JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# White Topping As A Rehabilitation Alternative For Bituminous Road

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***Abstract***

*Use of concrete overlay as a rehabilitation measure for strengthening of deteriorated bituminous pavements is increasing. This concept has so far not found significant applications in the country. This is one of the rehabilitation method which results in lower maintenance cost. This method of rehabilitation/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, the above method of strengthening has a lot of promise. By adopting whitetopping, a large network of roads can be rehabilitated at reasonable costs and these rehabilitated roads will have an improved lifespan than conventional flexible pavements. In the present work, an attempt is made to evaluate the structural and functional condition of the existing flexible pavements and provide a cost effective rehabilitation solution. A network of five low volume roads coming under Pune District was selected and extensive field, laboratory investigation, pavement analysis and design of rehabilitation alternative were carried out. The field work consists of road inventory, traffic studies, Bump Integrator and BBD studies. PCI was computed based on the selected distress parameters i.e., rut, patch, pothole, cracks. In addition, IRI and characteristic pavement deflections were computed from Bump Integrator and BBD surveys. Based on PCI, IRI and deflection values pavement rehabilitation measures were considered. The summary of overall condition assessment on functional and structural evaluation in majority of the cases resulted in 3 resurfacing and 1 overlay. In the present study, an attempt was made to design concrete overlay section and asphalt overlay as a rehabilitation alternative for the in-service flexible pavements. The concrete overlay design resulted in four 200mm thickness sections. Strengthening by asphalt overlay resulted in different overlay thicknesses for the selected roads. Finally cost comparison between concrete and asphalt overlay reveals that for majority of selected roads concrete overlay proves to be a cost effective rehabilitation solution than the asphalt overlay.*

***Keywords:*** **Concrete overlay, Asphalt overlay, Rehabilitation, Cost comparison**

## 1. Introduction

Today's focus is on the construction of long-term performing pavement. Most of our roads are bituminous pavements. Bituminous pavements are showing early sign of distresses worldwide due to increasing loads, intensity of traffic, high tyre pressure, etc. The rutting, cracking, ageing, etc. are quite common. Reflective cracking is another form of distress in bituminous overlay. These distresses get more pronounced in hot climatic regions like India, since bitumen is highly sensitive to temperature. Performance of bituminous pavements in hot climatic regions is thus becoming somewhat doubtful. Concrete on the other hand is known to be a relatively stiffen material and is relatively less sensitive to high temperature. Accordingly, concrete pavements can be adopted as an alternative to traditional bituminous pavements. Even in terms of rehabilitation and repair, the use of concrete is replacing the traditional bituminous overlay because of its better performance against rutting and cracking. This is the current international trend.

Most of our bituminous pavements today, which are badly suffering from distresses like rutting, shoving, cracking, etc. are overdue for rehabilitation/strengthening. This will involve huge cost and consumption of scarce physical resources like aggregates and bitumen. Therefore, cost-effectiveness of PCC overlays (whitetopping) over bituminous overlay needs to be examined. Whitetopped roads on an average have proved to be quite cost-effective besides giving an additional life of 20 to30 years on average.

Earlier, objection against the adoption of concrete pavement was that its repair is complex and difficult. It was wrongly believed that even in case of small distress, the entire road has to be dismantled and reconstructed. With the present growth of technology, all these misconceptions are gradually vanishing. PCC overlays are being provided even on concrete pavements, similar to bituminous pavements. Repair of concrete pavement is also not that difficult now. Concrete pavements are known to have lasted in the developed world for about 40 to50 years. Many investigators have attempted to evaluate the performance of whitetopping sections and have brought to notice that, bonded whitetopping can be a viable rehabilitation alternative for distressed asphalt pavements (Vandenbossche et al., 2002). It is necessary to have proper bonding between TWT/UTWT (Thin whitetopping/Ultra thin whitetopping) and asphalt, as without it the other design and construction parameters are void (Rodden et al., 2006). Factors like panel size and thickness will have major effect on the performance of bonded thin concrete overlay (Burnham, 2006). It is possible to achieve adequate behaviour of whitetopping even over smaller thickness of asphalt layer, offering whitetopping as an alternative to several developing countries which have a tradition of laying slim asphalt layers (Jose Balbo et al., 2001). The cost of initial construction of whitetopping is generally on the higher side compared to traditional asphalt overlay. But the whitetopping overlays require little maintenance with no seasonal weakening and repairs can be performed on single panels. Hence, it is necessary to perform feasibility studies to ensure proper decision making before choosing whitetopping as a rehabilitation alternative.

