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Structural Evaluation of Flexible Pavement

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***Abstract*:- Pavement maintenance is one of the most important aspect of highway engineering specially in a country like India because many of the pavements are reaching their end of service life. India witnesses mixed vehicular traffic thereby worsening the condition of the pavement. Rapid industrialization and urban growth in India has led to increased traffic and excessive usage of the roads which further adds as a catalyst to the same. Hence, pavement maintenance is a necessary measure for safety and cost efficiency as rehabilitation of pavement is very expensive. Pavement acts as a parameter for the progress of a nation, hence maintenance plays an important part for the growth of economy, commute and also increases the standard of living. The intention of this project is to study the structural stability of pavement using Benkelman Beam Deflection method and to decide the overlay to compensate for the structural instability if persists. Correction factors namely seasonal correction and temperature correction were also carried out. The results of these tests have been discussed in detail in this paper.**

***Key Words:* Benkelman Beam Deflection Method, Pavement maintenance, Structural Evaluation, Overlay**

I. INTRODUCTION

Highway engineering is an important discipline which comes under civil engineering it mainly deals with construction, maintenance and rehabilitation of roads, bridges and tunnels. India is approximately 3,060,500 square km in area and has a road network of over 3,315,231 kmThe road system carries 87% and 65% of passengers and freight respectively [2]. After India attained independence there was a spur growth in transportation sector due to industrialization, automation and urbanization. Because of which maintenance has to be given utmost importance in Highway maintenance.

All structures are designed for a span of time which is called as service life over which it witnesses failure[8]. Survive life can be increased by maintenance of the structure. The effective maintenance of the pavement is done through pavement evaluation process. In this paper structural evaluation of flexible pavement is discussed.

Structural evaluation of pavement could be defined as the measure of structural adequacy of the pavement. Pavement performance depends on the number of standard axle, drainage condition of pavement, temperature, soil present in subgrade, rainfall etc.

Non-destructive method is widely used because of its advantage of leaving the pavement un effected after the test as compared to destructive tests. The popular methods used under non- destructive pavement analysis are Falling Weight Deflection method and Benkelman Beam Deflection method (BBD). Benkelman Beam Deflection method is discussed in detail in this paper.

II. OBJECTIVES

The main objectives of this paper are:

- Asses the structural stability of pavement.
- Estimate the overlay thickness.

III. METHODOLOGY

III.I: TRAFFIC DATA COLLECTION:

Traffic data is collected by manual count method. Talley marks were used to represent the number of vehicles. For design purpose heavy commercial vehicles are to be considered. Initial traffic count is found out by this method which is then used for finding number of standard axels.

III.II. DEFLECTION DATA COLLECTION

To measure the rebound deflection using Benkelman Beam method we place the probe between the dual wheel arrangement of the truck's wheel. The standard load of the truck is to be of 8170 kg and a tyre pressure of 5.6 kg/cm^2 is to be used. The probe is placed over the point where the deflection has to be measured. Before trials are taken it is properly calibrated on a hard levelled ground. A set of 3 points are to be taken namely initial, intermediate and final dial gauge reading (Do, Di and Df) at a distance of 2.7 m and 9m from the measuring points. 140 readings were taken at an interval of 50m in our case. Along with deflection, temperature was also noted down simultaneously.

III.IIICORRECTIONS TO BE APPLIED:

The various corrections to be applied include variation of temperature and variation of seasonal changes. Which is explained below

III.III.I. CORRECTION FOR TEMPERATURE VARIATION:

A pavements deflection depends on the temperature and it has been seen that the pavement layers vary according to variation in the temperature. Hence, we record the temperature along with the deflection measurement. Measurement was made by using short stem mercury thermometer. A hole of 45 millimeters deep and 10 mm in diameter was made. Glycerol was poured into this hole and the measurement were taken after an interval of 5 mins.

