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Assessment of Pavement Shoulder Condition in Rural Roads

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ABSTRACT: Pavement shoulder is an imperative component of a road. Shoulder has a significant impact on the pavement structure as it provides emergency lane and lateral support to the pavement structure. Pavement shoulder should be maintained properly to increase the overall pavement serviceability. A rating system is very effective and usable to evaluate the performance of a structure. But there are no rating system found for a shoulder structure. In this paper, Shoulder Condition Index (SCI) has been introduced considering all the geometrical and functional properties of shoulder. A case study is conducted on some PMGSY (Pradhan Mantri Gram Sadhak Yojana) rural roads in different districts of Tripura, India. Different factors which affect the performance of the shoulder, are identified viz. narrow width, insufficient slope, bush covered area, shoulder depression, edge drop and improper compaction. Moreover, expert opinion survey has been conducted by giving rank from 1 to 10 based on the effectiveness of pavement shoulder on a road. Relating the expert opinion survey and the case study, a generalized model is established by Artificial Neural Network (ANN). The model is further validated by Regression Analysis. It is observed that edge drop has the highest effect on SCI, but variation of shoulder width has very low effect on SCI.

Keywords: Alyuda Forecaster, ANN, Pavement Shoulder, Regression Analysis, SCI.

Abbreviations: SCI, Shoulder Condition Index; ANN, Artificial Neural Network; PCI, Pavement Condition Index; PCR, Pavement Condition Rating; PSI, Pavement Serviceability Index; ODR, Overall Condition Index; IRC, Indian Road Congress; ODR, Other District Road; VR, Village Road; PMGSY, Pradhan Mantri Gram Sadhak Yojana; AADT, Annual Average Daily Traffic; CVPD; Commercial Vehicle Per Day; MDD, Maximum Dry Density; RMSE, Root Mean Square Error.

I. INTRODUCTION

The shoulder is that portion of the roadway contiguous with the travelled way and is intended for accommodation of stopped vehicles, emergency lane and lateral support to pavement structure. It is a common practice to determine a rating index for performance evaluation like, Pavement Condition Index (PCI), Pavement Condition Rating (PCR), Pavement Serviceability Index (PSI), etc. A number of literatures are found where; rating index is determined to evaluate the condition and performance of a pavement [1-8]. But all these studies are limited to pavement section only, when there are different road assets like shoulder, footpath, kerb, culvert etc. which have high impact on overall road performance [9-11]. So, there should be rating index for all road assets to evaluate their performance.

The characteristics of shoulder part have a great impact on the performance of a road. The width of shoulder should be adequate for giving working space around a stopped vehicle. A wide shoulder provides a temporary parking area and improves roadway capacity by increasing driver comfort [12]. Adequate shoulder protects the edge of the pavement structure from deterioration. It also provides lateral support to the carriageway. For rural roads, generally earthen shoulders are provided.

Earthen shoulder shall be compacted to density not less than 100 percent of laboratory dry density adopting standard proctor compaction [IS: 27020 (part 7) - 1980]. Maximum laboratory dry unit weight of the material for the shoulder shall not be less than 16.5 KN/m^3. Plasticity index and liquid limit shall not exceed 6 and 25 respectively as per IRC: SP: 20- 2002 [13].

In the present study, an attempt is taken to examine various factors effecting on the performance of the shoulder on different PMGSY rural roads, in Tripura, India. Ultimately these factors adversely affect the pavement structure as a whole. So, it is necessary to assess the general condition of shoulder and the Shoulder Condition Index (SCI) is established to evaluate the performance [14-17].

The important factors are: (i) Insufficient Surface Width – Sufficient width should be provided following the IRC (Indian Road Congress) guidelines as it serves lateral support to the pavement structure. (ii) Inadequate Cross Slope – Cross slope should be almost same or slightly greater than pavement camber slope (iii) Edge Drop – The elevation between shoulder surface and pavement surface which causes pavement edge break (iv) Bush Covered Area – Excessive vegetation on the shoulder surface, obstructs normal surface drainage and damage the structure.

(v) Surface Depression – It accumulates surface water and causes structural failure and (vi) Inadequate Dry

Density – As shoulder acts as an emergency lane, the subgrade soil of shoulder shall be compacted at its maximum dry density.

Now-a-days Artificial Neural Network (ANN) is a widely used prediction tool. A number of simulation works are conducted using ANN [18-21]. In this study, pavement performance models are established using this tool.

