Effect Assessment the Impact of Filler Types on the Input Design Parameter of Flexible Pavements

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Abstract

To meet the requirements of flexible pavements (safety, economy, limited the stresses on the natural subgrade and a smooth ride), good quality material of surface course must be used so to prevent pavement distresses caused by the different types of loadings (structural and environmental loadings), while the resilient modulus is important input data when flexible pavement was designed, it is selected to show its effect by different types of mineral filler as a partial replacement.

In this paving mix, to improve the quality of the mix material and to represent the effect of these replacements materials on the elastic characterization by measuring the resilient modulus of hot mix asphalt (HMA): Fly Ash (FA), Ordinary Portland Cement (OPC), Hydrated Lime (HL) and Silica Fume (SF) are used as a partial percent of filler (Limestone Dust) (LSD) replacement, where these materials are locally available including (40-50) penetration grade asphalt binder.

To achieve the goal of study; asphalt concrete mixes are prepared at their optimum asphalt content using Marshall Method of mix design. Four replacement percent's were used; 0, 1.5, 3.0 and 4.5 percent by total weight of aggregate for each filler types.

According to ASTM D4123 criteria (Resilient Modulus) was tested by UTM25. Mixes modified with (FA), (OPC), (HL) and (SF) were found to have average improvement in the value of Resilient Modulus by (13.37, 9.63, 11.14, 24.00) % at 1.5 percent of filler replacement and by (24.54, 16.63, 18.73, 38.31) % at 3.0 percent of filler replacement also the percent of improvement is: (39.55, 26.36, 29.82, 58.30) at 4.5percent of filler replacement sequentially.

Key words: Modification of HMA, Filler Replacement, Resilient Modulus. HMA, Marshall

الخلاصه

لغرض الوصول الى متطلبات التبليط الأسفلتي (السلامة، الأقتصاد، تقليل الأجهادات على مستوى الأرض الطبيعية مع توفير القيادة السلسة)، يجب إستخدام مواد ذات نوعية جيدة في الطبقة السطحية لمنع الأجهادات المتولدة بسبب الأنواع المختلفة للأحمال (أحمال إنشائية، أحمال بيئية)، وبما أنه معامل المرونة هو من المدخلات المهمة في عملية التصميم لذا تم أختياره لتحديد تأثير أنواع مختلفة من المادة المالئة عليه.

لتحسين خصائص مواد الخلطة الأسفلتية ولمعرفة تأثير هذه المواد المستخدمة كنسبة إستبدال من الوزن الكلي للركام في خصائص المرونة ، تم قياس معامل مرونة الخلطة الأسفلتية: الرماد المتطاير (FA)، الأسمنت البورتلاندي العادي (OPC)، الجير المطفأ (HL) والسيليكا (SF) أستخدمت كنسبة مئوية جزئية من المادة المالئة (غبار الحجر الجيري) (LSD) ، وهذه المواد متوفرة محليا بما في ذلك أسفلت (٤٠-٥٠) اختراق .

لتحقيق الهدف من الدراسة؛ تم تهيئة نماذج الخلطة الأسفلتية بالمحتوى الأمثل للأسفلت إستنادا إلى طريقة مارشال في التصميم. أربع نسب استبدال ٠، ١.٥، ٣.٠ و ٤.٥ من الوزن الكلي للركام لكل أنواع المادة المالئة المستخدمة تم إعتمادها.

إستناداً إلى معايير ASTM D4123 تم فحص معامل المرونة بواسطة UTM25 .تبين أن الخلطات المحسنة بالمواد المضافة أظهرت تحسناً في قيم معامل المرونة بنسبة (١٣.٣٧، ٩.٦٣، ١١.١٤، ٢٤.٠٠) عند نسبة إستبدال ١.٥ وبنسبة (٢٤.٥٤، ١٦.٥٤، ١٨.٧٣، ٣٨.٣١) عند نسبة إستبدال ٣.٠ وبنسبة (٣٩.٥٥، ٢٦.٣٦، ٢٩.٨٢، ٥٨.٣٠) عند نسبة إستبدال ٤.٥ وبالتعاقب .

الكلمات المفتاحية :- الخلطة الاسفلتية المحسنة ، استبدال الفلر ، معامل المرونة ، الخلطة الاسفلتية الحارة ، مارشال .

