# Development of Maintenance Management System by Functional Evaluation for Rural Roads in Himachal Pradesh

**Aakash Gupta, Ashok Kumar Gupta, Ashish Kumar**

***Abstract- Rural roads in Himachal Pradesh play a significant role in the economic and social development of the state in India. About 79% of the total length of the roads has been contributed by rural roads in Himachal Pradesh. The maintenance of this vast network of rural roads is challenging for the authorities of state highways. Also, the funds required for their periodic or daily maintenance are not in abundance, hence proper maintenance strategies are required to use the resources in a proper manner. The present study deals with the development of maintenance management plan of the rural road network in Himachal Pradesh. The pavement evaluation is required at regular intervals to determine the pavement performance and plan strategies accordingly. Pavement Evaluation can be done in two ways- Functional Evaluation and Structural Evaluation. The functional evaluation deals with the pavement distresses and pavement riding comfort i.e. roughness of the pavement and structural evaluation deals with the structural properties of the pavement i.e. pavement deflection, modulus reaction etc. In the present study functional evaluation is considered in which various pavement distresses have been studied which mainly prevails on the rural roads of Himachal Pradesh. Along with pavement distresses, skid resistance and mean texture depth has also been studied in the current study. Six sample road sections have been selected to conduct the study in the region of Shimla and Solan districts. The distress and roughness data has been collected on the selected stretches for a length of 2.5 km each. The 2.5 km length has been selected for conducting the tests on each road as the stretch represents the whole length of the road in respect of climatic factors and traffic volume. The study also aims at developing a mathematical model to predict the pothole volume using mean diameter and maximum depth of pothole as input parameters. It has been found that a non-linear model predicts a good value of volume of pothole with coefficient of determination i.e. $R^2$ = 0.85 which shows a very good correlation between observed volume and estimated volume of potholes.***

***Index Terms: Functional Evaluation, Distresses, Potholes, Regression***

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## I. INTRODUCTION

Every highway asset mainly the pavement structure that has been constructed deteriorates with passing time. Therefore it is important that these built structures, like in case of flexible pavements, are assessed periodically to evaluate their present condition and furthermore to assess the rest of the life of the roads and the amount of additional time the road can be used by the people effectively.
Thus, there must have some devices to assess pre-existing condition of the pavements, gather some reasonable data and to use the information which is acquired with a motive to increase the durability and improve the condition of pavements.

### A. Factors Affecting Pavement's Performance

- **Traffic**: Traffic is one of the main factor which affects pavement performance. The axle load spectrum, wheel load repetitions, axle configurations, classified traffic volume all affects the performance of pavement.
- **Moisture**: Moisture is the main cause of any pavement failure. It is the topmost enemy of any pavement which leads to complete disruption of pavement. The presence of moisture decreases particle interlocking and leads to particle displacement in the form of uneven settlement and various other distresses.
- **Subgrade**: The subgrade is the lifeline of any pavement because all the wheel load is ultimately borne by the lower most layer of pavement i.e. subgrade layer. The California bearing ratio (CBR) value of subgrade is the indicator of load bearing capacity of subgrade. The distresses like rutting, reflection cracking etc occurred due to low bearing capacity of subgrade which directly affects pavement performance.
- **Quality of Construction**: The construction quality plays an important role in performance of pavements. The use of good quality aggregates and binder material leads to good durability of pavements. The thickness of pavements should be strictly adhering with the IRC code provisions and quality check should be done at regular intervals.
- **Maintenance**: The maintenance of pavement at regular intervals leads to good performance in long run. If any pavement is deferred corresponding to any maintenance activity then it will lead to huge economic loss as well as poor pavement performance. Various distresses can be minimized if proper maintenance is done at required time intervals.

### B. Functional Evaluation

Functional Evaluation is the diagnosis or analysis of exterior surface conditions of the pavement. The assessment of pavements is needed in order to apply timely maintenance strategies. The various distresses present on a pavement are uncertain in nature and their progression is inevitable if proper maintenance is not done. Non-destructive technique is used in functional evaluation of pavements. Functional Evaluation mainly deals with pavement distress evaluation and riding quality evaluation. Further, riding quality evaluation involves Roughness evaluation and Safety evaluation.

