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CHARACTERISTICS OF FLEXIBLE PAVEMENTS: DETAILED STUDY BY USING FWD AND IIT-PAVE SOFTWARE

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ABSTRACT

This paper evaluates and compares the deflection of flexible pavement using two methods: The Falling Weight Deflectometer (FWD) test and IIT-Pave software. The data for the project road NH-129 (Numaligarh to Khatkhati) in Assam is utilized for the current investigation. The subgrade modulus and the pavement thickness are obtained from the FWD result and the trial pit data, respectively. These values are then used to calculate the deflection of flexible pavement using IIT-Pave software. Two types of loading are considered for the calculation of deflection values: 20 kN with dual wheel and 40 kN with single wheel. The results of the study reveal that the deflection values calculated from IIT-Pave software are on average 22% and 5% lower than the FWD results for 20 kN dual wheel loading and 40 kN single wheel loading, respectively. During the calculation of deflection values, horizontal tensile strain and vertical compressive strain is also determined for above mentioned two types of loading. The result reveals than the tensile strain values for 40 kN single wheel load are average 8% more than strain values for 20 kN dual wheel load for bituminous layer thickness more than 60mm. And where the bituminous layer is around less than 60mm, strain values for 40 kN single wheel load are average 9% less than strain values for 20 kN dual wheel load. Further for compressive strain, it is average 21% more for 40 kN single wheel than 20 kN dual wheel load. In case of growth of traffic, considering good pavement condition overlay design has been done for first 13 km stretch for different traffic. From the overlay design, it is found that, for increase of each 10 MSA traffic, there is an increase of around 50mm bituminous overlay thickness. These findings provide insight into the reliability and accuracy of IIT-Pave software for assessing the deflection of flexible pavements and emphasize the importance of selecting appropriate loading conditions for obtaining accurate deflection measurements.

Keywords: Pavement Evaluation, FWD, Structural Evaluation, Flexible Pavement, IIT-PAVE

1. INTRODUCTION

Pavement surface deflection measurements are the primary means of evaluating a flexible pavement structure and rigid pavement load transfer. Although other measurements can be made that reflect (to some degree) a pavement's structural condition. surface deflection is an important pavement evaluation method because the magnitude and shape of pavement deflection is a function of traffic (type and volume), pavement structural section, temperature affecting the pavement structure and moisture affecting the pavement structure. Deflection measurements can be used in back calculation methods to determine pavement structural layer stiffness and the subgrade resilient modulus. Thus, many characteristics of a flexible pavement can be determined by measuring its deflection in response to load. Furthermore, pavement deflection measurements are non-destructive.

Surface deflection is measured as a pavement surface's vertical deflected distance as a result of an applied (either static or dynamic) load. The more advanced measurement devices record this vertical deflection in multiple locations, which provides a more complete characterization of pavement deflection. The area of pavement deflection under and near the load application is collectively known as the "deflection basin".

There are three broad categories of nondestructive deflection testing equipment:

- Static deflections
- Steady state deflections
- Impact load deflections (FWD)

Subgrade rutting criteria is used in these guidelines for the design of bituminous pavements. An average rut depth of 20 mm or more, measured along the wheel paths, is considered in these guidelines as critical or failure rutting condition. The equivalent number of standard axle load (80 kN) repetitions that can be served by the pavement, before the critical average rut depth of 20 mm or more occurs. The rutting performance model developed initially based on the MoRTH R-6 Research Scheme performance data was subsequently developed into two separate models for two different reliability levels based on the additional performance data collected for MoRTH R-56 Research Scheme.

IIT-PAVE software is used in these guidelines for the analysis of pavements. For the computation of stresses, strains and deflections in the pavement, thicknesses and elastic properties (elastic modulus and Poisson's ratio) of different layers are the main inputs. Guidelines for the selection of the elastic modulus and Poisson's ratio values of different pavement layers are given in different sections of the guidelines. For the calculation of vertical compressive strain on top of the subgrade, horizontal tensile strain at the bottom of the bottom bituminous layer and the horizontal tensile strain at the bottom of base layer, the analysis is done for a standard axle load of 80 kN (single axle with dual wheels). Only one set of dual wheels, each wheel carrying 20 kN load with the centre to centre spacing of 310 mm between the two wheels, applied at the pavement surface shall be considered for the analysis. The shape of the contact area of the tyre is assumed in the analysis to be circular. The uniform vertical contact stress shall be considered as 0.56 MPa. However, when fatigue damage analysis of base is carried out, the contact pressure used for analysis shall be 0.80 MPa. The layer interface condition was assumed to be fully bound. The materials are assumed to be isotropic.

Here FWD is used to validate the deflection result from IIT-PAVE. All impact load devices deliver a transient impulse load to the pavement surface. The subsequent pavement response (deflection basin) is measured by a series of sensors. The most common type of equipment is the falling weight deflectometer (FWD). The FWD can either be mounted in a vehicle or on a trailer and is equipped with a weight and several velocity transducer sensors. To perform a test, the vehicle is stopped and the loading plate (weight) is positioned over the desired location. The sensors are then lowered to the pavement surface and the weight is dropped. Multiple tests can be performed on the same location using different weight drop heights (ASTM, 2000[1]). The advantage of an impact load response measuring device over a steady state deflection measuring device is that it is quicker, the impact load can be easily varied and it more accurately simulates the transient loading of traffic. Results from FWD tests are often communicated using the FWD AREA Parameter.

2. OBJECTIVE

The objectives of the study are as follows:

a) To compare the deflection obtained from FWD test and that for IIT PAVE analysis for different axle loading.
b) To compare the horizontal and vertical strain for different axle loading.
c) To compare the overlay thickness for a sample stretch for different loading.

