CORRELATION BETWEEN BENKELMEN BEAM AND FALLING WEIGHT DEFLECTOMETER TECHNIQUE

A

PROJECT REPORT

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

Of

BACHELOR OF TECHNOLOGY

CIVIL ENGINEERING

Under the supervision

Of

Dr. Saurabh Rawat

(Assistant Professor)

By

Ganga Ram Ghalley [171678]

Lokesh Sharma [171684]

Ritvik Mehta [171625]

To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN-173234

HIMACHAL PRADESH, INDIA

MAY-2021

DECLARATION

I hereby declare that the work presented in the project report entitled **“ Correlation between BBD *FWD”** submitted for the partial fulfilment of the requirement 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 **Dr. Saurabh Rawat**. 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.

Ganga Ram Ghalley [171678]

LOKESH SHARMA [171684]

RITVIK MEHTA [171625]

Department of Civil Engineering

Jaypee University of Information Technology,

Waknaghat, Solan, H.P., India

Dated: 16/05/2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"CORELATION BETWEEN BBD & FWD TECHNIQUE"** in the partial fulfilment of the requirement for the award of the degree of bachelor of technology in civil engineering submitted to the depart of civil engineering, **Jaypee University of Information Technology** , **Waknaghat** is an authentic record of the work carried out by **Ganga Ram Ghalley (171678), Lokesh Sharma (171684), Ritvik Mehta (171625),** during a period from August, 2020 to May, 2021 under the supervision of **Dr. Saurabh Rawat,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Dated: 16/05/2021

Signature of the supervisor
Dr. Saurabh Rawat
(Assistant professor)
Department of Civil Engineering
JUIT, Waknaghat

HOD
CE DEPT

Signature of HOD
Dr .Ashok Kr. Gupta
(Professor and head of department)
Department of Civil Engineering
JUIT, Waknaghat

External Examiner

AKNOWLEDGEMENT

We wouldn’t have been at this stage without the help of our generous and esteemed mentor **Dr. Saurabh Rawat**. We would like to offer our sincere gratitude for providing us with their guidance and suggestions which adds inspiration and energy in us to actively take part in this most benefiting project .

We are also indeed very grateful to sir for his keen professional observations and continued encouragement on the same.

We also would like to record our sincere gratitude to Professor Dr. Ashok Kumar Gupta (Head of department of civil engineering of Jaypee University of Information Technology) and also the faculty of the university for providing us this platform which was really helpful in our career.

We are equally grateful to the Learning resource centre (LRC) for providing us with various resources based on the project**.**

ABSTRACT

Most of the road network in India has a significant level of deterioration and therefore requires major improvement projects. In general, most of these activities involve a new asphalt layer on the original pavement structure. Knowledge and analysis of structural capacity of the pavement is essential to perform a durable and economical design.

Determination of the structural capacity of flexible pavements is a function of the deflections produced by the application of load. The techniques that is mostly used in many countries to measure pavement deflections is the Falling Weight Deflectometer (FWD) and Benkelman beam method (BBM) , FWD works under dynamic loading and the BBM works under static loading. The use of BBM under static loading has not been recommended by several design methods, including AASHTO, but BBM is still used widely in many countries including India, for this reason it is necessary to compare the deflections by Benkelman beam and falling weight deflectometer.

In this study deflections measure by BBD and FWD techniques on 30 deflection observation points on selected 1.5 km flexible urban highway stretch. Both tests are performed simultaneously on marking points. Data is collected by test as per IRC: 81-1997 and IRC: 115-2014.

Keyword 1: Flexible pavement
Keyword 2: Non-destructive test
Keyword 3: Benkelman beam
Keyword 4: FWD
Keyword 5: Deflection

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS & ABBREVIATIONS

BBD : Benkel Beam Deflectometer

CBR : California Bearing Ratio test

FWD : Falling Weight Deflection

IS : Indian Standard

ISC : Indian Standard Code

LRC : Learning Resource Centre

NDT : Non Destructive Testing

AASTHO: American Association of State Highway and Transportation Officials

PCC : Plain Cement Concrete

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The road transportation system is the most important mode of transport system which aids in the over all development of the country and the economic stability. The road transport system came into practice before any other kind of transportation system. Pavements are the most important element which promote various things like economics activities, transportation systems and to improve the living culture. The life of all these pavement structures are extended by maintenance because the structures begins to fail after some time when it is weathered by the different season and the traffic plying over it.

1.2 Pavement Evaluation Concepts:

Pavement evaluation is the most important practice to check the efficiency of the pavement structurally including various elements of the pavement. The pavement evaluation is done to determine the life and loading capacity of the pavement both presently and the future when it deteriorates over a time. The pavement evaluation is done literally using non-destructive techniques to ensure the future quality of the pavement.

The pavement evaluation:

- Functional Evaluation
- Structural Evaluation

Fig 1.1: Benkelman beam

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Already, various research studies and investigations have been conducted on the benkle beam method and falling way deflectometer and other aspects. Below are some of the reports and journals presented by the authors within India and outside India.

2.1.1 STUDY CONDUCTED IN INDIA

1. **S.K.KHANNA, C.E.G. JUSTO, A.VEERARAGAVAN:**

{Structural Evaluation of Flexible pavement. (Highway maintenance)}

When load is applied on pavement there is deflection and recovery of pavement called
Rebound Deflection.
Two methods Falling way deflectometer and benkle beam method

2. **PROF .A.K. Gupta, PROF. S.S .Jain**

(Deflection measurement By Benkle beam method)

Deflection measurement (static load), Calculation of deflection, Correction of temperature variation, correction for seasonal variation.

3. **A.V.SINHA, DR.SUNIL BOSE, S.K.NIRMAL:**

(Deflection measurement by falling weight deflectometer)

Deflection measurement (dynamic load), Calculation of E (modulus of elasticity),

As per IRC code correction for temperature, correction for seasonal variation

4. **DR.ANIMESH DAS:**

(Interpolation of falling weight deflectometer)

How to calculate E value, Process of the back calculation

5. **Mr. Pankaj Goyal, Prof.Srinath Karli, Mr. Vaibhav K.Solanki** :

(Comparative studies between Benkle beam and falling weight deflectometer test for flexible pavement)

Analysis with each other of benkle beam method and falling weight deflectometer can be correlated.

6. **Aditya Singha, Akash Sharma, Tanuj Chopra**:

(ANALYSIS OF THE FLEXIBLE PAVEMENT USING FALLING WEIGHT DEFLECTOMETER FOR INDIAN, NATIONAL HIGHWAY ROAD NETWORK)

India is using the salient features of KGPBACK, and IITPAVE. In this study, deflection measurements were carried out on the pavement using the established FWD system . The accountability of the provided overlay thickness was ensured by the KGPBACK software as it depicted a clear decrease in the cracking, ravelling, rutting and roughness distress values. The improvement in conditions of all pavement sections on modelling the bituminous overlay maintenance strategy suggested that if such strategies are applied on the Indian roads it would increase the lifetime of the Indian Highway Roads.

7. **DR. S.S. JAIN, PROFESSOR A.K. GUPTA, PROFESSOR S.K. KHANNA**

(PAVEMENT EVALUATION AND OVERLAY DESIGN FOR EFFICIENT MANAGEMENT SYSTEM IN INDIA)

Correlation between the basic 'stress/strain and surface deflection parameters of a three layered pavement have also been discussed here. FEPNLE model is found to be useful for design of different types and thicknesses of overlays for strengthening of existing flexible pavements.

8. **M/s Vishwa Samudra**

(Condition of pavement strength testing for selected road section)

Variability may be a reflection on variability of the pavement composition along the alignment. For each section, the available information only supports the consideration of provided pavement composition in that section.

