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A Study on Overlay Design of Repeatedly Deteriorating Flexible Pavement

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***ABSTRACT*: *A factor, which causes further concern in India, is very high and very low pavement temperature in some parts of the country. Under these conditions, flexible pavements tend to become soft in summer and brittle in winter. Further increase in road traffic during the last one decade with an unduly low level of maintenance has contributed to accelerated deterioration of road surfacing. To prevent this deterioration process, several types of measures may be adopted effectively such as improved design, use of high performance materials and effective construction technologies. Over the last two decades, traffic volume and the percentage of heavy truck traffic have increased enormously on the National High Way No 18. This pavement is a Flexible pavement with bituminous surfacing. The high traffic intensity in terms of commercial vehicles, overloading of axles and significant variations in daily and seasonal temperature of the pavement have been always responsible for early development of distress symptoms like undulations, rutting, cracking, bleeding, raveling, shoving and potholing of bituminous surfacing.*

***KEYWORDS* -** *Benkelman Beam, Bump Integrator, flexible pavement, integrator unit, pavement unevenness.*

I. INTRODUCTION

To conduct pavement unevenness tests on the selected stretch in Kurnool, Andhra Pradesh, India. Which is located at Longitude 78° 04' East of Prime Meridian and Latitude 150° 82' North of Equator in between Nandyal check post to towards G. Pulla Reddy Engg. College (550M) by using Bump Integrator. To evaluate strength on existing pavement and to design the thickness of overlay considering present traffic by using Benkelman Beam. The movement of agriculture and industrial loads on National Highway No.18 (369KM) is an important road which connects the city Kurnool with Chittoor via Nandyal and Kadapa is high. This road is a very important road to link three districts in Andhra Pradesh, where in the traffic and overloading of the commercial vehicles is on peak. Commercial activities in these districts are high and NH.18 plays a vital role by hooking these three districts. This road construction was undertaken during British rule. Temperature in this zone is very high during summer the pavement temperature reaches up to 50^{O} C and improper drainage facilities this leads to lot of distress in this pavement. In this road from Nandyal Check Post (In Kurnool) to towards G. Pulla Reddy Engg. College constructed with plain bituminous concrete. Because of this agricultural, industrial traffic, Heavy Temperature Variations and improper drainage facilities, causing repeated deterioration of this Stretch of 550M, hence now is the time comes to find the causes to this repeated deterioration and the design of Overlay for this Repeatedly Deteriorating Pavement.

II. DESCRIPTION OF FLEXIBLE PAVEMENT

Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The layers of flexible pavement reflect the deformation of the lower layers onto the surface of the layer. The flexible pavement layers transmit the vertical or compressive stress to the lower layer by grain to grain transfers through the point of contact into each granular structure. A well compacted granular structure consisting of strong graded aggregate can transfer the compressive stress through a wider area and thus forms a good flexible pavement layer. The load spreading ability of this layer therefore depends on the type of the materials and the mix design factors. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel. Due to the ability to distribute the stresses to a larger area in the shape of a truncated cone, the stress get decreased at the lower layers. Therefore by taking full advantage of the stress distribution characteristics of the flexible pavement may be constructed in a number of layers and the top layers has to be the strongest as the highest compressive stresses to be sustained by this layer, in addition to the wear and tear due to the traffic. The lower layers have to take up only lesser magnitudes of stress and there is no direct varying action due to traffic loads.

III. BUMP INTEGRATOR

The roughness measurements of the whole length of the test sections were carried out using Bump integrator at the left wheel path. The left wheel paths were identified at a distance of 0.6m from the edge of the pavement. Bump integrator also known as Automatic road unevenness recorder gives speedily a quantitative integrated evaluation of surface irregularities on an electromagnetic counter. It comprises of a trailer of single wheel with a pneumatic tire mounted on a chassis over which on integrating device is fitted. The machine has a panel board fitted with two sets of electromagnetic counters for counting the uneven index value. The operating speed of the machine is 30 +/- ½ km/hr. A vehicle, usually a jeep, towed the machine and tire pressure is 2.1 kg/cm^2. The calibration of BI unit was carried out by CRRI, New Delhi using Dip Stick. For calibration purpose, sections with a wide roughness range were covered to make the exercise meaningful. Sections of 100m long were selected for this purpose.

