Performance Studies on white topping layers over flexible pavement

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Abstract. The main focus of the present era is to construct a long-lasting and better performing pavement. Usually, with respect to the rehabilitation of the pavement, the construction agencies go with the bituminous overlays as their first priority without considering the condition of the existing pavement structure. But CC pavements have proved that they perform better and are long-lasting as new pavement as well as when used for rehabilitation of the existing pavement. And hence it is the era where the Thin and Ultra-Thin White Topping methods are gaining their popularity. Hence in this study, in order to arrive at the performance of the TWT and UTWT methods, various types of basic and the performance tests have been carried out with different combinations of concrete i). Plain Cement Concrete ii), Cement replaced by Ground Granulated Blast furnace Slag (GGBS) (50%) iii). With admixture (Conplast NC) iv) 50% Ground Granulated Blast Furnace Slag GGBS + Conplast NC. Later to understand the performance of these combinations, the composite beams with varying thickness are subjected to repeated wheel loads under Modified Immersion Wheel Tracking Equipment along with a bituminous layer of 50mm thick below the cement concrete layer. The performance results of 150mm thick admixture added CC beam and the 100mm thick GGBS & Admixture added CC beam has almost the same value. Hence, it can be concluded that the slab thickness can be reduced by 50mm by replacing 50% GGBS to the Admixture added CC beam.

1. Introduction
The Romans introduced the cement concrete roads during 300 BC - 476AD [1]. The Romans were highly interested in the using innovative materials like ‘Pozzolana’ cement, hairs of horses as fibers and admixtures in their primary form like animal fat and milk in construction of roads. These roads were scientifically designed and constructed and had a long life and thus it led to the era of concrete roads.

1.1 White Topping
White topping is nothing, but the concrete layer laid over an underlying asphalt pavement. The main goal of concrete overlay is to maximize the strength of the existing asphalt structure by rebuilding it. While achieving this aim, the overlay also brings back the riding-quality of the existing structure.
which had undergone deformations like rutting and also brings back the texture. The bituminous roads have been widely used in the world from many years since there is maximum supply of bitumen and its ease for the construction. Also, the bitumen is available at the cheaper rate. But as the time has passed, all the advantages of the bitumen are reversed viz., the petroleum industries have started using the technology of refined processing which has led to the reduction in bitumen production which in turn has increased the import cost. At present, there is a favourable economy of cement concrete and also the traffic animus changed so that existing pavements cannot withstand the effect of the changed traffic scenario. At the same time, the concrete technology and its applications have developed in a rapid rate and hence the concrete overlay has become a non-renewable option. In these times of Public-Private Partnerships, life-cycle cost analysis methods are becoming very popular rather than mere construction costs in construction of road.

1.1 Types of White Topping.

The Cement Concrete overlays have been used for the rehabilitation of the existing asphalt pavements since from 1918 in United States of America. There has been a researched interest in white topping technology, mainly on Ultra- Thin White Topping (UTWT) and Thin White Topping (TWT) over Conventional White Topping. White Topping technology can be classified as follows based on the types of bondage provided and the thickness of overlay [1].

(a) Ultra-Thin White topping (UTWT) - It is a Portland Cement Concrete overlay of below 100 mm thick. It is mandatory to obtain the bond between the overlay & the below asphalt layer.

(b) Thin White topping (TWT) - It is a Portland Cement Concrete overlay of thickness 100 to 200 mm. It can be designed either by considering or without considering the bond between the overlay & the underlying bituminous layer.

(c) Conventional White topping - It is a Portland Cement Concrete overlay of 200 mm thick or higher than 200mm. It can be designed and constructed without the consideration of bonding between the two layers (composite action is not assumed).

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

2. Literature Review

2.1 Bitumen and White toppings

A K Sehgal et al[1] have studied the advantages and benefits of Thin White Topping over bituminous overlays and have done comparison between the two considering the sustainability as the main criteria. The other factors considered are design life, life cycle cost and other environmental factors. Their study concludes that TWT overlays are considered more environmentally and economically sustainable as compared to that of bituminous overlays. V K Sinha et al[2] attempted to bring forth the concept of white topping over existing bituminous pavement. They computed the thickness for the bituminous overlay as well as for the concrete overlay and cost estimation for both. In their study, comparison is done based on total life cycle cost. And from the paper, it is noted that the savings in the construction cost of doing white topping against bituminous overlay is evidently convincing and hence life cycle cost is more economical.

