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Re-use of Marble Waste as Filler Substitute in Bituminous Roads

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ABSTRACT
This paper describes the re-use of marble waste as filler material in wearing course of bituminous roads which is the replacement of stone dust. Stone dust is conventionally used as filler by NHA, Pakistan. Modified mixes containing Marble dust as filler were prepared and compared with conventional mixes containing stone dust as filler. Three varying Percentages of fillers namely Marble dust and Stone Dust (3.5%, 4.5% and 5.5% by weight of total aggregates) in both types of mixes were used along with three varying contents of bitumen (4%, 4.3% and 4.6%). Effect of both types of mixes was assessed in terms of Marshal stability and Indirect Tensile fatigue testing and results were discussed. Marshal mix design showed that modified mixes result higher stability as compared to conventional mixes. Increase in stability of modified mixes is due to the fact that Marble dust acts as a bitumen extender. Stone dust absorbs more asphalt content and causes disintegration of aggregate particles by bleeding when temperature exceeds 40^0C in summer and further compaction by heavy loaded vehicles.

Keywords – Filler, wearing course, Marble Dust, Marshal Stability, Indirect Tensile Fatigue Test

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I. INTRODUCTION

Marble processing units produce a huge amount of Marble waste during Marble cutting operations. This waste is rarely degradable and causes serious environmental issues. 70% of Marble is wasted in marble industries and only 30% is treated as a saleable product. This 30% recovery causes 70% of burden on our environment. Marble industries dump marble waste in open fields or pits which causes water logging problems and reduces porosity of soils. Marble waste increases the alkalinity of soil and results in soil fertility problems. Marble stone is used as dimensional stone by the marble industries and is sold by its size rather than the weight. These industries aim to get large slabs of marble for selling purpose but larger sizes cause more wastage of marble. The possible solution to deal with problem of marble waste is its re-use in civil works especially roads because other works do not use such huge amount of waste. The aim of this research is to re-use marble waste as filler material in wearing course to get economical asphalt concrete. Experimental program was conducted to compare Marble dust modified mixes with conventional. Mixes were also subjected to Performance testing for determining resilient modulus using universal testing Machine. Experimental program indicated that Marble dust can be efficiently re-used as filler material in bituminous roads.

II. LITERATURE REVIEW

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

R. Muniandy et al. (2013) evaluated the influence of nature and size of dust on binder and filler mastic laboratory measured properties. Use of filler with binder in asphalt concrete develops thicker asphalt films around aggregate particles that increases resistance against permanent deformations in HMA concrete. Size of filler passing sieve No.200 has 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.

III. MATERIALS AND TESTING

Selection of gradation of aggregates plays an important role in preparation of Job Mix Formula for Bituminous mixes. National Highway Authority, Pakistan has classified wearing aggregates into two classes for Bituminous roads. Class A and Class B aggregate. Class B aggregates are considered finer as compared to Class A aggregates. In this research work, we have selected Class B aggregates and 60/70 penetration grade bitumen for wearing course. Aggregates were obtained from National Logistic Cell Peshawar crushing plants and bitumen from Attock oil refinery Rawalpindi, Pakistan

3.1 Preliminary Characteristics of Materials

Characterization of materials required for HMA concrete design is of vital role. HMA consists of blend of aggregates, binder and mineral fillers. All the ingredients are mixed in different proportions and coated by bitumen. Prior to the design of flexible pavements, characterization, selection, and proportioning of ingredients of HMA is necessary to get the desired characteristics of mix.

3.1.1 Structure of Mineral Aggregates for HMA

Aggregate structure mainly offers resistance ability to rutting and other permanent deformation characteristics. Aggregate particles size, shape, and surface texture greatly affects the performance characteristics of HMA. Angular and rough surface aggregate particles are used for improving interlocking. Results of preliminary characteristics of Mineral Aggregates and Fillers are given in Table 1 and Table 2 respectively.

Table 1: Summary of quality tests of Aggregates

S.No	Test Description	Results (%)
1	Los Angeles Abrasion	22.2
2	Aggregate Absorption	1.092
3	Soundness	7.88
4	Flakiness Index	4.98
5	Elongation Index	4.34

Table 2: Summary of quality tests of Fillers

S.No	Test Description	Filler Type	Results
1	Liquid Limit	MD	Non Plastic
		SD	Non Plastic
2	Plastic Index	MD	Non Plastic
		SD	Non Plastic
3	Sand Equivalent	MD	60.66%
		SD	87.04%

3.1.2 Characteristics of Bitumen

Results of consistency of Bitumen are given in Table 3.