3.1. Processing of results obtained with bump integrator

The results obtained with Bump integrator are the Integrator value of irregularities in inches (from BI counter reading), The number of wheel revolutions (from wheel revolution counter). Each set of are required to be converted to the unevenness index value (UI value) in terms of cms/km. The unevenness index value for the test section is arrived at by taking mean of UI values corresponding to the three sets of readings. The unevenness index value is calculated by dividing the BI counter values (in cms) by the distance traveled in kms.

$$UnEvenness\ Index\ UI = \frac{\text{Integrator Counter Value (cms)}}{\text{Distance Traveled (km)}}$$

3.2. Test results of bump integrator studies

3.2.1. Left lane details

S.NO	CHAINAGE		TYPE OF LANE	BUMP INTIGRATOR READING			UNEVENNESS INDEX	RIDING QUALITY
	FROM	TO		OUT WARD	RETURN	AVERAGE		
1	0.0	0.1	DOUBLE	36	36	36.00	3600	VERY POOR
2	0.1	0.2	DOUBLE	67	33	50.00	5000	VERY POOR
3	0.2	0.3	DOUBLE	57	62	59.50	5950	VERY POOR
4	0.3	0.4	DOUBLE	41	33	37.00	3700	VERY POOR
5	0.4	0.5	DOUBLE	35	50	42.50	4250	VERY POOR
6	0.5	0.6	DOUBLE	25	64	44.50	4450	VERY POOR
7	0.6	0.7	DOUBLE	68	50	59.00	5900	VERY POOR
8	0.7	0.8	DOUBLE	92	42	67.00	6700	VERY POOR
9	0.8	0.9	DOUBLE	61	48	54.50	5450	VERY POOR
10	0.9	1.0	DOUBLE	55	76	65.50	6550	VERY POOR
11	1.0	1.1	DOUBLE	19	28	23.50	2350	POOR
12	1.1	1.2	DOUBLE	35	21	28.00	2800	VERY POOR
13	1.2	1.3	DOUBLE	58	35	46.50	4650	VERY POOR
14	1.3	1.4	DOUBLE	18	15	16.50	1650	POOR
15	1.4	1.5	DOUBLE	15	24	19.50	1950	POOR
16	1.5	1.6	DOUBLE	28	30	29.00	2900	VERY POOR
17	1.6	1.7	DOUBLE	15	15	15.00	1500	POOR

