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Influence of Marble Dust Filler on Marshal Properties of Hot Mix Asphalt

Mohsin Raza[1], Dr Rawid Khan[2]
[1, 2]University of Engineering and Technology Peshawar Pakistan

***Abstract:** Literature review reveals that mineral fillers play a vital role in altering the properties of asphalt concrete. Despite filler being a small part of asphalt, has a predominant effect on the performance characteristics of asphalt concrete. Millions tons of marble waste is being generated by marble processing industries, leading to environmental pollution and loss of valuable land. Developed countries have strict policies for waste disposal whereas in developing countries there are almost no policies. Hence, in this research, an effort has been made to evaluate the influence of marble dust on the strength properties and permanent deformation resistance of asphalt concrete. For this purpose optimum binder content has been determined by using 5.5% conventional limestone dust filler and after determination of optimum binder content, stone dust has been replaced with marble dust in increments of twenty five percent (i.e 0%, 25%, 50%, 75%, 100%). The results of the tests performed on marble dust modified asphalt revealed that marble dust modified asphalt containing 50% marble dust have shown improvement in Marshal Stability and Flow values. Incorporation of marble dust up to 25% and 50% has resulted in better volumetric properties in comparison with stone dust made mixes. Keeping in view the improvement in properties of asphalt concrete in connection with marble dust, the utilization of freely available marble dust in asphalt concrete will have a marked impact in reducing the cost of asphalt concrete as well as minimizing the environmental problems due to disposal of waste marble dust.*
***Keywords:** Asphalt Concrete, Marble Dust, Limestone dust, Marshal Stability and Flow*

I. INTRODUCTION

God has bestowed Pakistan with huge deposits of dimensional stones such as marble and Onyx. According to an estimate Pakistan has 297 billion tons of extractable deposits. Pakistan's annual production of dimensional stones is about 3.82 million tons [1]. During marble cutting and processing operations almost 30 percent of stone is converted to scrap on account of smaller size or irregular shape. In addition to solid waste, marble slurry containing marble power is also produced during cutting and processing operation. Marble slurry is reused time and again till it becomes sufficiently thick, getting insoluble for additional marble powder [2]. Marble cutting and processing industries usually dumped their wastes in lands near marble factories, resulting in problems such as loss of valuable land, contamination of ground water and reduction in permeability and porosity of soil ultimately causing water logging of soil. Developed countries have strict policy for waste disposal, whereas developing countries like Pakistan have almost no policy to protect environment against problems caused by disposal of solid and liquid wastes. In addition to above several problems are being faced by pavement industry like continuously increasing axle load and traffic density. With the passage of time these problems are getting more and more complicated. Therefore, it is the need of the hour to search for new and improved construction equipment's, practices and materials.

Mineral Fillers are incorporated in asphalt for filling the voids spaces between aggregate. Mineral filler severs dual purposes within the asphalt mixture. Part of the mineral filler finer than asphalt film thickness blend with bitumen, form mastic and ultimately contributes to enhanced stiffness of asphalt concrete. Particles with size greater than asphalt film thickness serves as aggregate and contribute to contact point [3]. Several chemical and physical factors of filler including surface area, specific gravity etc influences the performance characteristics of asphalt. Affifa et al., evaluated the effect of few conventional and non-conventional fillers on Marshal Properties of hot mix asphalt. Stone dust and cement dust were used as conventional fillers whereas brick dust was used as non-conventional filler. Asphalt prepared by using brick dust had almost same Marshal Properties as conventional. Additionally, it can provide environment friendly, economical and long lasting pavement [4]. Ariyo et al., used broken tiles, broken bricks, cow bones ash and broken glass as filler for light, medium and heavy traffic roads in asphalt concrete. Samples prepared by using broken glass as filler have shown improvement in marshal stability [5].

Similarly broken tiles, broken bricks, cow bones ash, broken glass, fly ash, black rice husk ash, ground granulated blast furnace slag, hydrated lime, waste welded tuff material, glass powder, marble, granite, ceramic waste dust, steel slag mixture were used by researches as a replacement of conventional filler.

