EFFECT OF TYPE AND AMOUNT OF MINERAL FILLER ON PERFORMANCE OF HOT MIX ASPHALT IN YEMEN

تأثير نوع وكمية المادة المالئة على أداء الخلطة الاسفلتية الساخنة في اليمن

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ABSTRACT:

Mineral filler (MF) is considered one of the most important components of the asphalt hot mixture as it has significant role on its behavior in terms of mechanical properties such as stability and flow, as well as volumetric properties such as the air voids, density, etc. Despite the lack of production of the conventional filler in the local quarry, it is indispensable because it helps in obtaining asphalt mixtures that matches Marshall Mix Design criteria and accordingly reducing most of failures such as permanent deformation, rutting and stripping that can occur in the asphalt pavement due to traffic loads and environmental effects regardless of the effect of quality control and construction technics, or the quality of other materials, such as gravel and asphalt cement. This study has focused on the effect of mineral filler on the main properties of asphalt mixture and mineralogy of different types of fillers and their quantitative and qualitative effects on the volumetric and mechanical properties of the asphalt mixture and determining their proportions for local uses. The crushed aggregate of basalt was used in this study and the aggregate blend of the reference mixture was obtained after several trials of Marshall Mix Design using three samples for asphalt contents of 4.5%, 5%, 5.5% & 6% (with a total of 15 samples) with 5% basalt dust by weight of total aggregate as a reference MF. The optimum asphalt content was 5.2% by weight of the total mix which achieved the required limitations. Accordingly, asphalt mixtures were prepared for four types of local mineral fillers (Ordinary cement OC, Hydrated lime HL, granite waste powder GW, cement bypass BP) and applied individually in the mixtures for three samples with rates of 30%, 70%, and 100% of the weight of the reference mineral filler which was basalt dust. If the 15 samples of the job mix for reference mixture are considered, the total number of samples for this study are 129 samples. 36 samples were tested using Marshall test method ASTM D6927 and 78 samples were tested using Tensile Test ASTM D4867/4867M in order to specify the used mineral filler. The specific gravity and mineralogy composition were obtained using Wavelength Dispersive X-Ray Fluorescence Spectrometer. The asphalt cement was rheologically characterized by using standard penetration and ductility tests. The asphalt cement chosen for the study was 60/70 penetration grade bitumen which was manufactured in Aden refinery. All results were statistically analyzed using SPSS program. Results indicate that the mineral filler which have the highest CaO content increases asphalt and aggregate bonds and directly increases the Marshal Stability and tensile strength which was also supported by SPSS program. The results also show that excessive content (100%) of high specific gravity mineral filler of (OC) tend to produce very stiff and sticky mixture and that being difficult to compact. However, Cement Bypass (BP) has fulfilled design requirement regarding the selected Voids ratio of (4%) and minimum voids in mineral aggregate (VMA) of 14% for the appropriate nominal maximum size of aggregate gradation. The mixes of 70% HL, 100% BP and 70% GW have exceptionally increased trend of Tensile Strength Ratio (TSR) and acts as more as control filler which also reflected by SPSS program. The study concludes that the mineral fillers that were evaluated have exceptional effects on the mechanical and volumetric properties of the asphalt mixtures, especially the resistance to water susceptibility. The study recommends using of cement wastes and granite waste powder as mineral filler that is considered more economical, and the use of one of these two materials in the asphalt pavement as an alternative to natural or manufactured materials contributes to reducing the negative environmental impact of the road projects and consequently reducing the disposed waste on the environment. The study also recommends implementing site sections using ratios of successful mixes that conform to standards in a laboratory to demonstrate their effectiveness. We recommend continuing further researches in order to derive the optimum asphalt contents for each type and amount of fillers used in this study at void ratio 3 to 5%.

Key words: characterization, Mineral filler, Asphalt mixture, Yemen, Hydrated lime, Cement bypass, Granit powder.

الملخص

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ملخص:

تعتبر المادة المالئة أحد أهم مكونات الخلطة الإسفلتية حيث ان لها تأثير في سلوكها من حيث الخواص الميكانيكية مثل الثبات والانسياب وكذا الخواص الحجمية كنسبة الفراغات الهوائية والكثافة وغيرها. ورغم قلة انتاج المادة المالئة التقليدية ضمن كسارات الأحجار المحلية الا انه لا غنى عنها لدوها المساعد في الحصول على خلطة اسفلتية معيارية تطابق معايير مارشال القياسية وبالتالي التغلب على معظم الإشكالات مثل الهبوط الدائم، التخدد، التقشر وذلك اثناء تعرض سطح الطريق للحمولات المرورية والعوامل البيئية وبصرف النظر عن تأثير طرق واساليب التنفيذ أو جودة مواد الخلطة الاخرى كالحصى والأسفلت الرابط. ركزت هذه الدراسة على تأثير المادة المالئة على الخواص الرئيسية للخلطة الإسفلتية والتركيب المعدني للأنواع المختلفة من المواد المالئة وتأثيرها كمًا ونوعا على الخواص الحجمية والميكانيكية للخلطة الإسفلتية وتحديد نسبها للاستخدام المحلي. الركام المستخدم في الدراسة من نوع حجر البازلت المحلي المكسر آلياً وقد تم اعتماد التدرج الحبيبي للركام الخاص بالخلطة المرجعية بعد عدة محاولات باستخدام طريقة تصميم مارشال وبتكرار ثلاث عينات لكل نسبة من نسب الإسفلت 4.5%، 5%، 5.5%، 6% (عدد 15 عينه) وباستخدام غبار البازلت كمرجعية للتقييم بنسبة 5% من وزن الخلطة الحصوية. حيث كانت نسبة الإسفلت المثالية هي 5.2 % من الوزن الإجمالي للخلطة الإسفلتية والتي حققت المعايير المطلوبة. بناء على ذلك، تم اعداد خلطات اسفلتيه لأربعة أنواع مختاره من المادة المالئة المحلية (الاسمنت البورتلاندي، النورة، مخلفات مصانع الجرانيت، مخلفات مصنع الاسمنت) وتطبيقها في الخلطات بصوره منفردة على ثلاث عينات بنسب 30%، 70%، 100% من وزن المادة المالئة المرجعية وتم اخضاع 36 عينة لاختبارات مارشال ASTM D6927 و 78 عينة لاختبارات معدل الشد ASTM D4867/4867M و بهذا اصبح العدد الإجمالي للعينات في الدراسة 129 عينة. بغرض الحصول على توصيف واضح للمواد المالئة المستخدمة تم الحصول على بيانات الوزن النوعي والتركيب المعدني باستخدام جهاز(WDXRF)، كما تم عمل الفحوصات المتعلقة بالقوام كالغرز والممطولية للإسفلت المستخدم في الدراسة من النوع 70/60 من حيث مستوى الغرز والمنتج في مصفاة عدن. تم استخدام برنامج SPSS لتحليل النتائج احصائيا. أوضحت النتائج النهائية للفحوصات المعملية انه بزيادة محتوى اكسيد الكالسيوم CaO في التركيب المعدني للمادة المالئة تزيد فاعلية المادة في تعزيز قوة الترابط بين الحصى والأسفلت مما ينتج عنه ارتفاع قيم ثبات مارشال وارتفاع قيم مقاومة الشد و الذي أكدته نتائج التحليل الاحصائي. كما اظهرت النتائج ايضا أنه عند النسبة العالية أي 100% للمواد المالئة التي لها قيم عالية بالنسبة للوزن النوعي، تم الحصول على عينات لها صفة القساوة وغير سهلة التشكيل اثناء الخلط والدك، باستثناء مخلفات الاسمنت التي قدمت نتائج مرضية بما تقتضي متطلبات معهد الاسفلت للخلطة الاسفلتية عند نسبة فراغات تصميمية قدرها Va = 4 % وعند نسبة الفراغات بين الحبات الحصوية VMA=14% المختارتان مقابل القطر الأسمى الاعظمي للتدرج الحصوي. فيما يتعلق بمعدل مقاومة الشد TSR فان أعلى القيم تم الحصول عليها في الخلطات ذات المحتوى 70% من النورة والمحتوى 100% من مخلفات الاسمنت وايضا 70% من مخلفات الجرانيت بالمقارنة مع النتائج التي اعطتها المادة المالئة المرجعية ، غبار البازلت، لنفس الاختبار و هذا ما عكسه التحليل الاحصائي. تستنتج الدراسة ان المواد التي تم تقييمها لها دور مؤثر في الخواص الميكانيكية والحجمية للخلطات الاسفلتية بما في ذلك مقاومة تأثير المياه. توصي الدراسة باستخدام مخلفات الاسمنت ومخلفات حجر الجرانيت كمادة مالئة كونها أكثر اقتصادية، كما ان توظيف أي من تلك المادتين في الرصف الاسفلتي كبديل للمواد الطبيعية أو المصنعة، يساهم في تخفيف الاثر البيئي السلبي لمشاريع الطرق بشكل خاص وللبيئة بشكل عام نتيجة تقليل رمي المخلفات في البيئة. ولإثبات فعالية استخدام هذه المواد عملياً توصي الدراسة بتنفيذ مقاطع على الطريق باستخدام النسب للخلطات الناجحة المطابقة للمعايير معمليا. نوصي أيضاً باستمرار البحث في لاستنباط نسبة الأسفلت المثالية مع نوع وكمية كل مادة من المواد المالئة المستخدمة في هذه الدراسة عند نسبة فراغات بين3 الى 5%.

