Rehabilitation of Existing Roads by Using White Topping

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Abstract - The purpose is to summarize/to get the available information and to document how departments of transportation and other agencies and owners are currently using thin white topping (TWT) and ultra-thin white topping (UTWT) overlays among their various pavement rehabilitation alternatives. The goal of this dissertation is to collect and report information about the use of TWT and UTWT overlays within the highway community. Although TWT and UTWT overlays have been constructed for decades, their recent popularity is largely the result of a renewed demand for longer-lasting but cost effective solutions for hot-mix asphalt (HMA) pavement rehabilitation. White topping is a rehabilitation treatment on asphalt concrete road. Plain cement concrete overlay of higher grade preferably M-40 to M-60 on asphalt concrete of thickness 50 to 300 mm is termed as white topping. It provides as a new innovative method of rehabilitation at a reasonably low cost with very good results, low maintenance with a longer life. Rural roads, district roads, state highways having low to moderate traffic are best for adopting this rehabilitation/strengthening method. This paper explain a methodology to adopt white topping as a rehabilitation alternative.

Key Words: White topping, Hot-mix Asphalt, Pavement, Roads, Rehabilitation

1. INTRODUCTION

Road network of the nation is functioning like the arteries of the body. For achieving high economic growth and improving the quality of life, the Government of India and State Governments have been increasingly focusing their thrust on development of infrastructure in a big way. As a part of this thrust on improving and upgrading our road system to bring it in line with the best in the world, it would be imperative to provide long-lasting, maintenance-free pavements, which are unaffected by the weather. To renew worn-out or damaged bitumen pavements, by applying a layer of concrete on top is known as white topping. White topping has been hip, both in Europe and USA for several decades, and is now vigorously practiced there. However, the primary concrete road had been inbuilt India as far back as 1914, white topping as an engineering practice has got to gain greater acceptance in our country, despite the fact that it has all the advantages of a new concrete pavement, besides favorable life cycle cost. Portland cement concrete overlays over existing hot-mix asphalt (HMA) pavements have been used as a rehabilitation option for more than 80 years. White topping‖ overlays have been used on airports, interstate, primary and secondary highways, local roads and streets, and parking lots to improve the performance, durability, and riding quality of deteriorated HMA surfaces. Modern white topping overlays are classified by thickness and by bond with the HMA. Three distinct categories are found:

- Conventional white topping— a concrete overlay of 200 mm (8”) or more, designed and constructed without consideration of a bond between the concrete and underlying HMA.
- TWT— an overlay of greater than 100 mm (4”) and less than 200 mm (8”) in thickness. In most but not all cases, this overlay is designed and constructed with an intentional bond to the HMA.
- UTWT — with a thickness equal to or less than 100 mm (4”), this overlay requires a bond to the underlying HMA to perform well.

Responding to demand caused by rapidly deteriorating highways with only modest increases in funding, the concrete paving industry has adopted white topping as a key marketing strategy. TWT overlays are used on highways and secondary roads carrying a wide range of traffic, from light to heavy. General aviation airports have also used this class of white topping for runway, taxiway, and apron pavements. Because they are thinner, UTWT overlays are best suited for more medium to lightly loaded pavements. These pavements include some intersections, ramps, and lightweight aircraft aprons. Overall, it appears from the information gathered that the use of TWT and UTWT overlays is on the increase.

1.1 Aim:

The main aim is to study the rehabilitation of existing deteriorated roads by using ultrathin white topping and to provide measures to improve Performance, Repair and Rehabilitation of UTWT.

1.2 Objectives:

- To select the appropriate method for the rehabilitation of existing deteriorated roads
- To compile available information regarding the laying and practical use of UTWT through literature review
- To collect data for the design of UTWT.
- To design an appropriate thickness for laying of UTWT.
- To provide measures to improve Performance, Repair and Rehabilitation of UTWT.

2. HMA PAVEMENT STRENGTHENING

The behavior and performance of HMA pavements varies widely. Depending on the first design and supreme use of the pavement structure, the HMA can ultimately fail during a number of the way, or the sources of failure could also be combined. The most common failure modes of HMA pavements which will cause the necessity for rehabilitation include the following:

- **Rutting—**Pertains to permanent deformation in the wheel-paths caused by a combination of densification and shearing of the various pavement layers. The viscous properties of the asphalt binder (especially at high temperatures) are a big factor resulting in rutting within the HMA layer. Rutting within the underlying layers are often aggravated by the presence of moisture and high strains.

