DESIGN AND EXECUTION OF THIN WHITE TOPPING ROAD

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ABSTRACT: - 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. Rutting of bituminous pavement is a serious concern in hot climate like India, with heavy truck loads, operating under frequent start/stop conditions. White topping can be applied where rutting of bituminous pavement is a recurring problem. The first white topping overlay project has been laid down in India in 2003 and subsequently on experimental basis few more projects have been undertaken.

Conventional white topping, ultra-thin white topping and thin white topping projects have been built on experimental basis in India, but, there is no specific follow-up regarding their performance. The performance and life of pavement is affected by a number of factors such as the load imposed by the traffic plying on it, the climate, indigenous materials used and maintenance standards. To evaluate their performance under Indian traffic and climatic conditions road roughness test, compressive strength by taking concrete cores and visual inspection survey has been carried out. Deflections in overlay slab and load transfer efficiency (LTE) has also been obtained by conducting FWD. BBD test also proposed to carryout performance evaluation of UTW. In this study alternative method to FWD, using two Benkelman beams simultaneously has been proposed and validated to find out the deflection across the transverse joints for calculating LTE to overcome the limited use of FWD and difficulties encountered in maintaining the equipment. To study the cost effectiveness of conventional white topping and ultra-thin white topping life cycle cost analysis (LCCA) of these pavements has been carried out and same has been compared with flexible pavement/HMA and rigid pavement. This LCCA computation can guide to highway engineers in identification of the suitable alternative that yields the best value, by providing the desired performance at the lowest cost over the analysis period.

Keywords: White topping, finite element model, load transfer mechanism, HMA, Falling Weight Deflectometer, Benkelman beam deflection, life cycle cost analysis.

I. INTRODUCTION

Road traffic is increasing steadily over the years. This is an international phenomenon. An international forecast predicts that such increase will continue in future. Even in the case of the developed countries, there is a shortage of funds required for new infrastructure projects, both for constructing them and more significantly towards their maintenance and repairs. The increasing truck weights and tyre pressures on our pavements in recent years have pushed the demand on the performance of pavements to a higher level. 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. The cost of strengthening and repair by Conventional method of this large network will need huge resources both physical and financial which are quite scarce. Most of the existing flexible pavements in the network broadly have thin bituminous layers. The increasing truck weights and tyre pressures on our pavements in recent years have pushed the demand on the performance of our pavements to a higher level. Many asphalt pavements have experienced rutting while many others have experienced longitudinal cracking. One of the possible solutions to this problem is the use of white topping (WT), which is a cement concrete layer placed over an existing asphalt pavement. Concrete overlays have been used to rehabilitate bituminous pavements since 1918 in USA. There has been a renewed interest in white topping, particularly on Thin White Topping (TWT) and Ultra-Thin White Topping (UTWT) over Conventional White Topping. Based on the types of interface, these bituminous pavements, in general, have a problem that they get deteriorated with time. Most of our roads exhibit, in general, the following deficiencies:

i. Rutting

ii. Fatigue cracking

iii. Block crack (D-cracking)

Thermo cracking is one of the possible solutions to this problem is the use of white topping (WT), which is a cement concrete layer placed over an existing asphalt pavement.

Types of White Topping(WT): The following are the three types of white topping they are explained below,

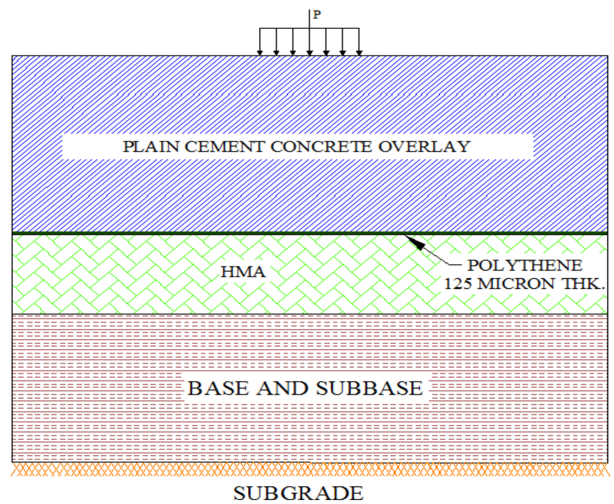
Conventional White topping – which consists of PCC overlay of thickness 200 mm or more, which is designed & constructed without consideration of any bond between existing overlay & underlying bituminous layer (without assuming any composite action).