1. Introduction

While the flexible pavement damage increases in recent years in Iraq, due to the increasing in the traffic loads, heavy axle load and high temperature, the need to construct flexible pavement with high quality materials to achieve safety, comfortable and less deformation and distress during its serves live.

Flexible pavement should be designed to achieve a required level of performance during its service life. The three major parameters to designs pavement successfully are: traffic and loading, material properties, and environment. Material properties show the crucial input data explained by resilient modulus at the design flexible pavement process.

Modification of asphalt concrete mix design is a major step to improve the performance of it. The major role of the properties and performance of asphalt concrete mixture was played by mineral filler because it reduces the voids in the asphalt concrete mixture and fill the voids in the aggregate.

(Kallas and Puzinauskas, 1967; Bouchard, 1992) reported that filler has a dual role in asphalt concrete mixtures to produce mixture with stiffer consistency one portion of the filler is: contact aggregate particles together and the other remaining in asphalt cement forms a mortar and contributes to improve stiffening of asphalt concrete mixtures; also they study its relationship with Marshall Stability and optimum asphalt content.

(Sarsam, 1984) shows that mineral filler plays a major role to reach the properties and performance of asphalt concrete mixture and aggregate interlocking effects. (**Naga Shashidhar1 and Pedro Romero1,1998)** explain the effect of mineral filler on stiffness and its relationship with resistance to rutting. **(Miro *et.al*., 2004)** study the effect of the characteristics of fillers on the durability of the asphalt concrete mixtures.

Mineral fillers used in asphalt concrete mixtures fill voids between aggregates and change properties of the asphalt, **(Yong-Rak *et.al*., 2003)**.

(Kandhal *et.al.*,1998) assessed that the properties of mineral filler (material passing 0.075mm (No. 200) sieve have a significant effect on the performance of flexible pavement in terms of permanent deformation, fatigue cracking, and moisture susceptibility. In spite of the particles size of filler are small in (passing sieve # 200), but it has a significant effect on the properties and performance of asphalt concrete mixture. **(Zulkati *et.al.*, 2011)**.

2. Previous Work

Many studies have been made to the asphalt concrete mixture with different types of mineral fillers which are presented briefly below.

2.1 Effect of Mineral Filler Type on The Asphalt Concrete Mixture Prosperities:-

Number of researcher studies the effect of filler on HMA properties, as:

- **Hanaa and Hayder 2014** reported that Marshall Stability increases with the increase of hydrated lime content, Air voids decreased with the increasing of the hydrated lime content, hydrated lime tend to reduce the effects of water and temperature on the cohesion and stiffness of mixtures,
- **Petresen, 2005** studied the effect of modifying the asphalt concrete mixture by hydrated lime and they presented improving asphalt concrete mixture properties.
- **Hanaa, 2013** showed that the asphalt concrete mixture properties improved when Portland cement and hydrated limewere added.
- **Debashish Kar, Mahabir Panda and Jyoti Prakash Giri, 2014** Recorded that Marshall Stability and unit weight values are improved when used Portland cement, lime stone dust and fly-ash filler were used frequently.
- **(Lee *et.al*., 2005),** believed that using silica fume in asphalt concrete mixture reducing its aging and increase its mechanical and physical properties such as stiffness, toughness, strength and thermal stability.
- **Nader *et.al.*, 2015** conducted that adding silica fume reduces loss of stability.

2.2 Effect of Mineral Filler Type on Performance Asphalt Concrete Mixture:-

- **Al-Suhaibani, 1992** said that the using of hydrated lime showed positive effect on rutting resistance and moisture damage resisting.
- **Tebid et.al.,2006** indicate the improving the resistance in moisture damage and rutting when two different application methods of adding hydrated lime (dry and wet) method were used.
- **AL-Jumaily, 2008** concluded that the permanent deformation characteristics, fatigue life, would be improved and moisture susceptibility was decreased when asphalt concrete mixtures were modified by hydrated lime and Portland cement.
- **Petresen, 2005** studied the effect of modifying the asphalt concrete mixture by hydrated lime and he represented the improvement of the moisture damage resisting.
- **Albayati** 2013 Replacement of hydrated lime with ordinary limestone filler generally improved the fatigue life characteristic that could be regardless the method of lime application. The test results seem to be sensitive to the method of adding lime.

