JISSE

ISSN: 2636-4425

Journal of International Society for Science and Engineering

Vol. 4, No. 2, 40-48 (2022)

JISSE

E-ISSN:2682-3438

Stability and Volumetric Properties of Hot – Mixes Asphalt (HMA) Using Marble Powder Waste

Mahmoud Abd Elhakem Eissa[1]*, Ahmed Osama Mashaly[2], Basel Nour El Din Shalaby[2], Abdelaziz Lotfy Abdeldayem[1], Gamal Eldin Said Mosa[1]

[1] *Geology Department, Faculty of Science, Tanta University, Tanta, Egypt - P.O. 315271*

[2] *Geological Sciences Department, National Research Centre, 33 El Bohooth st. (former El Tahrir st.) – Dokki - Giza - Egypt - P.O. 12622*

A R T I C L E I N F O

Article history:
Received:12-05-2022
Accepted:31-07-2022
Online: 31-07-2022

Keywords:
Hot - Mix Asphalt
Marble Powder Waste
Filler;
Volumetric properties; Marshall Stability

A B S T R A C T

The current study aims to evaluate the performance of hot -mix asphalt (HMA) in terms of physical and mechanical properties using marble powder waste (MPW) as a substituting material for bag-house mineral filler. The marble waste is the by-product of the sawing and polishing processes of marble blocks that represent about 25-30% of the block volume. These wastes were characterized in terms of chemical composition, particle size distribution, and specific surface area using X-ray fluorescence (XRF), BT, and BET; respectively. The abovementioned objective, was achieved by preparing five asphalt mixes according to Marshal Mix Design procedure using 0% (control mix), 25%, 50%, 75%, and 100% marble powder substituting for bag-house mineral filler. The prepared mixes were subjected to Marshall stability and flow, bulk specific gravity (Gmb), air voids (Va), void in mineral aggregates (VMA), and void filled with asphalt (VFA), and loss of stability (LOS). The results showed an increase in the stability while a drastically decreasing in loss of stability with increasing the marble waste. Moreover, the results of flow, air voids, voids of mineral aggregate, and voids filled with asphalt achieved the requirements of the Egyptian Code of Practice specification (ECP) for binder mix.

1. Introduction

The filling materials are the main constituents in the hot - mixes asphalt (HMA) that affecting the stability and durability performance of pavement especially its resistance to moisture susceptibility [1].

Mineral fillers serve as a portion of the mineral aggregate in a hot mix asphalt; therefore, they affect the load-carrying capacity and stability of the mix. The mineral fillers are used to increase the fine aggregate ratio, thus reducing the void ratio, and increasing the resistance of mix to plastic deformation such as rutting, fatigue cracks and moisture failures under high temperature conditions [2].

The most common and conventional filler materials used in the bituminous mixtures are lime and Portland cement. Other materials such as slaked lime, fly ash, blast furnace slag, silica fume, marble dust, limestone, and granite have been used in bituminous hot mixtures as mineral filler [2].

The reusing of industrial wastes as mineral fillers in bituminous hot mixtures was studied by many researchers such as:

Aljassar et al., (2004) [1] studied the effect of both ordinary Portland cement and pulverized limestone up to 6% by weight of aggregates on the strength of asphalt mixes. They found an insignificant effect on Marshall stability, however at 6% a decrease and an increase in Marshall stability were observed using ordinary Portland cement and pulverized limestone; respectively.

Karasahin and Terzi, (2007) [3] used marble dust resulting from the shaping process of marble blocks as a filler material in the asphalt concrete mixes. They observed a reduction in the plastic deformations by increasing the filler/bitumen ratio up to 7% filler, which increases afterward. They recommended that the asphalt mixtures containing marble dust could be used for low volume roads such as secondary roads and local roads.

Othman (2009), [4] investigated the effect of using white cement dust as a filler up to 30% of mineral filler on the mechanical performance of asphalt mixtures. The results revealed

* Mahmoud A. Eissa, Geology Depart., Faculty of Science, Tanta University, Tanta, Egypt, +201018162030, mahmoudhakim2@yahoo.com

an improvement in the Marshall stability, tensile strength, compressive strength, and unit weight of the mix, while a decrease in flow, VMA, and VTM with increasing the cement dust content.

Akbulut et al., (2012) [2] investigated the effect of granite sludge resulting from the purification of water in the cutting and polishing of rocks as mineral filler in bituminous hot mixtures. They found that the engineering properties of bituminous hot mixtures of wearing courses were improved using granite sludge as filler with an optimum ratio of 7.3%.

Abed and Eyada, (2012) [5] investigated the use of Sulaimania Marble Waste as filler in Hot Mix Asphalt Concrete. They observed an increase in both Marshall stability, air voids and flow, while a decrease in the density of mix with increasing marble waste. A high indirect tensile strength values were also observed which indicate a good cohesion effect of the mix.

Tomar et al., (2013) [6] studied the influence of brick dust and silica fume as non-conventional fillers in bitumen paving mixes. The results revealed similar and satisfactory Marshall properties to the conventional fillers such as cement and lime. The maximum stability and bulk density were observed at 6.5 and 6% binder content for brick dust and silica fume respectively.

Chandra and Choudhary, (2013) [7] studied the possibility of using industrial wastes such as marble and granite dust as filler materials in bituminous concrete mixes. They observed an enhancement in the rutting life of the bituminous mixes including granite and marble dust by 40% compared with conventional stone dust filler. The bituminous mix with marble dust demonstrated an enhancement toward fatigue life by 50–70% compared with conventional stone dust. Similarly, using up to 5.5 granite dust enhanced the fatigue life by 15–20%.

Sutradhar et al., (2015) [8] observed an enhancement in the Marshall stabilities of the bituminous concretes using waste concrete dust and brick dust as filler materials comparing to the conventional stone powder filler.

