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Study on Comparision of Life Cycle Cost Between White Topping and Btiuminuos Overlays

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Abstract: The focus of the present study is on construction of long-lasting and better performing pavements. Usually, with respect to the rehabilitation of the pavement, the construction agencies go with the bituminous overlays as their first priority without considering the condition of the existing pavement structure. But the advantages of cement concrete (CC) pavements that have proved to perform better and are considered to be long-lasting must be explored. The use of Thin White Topping (TWT), and Ultra-Thin White Topping (UTWT) pavements is currently gaining popularity in the area of pavement construction.. And hence it is the era where the Thin and Ultra-Thin White Topping methods are gaining their popularity. The present study provides details on the approaches adopted in measuring the performance of TWT and UTWT pavement surfaces built of plain cement concrete, cement in cement concrete replaced by 50% ground granulated blast furnace slag, cement in cement concrete replaced by an admixture called Conplast NC, and 50% of cement in cement concrete replaced by GGBS and Conplast NC. The study also includes comparison of strength of composite beams of various thicknesses when subjected to repeated wheel loads under Modified Immersion Wheel Tracking Equipment when supported by a 50mm thick bituminous layer below. The performance results on the tests on the specimens of 150mm thick admixture-added CC beam and the 100mm thick GGBS-cum-Admixture-added CC beam were almost the same.

This indicated that the thickness of cement concrete slabs could be reduced by 50mm by replacing 50% of cement in cement concrete with GGBS-cum Admixture-added CC beam. Based on the study on cement concrete, and composite beams, and the study of life cycle costs, it was observed that a road surface with cement concrete overlay would be more appropriate when compared to a bituminous concrete (BC) overlay. Together, these findings suggest that the concrete overlay acts as the most economic method.

Keywords: TWT, UTWT, Conplast NC, GGBS, Immersion Wheel tracking equipment, Life cycle cost.

I. INTRODUCTION

White topping is the concrete layer laid over a deteriorated asphalt pavement. The main aim of concrete overlay is to enhance the strength of the existing asphalt structure by rebuilding it.

While achieving this, the overlay also brings back the functional requirement of the existing structure which had undergone deformations like rutting and also brings back the texture. Bituminous roads have been widely used in the world from many years due to the availability of bitumen at a lower cost, and the ease of construction. Bu the adoption of refined petroleum processing technology has resulted in a reduction in the availability of bitumen, coupled by increased import costs. In the meanwhile, concrete technology, and its applications have improved. Also, apart from the initial cost of investment, the impact of life-cycle costs also need to be considered.

A. Types of White Topping

White Topping technology can be classified as follows based on the types of bondage provided and the thickness of overlay.

1) *Ultra-Thin White topping (UTWT):* It is a Portland Cement Concrete overlay of below 100 mm thick. It is mandatory to obtain the bond between the overlay & the below asphalt layer.
2) *Thin White topping (TWT):* It is a Portland Cement Concrete overlay of thickness 100 to 200 mm. It can be designed either by considering or without considering the bond between the overlay & the underlying bituminous layer.
3) *Conventional White Topping:* It is a Portland Cement Concrete overlay of 200 mm thick or higher than 200mm. It can be designed and constructed without the consideration of bonding between the two layers (composite action is not assumed).

Hence the UTWT and TWT methods are considered as Bonded overlays which are normally used for the resurfacing and also for rehabilitation of the distressed pavements.

II. LITERATURE REVIEW

1) *A K Sehgal et al;[1]* have studied the advantages and benefits of Thin White Topping over bituminous overlays and have done comparison between the two considering the sustainability as the main criteria. The other factors considered are design life, life cycle cost and other environmental factors. Their study concludes that TWT overlays are considered more environmentally and economically sustainable as compared to that of bituminous overlays. But the study does not presnt the comparisio between the cost of construction and maintenance with a flexible overlay.
2) *V K Sinha et al;[2]* attempted to bring forth the concept of white topping over existing bituminous pavement. They computed the thickness for the bituminous overlay as well as for the concrete overlay and cost estimation for both. In their study, comparison is done based on total life cycle cost. And from the paper, it is noted that the savings in the construction cost of doing white topping against bituminous overlay is evidently convincing and hence life cycle cost is more economical.
3) *Mustaque Hossain;[3]* carried out the study to build up a design catalogue for existing roadway which is to be overlaid with the TWT. The 3-D Finite Element (FE) analysis was used to expand the design catalogue. The results obtained from this study showed that the interface bonding condition between the overlay and the existing layer is the most important factor which affects the behavior of thin white topping.
4) *Dr. Abhijith C.C;[4]* study dealt with the performance of UTWT overlays of different combinations over bituminous concrete layer. From this study, the direct tensile test indicated that the ROFF cement interface improved the bond strength in all the combinations when compared to that of plain cement concrete beams. Also the results of Modified Immersion Wheel Tracking test indicated that the performance of composite beams directly depended upon the thickness of the cement concrete layer (as the thickness increases, yields very low rut value), radius of stiffness of the composite beams and also the admixture used and its percentage. But the statement of decrease in the rut value with the increase of thickness shall be checked for various combinations of the the concrete mix.

