Strengthening and Maintenance of a Flexible Road Pavement Using Benkelman Beam Deflection Method

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Abstract - *The expansion in commercial, industrial and residential regions has led to a rapid increase in the traffic further causing the deterioration of the pavements. A distressed pavement requires effective maintenance, and maintenance expenditure can be reduced through proper planning, design, construction and quality control. In order to keep the pavements in good serviceable condition, it is necessary to complete the functional and structural evaluation. In the present study, two stretches of 5km each of a Major District Road in Painavu in Idukki district, Kerala, is selected as study areas for the improvement. Functional evaluation is completed through visual observation and pavement evaluation survey is done using odometer. Structural evaluation using Benkelman Beam Deflection technique (BBD) to evaluate the deflection of the pavement and Core Cutting to understand about the existing pavement composition is done. Samples of the subgrade soils are collected and traffic of the area is also studied. Data obtained is analyzed and an appropriate overlay design is selected based on the characteristic deflection and design traffic.*

***Key Words*: Flexible pavement, Functional evaluation, Structural evaluation, Benkelman Beam Deflection test, Core Cutting, Moisture content test, Overlay designing**

1. INTRODUCTION

Pavements are the most important part of transportation networks. Pavements get easily deteriorated due to the continuous action of heavy loads. They also get damaged in the course of time and changes in the climatic conditions. There arises a need for strengthening the pavements. Overlaying method can be considered as one of the economical method for strengthening and maintenance of a flexible pavement with minor to modest damages. It is different from a total replacement of the pavement. The present study focuses on the functional and structural evaluation of two stretches of 5km each of a Major District Road in Painavu of Idukki district, Kerala, and hereby determining the thickness of the required overlay. Measure of structure adequacy is carried out by Benkelman Beam Deflection Method.

1.1 Objectives

- To evaluate functional performance of flexible road pavements.
- To collect soil samples for conducting the moisture content test of the subgrade soil.
- To determine the deflection of flexible pavement using Benkelman Beam Deflection method.
- To determine the thickness and layers of the pavement using core cutter.
- To study the traffic of the area. To design an overlay for an existing flexible pavement.

1.2 Scope

- BBD enables precise and Non Destructive measurement of the strength evaluation of the pavement surface layer, so an effective overlay can be achieved.
- Total replacement of the structure can be avoided so cost and time can be reduced.
- Evaluating the maximum load bearing capacity of the existing pavement and designing overlay for the pavement with an improved elastic recovery.
- Creating an efficient roadway facility for the road users.
- Contributes to the overall development of the locality

2. METHODOLOGY

The study location was the two stretches of 5km each of a Major District Road in Painavu of Idukki district, Kerala. Each stretch were divided into five sections of 1km each. The pavement evaluation comprise of functional evaluation, structural evaluation and subgrade soil tests. Functional evaluation is done in two steps. They are visual observation and pavement condition survey. Primary data collection is followed by visual observation. It is conducted to identify the presence of various distresses like rutting, potholes, patching, raveling, shoving, etc. in the pavement surface. Each stretch is rated as per the IRC: 82 - 2015 guidelines. The functional condition of the pavement is assessed to be good, fair or poor based on this rating and both the stretches are assessed to be poor. Pavement condition is evaluated using odometer. Trees, culverts, bridges, drains, bus shelters are noted for each kilometres and required information regarding these are collected. The overall pavement condition is also determined. The three day traffic of the area is noted and moisture content test of the subgrade soil samples are carried out. The characteristic deflection of the pavement is determined by using Benkelman Beam Deflection testing technique, the pavement composition is found and overlay thickness required for the pavement to withstand present as well as future traffic loading is calculated as per IRC: 81 – 1997 guidelines.

3. PAVEMENT EVALUATION

Performance of a pavement mainly depends on how the pavement and materials perform under repealed heavy loads. The performance evaluation of the pavement involves the study of various factors such as pavement thickness and composition, subgrade support, environmental conditions and traffic loading.

3.1 Location

Two locations of Painavu road are selected for the study, namely stretch 1 and stretch 2. Both the stretches are of 5 km each. Stretch 1 and stretch 2 are Thadiyambadu junction and Idukki junction respectively.