Shafi - Ullah et al., (2017) [9] studied the usage of marble waste substituting for stone dust as filler material in wearing course of bituminous roads. The results revealed an improvement in the Marshall properties in terms of Marshall stability and flow and indirect tensile strength upon using waste marble dust compared to the conventional stone dust.

Alkam et al., (2019) [10] used marble waste as filler material in asphalt wearing course and found an improvement in Marshall Stability performance up to 25% marble waste. Moreover, an improvement in the durability performance up to 48 h hot water immersion compared to the traditional stone filler.

Yohannes et al., (2020) [11] studied the effect of natural sub-base dust as alternative filler material in hot asphalt mixtures. They observed an improvement in the Marshall properties of the asphalt mixture with an optimum filler content of 6%.

This study aims to re-use marble waste generating from the processing operation of ornamental stones, substituting for bag-house conventional filler as filler material in the binder course for economic and technical purposes of asphalt concrete. The Experimental program was conducted to compare marble waste-modified mixes with conventional filler material.

2. Materials

The materials used in this study are bitumen, fine and coarse aggregates, filler, and marble powder wastes.

The asphalt binder (bitumen) is supplied by the local Bitumen Supply Company and is classified as 60–70 penetration grade. The physical properties of bitumen such as specific gravity, softening point, and flash and firing point are shown in Table 1.

Table 1: Test results of bituminous binder

Test	ASTM Specification	Results	ASTM specifications limits
Penetration at (0.01 mm)	(D5) **[Error! Reference**	67.60	60-70 (60/70 binder grade)
Ductility (cm)	(D113) **[Error!**	146.60	Min 100
Softening point (°C)	(D36) **[Error!**	50.5	(45 – 52)
Flashpoint (°C)	(D92) **[Error! Reference source not**	265	Min 250°C
Fire point (°C)		266	--
Specific gravity (g/cm3)	(D70) **[Error!**	1.023	1.00-1.05

The fine and coarse aggregates are of granite-based rocks and were obtained from local quarries. The aggregates are of several grades: 3/4", 1/2", and crushed sand (CS). The physical properties of these grades are given in Table 2 and the sieve analysis according to (ASTM C 136) [12] is plotted in Figure 1.

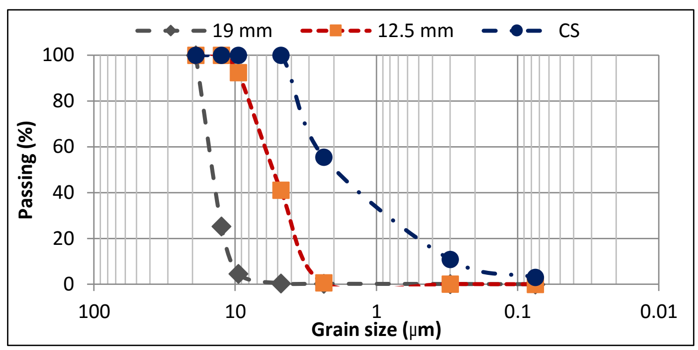


Figure 1: Sieve analysis of aggregates

The filler used in this study is called “Bag-house fines” (BH), which is separated as airborne particles from the gas stream on a bag-like filter. The specific gravity and plasticity index were determined and given in Table 2, while the grain size distribution is shown in Figure 2.

Marble powder waste (MWP) is a fine material in the form of sludge cake generated from the cutting and shaping processes of marble blocks and tiles. The physical properties and chemical composition are obtained and presented in Table 3. The grain size distribution is presented in Figure 2.

Table 2: Physical properties of aggregates and filler

Test	3/4"	1/2"	CS	BH	ASTM	Specification limits
Bulk Sp.gr. (OD)	2.792	2.771	2.703	2.624	C127 **Error! Reference source not found.**]	
Bulk Sp.gr. (SSD)	2.818	2.805	2.747	-		
Apparent Sp.gr.	2.866	2.870	2.827	-		
Water Absorption (%)	0.93	1.25	1.62	-	C128 [**Error! Reference**	< 5
Abrasion, (%)	21	22	-	-	C131 [**Error!**	< 40
Plasticity Index	--	--	NP	NP	D4318 [**Error!**	---

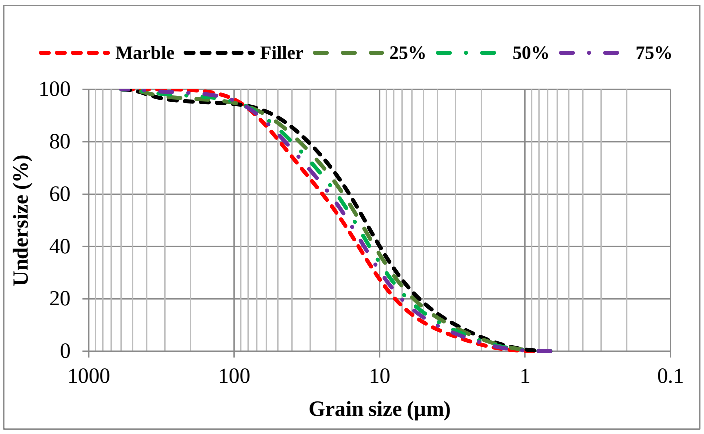


Figure 2: Particle size distribution of marble powder waste and bag-house **filler**

Table 3: Chemical analysis and physical properties of marble powder wastes and Bag-house filler

Oxide	MPW	BH	Physical properties		MPW	BH
SiO_2	2.52	74.71	Particle size distribution, μm	D10:	4.61	2.98
Al_2O_3	0.78	11.84		D25:	9.12	6.52
Fe_2O_3	0.55	2.16		D50:	19.1	12.4
MgO	0.25	0.13		D75:	41.15	25.91
CaO	53.21	1.01		D90:	70.77	52.85
Na_2O	0.20	2.09	Specific gravity, ASTM D 854 [Error! Reference		2.731	2.671
K_2O	0.05	4.06	Surface area, BET, m^2/g		0.162	0.200
SO_3	0.14	0.08				
P_2O_5	0.46	0.02				
TiO_2	0.06	0.08				
LOI	41.55	3.53				

3. *Experimental Program*

3.1. Aggregate Blend Design:

The preparation of the hot - mixes asphalt begins with selecting the suitable proportions of aggregate gradations to obtain the binder course gradation curve. The final proportions of each aggregate size as well as the combined gradation of the final aggregate mix satisfying to (ASTM D3515) [**Error! Reference source not found.**] for the nominal maximum aggregate size of 19.5 mm, are presented in Table 4 and shown in Figure 3.

