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WHITE TOPPING OR CONCRETE OVERLAY FOR HIGHWAYS

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Abstract: The study has been undertaken & investigate white topping is rehabilitation treatment on asphalt concrete. It is defined as plain cement concrete overlay on asphalt concrete. It provides a new innovative method of rehabilitation at a very low cost with very good results and low maintenance cost.

By adopting proper construction methods, we can rehabilitate large network of roads at reasonable cost and we get additional long life. This project presents a methodology to adopt white topping as rehabilitation treatment and cost-effective rehabilitation alternative for preserving bituminous pavements on long-term basis. Ultrathin white topping (UTW) is a concrete overlay of a distressed asphalt pavement, 50 to 100 mm thick, with close joint spacing. The overlay is specifically bonded to the existing asphalt pavement. It may or may not contain fibers. By bonding the UTW to the existing asphalt surface, the UTW forms a composite pavement section with the under- lying asphalt, which reduces the stresses in the concrete layer. This composite pavement section delivers the longer life and durable performance characteristics of concrete pavement and is cost competitive with ordinary asphalt.

In addition, rapid developments in concrete material technology and mechanization are favoring concrete overlays as a sustainable option. White topping is gaining momentum in road construction across the country. It can act as a long-term alternative for the rehabilitation or structural strengthening of roads.

Keywords : white topping, asphalt, Bitumen, Concrete, Overlay, Cement, PCC.

I. INTRODUCTION

a. The existing pavement is utilized as a subbase in a CDOT, TWT: the asphalt is simply milled and the new concrete overlay is constructed on the milled asphalt surface. Conventional concrete overlays of asphalt pavements (White topping) are a well-established rehabilitation technique. The first one was built in 1944 on an air field at the U.S. Air Force Base in Offutt, Nebraska. Since then, over 189 documented white topping projects have been built throughout the United States on all types of high-way, street, county road, airport, and parking area pavements. White topping is a relatively new rehabilitation technology for deteriorated Hot Mix Asphalt (HMA) pavement. Concrete overlays have been used to rehabilitate existing concrete pavements since 1913 and to rehabilitate existing asphalt pavements since 1918 in USA. Thin white topping, also known as thin bonded concrete overlay on asphalt (BCOA), is a rehabilitation alternative consisting of a 0.33 to 0.58 ft (100 to 175 mm) thick Portland cement concrete (PCC) overlay of an existing flexible or composite pavement. It has been used on highways and conventional roads in several U.S. states, including Minnesota, Colorado, Iowa, Missouri, Kansas, Mississippi, Washington, Ohio, and Kentucky, as well as in other countries, including Canada, Mexico, Brazil, Belgium, Austria, Japan, and France. In the past, this technology has been known as “thin white topping.” Currently, the term “bonded concrete overlay on asphalt” is preferred because it more accurately reflects the overlay’s mechanical behavior and differentiates it from unbonded concrete overlays.

Road traffic is increasing steadily over the years. This is an international phenomenon. An international forecast predicts that such increase will continue in near future. The position in the context of a developing country like India is obviously far worse. As a result, more and more roads are deteriorating and the existing pavement structure as a whole is often found to be inadequate to cope up with the present traffic. The proper strengthening and maintenance of roads (is urgently required to ensure balanced regional development and alleviation of poverty as they connect the villages and other small to big centers harboring backwardness. A majority of these roads do not have traffic worthy pavement. White topping is a rehabilitation method for moderately distressed hot mix asphalt (HMA) pavements by plain concrete (PC) or fiber reinforced concrete (FRC) overlay. White topping is constructed with thinner and shorter slabs. The structural stiffness of the existing HMA layer and the interface bonding between the concrete and HMA layers are accounted for in the mechanistic design procedure. This results in the need for a thinner concrete slab.

The main advantage of this type of overlay over the traditional HMA overlays is the use of the underlying HMA layer to carry the traffic load, and thus reducing the thickness of the overlay.