- **Fatigue cracking—** as with many engineering materials, repeated loading can damage an HMA, resulting in the event of visible cracking. This failure mode is complex and may develop during a number of the way. It is commonly aggravated by a weak support system (e.g., owing to a saturated condition) and/or a stiffening of the HMA.

- **Thermal cracking—** at low temperatures, HMA responds during a more elastic and brittle fashion. If the pavement temperature lowers rapidly or frequently, transverse cracking can form on the pavement surface.

Other common structural and material failures include block cracking (the result of oxidation and shrinkage of the HMA), stripping (separation of the asphalt binder from the aggregate owing to the presence of moisture), and bleeding (excess asphalt binder forced from the matrix to the outside of the HMA layer).

In addition to undergoing structural and material failures, an HMA pavement may experience a loss of function. These failure modes include degradation of ride quality (pavement smoothness), loss of skid resistance, and an increase in noise.

2.1 Effect of load on HMA pavements:

As a loaded wheel passes over a versatile pavement, a downward deflection occurs. The greater the magnitude of the load, the more is that the deflection. The deflection also depends upon the thickness of the pavement and its constituent layers and on the supporting strength of the subgrade. If the pavement is well-designed, the deflection is nearly entirely elastic and therefore the pavement should return to its original level after the wheel load has passed, the permanent deformation being negligible. But, due to repeated cycles of loading and heavier than the design loads, a certain amount of permanent deformation is caused, the cumulative effect of which results in rutting and shoving under the wheel paths, and tracking, which are the principal indicators of pavement deterioration. Figure 3.1 and Photo 3.1 show a pavement affected by serious rutting. The pavement which suffers with serious deformations, affecting the riding quality. Normal maintenance solutions like patching and resealing then act as temporary solution and unable to arrest the problem at its roots. The only solution is to supply an overlay of suitable thickness and specifications, such the structural strength of the pavement is increased and its life is further prolonged.

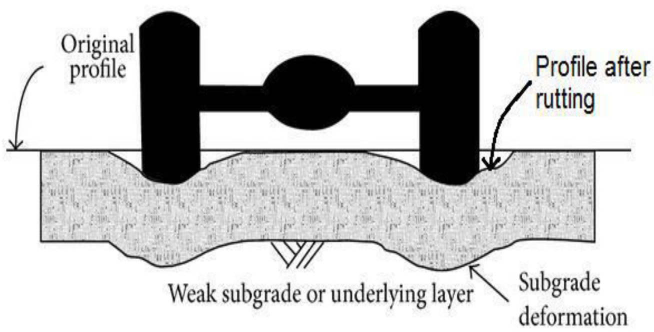

Fig. 2.1.1: Schematic diagram showing formation of rutting

Photo 2.1.1: A pavement effected by serious rutting

The problem is more serious if pavement is not constructed to the desired thickness and strength to meet the traffic requirements. Most of the Indian highway pavements are fall into this category. The embankments are very old, and were formed years ago with local earth and no proper compaction. The pavements were thickened as traffic grew. Till very recently, the layers were of stone soling, brick paving, or unbound aggregates (mostly Water Bound Macadam), surfaced with a thin bituminous wearing course. The introduction of bituminous bases and dense wearing courses has been comparatively recent, (since the late seventies), and that too was restricted to the heavily trafficked sections of the arterial roads. The road formation levels are slightly above or almost level with the adjoining fields. However, the worst blow of pavements comes from overloaded vehicles. As against a legally permitted axle load of 10.2 tones, axle loads of 20- 25 tones are quite common. A repetition of 150-300 million standard axles during the design life of a pavement is common on arterial highways. It has been assessed that with 30 per cent overload, a pavement will last for only 3.5 years. The Vehicle Damage Factor, which represents the damaging power of commercial vehicles, is very high (in the range of 3-10). As a result of poor condition of roads, it is estimated that nearly 20,000 cores per year are lost due to fuel wastage, tire wear and wear and tear of vehicles.

