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ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0249

International Journal of Earth Sciences and Engineering

April 2017, P.P. 455-461

Design Aspects of Modern Cement Concrete Pavements in India

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Abstract: *There is an increasing trend for using concrete pavement all over the world because of its ability to handle complex loading and environmental conditions that occur in highways. Finite element method is the best tool for analysis of the pavement slab. The pavement slab deteriorates under combined action of axle loads and temperature differential across the depth of slab. The present study illustrates a case study for thickness design and describes the different parameters associated with the design of rigid pavement for a National Highway in Punjab State using tied concrete shoulders. The possibility of bottom-up and top-down cracking was considered. The effect of moisture variations on the development of warping stresses is ignored. The thickness of a pavement slab reduces by about 30 percent if there is a tied concrete shoulder or when the slab has a widened outer lane.*

Keywords: *Concrete pavement, Axle loads, Temperature differential*

1. Introduction

India has the second largest road network across the world at 4.87 million km. Indian road network carries almost 85 per cent of the country’s passenger traffic and around 60 per cent of its freight. The economic growth of a developing nation like India depends on a well-connected, efficient and safe road network. This includes not only National Highways but other roads also which facilitate fast movement of goods and people. The construction of highways has reached an all-time high and the increased pace of construction is expected to continue for the coming years. Indian roads are primarily bitumen-based macadam roads and the share of concrete roads is very small. However, India’s Ministry of Road Transport and Highways has decided to shift towards making rigid pavement the default mode of construction on national highways after considering factors related to service life, fuel consumption, weather conditions and maintenance costs.

A concrete pavement is a rigid pavement structure which in general consists of three layers; subgrade, base course and the concrete slab. A concrete pavement distributes heavy axle loads over a large area by beam action which means that concrete pavements are less sensitive to the subgrade support and do not require the thick sub-base layers like asphalt concrete pavements. The design of concrete pavements has become more scientific with time. Efforts to avoid premature performance failing of concrete roads are, at a larger degree, considered than for other pavement alternatives since rehabilitation techniques are expensive. The development of Finite Element Method (FEM) and the use of softwares have made the evaluation of stresses under complex loading condition easy. A modern design methodology of IRC: 58-2015 aims at rationalizing the design procedure by considering cumulative fatigue damage due to the combined effect of wheel load and pavement temperature. In this paper, different parameters associated with the design of pavement with tied concrete shoulders are discussed for a National Highway in Punjab State.

2.0 Factors Governing Pavement Design

2.1 Axle Loads and Tyre Pressures

Though the legal axle load limits in India are 10.2, 19 and 24 ton for single, tandem and tridem axles respectively, the actual axle loads operating on highways in India are much higher due to lack of enforcement. It, therefore, becomes essential to collect the data on axle load spectrum of commercial vehicles both during the day and night hours to analyze and compute the flexural fatigue damage with a higher precision and determine the possibility of top-down cracking. The tyre inflation pressures of commercial highway vehicles may range from 0.7 MPa to 1.0 MPa. It is observed that the variation in tyre pressure for concrete pavement slab of thickness 200 mm or more has little effect on the stresses in pavement slabs [1].

2.2 Wheel Base Characteristics and Design Period

During night hours, the slab has a tendency to curl up and maximum fatigue develops when the axle loads acts close to transverse joints. The distance between steering axle and center point of driving axle group for different truck models generally range from 3.6m to more than 5.0m whereas the commonly used transverse joint spacing is 4.5m, so the axles with spacing between the front and rear axles greater than the proposed transverse joint widths do not contribute to top-down fatigue cracking. Therefore, it becomes essential to establish the typical spacing between successive axles of commercial vehicles and thus the proportion of axles contributing to top-down fatigue cracking during night period from axle load survey.

Received: December 02, 2016; Accepted: February 13, 2017; Published: April 26, 2017
International Journal of Earth Sciences and Engineering, 10(02), 455-461, 2017, DOI:10.21276/ijee.2017.10.0249

Cement concrete pavements are generally designed for a life period of 30 years or more. However, factors such as traffic volume, uncertainty of traffic growth rate, road capacity and possibility to boost the capacity by widening in future must be considered for taking the design period.

