Effect of Mineral Fillers on the Performance of Hot Mix Asphalt (HMA)

Usman Ghani[1], Zia Ur Rehman[2], Asad Iqbal[3,*], M.Kaleem Ullah[3], M.Hassan Ashfaq[3]

[1]Department of Civil Engineering, National University of Computer & Emerging Sciences, Lahore -Pakistan.
[2]Department of Transportation Engineering & Management, University of Engineering & Technology, Lahore-Pakistan.
[3]Department of Civil Engineering, The University of Lahore, Lahore-Pakistan.
[*]Corresponding author: asadcivil03@gmail.com

Abstract

Flexible pavements are commonly used in the world. The durable performance of flexible pavement is a very important factor that is being considered. Due to the large traffic loads, certain difficulties develop because flexible pavements undergo specific deformations. In developing countries such as Pakistan, where there is an economic problem, some special corrective measures are required to improve the performance of Hot Mix Asphalt (HMA). The performance of the HMA and its internal properties can be improved through the use of mineral waste fillers to save pavement construction. In this study, the performance of HMA was investigated using different mineral fillers. The type of minerals, used to verify the performance of HMA, was Stone Dust (SD), Brick Dust (BD) and Fly Ash (FA). The Marshall Mix Design criteria (ASTM D1559) were adopted to investigate the volumetric properties of HMA. In addition, the optimal amount of each mineral load was determined using the Marshall Mix design. The prepared conventional samples were compared with the modified filler samples. The modification of AMF using mineral load was made by varying the percentages of fines from 5% to 9% with an increase of 0.5% in each sample of the mineral load. However, the general modification was made by the weight of the aggregates present in the total mixture. The bitumen used was grade 60/70, taken from Attock Refinery Limited Pakistan. The use of 7% of FA showed the best results and the improvement of 31.60% of instability and against this stability, vertical deformation of 4.50 (mm) was observed. The results also showed that using 5% or less of mineral fillers have adverse effects on stability. This study highlighted the effect of mineral fillers to achieve a strong, durable resistance and the ability to withstand certain discomforts related to temperature and moisture load. Therefore, it can be concluded that the lasting performance of HMA is possible using mineral fillers.

Keywords—Brick Dust, Fly Ash, Flow, Hot Mix Asphalt, Mineral Fillers, Marshall Mix Design, Stone Dust, Stability.

1 Introduction

The flexible pavements are being constructed all over the world.The huge amount of economy is being consumed on the evaluation and rehabilitation of the flexible pavements.Some of the common distress are being found after the construction of the pavements like fatigue cracking, permanent deformation (rutting), thermal cracking is being observed soon after the opening of the pavements due to the heavy axle loads. As a result, it affects the pavement life and forces the Highway experts and researchers to rethink the pavement performance.Until now so many researches have been done to improve the performance-related distresses of the HMA in order to improve the life of the flexible pavement by the addition of small ingredients. The performance and for the achievement of the long-lasting benefits of in flexible pavements, it is necessary to add some additives for the modification of the HMA [2]. The addition of the mineral fillers in the HMA is founded to be very effective, as they improve the external as well as the internal properties of HMA and proved them to be the best modifier. To check and improve the performance of HMA especially in developing countries additions of the Mineral fillers HMA play a vital role. In this manner, the domestic waste can be reduced and the strong road structure can be achieved [3]. There are so many benefits of fillers as safe efficient and long-lasting roads that can withstand heavy traffic loading. One of the main merits is that the waste can be reduced while using the Mineral fillers of Fly Ash Stone dust and Brick Dust. While going through the economic analysis of these Mineral Fillers it can reduce the cost up to some extent. It can be also

