International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Structural Evaluation of Flexible Pavement – A Case Study of SH-2 from Balasinor (CH: 1.500 km) to Dev Junction (CH: 12.500 km)

Jheel A. Patel[1] , Prof. Amit A. Amin[2], Dr. L. B. Zala[3]

[1]*Student of Final year, M. Tech (Transportation System Engineering), B.V.M. Engineering College, Vallabh Vidyanagar, Gujarat, India, jheelpatel94@gmail.com*

[2] *Professor, Civil Engineering Dept., B.V.M. Engineering College, Vallabh Vidyanagar, Gujarat, India, aaamin@bvmengineering.ac.in*

[3] *Professor and Head, Civil Engineering Dept., B.V.M. Engineering College, Vallabh Vidyanagar, Gujarat, India, lbzala@bvmengineering.ac.in*

Abstract— ***Development of road infrastructure in India is presently being given high importance by the government of India to meet the necessity of increasing travel demand; it includes construction of new road, widening, and overlay of various roads in India. Pavement evaluation was carried out to determine the condition of pavement regarding its surface and structural adequacy. In this research paper, the main attempt made is to evaluate the condition of the selected section of pavement from Balasinor (CH: 1/500 km) to Dev Junction (CH: 12/500 km) on state highway 2. The structural evaluation of pavement is carried out using Benkelman beam to determine the capacity of the pavement withstand traffic loading from the analysis of data the overlay thickness, and the different alternative is suggested and cost analysis of overlay according to the required thickness was suggested on the selected stretch.***

Keywords— Structural evaluation, Distresses, Benkelman beam deflection survey, Overlay design, Cost estimation

I. INTRODUCTION

Flexible pavement consists of multiple layers constructed using granular materials. To serve in all weather conditions, its top layer is built to be impervious by using different types of binders, viz. bitumen, and tar and modified bituminous materials. Such layers are termed as bound layers and resist loads by developing tensile stresses at its bottom fibers.

An overlay is an operation that consists of laying either Portland Cement Concrete or Hot Mix Asphalt over an existing pavement structure. This is different than a total replacement of the structure and is typically done when there is only minor to modest damage to the current pavement structure. A standard method of squeezing more serviceable years from cracking or rutting flexible pavement roadways is to lay a new bituminous surface over the old. Such flexible pavement overlays can improve deteriorated pavement and enhance skid resistance, ride quality, and other functional characteristics of the roadway. The overlays also add structural capacity to the pavement.

Overlay Design Methods

1. Conventional Method: The total pavement thickness requirement is designed for the designed traffic and the existing conditions of the subgrade, e.g. CBR value or the subgrade soil is determined at the field density, and the CBR method of pavement design as recommended by the IRC is adopted.

2. Non-destructive Method**:** There are various methods and equipment available to find the overlay thickness. Some of these are:

- Steady State Deflection Equipment
- FDP System
- FWD
- Benkelman Beam

From all the above non-destructive methods mentioned; Benkelman Beam is one of the easier in use and economical method than many others. In this method, the design is governed by IRC: 81-2015.

II. STRUCTURAL EVALUATION

Structural evaluation of pavements commonly involves applying a standard load to the pavement and measuring its response. The response measured can be stress, strain or deflection. Both functional and structural evaluation Pavements are important. They supplement rather than replace each other. An observation of serviceability (functional) below the acceptable level is one way to trigger a structural evaluation. The rough pavement may be strong and require only a level-up surface layer, or it may be structurally weak and require replacement or a thick overlay. The structural evaluation is required to determine the answers. To complete the interrelationships, the structural evaluation should be capable of predicting the load carrying capacity of the pavement and its projected life for expected traffic.

As far as the structural evaluation of in-service pavements is concerned, since its development in 1953 [Zube and Forsyth, 1966], Benkelman Beam became a typical instrument used by several agencies for non-destructive testing of pavements. Indian Roads Congress (IRC) recommends the evaluation of in-service pavements using the Benkelman beam for design of flexible overlays. In the IRC design technique [IRC:81-1997], the observed pavement deflections, corrected for standard temperature and moisture, are used to determine the essential overlay thickness. As only one surface deflection is measured by means of this equipment, it is not possible to get adequate information about the structural condition of different layers of the pavement. Thus, this method does not permit a consistent prediction of the performance of pavements. With the modification made in the mechanistic approach, some efforts were made in India [Reddy and Pandey, 1994; Road Research Scheme R-56, 1999] to incorporate mechanistic principles in overlay design technique.