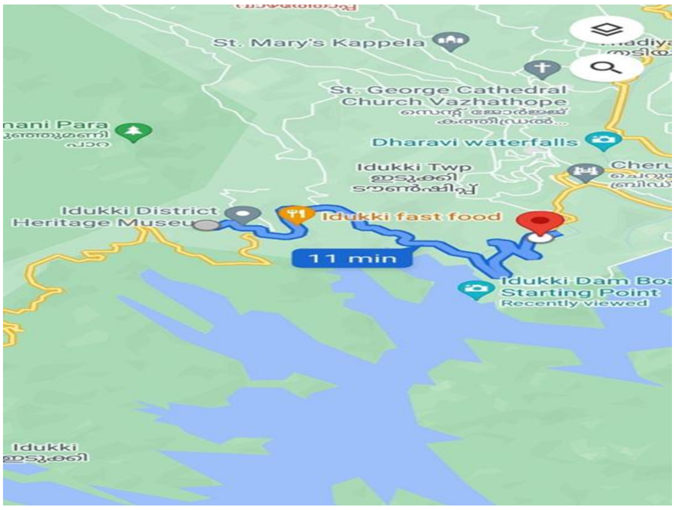

Fig -1: Stretch 1 Thadiyambadu junction

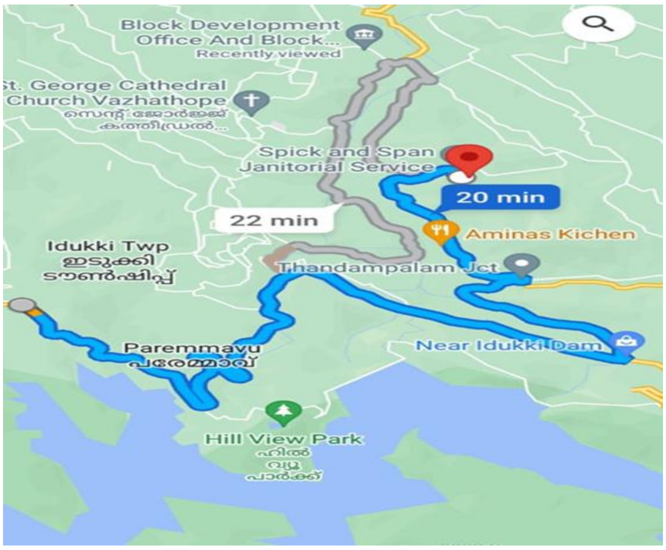

Fig -2: Stretch 2 Idukki junction

3.2 Functional evaluation

It is carried out by visual observation and pavement condition survey.

Table -1: Primary data of stretch 1 and stretch 2

Primary data	Stretch 1	Stretch 2
Length of the stretch	5 km	5km
Type of pavement	Flexible Pavement	Flexible pavement
Number of lanes	Two lane	Two lane
Divided/Undivided	Undivided	Undivided
Type of shoulder	Earthen shoulder	Earthen shoulder
Width of carriage way	4.20m	4.20m
Junction type	T junction	Y junction
Road safety measures	No road safety measures.	No road safety measures.
Drainage condition	Open	Open

Table -2: Rating provided as per IRC: 82-2015

Defect	Stretch 1 (Thadiyambadu junction)	Stretch 2 (Idukki junction)
Cracking	>20%	>20%
Ravelling	>25%	>25%
Potholes	>1%	>1%
Patching	>20%	>20%
Settlement	>5%	>5%

Rut depth	5mm	6mm
Rating	1	1
Conditioning	Poor	Poor

Pavement survey by means of odometer is completed for two stretches of location and following data is noted.

Table -3 Girth of trees along roadways

TREES IN ROW			
Chainage	Girth in meters		Remark
	LHS	RHS	
0/765	_	2.25	Jungle tree
5/317	1.70	2.00	Njaval tree
5/405	_	2.30	Mango tree
5/995	0.75	_	Nelli

3.3 Structural evaluation

The structural evaluation of pavement is related to the structural soundness or load carrying capacity of the pavement. It is measured in terms of the response of pavement to load application. There are two types of structural evaluation. They are Destructive and Non Destructive Tests. Destructive test causes damage to the pavement whereas Non Destructive testing is do not cause any damage or destruction to the pavements. Core Cutting and Benkelman Beam Deflection method are the examples of Destructive and Non Destructive tests respectively.

3.3.1 Benkelman Beam Deflection Method

The Benkelman Beam enables precise and non-destructive measurements of the load-bearing capacity of road surface layers made of asphalt or pavement It is a simple lever-arm device that measures deflection of flexible pavements under the action of moving wheel loads.