Table 4: Aggregate size proportions and combined aggregate mix

Materials	Aggregate # 1		Aggregate # 2		Aggregate # 3		Filler		Combined	Specification Limits ASTM D 3515 / D-4	
	3/4"		1/2"		Crushed Sand						
Proportions	14%		35%		47%		4%		100%		
Sieve size, mm	% Passing	% Batch	% Passing	% Batch	% Passing	% Batch	% Passing	% Batch	JMF	MIN	MAX
25.0 mm	100	14	100	35.0	100	47.0	100	4	100	100	100
19.0 mm	100	14	100	35.0	100	47.0	100	4	100	90	100
9.5 mm	4.6	0.6	41.1	14.4	100	47.0	100	4	66.0	56	80
4.75 mm	0.2	0.1	0.6	0.2	98.1	46.1	100	4	50.3	35	65
2.36 mm	0.1	0.0	0.1	0.0	55.5	26.1	100	4	30.1	23	49
0.3 mm	0.1	0.0	0.1	0.0	10.8	5.1	97.7	3.9	9.0	5	19
0.075 mm	0.1	0.0	0.1	0.0	3.1	1.5	66.0	2.6	4.1	2.0	8.0

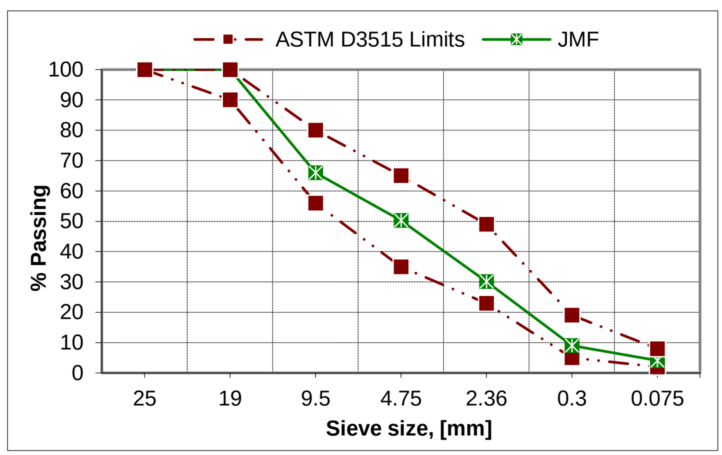


Figure 3: Design gradation for combined aggregate

3.2. Optimum Asphalt Content (OAC) and Marshal Design:

After selecting the suitable aggregate gradation, marshal design tests are performed to determine the optimum asphalt content for different aggregate mixtures. The determination of optimum asphalt content (OAC) requires series of test specimens with a range of different AC contents so that the test data curves show a well-defined optimum value.

The marshal method for (OAC) determination requires the preparation of hot mix asphalt samples of 10 cm in diameter and 6.5 cm high. The preparation procedure involves the preheating of aggregates and bitumen to 165 °C before mixing. Fifteen samples of 1200 g weight each were prepared using five different bitumen contents (from 4 - 6% with 0.5 % incremental) and subjected to 75-blow for each face according to (AASHTO T 245-08) [24] as shown in Figure 4-a.

After the preparation of asphalt molds with different bitumen contents, the compacted specimens were subjected to several tests such as bulk specific gravity (Gmb) (AASHTO T 166-02) [25], Marshall stability and flow (AASHTO T 245-08) [24], Air voids (Va) (ASTM D3203/D3203M) [26], voids in mineral aggregates (VMA), voids filled with asphalt (VFA) to obtain optimum asphalt content (Table 5). For the Marshall stability and flow test, the compacted specimens were firstly soaked in a 60°C water bath for 30 min and then placed in the loading device with a constant applied load rate (2 in/min) until the failure occurs Figure 4-b.

