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على محتوى الإسفلت الأمثل وخصائص المارشال

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كلية الاسراء الجامعة- قسم الهندسة المدنية بغداد - العراق

Studying the Effect of Mineral Filler Type of Hot Mix Asphalt on Optimum Asphalt Content and Marshall Properties

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ABSTRACT

The filler plays a major role in the properties and behavior of asphalt paving mixtures. Mineral filler were originally added to hot mix asphalt (HMA) to fill the voids of the aggregate gradation and to reduce the voids in the mixtures. The filler used in the asphalt mixtures to affect the mix design properties, especially the optimum asphalt content. To meet the objectives of this research, available local materials were used including asphalt cement, aggregate and mineral fillers. In this research, limestone dust, Portland cement and silica fume were used as a mineral filler. Three types of mixtures were prepared. The first type included limestone dust, the second type included Portland cement and the last type included silica fume. The optimum asphalt content of each type of mixtures was determined using Marshall Mix design method. Optimum asphalt content was 4.9 % for mixture type I and mixture type II and 5.1% for mixture type III. The result of optimum asphalt content showed that this percentage do not change when using Portland cement as a mineral filler if compared to mix with limestone dust, while it was increases when using silica fume as a mineral filler instead of limestone dust. The results of Marshall test showed that Marshall Stability was increased by 37.11 % when using Portland cement as a mineral filler instead of limestone dust, while it was decreased by 4.05 % when using silica fume as a mineral filler instead of limestone dust. The results also showed that the bulk density increases when using Portland cement as a mineral filler if compared to mix with limestone dust, while when using silica fume as a mineral filler instead of limestone dust, slight decrease in the bulk density is occurred. Also, the results revealed that the Air voids were decreased when using Portland cement and silica fume as a mineral filler if compared to limestone dust.

Keywords: Optimum Asphalt Content, Mineral Filler Type, Marshall Properties.

الملخص

المادة المعدنية المالئة تلعب دوراً رئيسياً في خصائص وسلوك الخلطات الاسفلتية. تتم اضافة المادة المعدنية المالئة لغرض ملأ الفراغات في التدرج وتقليل الفراغات في الخلطة. تستخدم المادة المعدنية المالئة للتأثير على خصائص الخلطة وخاصة نسبة الاسفلت المثلى. تم تحضير ثلاثة انواع من الخلطات, كانت الخلطة الاولى تحتوي غبار الحجر الجيري والثانية تحتوي على الأسمنت البورتلاندي والاخيرة تحتوي على ابخرة السيليكا. تم ايجاد نسبة الاسفلت المثلى لكل نوع من الخلطات باستخدام طريقة تصميم مارشال. كانت نسبة الاسفلت المثلى 4.9 % للخلطة الاسفلتية الاولى والثانية و 5.1 % للخلطة الاسفلتية الثالثة. اظهرت نتائج نسبة الاسفلت المثلى ان نسبة الاسفلت المثلى للخلطة الاسفلتية التي تحتوي على الاسمنت البورتلاندي لا تتغير اذا ما قورنت مع الخلطة الاسفلتية التي تحتوي على غبار الحجر الجيري بينما تزداد تلك النسبة في الخلطة التي تحتوي على ابخرة السيليكا كمادة معدنية مالئة. اظهرت نتائج اختبار مارشال ان مقياس ثبات مارشال يزداد بنسبة 37.11 % عند استخدام الاسمنت البورتلاندي كمادة معدنية مالئة بدلاً من غبار الحجر الجيري في حين انخفض مقياس ثبات مارشال بنسبة 4.05 % عند استخدام ابخرة السيليكا كمادة معدنية مالئة بدلاً من غبار الحجر الجيري. كذلك اظهرت النتائج ان الكثافة الحجمية تزداد عند استخدام الاسمنت البورتلاندي كمادة معدنية مالئة بدلاً من غبار الحجر الجيري. لوحظ ان التغيير في الكثافة الحجمية كان طفيفاً عند استخدام ابخرة السيليكا كمادة معدنية مالئة. اظهرت النتائج ايضاً ان الفراغات الهوائية قد انخفضت عند استخدام السمنت البورتلاندي وابخرة السيليكا كمواد معدنية مالئة.

الكلمات الرئيسيه: نسبة الاسفلت المثلى, نوع المادة المعدنية المالئة, خصائص مارشال.

1 - INTRODUCTION

As asphalt concrete wearing course is the first layer in the pavement structure, the material should be able to sustain stresses caused by direct traffic loading without causing premature cracking .In order to provide comfortable ride and withstand the effects arising from traffic loading and climate, pavement materials should be designed to achieve a certain level of performance which should be maintained during the service life of pavement. The filler plays a major role in the properties and behavior of asphalt paving mixtures. Mineral fillers were originally added to HMA to fill the voids in the aggregate gradation and to reduce the voids in the mixtures. The filler used in the asphalt mixtures to affect the mix design properties, especially the optimum asphalt content. The term filler is often used loosely to designate a material with a particle size distribution smaller than sieve no. 200. Mineral fillers play a dual role in asphalt mixtures, first; they act as part of the mineral aggregate by filling the voids between the coarser particles in the mixtures and thereby strengthen the asphalt mixture, second; when mixed with asphalt, fillers form mastic (Muniandy, et. Al., 2013).

2 - RESEARCH OBJECTIVE

The objective of this research is to study the influence of using three types of mineral filler on the optimum asphalt content and Marshall properties.

3 - BACKGROND

The Effect of the added mineral fillers on hot mix asphalt (HMA) is to fill voids between the aggregate and reduce the voids in the mixture. In general, filler have various purposes among which, they fill voids and hence reduce optimum asphalt content and increase stability (Bouchard, 1992).

