EVALUATION OF AGGREGATE AND MINERAL FILLER TYPES ON CHARACTERISTICS OF HOT MIX ASPHALT

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ABSTRACT

Aggregate properties can affect hot mix asphalt properties in different ways. Also, the filler plays an important role in asphalt mixtures behavior. This research represents a laboratory study of the effect of the aggregate type and mineral filler in hot mix asphalt (HMA). The aggregate types used in the mixtures were crushed limestone, crushed gravel and basalt. Two parameters were used to study the effect of the filler on HMA, the mineral filler type and content. Three types of mineral fillers used in the mix which were limestone powder, cement and hydrate limestone powder. The contents of fillers for this study were 4, 6 and 8%. Marshal tests and indirect tensile test were performed to investigate the difference in behaviors of different samples with different parameters that considered in this study. Also this study taking into account that the control mix contains crushed gravel, rough aggregate particles with medium gradation of aggregate and 4% of limestone powder as mineral filler. The results showed that, using basalt gives the highest values of each Marshall Stability, Marshall Stiffness, Marshall Quotient, Stiffness Modulus and the Indirect Tensile Strength of the mix than gravel and limestone. Unlike, using basalt gave the lowest values of each flow, density and air voids than gravel and limestone. The results also, showed that using of cement as mineral filler had good results than other types of mineral fillers and the mineral filler content in the mix shouldn’t increased than 4%.

Key words: HMA, Aggregate type, Mineral filler, and Indirect Tensile Strength.


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1. INTRODUCTION
Coarse aggregate is the material, which is substantially retained on No.4 sieve. Generally, the asphalt concrete mixture contains from 35-65 percent of coarse aggregate for a nominal maximum size of 19.0 mm. This content normally gives a suitable texture for a heavily trafficked road (ASTM, 2003). In (1970), Foster concluded that HMA mixtures containing crushed coarse aggregate showed no better performance than a mix containing uncrushed aggregates [1]. Aggregate type has a significant effect on the fatigue resistance and permanent deformation of asphalt mixtures [2]. Ahlrich also mentioned that HMA properties are highly affected by their aggregate characteristics [3]. Button et al have found nine possible factors cause rutting, but stated that the aggregate characteristics is the primary material quality factor influencing rut susceptibility [4]. Gandhi and Lytton investigated large number of aggregate tests and whether these tests can be used as indicators of performance of asphalt concrete mixes [5]. Additionally, Brown et al mentioned that Aggregate properties can affect mix properties in different ways. For example, if the aggregates used are weak they may disintegrated easily under the action of Marshall hammer during the mix design process. Consequently, fines and filler content in the mix are increased leading possibly, to a Marshall stability being higher than usual [6].

The filler plays an important role in asphalt mixtures behavior. The filler fills the voids between the coarse and fine aggregates in the mixtures and changes the asphalt binders properties, because it acts as an active part of the mastic. The mastic quality influences all the mechanical properties of asphalt mixtures, as well as workability. Resistances to compaction of bituminous mixes are affected by mix variables (filler content, binder content and type of asphalt binder) and the higher resistance of the mix to compaction leads to increasing its measured stiffness value and consequently better resistance to permanent deformation performance is expected in the pavement and increasing the percentage of fines in the mix leads to increase the measured stiffness of mix at a lower value of resistance to compaction [7]. Also, Mahesh al studied the suitability of used cement and hydrated lime as additives in the construction of bituminous concrete by different types of mixes were prepared for the study and found similar results [8]. Anderson et al stated that the importance of mineral filler fraction was often overlooked even though it is one of the most important components of HMA [9]. Mohammad et al concluded that the mineral filler had mostly increased the mixture stiffness [10]. Furthermore, Alijassar et al studied the effect of filler type (cement and lime stone) on the strength properties of asphalt mixes and they concluded that cement filler resulted higher values of retained strength [11]. Also, Hafeez and Kamal reported that the presence of high or low percentage of fillers affects design properties of HMA [12]. Asmael studied the effect of mineral filler type and content on properties of asphalt concrete mixes and found that Fly ash has less workability and less tensile strength of asphalt concrete mixtures when compared to other asphalt concrete mixes [13]. Mehari reported that for mixtures prepared with volcanic-cinder at higher filler contents (5% - 8%), higher optimum asphalt content values were required to fulfill the Marshal requirements and also, the bulk density increases up to some point and then decreases with increasing filler content in the mixture using crushed stone and volcanic-cinder [14]. Huang et al reported that filler content for mix design should be determined based on the overall performance of HMA mixture [15].