The results of the tests performed on asphalt concrete revealed that waste matter used as fillers greatly influence the marshal properties of asphalt concrete. Hence in this research an attempt has been made to utilize marble dust as a replacement of conventional stone dust filler in wearing course and determine its effect on the marshal properties of asphalt concrete.

II. MATERIALS

A. Aggregate

Aggregate is considered as structural skeleton of asphalt concrete. Mineral aggregate including coarse & fine particles and filler in asphalt concrete comprise approximately 90% of asphalt concrete volume. Therefore the characteristics of aggregate directly affect the performance of asphalt pavements [6]. In this research National Highway Authority class B aggregate gradation has been selected. In order to check the gradation of collected aggregates, aggregates were sieved through sieve sizes specified by National Highway Authority specification. The physical properties of aggregates are presented in table 1.

Table 1: Physical Properties of Aggregate

Test Description	Standard Used	Test Results (%)	Permissible Range
LA Abrasion Test	ASTM C131 AASHTO T 96	22.52	Less than 40%
Aggregates Absorption Test	AASHTO T 85	1.154	Less than 2%
Flakiness & Elongation Test	ASTM D 4791	5.13, 4.95	Less than 15%

B. Bitumen

For preparation of Marshal Samples, 60-70 penetration bitumen is used. The properties of bitumen are listed in table 2.

Table 2: Physical properties of Bitumen

Description	Unit	Test Standard	Results	Permissible Range
Penetration Grade	1/10 mm	AASHTO T 49 ASTM D5	64.5	-
Flash Point & Fire Point	^0C	AASHTO T48	271 & 284	-
Softening Point	^0C	AASHTO T53 ASTM D 36	50.25	-
Specific gravity	-	AASHTO T 228 ASTM D 70	1.03	1.01-1.06

C. Mineral Filler

Marble dust filler used in this research has been obtained from marble factories located in Peshawar. The test performed on fillers is illustrated in table 3.

Table 3: Physical Properties of Filler

Test Description	Standard Used	Test Results (%)	Permissible Range
Liquid limit & Plasticity Index	AASHTO T -89/90	Marble Dust Non Plastic	-

III. METHOD

Asphalt samples were prepared in accordance with guidelines of Asphalt Institute which are in line with AASHTO T-245 and ASTM D6926 & D6927. According to the selected aggregate gradation, fifteen samples were prepared by using conventional stone dust filler and five bitumen contents (3.5% to 5.5 %). These samples were tested for Marshal Stability & Flow Tests and Density and void analysis for determining the amount of optimum asphalt content. After determining the optimum binder content, fifteen more samples were prepared by replacing stone dust filler with marble dust filler in increments of 25% from zero to hundred percent i.e. 0%, 25%, 50%, 75%, and 100%). The marble dust modified samples were again tested for Marshal Stability & Flow Tests and Density and void analysis

A. *Combined Aggregate Gradation*

In this research National Highway Authority Class B aggregate gradation has been used. Sieve analysis has been performed on aggregate and filler material. On the basis of single filler content, aggregate gradation with maximum nominal aggregate size of 19mm has been obtained. Two types of filler material i.e stone dust and marble dust has been used in this study. Summary of the combined aggregate gradation used in this research is presented in table 4.

Table 4: Summary of Selected Aggregate Gradation

Sieve Designation		Blended Gradation of Wearing Course for NHA Class-B Aggregates	
Inches	mm	Blend	NHA Specifications Class B
1	25	100	100
¾	19.5	100	100
½	12.5	79.6	75-90
3/8	9.5	66.7	60-80
No.4	4.75	49.1	40-60
No.8	2.38	29	20-40
No.50	1.18	10.4	5-15
No.200	0.075	5.5	3-8

B. *Marshal Mix Design*

Marshal Mix Design method has been used for design of asphalt concrete as per Asphalt Institute guidelines which are in line with AASHTO T-245 and ASTM D6926 & D6927. Standard size cylindrical test specimens of height 2.5 inches (63.5mm) and of diameter 4 inch (101.6 mm) has been prepared in accordance with test procedures prescribed by AASHTO T245, ASTM D6926 and NHA General Specification, 1998.