Al-Qaisi T.A. (1981) studied the effect of filler type and proportions on the properties of filler-bitumen systems and bituminous paving mixtures. He investigated four types of fillers (Portland cement, limestone, dust, and powder of crushed gravel). He stated that the range of the filler-asphalt (F/A) ratio required to provide the desired properties of paving mixtures is influenced by the type of filler used.

Sadoon O.E. (1995) studied the effect of different filler types on performance properties of asphalt paving. Six different types of filler were used to evaluate the resistance to plastic flow using Marshall Stiffness test and low temperature cracking and temperature susceptibly using indirect tensile strength test. The results indicate that filler type has a great effect on the cohesion of the mix where such types shows high indirect tensile strength values with respect to other types of filler at different test temperature.

4 - MATERIALS and METHODS

4 - 1 - Material Characteristics

4.1.1 Asphalt Cement

Asphalt cement of (40-50) penetration grade brought from Dura refinery was used in this research. The main physical properties of this asphalt are listed in Table 1.

Table 1: Physical Properties of Asphalt Cement.

Property	Test Conditions	Specification used	Test Results	SCRB (2003) Specification
Penetration	(25℃, 100 gm., 5 sec)	ASTM D 5	41.5	40 – 50
Softening point	----	ASTM D 36	42	----
Ductility	(25 ˚C, 5 cm/min)	ASTM D 113	>100	>100
Flash point	----	ASTM D 92	310	>232
Specific Gravity	25℃	D-70	1.04	----

4.1.2 Aggregate

Coarse and fine aggregates were obtained from AL- nibaei quarry; the physical properties of aggregate are showed in Table 2.

Table 2: Physical Properties of Aggregate.

Property	Coarse Aggregate		Fine Aggregate	
	Test Result	Specification used	Test Result	Specification used
Bulk Specific Gravity	2.55	ASTM C 127	2.58	ASTM C 128
Apparent Specific Gravity	2.57	ASTM C 127	2.62	ASTM C 128
Water Absorption %	0.62%	ASTM C 127	1.01%	ASTM C 128
Los Angles Abrasion %	16.36%	ASTM C 131	----	----

4.1.3 Mineral Fillers

Three types of mineral filler were used in this research including limestone dust, Portland cement and Silica fumes. Table 3 shows the physical properties of the considered types.

Table 3: Physical Properties of Mineral Filler.

Filler Type	Physical Properties	
	% Passing Sieve No. 200	Specific Gravity
Limestone Dust	93.2	2.617
Portland Cement	96.4	3.15
Silica Fume	98.4	2.623

4 - 2 - Selection of Design Aggregate Gradation

The selected gradation in this research followed the State Commission of Roads and Bridges (SCRB 2003) specification, with 12.5 (mm) nominal maximum aggregate size. Figure 1 and Table 4 show the selected aggregate gradation.

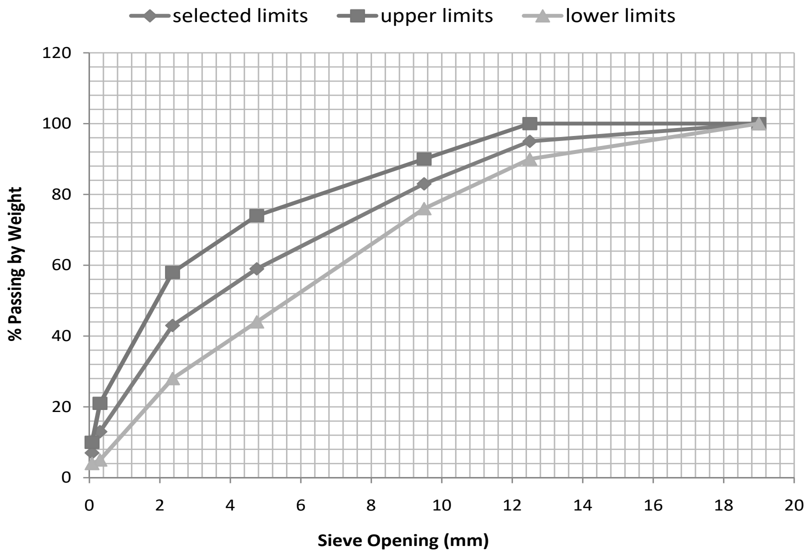


Figure 1: Selected Gradation According to SCRB (2003).

Table 4: Specification Limits and Selected Gradation of Mixtures for Wearing Course According to SCRB (2003).

Sieve Opening (mm)	Sieve Size	% Passing by Weight	
		Selected Gradation	SCRB Specification Limits
19	3/4"	100	100
12.5	1/2"	95	90 – 100
9.5	3/8"	83	76 – 90
4.75	No.4	59	44 – 74
2.36	No.8	43	28 – 58
0.3	No.50	13	5 – 21
0.075	No.200	7	4 – 10

4 - 3 Preparation of Marshall Specimen

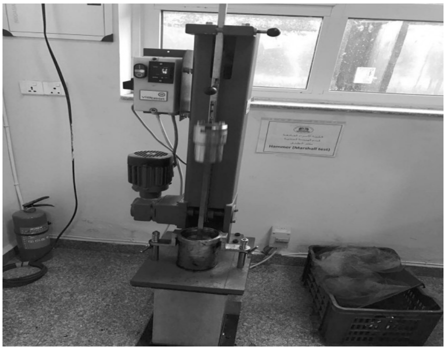
Three groups of Marshall Specimens were prepared and used in this research to find the optimum asphalt content; twelve (12) specimens were prepared for each type of mixture. Four percentages of asphalt cement (4, 4.5, 5 and 5.5) % were implemented for each type of mixture; these three groups of mixtures were as follows:

- Mixture Type I including limestone dust as a mineral filler (control mixture).
- Mixture Type II including ordinary Portland cement as a mineral filler.
- Mixture Type III including silica fume as a mineral filler.

