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Flexible Pavement Evaluation By Falling Weight Deflectometer Test Using IIT-Pave And KGP Back Software

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Abstract

Flexible pavements deteriorate with time due to axle load repetitions hence evaluation of such pavements is necessary to propose revised thicknesses. In this paper NH-218 (Bijapur to Hubballi) is selected for the study. FWD test has been conducted at the selected locations and the test results are analyzed using KGP Back software as per IRC 115-2014 and the design has been verified by IIT-Pave software. Equation 6.3 and 6.5 given in IRC 37-2012 are used to calculate the allowable strains which later compared with the calculated strains from IIT-Pave. A new thickness has been proposed based on the KGP back & IIT-Pave results. This paper discusses importance of KGP Back software while arriving at the revised thicknesses for pavements.

Keywords: IIT-Pave, KGP Back, FWD, Strain

Introduction

Detailed analysis of all aspects of pavement is necessary for better life and performance by identifying problems and their causes. Pavement condition can be determined by evaluating the critical aspects like structural adequacy, functional adequacy, drainage adequacy, material durability, shoulder strength etc. Because of lack of pavement evaluation studies performance of pavements is not satisfactory and pavements are failing well before the design life.Frazier [1] used a three-layer pavement model and compared moduli calculated from FWD with laboratory values. Procedures were developed to consider seasonal variations in FWD measurement. Ainalem et.al [2] conducted a dynamic analysis of FWD and prediction for the strength of flexible pavement has been achieved and recommended that FWD test should not be done at only one location to avoid unrealistic and uncertain results. XU et.al [3] developed a procedure to assess flexible pavement layer condition from FWDand structural temperature correction procedures have also been developed to study their effect on pavement condition. Donia Et.al [4] performed stress strain analysis using IRC-37-2012. Analysis was done using ken layer. Author observed that fatigue cracking was the critical parameter because which pavement failed. It was concluded that axle overloading has greater influence on cracking compared to fatigue. Bertuliene et.al [13] stated that according to AASHTO guidelines, pavement evaluation measurements and analysis had a significant impact using static and dynamic devices in the context of mechanistic-empirical approaches. Appea [12] concluded that subgrade moduli calculation should not have any error as moduli of other layers are dependent on the existing subgrade moduli. Bianchini and Bandini [5], Hoffman and Thompson [6] , Saltan et al. [7] observed that FWD will simulate traffic loads , and it requires a very short time to produce large amount of deflection data.

Sunny deol et al. [11]carried out a subgrade moduli study by static and dynamic deflection methods using LWD and Benkelman beam deflectometer on low volume roads and stated the following conclusions.

- Although correlation analysis between static and dynamic moduli of subgrade exhibits good correlation. Though, validation analysis with calculated CBR based moduli of subgrade shows the inability of adopting static moduli of subgrade as design strength parameter. Whereas the other measured and back calculated dynamic moduli of subgrade values can show better results.

- The LWD back calculated and composite dynamic moduli of subgrade values are validated effectively with laboratory measured dynamic moduli of subgrade values. This depicts the feasibility of LWD device.
- This study helps engineers and researchers to initiate and extend mechanistic-empirical techniques using dynamic non-destructive testing devices for the design and preservation of low volume road.

Methodology Adopted

The methodology adopted includes the following steps

1. Detailed condition survey was done to identify the issues related to the existing pavement stretch. This was followed by material investigation.
2. Collection of existing crust details for calculation in KGP back software.
3. Collection of 7day 24hr traffic volume data to calculate new thickness as per IRC-37-2012 followed by axle load survey of 20% of the traffic volume collected and FWD test.
4. Calculation of Vehicle Damage Factor using axle load data collected
5. Calculation of allowable strains using IIT Pave on the basis of thicknesses calculated using standard plates of ITC-37 2012
6. Calculation of revised thicknesses based on the KGP back software results.