III.III.II. CORRECTION FOR SEASONAL VARIATION

Consideration of subgrade soil moisture content, average annual rainfall data and type of soil in the subgrade. Average rainfall data could be divided into heavy rainfall (annual

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rainfall >1300 mm) or less rainfall(annual rainfall <=1300mm). Subgrade soil can be classified into sandy soil, clayey soil with high plasticity (PI>15) and clayey soil with low plasticity (PI<=15) based on its plasticity index. The soil sample was scooped 15 cm below the subgrade for moisture content and plasticity index test. For this purpose a test pit was made in the shoulder.

IV. DATA COLLECTION AND OVERLAY DESIGN

TRAFFIC DATA

The traffic volume for the selected stretch was carried out on each stretches for each direction of traffic from starting point towards the ending point and vice versa. The traffic volume count is represented as vehicles per day. Traffic composition of the roads undertaken for surveys considers all types of traffic vehicles including motorized and non-motorized traffic. Motorized traffic consists of two wheelers, four wheelers, Buses, Two-axle and multi-axle trucks while a non-motorized vehicle consist of Bicycles and three wheelers. Survey was carried out from 6:00 AM to 6:00 PM. The volume was noted by counting the number of vehicles passing through the road section at every 1 hour intervals by manual counting

TABLE 1: TRAFFIC DETAILS OF THE STUDY AREA

Traffic studies											
Name of the work		Overlay to Mayaganahalli Road to Sugganahalli Road from 0.55 km to 7.55 km (in Selected reaches) in Ramanagara taluk of Ramanagara District Via Dharapura									
Location		Mayaganahalli									
Enumerator		Narendra Kumar M, Chendan T M, Shivani Nagaraj, Sushmitha S									
Direction		Up and down									
Date		28/02/2019 TO 06/03/2019									
Sl. No.	**Vehicle type**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Total number of vehicles**	**Daily average number of vehicles/ ADT**	Commercial Traffic
1	Car, Jeep, Van	180	192	297	206	213	197	232	1517	217	130
2	Auto Rickshaw	203	174	283	192	200	196	236	1484	212	
3	Scooters/Motorbikes	1091	811	976	869	902	912	976	6537	934	
4	Bus / Minibus	24	25	30	26	27	27	29	188	27	
5	trucks	16	28	22	29	31	33	25	184	26	
6	Tractors with trailer	61	38	35	42	47	38	35	296	42	
7	Tractors without trailer	25	42	16	45	49	49	18	244	35	
8	Cycles	0	0	0	0	0	0	0	0	0	
9	Cycle Rickshaw / Hand Cart	0	0	0	0	0	0	0	0	0	
10	Horse cart / Bullock Cart	0	0	0	0	0	0	0	0	0	
Total non-motorised vehicle per day		**0**									

IV.II. DEFLECTION DATA

Deflection value D_o (initial dial gauge reading), D_i (intermediate dial gauge reading) and D_f (final dial gauge reading) are collected in divisions for every 50 meter interval all through the stretch, simultaneously the temperature is recorded along with the collection of soil samples and rainfall data. The moisture content and plasticity index are determined later. All the readings are tabulated as shown in Table 1. Later all the necessary correction in each section are applied. Thus the Corrected Characteristic deflection is calculated in millimeters

The correction for temperature is applied with the help of moisture content obtained. The moisture content obtained is 7.4% and the seasonal correction factor obtained was 1.037 by referring to fig 1.

