4th Conference on Sustainability in Civil Engineering (CSCE'22)
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Use of Marble Dust as a Filler Material in Flexible Pavements

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Abstract- Pakistan is leading towards a major motorway system. Infrastructure growth especially highways and most of the roads are flexible pavements which have higher susceptibility to Rutting. To overcome this issue we have to find ways to solve these problems. Keeping in view the current economic conditions, one must find material which is cost effective and locally available. One such material is the use of Marble Dust with the replacement of filler material in Flexible Pavements. Therefore different tests were conducted to investigate the effect of Marble Dust, on various Mechanical Properties such as Marshall Stability, Dynamic Stability and Rutting resistance. Marble Dust is cheap and locally available material. The modified asphalt mix were prepared by wet process which involves direct mixing of bitumen (60/70 penetration grade) and Marble dust at a high temperature (160-165°C) followed by aggregates during mixing process. The modified asphalt concrete specimens were prepared with the Marble dust percentages of (1%, 2%, 3%, and 4%). Both modified and un-modified Samples were prepared by Marshall Mix design (ASTM D6926), using NHA Class A gradation. Prior to sample preparation, the bitumen (60/70 penetration grade) and aggregates (Margalla aggregate) were tested to check their compatibility according to the standards of NHA. The optimum binder content (OBC) 4.4% was found using Marshall Mix design (ASTM D6926), which was then used in the preparation of both conventional and modified samples. Performance tests including Marshall Stability, flow, Rutting resistance and Dynamic stability were performed to check performance of modified mixes. The tests results revealed that modified mix containing 50% replacement of filler material with marble dust of the total replacement percentage provides best resistance against rutting and enhances dynamic stability of flexible pavement than the other modified percentages. The whole analysis concluded that replacement of filler material with marble dust gives better results regarding pavement performance.

Keywords- National highway authority, optimum binder content, hot mix asphalt, specific gravity

1 Introduction

Marble dust production contributes significantly to environmental problems [1]. Normally 25% of marble dust is produced by cutting marble blocks. In the world in many countries, marble dust is settled down by the sedimentation process which is then left in situ and causes the appearance of the environment ugly. It also produces dust which jeopardizes both agriculture and health [2]. The original reason for using marble dust is economy, sustainability, and the advantages offered in terms of the durability of optimum binder content [3]. The marble generation amount is considerable which is in the range 5-6 million tons [4].

Since ancient times, marble has been used as a construction material. As a result, marble waste being a by-product is a very important material that requires appropriate environmental disposal attempts. Marble dust, which is a solid waste material produced mostly from the actions on marble can be used as a filler material in road pavements in the preparation of bituminous concrete [5]. The production of economic and more long-lasting bituminous concrete using marble waste can help the civil engineer profession to ensure the economy in the construction project and rectify the environmental problems. This study aims to evaluate the effect of marble dust as filler material on the strength and stiffness-related

properties of bituminous mixes. Marble dust is the residue that is collected from cutting marble blocks into smaller pieces to achieve the required smooth and aesthetic shape. The waste utilization will not only be economical but may also help in creating a sustainable and pollution-free environment. Leaving the marble dust in an open environment will cause environmental problems. In this study, the rutting resistance of Marble dust modified hot mixed asphalt will be evaluated. The effect of different percentages of Marble dust on the performance of HMA mixtures will also be evaluated and the possibility of using Marble dust as a filler material will also be assessed. The main focus of this study is to find that optimum percentage of marblle dust as a filler replacement in HMA with having low rutting and high dynamic stability.

2 Research Methodology

2.1 Phases of Research

2.1.1 Phase-1 In this phase of the research, the required material (aggregate and bitumen) was collected from the respective sources.

2.1.2 Phase-2 Both aggregate and bitumen were then tested to check their quality as per NHA specifications in this phase of the project. All tests were performed in accordance with their respective ASTM/ AASHTO/ BS standards as shown in table 1 and table 2.

