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# A Laboratory Study on the Use of Rap in Bituminous Binder Course

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**Abstract**
*A good road network is one of the important infrastructure in development of country's economy. Road network in India is second largest in world after US which caters 65% of freight traffic and 87% of passenger traffic. To construct the bituminous surface large quantity of aggregates and binders are required. Also large energy is required in production of binder from petroleum. So here is attempt is made to decrease the use of fresh aggregates and binder by using the reclaimed asphalt pavement obtained from old pavement and mixtures has been design by the addition of two different content of RAP in place of new for Dense Bituminous Macadam Grade-II and same has been testify by marshal mix method achieving the design criteria as specified by MORTH.*

## 1. INTRODUCTION

Here in this study the emphasize was laid on the use on Reclaimed asphalt pavement. Large amount of RAP are generated by milling of HMA layer, removal of old pavement layer, complete demolition of old pavement layers, etc. A large amount of energy is required is required in the transportation of these material while site for dumping is also an issue. On the other hand the energy is also required in the production of new material. To save this the reclaimed asphalt pavement material can be used in the construction of new pavement, which will solve many problems associated like [1]

- Lowers the cost of construction.
- Reduces the consumption of natural resources.
- No increase in pavement thickness important in urban roads.
- Transportation of materials is minimized results in saving in energy.
- Existing mix deficiencies can be corrected.[1]

So here is attempt is made to use reclaimed asphalt pavement in construction of new layer of Dense Bituminous Macadam (DBM) grade-II.

## 2. MATERIALS

The major materials used in the construction of road pavement are aggregates and bituminous binder. Here along with the new materials the Reclaimed Asphalt Pavement (RAP) are used which considerable reduced the total mass of new materials used.

The material is used by checking the suitability as specified by Indian Standards code.

Following materials are used

### 2.1 Bitumen

Bitumen is the major binder in construction of most of layer of pavement. Bitumen is tested and following results were obtained after doing various tests on it. Here the virgin bitumen used was of VG-30 Grade.

**Table no.1** Test Results of Virgin Bitumen

| Test | Results |
|---|---|
| Penetration Test | 66 mm |
| Ductility Test | 81 cm |
| Softening point | 77˚ C |
| Flash point | 175.5˚ C |
| Fire Point | 183˚ C |

### 2.2 Coarse aggregates

The coarse aggregate form major volume of road pavement. It is use to resist,

- Wear due to abrasion action of traffic.
- Deterioration due to weathering.
- Highest magnitude of wheel load stresses.

Following necessary test have been done on the fresh aggregates used in the design.

**Table no. 2** Test Results on Fresh Aggregates

| Test | Results |
|---|---|
| Aggregate Impact Value | 15% |
| Aggregate Crushing Value | 20.2% |
| Aggregate Abrasion Value | 18% |
| Flakiness & Elongation Index | 24.5 % |
| Specific Gravity | 2.8 |
| Water Absorption | 0.98% |

### 2.3 Reclaimed Asphalt Pavement

Reclaimed asphalt pavement was collected from over bridge site on the Rajkot Morbi state Highway (GJ SH 24). And was checked for the suitability to be used in place of aggregates by performing all test as perform on the fresh aggregates.

**Table No. 3** Test Result on RAP Aggregates

| Test | Results |
|---|---|
| Aggregate Impact Value | 19.3% |
| Aggregate Crushing Value | 21.5% |
| Aggregate Abrasion Value | 21% |
| Flakiness & Elongation Index | 28.2% |
| Specific Gravity | 2.7 |
| Water Absorption | 1.2% |

After this test results it was concluded that RAP material can be used for the design of the DBM Grade-II.

**Figure No. 1:** RAP collected from the site.

Also Average Bitumen content of Reclaimed Asphalt Pavement (RAP) material collected from the site was 5.77%

## 3. BITUMINOUS MIX DESIGN

Marshall Mix design was adopted for the design DBM grade-II layer. Three trial content was adopted for the design was 3.5% , 4 % and 4.5% Bitumen content.

