Effect of Lab. Compaction Effort on Evaluation of Modified HMA Specimens

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Abstract

The only way to estimate the future performance of any asphalt pavement is reached through the laboratory test which was made for evaluating its expected lifetime. For that purpose the laboratory compaction considered as the main important factor that influence the expected lifetime of any asphalt pavement. In this study we evaluated the effect of compaction effort on the performance properties of asphalt pavement through examining two compaction methods which are the Marshall hammer compactor and the Superpave gyratory compactor (SGC), that conducted the best method which provides the best simulation of what really happen in the field compaction, through making many of laboratory tests involving the volumetric properties and the performance properties for the both methods. Two types of modifiers were used with two percentages which are polypropylene (1% and 2%) by weight of total mix, and hydrated lime (1% and 2%) by weight of the total mix as replacer part of the filler content, and then the results were compared for evaluating the most simulating method to the field compaction for control and modified mixes. The results showed that the Superpave gyratory compactor provide the best simulation to the field compaction compering to the Marshall Compaction method, The mixes compacted by using SGC have lower optimum asphalt content than those prepared by Marshall compaction method by about (1% and 2%) for binder and base course respectively. The volumetric and performance properties of mixes prepared by using the SGC were better than those of mixes prepared by Marshall compaction method.

Keywords: Superpave Gyratory Compactor, Marshall Hammer, Indirect Tensile Strength, Tensile Strength Ratio

1. Introduction

The importance of proper compaction of asphalt pavements has been recognized for many years. Investigators have shown that pavement stability, durability, tensile strength, fatigue resistance, stiffness, and flexibility are controlled to a certain degree by the density of asphalt concrete. To insure adequate compaction several agencies specify, "In-place" density requirements, these in-place requirements are commonly expressed as a percent of a standard laboratory compaction density. Laboratory tests are intended to give the engineer needed information about the density of the surfacing material as it ultimately appears on the roadway (**Bob M. Gallaway,1969).** Most current specification requires asphalt-paving mixture to be compacted to a specified density, which, in general, is equivalent to a certain percent of laboratory compaction. The application of such density requirement in condition of high service pavement temperatures and heavy traffic loading resulted in many cases reaching the measurement of excessive permanent deformation within the asphalt layers. for this reason, it is very important to be at a high level of accuracy in evaluating the laboratory properties as it give all the needed information about the expected performance of a new pavement (**F. T. Wagner, 1982**). Resistance asphalt mixture is not involved as a test procedure related to the Superpave design method of mixtures. This encouraged the “National Cooperative Highway Research Program” (NCHRP) to sponsor projects for developing a simple performance test for rutting potential with asphalt mixtures (**John P. Zaniewski, 2004**).

Superpave mix design is based on (1) volumetric properties of hot mix asphalt (HMA) and (2) the properties of asphalt binder and aggregate. The characteristics of the densification curve founded during gyratory compactor of hot mix asphalt are thought to be related to the resistance of the aggregate skeleton (**Anderson et al.2002**). Many years, the world has used the Marshall design method of asphalt mix. The method involves applying an a specified compaction effort supplied by a dripping mass to the asphalt-aggregate mixture and determines the proper asphalt content of the compacted samples by using the void structure of the sample. This method has served users of hot mix asphalt very well for many decades, but versus problems has grown recently because of developments in traffic loads. As traffic becomes heavier, the Marshall method may not simulate the kneading action of traffic, and achieving the wanted purpose, the prediction of mix voids after considerable traffic, becomes more difficult (Maupin, 1998). The Marshall and Hveem mix design methods are differ from Superpave mix design method by using performance-related and performance-based criteria to evaluate the proper design asphalt mix. This allows drawing a direct relationship between the field performance of the asphalt mix and the lab performance (Asphalt Institute, 1996).

2-Materials and Methods

2.1 Asphalt Cement

Materials used in this study are locally available. One penetration grade (40-50) of asphalt cement was used from Nasiriyah refinery, this penetration grade represented performance grade equal to (70-16), (Abbas, 2009). The physical properties of the asphalt are shown in Table (1).

Table (1): Physical properties of asphalt cement

Property	ASTM Designation	Base coarse aggregate	Binder Coarse aggregate	Fine aggregate	SCRB Specification
Bulk specific gravity	C-127 C-128	2.582	2.58	2.66	………..
Apparent specific gravity	C-127 C-128	2.671	2.67	2.68	……….
% water absorption	C-127 C-128	0.96	`0.86	0.63	……….
(Los Angeles)	C-131	24%		----------	Max. 30%
Angularity	D-5821	93 %		-----------	Min. 95%

2.2 Aggregate

The source of the coarse aggregate used is Al- Najaf quarry which was a crushed stone. This aggregate was widely used in the middle and south areas of Iraq for asphalt pavement.

The shape and color of aggregate was tended to have off white color with angular surface. The fine aggregate source was the quarries of Karbala. Both fine and coarse aggregate were sieved and remixed according to the required gradation recommended by (SCRB, R/9 2003) standard for base course and binder course. The physical properties of two gradation of aggregate are evaluated through many tests and compared to the specification limits that were setting by the SCRB, ASTM designation and the results are summarized in Table (2). The aggregate gradations with nominal maximum size of 25mm and 19mm are shown in Table (3)

Table (2): Physical properties of aggregate

Property	ASTM Designation	Base coarse aggregate	Binder Coarse aggregate	Fine aggregate	SCRB Specification
Bulk specific gravity	C-127 C-128	2.582	2.58	2.66	………..
Apparent specific gravity	C-127 C-128	2.671	2.67	2.68	……….
% water absorption	C-127 C-128	0.96	`0.86	0.63	……….
(Los Angeles)	C-131	24%		----------	Max. 30%
Angularity	D-5821	93 %		-----------	Min. 95%