The response of a pavement to a single application of a static load or a slow-moving load is generally obtained by measuring the deflection of the pavement surface under the load. There are number instruments that have been used to make such measurements, of Traveling and the most common being the Benkelman beam, the of each the Deflectograph. The basic operating principle of these devices is similar. The tip of an 8 to 10 ft-long beam probe is placed on the surface of the pavement very near the loaded wheel or in a position so that the loaded wheel will pass very near it. For dual tired axles, the probe point is usually placed between the dual tires. As the loaded wheel moves by the probe tip, the movement of the pavement's surface is recorded by an angular rotation of the beam probe.

The main Objectives of this research paper are:

- To identify pavement distress on selected stretch.
- Proposed overlay design according to codal provision.
- To evaluate construction cost and maintenance cost on the selected stretch.

III. STUDY AREA LOCATION

The selected study is on NH-2, starts from Balasinor CH 1.500 Km to Dev Junction CH 12.500 Km. The total length of study stretch is 11.0 Km. Balasinor is a city located in the Mahisagar district, Balasinor is situated at 22.95°N 73.33°E.

.

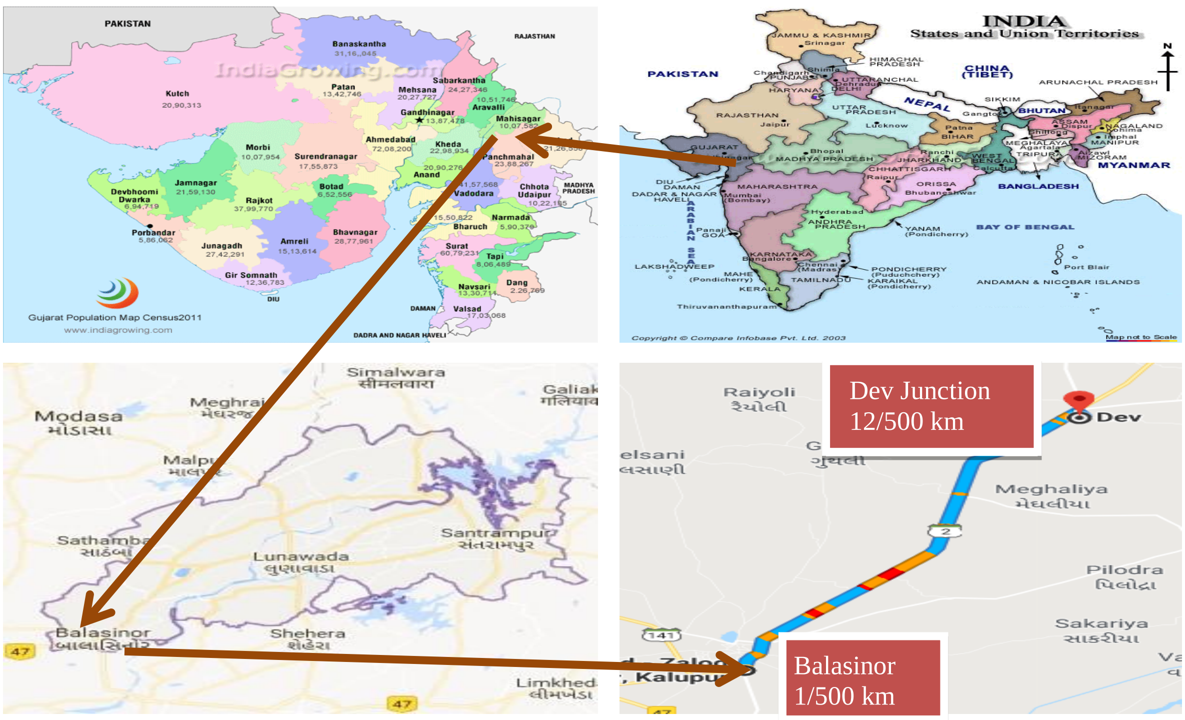

Figure 1: Study Area Location

IV. Data Collection And Analysis

A. *Pavement condition survey by visual inspection*

By visual observation survey on selected stretch various distresses were identified like longitudinal crack, transverse crack, alligator crack, raveling, patching, edge breaking are shown in figure 2.

