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Determination of Structural Strength of Pavement using FWD and Remaining Life Analysis

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ABSTRACT

Pavement structure is typically composed of several layers of different material,each of which receives the loads from the above layer ,spreads the mout, and then passes the monto the layer below.Material layers are usually arranged with in a pavement structure in order of descending load bearing capacity with the highest load bearing capacity material on the top and the lowest load bearing capacity material on the bottom. In general pavements should be designed to perform satisfactorily with out developing un acceptable level sofdistresses during the design life period.The structural adequacy of the existing pavement is demonstrated based on the study of structural performance of the pavement. If a pavement shows load associated distress like fracture, permanent deformation etc.,then it is considered to have failed structurally.To ensure that unacceptable levels of distressesd on ot occur during design period, the critical strains developed under the load should be less than the limiting strain values corresponding to the design traffic selected. Structural evaluation of pavements involves application of a standard load to the pavement and measuring its response interms of stress,strain ordeflection.Among the equipment available for structural evaluation of pavements,the Falling Weight Deflectometer (FWD) is extensively used world-wide because its imulates,to a large extent, the actual loading conditions of the pavement.

I. INTRODUCTION

The resulting load-deflection data can be interpreted through appropriate analytical techniques, such as back calculation technique,to estimate the elastic moduli of the pavement layers.The computed moduli are,inturn,used for[1][3]

- the strength evaluation of different layers of in-service pavements
- the estimation of the remaining life of in-service pavement
- determination of strengthening requirement,if any and
- Evaluation of different rehabilitation alternatives(overlay,recycling,partialreconstruction,etc.).

The guide lines for the test and evaluation of structural condition of in-service pavements is detailedinIRC- 115:2014.The

II. ANALYSIS METHODOLOGY

IRC:115-2014 provides detailed procedure for the evaluation of structural condition of in-service pavements using deflection data from Falling Weight Deflectometer as well as other pavement data as inputs to a back calculation model for determining the elastic moduli of pavement layers, and,the reafter,using these moduli as inputs to apavement design model for estimating the over layr equirement.[4]

Accordingly,the sequence of analys is steps as per the IRC: 115-2014 is as follows

- The recorded data will be normalized to a standard load (IRC115)
- The normalized deflections will be then processed and back calculated using KGP BACK to obtain Elastic Modulus value so fBituminous, Granular layer and Sub-grade.
- The corrections factors for temperature corrections and seasonal variations will be applied to all layers as suggested in IRC:115-2014
- Preparation of Homogenous sections and selecting 15thpercentile Moduli values for the purpose of design;[5][6]
- Checking the in-service ability of the Pavement layers through Performance criteria- analysing the Remaining life.

Sequence of FWD data analysis and snapshot of applications used for analysis are presented in figures below.

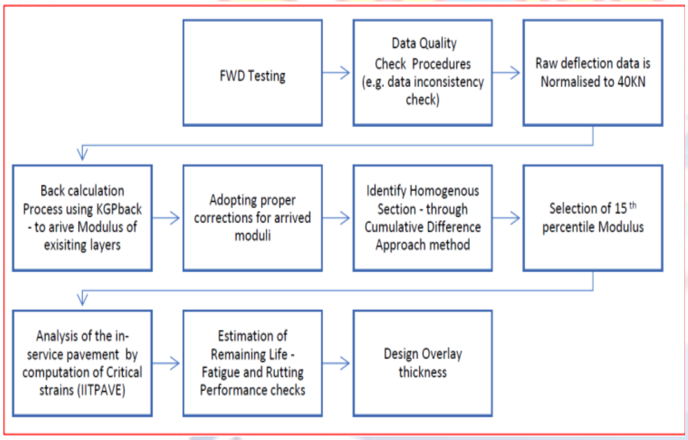


Figure 1 Flow chart of FWD data analysis

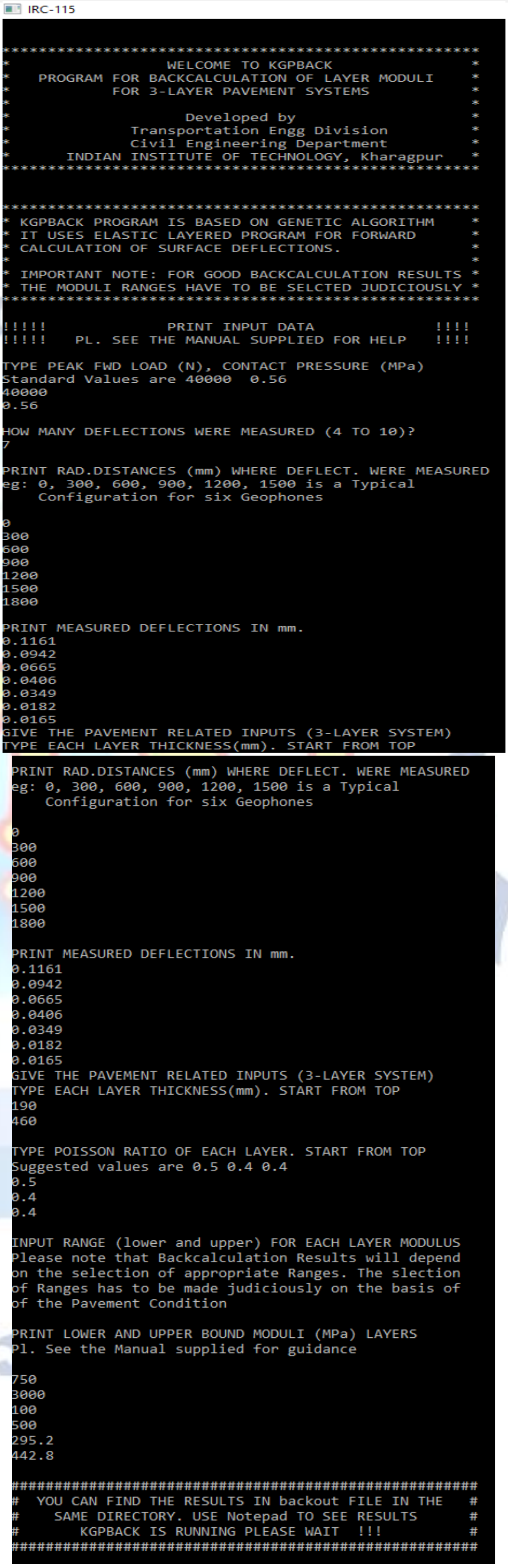
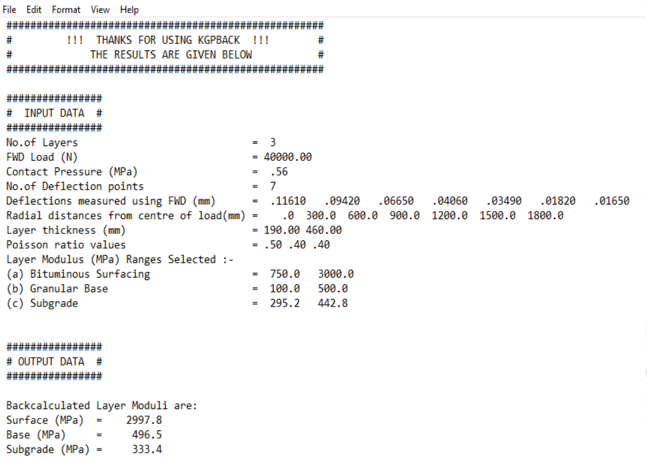