2.3 Design Traffic

Assessment of average daily traffic shall normally be based on seven day 24 hour count made in accordance with IRC: 9 “Traffic Census on Non-Urban Roads” [2]. As per IRC: SP: 84 annual growth rates of commercial vehicles shall be taken to be a minimum of 5% [3]. When the outer wheel of vehicles move tangentially to the longitudinal edge, the edge flexural stress for bottom-up cracking is highest and is considered critical for design thickness [4]. A very small percentage of wheel load repetitions (less than 2%) meet this condition for both 2-way 2-lane and 4-lane divided highways in India [5]. Design traffic of 25% of the total 2-lane 2-way commercial vehicles should be considered for thickness design. In case of 4-lane and multi-lane divided highways, 25% of the total traffic in the direction of predominant traffic may be considered for design of pavement. The design traffic for top-down cracking is usually fifty percent of the design traffic for bottom-up cracking analysis [1].

2.4 Temperature Differential

The temperature gradient in a slab of concrete pavement is generally non-linear during the day-time and nearly linear during the night hours. Several studies have shown that non-linear temperature variation prevails across the depth of slab and some parts of the concrete slab have a tendency to lift up when a moisture or temperature difference exists across the depth of slab [6][7][8][9]. Also, the peak temperature difference occurs only for a short duration. The peak temperature differential during the night is almost half of the day time maximum temperature differential.

Temperature differentials are considered positive when the top surface of a pavement slab curls to have a convex shape during the day hours and negative when the slab curls with a concave shape during the night. The axle load stresses should be computed for fatigue analysis when the slab is in a curled state due to the temperature differential during the day as well as night hours. The maximum temperature differentials for concrete slabs for different states/regions are recommended in Table 1 of IRC: 58-2015 [1].

2.5 Characteristics of Sub-Grade and Sub-Base

When a vehicle moves over a cement concrete pavement, the concrete slab deflects under the load similar to the beam action. This load is resisted by a reactive pressure from subgrade at the bottom of slab. The foundation of the pavement slab deforms only slightly and reverts back to its original shape when a vehicle passes over it. It is commonly assumed that the foundation or the sub-base is composed of springs bonded to the concrete slab, and the reactive pressure per unit deflection is termed as modulus of subgrade reaction (k). The k-value is determined by Plate Load Test from the pressure sustained at a deflection of 1.25mm. The standard test uses a 750mm diameter plate [10].

The plate load test is time-consuming, expensive, sometimes leads to overestimation of strength and does not give reliable results for different moisture conditions, therefore the design k-value is often estimated from soaked CBR value. A minimum CBR of 8% is recommended for the 500 mm of the select soil used as subgrade [1].

Falling Weight Deflectometer (FWD) tests can also be done to compute the value of modulus of subgrade reaction for an existing pavement or a prepared foundation. If the Falling Weight Deflectometer (FWD) tests are done at the corners, interiors and edge region, different k-values would be obtained on back calculation since the spring model is only a mathematical idealization though the behaviour of subgrade/sub-base under confined condition would be almost elastic under repeated loading. Hence, to evaluate the realistic stress and deflection values, different k-values must be used for corner, interior and edge loading [11].

A sub-base is responsible to provide support to the concrete slab. It must, therefore be uniform, stable and strong to resist erosion and disintegration due to adverse climatic variations and movement of heavy wheel loads. DLC sub-base being stronger than the conventional granular sub-base is recommended for all major highways in India [1]. A de-bonding inter layer of 125-micron thick polythene sheet is placed over the DLC layer before placing of concrete slab to reduce the inter layer friction and reflection cracking in pavement slab. In such pavement structures, composite action of the slab and the DLC is lost and both act independently in resisting the applied axle loads. If the pavement slab and the DLC layer are bonded, it will result in a monolithic action of the two layers, which will greatly reduce the pavement thickness because of low bending stresses [4]. Since the 7-day strength of DLC is usually 10 MPa or higher it is necessary to provide contraction joints in the DLC also below the contraction joints or slab.