Road traffic has been increasing rapidly over the years and such increase will continue in near future as well. Even in case of developed countries, there is a shortage of funds required for new infrastructure projects, both for construction and more significantly towards their repairs and maintenance. The position in the context of a developing country like India is obviously far worse. As a result, more and more roads are deteriorating and the existing pavement structure as a whole is often found to be inadequate to cope up with the increased traffic. India has a road network of more than 46 lakh kms which is second largest in the world after US. The length of National Highways is 92,851 km and the State Highways is 1,63,898 km (MORTH 2013). Most of the roads in the network have bituminous pavements which have a problem of getting deteriorated with time. Hence, proper strengthening and maintenance of the roads is required. The cost of strengthening by conventional methods of this large network needs huge resources both physical and financial which are quite scarce. Due to budget constraints, when pavements are left to deteriorate without timely maintenance treatment, they become candidates for rehabilitation.

A. Application in India

In recent years places like Mumbai, Indore Nagpur in India, concrete overlays (white topping) on existing flexible pavement have been constructed successfully. During last century several new concrete roads were constructed in South India which was up to the mark for a period over four decades. They were the Bangalore -Mysore road constructed by the then Maharaja of Mysore, the coastal roads in Kerala etc. Due to lack of experience and technology in white topping, these roads were converted to flexible overlays in recent times.

B. Types Of White-Topping

I. Conventional white-topping-

It consists of a PCC overlay of thickness more than 200 mm (on top of existing bituminous layer) which is designed and constructed without consideration of any bond between the concrete overlay and underlying bituminous layer. Conventional white-topping is designed and contacted like a new rigid pavement without assuming any composite action. It treats the existing bituminous surface as a sub-base like Dry Lean Concrete (DLC) and to this extent the condition of existing bituminous surface does not matter significantly, except that bituminous surface should not suffer from any isolated damages like subsidence or material related problems.

II. Thin White-topping

PCC overlay of thickness greater than 100 mm and less than or equal to 200 mm is classified as Thin White-topping (TWT). The bond between the over laid PCC and the underlying bituminous layer is often a consideration but it is not mandatory. The bonding consideration may be ignored in the design. High strength concrete with fibres are commonly used. Joints are at shorter spacing of 0.6 to 1.25m.

III. Ultra-Thin White-topping-

PCC overlay of thickness equal to or less than 100 mm is classified as ultra- thin white-topping (UTWT). Bonding between the overlaid PCC and the underlying bituminous layer is mandatory in this case. Milling the existing bituminous surface to a depth of 25-40 mm is normally done to provide the necessary bonding at the interface between the existing bituminous surface and PCC overlay. Such bonding can be provided by some other methods such as chiseling or mechanical means, but milling is considered desirable because effective bond between the existing and overlaid surface is absolutely essential for a better performance of UTWT. Fibers and high strength concrete are normally provided.

II. LITRATURE REVIEW:

Covering of asphalt pavement with a layer of cement concrete is termed as White topping. On the basis of thickness of the concrete layer it can be divided into bonded and unbonded or conventional White topping. When the thickness of the concrete layer is 200 mm or more and not bonded to the asphalt it is called unbonded or conventional White topping. Bonded White topping is of thickness of 50 mm to 150 mm bonded to Asphalt pavement layer and is of two types, thin and ultrathin. The bond is made by texturing the asphalt. Thin white topping is a bonded layer of concrete of thickness 100 mm to 150 mm while an ultrathin layer is 50 mm to100 mm thick. The use of ultrathin white topping (UTW) is preferred for deteriorated asphalt pavements with fatigue and rut distress.(1) Thin white topping, also known as thin bonded concrete overlay on asphalt (BCOA), is a rehabilitation alternative consisting of a 0.33 to 0.58 ft (100 to 175 mm) thick Portland cement concrete (PCC) overlay of an existing flexible or composite pavement. It has been frequently used in different U.S. states and in other countries in the Americas, Europe, and Asia. Thin white topping, also known as bonded concrete overlay on asphalt (BCOA), is a rehabilitation alternative consisting of a 0.33 to 0.58 ft (100 to 175 mm) thick Portland cement concrete overlay on an existing flexible or composite pavement.(2)

White topping is one of the strengthening can be adopted for rural road network and district roads as these roads have low to moderate traffic. Even on the state highways and some recently declared national highways, where traffic is moderate Even on the state highways and some recently declared national highways, white traffic topping, a large network of roads can be strengthened at reasonable costs and these strengthened roads coming under Nagpur District was selected and extensive field, laboratory investigation, pavement analysis and design of rehabilitation alternative were carried out. The laboratory investigation includes various test such as classification of soil, water content, maximum dry density, free swell index, California bearing ratio (CBR) test, Atterbergs test, etc. for determining the characteristics of existing bituminous pavement.(3)