2.1.3 Phase-3 This phase consists of the preparation of Marshall Mix Design. The blending of different sizes (coarse & fine) of aggregate was done to achieve the gradation according to NHA specifications. The bitumen was added to different percentages of 3.5%, 4%, 4.5%, and 5%. For each blend Gmb, Gmm, Marshall Stability, flow, and volumetric properties were determined. The results were then plotted and optimum bitumen content was determined to be used in the design.

2.1.4 Phase-4 In this phase, the filler material was replaced by marble dust in varying percentages in the asphalt mix, and checked its Gmb, Gmm, stability, flow, and volumetric properties.

2.1.5 Phase-5 In the last phase of this research project, the performance of HMA was checked for Rutting and Dynamic Stability of the modified and control mixes.

Table 1: Aggregate tests

S.No	Test Name	Standard	Objective
1	Sieve Analysis	ASTM C-136	Helps in obtaining the proportion of different aggregate sizes to be used in Marshall Mix samples.
2	Aggregate Impact Value Test	ASTM D5874-02	This test aims to determine the toughness of aggregates.
3	Los Angeles Abrasion Test	ASTM C 535	This test aims to determine the hardness of aggregates.
4	Aggregate Crushing Value Test	BS: 812	This test aims to determine the crushing value of aggregate.
5	Specific Gravity of Coarse Aggregates	ASTM C127-12	This test is performed to find out the specific gravity by density bottle method.
6	Flakiness & Elongation Test	ASTM D 4791-99	It is performed to determine the percentages of flaky and elongated particles.
7	Liquid & Plastic Limit Test	ASTM D4318 – 17	This test is performed to find out the liquid limit, plastic limit, and the plasticity index of soils.

Table 2: Bitumen and other tests

S.No	Test Name	Standard	Objective
1	Penetration Test	ASTM D5-95	It is used to find the hardness or consistency of bitumen which helps in evaluating the grade of bitumen.
2	Flow & Stability Test	ASTM D6927-06	It is conducted to measure the maximum load experienced by the bituminous material at a loading rate of 50.8 mm/minute.
3	Rutting Resistance	ASTM D2974	A Rutting resistance test is performed to evaluate the deformation that occurs due to heavy traffic with the wheel of vehicles.

3 Results and Discussion

Different tests were performed to evaluate the rutting resistance of HMA samples. Results of the tests are given below in table 3.

Table 3: Results of the tests

<table>
<tr><th>S.No</th><th>Test Name</th><th>Result</th><th>S.No</th><th>Test Name</th><th colspan="3">Result</th></tr>
<tr><td rowspan="4">1</td><td rowspan="4">Sieve Analysis</td><td rowspan="4">The final approved JMF is shown in table 4 and it's graph in figure 1</td><td rowspan="4">5</td><td rowspan="4">Specific Gravity of Coarse Aggregates</td><td>Aggregate Size</td><td colspan="2">Specific Gravity</td></tr>
<tr><td>3/4 inch</td><td colspan="2">2.66</td></tr>
<tr><td>1/2 inch</td><td colspan="2">2.51</td></tr>
<tr><td>3/8 inch</td><td colspan="2">2.71</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Aggregate Impact Value Test</td><td rowspan="4">19.52 % (Excellent)</td><td rowspan="4">6</td><td rowspan="4">Specific Gravity of fine Aggregates</td><td>Aggregate Size</td><td colspan="2">Specific Gravity</td></tr>
<tr><td>Crushed Sand</td><td colspan="2">2.57</td></tr>
<tr><td>Filler</td><td colspan="2">2.40</td></tr>
<tr><td>Marble Dust</td><td colspan="2">2.41</td></tr>
<tr><td rowspan="5">3</td><td rowspan="5">Los Angeles Abrasion Test</td><td rowspan="5">29.06 %</td><td rowspan="5">7</td><td rowspan="5">Flakiness & Elongation Test</td><td>Aggregate Size</td><td>Flakiness</td><td>Elongation</td></tr>
<tr><td>3/4 inch</td><td>12.44%</td><td>7.03%</td></tr>
<tr><td>1/2 inch</td><td>10.31%</td><td>8.92%</td></tr>
<tr><td>3/8 inch</td><td>11.67%</td><td>10.82%</td></tr>
<tr><td>Passing Sieve No. 4</td><td>10.44%</td><td>-</td></tr>
<tr><td rowspan="5">4</td><td rowspan="5">Aggregate Crushing Value Test</td><td rowspan="5">19.28%</td><td rowspan="5">8</td><td rowspan="5">Liquid Limit of filler material & Plastic Limit Test of filler material</td><td>Moisture Content</td><td colspan="2">No. of blows</td></tr>
<tr><td>35 %</td><td colspan="2">16</td></tr>
<tr><td>31%</td><td colspan="2">21</td></tr>
<tr><td>24.5%</td><td colspan="2">34</td></tr>
<tr><td colspan="3">5.43%</td></tr>
</table>