The research gaps from the above studies leads to find the new insights to carry out the study such as i). performance study various combinations TWT and ULTW layers along with a flexible layer below ii). Assessing the best combination from the performance study iii). Comparision of cost analysis between the best combination and the bituminous overlay.

III. OBJECTIVES AND METHODOLGY

The main objectives of this study are;

1) To evaluate the suitability of various composite-beam specimens based on tests using the Immersion Wheel Tracking equipment in the laboratory.
2) To compare the results of beam specimens made of CC, and specimens made with added admixtures and slag.
3) To arrive at the most economic option out of various combinations with respect to the cost and the strength.
4) And to compare the life cycle cost of best performing concrete overlay with the bituminous overlay of a distressed road.

The Methodology invovled is as follows;

a) Basic tests on all the materials (Bitumen, Aggregates, Cement and mix design for BC mix and CC mix) to be used
b) BC layer of 50mm representing the flexible surface has been casted and compressed using an I section girder plate.
c) Above the flexible layer, Concrete layers of varying thickness (50mm, 100mm and 150mm) have been casted.
d) Composite beams are cured.
e) And tested for performance under a Modified Immersion Wheel Tracking Equipment.
f) Design of concrete overlay for the best perfomring combination.
g) Design of a flexible overlay as well
h) Compriosn of life cycle cost between the rigid overlay and flexible overlay.

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IV. RESULTS AND DISCUSSIONS

A. Performance Test Results

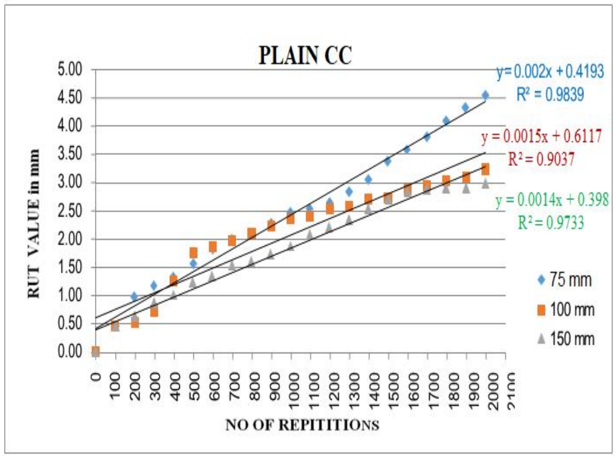

Fig 1: Linear Regression curve for Plain Cement Concrete (CC) beams

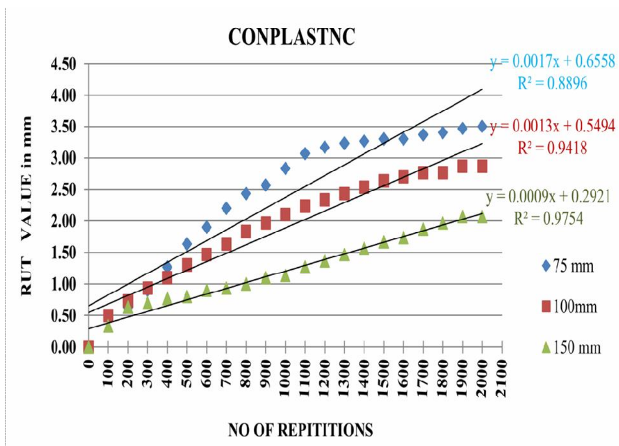

Fig 2: Linear regression curve of CC beams with Conplast NC

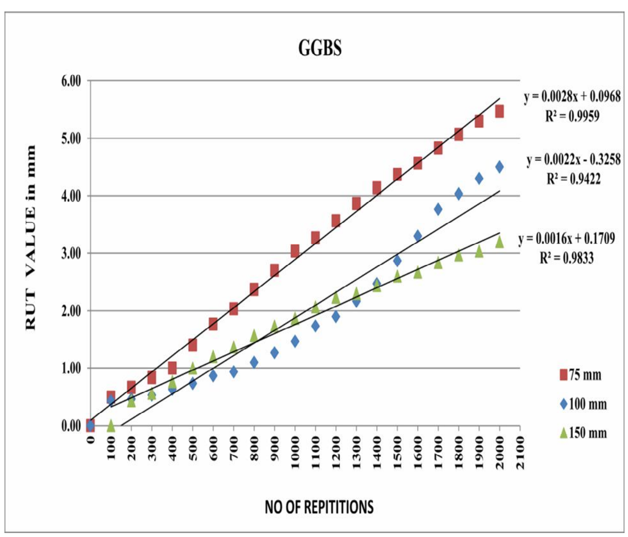

Fig 3: Linear regression curve of CC beams with Ground Granulated Blast furnace Slag (GGBS)

