Recycling Bitumen from Dismantled Road-A Case Study

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Abstract - In a developing country like India, many changes in urban planning and infrastructure facilities are proposed and brought into practice on a daily basis. One such commonly faced challenge is the proper handling of demolished pavements during road construction and rehabilitation. Also if the demolished pavement is not disposed off in the correct manner, it may cause serious environmental hazard. A possible solution to this is the reusing of demolished materials by recycling in proper manner. The solution, not very commonly adopted in India may become a possible alternative for pavement construction for the current ambitious road building programme underway. The present study involves the recycling of existing asphalt pavement materials of a dismantled road at Indore, India to produce new pavement materials. The results showed considerable savings of material, money, and energy.

Keywords – Infrastructure; pavement; recycling; environmental hazard

INTRODUCTION

Over the years, recycling has become one of the most attractive pavement rehabilitation alternatives in developed countries. Unfortunately, asphalt pavement recycling is yet to take off in India despite the current ambitious road building programme underway. Recycling of existing asphalt pavement materials to produce new pavement materials results in considerable savings of material, money, and energy. The specific benefits of recycling can be summarized as follows:

(a) Substantial savings over the use of new materials,
(b) Conservation of natural resources,
(c) Performance equal or even better than new materials,
(d) Pavement geometrics is maintained, and
(e) Saving of considerable amount of energy compared to conventional construction techniques.

The last benefit is very important due to the recent urgent need for reducing greenhouse gases that is, reducing carbon footprint thereby earning carbon credits for India.

The Asphalt Recycling and Reclaiming Association define five different types of recycling methods: (1) Cold Planning; (2) hot recycling; (3) Hot in Place Recycling; (4) Cold In-Place Recycling; and (5) Full Depth Reclamation. Only hot recycling of asphalt pavements at a central plant will be discussed in this article in the context of 4-laning and 6-laning of India’s state highways and national highways wherein road paving bitumen worth crores of rupees is being buried rather than recycled.

LITERATURE REVIEW

Arvind and Das (2006) adopted central plant hot mix recycling for recycling of asphalt pavement materials. Literature review reports varied levels of performances (laboratory as well as field) of recycled mix compared to the performances of corresponding virgin mixes. Thus, they conducted performance-related tests before finalizing any recycled mix design. They conducted laboratory study on recycled mix design of two different Reclaimed Asphalt Pavement (RAP) samples, and subsequently developed an integrated mix-design-structural-design approach for hot recycled mix. The total cost of the asphalt layer construction was estimated considering the constituent proportion and the pavement design thickness so that the designer may choose the best option.

Shunyashree, et al proposed that recycling of asphalt pavements is one of the effective and proven rehabilitation processes. For the laboratory investigations reclaimed asphalt pavement (RAP) from NH-4 and crumb rubber modified binder (CRMB-55) was used. Foundry waste was used as a replacement to conventional filler. Laboratory tests were conducted on asphalt concrete mixes with 30, 40, 50, and 60 percent replacement with RAP. These test results were compared with conventional mixes and asphalt concrete mixes with complete binder extracted RAP aggregates. Mix design was carried out by Marshall Method. The Marshall Tests indicated highest stability values for asphalt concrete (AC) mixes with 60% RAP. The optimum binder content (OBC) decreased with increased in RAP in AC mixes. The Indirect Tensile Strength (ITS) for AC mixes with RAP also was found to be higher when compared to conventional AC mixes at 30°C. Thus these previous studies were referred to before conducting the tests in this study.
METHODOLOGY

A sample of the bituminous layer was collected from the dismantled road at Malwa mill area in Indore. The sample was broken into small pieces, washed with water and then dried for one day. An amount of 250 grams of the washed sample was taken out for performing the bitumen extractor test to determine the initial bitumen content. Aggregates of different sizes were purchased from the market. Sieve Analysis was performed on each sample of the aggregates procured from the market. Grading of material was done according to section 509 of MORTH (Ministry of Road Transport and Highways) code. Samples of different grades of materials were then weighed (1200 grams each). Aggregate sample was then heated up to 160°C and then cooled up to 140°C in a pan. Another sample of heated bitumen grade of 60-70 was added to the heated material and then mixed. Mould was prepared with varying percentages bitumen content. Marshall Stability test (Figure 1) was performed for each sample having different percentage bitumen content to determine stability and flow value, voids in aggregate (VA), voids in mineral aggregate (VMA), and voids filled with bitumen (VFB) as given in MORTH.