The objective of this study was to investigate the effect of the aggregate type and mineral filler in hot mix asphalt (HMA). The parameters studied in this pace of paper
were aggregate type, mineral filler type and mineral filler content. Marshal test and indirect tensile test were conducted to study the effect of these parameters on HMA.

2. EXPERIMENTAL WORK

Three types of aggregate (crushed gravel, crushed limestone and basalt) were used as a coarse aggregate, siliceous sand as a fine aggregate. Three types of mineral filler (limestone powder, cement and hydrate limestone) were used as mineral filler. Two different sizes of each type of coarse aggregate were used named S1 and S2. The gradation of the combined aggregate along with the specification limit is presented in Fig.1. The bulk specific gravities for each size (S1 and S2) of crushed gravel, crushed limestone and basalt were (2.628, 2.626), (2.56, 2.55) and (2.732, 2.71) respectively. The bulk specific gravity of fine aggregate was 2.634. The bulk specific gravity of limestone powder, cement and hydrate limestone were 2.652, 3.14 and 2.652 respectively. The Los Angeles abrasion of crushed gravel, crushed limestone and basalt were 25.3%, 27.46% and 14.3% respectively. The asphalt cement used was AC 60/70. This asphalt material, supplied by El-Suez is the usual asphalt grade used for asphalt pavement construction in Egypt. The specific gravity of asphalt cement used was 1.035.

The coarse aggregate, fine aggregate, mineral filler and asphalt cement were used to prepare the Marshal test specimens with 65 mm height and 101.6 mm diameter. The tested asphaltic concrete mixes for control mix were composed of 60% coarse aggregate, 36% fine aggregate, 4% mineral filler and asphalt cement. Five different asphalt contents (4, 4.5, 5, 6 and 7%) were used to prepare Marshal test specimens. Specimens were compacted with 50 blows on each side. Three samples were made for each asphalt content. The results of Marshal Design indicated that the optimum asphalt content for control mixtures was 5.3 %. The parameters studied in this research were aggregate types, mineral filler types and percent of mineral filler. Marshal test and indirect tensile test were conducted to study these parameters. For Marshal Test, Stability, flow, bulk density, void ratio and Marshal Quotient (MQ) were determined.

The Marshall Quotient (MQ) was determined using the following equation:

\[
MQ = \frac{\text{Stability}}{\text{Flow}} \quad [N/mm^2] \quad (1)
\]

For indirect tensile test, both Indirect Tensile Strength (ITS), strain at failure \((\xi_f)\) and Stiffness Modulus \((S_M)\) values were determined using the following equations:

\[
\text{ITS} = \frac{2P}{\pi \times h \times d} \quad [N/mm^2] \quad (2)
\]

\[
\xi_f = \frac{6.63U}{\pi d} \quad \% \quad (3)
\]

\[
S_M = \frac{0.573P}{h \times U} \quad [N/mm^2] \quad (4)
\]
3. RESULT AND DISCUSSION

3.1. Effect of Aggregate type on Marshall Test Results and Analysis

Figure (2) shows the test results of marshal stability of all type of aggregate (crushed gravel, crushed limestone and basalt). The results had clearly shown that basalt gave higher values of stability than crushed gravel and limestone respectively. This result may come up because basalt is one of the most powerful rocks as is evident from the loss Anglos test and its mix had high interlock between particles which made the mix able to resist the external loads.