1. Scope of Work:

To meet the above objectives in the present study, the scope of the work is outlined as follows:

a) Trial pits of were dug at the pavement shoulder interface, extending through the pavement layers down to the subgrade level and the pavement composition (i.e. Bituminous layer, Granular Layer) thickness has been noted down.
b) Nondestructive FWD (Falling Weight Deflectometer) test on existing carriageway at specified intervals as per IRC 115-2014 were conducted and deflection values are measured along with subgrade modulus at all locations are tabulated.
c) Based on the above collected data, deflection value is calculated by IIT-PAVE Software for each location for the following considerations:

- Single Wheel Load = 20 KN, Dual Wheel
- Single Wheel Load = 40 KN, Single Wheel

And the following criteria has been kept same for above two considerations:

- Resilient modulus of Bituminous Layer (VG40) = 3000 MPa
- Poissons's Ratio = 0.35 for all layers
- Tyre Pressure = 0.56 MPa

d) The deflection value obtained from the IIT-PAVE has been compared and validated with the deflection value of FWD test.
e) The horizontal and vertical strains for the two types of loading have also been compared
f) Further, overlay design has been carried out for a selected section with different traffic and compared.

3. METHODOLOGY

a) Collection of Trial Pit data from site:
The trial pit data for the project road NH-129 (Numaligarh to Khatkhati) in Assam is utilized for the current investigation.
b) Collection of Falling Weight Deflectometer (FWD) Test Data:
The FWD test data for the project road NH-129 (Numaligarh to Khatkhati) in Assam is utilized for the current investigation.
c) Evaluation of Deflection of Pavement Layers with IIT-PAVE:
Based on the above collected data, deflection value is calculated by IIT-PAVE Software for each location for the following considerations:

- Single Wheel Load = 20 KN, Dual Wheel
- Single Wheel Load = 40 KN, Single Wheel

And the following criteria has been kept same for above two considerations:

- Resilient modulus of Bituminous Layer (VG40) = 3000 MPa (As per IRC 37: 2018)
- Poissons's Ratio = 0.35 for all layers (As per IRC 37: 2018)
- Tyre Pressure = 0.56 MPa (As per IRC 37: 2018)

Resilient modulus of the Granular Layer has been calculated based the below equation (As per IRC 37: 2018):

$M_{RGRAN} = 0.2(h)^{0.45} \times M_{RSUPPORT}$ ……………………………………………………………… (1)

Where, M_{RGRAN} = Resilient modulus of the Granular Layer (MPa)

$M_{RSUPPORT}$ = Resilient modulus of the Supporting Layer (MPa)

h = Thickness of Granular Layer (mm)

d) **Comparison of Deflection, Strain**:

The deflection values obtained from the IIT-PAVE have been compared and validated with the deflection value of FWD test. As well as, the strain generated for different loading also compared.

e) Comparison of Overlay thickness for different traffic:

As per the site pavement condition, it is found that, for the first 13 kM stretch is road condition, subgrade CBR is good and sufficient embankment height is present for overlay criteria. Hence, this stretch is selected for overlay design for different traffic. To determine the overlay thickness, following steps are followed:

- Resilient Modulus of Subgrade is determined using the following equation no. 4.2 (As per IRC 37: 2018)

  $M_{RS} = 17.6 \times (CBR)^{0.64}$ for CBR > 5 % ……….……..……………………………. (2)

  Where, M_{RS} = Resilient Modulus of Subgrade

  CBR = California Bearing Ratio of Subgrade
- Resilient modulus of the Granular Layer has been calculated based the below equation no. 4.3.(As per IRC 37: 2018)

  $M_{RGRAN} = 0.2(h)^{0.45} \times M_{RSUPPORT}$ ………………………………………………….……… (3)

  Where, M_{RGRAN} = Resilient modulus of the Granular Layer (MPa)

  $M_{RSUPPORT}$ = Resilient modulus of the Supporting Layer (MPa)

  h = Thickness of Granular Layer (mm)
- Allowable Horizontal Tensile Strain at Bottom of Bituminous Layer is calculated as per equation no. 4.4. (As per IRC 37: 2018)

$N_f = 0.5161 \times C \times 10^{-04} [1/\varepsilon_t]^{3.89} \times [1/M_{Rm}]^{0.854}$ (for 90 % reliability) ……...………… (4)

Where, $C = 10_M$, and $M = 4.84 \times ((V_{be} / (V_a + V_{be})) - 0.69)$

V_a = per cent volume of air void in the mix used in the bottom bituminous layer

V_{be} = per cent volume of effective bitumen in the mix used in the bottom bituminous layer

N_f = fatigue life of bituminous layer

ε_t = maximum horizontal tensile strain at the bottom of the bottom bituminous layer

M_{Rm} = resilient modulus (MPa) of the bituminous mix

- Allowable Vertical Compressive Strain at Top of Subgrade Layer is calculated as per equation 4.5 (As per IRC 37: 2018).

  $N_R = 1.4100 \times 10^{-08} [1/\varepsilon_v]^{4.5337}$ …………………………….…………………….... (5)

  Where, N_R = subgrade rutting life

  ε_v = vertical compressive strain at the top of the subgrade
- After computation of allowable strains for different traffic, an overlay thickness is assumed and the overall pavement composition is analyzed in IIT-Pave till the computed strains reaches the allowable limit.

