USE OF MARBLE DUST AS FILLERS IN ASPHALT PAVEMENT

Virendra Singh Shekhawat¹, Dr. Bharat Nagar² and Parvez Choudhary³

¹M.Tech Scholar, Jagannath University, Jaipur (Rajasthan) and Junior Engineer PWD Rajasthan
²Head of Department, Civil Engineering, Jagannath University, Jaipur (Rajasthan)
³Site Engineer at Raju Construction Company, B.Tech(Hons), M.Tech Jagannath University Jaipur

Abstract - The purpose of this study is to evaluate the use of Marble dust as filler in Dense Bituminous Macadam (DBM) layers of asphalt pavement. Marble dust is produced as wastes during the shaping and polishing of marble blocks and also during its extraction from mines. During extraction, shaping and polishing process nearly 25-30% raw marble is converted into dust/slurry which is a waste. In this study the use of marble dust /crushed marble, collected during the cutting/polishing process of marble blocks, is used as fillers in DBM layers of Asphalt Pavement has been studied by experimental study. Four mixes were prepared using aggregates of sizes in 20mm,10mm,6mm, stone dust and marble dust as fillers with incremental increase in the bitumen content of +0.5% starting from 4.5% bitumen content. The optimum binder contents were determined by Marshall Stability test procedure, and following graphs were drawn (a) Marshall Stability vs Bitumen content (b) Flow value vs Bitumen Content (c) Bulk Density vs Bitumen Content (c) Voids filled with bitumen(VFB) vs Bitumen (d) Voids in Mineral Aggregates(VMA) vs Bitumen Content (e) Air Void % vs Bitumen Content. The test results of study indicates the effective utilisation of Marble Dust as Fillers in DBM layers of Asphalt Pavement.

Keywords: DBM, Marble Dust as fillers, Marshall Stability , Bulk Density, Air Void %, VMA, VFB, Flow Value and Bitumen Content.

I. INTRODUCTION

Leaving the Marble waste material to the environment directly can cause environmental pollution which may be irreversible and hazardous in nature. Therefore research has been going on in many countries on how to reuse the Marble waste material so that they give fewer hazards to the environment and finds a safe passage for its disposal. A few investigations have been made to study the effect of marble as a filler and aggregate in hot mix asphalt concrete and Pavement Quality Concrete. This experimental study is done to determine the effects of using marble dust as filler in DBM layers of Asphalt Pavement and to determine the optimum bitumen content of mix at 4% filler content.

II. LITERATURE REVIEW

Huseyin Akbulut et al have studied the use of marble waste aggregate in asphalt pavement. In their study they compared the physical properties of all four types of aggregate (A= Recycled Marble Aggregate, B= Andesite Aggregate,C and D are conventional aggregate used in Asphalt pavement in the city of Afyonkarahisar city) i.e their Los Angeles abrasion, aggregate impact value, freezing and thawing, flakiness index and Marshall stability flow tests were carried out on the aggregate specimens. From the results of aggregate and hot mix tests they concluded that waste marble aggregates can be used in light to medium trafficked asphalt pavement binder courses.

Renowned Professor Dr. P S Kandhal in a conference “Mineral Fillers in Bituminous Mixes in India” have told about importance of using mineral fillers in Bituminous mixes. Following conclusion can be drawn from his conference they are as follows:

(a) According to him Marble dust can be used as mineral filler provided that it is used with Anti-Stripping Agent (0.8% by weight of bitumen as per MoRTH Specification) because marble dust has the potential to cause stripping.(b) The mineral filler has a dual role in HMA: (i) it fills the
interstices and provides contact points between larger aggregate particles and (ii) when mixed with bitumen binder it forms a high-consistency binder or mastic which cements larger aggregate particles together. Both of these roles affect the Marshall properties (void parameters and stability) of the bituminous mix. (c) He also said that there is no dividing line in term of size below which the filler become part of the bitumen which affects its viscosity and above which the filler just fills the voids between the larger particles, which is also needed to reduce the VMA to an acceptable level, and what size of particle this happens it is till now not found. (d) The ratio between fillers to bitumen should be in the range of 0.6 to 1.2, provided fillers are material which have 100% passing through 0.075 mm. When the total mineral fillers in the job-mix formula is used within this range of ratio based on the gradation of the available aggregates, it is ensured that there are sufficient fines to stiffen the bitumen and not excessive enough to make the fines/bitumen mortar brittle. (g) Normally, the percentage of the material passing through 0.075 mm sieve in the job-mix formula should be kept within 4 to 6 percent. According to him never use fillers less than 4% so that the mortar contributes adequately to mix rut resistance. The percentage of this material given in the MoRTH specification for DBM and BC should be revised to 3 to 7 percent.

