Pavement Design and Analysis for Overlaying of Flexible to Rigid Pavement

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Abstract

Normally, overlays of existing pavements are used to increase the load-carrying capacity of an existing pavement or to correct a defective surface condition on the existing pavement. Of these reasons, the first requires a structural design procedure for determining the thickness of overlay, whereas the second requires only a thickness of overlay sufficient to correct the surface condition and no increase in load-carrying capacity is considered. The design method for overlays included in this chapter determines the thickness required to increase load-carrying capacity. The study section is a part of the National Highway No. 5 (NH-5) which is a busy national highway passing throughout Andhra Pradesh. The long-term objective of the project is to construct a highway link, which is an integral part of a National Highway System, which can serve the country's transportation needs in the future, before any actual construction can begin many factors affecting the population near by the proposed project and future road users have to be examined. All the Traffic surveys in the form of CVC, ALS are conducted and analyzed.

Key words: Axle Load Survey, Pavement Condition Survey, Benkelman Beam Survey, Overlay Design, Pavement Design.

1. Introduction

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. Improper design of pavements leads to early failure of pavements affecting the riding quality also.

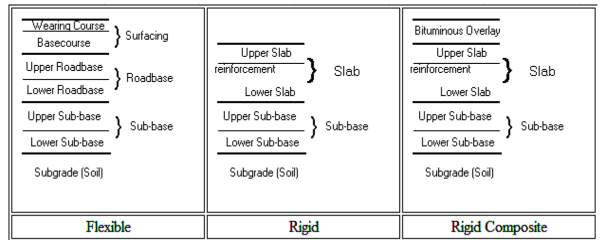

Figure 1: Pavement Types

Advantages of rigid pavements

- Low maintenance costs,
- Long life with extreme durability,
- High value as a base for future resurfacing with asphalt,
- Load distribution over a wide area, decreasing base and sub grade requirements,
- Ability to be placed directly on poor soils,
- No damage from oils and greases and
- Strong edges.

Disadvantages of rigid pavements

- High initial costs,
- Joints required for contraction and expansion,
- Generally rough riding quality and
- High repair costs.

Traffic loading in pavement design

Traffic is the most important factor in the pavement design. The key factors include contact pressure, wheel load, axle configuration, moving loads, load, and load repetitions.

Objectives

1. To conduct traffic volume surveys at Chilakapalem (Toll Gate).
2. To design a rigid pavement as per IRC: 58 – 2002.
3. To calculate the stresses of rigid pavement both by manual method (Westergaard's).

2. Traffic Survey

The Traffic Survey is categorized into two categories namely, Classified Volume Counts and Axle Load Surveys.

Classified Volume Count (CVC)

A classified count is conducted at location, which provides the information on the level of highway traffic along the project road. Vehicle classification is done as per Clause 6.2 of IRC SP: 19 – 2001. The number of observers needed to count the vehicles depends upon the number of lanes and the type of information desired. Traffic enumerators need to be posted on each arm. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. Manual count with 1 hour interval is used to obtain the traffic volume data. The data collection is carried out for 7 days in both directions.

Survey data is analyzed to bring out the following traffic characteristics,

i. Hourly Variation of traffic volume.
ii. Daily Variation of traffic volume.
iii. Directional Distribution

Directional Distribution is percentage ratio of total traffic in one direction to the total traffic in both directions.

iv. Average Daily Traffic (ADT)

The seven day traffic volume data collected at the survey locations is averaged out to arrive at the location wise ADT on the project road sections.

Axle Load Survey (ALS)

Axle load survey is needed to generate data for pavement design. Portable weigh bridges are very useful for this purpose.

This survey shall be carried out along with classified volume count survey. Number of days of survey will depend on project location, the type of project and the intensity and expected variation in traffic. This survey duration may vary between 24 hours and 3 days, but should be carried out at least for one day at the traffic count stations on a random basis for commercial vehicles. Buses may be omitted as their weight can be easily calculated and they do not result in excessive overloads.

Axle load survey is carried out for 24 hours to get the axle load spectrum and further analysis gives the Vehicle Damage Factor (VDF). This survey is done for the vehicles above 3 tones. An axle load pad is placed on the pavement and is connected to the digital meter which shows the weight of wheel passed. Every left wheel of the vehicle is passed over the pad. Vehicles will be stopped randomly. After 6 hours the axle load pad is shifted to the other lane of the pavement and the survey is continued for another 6 hours, later it is shifted back to same lane for another 6 hours. Wheel load is noted when wheel is passed over the pad. Axle load is obtained from wheel load.