2.1.2 STUDY CONDUCTED OUTSIDE INDIA

1. Kurt D.Smith, James E.Bruinsma ,Monty J.Wade, Karim Chatty:

(Back calculation of flexible pavement)

Back calculation can be done by:

-Regression equation

-Method of equivalent thickness

-Dynamic back calculation method

2. Analem Nega, Hamid Nikraz, Imad L.Al –qadi :

(Dynamic analysis Of falling way deflectometer)

BISDF computer program for back calculation of E it is an exact solution

3. Linda M. Pierce, James E. Bruinsma, Kurt D. Smith, Monty J. Wade, Karim Chatti, and Julie M. Vandenbossche:

(Using Falling Weight Deflectometer Data With Mechanistic-Empirical Design and Analysis , Volume III: Guidelines for Deflection Testing, Analysis, and Interpretation)

Deflection testing is recognized as an effective method for determining the material parameters of in-place pavement layers, the structural condition of existing pavements, PCC pavement joints and cracks, and the presence of voids beneath PCC pavements.

FWD testing guidelines are provided and include recommendations for sensor configuration, number of drops and load levels, testing location, testing increments, deflection testing data checks, and safety procedures for use during FWD testing. Back calculation guidelines include an overview of the back calculation process, data inputs and suggested default values, measures of convergence, and a summary of various studies that have verified back calculation results and evaluated back calculated versus laboratory determined moduli.

2.2 SUMMARY OF LITERATURE REVIEW

There are only two methods as per IRC to calculate the structural analysis of flexible pavement BBM and FWD method and in India till now BBM method is used.

To maintain High structural stability of pavement FWD is used. So to create high structural stability of pavement at low economic with the help of BBM we can correlate E (modulus of elasticity) of BBM and FWD, so that there is high structural stability at low economical cost .

BBM and FWD are very essential part of the overlay design without it as per Indian standards we cannot design the overlay the bankel beam uses the rebound deflection technique for the collection of the deflection data where as the fwd uses geo sensors of the calculation of the deflection data they both are very useful for design and with the help of correlation between them can design are overlay using fwd but instrument used is benkle beam.

2.3 OBJECTIVE OF THE STUDY

- Evaluation of structural capacity of any flexible road pavement.
- Design and estimation of overlays for strengthening of any weak pavement for highway.
- Corelation between them will help in high structural stability under Static loading

CHAPTER 3

METHODOLOGY

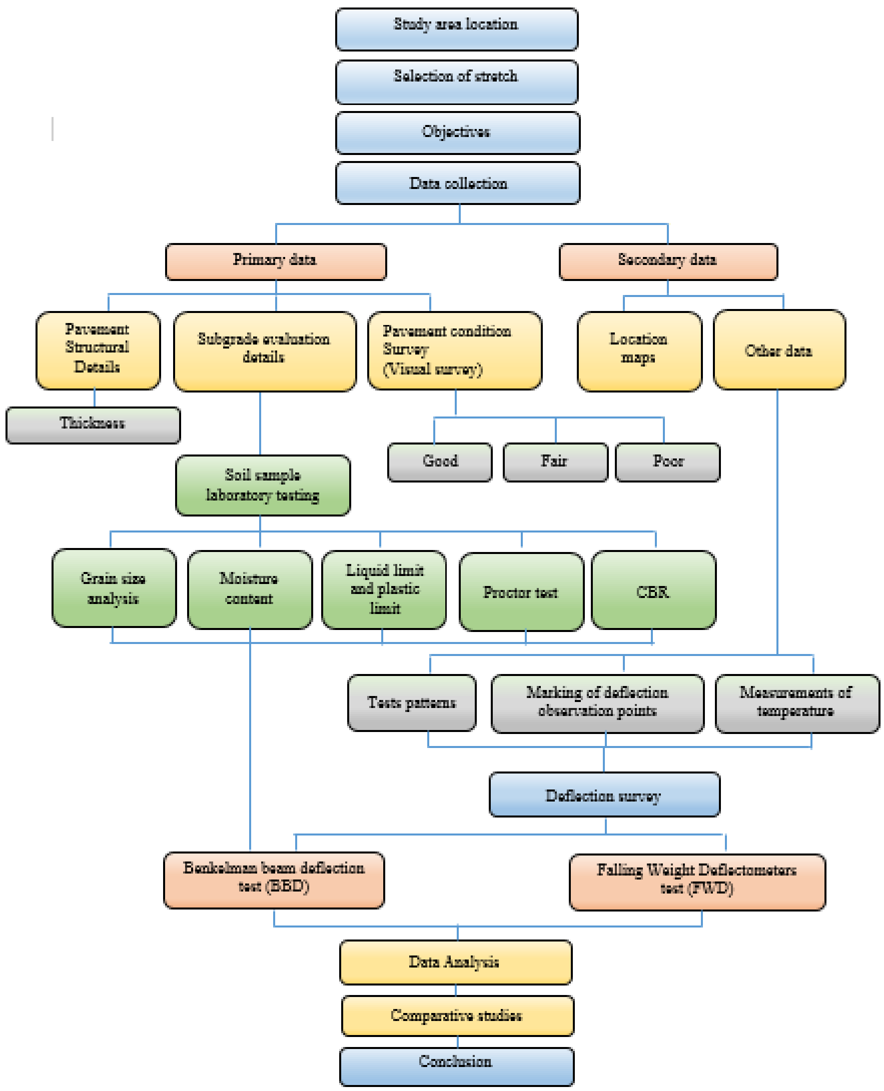

Fig 3.1: Methodology flowchart

3.1 GENERAL

Methodology covers the methods we (performer) must be abided by to find out the expected results in any experiment or test we perform. Here we had performed an experiment to find out the road deflection by using ***BENKELMAN BEAM DEFLECTION TECHNIQUE AND FALLING WEIGHT DEFLECTION TECHNIQUE.*** The below mentioned are the methodology of the mentioned techniques.

3.2 PRELIMINARY STUDY

Before carrying out the deflection test, the preliminary studies have to been done which covers the following aspects.

- Historical data
- Rainfall
- Map
- Temperature
- Condition of traffic data
- Road demarcation

After the preliminary studies are done, we get into the test in a chronological order as follows.

Marking of the deflection observation point.

The deflection points are mark on the road to carry out the test. And those deflection points are marked at the transverse distance of 1.5m from the pavement edge. Points are marked only at the outer edge of lane. After marking those points, we proceed the test either with Benkelman beam deflection technique or falling weight deflectometer technique.

3.2.1 Benkelman beam deflection technique.

Benkelman beam is used for measuring the pavement deflection at different point of the pavement. This device is less expansive and the method of study is simple and easy to carry on. In this technique, the magnitude of rebound deflection of a flexible pavement is measured when the loaded truck is moved forward after each testing at a respective distance. This technique is widely used for the structural capacity evaluation of flexible pavement and design of overlays to strengthen the weak pavement.