4. RESULTS

The results of the IIT-Pave analysis are presented below Table 1:

Table 1: Results from IIT-Pave Analysis

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
200	90	330	112	304.49	0.2593	0.363	0.2721	0.4316	0.479076
500	91	340	112	308.61	0.2534	0.3572	0.2654	0.4241	0.4584521
1000	93	348	112	311.86	0.2479	0.3511	0.2592	0.4156	0.4459388
1500	89	352	110	307.87	0.253	0.3603	0.2646	0.4293	0.4323051
2000	86	356	109.9	309.16	0.2533	0.3628	0.2653	0.4358	0.4824306
2500	84	368	110	314.09	0.2486	0.3607	0.2597	0.4331	0.4361317
3000	87	366	110	313.32	0.2475	0.3568	0.2584	0.427	0.473116
3500	85	368	110	314.09	0.2479	0.359	0.2565	0.4307	0.4509429
4000	86	372	96	275.45	0.2784	0.4025	0.2903	0.4789	0.5334946
4500	85	374	111	319.26	0.243	0.3538	0.2536	0.4244	0.428644
5000	83	378	102	294.78	0.2623	0.3829	0.2736	0.4593	0.5084451
5500	82	384	102	296.88	0.26	0.3821	0.271	0.4588	0.5051388
6000	80	380	108	312.86	0.2497	0.3685	0.2607	0.4437	0.4712094
6500	92	384	110	320.16	0.2359	0.3431	0.2454	0.4073	0.4386621
7000	105	386	110	320.91	0.2271	0.3269	0.2355	0.3804	0.3807804
7500	118	396	108	318.73	0.2194	0.3138	0.2265	0.3585	0.382878
8000	130	399	110	325.73	0.2082	0.2952	0.2145	0.3332	0.3338664

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
8500	145	408	110	329.02	0.1978	0.278	0.2031	0.3096	0.3445848
9000	160	408	109.9	328.72	0.191	0.2649	0.1957	0.2915	0.3081155
9500	171	410	108	323.75	0.1885	0.259	0.1929	0.2828	0.2963744
10000	180	410	110	329.74	0.1816	0.248	0.1857	0.2696	0.2787664
10500	175	406	110	328.29	0.1848	0.2528	0.1891	0.2755	0.281561
11000	161	396	110	324.63	0.1939	0.2668	0.1989	0.2933	0.305032
11500	145	374	110	316.38	0.2089	0.2875	0.2151	0.3198	0.3335514
12000	125	352	112	313.47	0.225	0.3108	0.2331	0.3523	0.3818932
12500	110	335	112	306.56	0.2422	0.3348	0.2523	0.3861	0.4119687
13000	91	318	109.9	293.85	0.2696	0.3736	0.2811	0.4354	0.4623948
13500	73	296	110	284.78	0.2928	0.4091	0.3179	0.5055	0.519654
14000	65	286	109.7	279.64	0.3145	0.4108	0.337	0.5398	0.5916208
14500	58	276	110	275.95	0.3288	0.4643	0.3549	0.5713	0.6330004
15000	45	250	107	256.74	0.3764	0.5367	0.4145	0.664	0.732392
15500	48	268	107	264.90	0.3559	0.5121	0.3879	0.6322	0.6992132
16000	51	288	112	286.40	0.3212	0.4685	0.3471	0.5767	0.6038049
16500	55	299	111	288.67	0.3116	0.454	0.3346	0.5579	0.6120163

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
17000	54	332	111	302.60	0.2898	0.4371	0.3085	0.5356	0.5345288
17500	52	351	108	301.89	0.2868	0.4425	0.3042	0.5471	0.558042
18000	58	366	107	304.78	0.2754	0.4232	0.2904	0.517	0.531476
18500	57	375	107	308.13	0.271	0.421	0.2854	0.5143	0.5328148
19000	60	382	107	310.70	0.2649	0.4106	0.2782	0.501	0.530058
19500	63	388	107	312.89	0.2596	0.4012	0.2721	0.4887	0.530058
20000	62	390	107	313.61	0.2592	0.4024	0.2717	0.4904	0.530058
20500	61	390	107	313.61	0.26	0.4046	0.2725	0.4933	0.530058
21000	65	390	107	313.61	0.2572	0.396	0.2693	0.4819	0.530058
21500	59	390	107	313.61	0.2614	0.4091	0.2742	0.4991	0.530058
22000	63	390	107	313.61	0.2586	0.4003	0.2709	0.4875	0.5148
22500	67	390	103	301.89	0.2661	0.4054	0.2765	0.4926	0.5453082
23000	69	390	103	301.89	0.2637	0.4012	0.2757	0.4868	0.5432688
23500	71	390	103	301.89	0.2623	0.3972	0.2741	0.4812	0.5331696
24000	72	390	103	301.89	0.2616	0.3951	0.2733	0.4784	0.5027984
24500	74	390	109	319.47	0.2467	0.3721	0.2577	0.4501	0.4487497
25000	75	400	95	281.63	0.2745	0.4135	0.286	0.4987	0.5515622
25500	71	392	114	334.90	0.2375	0.3622	0.2482	0.4392	0.463356

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Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
26000	69	388	108	315.81	0.3523	0.3856	0.2649	0.468	0.47736
26500	61	372	101	289.80	0.2848	0.4351	0.2995	0.5307	0.5349456
27000	67	384	101	293.97	0.2733	0.4154	0.2862	0.5047	0.5561794
27500	59	359	101	285.20	0.2943	0.4469	0.3106	0.546	0.566202
28000	52	312	101	267.74	0.3336	0.4945	0.3573	0.6074	0.6699622
28500	45	290	117	300.12	0.3127	0.4662	0.339	0.5727	0.5944626
29000	43	260	117	285.73	0.3393	0.4937	0.3728	0.6085	0.6772605
29500	35	245	110	261.55	0.3846	0.5646	0.4286	0.6935	0.7191595
30000	30	240	110	259.13	0.3966	0.5891	0.4454	0.719	0.759983
30500	35	257	110	267.23	0.3726	0.5539	0.4126	0.6788	0.6916972
31000	41	272	110	274.14	0.3513	0.5197	0.3844	0.6392	0.7069552
31500	49	299	110	286.07	0.3203	0.4748	0.3451	0.5836	0.6051932
32000	55	331	114	310.35	0.2823	0.4248	0.3006	0.5205	0.5522505
32500	67	372	116.9	335.42	0.2441	0.3698	0.2564	0.45	0.46665
33000	53	370	117	334.89	0.2546	0.3998	0.2688	0.4885	0.4899655
33500	49	396	114	336.43	0.2499	0.4063	0.2627	0.4955	0.52523
34000	51	419	115	348.12	0.2354	0.3881	0.2463	0.473	0.481041