### C. Functional Evaluation: Parameters

**Roughness**: Pavement Roughness as shown in Fig. 1 is one of the indicators of comfort quality of road users. It is defined as the undulations caused in vertical direction in the smoothness profile of pavement with respect to its planar surface. It is an undesirable deviation which affects the riding quality. It can be measured using various equipments such as Bump Integrator, MERLIN etc. The unit of measurement are m/km, mm/km etc.

**Fig.1: Roughness**

**Rut Depth**: Rutting is defined as the longitudinal depression caused along the wheel path of vehicles due to repeated movement. It can be measured using straightedge as shown in Fig. 2. It mainly occurs due to low load carrying capacity of the subgrade and subsequent layers of flexible pavement.

**Fig. 2: Rut Depth/Rutting**

**Skid Resistance:** Skid Resistance is the force developed when the tyre and pavement surface are in contact with each other to restrict the rotation of wheels which is opposite to the direction of motion after the application of brakes. Skid resistance is different in both the conditions when the surface is dry and wet. Skid Resistance of pavement surface can be measured using Skid Resistance Pendulum Tester Machine.

**Macro-Texture:** Surface texture of pavement is defined as the deviation of pavement surface with respect to its true planar surface. Skid resistance is a function of macro-texture which affects the resistance at high speeds on wet surface. Abrasive action of traffic leading to wearing and tearing of binder material is the main cause of inadequate depth of macro-texture.

**Pot Holes:** Potholes as shown in Fig. 3 are the bowl shaped depressions formed on the surface of pavements due to regular dislodgement of aggregate particles. These are localized distress which majorly affects the riding quality of road users. The potholes should be maintained timely because with time the severity level increases and may be hazardous to traffic movements.

**Fig. 3**: **Pothole Depression**

**Patching**: Patching as shown in Fig. 4 is defined as an aid provided or repair work done on pavement in order to treat any localized distress like pothole, raveling etc. However, a patching itself comes into a category of distress because it also affects the riding quality of vehicles.

**Fig. 4: Patching at RR-1**

**The objectives of the current study are as follows:**

1. To rate the pavement sections based on pavement distresses such as cracking, patching, potholes and their relative weightages and on the basis of IRI values determined by MERLIN.
2. To develop a mathematical relation using regression analysis to predict volume of pothole using mean diameter and maximum depth of volume as input parameters.

## II. LITERATURE REVIEW

**S. Chandra et al (2013)** proposed a relationship between Roughness and the various pavement Distress Parameters. The roughness and visual distress data was collected by using Network Survey Vehicle (NSV). Various models have been developed using linear, non-linear regression and Artificial Neural Network Technique. The study indicated that the ANN model yields a better forecast of road roughness for a provided set of distress parameters as compared linear and non-linear regression analysis.
**J.R. Prasad et al (2013)** also tried to develop Relationship amongst IRI and Visual Surface Distresses. Bump integrator was used to get the desired data. An equation amongst visual surface distresses and IRI Index values was developed.
**Y. U. Shah et al (2013)** developed overall pavement condition index to prioritize the maintenance strategies. The method includes determination of road surface portions, collection of pavement distresses, development of individual distresses index for a particular parameter and in the end developing a combined overall index. The four performance indices i.e. PCI Distress, PCI Roughness and PCI Skid Resistance have been developed on an individual basis.
**Jay N. Meegoda and Shengyangao (2014)** evaluated the time-sequence information of roughness to GPS information so as to develop a model to predict the progression of pavement roughness over pavement age. The developed deterioration curve was developed and normalized. The study mainly aimed to develop cost-effective treatment techniques for maintenance of pavement.
**Amer Abdulaziz Mustafa et al (2015**) developed relation amongst Functional and Manual condition of pavements. The study aimed at evaluation of the outcome of relating pavement condition index represented by UDI. Based on the type of distress, a relation has been set between the function evaluation like IRI and SR factor for a particular section of a pavement or recommendation to use the strategies so as to minimize the expenditure of money and precious time.
**Mubaraki Muhammad (2010)** carried out a research on the information of roughness index. A relationship between pavement distresses and IRI has been studied. The results indicate that a significant relationship exists between the factors with confidence level: 95. Also there was no significant relation between rutting and International Roughness Index. It can be deduced from the results that raveling and cracking can be taken as ride distress, whereas rutting can be represented as non-riding distress.
**Francisco Dalla Rosa and Nasir G. Gharaibeh (2017)** worked on the development of IRI prediction model along with the validation process especially for low to medium traffic loading conditions. The traffic conditions were mainly focused when compared to other distress parameters.
**A I Setianingsih et (2017)** showed that by providing the importance to the road maintenance at comparatively better conditions are economical. Recommendation of maintaining the road with good conditions was also setup.
**Hermawan et al (2017)** used IRI and Structural Number (SN) parameters for the maintenance and repairment purpose. Roughness along with the SN value data was collected using RoadRoid android application and internet dependent Geography Information System. This study predicted roughness value too.
**Prasanna Kumar R et al (2017)** evaluated the pavements based on both functional evaluation and structural evaluation parameters. The research studied the preexisting portion of a selected road from Budalur to Pudupatti and the analysis of various types of undulations data.