2.2 Effect of poor pavements:

With inadequately designed overloaded and ill-drained pavements in the country's network of roads, highway engineers are finding themselves at a great disadvantage in keeping the pavements in a traffic-worthy state. Strengthening with thin flexible overlays is common. But such strengthening is often overtaken by high traffic intensity and loading, causing quick rutting and deformations. Maintenance costs is high to patching and crack-sealing have to be attended to. After a time, the riding quality becomes very poor. A recent survey of the National Highway Authority of India has revealed that the average roughness of the roads as measured by a Bump Integrator is 4600 mm/km, which is too high. A quality laid bituminous surface should have a roughness value of 1500-2000 mm/km. Surface roughness has a major impact on fuel consumption and vehicle operating costs [7]. Thus, the country loses thousands of cores of rupees every year because of the poor state of its roads.

2.3 Neglect of maintenance:

Road transport has grown very fast over the past 50 years. The total length of the road network has increased from 0.4 million km in 1951 to 3.3 million km in 1999, (eightfold increase), and the number of motor vehicles has increased from 0.3 million in 1951 to 108 million in 2008 (170-fold increase). It is experienced that the maintenance of roads already does not receive adequate attention, even in the case of NHs, allocations for maintenance in the last several years have not exceeded 50-55 % of the requirements and the situation in case of other categories of roads is even bad. This is a grave situation, which can only be rectified by building road pavements which require minimum or zero maintenance.

3. LITERATURE SURVEY

1. “Guidelines for the Design and Construction of Ultra-Thin White Topping”, In this paper review the author; Ankit Sharma has explained the design and construction of UTWT for the rehabilitation of Roads. As per the author, there has been increased in demand for Highway Industry. The newer materials should be tried for the Road Construction for the optimization of the lifecycle, reduce the abrasion and reduce the maintenance cost of the Road. The Ultra-Thin White Topping (UTWT) is one of the best options for the rehabilitation of the Existing Roads.
   According to the Author, UTWT is a fast-track process and it has been adopted by some countries like US, Australia, etc. Many laboratory tests are carried out throughout the research institutions in India for the UTWT’s on field behavior and some high-performance fiber reinforced concrete mixes are also tested which can be used in UTWT for the practice. The Salient features of the UTWT are that it controls plastic shrinkage cracking by using micro fibers in it and they also help to control the enhancement of the post- cracking behavior. The construction joints are shorter and more flexible. The author also briefly explained about the Material, Mix proportioning and Strength of the concrete. The Design and Construction of the UTWT is explained in detail for the better rehabilitation of the Road. Overall, the author has given best review for the use of different materials in UTWT for various grades of concrete at different places for change in climatic conditions. Also explained very nicely about the design steps by considering load carrying capacity, thickness of the pavement and durability of the Roads.

2. “White Topping as a Rehabilitation Method: A Case Study of Budhel-Ghogha Road”, The Authors, Prof. P.S.Ramanuj, Bhavin Parma & Akash Parmar explains UTWT as a treatment for the recovery of the Asphalt pavement. They define UTWT as a revolutionary method with less cost investment and maintenance, which delivers better results for Roads. They suggest to use this technique in the rural or regional areas, so that the poverty level will decrease as Road is the one of the main sources of transportation which connects rural to urban areas. As the UTWT is comparatively cheap and it should be adopted in developing countries. The problems regarding the Roads are discussed in the paper which tends to decrease the life of the pavement. To increase the quality of the Roads, false practices should be banned by the government. The authors have compared UTWT, TWT and Conventional White Topping in view of thickness of the pavement, joints, performance and site conditions. The procedure for the White Topping implementation is also discussed. A case study of Budhel - Ghogha Road is also presented, it includes the comparison between bituminous pavement and White topping. The thickness computation and rate analysis of both the methods are determined. A case study suggests that the UTWT is not only provides better quality of pavement but also reduces cost by 20% to 30% depending on the thickness of the pavement. This technology is a sustainable and means of green construction.

3. “A Literature Review on UTW pavements in Indian context”, The authors, Purvesh Raval, Darsh Belani and Prof. Jayeshkumar Pitroda, have reviewed about the UTWT that it is an optimum material that can be overlay on the asphalt pavements than the conventional concrete pavements for the rehabilitation of the Roads. Depends on the grades of concrete used, thickness of the existing asphalt pavement after milling, intensity of traffic etc. the depth of UTWT is additionally determined.
   According to the author, the design of the UTWT can be used for construction taxiways & runways, street intersections, low speed, low volume traffic areas, etc. They also deeply informed about the Types of White topping, Factors affecting UTW performance, Concrete Mix Design & Mechanistic analysis. Also concisely explained, the conditions when the pavement has to be repaired & its repair procedures.
   The construction procedure is also described, including steps like Surface preparation, Placing, Finishing & Texturing, Curing, Joint sawing & Sealing, etc. Comparatively the emission of CO_2 is reduced during manufacturing and placing of the pavement material. One case study is also explained in the paper about the Life cycle cost analysis of the pavement studied at British Columbia. They have compared the UTWT over Traditional Asphalt.
   The authors have concluded that the utilization of UTWT is relatively eco-friendly. Overall the paper reviews why the UTWT is best overlaying material with the consideration of a rise in automobile use on the Road, rehabilitation and maintenance of the Road.