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Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		Deflection from FWD (mm)
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	
34500	54	442	117	362.79	0.2199	0.3664	0.2291	0.4463	0.4454074
35000	60	460	115	363.05	0.2129	0.3535	0.2201	0.4302	0.4697784
35500	61	460	115	363.05	0.2124	0.3516	0.2204	0.4278	0.4697784
36000	63	452	115	360.20	0.2145	0.3508	0.2227	0.4266	0.4726728
36500	59	434	103	316.77	0.2486	0.4031	0.2589	0.4911	0.4999398
37000	63	388	106	309.96	0.2619	0.4046	0.2745	0.2928	0.317688
37500	64	350	106	295.91	0.2825	0.4209	0.2988	0.5133	0.317688
38000	65	330	106	288.18	0.2941	0.4292	0.3116	0.5236	0.317688
55000	55	218	105	236.88	0.4019	0.5375	0.4447	0.6677	0.7131036
55500	58	227	105	241.23	0.3882	0.5201	0.4265	0.6441	0.7131036
56000	61	250	105	251.94	0.3623	0.4935	0.3935	0.6079	0.7131036
56500	60	288	105	268.50	0.3316	0.4624	0.356	0.4509	0.7131036
57000	57	314	105	279.15	0.3152	0.4622	0.3365	0.439	0.7131036
57500	59	332	105	286.24	0.3008	0.4464	0.3194	0.4251	0.7131036
58000	55	362	105	297.60	0.2852	0.44	0.3013	0.4139	0.7131036
58500	51	376	105	302.73	0.28	0.4429	0.2954	0.5414	0.7131036
59000	49	390	105	307.75	0.2735	0.4306	0.2878	0.5383	0.7131036

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59500	53	405	105	313.02	0.2624	0.4232	0.2749	0.5165	0.7131036
60000	50	410	105	314.75	0.2619	0.4282	0.2744	0.5225	0.5825875
60500	51	398	105	310.58	0.2675	0.4316	0.2809	0.5269	0.5542988
61000	49	374	105	302.00	0.2828	0.4493	0.2986	0.5491	0.6122465
61500	48	360	105	296.86	0.2922	0.4599	0.3097	0.5624	0.6051424
62000	53	346	112	311.05	0.2794	0.4284	0.2965	0.5245	0.5250245
62500	55	334	112	306.15	0.2852	0.43	0.3033	0.5267	0.5551418
63000	51	305	112	293.89	0.3085	0.4576	0.3314	0.5621	0.6008849
63500	49	284	111.9	284.35	0.3268	0.4774	0.354	0.5879	0.6037733
64000	48	295	112	289.51	0.3189	0.4726	0.3443	0.5811	0.5805189
64500	52	303	102	266.86	0.3375	0.4961	0.3624	0.61	0.67344
65000	50	304	102	267.25	0.3389	0.5017	0.3642	0.6168	0.6408552
65500	52	300	102	265.67	0.3399	0.4982	0.3653	0.6126	0.6426174
66000	55	313	102	270.79	0.3267	0.4807	0.3492	0.59	0.61065
66500	51	311	102	270.01	0.3323	0.4938	0.3562	0.6067	0.6364283
67000	50	308	102	268.83	0.3299	0.4989	0.3604	0.6132	0.6604164
67500	57	302	114	297.81	0.2998	0.4363	0.3214	0.5357	0.5646278

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
68000	59	299	105	273.07	0.3242	0.4661	0.3472	0.5719	0.6353809
68500	56	289	105	268.92	0.3352	0.481	0.3606	0.5915	0.604513
69000	59	292	106	272.75	0.3266	0.4666	0.3505	0.5729	0.6330545
69500	58	296	106	274.42	0.3246	0.4668	0.3482	0.5732	0.6330545
70000	60	300	106	276.08	0.3196	0.4589	0.3419	0.5627	0.6330545
70500	62	293	106	273.17	0.3227	0.458	0.3456	0.5613	0.6330545
71000	67	285	106	269.78	0.3234	0.4502	0.3461	0.5502	0.6330545
71500	71	279	106	267.21	0.3236	0.4441	0.3461	0.5412	0.6330545
72000	75	272	111	276.64	0.3108	0.4214	0.3324	0.5123	0.5107631
72500	77	264	105	258.19	0.3311	0.4428	0.3542	0.5368	0.5695448
73000	81	266	111	273.87	0.3087	0.4118	0.3296	0.4981	0.5364537
73500	83	267	111	274.34	0.3049	0.4092	0.3261	0.4914	0.5364537
74000	80	268	111	274.80	0.3084	0.4135	0.3292	0.4997	0.5364537
74500	84	267	111	274.34	0.3049	0.4076	0.3248	0.4885	0.5364537
75000	85	268	101	250.04	0.3307	0.4415	0.3517	0.5225	0.567435
75500	81	276	101	253.37	0.3294	0.4438	0.3505	0.5324	0.5760568
76000	79	292	101	259.88	0.32	0.4375	0.3396	0.5274	0.5760568

