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Effect of Lime Stone & Cement on the Mechanical Properties of Hot Mix Asphalt (HMA)

Bayan A. Taha [*] bayan.taha@dpu.edu.krd
Abdulkhalik AL-Taei [**] abdelkhaleq@uomosul.edu.iq
Shafika Sultan Abdullah [*] shafika.sultan@dpu.edu.krd

[*] Highways and Bridges Department, Collage of Engineering, Duhok Polytechnic University, Duhok, Iraq
[**] Civil Engineering Department, College of Engineering, University of Mosul, Mosul, Iraq

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ABSTRACT

Most of the roads in Iraq are paved using Hot Mix Asphalt (HMA) which is consisted of aggregates, asphalt cement and filler. In this study a laboratory investigation is conducted using two types of widely used fillers highly and locally available. Four different proportions of fillers are. Filler proportions used in this study are four proportion (i.e., 1.9%, 2.5%, 3.5%, and 4.5%) by total weight of aggregate for both types of fillers used. These proportions were blended using asphalt with penetration 40/50 and Performance Grade (PG70-10) using super-pave mix design methodology. The performance of bitumen binder with both types of filler was evaluated by: Penetration, Ductility, Softening Point, Penetration Index, Volumetric properties, Indirect Tensile Strength and Tensile Strength Ratio. The volumetric properties indicate that, the proportions of (1.9%, and 2.5%) for both type of filler are within the Super-pave criteria as the ITS increased with the increase of filler content and the highest TSR values for 2.5% Limestone dust is 90%, while for 3.5% Cement is 89.7%. Finally, it was concluded that the HMA is highly influenced by the amount and type of filler content.

Keywords:

HMA, Super-pave, Limestone, Cement, ITS, TSR

1. INTRODUCTION

Highways and Roads are an important part of the transportation infrastructure network because they provide a means of transferring goods and people and are the backbone of a prosperous economy.More than 90% of road is paved with Hot Mix Pavement which is common due to many factors comfortable for ride, Cost effective in terms of construction and maintenance, faster construction time[1]

One of the most severe problems faced by road networks is the excessive frequency of traffic loads, and this problem increases with the presence of water that will penetrate into the components of the asphalt paving, which leads to stripping, disintegration,or moisture damage. It is a loss of adhesion between the asphalt and aggregates or a loss of cohesion between the asphalt binder of that mixture in the presence of the two most important factors, water and traffic loads. This failure may result in other defects in the layers of asphalt pavements such as rutting, fatigue, cracking, and potholes[2].

Using additives has been found to be one of the most efficient methods for increasing pavement durability and performance under heavy wheel loads. The use of hydrated lime as a mineral filler and anti-stripping material has raised more and more for field application, Due to its availability, low cost and ease of manufacturing HMA compared to other additives such as polymers [3][[4].

According to the theory of the filler “the filler serves to fill voids in the mineral aggregate and thereby create dense mix" .According to this theory, each filler particle is independently coated with asphalt, and such coated particles, whether attached or discrete help to fill the voids in the asphalt mixture [5]. The moisture damage under traffic load, is greatly affected by the type and amount of filler[6].

When adding lime to the hot mix asphalt, it interacts with the aggregates, increasing the binding between the bitumen and the aggregate enhancing the resistance of HMA to rutting, fatigue and moisture damage improves the mechanical properties of the mixture [7][8][9]. Many research works have shown that, the quality of the filler content have a substantial influence on the properties of HMA [10][11].

There are two basic approaches for designing asphalt mixtures: Marshall and Super-pave method. These approaches incorporated the idea of volumetric characteristics, which may be assessed and estimated based on the volumetric proportions of the asphalt mixture's components [12].The Super-pave method is characterized by the ability to evaluate the filler content in the asphalt mixture, and the initial and maximum compaction percentages as a function of the number of Super-pave Gyratory Compaction (SGC) gyration [8].

The main objective of this research is to study the effect of limestone and cement in different contents on the mechanical properties of HMA and to examine these properties using super-pave technology by different types of standard mechanical tests..

1. TESTING PROGRAM

The materials used in this work are locally available materials that are currently used in road works taken out from the road manufacturing factories working right now. These materials include:

2.1 Asphalt Cement

The cement used in this research is Lenaz refinery/Irbil with penetration (40-50) and Performance Grade (PG70-10) the asphalt cement physical properties were tested according to ASTM and, AASHTO as shown in Table (1).

b. Aggregates Selection and Testing

The aggregate used is a crushed aggregates brought from (Qasurki Quarry) located at 15km south of Dohuk city. The crushed coarse and fine aggregates were sieved and recombined in the suitable proportion to match the Super-pave job mix specifications. All tests have been carried out on aggregates to assess the physical properties (i.e., Consensus and Source properties) as shown in Tables (2) and (3).