III. METHODOLOGY:

PAVEMENT DESIGN:

Pavement design aims at determining the total thickness of the pavement structure as well as the thickness of the individual structural components for carrying the estimated traffic loading under the prevailing environmental conditions. Many design methods, from purely empirical to rigorous analytical ones are available, and these are practiced in different parts of the world. The design methods adopted in other countries may not be applicable to Indian climatic conditions. In India, the generally adopted method of design of flexible pavement is based on IRC: 37. Accordingly IRC: 37-2012 "Tentative Guidelines for the Design of Flexible Pavements", has been adopted and used for the current project. The overlay design has been carried out based on the procedure of IRC: 81-1997.

DESIGN METHODOLOGY

Salient Features of Thin White Topping

The development of an effective bond between PCC overlay and the existing bituminous pavement is desirable for the better performance of TWT because the strength of the existing bituminous pavement is being relied upon to carry part of the traffic load.

i) Extensive surface preparation to promote significant bonding between the concrete overlay and the bituminous pavement is required. Some times chiselling may also be tried gently at certain locations where milling is difficult to make the bituminous surface rough. (Excessive roughened surface, however, should be avoided as this could enhance the frictional forces)

ii) Use of short joint spacing (generally between 1.0 and 1.5 m). Square spacing (e.g. about 1.0 m x 1.0 m) are preferred. Rectangular spacing wherever given should have a ratio not exceeding 1.2 between the long and the short arms.

iii) The minimum thickness of hot mix bituminous pavement is 75 mm (net excluding the milled thickness) for TWT. However, it is preferable to have this minimum thickness of 100 mm or more to ensure a reliable strong bituminous base.

3.5 Design of White Topping As per IRC 76-2015 :

1	e Overlay Thickness and Grade	200 mm thick M 40 grade concrete (Flexural strength of 4.5 Mpa) on top of
		1. Existing bituminous layer after roughening
		2. Profile correction thickness of 25 to 30 mm to added in the above are overlay thickness. Hence concrete overlay thickness halla be 180 mm to 200 mm
		3. Polypropylene fibers to be added to the concrete to reduce shrinkage cracking
2	Concrete slab dimensions	1000 mm x 1000 mm
		Spacing of Transverse Joints = 1000 mm
		Spacing of Longitudinal Joints = 1250 mm
		Joint cutting to done within 14 to 16 hours of casting of concrete
3	Dowel Bar sytem	32 mm dia MS bars (500 mm long) at 250 mm c/c at mid depth of slab only at the constructuon joint
4	Tie Bar System	12 mm dia deformed bars (650 mm long) at 600 mm c/c placed at mid depth iof slab only at the center of the slab (140) mm from top) at the central longitudinal joint only

Design Parameter:

Design Life	: 20.00 years
Traffic Growth Rate, r	: 0.08
Commercial Traffic	: 250 cvpd
Grade of Concrete	: M40
Cumulative Repetitions in 20 years	: 3951552
Design Traffic	: 25 % of 3951552 = 987888
CBR	: 8%
Corresponding 'k' value is determined from a graph developed by corps of engineers against a Benkelman Beam Deflection Value	: 5.15
Modulus of Subgrade reaction	: 5.15 Kg/ cm3

Properties of Concrete:

28-day Compressive Strength of Cement Concrete	: 40 MPa
90-day Compressive Strength of Cement Concrete	: 48 MPa
28-day Flexural Strength of Cement Concrete	: 4.5 MPa
90-day Flexural Strength of Cement Concrete	: 4.95 MPa
Elastic Modulus of Concrete E	: 30000 MPa
Unit Wt Of Concrete	: 24 kN/m^3
Poisson's Ratio of Concrete	: 0.15

Slab Thickness (m)	**0.15**	**0.20**	**0.25**	**0.30**
Temp. Differential (ºC)	17.3	19	20.3	21

Temperature Differentials (oC)

Max. Day-Time Temperature Differential in Slab (for Bottom-Up Cracking)	21
Night-time Temperature Differential in Slab (for Top-Down Cracking)	15.5

Radius of Relative Stiffness, $l = 4\sqrt{\frac{E^{3}}{12k(1+\mu^{2})}}$ l 46.309 cm

