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Pavement Design of National Highway A Case Study on Reducing Pavement Thickness

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ABSTRACT

Design for new pavement is worked out in accordance with prevalent practices in the country. The design of new flexible pavement is carried out as per IRC: 37-2001 [1]. The pavement design is done using Mechanistic-Empirical principles with non conventional materials i.e. laying cemented base/sub-base layer.

Keywords - **Pavement Design, Mechanistic-Empirical principles.**

I. INRODUCTION

The National Highway, NH-6, from Kolkata in West Bengal to Hazira Port in Gujarat is a major connecting link between West Bengal, Orissa, Chhattisgarh, Maharashtra and Gujarat. The project road stretches from Saraipali-Pitora-Tumgaon-Arang of NH-6 in the districts of Mahasamund & Raipur in the state of Chhattisgarh.

The Project in study starts at Chainage km 160 Manra Village and ends at Chainage km 180 Janpalli Village which is 92 km from Raipur, the Capital City of Chhattisgarh State. The project is located at approximately between **N: 21° 19’ 20’’ E: 83° 30’ 46” and N: 21° 11’ 36’’ E: 81° 58’ 19”** and passing through the Districts of Mahasamund and Raipur.

II. PAVEMENT DESIGN APPROACH

The Flexible Pavement has been modeled as a three-layer structure. Pavement design [1] has been based on CBR values of sub-grade soil, vehicle damage factor as consequent to number of commercial vehicles on the road corridor and considering life of the project as 15 years.

2.1 Traffic Surveys

Classified traffic volume count survey [2] is carried out at Km 173 along the project road in November 2011. The summary of the CVPD on the project road is given in Table 1.

TABLE 1
Base Year Traffic (AADT)

Direction	Buses	LCV	2-AT	3-AT	MAV
Towards Arang	7	116	205	869	302
Towards Saraipali	7	112	197	836	290
Total	**14**	**228**	**402**	**1705**	**592**

2.2 Lane Distribution (L)

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 0.75 from clause 3.3.5 of IRC 37-2001.

2.3 Directional Distribution (D)

The value of 0.50 has been adopted as the directional distribution factor in designing the pavement. This is established from volume count data were vehicle distribution on either direction is more or less equal. The directional distribution is given in Table 2.

TABLE 2
Directional Distribution

Direction	Distribution of Traffic	Percentage of Commercial Vehicles
Towards Arang	50.40	49.28
Towards Saraipali	49.60	50.72

2.4 Rate of Growth (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), it is said to adopt a realistic value of growth rate for pavement design which is obtained from the analysis as out lined in IRC: 108, 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.

2.5 Vehicle Damage Factor (F)

Axle load spectrum study is organized at Location km. 173.000 to estimate the Vehicle Damage Factor, which is the multiplier to convert the number of commercial vehicles of different axle loads and axle configuration to the number of standard axle load repetitions. The values are derived from the "fourth power rule" to achieve the standard axle load for the respective type. Maximum VDF value observed in each direction is considered for the pavement design. The summary of Vehicle damage factors are given in Table 3.

TABLE 3
Summary of Vehicle Damage Factors

Direction	Vehicle Damage Factor (VDF)					
	Bus	Mini Bus	LCV	2-AT	3-AT	MAV
Towards Arang	1.158	0.22	0.416	4.558	5.994	10.924
Towards Saraipalli	1.198	0.183	0.404	3.365	6.02	9.381
Maximum	**1.198**	**0.22**	**0.416**	**4.558**	**6.02**	**10.924**

2.6 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 10 and 15 years, using (1) by assuming that the project road will be open to traffic in the year 2015.

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times L \times D \times F \qquad (1)$$

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 construction in terms of no. of commercial vehicles per day
L : Lane Distribution Factor
D : Direction Distribution Factor
n : Design Life in years
r : Annual Growth Rate of commercial vehicles.
F : Vehicle Damage Factor

The traffic in the year of construction has been estimated using the following formula (2)

$$A = P\,(1+r)^x \qquad (2)$$

Where,

P : Number of commercial vehicles as per last count
x : Number of years between the last count and the year of completion of construction (3 years)

Based on the above mentioned parameters, the design traffic in terms of CMSA is computed and is summarized in Table 4

TABLE 4
Design Traffic (MSA)

Chainage	Design Traffic - 10 Years	Design Traffic - 15 Years
km. 160.000 - km. 180.000	37.25 (Say 40)	63.92 (Say 65)

2.7 Crust Particulars

A sub grade CBR of 10% is adopted for the design. If soil having a CBR of 10% is not available, suitable stabilization techniques shall be adopted to improve the sub grade strength. With the above input the following crust composition is arrived for new/widening portions as per IRC: 37-2001. Crust Composition is obtained from Pavement Design Catalogue of IRC: 37-2001 for 10% CBR and for Design Traffic in MSA. Crust Composition is given in Table 5.

