Minimal Cost Approach for Selecting the Flexible Pavement Type to Minimize the Construction Cost of Road

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***Abstract*—This study is done to choose the best suitable road type among the five flexible road types cited in IRC 37-2012 for optimum cost of the construction at various CBRs from 2% to 15 % and different traffic volume conditions from 2msa to 30 msa. The material, equipment and direct construction cost and their proportions are calculated based on the District schedule rates and the specification and standards of the Roads (MORTH Specifications). Co-relation between the cost, road types, CBRs and Traffic volumes is calculated, which could serve the purpose of selecting the low cost road crust type at a particular location of certain CBR.**

***Index Terms*—Direct Construction cost, Road Types, Traffic, CBRs & Material and construction cost proportions.**

I. INTRODUCTION

Indian road network of 33 lakh Km. is second largest in the world and consists of About 65% of freight and 80% passenger traffic is carried by the roads as per NHAI. National Highways constitute only about 1.7% of the road network but carry about 40% of the total road traffic. The traffic increase rate is about 10.16% for last five years. The construction industry is the tool through which a society achieves its goals of urban and rural development. Road construction includes higher direct costs and includes huge financial risk. Many studies were conducted on the cost deviation in construction projects. The average of cost deviation in road construction is 16.73% and it ranges from 20.33% to 56.01% [1].Various surveys conducted showed 89% of respondents agreed that their projects had the problem of cost overrun with an average overrun at 5 to 10% over the contract price.[2]. The variations between feasibility and contract cost, ranging between 28.5% and +36% , construction industry accounts 6–9% of GDP in many countries [3], thus it has a great impact on the economy of all country, it is very important to choose the best suited low economic construction methods to minimize the construction cost as well as minimize cost variation.

Based on the recent innovations and engineering properties of different the IRC 37-2012 has included some alternate material crusts for the road construction of having traffic more than 2 msa. Based on the same the different road types introduced are as follows, [7]

1. Granular Base and Granular Subbase.(GB and GSB)
2. Cementitious Base and Cementitious Subbase of aggregate interlayer forcrack relief. (CB and CSB)
3. Cementitious base and subbase with SAMI at the interface of base and the bituminous layer. (CB and CSB with SAMI)
4. Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase.(RAP)
5. Cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base. (CB and GSB with crack relief layer)

This paper would be helpful for choosing best suited pavement crust for the various subgrade CBRs and different traffic conditions On the basis of equipment cost, material cost and total construction cost and their proportions with each other's. This could serve as formation of baseline for budgeting direct cost of road construction, material and equipment's.

II. DIRECT COST ANALYSIS

Direct cost consist of material, equipment and labors, material and equipment hire cost for the analysis of construction cost of all above road types is calculated from the rates quoted in DSR of government of Maharashtra PWD for year 2017-18. Construction cost and labor and equipment requirement is calculated based on the *Basic approach and general conditions and assumption for the preparation of standard data book* published by NHAI and confirming to the MORTH specifications and standards. For quantity calculations purpose a sample road of 1km length, 3.75m width and depths confirming to the road crusts as per IRC is considered. Along with this the overhead charges and contractors profit is considered as 7.5%. The cross drainage works, structural works, road singes and indirect cost are not considered in this analysis as these will be constant throughout the different types of the roads. So the cost saving in different road types is purely based on the direct cost of the road construction.

A. Material cost of Granular Base and Granular Subbase.(GB and GSB)

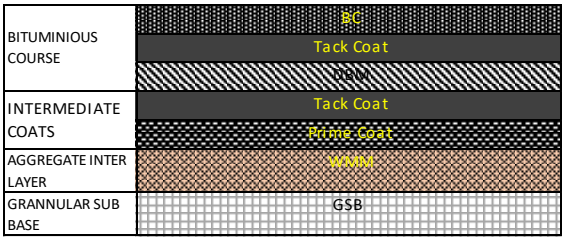

Fig.1. Bituminous surfacing with granular base and granular sub base [7]

This type of road crust consists of Bituminous Concrete, Dense graded Bitumen Macadam, granular sub base and subgrade. For the material cost calculations, the specifications considered as per MORTH and included in Table 1. The construction equipment, labors are considered as per the *standard data book* published by NHAI.

