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Traffic Analysis and Design of Flexible Pavement With Cemented Base and Subbase

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Abstract: The National Highways are the backbone of the road infrastructure and the major roads in India. They carry most of India's freight and passenger traffic. National highways (NH) presently totalling to a length of about 77000 km, carry nearly 40 per cent of the traffic, and are the most important category of roads. Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the load. The service life of a flexible pavement is typically designed in the range of 15 to 20 years. Required thicknesses of each layer of a flexible pavement varies widely depending on the materials used, magnitude and number of repetitions of traffic loads, environmental conditions and the desired service life of the pavement. The latest design method of IRC: 37-2012 is mechanistic approach of design and incorporates the use of non conventional kinds of materials also in the base and sub-base. The stretch of NH-1 between Karnal to Kurukshetra is taken for the study. The required data are collected from NHAI office Ambala which include previous year's traffic data, CBR value and VDF. Using the data, the cumulative design traffic in standard axles is calculated for the design life. The traffic data have been analyzed to find annual and monthly variation of traffic. Finally using the cumulative standard axles and effective CBR value, the pavement has been designed for period of 15 years, using IRC 37:2012 guidelines of flexible pavement design.

Keywords: Design; Flexible pavement; traffic; standard axles; thickness of pavement; CBR.

1. INTRODUCTION

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. Each layer receives the loads from the above layer, spreads them out, and then passes on these loads to the next layer below. The purpose of design is to provide a pavement structure which is capable of withstanding the traffic loads which would be coming onto it during the design life of a pavement. The design involves determining the thickness

of component layers based on the strength characteristics of the pavement materials. India is now a total about 33 lakh km is colossal. It requires not only adequate resources but also proper planning and innovative way of maintenance.

National highways (NH) presently totalling to a length of about 77000 km, carry nearly 40 per cent of the traffic, and are the most important category of roads. NH 1 is a National Highway in Northern India that links the national capital New Delhi to the town of Attari in Punjab near the India–Pakistan border. This was a part of Grand Trunk Road of Sher Shah Suri that ran from Lahore to Bengal, built on earlier roads that existed from time immemorial. This is one of the longest and oldest highways of India. The NH 1 passes through Amritsar, Jalandhar, Phagwara, Ludhiana, Rajpura, Ambala, Kurukshetra, Karnal, Panipat, Sonepat and Delhi. It runs for a distance of 456 km. The Delhi–Lahore Bus travels on NH 1 in India. It does not have a uniform laning. From the Wagah Border (between India and Pakistan) through Amritsar up to Jalandhar it is 4-laned. From Jalandhar up to the border between Haryana's Sonepat and the national capital Delhi, it is 6-laned. Its entire stretch in Delhi is 8-laned. This stretch comes under the northern highway i.e. Karnal to Kurukshetra (NH1), data available from Karnal toll plaza. Road Distance or driving distance from Karnal to Kurukshetra is 38 kms. The total travel time is approximately 35min(s); which may vary depending upon the road and traffic conditions.

2. OBJECTIVES OF STUDY

a. Collecting traffic data for the study stretch which would be used in the design
b. Analyzing the data to extract meaningful estimates of yearly and monthly variation of traffic.
c. Finding pavement composition from available data based on the IRC: 37-2012 guidelines [1].

3. METHODOLOGY

Indian Roads Congress Method: Indian Roads Congress Method is based on an empirical method where the thickness value of a pavement used was read from the CBR value of the sub-grade. From the design chart the total pavement thickness could be read for a given CBR value and cumulative standard axle load. The design procedure of the pavements based IRC: 37-2012 guidelines [1].

I. Selection of a trial pavement including the number of layers and thicknesses of all layers overlying the sub grade.
II. Selection of design loading (traffic) and determination of vertical stress (i.e., tire contact pressure) and radius of the tire contact area.
III. Determination of the elastic parameters of asphalt which include flexural modulus and Poisson's ratio.
IV. Determination of the cemented base and cemented sub base elastic parameters of the sub grade elastic modulus and Poisson's ratio.
V. Determination of the elastic parameters of the granular sub-layer as mentioned in step (IV) and which include elastic modulus and Poisson's ratio.
VI. Using the IITPAVE software to calculate the Actual Horizontal Tensile Strain in Bituminous layer and Actual Vertical Compressive Strain on sub-grade.