2.6 Concrete Strength

The flexural strength of cement concrete slab is the most important requirement as it distributes heavy axle loads over a large area by beam action. The 90 days and one year flexural strengths are about 110 and 117 percent respectively of the 28-day flexural strength [4]. The cumulative fatigue damage is very small in the first few months as the number of load repetitions is very few during the initial period. It is, therefore, logical that 90 day flexural strength of concrete should be used as design strength of concrete. For the initial 4 to 5 years, the joints of concrete pavements are impervious but the joint seals are lost with passage of time and rain water starts to enter freely through them. Hence, a permeable granular or cement treated sub-base can ensure better performance of heavy duty pavements helping in quick removal of rainwater by infiltration through the joints. The minimum value of 28-day flexural strength for pavement quality concrete (PQC) is 4.5 MPa [1].

2.7 Fatigue behaviour of Cement Concrete

A cement concrete pavement is subjected to dynamic loads due to repeated applications of vehicle loads. These cyclic loadings cause distress in cement concrete slab by gradual development of micro-cracks especially when the stress ratio, i.e., the ratio between applied flexural stress and flexural strength of concrete, exceeds 0.45. The number of load repetitions required to cause cracking decrease with an increase in stress ratio [1].

2.8 Flexural Stress & Fatigue Damage

The PQC slab is subjected to flexural stresses due to single, tandem and tridem axle loads; temperature differential between the top and bottom of slab and; warping caused by moisture variations across the depth of slab. However, the effect of moisture variation is generally ignored and is not considered critical to thickness design [1].

A slab is subjected to temperature differential between the top and bottom due to quick changes in daily temperature causing the slab to warp. It warps with convex upwards during the daytime when the top of the slab is much hotter than the bottom. Reverse is the case during the night hours, the self-weight of the slab causes warping stresses in the slab during the warping process.

The flexural stress at the bottom layer of the concrete slab is the maximum during the day hours when the axle loads act midway on the pavement slab while there is a positive temperature gradient as illustrated in Figures 1 and 2. The location of maximum flexural stress at the bottom of pavement slab with or without tied concrete shoulders for single, tandem and tridem axles is the same [1].

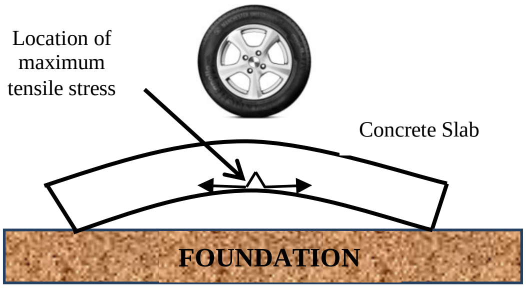

Figure 1: *Axle load placed in the middle of slab during day-time*

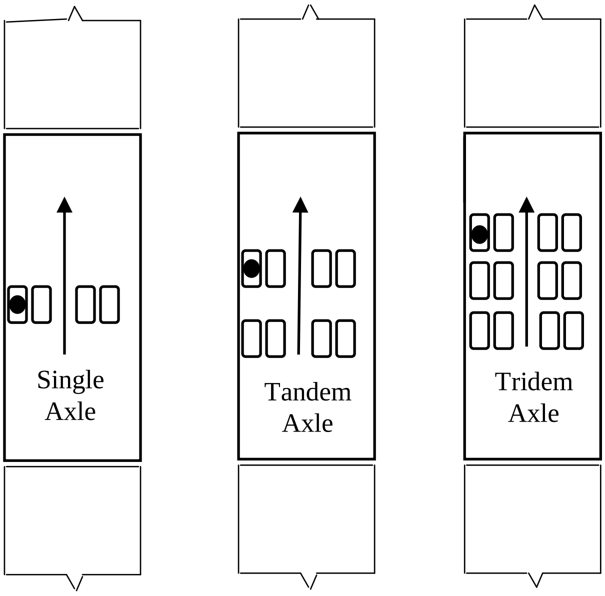

Figure 2: *Symbol ● gives the location of maximum edge flexural stress due to single, tandem and tridem axles*

The flexural stress at the top layer of the concrete slab is the maximum during night hours when axle loads act close to transverse joints on the pavement slab when there is a negative temperature gradient. Since, the top surface of a pavement slab is cooler than the bottom surface during the night hours; the ends of slab have a tendency to curl up in a concave shape which results in a loss of support for the slab. Due to the combination of high negative temperature gradient, moisture gradient and different axle loads, a high tensile stress develops at the top of slab near the middle of the critical longitudinal edge and thus initiating Top-Down Cracking (TDC) as shown in Figure 3 [1].