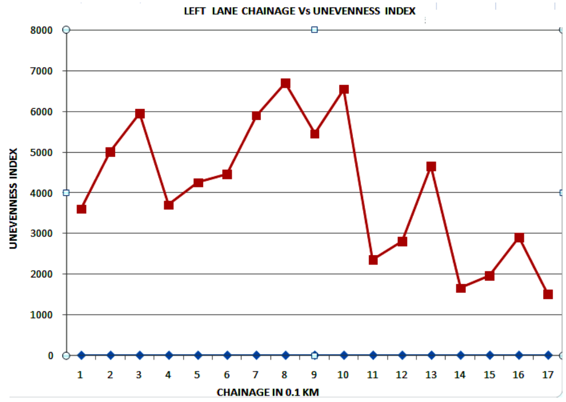
3.2.2. Right lane details

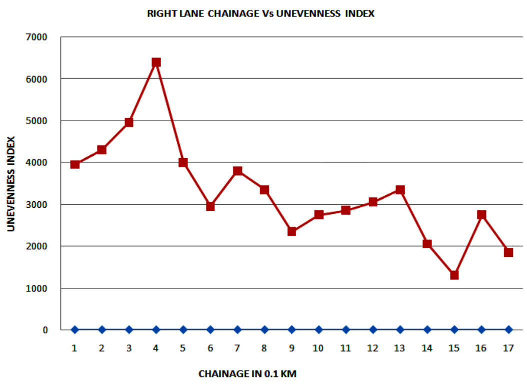
S.NO	CHAINAGE		TYPE OF LANE	BUMP INTIGRATOR			UNEVENNESS INDEX	RIDING QUALITY
	FROM	TO		OUT WARD	RETURN	AVG		
1	0.0	0.1	DOUBLE	41	38	39.50	3950	VERY POOR
2	0.1	0.2	DOUBLE	46	40	43.00	4300	VERY POOR
3	0.2	0.3	DOUBLE	36	63	49.50	4950	VERY POOR
4	0.3	0.4	DOUBLE	55	73	64.00	6400	VERY POOR
5	0.4	0.5	DOUBLE	28	62	40.00	4000	VERY POOR
6	0.5	0.6	DOUBLE	12	47	29.50	2950	VERY POOR
7	0.6	0.7	DOUBLE	15	61	38.00	3800	VERY POOR
8	0.7	0.8	DOUBLE	22	45	33.50	3350	VERY POOR
9	0.8	0.9	DOUBLE	35	12	23.50	2350	POOR
10	0.9	1.0	DOUBLE	23	32	27.50	2750	VERY POOR
11	1.0	1.1	DOUBLE	27	30	28.50	2850	POOR
12	1.1	1.2	DOUBLE	10	51	30.50	3050	VERY POOR
13	1.2	1.3	DOUBLE	16	51	33.50	3350	VERY POOR
14	1.3	1.4	DOUBLE	19	22	20.50	2050	POOR
15	1.4	1.5	DOUBLE	07	19	13.00	1300	FAIR
16	1.5	1.6	DOUBLE	37	18	27.50	2750	VERY POOR
17	1.6	1.7	DOUBLE	19	18	18.50	1850	POOR

3.4. Recomended roughness values in india in mm/km

UNEVENNES INDEX, MM/KM	RIDING QUALITY
In Old Pavements	
Below 950	Excellent
950 to 1190	Good
1200 to 1440	Fair
1450 to 2400	Poor (possible resurfacing)
Above 2400	Very poor (resurfacing required)
In New pavements	
Below 1200	Good (acceptable)
1200 to 1450	Fair (acceptable)
Above 1450	Poor (not acceptable)

3.5. Graphs chainage vs uneveness index





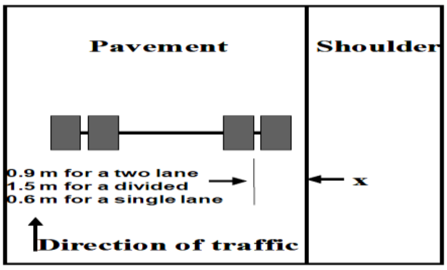
IV. DESIGN OF FLEXIBLE OVERLAY OVER RIGID PAVEMENTS

The overlay thickness required over a flexible pavement may be determined either by one of the conventional pavement design methods or by a non-destructive testing method like the Benkelman beam deflection method. The thickness of flexible overlay over rigid pavements is calculated using the following relationship h_f equal to $2.5(F*h_d - h_e)$, where h_f, h_e, h_d and F are Flexible overlay thickness, Existing rigid pavement thickness, Design thickness of rigid pavement and Factor which depends upon modulus of existing pavement. For calculating thickness of bituminous overlay, the following relation is used h_b equal to $h_f / 1.5$, i.e., h_b is equal to $1.66 (F*h_d - h_e)$.

4.1. Overlay design by benkelman beam deflection studies

Benkelman beam is a device which can be conveniently used to measure the rebound deflection of a pavement due to a dual wheel load assembly or the design wheel load. The Equipment consists of a slender beam of length 3.66m which is pivoted to a datum frame at a distance of 2.44 m from the probe end. The datum frame rests on a pair of front leveling legs and a rear legs and a rear leg with adjustable height. The probe end of the beam is inserted between the dual rear wheels of the truck and rests on the pavement surface at the center of the loaded area of the dual wheel load assembly. A dial gauge is fixed on the datum frame with its spindle in contact with the other end of the beam is twice the distance between the fulcrum and the dial gauge spindle. Thus the rebound deflection reading measured at the dial gauge is to be multiplied by two to get actual movement of the probe end due to the rebound deflection of the pavement surface when the dual wheel load is moved forward. A loaded truck with rear axial load of 8170 kg is use for the deflection study. The design wheel load is a wheel load assembly of gross weight 4085 kg with an inflation pressure of 5.6 kg/cm^2 and spacing between the rare tyre walls should be in between 30 - 40 mm. The stretch of road length to be evaluated is first surveyed to assess the general condition of the pavement with respect to the ruts, cracks and undulations. Based on the above pavement condition survey, the pavement stretches are classified and grouped into different classes such as good, fair and poor for the purpose of Benkelman beam deflection studies. The loading points on the pavement for deflection measurements are located along the wheel paths, on a line 0.9m from the pavement edge in the case of pavement of total width more than 3.5m; the distance from the edge reduce to 0.6m on narrower pavements. The number of loading points in a stretch and the spacing between them from for the deflection measurements are to be decided depending on the objective of the project and the precision desired. A minimum of 10 deflection observations may be taken on each of the selected stretch of pavement. The deflection observation points, the study is carried out in the following steps.