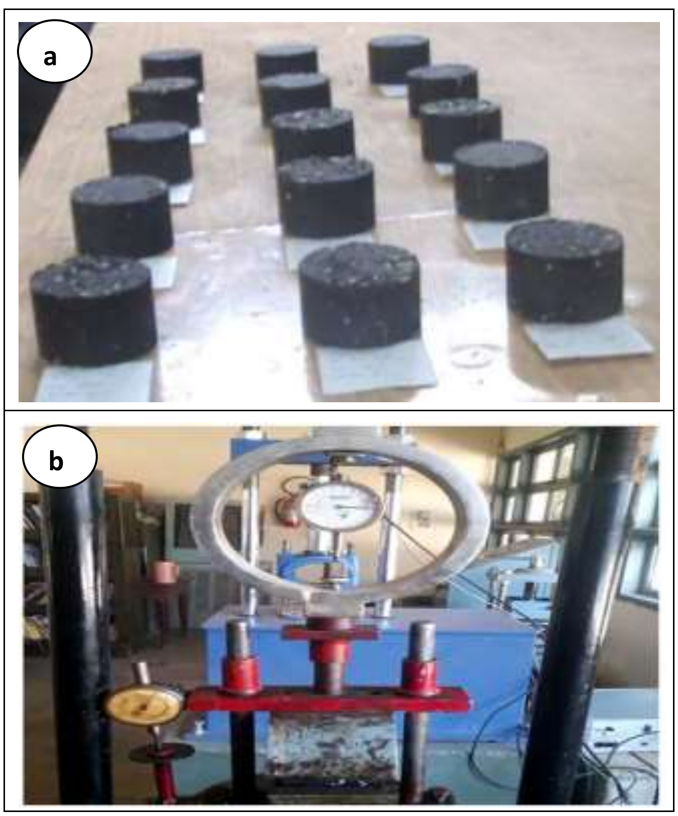
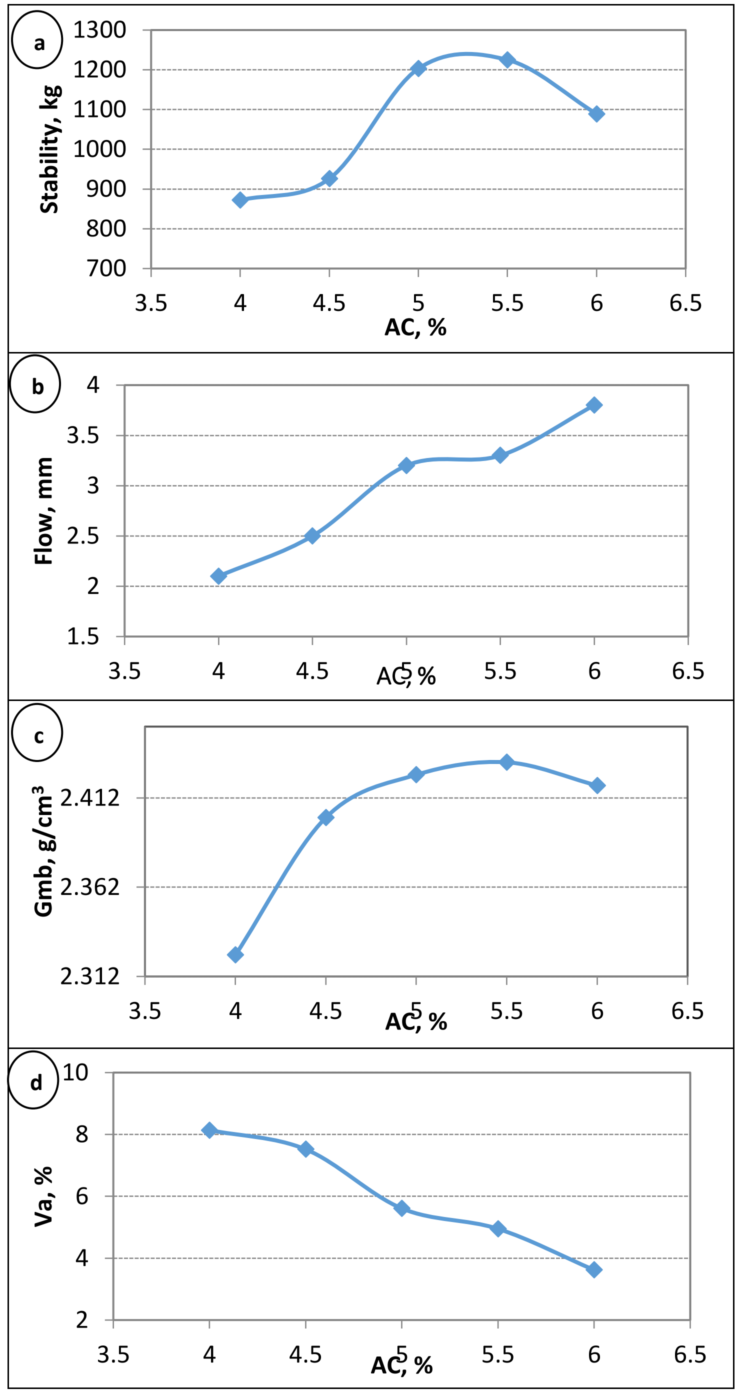


Figure 4: a) Marshall specimens for different bitumen proportions, b) Marshall loading device

Table 5: Marshall Summary of Marshall test results

AC %, total wt.	Stability (Kg)	Flow (mm)	Bulk Density (gm/cm^3)	Va (%)	VMA (%)	VFA (%)
4	872	2.1	2.324	8.14	16..88	51.80
4.5	926	2.5	2.401	7.52	16.84	55.14
5	1203	3.2	2.425	5.61	16.10	65.18
5.5	1225	3.3	2.432	4.95	15.52	68.56
6	1089	3.8	2.419	3.62	17.38	79.12



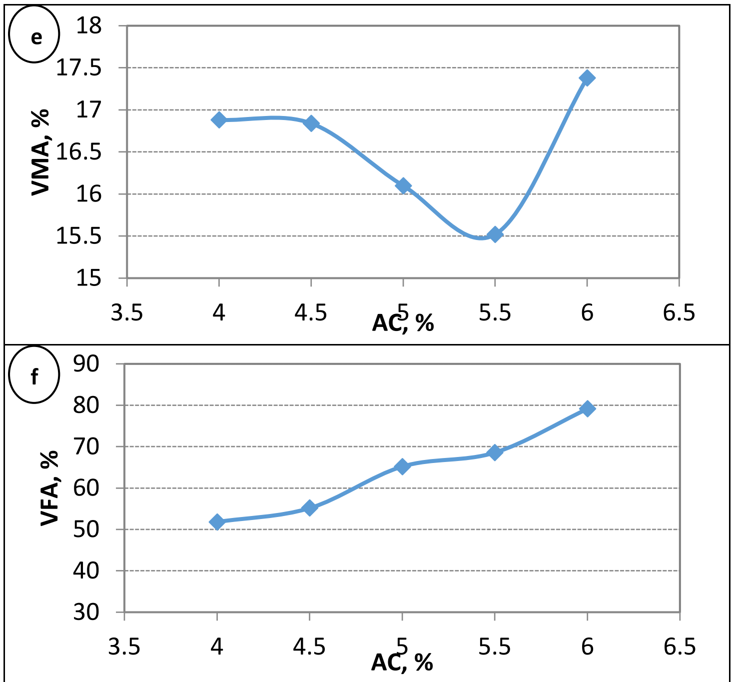


Figure 5: Relationship between different asphalt content and (a) Marshall stability, (b) Marshall flow, (c) Bulk density (Gmb), (d) air voids, (e) voids filled with asphalt (VFA), (f) voids of mineral aggregates (VMA)