C. *Marshal Stability and Flow Test (AASHTO T245)*

Marshal Stability and Flow tests were performed on conventional as well as marble dust modified asphalt samples. The results of these tests are presented in both tabular and graphical form in tables and figures. From the table 5 and figures 1 & 2, it can be seen that Marshal Stability values for 50% marble dust (MD) modified samples are higher than the control samples whereas the rest of the samples have shown lower values of marshal stability as compared to control samples, but all the values of stability are within the Asphalt Institute specified limits. Flow values for 50% marble dust modified samples are almost the same as for conventional samples whereas the rest of samples have shown higher values of flow, but flow values for all samples are well within the permissible range. Increase in percentage of marble dust to some extent i.e 50 %, results in increase in viscosity of bitumen which ultimately lead to an increase in Marshal Stability of MD modified asphalt.

Table 5: Marshal Stability and Flow Tests Results for MD Modified Asphalt

Sr.No	Mix Types	Stability (Kg)	Flow (mm)
1	Control	1256	9.03
2	25%	1131	9.40
3	50%	1267	9.10
4	75%	1163	9.33
5	100%	1115	9.60

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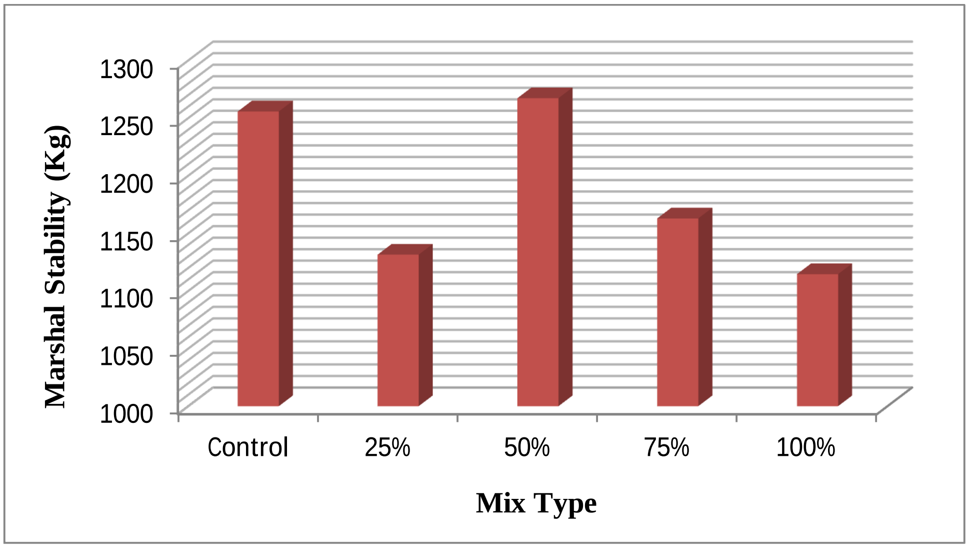