The shoulder failure data sets and SCI data sets are used as input parameters and output parameters respectively in ANN programming. The proposed model is developed by using Alyuda Forecaster and EasyNN Plus software. Again an equation is derived using Multi Linear Regression Analysis by SPSS software [22, 23].

For validation of the established models, an extra unknown data-set is run with both the models and result is compared to actual field data. F-Test is carried out for the comparison of the models. It is found that both the models are satisfactory to evaluate SCI. It is also analytically found that the width of shoulder has less impact on SCI than the other distress parameters; whereas edge drop has the highest impact on SCI.

II. LITERATURES

Tarawneh and Sarireh (2013) have examined different factors which are causing severe road deterioration for several years in roads of Jordan and they have assigned rating system from 1 to 5 indicting probable causes of road deterioration [1].

Prasad *et al.*, (2013) have conducted a case study on the PMGSY roads of different districts in Rajasthan, India and established relationship between the roughness and other surface distresses using multiple linear regression analysis [3]. Kumar and Patel (2009) have developed pavement deterioration model based on different distresses and roughness on PMGSY roads of Uttarakhand and Uttar Pradesh States. Regression analysis and ANN have been used to develop the models. Moreover, the maintenance priority index has been developed using three parameters: deflection, roughness and traffic [4]. Ammons and Brinson (2011) have examined the prevalence of street condition ratings among municipalities in North Carolina [17].

Thube (2012) has presented the timely identification of undesirable distress in pavements at network level using pavement management system [20]. Gowda and Shivananda (2018) conducted a case study on maintenance of road shoulder. They have identified some shoulder failures and recommended some maintenance strategies [24].

Most of the researchers have examined pavement distresses and serviceability. Several statistical rating systems: Pavement Condition Index (PCI), Pavement Condition Rating (PCR), Pavement Service Rating (PSR), Overall Condition Index (OCI) etc. are introduced for giving an index number to the carriageway to identify the performance level of pavement. A very few research works are found to identify shoulder failures.

But, there are no rating systems to determine the performance of shoulder sections. Again there is no explanation of the causes and effects of each shoulder failures. Deterioration of shoulder also affects the pavement strength and its serviceability. Therefore, it is necessary to identify the shoulder condition and provide a statistical rating to the shoulder which is referred as Shoulder Condition Index (SCI)

III. CLASSIFICATION OF RURAL ROADS

The rural roads in India are commonly referred to: Ot her District Roads (ODR) and Village Roads (VR). ODRs are the roads serving rural area of production which are providing them access to market centres, taluka headquarters, block development headquarters or major district roads. Village roads are roads connecting villages or cluster/group of villages with each other and to the nearest road of a higher category. These two categories of roads are called as rural roads. Pradhan Mantri Gram Sadhak Yojana (PMGSY) is a central scheme under which different rural roads are constructed in India.

IV. SITE SELECTION

In this study, 32 PMGSY rural roads are selected at different districts of Tripura, India. In each road section (having 200m length) is marked for conducting survey. Though, the failure types and its severity are varying at every location of road section; the failure data is collected at every 20m interval of a section. Roads are selected in such a way that they comprise with almost similar traffic movements, sub grade parameters and surrounding environmental conditions. The road networks details are listed in Table 1. Less numbers of vehicles are plying in all PMGSY rural roads. So, it is observed that AADT (Average Annual Daily Traffic) value is 10 to 15 CVPD (Commercial Vehicle per Day), whereas total numbers of motorised traffic per day (except two-wheeler) is 100 to 120 veh/day. Other general data is shown in Table 2.

V. OBSERVATION AND DATA COLLECTION

The basic failures and drawbacks have been identified on shoulder surface in rural roads. It is observed that only earthen shoulders are provided and these are not maintained properly. As a result severe distresses are observed in the pavement shoulder section. So, a preliminary survey is conducted over the selected roads to find out the general factors effecting on the performance of the shoulder section.

It is already mentioned that the major factors are specified as (i) insufficient surface width (ii) inadequate cross slope (iii) edge drop (iv) bush covered area (v) surface depression and (vi) Inadequate Dry Density. Accordingly, the data collection format is prepared which is shown in Table 3.

Table 1: Details of selected roads to analyze shoulder failures.