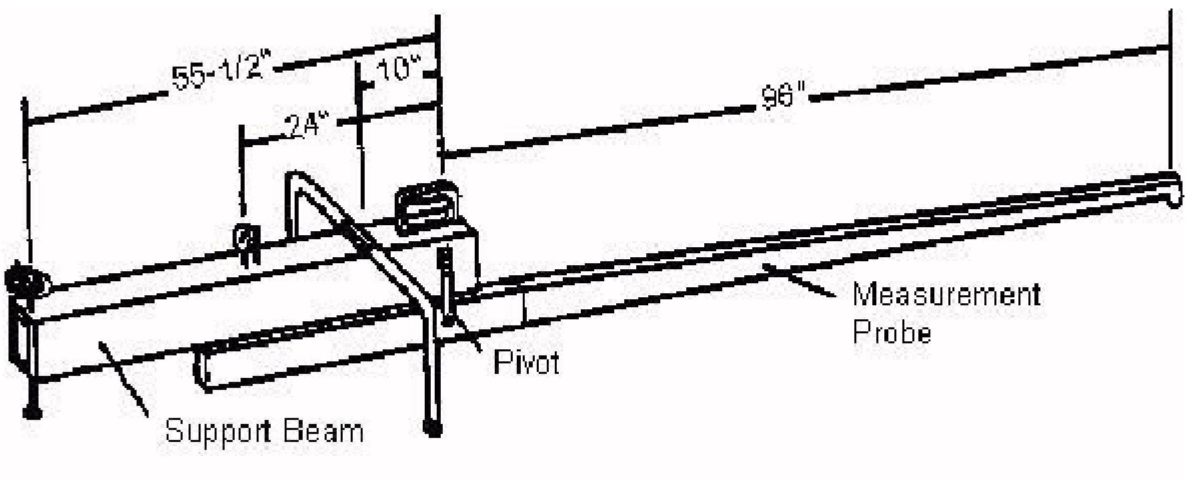

Fig 3.2: Probe

3.2.2 Falling weight deflectometer technique

Falling Weight Deflectometer (FWD) is a device widely used for the deflection measurement where deflection are measured through impulse-loading system. In this system, there will be a pavement deflection when a transient load is applied to the pavement and those pavement deflections are measured at various radial distances.

The process of pavement deflection measurement is simple where impulse load is applied by means of falling mass which is allowed to drop vertically on a system of spring placed over a circular loading plate. The deflection is measured by the deflection sensor.And those deflection sensors are placed at various radial distances starting from the centre of the loading plate. The load and pavement deflection data are acquired with the help of data acquisition system kept in the nearby car with computer system and the data recorded by technician

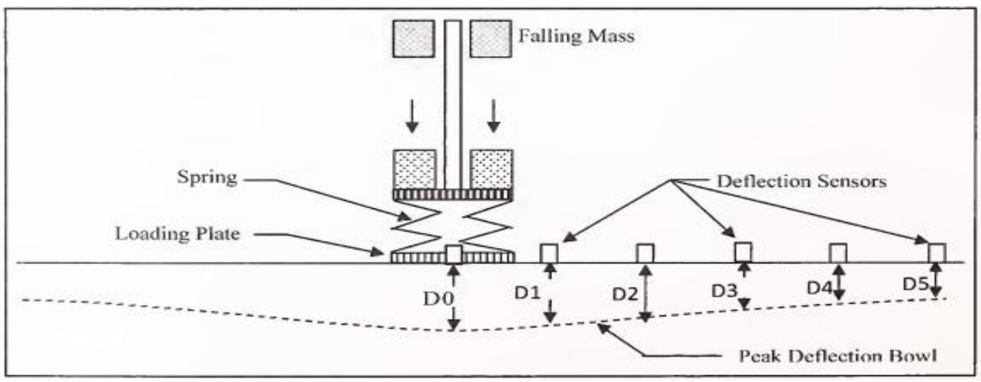

Fig 3.3: Falling weight deflectometer

Note:IRC-81-1997 by BBD technique & IRC-115-2014 by FWD technique

3.3 DATA ANALYSIS:

The soil sample is collected at 0.900 km at the pavement composition survey locations. Different test are done on the collected sample like:

- CBR test,
- Plastic limit, etc.
- Grain size analysis
- Liquid limit

Following analysis are done

1. Data analysis on BBD method

2. Data analysis on FWD method

3.3.1 Benkelman beam procedure.

- Keep truck /trailer with axle load of 8.2 (+_) 0.15 tonnes equally distributed on two dual tired wheels on the selected site of the road.

- Insert the probe of the device between the dual tyres of the test wheel.

- Release the locking device and adjust to contact plunger with the dual gauge and take the reading as Do (initial reading).

- Move the truck or trailer forward at a creep speed to a distance of 2.7m from the initial test point to take another test reading as Di(intermediate reading)

- And after that further move truck or trailer to a test of 9m from the previous test point to do the same and take reading as Df (final reading).

- Take mean of the three reading to do the analysis and calculation.

3.3.2 Correction in Readings :

1) Temperature correction:

- Dig a 45 mm deep and 10mm diameter hole and add glycerol to it to check the temperature.
- For a temperature of 35℃, we don't have to apply temperature correction as it is a standard temperature.
- The temperature correction of 0.01mm will be applied to each ℃ for the temperature other than 35℃

- The temperature will be negative for pavement temperature higher than 35 ℃ and positive for lower than 35 ℃.
- No need of applying correction on areas where altitude is more than 1000m and where average temperature is less than 20℃ for more than four months in a year.

2) Correction for seasonal variation:

- To apply seasonal variation correction, the deflection measurement must be done on monsoon season because pavement will be weak in monsoon season.
- Dig a soil 15 cm from sub grade at every km according to soil profile to check for seasonal variation.
- Take a soil sample weighing not less than 100g from auger.
- Take a soil sample from 50 mm-100 mm below the sub grade.
- The soil is divided as plasticity index less than 15 or more than 15 rainfall more than 1300mm and less than 1300mm and graph of sand, gravel and clayey soil are given as :

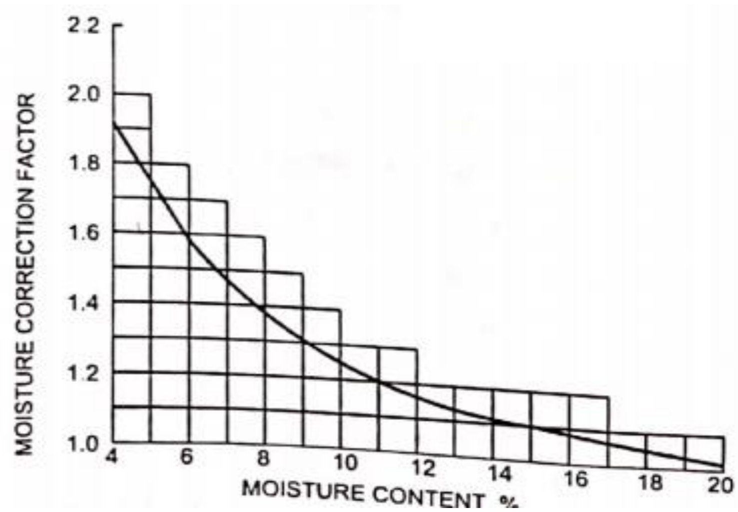

Fig 3.4: Moisture correction factor for clayey sub-grade with high plasticity for areas with annual rainfall>1300mm

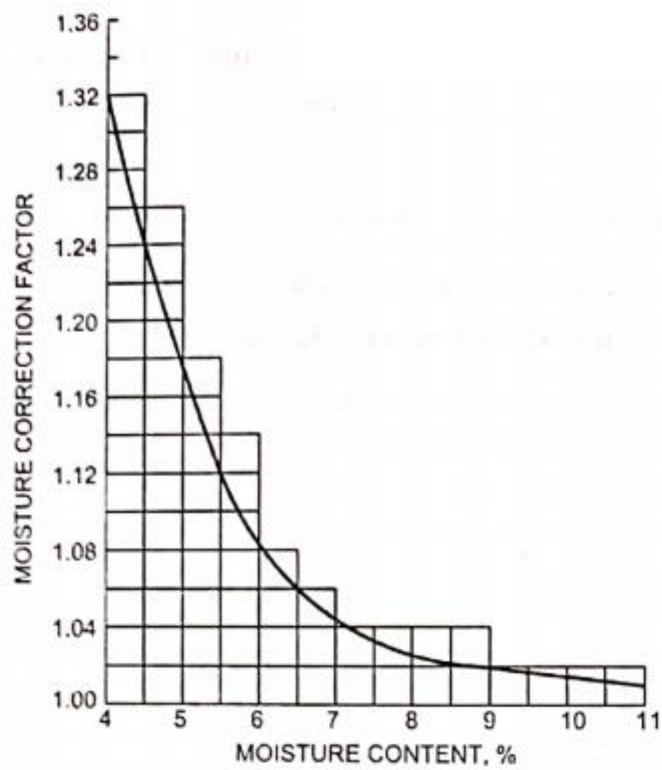

Fig 3.5: Moisture correction factor for sandy soil for areas with annual rainfall<1300mm