Table 3: Results of Consistency of Bitumen

S.No	Test Description	Unit	Results
1	Ring & Ball Softening Point	^{0}C	49.25
2	Penetration @ 25^{0}C	1/10mm	63.5
3	Specific gravity		1.03

3.2 Mix Design Method

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 NHA, Pakistan. Materials selected for this project conform to specifications of Asphalt Institute (MS-2), AASHTO and ASTM.

3.2.1 Combined Gradation of Mineral Aggregates

Class B mineral aggregates and two types of fillers were graded by sieve analysis method. Three types of gradations on basis of three varying percentages of filler (3.5%, 4.5% and 5.5%) with 19mm maximum aggregate size were designed from mean percent passing. Summary of combined gradation of aggregates is given in Table 4.

Table 4: Summary of gradation and specifications of selected aggregates

Sieve Size	Blend gradation of Class-B aggregates			
mm	3.5%	4.5%	5.5%	NHA Specifications
25	100	100	100	100
19.5	100	100	100	100
12.5	77.1	77.1	77.1	75-90
9.5	67.4	67.4	67.4	60-80
4.75	50.9	50.9	50.9	40-60
2.36	28.6	28.6	28.6	20-40
0.300	12.5	13.2	13.8	5-15
0.075	3.6	4.6	5.5	3-8

3.2.2 Marshal Mix Design Method

Marshall Mix Design criteria was used for the design of HMA mixtures (Asphalt Institute, 2003). Marshall Mix design (AASHTO T-245) is applicable only to HMA that contains aggregates with maximum size 1inch or less. Marshal mix design is used for preparation of HMA mixtures using standard cylindrical test specimens of height 63.5mm and diameter 102 mm. Test specimens were prepared according to test procedure as per AASHTOT-245 and NHA General Specification, 1998.

Table 5: Mix design properties according to NHA General Specification, 1998

Description	NHA General Specification, 1998
Compaction blows	75
Stability (kg)	1000 (Minimum)
Flow(0.01inch), 0.25mm	8-14

3.2.3 Designation of Specimens

On the basis of three varying contents of filler and three neat asphalt contents namely 4% (A), 4.3% (B) and 4.6% (C), mixes were designated as 3.5A, 3.5B, 3.5C for Blend gradation-01, 4.5A, 4.5B, 4.5C for Blend gradation-02 and 5.5A, 5.5B, 5.5C for Blend gradation -03.

3.2.4 Marshal Stability and Flow Test

Marshal stability of mixes is determined from load resistance offered by test specimen in kilogram or Newton at 60^0C at a deformation rate of 50mm per minute. Flow of test specimen is measured during stability test.

Table 6: Results of Marshal Stability and Flow

Mix Type	Stability (Kg)		Flow (0.25mm)	
	SD	MD	SD	MD
3.5A	1408.00	1999.36	12.60	9.29
3.5B	1320.70	1819.84	12.25	9.31
3.5C	1210.88	1686.67	13.16	9.53
4.5A	1510.78	1576.96	12.40	9.13
4.5B	1415.04	2258.67	12.00	9.33
4.5C	1313.66	1965.33	12.36	10.27
5.5A	1306.62	1538.53	13.20	9.93
5.5B	1299.58	1848.00	13.60	10.20
5.5C	1163.01	2128.13	13.95	11.00

3.3 Indirect Tensile Fatigue Test

UTS024 is a software application program that is used to investigate fatigue characteristics of HMA by repeated load indirect tensile testing using the Universal Testing System developed by Industrial Process Controls Limited. The fatigue test is used to measure the performance of asphalt mixtures for HMA pavement design by determining the fatigue characteristics. The indirect tensile fatigue test determines the resilient modulus, recoverable and permanent deformations in the horizontal axis of the specimen and conforms to the specifications and requirements of EN12697-24:2004(E). The resilient modulus calculations conform to ASTM D4123–82 with the Poisson's ratio value supplied as a constant parameter. Results of Indirect Tensile Strength and Resilient Modulus are presented in Table 7 and Table 8 respectively.