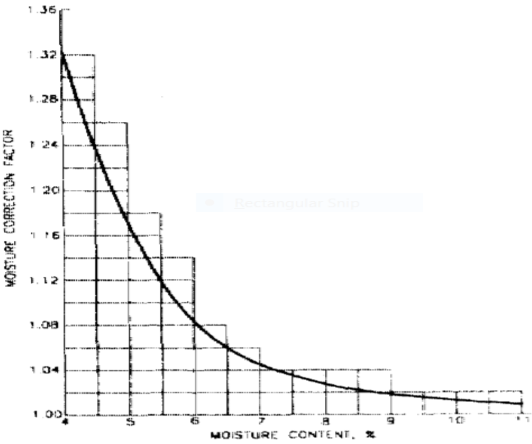

Fig 1: moisture content factor for sandy soil with annual rainfall <1300

TABLE 2: PAVEMENT DEFLECTION DATA ALONG WITH THE SUITABLE CORRECTION APPLIED

Name of Road :	Overlay to Mayaganahalli Road to Sugganahalli Road from 0.55 km to 7.55 km in Ramanagara taluk of Ramanagara District Via Dharapura		
No. of Traffic Lane :	2	Whether temperature correction is to be applied:	Yes
Date of Observation :	03-02-2019	Annual Rainfall, mm:	<1300

CHAINAGE : FROM 0+550 TO 7+550

Station	Dial Gauge Reading			Rebound Deflection D	Pavement Temp.	Temperature Corrected Deflection Dt	Field Moisture	Seasonal Correction Factor	Moisture Corrected Deflection Dm	Mean Deflection /km	Standard Deviation	Corrected Characteristic Deflection
	Do	Di	Df							Mean	S.D	
(Km)	(Div)	(Div)	(Div)	(mm)	(^{O}C)							
0.55	100	67	65	1.40	32	1.43	7.30%	1.037	1.48	1.67	0.04	1.70
0.6	100	66	64	1.44	33	1.46	7.30%	1.037	1.51		0.03	
0.65	100	62	60	1.60	32	1.63	7.30%	1.037	1.69		0.00	
0.7	100	65	63	1.48	34	1.49	7.30%	1.037	1.55		0.01	
0.75	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
0.8	100	65	63	1.48	33	1.50	7.30%	1.037	1.56		0.01	
0.85	100	68	66	1.36	32	1.39	7.30%	1.037	1.44		0.05	
0.9	100	61	59	1.64	35	1.64	7.30%	1.037	1.70		0.00	
0.95	100	66	64	1.44	31	1.48	7.30%	1.037	1.53		0.02	
1	100	68	66	1.36	32	1.39	7.30%	1.037	1.44		0.05	
1.05	100	66	64	1.44	32	1.47	7.30%	1.037	1.52		0.02	
1.1	100	68	66	1.36	33	1.38	7.30%	1.037	1.43		0.06	
1.15	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.05	
1.2	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
1.25	100	57	55	1.80	33	1.82	7.30%	1.037	1.89		0.05	
1.3	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
1.35	100	60	58	1.68	34	1.69	7.30%	1.037	1.75		0.01	
1.4	100	58	56	1.76	32	1.79	7.30%	1.037	1.86		0.04	
1.45	100	62	60	1.60	34	1.61	7.30%	1.037	1.67		0.00	
1.5	100	55	53	1.88	32	1.91	7.30%	1.037	1.98		0.10	
1.55	100	60	58	1.68	32	1.71	7.30%	1.037	1.77		0.01	
1.6	100	67	65	1.40	33	1.42	7.30%	1.037	1.47		0.04	
1.65	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
1.7	100	61	59	1.64	32	1.67	7.30%	1.037	1.73		0.26	
1.75	100	74	72	1.12	35	1.12	7.30%	1.037	1.16		0.01	
1.8	100	65	63	1.48	32	1.51	7.30%	1.037	1.57		0.37	
1.85	100	77	75	1.00	33	1.02	7.30%	1.037	1.06		0.46	
1.9	100	79	77	0.92	32	0.95	7.30%	1.037	0.99		0.35	
1.95	100	77	75	1.00	31	1.04	7.30%	1.037	1.08		0.36	
2	100	77	75	1.00	32	1.03	7.30%	1.037	1.07		0.37	
2.05	100	77	75	1.00	33	1.02	7.30%	1.037	1.06		0.05	
2.1	100	68	66	1.36	32	1.39	7.30%	1.037	1.44		0.03	
2.15	100	66	64	1.44	34	1.45	7.30%	1.037	1.50		0.31	
2.2	100	76	74	1.04	32	1.07	7.30%	1.037	1.11		0.52	
2.25	100	80	78	0.88	31	0.92	7.30%	1.037	0.95		0.04	
2.3	100	67	65	1.40	32	1.43	7.30%	1.037	1.48		0.05	
2.35	100	57	55	1.80	33	1.82	7.30%	1.037	1.89		0.00	
2.4	100	61	59	1.64	32	1.67	7.30%	1.037	1.73		0.14	