From the plotted curves, the optimum asphalt content (OAC) was determined that corresponding to the maximum stability value; the maximum bulk specific gravity value; the air voids at median limits of (3–8%) (ECP No. 104, 2008) [27]. The optimum asphalt content is then determined by calculating the arithmetic mean of the previous three values as follows:

Bitumen content at the maximum stability is 5.4 %............(1)

Bitumen content at the highest the maximum value of bulk density is 5.5 %......(2)

Bitumen content at the median percent of air voids is 4.8 %.... (3)

Optimum asphalt content (OAC) = 5.2 %

As shown in Figure 5, it was observed that the properties of hot mix asphalt (HMA) at 5.2% asphalt content are consistence with the ECP (Egyptian Code of Practice) for binder course as given in Table 6.

Table 6: Properties of the asphalt mix at 5.2% bitumen content

Property	Value	Egyptian Code for binder mix	
		Min.	Max.
Marshall Stability, (kg)	1200	700	---
Marshall Flow, (mm)	3.2	2	4
Air voids, (%)	5.2	3	8
Voids in mineral aggregates (VMA), (%)	16.1	15	---
Voids filled with asphalt (VFA), %	65.2	65	75

3.3. Preparation of asphalt mixes modified with marble powder waste (MPW):

The value of the optimum bitumen is used to prepare asphalt mixes modified with various percentages of marble powder waste (MPW) substituting for mineral filler.

After obtaining the optimum asphalt content (OAC), 15 asphalt mixtures of 1200 g weigh each were prepared using five proportions of marble powder waste (3 specimens for each MPW proportion) ranging from 0%, 25%, 50%, 75%, and 100% (Table 7) as a filling material substituting for the ordinary mineral filler (Baghouse fine "BH").

3.4. Mechanical and volumetric properties of the modified asphalt mixtures:

The prepared mixes were compacted using Marshall Method in the form of cylindrical molds of dimensions (10 cm Ø x 6.5 cm H), to investigate the effect of MPW on the mechanical (Marshall Stability and flow) and the volumetric properties of the asphalt mixture.

Table 7: Asphalt concrete mixtures modified with various proportions of MPW

	Materials					
	Aggregates, %			Filler (%)		OAC, %
Size fraction / Mix code	19 mm	12.5 mm	CS	BH	MPW	
Control	14	35	47	4	0	5.2
MPW/25	14	35	47	3	1 (25%)	5.2
MPW/50	14	35	47	2	2 (50%)	5.2
MPW/75	14	35	47	1	3 (75%)	5.2
MPW/100	14	35	47	0	4 100%)	5.2

3.5. Moisture Susceptibility:

The resistance of the asphalt concrete mixtures to moisture damage is one of the most important properties that measure the loss of cohesion resulting from the action of water on the compacted bitumen-aggregate mixtures. This property was conducted in accordance with (AASHTO T 165-02) [28]. The compacted modified asphalt mixtures were separated into two groups: the first group (dry) was stored in an air bath at 25°C for 4 hours, while the second group (submerged) was submerged in a water bath at 60°C for 24 hours then transferred to a water bath at 25°C for 2 hours. The samples of both groups were tested for compressive strength according to (AASHTO T 167-05) [29].

The index of retained strength (I.R.S) was calculated as percentage of the average strength of the second group of specimens (submerged) to the average stability for the first group (dry) as follows according to (AASHTO T 165-02) [28]:

Index of retained strength (I.R.S), % =

(Strength of Submerged Specimens (Group 2)) / (Strength of Dry Specimens (Group 1)) x 100 ……………………………. (1)

Loss of Stability (L.O.S), %= 1 – I.R.S ………………..…. (2)

4. *Results and Discussion*

The laboratory work in the present study is divided into three steps. The first step or aggregates blend design to obtain the optimum gradation curve, while the second step, aims at obtaining the optimum asphalt content (OAC) that achieving the maximum stability and density. The third step, which is the aim of the present work, is to study the effect of marble powder waste (MPW) as a mineral filler material substituting for Bag-house filler, on the volumetric and mechanical properties of asphalt mix as follows:

4.1. *Effect of MPW on the Marshall properties of the compacted asphalt mixtures:*