4. TRAFFIC GROWTH RATE (r)

As per Clause 5.5.4 of 4 laning Manual of Specifications and Standards IRC SP 84 – 2009 (Published by Planning Commission of India) [2], it is said to adopt a realistic value of growth rate for pavement design provided that the annual growth rate of commercial vehicles shall not be less than 5%. Considering this clause 5% growth rate is adopted for calculating the design traffic as given in [1].

5. VEHICLE DAMAGE FACTORS (F)

The Vehicle Damage Factor values for the commercial vehicles like LCVs, Bus, 2-Axle trucks, 3-Axle trucks and Multi Axle Vehicles (MAV) have been mentioned in Table 1. The VDF values for the Panipat-Jalandhar route have been adopted for the calculations in the study according to available NHAI data [3].

Table 1 Vehicle Damage Factors for different vehicle types

Vehicle Type	Vehicles Damage Factors	
	Panipat-Jalandhar	Jalandhar-Panipat
Bus	0.975	1.12
LCVs	0.480	0.31
2-Axle Trucks	4.48	3.50
3-Axle Trucks	5.97	5.80
MAV	8.11	2.67

6. LANE DISTRIBUTION (D)

The Lane distribution is a realistic assessment of distribution of commercial traffic by direction as it affects the total equivalent standard axle load. It is taken as 0.45 from clause 4.5.1 of IRC 37-2012.

7. TRAFFIC VOLUME

The previous year traffic data for Karnal Toll Plaza was collected from the NHAI office. This data was analyzed and following observations were made. Figure 1 shows the yearly variation in commercial traffic. The figure 1 shows that the minimum commercial traffic was observed in the year 2009-2010 and the maximum in the year 2010-2011.

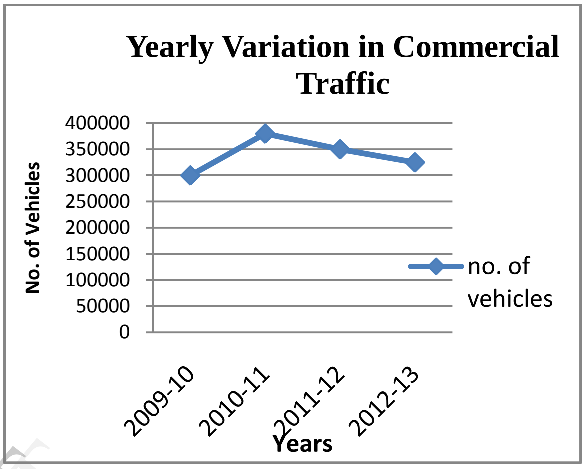

Figure 1 Yearly variation of commercial vehicles (May – Apr)

Figure 2 shows the yearly variation in LCV. The figure 2 shows that the minimum LCV were observed in the year 2009-2010 and the maximum in the year 2010-2011.

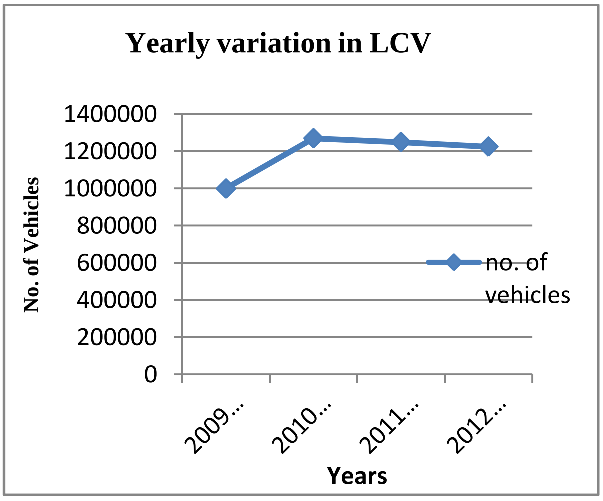

Figure 2 Yearly variation of LCVs (May - Apr)

Figure 3 shows the yearly variation in Truck/Bus. The figure 3 shows that the minimum Truck/Bus were observed in the year 2009-2010 and the maximum in the year 2010-2011.