The trial proportion of RAP was taken as 15%, 25% and 35% of aggregate mix.

The gradation of RAP, fresh aggregate and combined aggregate are given below.

**Table No. 4** Gradation of aggregate for 15% RAP Mix

| Sieve size(mm) | 20 mm | 10 mm | 6 mm | Filler | RAP | 15% RAP | 85% Fresh | Combined | DBM Grade-2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| 26.5 | 100 | 100 | 100 | 100 | 100 | 15 | 85 | 100 | 90-100 |
| 19 | 5 | 100 | 100 | 100 | 92.28 | 13.842 | 64.81 | 78.652 | 71-95 |
| 13.2 | 0 | 96.5 | 100 | 100 | 85.35 | 12.8025 | 62.7 | 75.5025 | 56-80 |
| 4.75 | 0 | 0 | 18.6 | 100 | 60.2 | 9.03 | 32.61 | 41.64 | 38-54 |
| 2.36 | 0 | 0 | 3.6 | 100 | 72.2 | 10.83 | 32.36 | 43.19 | 28-42 |
| 0.3 | 0 | 0 | 0 | 29 | 17.08 | 2.562 | 9.36 | 11.922 | 7-21 |
| 0.075 | 0 | 0 | 0 | 11 | 0 | 0 | 3.55 | 3.55 | 2-8 |

**Table No. 5** Gradation of aggregate for 25% RAP Mix

| Sieve size(mm) | 20 mm | 10 mm | 6 mm | Filler | RAP | 25% RAP | 75% Fresh | Combined | DBM Grade-2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| 26.5 | 100 | 100 | 100 | 100 | 100 | 25 | 75 | 100 | 90-100 |
| 19 | 5 | 100 | 100 | 100 | 92.28 | 23.07 | 57.1875 | 80.2575 | 71-95 |
| 13.2 | 0 | 96.5 | 100 | 100 | 85.35 | 21.3375 | 55.33125 | 76.66875 | 56-80 |
| 4.75 | 0 | 0 | 18.6 | 100 | 60.2 | 15.05 | 28.779 | 43.829 | 38-54 |
| 2.36 | 0 | 0 | 3.6 | 100 | 72.2 | 18.05 | 24.554 | 42.604 | 28-42 |
| 0.3 | 0 | 0 | 0 | 29 | 17.08 | 4.27 | 8.265 | 12.535 | 7-21 |
| 0.075 | 0 | 0 | 0 | 11 | 0 | 0 | 3.135 | 3.135 | 2-8 |

**Table No. 6** Gradation of Aggregate for 35% RAP Mix

| Sieve size(mm) | 20 mm | 10 mm | 6 mm | Filler | RAP | 35% RAP | 65% Fresh | Combined | DBM Grade-2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| 26.5 | 100 | 100 | 100 | 100 | 100 | 35 | 65 | 100 | 90-100 |
| 19 | 5 | 100 | 100 | 100 | 92.28 | 32.298 | 49.5625 | 81.8605 | 71-95 |
| 13.2 | 0 | 96.5 | 100 | 100 | 85.35 | 29.8725 | 47.95375 | 77.82625 | 56-80 |
| 4.75 | 0 | 0 | 18.6 | 100 | 60.2 | 21.07 | 24.9418 | 46.0118 | 38-54 |
| 2.36 | 0 | 0 | 3.6 | 100 | 72.2 | 25.27 | 16.7468 | 42.0168 | 28-42 |
| 0.3 | 0 | 0 | 0 | 29 | 17.08 | 5.978 | 7.163 | 13.141 | 7-21 |
| 0.075 | 0 | 0 | 0 | 11 | 0 | 0 | 2.717 | 2.717 | 2-8 |

The Marshall Mix specimen of various proportion are made and properties of each was tested and same was checked for Marshall Stability and flow value.

