Utilization of Reclaimed Asphalt Pavement Material in Wet Mix Macadam (W.M.M)

Ajaykumar Sejvani¹, A.A. Amin², Dr. L.B. Zala³

¹ M.Tech Transportation, Department of Civil Engineering, Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar, India
² Assistant Professor, Department of Civil Engineering, Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar, India
³ Professor & Head: Department of Civil Engineering, Department of Civil Engineering, Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar, India

Abstract. Reclaimed asphalt pavement (RAP) is one of the innovative and effective technologies in many places in the world. The utilization of RAP is rapidly increasing popularity and becoming an emerging technique in India. As per IRC-120:2015, removing or reprocessing pavement materials containing aggregates that are bitumen coated is termed as RAP. These materials are gained through a process in which the existing surface pavement is reclaimed and reused after processing for reconstruction, resurfacing, or repaving. Well graded and high-quality aggregate are achieved from this process. Proper utilization of RAP with specified properties and specified percentages, not only serve as an alternative useful pavement material but also helps in reducing the usage of natural construction material, that will directly reduce the overall cost of projects. By conducting tests as per MoRTH specifications (5th Revision), the various characteristics of RAP material and fresh aggregates are observed. The main objective of the study is to carry out the performance tests: Modified Proctor test on fresh material as well as on material mixed with reclaimed asphalt pavement i.e. 10%, 20%, and 30% of total mix and to achieve optimum moisture content and maximum dry density by using Modified Proctor Test. Attempts are carried out to design a new pavement using Indian Road Congress (I.R.C-37:2018) guidelines and utilization of RAP material. Economic benefits are calculated in terms of fresh and RAP (10%, 20%, and 30%) mix material pavement.

Index Terms—Flexible Pavement Layer, Reclaimed Asphalt Pavement (RAP), Wet Mix Macadam (WMM), Modified Proctor Test, IITPAVE Software, Costing, and Estimation

1. Introduction

In India, road network plays an important role in the increase in the rapid growth of the economy, industry trade, and tourism. All remote places are connected via a road network for caring out various economic activities. A Road network also integrates people from different places and cultures. By linking various facilities like airports, ports and railway stations, road network plays an important role in transport infrastructural development. A study on India roads indicates that excessive pollution growth and development in road construction have resulted in extensive usage of bituminous material and aggregates in the last 55-67 years. In our country, most of the roads are flexible pavement using and these roads have a disadvantage that it requires a periodic maintenance action due to heavy traffic loads and environmental conditions. (Mishra.B;2015). As we are constructing new roads day by day
that is of thousands of kilometers, we are consuming a large amount of non-renewable energy and materials from Mother Nature. Recycling, a logical and practically possible is one of the best ideas to control the never-ending demand for fresh construction material. By consuming recycled materials we also cut down a large number of construction costs. Near about 67% of Indian highway, roads were mainly constructed with Hot Mix Asphalt (HMA). As the years pass these infrastructure ages, so roads and highways require maintenance. The material can be reused to repair, reconstruct, and to maintain the original highway. These materials are gained through a process in which the existing surface pavement materials are reclaimed and reused after processing for reconstruction, resurfacing or repaving are known as Reclaimed Asphalt Material. RAP is a valuable material used in HMA to decrease or cope up the demand of fresh materials. RAP material controls the usage of fresh aggregate and fresh bitumen in pavement construction. In 1973, RAP was used for the first time, however, the usage percentage was low as during that time there was a lack of knowledge that how it will affect the pavement characteristics. Nowadays near about higher percentages i.e. 20% RAP is being utilized to reduce construction costs and fresh material and reuse of demolished old asphalt pavements. Mainly RAP designed pavements are used for rural road construction but with new technologies and proper knowledge, we can construct in urban areas also.