Table no.1 Pavement crust specification considerations for material cost calculations.[9]

Sr. no	Pavement Crust Layer	MoRTH Spec.
1	Bituminous Concrete	509
2	Dense Graded Bituminous macadam	507
3	Wet Mix Macadam	406
4	Granular Sub-Base with Coarse Graded Material	401
5	Prime Coat	501
6	Tack Coat	503
7	Aggregate interlayer for crack relief	406
8	Cement treated crushed rock base/sub base m3	403
9	Stress absorbing membrane (SAM) -Crack Prevention Courses	522
10	Recycling of Bituminous Pavement with Central Recycling Plant HOT MIX RAP	517

B. Material cost of Bituminous Pavements with Cemented Base and Cemented Subbase with Crack Relief Interlayer of Aggregate (CB, CTSB& Crack relief layer)[7]

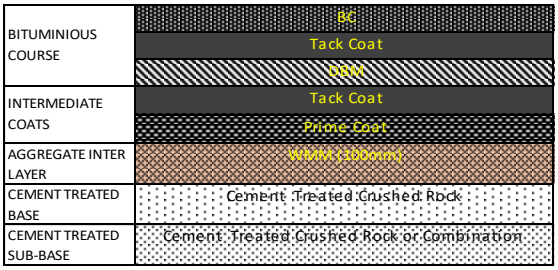

Fig 2. Bituminous surfacing, cement treated base and cement treated sub base with aggregate interlayer.[7]

This type of road is consist of Bituminous concrete, Dense graded bitumen (For traffic volume above 30 msa only), Wet mix macadam , cemented base and sub bases. For material cost calculations of this crust, the specifications considered as per Table. 1. The construction equipment, labors are considered as per the *standard data book* published by NHAI.

C. Cementitious base and subbase with SAMI at the interface of base and the bituminous layer. (CB and CSB with SAMI)

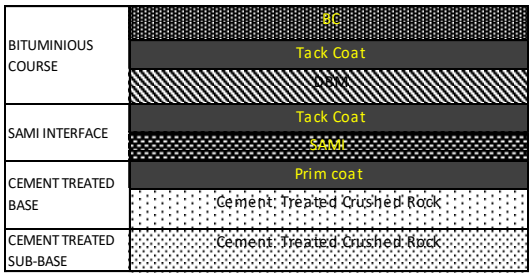

Fig.3. Bituminous surfacing with cemented granular base and cemented granular sub base with stress absorbing membrane interlayer (SAMI)[7]

This type of road consists of layers of Bitumen concrete, Dense graded Bitumen macadam, SAMI layer, cemented base and cemented sub base. For the material cost calculations the specifications considered same as per Table. 1. The construction equipment, labors are considered as per the *standard data book* published by NHAI.

D. Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase.(RAP)

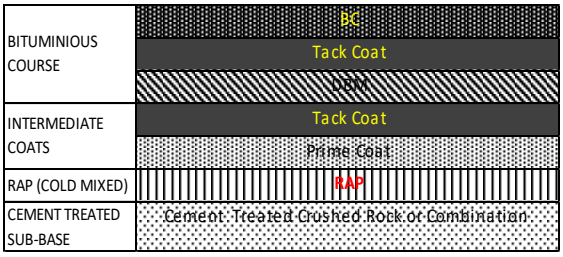

Fig.4. Bituminous surfacing with RAP and cemented granular sub base[7]

Such road crust consist of BC, DBM, Reclaimed asphalt (RAP) and cemented base For the material cost calculations the specifications considered as per Table. 1. The construction equipment, labors are considered as per the *standard data book* published by NHAI.

E. Cementitious base and granular subbase with crack relief layer of aggregate layer above the cementitious base. (CB and GSB with crack relief layer)

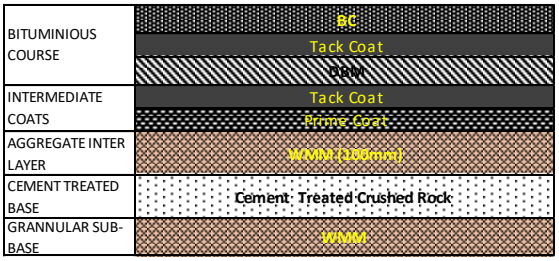

Fig.5. Bituminous surfacing, Cement Treated base and Granular sub base with aggregate Interlayer[7].

This crust consists of BC, DBM, WMM , CTB and GSB

For the material cost calculations the specifications considered as per Table. 1. The construction equipment, labors are considered as per the *standard data book* published by NHAI.