1. INTRODUCTION

Flexible pavement is being commonly used in Republic of Yemen since the government continuously aimed to upgrade the road network. On the other hand, it is reported that common asphalt pavement distresses such as stripping, permanent deformation (rutting) and fatigue cracking are being observed after traffic operations. Commercially, this requires large amount of maintenance work. Many researches have been conducted in other countries to produce mixes using local materials for purposes of improve Hot Mix Asphalt (HMA) properties. Mineral filler is one of the local materials that can play an important role for improving HMA performance.

Mineral filler defined as that portion in the total mix of aggregate that is finer than 0.075mm (no. 200) sieve. This material was originally added to dense-graded Hot Mix Asphalt (HMA) and can reduces the air voids in the mixture, the other interactions are depending on the chemical and physical composition of the Mineral Filler (MF).

During the mixing of asphalt binder and aggregates, the asphalt binder combines the fines material to form fines-asphalt mortar. Physically, the addition of fines to the combined can extend or stiffen the asphalt binder or both. Definitely, this modification of asphalt mastic should affect the HMA performance.

This study is not intended to investigate or compare similar ideas related to the effects of MF on HMA but to prove the ability of use local MF as a part of asphaltic mixture components that presumed to play main role on the performance of HMA by whether, physical or chemical effects.

Asphalt concrete mix design requires the designer to select a combination of aggregates, asphalt binder and air voids to produce a mix that meets the criteria of the technical specifications of the projects.

Historically, it has been found that air voids ratio in the range of 3 to 5 % is required for durable concrete mixes. Thus, the difficult thing is how the designer can satisfy all criteria of HMA design such as, stability and durability which depend on the attraction bond between asphalt and particles of Mineral Filler, also the voids in the mineral aggregate (VMA) which has significant influence in the volumetric properties of the mix.

[Adequate rut resistance can be achieved regardless of VMA by making certain that the proper binder grade is selected for a given application and that the aggregate blend contains sufficient fines relative to the design VMA [6].

The binder film thickness which depends on MF amount is to function on the volume of asphalt mastic within the mix and the attraction bond between asphalt and particles [16]. Since the purpose of the binder is to coat and bind the aggregates together, the binder film thickness is a key factor in asphalt concrete mix design.

On the other hand, in the construction of road, highway and airfield pavement, one of the main problems is insufficiency of amount/type of mineral fillers. Therefore, it is important to find an alternative type of mineral filler materials. Thus, this study was made with this intention.

Currently, Sana'a, as well as many other governorates, use the crushed basalt (coarse aggregate, fine aggregate and dust) for numerous mixes. Depending on cost, crushed basalt dust may be more economical than hydrated lime, Ordinary Cement, etc. The difference in physical and chemical properties of other mineral fillers versus basalt dust leads to the question of whether or not the use of other fillers is appropriate for HMA.

The visual survey for some of recently paved road in the Capital of Sana'a indicates to several damages and distortions of asphalt wearing course (especially after one or frequent rain season) and this research is trying to find out a new MF that can build more durable mixes.

2. OBJECTIVES

- Determine the main properties and Mineralogy of different types of fillers that can be used in local

HMA. This includes Ordinary cement (OC), Basalt dust (BD), By-pass product (BP), Granite waste (GW) and hydrated lime (HL).

- Determine the effect of the type and quantity of fillers on the volumetric properties of HMA (Va, VMA, Vfa, and Unit weight).
- Determine the effect of the type and quantity of fillers on the mechanical properties of HMA (Stability, Flow, and Resistance of moisture-induced damage).
- Recommend the most suitable filler type and content for local use.
- Participate in better management of wastes through the possible use of different type of wastes in roads construction as an environmental issue.

In order to achieve the objectives of this research comprehensive approach has been formulated as shown in Figure 1-1

3. METHODOLOGY

HMA material composite were brought from different places inside the Country. 129 HMA compacted specimens were conducted. Before that, these materials have been subjected to the required tests to satisfy HMA material specifications for the road and highway construction. The laboratory tests of physical properties for asphalt cement was achieved at the laboratory of Faculty of Engineering. Further experimental work was achieved at the laboratory of the Mix Plant of Military Construction Department during the period of twelve months, from 15th May 2013 to 29th May 2014 (about 180 working days) due to their administration and conditioned by the availability of electrical power that was working only at mixing time.

3.1. Selected Materials:

3.1.1. Asphalt Cement:

One type of asphalt cement was used in this research. Asphalt (60/70) penetration grade was brought from Aden Refinery Company, and it is widely used in flexible pavement constructions in Yemen.

