Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 4, Issue 3; April-June, 2017, pp. 188-191

http://www.krishisanskriti.org/Publication.html

Study on the Economy of Flexible Pavement Runway by Replacing Granular Base and Granular Sub Base by Cement Treated Base Course

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Abstract—*It has been observed that generally the conventional flexible pavement designed for a runway comprises of bituminous layer, stabilized base and/or granular base, granular sub-base course, and subgrade. It has been found that in the present time the pavement designer are shifting towards the composite pavement in which the cement treated granular/soil layer can be used in the place of granular base/sub-base course. This paper presents the result of the study in which the effect on the total pavement thickness and cost estimation has been studied by replacing the granular layer by the cement treated granular course in a flexible pavement of a runway. The design of a runway has been done by using the software FAARFIELD 1.305 for the varying strength of subgrade soil from CBR 3% to 8% and the cost estimation has been done on the basis of standard data book of MoRTH.*

Keywords*: FAARFIELD 1.305, Subgrade CBR, Flexible pavement, cost estimation, cement treated base course.*

1. INTRODUCTION

FAARFIELD 1.305 software is designed by Federal Aviation Authority (FAA) and it is easily available in their site (https://www.faa.gov/airports/engineering/design_software). This software is based on the standards defined in advisory circular (AC 150/5320 6E). It designs a flexible and rigid pavement of a runway based on layered elastic theory and 3-D finite element theory respectively. For flexible pavement, it computes the maximum horizontal strain at the bottom of the bituminous pavement and maximum vertical strain on the top of the subgrade in order to ensure the safe design. The cumulative damage factor of the subgrade is also evaluated and it should be equal to one for the safe and efficient design. Considering the traffic mix and the subgrade CBR value as the input value it automatically evaluates the designed thickness of the sub base, base and the surface course for a flexible pavement. Although, the surface course and base course thickness can be manually adjusted but software calculate the sub base course thickness and its thickness value cannot be altered by the user like base course and surface course thickness can be changed. The code [1] has also mentioned the minimum thickness for each course hence it is necessary to take care of these defined minimum thickness while deciding the thickness of the layers decided manually. Further, as per AC 150/5320 6E, if the total gross load on the runway is more than 45,450kg then it is necessary to provide the stabilized base course. Hence, it is important to take care of the design traffic mix and accordingly the base course should be provided.

As we know that flexible pavement comprises of different layers namely surface course; stabilized/unstabilized base course; stabilized/unstabilized sub base; subgrade. It is evident that the variation in the strength of any layer of the flexible pavement will inversely affect the total thickness of the pavement. In this paper, the cement treated base course completely replaces the granular base and sub-base course due to which change in the total designed thickness and cost of construction is being observed.

2. DESIGN OF FLEXIBLE PAVEMENT USING FAARFIELD 1.305

The flexible pavement is designed for a length of 1000 meters and width of 45 meters. The thickness of the pavement is computed by the software which is based on the traffic mix and the subgrade strength. The traffic mix used in the designing is mentioned in Table 1.

Table 1 TRAFFIC MIX USED IN THE DESIGN PROCESS

Serial no.	Name	Gross Weight (tonnes)	Annual Departures	Annual Growth
1	Single wheel 75	34.019	1200	0.00
2	Dual wheel 100	45.359	1200	0.00
3	Boeing 500	60.781	1200	0.00
4	Boeing 600	66.224	1200	0.00
5	Boeing 800	79.243	1200	0.00
6	Boeing 900 ER	85.366	1200	0.00

FAARFIELD 1.305 software also allows us to opt the pre-defined stabilized/unstabilized base course and surface course. It has been observed that a trend of the composite pavement is being practiced in highway design in which

bituminous layer is being placed on cement treated base course. It has been great success in highway so in this paper a comparative study is made to understand to extent to which reduction in total thickness of pavement can take place and also to observe that whether there is reduction in total cost.

Hence, two pavements of runway is designed one is conventional flexible pavement of runway whose details are shown in Table 2 which comprises of subgrade, granular sub-base, granular base (WMM), dense bituminous macadam as stabilized base course (because gross load is more than 45,450kg so stabilized base course is required) and bituminous concrete is used as surface course and second composite pavement comprises of subgrade, cement treated base course, dense graded bituminous macadam (this is being provided to arrest the probability of reflective crack) and bituminous concrete as surface course and details of this pavement is mentioned in Table 3.