In the present work, five different road stretches were selected in Pune district, Maharashtra, India for evaluation and to provide a rehabilitation solution. The selected roads were designated as R1, R2, R3, R4 and R5. Both field and laboratory investigations were carried out to evaluate the pavement performance. All the selected road stretches were evaluated both functionally and structurally. Pavement condition was computed based on the distress parameters such as rut, patch, pothole and cracks. In addition, Bump Integrator was used for evaluating the pavement roughness. Characteristic pavement deflection data was collected using Benkelman beam deflection device. The laboratory investigation consists of the determination of grain size distribution, Atterberg's limits, compaction characteristics and soaked CBR.

# 2. DATA COLLECTION AND FIELD STUDIES

| Geometric Features | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|
| Length | 300 m | 200 m | 400 m | 300 m | 600 m |
| Width | 3.75 m | 3.75 m | 3.75 m | 3.75 m | 7 m |
| Type of Surface | Asphalt Concrete | Asphalt Concrete | Asphalt Concrete | Asphalt Concrete | Asphalt Concrete |
| Number of Lanes | Single | Single | Single | Single | Double |
| Divided/ Undivide | U | U | U | U | U |
| Type of Shoulder | Earthen | Earthen | Earthen | Earthen | Earthen |
| Shoulder Width | 1 | 0.5 | 0.5 | 1 | 1.5 |
| Pavement Surface Drainage Condition | Poor | Poor | Poor | Poor | Poor |
| Road Side Drainage | Poor | NO Drains | No Drains | Fair | Good |
| Drainage Width | 0.6 | 0.5 | - | 0.6 | 0.4 m |
| Land Use Pattern | Residential | Residential | Residential | Residential | Market |
| Terrain | Plain | Plain | Plain | Plain | Plain |

The general data consists of geometric details of the roads which are collected visually walking along the entire stretch. All of these data will remain constant until the pavement undergoes maintenance or repair. The details are as shown in the Table 1 .

## 2.2 Existing Crust Details

When evaluating the condition of existing pavements, it is necessary to know the design features such as the thickness of the pavement component layers. The existing flexible pavements crust thickness were measured by excavating trail pits at the pavement-shoulder interface extending through the pavement layers and up to the level of subgrade. The details are as shown in the Table 2.

**Table 2** Summary of Section Crust Details of Roads

| Existing Layer Thickness | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|
| Surface course | 75 | 70 | 73 | 65 | 75 |
| Base course | 150 | 120 | 200 | 150 | 135 |
| Sub-base course | 180 | 190 | 245 | 210 | 200 |
| Total Thickness | 405 | 380 | 518 | 425 | 410 |

## 2.3 Traffic Volume Count

Traffic census is carried out to analyse the traffic characteristic. For the present study the classified traffic volume study was carried out. A 12 hour traffic volume count for 3 consecutive days was carried out on selected roads referring to IRC: 106-1990. Trucks with more than one rear axle were considered as Multi-axle vehicles. Vehicles like Two wheelers, three wheelers and cars were omitted from the count since they are not considered to be commercial vehicles, which affect the design process. The different vehicle classes were converted to PCU (Passenger Car Unit). Present traffic intensities are expressed in commercial vehicle per day (cvpd). The details are given in Table 3.

**Table 3** Summary of Classified Traffic Survey on Selected Roads

| Road section | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|
| Commercial Vehicle per day (ADT) | 188 | 80 | 200 | 237 | 585 |

## 2.4 Pavement Distress Survey

This is one of the key aspects required for assessing the pavement condition which would help in finding rehabilitation alternatives. In the present work four types of physical distress namely Cracks, Potholes, Patches and rutting were considered. The identification of distress type, severity and amount were done through on-site visual survey referring to ASTM: D6433-2011. The pavement distress measurements were carried out for every 10-m intervals for the selected roads manually. The measurements collected regarding four distress parameters in the field were used to calculate deduct values (DV), total deduct values (TDV), corrected deduct values (CDV) and Pavement Condition Index (PCI). This PCI which quantifies pavement condition was calculated as per ASTM: D6433-2011. Pavement condition index value is then used to verbally describe the existing pavement condition. To assess the current adequacy of the pavements, the PCI values obtained for each road were compared with the value ranges of Uday Kumar. et al. (1998), indicating the roads to be rated as good with resurfacing as the possible minor rehabilitation. The study showed that, rutting has been the major distress affecting the roads out of all the four distress parameters. The PCI values of all the selected roads are shown in Table 4.