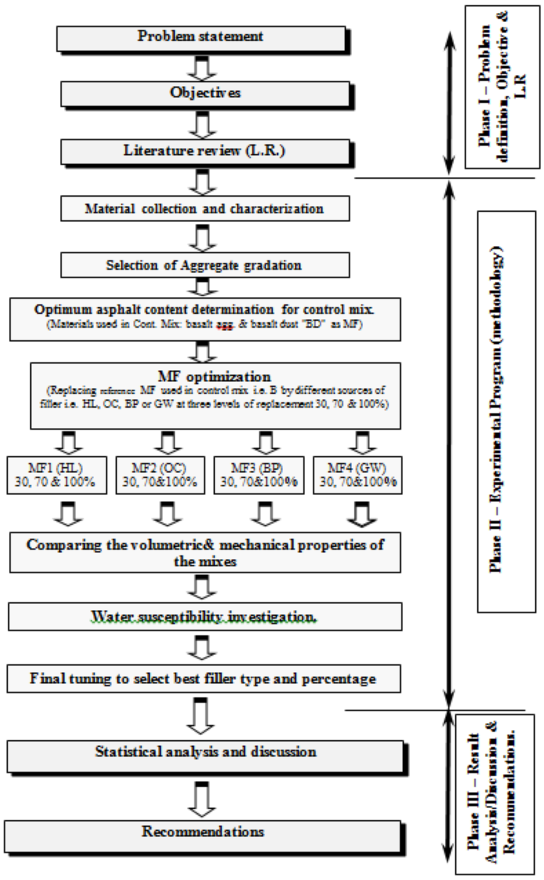


Figure (1-1): Research Framework

3.1.2. Mineral Aggregate

The crushed Basalt stone used in this research were subjected to several tests in order to assess their physical characteristics and suitability in the road construction. The mineral aggregates were obtained from the quarry of Military Construction Department located at Sawan area, east side of Sana'a Capital. The coarse and fine aggregate particles were separated into different sieve size and proportioned to obtain the chosen gradation for bituminous mixtures 12.5mm nominal maximum aggregate size. The selected fine and coarse aggregate was controlled by Standard Specification for Coarse & Fine Aggregate for Bituminous Paving Mixtures ASTM D 692 & ASTM D

1073. Incorporating mineral fillers, the Job-Mix-Formula (JMF) for the aggregate particle size distribution that used for the preparation of mixtures and the specified grading limits (according to Projects Department of Secretary of Capital) are shown in Figure 3-1 and Table 3-2.

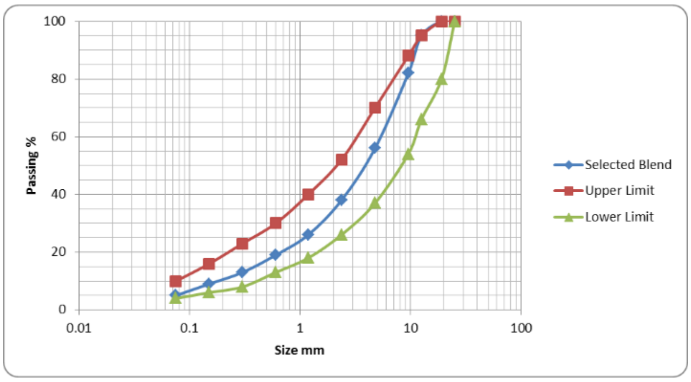


Figure (3-1): Aggregate Gradation

Table (3-1). Aggregate Gradation

Sieve size			Selected Blend	Specifications
			Passing %	
3/4''	19	mm	100	100
1/2''	12.5	mm	95	80 – 95
3/8''	9.5	mm	85	-
# 4	4.75	mm	56	48 – 62
# 8	2.4	mm	38	30 – 45
#16	1.18	mm	26	-
# 30	0.6	mm	19	-
# 50	0.3	mm	13	16 – 26
# 100	0.15	mm	9	8 – 18
# 200	0.075	mm	5	4 – 8

To investigate the physical properties of the aggregates and their suitability in road construction, several tests were conducted.

3.1.3.Mineral Fillers:

Five types of local Mineral Filler were studied in this research, basalt dust (BD) as control filler, Hydrated Lime (HL), Ordinary Cement (OC), Cement Bypass (BP), and granite waste powder (GW). The descriptions of all mineral fillers are shown in Table (3-2). One of the important information is the mineral composition and these tests were conducted at Ministry of oil & minerals.

Table (3-2): Description of Mineral Fillers (source: local market)

Type of MF	**Source**		**Special information**	**Normal Photograph**
(BD)	Quarry of Military Construction Department located at Sawan area		Low to medium price and poor production	
(HL)	Sayun City/ (traditional production)		Medium to high price	
(OC)	Amran Cement Plant		High price but available	
(BP)	Amran Cement Plant		Approachable by transportation cost only (up to 15% of Clinker)	
(GW)	Marib Governorate		Approachable by transportation cost only	

4. Experimental Work

4.1. Hypothesis

Based on the results of mineralogy test the percentage of calcium oxide (CaO) is highly presented in four types of MF (HL, OC, BP, GW) that expected to increasing the bond between aggregate and asphalt [2] [4] & [8]. Referring to the most of reviewed studies, it has concluded that the type and amount of MF has an effect on the performance of HMA. The hypothesis of this research is that using of three contents of different type of local mineral fillers could interact to create unconventional asphalt blends which have well properties concerning the stability and water susceptibility than the conventional or common blends.

4.2. Experimental Design

In this study, the effects of MF on HMA were evaluated by multiple laboratory test methods and conditioning procedures for several mineral fillers. Figure 4-1 illustrates the experimental program of the research.

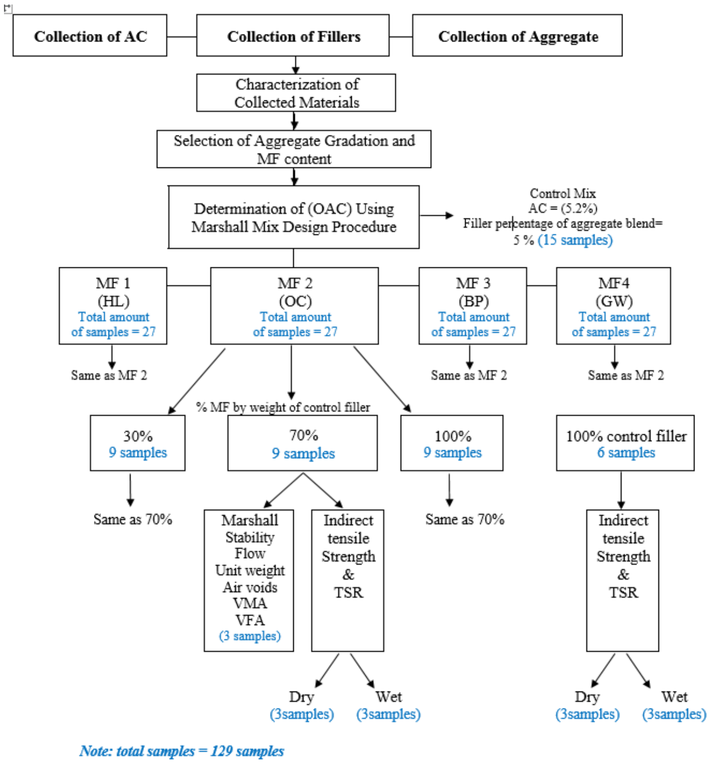


Figure (4-1): Experimental Program

4.3. Marshall Mix Design

This method is used in this study to evaluate the selected aggregate gradation & asphaltic mixtures. Standard test method ASTM D6926 & ASTM D6927 was conducted to determine the optimum asphalt content for the control mix. Before preparation of test specimens, mixing and compaction temperatures were determined using the physical properties of asphalt cement (viscosity). This was established by testing the asphalt cement viscosity at different temperatures and plotting the viscosity versus temperature relationship. The temperature that produce viscosities of 170 ± 20 centistokes kinematics and 280 ± 30 centistokes kinematics were established as the mixing and compaction temperatures respectively. In this study, mixing temperature was 160° C and the compaction temperature was 140° C.