S. No.	District	Name of Road	Length (Km)
1.	West District	Assam -Agartala Rd. (Kalabagan) to Joynagar	1.795
2.		Meglipara to Purba Champamura	1.802
3.		T.E.College to Hari Sardar Para	1.538
4.		Bel bari to Jai Krishnapara	6.230
5.	Shipahijala District	Sonamura Rd. to Paschim Nalchar	3.085
6.		Kalapania (Melaghar - Kakraban Rd.) to Debpara	3.868
7.		Sonamura-Boxanagar Rd to Manaimura	5.130
8.		Kalapania to Kamrangatali	6.227
9.	Gomati District	Udaipur to Jampuijala	5.092
10.		Purba Dhajanagar to Pitra Bazar	4.601
11.		Udaipur Kakraban main Road to Tulamura	6.225
12.		Chandraham Para to Maluonrai Para	3.869
13.	Khowai District	Bhati Fatikcherra to Tartara	3.706
14.		Santipara to Berimura	4.808
15.		Agartala-Simna Road to Barmantilla via tufani lunga	4.137
16.		Baishnab Colony (G M Para) to Sarat Thakur Para	4.247
17.	North District	Dharmanagar degree college to Sanicherra	5.585
18.		Ananda Bazar to Harsing Para	3.131
19.		Noagang to Jalabassa	9.993
20.		Dharmanagar (DRBS) to Satsangam	13.124
21.	Unakoti District	Kailashahar murticherra to Landless coloney	1.85
22.		Pecharthal to Laljuri	8.908
23.		DK road to Unakoti Debbarmapara	1.514
24.		Machmara-Karaicherra to Laljuri	10.006
25.	Dhalai District	Chawmanu Govindabari to Thalcherra	2.445
26.		Manu to Chiching Cherra	3.682
27.		Mog Para to Gira Ch. Para	7.924
28.		Dalubari to Ramratan Para	2.201
29.	South District	Dulanbari to Mandaibari	4.327
30.		Karbook-Jatanbari Rd to Bankacherra	2.468
31.		Karbook-Silachari Rd to Bhagaban Tilla	5.645
32.		L044 (UBC Nagar Road) to Nath Para	2.625

Table 2: Variation of the Basic Particulars of the Selected Roads.

Particulars	Variations
Temperature	4ºC – 39ºC
Annual Rainfall	2500 mm – 2570 mm
CBR value of soil	10-30
OMC	14% - 14.5%
Sp. Gr. of subgrade soil	2.6 - 2.7
Total pavement Thickness	170- 220 mm

Table 3: Data Collection Format.

Name of Road: **Date:** **Section No.**											
		Intervals									
S. No.	**Distress Type**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.	Width (m)										
2.	Cross Slope (%)										
3.	Edge drop (m)										
4.	Bush Covered Area (m^2)										
5.	Surface Depression (m^2)										
6.	Dry Density (g/cc)										

A. Shoulder Width

The width of shoulder for rural roads in different terrain can be directly obtained using Table 4 and 5.

As per IRC:SP: 20-2002 rural road manual, shoulder width will be one half the differences between the roadway width and carriageway width.

B. Cross Slope of Shoulder

In order to drain out the surface water rapidly, the cross slope of shoulder should be greater than that of pavement. As per PMGSY road construction guidelines, a cross slope of 1 in 24 is considered as adequate for earthen shoulders. In this study, the surface inclination is measured using straight edge and tape. Surprisingly, it is observed that for all the selected roads, the inclination of the shoulder section is in opposite direction i.e. towards the pavement. As a result, rain water is accommodated at the edge of the pavement section which is very harmful to the structure. In this study, this type of inclination is termed as Negative Slope and considered as a severe shoulder failure.

C. Edge drop

The pavement surface and shoulder surface should be levelled and joined properly. In some of the cases, the thickness of shoulder is not maintained and the surface is not levelled with pavement surface. Again, during the maintenance of pavement section, pavement overlay is applied without raising the shoulder level. As a result, a huge difference is observed between the elevated pavement surface and the shoulder surface. In a long run, the continuous application of traffic load, at the edge of pavement, breaks the pavement structure which further forms a severe pavement failure. So, this is considered as a major structural failure of shoulder and the difference of vertical elevation is measured using ruler at a regular interval.

D. Bush Covered Area

It is observed that some area of the earthen shoulder is covered by bush or small shrubs. The presence of these shrubs is also one kind of shoulder failure as the root zone of the plants enters the sub grade profile and causes structural failure. Also, it prevents the free flow of surface water to drain off. Excessive vegetation along the road also reduces the line of sight for traffic. So, the area covered by bush and shrubs is considered as a drawback of shoulder section. Such type of failure data is collected by measuring the affected area using tape and ruler.