Table (3): The selected gradations chart, nominal maximum size of aggregate: (19mm, 25 mm)

No.	Sieve size			Specification limits for base coarse (A) (SCRB)		Specification limits for binder coarse (A) (SCRB
	Standard sieves (mm)	English sieves (in)	Base gradation		Binder gradation	
1	37	13/4	100	100	-	-
2	25	1	95	90-100	100	100
3	19	3/4"	83	76-90	95	90-100
4	12.5	1/2"	68	56-80	80	76-90
5	9.5	3/8"	61	48-74	68	56-80
6	4.75	No.4	44	29-59	50	35-65
7	2.36	No.8	32	19-45	36	23-49
8	0.3	No.50	11	5-17	12	5-19
9	0.075	No.200	5	2-8	6	3-9

2.4 Mineral Filler

In this study, one type of mineral fillers has been used: ordinary Portland cement of (Al Gser). The physical properties of filler are presented in Table (4)

Table (4): Physical properties of cement (mineral filler)

SPECIFIC GRAVITY	3.13
% Passing Sieve No. 200	95
Specific Gravity	3.1
Fineness (Blaine in cm^2 /gm)	3200

2.5 Additives:

3-5-1 Polypropylene (PP)

The polypropylene as shown in plat (1) was added by (1% and 2%) by weight of total mix, Characteristics of polypropylene are presented in Table (5), The method for adding the polymer was by wet process which include increase the temperature of asphalt to the bleeding temperature, in a range of (160-170) CO, and the mixing was done by blending machine with speed of 2620 rpm for (60 min) (Al-Bana, 2009, physical research. 2005) .

Table (5): Characteristic of PP (SCPI, 2008)

Form	Virgin Polypropylene Fiber
Specific gravity	0.91
Alkali content	Nil
Sulfate content	Nil
Chloride content	Nil
Fiber thickness	(18 – 30) microns
Young modulus	(5500 – 7000) MPa
Tensile strength	350 MPa
Melting point	(150 – 160) ^{0}C
Fiber length	(12) mm

2-5-2 Hydrated lime (HL)

The Hydrated lime as shown in plate (2) was added by (1% and 2%) by weight of the total mix as replacer part of the filler content(dry process), For normal specification according to the National Association the lime has 15% or less retaining on No 200 sieve while for other special applications may obtain as 1.5% retained on No 325 sieve. In this study, the lime was brought from Al-Noora plant in Karbala Province. All tests are accomplished in the transportation and material laboratories of civil engineering at Babylon University.

Plate (1): Photo for polypropylene fiber

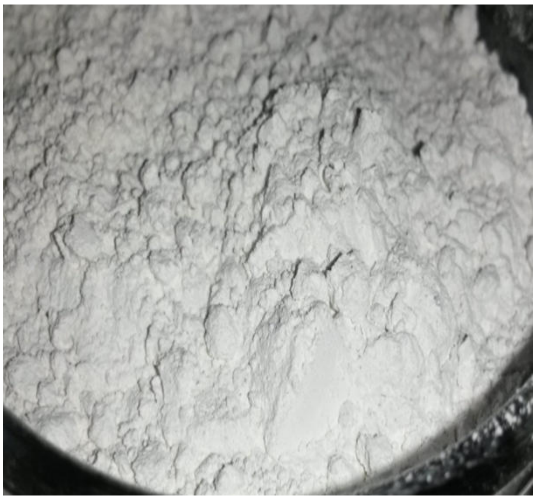

Plate (2): Photo for hydrated lime

3-Test Methods

The test methods employed in this study were to evaluate the performance of different mixtures compacted by different methods. Here we depended on two methods, the first one was the hammering compaction according to Marshall, and the second was the gyratory compaction according to the Superpave specification.

3-1 Marshall Design Method

The results of Marshall tests showed most of times time regular compatibility between asphalt content and the properties of Marshall mixes. The Optimum Asphalt Content (O.A.C) for each mix were evaluated using the Marshall Properties curves; (air voids, stability and bulk density), and it was 4.6 % and 4.2 % for binder and base course respectively. The results were shown in table (6).

Table (6): Volumetric Properties of asphalt concrete mixtures compacted by Marshall method

course type	Density (gm/cm^3)	Stability (KN)	Flow (mm)	Air voids (%)	Selected Optimum Asphalt Content (%)
Binder coarse	2.377	11.6	2.4	3.9	4.6
Base coarse	2.388	11.50	2.7	4.1	4.2

3-2 Superpave Design Methods

The optimum asphalt content for the binder and base course were 4.3 and 4 respectively which were as same as of the estimated one. Also the asphalt content for this compaction method was less than that of Marshall method by about 6% for both gradation type. The results were shown in table (7).

Table (7): Volumetric Properties of asphalt mixtures compacted by Superpave gyratory compactor

Course type	VFA %	VMA %	Density (gm/cm^3)	%G_{MM}	Air void (%)	Selected Optimum Asphalt Content(%)
Binder course	70	13.80	2.378	96	4.0	4.3
Base course	67	12.13	2.400	96	4.0	4.0

3.3 Effect of Compaction Method on the Volumetric Properties of both gradation

The Figures (1) through (6) for specimens compacted in SGC, the results of stability, density, air voids, and VFA values were higher than that specimens compacted using Marshall compaction method, also the value of the VMA and flow values for specimens of SGC were rarely less than that compacted by Marshall method. That's might be due to many different characteristics in the technique of compaction. The gyratory compactor provided rotation at a constant speed through the compaction process, this characteristic insured providing around a better arrangement for aggregate particles interlocking. While the compaction hammer of Marshall provided only one direction effect which is a vertical movement.

