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Effect of Varying Subgrade Strength on Cost of a Rigid Pavement

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Abstract: *It is generally believed that increase in subgrade strength leads to decrease in the thickness of a rigid pavement which helps in reducing the cost of pavement. The guidelines of Indian Roads Congress (IRC) for the design of rigid pavements also recommend the use of select soil of minimum CBR 8% in the subgrade for design of cement concrete pavement for roads having traffic greater than 450 CVPD. An attempt has been made in this paper to study the effect of variation in subgrade strength on thickness and cost of a rigid pavement. It is found that the thickness and cost of pavement may not decrease with an increase in the strength of subgrade soil. The provision of using select soil of minimum CBR 8% in the subgrade of the road as recommended by IRC, therefore, needs to be applied carefully.*

Keywords: *CBR, Cost of pavement, PQC, Rigid pavement, Subgrade strength*

1. Introduction

Rigid pavements are those pavements which possess high flexural rigidity and strength. Unlike flexible pavement which transfer load by grain to grain contact they transfer load by slab action. At present the proportion of rigid pavements in the country in the total road length of about 46 lacs km is less than 10%. Concrete pavements could not be provided in large number due to problems like more initial cost of construction, lack of stage construction, lack of expertise and slow progress of construction. However, a cement concrete road has the advantage of having more life, less maintenance and vehicle operation cost. The life cycle cost of a cement concrete pavement over its design life actually comes out to be less than a flexible pavement. The cement is less costly as compared to bitumen and it is also abundantly available in the country whereas bitumen is a petroleum by-product for which country has to spend its foreign reserves on its import which negatively affects our economy. The slow progress of work in case of rigid pavements has been overcome in recent past with the availability of more and more numbers of slip form pavers that are used in construction of cement concrete roads. In the last decade we have developed reasonably good expertise as well in the construction of cement concrete roads. Keeping in view the overall less cost of cement concrete pavement and cement being abundantly available in the country, the construction of cement concrete roads is bound to expand manifold in near future.

IRC:58 [1] recommends the use of select soil of minimum CBR 8% in the subgrade of the road having traffic more than 450 commercial vehicles per day (CVPD). The design and cost estimation of a rigid pavement has been taken up in this paper for varying strengths of subgrade with a view to determine the effect of this variation of subgrade strength on thickness and cost of the pavement and whether replacement of existing soil with select soil will help in economizing the cost. Some investigators [3,4,5,6] have worked on the design and cost analysis of rigid pavements and concluded that rigid pavements may be economical under certain conditions.

2. Methodology

IRC: 58 [1] which use finite element analysis of pavement slab has been used for designing thickness of the pavement. Cost estimation has been done based on rate analysis of MORTH data book [2]. The rates of labour, materials and machinery have been adopted as applicable in Kurukshetra, Haryana as per norms of Public Works Development.

3. Design of Pavement

The design of pavement is done for CBR value of subgrade soil varying from 2% to 10% and for traffic of 3000 CVPD in each direction considering the road to be a four lane road located in Haryana. The sub-base is taken as 150 mm Dry Lean Concrete (DLC) below which 150 mm Granular Sub base (GSB) layer is provided which serves the purpose of drainage layer. The shoulders are taken as earthen shoulders. The design life of pavement is taken as 30 years with annual growth rate of CVs as 7.5%. Slab Size is taken as 3.5 m width and 4.5 m length. Percentage of front single axle, rear single axle, rear tandem axle and rear tridem axle is taken as 45%, 15%, 25% and 15% respectively. Night time commercial vehicles traffic on the road is taken as 60%. The percentage of commercial vehicles with spacing between the front axle and the first rear axle less than 4.5 m is 55%. The average number of axles per commercial vehicles is 2.35. The axle load spectrum with frequency of different axle loads of single, tandem and tridem axle is assumed the same as given in IRC:58 [1].

The effective modulus of subgrade reaction has been

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obtained from relevant tables of IRC:58 [1] for the given CBR of the subgrade and subbase of 150 mm DLC. M-40 grade pavement quality cement concrete (PQC) is used in the pavement with 90 days flexural strength as 4.95 MPa and compressive strength as 48 MPa. The elastic modulus of concrete is taken as 30000 MPa, poisson's ratio of concrete as 0.15.

The fatigue damage analysis of the pavement is done in respect of bottom up cracking and top-down cracking using the procedure given in IRC:58 [1]. The safe design thickness values so obtained are given in table 1.

Table 1. *Thickness of pavement using existing ground as subgrade*

CBR of existing ground (%)	2	4	6	8	10
PQC Thickness over DLC subbase (mm)	340	340	330	330	330

As per IRC guidelines for traffic more than 450 CVPD, the select soil of minimum CBR value of 8% should be used in top 500 mm of the subgrade to increase the subgrade strength. The design safe thickness values in this case are obtained in table 2.

Table 2*. Thickness of pavement when existing ground is replaced with select soil of 8% CBR*

CBR of existing ground (%)	2	4	6
Effective CBR (%)	4.8	6.5	7.6
PQC Thickness over DLC subbase (mm)	340	330	330

4. Cost of Pavement

Cost of rigid pavement has been worked out as per analysis of rates computed with the help of MORTH data book [2]. The rates of various items of work as per design so obtained are given in table 3.