E. Surface Depression

Numbers of depressions are observed on the shoulder section. Such kind of surface depression accumulates rain water which percolates through the pavement layers and causes structural failure of the pavement. Again, this type of occurrence hampers the comfortability of passengers and drivers. It increases roughness and reduces the overall shoulder performance. Thus, surface depression is considered as a major failure occurred on shoulder surface. Usually, it occurs due to insufficient compaction of sub grade layer and excessive rutting by wheel load.

F. Dry Density

The subgrade soil of the carriageway section as well as the shoulder section shall be compacted properly i.e. the MDD value shall not be less than 100 percent of laboratory dry density adopting standard proctor compaction at its maximum dry density. If density is not proper during the compaction of shoulder, a huge settlement will occur after construction of the pavement. In this regard, to know the MDD value (lab), the DPR (Detailed Project Report) is collected from the construction agencies for the selected roads. In many cases, it is observed that compaction is done only in the carriageway portions and the shoulder portion is unmaintained due to the less priority of shoulder construction in rural roads. As shoulder serves as an emergency lane, in some of the roads, it is subjected to high settlement resulting in a huge shoulder drop.

Table 4: Recommended roadway width.

Terrain classification	Roadway width (m)
Plain and Rolling	7.5
Montanious and Steep	6.0

Table 5: Recommended carriageway width.

Terrain classification	carriageway width (m)
Rural roads (ODR and VR)	3.75

VI. EXPERT OPINION SURVEY

An expert opinion survey is carried out to give an authenticable grading to each shoulder section and to provide a stable benchmark to measure the present condition of the shoulder part. Different factors (narrow width, insufficient slope, edge drop, bush covered area, surface depression and inadequate dry density) of an ideal pavement shoulder are listed for rural roads. Total 20 site engineers are invited as experts to evaluate the failure data and to give a rating from 1 to 10 depending on the quality and serviceability of the existing structure. The most ideal section is rated as 10 and the worst condition is rated as 1 and the rests are rated as per their quality from 1 to 10. All the interviewers are experienced engineers in the field of road construction and maintenance work.

VII. ANN STUDY

Now a days, Artificial Neural Network (ANN) is treating as very effectual computational tool for simulation work. The concept of ANN is developed from the Biological Neural System, which is a combination of Dendron, Neuron and Axon. In Biological Neural System, the Dendron receives signals and passes to Neuron, where the signal is processed. And Axons emits the processed signal as output. The same concept is applied in the modeling of Artificial Neural Network. Basically the network consists of three layers- input layer, output layer and hidden layer. Input layer collects the set of input parameters, output layer combines the ultimate cumulative findings and the hidden layer contains the information processing nodes.

Different mathematical computations are measured in hidden layer in a trial and error basis, and the most appropriate result is processed through output layer. For developing a particular network model, it is required to train the model with known input and output layer to compute the mathematical analyses through trial and error basis. After training the model with known data parameters, the network model will be ready for test analyse.

SUMMARY
7 columns and 320 rows were analysed
0 columns and 3 rows were removed
6 data input columns were converted to 6 neural network input columns
Neural network used 6 input columns and 215 rows for its training.
Data Cleaning
3 values recognized as outlier.
Data Transformation
The following numeric columns were scaled:
WIDTH with Scale Factor = 0.8,
EDGE DROP with Scale Factor = 0.8,
CROSS-SLOPE with Scale Factor = 0.8,
DRY DENSITY with Scale Factor = 0.8,
BUSH COVERAGE with Scale Factor = 0.8,
SURFACE DEPRESSION with Scale Factor = 0.8,
SCI with Scale Factor = 0.01197.
Data Subset Selection
Training subset (67.82%): 215 randomly selected records.
Validation subset (16.09%): 51 randomly selected records.
Test subset (16.09%): 51 randomly selected records.

Fig. 1. Data Preparation Result.

NETWORK PREPARATION RESULTS

Network Topology
Network type: feed-forward fully connected network.
Number of inputs: 6
Number of hidden layers: 1
3 hidden units in the 1st hidden layer.
Number of outputs: 1
The topology was selected manually by user.
TRAINING ALGORITHM AND PARAMETERS
Training algorithm: Quick propagation.
Learning rate: 0.1
Quick propagation coefficient : 1.75
Best network was retaining and restored.
NUMBER OF RETRAINS
Network was trained 1 times.
Stop Training Conditions
MSE on training subset must drop below 0.01
Minimum improvement in error must be 0.0000001 during last 10 iterations.
Maximum allowed number of iterations: 1000
Training stop reason: error reduction became too low.
Training Results
Training subset.
Maximum absolute error: 0.4618
Minimum absolute error: 0.00097
Average absolute error: 0.10128
Average MSE: 0.01659
Test subset.
Maximum absolute error: 0.40417
Minimum absolute error: 0.00129
Average absolute error: 0.10447
Average MSE: 0.018

Fig. 2. Network Preparation Result.