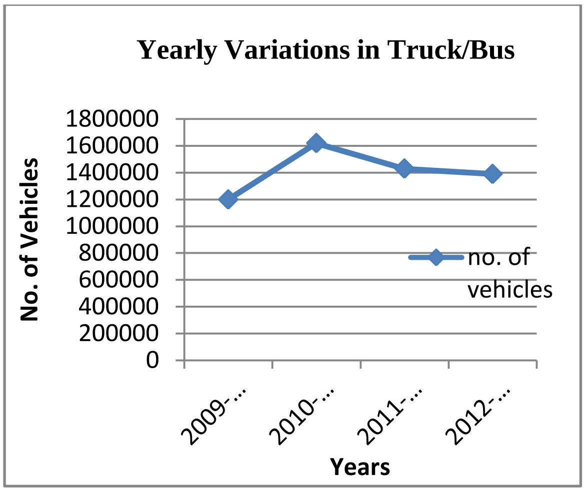

Figure 3 Yearly variation of truck (May - Apr)

Figure 4 shows the yearly variation in Heavy Construction Machine/Earth Moving Equipment. The figure 4 shows that the minimum HCM/EME was observed in the year 2009-2010 and the maximum in the year 2012-2013.

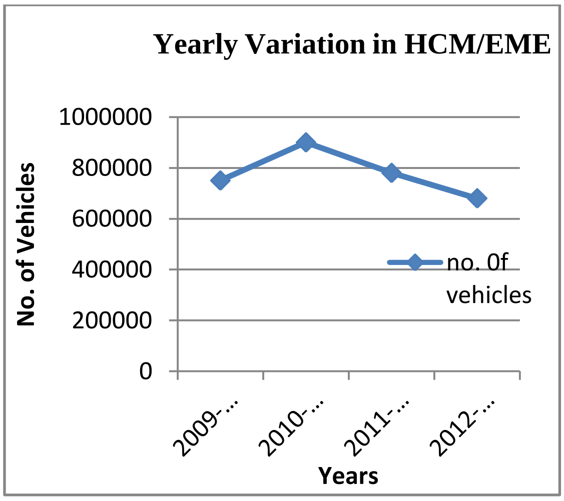

Figure 4 Yearly variation of HCM/EME (May - Apr)

Figure 5 shows the yearly variation in Car. The figure 5 shows that the minimum Cars were observed in the year 2009-2010 and the maximum in the year 2012-2013.

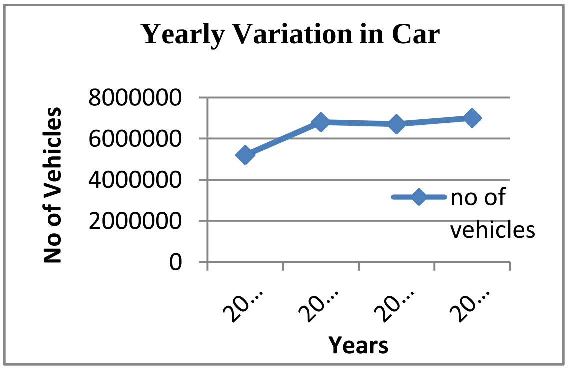

Figure 5 Yearly variation of Jeep/Car (May - Apr)

Figure 6 shows the monthly variation in LCV. The figure 6 shows that the minimum LCV were observed in the month of February and the maximum in December.