Percentage of differenct Axle Loads assumed are given in Table 1:

Table 1: Percentage of Axle Load for the Design of TWT

Single Axle		**Tandem Axle**		**Tridem Axle**	
Axle Load Class	**Frequency()%**	**Axle Load Class**	**Frequency()%**	**Axle Load Class**	**Frequency()%**
15-17	4.20%				
13-15	10.60%	26-30	0.60%	26-30	0.00%
11-13	22.90%	22-26	1.80%	22-26	0.00%
9-11	23.30%	18-22	1.50%	18-22	0.00%
7-9	0.00%	14-18	0.50%	14-18	0.00%
Less than 8	30.00%	Less than 14	2.00%		0.00%
Total	91.00%	Total	6.40%	**Total**	0.00%

Expected Repetitions are given Table 2 :

Table 2: Expected Repetitions for Axle Loads

Single Axle		Tandem Axle		Tridem Axle	
Axle Load Class	**Frequency()%**	**Axle Load Class**	**Frequency()%**	**Axle Load Class**	**Frequency()%**
15-17	41491		0.00		
13-15	104716	26-30	5927	26-30	0.00%
11-13	226226	22-26	17782	22-26	0.00%
9-11	230178	18-22	14818	18-22	0.00%
7-9	0	14-18	4939	14-18	0.00%
Less than 8	296366	Less than 14	19758		0.00%
Total	898978	Total	63225	**Total**	0.00%

Trial Thickness : 0.20 m

Subgrade Modules : 5.15 Kg / cm3
Design Period : 20.00 Years
Modulus of Rupture : 45.00 Kg / cm2
Load Safety Factor : 1.00

Spacing of Contraction Joints : 1000 mm
Width of Concrete Slab : 1000 mm
Avg. day-time Temperature Differential in Slab (for bottom-up cracking) :19 o C
Night-time Temperature Differential in Slab (for top-down cracking) : 14.33 o C

Analysis if Fatigue life Consumption

Table 3: Fatigue Life Consumed for Single Axle Load

Axle Load Class	Load Stress Kg/ cm^2	Stress Ratio	Expected Repetition	Fatigue Life N	Fatigue Life Consumed
16	24.78	0.551	41491	122301	0.34
14	21.79	0.484	104716	1830466	0.06
12	18.80	0.418	226226	Unlimited	0.00
10	15.81	0.351	230178	Unlimited	0.00
8	12.82	0.285	0	Unlimited	0.00
Less than 8	12.82	0.285	296366	Unlimited	0.00
Total	107	Total	898978	Total	0.40

Table 4: Fatigue Life Consumed for Tandem Axle Load

Axle Load Class	Load Stress Kg/ cm^2	Stress Ratio	Expected Repetition	Fatigue Life N	Fatigue Life Consumed
28	18.570	0.413	5927	Unlimited	0.00
24	15.981	0.355	17782	Unlimited	0.00
20	13.392	0.298	14818	Unlimited	0.00
16	10.803	0.240	4939	Unlimited	0.00
Less than 16	10.80	0.240	19758	Unlimited	0.00
Total	70	Total	63225	Total	0.00

Temperature Curling Stresses:

$$\sigma_T = 1.933\text{-}241000(\alpha\,\Delta T) + 1.267(L/l_e)$$

Delta T = -0.15 C/cm x Thickness of white Topping overlay

= -0.15 x 21

= -3.15 Degree C

α = 10 x 10-6 0.00001

L = Length of Square Slab = Radius of Relative Stiffness, l 100 cm 46.3 cm

Thus σ_T = 9.5245 Kg/cm2

Total flexural Stresses due to load and curling =

Design Life	: 20.00 years
Traffic Growth Rate, r	: 0.08
Commercial Traffic	: 250 cvpd
Grade of Concrete	: M40
Cumulative Repetitions in 20 years	: 3951552
Design Traffic	: 25 % of 3951552 = 987888
CBR	: 8%
Corresponding 'k' value is determined from graph developed by corps of engineers against a Benkelman Beam Deflection Value	: 5.15
Modulus of Subgrade reaction	: 5.15 Kg/ cm3

Maximum lad stress + curling Stress

= 24.78 + 9.5245

= 34.30 Kg/cm2

This is less than the minimum flexural strength of 45 Kg/cm2.