Figure 1: Influence of MD on Marshal Stability of Asphalt Concrete

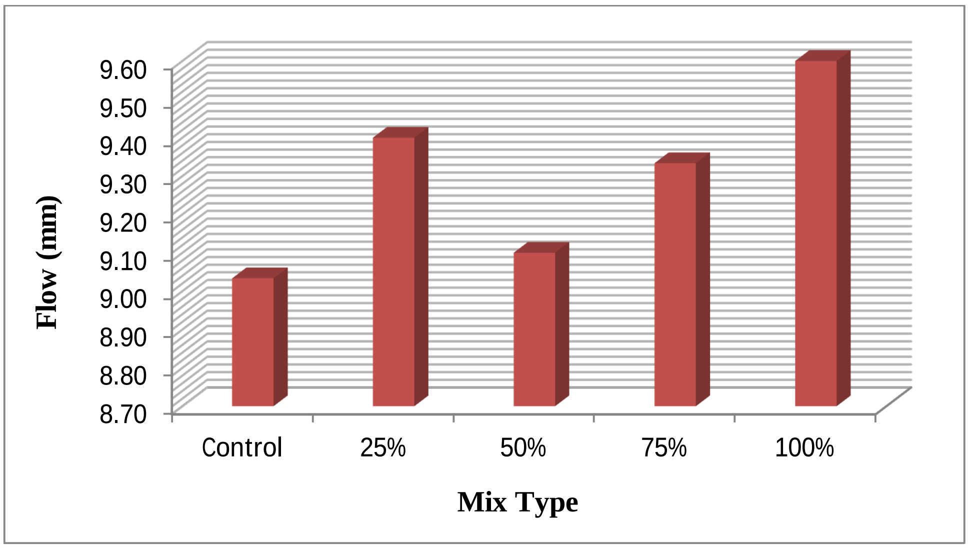

Figure 2: Influence of MD on Marshal Flow of Asphalt Concrete

D. Effect of Marble Dust on Bulk Specific Gravity (G_{mb}) of Asphalt Concrete

The values of G_{mb} for MD modified samples have been shown in table 6 and Figure 3. It can be observed that the value of G_{mb} for 25% MD modified asphalt is almost the same as for control mix whereas for 75% and 100% MD modified asphalt the values of G_{mb} are lower than control mix. Furthermore, 50% modified asphalt samples have shown higher values of G_{mb} as compared to controlled sample. This is due to the fact the Percent Air Voids and VMA for 50% MD modified samples is the least among all, which indicate better aggregate interlocking and hence increased value of bulk specific gravity.

Table 6: Bulk Specific Gravity Test Results for MD Modified Asphalt

Sr.No	Mix Type	G_{mb}
1	Control	2.364
2	25%	2.363
3	50%	2.371
4	75%	2.360
5	100%	2.356

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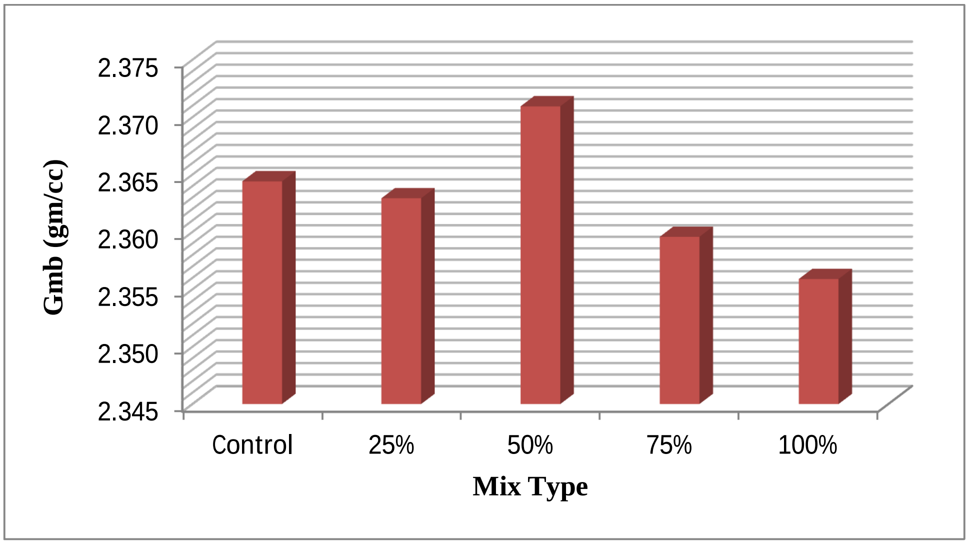

Figure 3: Influence of MD on Bulk Specific Gravity of Asphalt Concrete

E. Effect of Marble Dust on Percent Air Voids (Pa) of Asphalt Concrete

Table 7 and figure 4 illustrate that 50% MD replacement has resulted in lowest percent air voids whereas for 25% MD modified mix the percent air voids are almost the same as for control mix. For 75% and 100 MD modified asphalt percent air voids are higher than control mix but are within the range (i-e. 3-5%) as specified by asphalt institute. Marble dust particles are finer than limestone dust particles and resultantly the void spaces between aggregate are closely filled to some extent (in this case 50%) which result in low air voids. Upon Further increase in percentage of marble dust the aggregates are pushed apart which cause reduction in aggregate to aggregate contact, hence less cohesion and ultimately increase in air voids.