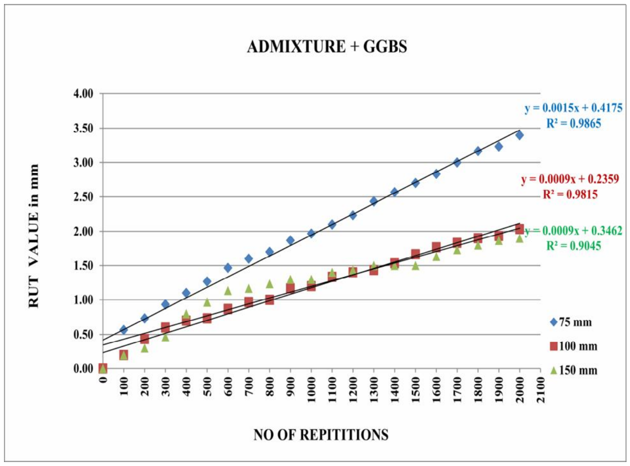

Fig 4: Linear regression curve of CC beams (with GGBS + Conplast NC)

Results based on Fig. 1 to Fig.4 indicate that the performance of beam specimens made of GGBS with a combination of Conplast NC admixture performs better even when compared to CC beam specimens of similar thicknesses.
And hence the 4th combination is treated as the most economic combination and the same is considered for the overlay design and the cost estimation.

B. Design of Concrete Overlay AS PER IRC SP 76 2008

Table 1: Road details

Name of the road	Mulberry main road (Bommasandra Industrial road, Bangalore)
Length of the road	900 m
Roadway width	10.90 m
Average carriageway width (existing)	6.1 m
Drains	BS Slab drain
Condition of drain	Silted

TABLE 2: Details of structural evaluation of pavement

Deflection from BBD studies	1.82 mm
Traffic volume	1500CVPD

TABLE 3: Details of functional evaluation of pavement

Potholes percentage	52.62%
Cracks percentage	2.98%
Pavement Condition Index (PCI)	24(POOR)

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Considering the structural evaluation by BBD for a Characteristic deflection of 1.82 mm and for the PCI value of 24 obtained, the pavement condition is POOR. Hence the pavement requires Strengthening.

TABLE 4: Design factors

Present traffic	1500 CVPD
Design life	20 years
Growth rate	7.5%
Cumulative repetitions in 20 years	23709313
Trial thickness	18cm
K value corresponding to the BBD value of 1.82mm	5.5 kg/cm³
Modulus of rupture	45 kg/cm²
Load safety factor	1
A minimum value of modifies modulus of Subgrade 10 kg/cm³ is considered for the design	

TABLE 5: Design from fatigue consideration using programme IITRIGID

Single Axle Load			Tandem Axle Load		
Axle load Range (Tons)	Total % of SA	Expected repetitions	Axle load Range(Tons)	Total % of TA	Expected repetitions
16	0.74	43862	28	0.29	17189
14	1.11	65793	24	0.29	17189
12	34.06	2018848	20	0.29	17189
10	30.94	1833915	16	0	0
less than 10	29.94	1774642	less than 16	2.79	165372
Total		5737061			216940

TABLE 6: Stress ratios at different axle loads under the category of single axle

Axle load in tons	AL*1	Stress kg/cm2 from IIT RIGID Programme	Expected repetition	Fatigue life N* 0.75	Fatigue life consumed
16	16	25.3	43862	70575	0.62
14	14	22.7	65793	571500	0.12
12	12	20	2018848	Infinity	
10	10	17.2	1833915	Infinity	
Less than 10	-	-	1774642	Infinity	
Total	-	-	-	-	0.74

TABLE 7: Stress ratios at different axle loads under the category of tandem Axle

Axle Load in tons	AL * 1	Stress from IITRIGID Programme in kg/cm²	Expected repetitions	Fatigue life N*0.75	Fatigue life consumed
28	28	17.8	17189	Infinity	0
24	24	15.8	17189	Infinity	0
20	20	-	17189	Infinity	0
16	16	-	0	Infinity	0
Less than 16	-	-	165372	Infinity	0
Total					0

0+0.74 = 0.74 < 1 and hence safe

Thickness of concrete overlay obtained as per Westergaard equation and warping stress equation is **180 mm.**