Figure 2: Sample Calculation – KGPBACK



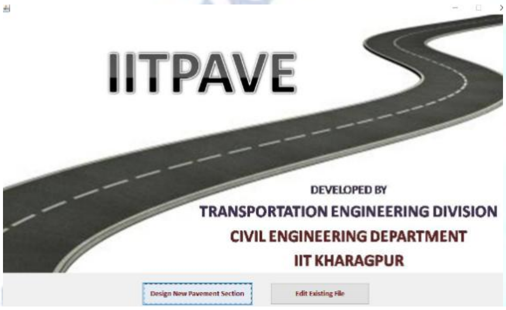
```
File  Edit  Format  View  Help
##################################################
#        !!!  THANKS FOR USING KGPBACK  !!!      #
#           THE RESULTS ARE GIVEN BELOW          #
##################################################

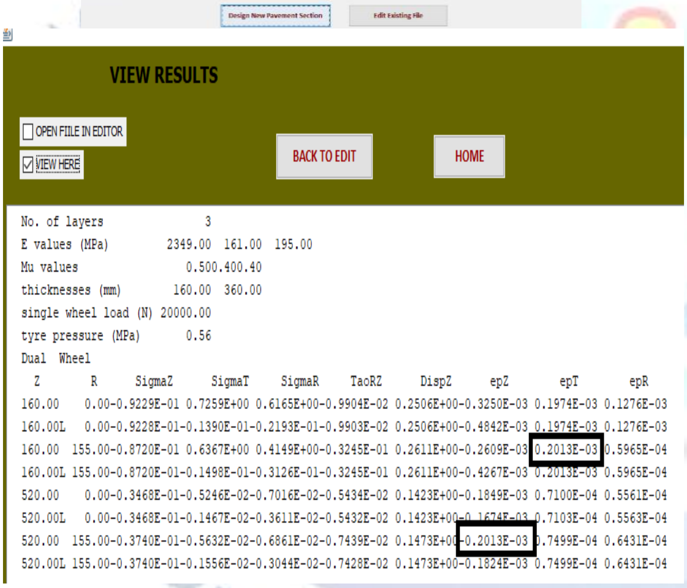
################
#  INPUT DATA  #
################
No.of Layers                              =  3
FWD Load (N)                              = 40000.00
Contact Pressure (MPa)                    =  .56
No.of Deflection points                   =  7
Deflections measured using FWD (mm)       =  .11610   .09420   .06650   .04060   .03490   .01820   .01650
Radial distances from centre of load(mm)  =    .0  300.0  600.0  900.0  1200.0  1500.0  1800.0
Layer thickness (mm)                      = 190.00 460.00
Poisson ratio values                      = .50 .40 .40
Layer Modulus (MPa) Ranges Selected :-
(a) Bituminous Surfacing                  =  750.0   3000.0
(b) Granular Base                         =  100.0   500.0
(c) Subgrade                              =  295.2   442.8


################
# OUTPUT DATA  #
################

Backcalculated Layer Moduli are:
Surface (MPa)  =    2997.8
Base (MPa)     =     496.5
Subgrade (MPa) =     333.4
```

Figure 3: KGPBACK Output





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VIEW RESULTS
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[x] VIEW HERE
BACK TO EDIT        HOME