B. *Classified volume count survey*

Classified volume count survey was carried out to found the PCU/hr and million standard axles. PCU values are taken according to the IRC: 64-1990. The classified traffic volume count survey was carried out at Gadhavada village (Ch. 05/720 km). Daily traffic volume at the location, by vehicle type is presented in figure 3.

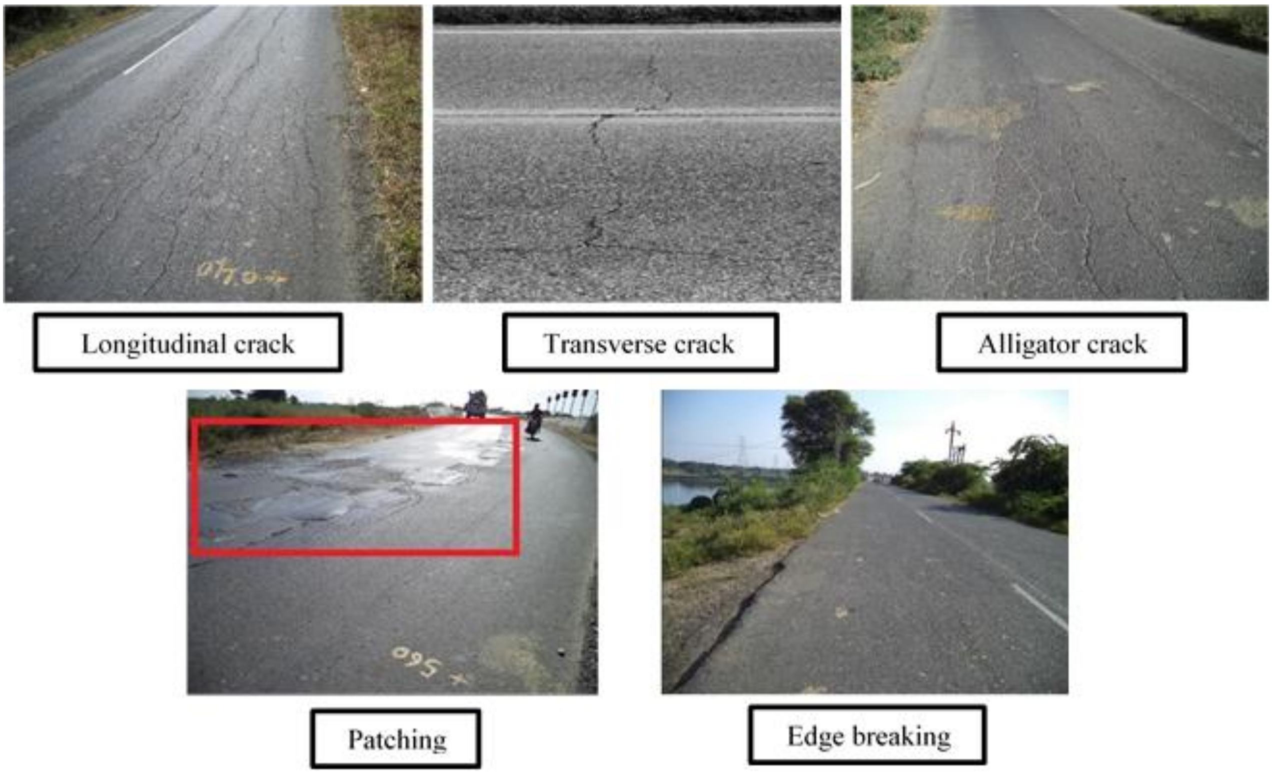

Figure 2: Pavement Distresses by Visual Inspection

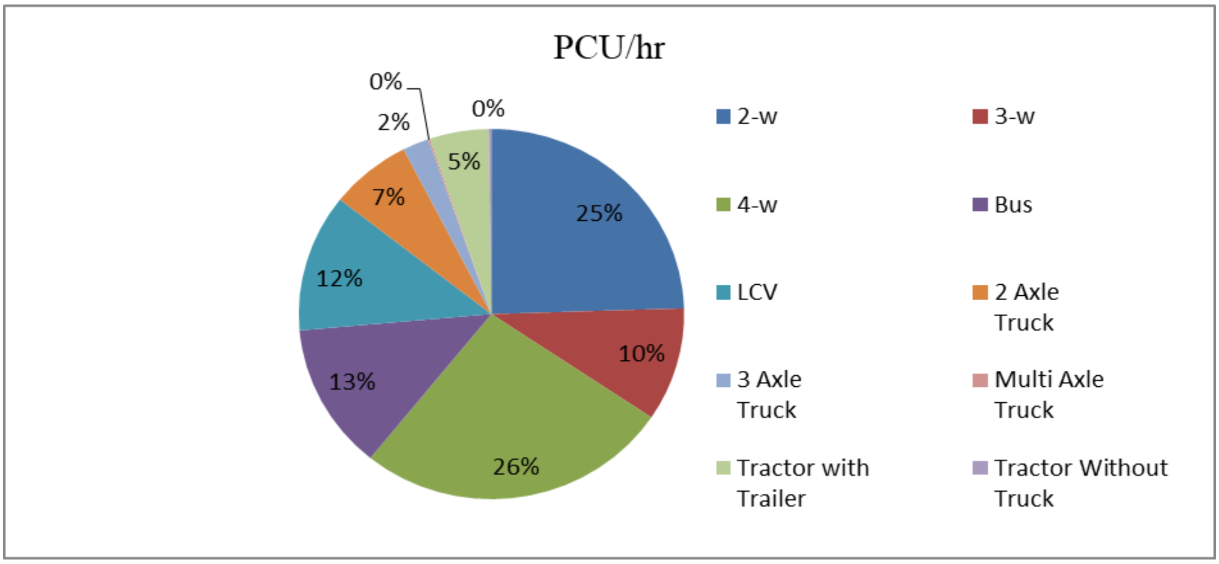

Figure 3: Traffic Volume Count

CVPD = 405+572+217+70+3+105+14 = 1386 CV/day

International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Volume 4, Issue 5, May-2018, e-ISSN: 2455-2585,Impact Factor: 3.45 (SJIF-2015)

The design traffic is considered regarding of the cumulative number of standard axles to be carried during the design life of the road. Its computation involves the estimates of the initial volume of commercial vehicles per day, lateral distribution of traffic, the growth rate and the design life in years and the vehicle damage factor to convert commercial vehicle in standard axle the following equation is used to make the required calculation:

$$N_S = \frac{365 * A[(1+r)^x - 1] * D * F}{r} \ldots\ldots\ldots\ldots\ldots (1)$$

Where,

N_s = Cumulative number of standard axles

A = Initial traffic in the year of finishing of construction; regarding CVPD

= $P(1+r)^x$ =1489.95

r = Yearly growth rate of commercial vehicles =7.5%

x = Design life =10 years

D = Lane distribution factor =0.75

F = Vehicle damage factor =3.5

From the Equation 1,

N_s = 20.9 msa

To increase the reliability of the data, assume 21 msa instead of 20.9 msa.

C. Trial Pit Investigation For Existing Subgrade Characteristics And Pavement Crust Thickness

Every 1km in zigzag way both side 1m x 1m x 1.5m pits were dug near edge of the carriage way and subgrade soil sample was taken and laboratory investigation was carried out for flexible overlay design. The summary of test results is shown in Table 1.