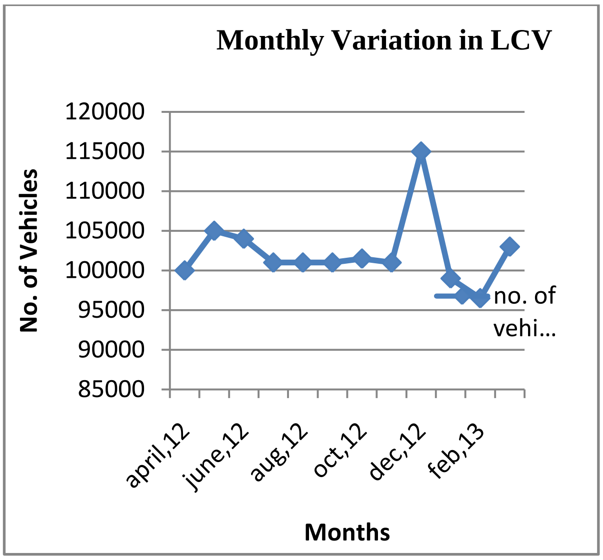

Figure 6 Monthly variation of Jeep/Car

Figure 7 shows the monthly variation in Truck/Bus. The figure 7 shows that the minimum Truck/Bus were observed in the month of February and the maximum in December.

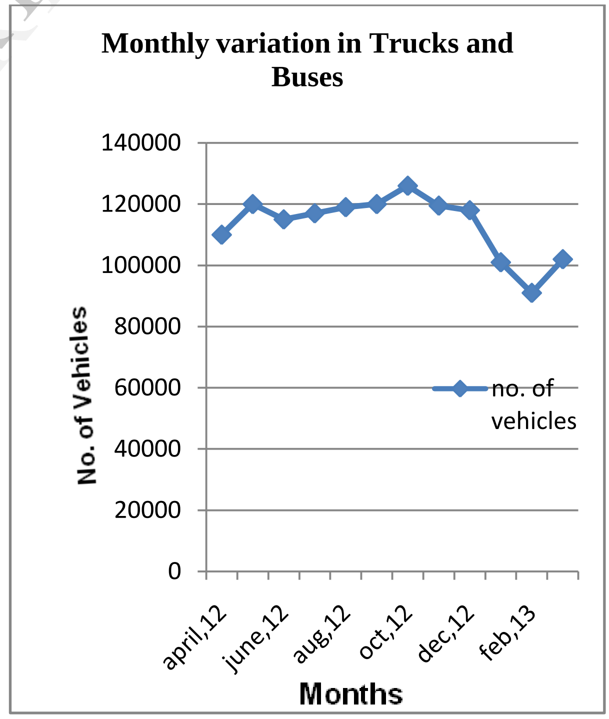

Figure 7 Monthly variation of Truck/Bus

Figure 8 shows the monthly variation in Car. The figure 8 shows that the minimum Car was observed in the month of September and the maximum in June.

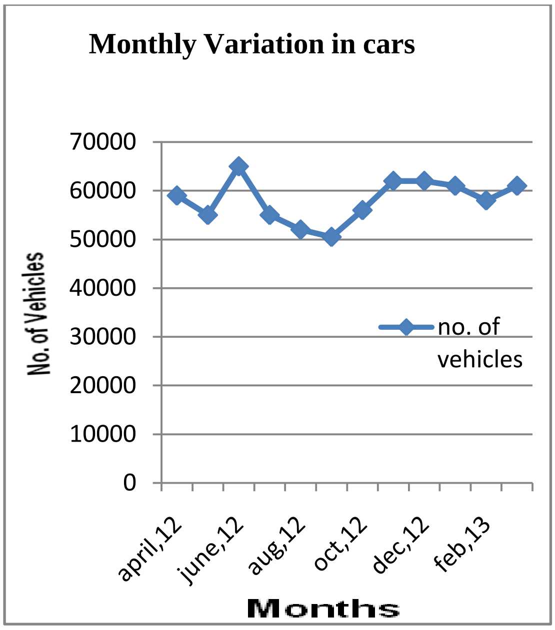

Figure 8 Monthly variation of Car

8. DAILY TRAFFIC VOLUME

The initial traffic survey data was available for the year 2014. Estimate of initial daily average traffic flow for any road should normally be based on at least 7 days, 24 hour classified traffic counts. Table 2 shows the daily traffic count observed at the Karnal Toll plaza in the year 2014. For this study only the counts for bus, Trucks (2 and 3 axles) and MAV were considered.