**Table 4** Possible Maintenance based on PCI Values

| Road Section | Pothole (DV) | Patches (DV) | Crack(DV) | Rut DV | PCI = 100 – CDV | Rating | Type of maintenace |
|---|---|---|---|---|---|---|---|
| R 1 | 6 | 1 | 3 | 38 | 80 | Good | Resurfacing |
| R 2 | 8 | 1 | 1 | 25 | 71 | Good | Resurfacing |
| R 3 | 10 | 1 | 2 | 30 | 77 | Good | Resurfacing |
| R 4 | 13 | 2 | 4 | 48 | 70 | Good | Resurfacing |
| R 5 | 11 | 4 | 3 | 32 | 80 | Good | Resurfacing |

## 2.5 Roughness Measurements

The graphical plot carried out for the selected road stretches on MERLIN from which roughness (D in mm) were obtained is used to express roughness in terms of International Roughness Index (IRI). The results of the study were compared with the range of IRI values for different pavements described by Sayers. et al. (1986). The compared results reveal that all the selected roads have IRI values above 6.0m/km which indicates that the roads are having frequent minor depressions, which is true with the existing field condition. The IRI data is given in Table 5. The type of maintenance based on roughness data was found out to be resurfacing. If untreated roughness may affect vehicle operating cost, comfort and safety.

**Table 5** Summary of Roughness in terms of IRI

| Road Section | Roughness on MERLIN, D (mm) | IRI (m/km) | Pavement Condition | Type of Maintenance |
|---|---|---|---|---|
| R1 | 140 | 7.18 | Frequent minor depression | Resurfacing |
| R2 | 130 | 6.72 | Frequent minor depression | Resurfacing |

| | | | | |
|---|---|---|---|---|
| R3 | 125 | 6.48 | Frequent minor depression | Resurfacing |
| R4 | 135 | 6.95 | Frequent minor depression | Resurfacing |
| R5 | 122 | 6.48 | Frequent minor depression | Resurfacing |

2.6 Deflection Measurements

The structural adequacy of pavements is ascertained by carrying out deflection testing. For the present study, deflection measurements were done as per IRC: 81-1997. For measuring the pavement deflection CGRA procedure, which is based on testing under static load was adopted. The average characteristic deflection values of the selected roads are shown in Table 6. Since each road exhibits some kind of structural deficiency and the existing crust details are inadequate as per standards to cope up with the present traffic, it may be appropriate to provide maintenance before the pavements undergo complete structural damage.

**Table 6** Summary of Deflection Measurement on the Selected Roads

| Deflection data | Road Section | | | | |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 |
| Average characteristic deflection (mm) | 1.20 | 1.28 | 1.11 | 1.20 | 1.76 |

2.7 Laboratory Investigation

The laboratory results would help in knowing the properties of materials used in the field at the time of construction. The data collected from the laboratory tests would help in providing proper rehabilitation for the in-service pavements. In the present study, the collected subgrade samples from the road sections were tested for their index and strength properties. The detailed laboratory investigations were carried out on the soil samples in accordance with the procedures followed in Indian standard specifications and the results are presented in Table 7. The existing CBR of R2 and R4 are very low compared to other roads because of high clay content and plasticity index. Subgrade soils of R1 are found out to be the best materials among other soil groups because of their group index values (G.I) being zero.

**Table 7** Properties of Existing Subgrade Soil

| Road Section | Grain Size | | | | Atterberg's Limits | | |
|---|---|---|---|---|---|---|---|
| | Gravel | Sand | Silt | Clay | LL | PL | PI |
| R1 | 4 | 68 | 22 | 6 | - | NP | - |
| R2 | 4 | 53 | 31 | 12 | 34 | 18 | 16 |
| R3 | 3 | 66 | 18 | 13 | 19 | 12 | 7 |
| R4 | 1 | 54 | 33 | 12 | 32 | 14 | 18 |
| R5 | 6 | 67 | 20 | 7 | 35 | 19 | 17 |

| Road Section | Strength Properties | | | HRB Grouping |
|---|---|---|---|---|
| | OMC | MOD | CBR | |
| R1 | 11.0 | 2.0 | 6 | A-3 |
| R2 | 13.0 | 1.94 | 2 | A-6 |
| R3 | 8.6 | 2.15 | 4 | A-2-4 |
| R4 | 12.0 | 1.97 | 2 | A-6 |
| R5 | 11.4 | 1.98 | 5 | A-2-6 |

The overall condition assessment of the pavements has shown that the in-service flexible pavements from the point of distress need resurfacing. The pavements exhibiting frequent minor depressions also need resurfacing to delineate roughness which is affecting the riding quality. These assessments recommend going in for a cost–effective minor rehabilitation design for the existing flexible pavements.