2.45	100	72	70	1.20	31	1.24	7.30%	1.037	1.29		0.31	
2.5	100	76	74	1.04	32	1.07	7.30%	1.037	1.11		0.05	
2.55	100	57	55	1.80	33	1.82	7.30%	1.037	1.89		0.36	
2.6	100	77	75	1.00	32	1.03	7.30%	1.037	1.07		0.03	
2.65	100	66	64	1.44	34	1.45	7.30%	1.037	1.50		0.27	
2.7	100	75	73	1.08	32	1.11	7.30%	1.037	1.15		0.45	
2.75	100	79	77	0.92	31	0.96	7.30%	1.037	1.00		0.12	
2.8	100	71	69	1.24	32	1.27	7.30%	1.037	1.32		0.28	
2.85	100	75	73	1.08	33	1.10	7.30%	1.037	1.14		0.19	
2.9	100	73	71	1.16	32	1.19	7.30%	1.037	1.23		0.06	
2.95	100	68	66	1.36	33	1.38	7.30%	1.037	1.43		0.02	
3	100	66	64	1.44	31	1.48	7.30%	1.037	1.53		0.27	
3.05	100	75	73	1.08	32	1.11	7.30%	1.037	1.15		0.01	
3.1	100	65	63	1.48	32	1.51	7.30%	1.037	1.57		0.21	
3.15	100	75	73	1.08	32	1.11	7.30%	1.037	1.15		0.04	
3.2	100	65	63	1.48	33	1.50	7.30%	1.037	1.56		0.00	
3.25	100	73	71	1.16	34	1.17	7.30%	1.037	1.21		0.02	
3.3	100	58	56	1.76	32	1.79	7.30%	1.037	1.86		0.02	
3.35	100	61	59	1.64	34	1.65	7.30%	1.037	1.71		0.01	
3.4	100	66	64	1.44	32	1.47	7.30%	1.037	1.52		0.00	
3.45	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.00	
3.5	100	65	63	1.48	31	1.52	7.30%	1.037	1.58		0.10	
3.55	100	61	59	1.64	34	1.65	7.30%	1.037	1.71		0.05	
3.6	100	62	60	1.60	31	1.64	7.30%	1.037	1.70		0.22	
3.65	100	55	53	1.88	32	1.91	7.30%	1.037	1.98		0.07	
3.7	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.04	
3.75	100	51	49	2.04	33	2.06	7.30%	1.037	2.14		0.05	
3.8	100	56	54	1.84	32	1.87	7.30%	1.037	1.94		0.07	
3.85	100	58	56	1.76	31	1.80	7.30%	1.037	1.87		0.04	
3.9	100	68	66	1.36	32	1.39	7.30%	1.037	1.44		0.05	
3.95	100	69	67	1.32	32	1.35	7.30%	1.037	1.40		0.07	
4	100	54	52	1.92	32	1.95	7.30%	1.037	2.02		0.12	
4.05	100	57	55	1.80	34	1.81	7.30%	1.037	1.88		0.04	
4.1	100	53	51	1.96	32	1.99	7.30%	1.037	2.06		0.15	
4.15	100	57	55	1.80	31	1.84	7.30%	1.037	1.91		0.06	
4.2	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
4.25	100	52	50	2.00	32	2.03	7.30%	1.037	2.11		0.19	
4.3	100	54	52	1.92	33	1.94	7.30%	1.037	2.01		0.12	
4.35	100	56	54	1.84	31	1.88	7.30%	1.037	1.95		0.08	
4.4	100	62	60	1.60	32	1.63	7.30%	1.037	1.69		0.00	
4.45	100	65	63	1.48	31	1.52	7.30%	1.037	1.58		0.01	
4.5	100	67	65	1.40	32	1.43	7.30%	1.037	1.48		0.04	
4.55	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
4.6	100	60	58	1.68	33	1.70	7.30%	1.037	1.76		0.01	
4.65	100	61	59	1.64	34	1.65	7.30%	1.037	1.71		0.00	
4.7	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
4.75	100	55	53	1.88	31	1.92	7.30%	1.037	1.99		0.10	
4.8	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.05	
4.85	100	58	56	1.76	32	1.79	7.30%	1.037	1.86		0.04	
4.9	100	59	57	1.72	33	1.74	7.30%	1.037	1.80		0.02	
4.95	100	63	61	1.56	34	1.57	7.30%	1.037	1.63		0.00	
5	100	64	62	1.52	32	1.55	7.30%	1.037	1.61		0.00	
5.05	100	66	64	1.44	31	1.48	7.30%	1.037	1.53		0.02	
5.1	100	70	68	1.28	32	1.31	7.30%	1.037	1.36		0.10	
5.15	100	71	69	1.24	31	1.28	7.30%	1.037	1.33		0.12	
5.2	100	72	70	1.20	33	1.22	7.30%	1.037	1.27		0.16	
5.25	100	52	50	2.00	34	2.01	7.30%	1.037	2.08		0.17	
5.3	100	53	51	1.96	32	1.99	7.30%	1.037	2.06		0.15	
5.35	100	55	53	1.88	31	1.92	7.30%	1.037	1.99		0.10	
5.4	100	56	54	1.84	33	1.86	7.30%	1.037	1.93		0.07	
5.45	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.05	
5.5	100	58	56	1.76	34	1.77	7.30%	1.037	1.84		0.03	
5.55	100	53	51	1.96	32	1.99	7.30%	1.037	2.06		0.15	
5.6	100	54	52	1.92	33	1.94	7.30%	1.037	2.01		0.12	
5.65	100	61	59	1.64	32	1.67	7.30%	1.037	1.73		0.00	
5.7	100	63	61	1.56	31	1.60	7.30%	1.037	1.66		0.00	
5.75	100	64	62	1.52	32	1.55	7.30%	1.037	1.61		0.00	
5.8	100	66	64	1.44	33	1.46	7.30%	1.037	1.51		0.03	
5.85	100	67	65	1.40	32	1.43	7.30%	1.037	1.48		0.04	
5.9	100	68	66	1.36	33	1.38	7.30%	1.037	1.43		0.06	
5.95	100	70	68	1.28	32	1.31	7.30%	1.037	1.36		0.10	