Results and Discussions

Calculation of Design Traffic for new Pavement and Overlay Design

Project traffic is indicated in terms of million standard axles. In this project for flexible pavement design only commercial vehicles with gross weight above 300kg are considered. Seven days 24hr traffic volume data has been collected and presented in terms of ADT in Table 1. As per IRC 37 2012 the present traffic is forecasted for 15 years by considering 5% annual growth and the same is presented in Table 2.

Table 1: Classified Traffic Volume Count (Year 2017)

S.No	Vehicle Type	Average Daily Traffic
1	Tempo/LCV	560
2	2 Axle Truck	400
3	3Axle Truck	363
4	Multi Axle Truck	472
5	Mini Bus	431
6	Tractor With Trailer	45
7	CVPD	2271

Axle load Survey for VDF Calculation

The vehicle damage factor is an important parameter in designing a new crust. In this study Vehicle Damage Factors are calculated using axle load data. The table below shows VDF values for different class of vehicles and highest value is considered for the design.

Table 2: Summary of VDF

S.No	Vehicle Type	VDF
1	2 Axle	1.73
2	3 Axle	12.2
3	LCV	0.88
4	Multi Axle	3.8

Table 3: Average Daily Traffic in the year 2017 & 2018

Year	LCV	2 Axle Truck	3 Axle Truck	MAV	Bus	Auto Trolley	Total
2017	545	405	363	475	432	47	2267
2018	573	426	382	499	454	50	2381

As per IRC 37 2012 the design traffic is calculated by using the formula below

Ns = the cumulative number of axles to be carried in the design period

Ns= 365*A[(1+r) ^x-a] *F*D/r

Based on the above formula, the design traffic for the project length has been calculated and summarized below.

Table 4a: Design Traffic for the Project Highway

CALCULATIONS FOR CULUMLATIVE NUMBER OF STANDARD AXLES						
Type of Vehicle	(A) Initial Traffic	(x) Design Life	(F) Vehicle Damage Factor	(D) Lane Distribution Factor	(r) Traffic Growth Rate	Number of Million Standard Axles
LCV	573	15	0.89	0.5	5	2.01
Two Axle Truck	426	15	1.73	0.5	5	2.90
Three Axle Truck	382	15	12.21	0.5	5	18.37
MAV	499	15	3.82	0.5	5	7.51
BUS	454	15	1.73	0.5	5	3.09
Auto Trolle y	50	15	0.89	0.5	5	0.18
Cumulative number of standard axles to be catered for in the design in terms of MSA						34.05

As per the above calculation the design traffic is 35 MSA but to ensure more Factor of Safety 50 MSA is considered for the design. The proposed crust thickness is worked out based on the standard plates of IRC 37 2012. The proposed thickness values are given in the table below.

Table 4b: Design Traffic for the Project Highway

Pavement Course	Pavement material	Proposed Pavement
Wearing	Bituminous Concrete (BC)	40
Bituminous Binder	Dense Bituminous Macadam (DBM)	95
Granular Base	Wet mix Macadam (WMM)	250
Granular Sub base	Granular Sub base (GSB)	200

Based on the above layer combination allowable horizontal tensile strain and vertical compressive strain are calculated using the equation 6.3 & 6.5 of IRC 37 2012

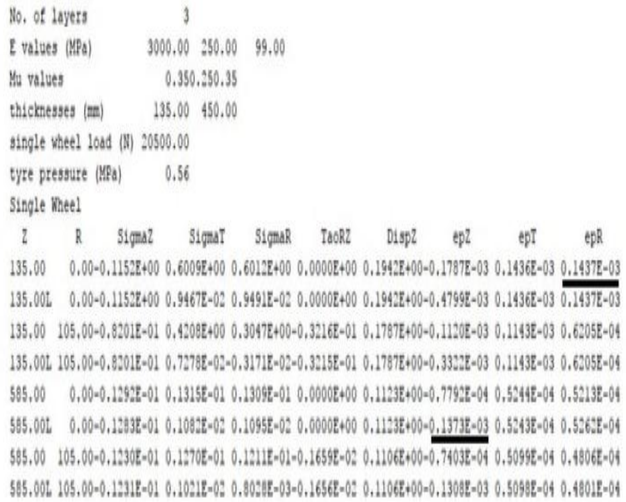
1.Allowable horizontal Tensile Strain bottom of Bituminous layer = 156 X 10^{-6}

