International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 8, August 2017, pp. 1299–1305, Article ID: IJCIET_08_08_140
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=8
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

FUNCTIONAL AND STRUCTURAL EVALUATION OF A ROAD PAVEMENT

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ABSTRACT

Pavement evaluation is carried out to determine the existing condition of pavements in terms of its surface and structural adequacy. In the present research work the pavement is evaluated using destructive and nondestructive methods. An attempt is made to evaluate the condition of a selected section of a pavement from Budalur to Pudupatti on State Highway 99. Based on the analysis of distress data, the pavement is rated by making use of IRC: 82 - 2015. Structural evaluation of pavement is carried out with Benkelman Beam to determine the capacity of the pavement to withstand future traffic loading. From the analysis of data the overlay thickness required to maintain the pavement in serviceable condition is determined.

Key words: Pavement Evaluation, Benkelman Beam, Distress, Functional Evaluation, Structural Evaluation, Overlay Design.

Cite this Article: B. Subramanyam, Aravind S, Prasanna Kumar R, Functional and Structural Evaluation of a Road Pavement. *International Journal of Civil Engineering and Technology*, 8(8), 2017, pp. 1299–1305.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=8

1. INTRODUCTION

Pavements deteriorate with age and traffic loading. Evaluation of in service pavements is very vital for keeping them in good serviceable condition. To get a complete idea of the existing condition of any pavement both structural and functional evaluation are necessary.

In the present it is proposed to carry out both of them for a selected section of pavement on a State Highway in Tamil Nadu, India, the details of which are given the methodology section of this article. Before starting the review of the available literature was made and presented below.

Bhatt Mayank et al. [1] measured various distresses present in the pavement section by conducting pavement condition survey from Sarsa Junction to Vasad Junction in State Highway 188 in Gujarat. The rebound deflection of the pavement was measured using Benkelman Beam Deflection Technique and related to the pavement performance. Overlay design was done and thickness of the overlay was estimated as ranging between 110mm to 210mm in terms of Bituminous Macadam. Agarwal et al. [2] studied the performance of flexible pavements in terms of its functional behavior. Roughness of the pavement was used to denote the overall surface condition of the pavement. Ride quality is measured using Bump Integrator. Four National Highways (NH3, NH12, NH69, NH 86) and one State Highway (SH23) were selected for the study. The pavement was evaluated both functionally and structurally. The rebound deflection of the pavement is measured with Benkelman Beam Deflection (BBD) Technique. It was concluded that the heavy traffic present in all the road sections leads to their premature failure. The pavement was found to be structurally inadequate in all the sections and hence an overlay is necessary in all the sections. The overlay thickness varied from 134mm to 167mm for different highway pavements. Sirin Jayswal et al. [3] conducted a study on the State Highway 73 in Gujarat, from Rampura Junction to Gozariya Junction. The various distresses present in the pavement section were identified by visual condition survey. The structural evaluation of the pavement is carried out using the Benkelman Beam Deflection technique to determine the capacity of the pavement to sustain traffic loading and the level of support the pavement would provide to overlay design. The overlay thickness found for all the sections ranged from 75mm to 150mm. Minu et al. [4] developed a Maintenance Priority Index (MPI) by studying six sections of State Highway 1 using certain factors affecting Pavement maintenance. Some of the factors considered in the study were pavement condition, ride quality, traffic characteristics, and characteristic deflection of the pavement. A relation between pavement roughness and distress in the pavement was developed. Cracking, raveling, potholes, etc are some critical distresses identified in the study area. The pavement distress survey was conducted on the State Highway 1 stretching from Vetturoad to Adoor. Benkelman Beam was used for taking deflection measurements while the roughness data in the pavement was collected using Bump Integrator. Pavement Condition Index (PCI) was determined for each of the section. A relation between PCI and roughness was developed with the technique of Multiple Linear Regression Analysis. Maintenance activity is prioritized using composite index method. Shabana Thabassum [5] correlates the deflection and Unevenness Index (UI) for evaluation of flexible pavements. For carrying out any type of maintenance activity, evaluating the flexible pavement is a pre-requisite. NDT is used for evaluation. BBD and Bump Integrator were used to evaluate the deflection and UI of the pavement of 4 lane divided carriageway of Nandigama - Ibrahimpatnam section of NH9 in the state of Andhra Pradesh. An attempt was made to develop and validate linear and logarithmic models between deflection and UI. A similarity of about 90% is achieved between the model and the measured value resulting in cost minimization of roughness survey. Saranya Ullas et al. [6] carried out studies for identifying various distresses in Kottayam to Kumili road and also on Varkala to Kallambalam road. Few roads are in hilly terrain while the others are in plain terrain. Data collection was done by considering five representative sections of equal length of 1 km. Details about previous maintenance activities performed on the pavement and the time on which they are performed were collected. CBR test was conducted to determine the sub grade characteristics of the soil to assess the strength of the pavement. BBD was used to measure the characteristic deflection of the pavement. Raveling, cracking, potholes and fretting were few of the distresses observed. Bump Integrator was used for measuring roughness Index. Regression models were developed using SPSS package. The roughness values measured and the roughness values obtained from the model was compared and validated. Bhagavan Raju et al. [7] studied the performance of flexible pavements on non-expansive soils. Six locations were selected for the study where the flexible pavement is laid on non-expansive soil. Each section is homogenous with the length of 1 km. The CBR value of the sub grade ranges from 10% to 14%. Soil samples were collected for laboratory experimentation. Moisture content, Atterberg limit, Free swell Index and CBR tests were conducted on the soil sample. Benkelman Beam Deflection testing was done to measure the characteristic deflection of the pavement surface and fifth wheel Bump Integrator was used to calculate the roughness index to assess the performance of the pavement. The Plasticity Index ranges between 12 and 18. The roughness values increases with time and the roughness index values are higher after the monsoon season when compared to the roughness index values measured before the monsoon season which is due to the volumetric changes in the sub-grade soil. Deflection also increases with age and there is significantly higher deflection after the monsoon season.