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
76500	72	309	101	266.58	0.3154	0.4431	0.3345	0.5381	0.5760568
77000	65	328	101	273.84	0.3091	0.4491	0.3276	0.5478	0.5932674
77500	50	329	110	298.65	0.2978	0.4531	0.3179	0.5555	0.5993845
78000	48	340	108	297.59	0.2974	0.4598	0.3167	0.563	0.57989
78500	45	354	108	303.04	0.2908	0.4601	0.3091	0.5621	0.57989
79000	41	358	108	304.58	0.2917	0.4694	0.3102	0.5718	0.5838078
79500	35	360	107.9	305.06	0.2969	0.4902	0.3153	0.589	0.622573
80000	30	368	108	308.38	0.2951	0.497	0.3143	0.596	0.63474
80500	39	370	108	309.13	0.2858	0.4683	0.3033	0.5688	0.577332
81000	46	371	112	320.97	0.27	0.4331	0.2857	0.5285	0.5839925
81500	58	372	112	321.36	0.2605	0.4033	0.2744	0.4925	0.5383025
82000	66	336	112	306.97	0.2749	0.4034	0.2908	0.4919	0.511576
82500	78	327	109.9	297.56	0.2752	0.39	0.2902	0.4713	0.5038197
83000	81	329	110	298.65	0.2714	0.3831	0.2858	0.4617	0.4732425
83500	82	339	110	302.70	0.265	0.3767	0.2785	0.4534	0.4570272
84000	85	353	110	308.26	0.2554	0.3653	0.2674	0.4383	0.4549554
84500	88	360	112	316.65	0.2456	0.3523	0.2566	0.4211	0.4484715

Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
85000	90	370	112	320.58	0.2395	0.3456	0.2498	0.4118	0.4398024
85500	81	357	112	315.46	0.2519	0.3647	0.2641	0.4393	0.4735654
86000	75	344	112	310.24	0.2632	0.3814	0.2771	0.4681	0.4735654
86500	71	342	112	309.43	0.2674	0.3901	0.282	0.4739	0.4735654
87000	64	330	112	304.49	0.2801	0.4109	0.297	0.5017	0.5588938
87500	61	316	112	298.61	0.2916	0.4253	0.3107	0.5207	0.5644388
88000	59	315	116	308.84	0.2845	0.4174	0.3037	0.5119	0.5717923
88500	55	300	116	302.13	0.2982	0.4358	0.3202	0.5354	0.5771612
89000	54	288	116	296.63	0.3078	0.4457	0.3319	0.5484	0.5632068
89500	52	277	113	283.94	0.326	0.4692	0.3535	0.5782	0.5886076
90000	50	270	110	273.24	0.3426	0.4917	0.3728	0.6067	0.6212608
90500	51	270	110	273.24	0.3416	0.489	0.3712	0.6029	0.6674103
91000	49	269	110	272.78	0.3446	0.4956	0.3754	0.6115	0.6757075
91500	48	274	109.9	274.80	0.3418	0.4955	0.3718	0.611	0.627497
92000	53	271	110	273.69	0.3384	0.4819	0.3672	0.5943	0.6263922
92500	55	268	107	264.90	0.3476	0.4901	0.3769	0.6044	0.6606092
93000	51	301	96.9	252.76	0.3572	0.5243	0.3838	0.6449	0.7035859

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Site Data				Required Modulus	Result with Dual Wheel load 20KN		Result with Single Wheel load 40KN		
Location Ex. Chainage (KM)	Bituminous Layer (mm)	Granular Layer (mm)	Elastic Modulus of Subgrade Soil from FWD (Mpa	Resilient modulus of the Granular Layer (MPa)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Displacement at Subgrade Top (mm)	Displacement at Bituminous Bottom (mm)	Deflection from FWD (mm)
93500	49	296	97	251.12	0.3634	0.5341	0.3917	0.6575	0.69432
94000	48	315	97	258.25	0.3486	0.5237	0.3731	0.6434	0.7000192
94500	52	329	96.9	263.08	0.3337	0.5019	0.3556	0.6157	0.6304768
95000	50	331	97	264.07	0.3339	0.5063	0.356	0.6212	0.627412
95500	51	330	97	263.71	0.3336	0.5039	0.3556	0.6182	0.6726016
96000	49	337	112	307.38	0.2884	0.4439	0.3073	0.5436	0.5620824
96500	48	352	112	313.47	0.2797	0.4381	0.2971	0.5357	0.5598065
97000	53	369	112	320.19	0.2658	0.4164	0.2807	0.509	0.516635
97500	55	382	112	325.22	0.2573	0.4053	0.2708	0.495	0.497475
98000	51	401	112	332.40	0.2502	0.4057	0.2626	0.495	0.544995
98500	49	410	112	335.74	0.247	0.4063	0.259	0.4953	0.4977765
99000	48	423	112	340.49	0.2414	0.4028	0.2526	0.4905	0.538569
99500	52	431	112	343.37	0.2352	0.3901	0.2445	0.4754	0.5196122
100000	50	440	112	346.58	0.2323	0.3908	0.2423	0.4759	0.4906529

5. DISCUSSION

a) Deflection of Flexible Pavements:

Two types of loading are considered for the calculation of deflection values: 20 kN with dual wheel and 40 kN with single wheel. The results of the study reveal that the deflection values calculated from IIT-Pave software are on average 22% and 5% lower than the FWD results for 20 kN dual wheel loading and 40 kN single wheel loading, respectively. These findings provide insight into the reliability and accuracy of IIT-Pave software for assessing the deflection of flexible pavements and emphasize the importance of selecting appropriate loading conditions for obtaining accurate

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deflection measurements. A comparison graph is plotted below in Figure 1 to show the deflections for the two cases along with the deflection values of the FWD test.