VIII. ANN ANALYSIS

As data collections are done at every 20m interval on each road section of 200m stretch. Therefore, for each section total 10 nos of observation sets are taken. Accordingly, for 32 roads, 320 nos of data sets are recorded. To conduct ANN analysis, it is required to train the software with a known input and output dataset. Once the model is established with known parameters, the model will be ready to perform with testing datasets. More the number of training data sets, the accuracy level of the model will be more. Accordingly, it is required to divide the whole data set into two groups i.e. training data sets and testing data sets. Out of the 320 data sets, almost 67.82% data sets (215 nos of data sets) are taken to train the artificial network. Among the remaining 32.18% data subset; almost 16.09% data sets (51 nos of data sets) are taken as validation data subset and rest 16.09% data sets (51 nos of data sets) are taken as test data subset. The divisions of training, validating and testing data sets are randomly done by the software itself. Here two different analytical softwares are used to grow the ANN network i.e. Alyuda Forecaster and EasyNN Plus. Results of both the networks are almost symmetrical and the more accurate network is selected and granted for testing. The established model is saved in ".fnn" format and it can be further used to determine SCI. A detail of the data preparation result is shown in Fig. 1 and a detail of the Network Preparation result is shown in Fig. 2. The Network diagram of the proposed model is shown in Fig. 3.

Using EasyNN Plus, a sensitivity analysis is conducted to determine the effect of each input parameter (Each failure types) on the output parameter (SCI). It is found that edge drop has the highest effect on SCI than other parameters and it is numbered as 0.6448 by the network. Whereas, Width of the Shoulder has the lowest effect on SCI and it is numbered as 0.1758 by the network. The result is shown in Fig. 4.

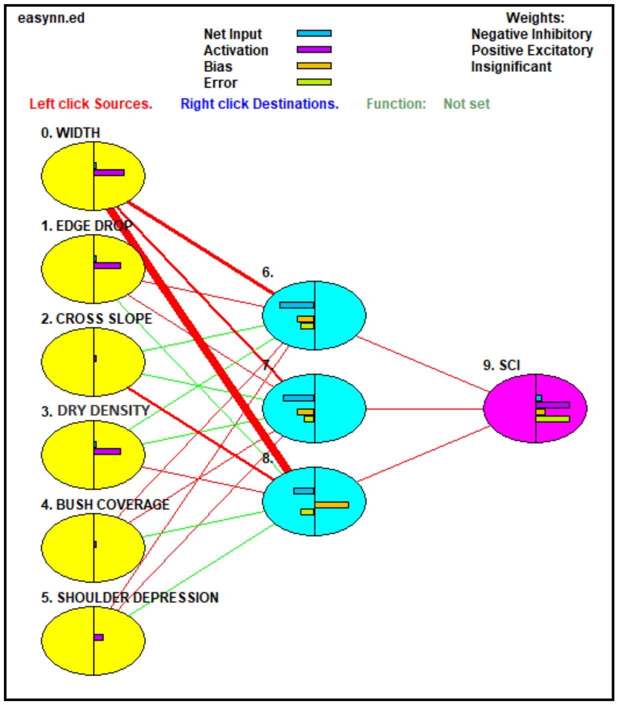


Fig. 3. Network Diagram.

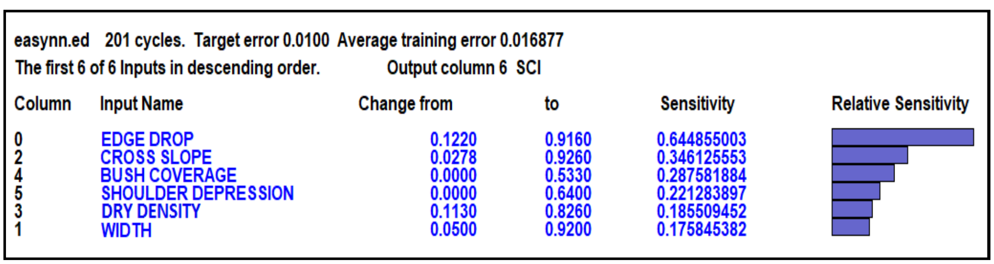


Fig. 4. Sensitivity Analysis.