3. Location of survey

The traffic studies include Classified Volume Count (CVC) and Axle Load Survey (ALS) which were conducted at Chilakapalem (Toll gate). The Figures 2 gives the route map of survey location and Figure 3 gives the location of the survey.

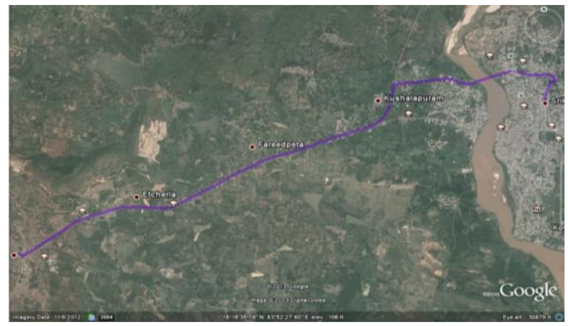

Figure 2: Route map of survey


Figure 3: Location of surveys

4. Traffic Surveys Data

Traffic studies include Classified Volume Count (CVC) and Axle Load Survey (ALS).

Classified Volume Count

Classified Volume Count conducted at location provides the information on the level of highway traffic along the project road. The seven day traffic data for both directions is shown in Table.

Based on observations obtained from traffic count survey, the average vehicles per hour (including commercial and non commercial vehicles) are 139 vehicles. Table 1 gives us the total number of vehicles per day.

The following figures are the few captures during the survey.

Table 1: Total number of vehicles day wise

Total number of vehicles			
Chilakapalem to Srikakulam		**Srikakulam to Chilakapalem**	
Day 1	3195	**Day 1**	3291
Day 2	3161	**Day 2**	3236
Day 3	3405	**Day 3**	3294
Day 4	3257	**Day 4**	3231
Day 5	3297	**Day 5**	3533
Day 6	3587	**Day 6**	3447
Day 7	3346	**Day 7**	3374

Axle load survey

Axle load survey was conducted at location provides the information on the level of highway traffic along the project road. The seven day traffic data for both directions is shown in Table 2.

Table 2: Axle load survey data

Single axle load		**Tandem axle load**	
Axle load class, tons	% of axle loads	Axle load class, tons	% of axle loads
20 - 22	0.44	35 - 40	1.74
18 - 20	1.18	30 - 35	1.29
16 - 18	2.71	25 - 30	0.65
14 - 16	5.56	20 - 25	0.50
12 - 14	13.26	15 - 20	0.94
10 - 12	24.24	10 - 15	1.26
> 10	44.50	> 10	1.74
Total	**91.88**	**Total**	**8.12**

5. Calculation of cement concrete pavement thickness

Flexural strength of cement concrete (F_{cr}) =45kg/sq. cm
Effective Modulus of sub grade reaction (k)=8kg/cub. cm
Elastic modulus of concrete (E) = 300000kg/sq. cm
Poission's ratio (μ) = 0.15
Coefficient of thermal expansion (α) = 0.00001/^{o}C
Tyre pressure (p) = 8kg/sq. cm
Rate of traffic increase (r) = 0.075
Spacing of contraction joints (L) = 4.5m
Width of slab (B) = 3.5m
Present traffic = 3600cvpd
Design life = 20years
Temperature difference (t) = 21^{o}C

Cumulative repetitions in design life = 56902351commercial vehicles

Design traffic = 14225588

Front axle of the vehicles carry much lower loads and causes small flexural stress in the concrete pavements and they need not be considered in the pavement design. Only the rear axles, both single and tandem, should be considered for the design. Therefore the total number of rear axles is 14225588. Assuming that midpoint of the axle load class represents the group, the total repetitions of the single axle and tandem axle loads are in Table 3.