Table 1: Summary of Soil Sample Testing Result

Sr No	Chainage (km)	Side	Moisture content in %	Sieve analysis % by weight				Atterberg's Limit			Modified proctor test		
				IS Classification	Gravel (> 4.75 mm) (%)	Sand (4.75 mm-0.075mm) (%)	Silt & Clay (<0.075mm) (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	MDD (g/cc)	OMC (%)	C.B.R.
1	1+000	RHS	4.55	SM	0.00	69.10	30.90	26.7	NP		1.795	10.3	19.4
2	2+000	LHS	4.87	SM	0.00	65.73	34.27	27.2	NP		1.82	9.9	18.2
3	3+000	RHS	5.51	SM	0.00	55.43	44.57	28.7	NP		1.848	11.3	11.7
4	4+000	LHS	5.63	SC	0.00	63.91	36.09	25.9	19.3	6.6	1.862	10.6	12.3
5	5+000	RHS	4.93	SC	0.00	75.19	24.81	26.3	21.3	5.0	1.802	9.5	19.3
6	6+000	LHS	5.01	SM	5.00	73.60	21.40	27.6	NP		1.832	11.25	19.87
7	7+000	RHS	5.50	SC	0.00	59.70	40.30	24.9	18.9	6.0	1.74	14.6	8.4
8	8+000	LHS	5.56	CL	0.00	67.28	32.72	24.7	16.7	8.0	1.79	10.4	14.3
9	9+000	RHS	4.48	CL	0.00	54.03	45.97	20.7	15.8	4.9	1.79	10.4	13.98
10	10+000	LHS	4.22	CL	6.00	39.00	55.00	25.5	22.5	3	1.635	16.8	6.8
11	11+000	LHS	6.84	CI	0.00	54.90	45.10	25.3	20.1	5.2	1.901	9.8	9.8

D. Benkelman Beam Deflection survey on existing pavement according to IRC 81-2015

The Benkelman beam, which was developed at the WASHO Road Test is a simple, hand-operated deflection device and is probably the most widely used method of measuring pavement deflections. It consists basically of simple lever arm attached to a lightweight aluminium or wood frame that is capable of being moved by hand. Typically, the probe point is placed between dual tires and the motion of the beam is observed on an Ame's dial, which records the maximum deflection to within 0.001 in. It is especially important to ensure that the support of the beam is not located within the deflection basin or zone of influence of the loaded tires when the initial beam reading is made. For this reason, at the actual AASHO Road Test and in the Canadian studies, a procedure was developed in which the tip of the beam probe is placed at the point for which the deflection is to be determined and immediately between the dual tires. The Ame's observed and the loaded vehicle is moved away from the point and the rebound or upward movement of the pavement is thus recorded. This equipment is versatile, simple, and inexpensive to operate; however, because it is a relatively static measurement method, it is quite difficult to use on heavily travelled highways carrying high-speed vehicles.

Based on the pavement condition survey, the road length to be surveyed was divided into homogeneous sections of lengths not less than 50 meters. The loading points on the pavement for deflection measurement were located along the wheel paths on a line 0.9 m from the pavement edge in the case of pavements of total width more than 3.5 m and the distance from the edge is reduced to 0.6 m on narrower pavements. The testing point shall be selected and marked in advance on the pavement. A minimum of 10 deflection observation points is taken on each of the selected stretches of pavement. The truck is driven slowly parallel to the edge and stopped such that the left side rear dual wheel is centrally placed over the first point for deflection measurement. The probe end of the Benkelman beam is placed between the gaps of the dual wheel and is positioned precisely over the deflection observation point.