Table 4 shows the Job mix formula which determines the contribution of each size of aggregate in the preparation of HMA samples. The upper and lower limit indicates the NHA Class A specifications. HMA samples were prepared according to these specifications and the results are shown in tabular form below.

Table 4: Final approved JMF

Project:			Use of Marble dust as a Filler Material in Flexible Pavements												
FINAL APPROVED JMF															
Nominal Maximum Size			19.0 mm										Approved Design Gradation *	NHA Specification Limits Part - 2 - Table 1b	
stock piles			3/4"		1/2"		3/8"		Crushed Sand		Filler				
Combination Percentages			27.00%		0.00%		27.00%		42.00%		4.00%				
Sieve No.	Sieve Size		Individual stockpile	Percentage	Individual stockpile	Percentage	Individual stockpile	Percentage	Individual stockpile	Percentage	Individual stockpile	Percentage			
inch	mm			27.00 %		0.00%		27.00 %		42.00 %		4.00%		Lower	Upper
1	25	4.26	100.0%	27.0%	100.0%	0.0%	100.0%	27.0%	100.0%	42.0%	100.0%	4.0%	100.0%	100%	100%
3/4	19	3.76	72.6%	19.6%	100.0%	0.0%	100.0%	27.0%	100.0%	42.0%	100.0%	4.0%	92.6%	90%	100%
1/2	12.5	3.12	5.3%	1.4%	95.0%	0.0%	100.0%	27.0%	100.0%	42.0%	100.0%	4.0%	74.4%		
3/8	9.5	2.75	2.5%	0.7%	74.0%	0.0%	76.4%	20.6%	100.0%	42.0%	100.0%	4.0%	67.3%	56%	70%
No 4	4.75	2.02	0.0%	0.0%	3.1%	0.0%	1.0%	0.3%	100.0%	42.0%	100.0%	4.0%	46.3%	35%	50%
No 8	2.36	1.47	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	55.0%	23.1%	100.0%	4.0%	27.1%	23%	35%
No 16	1.18	1.08	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.3%	5.2%	100.0%	4.0%	9.2%	5%	12%
No 80	0.18	0.46	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.1%	3.0%	100.0%	4.0%	7.0%		
No 200	0.075	0.31	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.0%	2.5%	43.0%	1.7%	4.2%	2%	8%
Pan	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			

Following is the graphical representation of JMF as shown in figure 1. The blue line shows upper limits, the orange lineshows lower limits of NHA specifications and the yellow line shows the design gradation of HMA samples.