4. “Sustainable Development for Roads with Thin and Ultra-Thin White Topping Overlays”, The author, Prof K

V Krishna Rao have explained that with more than 75% of the concrete road network in Mumbai being older than its 20-year design life, major investments into structure strengthening and system of the roads are required. Every municipality and state is facing the same pressures do more with less taxpayer money. So the keyword among today's material specifies is value, value that delivers more performance for each rupee spent. In road maintenance and repair, everyone recognizes the long life and superior performance characteristics of concrete paving. But budget constraints have often stopped specifies from choosing concrete. From above he concluded that new innovative pavement repair strategies need to be developed that will be more cost-effective. Bituminous pavements have many disadvantages. Unlike concrete pavements, they require repeated repairs and maintenance. Further, the planning lifetime of these pavements is assumed to be around 10 years after which they have upgrading and strengthening to cater to higher traffic. In case serious pavement deterioration within the sort of excessive rutting, cracking, stripping, settlements, etc., happens earlier, as often is that the case in India, their rehabilitation must be taken up before the expiry of the planning life. For both repairs and strengthening of the bituminous pavements, the present practice in India and lots of other countries is to travel certain equivalent basic materials of construction again, that is, bitumen. Recent experience within the USA and a few other countries, however, indicates that thin concrete overlays in situ of hot mix asphalt may convince be a viable and cost-effective solution for pavement rehabilitation.

The authors have concluded that one such possible innovative pavement repair strategy is Ultra-Thin White Topping (UTWT). With the event of Ultra-Thin Concrete White topping, material specifies in municipal and state governments are allowed to settle on a no-compromise material that delivers the looks and performance characteristics of concrete at a competitive price. Invented in the USA, UTWT has been utilized as pavement for low to medium traffic, parking lots, apron at airports, etc., in the USA, Europe, and recently in the rehabilitation of steel bridge decks in the Netherlands. This study provides a quick overview of the subject, supported the newest literature. Some laboratory work administered to develop concrete mixes for UTWT is additionally included.

5. "Pavement Rehabilitation Using Thin White Topping", (2016) The author Mr. Ashish P. Alapure reviewed that Thin White topping (TWT) is a technology to construct cement concrete overlay of thickness 100-200mm on distressed asphalt pavement as a rehabilitation technique. There are TWT projects completed in India, the first in Pune, then in New Delhi, Mumbai, Ghaziabad, and Thane. As per the author, all projects have shown good to excellent performance so far, indicating that this rehabilitation strategy can stand up to the Indian climate and traffic conditions. The suitability of TWT rehabilitation for a particular site is dependent on several factors including existing asphalt thickness, the volume of truck traffic, base and sub-grade support, and pavement conditions. This paper outlines the state-of-practice in India for construction of TWT considering mixed traffic, extreme climatic conditions, use of indigenous materials, and design aspects as per Indian Road Congress (IRC) guidelines.

3.1 Summary of Literature Review:

So far by reviewing and studying numerous research papers it has been analyzed that international experience on white topping has been encouraging with countries like USA, Australia, France, Britain, and Belgium. They have successfully designed and constructed white topping and their performance is satisfactory. But for the country like India, this is an upcoming technology; therefore it is necessary to construct few trial sections using indigenous materials and techniques. Carrying out long term performance evaluation of the same is necessary to develop this technique for Indian traffic and climatic conditions. Also bellow points have been observed:

1. Responding to demand caused by rapidly deteriorating highways with only modest increases in funding, the concrete paving industry has adopted white topping as a key marketing strategy.
2. UTWT is a less cost maintenance revolutionary method, which gives better results for Roads.
3. Concrete pavements are the most robust and resistant to changes in temperature and rainfall as it is impervious to water, their performance is only marginally affected by shifts in these conditions.
4. Initial cost of concrete overlays is slightly more than a bituminous overlay. But on a "life-cycle-cost" basis, it is always economical.
5. A concrete road that initially gives a smooth ride will maintain its quality of ride throughout its service life and not be subjected to rutting and surface deterioration.
6. Fiber reinforced concrete is beneficial when the thickness of pavement is restricted which gives higher compressive and flexural strength.
7. The Salient features of the UTWT are that it controls plastic shrinkage cracking by using micro fibers in it and they also helps to control the enhancement of the post cracking behavior.
8. Constructing more roads from concrete will conserve the earth's scarce materials for future generations.