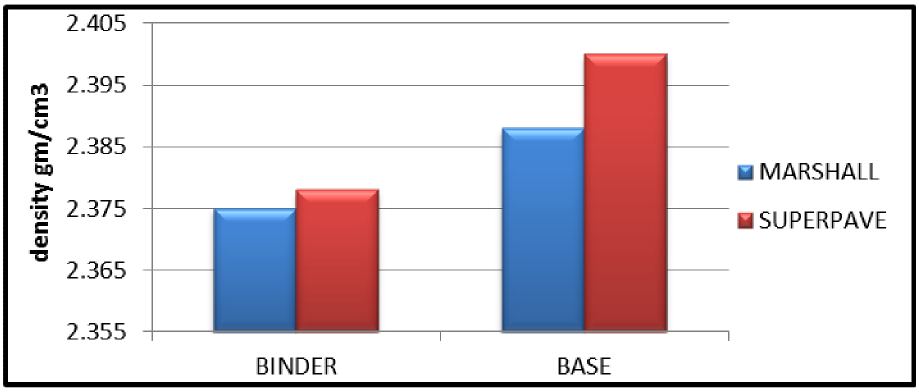

Figure (1): Effect of compaction effort on the density values for binder and base courses

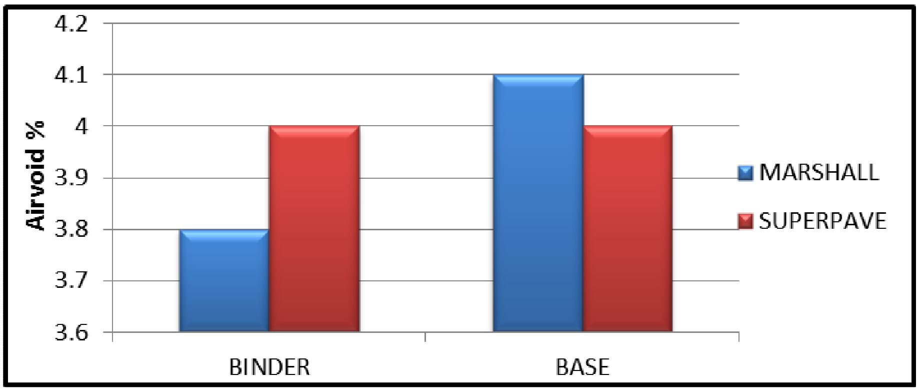

Figure (2): Effect of compaction effort on the air void values for binder and base courses

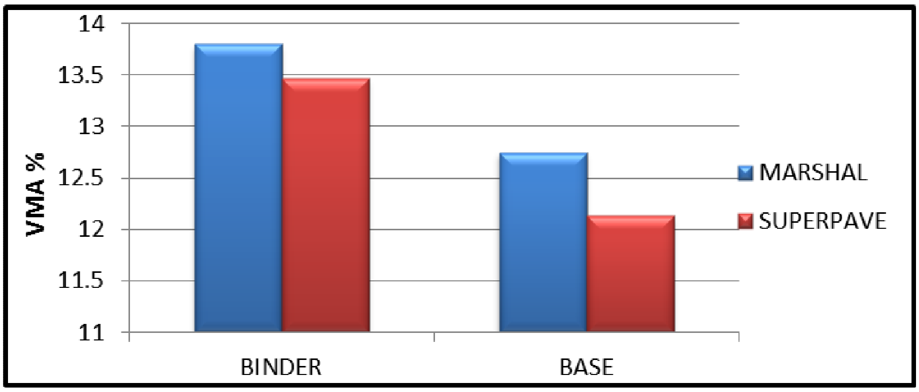

Figure (3): Effect of compaction effort on the VMA values for binder and base courses

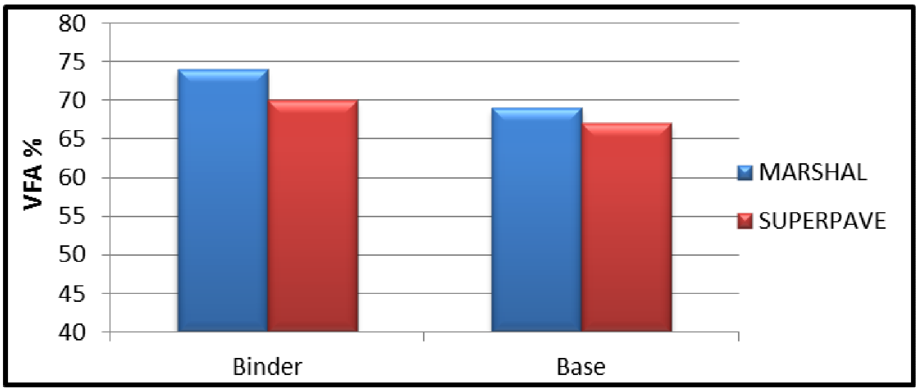

Figure (4): Effect of compaction effort on the VFA values for binder and base courses

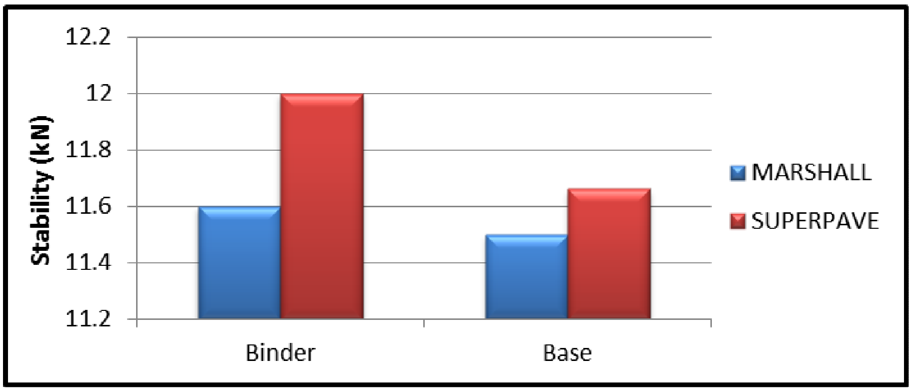

Figure (5): Effect of compaction effort on the stability values for binder and base courses