An aggregate weighing about 1200g and heated to a temperature of 170° C, the 60/70 asphalt grade was also heated to a temperature of 140° C. Then, these ingredients were mixed at a temperature of 160° C, as previously discussed. The percent by weight of asphalt content for was taken with respect to the total weight of the mixture. The mixture was then placed in the preheated mold and compacted using 75 blows on both ends of specimen. After compaction, the specimen was allowed to cool and removed from the mold by means of an extrusion jack. In accordance with Marshall Test Method, four different AC percentages were used (4.5, 5, 5.5 and 6%) with 5% of Basalt dust control filler and each compacted test specimens were subjected to determination of unit weight & void analysis, in addition to stability and flow tests. Then, plots were made to determine the optimum asphalt content. The selected optimum asphalt content OAC shall meet the standard requirement shown in Table 4-1.

After select the OAC, specimens were mixed with 5% control filler (by weight of total aggregate) in addition to the suggested mineral fillers (HL-OC-BP-GW) with different amount of 30%, 70% and 100% by weight of control filler. Same to the previous, each compacted test specimens were subjected to volumetric analysis and stability-flow test.

4.4. Tensile strength

ASTM D 4867/D 4867M was performed by compacting specimens (using Marshall hummer) to an air void level of six to eight percent. The steel loading strips were manufactured locally according to ASTM test method D4123. Three specimens are selected as a control and tested without moisture conditioning, and extra three specimens are selected to be conditioned by saturating with water in temperature of 60° C. The specimens are then tested for indirect tensile strength by loading the specimens at a constant rate and measuring the force required to break the specimen. The tensile strength of the conditioned specimens is compared to the control specimens to determine the tensile strength ratio (TSR).

As Marshall tests, charts were made to show the dry tensile strength, conditioned tensile strength and TSR values of each respective specimen prepared using control filler the Basalt dust and different types of mineral fillers (HL-OC-GW-BP) in addition to different ration (30%, 70% only) of MF by weight of control filler.

Table (4-1): Marshall Mix Design Criteria (Ms2) & Results of Control Mix Test

	Min.	Max.	Control mix AC = 5.2%
Compaction, number of blows each end of specimen	75		75
Stability Kg (lb.)	815.4 (1800)		1594 (3518)
Flow, 0.25 mm (mm)	8 (2)	14 (3.5)	12.2 (3.05)
Percent Air voids %	3	5	4.02
Percent voids in mineral aggregate (VMA) (Design Air voids=4%) Nominal Maximum particle size 12.5mm	14		15.1
Percent voids filled with asphalt (VFA)	65	75	73.4

5. RESULTS, ANALYSIS AND DISCUSSION

5.1. Preliminary tests

a- Asphalt cement:

The tests of ductility, penetration, flash point and specific gravity were conducted and the result are listed below in table 5-1.

Table (5-1): Physical Properties of Asphalt Cement

Property	Test Method	Test Result
Ductility at 25°C 5 cm/min, cm	**ASTM D113**	**116.7**
Penetration at 77°F (25°C) 100 g, 5 s	**ASTM D5**	**66.6**
Flash point, °C (Cleveland open cup)	**ASTM D92**	**280°**
Specific Gravity 25°C	**ASTM D70**	**1.028**

b- Mineral Aggregate:

Table 5-2 shows the results of physical properties of aggregate.

Table (5-2) Physical Properties of Aggregate.

Properties	Coarse Aggregate 44%	Fine Aggregate 51%	Test Method
Abrasion loss (%) (Los Angeles)	14		(ASTM C131)
Specific gravity	2.824	---	(ASTM C127)
Specific gravity		2.741	(ASTM C128)

Note:
G_{ef} (Effective specific gravity of aggregate mixture)=2.824
G_{sb} (Bulk specific gravity of aggregate mixture)= 2.782

c- Mineral fillers:

The results of specific gravity and mineral composition (using WDXRF machine) are presented in Table 5-3.

Table (5-3): Mineralogy of Mineral Fillers

		HL	OC	B	GW	BP
	G.S	2.52	3.12	2.85	2.63	2.82
SiO_2	*%*	*2.22*	*18.1*	*40.4*	*2.79*	*13.45*
Al_2O_3	*%*	*0.46*	*4.5*	*12.8*	*1.07*	*5.29*
Fe_2O_3	*%*	*0.39*	*3.43*	*13.4*	*1.11*	*2.68*
CuO	*(20ppm)*				*15*	*-*
CeO_2	*%*		*-*	*0.02*	*-*	
CaO	*%*	*61.23*	*58.74*	*8.63*	*52.4*	*57.68*
MgO	*%*	*13.7*	*0.06*	*3.64*	*0.79*	*2.89*
NiO	*(ppm)*	*-*	*-*	*16*	*-*	
SrO	*%*	*0.07*	*0.1*	*0.06*	*0.1*	*0.81*
Rb_2O	*(ppm)*	*-*	*-*	*16*	*-*	*0.03*
TiO_2	*%*	*-*	*0.44*	*3.34*	*0.13*	*0.32*
SO_3	*%*	*0.13*	*3.01*	*0.05*	*0.14*	*7.19*
MnO	*%*	*72 ppm*	*0.06*	*0.19*	*0.03*	*0.04*
K_2O	*%*	*0.11*	*1.1*	*0.1*	*0.09*	*5.97*
ZrO_2	*%*	*-*	*0.01*	*0.03*	*66 ppm*	*96 ppm*
Na_2O	*%*	*0.12*	*0.32*	*2*	*0.19*	*0.24*
P_2O_5	*%*	*-*	*0.07*	*0.48*	*0.04*	*-*
ZnO	*%*	*0.01*	*48 ppm*	*0.01*		
Nb_2O_5	Ppm	*-*	*-*	*35*		
L.O.I *	*%*	*33.88*	*6.17*	*14*	*40.1*	*4.09*
Total	*%*	*99.9*	*99.98*	*100*	*100*	*99.98*
** L.O.I = Loss on Ignition*						

5.2. Volumetric Properties

Results from Marshall test Method at 100% of MF that shown in Table 5-4 and Figure 5-1, specimens with lowest specific gravity MF (HL or GW) gains low air voids and high unit weight values, this indicates that the

HL & GW improve the workability of the mixture. Conversely, the other types of fillers that have higher specific gravity value (OC and BP) increase the air voids and decrease the unit weight of the mixtures. In fact, the excessive content of this type of mineral filler may tend to produce a mixture that is very stiff and sticky and difficult to compact. This effect decreases when increasing the amount of control filler (refer to air voids & unit weight results of 70 & 30% control filler shown in Fig. 5-2& 5-3. At these ratios, the specimens have low air voids value and high unit weight value comparing with the control mix.