TABLE 5
Crust Composition for New/Reconstruction Section

Existing Chainage	Period	CBR	BC (mm)	DBM (mm)	WMM (mm)	GSB (mm)	Total (mm)
km. 160.000 - km. 180.000	15 Years	10%	40	120	250	200	610

III. REDUCING THE THICKNESS OF DBM LAYER BY CONSTRUCTING CTB LAYER

3.1 Design of Non-Conventional Flexible Pavement

The design exercise has been carried out using Mechanistic Empirical Principles with non-conventional material that is by using the cemented subbase. The assumptions and procedure adopted for the Mechanistic Empirical design approach are briefly discussed below.

3.2 Materials, Assumptions and Inputs

3.2.1 BT Layers**:** VG-40 or Modified bitumen of equivalent stiffness is considered for bituminous layers (BC and DBM) with a stiffness of 3000 Mpa.

3.2.2 WMM: This layer shall be mixed with 1-2% of bitumen emulsion, to have a better stability during compaction after the construction. It is a common phenomenon that when cemented base/sub-base is used, the cemented layer undergoes fatigue failure first and then the fatigue cracking starts propagating through the bituminous layers. Hence a WMM layer will be considered between the BT layer and cemented base. It will act as a cushion and delays the propagation of reflection cracks into the BT layer.

3.3 Cement Treated GSB (CTB)

The Granular Sub-base shall be mixed with cement of about 2% to 4%. Cement Treated Bases normally have higher initial stiffness's in the order of 4500 to 5500 Mpa (with UCS Value of 4.5-5.5 Mpa), however, after fatigue cracking, the stiffness drops substantially to the order of about 10% of initial modulus (AUSTROADS) and hence a stiffness of 500 Mpa has been considered for pavement design.

3.4 Untreated GSB

It acts as a drainage layer and shall be extended over the full formation width. Elastic modulus will be calculated using the relations given in IRC 37-2001.

3.5 Subgrade

The elastic modulus of subgrade will be estimated as per IRC 37-2001.

3.6 Failure Criteria

The Fatigue cracking at the bottom of the BT and rutting on the top of subgrade are considered as failures which govern the design.

3.6.1 Fatigue Life of Pavement

As per Annexure 1 of IRC 37-2001, the fatigue life terms of MSA is worked out using the following (3).

$$N_F = 2.21 \times 10^{-4} \times [\frac{1}{\epsilon_r}]^{3.89} \times [\frac{1}{E}]^{0.854} \quad (3)$$

Where,

N_f = Number of Cumulative standard axles to produce 20% cracked surface area.

ϵ_r = Tensile Strain at the bottom of the BT Layer.

E = Elastic Modulus of BT Layer.

3.6.2 Rutting Life of Pavement

As per Annexure 1 of IRC 37-2001, the Rutting life terms of MSA is worked out using the following (4).

$$N_R = 4.1656 \times 10^{-4} \times [\frac{1}{\epsilon_z}]^{4.5337} \quad (4)$$

Where,

N_r = Number of Cumulative standard axles to produce rutting of 20 mm.

ϵ_z = Vertical Subgrade Strain.

E = Elastic Modulus of BT Layer.

3.7 Flexible Pavement Composition with Cemented Sub-base

Based on the above, the crust composition arrived through Mechanistic Analysis is summarized in Table 6.

TABLE 6
Crust Composition for Flexible Pavement with cemented Sub-base for 15 Years

Section	Design Traffic 15 Years (MSA)		Pavement Crust (mm)					
	BT - Layer	Granular Layer	BC	DBM	WMM	CTB	GSB	Total
Km. 160 to Km. 180	65	155	40	65	100	100	200	505

3.8 Cross Check for Safety

Design MSA is 65 as per Table 4 and it is cross checked for 70 MSA as in Table 7 and crust for main carriageway is given in Table 8.

TABLE 7
Assumed Traffic (MSA)

Design Traffic in MSA	70
Design CBR, %	10

TABLE 8
Crust for Main Carriageway

Crust for Main Carriageway	
BC (mm)	40
DBM (mm)	65
WMM (mm)	100
Cemented GSB (mm)	100
Untreated GSB (mm)	200
Sub Grade (mm)	500

As per IRC 37-2001 Annexure I, it is safe as stated in Table 9

TABLE 9
Horizontal and Vertical Strains

Description	Allowable Strains	Actual Strain
Horizontal Strain at the bottom of the Bituminous Layer	1.906E-04	1.839E-04
Vertical Strain at the top of the subgrade	4.383E-04	3.421E-04

IV. CONCLUSION

This pavement design study will help, if non conventional pavement design is adopted in the construction of pavement, there will be improved performance of the pavement thus increasing the life and leading to financial savings.

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