2. METHODOLOGY

The study location identified in the present work was between Budalur and Pudupatti section (8.6km to 11km) of State Highway 99 (Thirukattupalli - Sengipatti - Pattukottai road). For the purpose of functional evaluation the total the pavement length was divided into 8 sample units of equal size. Each sample unit is 300m x 7m. For convenience, 5 out of the 8 sample units were considered for inspection by random sampling technique. Manual distress survey is conducted to identify the presence of various distresses like rutting, potholes, patching, raveling, shoving, etc. in the pavement surface. The percentage area of each distress present in each of the inspected sample units was calculated. Each section 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. The overall pavement condition is also determined. The characteristic deflection of the pavement is determined by using Benkelman Beam Deflection testing technique 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. FIELD SURVEY AND DATA COLLECTION

3.1. Functional Condition Evaluation

Manual distress data collection is done to identify the various distresses present in the pavement section. A rating in the scale of 1 to 3 is given to each distress based on the percentage of distress present in the pavement and the weighted rating value of the pavement is calculated to assess the pavement condition as per the guidelines given in IRC82:2015. The results of the evaluation are as follows.

Figure 1 Distress survey

Table 1 Visual Surface Distress Measurement (%)

Section	Crack	Patch	Pothole	Edge Break	Raveling	Shoving
1	287.08	8.09	1.94			
2	468.52	41.96	2.305		9.75	
3	180.76	29.825	1.88	1.32		
4	116.1	87.115			1.76	4.14
5	175.09	157.37		1.6	50.37	

Section	Crack	Patch	Pothole	Edge Break	Raveling	Shoving
1	13.67	0.38	0.09			
2	22.31	2	0.11		0.46	
3	8.61	1.42	0.09	0.06		
4	5.53	4.14			0.08	0.2
5	8.34	7.49		0.08	2.4	

Table 2 Rutting survey

Section	Total Rut Depth (mm)	Average Rut Depth (mm)
1	603	15.075
2	461	11.525
3	607	15.175
4	670	16.75
5	653	16.325
Average rut depth of the entire section		14.97

Table 3 Final Rating Value

Section	Final Rating Value	Condition
1	1.7	Fair
2	1.6	Fair
3	1.7	Fair
4	1.5	Fair
5	1.5	Fair

Final Rating Value of the entire pavement = $\frac{(1.7+1.6+1.7+1.5+1.5)}{5}$ = 1.6

The condition of the road is fair.