Hence, design is safe. White topping thickness of 200 mm can be adopted.

IV. RESULTS & DISCUSSIONS

When we take above design parameter, then design is safe. White topping thickness of 200 mm can be adopted.

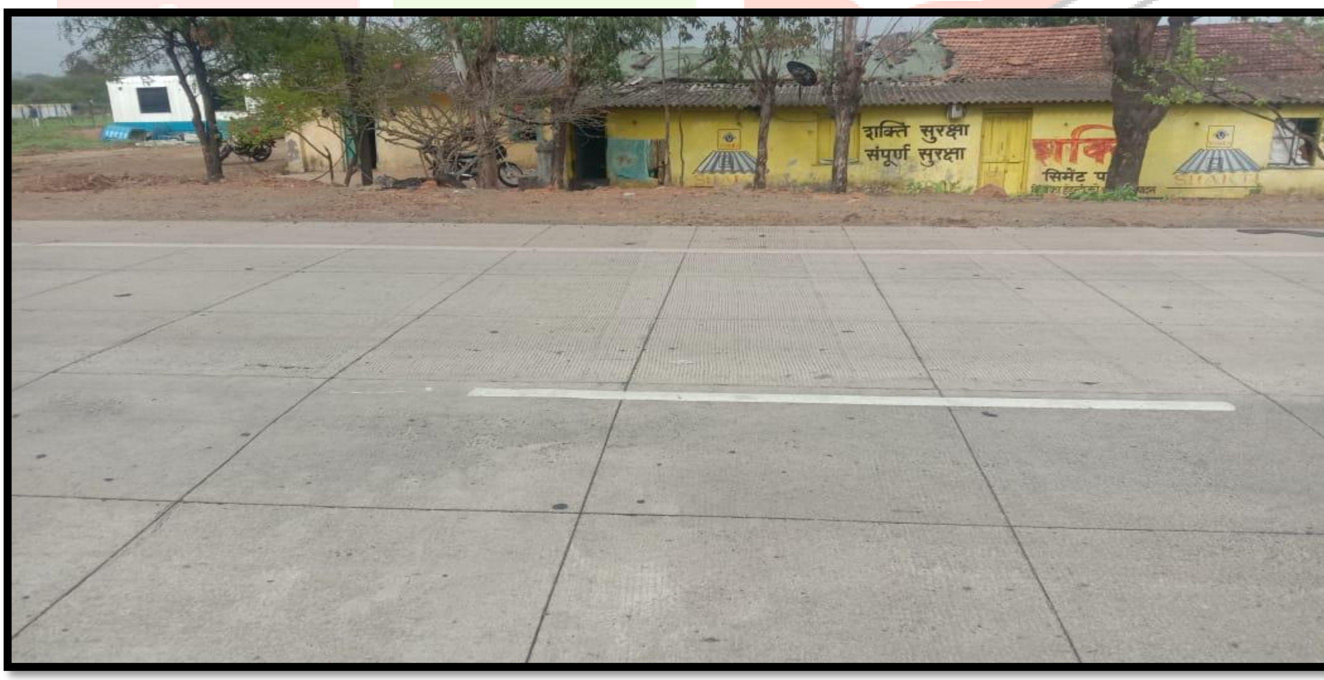

Figure 4.1: white topping road after finishing

V. CONCLUSION

Construction of White topping so speedy with the help of modern equipment's and techniques that it can be opened to traffic within a week of construction. Maintenance is minimized as the life of concrete overlay is around 20 years with slight maintenance.

White toppings Cost-effective in comparison to bituminous overlays when Life Cycle Cost analysis is performed. Its service life is improved due to superior riding quality and improved fuel efficiency of vehicles. Pre overlay repair is least. Road safety aspect is improved due to better reflection of light particularly in city roads. Around 20% of electricity will be saved as compared to flexible pavements.

Lower Operational costs and lower absorption of solar energy. Beneficial for environment as concrete roads are much greener and less polluting.

Finally, it can be concluded that by using modern equipment'sS, advanced techniques and speedy construction, White Toppings provide a sustainable as well as cost effective option for construction, treatment and safeguarding of the pavement. Thin white topping overlays are considered more environmentally and economically sustainable as compared to asphalt pavements.

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