Choudhary Ranjan et al have carried out their study to evaluate the use of marble dust and granite dust in asphalt concrete (bituminous concrete). They carried out Dynamic Shear Rheometer and ring and ball softening point test to evaluate the effect of different percentages of these industrial wastes on properties of asphalt-filler matrix. Marshall stability parameters, permanent deformation from static creep test and Tensile Strength Ratio (TSR) are also evaluated. From the test results they draw following conclusion as follows:

(a) The addition of marble and granite dusts to asphalt concrete can produce properties comparable to the conventional asphalt concrete mixes with stone dust as filler. (b) These fillers can be used up to 7% in asphalt concrete mixes. But it is suggested to use them in the range of 4 to 5.5% initially to observe their performance in field. (c) Rheological tests conducted on filler-asphalt mastic showed highest value of \((G^*/\sin\delta)\) of granite dust indicating high resistance to rutting of this filler. Optimum binder content of a mix reduces with increase in marble dust in the mix. This shows that this filler acts as bitumen extender also. (d) Other results of Marshall tests, creep tests and moisture susceptibility tests also indicate that marble dust and granite dust can be successfully utilized as filler in bituminous construction. Their use in road construction will alleviate the problem of their disposal and environmental pollution.

Sevil Kofteci et al have studied the possibility of using marble wastes as a substitute in place natural/conventional aggregates in hot mix asphalt (HMA) mixture. In their study they made three different mixes consists of mixture of following

C: Control mixture with 100% limestone aggregate
C1: Mixture with 50% limestone fine aggregate + 50% RMA
C2: Mixture with 100% RMA

Marshall stability tests were performed for each prepared samples and optimum bitumen content for three mixtures (C, C1, C2) were determined. From the results of Marshall Stability mix test, it was proved that when 100% RMA were used as a fine aggregate they had the best marshall stability performance when evaluated in terms of marshall stability. This mixture requires minimum bitumen ratio (4.18%) as well. In addition to all of this, it was showed that 100% RMA mixtures have had the best flexibility performance according to marshall flow values. From the test results of all values Marshall test, they concluded that 100% RMA can be used as fine aggregates in hot asphalt mixtures as binder layer.

III. MATERIAL AND METHODOLOGY

The aggregates for this study was brought from hathipura quarry site which is nearby Jaipur and the marble dust which is used as filler in this study is brought from Kishangargh. Following test were carried for study-
Table 1 Physical Properties of Aggregates and Marble Dust

| S. No. | Parameter                                      | Result      | MoRTH Specification       |
|-------|-----------------------------------------------|-------------|---------------------------|
| 1     | Average Impact Value (20 mm)                  | 13.64%      | Max. 27%                  |
| 2     | Elongation and Flakiness Index Combined       | 27.64%      | Max. 30%                  |
| 3     | Los Angeles Abrasion Value                    | 22.43%      | Max. 35%                  |
| 4     | Stripping Value                               | 98%         | Min. 95% Retained Coating |
| 5     | Water Absorption                              |             |                           |
| 6     | 20 mm                                         | 0.56        | Max. 2%                   |
|       | 10 mm                                         | 0.54        |                           |
|       | 6 mm                                          | 0.53        |                           |
|       | Stone Dust                                    | 0.79        |                           |
|       | Marble Dust                                   | 0.90        |                           |
| 7     | Specific Gravity                              |             |                           |
|       | 20 mm                                         | 2.72        |                           |
|       | 10 mm                                         | 2.69        |                           |
|       | 6 mm                                          | 2.69        |                           |
|       | Stone Dust                                    | 2.59        |                           |
|       | Marble Dust                                   | 2.46        |                           |
| 8     | California Bearing Ratio % of Marble Dust     | 13.68%      |                           |
| 9     | Maximum Dry Density of Marble Dust            | 1.82 gm/cc  |                           |