As for percent air voids and VMA, The Asphalt Institute [22] requires the achievement of 4% air voids in asphalt mixture specimen that have compaction of 75 blows on each end and minimum VMA is equal to 14 % for the same chosen air voids limitation and Nominal maximum Particle size 12.5mm. So, 100% OC, 100% BP and 30% GW are only fulfilled Asphalt Institute requirement for used mixes and other types and amount of MF need to be evaluated with alternative Job mix. Though, we can conclude that the mixes that contain HL&GW are more workable than other mixes since the compaction effort is constant (75 blows) and these MFs act as good fill and lubricant material, respectively.

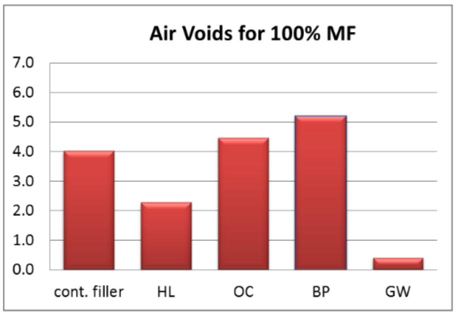
SPSS Statistical analyses was conducted for the results were compared with the control filler (Basalt dust) as a reference revealed the following results.

Regarding to the volumetric properties (Va and Unit Weight), most of the results reflected significant difference at 0.05 level with the mean values except 100%OC, 30%GW for VA results with 100%and 70%HL, and 70%PB, for Unit Weight results. This indicates that these mixes are identical with the control which is reasonable.

***Table (5-4): Test Results for Marshall Test Specimens**. ASTM D6927*

MF	Stability (Kg)	unit weight	Flow (0.25mm)	Va %	VMA %
Basalt 100% (Control Filler)	1593.78	2.492	12.92	4.016	15.10
HL 100%	2224.98	2.501	11	2.281	14.24
HL 70%	1978.45	2.510	15.2	2.780	14.31
HL 30%	1785.42	2.523	14.6	1.561	13.87
OC 100%	1097.23	2.462	17.4	4.470	16.46
OC 70%	1889.95	2.545	13.6	2.258	13.41
OC 30%	1961.49	2.547	14.4	1.782	13.31
BP 100%	1415.34	2.471	12.12	5.193	16.15
BP 70%	1972.40	2.534	9.32	2.206	13.61
BP 30%	1962.14	2.551	14.6	0.906	13.05
Granite 100%	1716.58	2.56	13.2	0.404	12.67
Granite 70%	1941.50	2.557	12.3	0.657	12.61
Granite 30%	1504.36	2.52	14.0	3.411	14.02

Note: AC=5.2 %



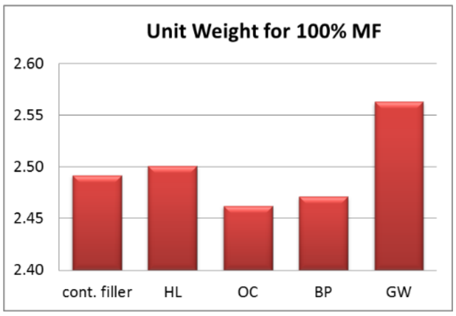


Figure (5-1): Air Voids & unit weight for Mixtures with control filler and 100% Lime, cement, Bypass and Granite

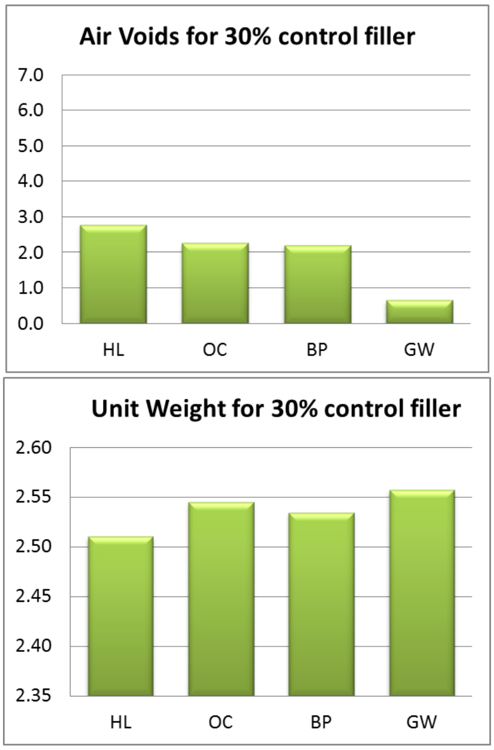


Figure (5-2): Air Voids & unit weight for Mixtures with 30% control filler.

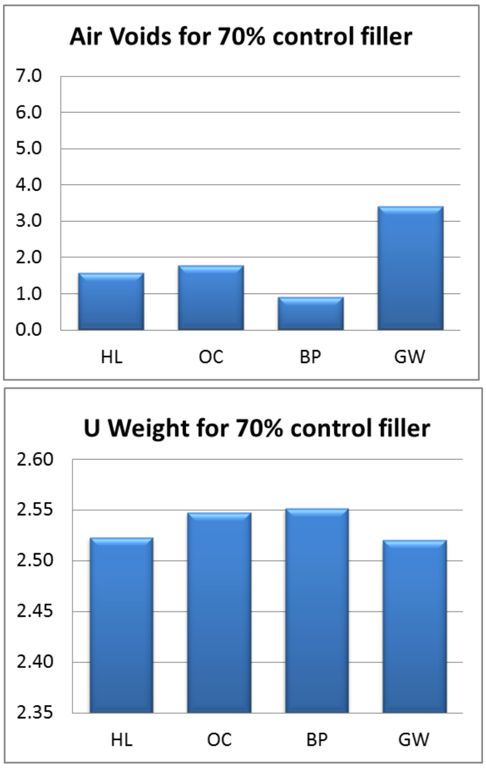


Figure (5-3): Air Voids & unit weight for Mixtures with 70% control filler.

5.3. Mechanical Properties

Generally, all test specimens provide stability values more than 1500 Kg except the mixtures with 100% OC and 100% BP which have lowest unit weight values. Referring to the results shown in Table 5-4, with respects to the upper and lower limits of flow (8 to 14); maximum Stability values were obtained using these rates of MF:(100% HL, 70% OC, 70% BP& 70% GW)

Figures 5-4, 5-5 & 5-6; show the variations between stability results or flow results for different type and same amount of MF, the large variation is clear at 0% control filler test specimen (100% Lime, 100% OC, 100% BP & 100% GW). This variation decreases with increasing HL, OC or GW instead of the control filler.

With Regard to the mechanical properties (Stability and Flow), most of the results reflected significant difference at 0.05 level with the mean values except 100%PB, 100% and 30%GW, 30%HL for Stability results with 100%PB and 100%, 70% and 30% GW, 70%OC for flow results. This indicates a significant improvement especially in stability of the mixes.