2.Allowable Vertical Compressive Strain at top of Sub grade layer = 372 X 10^{-6}

For the same combination the layered analysis is done using IIT Pave and the following stresses are calculated

1. Horizontal tensile strain=144X10^{-6}
2. Vertical Compressive Strain=138X10^{-6}

Since the calculated strain values from IIT Pave are less than the allowable strains the proposed section is safe. The output of IIT Pave is shown below



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No. of layers            3
E values (MPa)        3000.00  250.00   99.00
Mu values               0.350.250.35
thicknesses (mm)       135.00  450.00
single wheel load (N) 20500.00
tyre pressure (MPa)      0.56
Single Wheel
  Z       R     SigmaZ     SigmaT     SigmaR     TaoRZ      DispZ       epZ        epT        epR
135.00    0.00-0.1152E+00 0.6009E+00 0.6012E+00 0.0000E+00 0.1942E+00-0.1787E-03 0.1436E-03 0.1437E-03
135.00L   0.00-0.1152E+00 0.9467E-02 0.9491E-02 0.0000E+00 0.1942E+00-0.4799E-03 0.1436E-03 0.1437E-03
135.00  105.00-0.8201E-01 0.4208E+00 0.3047E+00-0.3216E-01 0.1787E+00-0.1120E-03 0.1143E-03 0.6205E-04
135.00L 105.00-0.8201E-01 0.7278E-02-0.3171E-02-0.3215E-01 0.1787E+00-0.3322E-03 0.1143E-03 0.6205E-04
585.00    0.00-0.1292E-01 0.1315E-01 0.1309E-01 0.0000E+00 0.1123E+00-0.7792E-04 0.5244E-04 0.5213E-04
585.00L   0.00-0.1283E-01 0.1082E-02 0.1095E-02 0.0000E+00 0.1123E+00-0.1373E-03 0.5243E-04 0.5262E-04
585.00  105.00-0.1230E-01 0.1270E-01 0.1211E-01-0.1659E-02 0.1106E+00-0.7403E-04 0.5099E-04 0.4806E-04
585.00L 105.00-0.1231E-01 0.1021E-02 0.8028E-03-0.1656E-02 0.1106E+00-0.1308E-03 0.5098E-04 0.4801E-04
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The above proposed thicknesses are based on the future traffic coming over the pavement and are calculated without considering the life of the existing layers on which new layers will be constructed which may lead to overdesign of the crust, hence the life of the existing granular and BT layer should be known before arriving at the thicknesses of different layers. In this study KGP back software is used as per IRC 115 2014which will back calculate the elastic moduli of different layers of the existing pavement using an appropriate back calculation technique developed by the Transportation Engineering Section of IIT Kharagpur.

Sr. No.	From	To	Length	Verified by IIT Pave
1	4.360	5.900	1.54	250+75+40
2	5.900	7.100	1.20	250+75+40
3	7.100	8.300	1.20	250+75+40
4	8.300	9.000	0.70	250+75+40
5	9.000	9.900	0.90	250+75+40
6	9.900	11.000	1.10	200+250+95+40
7	11.000	12.900	1.90	75+40
8	12.900	13.400	0.50	250+95+40
9	13.400	14.000	0.60	200+250+95+40
10	14.000	15.060	1.06	250+75+40
11	16.510	16.900	0.39	75+40
12	16.900	17.600	0.70	250+75+40