Mustaque Hossain[3] carried out the study to build up a design catalogue for existing roadway which is to be overlaid with the TWT. The 3-D Finite Element (FE) analysis was used to expand the design catalogue. The results obtained from this study showed that the interface bonding condition between the overlay and the existing layer is the most important factor which affects the behavior of thin white topping. Abhijith C.C[4] study dealt with the performance of UTWT overlays of different
combinations over bituminous concrete layer. From this study, the direct tensile test indicated that the ROFF cement interface improved the bond strength in all the combinations when compared to that of plain cement concrete beams. Also the results of Modified Immersion Wheel Tracking test indicated that the performance of composite beams directly depended upon the thickness of the cement concrete layer (as the thickness increases, yields very low rut value), radius of stiffness of the composite beams and also the admixture used and its percentage.

2.2 Bitumen, Concrete and industry rejects materials
Rajesh kumar et al [5] state that crumb rubber with HDPE coating of aggregates enhancing Impact strength and wear resistance properties of the coated aggregates. Moreover polymer coating reduces its affinity for water and may improve stripping susceptibility. 8% shredded HDPE improves its rutting resistance and load carrying capability of the bitumen mix [5]. Most of the construction components should be designed with durable and also be sustainable, hence employ of sustainable materials in hot mix asphalt and as well as in concrete should be included in all possible construction activity to reduce the CO₂ emission [6-13]. Also modern structural elements and components must be planned with employ sustainable materials to the control the environmental pollution [14-16].

3. Objectives and Methodology

3.1 The main objectives of this study are;
- To evaluate the design and methodologies for the overlay of PCC over existing Bituminous Concrete layer.
- To evaluate the various composition of composite Beam specimens to undergo test in the Immersion Wheel Tracking equipment in the laboratory.
- To compare the results of plain, added admixtures and the slag for various composite beam specimens.

3.2 The Methodology involved is as follows;
- Basic tests on all the materials (Bitumen, Aggregates, Cement and mix design for BC mix and CC mix) to be used
- BC layer of 50mm representing the flexible surface has been casted and compressed using an I section girder plate.
- Above the flexible layer, Concrete layers of varying thickness (50mm, 100mm and 150mm) have been casted.
- Composite beams are cured.
- And tested for performance under a Modified Immersion Wheel Tracking Equipment.
4. Test Results

Table 4. Physical properties of Aggregates

| SL NO | TESTS                             | RESULTS | MORT&H 5th REVISION SPECIFICATIONS |
|-------|-----------------------------------|---------|------------------------------------|
| 1     | Specific Gravity of fine aggregates | 2.72    | -                                  |
| 2     | Specific Gravity of Coarse aggregates | 2.64    | -                                  |
| 3     | Los Angeles Abrasion value         | 18.5%   | Less than 35%                      |
| 4     | Crushing value                     | 19.50%  | Less than 30%                      |
| 5     | Impact value                       | 15.50%  | Less than 35%                      |
| 6     | Combined index (EI+FI)             | 18.1    | Less than 35%                      |
| 7     | Water absorption                   | 1.65%   | Less than 2%                       |

Table 5. Physical properties of Cement

| SL NO | TESTS                | RESULTS |
|-------|----------------------|---------|
| 1     | Name                 | JP 43   |
| 2     | Specific Gravity     | 3.12    |
| 3     | Setting time         | 31 min  |
| 4     | Fineness             | 5%      |
| 5     | Standard Consistency | 30%     |

Table 6. Physical properties of Bitumen

| SL | TESTS                | RESULTS | Specifications as per IS |
|----|----------------------|---------|--------------------------|

Figure 1. Methodology Chart
Table 7. Physical properties of Admixtures

| SL NO | PROPERTY            | VALUE          |
|-------|---------------------|----------------|
| 1     | Conplast NC         |                |
| 2     | Specific gravity    | 1.260 - 1.270 at 300°C |
| 3     | Freezing point      | -160°C         |
| 4     | Chloride content    | Nil to BS 5075 |
| 5     | Air entrainment     | Less than 1%   |