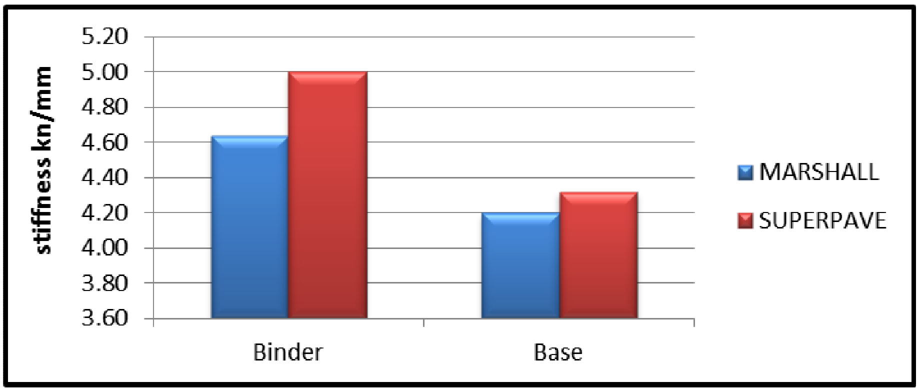

Figure (4-6): Effect of compaction effort on stiffness values for binder and base course

4 Effect of Compaction Effort on Modified HMA as Concert Binder Course

4-1 Indirect Tensile Strength

Figure (7) showed that adding of 1% of polypropylene to the specimen compacted by Marshall hammering as a percentage from the asphalt content to the mix with NMAS of 19 mm can improve the mix against the fatigue cracking, that because the noticeable increment in the indirect tensile strength of the modified specimen by about (9%). In the same Figure, for specimen compacted by Superpave gyratory compactor (SGC) it was found that adding 2% of polypropylene can improve the indirect tensile strength by a (5%), which that will improved the resistance of the mix to fatigue cracking.

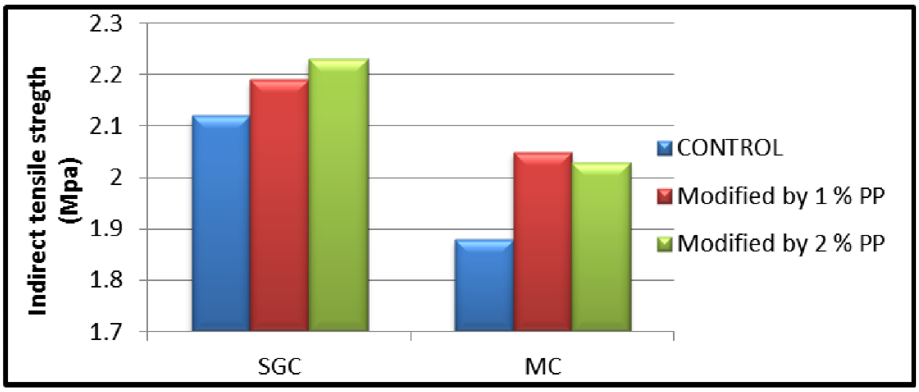

Figure (7): Effect of compaction effort on the (ITS) for binder course mixture modified by polypropylene additives

For specimen compacted by Marshall hammering in Figure (8), It was found that adding 1% of the hydrated lime as percentage from the total mix and replaced with apart of the filler content can improve indirect tensile strength by (7.5%), which improved the resistance of mix to the fatigue cracking. For the specimen compacted by the (SGC) in same Figure, it was observed that adding the 2% of hydrated lime of the total mix as replacer part of the filler content can improve the value of indirect tensile strength by about (1.4%), in the case the resistance of the mix to the fatigue cracking increased.

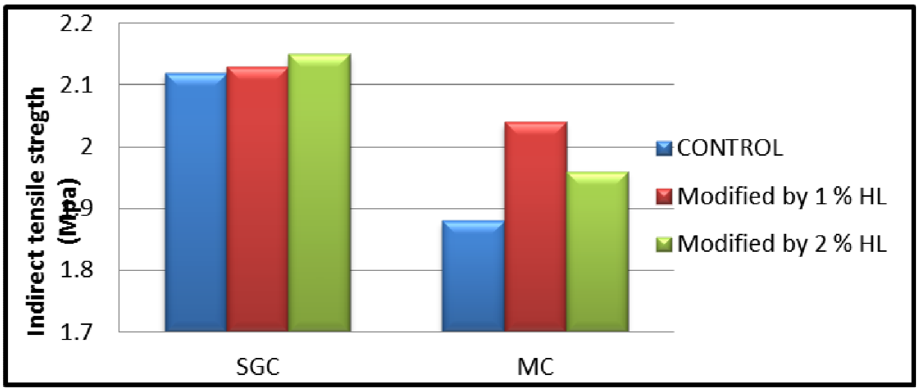

Figure (8): Effect of compaction effort on the (ITS) values for binder course mixture modified by hydrated lime additives

4-2 Indirect Tensile Strength Ratio

Figure (9) showed that the adding of 1% of polypropylene to the mixes compacted by Marshall hammering as a percentage from the asphalt content to the mix with NMAS of 19 mm can improve the mix against the moisture susceptibility, that because the noticeable increment in the indirect tensile strength ratio (TSR) for the modified specimen by (6%). In the same figures, for mixes compacted by superpave gyratory compactor (SGC) it was found that adding 2% of polypropylene can improve the indirect tensile strength ratio (TSR) by about (8.5%), which improved the resistance of the mix to moisture susceptibility .