## III. METHODOLOGY

### A. Selection of Rural Road Stretches

Six roads have been selected in the vicinity of Shimla and Solan district for the functional evaluation as given in Table 1. The length of each road has been taken as 2.5 km to conduct the various testing. The 2.5 km length has been selected keeping in mind that the selected 2.5 km road stretch depicts the full length of the road in terms of traffic volume and climatic factors. Each selected road has been divided into sections of 50 m to determine the measurements of various distresses. The maps of selected rural road stretches have been shown in Fig. 5 and Fig. 6.

**Table 1**: Selected Rural Roads

| Road ID | Name of the road |
|---|---|
| RR-1 | Domehar_Wakna_Road |
| RR-2 | Kyari_Bangla_Road |
| RR-3 | Industrial_Road |
| RR-4 | Salana_Road |
| RR-5 | Shoghi_Lagroo_Road |
| RR-6 | Nain_Basal_Road |


**Fig. 5**: Selected Rural Roads

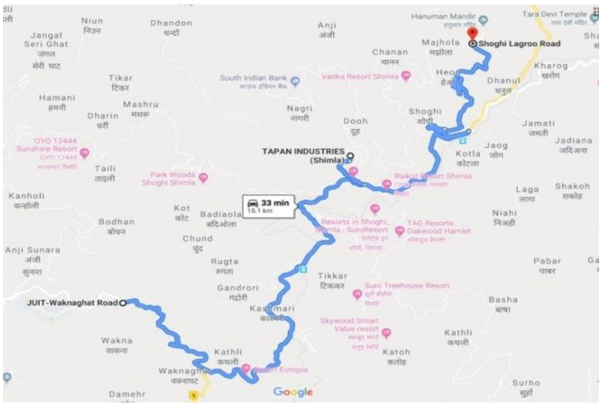


**Fig. 6**: Selected Rural Roads

## B. Measurement of Pavement Distresses

Pavement Distresses are basically the defects on the pavement which are easily visible to naked eye. There are various types of distresses such as raveling, cracking, patching, potholes, delamination, rutting, bleeding etc but in the present study, the distresses which are common on the selected rural road stretches has been taken into account. Hence, cracking, patching, potholes and rutting has been studied and measured in the present study.

## C. Measurement of Rutting

Rutting is defined as the longitudinal depression caused along the wheel path due to repeated movement of vehicles on the same path. In the present study, rutting has been determined by using the 3-m straightedge as shown in Fig. 7 which determines the rut depth. However, rutting has not been found on most of the segments of selected road stretches.

**Fig. 7**: Rutting

## D. Measurement of Volume of Potholes

The volume of potholes has been measured by replacing the known volume of sand with the bowl of pothole as shown in Fig. 8. This method of determining the pothole was very cumbersome and needs manpower, hence to eradicate such practice a mathematical model has also been found to determine the volume of pothole. Apart from determining the volume of pothole, the mean diameter and maximum depth of pothole has also been recorded corresponding to each volume of pothole. The volume of pothole has been correlated with the mean diameter and maximum depth of pothole in the present study.