### 3.1 Test Result for 15% RAP

Following results are obtained by testing the Marshall Specimen containing 15% RAP Material

**Table No. 7** Test Result for Specimen having 15% RAP and 3.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 100 | 2448.9 | 1.102 | 2698.68 | 3.5 | 2.41 | 5.03 | 62.21 | 13.31 |
| 2 | 65 | 100 | 1868.42 | 0.962 | 1797.42 | 3.1 | 2.46 | 3.06 | 73.42 | 11.51 |
| 3 | 65 | 100 | 1273.42 | 0.962 | 1225.03 | 3.6 | 2.45 | 3.44 | 70.96 | 11.86 |

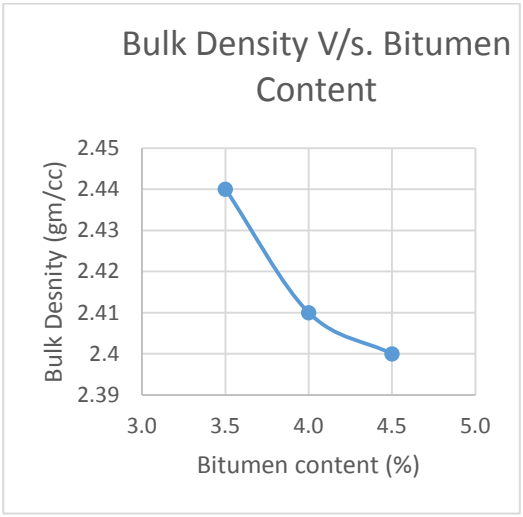
**Table No. 8** Test Result for Specimen having 15% RAP and 4 % Bitumen

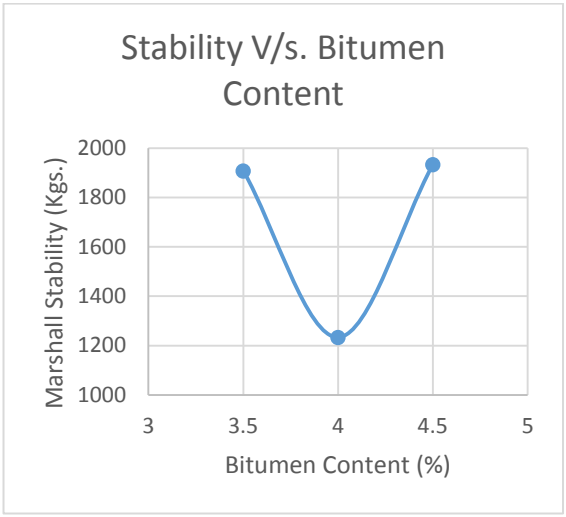
| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 65 | 101 | 1578.18 | 0.962 | 1518.20 | 4.5 | 2.43 | 3.18 | 75 | 12.71 |
| 2 | 64 | 100 | 1385.89 | 0.987 | 1367.87 | 5.2 | 2.38 | 5.05 | 64.92 | 14.40 |
| 3 | 64 | 101 | 823.55 | 0.987 | 812.84 | 3.8 | 2.43 | 3.19 | 74.93 | 12.72 |

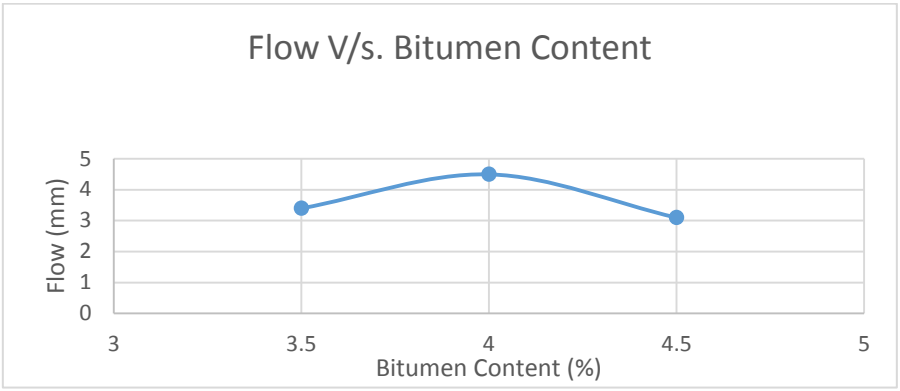
**Table no. 9** Test Result for Specimen having 15% RAP and 4.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 63 | 100 | 2866.12 | 1.012 | 2900.51 | 2.6 | 2.40 | 4.58 | 67.23 | 13.97 |
| 2 | 64 | 100 | 1650.74 | 0.987 | 1629.28 | 4.3 | 2.39 | 4.71 | 66.58 | 14.09 |
| 3 | 66 | 100 | 1342.36 | 0.945 | 1268.53 | 2.4 | 2.42 | 3.69 | 72.01 | 13.17 |

