DEVELOPMENT OF PAVEMENT DEFLECTION PREDICTION MODEL USING BENKELMAN BEAM FOR HILLY RURAL ROADS

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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HIMACHAL PRADESH, INDIA

MAY- 2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Development of pavement deflection prediction model using Benkelman beam for hilly rural roads"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Aakash Gupta**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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Aayush Jain 151669	Saksham Jain 151680	Divesh Narang 151682

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India

08/05/2019

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"DEVELOPMENT OF PAVEMENT DEFLECTION PREDICTION MODEL USING BENKELMAN BEAM FOR RURAL HILLY ROADS"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Aayush Jain (151669), Saksham Jain (151680), Divesh Narang (151682)** during a period from July 2018 to June 2019 under the supervision of **Mr. Aakash Gupta (Assistant Professor- Grade II)**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

Evaluation of in service pavements is very important for keeping them in good serviceable condition. Development of a good flexible pavement deterioration and maintenance management model is the need of implementing organizations to prioritize pavement maintenance and rehabilitation works, as this involves cost economics.

Pavement deterioration model, is an equation that relates to different parameters of structural evaluation example CBR, Traffic volume. based on this deflection model it will be easy to find deflection of roads which play important role in pavement deterioration and performance model and it will easy to maintenance of pavement or designing of new overlay.

To develop these models, the present study focuses on the Benkelman beam analysis of 6 stretches each of 1 km of hilly rural roads in vicinity of NH22. The Test took 1-year for completion in Himachal Pradesh state of India. Statistical analysis tools might be used to develop this model. CBR of subgrade and traffic are some of the output parameters. The results of the test are completed in April 2019.

Keywords: Falling Weight Deflectometer, Benkelman Beam Deflection, Impulse Response.

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LIST OF ACRONYMS & ABBREVIATIONS

ANN	Artificial Neural Network
BBD	Benkelman Beam Deflection
FWD	Falling Weight Deflectometer
GPR	Ground Penetrating Radar
IR	Impulse Response
TSDD	Traffic Speed Deflection Devices
NDT	Non-destructive Test
ADT	Average Daily Traffic
PHF	Per Hour Factor
PCU	Passenger Car Unit
MSA	Million Single Axles

CHAPTER 1
INTRODUCTION

1.1 GENERAL

Pavement evaluation is used to find existing condition of road, whether the road is functionally and structurally stable. For structure evaluation of road i.e. deflection in road, CBR testing and traffic studies are used. It is characterized by the occurrence of structural damage of road pavement layers which is neglected for long period and can affect the traffic condition. Increase in traffic intensity, more axle can lead to pavement deterioration. So, Structural evaluation is necessary which include pavement deflection, soil testing etc. at regular interval is necessary. For this development of a pavement deflection prediction model is important.

1.2 NEED OF STUDY

- To determine and specify the types of the failures in the pavement for the selected Rural roads.
- Cracking is the most common behavioural failure of a pavement and it mostly occur due to the loading action by the moving vehicles. So to determine the exact reason for the failure the test is performed.
- To determine the causes of failure and deterioration in order to be prevented in the future.
- The causes due to which a pavement fail and deteriorate with time are to be found in order to get it prevented from happening in future. The overlay thickness is found and preferred size is taken in order to reduce failure.
- To look into the causes of deflection in flexible pavement (bituminous pavement) before going into the strategies of the maintenance.
- The main cause of deflection in a pavement is the regular application of load from the moving automobiles and other vehicles. So to find out the traffic volume and decide the overlay thickness can help a lot in reducing the deflection phenomena of pavement.

- To select the proper and best treatment and maintenance type. To find the pavement treatment techniques deflection measurements comes as a major help. The methods are found out to treat the pavement's which includes patching, a new overlay etc.

1.3 Parameters of Structural Evaluation

- Benkelman beam deflection
- CBR value of subgrade soil
- Moisture content of soil
- Temperature
- Traffic studies

Fig.1.1 Benkelman Beam

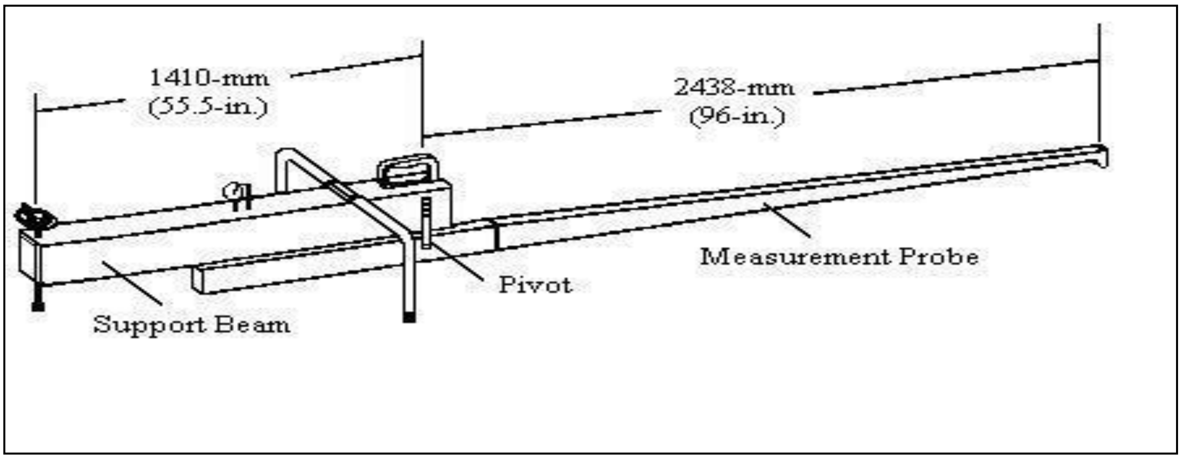

Fig.1.2 Benkelman Beam Cross Section

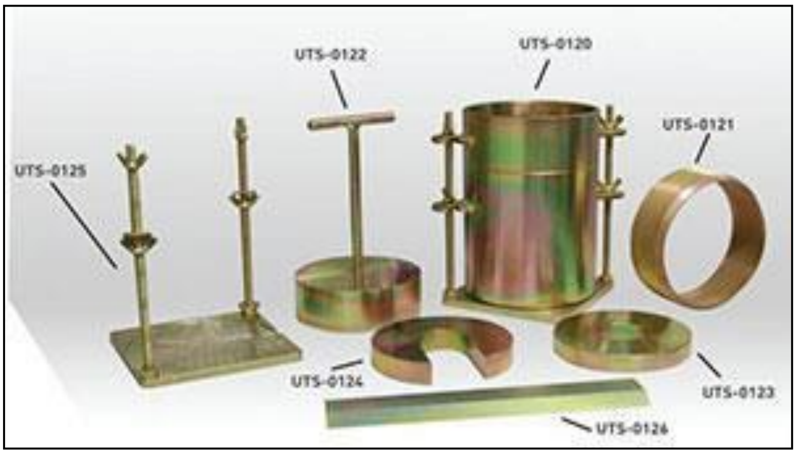

Fig.1.3 California Bearing Ratio Apparatus

1.4 PARAMETERS EXPLAINED

Benkelman Beam Deflection:

Benkelman beam deflection technique is broadly used for structural evaluation of existing pavement of roads or for designing of overlays for road. It is the one of the Non-destructive type method, placed between dual assembly real axle and reading is measured at every 100 m for every 1km of stretch.it is an economical method and broadly used all over the world.

Different standards for BBD technique are -

- AASHTO T 256: Pavement Deflection Measurements
- ASTM D 4695: General Pavement Deflection Measurements
- IRC 81 -1997

CBR value of Subgrade Soil:

California Bearing Ratio value shortly called as CBR value is measured on Subgrade Soil in order to find the bearing capacity of soil. It is a very common penetration test in which the subgrade strength can be found after the practical test by the use of certain formulas. The load values are seen at 2.5mm and 5mm and are further compared with the standard values which are 1370 kg for 2.5mm and 2055 kg for 5mm.

Moisture Content of Soil:

The moisture content of soil is mainly found by two test which are oven dry test and the speedy moisture test. However, the most common test widely used is the oven drying method because of its higher accuracy. The temperature ranges for the oven dying is in between 105 Degree Celsius with a +/- of Five Degree Celsius.

Temperature:

Standard temperature correction is taken as 35 Degree Celsius study is conducted between 30-35 Degree Celsius for increase in temperature from standard, the correction factor of 0.01mm is taken for each degree change.

Traffic Studies

Traffic Studies is an important parameter for the structural evaluation of pavement. Traffic on the pavement tells about the desired time of overlay and the depth of overlay required. In easy words we can say that more the traffic the overlay period will be less and the depth of the overlay will be more or we can say the depth of pavement will be more. Traffic volume is calculated in PCU (Passenger car unit) and it is calculated as per IRC-SP-72-2015.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

Rada, G.R, et al., (2018). In this paper they Selected Roads in USA for various field trials for finding deflection velocity and displacement parameters. For the test sensors are used and are embedded in the pavement. The deflection values are taken and further analysis. With the pavement thickness analysis, the pavement is classified as good, fair, poor. Based on the findings the pavement treatment is decided. The TSDD (Traffic Speed Deflection Devices) were used in the processes. The data which is found from TSDD's are further averaged to get deflection and displacement values but in a field research level of uncertainty should be verified.

Chou, Y.J, (1993). He proposed that, for calculating different parameters different non-destructive tests (NDT) are used and the most common NDT test used is deflection test. In this test deflection is found out by application of certain load. The deflection test is cost efficient and the results found are very certain. Two type of analysis are used are used to evaluate pavement on the basis of its structural performance. Both the shape deflections and magnitude are used to structurally evaluate the pavement.

Tang, B, (1993), He Carried out structural evaluation of jointed concrete airfield pavements is done. A concrete pavement is specially prepared for this test which consist of six slabs of different sizes with different voids beneath. The falling weight deflectometer (FWD) is used for creating a finite element model for measuring different pavement properties. Based on the deflection readings found by FWD the void and size properties of the slab can be found out. The main approach for this test is to find out that whether the use of jointed concrete pavement is suitable for air fields or not as it should not deteriorate for a particular usage period

.

Hachiya, Y, et al.,(2001). For calculating the structural properties of pavements the falling weight deflectometer (FWD) has become a worldwide standard for finding deflections because of its load characteristics which are very similar to those of aircrafts and automobiles. In this test the FWD system which is to be used can apply load to maximum level of 200KN with the help of a 450mm diameter loading plate. The deflection measurements are taken at seven points all from the Centre of the loading plate. For the results a strain based model is developed for asphalt pavements and further the loading cyclare estimated and the overlay thickness is determined.

Agarwal, P.K & Chakroborty ,P, (2006). Model developed in the paper is cost effective and efficient for calculating structural properties of the pavement. The models developed are derived from the long term pavement database of the US Transportation department. With the help of the model generated the remaining structural life of the pavement can be found out which is very helpful for future calculations and the tests are not needed to be performed extensively. The FWD, road rater method etc. are very cumbersome and needs money to be done and moreover these methods are not followed on around 75% of the Indian roads. So for the valuation of structural properties two very accurate and cost efficient models are developed and the models can be executed from a very minimal amount of data

Kanta Rao, V.V, et al., (2006). In his study Concrete pavements laid in Mumbai City were structurally evaluated using a falling weight deflectometer (FWD) and testing of concrete cores extracted from the pavement slabs. The structural quality of concrete in the PCC pavements tested in Mumbai, in terms of strength, pavement deflection, and the load transfer across the joints was generally good and as per the specifications.

Ethan c Dodge, his paper **(**structural evaluation and repair of internally damaged concrete) give overview of effective use of nondestructive testing, this paper present effective use of Impulse Response(IR), and explains IR can be used to measure success of repair. With proper calibration the IR testing allow the amount of damage to be accurately determined.

Umersalam , his study highlights the need of pavement evaluation and pavement evaluation measures for the road pavements of urban areas in Kashmir which are often being cut and refilled after laying of utilities like optical fibre cables, municipal water supply pipes, construction of severs etc. On evaluating the total existing pavements thicknesses for Site1 and Site 2 were 510 mm and 460 mm respectively. While comparing them with the new designed overall pavement thicknesses (870 mm for Site 1 and 780 mm for Site 2) it is evident that Site 1 falls short by 360 mm and Site 2 falls short by 320 mm.