c. Filler Type Testing

Two types of filler are used in this work namely: Lime stone dust and Ordinary Portland Cement (delta) from and the test results are as shown in Table (4):

Table (1): The Properties of Asphalt Cement

Property	Test condition	Specification used	Result	Super-Pave Criteria
Test on Original Binder				
Penetration	25ºC , 5sec	ASTM D5	43	40-50
Ductility	25ºC, 5cm/min	ASTM D-113	155	>100
Softening point	Ring& Ball	ASTM D-36	53	
Flash Point	open Cup	ASTM D-92	277	>232
Dynamic Shear,	10rad/s, passed @70º C, (1.6Hz)	AASHTO T315	1.345	G*/Sin D >1Kpa
Rotational Viscosity	Pa. Sec	ASTM D4402	575@135ºC	
			146@165ºC	
Bitumen Specific Gravity	25ºC	D-70-97	1.03	
Test on RTFO Residue				
Penetration	25C, 5sec	ASTM D5	27	---
Ductility	25C, 5cm/min	ASTM D-113	28	----
Softening point	(Ring& Ball)	ASTM D-36	60.5	---
Dynamic Shear,	10rad/s(1.6Hz), passed @70º C	AASHTO T315	3.165	G*/SinD>2.2Kpa
Test On RTFO+ PAV Residue :20 Hrs. @100C				
Dynamic Shear	10rad/s (1.6Hz), 30º C,	AASHTO T315	3.80447	G*Sin <5Mpa
Bending Beam Creep Stiffness	At 60Sec,) @ 0ºC	AASHTO T313	48.366	S<300Mpa
	At 60Sec,) @ -12ºC		198.133	
Bending Beam Creep Slope	At 60 Sec., @ 0 ºC	AASHTO T313	0.3734	m>0.3
	At 60 Sec., @ -12 ºC		0.288	

Based on Test Result PG-Grading (70-10)

Table (2): Consensus properties for aggregate

Property	Value	Specification	Super-pave Criteria
Coarse Aggregate Angularity 19mm	100/100	ASTM D 5821	100/100
Coarse Aggregate Angularity 12.5mm	100/100	ASTM D 5821	100/100
Flat and elongated particles larger than 4.75mm	1.4	ASTM D 4791	Max 10
Clay content for fraction less than 4.75(sand equivalent)	77	AASHTO T 176	Min. 50
Fine aggregate Angularity (Uncompact Void of Fine Aggregate)		AASHTO T 304	Min.45
Crushed Sand	47		

Table (3): Source properties for aggregate

Property	Value	Specifications	Super-pave criteria
Soundness	2.48%	AASHTO T104-99	Max.10 %
Toughness (Loss Angeles Abrasion)	21.2%	AASHTO T96-2	Max.25 %
Deleterious Materials	0.48%	AASHTO T112	Max 1 %

Table (4): Physical and Chemical Properties of Filler

Property	Result	Iraqi Standard
Limestone Dust		
Calcium Carbonate	97.50%	Max 85%
Specific Gravity	2.81	
Ordinary Portland Cement		
Loss on Ignition	2.35%	Max 4%
Residue Material	0.61%	Max 1.5%
Magnesium oxide MgO	3.26%	Max 5%
Sulfur trioxide SO3	1.84%	Max 2.8%
Specific Gravity	3.15%	
Specific Surface (m^2/kg)	390 m2/kg	Min 250 m2/kg
Soundness mm	1.10 mm	Max 10mm

2. SAMPLE PREPARATION AND TESTING METHOD

3.1. Preparation of Asphalt Mixture Sample

The preparation of asphalt mixtures according to the super-pave requires compaction and mixing at a temperature at which the asphalt binder reaches Dynamic viscosity of (0.28 ±0.3, 0.17±0.02) pa/sec, by testing the asphalt binder using (Brookfield Rheometer) the temperature of mixing and compaction is (160-165) and ºC (150- 155) ºC respectively[13]. The aggregate will be heated to the temperature of 160 ºC before mixing with the asphalt which is heated to the temperature as determined by the kinematic viscosity. After that, the asphalt cement is weighed in the required quantity and added to the heated aggregate and mixed to make sure that all the aggregate particles are coated with asphalt. After preparing the mixture to simulate what happen in the plant during the mixing process a short term of aging is (2 h @ 150ºC) conduct [12]. the compaction done using super-pave gyratory compaction (SGC) the vertical force is 600KPa and the rotation is 1.25, forces of SGC the tilt of the mold causes it to revolve at a pace of 30 rpm AASHTO T312. The number of Gyration chosen depending on the traffic level (Design EASL) in this study is more than 30million so the gyration number will be: N initial=9, Ndesign=125, Nmax=205[13].