Fig - 3: Benkelman beam placed on location

Procedure

- The points shall be preselected and marked for highway pavements, test points shall be located at a distance from the edge of the lane given in the table. The tyre pressure should be checked before the first test and at interval not exceeding 3 hours.
- The truck shall initially be positioned with the test wheel between 100 and 150mm to the rare of the test spot i.e., position A.
- The probe of the beam shall be inserted between the dues tyre of the test wheel with the toe located on the test spot.
- The locking device shall be released and the rear of the beam adjusted so that the plunger is in contact with the dial gauge.
- The truck shall be moved forward at creep speed so that the test wheel passes over the test spot and continues advancing to position 8 which is 2.7 ± 0.1 meters beyond the test spot.
- The start readings, is the maximum dial gauge reading occurring during this movement of the truck from position A to position B, and will normally occur as the wheel passes over the test spot. This reading shall be recorded.
- The intermediate reading I, is that figure indicated by the dial gauge at the moment the truck stops with the test wheel in position B. This reading shall be recorded.
- The truck shall be moved forward until the test wheel is in position V which is not less than 10 meters from position B.
- The final reading F, is that figure indicated by the dial gauge when the truck has stopped in position C. This figure shall be recorded.
- Temperature measurements must be made when the top layer of the pavement consists of 40mm or more of bitumen bound material. The following procedure should be followed:
- A hole should be made with the mandrel to a depth of 40mm or to such a depth that it does not break through the bitumen bound material.
- The hole should be filled with glycerol or oil and the thermometer inserted.
- The temperature should be recorded at least hourly, or at decreasing time intervals down to 15 minutes when successive temperatures differ by more than 3°C

Table -4 Benkelman Beam Deflection Data of Stretch 1

Sl No.	LHS/ RHS	Chainage	Initial	Inter mediate	Final	Temp
1	LHS	0/50	100	64	63	42
2	RHS	0/100	100	72	70	42
3	LHS	0/150	100	71	69	42
4	RHS	0/200	100	70	69	42
5	LHS	0/250	100	72	70	42
6	RHS	0/300	100	69	68	42
7	LHS	0/350	100	68	69	42
8	RHS	0/400	100	70	69	42
9	LHS	0/450	100	71	70	42
10	RHS	0/500	100	72	70	42
11	LHS	0/550	100	70	69	42
12	RHS	0/600	100	71	70	42
13	LHS	0/650	100	72	70	42
14	RHS	0/700	100	69	65	42
15	LHS	0/750	100	71	70	42
16	RHS	0/800	100	70	69	42
17	LHS	0/850	100	72	70	42
18	RHS	0/900	100	71	70	42
19	LHS	0/950	100	69	68	42
20	RHS	1/000	100	68	65	42
21	LHS	1/50	100	65	62	36
22	RHS	1/100	100	63	61	36
23	LHS	1/150	100	62	60	36
24	RHS	1/200	100	67	65	36
25	LHS	1/250	100	65	63	36
26	RHS	1/300	100	67	64	36
27	LHS	1/350	100	67	63	36
28	RHS	1/400	100	66	64	36
29	LHS	1/450	100	67	62	36
30	RHS	1/500	100	65	62	36
31	LHS	1/550	100	66	63	36
32	RHS	1/600	100	65	62	36
33	LHS	1/650	100	64	61	36
34	RHS	1/700	100	66	63	36
35	LHS	1/750	100	65	62	36
36	RHS	1/800	100	66	62	36
37	LHS	1/850	100	65	62	36
38	RHS	1/900	100	65	63	36
39	LHS	1/950	100	65	62	36
40	RHS	2/000	100	66	64	36
41	LHS	4/50	100	72	70	38
42	RHS	4/100	100	71	70	38
43	LHS	4/150	100	73	71	38
44	RHS	4/200	100	71	70	38
45	LHS	4/250	100	72	70	38
46	RHS	4/300	100	74	72	38
47	LHS	4/350	100	76	74	38
48	RHS	4/400	100	73	72	38
49	LHS	4/450	100	72	70	38
50	RHS	4/500	100	70	68	38
51	LHS	4/550	100	74	72	38
52	RHS	4/600	100	74	71	38
53	LHS	4/650	100	72	71	38
54	RHS	4/700	100	70	69	38
55	LHS	4/750	100	74	72	38
56	RHS	4/800	100	74	73	38
57	LHS	4/850	100	72	71	38
58	RHS	4/900	100	73	71	38
59	LHS	4/950	100	74	72	38
60	RHS	5/000	100	73	71	38