IX. REGRESSION ANALYSIS

Regression Analysis is used for estimating relationship among variables and predicting some occurrence. In this study, Multi Linear Regression Analysis is carried out using SPSS Software. Various factors: shoulder width, cross slope, edge drop, bush covered area, surface depression and Dry Density value are used as input variables, whereas the Shoulder Condition Index (SCI) is used as output variable. The equation is established to determine SCI with R^2 value of 0.68. The results are mentioned in Tables 6-8.

SCI = 2.52 + 2.22 × 1-3.168 × 2 – 3.78 × 3 + 0.1 × 4 – 0.9 × 5 – 0.232 × 6 (1)

where, SCI= Shoulder Condition Index;

X_1= width;

X_2= edge drop;

X_3= cross slope;

X_4= Dry Density value;

X_5= bush covered area;

X_6= surface depression

The impact of each distress parameter on Shoulder Condition Index is analyzed. Fig. 5 (a) shows the graph between SCI and Shoulder Width. Here the increased width of shoulder improves lateral support and the value of SCI is increasing. Fig. 5(b) shows the graph between SCI and Edge Drop. As edge drop weakens the edge of pavement, it reduces overall SCI.

Similarly, Fig. 5(c) shows the graph between SCI and Cross Slope. As the slope is in opposite direction, it is harmful to surface drainage purpose of the road. Thus, it reduces SCI value. Fig. 5(d) shows the graph between SCI and Dry density value. SCI increases with the increase of dry density of subgrade soil of shoulder. The Fig. 5(e) and (f) show the graph of SCI with Bush Coverage and Surface Depression. Both the trend lines are in reducing direction i.e. both the parameters adversely affect the SCI.

Table 6: Significance of the input parameters in Regression Analysis.

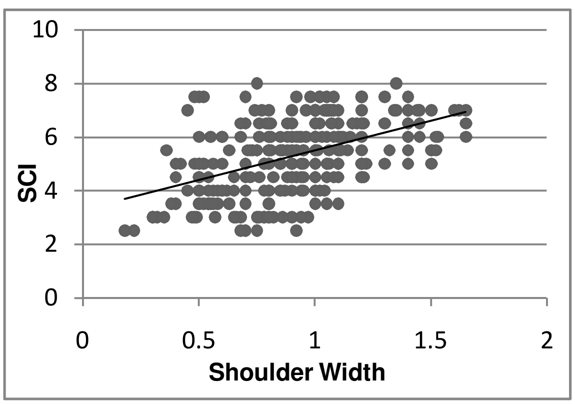
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.521	0.233		10.835	0.000	2.063	2.979
	WIDTH	2.228	0.168	0.488	13.232	0.000	1.896	2.559
	EDGE_DROP	-3.168	1.083	-0.104	-2.925	0.004	-5.299	-1.037
	CROSSSLOPE	-3.780	1.304	-0.103	-2.899	0.004	-6.345	-1.215
	DRY DENSITY	0.102	0.008	0.421	12.649	0.000	0.086	0.118
	BUSH_COVERAGE	-0.904	0.168	-0.198	-5.375	0.000	-1.236	-0.573
	SURFACE_DEPRESSION	-0.232	0.025	-0.300	-9.300	0.000	-0.282	-0.183

Table 7: Model Summary.

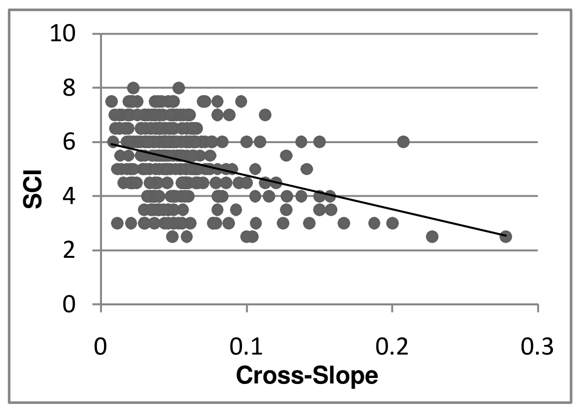
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.827[a]	0.684	0.678	0.75053	0.684	113.034	6	313	0.000

Table 8: ANOVA.