4. OVERVIEW AND APPLICATION

4.1 Definition of Overlay:

An overlay is a layer of suitable thickness provided on top of an existing pavement to improve its structural adequacy and riding quality. It should be distinguished from resurfacing or resealing, which are part of periodic maintenance operations and which involve thin layers (say up to 20 mm) intended to seal cracks, restore the anti-skid property and smoothen rough riding surfaces. Overlays are part of what are commonly termed "rehabilitation" or "strengthening" measures.

4.2 Purpose of Overlay:

The principal purpose of an overlay is to restore or increase the load-carrying capacity, or life, or both, of the existing pavement restoring the ride ability of the existing pavements.

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4.3 Types of Overlay:

- Bonded concrete overlay — a Plain Cement Concrete layer constructed directly atop an existing pavement. Specific construction techniques are introduced to ensure a sound bond between the layers.
- Unbonded concrete overlay — a PCC layer constructed directly atop an existing pavement but intentionally separated by a bond breaker, commonly consisting of HMA.

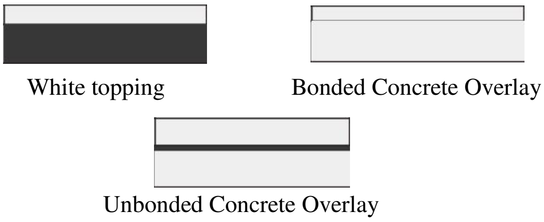

Fig. 4.3.1: Concrete overlay types.

Whitetopping can be further classified as under w.r.t. thickness:

Conventional Whitetopping	200 - 300 mm
Thin Whitetopping (TWT)	100 - 200 mm
Ultra-Thin Whitetopping (UTWT)	50 - 100 mm

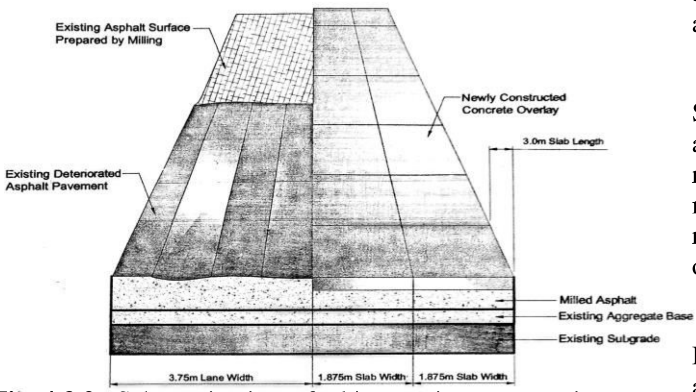

Fig. 4.3.2 : Schematic view of white topping construction after milling

5. DESIGN CONSIDERATIONS

This includes discussion of the various issues related to the design of TWT and UTWT overlays. Many aspects of the design of UTWT and TWT overlays are similar to those of a conventional concrete pavement design.

5.1 Existing Pavement:

A key to the success of any concrete pavement, including a UTWT or TWT overlay, is a uniform and stable support system. In such a case, the support is provided by an existing HMA pavement. Therefore, it should be recognized that any contributing factor to the failure of the HMA pavement might similarly lead to a failure of the overlay.

5.2 Pre-Overlay Repair:

Before overlay, it's recommended that consideration be made to repair the prevailing pavement, to supply the required uniformity to the network. Although many existing HMA distresses will not reflect through the white topping overlay as they might through an HMA overlay, some types of HMA distress may lead to different types of failures in the overlay. For example, a subgrade failure beneath the HMA that results in alligator cracking may ultimately cause faulting, roughness, or a shattered slab within the white topping, if left uncorrected.