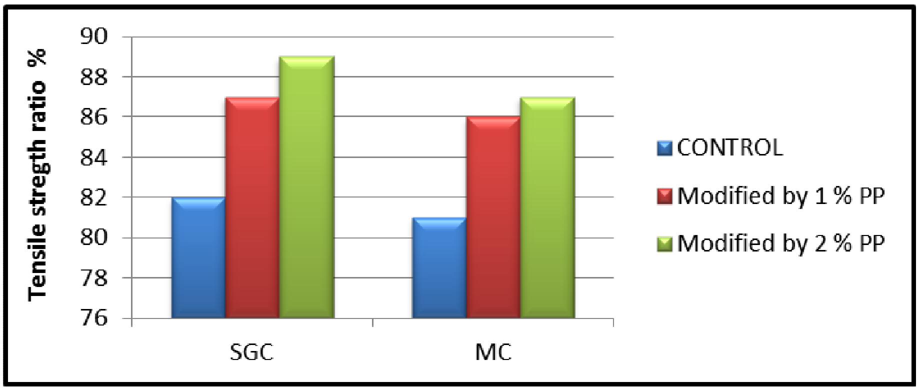

Figure (9): Effect of compaction effort on the (TSR) for binder course mixture modified by polypropylene additives

Through The mixes compacted by Marshall hammering in Figure (10) It was found that adding 1% of the hydrated lime as percentage from the total mix and replaced with apart of the filler content can improve indirect tensile strength ratio (TSR) by (6%), compared to the control specimen. In the same figure, for the mixes compacted by the (SGC) it was found that adding 2% of hydrated lime of the total mix as replacer part of the filler content can improve the value of indirect tensile strength ratio(TSR) by about (7%) and. For this case the resistance of the mix to moisture susceptibility.

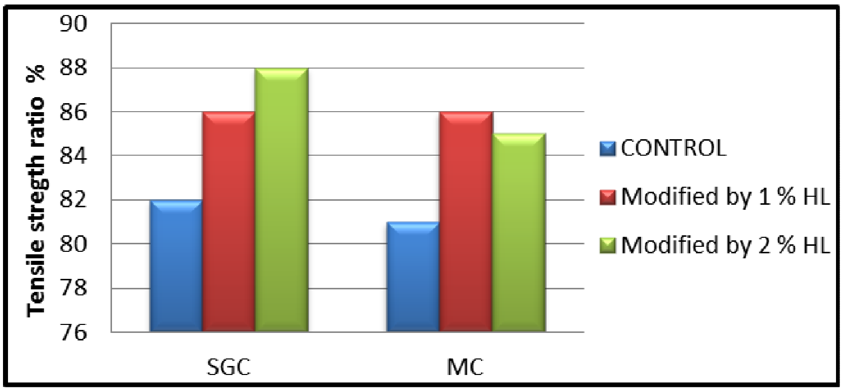

Figure (10): Effect of compaction effort on the (TSR) values for binder course mixture modified by hydrated lime additives

4-3 Volumetric Properties

5-3-1 Mixtures Modified by Hydrated Lime

From Figure (11) through Figure (16) we can find that the adding of 1% of polypropylene to the specimen compacted by Marshall hammering (M) as a percentage from the asphalt content to the mix with NMAS of 19 mm can increase the stability and VMA by about (7%) and (1%) respectively compared to the control specimen, while the VFA decreased by (7%). Also, we noted that the density and flow value decreased by (1.4%) and (10%) respectively. The air voids increased by about (5%) then the control. specimen. In Figure the same figures, for specimen compacted by Superpave gyratory compactor (SGC), it was found that adding 2% of polypropylene can increase the stability and VMA by (14%) and (6%) respectively compared to the control specimen, while the VFA decreased by (7%) compared to the control specimen. Also the density and flow values decreased by (1.6%) and (10%) respectively. The air void increased by (12.5%) compared to the control specimen.

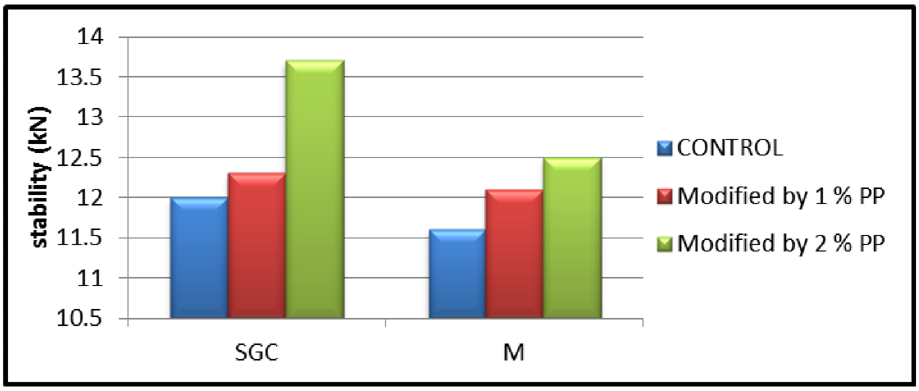

Figure (11): Effect of compaction effort on the stability values for binder course mixture modified by Polypropylene additives

