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LABORATORY INVESTIGATIONS ON MARBLE SLURRY AS A FILLER IN DENSE BITUMINOUS MACADAM GRADE- I

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***Abstract*— This Bituminous mixes are used in a flexible pavement to serve structural strength, sub-surface drainage, surface friction etc. Bituminous mixes classified based on nature of their gradation dense graded, semi-dense graded, open graded, gap graded etc. Dense graded bituminous mixes are most commonly used in bituminous pavements as binder course. Bituminous mixes consist of coarse aggregates, fine aggregates, filler and binder blended as per Marshall Mix Design. As natural materials used for highway construction being exhaustible in nature and their quantity is declining gradually that must be taken care of therefore present study investigate the suitability of marble slurry as filler with conventional stone dust.**

Marble processing unit produce marble slurry during processing of large size block into flat small size slab. This Slurry is a suspension of marble fines in water, generated during processing, polishing etc. This slurry is no longer use in industry and left in low laying area, in open fields, pits or anywhere else. In rainy season marble slurry infiltrate into pores of soil with water which results into reduction in porosity of soil and increases alkinity of soil. Fine marble dust suspends in the air and is slowly spread out through winds to the nearby area. It settles down on crops and vegetation, thus severely threatening the ecology of the marble clusters. It causes respiratory ailments in the nearby residential areas. When dumped along the catchment area of natural rain water, it results in contamination of over ground water reservoirs and also causes drainage problem.

So the present study incorporates, use of marble slurry in dense bitumen macadam (DBM) grade I layer with stone dust. DBM Gr-I layer properties can be improved with the incorporation of waste marble slurry. An experimental program was conducted to evaluate Marshall Mix properties with marble slurry by using binder VG-40. Marshall Method was adopted to find OBC with conventional stone dust. Samples were prepared and tested to check whether they meet the Marshall mix parameter. Aggregate gradation has been taken as per MORTH specification for DBM Grade-I. Three test specimens were prepared at each bitumen content. In first set, OBC for xi

Conventional bituminous concrete mix was found among varied binder content from 4%, 4.50%, 5.00%, 5.50% and 6.00% by wet of dry mix. In second set, marble slurry blended from 2.00%, 3.00%, 4.00%, 5.00% and 6.00% with stone dust at determined OBC. At each marble content three specimen were prepared and tested. Properties of marble slurry bitumen binder compared with MORTH specification. It is found that stability increases up to 4% marble content and then start decrease up to 6.00% at marble content. Flow value continuously increases from 2.20 mm at 2% marble content to 3.30mm at 6% marble content. Bulk density increases from 2.612 gm/cc at marble content 2% to 2.671gm/cc at 6% marble content. Percentage air voids continuously decreases from 4.96% at 2% marble slurry to 4.07% at 6% marble content. Voids in mineral aggregates (VMA) continuously reduce from 14.366% at 2% marble content to 13.541% at 6.00% marble content. Voids filled with bitumen (VFB) continuously reduce from 69.50% at 2% marble content to 66.50% at 6% marble content.

***Keywords*— Dense Bituminous Macadam, Voids filled with bitumen (VFB), Voids in mineral aggregates (VMA),**

I. INTRODUCTION

Transportation is considered one of the most significant elements of transport infrastructure and it plays an important role in our daily life. Transportation contributes to the social, economic, industrial and cultural development of any country. There are different modes of transport likewise NH, SH, MDR, ODR, VR etc. Indian road network is around 47 Lacs Km which is second largest in world & 0.66 km of highway per square kilo meter of the land density of India's highway network is higher than that of the America (0.65).