Table 8. Gradation of Aggregates for Bituminous Concrete

| IS Sieve Size(mm) | Material A 20mm↓ | Material B 10mm↓ | Material C 4.75mm↓ | Material D Filler (Cement) | Obtained Gradation as per MORT&H 5th Edition | Desired Mid Gradation as per MORT&H 5th Edition |
|-------------------|------------------|------------------|-------------------|-----------------------------|-----------------------------------------------|-----------------------------------------------|
| 19.000            | 100              | 100              | 100               | 100                         | 100                                          | 100                                          |
| 13.200            | 21.71            | 100              | 100               | 100                         | 92                                           | 89.5                                         | 79-100                                      |
| 9.500             | 2.08             | 83.75            | 100               | 100                         | 84                                           | 79                                           | 70-88                                       |
| 4.750             | 1.15             | 23.95            | 100               | 100                         | 60                                           | 62                                           | 53-71                                       |
| 2.360             | 0                | 5.64             | 88.68             | 100                         | 47                                           | 50                                           | 42-58                                       |
| 1.180             | 0                | 0                | 72.53             | 100                         | 37                                           | 41                                           | 34-48                                       |
| 0.600             | 0                | 0                | 56.25             | 100                         | 29                                           | 32                                           | 26-38                                       |
| 0.300             | 0                | 0                | 38.4              | 100                         | 20                                           | 23                                           | 18-28                                       |
| 0.150             | 0                | 0                | 24.92             | 95                          | 14                                           | 16                                           | 12-20                                       |
| 0.075             | 0                | 0                | 9.65              | 87                          | 6                                            | 7                                            | 4-10                                        |
Table 9. Marshal test values for varying BC percentage

| Sl No | Bitumen Content (%) | Marshall Stability (Kg) | Bulk Density (g/cc) | Flow (mm) | Air Voids (%) | VMA (%) | VFB (%) | Vb (%) |
|-------|---------------------|------------------------|---------------------|----------|---------------|---------|---------|-------|
| 1     | 5.2                 | 895.950                | 2.431               | 2.000    | 5.459         | 17.822  | 68.754  | 12.507 |
| 2     | 5.4                 | 1167.450               | 2.474               | 2.950    | 4.633         | 18.362  | 70.649  | 13.007 |
| 3     | 5.6                 | 1343.925               | 2.482               | 3.100    | 4.513         | 18.424  | 73.453  | 13.500 |
| 4     | 5.8                 | 1384.680               | 2.446               | 3.500    | 4.384         | 18.559  | 74.612  | 13.900 |
| 5     | 6.0                 | 1140.300               | 2.377               | 3.600    | 3.647         | 18.134  | 79.889  | 14.500 |

Table 10. Marshal test results of BC

| Marshall Properties | Results Obtained | Requirement as per MORT&H 5th Edition |
|---------------------|------------------|---------------------------------------|
| OBC (%)             | 5.7              | 5.4% minimum                           |
| Marshall Stability (Kg) | 1365.56         | 1200 kg minimum                        |
| Bulk Density (g/cc)  | 2.44             | …..                                    |
| Flow (mm)           | 3.3              | 2.5-4 mm                               |
| Air Voids (%)       | 4.02             | 3-5%                                   |
| VMA (%)             | 18.5             | 12 minimum                             |
| VFB (%)             | 74.03            | 65-75%                                 |

Table 11. Quantity details for Plain Concrete

| Materials          | Quantity in kg/m³ |
|--------------------|-------------------|
| Cement             | 465               |
| Water              | 186               |
| Fine aggregates    | 796               |
| Coarse aggregates  | 978               |
| W/C ratio          | 0.40              |

Table 12. Quantity details Concrete with Conplast NC

| Materials             | Quantity in kg/m³ |
|-----------------------|-------------------|
| Cement                | 426               |
| Water                 | 149               |
| Fine aggregates       | 797               |
| Coarse aggregates     | 1090              |
| Chemical admixture    | 4.26 at 1%        |
| W/C ratio             | 0.35              |

Table 13. Compressive strength of concrete cubes

| Name | Day | Result (M pa) |
|------|-----|---------------|
| 7th  |     | 29.91         |
Plain Cubes

| Sl No. | Name             | Result (MPa) |
|-------|------------------|--------------|
| 1     | Plain cube       | 4.7          |
| 2     | 50% GGBS         | 4.4          |
| 3     | With admixture   | 5.3          |
| 4     | 50% GGBS + admixture | 5.5    |

50% GGBS

| Sl No. | Name             | Result (MPa) |
|-------|------------------|--------------|
| 1     | Plain cube       | 25.63        |
| 2     | 50% GGBS         | 32.50        |
| 3     | With admixture   | 37.00        |
| 4     | 50% GGBS + admixture | 37.70     |