Graphs for the Marshall Parameter for 15% RAP Mix




### 3.2 Test Result for 25% RAP

Following results are obtained by testing the Marshall Specimen containing 25% RAP Material

**Table No. 10:** Test Result for Specimen having 25% RAP and 3.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 66 | 100 | 2314.66 | 0.945 | 2187.35 | 3 | 2.44 | 3.60 | 69.91 | 11.97 |
| 2 | 65 | 100 | 1886.56 | 0.962 | 1814.87 | 3.6 | 2.45 | 3.22 | 72.26 | 11.63 |
| 3 | 69 | 100 | 1578.18 | 0.877 | 1384.06 | 6 | 2.42 | 4.19 | 66.52 | 12.51 |

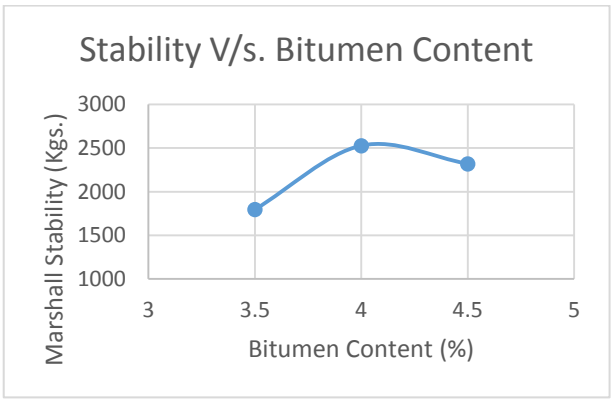
**Table No.11:** Test Result for Specimen having 25% RAP and 4 % Bitumen

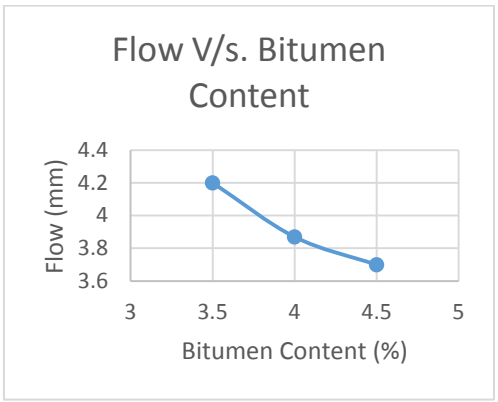
| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 62 | 100 | 2412.62 | 1.037 | 2501.88 | 4 | 2.39 | 4.46 | 64.77 | 12.65 |
| 2 | 62 | 100 | 2575.88 | 1.037 | 2671.18 | 4.1 | 2.4 | 3.84 | 68.24 | 12.09 |
| 3 | 63 | 100 | 2376.34 | 1.012 | 2404.85 | 3.5 | 2.4 | 3.86 | 68.14 | 12.10 |

**Table No. 12:** Test Result for Specimen having 25% RAP and 4.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 62 | 100 | 2213.08 | 1.037 | 2294.96 | 4 | 2.35 | 4.73 | 68.72 | 15.11 |
| 2 | 65 | 100 | 2525.08 | 0.962 | 2429.12 | 4 | 2.36 | 4.31 | 70.77 | 14.73 |
| 3 | 62.5 | 100 | 2176.8 | 1.025 | 2231.22 | 3.1 | 2.38 | 3.80 | 73.42 | 14.28 |