Table -5 Benkelman Beam Deflection Data of Stretch 2

Sl No.	LHS/ RHS	Chainage	Initia l	Inter mediate	Final	Temp
1	LHS	5/50	100	59	55	40
2	RHS	5/100	100	58	56	40
3	LHS	5/150	100	56	54	40
4	RHS	5/200	100	58	56	40
5	LHS	5/250	100	57	56	40
6	RHS	5/300	100	57	55	40
7	LHS	5/350	100	59	57	40
8	RHS	5/400	100	60	58	40
9	LHS	5/450	100	58	57	40
10	RHS	5/500	100	60	58	40
11	LHS	5/550	100	59	56	40
12	RHS	5/600	100	57	56	40
13	LHS	5/650	100	58	56	40
14	RHS	5/700	100	58	57	40
15	LHS	5/750	100	60	58	40
16	RHS	5/800	100	59	57	40
17	LHS	5/850	100	60	57	40
18	RHS	5/900	100	58	57	40
19	LHS	5/950	100	57	56	40
20	RHS	6/000	100	56	54	40
21	LHS	6/50	100	47	45	38
22	RHS	6/100	100	45	44	38
23	LHS	6/150	100	46	44	38
24	RHS	6/200	100	47	43	38
25	LHS	6/250	100	45	43	38
26	RHS	6/300	100	46	44	38
27	LHS	6/350	100	47	45	38
28	RHS	6/400	100	45	43	38
29	LHS	6/450	100	47	44	38
30	RHS	6/500	100	46	44	38
31	LHS	6/550	100	47	44	38
32	RHS	6/600	100	46	43	38
33	LHS	6/650	100	46	45	38
34	RHS	6/700	100	47	46	38
35	LHS	6/750	100	46	42	38
36	RHS	6/800	100	47	46	38
37	LHS	6/850	100	46	44	38
38	RHS	6/900	100	47	45	38
39	LHS	6/950	100	40	39	38
40	RHS	7/000	100	40	38	38
41	LHS	7/50	100	31	30	38
42	RHS	7/100	100	29	27	38
43	LHS	7/150	100	33	31	38
44	RHS	7/200	100	31	30	38
45	LHS	7/250	100	29	27	38
46	RHS	7/300	100	29	27	38
47	LHS	7/350	100	28	27	38
48	RHS	7/400	100	31	30	38
49	LHS	7/450	100	30	29	38
50	RHS	7/500	100	29	27	38
51	LHS	7/550	100	30	27	38

52	RHS	7/600	100	29	27	38
53	LHS	7/650	100	30	28	38
54	RHS	7/700	100	28	27	38
55	LHS	7/750	100	30	29	38
56	RHS	7/800	100	31	30	38
57	LHS	7/850	100	30	29	38
58	RHS	7/900	100	29	27	38
59	LHS	7/950	100	31	30	38
60	RHS	8/000	100	30	29	38
61	LHS	8/50	100	70	68	38
62	RHS	8/100	100	72	70	38
63	LHS	8/150	100	70	68	38
64	RHS	8/200	100	68	67	38
65	LHS	8/250	100	74	72	38
66	RHS	8/300	100	72	70	38
67	LHS	8/350	100	70	69	38
68	RHS	8/400	100	71	70	38
69	LHS	8/450	100	70	69	38
70	RHS	8/500	100	69	68	38
71	LHS	8/550	100	70	68	38
72	RHS	8/600	100	71	70	38
73	LHS	8/650	100	70	68	38
74	RHS	8/700	100	71	70	38
75	LHS	8/750	100	72	70	38
76	RHS	8/800	100	71	70	38
77	LHS	8/850	100	70	68	38
78	RHS	8/900	100	71	69	38
79	LHS	8/950	100	72	70	38
80	RHS	9/000	100	70	68	38
81	LHS	9/50	100	88	87	36
82	RHS	9/100	100	86	85	36
83	LHS	9/150	100	84	82	36
84	RHS	9/200	100	86	85	36
85	LHS	9/250	100	83	81	36
86	RHS	9/300	100	86	85	36
87	LHS	9/350	100	84	82	36
88	RHS	9/400	100	84	82	36
89	LHS	9/450	100	82	80	36
90	RHS	9/500	100	80	78	36
91	LHS	9/550	100	86	84	36
92	RHS	9/600	100	84	82	36
93	LHS	9/650	100	88	86	36
94	RHS	9/700	100	90	89	36
95	LHS	9/750	100	87	86	36
96	RHS	9/800	100	87	85	36
97	LHS	9/850	100	88	86	36
98	RHS	9/900	100	80	79	36
99	LHS	9/950	100	88	87	36
100	RHS	10/000	100	88	86	36

3.3.2 Core cutting

Core cutting test carried out to determine density of asphalt, thickness of the layers, materials used in the construction and period of the pavement.