With admixture

| Sl No. | Name             | Result (MPa) |
|-------|------------------|--------------|
| 1     | Plain cube       | 35.59        |
| 2     | 50% GGBS         | 41.00        |
| 3     | With admixture   | 48.00        |
| 4     | 50% GGBS + admixture | 41.02    |

| Sl No. | Name             | Result (MPa) |
|-------|------------------|--------------|
| 1     | Plain cube       | 3.55         |
| 2     | 50% GGBS         | 3.06         |
| 3     | With admixture   | 3.62         |
| 4     | 50% GGBS + admixture | 3.69    |

| Sl No. | Name             | Result (mm)  |
|-------|------------------|--------------|
| 1     | Plain cube       | 45           |
| 2     | 50% GGBS         | 44           |
| 3     | With admixture   | 40           |
| 4     | 50% GGBS + admixture | 41      |

Table 14. Flexural strength of concrete cubes

Table 15. Split Tensile strength of concrete cubes

Table 16. Workability of Concrete (Slump test Results)

Table 17. Summary of Concrete Test Results
The obtained gradation is within the limits set by the MORT&H guidelines shown in figure 2. From the above graph- Figure 3, we can infer the variation of rut values along with the thickness of plain concrete beam, and it is observed that the rut values of 75mm thick beams are higher than 100mm and 150mm thick beams. In graph- Figure 4, it is observed that higher the thickness, lower are the corresponding rut values.

|   |                  |       |   |   |   |
|---|------------------|-------|---|---|---|
| 1 | Plain cube      | 41.02 | 4.7| 3.55|45 |
| 2 | 50% GGBS        | 37.00 | 4.4| 3.06|44 |
| 3 | With admixture  | 48.00 | 5.3| 3.62|40 |
| 4 | 50% GGBS + admixture | 46.50 | 5.5| 3.69|41 |

Figure 3. No. of repetitions v/s Rut value for Plain CC beams

Figure 4. No. of repetitions v/s Rut value for CC beams with Admixture
Figure 5. No. of repetitions v/s Rut value for CC with GGBS

In the above graph - Figure 5 indicating the variation of rut value along with the thickness of concrete beam with GGBS. It can be observed that the performance of 100mm thick beam is better up to 1450 repetitions than 75mm thick and 150mm thick beams.

Figure 6. No. of repetitions v/s Rut value for CC with Conplast NC admixture and GGBS

The above graph - Figure 6 indicates the variation of rut value along with the thickness of concrete beam with GGBS and admixture. It is observed that the performance of both 150mm and 100mm thick beam are almost same when both GGBS and admixture are added to concrete.
Figure 7. Performance results of 75mm thick composite beams

From the above graph - Figure 7 which represents the performance results of 75mm thick concrete beams (all 4 combinations) laid over 50mm bituminous concrete layer, it is observed that the concrete beams with both GGBS and Conplast NC have performed well and beams with only GGBS has given less performance compared to plain concrete beams.

Figure 8. Performance results of 100 mm thick composite beams

The above graph-figure 8 represents the performance results of 100 mm thick concrete beams (all 4 combinations) laid over 50mm bituminous concrete layer. The concrete beams with GGBS and Conplast NC have performed well and beams with only GGBS has given less performance.
Figure 9. Performance results of 150 mm thick composite beams

The above graph-figure 9 represents the performance results of 150 mm thick concrete beams (all 4 combinations) laid over 50mm bituminous concrete layer. The concrete beams with GGBS and Conplast NC have performed well and beams with only GGBS has given less performance.

5. Conclusions

- Among the four different combinations like Plain CC, with GGBS, with Admixture and with GGBS + Admixture, the GGBS added concrete had shown low results and the GGBS + Admixture added concrete shown high results regarding strength parameters.
- Even the slump values were also within the standard limits as per MORT&H 5th revision.
- From the performance results it is known that the rut value decreases with the increase in the thickness of the beam.
- And hence it is noted that the performance of the slab increases with the increase in the thickness of the slab.
- The correlation values are less than or close to 1 for each combinations of concrete at a tyre pressure of 8kg/cm² on the slab, which signifies that deflection and repetitions are strongly correlated.
- By comparing the performance results of various concrete combinations, it is known that the GGBS + Admixture combination had performed well.
- The GGBS added concrete has the least performance when compared to all other combinations.
- From the performance results it is observed that the performance results of 150mm thick Plain CC beam and 100mm Admixture added beam has almost the same value.
- And hence it can be concluded that the slab thickness can be reduced by 50mm with the addition of admixture.
- And also, the performance results of 150mm thick admixture added CC beam and the 100mm thick GGBS & Admixture added CC beam has almost the same value.
- Hence it can also be concluded that the slab thickness can be reduced by 50mm by replacing 50% GGBS to the Admixture added CC beam.

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