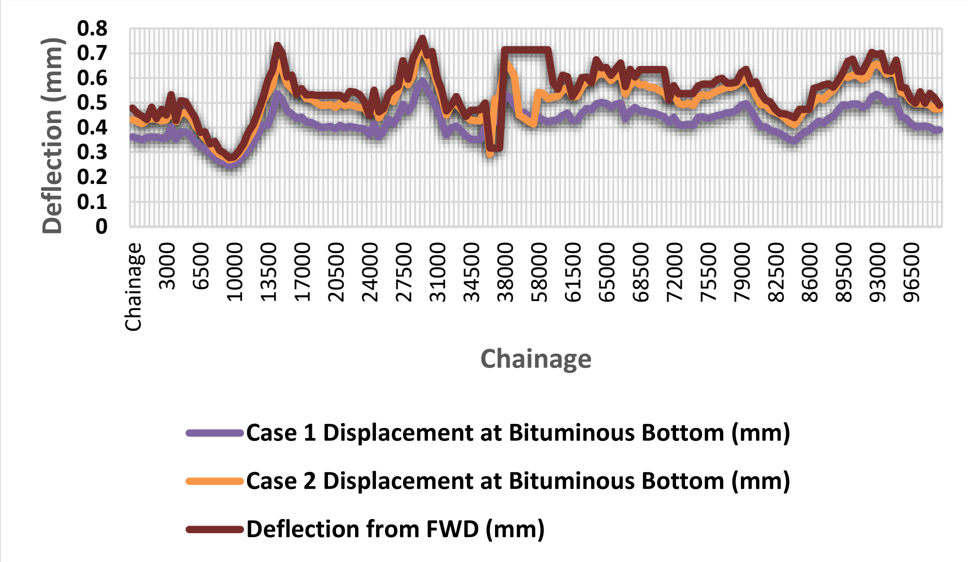

Figure 1: Comparison of Deflection

b) Horizontal & Vertical Strain:

Two types of loading are considered for the calculation of strains: 20 kN with dual wheel and 40 kN with single wheel. A comparison graph is plotted below in Figure 2 & 3 to show the strains for the two cases.

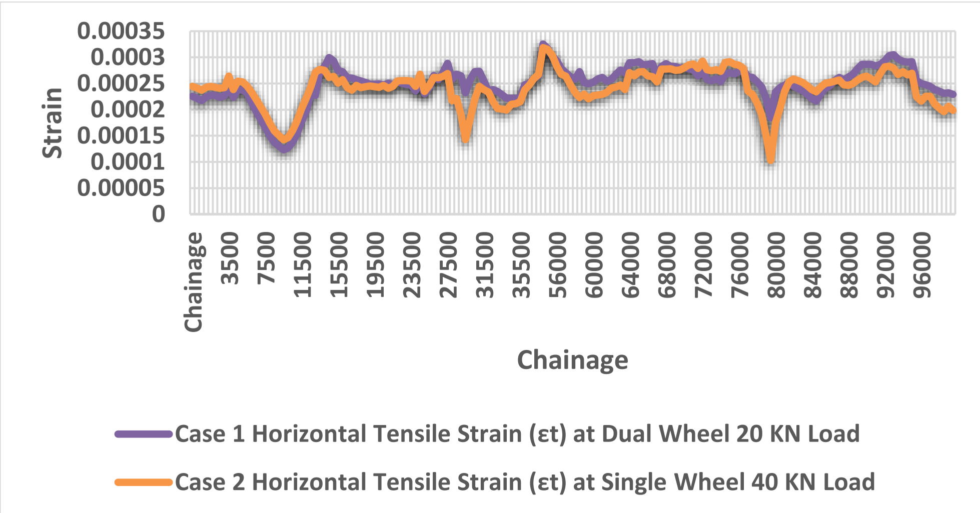

Figure 2: Comparison of Horizontal Tensile Strain

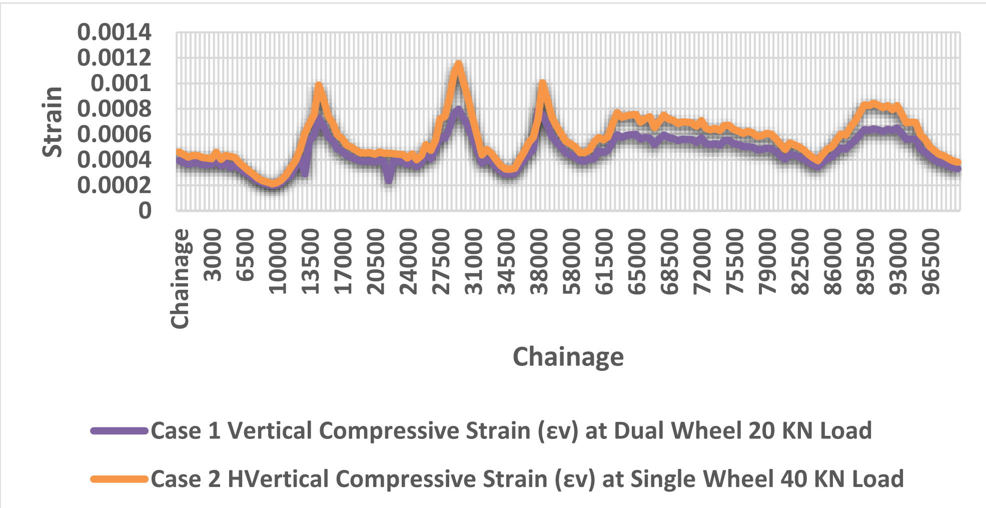

Figure 3: Comparison of Vertical Tensile Strain

c) Overlay thickness for different MSA:

As per the site pavement condition, it is found that, for the first 13 kM stretch is road condition, subgrade CBR is good and sufficient embankment height is present for overlay criteria. Hence, this stretch is selected for overlay design for different traffic.