Table 2: Daily Traffic Volume Counts observed at Karnal Toll Plaza (Km 98)

Year	Bus		Truck			
	Mini	Standard	LCV	2-A	3-A	MAV
2014	380	2570	4570	4320	1970	730

8.1 Design Traffic – Cumulative Million Standard Axles

Based on the above said parameters the design traffic in terms of CMSA is computed for a design period (n) of 15 years.

$$N = \frac{365\times[(1+r)^{n}-1]}{r} \times A \times D \times F \;\ldots\ldots\ldots\ldots\ldots\ldots\; (1)$$

Where,

N: The cumulative number of standard axles to be catered for in the design in terms of MSA A: Initial traffic in the year of completion of construction in terms of number of commercial vehicles per day.

D: Lane distribution factor.

F: Vehicle Damage Factor (VDF).

n: Design life in years.

r: Annual growth rate of commercial vehicles (for 5% annual growth rate r=0.05).

Table 3 Design Traffic MSA

Location	Design Traffic for 15 Years
Karnal Toll Plaza (KM 98)	149.23 (Says 150)

8.2 Design Thickness of Conventional Layer

A sub grade effective CBR of 7.3% is adopted for the design. If soil having an effective CBR of 7.3% is not available, suitable stabilization techniques shall be adopted to improve the sub-grade strength. Crust Composition is obtained from Pavement Design Catalogue of IRC: 37-2012 for 7.3% CBR and for Design Traffic in MSA. Crust Composition is given in Table 4.

Table 4 Crust Composition for Conventional materials

Design Period	15
Effective CBR	7.3
BC (mm)	50
DBM (mm)	140
WMM (mm)	250
GSB (mm)	230
TOTAL (mm)	670

8.3 Design Thickness of Non-Conventional Layer

In place of conventional layers of GSB and WBM/WMM in sub-base and base course of the pavement, cement treated base and cement treated sub-base layers can also be provided. A crack relief layer of wet mix macadam of thickness 100 mm sandwiched between the bituminous layer and treated layer is much more effective in arresting the propagation of cracks from the cementitious base to the bituminous layer, given in Table 5.

Table 5 Crust Composition for Non-conventional materials

Design Period	15
Effective CBR	7.3
BC (mm)	50
DBM (mm)	50
Aggregate Inter-layer (mm)	100
CT-Base (mm)	120
CT-Sub-Base (mm)	250
Total (mm)	570

8.4 Cross Check for Safety

The actual values of strain as calculated using IITPAVE software. The comparison of these values is tabulated below:

Table 6 Horizontal and Vertical Strains

Location/Type of Strain	Allowable Strain	Actual Strain From IITPAVE	Remarks
Horizontal Tensile Strain in Bituminous Layer	$187.78*10^{-06}$	$132.6*10^{-06}$	Safe
Vertical Compressive Strain on sub-grade	$291.70*10^{-06}$	$222.1*10^{-06}$	Safe
Tensile Strain in Cementitious Layer	$57.12*10^{-06}$	$54.0*10^{-06}$	Safe

9. CONCLUSION

We can conclude that the design of Flexible Pavement using non-conventional layer requires less thickness of pavement and less quantity of bitumen (which is one of costlier material of pavements, saving of bitumen layer up to 47 %) which leads to less usage of material specially the aggregate which is good for environmental point of view. Saving of bitumen and more usage of cement is a better practice as cement is abundantly available which bitumen depends on the imports. The traffic and sub-grade soil characteristics are necessary in order to design a pavement. The IRC method of design can be used to find the total pavement thickness due to its simple approach. A decline in the yearly variation of commercial vehicles like bus, truck and HCM/EME was observed from the data analysis of traffic volume data. An increase in the yearly volume of cars was also observed from the analysis. The volume of commercial traffic has decreased in 2013 as compared to previous years probably due to imposition of heavy toll tax and construction work of widening of road from 4 to 6 lanes going on the road.

10. REFERENCES

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2. IRC: SP: 84 – "Manual of specifications & standards for Four Laning of Highways through Public Private Partnership" New Delhi, 2009.
3. National Highways Authority of India, 2007. *Feasibility for 6-laning of NH-1 from Panipat Jalandhar in the State of Haryana/Punjab on DBFO basis.* New Delhi.