As a part of the highway, the pavement is consisting of different superimposed pavement layers of sub-grade, sub-base, base-course, wearing course etc. that primary function is to distribute the load from the upper layer to the lower layer. The pavement should be able to withstand higher impact load of the vehicle and another type of load on roadways. It should also enough strength, durable, riding quality, adequate skid resistance, light reflecting characteristics, low noise pollution etc. So each pavement layer is its own importance for highway section and its design matters to a great extent. Therefore, the overall functioning of the highway system greatly depends upon on performance of its pavement layers. In India, roadways pavements are constructed generally type of flexible and rigid pavement. Flexible pavement is

commonly constructed for highways or another type of road in India & somewhere rigid pavements are also constructed. Various studies have been done to enhance pavement properties. Due to increasing traffic Load, distress such as rutting and cracking of pavements are very common in Indian roads. Under periodic temperature variation flexible pavement tend to become soft in summer and brittle in winter. In India almost 90 percent road network is occupied by bituminous pavement only which are constructed by using naturally available road aggregates & bitumen.

2. Literature Review

HuseyinAkbulut et al. (2006)[1] had 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 in binder courses.

Kandhal and Chattaraj (2013)[2] assesed that conference "Mineral Fillers in Bituminous Mixes in India have told about the importance of using mineral fillers in Bituminous mixes. .

Choudhary and Chandra (2014)[3] had 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 the asphalt-filler matrix. Marshall stability parameters, permanent deformation from static creep test and Tensile Strength Ratio (TSR) are also evaluated

Zulkati et al. (2012) [5] worked on the influence of mineral filler on mechanical properties HMA. An experimental program was conducted to determine the impact of fillers on tensile characteristics of HMA using indirect tensile strength test. Laboratory investigation indicated that performance of HMA is considerably affected by the use of mineral fillers because of its affinity property for the binder. Use of filler controls the compaction of mixes and moreover bitumen-filler mastic provides thick asphalt films around aggregates particles which increase resistance against weathering and moisture induced damages.

R. Muniandy et al. (2013) [6] had evaluated the influence of nature and size of dust on binder and filler mastic laboratory measured properties. Use of filler with a binder in asphalt concrete develops thicker asphalt films around aggregate particles that increase resistance against permanent deformations in HMA concrete. Size of filler passing sieve No.200 has a greater influence on HMA properties. AASHTO suggests at least 70% passing by weight through sieve No 200. Laboratory results revealed that filler passing 100% through sieve No. 200 improves the marshal design properties of asphalt mixes.

3. Materials and Testing

Selection of gradation of aggregates plays an important role in preparation of Job Mix Formula for Bituminous mixes. In this research work, we have selected marble slurry as a filler in dense bituminous macadam GRADE-I

3.1 Preliminary Characteristics of Materials

The material properties used during the laboratory testing such as aggregates and bitumen also compare with MORTH standard. It illustrates how experimental work has been done to achieve the objectives of the research.

3.1.1 Aggregates Result.

Aggregates are principal material in the pavement which enables pavement to bind with bitumen and make a composite mass that can withstand with traffic load. Aggregates have to withstand the load of the upper layer and transmit it to ground, from successive layers. The top layer of pavement has to resist wear due to abrasion action of traffic. The aggregate of different nominal sizes used in different layers of pavement as per gradation of that particular layer as per MORTH specification. Results of Aggregates are given in Table 1.

Table .1:Physical Properties of aggregate

S.No.	Property	Name of Test	Test Result Obtained	Specific Limit	Method of Test
1	Strength	Aggregate Impact Value Test	8.70	Max. 27%	IS: 2386 (Part IV)
		Los angeles abrasion test	11.08	Max. 35%	IS: 2386 (Part IV)
		Crushing Value Test	17.40	Max. 45%	IS: 2386 (Part IV)
2	Particle Shape	FI+EI	15.46	Max.35%	IS:2386 (Part I)
3	Specific Gravity	Specific Gravity	2.945		IS:2386 Part III
4	Water Absorption	Water Absorption Test	0.651	Max. 2%	IS:2386 Part III

3.1.1 Bitumen Result.
Bitumen (VG-40) was used in the design. The bitumen was tested for its physical properties (as per relevant IS code specifications) to check its suitability for use in the preparation of mix samples. The various tests result is given in Table 2.