Regarding the test results of flow for all type of aggregate (Figure, 3), it reveals that the flow value increased with using crushed limestone than crushed gravel and basalt respectively. This may come up because crushed limestone is a weak rock as shown in loss Anglos test and stability value. Basalt had the lowest value of flow that may come up because it is stiff rock as shown from its high value of stability. Also, the same trend of this result was noticed in he relationship between aggregate type and bulk density (figure, 4). That may come up because its good workability which let the specimen to compacted well while basalt had the lowest value because it's weak workability.

The results of air voids versus aggregate type (figure, 5) revealed that the crushed limestone had the lowest value of air voids followed by crushed gravel, followed by basalt. This result may be due to its good compaction as shown from its high bulk density than crushed gravel and basalt. Additionally, basalt had the highest value of VTM that may be because it was difficult to compact basalt mix.

Figure (6) represents the relationship between aggregate type and Marshal Stiffness Modulus (MS) which reveals that crushed limestone had the lowest value of MS than crushed gravel and basalt. This result might be due to the low stability and the high value of flow of limestone mix while basalt had the highest value of MS as it had high value of stability and low value of flow. Similarly to this result, Marshal Quotient (MQ) among different aggregate types had the same trend of result and this may come up because limestone mix had low stability and thus it had low resistance against the deformation of the asphalt concrete, while basalt had the highest value of MQ as it had high stability which made the mix had high ability to resist deformation, and that shown in Figure (7).

3.2. Effect of Mineral Filler Type on Marshall Test Results and Analysis

The test results of stability for different types of mineral filler (limestone powder, cement and hydrate limestone powder) are shown in figure (8). The results had clearly shown that cement gave higher values of stability than hydrate limestone powder and limestone powder respectively and this may be explained by that the cement mix had strong correlation between the particles and strong mix which able to resist loads. The mix which contains limestone powder as mineral filler had the lowest value of stability. For the results of flow for different types of mineral filler (figure, 9), the flow value increased with using hydrate lime stone powder than limestone powder and cement mineral filler respectively and this may be due to using Hydrate limestone powder as mineral filler which give the sample the relative flexibility.

As regard that relationships between mineral filler types and bulk density (figure, 10), The results indicated that the Hydrate limestone powder mix had the higher value of bulk density that may come up because its good workability which let the specimen to compacted well and the mix had overlap and a strong correlation between the
grains. Additionally, the limestone powder mix had the lowest value of density because it had more voids than others. For the results of air voids of different types of mineral filler (figure, 11), the results revealed that Hydrate limestone powder mix had the lower value of air voids than using both cement and limestone powder respectively. This may explained by the good compaction as shown from its high bulk density while the limestone powder mix had the highest value of VTM that may be resulted from its low value of density.

Figure (12) shows the Marshal Stiffness Modulus (MS) of different types of mineral fillers. The results revealed that cement mix had the highest value of MS than Hydrated limestone and limestone powder mixes respectively and this results may be obtained by high value of cement mix stability and the low flow value. Also, the same results was obtained in Marshal Quotient (MQ) among different mineral fillers (figure, 13) which may also due to that the cement mix had high value of stability and flow values. While, the limestone powder had the lowest value of MS that may come up because it had the low values of flow and stability.

3.3. Effect of Aggregate Type on Indirect Tensile Strength

Figure (14) shows the test results of indirect tensile strength (ITS) for the three studied types of aggregate. The results revealed that the indirect tensile strength value increased with using basalt than both crushed gravel and crushed limestone. This result may come up because basalt is one of the most powerful aggregate which gave its sample good internal resistance against external loads as is evident from the loss Anglos test and Marshal Stability value. Additionally, crushed limestone had the lowest value of ITS which may resulted from its low value of stability. The test results of stiffness modulus (SM) for all types of aggregate (figure, 15) revealed that using basalt had the higher value of stiffness modulus than the other two types and this result may be explained by that basalt had high value of indirect tensile strength and the lowest SM of crushed limestone may come up because its low value of ITS. The test results of failure strain for all types of aggregate were illustrated in figure (16), the failure strain value increased with using crushed limestone than both crushed gravel and basalt. It is clear from the results that crushed limestone mix had the highest value of failure strain this may come up because crushed limestone is a weak type of aggregate as shown in loss Anglos test and stability value.