Table 3*. Rate of various items obtained from rate analysis*

S. No.	Description of items	Rate (Rs per cum)
1	Construction of Subgrade and earthen shoulders with borrowed select soil	311
2	Compacting existing ground for preparing subgrade	54
3	Granular sub-base for grading-I material using Plant mix method	1338
4	Dry lean cement concrete sub-base	2372
5	PQC M-40 grade with other component materials for cement concrete pavement	5439

By using these rates of various items obtained from rate analysis, cost of pavement has been estimated in this paper. The cost of pavement when existing ground having CBR value of 2% is used as subgrade without replacement with select soil is worked out as in table 4.

Table 4. *Cost estimation when existing ground of CBR value 2% is used as subgrade without replacement with select soil*

Item	Dimensions (in metres)			Qty. (cum)	Rate (Rs per cum)	Cost (per km length) in lacs
	Length	Width	Thickness			
Sub grade	1000	7	0.5	3500	54	1.89
GSB	1000	7	0.15	1050	1338	14.05
DLC	1000	7	0.15	1050	2372	24.91
PQC	1000	7	0.34	2380	5439	129.45
			Total			170.30

The cost of pavement when original ground having CBR value of 2% is replaced with select soil of 8% CBR is worked out as in table 5.

Table 5*. Cost estimation when existing soil of CBR value 2% is replaced with select soil of 8% CBR*

Item	Dimensions(in metres)			Qty. (cum)	Rate (Rs per cum)	Cost (per km length) in lacs
	Length	Width	Thickness			
Sub-grade	1000	7	0.50	3500	311	10.89
GSB	1000	7	0.15	1050	1338	14.05
DLC	1000	7	0.15	1050	2372	24.91
PQC	1000	7	0.34	2380	5439	129.45
					Total	179.30

The cost estimation for rest of the CBR values for both the cases have been carried out in the same manner and these are tabulated in table 6 and table 7 respectively when existing ground is used as subgrade without replacement with select soil and when existing ground is replaced with select soil of 8% CBR value.

Table 6. *Cost of pavement when existing ground is used as subgrade*

CBR of exisitng ground (%)	2	4	6	8	10
Cost per km (In lacs)	170.30	170.30	166.48	166.48	166.48

Table 7*. Cost of pavement when existing soil is replaced with select soil of 8% CBR value*

CBR of existing ground (%)	2	4	6
Effective CBR (%)	4.8	6.5	7.6
Cost per km (in lacs)	179.30	175.48	175.48

5. Results and Discussions

5.1 Effect on thickness of Pavement

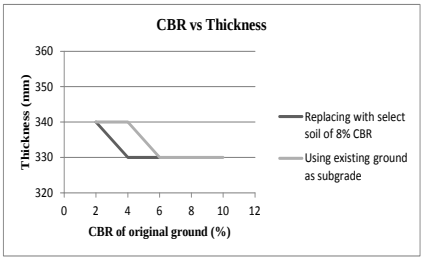

Figure 1. *Variation in thickness with CBR*

It is observed from fig. 1 that the existing subgrade of CBR 2% when replaced with select soil of CBR 8% does not decrease the thickness of the pavement. Similarly the existing subgrade of CBR 6% when replaced with select soil of CBR 8% does not decrease the thickness of the pavement. The existing subgrade of CBR 4% however showed a marginal decrease in the thickness of the pavement from 340 mm to 330 mm when replaced with select soil of CBR 8%. The increase in CBR of the subgrade soil does not lead to reduction in thickness of the pavement as the reduction in load stresses due to stronger subgrade gets compensated by increase in temperature stresses caused due to stronger subgrade.

5.2 Effect on Cost of Pavement

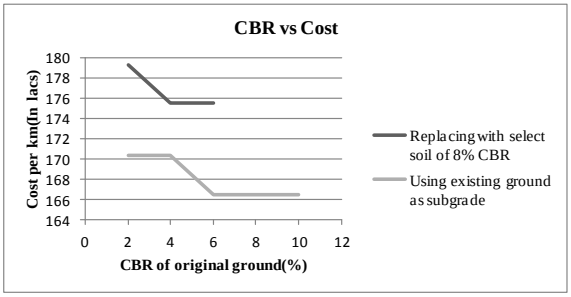

Figure 2. *Variation in cost with CBR*

As the replacement of existing subgrade soil with select soil of CBR 8% does not lead to any decrease/appreciable decrease in the thickness of the pavement, on the other hand it adds to the cost of pavement due to the cost of borrowed soil and preparation of subgrade with the same. This leads to actually increasing the cost of pavement as shown in fig. 2. It is observed that the cost of pavement increases by about rs 5-10 lacs per km when existing subgrade of CBR 2%, 4% and 6% is replaced with borrowed select
soil of CBR 8%.

6. Conclusions

The paper has brought out the effect of replacing the existing subgrade soil of CBR 2-6% with borrowed select soil of CBR 8% on thickness and cost of pavement. It is found that the replacement does not lead to any decrease or an appreciable decrease in the thickness of the pavement. The cost of pavement is actually found to increase with replacement of existing subgrade soil of low CBR values with select soil of CBR 8%. The IRC:58 [1] recommendations of using select soil of minimum CBR 8% in the subgrade of the pavement for traffic more than 450 CVPD, therefore, need to be applied carefully and judiciously.

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