III. Observations & Discussion

The cost comparisons figures obtained from the detailed cost analysis as per the specification given in the MORTH and the *standard data book* published by NHAI are included below. From the figures its very easy at preconstruction phase to choose the minimal cost road type.

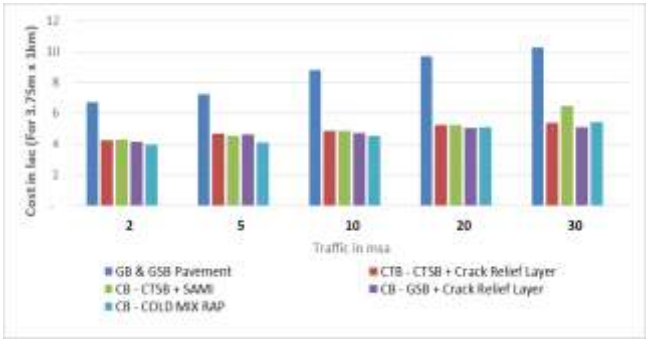

Fig. 6 Cost comparison for 3% CBR

For 3% CBR most cost efficient road is Foamed bitumen/bitumen emulsion treated RAP or fresh aggregates over 250 mm cementitious subbase.(RAP) upto 10msa traffic volume. Above 10msa Cementitious base and granular subbase with crack relief layer is most cost efficient road crust type. Grannular Base and Grannular sub base road type is having initial high direct construction cost in all CBRs among five road types cited in IRC 37-2012.

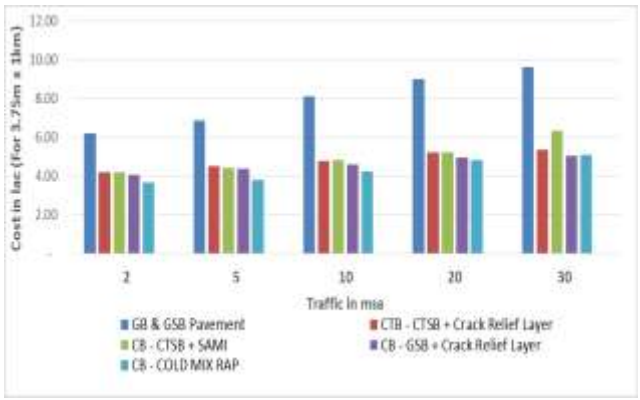

Fig. 7 Cost comparison for 4% CBR

From the Fig. 7 it can be easily observed that for subgrade CBRs 4%, 7% & 8% , for traffic volume upto 20msa, the most cost efficient road *is Foamed bitumen/bitumen emulsion treated RAP*. Above 20msa *Cementitious base and granular subbase with crack relief layer* is most cost efficient road crust type.

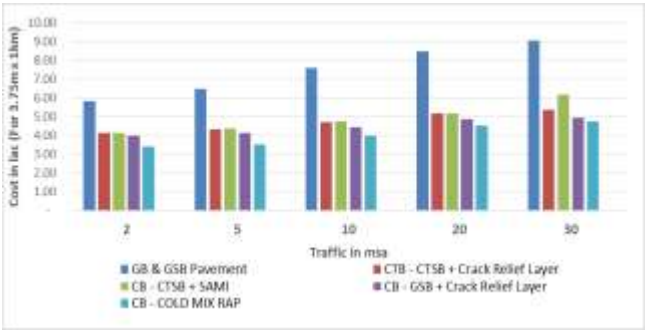

Fig. 8 Cost comparison for 5% CBR

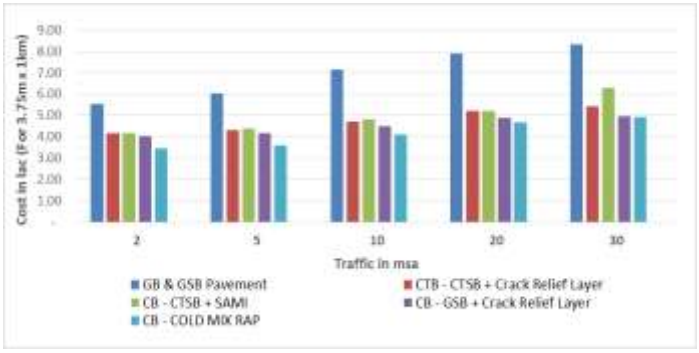

Fig. 9 Cost comparison for 6% CBR

For subgrade CBR 5% and 6% , upto 30msa Traffic volume the cost optimum road crust type is Foamed bitumen/bitumen emulsion treated RAP.