- *Rutting and Shoving*

Where moderate to severe rutting or shoving exists, appropriate action should be taken. The ACPA identifies this situation as rutting greater than 50 mm. If only minor rutting or shoving is observed, the distress can be ignored. When the rutting has occurred within a period of time that was much shorter than normal is the exception to this situation. In such cases, the HMA (or another support layer) may be highly susceptible to permanent deformation and it should be replaced or otherwise mitigated before the overlay.

- *Potholes*

The ACPA recommends that small potholes that do not have further widespread subsurface failures be repaired before the placement of any white topping layer. The presence of severe potholes may be an indication of a weakened pavement structure. The performance of the overlay will be adversely affected by a weak support system therefore, those who design a white topping overlay should proceed with caution.

- *Subgrade Failure*

Subgrade failures are often by surface failures like potholes and map or alligator cracking. The affected area should be removed and replaced before overlay in such cases. All of the material affected by the failure to future failures should be removed and the existing HMA pavement reconstructed to its original elevation.

- *Cracking*

If the crack width is larger than the maximum size of the aggregate in the white topping concrete mix the ACPA recommends that cracks in the existing HMA pavement be filled. Some researchers have also noted reflective cracking from an underlying HMA pavement through a UTWT overlay. Therefore, if severe cracks are observed, especially thermal cracks, measures may be taken to repair these cracks before overlay. Because cracking can often be extensive, a cost analysis should be considered to optimize the degree of pre-overlay repair.

5.3 Design Procedures:

There are well established design procedures available. The overlay thickness equations based on effective thickness concept developed by the US Corps of Engineers (1958) depending on the empirical equations formulated from full-scale accelerated tests [8].
The thickness of concrete overlay can be determined by using the following modified version of an equation developed by the US Army Corps of Engineers [9].

$$T = \sqrt{(RT)^2 - (ET)^2}$$

Where:

T = the thickness of the concrete overlay (cm)

RT = required thickness of new concrete pavement on the existing subgrade and the anticipated truck loading, cm; the existing subgrade strength can be determined from original construction and design records or from non-destructive testing

ET = effective thickness of existing concrete pavement as determined by non-destructive testing, cm

These equations were developed initially for airfield pavements but subsequently they were adopted for roads. The AASHTO Design Guide (1993) has adopted the Corps of Engineers designs [10] as under:

For Bonded Overlay

$D_{OL} = D_T - D_{eff}$

For Unbounded Overlay

$(D_{OL})^2 = (D_T)^2 – (D_{eff})^2$

Where:

D_{OL} = overlay thickness

D_T = slab thickness required if a new pavement was to be constructed on the existing subgrade

D_{eff} = effective thickness of pavement which is determined by either condition survey method or the remaining life method Similarly PCA also have their design procedure.

6. ADVANTAGES OF CONCRETE OVERLAYS

6.1 Environment:

- As a result of their stiffness, concrete roads reduce fuel consumption and CO2 emission (for trucks even up to 3.9 %). 10 to 25% of the CO2 released in the production and construction of a concrete road, is absorbed again during its lifecycle. Concrete offers the benefit of carbon capture in the form of carbonation by the concrete material during its lifetime. The process of carbonation in concrete removes carbon dioxide from the air, whereby the carbon atom is fixated into calcium carbonate and locked into the concrete. Concrete becomes a carbon sink over its lifetime by absorbing carbon from the atmosphere.
- Concrete is a chemically stable material that is safe for soil and groundwater.
- A further reduction of environmental impact is possible by the co-incineration of industrial wastes in the cement kiln during the manufacture of cement. Industrial wastes such as rubber tires, solvents, waste oil, waste water treatment sludge and paint residues are used as alternative fuels to fire the cement kiln. When these waste materials are not incinerated during cement production they have to be eliminated by means of traditional incineration; utilizing co-incineration in cement kilns thus reduces concrete's overall environmental impact.
- The environmental impact of concrete is further reduced when portland cement is partially replaced by the recycled by-products of coal power station fly ash and steel works slag.
- It can utilize upto 35 % of fly ash disposal which is a great problem.
- Its surface is not affected by spillage of oil.

6.2 Society:

- The low maintenance of concrete roads reduces traffic congestion.
- Long life skid-resistance and evenness of a concrete road surface, no rutting, guarantees safety and comfort.
- Concrete surfaces improve night vision and road safety.
- Low noise solutions are possible without compromising road safety.
- An incombustible and non-toxic concrete pavement contributes to fire safety in tunnels.
- Concrete roads provide a durable, safe pavement surface which facilitates travel for business and leisure.