3.1 GRADATION OF MARBLE DUST

Table 2 Gradation of Marble Dust

| IS sieve In mm | Weight of Dust retained | %Weight retained | Cumulative weight retained | % Passing | MoRTH specification |
|----------------|-------------------------|------------------|---------------------------|-----------|---------------------|
| 0.600 mm       | 0                       | 0                | 0                         | 100       | 100                 |
| 0.300 mm       | 56                      | 5.6              | 5.6                       | 94.40     | 95-100              |
| 0.075 mm       | 92                      | 9.20             | 14.80                     | 85.20     | 85-100              |

3.2 COMBINED GRADING OF AGGREGATE, STONE DUST AND FILLERS

The coarse aggregate, fine aggregate and fillers material (marble dust) are proportioned and mixed in such a way that final gradation of the mixture is within the specified range of bituminous mix of MoRTH specification 2013. The gradation of the mix is obtained by trial and error method. The aggregate of nominal size 20 mm 10 mm 6 mm stone dust and fillers are blended in suitable proportions to satisfy the selected gradation the percentage of each type of aggregate depends on the individuals gradation of the grading of individual aggregate.

3.3 COMBINED GRADING FOR MARSHALL TEST

The proportioning of various sizes of aggregates is done by trial and error method from grading of individual of types of aggregates the blend proportion 35%, 30%,20%,15%. The grading of the blend is given below the combined grading along with limits of selected grading is also given below. The combined grading along with limits of selected grading is also given belowwith 4% marble dust

Table 4 Combined Grading with 4% Filler Content

| IS Sieve | Aggregate 20 mm | Aggregate 10mm | Aggregate 6 mm | Stone Dust | Fillers | Combined Grading | MoRTH Specification |
|----------|-----------------|----------------|----------------|------------|---------|------------------|---------------------|

@IJMTER-2017, All rights Reserved 198
IV. PROPERTIES OF BITUMEN VG-30

Table 4 Combined Grading with 4\% Filler Content

| Characteristics                        | VG-30  | Test Results |
|----------------------------------------|--------|--------------|
| Absolute Viscosity at 60\degree C poises, min | 2400   |              |
| Kinematic Viscosity at 135\degree C CST, min | 350    |              |
| Flash Point in 0\degree C              | 220    | 220\degree C |
| Solubility in trichloroethylene % min.  | 99     |              |
| Penetration at 25\degree C             | 50-70  | 69           |
| Softening at C in Min.                 | 47     | 47\degree C  |
| Test on residue from thin film over test/RTFOT |        |              |
| Viscosity ratio at 60\degree C max     | 4      |              |
| Ductility at 25\degree C in cm         | 40     | 39.66 cm     |
| Specific Gravity of Bitumen            | 0.97-1.02 | 1.011       |

4.1 MARSHALL STABILITY TEST

The Marshall stability of the bituminous mix specimen is defined as a maximum load carried in Kg at the standard test temperature of 60\degree C. The flow value is the total deformation of Marshall test specimen at maximum load, expressed in mm units. The Marshall stability of a compacted specimen of bituminous mix indicates its resistance to deform under applied incremental load and the flow value indicates its extent of deformation it undergoes due to loading or its flexibility. The test is
conducted on compacted cylindrical specimens of bituminous mix of diameter 101.6 mm thickness 63.5 mm.

### 4.2 SPECIFIC GRAVITY OF COMPACTED SPECIMEN

#### Table 6 Specific Gravity of Specimen

| Wt. of Sample in air (gm) | 1063.4 |
| Wt. of Sample in Water(gm) | 628.4 |
| Wt. of Sample in SSD condition (gm) | 1064.9 |
| Specific gravity of Sample | 2.436 |
| Wt. of Sample in air (gm) | 1063.4 |
| Specific Gravity of Sample | 2.436 |

### 4.3 MARSHALL STABILITY TEST CALCULATION

#### Table 7 Marshall Stability Test Calculation

| Height of Sample in mm | 58.11 | 56.26 | 55.88 | 57.59 |
| Diameter of Sample in mm | 101.6 | 101.6 | 101.6 | 101.6 |
| Volume of Sample in mm³ | 471.27 | 456.26 | 453.22 | 467.05 |
| Correction Factor | 1.14 | 1.25 | 1.25 | 1.19 |
| Marshall Stability Value @ 60°C in KN | 10.95 | 11.55 | 12.95 | 11.70 |
| Flow value in mm | 2.30 | 2.65 | 3.05 | 3.50 |
| Air Void % | 4.75 | 4.35 | 3.95 | 3.70 |
| Bulk Density in gm/cc | 2.325 | 2.345 | 2.365 | 2.350 |
| Voids filled with Bitumen (VFB) | 67.75 | 69.25 | 71.40 | 72.85 |
| Voids in Mineral Aggregates (VMA) in % | 13.65 | 12.75 | 11.95 | 11.65 |