2.3 Effect of Mineral Filler Type on Resilient Modulus Values of Asphalt Concrete Mixture:-

- **asphalt institute, 1993** indicated that resilient modulus values increases while replacing limestone dust by either hydrated lime or Portland cement in the hot mix asphalt.
- **Albayati, 2013** reported that resilient modulus values of paving mixtures increased when hydrated lime content increased up to 3.0% at 25°C with dry, wet and slurry method.
- **Albayati, 2011** illustrated **t**he relationships between percent of content of hydrated lime with resilient modulus of HMA is in verse relation up to 1 percent content of hydrated lime then further increase in hydrated lime content increased the resilient modulus of the mixes with 3 percent hydrated lime about 1.4 times the value for mixes with 1 percent hydrated lime at 40°C.

3. Characteristics of Materials

In order to prepare the Hot Mix Asphalt, material must be selected to meet the requirements of specification, (aggregates and mineral fillers coated with asphalt cement), below explanation of the characteristics of each material that asphalt concrete mixture consists of.

3.1 Asphalt Cement

Asphalt cement with (40-50) penetration grade brought from AL-Daurah refinery south-west of Baghdad was used to achieve the requirements of this study. The physical properties of the selected asphalt cement will be compared with Iraqi Specification **(SCRB, 2003/ R9)** as its shown in **Table (1)**.

3.2 Mineral filler

The mineral filler is a non-plastic material that passes sieve No.200 (75μm). Control mix is prepared according to the mid specification of **(SCRB, 2003/ R9)** of surface course with limestone dust and a mix specimens is prepared with the percentage of replacement rang between (0-4.5) % of limestone dust by total weight of aggregate with four types of mineral filler were used in this study; Limestone Dust, Fly Ash, Portland Cement Hydrated Lime and Silica Fume. A brief explanation is shown below:

3.2.1 Limestone Dust:-

Limestone dust used in this study was obtained from lime factory in Karbala governorate, south east of Baghdad, physical properties and chemical composition as it's shown in **Table (2) and Table (3)**.

3.2.2 Ordinary Portland Cement:-

Ordinary Portland Cement (OPC) manufactured in Iraq is used in the present study, according to the Iraqi specification **(IQS, No.5:1984)**. The physical properties are shown in **Table (2)** and the chemical analysis of the cement used is explained in **Table (3)**.

3.2.3 Hydrated Lime:-

The Hydrated lime used in this study was obtained from lime factory in Karbala governorate, south east of Baghdad, physical properties and chemical composition are shown in **Table (2) and Table (3)**.

3.2.4 Fly Ash:-

Fly Ash results from the combustion of pulverized coal are finely divided residue. The first edition of Fly Ash was by Highway Engineers in 1986. Because its availability in the local markets with its low cost and low specific gravity Fly Ash has been commonly used to product asphalt concrete mixture with low cost and less weight. Physical properties are illustrated in **Table (2)** and chemical composition is shown in **Table (3)**.

3.2.5 Silica Fume:-

Silica Fume as a pozzolainc material has a white, fluffy powder according to (**ACI 234R, 1996)**. Physical properties are illustrated in **Table (2)** and chemical composition is shown in **Table (3)**.

3.3 Aggregate

Coarse and fine aggregate used in this study were obtained from AL-Ukhaydir-Karbala quarry; coarse and fine aggregate were sieved and recombined according to the requirements of surface course gradation of **(SCRB, 2003/ R9)** specification. Selected gradation and specification limits of asphalt concrete mixtures for surface course are shown in **Table (4)** as well as in **Figure (1)** and their physical properties are illustrated in **Table (5)**.

4. Experimental Work

The experimental work included preparing groups of Marshall Specimens to determine the optimum asphalt content, these groups are:

- Control mix uses limestone dust only as mineral filler with 7 percent.
- Group one uses Fly Ash as a partial replacement of limestone dust with percentages of 0, 1.5, 3.0, and 4.5% by total weight of aggregate.
- Group two uses Portland Cement as a partial replacement of limestone dust with percentages of 0, 1.5, 3.0, and 4.5% by total weight of aggregate.
- Group three uses Hydrated Lime as a partial replacement of limestone dust with percentages of 0, 1.5, 3.0, and 4.5% by total weight of aggregate.
- Group four uses Silica Fume as a partial replacement of limestone dust with percentages of 0, 1.5, 3.0, and 4.5% by total weight of aggregate.