Thin White topping (TWT) – which has PCC overlay between 100 – 200 mm. It is designed either considering bond between overlay & underlying bituminous layer or without consideration of bond. High strength concrete (M 40 or higher) is normally used to take care of flexure requirement. Joints are at shorter spacing of 0.6 to 1.25 m.

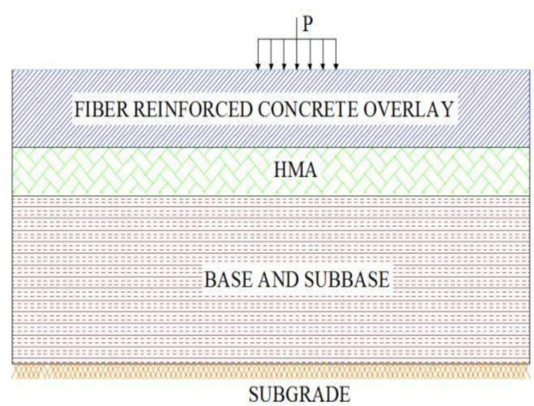
Ultra-Thin White topping (UTWT) – which has PCC overlay of less than 100 mm. Bonding between overlay & underlying bituminous layer is mandatory. To ensure this, the existing layer of bitumen is either milled (to a depth of 25 mm) or surface scrapped (with a non impact scrapper) or gently chiseled. Joints are provided at a spacing of 0.6 to 1.25 m.

Benefits of White Topping :-

- Long life, low maintenance, low life-cycle cost, improved safety and environmental benefits.
- Deformation like rutting and cracking predominant in case of bituminous pavements is normally absent with concrete surfaces of White topping. This is particularly true in a hot climate like India.
- Conventional White topping improves structural capacity of existing bituminous pavement, if built on a strong base course, and it impedes structural distresses.
- White topping requires much less maintenance and as such involves much less frequent lane closures of road, as compared to bituminous surfaces.
- White topping is quite cost-effective to tackle annual budget constraints and high traffic levels. It is, therefore, quite relevant to Indian conditions.
- White topping can uniformly fill ruts in the wheel path of bituminous pavements more effectively because concrete is far more stiff and consistent at high temperature than bituminous mixes.
- Concrete is relatively light in colour and hence concrete surface is more reflective to light, absorb less heat and reduce the urban heat island effect,
- Improved reflection of lights from vehicles enhances safety, lowers energy requirement of external lighting, lower contribution to heat in environment.
- Fuel consumption on concrete roads has been found to be less than the bituminous roads.



Conventional White topping



Ultra-Thin White topping

STRUCTURAL BEHAVIOR OF WHITETOPPING: Conventional white topping is designed and constructed like a new rigid pavement without assuming any composite action. In this type of white topping dowel bars are provided across the transverse joints for load transfer and longitudinal joints are generally provided with tie bars for holding the slab together. The load transfer across the joints is possible through dowel bars, granular interlocking or by combined action of both these mechanisms. The dowel bars are not used in TWT/UTW. Conventional white topping is un bonded while TWT/UTW is bonded (IRC: SP:

76-2008). Figure 1.1 shows a schematic arrangement of conventional WT and TWT/UTW.

TWT and UTW are designed on the principle of a composite pavement structure which distribute traffic and environmental loading in a different manner than in case of conventional rigid or flexible pavements. In case of such bonded system due to the composite action between concrete and flexible layer, the neutral axis shifts downward. This results in a situation in which more area of PCC slab comes under compression and therefore a lesser thickness is required. Joint spacing recommended in IRC: SP: 76-2008 ranges from 0.6 to 1.25 m. As the spacing of joints is considerably reduced the loading and curling stresses get reduced. Load transfer mechanism is by aggregates interlocking system in TWT and UTW.

OBJECTIVES AND SCOPE OF THE PRESENT STUDY

The broad objective of this study is "analysis and performance evaluation of white topping subjected to various traffic and climatic conditions subjected to Indian scenario". The specific objectives and scope of the present study can be summarized as:

- To review and identify the gap in the literature for the analysis and performance evaluation of white topping.
- To investigate the structural adequacy of the existing flexible/HMA pavement using Benkelman Beam Deflection (BBD) and to carry out various soil investigations.
- To develop a three dimensional Finite Element non-linear model of conventional white topping for un-bonded condition and linear model of UTW for bonded condition by considering static wheel loading and temperature loading.
- To validate the FE model by computing stresses and deflections at edge, corner and interior loading positions and comparing the same by conducting FWD/BBD test and using closed form formulae.
- To evaluate the performance of white topping for Indian traffic and climatic conditions.
- To develop an alternative tool to FWD test for measuring LTE across transverse joints and also developing correlation between Benkelman Beam and FWD deflection for conventional white topping.
- To carry out life cycle cost analysis (LCCA) of conventional white topping and UTW to study their cost effectiveness.