## 3. WHITETOPPING DESIGN

The flexible pavements being low volume urban roads and residential streets showing rutting and roughness, it would be appropriate to go for whitetopping design. The load stress in the critical edge region was obtained as per modified Westergaard's equation by Teller and Sutherland. The kind of overlay thickness and the joints layout obtained for different traffic condition from the design is given in Table 8. The minor rehabilitation design analysis has resulted in 4-Thin whitetopping sections and 1–Ultra-thin whitetopping section. R3 resulted in thinnest overlay of 100-mm with shorter joint spacing 1-m×1-m.Whereas, R5 has resulted in thicker overlay of 140-mm with largest joint spacing 1.5-m×1.5-m.

**Table 8** Design Features of Whitetopping for Selected Roads

| Road section | Design life (years) | Design traffic (msa) | Type | PCC thickness (mm) | HMA thickness (mm) | Panel size (m) | Fibre type |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R 1 | 30 | 7. 86 | T W T | 120 | 75 | 1x 1 | Pol ypr opy lene |
| R 2 | 30 | 3. 68 | T W T | 130 | 70 | 1x 1 | Pol ypr opy lene |
| R 3 | 30 | 9. 20 | U T W T | 100 | 73 | 1x 1 | Pol ypr opy lene |
| R 4 | 30 | 10 .9 0 | T W T | 120 | 65 | 1. 2x 1. 2 | Pol ypr opy lene |
| R 5 | 30 | 26 .9 2 | T W T | 140 | 75 | 1. 5x 1. 5 | Pol ypr opy lene |

The load- related stress in the PCC slabs decreases with the increase in thickness of PCC overlay. R3 with the thinnest overlay (100-mm) and shorter joint spacing (1-m×1-m) has resulted in highest critical stress combination. The 120-mm (R1 & R4) overlay with different panel sizes (1-m×1-m, 1.2-m×1.2-m) shows increase in critical stress combination when compared with the 140-mm ( R5) overlays with the different joint spacing's (1.5-m×1.5-m). This is because the load-related stress is significantly higher in the thin overlay. But for the same overlay thickness (120-mm & 140-mm) with different joint spacing (1-m×1-m, 1.2-m×1.2-m & 1-m×1-m, 1.2-m×1.2m) the critical stress combination increases with the increase in joint spacing. This is mainly due to increase in warping stresses. The decrease in joint spacing decreases the warping stress. So to ensure better performance of whitetopping sections during their design life factors like short joint spacing and appropriately thick overlays is necessary. Other factors like effective modulus of asphalt base (K), radius of relative stiffness (l) and quality of the bond between the concrete overlay and the asphalt (Reduction in stresses) have a significant effect in arriving at the appropriate thickness and joint spacing of the PCC overlay.

## 4. ASPHALT CONCRETE OVERLAY DESIGN

The selected road stretches were also designed for asphalt overlay based on Benkelman beam deflection studies which were carried out in the field. The IRC: 81-1997 procedure was followed in strengthening the existing flexible pavements by asphalt overlay. The kind of asphalt concrete overlay for the selected roads is presented in Table 9.

**Table 9** Summary of Asphalt Concrete Design for Selected Roads

| **Road Section** | **Design Life (years)** | **Deflection (mm)** | **ESALs** | **Overlay Thickness (mm)** |
|---|---|---|---|---|
| R1 | 15 | 1.20 | 5.8 million | 55 |
| R2 | 15 | 1.28 | 1.0 million | 25 |
| R3 | 15 | 1.11 | 6.0 million | 50 |
| R4 | 15 | 1.20 | 7.2 million | 65 |
| R5 | 15 | 1.72 | 9.0 million | 150 |

The summary of bituminous overlay design reveals that, R5 occupies the highest number of repetitions of axle loads (9.0 million) which has resulted in highest deflection (1.72) requiring the highest overlay thickness (150-mm). But R2 with lowest repetitions of axles (1.0 million) and a characteristic deflection of 1.28 needs the lowest overlay thickness (25-mm).This indicates that with increase in the repetitions of axles of commercial vehicles and structural inadequacy the overlay thickness needed for strengthening the existing pavement in the form of bituminous concrete also increases.