(4.0, 4.5, 5.0, 5.5 and 6.0) % of asphalt cement was used for each type of asphalt concrete mixture at each percent of limestone replacement to determine the optimum asphalt content. Filler content was constant at 7 percent in this study; it is represent the mid specification of SCRB. **Table (6)** illustrated the prepared asphalt concreter mixture specimens. **Table (7)** shows the determining value of optimum asphalt content.

5. Resilient Modulus Test:

According to the ASTM D4123 criteria, resilient modulus was tested using UTM-25 devices adopting two testing temperatures (10°C, 40 °C) at two load durations (50ms,200ms).

6. Test Results:

From the result illustrated in **Table (8)**, it can be seen that there are significant effects of partial filler replacement in the value of resilient modulus of asphalt concrete mixture compared with resilient modulus value of control mix at each types of filler and percent of replacement for the two tested temperature and two applied load duration, also **Table (9)** show the final average percent of improvement in the value of resilient modulus to each percent of filler replacement for all the fillers used as mineral fillers in the preparing mixture.

7.Conclusions:

The following points of conclusions were concluded depending on the test program results:

1. All the used percentages and types of filler replacement improved the resilient modulus value of hot mix asphalt.
2. Using fly ash as a partial replacement (1.5%, 3.0% and 4.5% by total weight of aggregate) has an average percent increase in resilient modules value of HMA by 13.38%, 24.54% and 39.55% sequentially.
3. Using Ordinary Portland Cement as a partial replacement (1.5%, 3.0% and 4.5% by total weight of aggregate) has an average percent increase in resilient modules value of HMA by 9.64%, 16.63% and 26.37% sequentially.
4. Using Hydrated Lime as a partial replacement (1.5%, 3.0% and 4.5% by total weight of aggregate) has an average percent increase in resilient modules value of HMA by 11.14%, 18.73% and 29.82% sequentially.
5. Using Silica Fume as a partial replacement (1.5%, 3.0% and 4.5% by total weight of aggregate) has an average percent increase in resilient modules value of HMA by 24.01%, 38.31% and 58.30% sequentially.
6. Silica Fume as a partial replacement (1.5%, 3.0% and 4.5% by total weight of aggregate) has a higher average increase percent in resilient modules value, this may be due to its higher surface area rather than the other filler types replacement.

Table (1): Properties of Asphalt Cement (40-50) Penetration Grad

Property	ASTM designation	Test Results	SCRB Specification
Penetration at 25°C,100 gm,5 sec. (0.1mm)	D-5	48	40 – 50
Rotational viscosity at 135°C (cP.s)	D-4402	491	------
Softening Point. (°C)	D-36	45	------
Ductility at 25 °C, 5cm/min,(cm)	D-113	>100	>100
Flash Point, (°C)	D-92	281	Min.232
Specific Gravity	D-70	1.036	------
Residue from thin film oven test - Retained penetration,% of original - Ductility at 25 °C, 5cm/min,(cm)	D-1754 D-5 D-113	 60.2 83	 >55 >25

Table (2): Physical Properties of Mineral Filler

Tested Properties	Filler Types				
	Limestone Dust	Fly Ash	Portland Cement	Hydrated Lime	Silica Fume
Specific Gravity	2.44	2.05	3.15	2.77	2.16
Specific Surface (m^2/kg)	244	650	305	395	16000
Percent Finer than 75 microns	96	94	95	98	100

Table (3): Chemical Composition of Mineral Filler

Chemical Composition (%)	Filler Types				
	Limestone Dust	Fly Ash	Portland Cement	Hydrated Lime	Silica Fume
SiO_2	2.23	61.95	20.54	1.38	99.1
Fe_2O_3	-----	2.67	3.28	0.12	35 ppm
Al_2O_3	-----	28.82	5.88	0.72	0.03
CaO	68.3	0.88	60.78	56.1	0.03
MgO	0.32	0.34	1.93	0.13	52 ppm
SO_3	1.2	<0.07	1.87	0.21	<0.07
Loss on Ignition	27.3	0.86	3.31	40.6	0.70

Table (4): Aggregate Gradation for Surface Course (Type IIIA)

Sieve size (mm)	19	12.5	9.5	4.75	2.36	0.3	0.075
%Passing Selected	100	95	83	59	43	13	7
%Passing(SCRB)*	100	90-100	76-90	44-74	28-58	5-21	4-7

*: State Commission of Roads and Bridge specifications (SCRB/R9, 2003) for Iraq.