### 4.5 TEST RESULTS GRAPHS

#### STABILITY VS BITUMEN CONTENT

![Stability vs Bitumen Content Graph](image)
Figure 3 Flow Value (mm) vs Bitumen Content %

Figure 4 Bulk Density vs Bitumen Content

Figure 5 Air Void % vs Bitumen Content %
(i) Marshall Stability vs Bitumen Content

The stability of bituminous mix depends upon ratio by weight of fillers to bitumen, as per MoRTH specification for DBM mix this ratio lies between 0.6 to 1.2. Higher this ratio lesser will be the stability of mix because as the finer particles increases in mix surface area of particles get increased therefore lesser quantity of bitumen is available for coating the surface area of particles. Lower the ratio of filler to bitumen indicates higher quantity bitumen available for coating the surface areas of aggregates and fillers sand it will be bitumen that would fill the interstices voids of aggregates and fillers. Mineral fillers are added by per cent by weight of job mix to fill the internal voids of mineral aggregates which increase the density and prevent the infiltration of rain water, thus not making BT surface prone to stripping. The highest value (12.95 KN) in figure 2 is obtained at 5.5% bitumen content which is indicating the optimum bitumen/binder(OBC) content for this combination of aggregate, stone dust, fillers and bitumen. The stability value remains highest at OBC, the stability values below and above OBC remains lower than at OBC. In case of using conventional fillers the OBC comes out to be generally in the range of 4.5-4.75% bitumen whereas in
this case of using marble dust as filler the OBC comes out to be 5.5% at 4% filler content for which stability value is highest.

(ii) Flow Value vs Bitumen Content

While using the conventional fillers such as lime, cement, stone dust etc. we get similar results in case of flow value rising linearly with bitumen content and as the bitumen content decreases the flow value also decreases. Mineral filler has got great effect on flow value if bituminous mix is designed with fillers then we get high flow value at OBC as compare to when bituminous mix is designed without fillers. The flow value as in this study is achieved highest at 6% bitumen content whose value comes out to be 3.50 mm which well in defined range of MoRTH specification.

(iii) Bulk Density vs Bitumen Content

Highest Bulk density (2.365 gm/cc) is achieved at OBC with fillers, which in this study is achieved at 5.5% bitumen content. At lower bitumen content aggregate surface does not have sufficient bitumen to lubricate the one particle surface over another particle surface which prevent it to attend closer packing and hence density is lower at bitumen content lower than OBC. Whereas at OBC bitumen is just sufficiently available to coat the aggregate surface and provide sufficient lubrication of one particle over another and achieve highest density. At bitumen content greater than OBC bitumen is available in excess which provides greater lubrication than required and hence bulk density decreases at bitumen content greater than OBC.

(iv) Air Void % vs Bitumen Content

Greater the fillers % added to the asphalt mixture generally the lower the air voids but increases the bitumen consumption due to increase in surface area of particles.

In the figure 5 as the bitumen content increases air void % decreases because the voids of aggregates are being filled by bitumen and filler, therefore air void % decreases. Some air voids % are essential in mix so that bitumen coating on aggregate in summers can expand. At high temperature bitumen becomes soft i.e loses its viscosity required some space in mix to become soft. As per MoRTH specification 2013 the Air Void % for Dense bituminous Mix lies in the range of 3-5% and in this study all values corresponding to different filler content lies between 4.75% to 3.70% and hence it is acceptable to use of Marble Dust as filler in DBM.

(v) Voids Filled with Bitumen vs Bitumen Content

Voids filled with bitumen (VFB) are the void spaces that exist between the aggregate particles in the compacted paving DBM mixture that are filled with binder. VFB is expressed as a percentage of the VMA that contains binder. From the Figure 6 it is clear that as the Bitumen content increases VFB increases because as the bitumen content increases at constant filler content in mix there would be greater quantity of bitumen available to fill voids of aggregates particles, hence therefore VFB increases with increase in bitumen content.