Table 7: Results of Indirect Tensile Strength using Marble Dust and Stone Dust as filler

Mix Type	Cyclic Force (N)		Indirect Tensile Strength (Kpa)	
	SD	MD	SD	MD
3.5A	1491	2117	149	212
3.5B	1413	1948	142	195
3.5C	1296	1805	130	181
4.5A	1617	1688	162	169
4.5B	1497	2391	150	240
4.5C	1391	2082	140	209
5.5A	1399	1647	140	165
5.5B	1377	1958	138	196
5.5C	1231	2253	123	226

Table 8: Results of Resilient Modulus using Marble Dust and Stone Dust as filler

Mix Type	Resilient Modulus (Mpa)	
	SD	MD
3.5A	1451	2668
3.5B	1284	2255
3.5C	1092	1951
4.5A	1574	1713
4.5B	1537	3373
4.5C	1299	2591
5.5A	1208	1637
5.5B	1243	2294
5.5C	1129	3005

IV. RESULTS AND DISCUSSIONS

4.1 Effect of different contents of fillers on Marshal Stability

As Stone Dust content in the mixes increase, Marshal Stability increases to a maximum level then starts decreasing. While MD made mixes develop increased stability values with increase in filler content except 3.5% MD mixes that reduces stability with percentage increase in bitumen. Stability of SD mixes is reduced because air voids at low content of filler are high and the aggregate particles become finer as percentage of filler starts increasing. Moreover, Marshal stability is increased by anything that improves the viscosity of the bitumen. Therefore, a small increase in percentage of filler in mixture affects making the binder and dust mixture act as a more viscous binder which increases the Marshal stability of MD made mixes. If dust is extremely fine it causes the binder making act like higher binder content and lowers the stability which occurs in case of 3.5% MD mix and all mixes of SD.

4.2 Effect of different contents of fillers on Marshal Flow

Stone Dust made mixes exhibited greater values of flow as compared to marble dust mixtures.

The flow indicates the vertical deformation of the test specimen in 0.01 inch or 0.25mm from start of loading up to the point where the stability starts decreasing. Plasticity in mix is achieved by more flow which is less resistant to permanent deformation characteristics due to traffic loads. High flow shows a mix that has more air voids and low binder content for durability. On the basis of laboratory tests it can be suggested that Marble Dust made mixes provide better resistance to permanent deformation due to heavy traffic loads as compared to SD made mixes.

4.3 Effect of different contents of fillers on Indirect Tensile Strength

Presence of filler provided good adhesion between bitumen and aggregate causing reduction in stripping of aggregate. Moreover, voids were filled by dust particles resulting in a low void ratio. Thus density of mixes increased and as a result, Indirect Tensile Strength of asphalt mixes was increased. MD made mixes showed higher Indirect Tensile Strength values with increase in filler content except 3.5% marble made mixes. The density of Marble filler made mixes increased with increase in asphalt content because aggregates are lubricated by bitumen and enhance compaction process. Stone dust made mixes showed decrease in Indirect Tensile Strength values with increase in filler. In case of SD, the bulk specific gravity gains maximum value and then starts decreasing because further bitumen content yields thick films around the aggregate particles which tends to push aggregates away resulting in less dense mixes and poor tensile strength of the mix.

4.4 Effect of different contents of fillers on Resilient Modulus

Resilient modulus values increased with percentage increase in filler in case of mixes made with MD as filler except 3.5% mixes because mineral fillers fill the voids and densify mix. While in case of mixes containing SD as filler the trend is opposite. Resilient modulus of SD made mixes is decreasing with increase in both filler and bitumen content because of less effective asphalt content of stone dust made mixes. SD absorbs more asphalt as compared to MD causing lower effective asphalt content. Stiffness of mixes is considered as a function of effective asphalt content that exists around aggregate particles forming a film that protects aggregates from moisture induced damages and other weathering effects. Too much higher effective asphalt contents in the mix result in thicker film thickness and more flexible mixes can be obtained. Thick films do not age as easily as thin films harden and as a result retain its original characteristics for long time. This makes mixtures more durable and stiff over time. Thus mixtures made with SD as filler are probably less stiff than MD. The effective asphalt content in mixes made with SD is lower than MD made mixes. This shows that SD filler is finer than MD and believed to be more asphalt absorbent and causes durability problems.