3.2. BBD Testing

The deflection in the pavement is measured using BBD technique. The procedure followed is as per IRC:81- 1997. Digital dial gauge which shows direct deflection readings has been used for the experiment. All the necessary data like pavement temperature, drainage system, etc. were collected during testing. Soil samples were collected at the test site for every 1 km interval and tested for moisture content and Plasticity Index values. The truck was placed at about 0.6m offset and the readings were taken for every 25m in alternating lanes. The readings are as follows.

Location: Budalur - Pudupatti (SH99)

CH: 8.6km - 9.6km

Soil: Clay

Air temperature: 37^{o}C

Pavement temperature: 42^{o}C
Drainage: Good
Annual Rainfall: 1180 mm
Classification of road: SH
Traffic: 3150 CV/day

Table 4 Benkelman Beam Deflection Data

Location(km)	Lane	Initial(mm)	Inter (mm)	Final (mm)	Average (x)	Mean ($\bar{x}$)	($\bar{x}$-x)	($\bar{x}$-x)^2
0	L	2.182	1.44	1.438	1.687	1.412	-0.275	0.076
0.025	R	1.433	1.433	1.432	1.433	1.412	-0.021	0.000
0.05	L	1.582	1.568	1.568	1.573	1.412	-0.161	0.026
0.075	R	1.454	1.453	1.453	1.453	1.412	-0.042	0.002
0.1	L	1.614	1.614	1.614	1.614	1.412	-0.202	0.041
0.125	R	1.36	1.359	1.358	1.359	1.412	0.053	0.003
0.15	L	1.615	1.614	1.613	1.614	1.412	-0.202	0.041
0.175	R	1.537	1.531	1.529	1.532	1.412	-0.121	0.015
0.2	L	1.472	1.471	1.469	1.471	1.412	-0.059	0.003
0.225	R	1.577	1.573	1.572	1.574	1.412	-0.162	0.026
0.25	L	1.351	1.348	1.347	1.349	1.412	0.063	0.004
0.275	R	1.441	1.438	1.436	1.438	1.412	-0.027	0.001
0.3	L	1.347	1.345	1.344	1.345	1.412	0.066	0.004
0.325	R	0.841	0.772	0.772	0.795	1.412	0.617	0.380
0.35	L	1.364	1.362	1.361	1.362	1.412	0.049	0.002
0.375	R	1.369	1.366	1.366	1.367	1.412	0.045	0.002
0.4	L	1.368	1.367	1.366	1.367	1.412	0.045	0.002
0.425	R	1.352	1.35	1.35	1.351	1.412	0.061	0.004
0.45	L	1.53	1.528	1.527	1.528	1.412	-0.117	0.014
0.475	R	1.413	1.413	1.413	1.413	1.412	-0.001	0.000
0.5	L	1.334	1.333	1.332	1.333	1.412	0.079	0.006
0.525	R	1.535	1.534	1.533	1.534	1.412	-0.122	0.015
0.55	L	1.403	1.402	1.402	1.402	1.412	0.009	0.000
0.575	R	1.374	1.373	1.373	1.373	1.412	0.038	0.001
0.6	L	1.352	1.35	1.349	1.350	1.412	0.061	0.004
0.625	R	1.448	1.482	1.482	1.471	1.412	-0.059	0.003
0.65	L	1.441	1.439	1.437	1.439	1.412	-0.027	0.001
0.675	R	1.428	1.426	1.425	1.426	1.412	-0.015	0.000
0.7	L	1.307	1.287	1.287	1.294	1.412	0.118	0.014
0.725	R	1.361	1.36	1.36	1.360	1.412	0.051	0.003
0.75	L	1.501	1.5	1.49	1.497	1.412	-0.085	0.007
0.775	R	1.406	1.406	1.405	1.406	1.412	0.006	0.000
0.8	L	1.332	1.332	1.331	1.332	1.412	0.080	0.006
0.825	R	1.333	1.332	1.331	1.332	1.412	0.080	0.006
0.85	L	1.389	1.388	1.386	1.388	1.412	0.024	0.001
0.875	R	1.479	1.478	1.477	1.478	1.412	-0.066	0.004
0.9	L	1.363	1.361	1.36	1.361	1.412	0.050	0.003
0.925	R	1.431	1.431	1.431	1.431	1.412	-0.019	0.000
0.95	L	1.339	1.338	1.338	1.338	1.412	0.073	0.005
0.975	R	1.358	1.352	1.35	1.353	1.412	0.058	0.003
1	L	1.354	1.352	1.351	1.352	1.412	0.059	0.004