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6	100	71	69	1.24	34	1.25	7.30%	1.037	1.30		0.14	
6.05	100	52	50	2.00	32	2.03	7.30%	1.037	2.11		0.19	
6.1	100	53	51	1.96	31	2.00	7.30%	1.037	2.07		0.16	
6.15	100	54	52	1.92	32	1.95	7.30%	1.037	2.02		0.12	
6.2	100	55	53	1.88	33	1.90	7.30%	1.037	1.97		0.09	
6.25	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.05	
6.3	100	58	56	1.76	34	1.77	7.30%	1.037	1.84		0.03	
6.35	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
6.4	100	61	59	1.64	31	1.68	7.30%	1.037	1.74		0.00	
6.45	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
6.5	100	64	62	1.52	33	1.54	7.30%	1.037	1.60		0.00	
6.55	100	66	64	1.44	32	1.47	7.30%	1.037	1.52		0.02	
6.6	100	55	53	1.88	31	1.92	7.30%	1.037	1.99		0.10	
6.65	100	57	55	1.80	32	1.83	7.30%	1.037	1.90		0.05	
6.7	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
6.75	100	60	58	1.68	33	1.70	7.30%	1.037	1.76		0.01	
6.8	100	61	59	1.64	32	1.67	7.30%	1.037	1.73		0.00	
6.85	100	62	60	1.60	31	1.64	7.30%	1.037	1.70		0.00	
6.9	100	63	61	1.56	32	1.59	7.30%	1.037	1.65		0.00	
6.95	100	52	50	2.00	33	2.02	7.30%	1.037	2.09		0.18	
7	100	53	51	1.96	32	1.99	7.30%	1.037	2.06		0.15	
7.05	100	54	52	1.92	34	1.93	7.30%	1.037	2.00		0.11	
7.1	100	55	53	1.88	32	1.91	7.30%	1.037	1.98		0.10	
7.15	100	58	56	1.76	32	1.79	7.30%	1.037	1.86		0.04	
7.2	100	59	57	1.72	31	1.76	7.30%	1.037	1.83		0.03	
7.25	100	60	58	1.68	32	1.71	7.30%	1.037	1.77		0.01	
7.3	100	52	50	2.00	33	2.02	7.30%	1.037	2.09		0.18	
7.35	100	54	52	1.92	32	1.95	7.30%	1.037	2.02		0.12	
7.4	100	55	53	1.88	31	1.92	7.30%	1.037	1.99		0.10	
7.45	100	59	57	1.72	32	1.75	7.30%	1.037	1.81		0.02	
7.5	100	58	56	1.76	32	1.79	7.30%	1.037	1.86		0.04	
7.55	100	54	52	1.92	32	1.95	7.30%	1.037	2.02		0.12	