Table 2. Physical Properties of Bitumen

S. No.	Type of test	Test results	Specifications as per IS 73-2013	Test method
1	Penetration Test	43	Min. 35	IS: 1203
2	Ductility test	90cm	Min. 25cm	IS: 1208
3	Softening Point test	56.5^0 C	Min. 50^0C	IS: 1205

3.2. MARSHALL MIX DESIGN
Mix design method provides combined gradation of aggregates to get volumetric properties of mixtures for a selected type of binder. Mixes are designed according to specifications of MORTH.

3.2.1Combined Gradation of Aggregates
DBM GARDE -I aggregate and fillers were graded by sieve analysis method. The gradations on basis of varying percentages of filler (2.00%,3%,4%,5% and 6%)with 2% stone dust and 19mm maximum aggregate size were designed from mean percent passing. Summary of combined gradation of aggregates is given in Table 3.

Table No.3 Combined Gradation of the Sample Taken

IS Sieve (mm)	Combined gradation for Dense Bituminous MacaddamGr-1															
	% passing of individual aggregate.						Mix proportion of aggregate						% passing	Sp. limit as per MORTH 500-10		
	37.5-22	22-16	16-12	12-6	6-0	Filler	37.5-22	22-16	16-12	12-6	6-0	Filler		Mid Value	Lower	Upper
							18%	15 %	8%	17%	40%	2%				
45	100	100	100	100	100	100	18	15	8	17	40	2	100	100	100	100
37.5	95.5	100	100	100	100	100	17.19	15	8	17	40	2	99.19	97.5	95	100
26.5	18.61	100	100	100	100	100	3.35	15	8	17	40	2	85.35	78	63	93
13.2	0.15	2.74	68.58	99.88	100	100	0.027	0.411	5.49	16.98	40	2	64.90	65	55	75
4.75	0	0.42	0.16	10.42	91.51	100	0	0.063	0.01	1.77	36.6	2	40.45	46	38	54
2.36	0	0	0	7.59	71.9	100	0	0	0	1.29	28.7	2	32.05	35	28	42
0.3	0	0	0	1.93	15.8	100	0	0	0	0.33	6.32	2	8.65	14	7	21
0.075	0	0	0	1.09	5.14	75.38	0	0	0	0.19	2.06	1.51	3.75	5	2	8

Table 4. Marble Slurry Gradation

Weight of marble slurry taken =1000gm					
IS sieve in (mm)	Weight of dust retained	% Weight retained	Cumulative weight retained	% Passing	MORTH Specification Table 500-9
0.600mm	0	0	0	100	100
0.300mm	56	5.6	5.6	94.40	95-100
0.075mm	92	9.20	14.80	85.20	85-100

3.2.2. Marshall Method of Mix Design

For investigating the properties of asphalt conventional mix & suitability of using marble waste in asphalt mixtures, an extensive experimental work was conducted. After evaluating the properties of used materials like bitumen, aggregates, and waste marble, carrying out sieve analysis for waste marble and each aggregate type, blending of aggregate carried out to obtain the binder course gradation curve which used in the preparation of the asphalt mix. After that, with different bitumen contents asphalt mixes are prepared to obtain optimum bitumen content by Marshall test. Then optimum bitumen content is used to prepare asphalt mixes with various percentages of marble waste crushed

3.2.3. Optimum Binder Content (OBC) for Conventional Mix with Stone Dust:

Optimum binder content is found out by taking the average value of bitumen content w.r.t. following Marshall parameter:

- Bitumen content corresponds to maximum stability is 5.00%
- Bitumen content corresponds to maximum unit weight 5.00%
- Bitumen content corresponding to the median of designed limits of percentage air voids (4.00%) in total mix w.r.t. to bitumen content is 4.50%

The optimum binder content was found Average of (5+5+4.50)/3 = 4.83% Say 4.80%

3.2.4 Marshall Mix with Marble Slurry at Different (%):

To determine the properties of Asphalt mix we will evaluate Marshall mould properties at differentmarble percentage (2.00%,3%,4%,5% and 6%) with 2% stone dust at determined optimum binder content(OBC) 4.80% (by weight of total aggregate) and will see how different marble percentage affect the Marshall mould properties. At each percentage of marble content, we will prepare three moulds and for all fifteen moulds. The weight of each mould will be 4500gm as per MS-2 for large size aggregate.