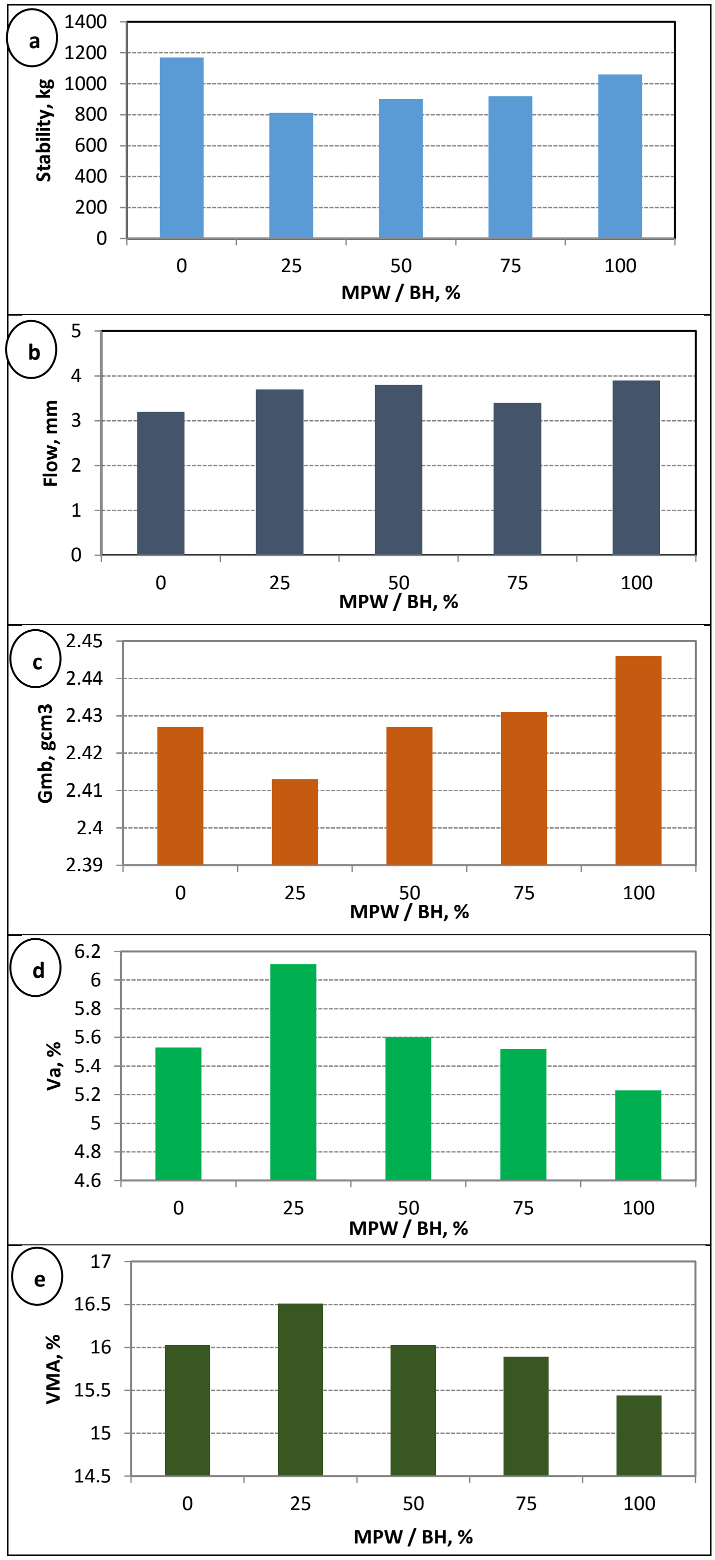
The Marshall Properties (mechanical and volumetric) of the compacted asphalt mixtures modified with different proportions of marble powder waste (MPW) substituting for "Bag-House" mineral filler at optimum asphalt content (OAC) of 5.2% are summarized in Table 8 and graphically plotted in Figures. 6–8.

Table 8: Marshall Properties of compacted asphalt mixtures modified with MPW

Mix code	Marshall Stability (kg)	Flow (mm)	Maximum theoretical specific gravity, Gmm	Bulk Density (g/cm^3)	Va (%)	(VMA) (%)	(VFA) (%)
Control	1226	3.2	2.569	2.427	5.53	16.03	65.52
MPW/25	762	3.7	2.570	2.413	6.11	16.51	63.01
MPW/50	866	3.8	2.571	2.427	5.60	16.03	65.03
MPW/75	871	3.2	2.573	2.431	5.52	15.89	65.27
MPW/100	1026	3.9	2.581	2.446	.23	5.44	5.97
Egyptian Code No. 104, 2008	≥ 700	2 -4	---	---	3 - 8	≥ 15	65 - 75

4.1.1. *Relationship between Marshall Stability versus MPW content:*

Marshall Stability is one of the most important properties of hot mix asphalts (Akbulut and Gürer, 2007) [30]. It is the resistance of hot mix asphalt to the continuous dynamic loads with the long-term effects of static loads caused by vehicles, compression, tension, and shear forces that occur under accelerating or decelerating wheel effects (Gürer and Selman, 2016) [31]. As given in Table 8, the stability values with all replacement levels of MPW content complied with the specification limits according to Egyptian code (ECP No. 104, 2008) [27] (≥ 700 kg). As shown in Figure 6-a, the stability of the marble powder - modified asphalt mix increases with increasing marble powder content, which ranges from 762 kg (at 25% MPW) to 1026 kg (100 %), however, it is lower than that of the control asphalt mix (1226 kg). The reduction in the stability of the marble powder-modified asphalt mixes compared to the control asphalt mix may be due to the coarser grain size of marble waste compared to the bag-house filler resulting in a reduction in asphalt film thickness.



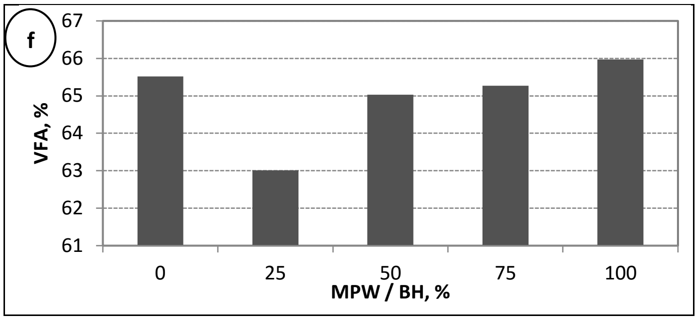


Figure 6: Relationship between MPW/BH ratio and (a) stability, (b) flow, (c) Gmb, (d) Va, (e) VMA, (f) VFA

4.1.2. Relationship between Flow versus MPW content:

The values of Marshall Flow give an idea of the plasticity and flexibility of the hot mix asphalt (Gürer and Selman, 2016) [31].