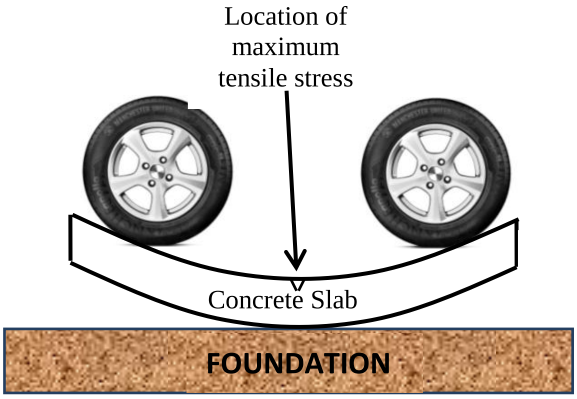

Figure 3: *Placement of two axles of a commercial vehicle on a warped pavement slab during the night hours*

A pavement slab is gradually damaged due to repeated flexural stresses, low or high in magnitude, causing crack propagation in a pavement and ultimately to the development of micro-cracks under repeated loading and thus failure. Analysis indicates that contribution to Cumulative Fatigue Damage (CFD) for bottom-up cracking is significant only during 10 A.M. to 4 P.M. because of higher flexural stresses caused by axle load and warping. For the top-down cracking analysis, only the CFD caused during the night between 0 A.M. and 6 A.M. is significant [1].

Finite Element Analysis is done for stress computation by using IITSLAB-II, software developed at IIT Kharagpur, to compute flexural stress due to combined action of load and different temperature differentials. The flexural stresses can also be computed using Appendix I and Appendix II given in IRC: 58 [1].

2.9 Design Criterion of Rigid Pavements

If the sum of Cumulative Fatigue Damage (CFD) due to (i) wheel load and curling stresses at the bottom and (ii) wheel load and curling stresses at the top is less than 1, the pavement is safe. Thus if CFD (BUC) + CFD (TDC) = 1, the pavement is safe from large scale cracking. The design thickness may be increased by 10mm to (i) to permit two texturing and (ii) grinding to rectify faulting during the service life [1].

2.10 Tied Concrete Shoulder and Widened Outer Lane

Tied concrete shoulders and widened outer lanes can significantly improve the cracking by reducing flexural stresses at the edges of high volume highway pavements where critical loadings occur. Widening of outer lanes by 0.5m to 0.6m reduce the edge flexural stress by 20 percent to 30 percent. In tied concrete shoulders, the stress at edges is reduced by about 30 percent. Figure 4 shows the widened part of the outer lane, which can be given a rough texture to discourage vehicles from coming over the shoulder from safety consideration.

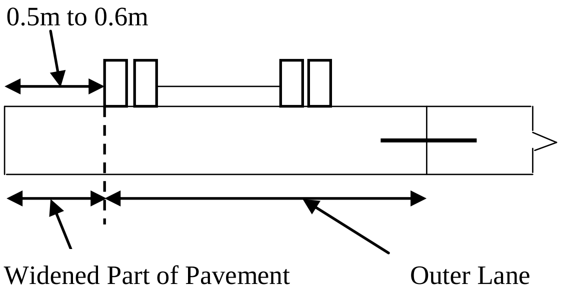

Figure 4: *Concrete pavement with widened outer lane*

2.11 Bonded Rigid Pavement

If the PQC slab is laid directly over the DLC layer and a proper bond is ensured between them, then it leads to considerable reduction in the pavement thickness. It is because the monolithic action of the two layers reduces the overall flexural stress in both the pavement slab and DLC layer. The surface of DLC layer shall be roughened within 3 to 6 hours of its placement by using wire brush and a bonding agent in the form of cement slurry may be applied over it before laying the pavement slab. In order to promote monolithic action between the two layers, transverse joints shall be provided in the DLC layers also to one-third of its depth exactly below the regions where transverse joints will be provided in the pavement slab. The minimum 7-day compressive strength of a DLC layer should be 10MPa.