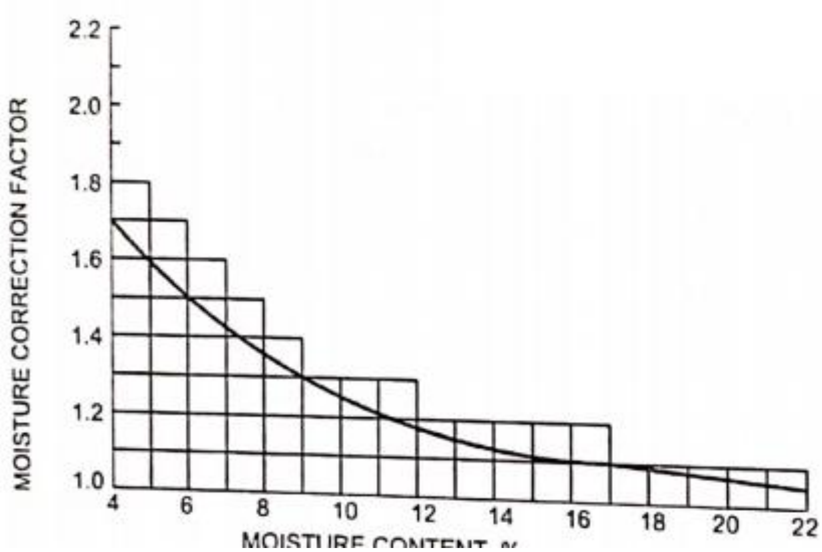

Fig: 3.6: Moisture correction factor for clayey sub-grade with low plasticity for areas with annual rainfall>1300mm

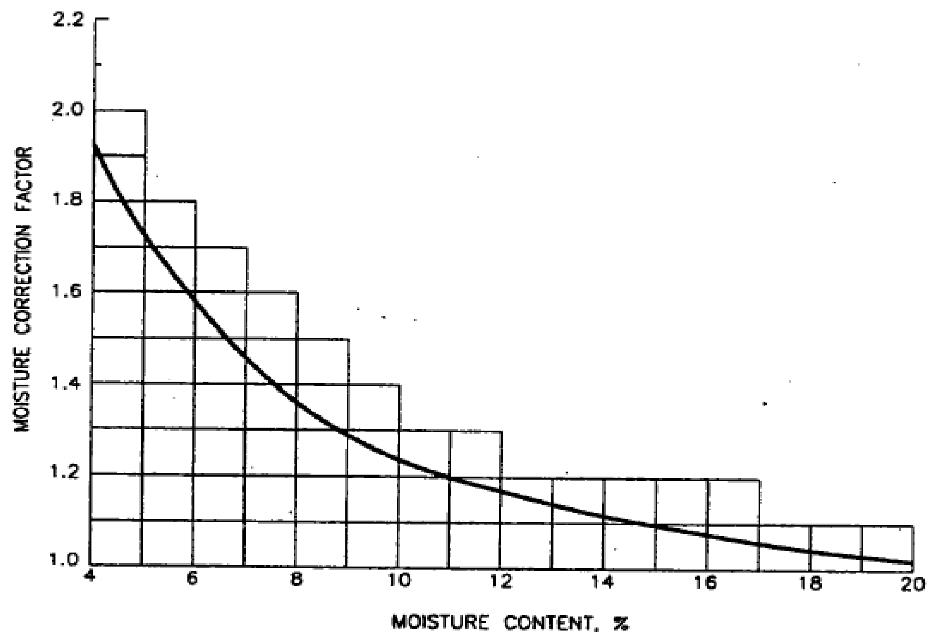

Fig 3.7: Moisture correction factor for clayey sub-grade with high plasticity for areas with annual rainfall<=1300mm

3.3.3 Falling weight Deflectometer Test

- Marked the test point on the pavement.
- Raised the mass to the required height for producing a target load of 40KN.
- Raised the mass and dropped and recorded the load and deflection data into a computer through a data acquisition system.
- Record pavement temperature at hourly interval.
- Drilled a 40mm depth holes in a pavement to check the temperature of the pavement. we should not measure the pavement deflection when the temperature of the pavement is more than 45°C.

3.3.4. Correction for temperature:

- Standard temperature is 35 ℃
- Temperature correction is not needed for thin bituminous layer less than 40 mm thick.

3.3.5. Correction for seasonal variation

- This equation is applicable only for modulus of sub grade. Minimum winter modulus of 20 Mpa or more & minimum summer modulus 30 Mpa or more

Esub_mon=3.351*(Esub_win)^0.7688-28.9

Esub_mon= 〖0.8554〗^∗(Esub_sum) - 8.461

where,

Esub_mon = subgrade modulus in monsoon (MPa)

Esub_win = subgrade modulus in winter(MPa

- This equation is applicable only for modulus of granular layer 60 mpa or more and minimum winter modulus of 80 Mpa and minimum summer modulus 100Mpa :

Esub_sum =subgrade modulus in summer (MPa)

seasonal correction factors for granular layers are given by equations 8 and 9 .

Egran_mon = - 〖0.0003〗^∗(Egran_sum)^2 + 〖0.9584〗^∗(Egran_sum) - 32.989

Egran = 〖 10.5523〗^∗(Egran_win)^0.624 - 113.857

Egran_mon = granular level modulus in monsoon(MPa)

Egran_win = granular level in winter (MPa)

Egra_sum = granular level in summer(MPa)

CHAPTER 4
RESULTS AND DISCUSSION

4.1. General

The Benkelman Beam survey is carried out at every 50 meter interval. Total 1.5 km stretch divided into three 500 m sub stretch or section. The Benkelman beam survey data with analysis are shown in table below. In the selected area, we performed an experiment to find the deflection of the pavement using the Benkelman Beam method following the procedures mentioned above using standard probes.

To compare the results we also did falling weight deflectometer test where 40kN of load is allowed to fall freely from design height and deflection data is recorded in data acquisition system connected to the vehicle.

4.2 Results

We performed the test on the selected pavement to find the rebound deflection of the road. We used both the techniques to find out the pavement deflection through respective procedures of the same. The data of each technique is tabulated below.

4.2.1. Deflection from BBD

The deflection of the pavement is noted from the standard device called probe. The place has an annual rainfall of 775mm. After noting the readings from the dial guage, we applied different temperature correction for different test point and a seasonal correction of 1.18 is applied. We applied the correction for the deflection and found the total deflection as 0.37mm and calculated the mean deflection as 0.051mm through which we calculate the standard deviation of each test point and after which we calculate and found out the characteristic deflection of each test point

Name of the road : Divine Road (230 33' 53.16" N 720 25' 30.55" E) is one of the Urban Highway in Ahmedabad city in Gujarat State.	Date and time of observation of climatic condition :	whether temperature correction is to be applied :	YES
	10-Apr-17		
Section :The Urban highway connecting the Sola Gam Road is taken as study area having of 1.5 km	Annual rainfall :776 mm	whether correction for sesaonal variation is to be applied :	YES
No. of traffic lanes :lane width is more than 3.75m and it is four lane divided road.			