2. Laboratory Investigations
   To check materials that are to be used is suitable in bituminous mixes, it is necessary to carry out the physical tests on materials. In the present research different materials used are RAP aggregate and natural aggregate. The purpose of this research is to examine the performance between natural aggregate and various RAP aggregate mixtures that is 10%, 20%, and 30% of Wet Mix Macadam obtained from standardized laboratory tests. The procedure includes Modified Proctor Test parameters that are Maximum Dry Density and Optimum Moisture Content mixes using RAP materials.

• RAP Material Properties
   RAP sample was obtained from the stockpile at RKC infra built, Vasad. The obtained RAP material was milled by the milling operation done on Vasad-Tarapur state highway in Anand district of Gujarat state, India. The milling process is shown in Figure 1 done on Vasad-Tarapur state highway road and Figure 2 shows the RAP material stockpiled at RKC hot mix plant.

![Figure 1: Milling operation Vasad-Tarapur S.H, Gujarat](Image)

![Figure 2: Material Stockpiled at Vasad](Image)

| Property of RAP materials | Test Method | Test Results | MORTH 2013 5th Revision Specification |
|---------------------------|------------|--------------|---------------------------------------|
| Specific Gravity          | IS 2386 (Part III) | 2.733 | 2.650 | 2.623 | 2.611 | 2.6 to 2.9 |
| Water Absorption          | IS 2386 (Part III) | 1.30 | 1.33 | 0.87 | 0.70 | Max. 2% |

• Properties of Natural aggregate:
   For study and test purposes the fresh aggregate were obtained from Kamal Infrastructure Pvt Ltd, Mogri. The obtained aggregate were tested to check their suitability for the design of Wet Mix Macadam (WMM) for various physical properties for the design mix. All the tests were carried out in
the laboratory and the Indian Standard Test procedure was followed. The following are the test results summary shown in Table-2 of fresh aggregates done as per MoRTH specifications.

**Table 2: Physical Properties of Aggregate**

| Property of Aggregates Test Method | Test Results | MORTH 2013 5th Revision Specification |
|-----------------------------------|--------------|----------------------------------------|
| Aggregate Impact Value IS:2386(Part IV) | 14.72% 11.15% - | Maximum. 27% |
| Combined (EI+FI) index IS:2386(Part I) | 27.14% - - | Maximum. 35% |
| Specific Gravity IS:2386(Part III) | 2.831 2.738 2.730 | 2.6 to 2.9 |
| Water Absorption IS:2386(Part III) | 1.242 1.541 1.459 | Maximum. 2% |

3. **Non-Bituminous Macadam Design (Wet Mix Macadam)**

*A Job Mix Formula for WMM Fresh Mix*
To obtain percentages of job mix formula Mix design was performed for fresh material according to Table 400-13 referring MORTH 5th revision. Individual gradation was done on a trial and error bases and the final results are shown in Table-3 a graph representing the Job mix for WMM fresh mix is shown in Figure: 3.

*B. Job Mix Formula for WMM using Fresh material + RAP material*
We performed a Mix design with and without RAP mixture i.e. 0%, 10%, 20%, and 30%, of WMM grade-II. Blending of RAP material and fresh material was prepared i.e. 10% of RAP materials + 90% fresh materials. Table-4 shows the combined gradation of RAP and fresh aggregates meeting the requirement as per MORTH 5th revision specification. Respective blend graphs were plotted and shown in Figure: 3.

**Table 3: Blending average of Sample for WMM (Fresh Material) - Table 400-13**

| IS Sieve mm | Individual % Passing | Individual % Blending | % Passing (JMF) | Specified Limits |
|-------------|----------------------|-----------------------|-----------------|-----------------|
| 53.000      | 100.000              | 100.000               | 100.000         | 100.000         |
| 45.000      | 95.000               | 100.000               | 100.000         | 100.000         |
| 22.400      | 90.000               | 100.000               | 100.000         | 100.000         |

After the extraction of binders, the aggregates were recovered and kept for oven drying for 24 hours. After oven drying the gradation of recovered aggregate was performed, shown in Figure:3, and from the figure, we can conclude that gradation of RAP aggregates fall below the lower limit of WMM (Grading-II) as per table 400-13 which is shown in Table 4.