3.4. Effect of Mineral Filler Type on Indirect Tensile Strength

The test results of indirect tensile strength for all types of mineral fillers are resented in (figure, 17). The results revealed that the indirect tensile strength value increased with using cement as mineral filler than using both hydrate limestone powder and limestone powder respectively. This result may come up because cement mixes had high interlock and internal friction between aggregate particles which give the mix good internal resistance against external loads as it noted from its high value of Marshal Stability. Unlike, limestone powder mixes do. The stiffness modulus value increased with using crushed gravel mix with limestone powder as a mineral filler than the other two types of fillers, this may be due to limestone powder mixes had the lowest value of failure strain although it had lowest value of ITS. Oppositely, the Hydrate Limestone powder mixes had the lowest value of stiffness modulus because it had the highest value of failure strain and low value of ITS (figure, 18). Regarding the effect of types of test mineral fillers on failure strain (figure, 19). It reveals that the failure strain value increased with using crushed gravel mix with Hydrate limestone powder as mineral filler than cement and limestone powder mixes respectively.
Hydrate limestone powder mixes had low internal resistance against horizontal deformation as it noted from its high value of Marshal Flow also limestone powder mixes had the lowest value of failure strain this may come up because limestone powder mixes had high internal resistance against horizontal deformation as it noted from its low value of Marshal Flow.

4. CONCLUSIONS

Based on the analysis of the experimental investigation, the following conclusions were drawn:

1. Marshall Stability, VTM and MQ were increased by using basalt than using crushed gravel and crushed limestone. Otherwise, the values of flow and bulk density were decreased by using basalt than using crushed gravel and crushed limestone.

2. The values of MS and MQ were higher by using cement as mineral filler comparing with limestone powder and hydrate limestone powder. Otherwise, the values of density, VTM and flow were decreased.

3. By using basalt, the values of ITS and stiffness modulus were higher than using crushed grave and crushed limestone. Otherwise, the failure strain was lower.

4. By using cement as mineral filler, the values of ITS was higher than using limestone powder and hydrate limestone powder. Otherwise, the failure strain and stiffness modulus were lower.

![Gradation curves for coarse aggregate.](image1)

**Figure (1)** Gradation curves for coarse aggregate.

![Effect of aggregate type on Marshal Stability.](image2)

**Fig. (2):** Effect of aggregate type on Marshal Stability.

![Effect of aggregate type on Flow.](image3)

**Fig. (3):** Effect of aggregate type on Flow.
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Fig. (4): Effect of aggregate type on Density.

Fig. (5): Effect of aggregate type on VTM.

Fig. (6): Effect of aggregate type on MS.

Fig. (7): Effect of aggregate type on MQ.

Fig. (8): Effect of mineral filler type on Marshal Stability.

Fig. (9): Effect of mineral filler type on flow.

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Fig. (10): Effect of mineral filler type on Density.

Fig. (11): Effect of mineral filler type on VTM.

Fig. (12): Effect of type of mineral filler on MS.

Fig. (13): Effect of mineral filler type on MQ.

Fig. (14): Effect of aggregate type on ITS.

Fig. (15): Effect of aggregate type on Stiffness Modulus.
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**Fig. (16):** Effect of aggregate type on Failure strain.

**Fig. (17):** Effect of mineral filler type on ITS.

**Fig. (18):** Effect of mineral filler type on stiffness modulus.

**Fig. (19):** Effect of mineral filler type on failure strain.

**REFERENCES**