- Average thickness of Existing Bituminous Layer = 87mm
- Average thickness of Existing Granular Layer = 359mm
- Average Elastic Modulus of Subgrade Soil = 109 MPa
- Resilient modulus of the Granular Layer = 307.786 MPa

Based on the above data the overlay thickness for different MSA given in following Table 2.

Table 2 : Overlay thickness for different MSA

MSA	Allowable Horizontal Tensile Strain at Bottom of Bituminous Layer	Allowable Vertical Compressive Strain at Top of Subgrade Layer	Required Overlay Thickness (mm)	Horizontal Tensile Strain at Bottom of Bituminous Layer	Vertical Compressive Strain at Top of Subgrade Layer
20	0.000225442	0.000454945	30	0.0001881	0.0002328
30	0.000203127	0.000416024	80	0.0001948	0.0003555
40	0.000188647	0.000390446	140	0.0001820	0.0003515
50	0.00017813	0.000371694	190	0.0001738	0.0003521
60	0.000169974	0.000357043	240	0.0001643	0.0003461

A graph is plotted below in Figure 4 to overlay thickness for different msa.

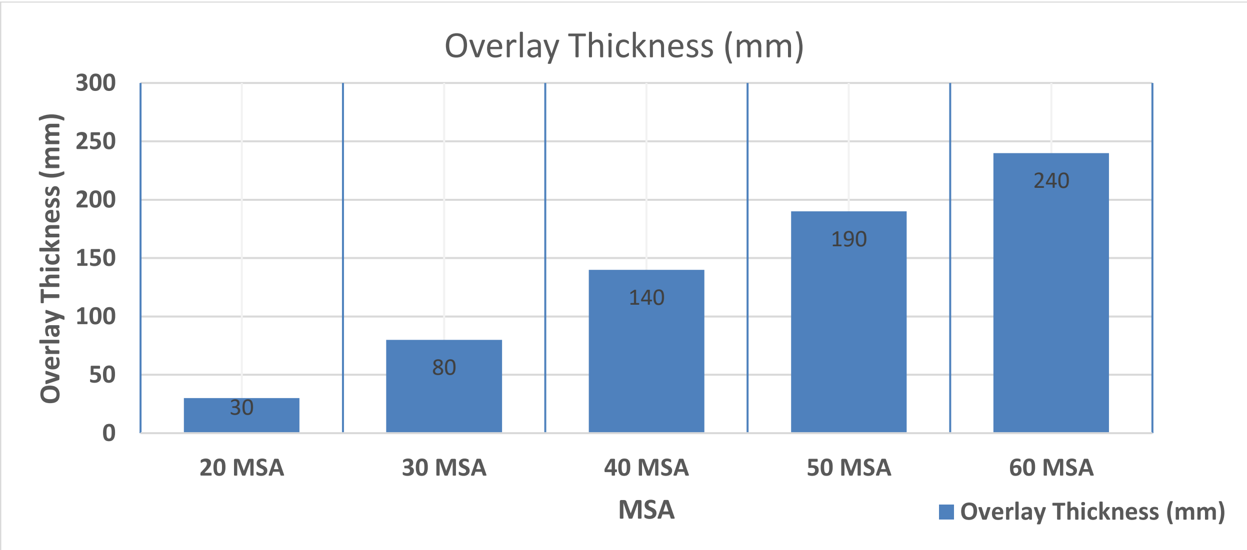

Figure 4: Overlay thickness for different MSA

As per Table 1 & Figure 1 following observations can be drawn:

a. Deflection values calculated from IIT-Pave software are on average 22% and 5% lower than the FWD results for 20 kN dual wheel loading and 40 kN single wheel loading, respectively.
b. For first 13km, the deflection values obtained from IIT-Pave for 20 kN dual wheel load is average 10% lower than the deflection values obtained from FWD results.
c. In figure 1, it can also be observed that from 55000 to 60000, the line for FWD defection is straight as FWD results cannot be done due to poor road condition.
d. It can also be observed that, the deflection for each loading as well as FWD are decreasing from chainage 6000m till 10000m and again increasing till 13000m. From Table 5.3 it can be observed that the subgrade modulus is increasing from chainage 6000m to till 10000m and again decreasing till 13000m and the existing pavement thickness is also in higher side (more than 500mm) near chainage 10000m.
e. This same less deflection can be observed near chainage 29000m where modulus of subgrade reaction is 117 MPa and near design chainage 88000m to 89000m where modulus of subgrade reaction is 116 MPa.