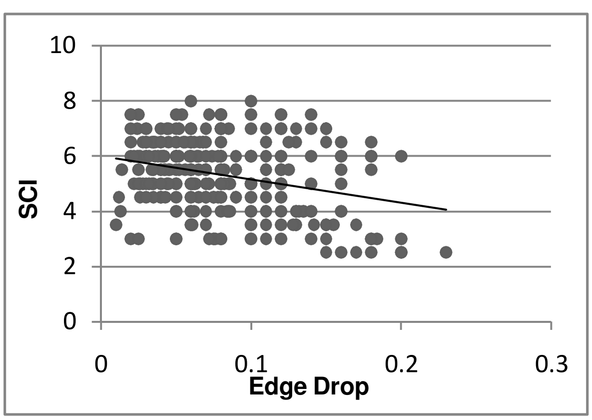
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	382.031	6	63.672	113.034	0.000[b]
	Residual	176.312	313	0.563		
	Total	558.343	319			



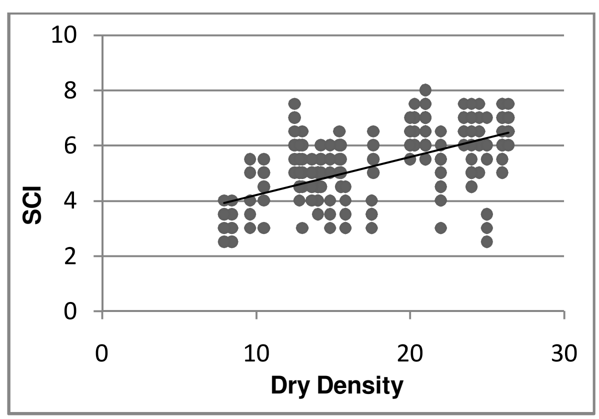
(a) Impact of Shoulder Width.



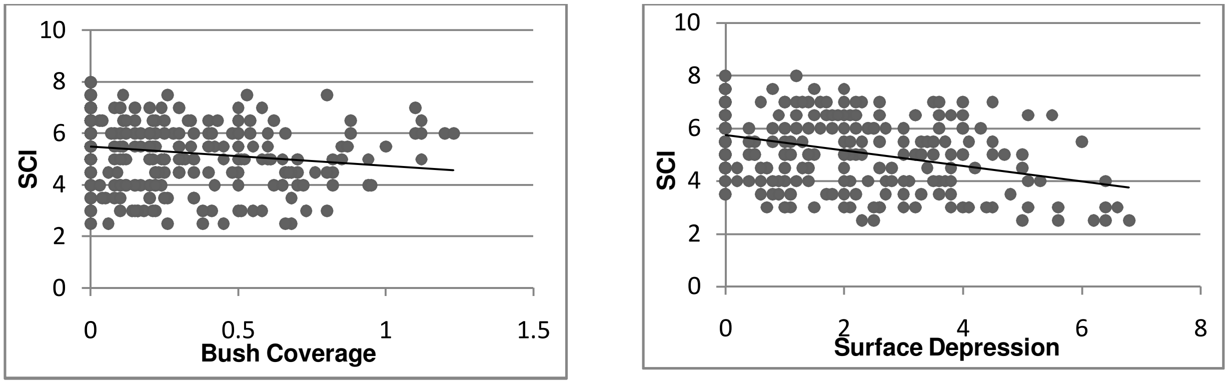
(c) Impact of Cross Slope.



(b) Impact of Edge Drop.



(d) Impact of dry density.



(e) Impact of Bush Covered Area

(f) Impact of Surface Depression.

Fig. 5. Impact of each distress parameter on SCI.

X. VALIDATION

The results of Regression Analysis and Artificial Neural Network models are validated by forecasted result & actual survey data. Another 20 data sets are run through the equation developed by regression analysis as well as the artificial neural network model and the output parameter, SCI, is predicted. The predicted result is shown in Table 9. The Bar diagram of the result is shown in Fig 6. To compare both the predicted results & actual survey data, RMSE is calculated. It is found that RMSE values are 0.5149 & 0.5318 for regression and ANN respectively. F test is also conducted. Results are satisfactory. Details of the tests are shown in Table 10 and 11.