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concluded that modified pavements are more economical as compared to the unmodified asphalt pavements. The above-mentioned fillers generally passing #200 sieve are the components of the mineral aggregate that fill up the voids and occupied the spaces between the coarse aggregates and increases the stability and density of HMA. One type of small ingredients that can change the function of HMA is different types of Mineral fillers.Therefore during the processing of HMA Design, one should have to take care while selecting the materials. For the performance of pavement, in the long run, the addition of adequate materials at an appropriate proportion is very necessary. Basically, the HMA is a combination of binder, aggregates, and air present in it resembles the physical properties of HMA and also shows the performance of HMA as a pavement [3]. Mineral fillers having the physical size passing 200-mesh sieve (smaller than 75 microns). Mineral fillers were only considered for filling up the voids and for the gradation criteria beside these it has great importance and it can improve the performance of HMA [5]. The use of mineral fillers in a mixture commands over the internal properties of a bitumen as the aggregate and bitumen has the better adhesion. It increases the fatigue resistance and the overall reduces the pavement deformation. About the air voids the statement was not to be more than 4% [8]. After going through number of researches I conclude that using fillers in bituminous mixes enhance various properties. Use of fillers not only helps in improving the quality of mixes but also helps in usage of various waste materials as the basic ingredients of the paving mixes thus, reducing the problem of these materials going as a waste [11], if the benefits of the fillers are considered, then along with filling the empty spaces, less amount of asphalt is required in HMA, good gradation of aggregates can be achieved, shows an increment in the stability of HMA, along with that better bonding properties can be achieved [9]. Marshall Stiffness is the sign of opposition to the vertical deformation caused by heavy loading. If the value of stiffness is high then it means that HMA will show good opposition to permanent deformation which can be made possible by using mineral fillers [10]. Durable mix have the capability to show resistance against abrasion which is occur due to tires [4]. For mixes prepared using 5%, to 9% mineral fillers, the desirable flow and stability values can be achieved relatively [1]. Marshall Stability test is performed to determine the OAC and the testing specimen shall be prepared by combining varying percentages of bitumen ranging from 4.5% by the weight of aggregates to 6.5% with an increase of 0.5% for each type of fillers. The key function of fillers is to fill the remaining voids by coarse and fine aggregates in the hot mix. Fillers used in this study are brick dust, stone dust and fly ash. Fly Ash, Stone dust and brick dust finer than 0.075 mm size sieve can be used in the Asphalt concrete for the comparison and can be economical. According to Asphalt Institute (AI) the use of Mineral fillers in the HMA are recommended from 4 to 8%.FA is achieved through the practice of burning of organic material named as coal. Fly ash possesses pozzolanic properties similar to those of natural volcanic pozzolans. A pozzolans has limited cementations value by itself. If fly Ash is chemically, analyzed it has the different ingredients like iron oxide, silicon dioxide and aluminum oxide. Advantages of using fly ash besides the economic and ecological benefits include improvement in workability and reduction in bleeding.

2 Research Objectives

The main objectives of this research is the bond formed between the binder and aggregate particles should be pure, to achieve the best performance of HMA. To conclude the optimum amount of AC for different Mineral fillers ratios of HMA. And to check out the stiffness of Hot Mix Asphalt by the addition of Mineral fillers. To find out a reasonable range of Mineral fillers that synthesis the best performance of Hot Mix Asphalt (HMA) in all respects. To achieve the best volumetric properties Of Marshall Mix by the addition of the Mineral Fillers.

3 Material & Mixed Design

The following sections cover the description of the coarse aggregate, fine aggregate, bitumen and mineral fillers used in this study. The gradation of these particles has been summarized in Table 1. The material characterization of the aggregates used has been summarized in Table 2. The bitumen used in this study was of 60/70 grade Attock Refinery limited Pakistan. The physical properties of bitumen have been summarized in Table 3. The filler's gradation specifications have been summarized in Table 4. For the achievement of OAC (Optimum Asphalt Content), all the ingredients of the HMA should have to be blended in the specified amount. The physical properties of the hot mix are highly dependable on the amount of binder and the aggregate that has been used in the mix. For the determination of these properties Marshall Mix design (ASTM D 1559) criterion has been used. Some of the volumetric properties and the behavior of the mix design on conventional samples have been summarized in Table 5.