Table 3: Total repetitions of the single and tandem axle

Single axle load		**Tandem axle load**	
Load in tonnes	Expected repetitions	Load in tonnes	Expected repetitions
21	62760	37.5	246856
19	167360	32.5	184096
17	384928	27.5	92048
15	790775	22.5	71128
13	1886982	17.5	133888
11	3447613	12.5	179912
> 11	6330387	> 12.5	246856

Trail 1
Trail thickness (h) = 32cm
Load safety factor = 1.2

Table 4: Trail 1 fatigue life consumed

Axle load (AL), tonnes	AL x 1.2	Stress kg/sq. cm from charts	Stress ratio **(**Clause 3.3.3.1[3]**)**	Expected repetitions	Fatigue life, N **(**Clause 3.3.3.1[5]**)**	Fatigue life consumed (ratio)
Single axle						
21	25.2	25.0	0.56	62760	94100	0.67
19	22.8	23.0	0.51	167360	485184	0.34
17	20.4	21.0	0.47	384928	5202474	0.07
15	18.0	18.0	0.40	790775	Infinite	0.00
13	15.6	16.0	0.36	1886982	Infinite	0.00
11	13.2	12.0	0.27	3447613	Infinite	0.00
Tandem axle						
37.5	45.0	20.0	0.44	246856	1001022592	0.00025
32.5	39.0	19.0	0.42	184096	Infinite	0.0
27.5	33.0	15.5	0.34	92048	Infinite	0.0
22.5	27.0	10.5	0.23	71128	Infinite	0.0
17.5	21.0	7.0	0.16	133888	Infinite	0.0
12.5	15.0	6.0	0.13	179912	Infinite	0.0
Cumulative fatigue life						**1.08613**

Since the cumulative fatigue life is not <1 hence the assumed thickness is unsafe.

Trail 2
Trail thickness (h) = 33cm
Load safety factor = 1.2

Table 5: Trail 2 fatigue life consumed

Axle load (AL), tonnes	AL x 1.2	Stress kg/sq. cm from charts	Stress ratio (Clause 3.3.3.1[3])	Expected repetitions	Fatigue life, N (Clause 3.3.3.1[5])	Fatigue life consumed (ratio)
Single axle						
21	25.2	24.0	0.53	62760	229127	0.27
19	22.8	22.0	0.49	167360	1286914	0.13
17	20.4	20.0	0.44	384928	Infinite	0.00
15	18.0	17.0	0.38	790775	Infinite	0.00
13	15.6	15.0	0.33	1886982	Infinite	0.00
11	13.2	12.0	0.27	3447613	Infinite	0.00
Tandem axle						
37.5	45.0	20.0	0.44	246856	Infinite	0.00
32.5	39.0	19.0	0.42	184096	Infinite	0.00
27.5	33.0	15.5	0.34	92048	Infinite	0.00
22.5	27.0	10.5	0.23	71128	Infinite	0.00
17.5	21.0	7.0	0.16	133888	Infinite	0.00
12.5	15.0	6.0	0.13	179912	Infinite	0.00
Cumulative fatigue life						0.40396

Since the cumulative fatigue life is <1 hence the assumed thickness is safe.

Check for temperature stress

L = 450m
B = 350m
l = 103.5cm
L/l = 4.34783
C = 0.55

Edge warping stress = 17.325 kg/sq. cm

Total temperature warping stress and the highest axle load stress = 42.525 kg/sq. cm

Since the total temperature stress is <45 (Flexural strength of cement concrete) hence the assumed thickness is safe.

So the pavement thickness of 33cm is safe under the combined action of wheel load and temperature.

6. Calculation of interior, edge and corner stresses

Wheel Load (P) = 10200kg

Modulus of Elasticity (E) = 300000kg/sq. cm

Pavement Thickness (h) = 33cm

Poission's Ratio (**μ**) = 0.15

Modulus of Sub Grade Reaction (k) = 8kg/cub. cm

Radius of Contact area (a) = 14cm

Radius of relative stiffness (l) = 103.53cm

a/h = 0.42

b = 15.18cm

Stress at the interior (S_i) = 14.89kg/sq.cm

Stress at the edge (S_e) = 19.79kg/sq.cm

Stresses at the corner (S_c) = 17.68kg/sq.cm

7. CONCLUSIONS

The following conclusions have been drawn out from the study,

1. From Traffic Surveys,
   - It is observed that 3600 vehicles (2 wheelers to multi axle vehicles) are moving in each direction per day.
   - From Classified Volume Count Survey (CVC), the average numbers of

commercial vehicles are 139 vehicles per hour.

- Directional distribution of traffic is observed to be same (approximately) in each direction.

2. The pavement thickness is computed as 33cm with load safety factor as 1.2, rate of traffic increase as 7.5% and design life of 20years as per IRC: 58-2002.
3. The stresses on the designed pavement thickness were calculated by Westergaards equation and were found as follows:
   - Stress at the interior (S_i) = 14.89kg/sq. cm
   - Stress at the edge (S_e) = 19.79kg/sq. cm
   - Stresses at the corner (S_c)=17.68kg/sq. cm

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