Yousuf, N & Mohsin, H.K., (2015). His paper investigations the strategy for flexible pavement strengthen by making use of Benkelman beam deflection procedure. Out of all the redirection estimating strategies the BBD strategy is the least difficult and solid technique. This strategy is utilized to gauge the bounce back diversion of pavement under static applied load. The amendment of temperature is required when bituminous layer is apparently thick and temperature is institutionalized to 350C. In colder territories where the normal day temperature is under 200C for over 4 months in a year, the standard temperature of 350C won't have any significant bearing.

Simona Fontul, paper (*structural evaluation of flexible pavements using non-destructive tests*) add to the improvement of the procedures utilized in basic assessment of structural pavement, worried specifically about the back count of layer moduli dependent on Falling Weight Deflectometer (FWD) together with Ground Penetrating Radar (GPR) test results and utilizing Artificial Neural Network (ANN) strategy for the examination.

B. Subramanyam Study area recognized in the present work was among Budalur and Pudupatti segment (8.6km to 11km) of State Highway 99. From the examination of information, the overlay thickness required to keep up the road in useful condition is resolved. It is seen that there are a few troubles like alligator type of cracking, longitudinal breaking, transverse breaking, rutting, potholes, patching and fixing, and so on present on the road. The deflection found on the road was 1.9mm for one segment and 2.1 mm for another.The thickness of overlay as far as Bituminous Macadam ranges from 200mm to 210 mm.

Shamil Ahmed Flamarz Al-Arkawazi, paper (*Flexible Pavement Evaluation: A Case Study, August 2017*) included visual assessment and examination of existing flexible pavement conditions including the failure of pavement, the second to decide and discover the genuine reasons for these failures in the road pavement, and the third is to choose the most and successful remedies and up keep types of method. The outcomes were a large portion of the failures in the pavement are beyond normal limits and extraordinary surface distortion, splits, breaking down, and surface deformities. These failures are brought about by weariness and different kinds of failures that occur because of the development of substantial heavy loaded vehicles and trucks, poor seepage plan, unacceptable road layers' thickness structure, and ill-advised road mixture and materials chosen to make the mixture.

Gupta, A, et al., (2011). Study reasons that if roads are characterized based on parameters affecting pavement condition, for example, asphalt age, traffic, CBR of subgrade and road thickness then it predicts the condition of the pavement in a better manner as far as factual exactness. Age and traffic are the most significant execution marker for low volume streets.

Pankaj Goyal He took measurement of the deflection caused by BBD and FWD systems on 30 points at proper interval on a chosen 1.5 km of adaptable urban thruway extend. Both the test was performed at the same time and information gathered by the test were according to IRC: 81-1997 and IRC: 115-2014. The propensity of the avoidance bends is profound and of short length, which implies that the subgrade relates to a low quality soil and insufficient pavement performance. It was seen that the deflection that he got from the Benkelman beam are a lot further (12 to 232 mm^2) than those acquired utilizing FWD (31, 29 to 164, 14 mm^2) giving increasingly basic nature of the structure.

Rabi Das1 He completed different endeavour to improve the quality of strength of soil by including distinctive sorts of ground improvement materials. Also, contrasting which material is best according to his analyses for strengthening the soil according to the rules of IRC 37-2001. The examination reasons that CBR esteems with various materials are more noteworthy than that of ordinary soil test and the soil sample with rice husk gives more CBR esteem than rest of the materials.

CHAPTER 3

3.1 OBJECTIVES

- Development of pavement deflection prediction model using Benkelman beam in hilly rural road.
- Prediction model development in Nearby future.
- To study the Bearing capacity of soil.
- Analysis of maximum traffic volume on rural roads.

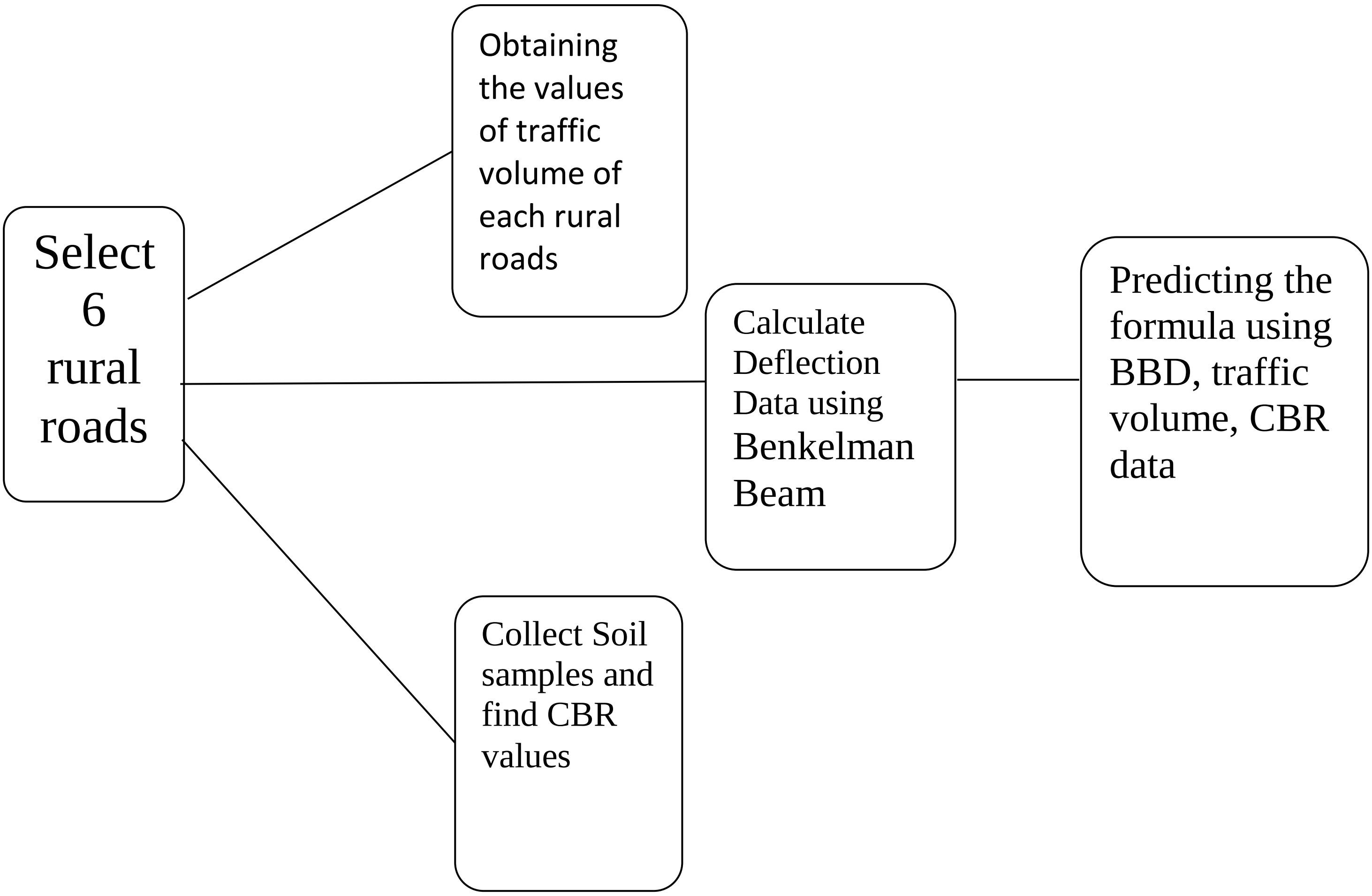

Fig. 3.1 Flow Chart of Objectives.

3.2 OBJECTIVES ACHIEVED

- Calculation of CBR values of soil sample collected from 6 rural roads both soaked and unsoaked CBR.
- Calculation of BBD deflection values of 6 rural roads were calculated twice.
- Development of pavement deflection model on basis of deflection values.
- Calculated Average daily traffic and traffic volume on selected roads.

3.3 METHODOLOGY

Deflection measurements are used for calculating the deflections in rural roads, for this Benkelman Beam is used.

PROCEDURE

3.3.1 Procedure for deflection measurement using Benkelman Beam

- ➢ A dual wheel loaded truck of 8.17 tonnes and tyre pressure of 5.6 kg/sq.cm. is taken for measurement of deflection.
- ➢ A stretch of one kilometre is taken on the selected road and ten points on every 100 metre is marked.
- ➢ The probe end of the beam is placed in between the rear axle assembly of the loaded truck
- ➢ Now from the front wheel of the truck two points are marked at an interval of 2.7 meters and 9 meters.
- ➢ First the truck is stopped after moving a distance of 2.7m and the deflection reading (D initial Di) is noted.
- ➢ Further the vehicle is moved at a distance of 9m and the deflection reading (D final Df) is noted.
- ➢ The rebound deflection value D at any point is given by one of the following two conditions.

If Di - Df<=2.5 divisions of the dial gauge or 0.025mm, D = 2 (Do - Df) divisions of 0.01mm units = 0.02 (Do - Df) mm

If Di- Df> 2.5 divisions of the dial gauge or 0.025mm, this indicates that correction is needed for the vertical movement of the front legs. Therefore, D = 2 (Do - Df) + 2 K (Di- Df) divisions.

3.3.2 Procedure for calculating California Bearing Ratio

1) 3 specimens of about 5 kg are compacted so that their compacted densities are in range of 95% to 100% with the application of 55 blows.
2) Take the weight of empty mould.
3) Add OMC in the specimen with giving 55 blows in 5 layers.
4) After application of blows remove the collar and plain the soil surface
5) Moisture Content of soil sample is determined.
6) Weigh the mould and the compacted specimen.
7) For soaked CBR place the mould in water tub for 96 hours. (Ignore this step in case of Unsoaked CBR
8) After 96 hours find the swell reading and further the percentage swell is found.
9) Then remove the mould from tank and the allow the water to get drained out
10) Next Step is to place the specimen in the CBR testing machine to find the penetration.
11) Apply load and further plot the penetration curves.
12) Graphs should be drawn between the penetration (mm) and penetration load (kg) to find the value of CBR.
13) Graph in between the %age CBR and Dry Density are drawn, and CBR is found at required degree of compaction

3.3.3 Procedure for Traffic Volume Studies

The design traffic is an important parameter for structural evaluation .it is calculated as per IRC-SP-72-2015. it is: calculated in terms of million standard axels (MSA)
The formula is used as**:**

Table 3.1 Traffic volume formula as per IRC-SP-72-2015

$$N = \frac{365 \times [(1 + r)^n - 1]}{r} \times A \times D \times F$$

Where

A = Initial Traffic in the year of completion of construction on road

r = Annual growth rate of commercial vehicles

n = Design life in years

F = Vehicle Damage Factor

Six roads are selected for the calculation of deflection of pavement. All selected roads are the rural roads connected to the National Highway 22. Criteria for selection of road:

- **i.** All roads must be rural roads.
- **ii.** BBD technique is used on stretch of 1km

Total number of vehicles passing from a reference point are calculated in time frame of 9am to 5pm.on the basis of that Average daily traffic (ADT) is calculated for 24 hours for each vehicle.

From IRC -SP-72-2015 design life is taken as 10 years and annual growth rate of 8% is taken.

THE SELECTED ROADS ARE –

ROAD ID	NAME OF ROAD	CARRIGE WAY LENGTH
RR1	Waknaghat-Domehar Road	3.5
RR2	Waknaghat Link Road	3.25
RR3	Kyari-Bangla Road	3.35
RR4	Kandaghat-Chail Road	3.4
RR5	Nain-Basal Road	3.35
RR6	Salogra-Ashwini Khad Road	3.35

Table 3.2 List of Rural Roads

Fig 3.2 Selected Rural Roads

3.3 Data Collection

Soil samples of six selected road are collected for soaked and unsoaked CBR test. CBR is done for the samples including optimum moisture content, with the help of proctor test.