3.2. Selection of Aggregate Gradation

The mechanism of super-pave has been developed to use chart of power 0.45 prepared by the US Federal Highway Administration (FHWA). which uses a planning technique to control the distribution of the accumulated sizes of the mixtures.This chart is drawn using the ratio of the passing aggregate (the y-axis) and the size of the sieves in mm raised to the power of 0.45 (the x-axis) provided that it overlaps with the maximum density line and also include (control point, restricted zone). Therefore, in order to choose the design structure of the aggregate, sieve analysis of the aggregate was carried out according to the specification ASTM C136 with a maximum aggregate size 25mm and nominal aggregate size which 19mm. In this process five stockpiles (three type of coarse aggregate matrial , one crushed sand and lime stone dust)were sieved on different sieves and each gradient was isolated accordingly to the sieves sizes, then three variable proportions were selected for each stack to obtain three different trail blend gradation, The Bulk specific gravities (Gsb) and Apparent specific gravity (Gsa) are determined for each trail, as shown table (5),Table (6) and Figure (1) below show aggregate gradation

Table (6): Aggregate Specific Gravity Results

Aggregate	19 mm	12.5 mm	9.5 mm	Crushed. Sand	Filler (Lime)
Gsb	2.641	2.642	2.637	2.610	2.81
Gse	2.688	2.703	2.710	2.753	2.80

Table(5) Gradation of Aggregate

	Agg. 19mm	Agg. 12.5mm	Agg. 9.5mm	Crushed. Sand	Filler	Gradation of Blend1	Gradation of Blend2	Gradation of Blend3	Super-pave Requirement				SCORB 2003	
Blend 1	11.0%	19.1%	34.0%	34%	1.9%									
Blend 2	9.0%	15.1%	35.0%	39.0%	1.9%				Control Point		Restricted Zone			
Blend 3	9.0%	10.0%	34.0%	45.0%	2.0%									
Sieve Size	Gradation Passing %								Min.	Max	Min.	Max	Min.	Max
50mm	100	100	100	100	100	100	100	100	_	_	_	_		
37.5mm	100	100	100	100	100	100	100	100	_	_	_	_		
25mm	100	100	100	100	100	100	100	100	_	_	_	_		
19mm	53	100	100	100	100	95	96	96	100		_	_	90	10
12.5mm	0	42	100	100	100	78	82	85	_	90	_	_	70	90
9.5mm	0	2	75	100	100	62	67	73	_	_	_	_	56	80
4.75mm	0	0	9	99	100	39	44	50	_	_	_	_	35	65
2.36mm	0	0	1	69	100	26	29	33	23	49	34.6	34.7	23	49
1.18mm	0	0	0	43	100	17	19	21	_	_	22.3	28.3		
0.6mm	0	0	0	27	100	11	13	14	_	_	16.7	20.7		
0.3mm	0	0	0	16	100	7	8	9	_	_	13.7	13.7	5	19
0.075mm	0	0	0	4	89	3	3	4	2	8	_	_	3	9

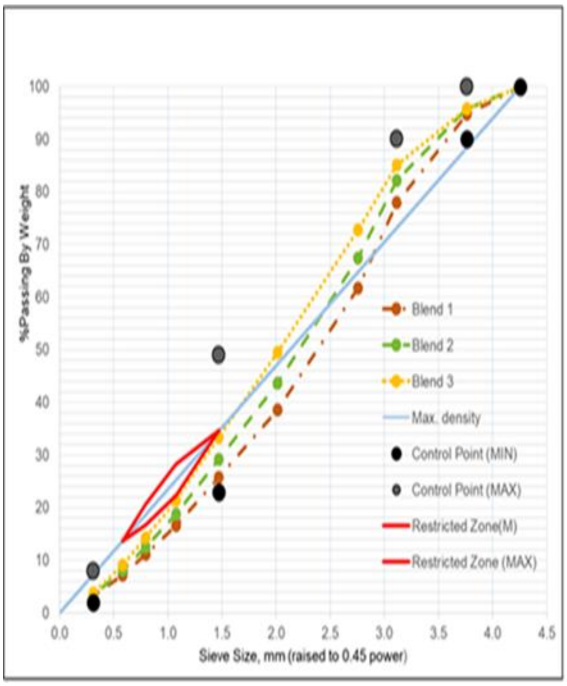


Figure (1) Aggregate gradation 19mm Nominal Max Size

For the purpose of knowing which of the three gradients can be chosen to design the asphalt mixture two samples of each trail will be mixed with 4.5% as initial asphalt content (Pbi)[12] and compacted using Super-pave Gyratory Compaction , then volumetric properties for each blends estimated and determined N initial=9 and N design =125 In this study Blend Two have been chosen it shows best properties according to the super-pave specification (air voids4%,VMA >13,VFA65-75,Dp0.8-1.2) as shown in Table (7), Then, at air voids equal 4% the volumetric properties is measured and evaluated again by the estimation of the effective binder content(Pbe) as shown in Table(8).