Figure 2 BBD data collection in Progress

3.3. Soil Sampling and Testing

A pit is made of about 1 feet depth at the test location and soil is collected at 1km interval. The sample is tested in laboratory to determine the properties such as moisture content, grain size distribution, Liquid Limit, Plastic Limit and Plasticity Index.

Soil type: Clay

Moisture Content: 7%

Plasticity Index: 12

Overlay Design

Computation of design traffic

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

N_s = Cumulative no. of standard axles to be catered for in the design

A = Initial traffic in the year of completion of construction on design lane = 3150

R = Annual growth rate = 7.5%

X = Design life in years = 10 years

F = Vehicle Damage Factor = 4.5

Design traffic N_s = $\frac{365*3150*[(1+0.075)^{10}-1]*4.5}{0.075}$

= 73.2 MSA

Table 5 Overlay thickness

Dc	Overlay thickness in terms of BM	Overlay thickness (DBM/AC)
1.9 mm	200 mm	140 mm
2.1 mm	210 mm	147 mm

Provide 100mm DBM + 40 mm AC overlay for section 1 and provide 110mm DBM + 40 mm AC overlay for section 2.

4. RESULTS AND DISCUSSIONS

It is observed that there are several distresses like alligator cracking, longitudinal cracking, transverse cracking, rutting, potholes, patching, etc present in the pavement. The pavement is divided into sample units of equal size as there is homogeneity in the pavement and 5 out of 8 sample units are inspected by the principle of random sampling technique. All the sections have about 10% to 20% distresses in terms of surface area of distresses. The pavement is rated taking into consideration distress type and its quantity and it is found that all the pavement sections are in fair condition with the rating ranging from 1.5 to 1.7 on a scale of 1-3. The characteristic deflection of the pavement is 1.9mm for one section and 2.1 mm for another. High deflection value along with heavy traffic necessitates overlay design.

5. CONCLUSIONS

The pavement is in fair condition with the percentage of surface area of distresses varying between 10% and 20%. This indicates that proper maintenance activity needed in the near future. Further, there is heavy traffic present in the pavement section which in turn leads to premature failure of the pavement. The high characteristic deflection of the pavement signifies that the pavement thickness is not sufficient to withstand the traffic loading. Hence, an overlay is required in the pavement to sustain present as well as future traffic loads. The thickness of overlay in terms of Bituminous Macadam ranges from 200mm to 210 mm. Hence, 100mm DBM along with 40mm AC overlay can be provided for one section while 110mm DBM along with 40 mm AC overlay can be provided for another section.

ACKNOWLEDGEMENTS

The authors are grateful to the Vice Chancellor of SASTRA University for his encouragement and also extremely thankful to the Assistant Engineers of State Highways Department, Thanjavur, Tamil Nadu, and India.

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