FLEXIBLE PAVEMENT DESIGN OF CHENNAI OUTER RING ROAD PHASE 2

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Abstract - *As Traffic increases day by day we need to design a flexible pavement in order to reduce the traffic and to find the shortest route . The aim of this study is to identify new parameters and design conserns in design of flexible pavement. Design of flexible pavement depends on the strength of subgrade soil (CBR value) and the design traffic in terms of cumulative number of standard axles. The* ***Chennai Metropolitan Area(CMA)*** *is the fourth largest metropolitan area in India. Chennai city has four major arterial roads i.e.* ***NH- 5, NH-205, NH-4, and NH-45*** *which connects Chennai port and other industrial areas in CMA area. Two ring roads are existing for connecting these radial roads . This project briefly explains the concept of laying , designing and executing a roadway project by properly analyzing all the parameters.*

Keywords: Flexible pavement, Traffic Growth, Design, Overall thickness

1. INTRODUCTION

Pavement is the actual travel surface especially made durable and serviceable to withstand the traffic load commuting upon it. Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. All hard road pavements usually fall into two broad categories namely: Flexible and rigid pavements.

The area selected for this study was the Chennai Outer Ring Road Phase-II from connecting Nemilicheri in NH 205 ToMinjur in Thiruvottiyur– Ponneri–Panchetti (TPP) road". The **Chennai Metropolitan Area(CMA)** is the fourth largest metropolitan area in India. The CMA consists of the metropolitan city of Chennai and its suburbs such as Kanchipuram and Tiruvallur district respectively. CMA area encompassing 1189 sq km around the city and the **Chennai Metropolitan Development**

Authority(CMDA) has been designated as the authority to plan the growth of the city and the area around it .Chennai city has four major arterial roads i.e. **NH- 5, NH-205, NH-4, and NH-45** which connects Chennai port and other industrial areas in CMA area.

This has caused lot of strain on the port roads through which not just container trucks but now commercial vehicles also pass through, thus worsening the existing conditions of the facility and there is a need for examining the performance of the facility. Also, an influx of traffic from the city and away from it passes through the relatively less reinforced road pavement which may lead to its steady deterioration. If a thorough analysis is not done and suitable rehabilitation measures aren't provided, there shall be increased frequency of vehicular related accidents and other undesirable effects. Keeping these issues in mind, the aim of this study is to analyze the capacity of existing carriageway and also the design methodology adopted for the strengthening and rehabilitation of the same.

2. BACK GROUND AND METHODOLOGY

The Initial cost is generally the major factor in deciding the type of the pavement in design. It is often considered that flexible pavements are cheaper than the rigid pavements. In fact this is not always the case. In the last decade the price of bitumen, the main ingredient of flexible pavement, has increased because of the increase in crude oil prices.

Goliya et. al. (2013) suggested that flexible pavements are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. Bruhaspathi (2012) says that if non-conventional pavement design is adopted in the construction of pavement, there will be improved performance of the pavements thus increasing the life and leading to financial savings. Nantung et. al. (2008) suggested that the traffic data includes average annual daily traffic, average monthly and hourly traffic, adjustment factors, axle load spectra, and axle weight and spacing values. Various steps involved in the present study are:

1. Axle load survey which involves survey of types and number of vehicles entering the port road.
2. Determination of necessary parameters required (design traffic, CBR value) by performing various tests on soil.
3. Design of flexible pavement according to IRC 37: 2012
4. Forecasting the traffic data and design of flexible pavement for the horizon year.

5. Analyzing the existing pavement and checking its suitability for the horizon year.
6. Design of overlay thickness.

Road Owner	TNRDC
Road Length	33.1
No of Lanes	6
Road Width	12.5 (On both sides)
Material Of Construction	Gravel, sand, aggregate, borrow material, bitumen, high yield strength steel, cement
Paved Shoulder	1m on both sides
Availability of Bus shelter	Provided at suitable intervals considering the habitat area
Availability of Parking bay	Separate parking bays were provided for container lorries

4. DESIGN APPROACH AND DETAILS

The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 degree Celsius. Using the following input parameters, appropriate designs were chosen for the given traffic and soil strength: 1.) Design traffic in terms of cumulative number of standard axles; and2.) California Bearing Ratio value of subgrade.