## 5. COST ANALYSIS

The basic rates for items of works are given in Table 10. The rates are applicable and used for computation of the cost of asphalt concrete overlay as well as of whitetopping. Factors like contingencies cost, escalation cost and traffic diversion cost (5% of construction cost) were considered for the bituminous overlay because of the periodic maintenance (every 5 years) to be carried out after the design life. For whitetopping overlay, to achieve the bond between the existing asphalt surface and concrete it is necessary to mill the surface to a certain depth by employing the appropriate milling equipment. The cost of construction of plain cement concrete includes use of high grade of concrete (like M 40) with fibres like polypropylene or polyolefin, laying, compaction, finishing, curing, joint cutting and joint sealing.

**Table 10** Basic Rates for Various Items of Works

| **Serial Number** | **Items of Works** | **Current Rates (Rs)** |
|---|---|---|
| 1. | Tack Coat | 17 /m2 |
| 2. | Prime Coat | 15/m2 |
| 3. | Bituminous Macadam | 8000/m3 |
| 4. | Dense Bituminous Macadam | 8500/m3 |
| 5. | Semi Dense Bituminous Concrete | 9000/m3 |
| 6. | Bituminous Concrete | 9700/m3 |
| 7. | Pavement Quality Concrete | 9500/m3 |
| 8. | Milling /Scarifying | 1200/m3 |

The cost comparison between whitetopping and asphalt concrete overlay is presented in Table The cost of asphalt concrete overlay for R5 (142.44 lakhs) has worked out to be the highest among other roads while R2 has resulted in lowest cost (9.23 lakhs). The cost of White topping for R5 (61.61 lakhs) has worked out to be the highest among others whereas R2 has resulted in lowest cost (9.57 lakhs). The costs for construction of thin whitetopping for R1 and R4 resulted in identical cost while for the same roads with the asphalt overlay has resulted in different cost. White topping for R5 (61.61 lakhs) has worked out to be the highest among others whereas R2 has resulted in lowest cost (9.57 lakhs). The costs for construction of thin whitetopping for R1 and R4 resulted in identical cost while for the same roads with the asphalt overlay has resulted in different cost. The cost of thin whitetopping (9.57 lakhs) for R2 is slightly higher than cost of asphalt overlay (9.23) for the same road. The cost of placing of pavement quality concrete (PQC) of required thickness is found to be initially high when compared to laying of asphalt concrete of required. thickness for the roads for that design period respectively.

**Table 11** Comparative Cost of Asphalt Concrete Overlay versus Whitetopping

| Scenario | Road Section | | | | |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 |
| Bituminous Overlay Thickness (mm) | 55 | 25 | 50 | 65 | 150 |
| Whitetopping Type and Thickness (mm) | 120 TWT | 130 TWT | 100 UTWT | 120 TWT | 140 TWT |
| Total Cost of Bituminous overlay (Rs in lakhs) | 16.86 | 9.23 | 21.16 | 17.99 | 142.44 |
| Total Cost of Whitetopping overlay (Rs in lakhs) | 13.34 | 9.57 | 14.92 | 13.34 | 61.61 |
| Saving in Whitetopping (Rs in lakhs) | 3.58 | -0.34 | 6.24 | 3.09 | 80.83 |
| Saving in (%) | 20.87 | -3.70 | 29.48 | 25.80 | 56.74 |

## 6. CONCLUSIONS

A detailed flexible pavement evaluation has been carried out and the following conclusions are drawn from the present investigation.

1.From the cost comparison between whitetopping and asphalt overlay, it is observed that, whitetopping design for four roads proves to be cost effective than the asphalt overlay. Whereas on one road the cost of whitetopping is slightly higher than the asphalt concrete overlay. This is due to higher initial cost involved in construction of plain cement concrete on existing asphalt pavement. But once constructed, whitetopping requires little maintenance unlike asphalt concrete overlay which undergoes periodic maintenance.

2. Rut is the major distress affecting the selected road stretches. Based on PCI and IRI values all road sections require-- “Resurfacing”.

3. Based on deflection data and existing crust details, it is found out that the existing flexible pavements are structurally inadequate keeping in mind the present traffic condition. Hence the selected roads need structural overlay.

4. The whitetopping design data shows that, R3 with shorter joint spacing and thinnest overlay has resulted in highest critical stress combination while R5 with thickest overlay and shorter joint spacing has resulted in lowest critical stress combination. Hence as the panel thickness decreases, so too should the overall panel size. .

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