Table (7): Volumetric Properties of Trial Blends

Blind	Va	VMA	VFA	Pbe	Dp	%Gmm @N_{min}	%Gmm @N_{des}
1	3.20	12.69	74.7	4.06	0.79	87.1	96.8
2	4.02	13.14	69.4	3.92	0.87	86.9	96.0
3	4.37	13.44	67.5	3.92	0.96	86.9	95.6

Table(8): Estimation Volumetric properties at Air void=4 %

Pb_{est}	VMA_{est}	VFA_{est}	Pb_{est}	Dp_{est}	%G_{mm} @N_{min}	%G_{mm} @N_{des}
4.18	12.7	68.7	3.2	0.85	86.30	96.1
4.51	13.1	69.5	3.9	0.87	86.90	96.5
4.65	13.3	70.1	4.0	0.93	87.20	96.7

%Gmm@Nmax ≤ 98 according to super-pave

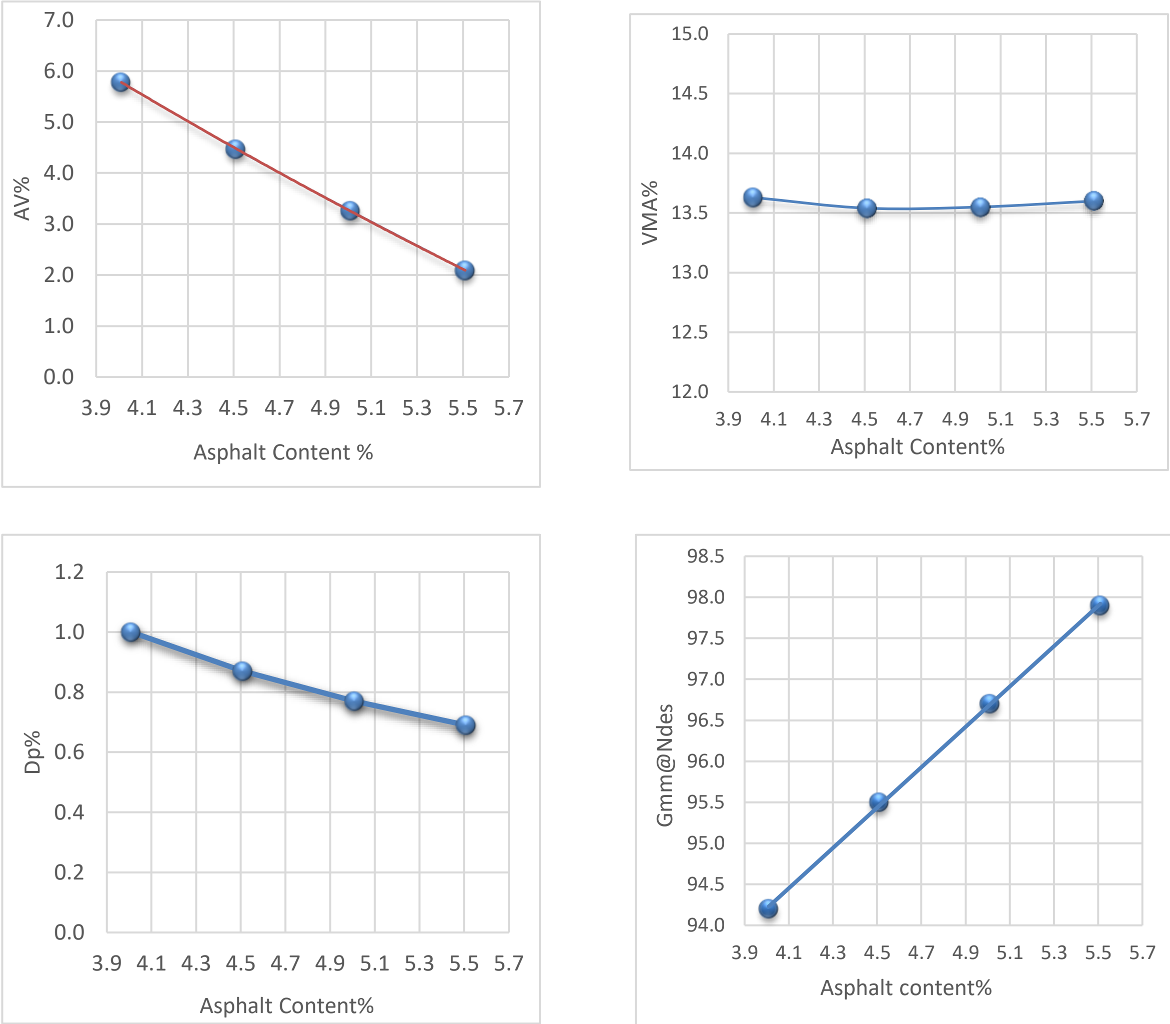


Figure 2 Superpave properties curves for hot mix design data

3.3. Selection of Design Asphalt Content

The selection of design asphalt content (i.e., Design asphalt) included, preparing samples using different asphalt contents and estimate the volumetric characteristics of each sample then compare with the specified mix requirements in order to choose the Design asphalt binder content. Two samples of design gradation (Blend No.2) were mixed and compacted at four different asphalt content (Estimated asphalt 4.51%, 0.5% above, 0.5% below and 1% above) using(SGC).estimating the volumetric properties according to the super-pave specification(%Gmm@Nin.≤89,%Gmm@Ndes.≥ 96)Table No(9).With the relation of asphalt content Ac and AV%, VMA,VFA, and Dp drawn Figure (2) the asphalt content at air void 4% evaluated which is 4.7% .Finally, two samples are prepared and compacted at Nmax to check the criteria Table No.(10).

Table(9): Volumetric properties for different asphalt content @Ndes

AC%	VA%	VMA%	VFA%	Dp%	%Gmm @Nmin	%Gmm @Ndes
4.01	5.78	13.63	57.62	1.00	84.90	94.20
4.51	4.47	13.54	66.95	0.87	85.80	95.50
5.01	3.26	13.55	75.90	0.77	86.60	96.70
5.51	2.09	13.60	84.62	0.69	87.50	97.90

3.4. Indirect Tensile Strength and Tensile Strength Ratio

This test was carried out according to the specification of AASHTO T-283, through which the performance of the asphalt mixture is evaluated for both tensile strength as well as resistance to moisture damage. The test conduct by dividing it into two groups, conditioned and un-conditioned samples (three specimens for each group).
Un-conditioned (dry) specimen immersed in water for 2h at temperature 25ºC. The conditioned (wet) specimen should be saturated for (55-80) % and immersed in water at 60ºC for 24h after being subjected to a freezing for 16h at (-18ºC) then immersed in water again for 2h at temperature 25ºC both groups tested by applying static Load at a rate of (50mm/min) .The Indirect Tensile Strength (ITS), and Tensile Strength Ratio (TSR) were obtained using the following Equation:

$$ITS = \frac{2000P}{DT\pi} \quad .....(1)$$

ITS= Indirect Tensile Strength
P = maximum load at failure, N
D = Diameter of specimen, mm. and
T = Thickness of specimen, mm.

$$TSR = \frac{S2}{S1} \quad ......(2)$$

TSR = tensile strength ratio %.
S1= average ITS for unconditioned specimen.
S2= average ITS for moisture conditioned specimen.

4. RESULT AND DISCUSION

4.1 The effect of filler content on the rheological properties of the asphalt binder

The rheological properties of asphalt binder were studied by preparing five percentages of limestone dust and cement by weight of asphalt and compared them with the origin asphalt, which are (1.9%, 2.5%, 3.5%, and 4.5%). It is shown that, for lime stone and cement filler paste, the penetration decreases with the increase filler content. Ductility at 4.5% decreases for both lime stone and cement paste by 30.4% and 28.2%, meanwhile, the softening point increases with the increase of both filler contents as shown in Table (11).

Table (11): Results of the Rheological Properties of Both Fillers-Asphalt Cement

Filler %	Limestone-Asphalt Paste			Cement-Asphalt Paste		
	Penet-ration (25 °C,	Ductili-ty (25 °C, cm)	Softening Point (°C)	Penet-ration (25 °C)	Ductility (25 °C, cm)	Softening Point
0	46	160	52.5	46	160	52.5
1.9	41	150	52.6	44	150	52.9

Table (10): Volumetric Properties for Design asphalt content (4.7) at Nmax

Mix Property	AV	VMA	VFA	Dp %	%Gmm @Nini	%Gmm @ Ndes	%Gmm @ N.Max
Result	3.9	13.1	70.4	0.8	85.3	94.7	96.4
Super-pave Criteria	Min .4%	≥ 13	65-75	0.6 - 1.2	<89	Max 96	Max 98
2.5	39	130	52.9	42		145	53.25
3.5	36	103	53.9	39		130	53.8
4.5	34	83	54.1	36		122	54.3

4.1 Penetration Index

The penetration index (PI) is the best way which describes the temperature susceptibility of the penetration of a filler-bitumen paste behaviour. The value of PI range from (-3 for high temperature susceptibility to+7 for low temperature is considered as suitable for preparing Asphalt binder with both filler .The PI value of lime stone paste and ordinary Portland cement paste contents using the following equation [12]:

$$A = \frac{\log P - \log 800}{25 - S} \quad ……(3)$$

$$PI = \frac{20 - 500A}{1 + 50A} \quad ……..(4)$$

P: Penetration at 25ºC, S: Softening point
Figure (3) shows that, PI index for both fillers are sufficiently susceptible to temperature changes during their exposure to high and/or low degrees