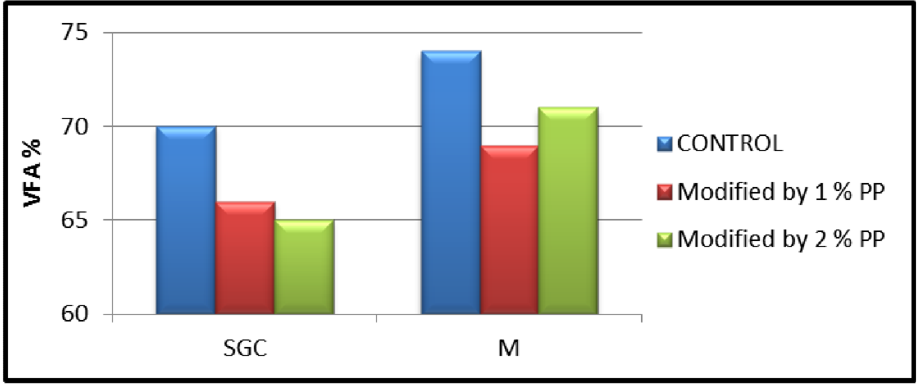

Figure (12): Effect of compaction effort on the (VFA) for binder course mixture modified by Polypropylene additives

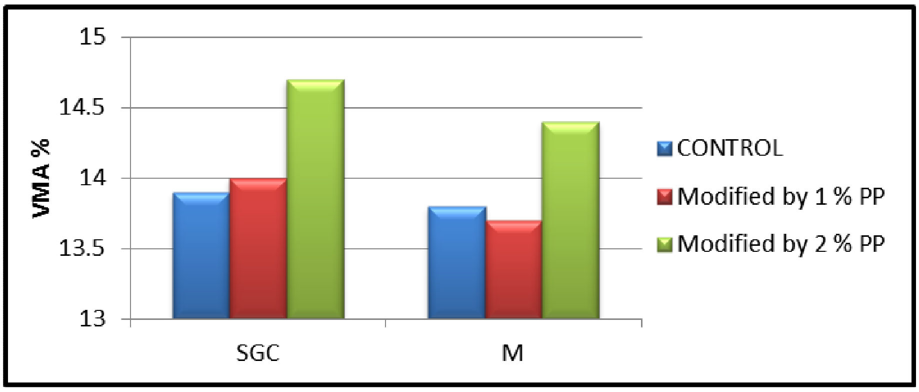

Figure (13): Effect of compaction effort on the (VMA) for binder course mixture modified by Polypropylene additives

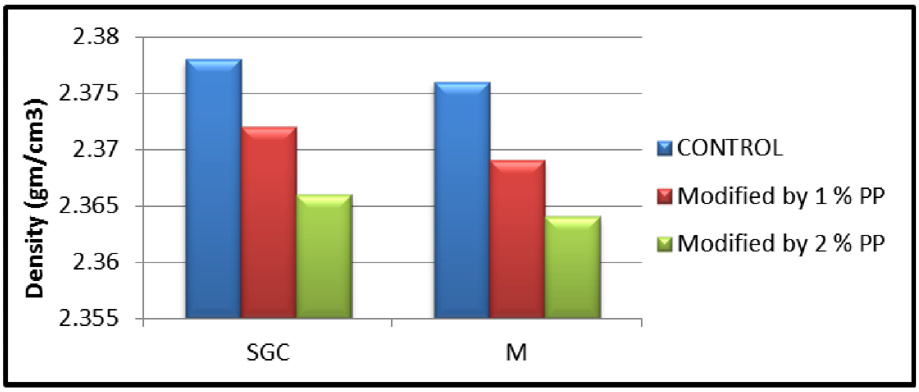

Figure (14): Effect of compaction effort on the density values for binder course mixture modified by Polypropylene additives

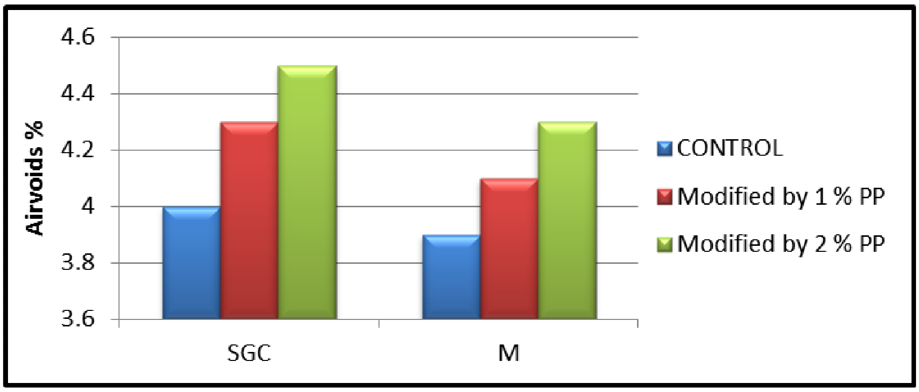

Figure (15): Effect of compaction effort on the (air void) values for binder course mixture modified by Polypropylene additives

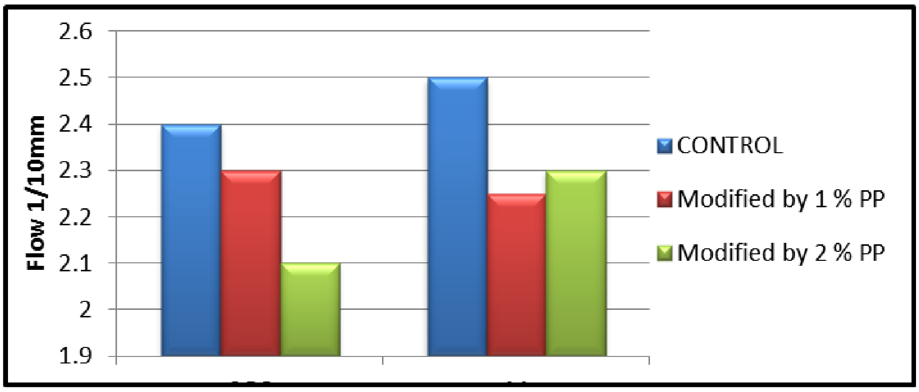

Figure (16): Effect of compaction effort on the flow values for binder course mixture modified by Polypropylene additives