S.NO.	LOCATION OF TEST POINTS		PAVEMENT TEMPERATUR(C)	TYPE OF SOIL AND PI		MOISTURE CONTENT%	DAIL GAUGE READING (mm)			REBOUND DEFLECTION (mm)		
							INTIAL (Do)	INTERMEDIATE (Di)	FINAL(Df)	(Do-Df)	(Di-Df)	2*(Do-Df)
1	0.00	L.H.S	39.4	SM	2.19	4.76%	0	-0.00522	-0.006	0.006	0.00078	0.012
2	0.250		39.4	SM	2.19	4.76%	0	-0.00244	-0.00384	0.00384	0.0014	0.00768
3	0.500		40.2	SM	2.19	4.76%	0	-0.00699	-0.00765	0.00765	0.00066	0.0153
4	0.750		40.2	SM	2.19	4.76%	0	-0.00344	-0.00387	0.00387	0.00043	0.00774
5	1.000		41.9	SM	2.19	4.76%	0	-0.00827	-0.00829	0.00829	2E-05	0.01658
6	1.250		41.9	SM	2.19	4.76%	0	-0.00764	-0.00782	0.00782	0.00018	0.01564
7	1.500		41.9	SM	2.19	4.76%	0	-0.0083	-0.00833	0.00833	3E-05	0.01666

s.no	location of test points		measured deflection		correction for temperature			correction for seasonal		corrected deflection	mean deflection (mm)	standard devation		characeristics deflection (mm)
1	0.00	L.H.S	0.012	MM	4.4	0.044	0.032	1.18		0.03776		0.05039304	0.091645	0.22105
2	0.250		0.00768	MM	4.4	0.044	0.03632	1.18		0.042858	0.051818857	8E-05	0.003658	0.050174
3	0.500		0.0153	MM	5.2	0.052	0.0367	1.18		0.043306		0.00187541	0.01768	0.078665
4	0.750		0.00774	MM	5.2	0.052	0.04426	1.18		0.052227		0.002727639	0.021322	0.09487
5	1.000		0.01658	MM	6.9	0.069	0.05242	1.18		0.061856		0.003826115	0.025252	0.11236
6	1.250		0.01564	MM	6.9	0.069	0.05336	1.18		0.062965		0.003964566	0.025705	0.114375
7	1.500		0.01666	MM	6.9	0.069	0.05234	1.18		0.061761		0.003814446	0.025214	0.112189
									TOTAL=	0.362732				

Table 4.1: BBD Deflection

4.2.2: Deflection from FWD

After applying a peak load of approximately about 40kN at each test point, the rebound deflection at respective radial distance is recorded in a data acquisition system. And also the temperature of each test point is recorded. And different temperature correction is applied for all the bituminous macadam, granular sub-base and sub-grade for all the test point as tabulated below. And also the KGPBACK software is used to find out layer moduli using back calculation where we applied a load of 40.5KN with contact pressure of 56 MPa with three layers performed at seven numbers of deflection test point.

NOTE: RUTTING IS LESS THAN 10MM AND THERE IS NO CRACKING SO IT WILL BE CLASSIFIED AS GOOD.

Perefoma for Recording Pavement Deflection Data

S.No.	Lane Position		LOCATION OF TEST POINT	Pavement Temp	Load Drop No.	Peak Load	Peak Deflection in Observed At radial distance (mm)						
							0	300	600	900	1200	1500	1800
1	0.05	L.H.S	1	39.4	1	41.41	556	454.8	394.5	320.7	250.4	162.6	113
2	0.25	L.H.S	5	39.4	2	40.5	1059.5	798	621.5	419.5	275.2	149.6	100.4
3	0.5	L.H.S	10	39.4	3	39.61	942.8	942.8	686.4	433.2	274.9	144.7	93.3
4	0.75	L.H.S	15	40.2	4	40.64	1006.5	753.1	568.5	380.6	261.9	153.3	106.5
5	1	L.H.S	20	40.2	5	40.72	1001	764.8	575.2	367.3	228.7	113.4	73.3
6	1.25	L.H.S	25	41.9	6	40.11	1206.3	946.1	766.6	561	377.9	194.4	117.7
7	1.5	L.H.S	30	41.9	7	40.4	927.2	672.6	514.8	351.2	236.8	130.2	82.4

S.no	Layer Moduli(mpa)		
	Bituminou	GSB	Subgrade
1	794	102	44.5
2	765.4	100	44.4
3	769.4	101.6	44.5
4	750	101.2	44.6
5	750	102.3	44.5
6	758.8	105.9	44.6
7	763.2	102.3	44.4

S.no	Layer Moduli(mpa)			temp correction factor	corrected values of layer moduli			IIT Pave calculated deflection value
	Bituminou	GSB	Subgrade		Bituminou	GSB	Subgrade	
1	794	102	44.5	1.22	968.68	124.44	54.29	0.8625
2	765.4	100	44.4	1.22	933.788	122	54.168	0.8722
3	769.4	101.6	44.5	1.22	938.668	123.952	54.29	0.8663
4	750	101.2	44.6	1.27	952.5	128.524	56.642	0.8343
5	750	102.3	44.5	1.27	952.5	129.921	56.515	0.8257
6	758.8	105.9	44.6	1.38	1047.144	146.142	61.548	0.7563
7	763.2	102.3	44.4	1.38	1053.216	141.174	61.272	0.7659

Table 4.2: FWD Deflection

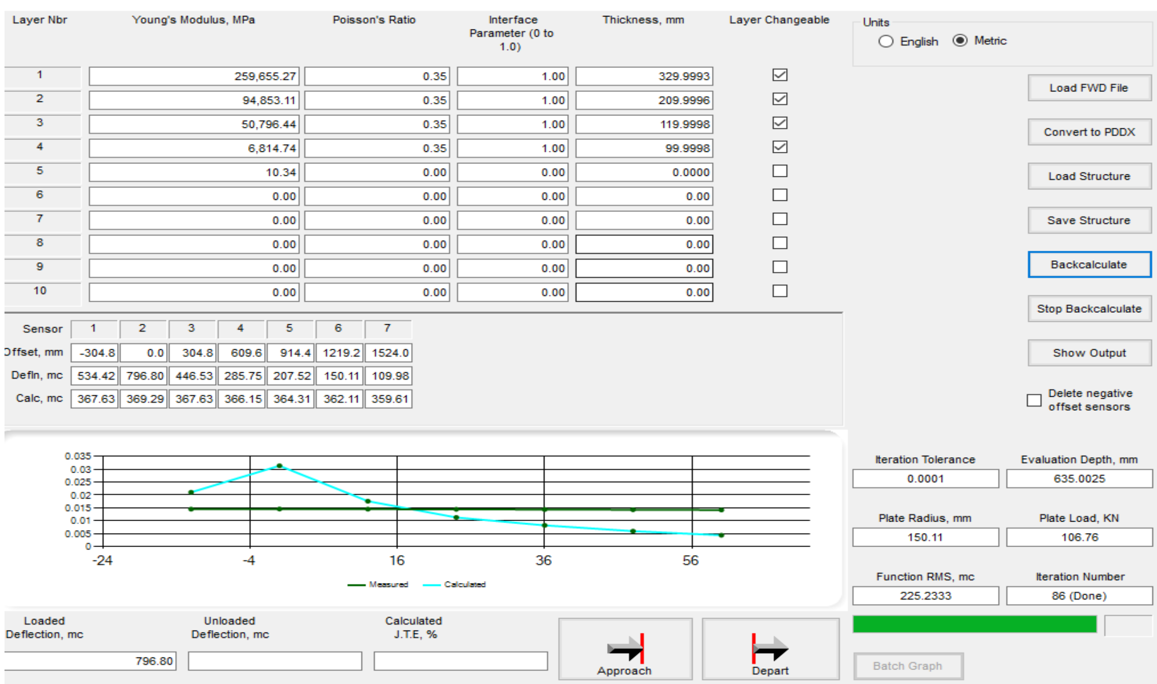

Fig 4.1: KGPBACK Backcalculate

```
Structure Information

Layer  Young Modulus, MPa    Poisson's  Interface  Thickness, mm  Changeable?
    1            259,655.27       0.35       1.00         330.00          Yes
    2             94,853.11       0.35       1.00         210.00          Yes
    3             50,796.44       0.35       1.00         120.00          Yes
    4              6,814.74       0.35       1.00         100.00          Yes
    5                 10.34       0.00       0.00           0.00           No


FWD Information

Station      = 0
Plate Radius = 150.11 mm
Plate Load   = 107 kN
ISM          = 134 kN/mm

Sensor                  1      2      3      4      5      6      7
Offset, mm           -305      0    305    610    914  1,219  1,524
Meas Defl, mc         534    797    447    286    208    150    110
Calc Defl, mc         368    369    368    366    364    362    360

Function RMS, mc     = 225.2333
Number of Iterations = 86
```