3.0 Stress Charts and Regression Equations

Appendix-1 gives the stress charts for Bottom-up Cracking Analysis for different categories of axles and modulus of subgrade reaction used in the design of pavement thickness in this paper. The empirical formula given in Appendix-5 of IRC: 58 – 2015 may be referred for the calculation of Top-down Cracking Analysis [1].

4.0 Limitations and Future Scope of Work

The subgrade is considered as a Winkler's foundation However, this may not be a very practical approach as it may not give an exact estimation of the strength of foundation and also the DLC layer has high shear strength. Modeling of the foundation as a solid elastic mass may be more realistic. The study of annual temperature differentials across the country shall be done to cover different climatic zones and thus for correct evaluation of stresses. Currently, there are no specifications for retexturing and its methodology. The issues highlighted above shall be examined and incorporated in the revised guidelines for the design and construction of concrete roads in India.

5.0 Conclusions

Based on the research work done in this paper, following conclusions are drawn which should help in rationalizing the design procedure to suggest a mechanistic design for concrete pavements in India.

- Care must be taken to select the value of modulus of subgrade reaction (k) by considering factors such as loss of support due to erosion, slab deformation and moisture variations.
- If the pavement slab thickness is greater than or equal to 200mm, then tyre pressure has little effect on flexural stresses.
- The vehicles travelling tangential to the outer edge cause highest flexural stresses in a pavement. However, the percentage of wheels falling tangentially to the longitudinal edge is generally very small.
- The flexural stress shall be computed for the combined effect of axle loads and temperature differential. Since majority of heavy vehicles travel during night hours, therefore, roads shall be examined for top-down cracking.
- The cumulative fatigue damage due to the combined action of axle loads and warping stress shall be computed during 10A.M. to 4P.M. for

Bottom-up Cracking and between 0A.M. to 6A.M. for Top-down Cracking.

- If the concrete slab is bonded to cemented sub-base, monolithic action prevails leading to a reduced thickness design and increased economy.
- Widening of outer lanes and use of tied concrete shoulders reduce the overall stress at edges by about 30 percent.
- A lot of work needs to be done to evaluate the parameters associated with subgrade and temperature of a region due to varying soil and climatic condition in India.

A Case Study of Thickness Design for a National Highway in Punjab State

A cement concrete pavement with tied concrete shoulders with doweled transverse joints is designed for a 4-lane divided National Highway with 2-lanes in each direction in the state of Punjab. The road is expected to carry, about 4000 commercial vehicles per day in each direction, in the year of completion of construction. The design parameters are:

28-days flexural strength of concrete: 4.5MPa
90-days flexural strength of concrete: 4.5 × 1.1 = 4.95MPa
Effective CBR of compacted subgrade: 10%
Effective k-value of subgrade: 55MPa/m
Thickness of DLC layer: 150mm
Elastic modulus of concrete: 30000MPa
Effective modulus of subgrade reaction (k_{eff}): 300MPa/m
Poisson's ratio of concrete: 0.15
Temperature differential: 13ºC
Lane width: 3.5m
Transverse joint spacing: 4.5m

Table 1: *Axle Load Spectrum*

Single Axle		Tandem Axle		Tridem Axle	
Load Class	% of Axle Loads	Load Class	% of Axle Loads	Load Class	% of Axle Loads
185-195	18	380-400	14.6	530-560	5
175-185	17	360-380	10.4	500-530	5
165-175	18	340-360	4	470-500	3
155-165	13	320-340	2.4	440-470	7
145-155	3	300-320	2.6	410-440	10
135-145	2	280-300	2	380-410	12
125-135	3	260-280	4	350-380	16
115-125	3	240-260	5	320-350	13
105-115	3	220-240	6	290-320	5
95-105	3	200-220	6	260-290	3
85-95	3	180-200	9	230-260	3
<95	14	<180	34	<230	18
	100		100		100