Graphs of Marshall Parameters for 25% RAP Mix



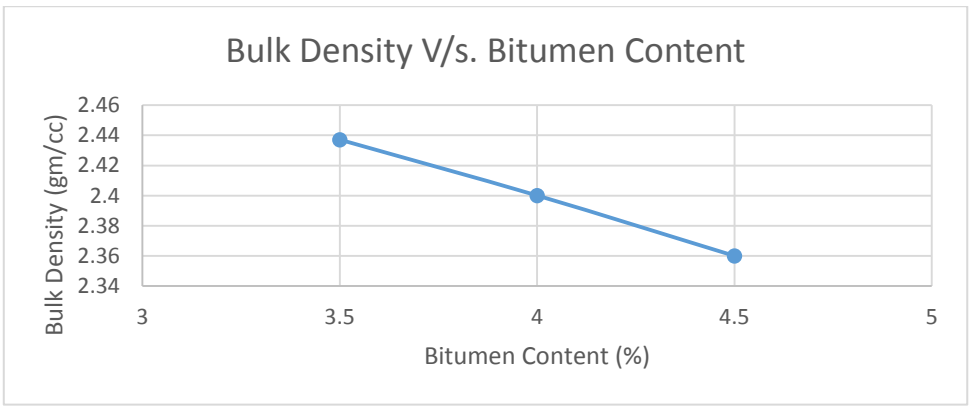




**Figure No. 2:** Prepared Marshall Specimen

### 3.3 Test Results for 35% RAP

Following results are obtained by testing the Marshall Specimen containing 35% RAP Material

**Table No. 13:** Test Result for Specimen having 35% RAP and 3.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 68 | 100 | 2267.5 | 0.896 | 2031.68 | 3.5 | 2.39 | 5.16 | 61.40 | 13.36 |
| 2 | 63 | 100 | 2630.3 | 1.012 | 2661.86 | 4 | 2.44 | 3.10 | 73.03 | 11.47 |
| 3 | 66 | 100 | 2793.56 | 0.945 | 2639.91 | 4 | 2.41 | 4.26 | 66 | 12.54 |

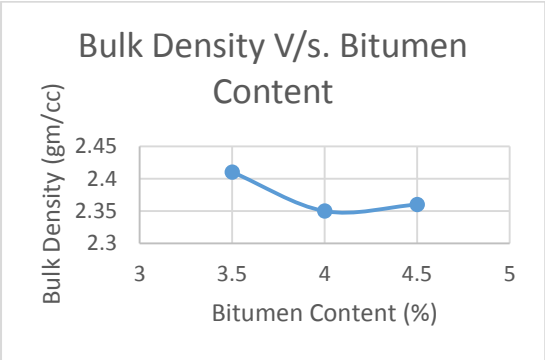
**Table No. 14:** Test Result for Specimen having 35% RAP and 4 % Bitumen

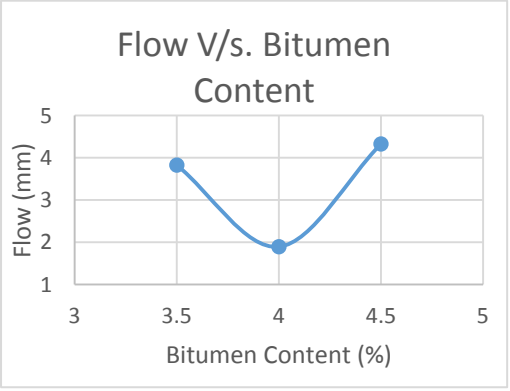
| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 64 | 100 | 2379 | 0.987 | 2348.07 | 2.5 | 2.36 | 3.14 | 74.71 | 12.41 |
| 2 | 65 | 100 | 2157 | 0.962 | 2075.03 | 0.8 | 2.36 | 3.13 | 74.76 | 12.40 |
| 3 | 62 | 100 | 2120 | 1.037 | 2198.44 | 2.4 | 2.35 | 3.75 | 71.04 | 12.96 |