**Fig. 8**: Volume Determination by Replacing Sand with Bowl of Pothole

## E. Measurement of Patching

Patching which is commonly used to undermine any distress on pavement has been measured using simple measuring tape. Normally, the patching is done in rectangle shape or square shape, consequently making it easier to calculate the area of patching. The sample of patching on RR-6 is shown in Fig. 9.


**Fig. 9:** Sample Patching on RR-6

## F. Measurement of Cracking

Various types of cracking such as longitudinal cracking, transverse cracking, alligator cracking, fatigue cracking, edge cracking, reflection cracking etc has been found on the selected rural road stretches.

The cracked portion of the roads has been measured using a simple measuring tape converting the area in approximately a rectangle or a square area which makes it easy to calculate the area. All the different types of cracking have been summed up to determine the final cracked area of each particular road.
Various types of cracking that has been found on the selected rural roads are shown in Fig. 10 – Fig. 12.

**Fig. 10**: Sample of Longitudinal cracking

**Fig. 11**: Sample Transverse cracking

**Fig. 12: Sample Alligator cracking**

## G. Rating of Pavement Sections

The distress data has been collected on the selected rural road stretches. The distress parameters i.e. cracking, potholes and patching have been mainly found on the selected rural roads. Each pavement section has been rated based on the rating system given in IRC: 82-2015 as shown in Table 2. The weightage to each distress parameter is also given in Table 3 which determines the importance of each distress corresponding to its severity in maintenance strategies or pavement performance. The distress data collected on each road stretch has been converted into percentage by dividing the total area of distress to the total area of pavement section. The average of all the ratings of each selected rural road has been depicted as final rating of that particular road stretch.

**Table 2:** Pavement Performance Rating based on Distress

| Distress (%) | Range of Distresses | | |
|---|---|---|---|
| Cracking | > 20 | 10 to 20 | < 10 |
| Potholes | > 1 | 0.5 to 1 | < 0.5 |
| Patching | > 20 | 5 to 20 | < 5 |
| Rating | 1 | 1.1 to 2 | 2.1 to 3 |
| **Condition** | **Poor** | **Fair** | **Good** |

**Table 3:** Weightage of Distresses

| **Distress** | **Weightage corresponding to Maintenance** |
|---|---|
| Cracking | 1 |
| Pothole | 0.5 |
| Patching | 0.75 |

## H. Measurement of International Roughness Index

International Roughness Index is a measure of the smoothness of the road which in turn helpful in strategizing the maintenance activities needed. The roughness index of the roads is basically the summation of undulations caused in the comfort ride of road users due to the presence of various pavement distresses such as cracking, raveling, potholes etc. Various equipments can be used to determine the roughness index such as bump integrator, network survey vehicle etc but in the present study MERLIN i.e Machine for Evaluating Roughness with Low-cost Instrumentation has been used to determine the IRI value in mm/km. MERLIN has been used because its economical and easy to use as compared to other equipments.
The device as shown in Fig. 13 and Fig. 14 consists of a probe which is attached to a moving pointer on a graph paper placed on the top so that when probe rests on the ground its corresponding displacement of pointer on graph paper is recorded and a cross is marked in the box of graph paper at each point where reading has to be taken. The process is continued till 200 cross marks has been obtained on graph paper. The D-value has been calculated from the graph by excluding 5% of the cross marks from each side of the graph. The calculated D-value is used to arrive finally on IRI value in mm/km using following equation recommended by the TRL:

$$IRI = 0.593+0.0471*D$$

Where, IRI = International Roughness Index in mm/km
D = D-value in mm

The same procedure has been conducted on all the selected rural road stretches and finally after taking the average of all the readings IRI has been obtained.