Figure 4: BBD Survey

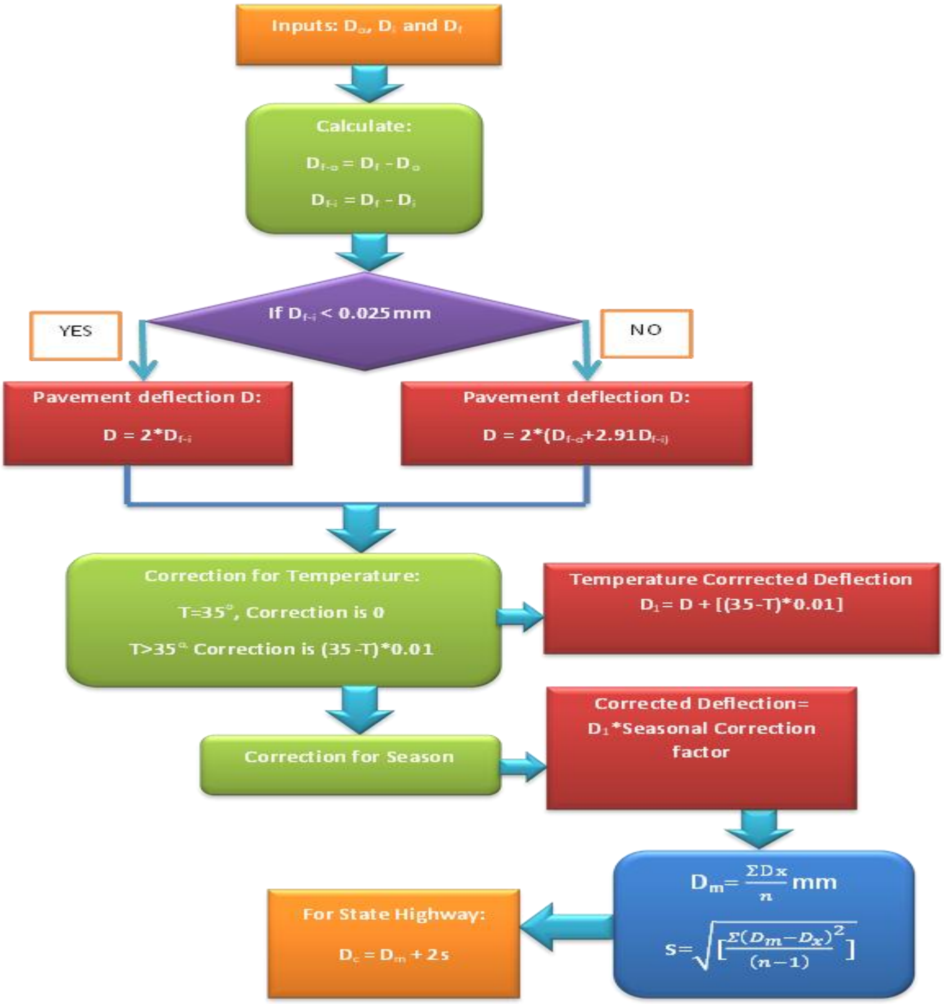

Figure 5: Methodology Flowchart for Calculation of BBD Survey

Table 2: Sample of B.B.D. test analysis sheet

B.B.D. Test Analysis

Section :	01+500 km to 02+500 km (RHS)	Climatic conditions :	Sunny	Avg. rainfall in mm :	<1300
Direction :	Balasinor to Dev Junction	Air temperature in °C :	41.30	Moisture Content % :	4.55
Design Traffic in msa :	21	Pavement Temp. in °C :	51.50	Plasticity Index (PI) :	<15
No. of Lane :	Two lane single carraige way	Terrian:	Plain	Seasonal correcttion factor:	1.233
Category of Road :	State Highway	Month :	March	Design life in years :	10

Chainage Point	Dial Gauge Reading			Measured rebound deflection	Correction for temperature in mm	Temp. corrected deflection in mm	Seasonal correctionfactor	Corrected deflection in mm	Mean deflection in mm	Std. deviation in mm	Characteristic deflection in mm	Overlay required in mm	Remarks
	Initial	Intermediate	Final										
01+500	0.00	-0.36	-0.38	0.76	-0.165	0.60	1.233	0.73	0.77	0.61	1.98	190	Moderate
01+600	0.00	-0.39	-0.42	1.01	-0.165	0.85	1.233	1.05					
01+700	0.00	-0.09	-0.12	0.41	-0.165	0.25	1.233	0.31					
01+800	0.00	-0.14	-0.2	0.75	-0.165	0.58	1.233	0.72					
01+900	0.00	-0.27	-0.42	1.71	-0.165	1.55	1.233	1.91					
02+000	0.00	-0.32	-0.36	0.95	-0.165	0.79	1.233	0.97					
02+100	0.00	-0.32	-0.35	0.87	-0.165	0.71	1.233	0.87					
02+200	0.00	-0.09	-0.09	0.18	-0.165	0.02	1.233	0.02					
02+300	0.00	-0.26	-0.26	0.52	-0.165	0.36	1.233	0.44					
02+400	0.00	-0.05	-0.05	0.10	-0.165	-0.07	1.233	-0.08					
02+500	0.00	-0.52	-0.57	1.43	-0.165	1.27	1.233	1.56					