3.2.5 Optimum Binder Content (OBC) with Marble Slurry:

A number of laboratory investigations were performed in order to determine the mix properties of asphalt mix with marble slurry. Mixtures are prepared with the optimum binder content 4.80% with stone dust constant (2%) and marble slurry 2%, 3%, 4%, 5% &6% respectively. Optimum marble content is the percentage of marble where all mechanical properties of marble-asphalt mx satisfy or within the limit as per MORTH 2013 5th revision specification.

Table.5. Summarizes the Properties of Asphalt Mix with Different Marble Slurry Content

Property	Marble content (%)				
	2.00%	3.00%	4.00%	5.00%	6.00%
Stability (kN)	25.31	26.57	28.24	26.05	25.34
Flow(mm)	2.20	2.35	2.60	2.90	3.30
Bulk density (gm/cc^3)	2.612	2.623	2.638	2.654	2.671
% Air voids in Mix	4.96	4.73	4.51	4.32	4.07
VMA (%)	14.37	14.14	13.94	13.77	13.54
VFB (%)	69.50	68.85	67.90	67.10	66.50

4.Results and Discussions

4.1. Marshall Stability – Marble Content Relationship

It's noticed that all values of stability with different marble content achieve the specification requirements as per MORTH for DBM Gr-1 i.e. 9.00KN. In the below graph where the dash line represents the minimum value of stability requirement. The figure shows that the stability of marble-asphalt mixes increase as the Marble content increases till it reaches the maximum stability at 4.0% marble content then it starts to decline after 4% marble content.

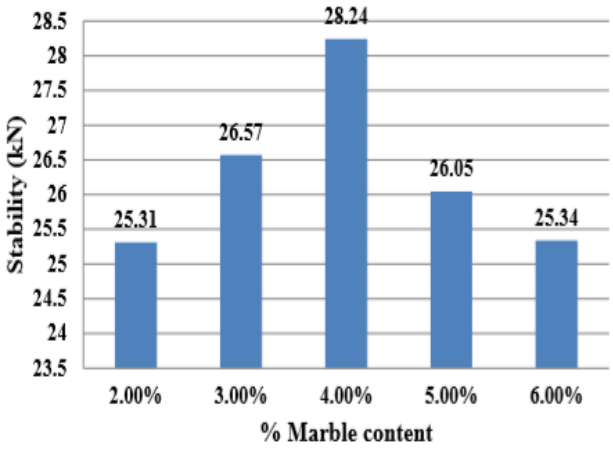

Figure .1. Variation of stability vs marble content

4.2. Flow –Marble Content Relationship

The flow of marble asphalt mix start increases continuously in increasing order as the marble % increase from 2% to 6% and at 4% marble content it is 2.60mm which is within the limit of 2-4mm and median flow value.

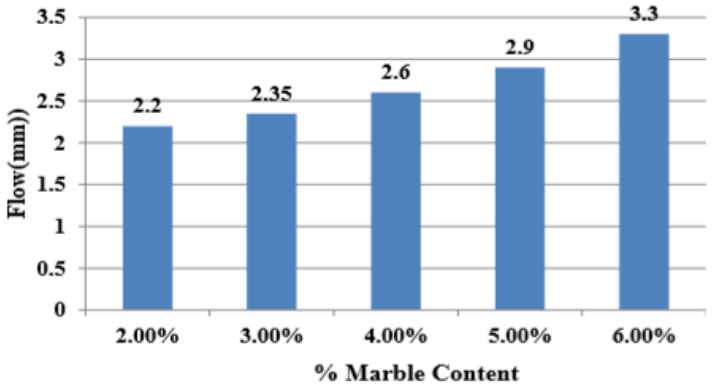

Figure 2. Variation of flow vs marble content

4.3 Bulk Density – Marble Content Relationship

The bulk density of Marble-asphalt mixes with the different percentages of marble content continuously increase from 2.612 to 2.671 achieves maximum bulk density at 6% which is 2.671 g/cm3. The general trend shows that the bulk density increases as the marble content increases.