As per Table 1, Figure 2 & 3 following observations can be drawn:

a. For the first 13 km, tensile strain values for 40 kN single wheel load are average 8% more than strain values for 20 kN dual wheel load.
b. The tensile strain values for 40 kN single wheel load are average 8% more than strain values for 20 kN dual wheel load for bituminous layer thickness more than 60mm.
c. And where the bituminous layer is around less than 60mm, strain values for 40 kN single wheel load are average 9% less than strain values for 20 kN dual wheel load.
d. Further for compressive strain, it is average 21% more for 40 kN single wheel compared to 20 kN dual wheel load.
e. It can also be observed that, the strains for each loading as well as FWD are decreasing from chainage 6000m till 10000m and again increasing till 13000m. From Table 5.3 it can be observed that the subgrade modulus is increasing from chainage 6000m to till 10000m and again decreasing till 13000m and the existing pavement thickness is also in higher side (more than 500mm) near chainage 10000m.
f. This same less strain can be observed near chainage 29000m where modulus of subgrade reaction is 117 MPa and near design chainage 88000m to 89000m where modulus of subgrade reaction is 116 MPa.
g. Further, in Figure 3, it can be observed that, the compressive strain reaches the peak value near chainage 15000m, 30000m & 55000m. From Table 5.3, it can be observed that the pavement thickness is on lower side (i.e., 295mm, 270mm and 273mm respectively).
h. The strain lines are flat from chainage 16000m to 25000m and from 64000m to 74000m. From Table 1, it can be observed that, the modulus of subgrade reaction and the pavement thickness are not varying too much.

Hence it is very clear that, strength of subgrade modulus is very important factor for determination of deflection of pavement and generated strain (tensile and compressive). Where, subgrade strength is good, deflection and strains are on lower side. And where the subgrade strength is poor, deflection and strains are on higher side.

As per Table 2, Figure 6.4 following observations can be drawn:

a. For increase of each 10 MSA traffic, there is an increase of around 50mm bituminous overlay thickness, which is normal as cumulative wheel load will also increase with increase with traffic.
b. For increase of traffic from 20 MSA to 30 MSA bituminous overlay thickness increases for 167%, from 30 MSA to 40 MSA bituminous overlay thickness increases for 75%, from 40 MSA to 50 MSA bituminous overlay thickness increases for 36%, from 50 MSA to 60 MSA bituminous overlay thickness increases for 26% (Refer. Figure 5), however this percentage increase for overlay thickness is site specific, it may vary in different location.

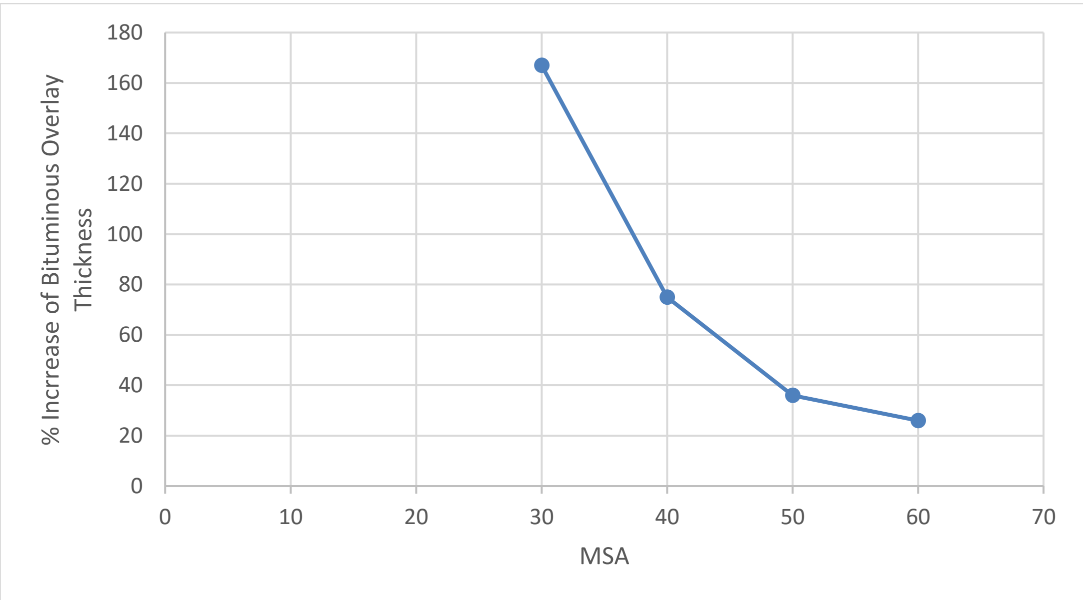

Figure 5: Percentage Increase of Bituminous Overlay for Different MSA

6. CONCLUSION

The following conclusions may be drawn from the present study:

a. The IIT-Pave analysis result has been successfully validated with the FWD test data reported by M/s. Voyants Solutions Pvt. Ltd. for existing Numaligarh – Khatkhati Road (NH-129) at Assam, India.
b. Two types of loading are considered for the calculation of deflection values: 20 kN with dual wheel and 40 kN with single wheel. The results of the study reveal that the deflection values calculated from IIT-Pave software are on

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average 22% and 5% lower than the FWD results for 20 kN dual wheel loading and 40 kN single wheel loading, respectively.

c. These findings provide insight into the reliability and accuracy of IIT-Pave software for assessing the deflection of flexible pavements and emphasize the importance of selecting appropriate loading conditions for obtaining accurate deflection measurements.
d. During the calculation of deflection values, horizontal tensile strain and vertical compressive strain is also determined for above mentioned two types of loading. The result reveals than the tensile strain values for 40 kN single wheel load are average 8% more than strain values for 20 kN dual wheel load for bituminous layer thickness more than 60mm. And where the bituminous layer is around less than 60mm, strain values for 40 kN single wheel load are average 9% less than strain values for 20 kN dual wheel load.
e. Further for compressive strain, it is average 21% more for 40 kN single wheel compared to 20 kN dual wheel load.
f. From this study, it is very clear that, strength of subgrade modulus is very important factor for determination of deflection of pavement and generated strain (tensile and compressive). Where, subgrade strength is good, deflection and strains are on lower side. And where the subgrade strength is poor, deflection and strains are on higher side. From the overlay design, it is found that, for increase of each 10 MSA traffic, there is an increase of around 50mm bituminous overlay thickness.

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