Table 7: Percent Air Voids Results for MD Modified Asphalt

Sr.No	Mix Type	Bitumen Content (%)	G_{mm}	G_{mb}	P_a (%)
1	Control	4.59	2.465	2.364	4.06
2	25%	4.59	2.464	2.363	4.10
3	50%	4.59	2.467	2.371	3.91
4	75%	4.59	2.470	2.360	4.46
5	100%	4.59	2.468	2.356	4.54

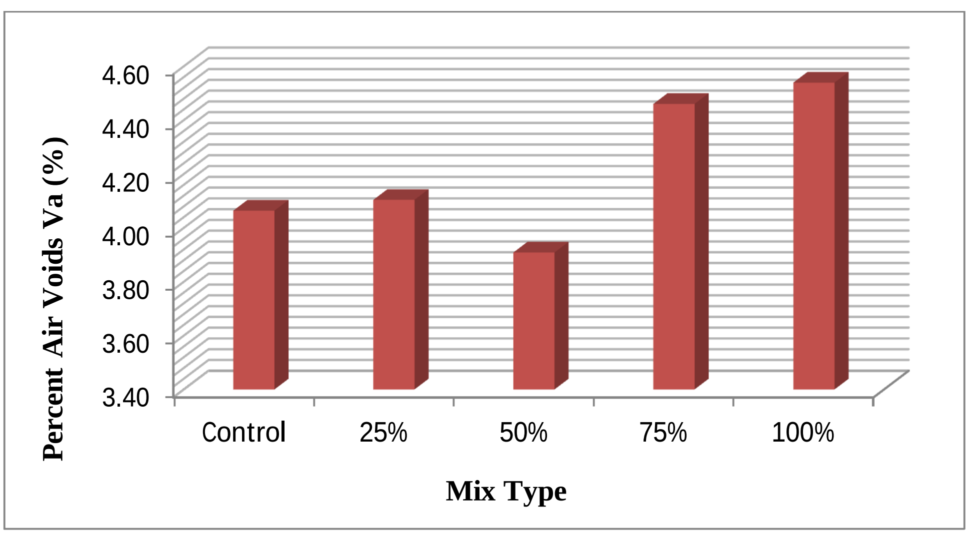

Figure 4: Influence of MD on Percent Air Voids of Asphalt Concrete

F. Effect of Marble Dust on VMA of Asphalt Concrete

Since VMA, VFA and percent air voids are interrelated, the results of VMA for MD modified follow the same trend as percent air voids. The results of VMA for MD modified asphalt are presented in table 8 and figure 5. Value of VMA is least for 50% MD modified Asphalt whereas for 25% MD modified asphalt the values are almost the same as for control specimen. Samples prepared by the rest of percentages of marble dust have shown high values of VMA as compared to control sample. VMA is comprised of volume of air voids and effective asphalt content. A possible reason for low VMA in case of 50% MD modified asphalt is that marble dust due to its fine size (high surface area) as compared to limestone dust, combine with bitumen and increases the lubrication of aggregate particles which helps in bringing aggregate particles closer together, leading to low values of VMA as compared to control mix. But this effect is predominant up to some percentage of marble dust (in this case 50%), after which the increase in percentage of marble dust results in increase in VMA, because on account of high percentage of high surface area marble dust, binder will be absorbed by marble dust resulting in low effective bitumen, reduced lubrication of aggregate particles, low compaction and consequently increased VMA.

Table 8: VMA Results for MD Modified Asphalt

Sr.No	Mix Type	Bitumen content (%)	P_s	G_{sb}	G_{mb}	VMA
1	Control	4.59	95.41	2.64	2.364	14.550
2	25%	4.59	95.41	2.64	2.363	14.603
3	50%	4.59	95.41	2.64	2.371	14.314
4	75%	4.59	95.41	2.64	2.360	14.725
5	100%	4.59	95.41	2.64	2.356	14.858