Fig. 3.3 and **3.4** Collection of Soil Samples for CBR test

Fig. 3.5 Collection of 3 Soil Samples from each 1 km of Test Road

CHAPTER 4

DATA COLLECTION

4.1 BBD Data Collection (Nov 2018)

Fig. 4.1 Weight of rear Axle of truck

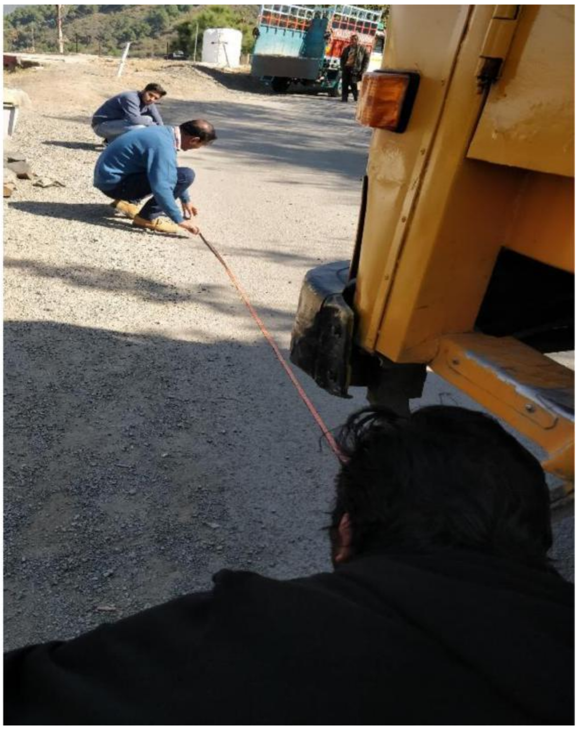

Fig. 4.2 Measuring 2.7m & 9m from truck

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Fig. 4.3 Benkelman Beam in middle of rear axle rear Axle of truck

Fig. 4.4 Readings taken at 2.7m & 9m

- For BBD deflection data readings were taken when truck passes from points 2.7 m and 9m, as deflection is calculated in reading gauge.

@2.7m = 0.462mm

Fig.4.5 Readings taken at 2.7m

- When truck is moved from 0m to first initial point i.e. 2.7m

@9.0 m =0.468

Fig. 4.6 Readings taken at 9m

- When truck is move from its first initial point to the final stop point.

Fig. 4.7 Road condition of RR2

The following figure defines actual condition of road during the time of experiment patching work is required on different part of roads. BBD data was found to be less on these kind of stretches.

4.2 BBD Data Collection (April 2019)

Fig. 4.8 Distance marking of 2.7m and 9m at RR1

Fig 4.9 Initial Start point of RR1

- As shown in figure we can clearly see the Initial start point of our first reading on Domehar Waknaghat road i.e. Domehar 0 km.
- Initially the traffic was stopped and after when readings were taken the traffic was allowed to move.

Fig 4.10 Marked distances before movement of truck at RR1

Fig 4.11 Marked distances before movement of truck at RR4

4.3 CBR Data Collection Studies

Fig 4.12 proctor test apparatus mould for OMC

Fig 4.13 CBR of unsoaked sample

The moisture content of each of selected 18 samples is found as soon as they were brought further the OMC is calculated and after that the final CBR test was performed.

4.4 Traffic Volume Study

Fig. 4.14 (a) Traffic volume calculating on RR1

Fig. 4.14 (b) Traffic volume Kandaghat Chail on RR4

- As shown in figure, traffic volume of each road is calculated as the vehicles are passing by from the benchmark point on Six different roads.
- Traffic volume on Kandaghat Chail road and Ashwini Khad road was much larger than other four roads due to tourist places.

CHAPTER 5
CONCLUSION

5.1 DISCUSSION

On the basis of all the theoretical and practical work done by us, we can say that the deflection in rural hilly roads mostly depends on its soil type as the traffic movement on most of these roads is very low. Six rural roads are taken and various tests were performed which mainly include CBR, Proctor test, Benkelman beam deflection, traffic volume, etc. The soil mainly found in the region of our work is gravel-sand mixtures, gravelly sands and poorly graded gravels. We can say about the soil types on the basis of their calculated CBR values corresponding to which these soil types are found. The corrections to be applied during the Benkelman Deflection Test are the Pavement Temperature Correction and the Seasonal Variation Correction. These corrections are not taken into consideration because pavement temperature correction is taken when pavement temperature is greater than 35 Degree Celsius which is not found in our area of practical work. The Seasonal Variation Correction or Moisture Correction Factor is applying in an area where rainfall is less than 1300mm where as in the area of our practical work the average rainfall is 1460mm is found using a three different set of values calculated on different time.

Because of the deflection formula the maintenance period can be found out which will be efficient and cost effective. The overlay thickness will be much effective and will benefit the serviceability condition of the pavement. This will help strengthen all the rural road network. All the test performed are non-destructive.

5.2 CONCLUSION

Based on basis of study done we have derived the formula on the basis of the Benkelman beam deflection data of 2017,2018 and 2019 of six rural road. A deflection prediction model has been made using regression analysis, in which average of BBD data from past three years is taken as dependent variable and it depend on both traffic volume and CBR test which are done by us. On the basis of this we can derive deflection values of road.

We have concluded a formula

$$Y=0.66937378+X_1(0.008)+X_2(0.0027)+X_3(0.010)-X_4(0.01098)$$

Table 5.1 Deflection Prediction Formula

WHERE:

X_1= Traffic volume (MSA)

X_2= CBR Soaked values

X_3= CBR Unsoaked values

X_4= CBR Unsoaked values

Y= BBD deflection values

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APPENDIX

Annexure-I

Benkleman Beam deflection readings of rural roads (2018)

RR 1: Domehar-Waknaghat Road

Benkelman Beam Deflection Data, Domehar waknaghat road										
location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df)*	*mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.178	0.181	0.003	0.181	0.362	0.4138	0.081575868	0.576952
0.1	L	0	0.195	0.199	0.004	0.199	0.398			
0.2	L	0	0.182	0.187	0.005	0.187	0.374			
0.3	L	0	0.248	0.264	0.016	0.264	0.528			
0.4	L	0	0.152	0.153	0.001	0.153	0.306			
0.5	L	0	0.198	0.204	0.006	0.204	0.408			
0.6	L	0	0.223	0.231	0.008	0.231	0.462			
0.7	L	0	0.28	0.284	0.004	0.284	0.568			
0.8	L	0	0.16	0.184	0.024	0.184	0.368			
0.9	L	0	0.177	0.182	0.005	0.182	0.364			

Table 6.1 Deflection data of RR 1 (Domehar-Waknaghat Road)

RR 2: Waknaghat Link road

Benkelman Beam Deflection Data, waknaghat village road										
Location	*Lane*	*d_o*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df)*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.321	0.326	0.005	0.326	0.652	0.5604	0.11142232	0.783245
0.1	L	0	0.274	0.28	0.006	0.28	0.56			
0.2	L	0	0.268	0.271	0.003	0.271	0.542			
0.3	L	0	0.284	0.293	0.009	0.293	0.586			
0.4	L	0	0.172	0.176	0.004	0.176	0.352			
0.5	L	0	0.217	0.23	0.013	0.23	0.46			
0.6	L	0	0.232	0.243	0.011	0.243	0.486			
0.7	L	0	0.272	0.281	0.009	0.281	0.562			
0.8	L	0	0.323	0.331	0.008	0.331	0.662			
0.9	L	0	0.362	0.371	0.009	0.371	0.742			

Table 6.2 Deflection data of RR 2 (Waknaghat village road)

RR 3: Kyari Bangla Road

Benkelman Beam Deflection Data, Kyari Bangla Road										
location	***Lane***	***d_o***	***di***	***df***	***di-df***	***do-df***	***d=2(do-df***	***Mean***	***Standard Deviation(sd)***	***d+2sd***
0	L	0	0.342	0.34	0.002	0.34	0.68	0.6236	0.126564169	0.876728
0.1	L	0	0.276	0.263	0.013	0.263	0.526			
0.2	L	0	0.217	0.222	0.005	0.222	0.444			
0.3	L	0	0.223	0.231	0.008	0.231	0.462			
0.4	L	0	0.374	0.41	0.036	0.41	0.82			
0.5	L	0	0.363	0.371	0.008	0.371	0.742			
0.6	L	0	0.334	0.343	0.009	0.343	0.686			
0.7	L	0	0.284	0.291	0.007	0.291	0.582			
0.8	L	0	0.273	0.282	0.009	0.282	0.564			
0.9	L	0	0.359	0.365	0.006	0.365	0.73			

Table 6.3 Deflection data of RR 3 (Kyari Bangla Road)

RR 6: Salogra Ashwini Khad Road

Benkelman Beam Deflection Data, Salogra Ashwini Khad Road										
Location	***Lane***	***d_o***	***di***	***df***	***di-df***	***do-df***	***d=2(do-df***	***mean***	***Standard Deviation(sd)***	***d+2sd***
0	L	0	0.146	0.151	0.005	0.151	0.302	0.4136	0.195629582	0.804859
0.1	L	0	0.21	0.213	0.003	0.213	0.426			
0.2	L	0	0.144	0.147	0.003	0.147	0.294			
0.3	L	0	0.18	0.186	0.006	0.186	0.372			
0.4	L	0	0.218	0.219	0.001	0.219	0.438			
0.5	L	0	0.058	0.063	0.005	0.063	0.126			
0.6	L	0	0.179	0.184	0.005	0.184	0.368			
0.7	L	0	0.154	0.159	0.005	0.159	0.318			
0.8	L	0	0.377	0.379	0.002	0.379	0.758			
0.9	L	0	0.365	0.367	0.002	0.367	0.734			

Table 6.4 Deflection data of RR 6 (Salogra Ashwini Khad)

RR 4: Chail Kandaghat Road

Benkelman Beam Deflection Data, Chail Kandaghat Road										
location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2*(do-df*	*mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.215	0.218	0.003	0.218	0.436	0.4782	0.139243831	0.756688
0.1	L	0	0.243	0.248	0.005	0.248	0.496			
0.2	L	0	0.221	0.231	0.01	0.231	0.462			
0.3	L	0	0.28	0.283	0.003	0.283	0.566			
0.4	L	0	0.337	0.347	0.01	0.347	0.694			
0.5	L	0	0.274	0.279	0.005	0.279	0.558			
0.6	L	0	0.242	0.248	0.006	0.248	0.496			
0.7	L	0	0.137	0.141	0.004	0.141	0.282			
0.8	L	0	0.101	0.112	0.011	0.112	0.224			
0.9	L	0	0.28	0.284	0.004	0.284	0.568			

Table 6.5 Deflection data of RR 6 (Chail Kandaghat Road)

RR 5: Basal Road Road

Benkelman Beam Deflection Data, Basal Road										
location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2*(do-df*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.272	0.276	0.004	0.276	0.552	0.5042	0.127626016	0.759452
0.1	L	0	0.112	0.115	0.003	0.115	0.23			
0.2	L	0	0.198	0.196	0.002	0.196	0.392			
0.3	L	0	0.169	0.218	0.049	0.218	0.436			
0.4	L	0	0.243	0.231	0.012	0.231	0.462			
0.5	L	0	0.305	0.309	0.004	0.309	0.618			
0.6	L	0	0.326	0.331	0.005	0.331	0.662			
0.7	L	0	0.291	0.298	0.007	0.298	0.596			
0.8	L	0	0.274	0.278	0.004	0.278	0.556			
0.9	L	0	0.265	0.269	0.004	0.269	0.538			

Table 6.6 Deflection data of RR 5 (Basal Road)

Benkleman Beam deflection readings of rural roads (2019)

RR 1: Domehar-Waknaghat Road

Benkelman Beam Deflection Data, Domehar waknaghat road										
Location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.196	0.198	0.002	0.198	0.396	0.2128	0.181226	0.5752
0.1	L	0	0.084	0.086	0.002	0.086	0.172			
0.2	L	0	0.314	0.332	0.018	0.332	0.664			
0.3	L	0	0.041	0.042	0.001	0.042	0.084			
0.4	L	0	0.042	0.043	0.001	0.043	0.086			
0.5	L	0	0.063	0.064	0.001	0.064	0.128			
0.6	L	0	0.066	0.068	0.002	0.068	0.136			
0.7	L	0	0.084	0.086	0.002	0.086	0.172			
0.8	L	0	0.074	0.077	0.003	0.077	0.154			
0.9	L	0	0.065	0.068	0.003	0.068	0.136			