5-3-2 Mixtures modified by hydrated lime

For specimen compacted by Marshall hammering in Figure (17) through (22), It was found that adding 1% of the hydrated lime as percentage from the total mix and replaced with a part of the filler content can increase the stability and VMA by (8%) and (1.5%) respectively while the VFA were decreased by (8%) compared to the control specimen. Also, it was found that that density and flow value decreased by (1.4%) and (18%) respectively. The air voids were increased by about (1.5%) compared to the control specimen. For the specimen compacted by the (SGC) in the same figures, it was noted that adding the 2% of hydrated lime of the total mix as replacer part of the filler content can increase the stability and VMA by (12.5%) and (3%) respectively compared to the control specimen, while the VFA decreased by(3%) . Also, we found that the density and flow values.

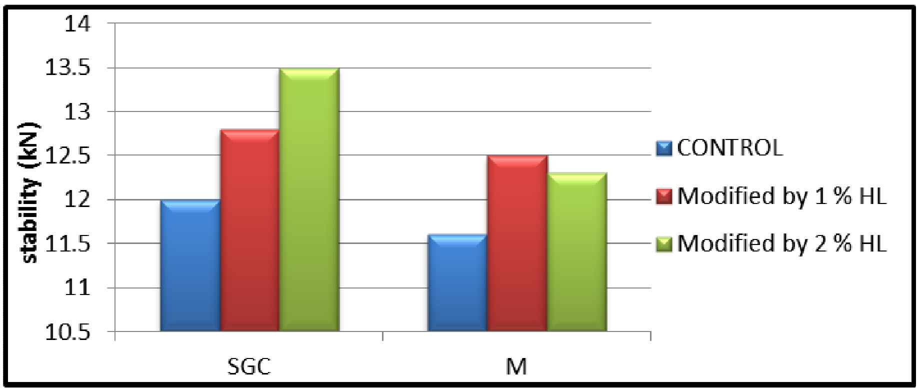

Figure (17): Effect of compaction effort on the stability values for binder course mixture modified by hydrated lime additives

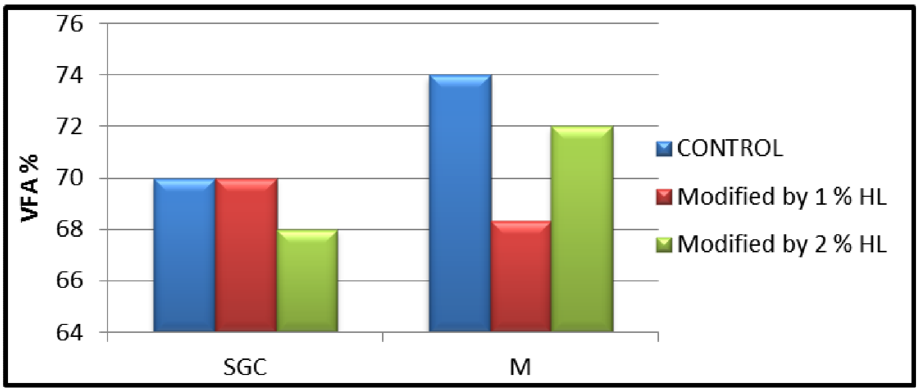

Figure (18): Effect of compaction effort on the (VFA) for binder course mixture modified by hydrated lime additives

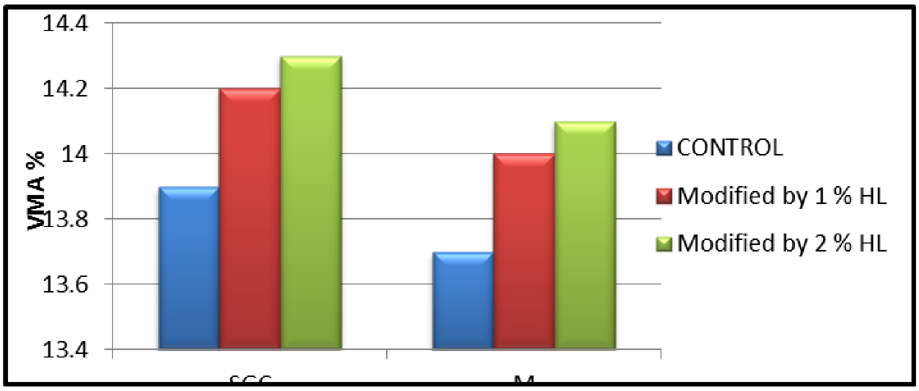

Figure (19): Effect of compaction effort on the (VMA) values for binder course mixture modified by hydrated lime additives

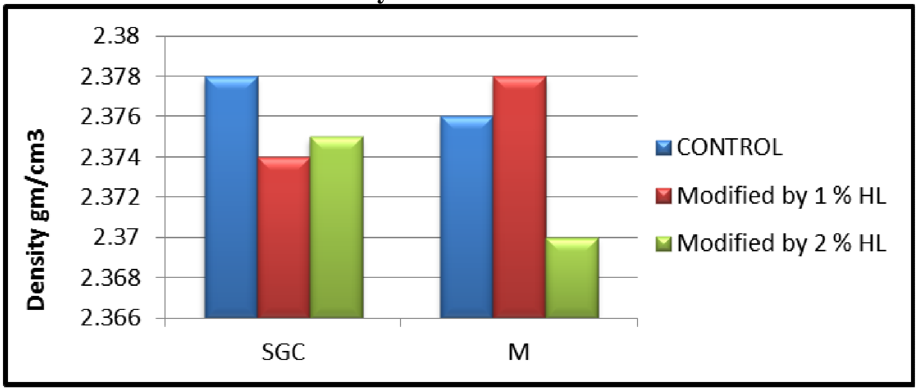

Figure (20): Effect of compaction effort on the density values for binder course mixture modified by hydrated lime additives