Nine (9) specimens were prepared according to the optimum asphalt content to studying the effect of mineral filler type on Marshall Properties. The specimens were prepared according to ASTM D1559; mold, spatula, and compaction hammer were heated on a hot plate to a temperature of (150 ºC). The aggregate was first sieved, washed, and dried. Coarse and fine aggregates were combined with mineral filler to meet the specified gradation in section (4.2). Aggregates and filler were heated to (150 ºC); asphalt was heated up to (150) ºC before mixing. The asphalt was added to the hot aggregate and mixed for two minutes on hot plate until all aggregate particles were coated with asphalt cement. The mold is (4˝) in diameter and (2.5˝) in height. Filter papers were placed at the bottom of the mold before the mixture is inserting in the mold; the mixture was prepared and then placed in the mold, and subjected to the spatula for (15) times around the perimeter and (10) times over the interior. The compaction temperature was (140) ºC which gives a viscosity of (280 30) cSt. The (75) blows of compaction hammer are applied for each face of specimen. The specimen inside mold was left at room temperature for 24 hours and then it was extracted from the mold using mechanical jack. Figure 2 shows preparation of Marshall Specimens.

a: Sieve Analysis of Aggregate.

b: Preparation of Aggregate Sample.



d: Compaction of Specimens.

e: Extraction of Specimens from the Mold Using Mechanical Jack.

f: Marshall Specimens after Extraction from Molds.

g: Marshall Specimens According to Optimum Asphalt Content.

Figure 2: Preparation of Marshall Specimens.

5. DETERMINATION OF MARSHALL PROPERTIES

5.1 Determination of Stability and Flow of Specimens

Procedure of preparing and testing specimens were carried out according to ASTM D1559 .This method covers the measure of the resistance to plastic flow of cylindrical specimens (2.5 in. height × 4.0 in. diameter) of asphalt paving mix after conditioning in water bath at 60 °C for 30 minute. A load was applied with a constant rate of (50.8) mm/min. The load was increased until it reached a maximum then when the load just begins to decrease, the loading is stopped and the maximum load is recorded. According to the calibration data suitable formula to calculate stability for each specimen was obtained. Figure 3 shows stability curve fitting obtained from the calibration data. Stability can be determined using the following formula:

$$Y = (0.0051X + 0.2212) * F \qquad (1)$$

where:

Y: Stability, kN.

X: Dial Gauge Reading Multiplied by 100.

F = Correction Factor of Height.

During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading .The flow value was recorded at the same time of recording the maximum load. Three specimens for each type of mixture were prepared and tested and the average results were reported. Figure 4 shows the Marshall test apparatus.

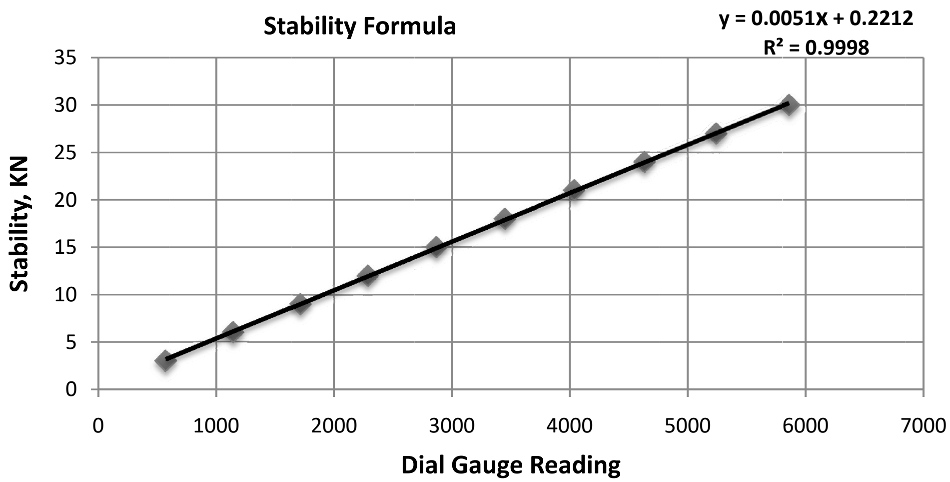


Figure 3: Stability Curve Fitting obtained from the Calibration Data.

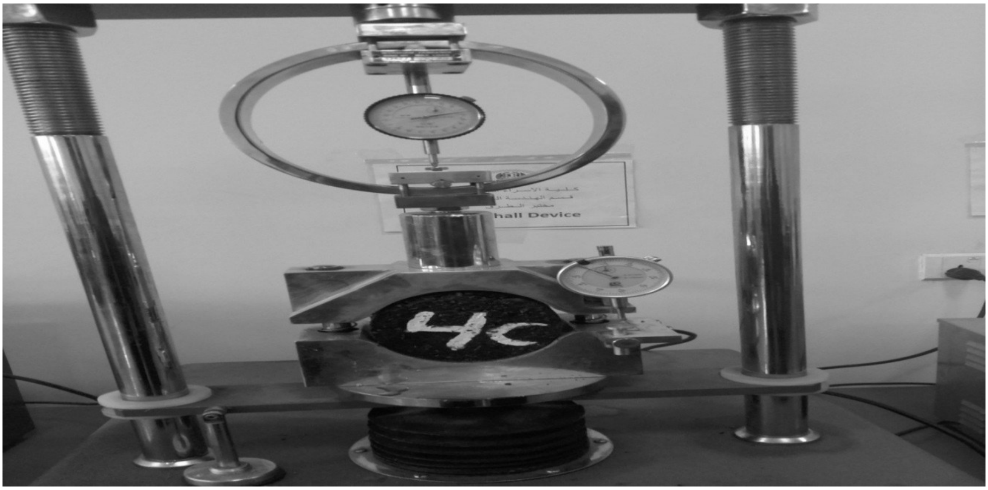


Figure 4: Marshall Test Device.