V. CONCLUSIONS

i. Higher stability was achieved from mixtures made with MD for all percentages of marble dust. Highest stability was achieved at 5.5% MD and 4.6% bitumen (5.5C mix). While mixes made with SD as filler, produced relatively low stability values as compared to marble dust at same percentage of filler and bitumen. Highest stability in case of SD filler was achieved by 4.5A mix (4.5% SD and 4% bitumen).

ii. Marshal flow of mixes made with both MD and SD was found to be increasing with increase in percentage of SD and bitumen. However, MD made mixes exhibited less amount of flow as compared to SD made mixes for all percentages of filler and bitumen.

iii. The resilient modulus of SD made mixes decreased with increase in percentage of both SD and bitumen while for MD mixes, Resilient Modulus is increasing with percentage increase in MD and bitumen except 3.5% MD made mixes.3.5% MD acted like SD made mixes but as a whole MD made mixes indicated better results of resilient modulus as compared to SD mixes because of higher effective asphalt content of MD made mixes. SD is considered as absorptive material that absorbs more asphalt content and leaves less percentage of binder for future purposes. In other words, it makes the mix dry and causes cracking in pavements.

VI. RECOMMENDATIONS

It is necessary to conduct further investigation on effect of Marble Dust as filler substitute with percentage more than 5.5% in asphalt concrete and different grades of bitumen like 40/50 and 80/100. In present study 60/70 penetration grade bitumen was used as an asphalt cement obtained from Attock oil refinery, Pakistan. More investigations should be made using MD as a filler with different percentages of aggregates and fillers satisfying lower and upper limits for Class B aggregate according to NHA General specifications for wearing course aggregates. Class B aggregates for wearing course by NHA Pakistan were used in this research work. In future it is recommended to re-use Marble Dust as filler in NHA, Class A aggregates and compare the effect of Marble Dust as filler on results of both gradations.

REFERENCES

[1] Zulkati, Anggraini, Wong Yiik Diew, and Darren Sun Delai. " Effects of Fillers on Properties of Asphalt -Concrete Mixture", Journal of Transportation Engineering, 2012.

[2] Muniandy, Ratnasamy and Aburkaba, Eltaher." The effect of type and particle size of industrial wastes filler on Indirect Tensile Stiffness and Fatigue performance of Stone Mastic Asphalt Mixtures", Journal of Applied Sciences Research, 2011.

[3] Agarwal R.K.; 'Modern marble processing techniques and their suitability for Indian condition"; A company report by Rajasthan Udyog, Jodhpur.

[4] Battacharya B.C.; "Possible utilization of waste marble powder / slurry - a case study". Seminar on gainful utilization of marble slurry in various construction activities; UCCI, Udaipur; Sept. 18,2002.

[5] Ahmad, H. Alijassar, Sayed Metwali, Mohammad A.Ali, 2004."Effect of Filler Types on Marshall Stability and Retained Strength of Asphalt Concrete" International Journal of Pavement Engineering,5:1 pp 47-51.

[6] Asphalt Institute, 2003. "Asphalt Hand Book," Manual series No. 04, Six Edition, Kentucky, USA

[7] ASTM D 1559, Resistance to Plastic Flow of Bituminous Mixtures Using the Marshall Apparatus

[8] ASTM D 4123 Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures.

[9] Ramadan, Khaled Z. Ashteyat, Ahmed M.." Utilization of white cement bypass dust as filler in asphalt concrete mixtures. (Report)", Canadian Journal of Civil Engineering, Feb 2009 Issue.

[10] Chandra, Satish, and Rajan Choudhary." Performance Characteristics of Bituminous Concrete with Industrial Wastes as Filler ", Journal of Materials in Civil Engineering, 2013.

[11] Arabani, M., S. Babamohammadi, and A. R. Azarhoosh." Experimental investigation of sea shells used as filler in hot mix asphalt ", International Journal of Pavement Engineering, 2015

[12] Dipu Sutradhar, Mintu Miah, Golam Jilany Chowdhury, Mohd. Abdus Sobhan. Effect of Using Waste Material as Filler in Bituminous Mix Design. American Journal of Civil Engineering. Vol. 3, No. 3, 2015, pp. 88-94. doi: 10.11648/j.ajce.20150303.16

[13] Sung Do, H. " A study on engineering characteristics of asphalt concrete using filler with recycled waste lime", Waste Management ,2008.

[14] Hdabi, Abbas Al -. " Laboratory investigation on the properties of asphalt concrete mixture with Rice Husk Ash as filler. ", Construction and Building Materials, Nov 15 2016 Issue.

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