No. of layers              3
E values (MPa)        2349.00  161.00  195.00
Mu values                0.500.400.40
thicknesses (mm)       160.00  360.00
single wheel load (N) 20000.00
tyre pressure (MPa)      0.56
Dual  Wheel
  Z        R      SigmaZ     SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
160.00    0.00-0.9229E-01 0.7259E+00 0.6165E+00-0.9904E-02 0.2506E+00-0.3250E-03 0.1974E-03 0.1276E-03
160.00L   0.00-0.9228E-01-0.1390E-01-0.2193E-01-0.9903E-02 0.2506E+00-0.4842E-03 0.1974E-03 0.1276E-03
160.00  155.00-0.8720E-01 0.6367E+00 0.4149E+00-0.3245E-01 0.2611E+00-0.2609E-03 0.2013E-03 0.5965E-04
160.00L 155.00-0.8720E-01-0.1498E-01-0.3126E-01-0.3245E-01 0.2611E+00-0.4267E-03 0.2013E-03 0.5965E-04
520.00    0.00-0.3468E-01-0.5246E-02-0.7016E-02-0.5434E-02 0.1423E+00-0.1849E-03 0.7100E-04 0.5561E-04
520.00L   0.00-0.3468E-01-0.1467E-02-0.3611E-02-0.5432E-02 0.1423E+00-0.1674E-03 0.7103E-04 0.5563E-04
520.00  155.00-0.3740E-01-0.5632E-02-0.6861E-02-0.7439E-02 0.1473E+00-0.2013E-03 0.7499E-04 0.6431E-04
520.00L 155.00-0.3740E-01-0.1556E-02-0.3044E-02-0.7428E-02 0.1473E+00-0.1824E-03 0.7499E-04 0.6431E-04
```

Figure 4: IITPAVE Module and Sample Results

2.1 Procedure

The FWD measurements have been carried out at spacing of 250 and 500 m per lane at slow lane and fast lane respectively in the provided stretches.

Fig 5: FWD Photos

Deflections measured by the FWD equipment are influenced by pavement temperature. Measurements made when the pavement temperature is different than standard temperature has be corrected. The deflection measurements, pavement temperature, subgrade soil & deflection, and other information collected during the deflection study have been recorded.[7][9]

Following procedure has been followed for measurement of FWD:

The test location is marked on the field.

The loading plate along with the deflection sensors have been lowered at the test location.

The target load has been applied and the deflections have been measured for 3 times.

The first load is considered as a seating load and the values are not adopted for analysis.

2.2 Temperature Measurement

The standard temperature for doing the experiment is 35°C. Since it is not possible to conduct the test at the standard temperature, a correction factor has to be applied for the deflection. The correction factor is determined by knowing the temperature at the time of the survey. The pavement temperature during the survey has been measured for every one hour by drilling a hole of 40mm in the pavement and filling it with glycerol[10].[4]

III. BACK CALCULATION AND DATA REQUIRED

Software used:

KGPBACK – Genetic Algorithm based software for back calculating the layer moduli. Works on three layer system (Bituminous, Granular & Subgrade)

3.1 Data required:

Deflections at various radial distances are given in Annexure-9.

Existing layer thickness – the existing layer thicknesses of various stretches have been obtained from the test pit results[11][12]

Layer moduli range – the layer moduli adopted for the analysis is shown in next section

Poisson's ratio: BT-0.5, Granular-0.4, Subgrade-0.4 (For Back calculation and IITPAVE analysis without considering overlay).

3.2 Existing Layer thickness

Thickness of existing bituminous and granular layer is as given below.

Table 1 Existing crust thickness (MPa)

Test Location	Applicable Chainage		Side	Crust Thickness	
	From	To		Bituminous	Granular
2+000	0+000	3+000	LHS	200	430
4+000	3+000	5+000	LHS	190	380
6+000	5+000	7+000	LHS	160	450
8+000	7+000	8+900	LHS	180	440
9+800	8+900	10+900	LHS	160	430
12+000	10+900	13+080	LHS	155	430
14+160	13+080	16+080	LHS	190	350
18+000	16+080	19+000	LHS	195	360
20+000	19+000	22+950	LHS	190	365
25+900	22+950	26+950	LHS	180	380
28+000	26+950	29+000	LHS	200	500
30+000	29+000	30+950	LHS	190	430
31+900	30+950	32+950	LHS	200	420
34+000	32+950	35+000	LHS	200	500
36+000	35+000	37+000	LHS	190	480
38+000	37+000	39+000	LHS	180	410