**Table No. 15:** Test Result for Specimen having 35% RAP and 4.5 % Bitumen

| Mould No. | Thick. (mm) | Dia. (mm) | Stability (kgs.) | Correction Factor | Corrected Stability | Flow Value (mm) | Bulk Density | Air voids (%) | VFB | VMA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 64 | 100 | 2013.54 | 0.987 | 1987.36 | 5 | 2.37 | 3.63 | 74.23 | 14.09 |
| 2 | 63.5 | 100 | 2757.28 | 1.00 | 2757.28 | 3 | 2.37 | 3.78 | 73.40 | 14.23 |
| 3 | 64 | 100 | 2369.08 | 0.987 | 2338.28 | 5 | 2.34 | 4.73 | 68.62 | 15.07 |

Graphs of Marshall Parameter for 35 % RAP Mix



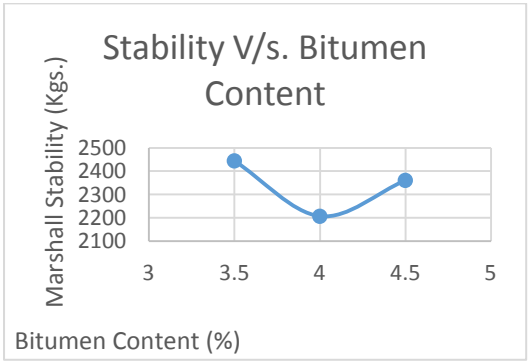




**Figure No. 3**: Checking various Marshall properties

**Figure No. 4:** Testing of Marshall Specimen

## 4. RESULTS AND DISCUSSIONS

From the test of Marshall Specimen the following results can be concluded:

**Table No. 16:** Optimum Binder Content for 15% RAP

| OPTIUMUM BINDER CONTENT | |
|---|---|
| Binder Content for maximum Stability | 4.5 |
| Binder Content for maximum Bulk Density | 3.5 |
| Binder Content for mid-range of voids | 4.22 |
| Binder content for mid-range of VFB | 3.75 |
| Binder content for mid-range of Flow | 3.5 |
| Average Binder Content | 3.90 |

**Table no. 17:** Optimum Binder Content for 25% RAP

| OPTIUMUM BINDER CONTENT | |
|---|---|
| Binder Content for maximum Stability | 4 |
| Binder Content for maximum Bulk Density | 3.5 |
| Binder Content for mid-range of voids | 3.96 |
| Binder content for mid-range of VFB | 4.3 |
| Binder content for mid-range of Flow | 3.84 |
| Average Binder Content | 3.92 |

**Table No. 18** Optimum Binder Content for 35% RAP

| OPTIUMUM BINDER CONTENT | |
|---|---|
| Binder Content for maximum Stability | 3.5 |
| Binder Content for maximum Bulk Density | 3.5 |
| Binder Content for mid-range of voids | 4 |
| Binder content for mid-range of VFB | 3.84 |
| Binder content for mid-range of Flow | 3.7 |
| Average Binder Content | 3.708 |

## 5. CONCLUSIONS

From above all tests and mix design adopted from Marshall Mix method following conclusions can be drawn:

1) From Marshall mix design using various percent of RAP, we get optimum binder content at the use of 35% RAP in the mix i.e. 3.70 % Bitumen
2) The use of RAP (Reclaimed Asphalt Pavement) material in the construction of new Pavement (Dense Bituminous Macadam Grade – II) will considerably reduce the use of fresh aggregate in the construction.
3) Use of RAP satisfies the design requirement as per Marshall Mix method.
4) Use of RAP also improve the water resistant capacity of pavement as we can conclude from the Indirect Tensile Strength test (ITS).
5) So by using the RAP we can achieve overall economy simultaneously satisfying design criteria as recommend by MORTH for DBM Grade-II.

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