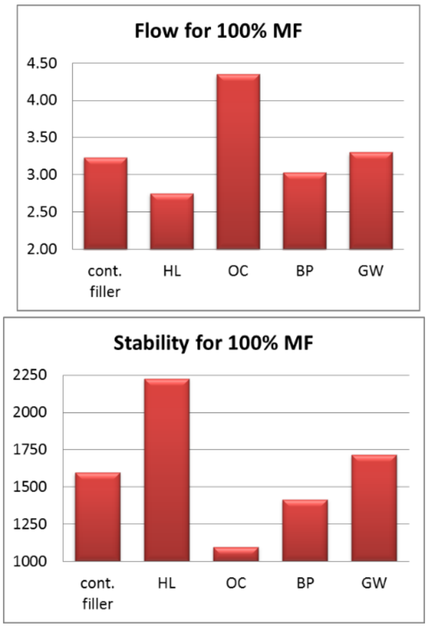


Figure (5-4): Flow & Stability for Mixtures with 100% MF.

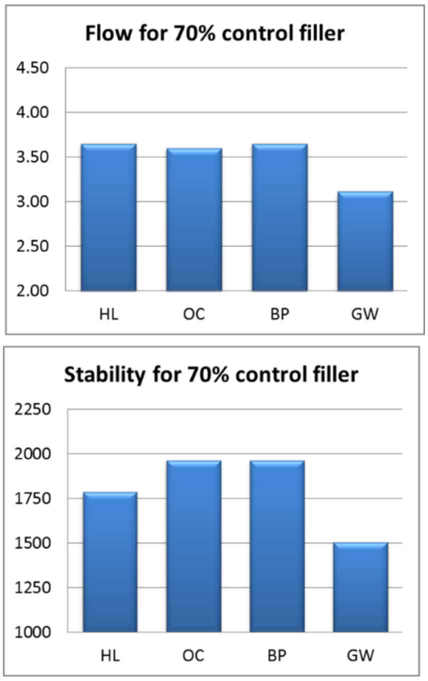


Figure (5-5): Flow & Stability for Mixtures with 70% control filler.

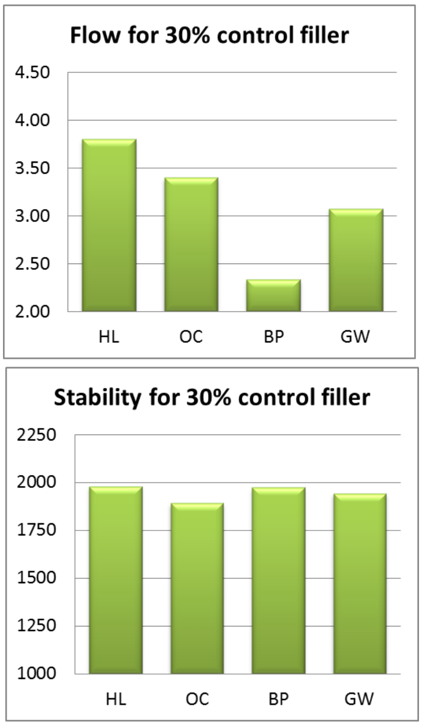


Figure (5-6): Flow & Stability for Mixtures with 30% control filler.

Table (5-5): Test Results for TSR Test Specimens. ASTM D 4867/D 4867M

% Filler	Type of Filler	AC	Average strength (Dry)	Average Moisture-conditioned strength	TSR	No. of Blows
		%	(Kpa)	(Kpa)	%	
100%	Control filler	5.2	1472.69	968.20	65.74	45
	HL	5.2	926.12	845.30	91.27	20
	OC	5.2	901.23	478.00	53.04	30
	BP	5.2	783.00	640.72	81.83	60
	GW	5.2	823.34	559.28	67.93	25
70%	HL	5.2	705.93	679.40	96.24	25
	OC	5.2	1317.95	429.43	32.58	25
	BP	5.2	1445.97	982.38	67.94	30
	GW	5.2	677.06	554.66	81.92	15
30%	HL	5.2	1003.34	629.48	62.74	18
	OC	5.2	1208.10	590.66	48.89	15
	BP	5.2	1251.08	618.54	49.44	15
	GW	5.2	1265.04	659.02	52.09	35

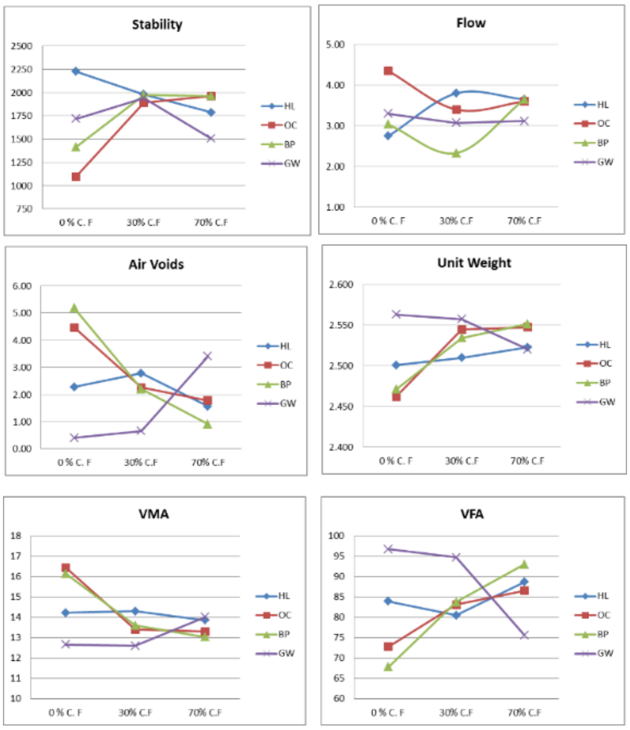


Figure (5-7): Stability& Flow, Air Voids, unit weight, VMA & VFA for Mixtures with 0%, 30% &70% control filler (C.F).

5.4. Tensile Strength

Trial and error method was conducted to determine number of blows for the requirement of water susceptibility test (ASTM D 4867/D 4867M), and the chosen number of blows indicates that the specimen that has a low value of air voids ratio at marshal test (75 blows) needs lower compaction effort (18 to 25 blows) than specimen with high value of air voids ratio to reach 6-8% air voids. This fact is observable at the results of test specimen with 70% control filler.

As expected, test results for the mixes of 70% HL, 100% BP and 70% GW; by weight of control filler; with blows of 25, 60 and 15, respectively, have exceptionally increases trend of TSR and acts as well or better than control filler. The HMA resistance to moisture depends on the available calcium oxide content in MF that interacts with asphalt bitumen [20], [2], [24] & [8]. Table 5-5 and figures 5-8, 5-9 & 5-10; show the results for the rates of 100%, 70% and 30% for all type of mineral filler. At 70% control filler, TSR values for all types of MF are in the range of (min. = 49% & max. = 63%). On the other hand, TSR values for all MF at 30% control filler, have big differences between each other.