A.DESIGN TRAFFIC

In case of a new road, an approximate estimate should be made of traffic that would pay on the road considering the number of villages and their population along the road alignment and other socio-economic parameters. Traffic counts can be carried out on an existing road in the vicinity with similar conditions and knowing the population served as well as agricultural/ industrial produce to be transported, the expected traffic on the new proposed road can be estimated.The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information

- Initial traffic in terms of CVPD:Initial traffic is determined in terms of commercial vehicles per day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tons or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts.

- Traffic growth rate during the design life: Traffic growth rates can be estimated (i) by studying the past trends of traffic growth, and (ii) by establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted.

- Design life in number of years: For the purpose of the pavement design, the design life is designed in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and other categories of roads for 10 to 15 years.

- Vehicle damage factor (VDF): The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the axle configuration, axle loading, terrain, type of road, and from region To region. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC 37: 2001. The exact VDF values are arrived after extensive field surveys.

1. Distribution of commercial traffic over the carriage way: A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

i. Single lane roads: Traffic tends to be more channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.

ii. Two-lane single carriageway roads: The design should be based on 75 % of the commercial vehicle sin both directions.

iii. Four-lane single carriageway roads: The design should be based on 40 % of the total number of commercial vehicles in both directions

iv. Dual carriageway roads: For the design of dual two-lane carriageway roads should be based on 75 % ofthe number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway the distribution factor will be 60 % and 45 % respectively.

Subgrade Strength Evaluation

California Bearing Ratio (CBR) is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. This test is a penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

C.B.R. = Test load/Standard load * 100

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%.

TABLE 1

Standard load Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

This test method covers the determination of the California Bearing Ratio (CBR) of pavement subgrade, sub-base, and base course materials from laboratory compacted specimens. The test method is primarily intended for, but not limited to, evaluating the strength of materials having maximum particle size less than 3/4 in. (19 mm).A large experience database has been developed using this test method for materials for which the gradation has been modified, and satisfactory design methods are in use based on the results of tests using this procedure. Past practice has shown that CBR results for those materials having substantial percentages of particles retained on the 4.75 mm sieve are more variable than for finer materials. Consequently, more trials may be required for these materials to establish a reliable CBR.

The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater that at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design.

C. Projection of normal traffic based on elasticity of transport demand

In this method the passenger vehicle and goods vehicles were separately treated. For deriving the growth rates of passenger vehicles, population growth and real per capita income growth were used as parameters. In the case of goods vehicles, the growth rate was considered to be dependent upon the growth in agriculture, industrial, mining and trade and commerce sectors. From the point of view of the stud. The state level data is moderated to reflect conditions in the road influence area by comparison with district-wise factors, there by accounting for the impact of the following:

Macro-economic scenario growth rates and composition of NSDP; Road influence area economy, sectoral production and potential; Spatial distribution of economic activities along the corridor; Road influence area, population size and urbanization; Reduction in truck overloading and changes in trucking fleet; Increase in vehicle productivity due to improved road condition; Shift in personalized travel modes over time; and Changes in the inter-modal share of passenger and freight demand. The above mentioned factors are utilized to generate the transport demand elasticity coefficients presented in Table 2.

TBLE 2

TRANSPORT DEMAND ELASTICITY COEFFICIENT BASED ON NSDP

Mode	2005	2010	2015	2020	2025
Car	1.8	1.7	1.6	1.5	1.4
Buses	1.5	1.4	1.3	1.2	1.2
Trucks	1.6	1.5	1.4	1.1	1.1

The elasticity coefficients recommended by World

Banks are summarized in Table 3.