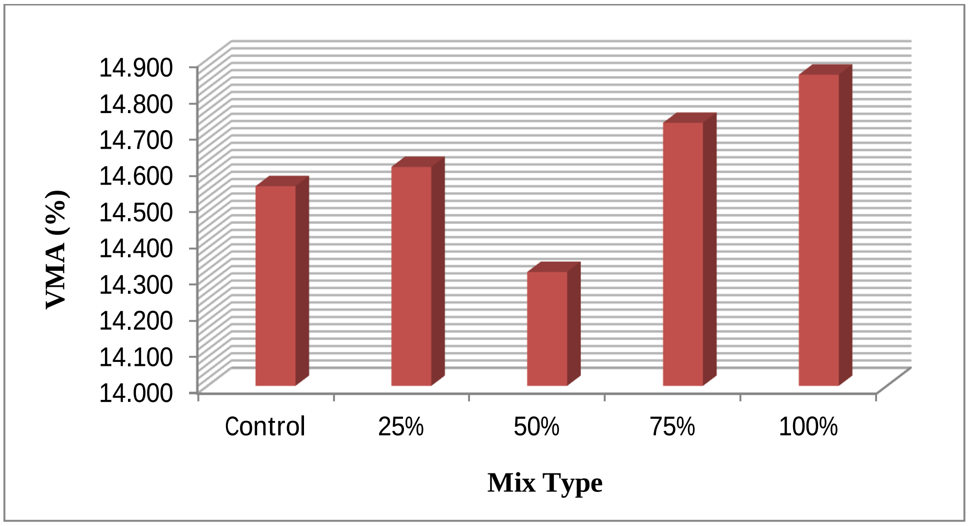

Figure 5: Influence of MD on VMA of Asphalt Concrete

G. Effect of Marble Dust on VFA of Asphalt Concrete

The results of VFA for MD modified asphalt are presented in table 9 and figure 6. It can be seen that VFA for 25% MD modified asphalt is almost equivalent to control mix, whereas VFA values for 50% MD modified asphalt are comparatively higher than control mix. 75% and 100% MD modified samples have shown relatively lower values of VFA. The values of VFA for all samples are well within the range specified by Asphalt Institute (i.e 65-75). VFA plays a predominant role in affecting the durability of asphalt mixtures and is dependent on effective binder content. If VFA in an asphalt mixture is less than the specified range by asphalt institute, absorbed binder will be more and there will be less asphalt film around the aggregate. Lower asphalt films are more liable to moisture damage, since it can be easily removed by water or other weathering agents and results in pavement deterioration. Moreover, if excessive voids are filled with asphalt than the specified limit, durability problems will occur during service life of pavement because the presence of thick film of asphalt around aggregate will cause lower air voids and hence increased effective asphalt content may results in tenderness in the mix.

Table 9: VFA Results for MD Modified Asphalt

Sr.No	Mix Type	Bitumen content (%)	VMA	P_a	VFA
1	Control	4.59	14.550	4.06	72.07
2	25%	4.59	14.603	4.10	71.90
3	50%	4.59	14.314	3.91	72.70
4	75%	4.59	14.725	4.46	69.71
5	100%	4.59	14.858	4.54	69.45