Sieve Sizes (in)	Sieve Sizes (mm)	% Passing
1	25.4	100
3/4	19.1	95
1/2	12.7	83
8-Mar	9.5	65
#4	4.75	46
#8	2.36	30
#16	1.18	20
#30	0.6	13
#50	0.3	9
#100	0.15	6

TABLE 1: Target gradation for aggregates

Material Properties	Specifications	Results	Range
Abrasion value	ASTM C 535 AASHTO T 96	16%	<40 %
Crushing strength	B.S 812 & IS 383	6%	<15%
Impact value	BS 812 & IS 383	8.17%	<10 %
Flakiness	ASTM D 4791	12.21%	<15 %
Elongation	ASTM D 4791	11.82%	<15 %
Angularity No	ASTM D 4791	8	0-11
Specific gravity	AASHTO T 85-88	2.69	2.5-3
Water absorption	AASHTO T 85-88	0.29%	Max 2%

TABLE 2: Material characterization of aggregates

Property	Specifications	Results	Range
Bitumen grade	AASHTO T49	60/70	60/70
Penetration at 25c	AASHTO T49	64mm	60-70mm
Softening point	AASHTO T53-89	42 C	30- 157 C
Flashing Point	ASTM-D-92(C)	248 C	240- 260 C
Fire Point	ASTM-D-92(C)	268 C	260- 290 C
Ductility test	AASHTO T179	73 cm	60-85 cm

TABLE 3: Physical properties of Bitumen

Size		OI	PI
Sieve Size	%Passing	Mineral filler should avoid an organic content or impurities	PI<4
#30	100		
#50	95- 100		
#200	70-100		

TABLE 4: Fillers gradation specifications

AC%	GMB	GMM	Air Void	VMA	VFA
3.5	2.35	2.56	5.9	19.9	70
4	2.33	2.58	4.6	19.8	76.8
4.5	2.34	2.54	3.5	20	82.6
5	2.32	2.51	1.8	19.8	90.8
5.5	2.3	2.5	1.3	19.4	93.3

TABLE 5: Marshall mix design results for conventional samples

AC %	Stability (kN)
3.5	16.84
4	18.34
4.5	19.55
5	24.98
5.5	15.04

TABLE 6: Stability results

4 Testing & Methods

For the characterization of the aggregates the Abrasion value test, Crushing strength of the aggregate test, Impact value of the aggregate, Flakiness test, Elongation test, and the specific gravity test has been carried out. For finding the physical properties of a binder used in the hot mix asphalt, the penetration test using a penetrometer, Softening point test using ring ball apparatus, ductility test by using ductile meter along with the flash and fire point using cleave open cup apparatus have been carried out. The optimum Asphalt content (OAC) has been found out by the Marshall Design Criterion. In Marshall Mix design three tests have been carried out. These three tests were the Gmb test, Marshall Stability and flow test along with the Gmm test. For the aggregate characterization, the gradation curve has been followed. For the determination of the optimum Asphalt content 15 samples have been prepared for the various percentages of the bitumen (3.5%, 4%, 4.5%, 5%, and 5.5%). The optimum Asphalt Content was founded to be 4.30% shown in figure 2. For the purpose of OAC for the modified samples using mineral fillers, the same Mix design has been followed. The percentages of mineral fillers were 5%, 5.5%, 6%, 6.5%, 7%, 7.5%, 8%, 8.5% and 9%.Furthermore, the Marshall properties have been compared with conventional samples along with the volumetric analysis. The stability values have been summarized in Table 6 and Figure 1.

The optimum Filler content for BD against 4% recommended by the AI is determined to be 7.8%. Figure 4 shows that as the quantity of BD is increasing the AV is decreasing. The optimum Filler content for FA against the 4% AV recommended by the AI is determined to be 7%. Figure 5 shows that as the

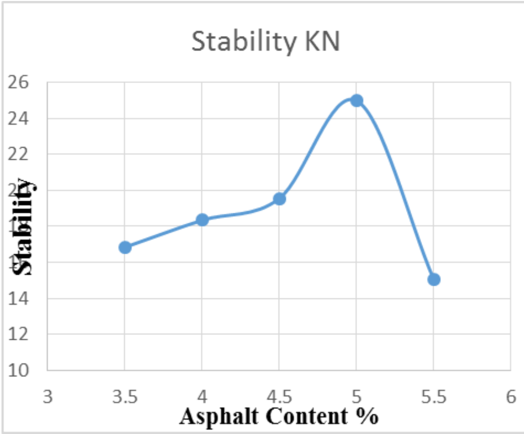

Fig. 1: Determination of optimum Asphalt content

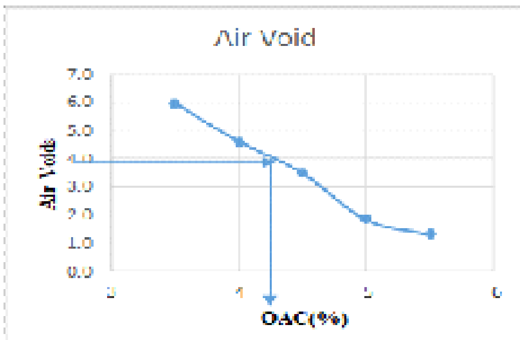

Fig. 2: The optimum asphalt content of Conventional samples was founded to be 4.30%