TABLE 3

TRANSPORT COEFFICIENT DEMAND ELASTICITY

Mode	World Bank guidelines		
	First 5 years	Next 5 years	There after
Car, Jeep, Van	2.0	2.0	1.8
Buses	1.6	1.6	1.5
Two wheelers	2.5	2.3	2.1
Trucks	1.5	1.3	1.0

For the calculation of growth rates of passenger vehicles, the projected growth rates of population and per-capita income of Kerala state were used. Based on population growth rates, per-capita income growth rate and also including the elasticity values of transport demand, the growth rates of passenger vehicles for different time intervals were worked out using the formula: Annual Growth Rate of Passenger Traffic:

$[(1+P/100) \times (1+I/100) -1] \times 100 \times E$

Where:

P = Annual population growth rate

I = Annual per capita income rate

E = Elasticity coefficient

TABLE 4

PROJECTED TRAFFIC GROWTH RATES (%)BASED

ON TRANSPORT DEMAND ELASTICITY

	Car	Mini Bus	Bus	LCV	2A	3A
2013-2015	14.95%	13.51%	13.55%	13.58%	12.82%	12.79%
2016-2017	13.45%	12.01%	12.05%	13.58%	11.32%	11.29%
2018-2020	11.95%	10.51%	10.55%	12.58%	9.82%	7.79%
2021-2022	8.95%	7.51%	7.55%	6.58%	6.82%	6.79%
2023-2027	7.45%	6.01%	6.05%	5.93%	5.32%	5.29%
2028-2032	6.26%	5.10%	5.13%	5.48%	5%	5%
2033-2037	5.83%	5%	5%	5.14%	5%	5%

5. DATA COLLECTION AND ANALYSIS

Based on the vehicle damage factors and the projected traffic volumes, the trafficloading in terms of cumulative number of equivalent 8.0 t standard axle loads have beencomputed for the period, 2016-2036.As per mentioned earlier parametersDesign Traffic:

Design Traffic: (MSA, Million Standard Axles) is worked as below

$$N = [365 \times A \times \{(1+r)^{n}-1\} \times D \times F] / [r] \text{ MSA}$$

Where:

N= Cumulative number of standard axles to be catered for in the design in term of MSA

A= Initial traffic in the year of complication of construction in terms of the number of CVPD

D= Lane distribution factor

F= Vehicle damage factor

n= Design life

r = Annual growth rate

The projected traffic and required MSA have been shown in below Table 5 for the project.

Year	LCV	Mini Bus	Bus	2-axle	3-axle Truck	MAV	Cum. MSA	No of Years	Design MSA	MSA as per Schedule
2013	238	105	112	262	266	151	1			2
2014	270	119	127	295	300	170	3			3
2015	307	135	144	333	338	192	4			5
2016	349	151	162	371	377	217	6	0		7
2017	396	169	181	412	419	244	8	1		10
2018	446	187	200	453	460	258	10	2		12
2019	502	206	222	497	503	273	12	3		15
2020	563	228	245	546	553	289	13	4		18
2021	602	245	265	584	592	306	15	5	18 MSA	22 MSA
2022	642	263	283	625	633	324	21	6		25
2023	680	279	300	657	666	340	24	7		29
2024	720	296	319	691	701	358	27	8		33
2025	763	314	338	728	738	376	30	9		37
2026	808	333	358	767	777	396	34	10	34 MSA	42 MSA
2027	856	353	380	808	818	416	38	11		46
2028	905	371	399	848	859	437	42	12		51
2029	955	390	420	891	902	459	46	13		56
2030	1005	409	441	935	947	482	50	14		62
2031	1060	430	464	982	995	506	55	15	55 MSA	67 MSA
2032	1118	452	488	1031	1045	531	60	16		73
2033	1175	475	512	1083	1097	558	65	17		79
2034	1236	499	538	1137	1152	586	70	18		86
2035	1299	524	565	1194	1209	615	76	19		93
2036	1366	550	593	1253	1270	646	82	20	82 MSA	100 MSA