COMPUTATION OF DESIGN TRAFFIC

The design traffic is considered in terms of the cumulative number of standard axles to be carried during the design life of the overlay. It is given by the formula mentioned below

$$N_s = 365*A*[(1 + r)^X - 1] * \frac{F}{r}$$

where,
N_s = The cumulative number of standard axles to be catered for in the design
A = Initial traffic, in the year of completion of construction, in terms of the number of commercial vehicles per day duly modified to account for lane distribution = 130 cv/day
r = Annual growth rate of commercial vehicles = 7.5%
X = Design life in years = 10 years
F = Vehicle damage factor (number of standard axles per commercial vehicle) = 1.5

Thus cumulative axle load, N_s = 1.0069 million standard axle

DESIGN OF OVERLAY

As per Fig. 2; for the selected stretch of 7.00 km, the characteristic deflection of 1.70 mm and the design traffic of 1.0069 million standard axle (*msa),* an overlay of 25 mm is to be provided. But as per the guidelines of IRC, an overlay of 50 *mm* BM and 40 *mm* BC is recommended.

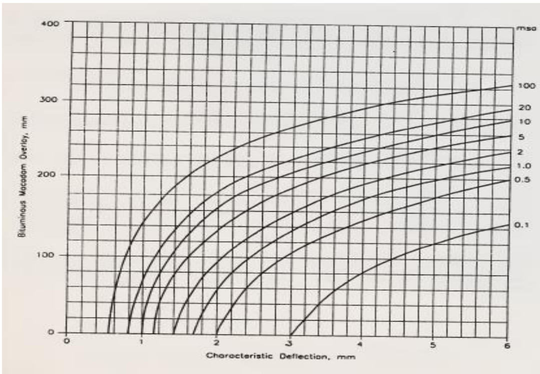

Fig 2: Overlay Thickness Design Curves

V. CONCLUSION

Structural evaluation of pavement is carried out to determine the capacity of the pavement to withstand future traffic load. The experimental results of the project will help in studying the existing condition of the pavement in terms of structural adequacy.

Thus from clause 7.5 of IRC 81, to serve the structural inadequacy it is recommended to provide 50 mm BM and a surface course of 40 mm BC.

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