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Design of Highway with Major Bridge on Stagnant Water

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Abstract - *One of the most important aims of the Indian Government is to provide and improve the quality of Road Transportation in the country. Hence, it becomes of the top priorities to study and understand the latest and revised editions of rules set forth by the government. To fulfil this requirement, a project undertaken by NHAI (National Highways Authority of India) has been studied and taken into consideration. This paper aims at understanding the designing process of the project pavement in accordance with Indian Standards of Road Congress. This paper also gives a brief idea about the designing of a major bridge that coincides with the road section of the project. The project available for concessionaire is in Bhandara, Nagpur, Maharashtra, India. It was found by laboratory tests that the CBR of the soil sample is quite low, and hence to achieve strength for construction it is suggested that the sub-base should be cement treated. The overall traffic is quite high over the span and it is suggested that six – lane construction must be done over the desired span. This paper also aims at suggesting the most economical sections for design of bridge as per the hydraulic catchment of the dam. Old records were collected for the calculation purposes.*

Key Words: Design, Pavement, Bridge, Catchment

1.INTRODUCTION

1.1 General

Roads are one of the most important modes of transportation in India. India has a network of over 6,215,797 kilometers of roads as of 31 March 2020. This accounts for the second largest road network in the world after the United States. The current condition of the nation's transportation system is of great concern to National and State Departments of Transportation.

The project includes the 6 – Lane divided carriageway with fully paved shoulders. The design speed is proposed to be ruling design of 100 km/hr. as per contract terms. Minimum design life of 20 years with minimum effective CBR of 8% is proposed in the contract of this project.

1.2 Objective of Study:

- To analyze traffic count and design sustainable pavement in accordance with the requirement.
- To analyze hydraulic catchment of the river for making safe design of major bridge.
- To understand the design procedures involved.

2. LITERATURE REVIEW

Zhang et al. (2013) described about the development of a new pavement network management system that helps analysis and optimization. This LCCA optimization was implemented to regulate the optimum conservation scheme for a pavement network and to reduce supportability metrics within a given analysis period. They discussed about pavement deterioration, which is a main aspect to focus future pavement conservation procedures and is extremely difficult to focus faultlessly.

Pradhan Mantri Gram Sadak Yojana (2006) [12] presented the choice of the appropriate economical and advantageous pavement type, was made by carrying out life cycle cost analysis, which considers the initial cost and the maintenance cost. They also presented the methodology of construction for both rigid and flexible pavements.

Arijit Dutta (2014) [5] described the life cycle cost analysis for roads. The report included various details about the parameters to be dealt with while designing the pavement economically. The report also consisted of consideration for several possible ways for routine maintenance action to reconstruction of road networks.

It is obvious from all the literature reviewed in this study that despite adapting different methodologies and designs, there were some common factors of same centrality. It gives us the scope to understand the basics that can be put forward while finalizing the design and construction of pavements and bridges. Another thing is that optimization of cost and duration of project can economically affect the entire transportation system in future.

3. METHODOLOGY

3.1 Methodology for Design of Pavement –

Traffic surveys have been carried out in accordance with the guidelines specified by IRC: 9-1972 [9] and IRC: 102-1988 [13] to calculate the wheel load and traffic intensity. The methodology adopted for the traffic study is detailed as below:

- The project road corridor is divided into two traffic homogeneous sections based on change in traffic flow pattern.
- The traffic surveys including classified traffic volume count is carried out for each traffic homogeneous section.
- The classified directional traffic volume is counted over seven consecutive days for 24 hours on each day. The vehicle classification considered was in accordance with IRC – 64. [14] Number of vehicles in either direction was noted at 1-hour intervals in accordance with their classification by observers specially trained for this purpose.

3.2 Methodology for Design of Major Bridge –

- Geotechnical investigation is carried out for the proposed construction of Major Bridge Across River Wainganga near Bhandara. Investigation was intended to evaluate allowable bearing capacity of available soil/rock stratum and other physical parameters necessary for the design of suitable foundation. Scope of work included boring, Standard Penetration Tests as well as disturbed & undisturbed soil sampling at field and necessary laboratory testing on available soil / rock samples.
- Bore logs were obtained by rotary drilling rig.

4. FINDINGS AND ANALYSIS

4.1 Findings of Traffic Survey

The classified traffic count data collected has been analyzed for hourly and daily traffic intensity, traffic composition, peak hour factor (PHF), directional distribution, average daily traffic (ADT) and finally annual average daily traffic (AADT) by applying the seasonal correction factors. The AADT factor is considered as 1.00 from the prevailing studies in the state.

Traffic volume analysis has been carried out to assess the volume of traffic, composition, hourly variation in traffic over 24 hours, and the daily variation in the traffic over 7 days at the project locations. The compiled data obtained from field traffic survey has been analyzed to work out the average daily traffic in terms of total vehicles and total PCUs.