5.2 Theoretical Maximum Specific Gravity

The theoretical maximum specific gravity and density of hot mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and bituminous materials. They are used to calculate values for percent air voids in compacted hot-mix asphalt paving mixtures. They provide target values for the compaction of paving mixtures. The theoretical maximum specific gravity ( ) of specimens can be found by using the following formula according to ASTM D2041:

$$G_{mm} = \frac{w_t}{\frac{w_{as.}}{G_{as.}}+\frac{w_{ca.}}{G_{ca.}}+\frac{w_{fa.}}{G_{fa.}}+\frac{w_{f.}}{G_f}} \quad \text{.......... (2)}$$

where:

w_t: Total Weight of Specimen

w_{as}: Weight of Asphalt Cement,

G_{as}: Specific Gravity of Asphalt Cement,

w_{ca} : Weight of Coarse Aggregate,

G_{ca} : Specific Gravity of Coarse Aggregate,

w_{fa}Weight of Fine Aggregate,

G_{fa} : Specific Gravity of Fine Aggregate,

w_f: Weight of Mineral Filler, and

G_f: Specific Gravity of Mineral Filler.

5.3 Bulk Specific Gravity

The bulk specific gravity test on the freshly compacted specimens may be performed as soon as when they have cooled to room temperature. This test is conducted according to ASTM D 2726, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface dry Specimens". The bulk specific gravity () of specimens can be found by using the following formula:

$$\mathbf{G_{mb}} = \frac{\boldsymbol{A}}{\boldsymbol{B-C}} \qquad \text{………. (3)}$$

where:

A = Dry Weight of Specimen in Air,

B = Weight of Saturation Surface Dry of Specimen,

C = Weight of Specimen in Water.

5.4 Voids in Total Mixture

The Voids in Total Mixture (VTM) are that part of the compacted mixture not occupied by aggregate or asphalt expressed as a percentage of the total volume. The VTM obtained by using the following formula:

$$\%\ \mathbf{VTM} = \left[\mathbf{1} - \frac{\mathbf{G_{mb}}}{\mathbf{G_{mm}}}\right] \times \mathbf{100}\ \% \qquad \text{………. (4)}$$

where:

G_{mb} : Bulk Specific Gravity,

G_{mm} : Maximum Theoretical Specific Gravity.

5.5 Voids in Mineral Aggregate

Voids in the Mineral Aggregate (VMA) are the air void spaces that exist between the aggregate particles in a compacted paving mixture, including spaces filled with asphalt. VMA represents the space that is available to accommodate the asphalt and the volume of air voids necessary in the mixture. Voids in the mineral aggregate obtained by using the following formula:

$$\% \mathbf{VMA} = \left[\mathbf{100} - \frac{\mathbf{G_{mb}} * P_a}{\mathbf{G_{ba}}} \right] \qquad \text{..........} (5)$$

$$\mathbf{G_{ba}} = \frac{\mathbf{100}}{\frac{P_{ca.}}{G_{ca.}} + \frac{P_{fa.}}{G_{fa.}} + \frac{P_{f.}}{G_f}} \qquad \text{..........} (6)$$

where:

G_{mb}: Bulk Specific Gravity,

P_a : Percent of Aggregate,

G_{ba} : Bulk Specific Gravity of Aggregate

P_{ca} : Percent of Coarse Aggregate,

G_{ca} : Specific Gravity of Coarse Aggregate,

P_{fa} : Percent of Fine Aggregate,

G_{fa} : Specific Gravity of Fine Aggregate,

P_f : Percent of Mineral Filler, and

G_f : Specific Gravity of Mineral Filler.

5.6 Voids Filled with Asphalt

The Void Filled with Asphalt (VFA) is the percentage of voids in the compacted aggregate mass that are filled with asphalt cement. Figure (5) shows voids in compacted specimens. The voids filled with asphalt obtained by using the following formula:

$$\% \mathbf{VFA} = \frac{\mathbf{VMA - VTM}}{\mathbf{VMA}} \qquad \text{..........} (7)$$

Where:

VMA = Voids in Mineral Aggregate,

VTM = Voids in Total Mixture.

6. RESULTS and DISCUSSION

6 - 1 - Optimum Asphalt Content (OAC)

According to test results, the optimum asphalt content was 4.9 % for mixture type I and type II and 5.1 % for type III. Figures 5, 6 and 7 show optimum asphalt content for each type of fillers. The optimum asphalt content do not change when using Portland cement as a mineral filler if compared to mix with limestone dust, however, the optimum asphalt content increases when using silica fume as a mineral filler. This increment due to smoothness of Portland cement (high specific surface area). As the specific surface area increases, the required percentage of asphalt also increases. These results are clear from figure 8. Table 5 shows the properties of the Marshall mixture with the optimum asphalt content for each type of mixture.