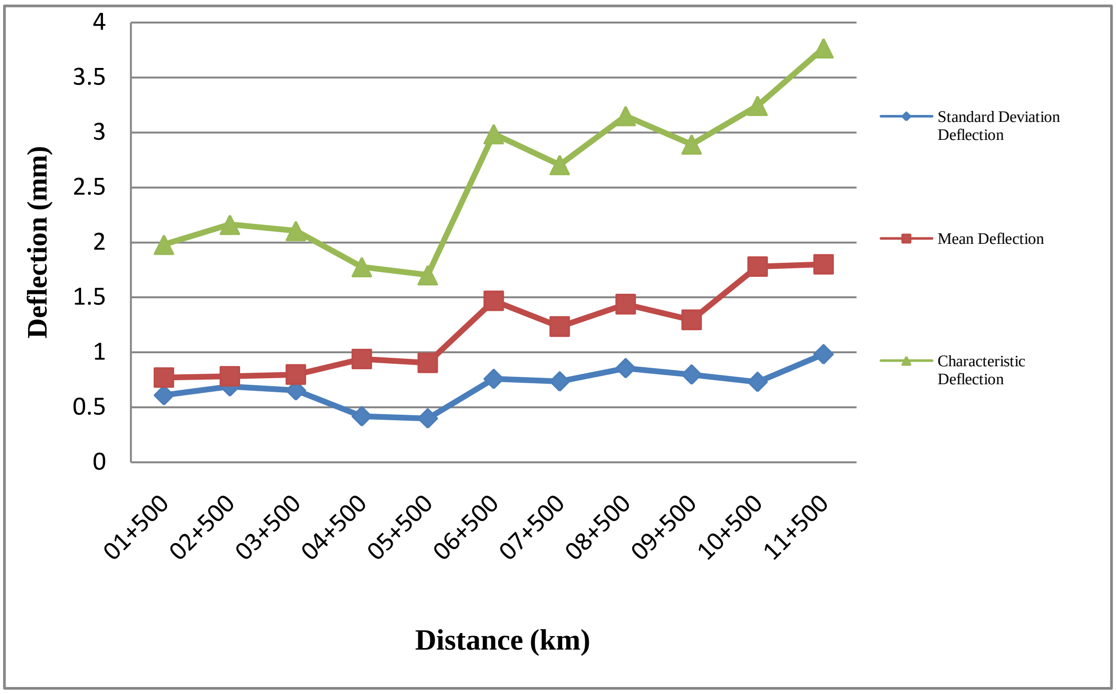

Figure 6: Deflection Variation between Chainage 01+500 to 11+500

Table 3: Chainage wise Characteristic Deflection and Overlay requirement

Chainage		Mean Deflection (in mm)	Standard Deviation Deflection (in mm)	Characteristic Deflection (in mm)	Overlay Required in terms of BM for Individual 1 km (in mm)	Proposed other Composition Overlay Required (in mm) (0.7*BM)	
From	To					DBM	BC
01+500	02+500	0.77	0.61	1.98	190	85	50
02+500	03+500	0.78	0.69	2.16	175	75	50
03+500	04+500	0.80	0.65	2.11	195	90	50
04+500	05+500	0.94	0.42	1.78	170	70	50
05+500	06+500	0.90	0.40	1.70	170	70	50
06+500	07+500	1.47	0.76	2.99	225	110	50
07+500	08+500	1.23	0.74	2.71	215	110	50
08+500	09+500	1.44	0.86	3.15	230	110	50
09+500	10+500	1.30	0.80	2.89	225	110	50
10+500	11+500	1.78	0.73	3.24	235	115	50
11+500	12+500	1.80	0.98	3.77	250	125	50

V. Estimation Of Quantity And Construction Cost

According to schedule of rate (SOR) 2018-19 of Mahisagar district, the rate for BC and DBM were taken and quantity and rate derived for overlay for the overall stretch.

- Width = 7.0 m
- Shoulder = 1.5 m (each side)
- Total length = 11000 m

Table 4: Quantity And Estimate of Flexible Overlay Over Flexible Pavement

Chainage (m)	BC (m)	DBM (m)	Width (m)	Length (m)	Quantity (m^3)	
					BC	DBM
1500 to 2500	0.05	0.085	10.0	1000	500	850
2500 to 3500	0.05	0.075	10.0	1000	500	750
3500 to 4500	0.05	0.090	10.0	1000	500	900
4500 to 5500	0.05	0.070	10.0	1000	500	700
5500 to 6500	0.05	0.070	10.0	1000	500	700
6500 to 7500	0.05	0.110	10.0	1000	500	1100
7500 to 8500	0.05	0.110	10.0	1000	500	1100
8500 to 9500	0.05	0.110	10.0	1000	500	1100
9500 to 10500	0.05	0.110	10.0	1000	500	1100
10500 to 11500	0.05	0.115	10.0	1000	500	1150
11500 to 12500	0.05	0.125	10.0	1000	500	1250
Total quantity					5500	10700
Cost per m^3 (in ₹)					8498	7124
Total cost per m^3(in ₹)					46739000	76226800
Total cost (in ₹)					122965800	
Add 1% Quality control charge (in ₹)					1229658	
Total cost (in ₹) including Quality control charges					124195458 (12.42 Crore)	