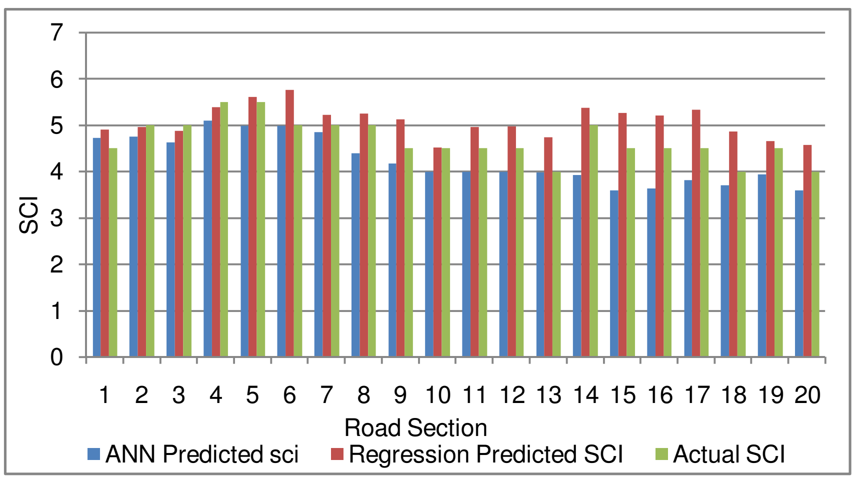


Fig. 6. Comparison of actual values and the predicted values.

Table 9: Comparison of Regression Analysis and Artificial Neural Network Results with Actual Data.

ANN Predicted SCI	Regression Predicted SCI	Actual SCI
4.73	4.90453	4.5
4.76	4.9654	5
4.63	4.8802458	5
5.1	5.381616	5.5
4.99	5.604516	5.5
4.99	5.7624792	5
4.85	5.227941	5
4.39	5.25292	5
4.17	5.13144	4.5
4	4.52646	4.5
3.99	4.9651852	4.5
3.99	4.976234	4.5
3.98	4.74032	4
3.93	5.37653	5
3.6	5.259932	4.5
3.64	5.2086694	4.5
3.82	5.32612	4.5
3.71	4.8635712	4
3.94	4.6606154	4.5
3.6	4.5790098	4

Table 10: Result of F-Test comparing Actual SCI and predicted SCI using Regression Analysis.

F-Test Two-Sample for Variances		
	Variable 1	**Variable 2**
Mean	4.675	5.079687
Variance	0.191447	0.109843
Observations	20	20
df	19	19
F	1.74292	-
P(F<=f) one-tail	0.117506	-
F Critical one-tail	2.168252	-

Table 11: Result of F-Test comparing Actual SCI and predicted SCI using ANN.

F-Test Two-Sample for Variances		
	Variable 1	**Variable 2**
Mean	4.675	4.2405
Variance	0.191447368	0.263131316
Observations	20	20
df	19	19
F	0.727573485	-
P(F<=f) one-tail	0.247403888	-
F Critical one-tail	0.461201089	-

XI. DISCUSSION

All the failures found in the shoulder sections in this study, are the result of lack importance in shoulder structure. All these failures affect the overall shoulder performance. Among these shoulder failures, edge drop affects the shoulder performance more. It creates a high elevation with pavement surface and may lead to severe accidents. The analytical tool shows satisfactory results to evaluate Shoulder Condition Index with F value 1.74 for Regression Analysis and 0.72 for ANN.

XII. CONCLUSION

In this study, a prediction model is developed to determine Shoulder Condition Index (SCI) of rural roads. The key findings of the study are expressed as follows:

– The major factors are found viz. narrow width, insufficient cross slope, bush covered area, surface depression, edge drop and inadequate density. All these factors have a vital role on the performance of pavement shoulder.

– A model (SCI = 2.52 + 2.22 × 1 – 3.168 × 2 – 3.78 × 3 + 0.1 × 4 – 0.9 × 5 – 0.232 × 6) is established to determine SCI using ANN and Multi Linear Regression.

– ANN model and Regression equation are validated by comparing the predicted results with original field data. The RMSE values for the predicted results are 0.5149 and 0.5318 for Regression Equation and ANN model respectively. F Test is also conducted to validate the results.

The F values are 1.74 and 0.7275 for Regression Equation and ANN model respectively. Therefore, both the models are suitable to evaluate shoulder condition index.

– It is also observed that edge drop has more effect on SCI compared to the other factors; whereas the shoulder width variation has the lowest effect on SCI.

XIII. FUTURE SCOPE

Some future recommendations of this present work may be suggested as per the following points:

– The evaluation process in the study is conducted for pavement shoulder, which may be extended for other road assets.

– The characteristics of roads, selected in the study are limited and a variation in the analysis can be done by changing the road particulars.

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