As shown in Figure 6-b, the values of Marshall flow increase continuously as the marble powder content increases. The flow values range from 3.7 mm (at 25% MPW) to 3.9 mm (at 100% MPW) which complied with Egyptian specification limits (ECP No., 2008) (2 – 4 mm) (Table 8). The increase in the Marshall flow with increasing the content of marble powder compared to the control mix may be due to the decrease of the cohesion between the mix components as a result of the air voids increase.

4.1.3. Relationship between Bulk specific gravity (Gmb) versus MPW content:

As shown in Figure 6-c, the bulk density of modified hot mix asphalt increases with increasing the marble powder content. It was found that the bulk density of modified asphalt mix ranges from 2.413 g/cm3 (at 25% MPW) to 2.446 g/cm3 (at 100% MPW). This means that the bulk density at 75% (2.431 g/cm3) and 100% (2.446 g/cm3) MPW addition is higher than that of the control mix (2.427 g/cm3). This increase in bulk density can be attributed to the higher specific gravity of the marble powder waste (2.731) more than Bag-house fines (2.671) as given in Tables 2-3.

4.1.4. Relationship between Air voids (Va) versus MPW content:

Figure 6-d shows that the proportion of air voids of modified asphalt mixes decreases gradually as the MPW content increases. Such decrease in the air voids may be attributed to the grain size of the marble waste, which is coarser than that of BH filler. The results of air voids ranged between 6.11 % (at 25% MPW) to 5.23% (at 100% MPW) which satisfy the ECP specification limits [27] for dense graded hot mix asphalt for binder course in the range of 3 - 8%.

4.1.5. Relationship between Voids in Mineral Aggregates (VMA) versus MPW content:

The percentage of voids in mineral aggregates is an important parameter for the interlocking of aggregates as well as durability (Akbulut et al., 2012) [2]. As shown in Figure 6-e, it is noticed that the VMA % of modified asphalt mixes decreases with increasing the content of marble powder up to a minimum value 15.44% at an MPW content of 100%. The initial increase in VMA at 25% MPW substituting for BH may be caused due to the increase in voids ratio.

According to the results of VMA, it was found that the prepared asphalt mixes with different proportions of MPW satisfy the requirement of ECP Specification of a minimum VMA value of 14% for the nominal maximum aggregate size of 19 mm.

4.1.6. Relationship between Voids filled with Asphalt (VFA) versus MPW content:

Voids Filled with Asphalt control the plasticity, durability, and friction coefficient of the mixtures and provide a final asphalt coating around the aggregate particles (Gürer and Selman, 2016) [31].

The relationship between MPW and VFA was shown in Figure 6-f. It was observed that the values of VFA increase with increasing replacement ratio of marble powder waste. This increase may be attributed to the decrease in Va as well as the decrease in VMA. The highest value of VFA was recorded as 65.97% in the asphalt mixture including 100% MPW, while the lowest value was recorded as 63.01% in the asphalt mixture including 25% MPW. It was noticed that the values of VFA for all replacement ratios fall within the range of 65 - 75% that satisfy the standard specification limits of ECP.

4.1.7. Moisture Sensitivity

Table 9 shows the decrease in Marshall Loss of Stability (L.O.S) with increasing the MPW replacement ratio. This may be due to the increase of VFA resulting in a reduction in air voids providing good adhesion between bitumen and aggregate causing reduction in stripping of aggregate. The highest value of LOS was recorded at 25% MPW replacement by 24.66%, while the lowest value was recorded at 100% MPW by 11.13%, which satisfy the requirement of ECP [27] (25% max.). Fig 7 shows the relationship between the loss in Marshall Stability and different ratios of marble powder waste

Table 9: Effect of MPW addition on the Marshall stability index

Mix code	Stability		Index of retained strength	Loss of Marshall Stability
	Dry Group	Submerged Group		
Control	1169	953	81.52	18.48
MPW/25	811	611	75.34	24.66
MPW/50	901	700	77.69	22.31
MPW/75	920	761	82.72	17.28
MPW/100	1060	942	88.87	11.13

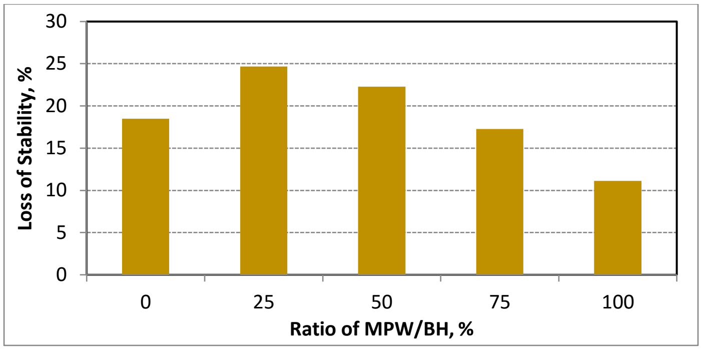


Figure 7: Loss of stability for control and modified specimens

5. Conclusion

The present work aimed to study the effect of marble powder waste as mineral filler on the volumetric properties and stability of hot mix asphalt as follows:

- An improvement in Marshall Stability with increasing the marble powder waste ratio that ranges from 762 kg (at 25% MPW) to 1026 kg (100 %).
- An increase in bulk density (Gmb) ranging from 2.413 g/cm3 (at 25% MPW) to 2.446 g/cm3 (at 100% MPW).
- An enhancement in Marshall flow with increasing the ratio of MPW ranging from 3.7 mm (at 25% MPW) to 3.9 mm (at 100% MPW).
- An increase in VFA values with increasing the ratio of MPW and the highest value was recorded as 65.97% in the asphalt mixture including 100% MPW, while the lowest value was recorded 63.01% in the asphalt mixture including 25% MPW.
- A slight reduction in the air voids with increasing the MPW content, which ranges from 6.11 % (at 25% MPW) to 5.23% (at 100% MPW).
- The values of VMA decreased with increasing the marble powder waste ratio that ranging from 16.51% (at 25% MPW) to 15.44% % (at 100% MPW).
- A remarkable improvement in the results of stability loss was observed with increasing the MPW content, which ranges from 24.66% (at 25% MPW) to 11.13% (at 100% MPW).
- Overall, the results showed that all modified asphalt mixes with various proportions of MPW achieved acceptable values for all volumetric and mechanical properties according to the Egyptian code of practice (ECP) for the asphalt binder course.