With Regard to the Tensile Strength Ratio (TSR), the majority of the results indicated significant difference at 0.05 level with the mean values. This reflected a significant improvement of the mixes.

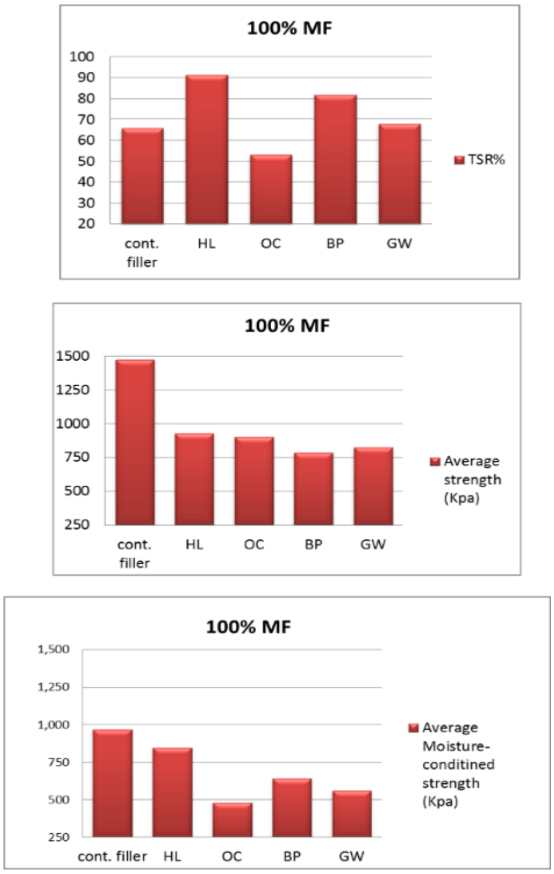


Figure (5-8): Indirect tensile strength & TSR for Mixtures with 100% MF.

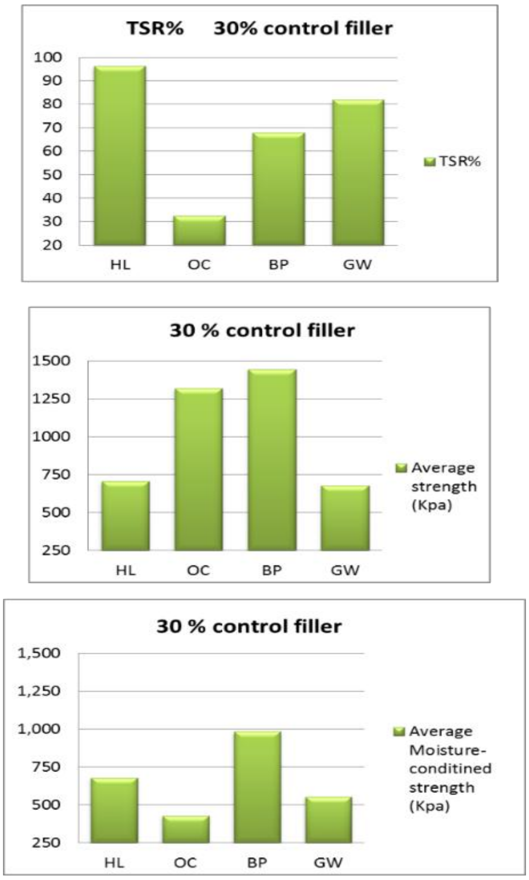


Figure (5-9): Indirect tensile strength & TSR for Mixtures with 30% control filler.

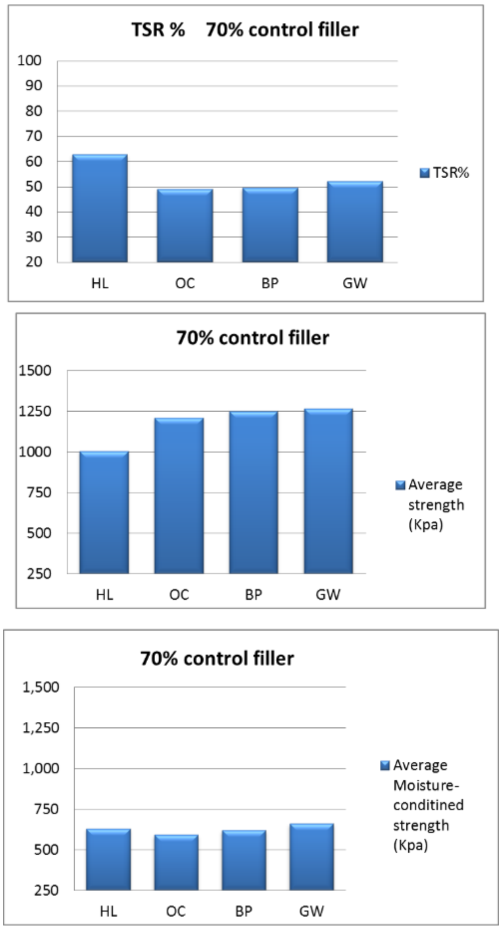


Figure (5-10): Indirect tensile strength & TSR for Mixtures with70% control filler.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion:

This research identifies four types of local material (HL, OC, BP and GW) that can be used as MF in the HMA and play a critical role on the mechanical performance, Moisture resistance and/or change the volumetric characteristics of the HMA, it also draws attention to the parameters that influence HMA performance and the shortage of research data concerning the effects of these materials on HMA. The test specimens contain 30%, 70% & 100% MF of the 5% filler content by weight of total aggregate. The primary conclusions from the test results and analysis are described below:

- HL has the highest CaO content that influences the bonds between asphalt and aggregate particles;

- The HMA resistance to moisture depends on the available calcium oxide content in MF that interacts with asphalt bitumen;
- The HL & GW improve the workability of the mixture;
- The excessive content (100%) of high specific gravity mineral filler (OC & BP) tend to produce very stiff and sticky mixture and that being difficult to compact;
- The specimens with 70% & 30% control filler contents have a high unit weight value more than 0% control filler;
- 100% OC, 100% BP and 30% GW are only fulfilled Asphalt institute regarding to the selected Va ratio (4%) and minimum VMA (14%) and respecting to the flow value limits (2 to 3.5mm) with the designed mix and aggregate gradation. These mineral fillers are more economic than other mineral filler even the dust of Basalt, and using Cement Bypass and Granite waste powder will reduce the environmental impact.
- TSR test results for the mixes of 70% HL, 100% BP and 70% GW have the exceptionally increases trend of TSR and acts as well or better than control filler.

6.2. Recommendations and Further Research:

- Using BP and GW mineral fillers in the flexible pavement is highly recommended for economic and environmental benefit.
- With respect to the Marshall and TSR test results, further investigation should be done with each MF type and percentage to obtain the optimum asphalt content at 3% to 5% air voids.
- Before widely adapting these mineral fillers in asphalt paving, trial sections and adequate provisions should be provided.

REFERENCES:

1- Ahmad H. Al Jassar, Sayed Metwali and Mohammed A. Ali. EFFECT OF FILLER TYPES ON MARSHALL STABILITY AND RETAINED STRENGTH OF ASPHALT CONCRETE, *The international Jornal of Pavement Engineering,Vol. 5(1)* (2004).