40+000	39+000	42+000	LHS	190	370
44+000	42+000	45+000	LHS	190	400
46+000	45+000	47+000	LHS	185	410
48+000	47+000	48+850	LHS	170	400
49+700	48+850	50+775	LHS	180	420
0+900	0+000	4+850	RHS	200	430
8+800	4+850	10+900	RHS	170	400
13+000	10+900	15+000	RHS	185	360
17+000	15+000	19+020	RHS	190	360
21+040	19+020	23+100	RHS	185	430
25+160	23+100	25+955	RHS	180	380
26+750	25+955	27+945	RHS	200	430
29+140	27+945	30+070	RHS	190	400
31+000	30+070	32+000	RHS	200	430
33+000	32+000	34+000	RHS	285	300
35+000	34+000	36+000	RHS	200	380
37+000	36+000	40+000	RHS	200	420
43+000	40+000	44+000	RHS	200	410
45+000	44+000	46+000	RHS	210	420
47+000	46+000	48+000	RHS	220	450
49+000	48+000	51+000	RHS	210	450

3.3 Range of Moduli

Table 2 Range of moduli (MPa)

Type of Layer	Lower and Upper Limit (Mpa)
Subgrade	Based on deflections at 1200, 1500 and 1800 mm; Equation III. 2 (of Appendix-III)-IRC:115-2014
Granular	100 to 500
Bituminous	750 to 3000

3.4 Correction for Temperature

The stiffness of bituminous layer is highly susceptible to temperature and hence consequently the surface deflections of a given pavement will vary depending on the temperature of the constituent bituminous layers. If the depth of the BT surface is more than 40mm, then correction factor has to be applied. If the depth is less i.e., if it is a thin bituminous surfacing like premix carpet and surface dressing, then no correction is required. Correction for temperature variation on deflection values measured at temperature other than 35°C should be calculated by the formula provided in IRC 115[15].

The key points to consider are:

Pavement temperature range applicable for correction factor – 20°C to 45°C.

FWD shall not be carried for pavement temperature more than 45°C

Temperature correction not required for following cases

Bituminous layers (depth < 40 mm)

"Poor" sections

Where average daily temperature is < 20°C for more than 4 months

3.5 Correction for Seasonal Variation

Moisture content affects the strength of subgrade and granular subbase/base layers. The extent to which the strength is affected will depend on the nature of subgrade soil, gradation and nature of fines in the granular layers, etc. For the purpose of applying these guidelines, it is intended that the pavement layer moduli values should pertain to the period when the subgrade is at its weakest condition. As per IRC: 115-2014, granular layers and subgrade will be in its weakest condition during the post-monsoon season. Since survey was conducted during winter season seasonal correction as per Equation 6 and Equation 9 of IRC: 115-2014 were applied.[16][17]

IV. REMAINING LIFE AND OVERLAY ESTIMATION

The in-service three-layer pavement system has been analysed with the back-calculated corrected layer moduli and layer thicknesses. The critical strain shave been calculated by IIT PAVE program. From the performance criteria equations, the residual/remaining rutting and fatigue life have been estimated.

4.1 Performance Criteria

The layer moduli of in-service pavement back calculated from FWD deflection data are used to analyse the pavement for critical strains which are indicators of pavement performance in terms of rutting and fatigue cracking. The remaining life of pavement can be obtained using the Fatigue and Rutting criteria mentioned in IRC – 115:2014 and in IRC-37:2012, the same approach can be used for design of bituminous overlays for existing flexible pavements. The performance models are as follows.[19][21]

4.2 Fatigue in Bituminous layer:

As it specified inIRC-37:2012, the fatigue model for90 percent reliability (4.35% air voids and 13.0% bitumen)was used as below; $N_f = 1.0*10^{-04} x[1/\varepsilon_t]^{3.89} * [1/M_R]^{0.854}$

Where,

N_f =fatigue life in number of standardaxles,

ε_t=Maximum Tensile strain at the bottom of the bituminous layer

M_R=resilient modulus of the bituminous layer.

4. 3 Rutting in Subgrade:

