varied from 1.20 to 3.54.

➢ Non-Technical panel members were over sensitive to variation in pavement distress and riding comfort. They tend to rate with extreme values compared to other two panels for the same condition of the pavement.

➢ The Present Serviceability Index models were developed

in the line of AASHO road test models using the field measurements such as IRI, cracking, raveling, rut depth and mean PSR value. The PSI equation was developed for both the visual and ride rating using analysis tool pack (Excel).

For Visual Rating

Visual Rating(VR)

=0.8035×(IRI)+0.1494×√(5&Rut Depth))-0.23×√(5&Pot Holes)+0.0045×√Ravelling-0.444 × √(5&Patching)-0.191×√Cracking

For Riding Rating

RideRating(RR)

=0.8584×(IRI)-0.5374×√(5&Patching)-0.0331×⟦Potholes⟧^2+0.00397×√Ravelling-0.0776 ×Log(1+RutDepth)- 0.151×√Cracking

- The model indicates that the IRI plays a significant role in determining the PSI value for both Visual and ride rating studies. IRI has a major role in ride rating compared to visual rating model it can be said that IRI effect Riding quality.
- By using distress data, the PCI values were evaluated for the test stretches based on IRC 82: 2015. The severity level and extent of distress had major influence on the PCI values. The PCI value for the test stretches varies from 38 to 80. Based on the PCI values and ASTM guidelines the test stretches can be classified under Good to Poor.
- The PCI model was developed by considering distress parameter as independent variable and PCI value as dependent variable.
- PCI=73.61-0.8489(Cracking)-0.1853(Patching)-0.318(Ravelling)-4.054(Potholes)-1.410(Rut Depth.

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