Table 6.7 Deflection data of RR1 (Domehar-Waknaghat Road)

RR 2: Waknaghat village road

Table 2. Benkelman Beam Deflection Data, waknaghat village road										
Location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	**L**	**0**	**0.028**	**0.031**	**0.003**	**0.031**	**0.062**	**0.1484**	**0.154188**	**0.4567**
0.1	L	0	0.012	0.013	0.001	0.013	0.026			
0.2	L	0	0.019	0.021	0.002	0.021	0.042			
0.3	L	0	0.036	0.037	0.001	0.037	0.074			
0.4	L	0	0.131	0.135	0.004	0.135	0.27			
0.5	L	0	0.233	0.266	0.033	0.266	0.532			
0.6	L	0	0.027	0.031	0.004	0.031	0.062			
0.7	L	0	0.038	0.041	0.003	0.041	0.082			
0.8	L	0	0.076	0.079	0.003	0.079	0.158			
0.9	L	0	0.085	0.088	0.003	0.088	0.176			

Table 6.8 Deflection data of RR2 (Waknaghat village road)

RR 3: Kyari Bangla Road

Benkelman Beam Deflection Data, Kyari Bangla Road										
Location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.008	0.011	-0.003	0.011	0.022	0.5422	0.623528	1.7892
0.1	L	0	0.11	0.115	-0.005	0.115	0.23			
0.2	L	0	0.088	0.091	0.003	0.091	0.182			
0.3	L	0	0.047	0.051	0.004	0.051	0.102			
0.4	L	0	0.374	0.41	0.036	0.41	0.82			
0.5	L	0	0.168	0.171	0.003	0.171	0.342			
0.6	L	0	1.011	1.088	0.077	1.088	2.176			
0.7	L	0	0.252	0.255	0.003	0.255	0.51			
0.8	L	0	0.207	0.211	0.004	0.211	0.422			
0.9	L	0	0.301	0.308	0.007	0.308	0.616			

Table 6.9 Deflection data of RR3 (Kyari Bangla Road)

RR 6: Salogra Ashwini Khad Road

Benkelman Beam Deflection Data, Salogra Ashwini Khad Road										
Location	*Lane*	*do*	*di*	*df*	*di-df*	*do-df*	*d=2(do-df*	*Mean*	*Standard Deviation(sd)*	*d+2sd*
0	L	0	0.009	0.01	0.001	0.01	0.02	0.1944	0.23586	0.66612
0.1	**L**	**0**	**0.011**	**0.012**	**0.001**	**0.012**	**0.024**			
0.2	L	0	0.083	0.086	0.003	0.086	0.172			
0.3	L	0	0.092	0.095	0.003	0.095	0.19			
0.4	**L**	**0**	**0.421**	**0.422**	**0.001**	**0.422**	**0.844**			
0.5	L	0	0.064	0.068	0.004	0.068	0.136			
0.6	L	0	0.054	0.055	0.001	0.055	0.11			
0.7	L	0	0.072	0.072	0	0.072	0.144			
0.8	L	0	0.091	0.092	0.001	0.092	0.184			
0.9	L	0	0.058	0.06	0.002	0.06	0.12			

Table 6.10 Deflection data of RR6 (Salogra Ashwini Khad)

RR 4: Chail Kandaghat Road

Benkelman Beam Deflection Data, Chail Kandaghat Road										
Location	***Lane***	***do***	***di***	***df***	***di-df***	***do-df***	***d=2*(do-df***	***mean***	***Standard Deviation(sd)***	***d+2sd***
0	L	0	0.114	0.116	0.002	0.116	0.232	0.3132	0.290042	0.8932
0.1	L	0	0.022	0.023	0.001	0.023	0.046			
0.2	L	0	0.435	0.437	0.002	0.437	0.874			
0.3	L	0	0.227	0.232	0.005	0.232	0.464			
0.4	L	0	0.01	0.009	-0.001	0.009	0.018			
0.5	L	0	0.35	0.36	0.01	0.36	0.72			
0.6	L	0	0.083	0.094	0.011	0.094	0.188			
0.7	L	0	0.081	0.082	0.001	0.082	0.164			
0.8	L	0	0.165	0.169	0.004	0.169	0.338			
0.9	L	0	0.045	0.044	-0.001	0.044	0.088			

Table 6.11 Deflection data of RR4 (Chail Kandaghat Road)

RR 5: Basal Road Road

Benkelman Beam Deflection Data, Basal Road										
location	***Lane***	***do***	***di***	***df***	***di-df***	***do-df***	***d=2*(do-df***	***Mean***	***Standard Deviation(sd)***	***d+2sd***
0	L	0	0.064	0.065	0.001	0.065	0.13	0.1506	0.113443	0.377487
0.1	L	0	0.031	0.033	0.002	0.033	0.066			
0.2	L	0	0.047	0.048	0.001	0.048	0.096			
0.3	L	0	0.011	0.013	0.002	0.013	0.026			
0.4	L	0	0.085	0.087	0.002	0.087	0.174			
0.5	L	0	0.101	0.103	0.002	0.103	0.206			
0.6	L	0	0.045	0.051	0.006	0.051	0.102			
0.7	L	0	0.027	0.033	0.006	0.033	0.066			
0.8	L	0	0.108	0.111	0.003	0.111	0.222			
0.9	L	0	0.203	0.209	0.006	0.209	0.418			

Table 6.12 Deflection data of RR5 (Basal Road)

Annexure-II
Traffic volume of Rural Roads

STANDARD PCU VALUES	
CAR	1
MOTORCYCLE	0.5
BICYCLE	0.2
LCV	2.2
BUS,TRUCK	3.5
3 Wheeler	0.8

Table 7.1 Traffic standard as per IRC

Traffic data RR1

ROAD: WAKNAGHAT DOMEHAR (RR1)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	45	28	3	5	83.1
10:00-11:00	34	17	8	2	67.1
11:00-12:00	28	14	7	4	64.4
14:00-15:00	20	16	5	6	60
15:00-16:00	23	14	11	5	71.7
16:00-17:00	29	23	9	4	74.3
					420.6

Table 7.2 Traffic volume of RR1

PHF= 0.843561974 **PCU/hr=** 498.6 **MSA=** 1.2860556

Traffic data RR6

ROAD: ASHWINI KHAD (RR6)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	28	11	2	7	62.4
10:00-11:00	22	10	4	9	67.3
11:00-12:00	25	8	5	11	78.5
14:00-15:00	32	18	7	8	84.4
15:00-16:00	36	16	4	11	91.3
16:00-17:00	29	9	3	10	75.1
					459

Table 7.3 Traffic volume of RR4

PHF= 0.837897 **PCU/hr=** 547.8 **MSA=** 1.4129588

Traffic data RR4

ROAD: KANDAGHAT CHAIL (RR4)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	76	41	14	9	158.8
10:00-11:00	69	39	13	9	148.6
11:00-12:00	62	18	12	8	125.4
14:00-15:00	51	21	9	6	102.3
15:00-16:00	58	25	11	10	129.7
16:00-17:00	65	35	9	12	144.3
					809.1

Table 7.4 Traffic volume of RR5

PHF= 0.8491814 **PCU/hr=** 952.8 **MSA=** 2.4575888

Traffic data RR5

ROAD: NAIN BASAL (RR5)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	5	8	3	1	19.1
10:00-11:00	1	3	2	1	10.4
11:00-12:00	4	6	2	0	11.4
14:00-15:00	3	4	1	1	10.7
15:00-16:00	5	5	4	2	23.3
16:00-17:00	4	5	3	1	16.6
					91.5

Table 7.5 Traffic volume of RR6

PHF= 0.6545064 **PCU/hr=** 139.8 **MSA=** 0.3605908

Traffic data RR2

ROAD: WAKNAGHAT LINK ROAD (RR2)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	2	4	1	0	6.2
10:00-11:00	1	2	0	0	2
11:00-12:00	3	4	0	0	5
14:00-15:00	1	3	0	1	6
15:00-16:00	0	3	2	0	5.9
16:00-17:00	4	5	0	1	10
					35.1

Table 7.6 Traffic volume of RR2

PHF= 0.6545064 **PCU/hr=** 139.8 **MSA=** 0.3605908

Traffic data RR3

ROAD: KYARI BANGLA ROAD (RR3)					
TIME	**CAR**	**MOTORCYCLE**	**LCV**	**BUS/TRUCK**	**PCU VALUE**
9:00-10:00	4	11	3	2	23.1
10:00-11:00	5	14	1	1	17.7
11:00-12:00	3	9	2	2	18.9
14:00-15:00	6	8	4	4	32.8
15:00-16:00	8	8	2	2	23.4
16:00-17:00	10	10	2	1	22.9
					138.8

Table 7.7 Traffic volume of RR3

PHF= 0.7052846 **PCU/hr=** 196.8 **MSA=** 0.5076128

Annexure-III

CALRIFONIA BEARING RATIO VALUES

OPTIMUM MOISTURE CONTENT

CALCULATION FOR OMC USING PROCTOR TEST					
volume of mould=2250 cm3					
WEIGHT OF MOULD+COLLAR+BASE plate=7445.0 gm					
WATER CONTENT %	**WEIGHT OF M+C+B+S (Grams)**	**weight of soil**	**bulk density**	**water content**	**dry density**
		(b- wt of mould)			
8	12370	4925	2.188888889	7.1	2.043780475
12	12725.6	5280.6	2.346933333	8.6	2.161080417
16	13254.9	5809.9	2.582177778	14.13	2.262488196
18	13253	5808	2.581333333	14	2.264327485
20	13171	5726	2.544888889	16.5	2.184453982

Table 8.1 OMC of roads sample

AT DIFERENT WATER CONTENT

OPTIMUM MOISTURE CONTENT	
WATER CONTENT IN %	**DRY DENSITY (gm/cm^3)**
8	2.04378
12	2.16108
16	2.26249
18	2.26433
20	2.18445