TABLE 8: Cost estimation for rigid overlay (KPWD S2014-2015)

Sl no	Item of work	Cost
1	Scarification of existing bituminous surface	164543
2	Application of tack coat	114189
3	Pavement Quality Concrete M40 grade(180mm thick)	7863917
4	Earthwork excavation for desilting of drains	38934
Total Construction cost		8181583
Maintenance cost for 20 years(Generally an average of 50000/year & needs no overlay for first 20 years		1000000
Total cost		9181583

C. Design of Flexible Overlay as Per IRC 87 1997 & ASTM 6433 – 11)

Considering the structural evaluation by BBD for a Characteristic deflection of 1.82mm and for the PCI value of 24 obtained, the pavement condition is POOR. Hence the pavement requires Strengthening**.**

TABLE 9 :Additional thickness of flexible overlay

Bituminous Concrete (BC) layer	40mm grade II
Dense Bituminous Macadam (DBM) layer	50 mm grade II
Wet Mix Macadam (WMM) layer	50 mm single layer

TABLE 10: Cost estimation for flexible overlay (KPWD S2014-2015)

Sl no	Item of work	Cost
1	Scarification of existing bituminous surface	164543
2	Construction of Wet mix Macadam(50mm single layer)	1315024
3	Application of primer tack coat	214576
4	Application of tack coat	11419
5	Construction of Dense Bituminous Macadam (50mm grade II)	2777477
6	Construction of Bituminous concrete(40mm grade II)	2796959
7	Earthwork excavation for desilting of drains	38934
Total Construction cost		5839366
Maintenance cost for 20 years (1.5 Lakh/year @ resurfacing for every 5 years		10800000

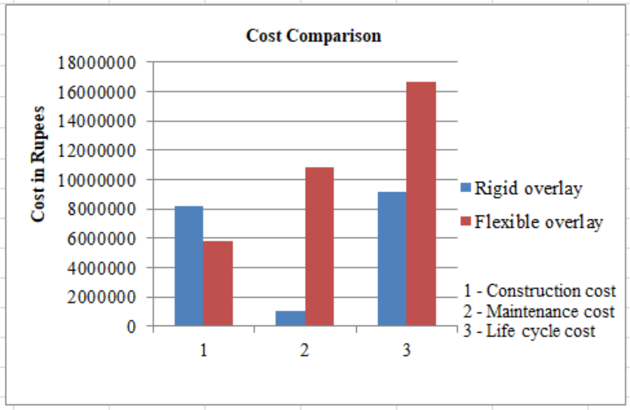

Figure 5: Cost comparison b/n Rigid and Flexible overlay

From the estimation of life cycle cost for the rigid and the flexible overlay, it is known that the initial cost or construction cost is very high for the rigid overlay when compared to that of flexible one. But the concrete overlay behaves more economic when the life cycle cost is considered. The maintenance cost for the flexible overlay is very high when compared to that of rigid overlay.

V. CONCLUSION

1) From the performance results it is known that the rut value decreases with the increase in the thickness of the beam.
2) And hence it is observed that the performance of the slab increases with the increase in the thickness of the slab.
3) The correlation values are less than or close to 1 for each combinations of concrete at a tyre pressure of 8kg/cm^2 on the slab, which signifies that deflection and repetitions are strongly correlated.
4) By comparing the performance results of various concrete combinations it is known that the GGBS + Admixture combination had performed well.
5) The GGBS added concrete has the least performance when compared to all other combinations.
6) From the performance results it is observed that the performance results of 150mm thick Plain CC beam and 100mm Admixture added beam has almost the same value.
7) And hence it can be concluded that the slab thickness can be reduced by 50mm with the addition of admixture.
8) And also the performance results of 150mm thick admixture added CC beam and the 100mm thick GGBS & Admixture added CC beam has almost the same value.
9) Hence it can also be concluded that the slab thickness can be reduced by 50mm by replacing 50% GGBS to the Admixture added CC beam.
10) From the cost analysis it is known that the construction cost is very high for the Rigid overlay than the flexible overlay.
11) But the maintenance cost is very low for the rigid overlay.
12) Rigid overlay has the most economic life cycle cost when compared with that of flexible overlay.

VI. STUDY LIMITATIONS AND FUTURE SCOPE OF WORK

1) The present work can be extended by studying the performance with the application of bonding agent between the layers.
2) The performance results can also be assessed by other tests like pull out test, fatigue test etc.
3) The performance results can also be assessed in immersion condition using the same equipment.
4) Study can be furthered continued by replacing the conventional concrete by geo polymer concrete.
5) Study can be furthered continued by replacing the conventional concrete by Engineered Cementitious Concrete.

VII. ACKNOWLEDGMENT

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