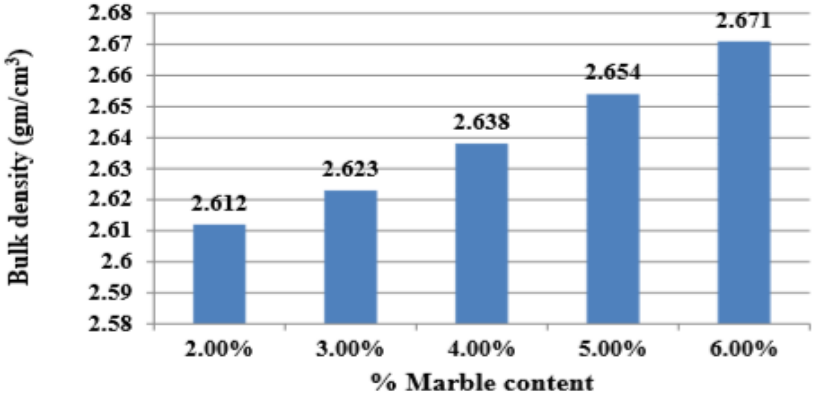

Figure 3. Variation of bulk density vs marble content

4.4 Air Voids (Va) – Marble Content Relationship

The air voids of marble-asphalt mix continuously decrease gradually as the marble content increases. At 6 % marble content it is 4.07 % which is desired medium air voids (3-5%).

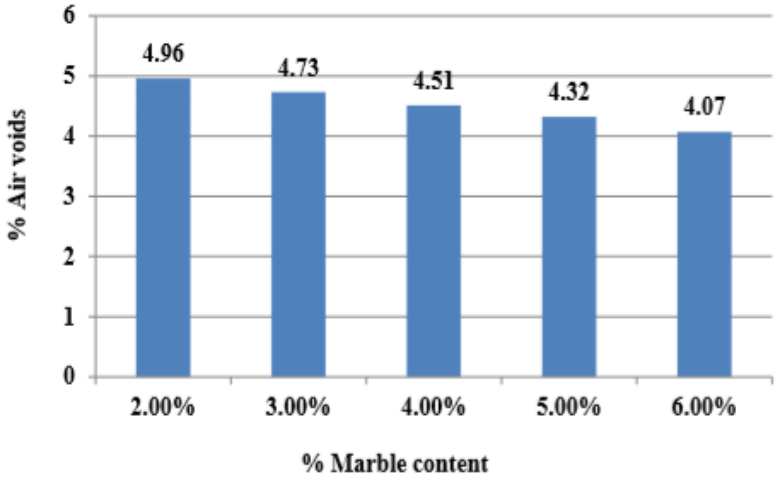

Figure 4.Variation of % Air Voids vs Marble Content

4.5 Voids in Mineral Aggregate (VMA)-Marble Content Relationship

From Figure (5) it's noticed that the VMA decrease gradually as marble content increases as the increased marble reduces the voids in mineral aggregate. At 6% it is 13.541% which is desired median (13-15%) value of VMA.