**Table 4: Obtained Gradation of RAP Mixes with Fresh Mixes (Table: 400-13)**

| IS Sieve mm | Specification limits | Average limit | Fresh material | RAP Gradation | COMBINED GRADATION |
|-------------|----------------------|---------------|----------------|---------------|--------------------|
| 53.000      | 100                  | 100           | 100.00         | 100.00        | 100.00             |
| 45.000      | 95-100               | 95            | 100.00         | 100.00        | 100.00             |
| 22.400      | 60-80                | 82.5          | 79.65          | 72.48         | 78.93 78.21 77.30 78.2 |
A. Modified Proctor Test
The parameters of the Modified Proctor Test for WMM fresh mix and mix containing different percentages of RAP material i.e. 10%, 20%, and 30% are carried out, as per MoRTH specifications (5th Revision). Parameters of the mix like maximum dry density and optimum moisture content are observed for various test % of RAP mixes shown in Table 5.

Table 5: Modified Proctor Test Results (Table: 403-13)

| Mix Type          | OMC (%) | MDD (gm/cc) |
|-------------------|---------|-------------|
| Fresh material    | 6.00    | 2.40        |
| 10% RAP material  | 9.14    | 1.79        |
| 20% RAP material  | 9.05    | 1.74        |
| 30% RAP material  | 8.96    | 1.69        |

4. Flexible Pavement Design (IRC- 37:2018)

A. Pavement Design
A stretch of 1 KM length is selected for pavement design and the various design traffic parameters are shown in Table 6. Using the below Equation described in IRC: 37-2018 guidelines, we could calculate a million standard axel (MSA).

Table 6: Design Parameter

| Lane Distribution factor (LDF) | 0.5 |
|---------------------------------|-----|
| Initial Traffic (A)             | 1000|
| Vehicle Damage Factor (VDF)     | 5.0 |
| Traffic growth rate(r)          | 5%  |
| Design life(n)                  | 15 years |
| Terrain                         | Plain |
| Effective CBR of sub-grade      | 9%  |

\[ N = \frac{365[(1 + r)^n - 1]}{r} \times A \times D \times F \approx 20 \text{msa} \]

A.1 Data input and analysis by IIT PAVE Software
### Table 7: Calculation of fatigue and rutting model by IITPAVE

| Material                  | Horizontal Tensile Strain in Bituminous Layer | Vertical Compressive Strain on Sub grade |
|---------------------------|-----------------------------------------------|-----------------------------------------|
|                           | Allowable Strain | IITPAVE calculated Strain | Result | Allowable Strain | IITPAVE calculated Strain |
| FRESH MATERIAL           | 0.0003350 | 0.000267 | SAFE | 0.000578 | 0.000365 | SAFE |
| 10% RAP                  | 0.0003268 | 0.000025 | SAFE | 0.000578 | 0.000542 | SAFE |
| 20% RAP                  | 0.0003176 | 0.000025 | SAFE | 0.000578 | 0.000542 | SAFE |
| 30% RAP                  | 0.0003145 | 0.000025 | SAFE | 0.000578 | 0.000542 | SAFE |

### B. Quantity Estimation

For pavement design, a 2 Lane road is taken into consideration, with a length of 1KM, a width of 10.0 meters, and thickness as per catalog of IRC guidelines. With N= 20msa calculated, the thickness of various road layers was obtained from IRC: 37-2018 design guideline and was taken into account to estimate the quantity of the pavement layer for 1-kilometer length as shown in Table 8. The thickness of various pavement layers is obtained from catalog No. 12.5(plate-5) of IRC 37-2018, as we have considered the CBR value as 9%.