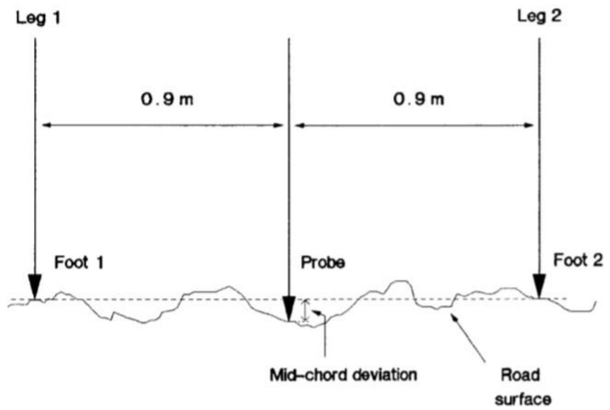


**Fig. 13**: Working Principle of MERLIN

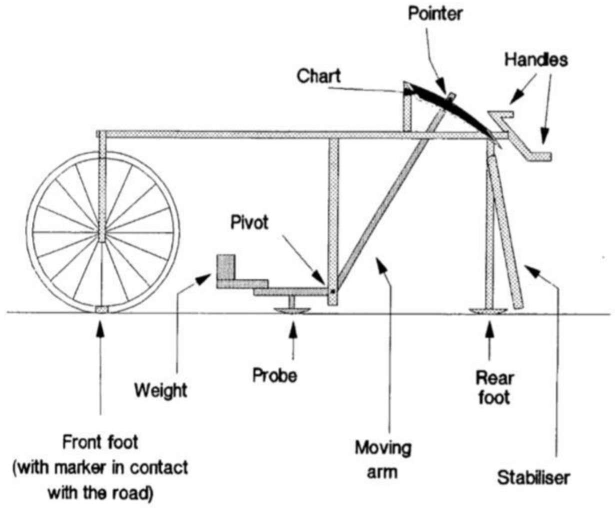


**Fig. 14**: **Component parts of MERLIN**

The pavement can be categorized using the IRI values as suggested by IRC: 82-2015 and shown in Table 4.

**Table 4**: Relationship between IRI and condition of the pavement

| Range of IRI (m/km) | Categorization of Pavement |
|---|---|
| < 2.5 | Excellent |
| 2.5 - 4 | Very good |
| 4 - 6 | Good |
| 6- 8.5 | Fair |
| 8.5- 13.5 | Frequent undulations |
| 13.5- 16.5 | Rougher surface |
| 16.5-22.5 | Very rough surface and unsatisfactory ride |

## I. Measurement of skid resistance

Skid Resistance is the measure of resistance force which a pavement applies on wheels or restricts the rotation of wheels after the application of brakes. Skid Resistance is measured using Skid Resistance Tester as shown in Fig. 15 in which a pendulum arm is allowed to fall freely under the action of gravity along with reading pointer as a result of which the rubber slider provided at the bottom of pendulum touches the pavement surface and provides a reading known as skid resistance number. It is an easy method to determine the frictional properties of any pavement. The skid resistance tester is leveled by adjusting its legs before conducting the test. Also, the pendulum arm has been checked and lowered such that the rubber slider just touches the top surface of pavement. The test is conducted both on wet and dry surface of pavement.

The test has been conducted at an interval of 100 m on each selected rural road stretches in Himachal Pradesh. The standard minimum resistance value suggested by TRL has been shown in Table 5.

**Fig. 15**: Sample Data Collection using Skid Resistance

**Table 5**: Minimum Skid Resistance Value suggested by TRL

| Category | Type of Road Section | Minimum Value (Wet-Surfaces) |
|---|---|---|
| A | Rotaries/Roundabout | 65 |
| B | NH/SH | 55 |
| C | All other surfaces | 45 |

## J. Measurement of macro-texture

Macro-Texture of Pavement Surface directly affects the skid resistance value due to exposure of aggregates due to rubbing action of wheels on the top surface of pavements. The mean texture depth (MTD) has been obtained on each selected rural road stretch using Sand Patch Apparatus Method as shown in Fig. 16 following standard codal provision given in ASTM E965.

The fine sand of Grade 2 with natural silica sand has been used in the present study to conduct sand patch method which has been spread in a circular sophisticated manner using 64 mm round rubber disc having 16 mm rubber thickness. The pavement surface having aggregates exposure gets filled due to gradual load applied using circular rubber disc up to its peak level. The mean diameter is measured after taking four sample of diameter reading in each direction. The mean texture depth (MTD) value in mm can be determined using the following relation-

MTD (Mean Texture Depth in mm) =

Volume of sand used / Area of circular patch

.