Fig - 4: Core Cutting operation

Fig - 5: Core obtained from location

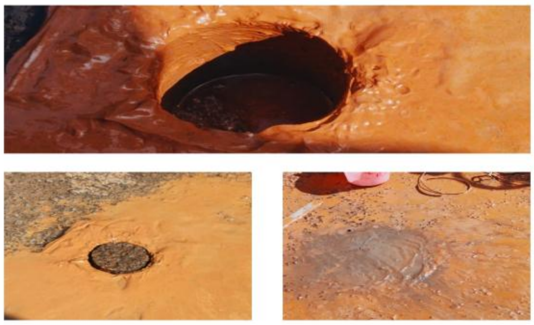

Fig - 6: Filling of the hole of coring operation

3.4 Traffic Survey

Traffic study
Estimate of the initial average traffic flow for any road should normally be based on 7 days 24 hours classified traffic counts. In special cases 3 day count could also be used and 3 day counts are commonly used. Traffic study is conducted on Thadiyambadu junction for 3 days.

Design life
As per IRC: 81-1997 design life is 10 years

Computation of design traffic

Table -6 Computation of design traffic

Traffic	Equation	Value
Present Traffic	3 day 24 hours count	2636 CVPD
Initial Traffic	$P(1+r)^x$	2834 CVPD
Design Traffic	$\frac{365 \times [(1+r)^n - 1] \times A \times D \times F}{r}$	49.38MSA

3.5 Soil sample collection and soil test

The soil sample for the determination of field moisture content shall be scooped from the shoulder which is adjacent to the pavement edge Test pit dug to depth up to 15cm below the subgrade level in every kilometer depending on Uniformity of subgrade soil, Topography of road area. Road profile.

Table -7 Moisture content of the subgrade soil

Sl No.	chainage	Moisture content
1	0/50	11.64
2	1/150	11.3
3	4/200	12.09
4	5/150	13.01
5	6/000	12.08
6	7/250	11.99
7	8/200	11.53
8	9/500	11.31

4. OVERLAY DESIGNING

Overlay design (as per IRC: 81-1997) using Benkelman beam
Deflection observations:

- Date of Test: January 20 2022
- Category of Road: Major District Road
- Name of the Road: Idukki Painavu Road
- Test Stretch (Chainage in km): 0/00 to 10/000 km
- Annual Rainfall: 3600mm
- Last Traffic volume Count (2022): 1318 CVPD
- Construction Period (assumed): 1 year
- Design Life: 10 years
- Least count of the dial gauge: 1 div = 0.01mm
- Average Deflection = 0.859mm
- Standard Deviation = 0.352
- Characteristic Deflection = 1.56mm
- Design Traffic = 49.38 MSA

Table -8 Result data

Mean deflection	$\bar{x} = \sum \frac{x}{n}$	0.859mm
Standard deviation	$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}}$	0.352
Characteristic deflection	$D_C = \bar{x} + \sigma$	1.56mm

Bituminous Macadam Overlay thickness = Minimum thickness recommended as per IRC: 81-1997

Bituminous Macadam Overlay thickness = 180mm
1cm Bituminous Macadam = 0.7 cm of Dense Bituminous Macadam(DBM)
According to IRC: 81-1997 Cl(7.4)Pg No. 20,

The recommended minimum bituminous overlay thickness is 50 mm bituminous macadam with an additional surfacing coarse of 50mm DBM or 40 mm bituminous concrete.

5. CONCLUSIONS

Overlay to be provided 40mm Bituminous Concrete over 90mm dense bituminous macadam is considered to be the most appropriate overlay design to be provided on both stretches (Thadiyambadu and Idukki junction). Stretch 1 as well as stretch 2 are considered to be poor because of severe distresses. Based on Benkelman beam deflection and design traffic data obtained overlay to be provided is 40mm Bituminous Concrete over 90mm Bituminous Macadam for both stretches.

From rough cost estimation, it was observed that cost of building a new road is costlier than provided required overlay for both stretches. Providing the required overlay can maintain the pavement in fair condition for an average design life of 10 years. Periodic maintenance should be conducted on the pavement so that distress is cleared at the earliest and maintenance expenditure can also be reduced. Proper maintenance and strengthening of pavement result in creating an efficient roadway facility for the road users and also contributed to overall development of the locality.

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