2- Arno Hefer and Dallas Little. ADHESION IN BITUMEN-AGGREGATE SYSTEMS AND QUANTIFICATION OF THE EFFECTS OF WATER ON THE ADHESIVE BOND, Research Sponsored by International Center for Aggregates Research Research Project No. ICAR 505, (December 2005)

3- BRENO BARRA, LETO MOMM, YADER GUERRERO and LIEDI BERNUCCI, CHARACTERIZATION OF GRANITE AND LIMESTONE POWDERS FOR USE AS FILLERS IN BITUMINOUS MASTICS DOSAGE. Anais da Academia Brasileira de Ciências (Annals of the Brazilian Academy of Sciences) (2014) 86(2): 995-1002 Printed version ISSN 0001-3765/Online version ISSN 1678-2690 http://dx.doi.org/10.1590/0001376520142013016

4- Didier Lesueur , Joëlle Petit & Hans-Josef Ritter THE MECHANISMS OF HYDRATED LIME MODIFICATION OF ASPHALT MIXTURES: A STATE-OF-THE-ART REVIEW, road materials and pavement design, 14:1, 1-16, DOI: 10.1080/14680629.2012.743669, (2013)

5- Didier Lesueur and Dallas N. Little. EFFECT OF HYDRATED LIME ON RHEOLOGY, FRACTURE, AND AGING OF BITUMEN, article in transportation research record journal of the transportation research board (January 1999)

6- Donald W. Christensen and Ramon F. Bonaquist, VMA: ONE KEY TO MIXTURE PERFORMANCE *Submitted to the South Central Superpave Center for Publication in the National Superpave Newsletter. (February 2005)*

7- F. Khodary, M.S. Abd El-Sadek, H. S. El-Sheshtawy, NANO-SIZE CEMENT BYPASS AS ASPHALT MODIFIER IN HIGHWAY CONSTRUCTION. Journal of Engineering Research and Applications ISSN: pp.645-648/ 2248-9622, Vol. 3, Issue 6, (Nov-Dec 2013)

8- Farag Khodary, M.S. Abd El-sadek &H.S. El-Sheshtawy. CaO/BITUMEN NANOCOMPOSITE: SYNTHESIS AND ENHANCEMENT OF STIFFNESS PROPERTIES FOR ASPHALT CONCRETE MIXTURES. International Journal of Scientific & Engineering Research, Volume 6, Issue 1, ISSN 2229-5518, (January-2015)

9- Farag Khodary, LABORATORY EVALUATION OF ASPHALT CONCRETE MIXTURES PROPERTIES MODIFIED WITH NANO-HYDRATED LIME (NHL). International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-5, Issue-1, (May 2016)

10- Hassan Y. Ahmed, Ayman M. Othman and Afaf A. Mahmoud. EFFECT OF USING WASTE CEMENT DUST AS A MINERAL FILLER ON THE MECHANICAL PROPERTIES OF HOT MIX ASPHALT, Assiut. Univ. Bull. Environ. Res. Vol. 9 No. 1, (March 2006)

11- Ibrahim Asi and Abdullah Assa'ad. Effect of Jordanian Oil Shale Fly Ash on Asphalt Mixes, *Journal of Materials in Civil Engineering*, Vol. 17, No. 5, (October 1, 2005).

12- Jaya R.S. and Asif, DETERMINATION OF BINDER FILM THICKNESS FOR BITUMINOUS MIXTURES PREPARED WITH VARIOUS TYPES OF FILLERS. *International Conference on Structural Engineering and Construction Management, Kandy, Sri Lanka, (December 2015)*

13- M.Satyakumar, R.Satheesh Chandran and M.S. Mahesh, INFLUENCE OF MINERAL FILLERS ON THE PROPERTIES OF HOT MIX ASPHALT. International Journal of Civil Engineering and Technology (IJCIET) ISSN 0976 – 6308. (Print), ISSN 0976 – 6316(Online) Volume 4, Issue 5, (September – October 2013)

14- Mazen Kamel Al-Haddadin. THE USAGE OF WHITE CEMENT-INDUSTRY POWDER WASTE AS A FILLER MATERIAL IN HOT ASPHALT MIXES, *University of Jordan*, (1994)

15- Menglan Zeng and Chaofan Wu, EFFECTS OF TYPE AND CONTENT OF MINERAL FILLER ON VISCOSITY OF ASPHALT MASTIC AND MIXING AND COMPACTION TEMPERATURES OF ASPHALT MIXTURE *Transportation Research Record: Journal of the Transportation Research Board, No. 2051*, (2008)

16- NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM, A MANUAL FOR DESIGN OF HOT MIX ASPHALT WITH COMMENTARY, NCHRP REPORT 673, (2011)

17- Ramzi Taha, A. M. ASCE, Amer Al-Rawas, and Ali Al-Harthy; and Ahmed Qatan. USE OF CEMENT BYPASS DUST AS FILLER IN ASPHALT CONCRETE MIXTURES, Journal of Materials in Civil Engineering (July/August, 2002).

18- Rania Arnaout. THE EFFECT OF MINERAL FILLER TYPE USED IN ASPHALT CONCRETE SURFACE COURSE ON THE PROPERTIES AND PERFORMANCE OF HIGHWAY PAVEMENTS, University of Jordan, (1995).

19- Suched Likitlersuang, Thanakorn Chompoorat. LABORATORY INVESTIGATION OF THE PERFORMANCES OF CEMENT AND flY ASH MODIfIED ASPHALT CONCRETE MIXTURES. International Journal of Pavement Research and Technology 9 /337–344 (2016)

20- Tarrer, A.R. and Wagh, V. THE EFFECT OF THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE AGGREGATE ON BONDING, SHRP-A/UIR-91-507, (1991)

21- Tayebali, AA; Malpass, GA; Khosla, NP. EFFECT OF MINERAL FILLER TYPE AND AMOUNT ON DESIGN AND PERFORMANCE OF ASPHALT CONCRETE MIXTURES, Transportation Research Record (1998)

22- The Asphalt Institute. MIX DESIGN METHODS FOR ASPHALT CONCRETE AND OTHER HOT-MIX TYPES, (MS-2), 6th Ed. (1997)

23- Tienfuan Kerh, Yu-Min Wang and Yulern Lin. EXPERIMENTAL EVALUATION OF ANTI-STRIPPING ADDITIVES MIXING IN ROAD SURFACE PAVEMENT MATERIALS, *American Journal of Applied Sciences, 2005*

24- Wang, H., Al-Qadi, I. L., Faheem, A. F., Bahia, H. U., Yang, S. H., & Reinke, G. H. EFFECT OF MINERAL FILLER CHARACTERISTICS ON ASPHALT MASTIC AND MIXTURE RUTTING POTENTIAL. *Transportation Research Record*, (2208), 33-39. DOI: 10.3141/2208-05 (2011)

25- West, Randy C. and James, Robert S. EVALUATION OF A LIME KILN DUST AS A MINERAL FILLER FOR STONE MATRIX ASPHALT, *the 85thAnnual Meeting of the Transportation Research Board, Washington, D.C. (2005)*