Fig 4.2: Structure information

4.2.3: Result of KPGBACK

```
VIEW RESULTS

[ ] OPEN FIILE IN EDITOR        BACK TO EDIT        HOME
[x] VIEW HERE

No. of layers                3
E values (MPa)          933.79  122.00   54.17
Mu values                 0.350.350.35
thicknesses (mm)        100.00  230.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT      SigmaR      TaoRZ       DispZ       epZ         epT         epR
100.00     0.00-0.2148E+00 0.6718E+00 0.5394E+00-0.2188E-01 0.8640E+00-0.6840E-03 0.5977E-03 0.4064E-03
100.00L    0.00-0.2148E+00-0.1277E-01-0.3006E-01-0.2188E-01 0.8640E+00-0.1638E-02 0.5977E-03 0.4064E-03
100.00  155.00-0.1461E+00 0.4575E+00-0.1688E-01-0.1073E+00 0.8722E+00-0.3216E-03 0.5510E-03-0.1348E-03
100.00L 155.00-0.1461E+00-0.8610E-02-0.7059E-01-0.1073E+00 0.8722E+00-0.9701E-03 0.5510E-03-0.1348E-03
430.00     0.00-0.4194E-01 0.2922E-02-0.9177E-03-0.7829E-02 0.5463E+00-0.7873E-03 0.3309E-03 0.2352E-03
430.00  155.00-0.4594E-01 0.3213E-02-0.2161E-05-0.1263E-01 0.5700E+00-0.8689E-03 0.3562E-03 0.2760E-03
```

Fig 4.2: Results with E values of 939.79, 122.00, 54.17 (MPa)

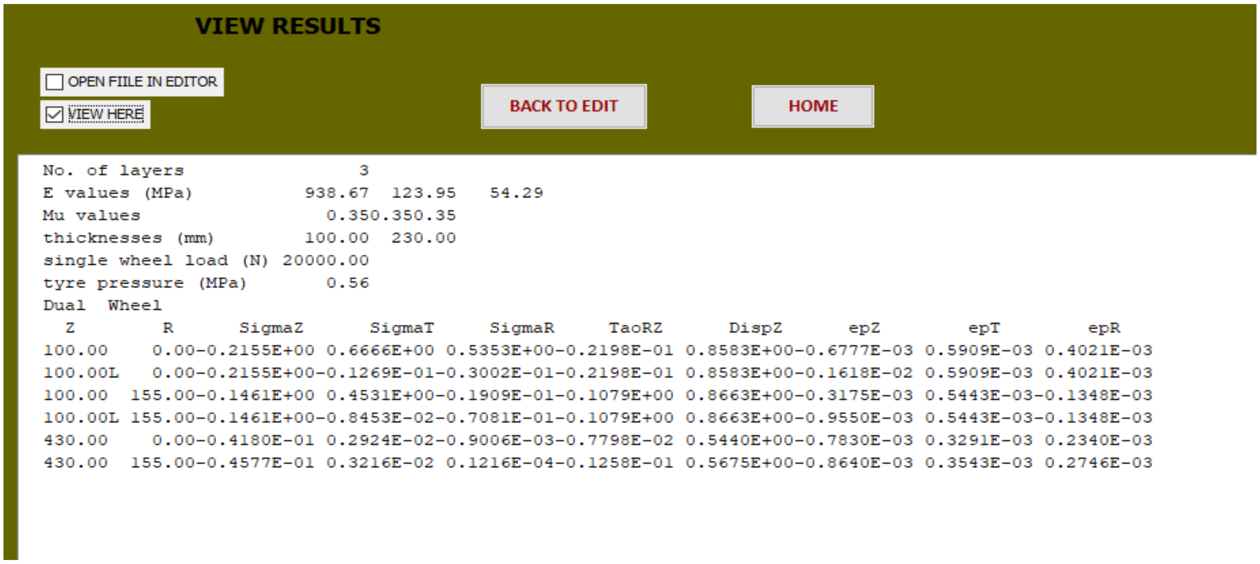

Fig 4.3: Results with E values of 538.67, 123.95, 54.29 (MPa)

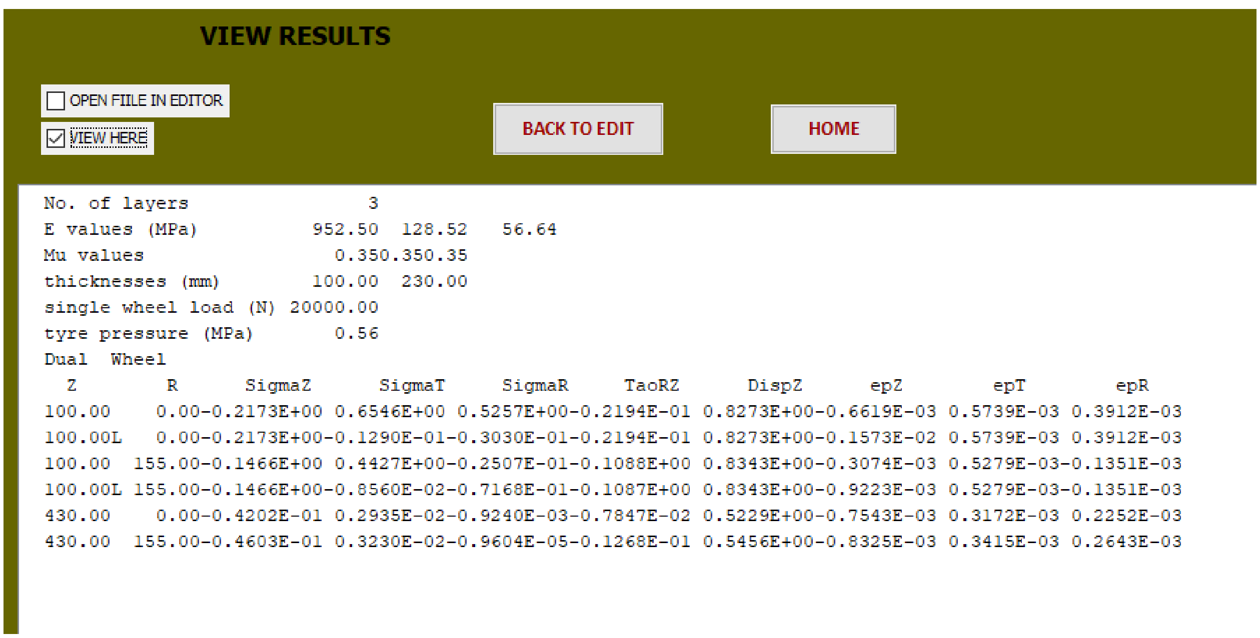

Fig 4.4: Results with E values of 952.50, 128.52, 56.64 (MPa)