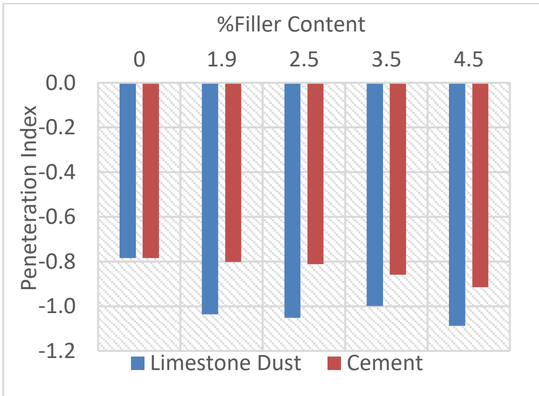


Figure (3) Penetration Index of Filler-Bitumen Contents Paste

4.2 Effect of Filler Content on Air Voids (AV) of Compacted Mixture.

The air voids are highly affected by the performance and durability of HMA'S as shown in Figure (4). When the air void content is too high, resulting mixture may be more permeable to air and water, causing moisture damage and age hardening. Increasing filler content will produce high stiff asphalt mastic (filler asphalt) which in turn gives more cohesive strength and binding force between coarse aggregate that make more easy to be compacted Air voids content decreased by 45 percent as limestone filler content increases from control content up to 4.5 percent. Cement filler produced air voids content variation of 42.5 percent lower than 4.5 percent filler cement content HMA^eS as shown in Figure (3). Lime stone filler produced harder HMA eS than cement mainly due to higher viscosity of the binder paste covering the mixture aggregates, but all the limestone contents are giving an acceptable air voids limits within SORB/2003 standards[14]. The same behavior is noticed for cement filler HMA^eS, but with lower air void contents producing lower values of air void content values than limestone HMA^eS as its filler paste have high viscosity which is more efficiently covering the aggregate surfaces. Lower penetration values given in Table (11) for limestone fillers than their values for cement-filler paste is the reason for that behavior. Air voids variation is usually the measure of HMA durability and external badly affecting factors like loads with the existence of moistening factors producing high water pressure to damage the binder film adhesion forces.

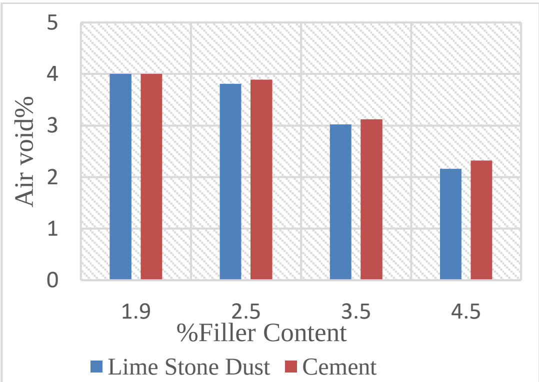


Figure (4): Effect of Filler Content on the Air Voids

4.4 The Effect of Filler Content on Percent Voids in Mineral Aggregates (VMA)

The higher the VMA values in the dry aggregate, the more surface area there is for the asphalt film[15]. Most specifications specify that a particular minimum criterion for VMA based on the belief that the thicker the asphalt binder film on the aggregate particles, the more durability of the mix. Therefore, decreasing VMA to reduce asphaltcontent is actually counter-productive and damaging to pavement condition [15].Figure (5), illustrates the effect of filler content on the VMA of HMA^eS at different filler contents for super-pave prepared specimens. The increase of filler decreases the VMA for both types of fillers used in this study. Highest value of VMA was resulted at 1.9% and lowest one at 4.5% lime stone and cement filler contents respectively. Generally, limestone dust has a lower VMA when compared to the cement with the same content proportion. In comparison with the required percentage of the minimum specification VMA which is usually calculated as at least 13% for this HMA blend design, the results obtained were above the standard required which is (13) according to SORB/3 for 1.9% and 2.5 % for both type of filler which produced highly stiff HMA mixtures.

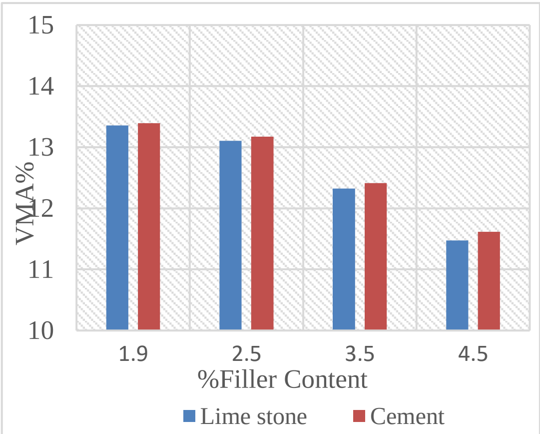


Figure (5): Effect of Filler Content on the Voids in Mineral Aggregate

4.3 The Effect of Filler Content on the Percentage of Voids Filled with Asphalt (VFA)

Voids filled with asphalt characteristic is significant not just as a measure of relative durability, but also because it has a strong relation with density ratio. When the VFA is very low, there will be insufficient asphalt to offer durability, over-density under traffic, and bleeding of the asphalt binder will be resulted[15]. The effect of different filler types in various proportions on the VFA of HMA is shown in Figure (6), which indicates that the VFA is increasing with decrease of filler content proportion for limestone dust and cement filler.