Optimum bitumen content was determined from stability and flow value. Washed and dried Malwa Mill road material passed from 12.5 mm I.S. sieve and retained on 10 mm sieve was taken. Material was then weighed and then heated up to 160°C and then cooled up to 140°C. Required bitumen content was added to the material and then mixed to prepare moulds as shown in Figure 2.

Marshall Stability test was preformed for these samples to determine stability and flow value. Stability and flow value of each sample was compared. Result analysis and cost analysis was done. Conclusions were derived from the same.

RESULTS

Sieve Analysis on aggregates 4.75mm, 6mm, stone dust and cement were first performed in the material testing laboratory as prescribed by Indian Standards.

As an example a sample table for sieve analysis of cement is given below in the form of Table 1.

| Sieve size | Weight retained | Percentage retained | Cumulative frequency | Percentage passing |
|------------|----------------|---------------------|----------------------|-------------------|
| 600µ | 0 | 0 | 0 | 100 |
| 300µ | 0 | 0 | 0 | 100 |
| 150µ | 0 | 0 | 0 | 100 |
| 75µ | 94 | 94 | 6 | |

According to IRC 29-1968 specifications, the mineral aggregates including mineral filler should be so graded or combined so as to confirm to the grading. Unless otherwise specified, for compacted layer thickness of 24 to 40 mm, any of the two grading can be used, but for layer thickness of 40 to 50 mm, only grading no.2 can be used.
Table 2 gives the aggregate gradation for bituminous concrete. First the initial bitumen contained for the sample was calculated by bitumen extractor. Then the optimum bitumen contained by marshal stability test, and finally the required bitumen to be added in sample was calculated.

Table 3 gives the results of sieve analysis for bituminous concrete.

Table 2: Aggregate gradation for bituminous concrete

| Sieve designation | Percent by weight passing the sieve |
|-------------------|-----------------------------------|
|                   | Grading 1 | Grading 2 |
| 20 mm             | -         | 100       |
| 12.5 mm           | 100       | 80-100    |
| 10 mm             | 80-100    | 70-90     |
| 4.75 mm           | 55-75     | 50-70     |
| 2.36 mm           | 35-50     | 35-50     |
| 600 micron        | 18-29     | 18-29     |
| 300 micron        | 13-23     | 13-23     |
| 150 micron        | 8-16      | 8-16      |
| 75 micron         | 4-10      | 4-10      |

Table 3: Sieve Analysis for bituminous concrete

| Sieve designation | Aggregate 6mm | Aggregate 4.75mm | Stone dust | Filler cement | Blended grading | Desired grading | Remark |
|-------------------|---------------|------------------|------------|---------------|-----------------|-----------------|--------|
| 12.5 mm           | 100           | 100              | 100        | 100           | 100             | 100             | Ok     |
| 10 mm             | 100           | 100              | 100        | 100           | 100             | 80-100          | Ok     |
| 4.75 mm           | 27.01         | 91.54            | 77.98      | 100           | 74.33           | 55-75           | Ok     |
| 2.36 mm           | 1.16          | 42.17            | 46.85      | 100           | 41.73           | 55-50           | Ok     |
| 600 micron        | 0.34          | 3.99             | 21.25      | 100           | 18              | 18-29           | Ok     |
| 300 micron        | 0.24          | 0.32             | 15.89      | 100           | 13.35           | 13-23           | Ok     |
| 150 micron        | 0.18          | 0.2              | 7.68       | 100           | 8               | 8-16            | Ok     |
| 75 micron         | 0.10          | 0                | 3.16       | 94            | 4.13            | 4-10            | Ok     |
| Mixing %          | 12            | 15               | 71         | 2             |                 |                 |        |

The obtained bitumen mix was compared with the standard requirements and the results of the same have been summarized in Table 4.

Also a clear comparison between old sample and new sample has been given in Table 5 for two parameters viz. stability and flow for different bitumen content.

Also the variation of strength and flow parameters with varying bitumen content has been further indicated graphically in Figure 3 and Figure 4 respectively.