The above Table 3 shows the MSA calculation on yearly basis, 34 MSA is achieved in 10 years and 82 MSA achieved in 20 years. As per concessionaire agreement the pavement should design for 20 years with a MSA of 100 and for each year it has been calculated and shown in Table 3. For main carriage way stage construction is proposed for the pavement design so for 10 years of design life 42 MSA is calculated as per concessionaire agreement. For main carriageway 45 MSA is considered for pavement design and for service road 10MSA is adopted as per "Manual of Specification for 6 laning of Highways through Pubic Private Partnership".

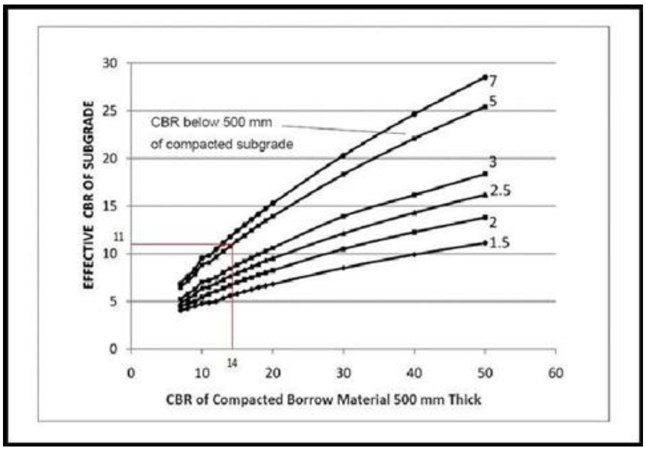
2. CBR Test*:* Calculations for the CBR Test is tabulated in Table 6

LOAD PENETRATION TEST DATA:-

INFORMATION	Penetration (mm)	Providing ring reading	Corrected load (kg)	Providing ring reading	Corrected load (kg)	Providing ring reading	Corrected load (kg)
Type of compaction used : static / dynamic	0.0	-	-	-	-	-	-
Period of soaking : days	0.5	13	80.5	14	86.7	13	80.5
Wt. of surcharge used (kg) :	1.0	20	123.8	21	130.0	20	123.8
Proving ring capacity :	1.5	30	185.7	27	167.2	28	173.3
Least count of proving dial gauge :	2.0	38	235.3	35	216.7	34	210.5
	2.5	45	278.6	41	253.8	43	266.2
	3.0	49	303.4	46	284.8	46	284.8
	4.0	58	359.1	52	321.9	54	334.3
	5.0	64	396.2	58	359.1	61	377.7
	7.5	72	445.8	63	390.0	70	433.4

	10.0	78	482.9	71	439.6	76	470.5
	12.5						
Corrected unit load from graph (1370 kgf) for 2.5 mm		278.6		253.8		286.2	
Corrected unit load from graph (2055 kgf) for 5.0 mm		396.2		359.1		377.7	
CBR at 2.5 mm (%)		20.34		18.53		19.43	
CBR at 5.0 mm (%)		19.28		17.47		18.38	
CBR reported (%)		19.43					

If there is a significant difference between the CBRs of the select subgrade and embankment Soils, the design should base on effective CBR as per IRC 37-2012. The embankment CBR is considered as 5% and subgrade CBR as 14%, so the effective CBR of the subgrade is determined as 11% all along the stretch by using the graph as shown in Figure 3.



Pavement thickness: Now, the total pavement thickness for CBR 11% and traffic 103 msa from IRC: 37 2012 chart 2 is 956.2 mm. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC37: 2001):

Description	Thickness
BC	40
DBM	75
Granular base	250
Granular subbase	200
Total Thickness	565

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