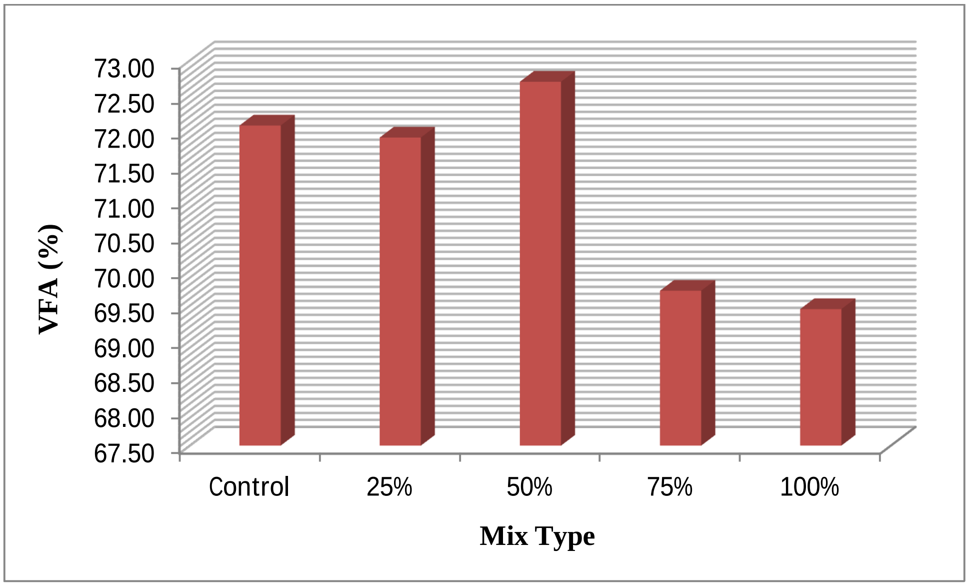

Figure 6: Influence of MD on VFA of Asphalt Concrete

H. Effect of Marble Dust on Effective Asphalt Content (Pbe) of Asphalt Concrete

The results of Effective Asphalt Content for MD modified asphalt presented in table 10 and figure 7 depicts that effective asphalt content is more for 25% MD modified asphalt concrete samples as compared to control mix, whereas for the rest of MD modified asphalt (i.e. 50, 75 and 100%) effective asphalt content is less than control mix. Effective asphalt content greatly influences the performance of asphalt concrete. High effective asphalt content provide better durability, fatigue resistance and resistance to moisture damage but effectives asphalt content should not exceed the specified limit because excessive effective asphalt content cause bleeding when the temperature and loading is increased. Too low effective asphalt content can cause permeability problems which ultimately lead to damage in flexible pavement. Since marble dust up to some extent provides high effective binder than stone dust, resulting in thick film of asphalt around the aggregates, helps them in retaining their characteristic upon application of load and are less prone to aging as compared to thin film around aggregate.

Table 10: Effective Asphalt Content (P_{be}) Results for MD Modified Asphalt

Sr.No	Mix Type	Bitumen content (%)	P_{ba}	P_{be}
1	Control	4.59	0.023	4.57
2	25%	4.59	0.014	4.58
3	50%	4.59	0.073	4.52
4	75%	4.59	0.114	4.48
5	100%	4.59	0.083	4.51

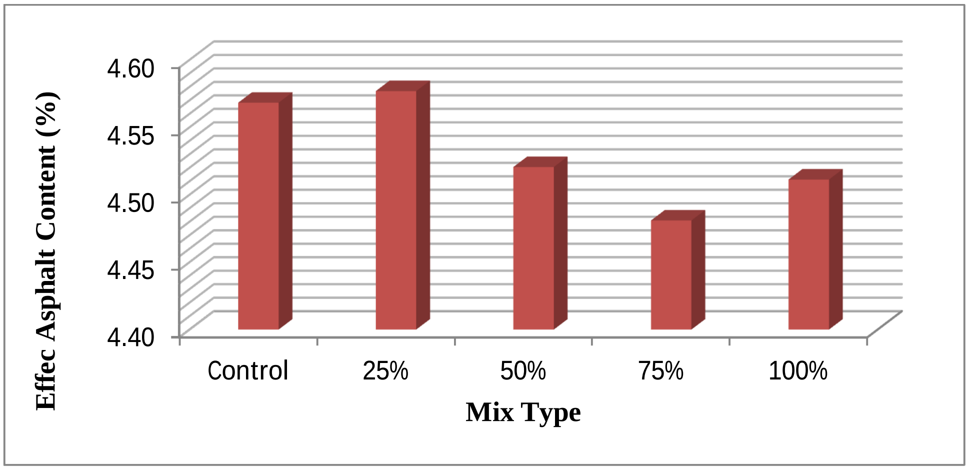

Figure 7: Influence of MD on P_{be} of Asphalt Concrete

IV. CONCLUSIONS

Incorporation of 50% MD in asphalt mixes has resulted improvement in Marshal Stability and Bulk Specific Gravity values as compared to limestone dust filler. 50% marble dust modified samples have shown almost the same values of Flow as for asphalt mixes with limestone dust filler. 50% MD replacement has resulted in lowest percent air voids in comparison with mixes having limestone dust filler. Marble dust made mixes have shown similar trend for VMA values as for Percent Air Voids. VFA values for 25% MD modified asphalt are equivalent to mixes with limestone dust filler whereas for 50% MD, the values of VFA are comparatively high. The effective asphalt content for mixes made with 25% MD is more than that of control mix. It can be concluded that mixes containing marble dust up to 50% have shown satisfactory results for all the above mentioned parameter. Hence marble dust may be used as partial replacement of conventionally used limestone dust filler in asphalt concrete. The incorporation of marble dust in asphalt concrete will considerably reduce the environmental problems caused due to dumping of marble dust.