### Table 8: Quantity Estimation of Flexible Pavement (Fresh Mix. plus RAP Mix)

| FRESH MATERIAL | Sr. No | Layer type | Length (m) | Width (m) | Thickness (m) | Quantity (m³) | Cost/m³ | Total Amount(Rs) |
|----------------|--------|------------|------------|-----------|---------------|---------------|---------|------------------|
|                | 1      | BC/SDBC    | 1000       | 10        | 0.04          | 400           | 9,881.90| 3952760          |
|                | 2      | DBM        | 1000       | 10        | 0.075         | 750           | 7565    | 5673750          |
|                | 3      | WMM( FRESH MATERIAL) | 1000    | 12        | 0.25          | 3000          | 2710    | 8130000          |
|                | 4      | GSB        | 1000       | 12        | 0.2           | 2400          | 3,580.00| 8592000          |
| TOTAL CONSTRUCTION COST |       |            |            |            |               |               | 26,348,510.00 |       |

| 10% RAP | Sr. No | Layer type | Length (m) | Width (m) | Thickness (m) | Quantity (m³) | Cost/m³ | Total Amount(Rs) |
|---------|--------|------------|------------|-----------|---------------|---------------|---------|------------------|
|         | 1      | BC/SDBC    | 1000       | 10        | 0.04          | 400           | 9,881.90| 3952760          |
|         | 2      | DBM        | 1000       | 10        | 0.075         | 750           | 7565    | 5673750          |
|         | 3      | WMM(NA+10% RAP) | 1000       | 12        | 0.225         | 2700          | 2710    | 7317000          |
|         | 4      | GSB        | 1000       | 12        | 0.2           | 2400          | 3,580.00| 8592000          |
| TOTAL CONSTRUCTION COST |       |            |            |            |               |               | 25,535,510.00 |       |

| 20% RAP | Sr. No | Layer type | Length (m) | Width (m) | Thickness (m) | Quantity (m³) | Cost/m³ | Total Amount(Rs) |
|---------|--------|------------|------------|-----------|---------------|---------------|---------|------------------|
|         | 1      | BC/SDBC    | 1000       | 10        | 0.04          | 400           | 9,881.90| 3952760          |
|         | 2      | DBM        | 1000       | 10        | 0.075         | 750           | 7565    | 5673750          |
|         | 3      | WMM(NA+20% RAP) | 1000       | 12        | 0.2           | 2400          | 2710    | 6504000          |
|         | 4      | GSB        | 1000       | 12        | 0.2           | 2400          | 3,580.00| 8592000          |
| TOTAL CONSTRUCTION COST |       |            |            |            |               |               | 24,722,510.00 |       |
Table- 8 shows the calculation of total quantity estimate of each layer of flexible pavement, containing fresh material mix, i.e. 0% RAP material. The table also shows the calculated total quantity of each layer of flexible pavement, containing fresh material mixed with various percentage of RAP material, i.e. 10%, 20%, and 30%. Total pavement construction cost of each mix is also calculated.

5. Conclusion

[1] Usage of RAP material up to 30% shows the overall saving of 2.44 million Rs in total flexible pavement construction cost.

[2] Based on the pavement design, material quantity of the WMM layer for 1-kilometer length was found to be 3000 m$^3$. By replacing with RAP material, it was found saving in quantity from 300.00 m$^3$ to 900.0 m$^3$ respectively.
Based on the pavement design it is observed that cost of the fresh WMM layer for 1 km length is 8.13 million Rs, further replacing with RAP aggregates, the actual layer cost reduces up to 7.84 million Rs (3.16%) to 7.11 million Rs (12.20%).

Based on pavement design, aggregate cost for 1 km length of the fresh WMM layer is found to be 6.82 million Rs. By replacing with RAP material, the actual aggregate cost reduces from 6.61 million Rs (3.54%) to 5.99 million Rs (12.55%) respectively.

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