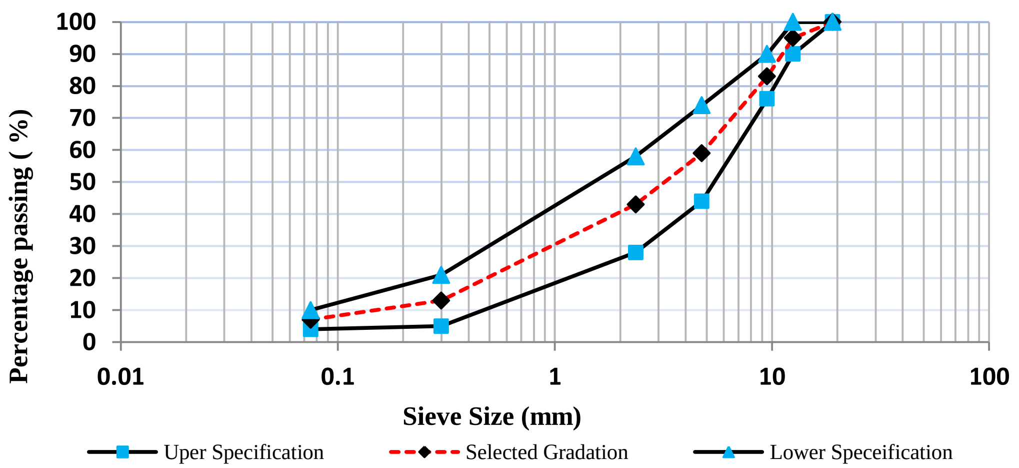

Figure (1): Gradation Limit of Asphalt Concrete Mixtures for Surface Course

Table (5): Physical Properties of Aggregate

Property	ASTM Designation	Test Results	SCRB Specification
Coarse Aggregate			
Bulk Specific Gravity	C - 127	2.617	------
Apparent Specific Gravity	C - 127	2.693	------
Water Absorption, %	C - 127	0.503	------
Percent Wear by Los Angeles Abrasion, %	C - 131	19.70	30 Max.
Soundness Loss by Sodium Sulfate Solution, %	C - 88	4.5	10 Max.
Fractured pieces, %	------	96	90 Min.
Fine Aggregate			
Bulk Specific Gravity	C - 127	2.675	------
Apparent Specific Gravity	C - 127	2.707	------
Water Absorption, %	C - 127	0.761	------
Sand equivalent,%	D-2419	62	45 Min.

Table (6): Asphalt Concrete Mixture Types Prepared and Tested

Mix Symbols	Filler composition %				
	Limestone Dust	Fly Ash	Portland Cement	Hydrated Lime	Silica Fume
M_{C0}	7.0	0	0	0	0
M_{F1}	5.5	1.5	0	0	0
M_{F2}	4.0	3.0	0	0	0
M_{F3}	2.5	4.5	0	0	0
M_{P1}	5.5	0	1.5	0	0
M_{P2}	4.0	0	3.0	0	0
M_{P3}	2.5	0	4.5	0	0
M_{H1}	5.5	0	0	1.5	
M_{H2}	4.0	0	0	3.0	0
M_{H3}	2.5	0	0	4.5	0
M_{S1}	5.5	0	0	0	1.5
M_{S2}	4.0	0	0	0	3.0
M_{S3}	2.5	0	0	0	4.5

Table (7): Optimum Asphalt Content

Percent of Replacement	Optimum Asphalt Content*			
	Fly Ash	Portland Cement	Hydrated Lime	Silica Fume
1.5	5.54	4.76	4.88	5.73
3.0	5.67	4.93	5.29	5.81
4.5	5.72	5.04	5.64	5.87

*: Optimum Asphalt Content for control mixed with zero replacement (Only limestone Dust) = 4.71

Table (8): Result of Resilient Modulus Tested by UTM-25 with Different Types of Filler Replacement

Mineral Filler Types	Mix Symbols	Resilient Modulus, mpa			
		Load Duration			
		50ms		200ms	
		Tested Temperature			
		10°C	40°C	10°C	40°C
Limestone Dust	M_{C0}	8060	2591	3757	1061
Fly Ash	M_{F1}	9284	2964	4216	1185
	M_{F2}	10209	3286	4607	1295
	M_{F3}	11476	3656	5233	1437
Portland Cement	M_{P1}	8885	2863	4015	1177
	M_{P2}	9333	3022	4415	1237
	M_{P3}	9986	3316	4683	1368
Hydrated Lime	M_{H1}	9002	2868	4169	1180
	M_{H2}	9541	3024	4453	1287
	M_{H3}	10327	3341	4872	1406
Silica Fume	M_{S1}	10024	3188	4628	1331
	M_{S2}	11074	3638	5278	1432
	M_{S3}	12436	4184	6073	1653