Rutting modelfor90percentreliability level as specified in IRC:115-2014was used as below; $N = 1.41 \times 10^{-08} [1/\varepsilon_v]^{4.5337}$

Where,

N= Number of cumulative standardaxles, and

ε_v=Verticalstrain inthesubgrade

Table3 : Remaining Life of Existing Pavement

Sl. No.	Homogenous Sections		Side (LHS/RHS)	Thickness, mm		Moduli, MPa			Strains		Remaining Life 90% reliability(msa) :4.35% air voids and 13% bitumen		
	From	To		Existing BT	Existing Granular	BT	Granular	Subgrade	Tensile	Vertical	Fatigue	Rutting	Remaining life
1	0+000	24+250	LHS	160	360	2349	161	195	0.0002013	-0.0002013	31.57	806.27	31.57
2	24+250	31+250	LHS	180	380	2103	77	187	0.000232	-0.0002675	19.98	222.16	19.98
3	31+250	38+750	LHS	180	410	2112	146	231	0.000194	-0.0001711	39.92	1684.74	39.92
4	38+750	49+500	LHS	170	370	2277	117	198	0.000211	-0.0002215	27.00	522.63	27.00
1	0+000	25+360	RHS	170	360	2359	116	182	0.0002071	-0.0002273	28.17	464.84	28.17
2	25+360	35+500	RHS	190	300	1894	73	175	0.0002333	-0.0003161	21.38	104.22	21.38
3	35+500	41+250	RHS	200	410	2302	132	208	0.0001664	-0.0001612	67.37	2207.44	67.37
4	41+250	49+500	RHS	200	410	2496	75	209	0.0001787	-0.0002144	47.64	605.82	47.64

Table 4 : Overlay requirement for a design period of 10 years

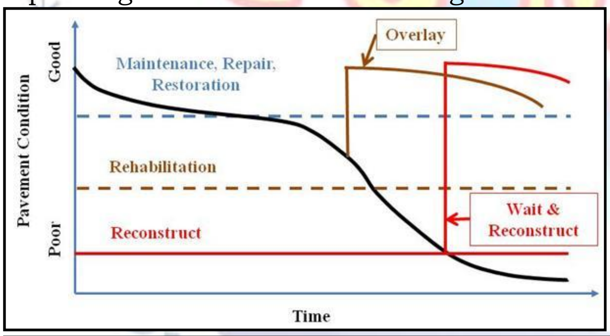
Sl. No.	Homogenous Sections		Side (LHS/RHS)	Overlay		Thickness, mm		Moduli, MPa			Strains		Remaining Life 90% reliability(msa) :4.35% air voids and 13% bitumen			Design msa	Check
	From	To		Thickness	Moduli, MPa	Existing BT	Existing Granular	BT	Granular	Subgrade	Tensile	Vertical	Fatigue	Rutting	Remaining life		
Overlay for design period of 10 years																	
1	0+000	24+250	LHS	-	-	160	360	2349	161	195	0.0002013	-0.0002013	31.57	806.27	31.57	25.3	Safe
2	24+250	31+250	LHS	40	3000	180	380	2103	77	187	0.0001786	-0.0002085	55.27	687.52	55.27	25.3	Safe
3	31+250	38+750	LHS	-	-	180	410	2112	146	231	0.000194	-0.0001711	39.92	1684.74	39.92	25.3	Safe
4	38+750	49+500	LHS	-	-	170	370	2277	117	198	0.000211	-0.0002215	27.00	522.63	27.00	25.3	Safe

Sl. No.	Homogenous Sections		Side (LHS/ RHS)	Overlay		Thickness, mm		Moduli, MPa			Strains		Remaining Life 90% reliability(msa) :4.35% air voids and 13% bitumen			Design msa	Check
	From	To		Thickness	Moduli, MPa	Existing BT	Existing Granular	BT	Granular	Subgrade	Tensile	Vertical	Fatigue	Rutting	Remaining life		
1	0+000	25+360	RHS	-	-	170	360	2359	116	182	0.0002071	-0.0002273	28.17	464.84	28.17	25.3	Safe
2	25+360	35+500	RHS	40	3000	190	300	1894	73	175	0.0001799	-0.0002434	58.76	340.85	58.76	25.3	Safe
3	35+500	41+250	RHS	-	-	200	410	2302	132	208	0.0001664	-0.0001612	67.37	2207.44	67.37	25.3	Safe
4	41+250	49+500	RHS	-	-	200	410	2496	75	209	0.0001787	-0.0002144	47.64	605.82	47.64	25.3	Safe

V. SUMMARY OF OBSERVATIONS AND FIELD INVESTIGATIONS

5.1 Determination of Maintenance Requirement

The performance of a pavement is affected by the type, time of application, quality of the maintenance it receives. Preventive timely maintenance slows the rate of pavement deterioration due to traffic and environmentally applied loads. Delays in maintenance and deferred maintenance increase the quantity of defects and their severity so that, when corrected, the cost of repair is greater as shown in the figure below.



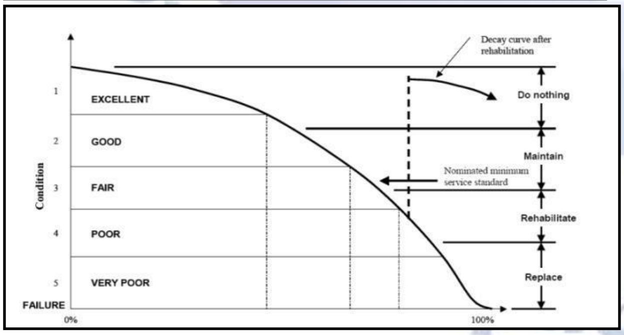


Figure6 : Pavement Deterioration / Rehabilitation Relationship

As the operation period is 30 years (i.e. from FY 2019 to 2048), the operation period is divided into 4 cycles for the purpose of analysis and the functional and structural overlays are proposed to be carried as mentioned in the table below. The maintenance cycles in 30-year period is divided as follows.

S. No.	Description	Year ofOverlay	DesignTraffic Period		Remarks
			From	To	
1	Base Year Cycle	2023	2018	2027	Overlay as per FWD analysis As per Table 8-12
2	Cycle 1	2025	2025	2034	Functional Overlay as per AASHTO analysis.