Table 2: TOTAL DESIGNED THICKNESS OF CONVENTIONAL FLEXIBLE PAVEMENT FOR DIFFERENT CBR VALUE OF SUBGRADE

CBR (SUBGRADE)	P154(GSB) (mm)	P209(WMM) (mm)	P401/P403(DBM) STABILIZED COURSE (mm)	P401/P403(BC) SURFACE COURSE (mm)	TOTAL THICKNESS (mm)
3	750	250	127	102	1229
4	620	250	127	102	1099
5	500	250	127	102	979
6	420	250	127	102	899
7	330	250	127	102	809
8	260	250	127	102	739

It has been observed that difference in the total thickness of the pavement of the conventional and composite pavement is about 57.40% when subgrade strength is 3% and this difference decreases to 44.70% when the subgrade strength is 8%.

Table 3: TOTAL DESIGNED THICKNESS OF COMPOSITE PAVEMENT FOR DIFFERENT CBR VALUE OF SUBGRADE

CBR (SUBGRADE)	P304(CTB) STABILIZED COURSE (mm)	P401/P403(DBM) SAMMI LAYER (mm)	P401/P403(BC) SURFACE COURSE(mm)	TOTAL THICKNESS (mm)
3	295	127	102	524
4	260	127	102	489
5	235	127	102	464
6	210	127	102	439
7	195	127	102	424
8	177	127	102	409

The composite pavements total thickness is comparatively less than the conventional flexible pavement of a runway but it has be observed that will it be economical to use composite pavement in place of conventional flexible pavement or not. Further, to answer this question cost estimation is being done.

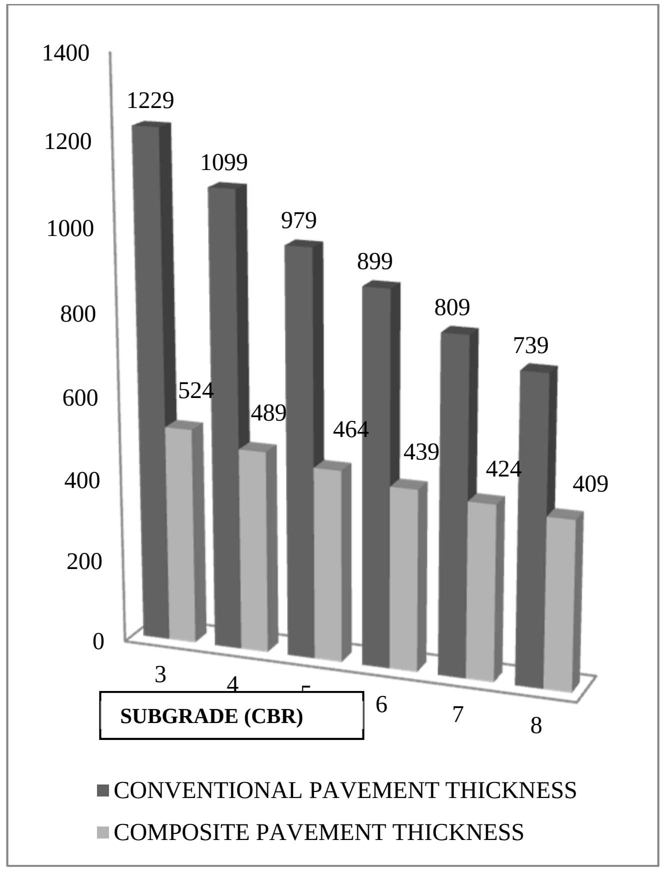

Fig. Error! Use the Home tab to apply 0 to the text that you want to appear here.**1: Comparison between total pavement thickness of conventional flexible and composite pavement**

3. RATE ANALYSIS

The total cost analysis of the construction has been done on the basis of Standard data book for the analysis of rates for road and bridge works of MoRTH (4th revision). Rate per unit of each item that is required in the construction of a flexible pavement of a runway has been mentioned in the Table-4

Table 4: ITEM DESCRIPTION AND THEIR RESPECTIVE COST

S.N	Item description	Unit	Rate (Rs)
1	Compacting original ground supporting subgrade	m3	56
2	GB(Granular base WMM)	m3	1110
3	Construction of GSB by providing close graded material of grading I	m3	1071
4	Prime Coat @0.60kg/m2	m2	19.50
5	Tack Coat @0.20kg/m2	m2	8.0

6	Cement treated base course (cement content 4%)	m3	1700
7	DENSE BITUMINOUS MACADAM(With VG 30 and Grading II)	m3	5543
8	BC(Bituminous concrete) (Grading I)	m3	6269

4. COST ESTIMATION

Using the rate of the individual items as mentioned in Table 4, the estimation of the cost is conducted. In the Table 5 and Table 6 the total cost incorporated during the construction of each layer of the flexible pavement of the runway when the subgrade CBR is 8% has been shown.