(vi) Voids in Mineral Aggregate vs Bitumen Content

Voids in the mineral aggregate (VMA) are the void spaces that exist between the aggregate particles in the compacted paving mixture of DBM including the space filled with the binder. VMA represents the space that is available to accommodate the effective volume of binder (i.e., all of the binder except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the DBM mixture. Voids in mineral aggregates should fulfil the requirement based on the nominal maximum size of aggregate in the selected mix as given below:

| Table 8 VMA as per Nominal Size of Aggregate |
|---------------------------------------------|
| Nominal maximum size of the aggregates in the mix, in mm | Minimum VMA % for the design air voids of 3 to 5 % in the mix |
| 12.5 | 13-15 |
| 19.0 | 12-14 |
From the figure 7 it is clear that as the bitumen content increases VMA decreases within the specified limits of MoRTH specification.

VI. CONCLUSION

- The marble dust as fillers material can be effectively used in DBM layer of Asphalt Pavement.
- Marble Slurry/Dust can be effectively utilised and safe to dispose in environment.
- OBC at 4% filler content is 5.5% for which density and stability values are highest.
- Conventional Mineral Fillers (Lime Powder) is available in market at Rs. 5 per kg in market whereas marble dust is a waste it is available for free of cost.
- The use of Marble Dust as mineral filler would consume more bitumen and bitumen is the most costly (Rs. 50 per kg) constituents of asphalt pavements and therefore in 100 kg of mix we have to spend (Rs. 50-5=45) extra for bitumen.
- The use of marble dust in big infrastructure projects (Multilane National Highways Construction) would zooms the cost of projects.
- Choice has to be made between economic of road construction material (bitumen) and environmental pollution (caused by Marble Dust) which is irreversible and hazardous in nature.

REFERENCES

[1] Huseyin Akbulut and Cahit Gurer (2006) “Use of Aggregates produced from Marble Quarry Waste in Asphalt Pavement” Science Direct (Elsevier) Building and Environment 42 (2007) Pages 1921–1930
[2] Dr. P S Kandhal and Rajib Chattaraj (2013) “Mineral Fillers in Bituminous Mixes in India”, Pages 1-13.
[3] Ranjan Choudhary and Satish Chandra “Granite and Marble Dust as Fillers in Asphalt Pavement” Reference number 160, Pages 1-12
[4] Sevil Kofteci, Niyazi Ugur Kockal “Using Marble Wastes as Fine Aggregate in Hot Mix Asphalt Production” Proc. of the Intl. Conf. on Advances In Civil, Structural And Construction Engineering - CSCE 2014. Copyright © Institute of Research Engineers and Doctors. All rights reserved. ISBN: 978-1-63248-020-0 doi: 10.15224/978-1-63248-020-0-34 Pages 117-121
[5] S Khedr , A EI-Desouky , N Nagy and A Abbas (2010) “Use of Marbles in Asphalt Mixtures” Eighth International Conference On Civil and Architecture Engineering & Military Technical College Korby El-Kobbah, Cairo, Egypt, Pages 1-12
[6] Dr. Adil N Abed and Sadoon O Eyada “The Use of Sulaimania Marbles Waste to Improve the Properties of Hot Mix Asphalt Concrete” Anbar Journal for Engineering Sciences Pages 139-151
[7] Tom V Mathews and K V Krishna Rao (2007) Introduction to Transportation Engineering Chapter 26 “Marshall Mix Design” NPTEL Pages 26.1-26.7
[8] Tom V Mathews and K V Krishna Rao (2007) Introduction to Transportation Engineering Chapter 23 “Pavement Material: Bitumen” NPTEL Pages 23.1-26.8
[9] S K Khanna & C E Justo Ninth Edition (2010) “Highway material and Pavement Testing” Chapters 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 23.
[10] S K Khanna & C E Justo Ninth Edition (2010) “Highway Engineering” Chapter 6, Pages 268-329
[11] Specifications for Road and Bridge Works by Ministry of Road Transportation & Highway Fifth Edition November 2014 Published by Indian Road Congress, New Delhi.
[12] IRC-94(1986) Specification for Dense Bituminous Macadam, clause 4.2.4, Page 4,5.