Stresses and Deflections in Conventional White topping by FWD Test

In order to determine the stresses and deflections in conventional white topping, FWD test has been carried out after two years of its construction on 21 locations on constructed conventional white topping under this study as described in. The stresses and deflections are normalized for 50 kN wheel load. The stresses and deflections obtained from FE model, closed form formulae and FWD test conducted on conventional white topping show that even after service of two years, performance of the pavement is satisfactory.

Deflections in Conventional White topping by BBD Test

Benkelman Beam test is one of the static load deflection equipment that measures the maximum deflection response of a pavement to static or slowly applied loads. Advantages of the Benkelman Beam include ease to use, low equipment cost, and large database can be created about performance of the pavement over the years.

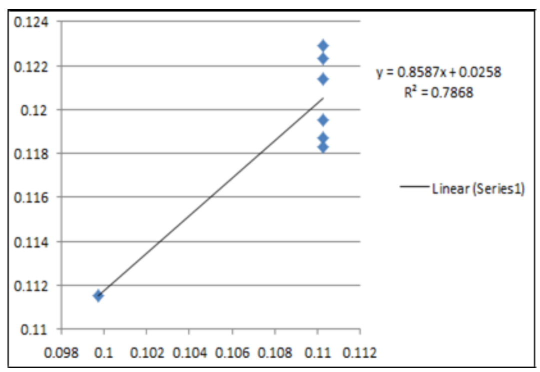


Fig. 4.1: Linear Relationship

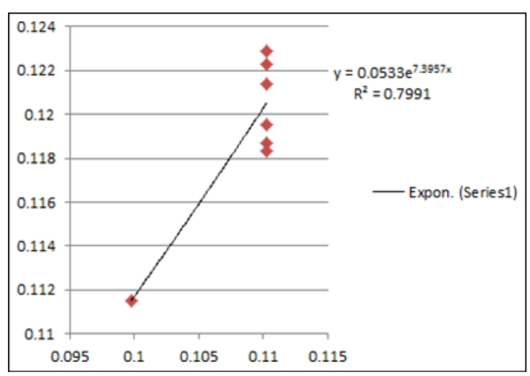


Fig. 4.2: Exponential Relationship

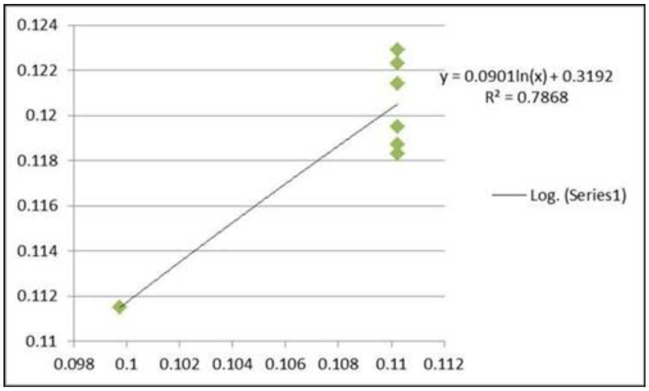


Fig. 4.3: Logarithmic Relationship

Deflections in UTW

Benkelman Beam Deflection test is one of the static load deflection equipment that measures the maximum deflection response of a pavement to static or slowly applied loads. Advantages of the Benkelman beam include ease to use, low equipment cost, and large database can be created about performance of the pavement over the years. But, the guidelines given by IRC:81-1997 for conducting BBD are applicable only for flexible pavements. In this study attempt has been made to conduct this test on the top of UTW. Performance evaluation of in-service 100 mm thick UTW constructed in venkata ramana Colony, Hyderabad city(India), has been carried by conducting non-destructive test i.e. BBD test to find deflection on top of UTW, as per IRC:81-1997 at interior, corner and edge of each slab.