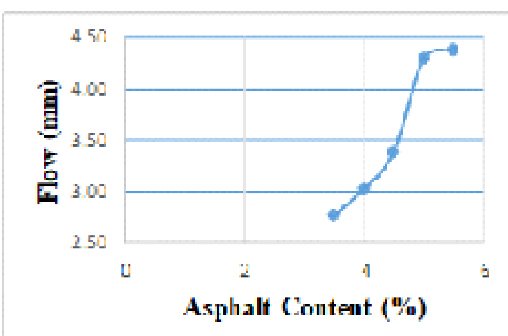

Fig. 3: Flow (mm) vs. Asphalt content

BD (%)	Gmb	Gmm	Aid Void(%)	VMA (%)	VFA (%)
5	2.3	2.5	8.11	12.13	46.56
5.5	2.3	2.5	8.11	15.72	62.27
6	2.3	2.44	5.78	17.55	90.7
6.5	2.31	2.44	5.41	19.76	76.94
7	2.35	2.47	5.01	21.73	73.8
7.5	2.35	2.46	4.7	23.89	68.34
8	2.41	2.5	3.68	26.32	92.15
8.5	2.43	2.5	2.96	26.32	92.15
9	2.48	2.48	0.32	26.31	92.15

TABLE 7: Final results

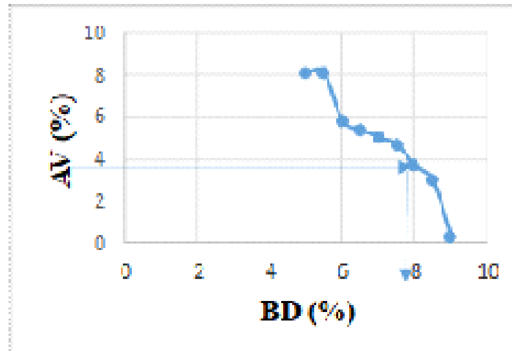

Fig. 4: Brick dust vs. Air Voids

BD (%)	Gmb	Gmm	Aid Void(%)	VMA (%)	VFA (%)
5	2.3	2.46	6.61	11.43	49.79
5.5	2.31	2.46	6.28	14.29	55.26
6	2.4	2.54	5.61	17.6	62.79
6.5	2.43	2.54	4.41	19.6	96.9
7	2.4	2.5	4.06	19.67	81.99
7.5	2.35	2.42	3.24	24.18	73.14
8	2.41	2.48	2.99	27.47	79.05
8.5	2.41	2.48	2.97	27.47	79.05
9	2.45	2.52	2.8	27.47	79.05

TABLE 8: Final results of fly ash

quantity of FA is increasing the AV are decreasing.

5 Conclusion

The optimum amount of Fly Ash was found to be 7%. By the addition of 7%, FA has shown an improvement of 31.60% in dry condition. The Gmm value was found to be 2.50 and the Gmb was found to be 2.40. So it was satisfying the condition that Gmm should be greater than Gmb. The value of flow against 7% FA was 4.50 (mm) which was within the specified criteria. The volumetric properties like Voids Mineral aggregate and voids fillers aggregate 19.67% and 81.99%. The optimum amount of stone dust (SD) was found