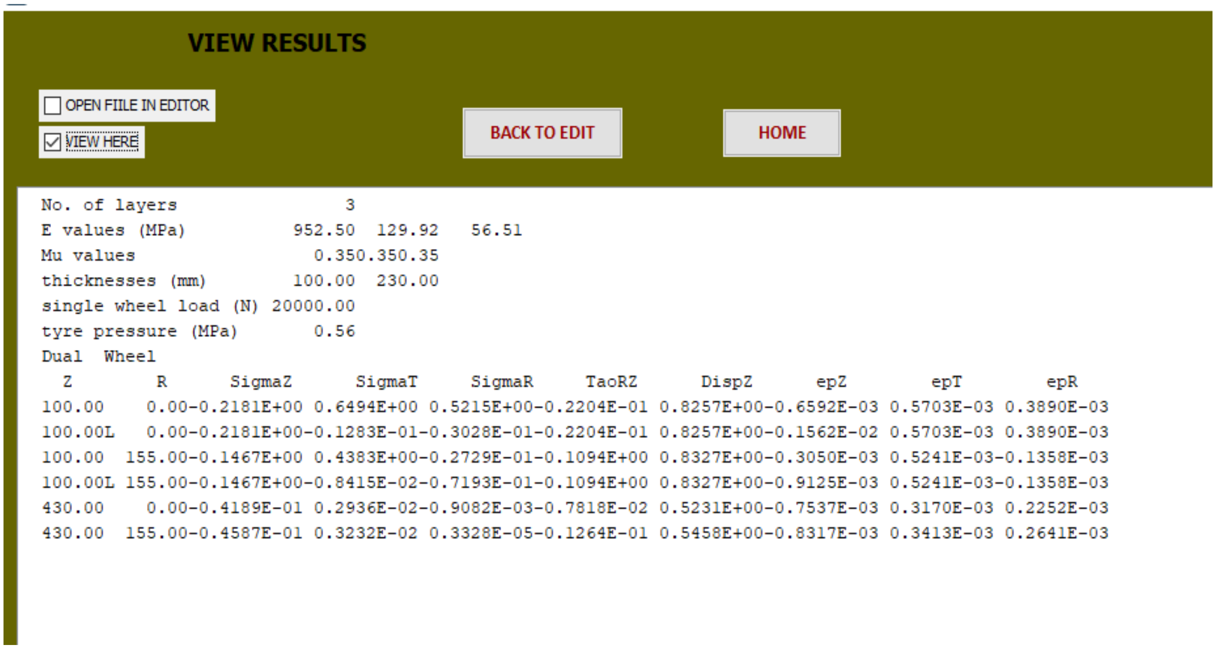

Fig 4.5: Results with E values of 952.5, 129.92, 56.51 (MPa)

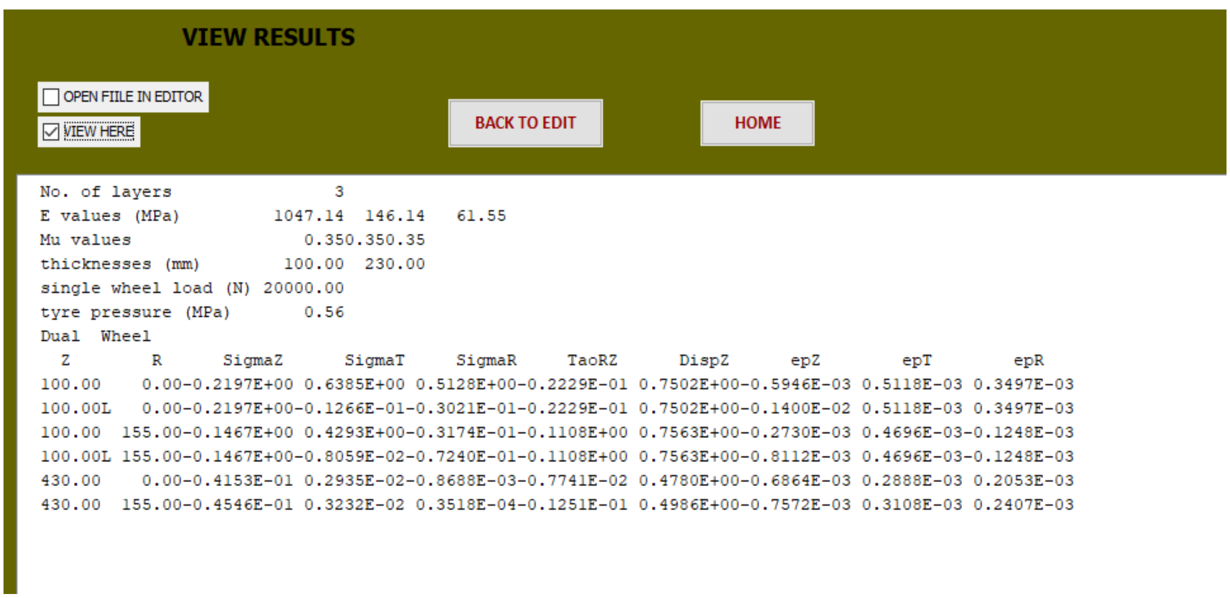

Fig 4.6: Results with E values of 1047.14, 146.14, 61.55 (MPa)

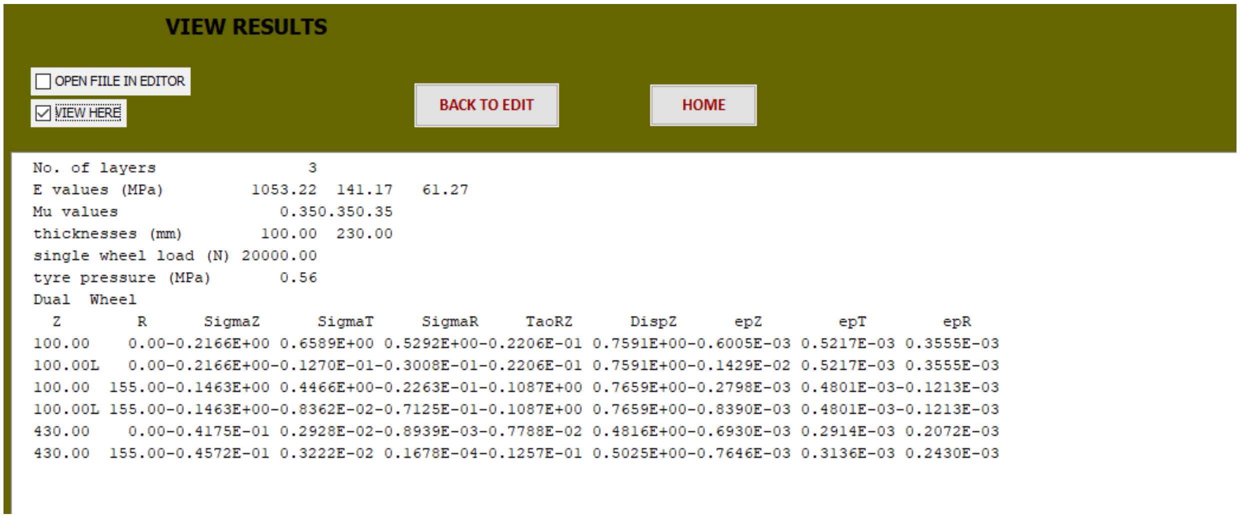

Fig 4.7: Results with E values of 1053.22,141.67, 61.27 (MPa)

Deflection		
S.no	FWD Deflection	BB Deflection
1	0.8625	0.22105
2	0.8722	0.0507
3	0.8663	0.07867
4	0.8343	0.09487
5	0.8257	0.11236
6	0.7563	0.11438
7	0.7659	0.11219