Table 8.2 Dry density at different water content

OPTIMUM MOISTURE CONTENT - 17%

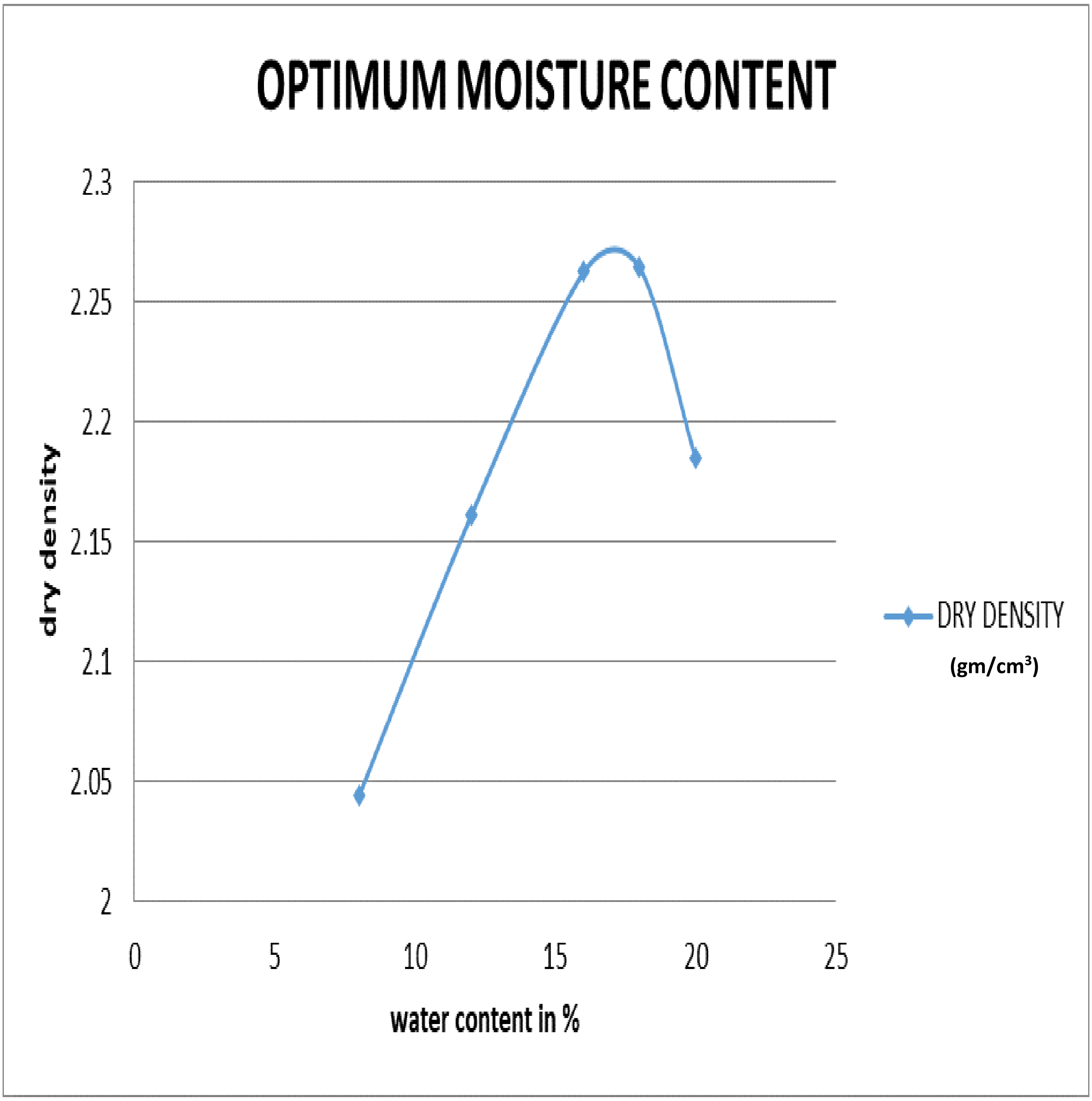

Fig. 5.1: OMC USING PROCTOR TEST

CBR Calibration Factor

CBR MACHINE CALIBERATION				
LOAD(KN)	**PROVING RING**	**LOAD (KG) = A*101.937**	**LOAD/DIVISION**	
3	79.1	305.8104	0.038	3.866123894
6	158.3	611.6208	0.038	3.863681617
9	237.4	917.4312	0.038	3.864495366
12	316.6	1223.242	0.038	3.863682881
15	395.7	1529.052	0.038	3.864169826
18	474.9	1834.562	0.038	3.863049063
21	544	2140.673	0.039	3.935060662
24	633.2	2446.483	0.038	3.863681301
27	712.4	2752.294	0.038	3.863411005
30	791.5	3058.104	0.038	3.863681617
			average=3.877	

Table 8.3 CBR calibration values

Proving Ring Constant- 3.877

CBR data (Unsoaked) of selected road stretches

CBR data of sample-2 RR2

PENETRATION (mm)	DIVISION	CORRESPONDING LOAD VALUES (KN)	STANDARD VALUE	CBR VALUES %
0.5	13	50.3243		
1	30	116.133		
1.5	65	251.6215		
2	105	406.4655		
2.5	140	**541.954**	1370	39.55868613
4	250	967.775		
5	325	**1258.1075**	2055	61.22177616

Table 8.4 CBR data of sample 2 RR2

California Bearing Ratio- 61.2%

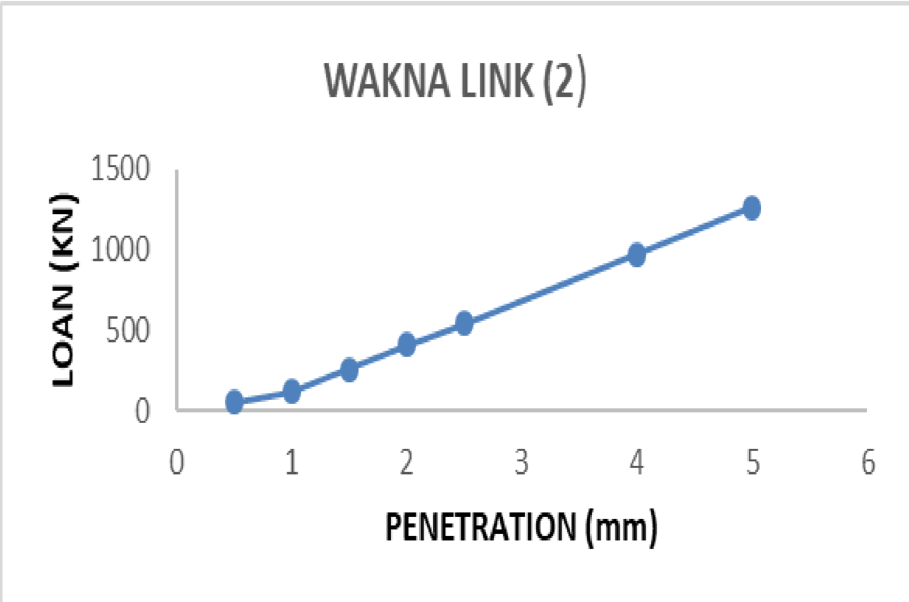

Fig. 5.2 Load Penetration Curve of sample-2 RR2

CBR data of sample-3 RR2

CBR VALUE OF WAKNA LINK (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	20	77.422		
1	32	123.8752		
1.5	71	274.8481		
2	113	437.4343		
2.5	148	**572.9228**	1370	41.81918248
4	267	1033.5837		
5	341	**1320.0451**	2055	64.23577129

Table 8.4 CBR data of sample 3 RR2

California Bearing Ratio- 64.23%

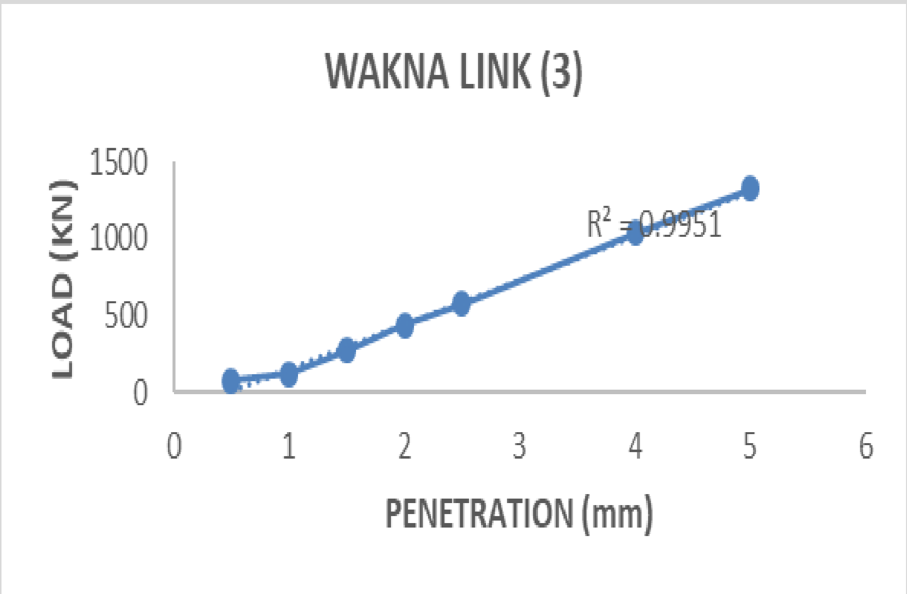

Fig. 5.3 Load Penetration Curve of Sample-3 RR2

CBR data of sample-2 RR5

PENETRATION (mm)	DIVISION	CORRESPONDING LOAD VALUES (KN)	STANDARD VALUE	CBR VALUES %
0.5	30	116.133		
1	73	282.5903		
1.5	145	561.3095		
2	220	851.642		
2.5	297	**1149.7167**	1370	83.92092701
4	430	1664.573		
5	567	**2194.9137**	2055	106.8084526

Table 8.5 CBR data of sample 2 RR5

California Bearing Ratio- 106.8%

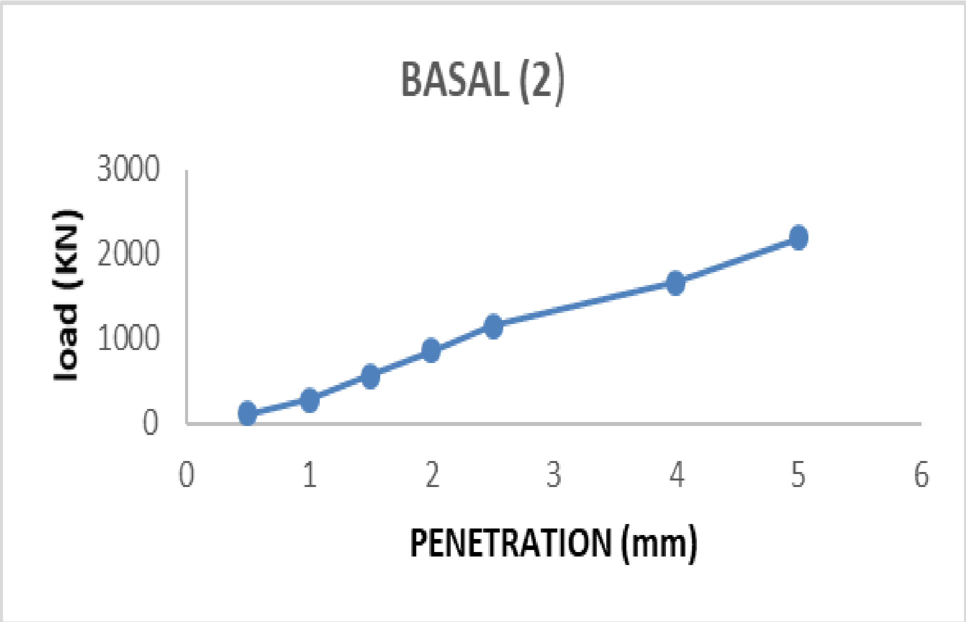

Fig. 5.4 Load Penetration Curve of Sample-2 RR5

CBR data of sample-3 RR5

CBR VALUE OF BASAL (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	22	85.1642		
1	67	259.3637		
1.5	137	530.3407		
2	201	778.0911		
2.5	265	**1025.8415**	1370	74.87894161
4	395	1529.0845		
5	517	**2001.3587**	2055	97.38971776

Table 8.7 CBR data of sample 3 RR5

California Bearing Ratio- 97.389%

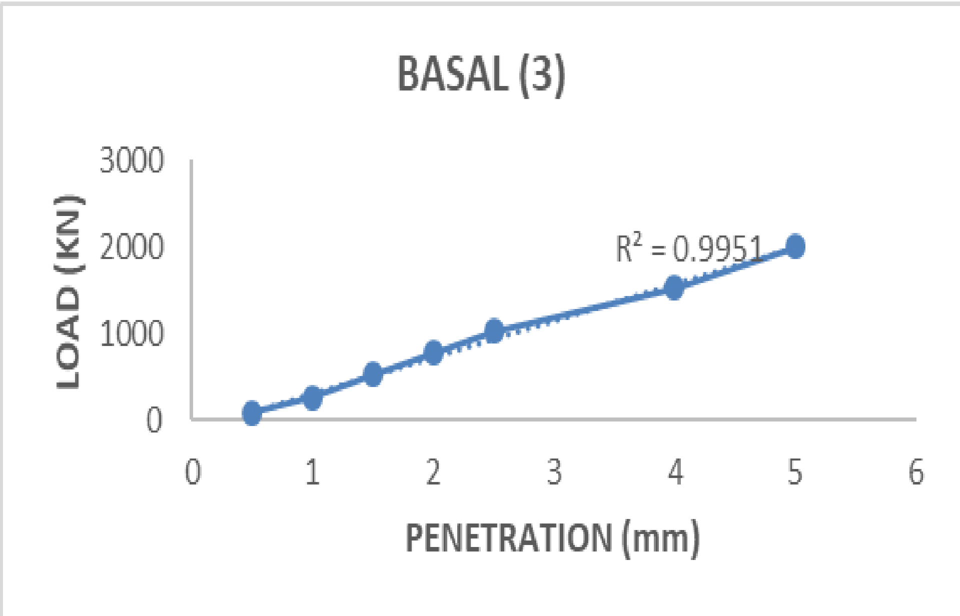

Fig 5.5 Load Penetration Curve of Sample-3 RR5

CBR data of sample-2 RR4

CBR VALUE OF CHAIL (2) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	32	123.8752		
1	50	193.555		
1.5	67	259.3637		
2	92	356.1412		
2.5	107	**414.2077**	1370	30.23413869
4	223	863.2553		
5	280	**1083.908**	2055	52.74491484