3	Cycle 2	2032	2032	2041	Functional Overlay as per AASHTO analysis.
4	Cycle 3	2039	2039	2048	Functional Overlay as per AASHTO analysis.

Table 5: Maintenance Cycles

VI. FUTURE MAINTENANCE REQUIREMENTS

Thecycle1, 2 and 3 overlay isworked out as per AASHTO guidelines.

6.1 Overlay (Cycle 1, 2 and 3)

The overlay thickness wascalculatedasperAASHTOguidelines. The design methodology/ procedure is explained asbelow;

The design MSA (n1) adopted for design is mentioned in the table below.

Sl.No.	Description	Design MSA(n1)
1	Cycle 1	33
2	Cycle 2	40
3	Cycle 3	47

Table6: Design msa for cycle 1, 2 and 3

Step-A:Calculationof existingstructuralthickness(SN_e)

SN_e=a1*D1+a2*D2*m3+a3*D3*m3

a1, a2, a3= layer coefficients for surface, base and subbase courses respectively.

D1, D2, D3= layer thickness for surface, base and subbase courses respectively (in inches)

m2, m3=1, Drainage coefficients.

Step-B: Calculation of required structural thickness (SN_f)for the design traffic

The required pavement crust thickness for the design traffic is calculated with the given below equation; this empirical equation is widely used and has the following form:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36\times\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40+\frac{1094}{(SN+1)^{5.19}}} + 2.32\times\log_{10}(M_R) - 8.07$$

Where,

W_{18} =Predicted numberof80 kN(18,000 lb.)ESALsi.e.,design life

Z_R =standardnormaldeviate

S_o =combinedstandarderrorofthe trafficpredictionand performanceprediction

SN =Structural Number(an index thatisindicative ofthetotal pavementthickness required)required forthedesign traffic

ΔPSI =differencebetween the initialdesignserviceability index,p_o,andthedesign terminalserviceability index,p_t

M_R =subgraderesilientmodulus(inkpsi)

Step-C: Determination of Overlay Index

The thickness of Overlay is computed as follows;

SN_{ol}= required overlay structural Number= SNf-SNe

a_{ol}= StructuralCoefficientfortheBituminousOverlay (0.44wasconsiderasperAASHTO)

D_{ol}= RequiredOverlayThickness,inches

SNol= aol*Dol.

Asitisdescribed intheabovestatedstepsAtoC,therequired overlay thicknesswascalculated forthe cycle 1, 2 and 3.Obtained recommended overlay thicknessispresented in Table below.Iftheobtained calculated thicknessislessthan30 mm,aminimumof 30mmof overlayisassumed forexecution.

Table 7: Cycle 1, 2 and 3 overlay

CYCLE-1													
`	Homogenous Sections		Side (LHS/RHS)	Thickness after first overlay, mm			SN Existing (inch)	Design msa	Subgrade Moduli, MPa (MR)	SN required (inches)	SN for Overlay (inches)	Thickness for Overlay (mm)	Adopted overlay (mm)
	From	To		BT, h1	WMM, h2	GSB, h3							
1	0+000	24+250	LHS	160	160	200	4.43	33	195	3.81	0.00	0	30
2	24+250	31+250	LHS	220	180	200	5.58	33	187	3.87	0.00	0	30
3	31+250	38+750	LHS	180	200	200	5.00	33	231	3.58	0.00	0	30
4	38+750	49+500	LHS	170	240	130	4.77	33	198	3.79	0.00	0	30
1	0+000	25+360	RHS	170	160	200	4.61	33	182	3.91	0.00	0	30
2	25+360	35+500	RHS	230	200	100	5.48	33	175	3.97	0.00	0	30
3	35+500	41+250	RHS	200	220	180	5.38	33	208	3.72	0.00	0	30
4	41+250	49+500	RHS	200	230	180	5.43	33	209	3.71	0.00	0	30
CYCLE-2													
Sl. No.	Homogenous Sections		Side (LHS/RHS)	Thickness after cycle-1, overlay, mm			SN Existing (inch)	Design msa	Subgrade Moduli, MPa (MR)	SN required (inches)	SN for Overlay (inches)	Thickness for Overlay (mm)	Adopted overlay (mm)
	From	To		BT, h1	WMM, h2	GSB, h3							

1	0+000	24+250	LHS	190	160	200	4.95	40	195	3.93	0.00	0	30
2	24+250	31+250	LHS	250	180	200	6.10	40	187	3.99	0.00	0	30
3	31+250	38+750	LHS	210	200	200	5.52	40	231	3.69	0.00	0	30
4	38+750	49+500	LHS	200	240	130	5.29	40	198	3.91	0.00	0	30
1	0+000	25+360	RHS	200	160	200	5.13	40	182	4.03	0.00	0	30
2	25+360	35+500	RHS	260	200	100	6.00	40	175	4.09	0.00	0	30
3	35+500	41+250	RHS	230	220	180	5.90	40	208	3.83	0.00	0	30
4	41+250	49+500	RHS	230	230	180	5.95	40	209	3.83	0.00	0	30
CYCLE-3													