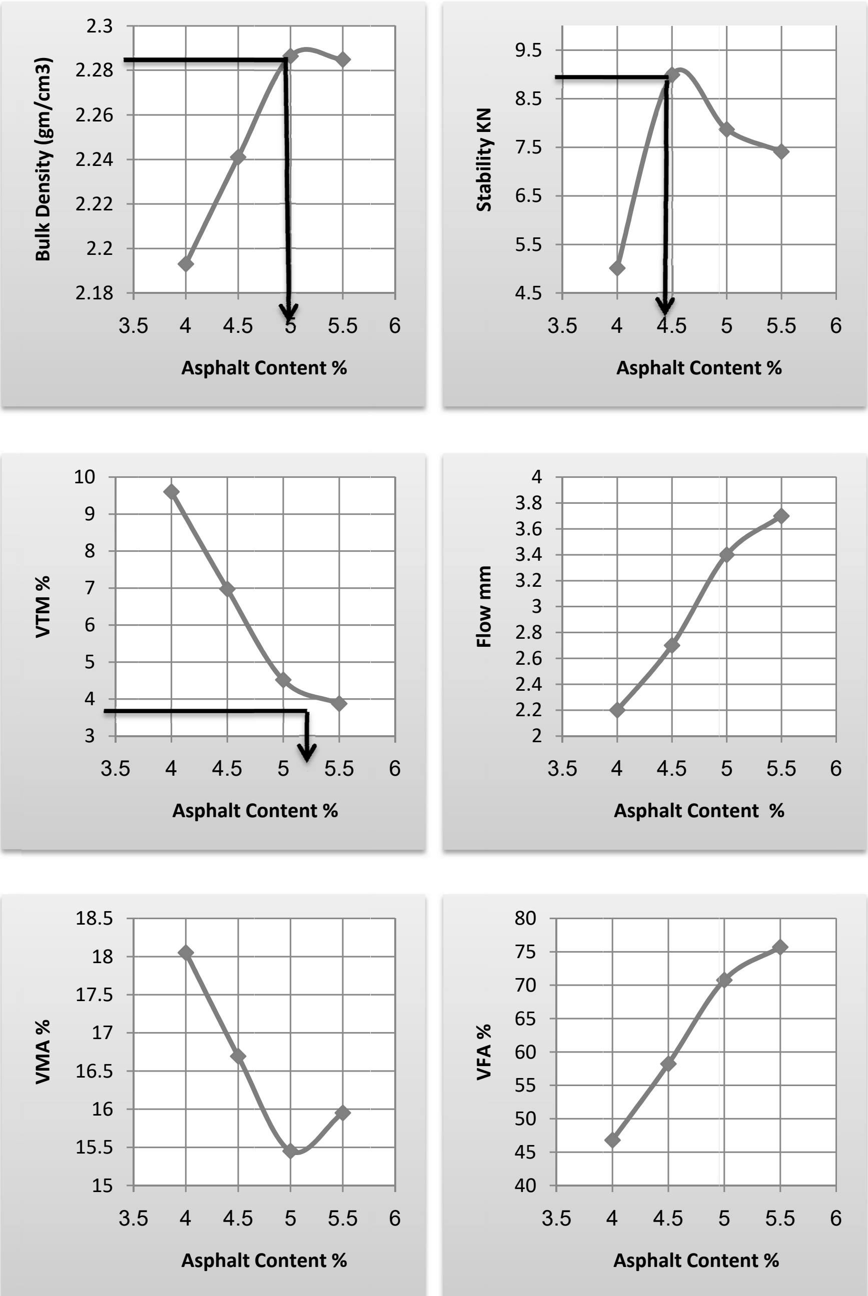


Figure 5: Marshall Test Results for Mixture Type I.

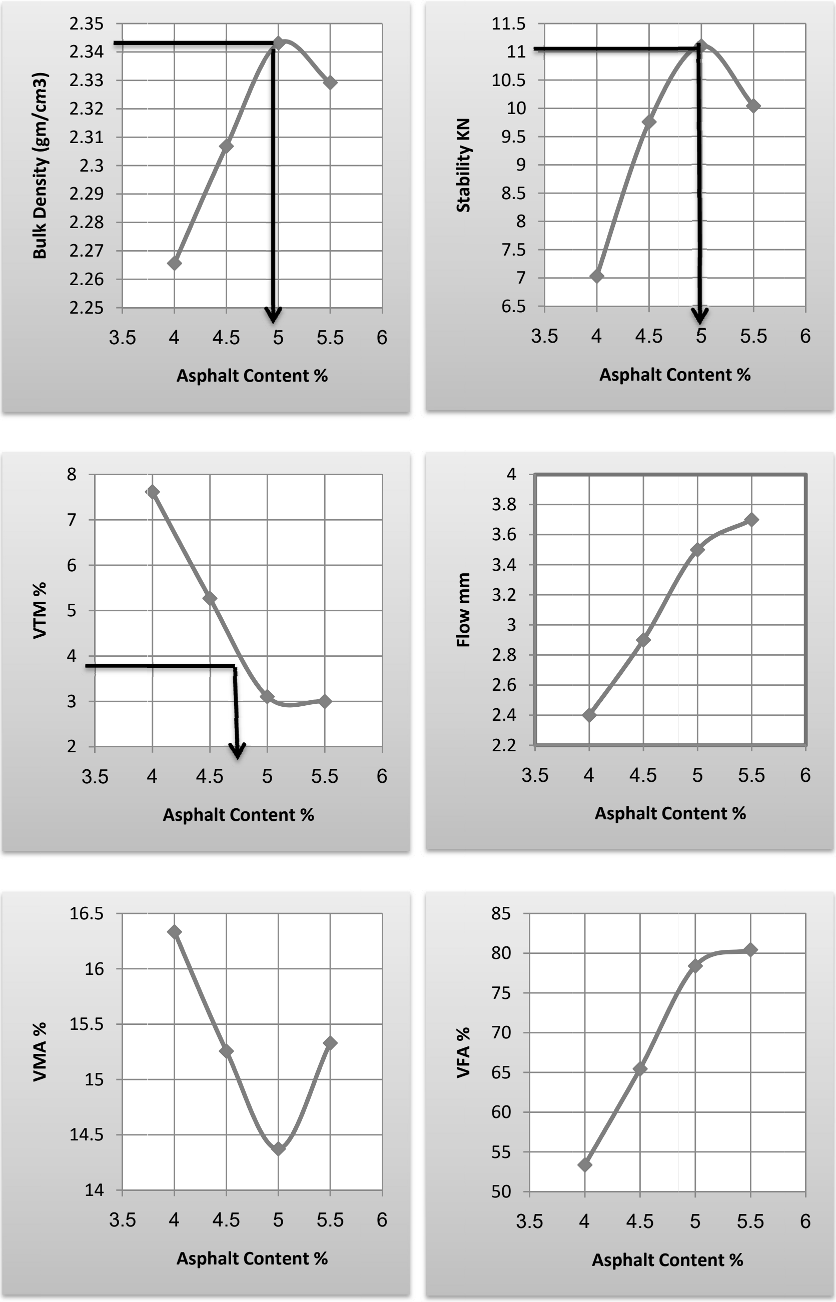


Figure 6: Marshall Test Results for Mixture Type II.