Analysis was carried out to find the composition of traffic in terms of fast- and slow-moving traffic and in terms of various types of vehicles. The observed vehicular compositions are shown in Table 1

Table -1: Summary of Composition of Traffic

Type of Vehicle		
Name of Vehicle	**Number**	**PCU**
Two - Wheeler	27.473%	6.124%
Car / Jeep / Van / Taxi	21.186%	9.445%
Three-Wheeler	0.354%	0.158%
LCV	7.312%	4.890%
Govt. Bus	1.284%	1.717%
Private Bus	0.877%	1.173%
Minibus	0.207%	0.138%
Tractor	0.089%	0.059%
Tractor With Trolley/ Trailer	0.574%	1.151%
2 - Axle	8.373%	11.198%
3 - Axle	12.272%	24.621%
Multi Axle Truck	19.552%	39.226%
Total Fast Moving (A)	**99.552%**	**99.9%**
Cycle	0.448%	0.100%
Rickshaws	-	-
Bullock Cart	-	-
Total Slow Moving (B)	**0.448%**	**0.100%**
Total ADT (C) = (A) + (B)	**100%**	**100%**

4.2 Analysis of Traffic Growth

Traffic demand forecasting is to be done for future traffic volumes the project road is supposed to cater. This is primarily based on the present-day traffic volume and likely traffic growth rates periodically during the forecasting period of 30 years for the proposed road improvements.

The traffic growth rates are dependent on various factors such as growth in national economy, changes in socio-economic conditions of the people etc. Forecasted traffic forms the basis for determining the requirements for capacity augmentation by way of widening of existing carriageway, pavement design and economic / financial deciding viability of project.

Econometric modelling is attempted to estimate traffic demand forecasting considering several variables such as population, per capita income, net state domestic product (NSDP) and past vehicle registration data. Time series data on vehicle registration in the state was collected from secondary sources. Similarly, time series past data on population, state income (NSDP) and per capita income for the state has also been obtained from the concerned departments of Government.

The economic indicators of state are used for the regression analysis along with vehicle registration data as presented in Table 2.

Table -2: Economic Indicators for Maharashtra State.

Year	NSDP	Population	Per Capital Income
2010	1	599338	111118000
2011	2	667625	112372972
2012	3	695904	114170968
2013	4	749137	115969272
2014	5	805593	117766794

Based on the moderated elasticity values and average growth rate of NSDP 2010-2014 and with the given model as follows, the future average annual compound traffic growth rates for vehicle type are estimated as below:

- OPTIMISTIC: {Trend Growth of Vehicles} – Average Growth Rate: 4.44%
- REALISTIC: {Growth from Regression Analysis} - Average Growth Rate: 4.39%
- PESSIMISTIC: {Considered for Revenue Capacity} – Average Growth Rate: 6.16%

4.3 Findings in Subgrade Soil Investigation

Subsoil investigation consisted of Drilling and sampling in four boreholes, carrying out relevant laboratory tests on representative soil and rock samples, preparation of engineering report based on field and laboratory data.

The observed CBR of soil is 3%, since the required CBR for pavement is 8%. The base course must be treated with manufactured aggregates with measured amounts of Portland cement and water that hardens after compaction and curing to form a strong, durable, frost-resistant paving material. CTB is versatile as it can be either mixed in place and compacted after blending or mixed in a central plant where it is hauled to the placement area and spread on a prepared subgrade or subbase and compacted.

5. DESIGN

1.1 Design of Pavement

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. Using Design traffic in terms of cumulative number of standard axles and CBR value of subgrade, appropriate designs could be chosen for the given traffic and soil strength.

As specified in the IRC:37 2018 [3], the pavement design has been done as follows:

- The effective CBR of soil subgrade is 5%.
- The design life specified in the contract is 30 years.
- VDF has adopted as 5.35.
- The ADT, i.e., Average Daily Traffic of the given section of bypass is computed to be 12075 CVPD.
- The realistic growth of the traffic is 4.39%.
- Distribution Factor = 0.45
- Initial Directional Traffic = 12075/6 (Since the bypass is proposed to be a Six Lane Road)
- Cumulative number of standard axles to be catered for in the design

$$N = \frac{6038 \times 365 \times ((1+0.0439)^{30} - 1)}{0.0439} \times 0.75 \times 5.35$$

Therefore, N = 106 msa

- Effective resilient modulus of subgrade = 17.6 × (5.0)0.64 = 49.30 MPa (less than 100 MPa, the upper limit)
- With respect to catalogue for Pavement with Bituminous Surface Course with Granular Base & Sub – base of IRC:37 – 2018[3], design traffic is more than 50 msa. Hence, let us provide a SMA/ GGRB or BC with modified bitumen surface course and DBM binder/ base layer with VG40 with viscosity more than 3500 Poise (at 60°C).
- Select crust for pavement is 50 mm Bituminous Concrete (BC), 115 mm Dense Bituminous Macadam (DBM), 150 mm Wet Mix Macadam (WMM), 200 mm Cement Treated Sub Base (CTSB) & 500 mm Subgrade (Compacted), in conformity with the Schedule B of the contract.