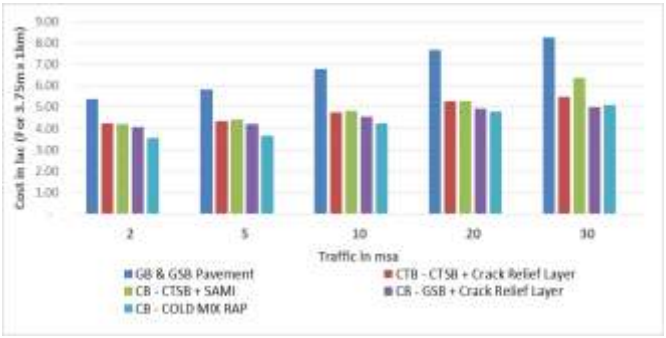

Fig. 10 Cost comparison for 7% CBR

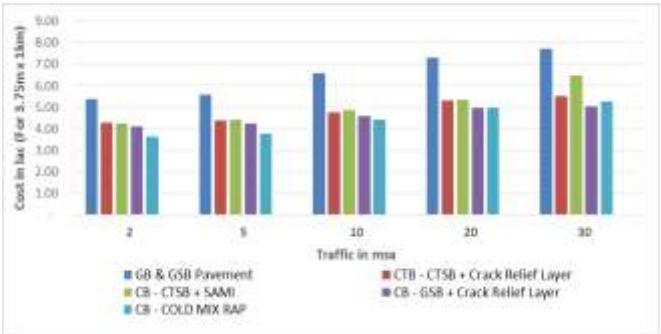

Fig. 11 Cost comparison for 8% CBR

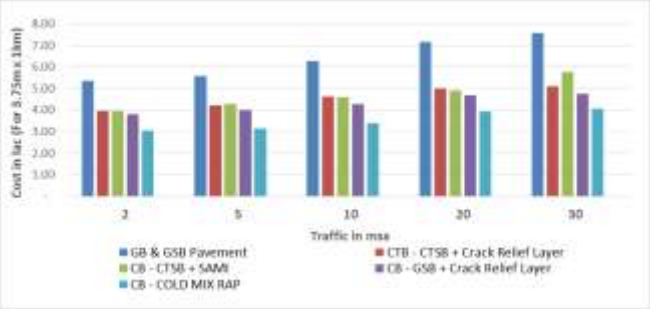

Fig.12 Cost comparison for 9%& 10% CBR

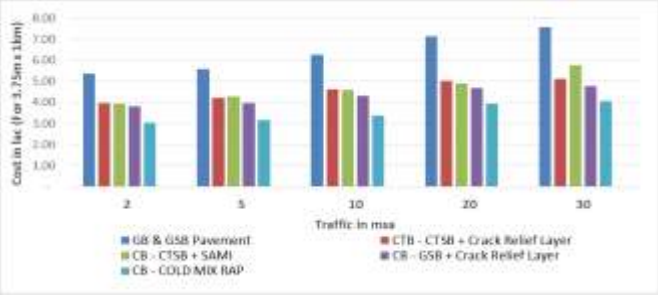

Fig. 13 Cost comparison for 15% CBR

As subgrade strength increases above 10 CBR the most suitable road crust type is Cementitious base and granular subbase with crack relief layer is most cost efficient road crust type for traffic volumes above 50msa. Upto 10 msa the *Foamed bitumen/bitumen emulsion treated RAP* is most efficient on the basis of the minimum direct construction cost.

IV. CONCLUSIONS

As the structural work, cross drainage work, road signs and traffic signs, manpower employed and indirect expanses are common in all the road types , it is possible to choose the minimum construction costing road among the five road types cited in IRC 37-2012, Provided that the final road type should be chosen by considering the availability of the construction equipment's and materials at a location. By using fig. 6 to fig. 13, at prima phase of the selecting road type for tendering and designing can be done easily and suitability can be checked and implemented.

V. FUTURE SCOPE

Minimum construction cost approach can be applied for traffic above 50 msa, 100msa and 150msa. The cost proportions as *Material cost: Equipment cost: Construction cost*, for the five road types as per IRC can be obtained by same analysis by referring the MORTH and standard data book published by NHAI. The variations between feasibility and contract cost for the construction cost based on the road type and the CBR of a soil can be obtained.

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