PAVEMENT ROUGHNESS IN CONVENTIONAL WHITETOPPING

The roughness of road surfaces has been recognized as an important measure of its performance. Roughness has a direct influence on ride comfort, safety, and vehicle wear by dynamic excitation of the vehicle. In turn, the dynamic wheel loads produced are implicated as causative factors in roadway deterioration. The term 'roughness,' as used here, means the variations in surface elevation along a road which excite vibrations in traversing vehicles. As a consequence, the characterization and measurement of road roughness is of interest to highway engineers worldwide. The several instruments have been developed and standardized at a particular speed for the collection of pavement roughness data (Wambold et. al., 1999; Sayers et. al., 1986; Cundill, 1991; Morosiuk et al., 1992 and Bennett, 1986). Among these instruments, Car Axle Mounted Automatic Road Unevenness Recorder (ARUR) calibrated by Central Road Research Institute (CRRI), New Delhi is one of the equipment being used in India. In this study, roughness test has been carried on conventional white topping using this equipment.

LTE of Conventional White topping

Load transfer designs for conventional white topping are identical to those for new jointed concrete pavements. In general, doweled joints are recommended for all pavements that will be subjected to significant commercial vehicles. FWD test has been conducted on conventional white topping considered in this study after service of two years as per method discussed in Chapter 5. FWD test is one of the methods used to obtain the LTE of the transverse joints by measuring deflections at loaded and unloaded slabs. However, the use of FWD in India has been very limited so far because of its high cost and difficulties encountered in maintaining the equipment. Therefore in this study two Benkelman beams have been used simultaneously for measuring deflections in loaded and unloaded slabs and LTE has been calculated. There is good agreement between LTE values obtained from FWD test and proposed BBD test. This agreement in LTE values indicated that two Benkelman beams simultaneously can be an alternative tool to FWD for calculating LTE of conventional white topping.

LIFE CYCLE COST ANALYSIS OF CONVENTIONAL WHITETOPPING AND UTW

In this study, comparative LCCA for a length of one kilometre pavement has been carried out for five different cases namely conventional white topping, UTW, existing distressed flexible (HMA) pavement to be reconstructed as a conventional rigid pavement with two cases i.e. high and low volume type and flexible pavement with flexible overlay for strengthening. Two different cases of rigid pavements have been considered for low volume and high volume roads so that while comparing LCCA with conventional white topping cost of high volume rigid pavement can be used and for comparison with UTW, cost of low volume rigid pavement to be considered.

The life cycle cost of conventional white topping is less as compared to other type of pavement. By considering life cycle cost, conventional overlays are 6.88% cheaper as compared to rigid pavement and 13.93% cheaper as compared to flexible overlay on existing flexible pavement. The life cycle cost of UTW is less as compared to other type of pavement. By considering LCCA, UTW are 42.98% cheaper as compared to rigid pavement and 46.43% cheaper as compared to flexible overlay on existing flexible pavement.

CONCLUSIONS FROM THE PRESENT RESEARCH WORK

Conventional white topping, ultra-thin and thin white topping pavements have been built in India since 2003, but, there is no specific follow-up regarding their performance. In this study, their performance has been evaluated for Indian traffic and climatic conditions by calculating the stresses and deflections using FWD test, road roughness test, BBD test and taking concrete cores for compressive strength. The performance of the pavement has been also evaluated by visual inspection survey. The results obtained from these tests and visual inspection surveys are within permissible limit which indicates that the short term performance of these pavements is satisfactory.

Generally, FWD deflection measurements are used to obtain the LTE of the transverse joints. However, the use of FWD in India has been very limited so far because of its high cost and difficulties encountered in maintaining the equipment. Therefore, a need has been aroused to identify an alternative to FWD test, which can be cost effective and equipment easily available. In this study using two Benkelman beams simultaneously deflections have been measured in loaded and unloaded slabs and LTE has been calculated. LTE values obtained in this study have been compared with FWD test results, values computed using KENSLAB computer program and FE model by other researchers. This shows good agreement and use of two Benkelman beams simultaneously can be an alternative tool to FWD test for calculating LTE. It is also proved that, BBD test can be used as alternative technique to FWD test for measuring deflection in conventional white topping and UTW.

The Life Cycle Cost Analysis has been carried out for conventional white topping, UTW, rigid pavement and flexible pavement. This analysis shows that conventional white topping is cost effective as compared to rigid pavement and flexible pavement rehabilitated using flexible overlays. UTW is most cost effective when it is compared with rigid pavement (low volume traffic case) as well as flexible pavement rehabilitated using flexible overlays.

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