Acknowledgment

The authors appreciate the assistances offered by the unit of Marble and Granite Testing lab (MGTL) at National Research Centre for conducting the analysis. Special thanks to my dear friend, Dr. Mohammed Rashwan for his efforts and helping me during all times of the work.

References

[1] Aljassar, A.H., Metwali, S., Ali, M.A., Effect of filler types on Marshall stability and retained strength of asphalt concrete. International Journal of Pavement Engineering, 5(1) (2004), pp. 47–51.

[2] Akbulut, H., Gürer, C., Çetin, S., Elmacı, A., Investigation of Using Granite Sludge as Filler in Bituminous Hot Mixtures, Construction and Building Materials 36(2012), pp, 430–436

[3] Karaşahin, M. Terzi, S., Evaluation of Marble Waste Dust in the Mixture of Asphaltic Concrete, Construction and Building Materials, 21 (2007), pp. 616–20.

[4] Othman, A.M., Incorporation of white cement dust on rubber modified asphalt concrete mixtures, International journal of civil & environmental engineering IJCEE, 9 (10) (2009), pp. 40-51.

[5] Abed, N.A., Eyada, S., The Use of Sulaimania Marble Waste to Improve The Properties of Hot Mix Asphalt Concrete, Anbar Journal for Engineering Sciences, (2012), pp. 139–151.

[6] Tomar, R., Jain, R.K., Kostha, M.K., Effect of Fillers On Bituminous Paving Mixes, International Journal of Engineering Research and Science & Technology 2(4) (2013), pp. 137–142

[7] Chandra, S. Choudhary, R., Performance Characteristics of Bituminous Concrete with Industrial Wastes as Filler, Journal of materials in civil engineering 25(11) (2013), pp. 1666–1673

[8] Sutradhar, D., Miah, M., Chowdhury, G.J., Sobhan, M.A., Effect of Using Waste Material as Filler in Bituminous Mix Design, American Journal of Civil Engineering, 3 (3)(2015), pp. 88-94.

[9] Shafi - Ullah, Alam, M., Khan, R., Re-use of Marble Waste as Filler Substitute in Bituminous Roads, Journal of Engineering Research and Application 7(2017), pp.58-62

[10] Alkam, R.B., Said, L.B., Abd. Muin, S., Durability Performance of Asphalt Concrete Wearing Course Using Marble Waste as Filler, Journal of the Eastern Asia Society for Transportation Studies 13(2019), pp. 1571–1588

[11] Yohannes, B., Quezon, E.T., Tsegaye, M., Evaluation on the Potential Use of Pulverized Natural Subbase Dust as Alternative Filler Material for Hot Mix Asphalt Design, Jimma Town, American Journal of Civil Engineering and Architecture 8(2) (2020), pp. 62–77

[12] ASTM C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. American society for testing and materials, West Conshohocken, 2006. PA (USA).

[13] ASTM D5/D5M: Standard Test Method for Penetration of Bituminous Materials. American society for testing and materials, West Conshohocken, 2006. PA (USA).

[14] ASTM D113: Standard Test Method for Ductility of Bituminous Materials. Annual Book of Standards. American society for testing and materials, West Conshohocken, 2007. PA (USA).

[15] ASTM D36: Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus. American society for testing and materials, West Conshohocken, 1995. PA (USA).

[16] ASTM D92: Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester. American society for testing and materials, West Conshohocken, 2016. PA (USA).

[17] ASTM D70: Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method). American society for testing and materials, West Conshohocken, 2009. PA (USA).

[18] ASTM C127: Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate. American society for testing and materials, West Conshohocken, 2001. PA (USA).

[19] ASTM C854: Standard test methods for specific gravity of soil solids by water pycnometer. American society for testing and materials, West Conshohocken, 2002. PA (USA).

[20] ASTM C128: Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate. American society for testing and materials, West Conshohocken, 2001. PA (USA).

[21] ASTM C131: Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine. American society for testing and materials, West Conshohocken, 2006. PA (USA).

[22] ASTM D4318: Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. American society for testing and materials, West Conshohocken, 2005. PA (USA).

[23] ASTM D3515: Standard Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures. American society for testing and materials, West Conshohocken, 2001. PA (USA).

[24] AASHTO T245: Standard Method of Test for Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus; American Association of State Highway and Transportation Officials: Washington, DC, 2008, USA.

[25] AASHTO T166: Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens; American Association of State Highway and Transportation Officials: Washington, DC, 2002, USA.

[26] ASTM D 3203: Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures. American society for testing and materials, West Conshohocken, 2011. PA (USA).

[27] ECP (Egyptian Code of Practice) Egyptian code of practice for urban and rural roads, edition 1: road materials and their tests (part four), Ministry of Housing, Utilities and Urban Communities, Cairo, (2008)

[28] AASHTO T165: Standard method of test for effect of water on cohesion of compacted Bituminous mixtures; American Association of State Highway and Transportation Officials: Washington, DC, 2002, USA.

[29] AASHTO T167: Standard Method of Test for Compressive Strength of Hot-Mix Asphalt; American Association of State Highway and Transportation Officials: Washington, DC, 2005, USA.

[30] Akbulut, H., Gurer, C., Use of aggregate produced from Marble Quarry Waste in asphalt pavements, Building and environment 42 (5) (2007) pp. 1921-1930

[31] Gurer, C., Selman, G., Investigation of properties of asphalt concrete containing Boron waste as mineral filler, Materials Science (Medziagotyra), 22(1) (2016), pp. 118-125