As it is clear from the Table 5 and Table 6 that the composite pavement is more economical than the conventional flexible pavement and it has been found that the total cost in the construction of the each layer of composite flexible pavement is 4.3% lesser than conventional flexible pavement

Table 5: Total cost of the conventional flexible pavement of a runway when subgrade CBR is 8%

ITEM	**DIMENSIONS**			**QUANTITY (a)**	**UNIT**	**RATE (Rs) (b)**	**COST (Rs) =(a*b)**
	LENGTH (L)	WIDTH (B)	DEPTH (D)				
SUBGRADE	1000 m	45 m	0.5 m	22500	m3	56	1260000.00
GSB	1000 m	45 m	0.26 m	11700	m3	1071	278460.00
WMM	1000 m	45 m	0.25 m	11250	m3	1110	277500.00
DBM	1000 m	45 m	0.127 m	5715	m3	5543	703961.00
BC	1000 m	45 m	0.102 m	4590	m3	6269	639438.00
PRIME COAT	1000 m	45 m	-	45000	m2	19.50	877500.00
TACK COAT	1000 m	45 m	-	45000	m2	8.0	360000.00
TOTAL	-	-	-	-	-	-	4396859.00

Table 6: Total cost of the composite pavement of a runway when subgrade CBR is 8%

ITEM	**DIMENSIONS**			**QUANTITY (a)**	**UNIT**	**RATE (Rs) (b)**	**COST (Rs) =(a*b)**
	LENGTH (L)	**WIDTH (B)**	**DEPTH (D)**				
SUBGRADE	1000 m	45 m	0.5 m	22500	m3	56	1260000.00
CTB	1000 m	45 m	0.18 m	8100	m3	1700	306000.00
DBM	1000 m	45 m	0.127 m	5715	m3	5543	703961.00
BC	1000 m	45 m	0.102 m	4590	m3	6269	639438.00
PRIME COAT	1000 m	45 m	-	45000	m2	19.50	877500.00
TACK COAT	1000 m	45 m	-	45000	m2	8.0	360000.00
TOTAL	-	-	-	-	-	-	4146899.00

5. RESULT AND DISCUSSION

The cement treated base course has replaced the granular sub-base and granular base (WMM). The modulus of resilience of the cement treated base course taken in the design is 3447.38 Mpa which is much higher than that of granular base(WMM) whose modulus of resilience is 372.36 Mpa and that of granular sub-base is 158.26 Mpa when the subgrade CBR is 8% . It has to be taken care of that modulus of resilience of granular layer depends on the strength of the underlying layer and its thickness although the modulus of resilience is cement treated base course is constant and in the program it is taken as fixed value of 3447.8 Mpa. As evident from the modulus of resilience value that cement treated base course is much stronger than that of granular course due to which more than 50% decrease in the total thickness has been observed. The effectiveness of providing the cement treated base course in place of granular course when the subgrade strength is low. When the subgrade CBR was 3% then the reduction in the total thickness was 57.40% and when the subgrade CBR was 8% then decrease in total thickness of pavement is 44.70%. Moreover, reduction in the cost was 11.80% when CBR of subgrade is 3% and reduction in the cost was 5.70% when CBR of subgrade is 8%. These results shows that the use of cement treated base course is economical but there is one disadvantage of using cement treated base course is that there is high probability of reflective cracking on the bituminous surface layer due to shrinkage in the cement treated base course although this can be avoided by either providing crack relief layer or SAMMI layer as mentioned in IRC 37:2012. Moreover, in other countries thick bituminous layer is provided above cement treated base course approx. 150mm to 200mm to avoid reflective crack. The cement content required in the design mix of cement treated base course may vary after considering the fatigue analysis and making sure that tensile strain at the bottom of the cement treated base course is sufficient enough that does not lead to develop a crack.

6. CONCLUSION

The use of cement treated course by replacing the granular base and sub-base course will lead to decrease in the total pavement thickness and the construction cost also as observed from a design example designed by FAARFIELD 1.305 software. This replacement not only reduces the total cost of construction but also reduces the total thickness due to which the construction period of composite pavement will be also less.

REFERENCES

[1] AC 150/5320 6E *"AIRPORT PAVEMENT DESIGN AND EVALUATION"*, FEDERAL AVIATION ADMINISTRATION.

[2] AC 150/5370 10G *"STANDARDS FOR SPECIFYING CONSTRUCTION OF AIRPORTS DOCUMENT INFORMATION"*, FEDERAL AVIATION ADMINISTRATION

[3] STANDARD DATA BOOK FOR THE ANALYSIS OF RATE, BASED ON *"SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (4TH REVISION)"*, MINISTRY OF ROAD AND TRANSPORT HIGHWAYS, INDIAN ROAD CONGRESS, NEW DELHI.