The truck is driven slowly parallel to the edge and stopped such that the left side rear dual wheel is centrally placed over the first point for deflection measurement. Probe end of the Benkelman beam is inserted between the gaps of the dual wheel and is placed exactly over the deflection observation point. When the dial gauge reading is reading is stationary or when the rate of change of pavement deflection is less than 0.025mm per min, the initial dial gauge reading D_O is noted. Both readings of the large and small needles of the dial gauge may be noted, the large needle may also be set zero if necessary at this stage. The truck is moved forward slowly through a distance of 2.7m from the point and stopped. The intermediate dial gauge reading D_i is noted when the rate of recovery of the pavement is less than 0.025mm per minute. The truck is then driven forward through a further distance of 0.9 m and the final dial gauge reading D_f is recorded as before.



Position of vehicle axle on road

4.2. Correction for pavement temprature and subgrade moisture variations

When the pavement consist of relatively thick bituminous layers like the bituminous macadam or asphaltic concrete in the base/binder/surface course ,variations in temperature of pavement surface course cause variation in pavement deflection under the standard load. The IRC has suggested a standard temperature of 35^0C and correction factor of 0.0065mm per ^OC to be applied for the variation from this standard pavement temperature. The correction will be negative when the pavement temperature is above $35^\circ C$ and positive when it is lower. However it is suggested that deflection studies should be carried out when the pavement temperature is above $30^\circ C$, if this correction factor is to be applied. A seasonal variations cause variation is sub grade moisture. As it is always not possible to conduct deflection studies during monsoon season when subgrade moisture content is the highest the IRC has suggested that tentative correction factors of 2 for clayey soils and 1.2 to 1.3 for sandy subgrade soils may e adopted if the deflection observations are made during day seasons. The deflection under the worst subgrade moisture may therefore into be estimated by multiplying the summer deflection value by the appropriate correction factor.

4.3. Analysis of data

The rebound deflection values $D_{1,}$ $D_{2,}$ D_3 are determined in mm after applying the leg corrections if necessary to the observed values of $D_{O,}$ D_f and D_i in each case. The rebound deflection is calculated by taking the average of initial, intermediate and final readings and multiplying with the least count of dial gauge 0.025mm The average deflection calculated by$D = \frac{Do+Di+Df}{3}$ X 0.025 mm, the mean value of the deflections at n points is $\overline{D} = \sum \frac{D}{n}$ mm , standard deviation of the deflection values is $\sigma = \sqrt{\frac{\sum(\overline{D}-D)^2}{(n-1)}}$, characteristic deflection $D_C = \overline{D} + t\sigma$. Here the value of 't' is to be chosen depending upon the percentage of the deflection values to be covered in the design. When t = 1.0, $DC = \overline{D} + \sigma$ covers about 84 percent of the cases; when t_o = 2.0, $DC = \overline{D} + 2\sigma$ about 97.7 percent of the cases of deflection values on the pavement section, assuming normal distribution of rebound deflation values. The IRC recommends the former case, i.e., $DC = \overline{D} + \sigma$, whereas in many other countries they adopt the later case for overlay design. The necessary corrections for pavement temperature and sub grade moisture may be applied to the characteristic deflection value, D_C before designing the overlay thickness.