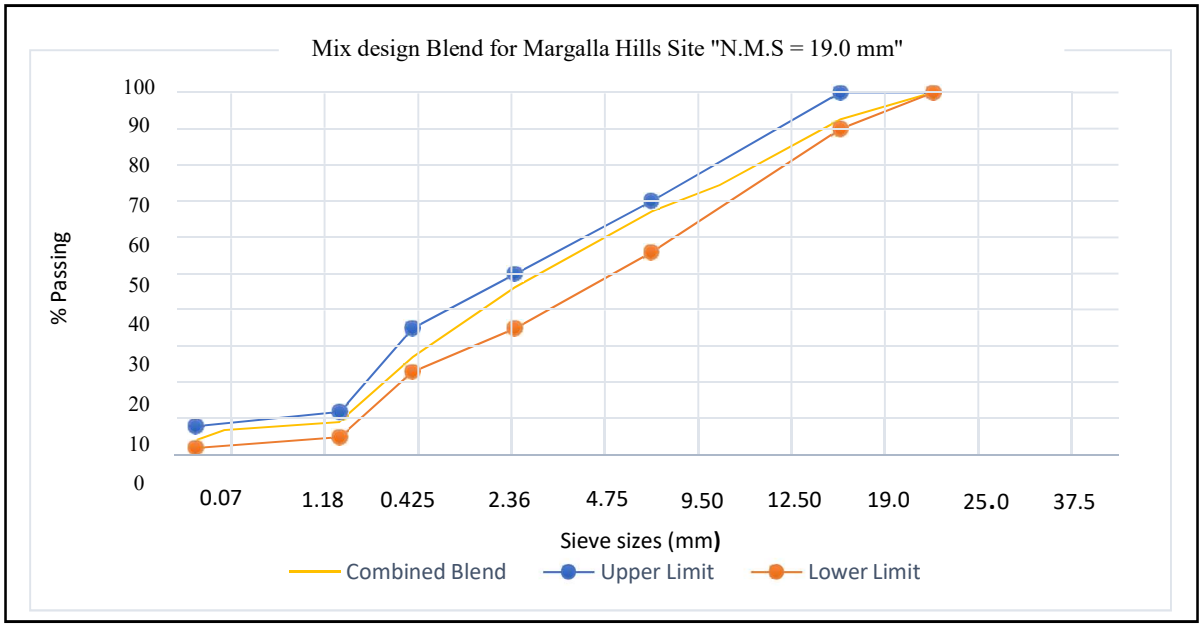

Figure 1 Graphical Representation of Final Approved JMF

3.1 Marshall Mix Design

The purpose of the Marshall mix design is to select the asphalt binder content that satisfies the minimum stability and range of flow values at the desired density.

3.1.1 Flow and Stability Tests

Flow & stability tests were performed with increments of 0.5% of binding material used in HMA samples. These tests were carried out to find out the optimum binder content (OBC) used in HMA samples. The results produced are given below in table 5.

Table 5: Determination of OBC

% Bitumen Content by Mass ofAggregate	**3.50**	**4.00**	**4.50**	**5.00**
Unit weight (G_{mb})	2.336	2.339	2.356	2.352
Maximum theoretical specific gravity (G_{mm})	2.493	2.462	2.465	2.426
Stability (kN)	9.14	9.91	10.48	10.89
Air voids (% V_a)	6.29	5.01	4.46	3.04
VMA %	14.05	14.39	14.24	14.82
VFA %	55.27	65.22	68.70	79.48
Flow (mm)	1.97	2.30	2.67	2.90

The results of HMA standard samples prepared at OBC were compared with specifications, which showed that the samples comply with NHA specifications.

3.1.2 Flow & Stability Results of Modified Samples

The modified samples are prepared at OBC with the replacement of marble dust with the filler at different percentages from (25-100) %.
Following are the results of unit weight (Gmb), Flow & Stability, % Air voids, % Air voids in mineral aggregates (VMA), and % Air voids filled with the bitumen (VFA) of Marshall Mix samples prepared at OBC as shown in table 6.