**Fig. 16**: Sample of Sand Patch Method

## IV. RESULTS

The MERLIN test results used to determine International Roughness Index is shown in Table 6. Six readings of D value has been taken on each selected road stretch and after taking the average of D-values the final IRI has been arrived for each road stretch and the condition of road has also been suggested on the basis of IRI values.

**Table 6.** Pavement Performance on Basis of IRI

| Section | D-value (mm) | Average value of D (mm) | IRI (m/km) | Pavement Condition |
|---|---|---|---|---|
| **RR-1** | | | | |
| 1 | 120.820 | 106.841 | 5.619 | Good surface profile |
| 2 | 64.167 | | | |
| 3 | 113.323 | | | |
| 4 | 142.252 | | | |
| 5 | 112.263 | | | |
| 6 | 88.188 | | | |
| **RR-2** | | | | |
| 1 | 82.858 | 116.67 | 6.091 | Fair surface profile |
| 2 | 91.143 | | | |
| 3 | 121.251 | | | |
| 4 | 138.760 | | | |
| 5 | 122.362 | | | |
| 6 | 143.630 | | | |
| **RR-3** | | | | |
| 1 | 106.120 | 142.40 | 7.302 | Fair surface profile |
| 2 | 145.823 | | | |
| 3 | 123.332 | | | |
| 4 | 175.680 | | | |
| 5 | 158.621 | | | |
| 6 | 144.363 | | | |
| **RR-4** | | | | |
| 1 | 70.841 | 71.19 | 3.951 | Very good surface profile |
| 2 | 61.881 | | | |
| 3 | 64.749 | | | |
| 4 | 70.419 | | | |
| 5 | 82.349 | | | |
| 6 | 77.138 | | | |
| **RR-5** | | | | |
| 1 | 101.668 | 116.59 | 6.091 | Fair surface profile |
| 2 | 115.100 | | | |
| 3 | 122.918 | | | |
| 4 | 137.495 | | | |
| 5 | 94.361 | | | |
| 6 | 128.537 | | | |
| **RR-6** | | | | |
| 1 | 155.841 | 153.88 | 7.838 | Fair surface profile |
| 2 | 154.005 | | | |
| 3 | 160.011 | | | |
| 4 | 152.078 | | | |
| 5 | 146.229 | | | |
| 6 | 155.199 | | | |

The selected six rural road stretches has been rated based on the distress based rating system as per IRC 82:2015. The final rating of each selected rural road has been determined based on weighted rating values and all the corresponding results is shown in Table 7- Table 12.

**Table 7**: Pavement Rating on basis of Distress (RR1)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 3.34 | 2.44 | 1 | 2.44 |
| Net Patching | 1.68 | 2.29 | 0.75 | 1.72 |
| Net Pothole | 0.02 | 2.08 | 0.50 | 1.04 |
| Final rating | | | | **1.74** |
| **Road condition** | | | | **FAIR** |

**Table 8**: Pavement Rating on basis of Distress (RR2)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 0.714 | 2.173 | 1 | 2.173 |
| Net Patching | 0.115 | 2.115 | 0.75 | 1.586 |
| Net Pothole | 0.0006 | 2.108 | 0.50 | 1.054 |
| Final rating | | | | **1.62** |
| **Road condition** | | | | **FAIR** |

**Table 9**: Pavement Rating on basis of Distress (RR3)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 0.034 | 2.104 | 1 | 2.104 |
| Net Patching | 0.001 | 2.102 | 0.75 | 1.576 |

| | | | | |
|---|---|---|---|---|
| Net Pothole | 0.005 | 2.102 | 0.50 | 1.051 |
| Final rating | | | | 1.59 |
| **Road condition** | | | | **FAIR** |

**Table 10**: Pavement Rating on basis of Distress (RR4)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 0.748 | 2.177 | 1 | 2.177 |
| Net Patching | 1.848 | 2.284 | 0.75 | 1.715 |
| Net Pothole | 0.0009 | 2.104 | 0.50 | 1.052 |
| Final rating | | | | 1.66 |
| **Road condition** | | | | **FAIR** |