6.3 Economic Considerations:

- Fuel saving upto 50 % in road construction.
- Faster vehicle movement and reduced travel time leading to fuel saving in all vehicles.
- The long lifetime and low maintenance characteristics make concrete roads up to 25% cheaper in the long term.
- Due to the bright colour of concrete the investment and electricity costs for lighting may be reduced by 30 %.
- Competition in materials for road construction has a positive impact on the market situation.
- Concrete roads are an attractive economic proposition with their cost of construction, operation and maintenance distributed over their long service life, combined with the additional economic bonus of attractive energy cost savings for the traffic using them and for lighting.

6.4 Life-cycle assessment and cost:

- Concrete pavements are very durable and typically have service lives of over 40 years. They also require very little maintenance in comparison to other types of pavement. Consequently, with their initial construction cost amortized over a longer period combined with a lower annual maintenance requirement; their whole-of-life cost produces the most economical form of pavement on a life-cycle cost basis.
- Concrete's long service life and low annual maintenance cost make it the most economically favored pavement on a life-cycle basis.

6.5 Traffic energy cost:

- The type of pavement surface and its resistance to a rolling wheel influences the energy efficiency of a travelling vehicle's performance. Concrete is a material that does not elastically deform to the dynamic application of a rolling wheel on its surface, does not rut, shove or plastically deform and consequently has a higher energy efficiency and results in lower fuel consumption for heavy vehicles.

6.6 Recycling:

- Concrete is 100 % recyclable and at the end of the pavement's service life can be crushed and recycled into road bases and sub-bases for use as a bound or unbound aggregate.
- Environmentally this means that the resources used to manufacture concrete are preserved and re-used over and again.
- Waste material like ultrafine flyash, microsilica, silica fumes, flyash by replacing some percentage of cement can be used which can be environmentally beneficial with gain in strength of concrete

6.7 Climate change proof pavements:

- Concrete pavements are the most robust and resistant to changes in temperature and rainfall as it is impervious to water, their performance is only marginally affected by shifts in these conditions. Alternative pavement materials are also less tolerant of wetter subgrades which cause their premature structural failure. Both of these aspects make concrete a far more durable and robust pavement material and more resistant to the possible consequences of climate change.

6.8 Preserving earth's scarce resources:

- Crude oil and its derivatives are valuable earth resources which are in limited supply and will one day be exhausted. These hydrocarbons are not only used for the road-building industry but find application in many other diverse areas including plastics, building materials and synthetics manufacture. In contrast, concrete is made from the abundant earth supplies of limestone, clay, sand and stone. Constructing more roads from concrete instead of crude oil derivatives will conserve the earth's scarce materials for future generations.

7. CONCLUSIONS

1. International experience on white topping has been encouraging with countries like France, Britain, USA and Belgium. They have successfully designed and constructed white topping and their performance is satisfactory. But for the country like India, this is an upcoming technology; therefore it is necessary to construct few trial sections using indigenous materials and techniques. Carrying out long term performance evaluation of the same is necessary to develop this technique for Indian traffic and climatic conditions.
2. Though the usual practice is to cure the concrete for 14 days and allow traffic only after it has attained the desired strength, "fast-track" construction cuts down the traffic delays and the road can be opened to traffic in 3 to 4 days after concreting.
3. Initial cost of concrete overlays is slightly more than a bituminous overlay. But on a "life-cycle-cost" basis, it is always economical. Besides, there are additional benefits such as saving in Vehicle Operating Costs and diesel consumed by commercial vehicles, and maintenance and repairs costs to a greater extent.
4. The concrete roads have a long life of more than 30 years and do not develop ruts or potholes. They require only minimum maintenance such as repair of edge spalls and minor cracks. Surface renewals and overlays, needed in bituminous roads are fully avoided. Concrete roads are also not adversely affected by floods and other vagaries of weather. They also reduce fuel consumption of heavy commercial vehicles using them. Hence, apart from constructing new roads out of concrete, it would be in the country's interest, to renew worn-out or damaged bitumen pavements, by applying a layer of concrete on top.

8. FUTURE SCOPE

The government of India and State governments should insist upon the use of TWT & UTWT on all the state highways and other roads in a big way to avoid the consistent problems of repair and maintenance of these roads. In view of great advantages of cement concrete overlays, the government should issue instructions for adoption of concrete roads and concrete overlays over the existing bitumen roads.

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