Table 6: Results of modified HMA sample

Percent replacement of filler with marbledust	**0%**	**25%**	**50%**	**75%**	**100%**
Unit weight (G_{mb})	2.338	2.505	2.523	2.536	2.469
Max theoretical specific gravity (G_{mm})	2.348	2.509	2.528	2.545	2.476
Stability (kN)	11.05	12.27	12.70	14.67	12.35
Air voids (% Va)	4.4	4.40	3.71	3.19	5.78
VMA %	14.8	15.64	14.58	13.67	16.86
VFA %	70	71.85	74.55	76.63	65.71
Flow (mm)	0.91	3.41	3.54	4.16	3.94

3.1.3 Results of Rutting Test and dynamic stability of Standard & Modified HMA Samples

The following table 7 shows the results of the rutting test performed on standard and modified samples of HMA. Table 8 shows the results of the dynamic stability of standard and modified HMA samples.

Table 7: Rutting Test Results

Percentage of Filler Replacement	Average Rutting Values (mm)
0	4.407
50	3.95
100	4.29

Table 8: Dynamic Srability Test Results

Percentage of Filler Replacement	Average Dynamic Stability Values (kN/ m^2)
0	1513
50	2163
100	1623

The results of rutting of standard and modified HMA samples prepared with 50% and 100% replacement of filler material with marble dust. The value of rutting is minimum at 50% replacement of filler material as shown in figure 2. Also, the value of dynamic stability is maximum at 50% filler replacement with marble dust. If we increase the filler replacement above 50%, the value of dynamic stability (DS) decreases as shown in figure 3.

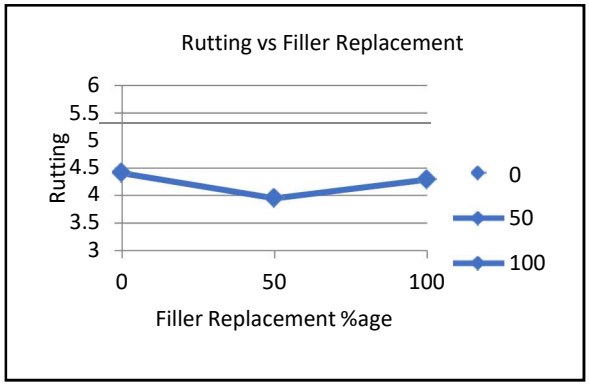

Figure 2: Graph of Rutting vs Filler Replacement %

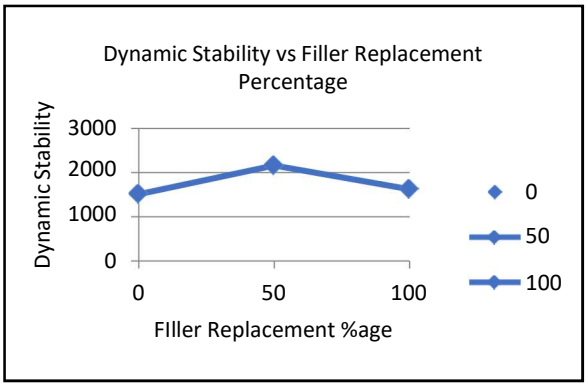

Figure 3: Graph of DS vs Filler Replacement %

4 Conclusion

Following are the conclusions from the conducted study:

1 When 50% filler is replaced with marble dust, the stability and flow of the hot mix asphalt have improved that is 2163 KN/m^2, at 0% of marble as a filler replacement the dynamic stability of HMA is 1513 KN/m^2, and at 100% of filler replacement the dynamic stability is 1623 KN/m^2. Adding the filler improves the Dynamic Stability and Rutting Resistance of the HMA.

2 50% replacement gives a maximum improvement in resisting the Rutting and Dynamic Stability of the HMA that is 3.95mm, at 0% of marble as a filler replacement the rutting of HMA is 4.407mm, and at 100% of filler replacement the rutting of HMA is 4.29mm.

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