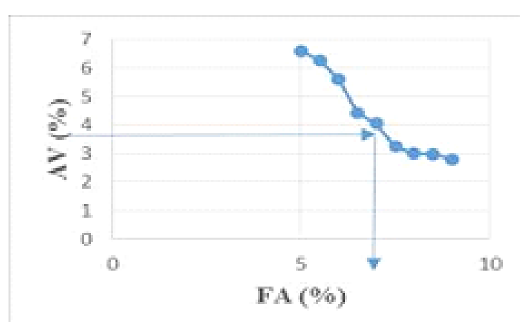

Fig. 5: Fly Ash Vs Air Voids

BD (%)	Gmb	Gmm	Aid Void(%)	VMA (%)	VFA (%)
5	2.3	2.63	9.31	12.88	43.45
5.5	2.34	2.52	7.33	16.17	92.16
6	2.35	2.51	6.38	17.73	87.65
6.5	2.36	2.51	6.34	18.94	101.05
7	2.4	2.52	5.02	21.16	94.81
7.5	2.38	2.47	3.65	22.85	142.2
8	2.45	2.52	2.78	25.41	87.9
8.5	2.45	2.51	2.56	27.41	87.9
9	2.47	2.52	2.16	25.41	87.9

TABLE 9: Final results of stone dust

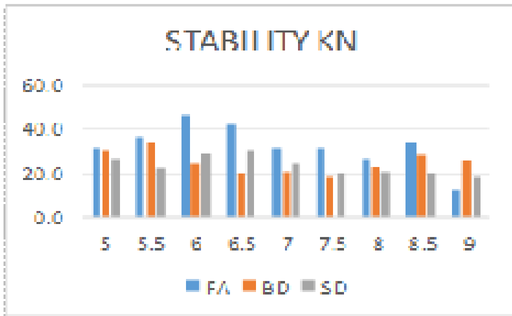

Fig. 6: Stability analysis

to be 7.5%. By the addition of 6.5%, SD has shown an improvement of 20% in dry conditions. The Gmm value was found to be 2.47 and the Gmb was found to be 2.38. So it was satisfying the condition that Gmm should be greater than Gmb. The value of flow against 7.5% SD was 3.4 (mm) which was within the specified criteria. The volumetric properties like Voids Mineral aggregate and voids fillers aggregate 22.85% which was exceeding and 142.05%. The VFA and VMA have exceeded the specified criterion. The optimum amount of Brick dust (BD) was found to be 7.8%. By the addition of 7.8%, BD has shown an improvement of 29.25% in dry conditions. But below 5.5% BD reduces stability. The Gmm value was found to be 2.48 and the Gmb was found to be 2.38. So it was satisfying the condition that Gmm should be greater than Gmb. The value of flow against 7.8% BD was 4.10 (mm) which was within the specified criteria. The volumetric properties like Voids Mineral aggregate and voids fillers aggregate 25.10% and 80.24%. The value of VMA is increasing from the specified criterion. From the above conclusions, the addition of 7% FA is recommended to be the best mineral filler and has shown the better performance of the HMA.

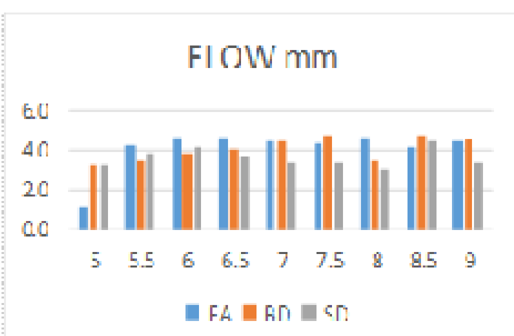

Fig. 7: Flow analysis

6 Recommendations

The stability and the performance of HMA can be improved by using FA as a mineral filler. The waste FA can be easily available from the factories so it can be used as a modifier in HMA which decreases the reconstruction and maintenance budget of the total economy in developing countries like Pakistan. At presently no proper specifications are available for such areas where the temperature, moisture, and loading related distress are more than a required level. For such areas, FA is recommended strongly. Mixing of mineral fillers can be done by two processes, one is to reduce the amount of the AC and the other is to add the mineral fillers by reducing the percentages of fine in a specified gradation. SD and BD have the ability to absorb the bitumen up to some extent which affects the binding properties of HMA. Further research work can be carried out in this area. By the chemical analysis of the FA, it has some of the same ingredients that are also found in bitumen. More focus is required to enhance the properties of FA. Repeated load of the heavy traffic has an adverse effect on the stability and other volumetric properties, therefore, a further study is required in order to modify the HMA using mineral fillers at economical and a reasonable cost. The stability of modified HMA by mineral fillers especially using FA may be studied further for the betterment of the road networks.

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