4.4. Benkle man beam test observations and results

S. No	Dial Gauge Reading			Deflection	Temp.	Deflection After temp. Correction	MC=2 After Deflection MC	Mean deflection	Standard deflection	Characteristic deflection
1	6	30	9	0.375	46	0.304	0.607	1.823	0.867	2.69
2	10	6	7	0.192	46	0.12	0.24			
3	48	65	68	1.508	46	1.436	2.873			
4	60	0	75	1.125	46	1.053	2.106			
5	82	2	63	1.225	54	1.101	2.202			
6	65	41	46	1.226	54	1.142	2.284			
7	42	1	92	1.125	54	1	2.002			
8	62	38	81	1.508	54	1.384	2.768			
9	20	23	25	0.566	54	0.442	0.884			
10	40	34	16	0.75	54	0.626	1.252			
11	48	49	45	1.183	54	1.059	2.118			
12	54	56	54	1.366	49	1.275	2.55			

V. OVERLAY THICKNESS DESIGN

The overlay thickness required h_O may be determined after deciding the allowable deflation D_a in the pavement under the design load. According to Ruiz's equation overlay thickness h_O in m is given by $h_O = \frac{R}{0.434}\log_{10}\frac{D_C}{D_a}$ cm. Where $h_{O,}$ R and D_a are the thickness of bituminous overlay in cm, deflection reduction factor depending on the overlay material (usual values for bituminous overlay range from 10 to 15, the average values that may be generally taken being 12) and allowable deflection which depends upon the pavement type and the desired design life values ranging from 0.75 to 1 .25mm respectively. Which are generally used in flexible pavement for design of overlay thickness equivalent to granular material WBM layer. When superior materials are used in the overlay layer, the thickness value has to be suitably decreased taking "equivalent factor" of the material into consideration, then $h_O = 550 \log_{10}\frac{D_C}{D_a}$ mm. where h, D_C, Thickness of granular of WBM overly in mm, pavement temperature and sub grade moisture $\overline{D} + \sigma$ (after applying the corrections) respectively. D_a will be taken as 1.00, 1.25 and 1.5 mm if the projected design traffic A is 1500 to 4500, 450 to 1500 and 150 to 450 respectively, here

A	=	Design traffic	=	$P[1 + r]^{(n+10)}$
r	=	Assumed growth rate	=	7.5%
n	=	Construction period	=	2 Years

When bituminous concrete or Bituminous Macadam with bituminous surface course is provided as the overlay, an equivalency factor of 2.0 is suggested by the IRC to decide the actual overlay thickness required, thus, the thickness of bituminous concrete overlay in mm will be $\frac{h_o}{2}$ when the value of h_O is determined from above equation. According to R&B dept. present amount of traffic P is 700 CVPD, then design traffic is 1667 CVPD, therefore allowable deflection D_a is 1.00 for traffic in between 1500 to 4500. Here characteristic deflection is greater than allowable deflection hence overlay design is required. Then$h_0 = 550 \log_{10} \frac{D_c}{D_a}$ mm = 236mm, by considering equivalency factor 2.00 for bituminous concrete layer actual overlay thickness required $= \frac{h_0}{2} = 11.8$ cm.

VI. CONCLUSIONS & DISCUSSIONS

The designed overlay thickness for this repeatedly deteriorating pavement after conducting above tests is found to be 11.8cm, apart from this design the following conclusions are to be made. The growth of traffic on this stretch from last two decades are tremendously increased, increased traffic and heavy axle load vehicles are causing repeated deterioration of this road, hence the road stretch is redesigned for contemporary traffic condition, tonnage suitably. The drainage system both longitudinal and transverse on the selected stretch are inefficient and is not working properly especially at check post, leading to failures pertaining to improper drainage system, namely Pot holes, Stripping etc. Observing the nearest sites it is found that the ground water table at this site is very closer to ground surface, which leading to different types of pavement distress, hence it is necessary to take care to minimize this GWT by using techniques like Inverted sand filters, and by increasing the base course thickness, by observing the Benkelman Beam and Bump Integrator test results it is clear that on the road curve, the thickness of inner edge of the lane is very thinner than the outer edge, so the maximum deterioration is occurring on the inner edge, hence proper thickness of bitumen layer is provided on the inner edge of the road curve. Surface course has lack of binding with base course, which causing the keying hence necessary steps are taken while overlying is done to make good bond between surface course and base course.

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