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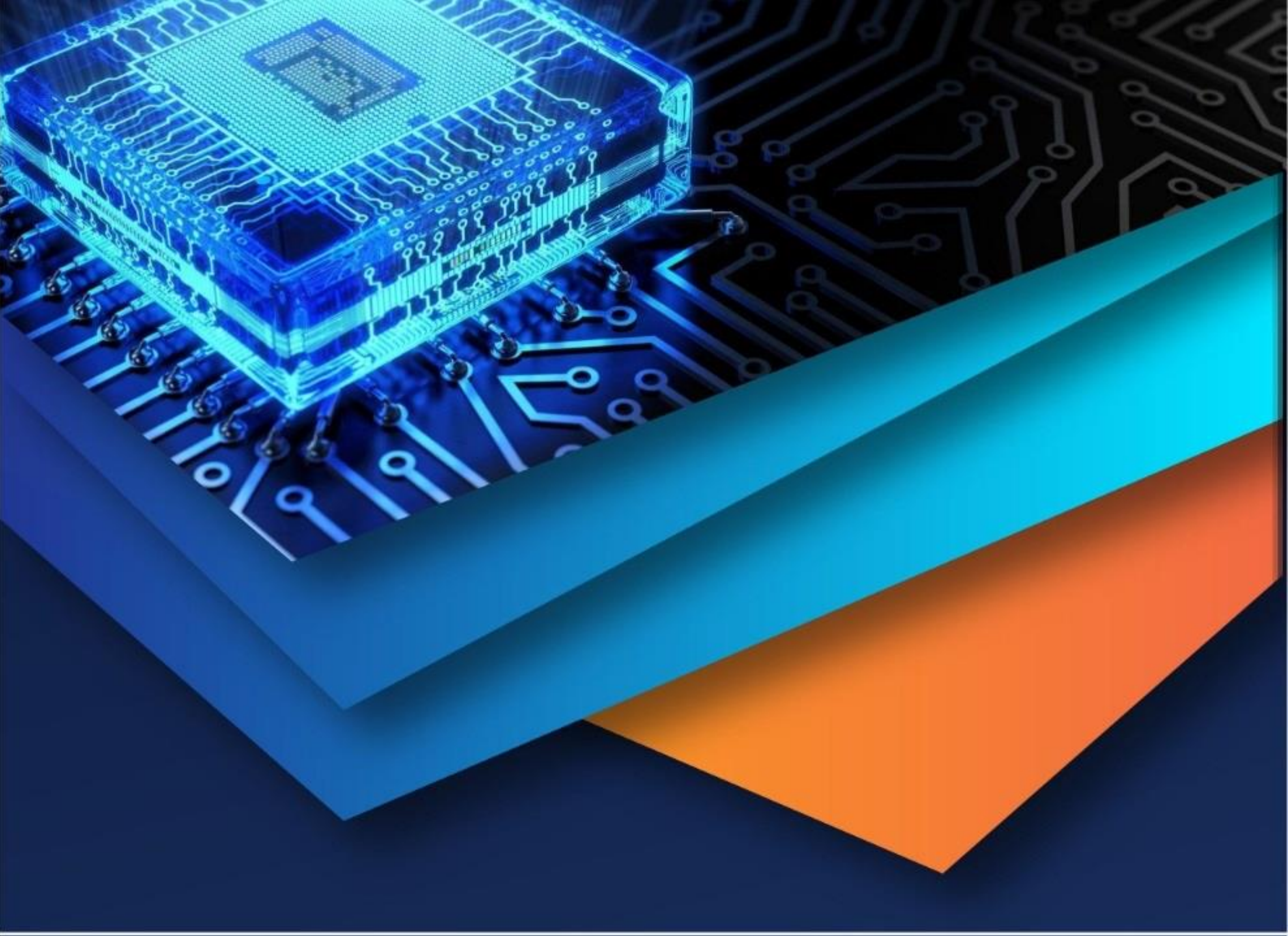

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