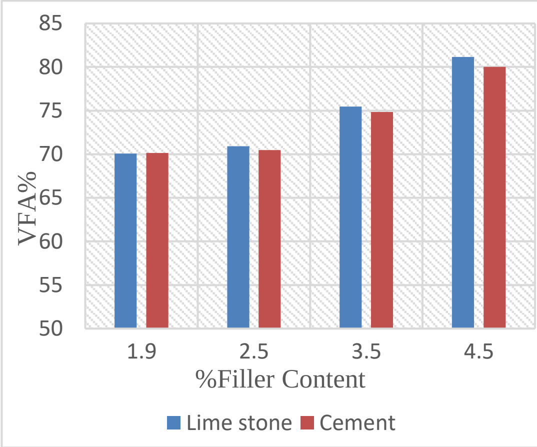
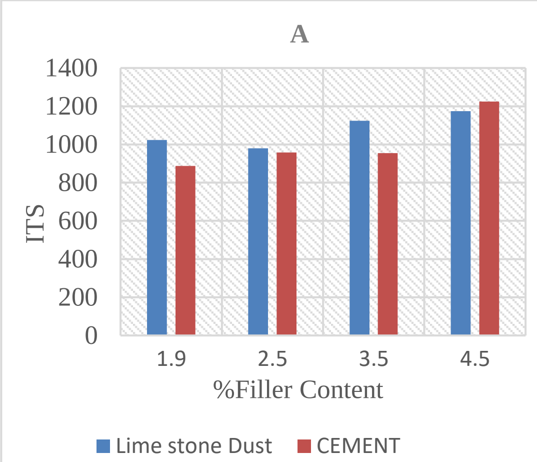


Figure (6): Effect of Filler Content on the Voids in Mineral Aggregate

4.4 Indirect Tensile Strength (ITS) and Tensile Strength Ratio (TSR)

Environmental factors such as, temperature may have a profound impact on the durability of asphalt pavements and have a negative impact on the mechanical behavior of the HMA in the future after being subjected to loads in the same conditions. Moisture sensitivity is evaluated by conducting an Indirect Tensile Strength Test (ITS), from which, the tensile strength ratio (TSR) could be calculated. Figure (7) shows that, there is an increase in the ITS with the increase of filler content for both Limestone dust and ordinary Portland cement fillers in both cases of unconditioned and conditioned before loading in the testing machine. It is shown that, the highest value of ITS for unconditioned and conditioned is at 4.5% filler content with 1174Pa, 1225 and 1025.7, 997.8 Pa respectively for Limestone dust and Portland cement fillers. Regarding the Tensile Strength Ratio (TSR), where the percentages exceeded 80% for all filler proportions for both filler type limestone dust and cement due to higher adhesion between the asphalt binder and the aggregate, which leads to less probability to have stripping between binder paste and aggregate surfaces. As shown in Figure (8), the highest value were 90 percent at 2.5 percent Limestone dust content, while the highest value for Portland cement was 89.7 percent at 3.5 percent were 90 percent at 2.5 percent Limestone dust content, while the highest value for Portland cement was 89.7 percent at 3.5 percent.



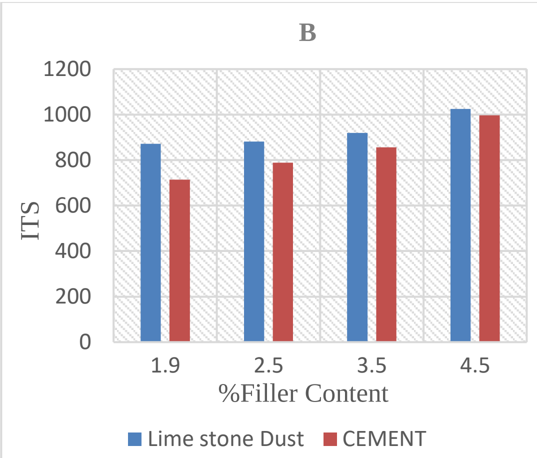


Figure (7) The Effect of Filler Content on the Indirect Tensile Strength test of
(A) Unconditioned (B) Conditioned