4.1

Analysis of Falling Weight Deflect meter test Data

Among different responses of the pavement due to wheel load coming over it like stresses, strains and deflections only deflection can be measured practically since deflection test is a nondestructive FWD test is very useful and attractive. FWD provides an impact load to the pavement and deflections are measured with the help of a sensors placed in it. Layer thicknesses, Poisson's ratio values of different layers, load and loading plate radius, are used in the KGPBACK to back calculate the elastic moduli of different layers of the existing pavement using an appropriate back calculation technique. The back calculated moduli are used for the analysis of the existing pavement section and to assess the structural condition of the pavement. KGPBACK, is a specific version of BACKGA program developed by the Transportation Engineering Section of NT, Kharagpur for the research scheme R-81 (2003) of the Ministry of Road Transport and Highways. Results from the KGPBACK using FWD data are summarized in the table below

Based on the standard plates of IRC 37 using 15% CBR and 50msa traffic new crust thickness has been proposed without considering FWD results hence The FWD test has been conducted on the proposed stretch and test results are analyzed using kgp back software as per IRC 115 2014 and the design has been verified by IIT Pave software. Equation 6.3 and 6.5 given in the IRC 37-2012 are used to calculate the allowable strains which later compared with the calculated strains from IIT Pave.

Table 5: Revised Thicknesses

		Existing Crust thickness, mm		KGP back results			Corrected Moduli, Mpa		
				BT	N BT	S G	BT	N BT	S G
Chainage	Direction	Bt	Gran	E1	E2	E3	E1 Temp	E2 Mon	E3 Mon
4.365	LHS	120	300	1494.6	387.8	194	1206.78	321.29	163.43
4.4647	LHS	120	300	796.8	193.1	194	643.36	167.77	163.43
4.5089	RHS	120	300	1004.3	100.8	110.8	920.5	73.86	96.13
4.6221	LHS	120	300	1487.1	142.6	186.8	1200.73	119.23	157.91
4.695	RHS	120	300	1496.8	100.4	132.2	1371.91	73.4	114.31
4.7977	LHS	120	300	1441.9	157.5	193.7	1164.23	134.14	163.2
4.9012	RHS	120	300	1478.5	256.4	194	1355.13	222.28	163.43
5	LHS	120	400	1486	310.8	257.8	1199.84	265.16	210.41
5.198	LHS	120	400	1500	110.6	207.9	1211.14	85.05	173.93
5.3052	RHS	120	400	1492.5	373.7	289	1367.96	311.35	232.38
5.4017	LHS	120	400	1487.1	221.6	195	1200.73	193.03	164.19
5.4887	RHS	120	400	1441.9	295.1	167.7	1321.59	253.0	143.05
5.627	LHS	120	400	1492.5	163.3	273.8	1205.09	139.8	221.75
5.7011	RHS	120	400	1422.6	138.7	133.8	1303.9	115.23	115.64
5.8136	LHS	120	400	1496.8	338.5	385.3	1208.56	285.9	297.04
5.896	RHS	120	400	1500	225.9	319.4	1374.84	196.74	253.27
6	LHS	120	350	1479.6	494.1	75.9	1194.67	392.3	64.58

Computation of revised thickness from IIT Pave using KGP Back Results

From the KGP back software results it can be clearly seen that at some stretches non bituminous layer and existing subgrade have very good moduli and existing crust has sufficient thickness hence the pavement design has been verified using IIT Pave by considering 50% existing thickness and average moduli values obtained from the software to calculate permissible strain values. Thicknesses have been revised at some stretches and some of the revised values are given in Table 5.

Conclusions

From this study following conclusions are drawn

1. For crust designs of flexible pavements FWd test results should be analyzed using KGP back so that remaining life of the existing layers can be considered for the realistic and economical designs.
2. Based on this study, it can be concluded that LWD can be used as BT and Granular layer subgrade strength evaluating tool for the construction and maintenance of the pavement.

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