Table 8.8 CBR data of sample 2 RR4

California Bearing Ratio- 52.74%

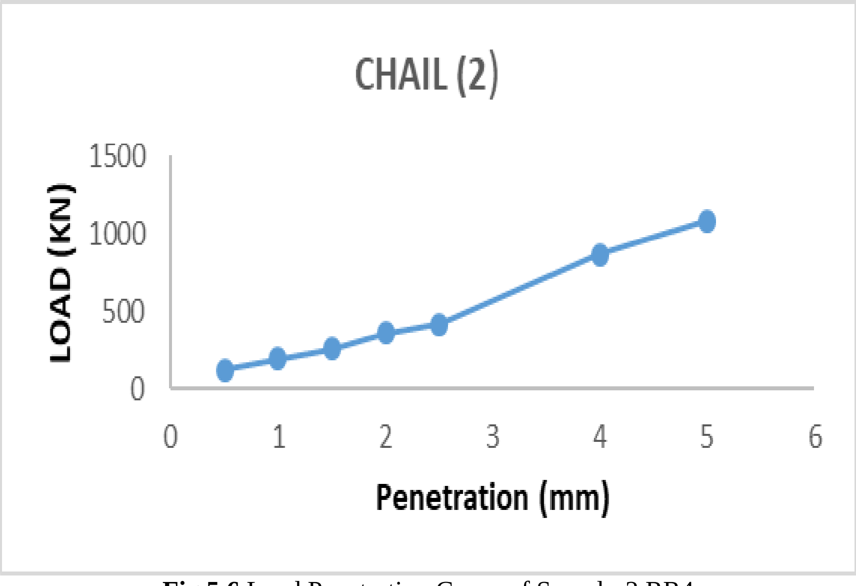

Fig 5.6 Load Penetration Curve of Sample-2 RR4

CBR data of sample-3 RR4

CBR VALUE OF CHAIL (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	27	104.5197		
1	41	158.7151		
1.5	61	236.1371		
2	83	321.3013		
2.5	95	**367.7545**	1370	26.84339416
4	211	816.8021		
5	259	**1002.6149**	2055	48.78904623

Table 8.9 CBR data of sample 2 RR4

California Bearing Ratio- 48.78%

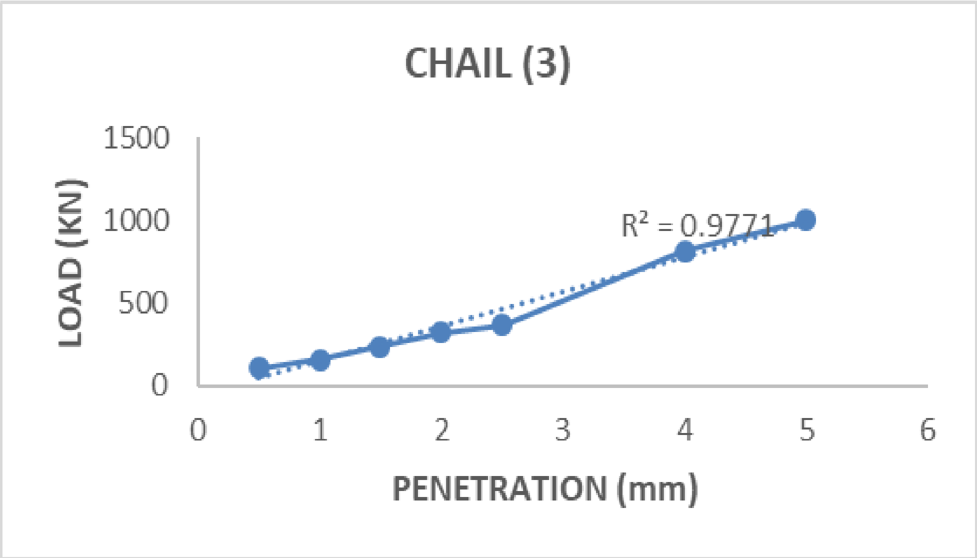

Fig. 5.7 Load Penetration Curve of Sample-3 RR4

CBR data of sample-2 RR3

CBR VALUE OF KYARI BANGLA (2) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	20	77.422		
1	40	154.844		
1.5	65	251.6215		
2	95	367.7545		
2.5	125	**483.8875**	1370	35.32025547
4	250	967.775		
5	260	**1006.486**	2055	48.97742092

Table 8.10 CBR data of sample 2 RR3

California Bearing Ratio-48.97 %

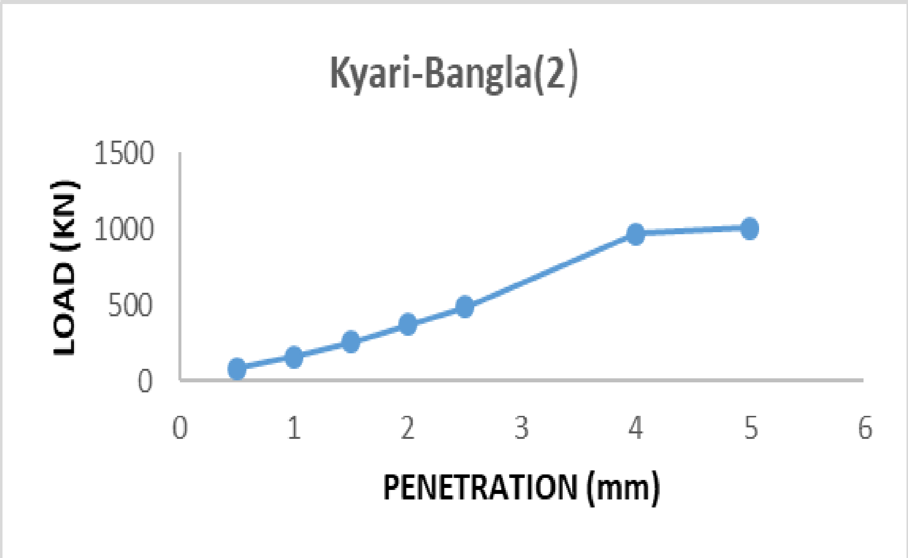

Fig 5.8 Load Penetration Curve of Sample-2 RR

CBR data of sample-3 RR3

CBR VALUE OF KYARI BANGLA (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	19	73.5509		
1	29	112.2619		
1.5	41	158.7151		
2	63	243.8793		
2.5	77	**298.0747**	1370	21.75727737
4	98	379.3678		
5	129	**499.3719**	2055	24.30033577

Table 8.11 CBR data of sample 3 RR3

California Bearing Ratio- 24.30%

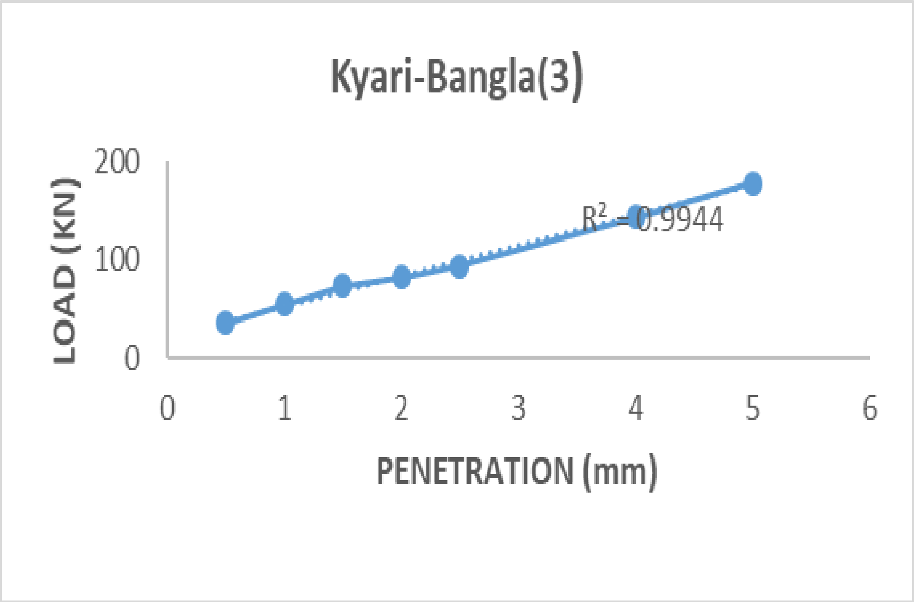

Fig 5.9 Load Penetration Curve of Sample-3 RR3

CBR data of sample-2 RR6

CBR VALUE OF ASHWINI KHAD (2) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	20	77.422		
1	40	154.844		
1.5	60	232.266		
2	75	290.3325		
2.5	78	**301.9458**	1370	22.03983942
4	120	464.532		
5	150	**580.665**	2055	28.25620438

Table 8.12 CBR data of sample 2 RR6

California Bearing Ratio- 28.25%

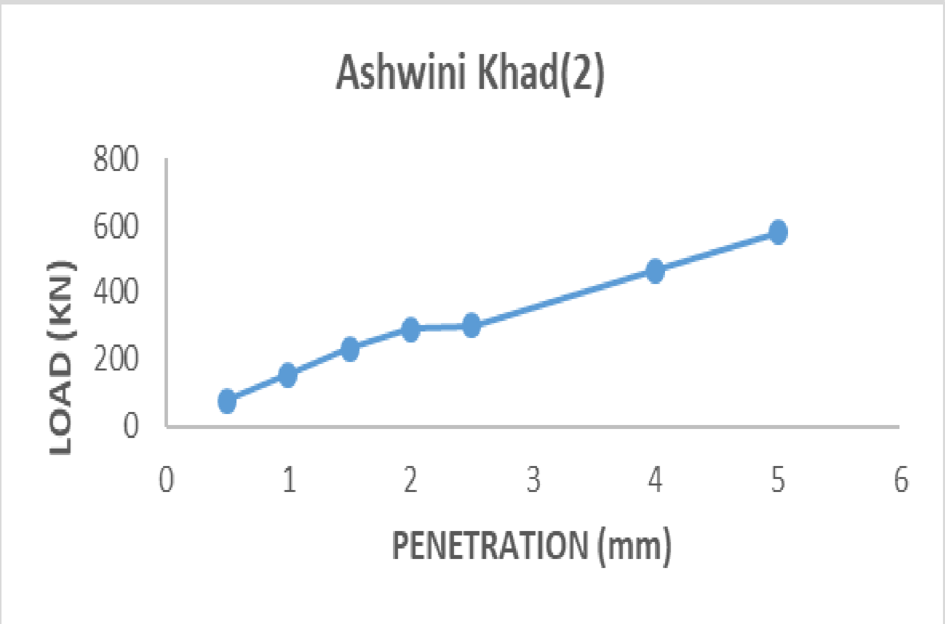

Fig. 5.10 Load Penetration Curve of Sample-2 RR6

CBR data of sample-3 RR6

CBR VALUE OF ASHWINI KHAD (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	17	65.8087		
1	31	120.0041		
1.5	46	178.0706		
2	62	240.0082		
2.5	80	**309.688**	1370	22.6049635
4	124	480.0164		
5	163	**630.9893**	2055	30.70507543