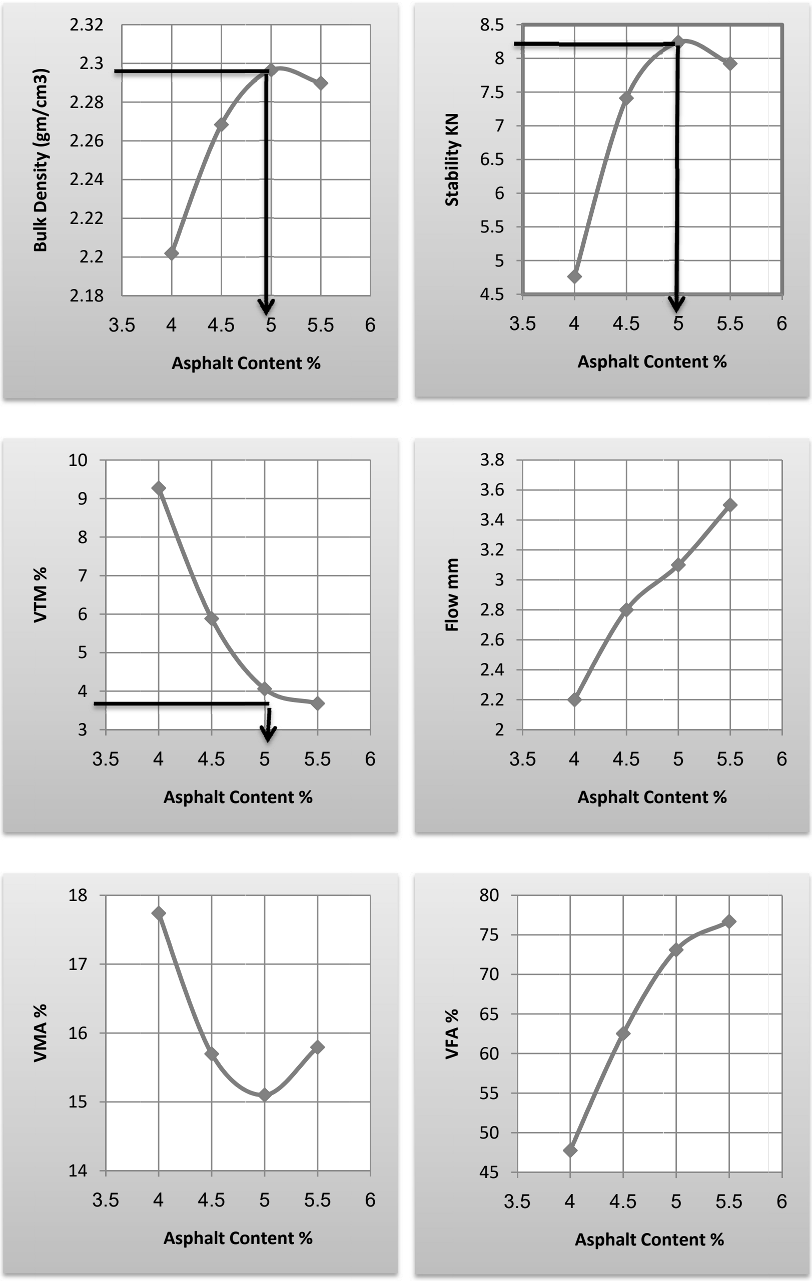


Figure 7: Marshall Test Results for Mixture Type III.

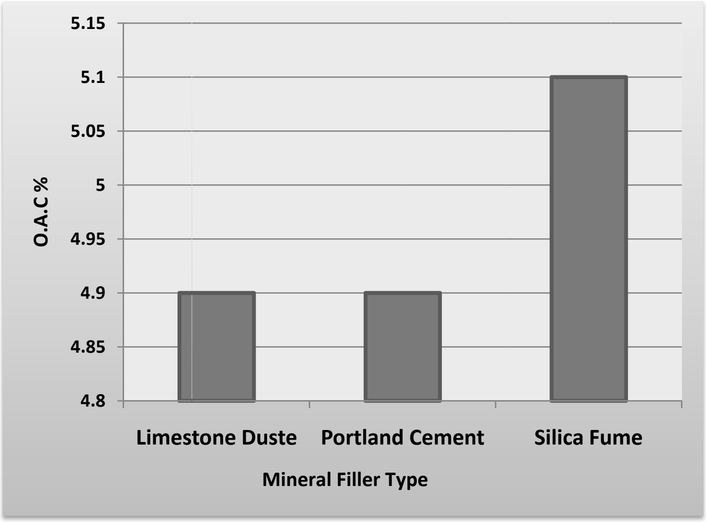


Figure 8: Effect of Filler considered Type on Optimum Asphalt Content.

Tables 5: Marshall Properties of the Mixtures at the Optimum Asphalt Content.

Marshall Properties	Mineral Filler Type		
	Mixture Type I	Mixture Type II	Mixture Type III
	Limestone Dust	Portland Cement	Silica Fume
O.A.C	4.9	4.9	5.1
Stability (KN)	8.1	11	8.2
Flow (mm)	3.1	3.4	3.2
Bulk Density (gm./cm3)	2.28	2.34	2.29
V.T.M	4.8	3.4	3.9
V.M.A	15.6	14.4	15.2
V.F.A	70	76	74

6.3 Marshall Stability

It is noted that the Marshall stability was increased by 37.11 % when using Portland cement as a mineral filler instead of limestone dust. The large increment in stability was due to high cement specific gravity when compared with the specific gravity of limestone dust. Also the Marshall stability was decreased by 4.05 % when using silica fume as a mineral filler when compared to mix with limestone dust. The change in stability was slight when using silica fume as a mineral filler because specific gravity of limestone and silica fume is very close. Table 5 shows the data of Marshall test Specimens According to the Optimum Asphalt Content. Figure 9 shows the effect of filler type on Marshall Stability.