**Table 11**: Pavement Rating on basis of Distress (RR5)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 0.252 | 2.126 | 1 | 2.126 |
| Net Patching | 0.246 | 2.127 | 0.75 | 1.595 |
| Net Pothole | 0.005 | 2.110 | 0.50 | 1.055 |
| Final rating | | | | 1.60 |
| **Road condition** | | | | **FAIR** |

**Table 12**: Pavement Rating on basis of Distress (RR6)

| Distress | Input(%) | Rating | Weightage | Weighted rating value |
|---|---|---|---|---|
| Net Cracking | 1.010 | 2.212 | 1 | 2.212 |
| Net Patching | 0.710 | 2.169 | 0.75 | 1.627 |
| Net Pothole | 0.002 | 2.102 | 0.50 | 1.051 |
| Final rating | | | | 1.64 |
| **Road condition** | | | | **FAIR** |

## V. Development of Pothole Volume Prediction Model

Attempts have been made to generate a prediction mathematical model which can predict the volume of pothole when physical dimension parameters of potholes i.e. mean diameter and maximum depth of pothole are given as input parameter. As many as 77 pothole data has been collected which includes pothole volume determined by using sand replacing the bowl of pothole, mean diameter and depth of pothole. 80% of the pothole data has been used to generate the regression model and remaining 20% has been used for testing. Linear regression model and non-linear regression model has been generated and it has been found that non-linear model predicts better results than linear model. The $R^2$ value i.e the coefficient of determination of 0.85 as shown in Fig. 17 has been achieved in case of non-linear model which shows a good model prediction. The non-linear model has been presented in Eq. 1.

$$PV = \alpha_1 + \alpha_{2*} (MDP)^{\alpha 3} - \alpha_4 (DP)^{\alpha}{}_5 \qquad \text{...........(Eq. 1)}$$

Where, PV = volume of the pothole in ml (which can be further converted into $m^3$)

$\alpha_1$ = 3548.218
$\alpha_2$ = 15.58179
$\alpha 3$ = 1.433864
$\alpha_4$ = -5164.34
$\alpha 5$ = -0.3951
MDP = mean diameter of pothole
And, DP = depth of pothole.

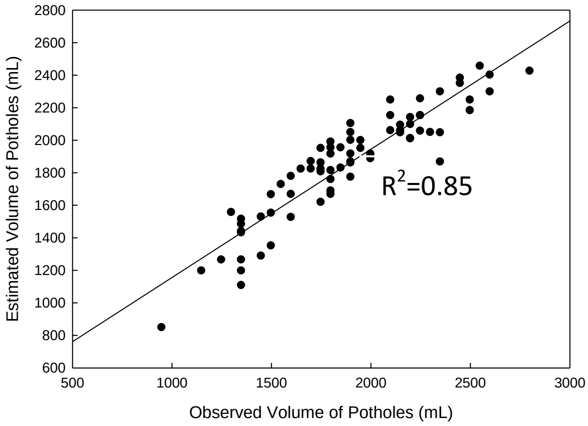


**Fig. 17:** Correlation Between Observed Volume and Estimated Volume of Potholes

## VI. CONCLUSION

The following conclusions can be ascertained from the present study-

1. The selected six rural road stretches in the vicinity of Himachal Pradesh has been found to be in fair condition on the basis of weightage and rating given corresponding to distress type and level of distress.
2. The International Roughness Index of all the roads has been found to be at satisfactory level. RR-1 and RR-4 has been found good surface profile with IRI value of 5.62 and 3.95 mm/km respectively. However, rest of the remaining selected rural road stretches has been found an IRI value above 6 mm/km as shown in Table 6.
3. The skid resistance value found by using skid resistance tester and macro texture depth found by sand patch apparatus has been found to be on safer side when compared with the standard values given in IRC: 82-2015.
4. Also, the rut depth has not been found very significant on the selected rural road stretches. Hence, rutting has no impact on the pavement performance and not been taken in rating of pavements.
5. The coefficient of determination i.e. $R^2$ = 0.85 has been found in case of non-linear regression model given in Eq. 1 which shows that there is good correlation between the observed volume of potholes and estimated volume of potholes. This mathematical model can be used by various highway

6. agencies/engineers in order to directly find the volume of pothole corresponding to its mean diameter and depth without wasting any time.

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