Table 8.13 CBR data of sample 3 RR6

California Bearing Ratio-30.7 %

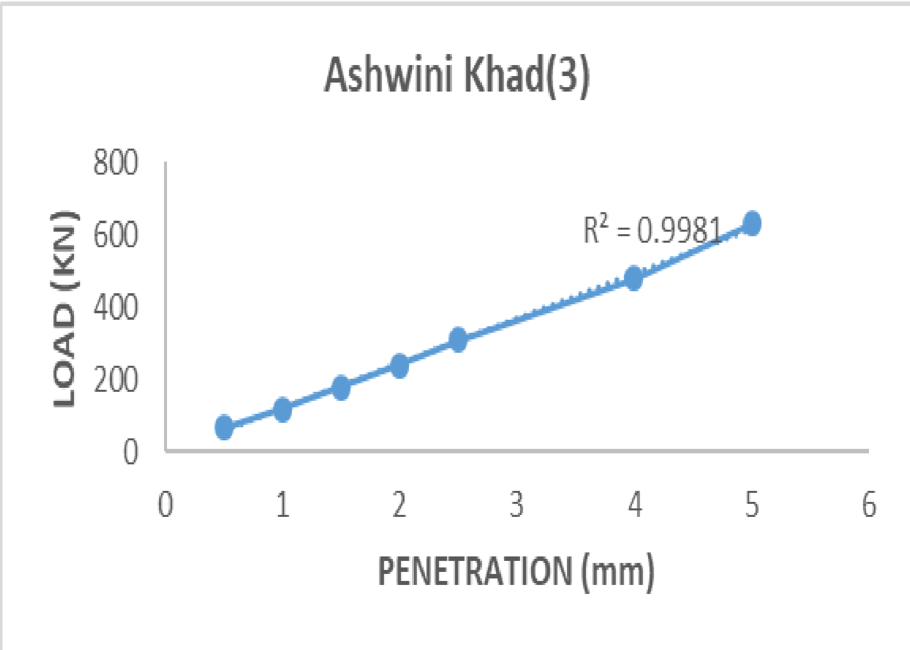

Fig. 5.11 Load Penetration Curve of Sample-3 RR6

CBR data of sample-2 RR1

CBR VALUE OF WAKNAGHAT DOMEHAR (2) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	24	92.9064		
1	36	139.3596		
1.5	55	212.9105		
2	71	274.8481		
2.5	75	**290.3325**	1370	21.19215328
4	115	445.1765		
5	142	**549.6962**	2055	26.74920681

Table 8.14 CBR data of sample 2 RR1

California Bearing Ratio-26.74 %

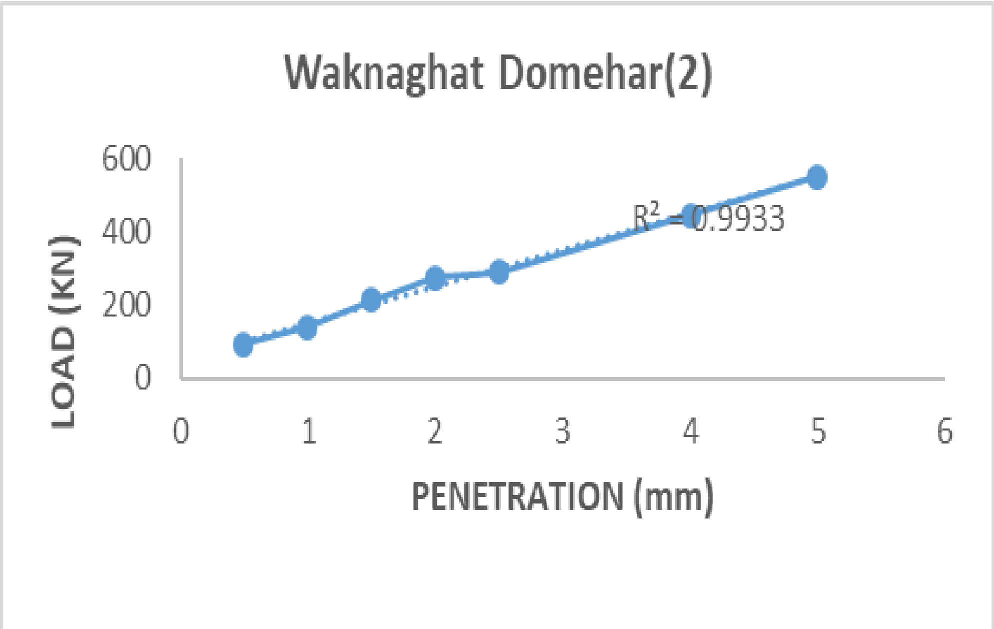

Fig. 5.12 Load Penetration Curve of Sample-2 RR1

CBR data of sample-3 RR1

CBR VALUE OF WAKNAGHAT DOMEHAR (3) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	27	104.5197		
1	39	150.9729		
1.5	62	240.0082		
2	77	298.0747		
2.5	81	**313.5591**	1370	22.88752555
4	125	483.8875		
5	150	**580.665**	2055	28.25620438

Table 8.15 CBR data of sample 3 RR1

California Bearing Ratio- 28.25%

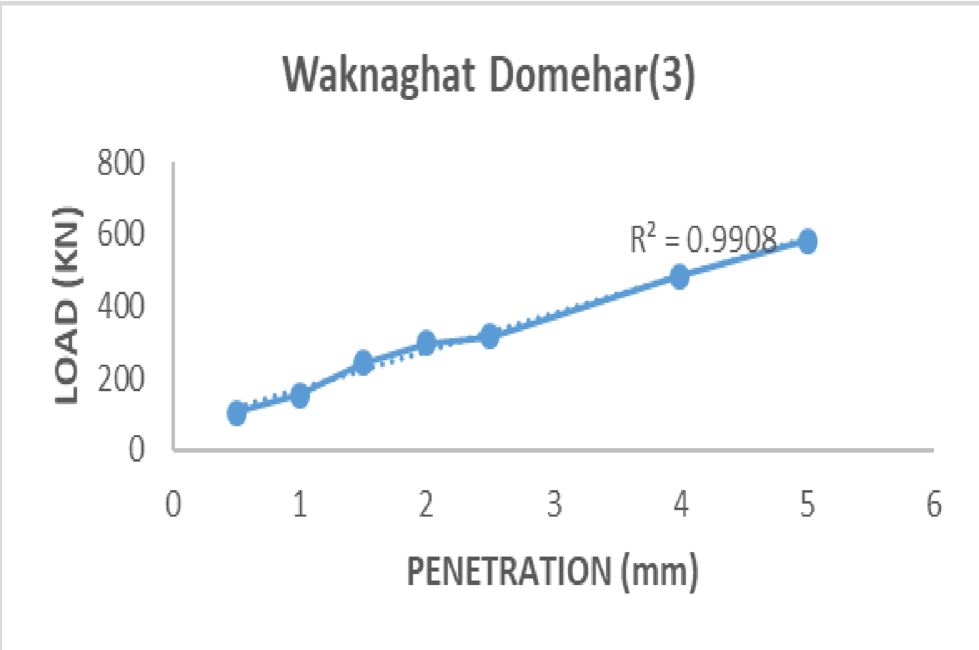

Fig. 5.13 Load Penetration Curve of Sample-3 RR1

CBR data (Soaked) of selected road stretch

CBR data of sample-1 RR1

CBR VALUE OF WAKNAGHAT DOMEHAR (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	10	38.711		
1	28	108.3908		
1.5	33	127.7463		
2	39	150.9729		
2.5	47	**181.9417**	1370	13.28041606
4	75	290.3325		
5	84	**325.1724**	2055	15.82347445

Table 8.16 CBR data of sample 1 RR1

California Bearing Ratio- 15.82%

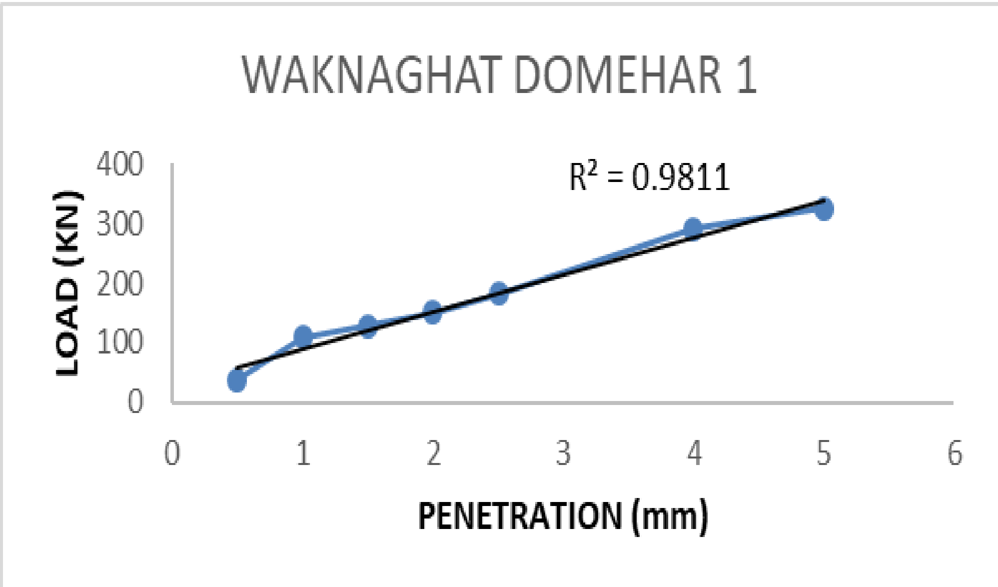

Fig 5.14 Load Penetration Curve of Sample-1 RR1

CBR data of sample-1 RR2

CBR VALUE OF WAKNA LINK (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	15	58.0665		
1	35	135.4885		
1.5	55	212.9105		
2	79	305.8169		
2.5	100	**387.11**	1370	28.25620438
4	192	743.2512		
5	217	**840.0287**	2055	40.877309

Table 8.17 CBR data of sample 1 RR2

California Bearing Ratio- 40.87%

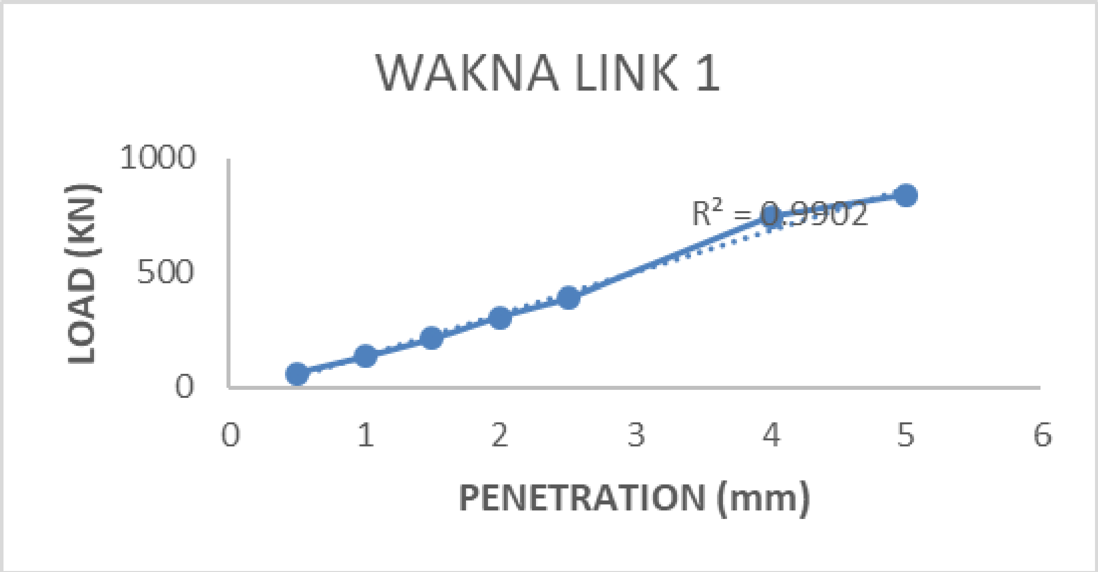

Fig. 5.15 Load Penetration Curve of Sample-1 RR2

CBR data of sample-1 RR3

CBR VALUE OF KYARI BANGLA (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	23	89.0353		
1	46	178.0706		
1.5	57	220.6527		
2	63	243.8793		
2.5	78	**301.9458**	1370	22.03983942
4	156	603.8916		
5	175	**677.4425**	2055	32.96557178