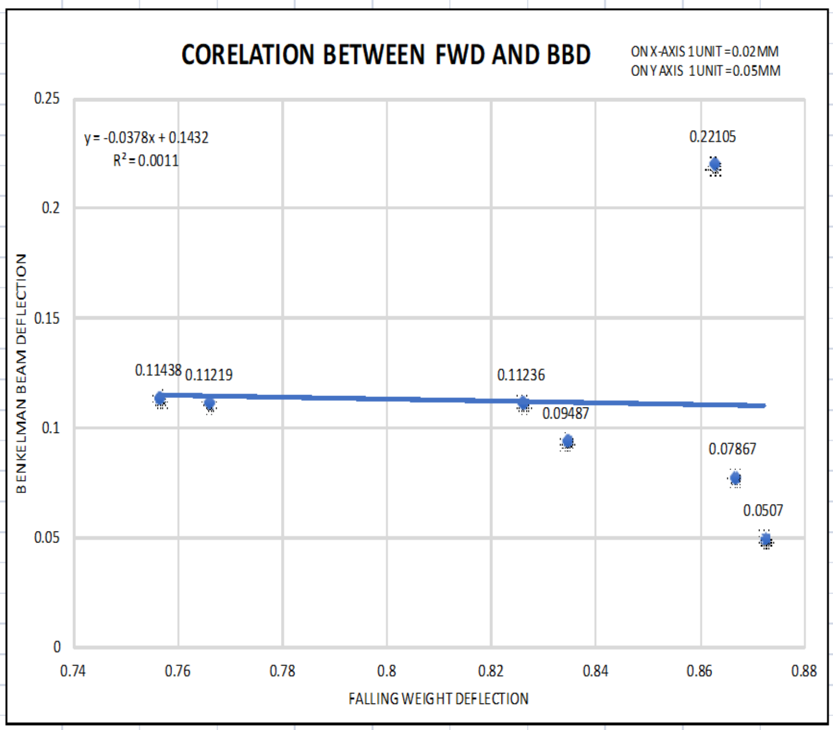

Table 4.3: Relation between BBD & FWD

4.2.4: Correlation between BBD and FWD technique.

Finally to draw the correlation between benkleman beam method and falling weight deflectometer techniques in finding out the deflection, we plotted the graph between the deflection found using two mentioned techniques by plotting the bankelman beam deflection data in Y- axis and falling weight deflectometer test data in X-axis. Here we obtained a straight graph between two methods. The straight graph signifies that the deflection found using two afore mentioned techniques does not shows much variation in the deflection.

Both the techniques enhance a better quality of road network around the world. It has been in use since long time back but in India, bankelman beam deflection has been in predominant use due its simpler mode, easy and cheap. The techniques enhance good quality road in any road network because it usually detects the quality of road which actually identifies a major problems of road like rotting,etc.

CHAPTER 5

CONCLUSIONS

5.1 General

BBM and FWD are the instrument for calculation of deflection in pavement surface .BBM is more advantageous, cost efficient and resource efficient but FWD is more accurate but requires more skill and is not cost efficient so with the help of benkle beam we are able to calculate more accurate deflection by creating the modulus E of pavement surface of FWD and BBM.

5.2 CONCLUSIONS

On the idea of the result obtained during the study of research paper and data , the subsequent conclusion was drawn:

- ✓ Structural stability of the pavement can be calculated from Benkle beam method and falling way deflectometer
- ✓ Benkle beam is simple and tedious method for calculation of deflection in static loading
- ✓ Falling weight deflectometer is complex method but due to dynamic loading it is more accurate method
- ✓ Comparison between them is possible through the value of E (modulus of elasticity of pavement)
- ✓ Back calculation software for calculation of pavement thickness used is as per IRC is KGPBACK which is a specific version of BACKGA program developed by the transportation engineering section of IIT Kharagpur.

5.3 SCOPE FOR FUTURE WORK.

India is very large country where many people die due to road accidents due to:

Improper overlay

Pot holes in the pavement

With the help of correlation between BBM and FWD we will be able to create a high structural stability of pavement surface using BBM technique
And using results of FWD as it can be used as a replacement of old technique of BBM and many accidents can be avoided and many lives can be saved.
The overlay designed can be more cost effective and cost efficient.

Correlation between FWD and BBM give us rays of hopes in the research field and ways to work in innovative ideas and come up with inventions related to overlay design and broad scope in future.

In future this technique can also be used in calculation of deflection in embankments .so that the embankments are designed for high structural stability.

REFERENCES

1..*IRC(Indian Road Congress)-81-1997*

2..*IRC(Indian Road Congress)-115-2014*

3.*IJSTE - International Journal of Science Technology & Engineering | Volume 3 | Issue 10 | April 2017*

ISSN (online): 2349-784X

4.*OLLE THOLEN, JAY SHARMA, and RONALD L. TERREL*

5.*Dr. Mesh Sharma, "Non-Destructive Evaluation of an Internal Road of Chandigarh - A Critical Study" International Conference on Biological, Civil and*

6.*Environmental Engineering (BCEE-2014) March 17-18, 2014 Dubai (UAE).*

7.*Ujjval J. Slinky, Prada J. Gondola," A Review on Structural Evaluation of Flexible Pavements using Falling Weight Deflect meter" Trends in Transport*

8.*Engineering and Applications (STM) Journals, January 2014.Highway Capacity Manual, 2000, "Transportation Research Board, Washington D.C: Chapter*

9.*Sunny Deal Guzzarlapudi, Vend Kumar Adigopula, Rakish Kumar "Comparative studies of lightweight deflect meter and Benkelman beam deflect meter*

10. *in low volume roads" journal of traffic and transportation engineering, 1 October 2016.*

11. *Murillo Foe, Bearing Urrego L.E, "Correlation between deflections measurements on flexible pavements obtained under static and dynamic load*

12. *techniques" 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris 2013.*

13. *S.K. khanna, C.E.G Justo, A. Veeraragavan, "Highway Engineering", Nem Chand and Brothers, Roorkee, Tenth Edition, 2015.*

14. *R Srinivasa kumar, "Textbook of highway engineering".*

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT

PLAGIARISM VERIFICATION REPORT

Date: 15-05-2021

Type of Document (Tick): B.Tech Project Report

Name: 1/Ganga Ram Ghalley 2/ Lokesh Sharma 3/Ritvik Mehta **Department: Enrolment No** 1/ 171678 2/ 171683 3/ 171625

Contact No. 1/97517245616 2/9459476603 3/898247304 **E-mail:** 171678@juitsolan.in 2/ 171683@juitsolan.in 3/ 171625@juitsolan.in

Name of the Supervisor: Dr. aurabh Rawat

Title of the Thesis/Dissertation/Project Report/Paper (In Capital letters): CORRELATION BETWEEN BENKEL BEAM METHOD AND FALLING WEIGHT DEFLECTOMETER METHOD.

UNDERTAKING

I undertake that I am aware of the plagiarism related norms/ regulations, if I found guilty of any plagiarism and copyright violations in the above thesis/report even after award of degree, the University reserves the rights to withdraw/revoke my degree/report. Kindly allow me to avail Plagiarism verification report for the document mentioned above.

- Total No. of Pages =36
- Total No. of Preliminary pages =5
- Total No. of pages accommodate bibliography/references =1

Ganga Ram Ghalley (171678)

Lokesh Sharma(171683)

Ritvik Mehta(171625)

(Signature of Student)

FOR DEPARTMENT USE

We have checked the thesis/report as per norms and found **Similarity Index** at 24(%). Therefore, we are forwarding the complete thesis/report for final plagiarism check. The plagiarism verification report may be handed over to the candidate.

(Signature of Guide/Supervisor) **Signature of HOD**

HOD CE DEPT

FOR LRC USE

The above document was scanned for plagiarism check. The outcome of the same is reported below:

Copy Received on	**Excluded**	**Similarity Index (%)**	**Abstract & Chapters Details**	
	• All Preliminary Pages • Bibliography/ Images/Quotes • 14 Words String		Word Counts	
			Character Counts	
Report Generated on		**Submission ID**	Page counts	
			File Size	

Checked by
Name & Signature **Librarian**

………