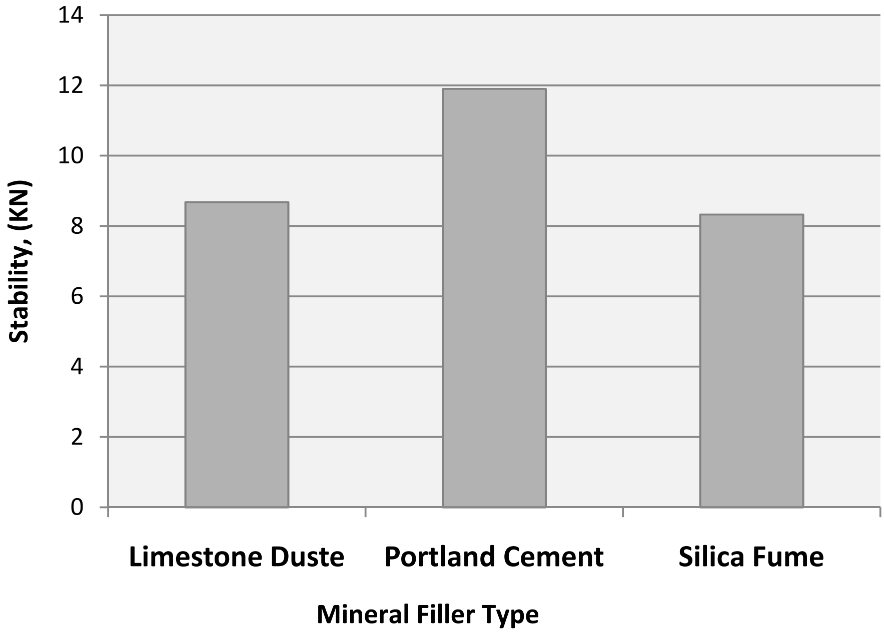


Figure 9: Effect of Filler Type on Marshall Stability.

6.4 Marshall Flow

It can be observed that the Marshall flow was decreased by 3.22 % when using Portland cement as a mineral filler instead of limestone dust. It can be noted that the Marshall flow was increased by 9.67 % when using silica fume as a mineral filler instead of limestone dust. This is due to the increased optimum asphalt content when using silica fume as a mineral filler if compared with optimum asphalt content of limestone dust. Figure 10 shows the effect of filler type on Marshall Flow.

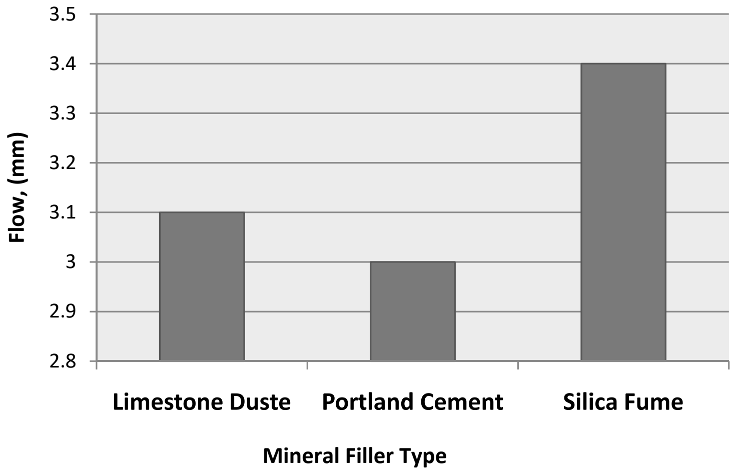


Figure 10: Effect of Filler Type on Marshall Flow.

6.5 Bulk Density

It was found that the bulk density increases when using Portland cement as a mineral filler when compared to mix with limestone dust. This is due to high cement specific gravity if compared with the specific gravity of limestone. In the case of using silica fume instead of limestone, It was noted that a slight decrease in the bulk density. This slight decrease is due to the convergence of the specific gravity of both types of filler. The effect of filler type on bulk density is illustrated in Figure 11.

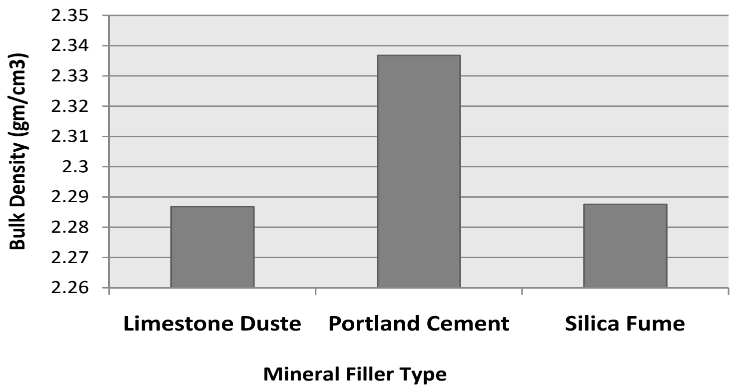


Figure 11: Effect of Filler Type on Bulk Density.

6 - 6 - Voids in Total Mixture (VTM %)

According to test resulting, the air voids were decreased when using Portland cement and silica fume as a mineral fillers if compared to limestone dust. The decrease in the percentage of air voids when using Portland cement and silica fume was due to smoothness of cement and silica fume (high specific surface area) which leads to good interlock of aggregate which in turn leads to decrease the percentage of air voids. Figure 12 shows the effect of aggregate gradation and filler type on voids in total mix (VTM) percent.