Table (9): Percent Improvement on Resilient Modulus Compared with Control Mix

Mineral Filler Types	Mix Symbols	Percent Improvement at Resilient Modulus			
		Load Duration			
		50ms		200ms	
		Tested Temperature			
		10°C	40°C	10°C	40°C
Fly Ash	M_{F1}	15.19	14.40	12.22	11.69
	M_{F2}	26.66	26.82	22.62	22.05
	M_{F3}	42.38	41.10	39.29	35.44
Portland Cement	M_{P1}	10.24	10.50	6.87	10.93
	M_{P2}	15.79	16.63	17.51	16.59
	M_{P3}	23.90	27.98	24.65	28.93
Hydrated Lime	M_{H1}	11.69	10.69	10.97	11.22
	M_{H2}	18.37	16.71	18.53	21.30
	M_{H3}	28.13	28.95	29.68	32.52
Silica Fume	M_{S1}	24.37	23.04	23.18	25.45
	M_{S2}	37.39	40.41	40.48	34.97
	M_{S3}	54.29	61.48	61.64	55.80

Figure (2) to **Figure (5)** illustrated the effect of filler types on the value of resilient modulus of HMA.

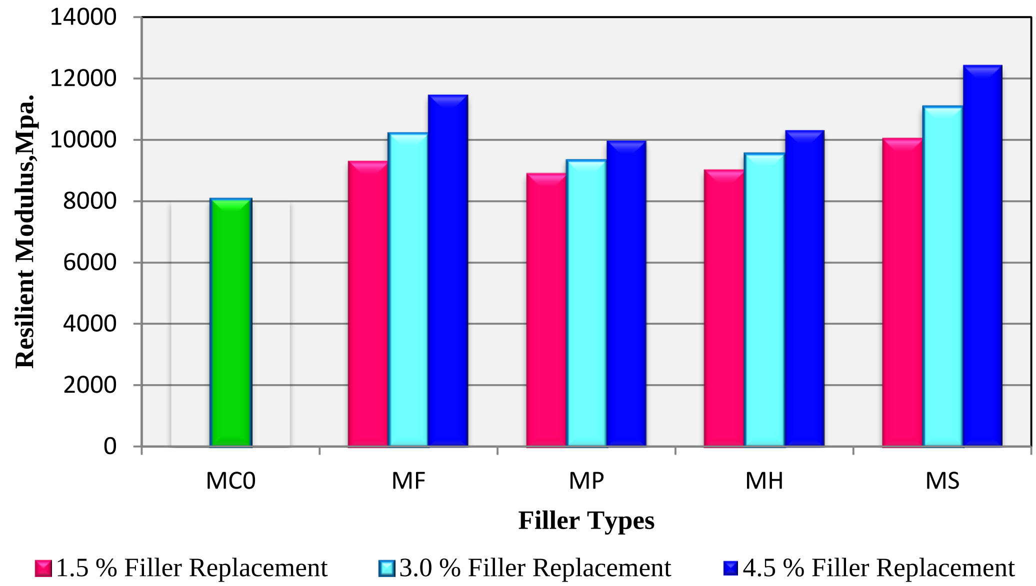

Figure (2): Effect of Different Types of Filler Replacement on Resilient Modulus Value at 50 ms Load Duration and 10 °C Testing Temperature