Sl. No.	Homogenous Sections		Side (LHS/RHS)	Thickness after cycle-2 overlay, mm			SN Existing (inch)	Design msa	Subgrade Moduli, MPa (MR)	SN required (inches)	SN for Overlay (inches)	Thickness for Overlay (mm)	Adopted overlay (mm)
	From	To		BT, h1	WMM, h2	GSB, h3							
1	0+000	24+250	LHS	220	160	200	5.47	47	195	4.03	0.00	0	30
2	24+250	31+250	LHS	280	180	200	6.62	47	187	4.09	0.00	0	30
3	31+250	38+750	LHS	240	200	200	6.04	47	231	3.79	0.00	0	30
4	38+750	49+500	LHS	230	240	130	5.81	47	198	4.01	0.00	0	30
1	0+000	25+360	RHS	230	160	200	5.65	47	182	4.13	0.00	0	30
2	25+360	35+500	RHS	290	200	100	6.52	47	175	4.19	0.00	0	30
3	35+500	41+250	RHS	260	220	180	6.42	47	208	3.94	0.00	0	30
4	41+250	49+500	RHS	260	230	180	6.47	47	209	3.93	0.00	0	30

6.2 Summary of Structural / Functional Overlays

The recommended structural/functionaloverlayis given in Table below

S. No	Year	Description	RecommendedOverlay
	2023	Overlay (thicknessasperFWD analysis)	Asspecified inTable8-12(Average 40 mm on LHS and 40 mm on RHS)
	2025	Functional Overlay as per AASHTO	Asspecified inTable8-15(Average 30 mm BC)
	2032	Functional Overlay as per AASHTO	As specified in Table 8-15(Average 30 mm BC)
	2039	FunctionalOverlay as per AASHTO	As specified in Table 8-15(Average 30 mm BC)

VII. ANALYSIS OF NSV DATA -PAVEMENT CONDITION

The analysis of various performance parameter data collected during NSV survey is presented in this section.

7.1 pavement Condition Index (PCI)

Analysisofpavementdistresses(cracks,potholes,patching,etc.)isundertaken to determine Pavement Condition Index (PCI) of the Project Stretch. The PCI rates condition of surface of aroad and provides a numerical rating for the condition of pavement segments within the Project Stretch, where 0 is the worst possible condition and 100 is the best possible condition.[22][23] PCI provide same a sure of present condition of pavement based on distress observed on surface of pavement, which also indicates structura lintegrity and surface operational condition (localized roughness and safety). PCI cannot measure structural capacity nor does it provide direct measurement of skid resistance or roughness. It provides an objective andrationalbasisfordeterminingmaintenanceandrepairneedsandpriorities.

100	*GOOD*
85	*SATISFACTORY*
70	*FAIR*
55	*POOR*
40	*VERY POOR*
25	*SERIOUS*
10	*FAILED*

Figure 7: Pavement Condition Index (PCI) rating scale

7. 2 PavementCondition Index(PCI) rating scale

The PCIfora section of the pavement is calculated in following five steps.

Step I

The first step is the determination of distress types and severity levels of each distress type in the inspection units. This data is obtained after processing the field survey data. Firstly, the total quantity of each distress type a teach severity level is added. Then the total quantity of each distress type at each severity level is divided by the total area of the sample unit(10m section)and multipliesby100to obtain the percent density of each distress.

Step II

Determination of deduct values for each of the distresses and under each severity level from the distress deduct value curves as shown in the Figure 8.

Step III

Computation of total deduct value by adding the deduct values of all distress types under each severity levels.

Step IV

Determination of the maximum corrected deduct value(CDV)from the graph as shown intheFigure8-16.

Step V

Compute Pavement Condition Index(PCI)= 100–CDVforeach sample unit in spected

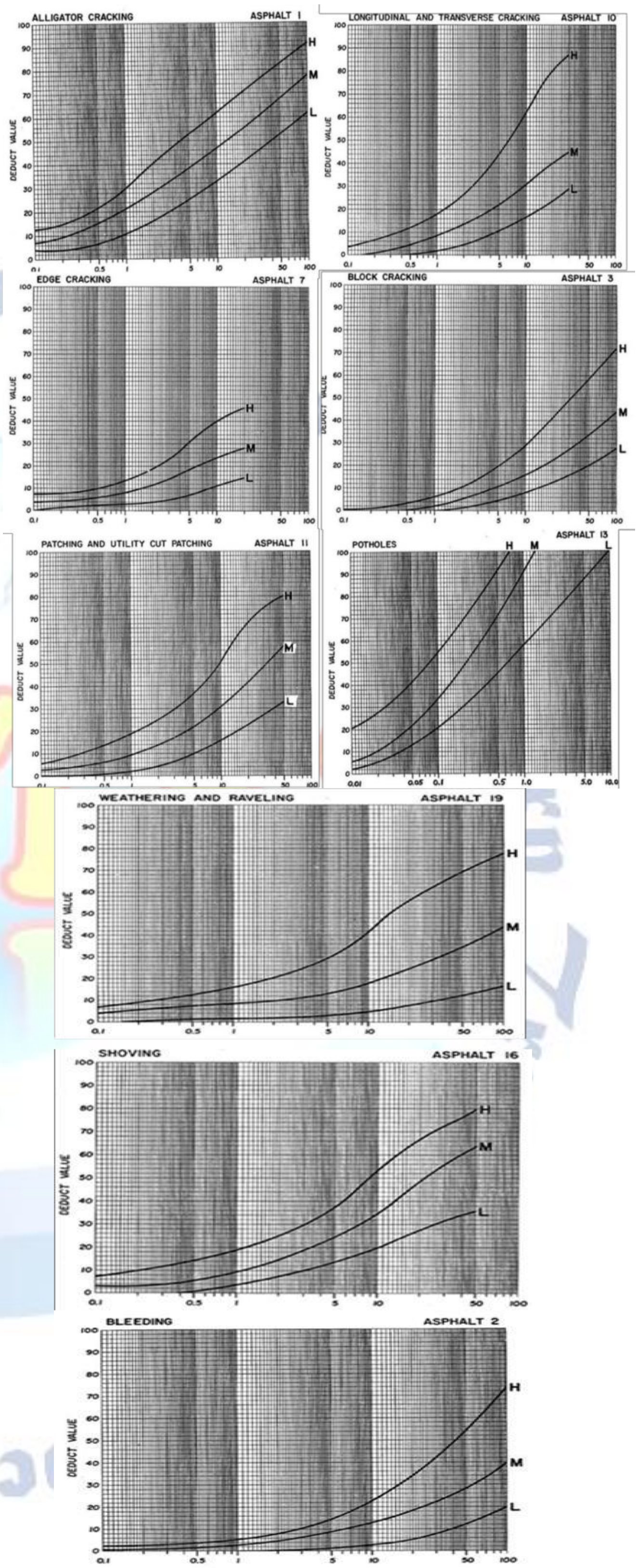


Figure 8: DeductValueCurves

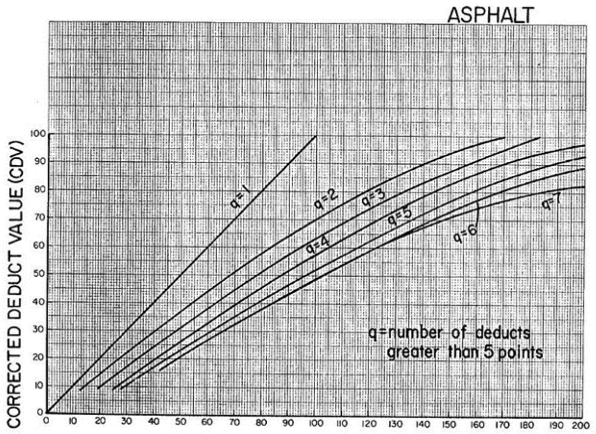


Figure 9:CorrectedDeductValue(CDV)curve

The PCIobservedforall 4lanes(2-LHSand 2-RHS) are presented in the figuresbelow. Itcanbeseenfromtheabovefiguresthat PCIvalueissimilarinbothlanes.Fromfieldsurvey,similartypesof distress have been observed atboth the lanesforboththedirection.

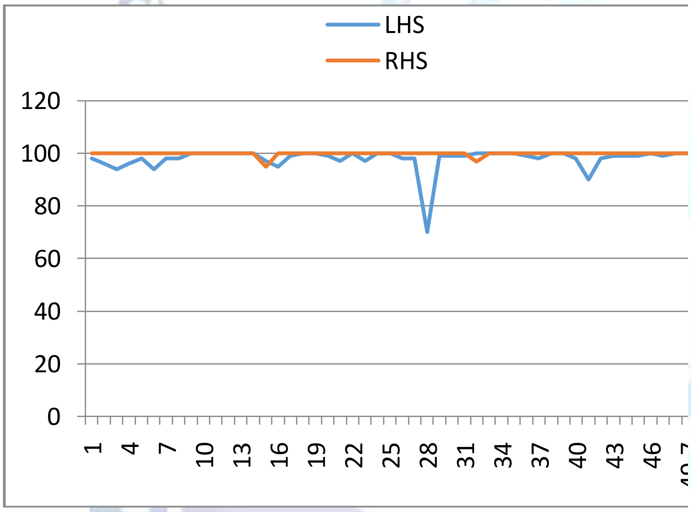


Figure 10 PavementConditionIndexforLHSandRHS carriageway