Table 4: Requirements of bituminous concrete mix

| Serial No. | Description                                                                 | Requirement | Obtained |
|------------|------------------------------------------------------------------------------|-------------|----------|
| 1          | Marshal stability (ASTM designation D 1599) determined in Marshall specification compacted by 50 compaction blows on each end. | 340 kg minimum | 390 kg   |
| 2          | Marshall flow (25mm)                                                         | 8-16        | 15       |
| 3          | Per cent voids in mix                                                        | 3-5         | 3.94     |
| 4          | Per cent voids in mineral aggregate filled with bitumen                     | 75-85       | 81.25    |
| 5          | Binder content per cent by weight of mix                                     | 5-7.5       | 6.5      |

Table 5: Comparison of fresh material and old material

| Bitumen content (%) | 4.5 | 5.5 | 6.5 (new sample) | 6.5 (old sample) | 7.5 |
|---------------------|-----|-----|------------------|------------------|-----|
| Stability (k.G.)    | 490 | 540 | 580              | 390              | 500 |
| Flow (mm)           | 8   | 10  | 13               | 10               | 15  |
The density of the sample (G) was found to be \( \frac{2.44}{G} \). The specific gravity of the total blended mineral was calculated after determining the specific gravities of different aggregate used in the mix.

\[
G_a = \frac{100}{(W_1/g_1+W_2/g_2+W_3/g_3+W_4/g_4)}
\]  
(1)

Where \( G_a \) = specific gravity of combined aggregate.
\( W_1, W_2, \ldots \) = respective per cents by weight of aggregate 1, 2, 3.
\( g_1, g_2, \ldots \) = respective specific gravities of aggregate 1, 2, 3.
\( W_4 \) and \( g_4 \) = weight and specific gravity of binder material.

The value was calculated as \( G_a = 2.85 \). The theoretical maximum specific gravity which is the theoretical density of a void less mixture of a bituminous paving mix may be expressed as follows:

\[
G_t = \frac{100}{(100-W_b)/G_a+W_b/g_b}
\]  
(2)

where \( G_t \) = maximum theoretical specific gravity at 25°C and \( W_b \) = bitumen content, per cent by weight

The calculated value of \( G_t = 2.54 \).

Per cent of maximum density of the mix (M) was calculated as 96.06. \( V_a \) = per cent voids in specimen = 3.94

VMA = voids in mineral aggregate (VMA) = 21.55

VFB = per cent voids, filled with bitumen = 81.25

Table 6 below gives the abstract sheet of recycled material followed by Table 7 which is the abstract sheet of the fresh material.
Table 6: Abstract sheet of recycled material

| Item no | Particulars of items                  | Quantity | Unit    | Rate  | Qty | Quantity saved | Rate  | Quantity | Unit | Cost | Cost saved |
|---------|--------------------------------------|----------|---------|-------|-----|----------------|-------|----------|------|------|------------|
| 1       | Aggregate 6 mm                       | 3.6      | m³      | 650   | per | 3.6            | 650   | m³       | 3.6  | 2340 | 2340       |
| 2       | Aggregate 4.75 mm                    | 4.5      | m³      | 630   | per | 4.5            | 630   | m³       | 4.5  | 2835 | 2835       |
| 3       | Stone dust                           | 21.3     | m³      | 600   | per | 21.3           | 600   | m³       | 21.3 | 12780| 12780      |
| 4       | Cement                               | 17.28    | bags    | 280   | per | 17.28          | 280   | bags     | 17.28| 4838 | 4838       |
| 5       | Bitumen 60/70 grade                  | 1142.31  | kg      | 65    | per | 827.19         | 1142.31| kg  | 74250| 53767      |
| 6       | Washing of dismantled material       | 30       | m³      | 371   | per | 30             | Nil   | m³       | 11137.5| 0    | 74892      |

Table 7: Abstract sheet of fresh material

| Item no | Description                                                                                                                                                                                                 | Quantity | Unit | Rate  | per cost |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------|-------|----------|
| 1       | Providing and laying bituminous concrete with hot mix plant using crushed aggregates of specified grading, premixed with bituminous binder, transporting the hot mix to work site, laying with a mechanical paver finisher to the required grade, level and alignment, rolling with smooth wheeled vibratory and tandem rollers to achieve the desired compaction in all aspects and as per clauses of section 509. Only cement will be used as filler. | 30       | m³   | 8226  | 246780   |

CONCLUSIONS

- Cost of construction of bituminous concrete layer of 100 meter length, 7.5 meter wide and 4 cm thick (quantity 30 m³) is Rs 246780 only, while recycled dismantled road cost is Rs 74893. Thus a saving of around 70% is observed in cost incurred when recycled bitumen is used as a partial substitute of fresh concrete.
- The stability as well as flow values were found to be increased for new sample.
- It was found experimentally that around 70% of the bitumen of the dismantled road may be recycled and used for further pavement construction activities.
- This may also serve as a lucrative option for the disposal of bitumen for dismantled roads. As bitumen resulting in dump yards poses a serious threat to the environment, recycling of this bitumen can protect mankind from this ecological hazard.

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