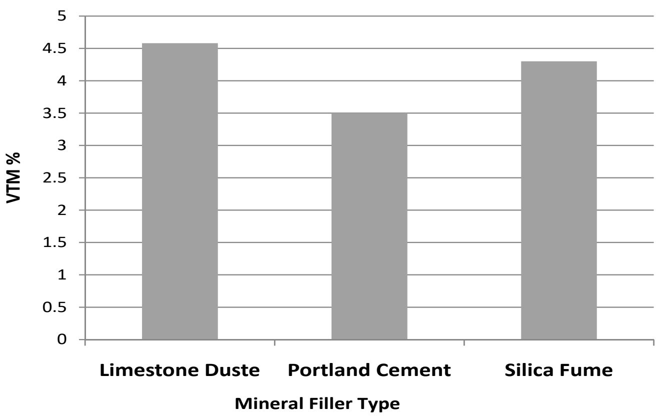


Figure 12: Effect of Filler Type on VTM.

6 - 7 - Voids Filled with Asphalt (VFA %)

Test results showed that the void filled with asphalt was increased when using Portland cement and silica fume as a mineral fillers if compared to limestone dust. The increment in the percentage of voids filled with asphalt (VFA) when using Portland cement and silica fume was due to the few voids (VTM) in the mixtures when compared with voids (V.T.M) of the mixture that contain limestone dust. Figure 13 shows the effect of filler type on void filled with asphalt.

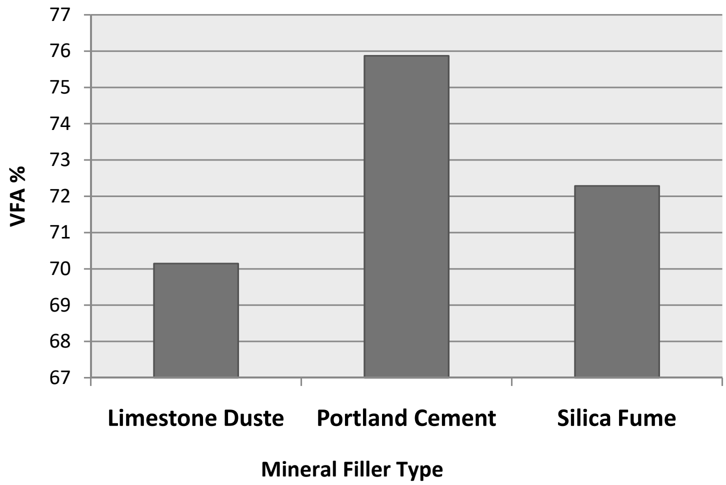


Figure 13: Effect of Filler Type on VFA.

6 - 8 - Voids in Mineral Aggregate (VMA %)

Test results revealed that the voids in mineral aggregate were decreased when using Portland cement as a mineral filler when compared with the limestone dust. The decrease in the void of the mineral aggregate was due to smoothness of Portland cement (high specific surface area). Figure 14 shows the effect of filler type on void in mineral aggregate (VMA).

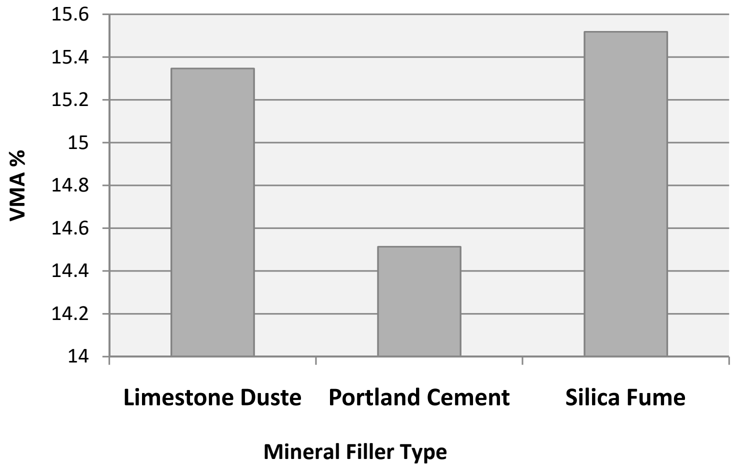


Figure 14: Effect of Filler Type on VMA.

7 - CONCLUSIONS

According to the test results obtained in this research work, the following conclusions are drawn:

1. Marshall Stability was increased by 37.11 % when using Portland cement as a mineral filler instead of limestone dust.
2. Marshall Flow was increased by 9.67 % when using silica fume as a mineral filler instead of limestone dust.
3. Air voids were decreased when using Portland cement and silica fume as a mineral filler if compared to limestone dust.
4. Voids in mineral aggregate were decreased when using Portland cement as a mineral filler if compared to limestone dust and increasing when using silica fume as a mineral filler.
5. Voids filled with asphalt were increased when using Portland cement and silica fume as a mineral fillers if compared to limestone dust.

6. The optimum asphalt content do not change when using Portland cement as a mineral filler if compared to mix with limestone dust.
7. The optimum asphalt content was increases when using silica fume as a mineral filler instead of limestone dust.

REFFRENCES

- **Al-Qaisi T.A., (1981), "The Effect of Mineral Filler on the Asphalt Paving Mixtures", M.Sc. Thesis, College of Engineering, University of Baghdad.**
- **Bouchard, G. P., (1992), "Effect of Aggregates and Mineral Fillers On asphalt Mixtures Performance", ASTM, STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia**
- **Muniandy*, E Aburkaba and R Taha, (2013), "Effect of Mineral Filler Type and Particle Size on the Engineering Properties of Stone Mastic Asphalt Pavements", Vol. 10, No. 2, 13-32, TJER.**
- **Sadoon O.E., (2010), " The influence of Filler Type on Asphalt Mastic and Performance Properties of Asphalt Paving Materials" ,M.Sc Thesis, College of Engineering , University Anbar.**

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