Table 8.18 CBR data of sample 1 RR2

California Bearing Ratio- 32.96%

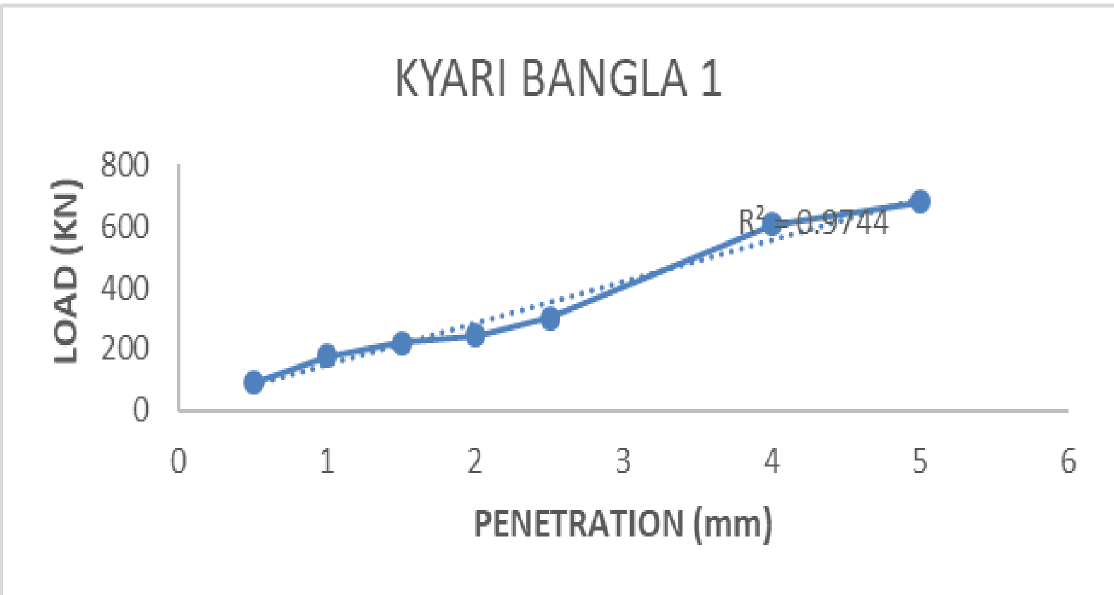

Fig. 5.16 Load Penetration Curve of Sample-1 RR3

CBR data of sample-1 RR4

CBR VALUE OF CHAIL (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	37	143.2307		
1	58	224.5238		
1.5	60	232.266		
2	63	243.8793		
2.5	65	**251.6215**	1370	18.36653285
4	197	762.6067		
5	218	**843.8998**	2055	41.0656837

Table 8.19 CBR data of sample 1 RR4

California Bearing Ratio- 41.06%

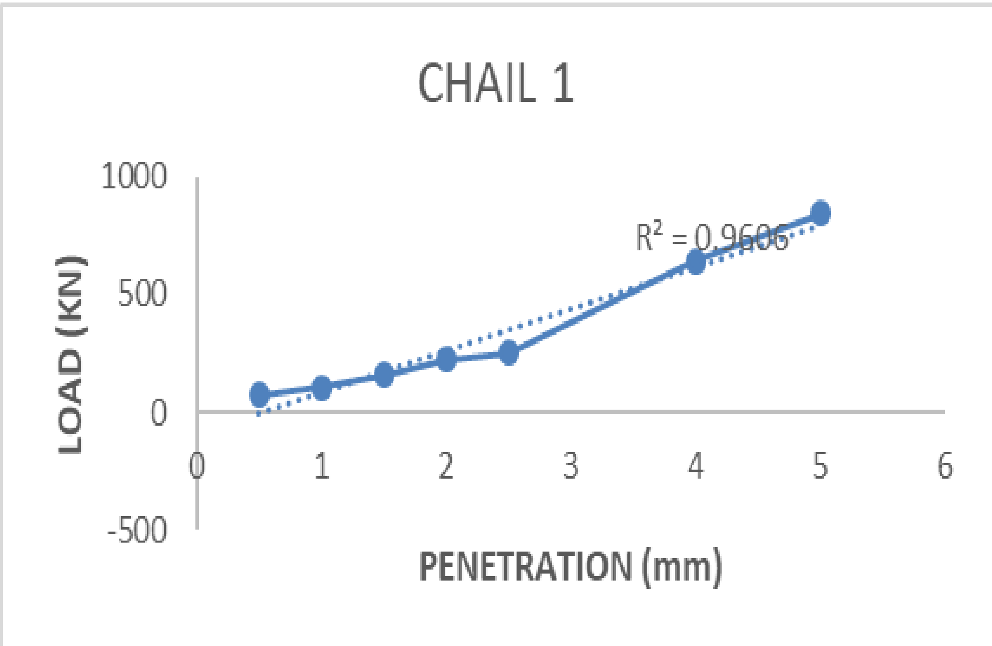

Fig. 5.17 Load Penetration Curve of Sample-1 RR4

CBR data of sample-1 RR6

CBR VALUE OF ASHWINI KHAD (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	11	42.5821		
1	32	123.8752		
1.5	37	143.2307		
2	42	162.5862		
2.5	47	**181.9417**	1370	13.28041606
4	86	332.9146		
5	95	**367.7545**	2055	17.89559611

Table 8.19 CBR data of sample 1 RR6

California Bearing Ratio- 17.89%

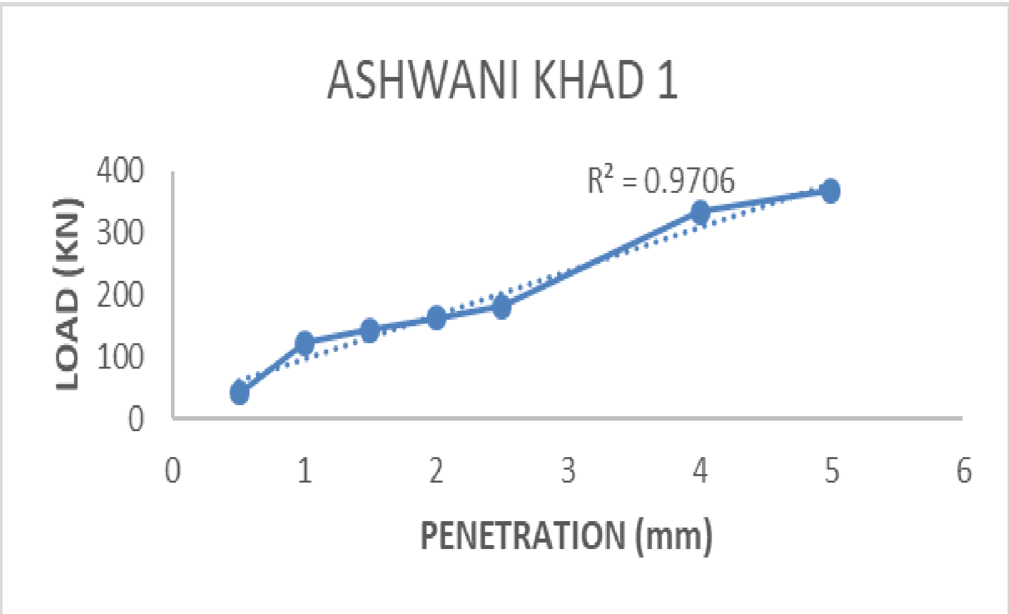

Fig. 5.18 Load Penetration Curve of Sample-1 RR6

CBR data of sample-1 RR5

CBR VALUE OF BASAL (1) ROAD				
PENETRATION (mm)	**DIVISION**	**CORRESPONDING LOAD VALUES (KN)**	**STANDARD VALUE**	**CBR VALUES %**
0.5	9	34.8399		
1	30	116.133		
1.5	69	267.1059		
2	110	425.821		
2.5	144	**557.4384**	1370	40.68893431
4	205	793.5755		
5	210	**812.931**	2055	39.55868613

Table 8.20 CBR data of sample 1 RR3

California Bearing Ratio- 32.96%

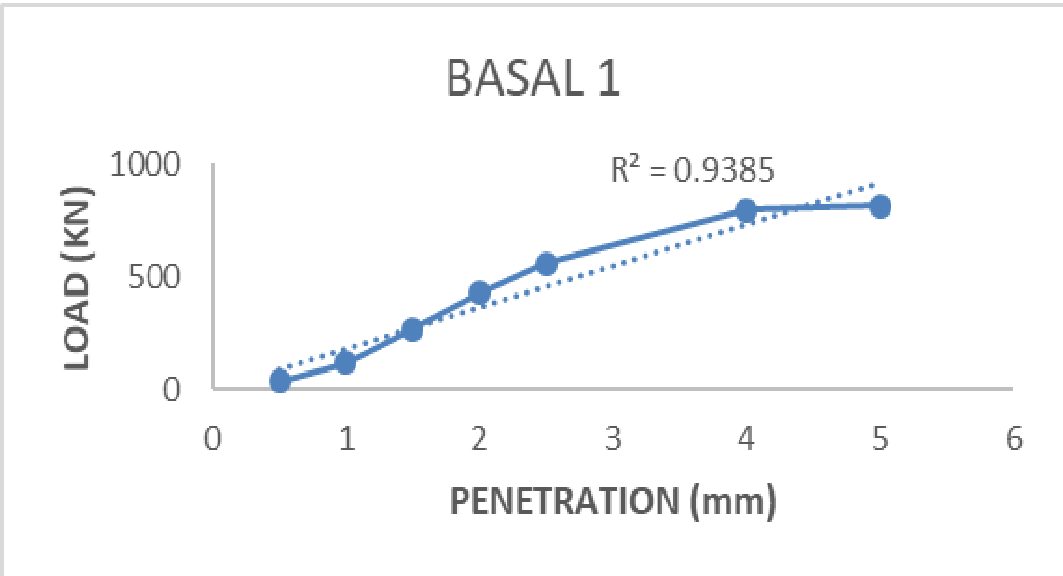

Fig. 5.19 Load Penetration Curve of Sample-1 RR5

Annexure-IV

DEFLECTION PREDICTION MODEL

1. Traffic Volume as Parameter of Time:

$$X_1 = 2.1582e^{0.0471x}$$

Table 9.1 Traffic Volume prediction formula

X= TIME IN YEARS
X_1= TRAFFIC VOLUME (MSA)

$$D=0.66937378+X_1(0.008)+X_2(0.0027)+X_3(0.010)-X_4(0.01098)$$

Table 9.2 Deflection prediction formula

Regression Statistics	*VALUES*
Multiple R	0.999247829
R Square	0.998496224
Adjusted R Square	0.992481119
Standard Error	0.016064462
Observations	6

Table 9.3 Statistical data of regression

X_1= TRAFFIC VOLUME(MSA)
X_2= CBR SOAKED
X_3= CBR UNSOAKED 1
X_4= CBR UNSOAKED 2
D= DEFLECTIONS OF BB

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.662	0.031	21.655	0.029	0.273	1.050	0.273	1.050
TRAFFIC VOLUME MSA	0.016	0.019	0.876	0.542	-0.220	0.252	-0.220	0.252
CBR SOAKED	0.002	0.001	1.556	0.364	-0.015	0.020	-0.015	0.020
CBR UNSOAKED 1	0.010	0.001	12.457	0.051	0.000	0.021	0.000	0.021
CBR UNSOAKED 2	-0.011	0.000	-24.562	0.026	-0.017	-0.005	-0.017	-0.005

Table 9.4 Regression values

2. Traffic Volume and Time as Parameters:

$$T_1 = -0.933143 * \text{Traffic volume} + \text{Time} * (-0.5818257) + 0.128040$$

$$H_1 = \log(1+e^{T1})$$

$$T_2 = 0.177922 * \text{Traffic volume} + \text{Time} * (0.143096) - 0.235725$$

$$H_2 = \log(1+e^{T2})$$

T_1, H_1, T_2, H_2 = Random Variables
Time= Years from base 2017

Table 9.5 General variable calculation formula

$$\text{Deflection} = H_1 * 1.009481 + H_2 * 0.711198 + 0.047402$$

Table 9.6 Deflection formula Traffic Volume and Time as Parameters

3. Traffic Volume, CBR and Time as Parameters:

$$T_1 = -0.771 * \text{Traffic volume} + \text{Time} * (-0.625) + \text{CBR} * (-0.191) + 0.307$$

$$H_1 = \tan h\,(T_1)$$

$$T_2 = 0.650 * \text{Traffic volume} + \text{Time} * (0.559) + \text{CBR} * (1.139) + 0.112$$

$$H_2 = \tan h\,(T_2)$$

Tan h = tan Hyperbolic
Time= Years from base 2017
T_1, H_1, T_2, H_2 = Random Variables

Table 9.7 General variable calculation formula

$$\text{Deflection} = H_1 * 0.596 + H_2 * 0.550 + 0.047402 + 0.798$$

Table 9.8 Deflection formula with Traffic Volume, CBR and Time as Parameters