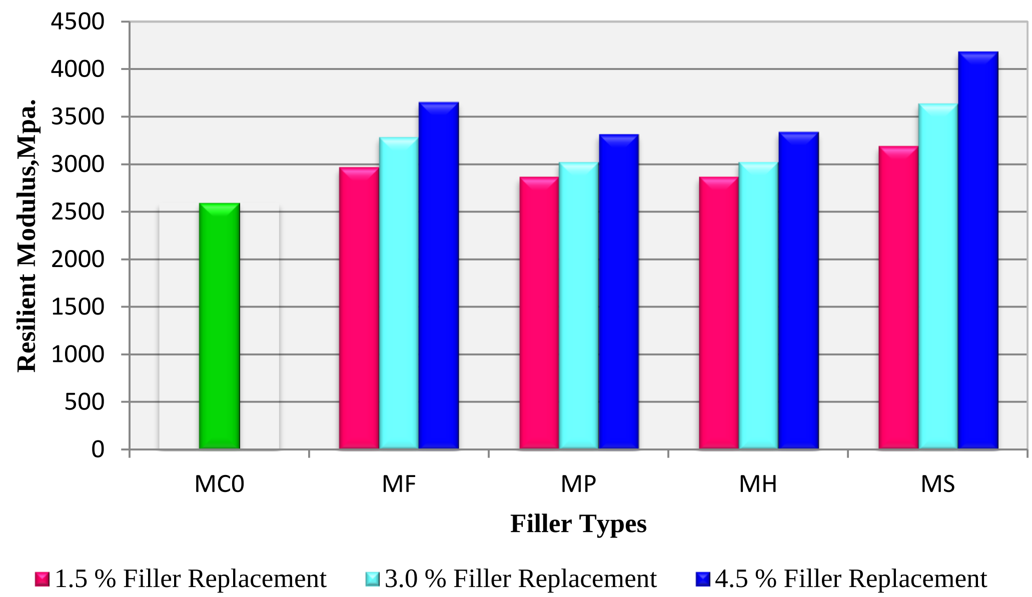

Figure (3): Effect of Different Types of Filler Replacement on Resilient Modulus Value at 50 ms Load Duration and 40 °C Testing Temperature

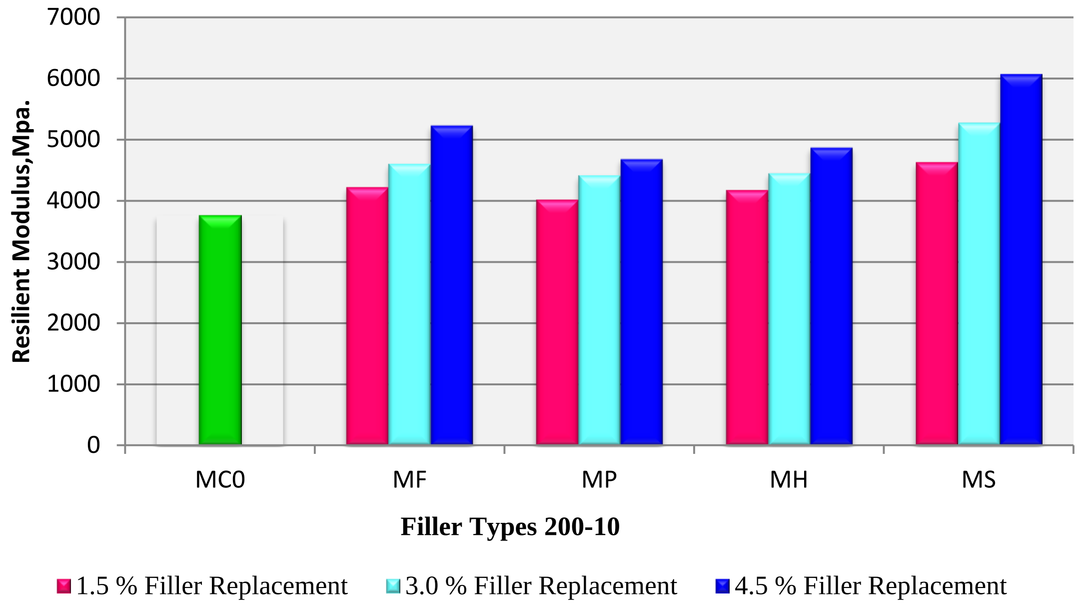

Figure (4): Effect of Different Types of Filler Replacement on Resilient Modulus Value at 200 ms Load Duration and 10 °C Testing