Distribution of truck traffic

Day time: 40%
Night time: 60%

Design Steps

Present traffic (cvpd) = 4000 in each direction
Design period (years) = 30
Traffic growth rate (decimal) = 0.075
% traffic in predominant direction = 50%
Total 2-way commercial vehicles during 30 years:
$C = 365 \times 8000 \times ((1+0.075)^{30} - 1) / 0.075$
Therefore, C = 301,926,255 CV's

Provide a debonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

Average number of axles (steering/single/tandem/tridem) per commercial vehicle = 2.35
Total two-way axle load repetitions during the design period = 301,926,255 × 2.35 = 709,526,700 axles.
Number of axles in predominant direction = 709,526,700 × 0.5 = 354,763,350
Design traffic after adjusting for lateral placement of axles (25% of predominant direction traffic for multi-lane highway) = 354,763,350 × 0.25 = 88,690,838
Night time (12-hour) design axle repetitions = 88,690,838 × 0.6 = 53,214,503 (since 60% traffic during night time).
Day time (12-hour) design axle load repetitions = 88,690,838 × (1-0.6) = 35,476,335
Day time 6-hour axle load repetitions = 35476335/2 = 17,738,168
Hence, design number of axle load repetitions for bottom-up cracking analysis = 17,738,168
Night time 6-hour axle load repetitions = 53214503 / 2 = 26,607,251
Percentage of commercial vehicles having spacing between the steering axle and the first axle of the rear axle unit less than, 4.50m = 55%. Hence, the 6-hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5 m) = 26607251 × 0.55 = 14,633,988.

The axle load category-wise design axle load repetitions for bottom-up and top-down fatigue cracking analysis are given in the following table:

Table2: *Design Axle Load Repetitions for Bottom-up & Top-down Cracking Analysis*

Axle Category	Proportion of the Axle Category	Category-Wise Axle Repetitions for Bottom-up Cracking Analysis	Category-Wise Axle Repetitions for Top-Down Cracking Analysis
Front (steering) single	0.45	7982176	6585295
Rear Single	0.15	2660725	2195098
Tandem	0.25	4434542	3658497
Tridem	0.15	2660725	2195098

Maximum day-time Temperature Differential in slab (for bottom-up cracking) = 13ºC.
Night-time Temperature Differential in slab (for top-down cracking) = 13 º - 5º = 8º

Concrete Pavement with Tied Concrete Shoulders with Dowel Bar across Transverse Joints

Trial thickness of slab, h = 0.27 m

Radius of relative stiffness, $l = \{\frac{Eh^3}{12k(1-\mu^2)}\}^{0.25}$

Therefore, l = 0.64002

Beta factor in the stress equations given in Appendix V.2 of IRC: 58 will be 0.66 for doweled transverse joints for carrying out Top-down Cracking analysis [1].

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in Tables below.

In order to compute the flexural stresses, mid-point of axle load class from axle load spectrum given in Table-1 is considered. The flexural stress in day time is computed using the stress charts given in IRC: 58-2015.

If the sum of Cumulative fatigue damage due to Bottom-up Cracking and Top-down Cracking is less than 1, the pavement slab is considered to be safe from large scale cracking.

Table 3: *Fatigue Life Analysis for Rear Single Axles for a period of 6-hour during day time when Temperature Gradient is Positive*

Expected Rep (ni)	Flex Stress (MPa)	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
478930	2.425	0.48989899	1301652	0.367940125
452323	2.35	0.474747475	3536902	0.127886778
478930	2.275	0.45959596	15221144	0.0314
345894	2.2	0.444444444	Infinite	0
79822	2.125	0.429292929	Infinite	0
53214	2.05	0.414141414	Infinite	0
79822	1.975	0.398989899	Infinite	0
79822	1.9	0.383838384	Infinite	0
79822	1.825	0.368686869	Infinite	0
79822	1.75	0.353535354	Infinite	0
79822	1.675	0.338383838	Infinite	0
372501	1.638	0.330909091	Infinite	0
2660724	**Fat Dam From Single Axles =**			**0.5271**

The design is safe since the fatigue life consumed is less than 1.