VI. CONCLUSIONS

- It has been concluded that traffic is in the range of the traffic capacity for the two- lane road. The buses, trucks, other commercial vehicles from district Mahisagar and nearby villages passing through villages; therefore this creates heavy loading on the road and causes heavy stresses in the pavement.
- The Benkelman beam study was conducted on the pavement and the overlay thickness regarding Bituminous Macadam was found for all the stretches; it ranges from 170 mm to 250 mm.
- The estimated cost for Overlay design is 12.42 Crore ₹.

REFERENCES

[1] Burmister, D.M. (1945). The General Theory of Stresses and Displacements in Layered Systems. Journal of Applied Physics, Vol. 16, Nos. 2, 3 and 5.

[2] Dr. Umesh Sharma, “Non-destructive evaluation of an Internal road of Chandigarh – A Critical Study”, BCEE 2014, Pg 67-71

[3] IRC: 37- 2012, “Guidelines for the design of flexible pavements”, New Delhi: Indian Roads Congress.

[4] IRC: 64-1990, “Guidelines for capacity of roads in rural areas”, New Delhi: Indian Roads Congress.

[5] IRC: 81- 1997, “Guidelines for strengthening of flexible road pavements using Benkelman beam deflection technique”, New Delhi: Indian Roads Congress.

[6] IS 2720 (Part 16)-1987, “Laboratory determination of CBR”, New Delhi: Indian Roads Congress.

[7] IS 2720 (Part 2)-1973, “Determination of water content”, New Delhi: Indian Roads Congress.

[8] IS 2720 (Part 4)-1985, “Grain size analysis”, New Delhi: Indian Roads Congress.

[9] IS 2720 (Part 5)-1985, “Determination of liquid limit and plastic limit”, New Delhi: Indian Roads Congress.

[10] Is 2720 (Part 8)-1983, “Determination of water content-Dry density relation using Heavy Compaction”, New Delhi: Indian Roads Congress.

[11] Kumar, Srinivasa R; “A test book ok Pavement Design”

[12] Liang Zhou et.al. “Comparison of FWD and Benkelman Beam in Evaluation of Pavement Structure Capacity” Geo Shanghai 2010, International Conference.

[13] M. Amaranatha Reddy, K. Sudhakar Reddy and B.B. Pandey. Evaluation of Effective Pavement Layer Moduli Using Genetic Algorithms, International Journal of Pavement Engineering & Asphalt Technology, UK, Vol. 3, Issue 1, October 2002, pp. 6-19

[14] Mayank Bhatt, Amit Vankar, L. B. Zala, “Structural evaluation using Benkelman beam deflection technique and rehabilitation of flexible pavement for stste highway 188 (Sarsa junction to Vasad junction)”,JIARM 2013, Vol. 1, Issue 4, Pg. 452-462

[15] Priyanka Sarker,Erol Tutumluer, and Scott Lackey(2016),“Non-destructive Deflection Testing based Mechanistic-Empirical Overlay Thickness Design Approach for Low Volume Roads: Case Studies”, 3rd International Conference on Transportation Geotechnics, Volume 143, 2016, Pg 945-953

[16] S.K.khanna,C.E.G.Justo and A.Veeraragavan, “A text book of Highway engineering”,10th edition, Nem chand & bros,Roorkee

[17] Vibhav Solanki, Prof. Srinath Karli, Mr. Pankaj Goyal, “Comparative studies between Benkelman Beam Deflections (BBD) and Falling Weight Deflectometer (FWD) Test for Flexible road Pavement”, April 2017,Vol. 3,Pg 63-69

[18] Zube, E. and Forsyth, R. (1966). Flexible Pavement Maintenance Requirements as Determined by Deflection Measurement. Transportation Research Record No. 139, Washington, DC, pp. 60-75.