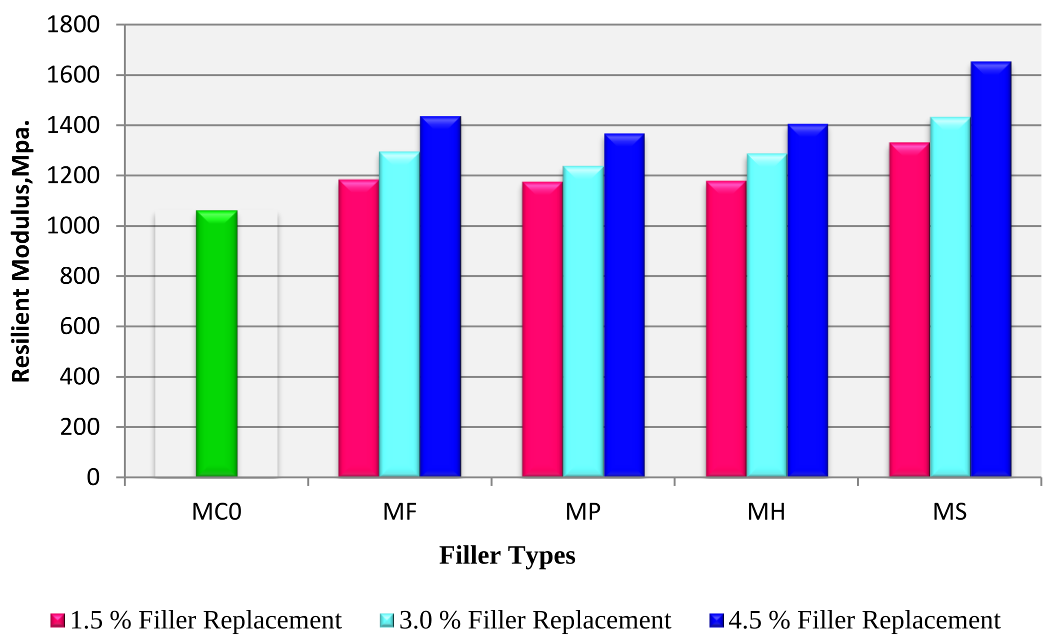

Figure (5): Effect of Different Types of Filler Replacement on Resilient Modulus Value at 200 ms Load Duration and 40 °C Testing Temperature

Table (10) and **Figure (6)** show the average percent of improvement effect of filler types on the value of resilient modulus of HMA.

Table (10): Average Percent Improvement in Resilient Modulus with Different Types of Filler Replacement

Percent of Replacement	Percent of Improvement			
	Fly Ash	**Portland Cement**	**Hydrated Lime**	**Silica Fume**
1.5	13.38	9.64	11.14	24.01
3.0	24.54	16.63	18.73	38.31
4.5	39.55	26.37	29.82	58.30

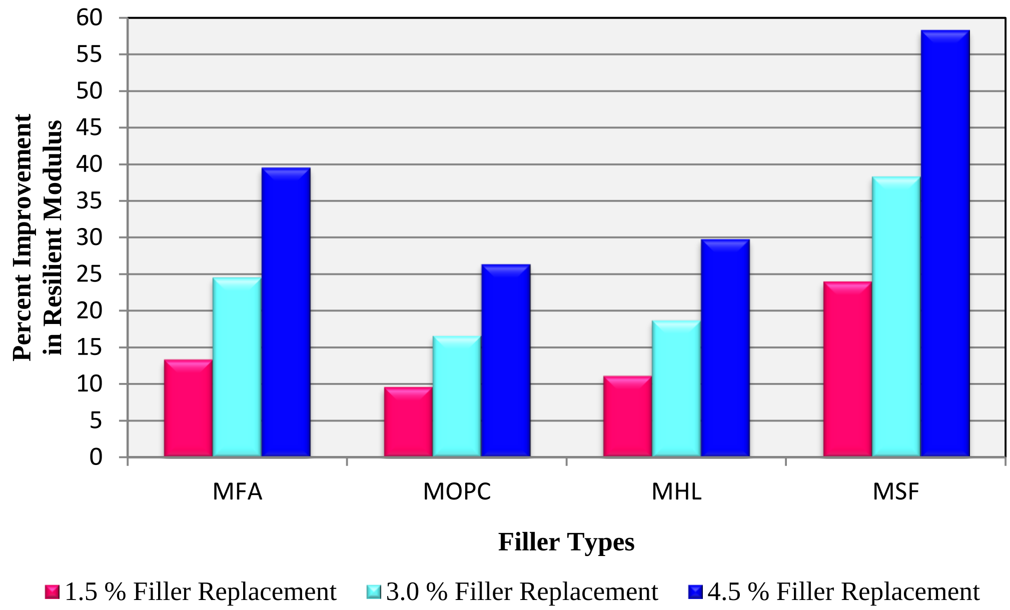

Figure (6): Average Percent Improvement in Resilient Modulus with Different Types of Filler Replacement

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