Table 4: *Fatigue Life Analysis for Rear Tandem Axles for a period of 6-hour during day time when Temperature Gradient is Positive*

Expected Rep (ni)	Flex Stress (MPa)	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
647443	1.775	0.358585859	Infinite	0
461192	1.725	0.348484848	Infinite	0
177382	1.675	0.338383838	Infinite	0
106429	1.625	0.328282828	Infinite	0
115298	1.575	0.318181818	Infinite	0
88691	1.525	0.308080808	Infinite	0
177382	1.475	0.297979798	Infinite	0
221727	1.425	0.287878788	Infinite	0
266072	1.388	0.28040404	Infinite	0
266072	1.362	0.275151515	Infinite	0
399209	1.338	0.27030303	Infinite	0
1507744	1.312	0.265050505	Infinite	0
4434641	**Fat Dam From Single Axles =**			**0**

The design is safe since the fatigue life consumed is less than 1.

Table 5: *Fatigue Life Analysis for Rear Single Axles for a period of 6-hour during night when Temperature Gradient is Negative*

Expected Rep (ni)	Flex Stress (MPa)	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
395118	1.8864	0.381090909	Infinite	0
373167	1.8267	0.369030303	Infinite	0
395118	1.767	0.356969697	Infinite	0
285363	1.7073	0.344909091	Infinite	0
65853	1.6476	0.332848485	Infinite	0
43902	1.5879	0.320787879	Infinite	0
65853	1.5282	0.308727273	Infinite	0
65853	1.4685	0.296666667	Infinite	0
65853	1.4088	0.284606061	Infinite	0
65853	1.3491	0.272545455	Infinite	0
65853	1.2894	0.260484848	Infinite	0
307314	1.25955	0.254454545	Infinite	0
2195100	**Fat Dam from Single Axle =**			**0**

The design is safe since the fatigue life consumed is less than 1.

Table 6: *Fatigue Life Analysis for Rear Tandem Axles for a period of 6-hour during day time when Temperature Gradient is Negative*

Expected Rep (ni)	Flex Stress (MPa)	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
534140	1.91625	0.387121212	Infinite	0
380484	1.85655	0.375060606	Infinite	0
146340	1.79685	0.363	Infinite	0
87804	1.73715	0.350939394	Infinite	0
95121	1.67745	0.338878788	Infinite	0
73170	1.61775	0.326818182	Infinite	0
146340	1.55805	0.314757576	Infinite	0
182925	1.49835	0.30269697	Infinite	0
219510	1.43865	0.290636364	Infinite	0
219510	1.37895	0.278575758	Infinite	0
329265	1.31925	0.266515152	Infinite	0
1243889	1.2894	0.260484848	Infinite	0
3658498	**Fat Dam from Tandem Axle =**			**0**

The design is safe since the fatigue life consumed is less than 1.

Table 7: *Fatigue Life Analysis for Rear Tridem Axles for a period of 6-hour during day time when Temperature Gradient is Negative*

Expected Rep (ni)	Flex Stress (MPa)	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
109755	1.8267	0.369030303	Infinite	0
109755	1.767	0.356969697	Infinite	0
65853	1.7073	0.344909091	Infinite	0
153657	1.6476	0.332848485	Infinite	0
219510	1.5879	0.320787879	Infinite	0
263412	1.5282	0.308727273	Infinite	0
351216	1.4685	0.296666667	Infinite	0
285363	1.41477	0.285812121	Infinite	0
109755	1.35507	0.273751515	Infinite	0
65853	1.29537	0.261690909	Infinite	0
65853	1.26552	0.255660606	Infinite	0
395118	1.20582	0.2436	Infinite	0
2195100	**Fat Dam from Tridem Axle =**			**0**

The design is safe since the fatigue life consumed is less than 1.

The cumulative fatigue damage consumed for Bottom-up cracking = 0.5271 + 0 = 0.5271

Similarly, the cumulative fatigue damage consumed for Top-down cracking = 0 + 0 + 0 = 0

Hence, the cumulative fatigue life consumed = 0.5271 + 0 + 0 + 0 + 0 = 0.5271 which is less than 1, the pavement is safe. Therefore, adopt the thickness of pavement slab as 270 mm.

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