1.2 Design of Bridge

➢ *Topographical Details:*

i. Catchment Area = 22597.55 Sq. Km. (This catchment area is taken from Water Resource Dept GOM) 59.55 Sq. km Catchment area up to Proposed site Wainganga Bridge (From local Nala) + 22538 Sq. km Catchment Area up to Existing Wainganga Bridge (This Catchment Area taken from Water Resources Dept GOM (India))

ii. Bed Width at proposed section = 163. 00 m

iii. Bank Width at proposed section = 374.00 m

iv. L.B.L. At proposed section = 232.080 m

v. Slope = 0.0009

vi. Hydraulic Gradient = 1 IN 1149.425

➢ *Calculations:*

Discharge has been calculated using Manning's Formula. The calculations of discharge have been tabulated in Table 3.

Table -3: Calculation of Discharge by Manning's Formula

Rugosity Coefficient		0.040	0.035	0.040	
Bed =	Clean, straight bank, full stage, no rifts or deep pools but some weeds and store				
Bank =	Winding, some pools and shoals, clean, some weeds and stones				
Compartment		II	I	III	
Wetted Area	²2	1034.918	3786.424	572.994	**5394.336**
Wetted Perimeter	m	326.949	318.544	415.080	**1060.573**
Hydraulic Mean Depth	m	3.165	11.887	1.38	
s		0.0009	0.0009	0.0009	
Velocity	m/sec	1.590	4.389	0.914	**4.389**
Discharge	Cu.m./sec	1645.215	16619.870	523.836	**18788.921**
Total Manning's Discharge at H.F.L.		246.398	=	**18788.921**	Cu. m./ sec
Total Design Discharge Calculated as Above			=	**18786.446**	Cu. m. / sec
The discharge calculated by Manning's formula is fairly tallied with the discharge by Inglis formula, i.e., which is within the permissible limit of 2%				**0.01%**	

The calculations of waterway at HFL have been tabulated in Table 4.

Table -4: Calculation of Waterway at HFL

Tallied H.F.L.	=	246.398	Mtr.
L.B.L.	=	232.080	Mtr.
Max. Flood Depth	**D (Tallied H.F.L. – L.B.L.) =**	14.318	Mtr.
Wetted Area at H.F.L.	**A =**	5394.336	Sq.m.
Linear Waterway at H.F.L.	**L = A/D =**	376.75	Mtr.
Linear Waterway by Lacey's formula	**L = 4.8 ×²**	657.95	Mtr.
It is Proposed to Provide	**12 Spans of**	**50.00**	**C/C**
	12 Spans of	**47.00**	**Clear**
Linear Water way is Proposed	=	**600.00**	Metre.
The Span Arrangement of Bridge is as shown Above			
H.F.L.	**246.398**	Mtr.	
L.B.L. at Proposed Section	**232.080**	Mtr.	
Total Discharge	**18788.921**	cumec	

For finalizing a design, it is important to calculate a safer RTL for the bridge. The calculations are tabulated below.

Table -5: Calculation of RTL for the proposed Site

	Particulars	At Proposed Site	At Observed HFL by CWC	At Observed FTL by Irrigation
R.T.L. =	Designed H.F.L.	246.398	247.300	246.000
+	Afflux	0.105	0.105	0.105
+	Clearance	2.650	2.650	2.650
+	Soffit of Slab	**249.153**	**250.055**	**248.755**
+	Slab Thickness + Box Girder Depth (At Centre)	3.000	3.000	3.000
+	Camber 2.5%	0.155	0.155	0.155
+	Wearing	0.065	0.065	0.065

	Coat			
=	**Proposed R.T.L.**	**252.373**	**253.275**	**251.975**
As Per Clause 107.1 of IRC:5 – 1998				
	Particulars	At Proposed Site		
R.T.L. =	Designed H.F.L.	246.398		
+	Afflux	0.105		
+	Freeboard	1.750		
+	Camber	0.155		
+	Wearing Coat	0.065		
=	**Proposed R.T.L.**	**248.473**		
The Final Proposed RTL is =		**253.275**		

The suggested span arrangement is *Balanced Cantilever Bridge*. Proposed Span Arrangement will be 5 modules of balanced cantilever with total length of 600m divided into ratio of 50m + 5 x 100m + 50m span. The superstructure proposed is box type of structure with cast in-situ type of construction using overhead crane under cantilever type of construction. Superstructure will PSC in longitudinal direction and RCC in transverse direction. There will be 6 piers and 2 abutments under this arrangement.

6. CONCLUSIONS

This study analyzed the process of design of pavement and bridge. It can be concluded that Cement Treated Sub Base should be provided since the traffic count is considerably high. Also, it should be noted that regular crust of Bituminous Cement cannot prove sufficient as per the traffic reports. In order to meet with the design requirement of 30 years, it becomes crucial to provide Bituminous Concrete of 50 mm thickness. It should be noted that Dense Bituminous Macadam (DBM) and Wet Mix Macadam (WMM) have also been increased in percentage. The recommended Option considering the site situation and time of construction, i.e., Balanced Cantilever Bridge with cast in – situ construction. Spans between Abutment and Piers shall be constructed by trestle support. The spans which are in the deep river portion shall be constructed as cantilever cast in – situ construction using formwork.

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