ItisobservedthatPCIvaluewassimilarin boththedirection.100%PCIvalue condition wasgoodatboththe directions.

7.3 Roughness

Roughnessisoneoftheimportantparametersfordeterminingthefunctionalcharacteristicsof pavements. According toAmericanSocietyforTestingandMaterials(ASTM),roughnessisdefinedas“*thedeviationsofapavement surfacefroma trueplanarsurfacewith characteristicdimensionsthataffectvehicledynamics, ridequality,dynamic loads,anddrainage,forexample,longitudinalprofile,transverseprofile and crossslope*”.

The InternationalRoughnessIndex(IRI),Bump IntegratorRoughness(BI)isusedtodefinethecharacteristicsofa longitudinal road profileandconstitutesastandardizedroughnessmeasurement.IRI,BIismeasuredinmetresperkilometre (m/km)ormillimetrespermetre(mm/m).

The roughnessofroadsurfacesismeasuredusingdifferent equipment/techniquessuchasrodand level survey, dip stick profiler,profilographs, response typeroadroughnessmetersandprofilingdevices.

In India,theroughnessismeasured using fifth wheel bump integrator(developed by CRRI)and isreportedasUnevennessIndex(UI)inmm/km. However,NationalHighwayAuthorityofIndia(NHAI), vialetterno.11041/218/2007–Admndated03.11.2009 on POLICYMATTERS–TECHNICAL(37/2009)hasapproved the use ofLaserProfilingdevicesforNHAIworks.

CorrelationbetweenBumpIntegratorRoughnessandInternationalRoughnessIndex(IRI)

The accepted worldstandardistheInternationalRoughnessIndex(IRI)forroughness.TheIRIwasan outcome of theInternationalRoadRoughnessExperimentconductedinBrazil(Sayersetal.,1986a)and is reproducible, portableandstablewithtime.Theequipmentisincluded with software tocalculateandprintvariousprofilestatisticsincludingtheIRIaswellastheindividualpointelevationandlocalsurface curvatures.Forcorrelationwith BIvaluesthefollowingrelationshouldbeused:

$BI=630*(IRI)^{1.12}$

Where,BI= BumpIntegratorRoughnessorUnevennessIndex in mm/km

IRI= InternationalRoughnessIndex

Roughnesscondition detailslength wise forboth the directiongiven in table below

The RoughnessIndex observed forall 4lanes(2-LHSand 2-RHS)are presented in thefiguresbelow

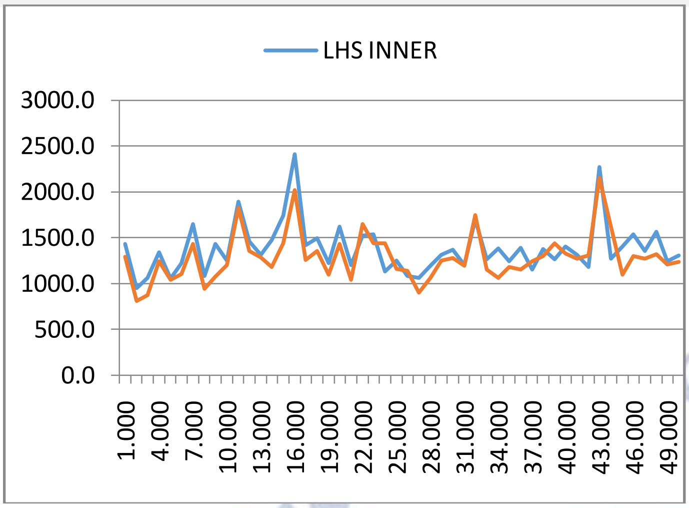


Figure 11 :Roughness Index for Inner and Outer Lane for LHS carriageway

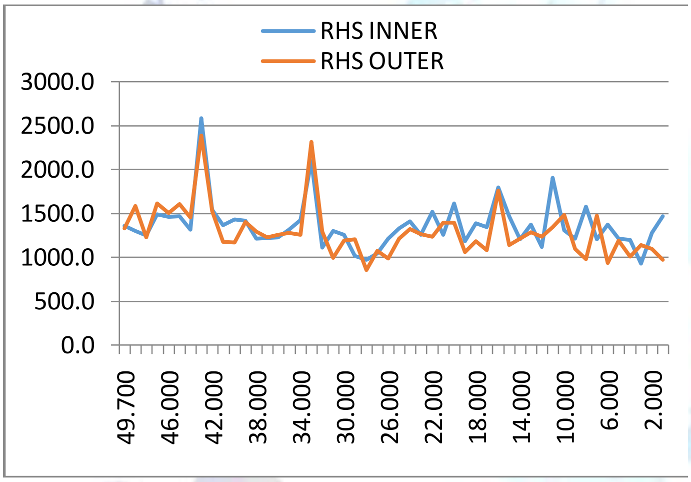


Figure 12 Roughness Index for Inner and Outer Lane for RHS carriageway

It isobservedthatroughnessindexwassimilarin both lanesforRHSbutinLHSouterlaneroughnessis higher as compare toinner.TheRoughnessIndexofouterlaneofLHSatmanysectionswere beyond thedesirablelimitof 2000 mm/km.

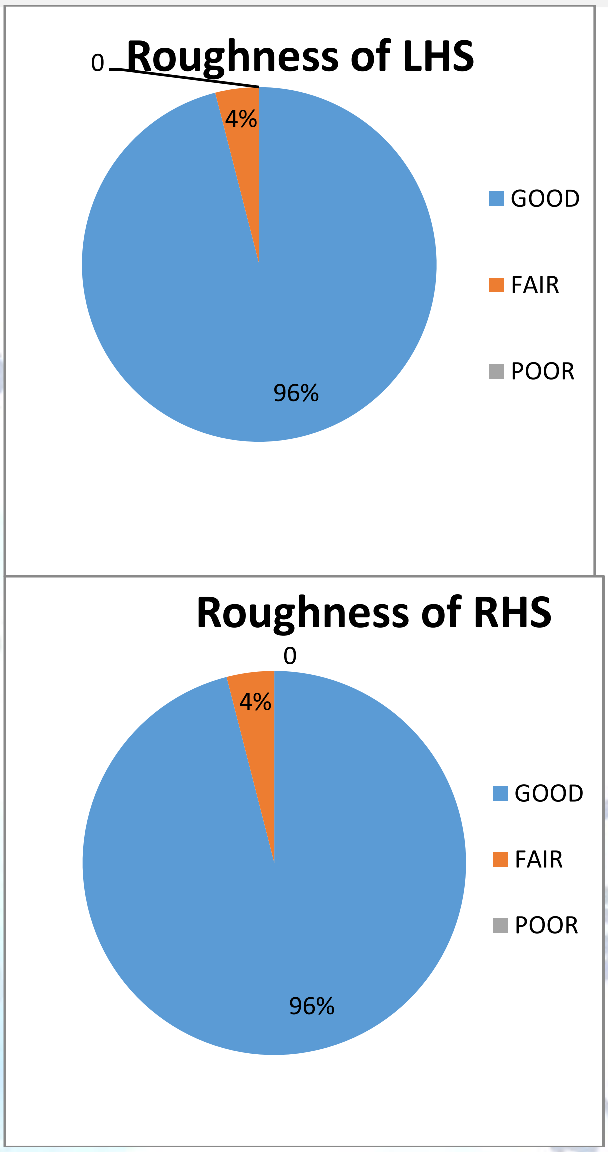


Figure 13 : Roughness Index for LHS and RHS carriageway

It isobservedthatRoughnessIndex in LHS washigherascomparedtoRHS,because more numberofloadedand overloaded vehicle observed inLHS.Also,LHShashigherVDF compared toRHS.

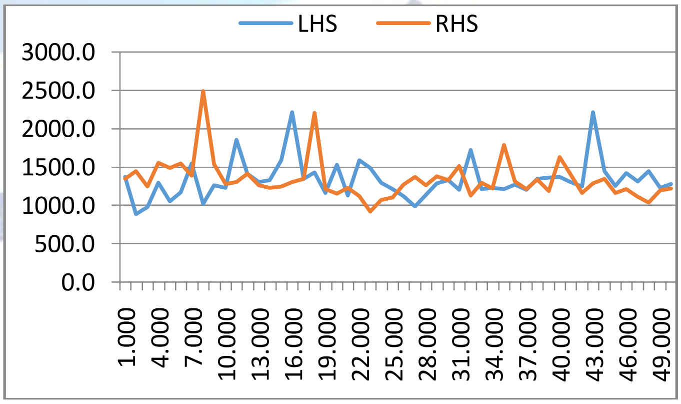


Figure 14: Roughness Condition Index for LHS and RHS carriageway

Itisobservedfrom pie-chart,90% of the

projectstretchonLHShasroughnessvaluein good condition whereas 97% inRHS.

VIII. CONCLUSIONS

The structural adequacy of the existing pavement is demonstrated based on the study of structural performance of the pavement. If a pavement shows load associated distress like fracture, permanent deformation etc.,then it is considered to have failed structurally.To ensure that unacceptable levels of distressesd on ot occur during design period, the critical strains developed under the load should be less than the limiting strain values corresponding to the design traffic selected. Structural evaluation of pavements involves application of a standard load to the pavement and measuring its response interms of stress,strain ordeflection.Among the equipment available for structural evaluation of pavements,the Falling Weight Deflectometer (FWD) is extensively used world-wide because its imulates,to a large extent, the actual loading conditions of the pavement

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