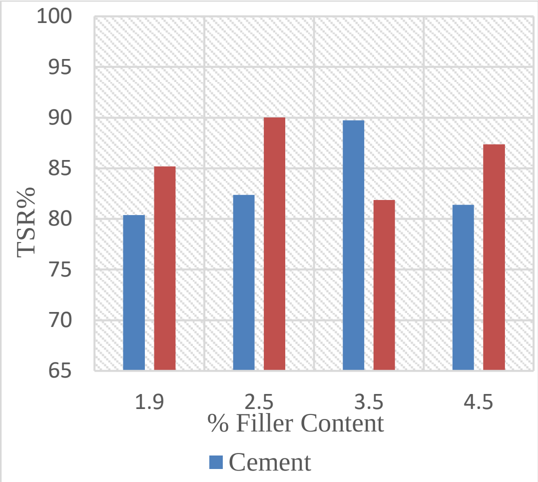


Figure (8): Effect of Filler Content on the Percent of Tensile Strength Ratio (TSR)

3. CONCLUSION

1. The ductility is decreased with the increase of filler the, decrease percentage for (10.8%,15%,21%and 26%) while for cement was (4.3%,8.6%,15.2% and 21.7) for filler content(1.9%,2.5%,3.5%and 4.5%)
2. The softening point increased with the increase of filler content for Limestone dust and Portland cement highest value was at 4.5% by 3.04%and 3.4% respectfully that is indicating some improvement in deformation resistance and temperature susceptibility;
3. Regarding the penetration, decreased with the increase filler content ,decreased for limestone by(6.3%,18.7%,35.6 and 48%) for filler percent (1.9%,2.5%,3.5% and 4.5) ,While cement decreased by(6.2%,9.3%18.7,and 23.7%).
4. Volumetric properties for the HMA are improved with the filler content as the AV and VMA percentages are increasing with the increase of filler content and the results obtained are higher for cement compared with limestone dust for the same filler content ,there is slight different between the limestone and cement. The VFA percentage is increased with the increase of filler content. It is shown that, volumetric contents of 1.9 and 2.5 percent of filler is within the requirement of the super-pave criteria.
5. The ITS increase with the increase of limestone dust and cement by 14.6% and 37.0% respectively for unconditioned while it increase by 17.6% and 39.7% for conditioned, TSR for all ratios were more than 80 percent its increase by 5.6% for 2.5% limestone dust while increase by11.6% for 3.5% cement indicating that filler content improved moisture resistance of hot mix asphalt under wheel load applications by 17.6% and 39.7% for conditioned.

It is recommended, same study could be conducted on limestone and back house dust filler to show and compare the behavior of each one of them for better application in the real construction field.

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تأثير الحجر الجيري والأسمنت على الخواص الميكانيكية للخلطة الاسفلتية الساخنة

بيان عبدالله طه*
bayan.taha@dpu.edu.krd

عبدالخالق مال الله**
abdelkhaleq@uomosul.edu.iq

شفيقة سلطان عبدالله*
shafika.sultan@dpu.edu.krd

* جامعة بوليتكنيك دهوك - كلية الهندسة - قسم الطرق والجسور
** جامعة الموصل - كلية الهندسة - قسم الهندسة المدنية

الملخص

*يتم رصف معظم الطرق في العراق باستخدام خليط الإسفلت الساخن الذي يتكون من الركام الاسفلت والفلر. في هذه الدراسة ، تم إجراء دراسة باستخدام نوعين من الفلر المستخدمة على نطاق واسع وهما غبار الحجر الجيري والأسمنت البورتلاندي العادي والمتوفر محليًا والمستخدم بكثرة.النسب المستخدمة في هذه الدراسة هي أربع نسب (أي 1.9٪ ، 2.5٪ ، 3.5٪ ، 4.5٪) من إجمالي وزن الركام لكلا النوعين . تم خلط هذه النسب باستخدام الأسفلت اختراق 50/40 ودرجة الأداء (*PG70-10*) باستخدام نظام الاداء الفائق(*Super-pave*). تم تقييم أداء مادة ربط البيتومين بكلا النوعين من الفلر من خلال:نقطة الاختراق ، الليونة ، نقطة التليين ، مؤشر الاختراق ، الخصائص الحجمية ، قوة الشد غير المباشرة ونسبة قوة الشد. تشير الخصائص الحجمية إلى أن نسب (1.9٪ و 2.5٪) لكلا النوعين من مواد الحشو تقع ضمن معايير نظام الاداء الفائق* Super-pave *حيث زادت قوة الشد المباشر* ITS *مع زيادة محتوى الحشو وأعلى قيمة لنسبة قوة الشد* TSR *لـ 2.5٪ من غبار الحجر الجيري. 90٪ بينما الاسمنت ل 3.5٪ بنسبة 89.7٪. هذا يكشف أن الخلطة الاسفلتية تتأثر بشكل كبير بكمية ونوع محتوى الفلر.*

الكلمات الداله :

الخلطة الاسفلتية ، نظام الاداء الفائق،الحجر الجيري،قوة الشد الغير مباشر ، نسبة قوة الشد