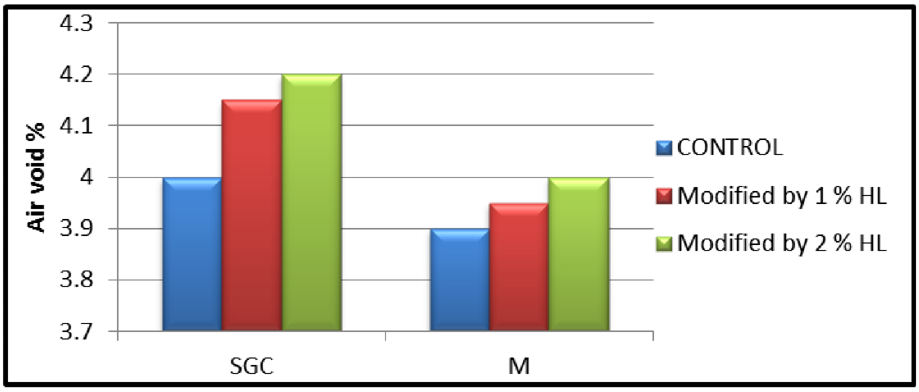

Figure (21) Effect of compaction effort on the air void values for binder course mixture modified by hydrated lime additives

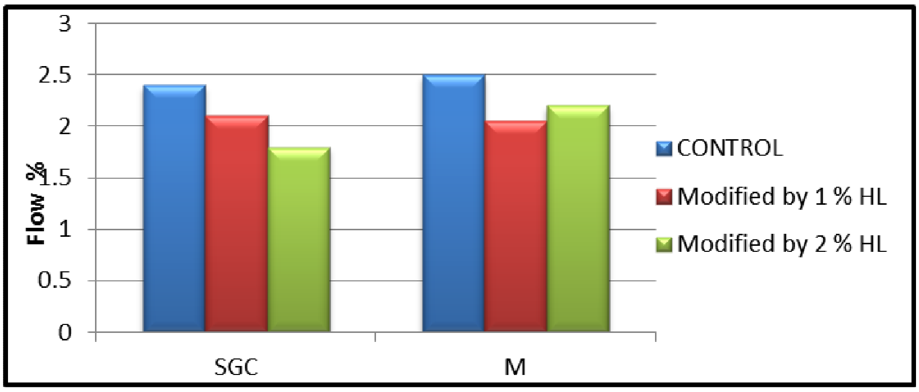

Figure (22) Effect of compaction effort on the flow values for binder course mixture modified by hydrated lime additives

We could see from Figure (17) through (22) all the results were according to the Iraqi specification (section R9) and SHRP, 2011. The results showed that the Superpave gyratory compactor gave the superior properties for the both modifiers. It was observed that increasing the additive per cent of both additive will improve the properties of mixes compacted by the SGC, that was might come back to the ability of the SGC to resist the loss in mix workability due to the use of both modifiers, while For Marshall mixes, when using more than 1% per cent of polypropylene and hydrated lime, the performance properties of the mix tended to decrease. That may be due to inability of Marshall compactor to resist the loss in mix workability due to use both modifiers.

5. Conclusions

1. Superpave gyratory compactor mixes had lower air void content than Marshall mixes by about 3% for binder course and about 5% for base course; This prevented additional compaction under traffic, which could result in the wheel path.

2. Superpave gyratory compactor mixes yielded lower asphalt content than Marshall mixes by about 7% for binder coarse and about 5% for base coarse. Therefore, Superpave mixes were better from the economical point of views than Marshall mixes is.

3. Superpave mixes showed better resistance to moisture susceptibility than Marshall mixes by about 1% for binder and about 2% for base course. That caused the superpave mixes yielded more resistance to the stripping due to wet condition, which resulted in more strength mixes under wetted condition.

4. Superpave gyratory compactor mixes showed higher indirect tensile strength than Marshall method by about 13% for binder course and about 12 % for base course, which means a good resistance to the fatigue cracking for superpave compactor mixes.

5. It was found that using 2% of polypropylene fiber for mixes compacted by superpave gyratory compactor improved the TSR, IRS, and stiffness by about 10%, 6% and 30% respectively. While the optimal polypropylene content for Marshall mixes, was 1%, which improved the TSR, IRS, and stiffness by about 6%, 12 %, and 8% respectively, and began to decrease with the addition of 2% of polypropylene due to the loss in workability, means that gyratory compactor resisted the loss in workability due to adding the polypropylene fiber.

6. The same thing happened when using 2% of hydrated lime for mixes compacted by superpave gyratory compactor; we have seen that the TSR, IRS, and stiffness increased by about 10%, 6% and 30% respectively. While the optimal hydrated lime content for Marshall mixes was 1%, which improved the TSR, IRS, and stiffness by about 6%, 12 %, and 8% respectively, and this properties began to decrease when adding the 2% of HL due to the loss in workability, means that gyratory compactor, resisted the loss in workability due to the addition of hydrated lime.

7. The mixes prepared under the Superpave method agree with Iraqi specification, which indicating that using Superpave method to design and construct pavement should not face unusual difficulties with Superpave mixes.

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