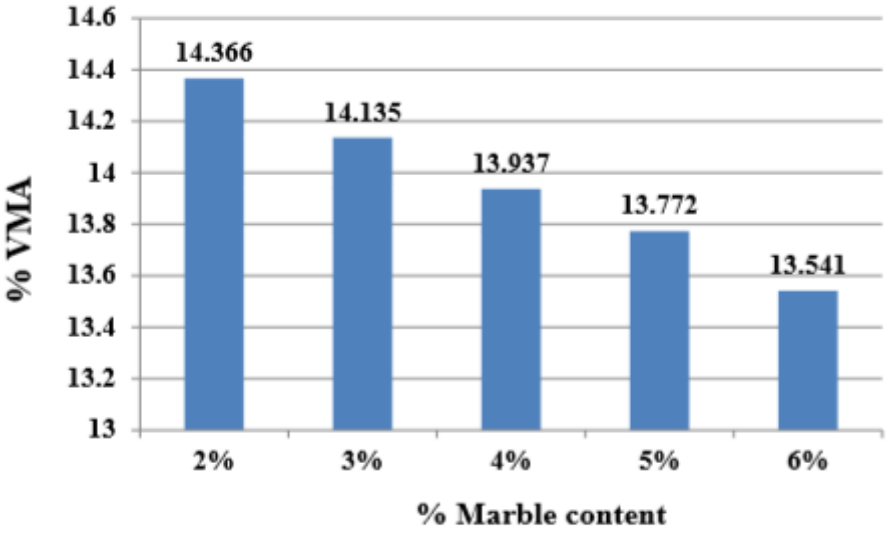

Figure 5. Variation of Voids in Mineral Bitumen (VMA %) vs Marble Content

4.6 Voids filled with Bitumen (VFB) vs Marble Content Relationship

Voids filled with bitumen continuously increases as the percentage of marble content increases and at 6% it is 69.97 % which is the median of 65-75% as specified in MORTH.

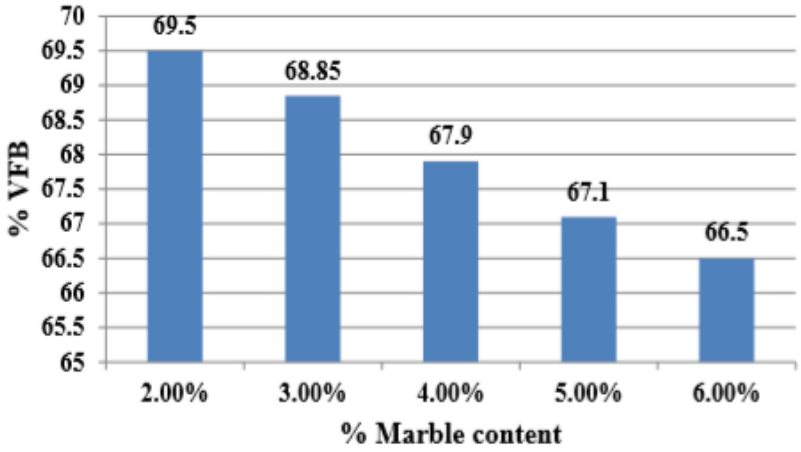

Figure 6. Variation of % Voids filled with Bitumen (VFB) vs Marble Content

5.Conclusions:

The objective of this study is to investigate the effect of using waste marble slurry as filler material with stone dust in the asphalt mix, where the results can be concluded as the following:

The use of waste marble slurry in the asphalt mix can be utilized as a sustainable disposal of the slurry as it is the same property as stone dust i.e. non plastic and passes through 0.075mm sieve. The results of marble-asphalt mix found maximum marshall stability Ii.e. 28.24KN is at 4% marble content.

The results of marble-asphalt mix found medium flow i.e. 2.90mm at 5% marble slurry content The results of marble-asphalt mix found satisfactory at 6% marble slurry content which results maximum bulk density i.e. 2.671gm/cm3, medium percentage of air voids (Va) 4.07%, medium percentage of voids in mineral aggregate (VMA) 13.541% Maximum percentage voids filled with bitumen (VFB) i.e. 69.50% is found at 2% marble content.

Investigation shows that the marble slurry can be used as a filler in DBM Grade-I within 2-6%. Further studies are needed using various marble slurry gradation and at different percentages. More studies are needed to study the effect of waste slurry in GSB, base course Gr-I & II and wearing course layers of asphalt pavement.

The investigation can also be done as similar waste fine dust that has similar properties like stone i.e. gradation and non-plastic.

6.Future Scope:

The above study has some suggestions as the future scope of this work:
Further studies are needed using various marble slurry gradation at different percentages of marble content. More studies are needed to study the effect of marble slurry in granular sub base, base course and wearing course layers of asphalt pavement. Investigate the effects of using marble slurry incorporate with other waste material such as granite slurry or sand stone slurry on the asphalt pavement properties. It's recommended to encourage the field application and evaluation to find out the performance of hot mix asphalt containing waste materials as filler.

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