Producing of Warm Mix Asphalt Using Sasobit

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ABSTRACT Organic additive (Sasobit) is used in order to produce WMA due to its Environmental, economic and paving operations benefits. Adding both Sasobit with cement dust filler (S.C.D.F) and Sasobit with limestone filler (S.L.S.F) to WMA mixture enhanced mix properties. Maximum stability was achieved by adding 20% of (S.C.D.F) which increased stability from 1020 to 2070 Ib and then decreased, while adding 2.5 % of (S.L.S.F) increased stability from 1830 to 2050 Ib and then decreased. The Flow decreased with the increase of (S.C.D.F) and (S.L.S.F) percentages. The total cost of 1 ton of WMA was found 474.55 and 271.94 (L.E/ton) for (20%S.C.D.F) and (2.5%S.L.S.F) respectively, but using (0.5%S.L.S.F) cost 249.68 (L.E/ton) which is almost the same cost of HMA. The percentages in reduction in Carbon dioxide (CO2), Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs) were 14.10, 31.71 and 5.48% respectively at the optimum S.C.D.F, while the reduction percentages were 14.94, 32.91 and 9.86% respectively at the optimum S.L.S.F.

Index Terms: Sasobit, organic additive, cement dust filler, lime stone filler.

INTRODUCTION AND BACKGROUND

Warm mix Asphalt (WMA) is always produced and mixed with a relatively low temperature ranging from (100-140) °C, a temperature which is lower than the hot mix asphalt (HMA) traditional method, that is produced and mixed at high temperature (150-170) °C. Referring to previous researches, it was found that using of WMA reduces the fuel consumption by 20% than the traditional method (HMA). As it needs a little power when heating asphalt mixture; thus needs a little amount of fuel to produce WMA D'Angelo, et al. (2008).

One of the most common techniques to produce WMA is adding organic or chemical additives. Environmentally, the addition of chemical additives to WMA reduces CO2 between (3.20 to 46%), NOx between (6.10 to 62%), SO2 between (17.60 to 81%), volatile organic compounds (VOCs) between (8-25%) and reduces carbon monoxide (CO) between (29-63%). Also, WMA is produced in low temperature which is considered to be an economical benefit.

WMA has lower temperature compared to HMA, therefore it consumes a relatively little time to cool to normal temperature. However, the lower mixing and paving temperatures minimize fume and odor emissions and creates cooler working environment for the asphalt workers John Wiley, et al. (2009).

In Egypt, where the economic circumstances are very hard and the fuel prices are increasing every day, it is worth to think of carrying out a lot of researches to achieve the WMA which save a much amount of fuel and money to the Egyptian Government. There are many techniques that can be used to produce WMA. According to the previous researches, one of well-known forming techniques is the addition of a synthetic zeolite called Aspha-min® to create a foaming effect in the binder during mixing in the plant. Aspha-min® is a product from Eurovia Services (2013) GmbH (Bottrop, Germany). It is a manufactured synthetic zeolite (sodium aluminum silicate).

WAM-Foam® is a technology developed by Shell International Petroleum Company, Ltd. in London and Kolo-Veidekke in Oslo, Norway Button, et al. (2007). The process consists of a soft binder that is mixed first with aggregate until the aggregate is fully coated. Cold water is then added to the hardened binder at a rate of 2% to 5% by mass of hard binder to cause a foaming action, and the foamed binder is then added to the soft binder

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mixture, Button, et al. (2007) and D'Angelo, et al. (2008). The soft and hard binder blend produces the required final binder grade Middleton, and Forfylow (2009).

Low energy asphalt (LEA) is a foaming process that employs a different method than the other foaming technologies. To produce LEA, hot asphalt is first mixed with heated coarse aggregate only. Once all the coarse aggregate particles are coated, a fine aggregate or RAP mixture is mixedwith water and added to the asphalt coarse aggregate mix, Carter, et al. (2010).

Sasobit is a type of paraffin which has a long chain aliphatic hydrocarbon with chain lengths of 40 to 115 carbon atoms. It melts in the asphalt binder at temperatures of 85 to 115°C to reduce the mixing and handling temperatures by 30 to 50°C. They are manufactured from coal gasificationSasol Wax (2013). The benefit of decreasing the viscosity of the binder is to allow working temperatures to be reduced by 15–55 °C. It has high viscosity at lower temperatures and low viscosity at high temperatures. At temperatures below its melting point, Sasobit forms a crystalline network structure in the binder that leads to added stability D'Angelo, et al. (2008).

Evotherm® is a chemical WMA additive. Evotherm® ET (emulsion technology) is an asphalt emulsion agent Middleton, and Forfylow (2009). It is a combination of chemicals that allows water to be present in the binder, which improves the coating of aggregates by the asphalt. When mixed with hot aggregate particles, the water evaporates out of the mix as steam D'Angelo, et al. (2008), and only the asphalt and aggregate are left Hurley, and Prowell (2006).

In this research, chemical additive (Sasobit) is used in order to produce WMA. Chemical additive has been successful in reducing the temperature compaction by (20-30) °C and also succeeded in improving the performance of WMA, due to its Environmental, economic and paving operations benefits.

The general objective of this research is to evaluate the performance of adding Sasobit cement dust filler (S.C.D.F) and Sasobit limestone filler (S.L.S.F) at different percentages of bitumen at 120ºC and to investigate the optimum Sasobit content (O.S.C) from Sasobit cement dust filler (S.C.D.F) and from Sasobit Limestone filler (S.L.S.F). Also investigate the reduction of emissions of the WMA using (S.C.D.F) and (S.L.S.F).

MATERIALS AND METHODS

Many test specimens of type (4C) according to ECP, were collected from site for analysis. A sufficient number of samples were taken for laboratory investigations. The specimens were divided using either squaring or mechanical division method which illustrated in AASHTO. The source of the used crushed stones of Dolomitic aggregate with angular particles and rough surface texture is Attaka from Arab – Contractors Company located in Kattamia and the Binder (60/70) obtained from ELNASR COMPANY – located in Suez city with specific gravity 1.02. The results of the evaluation tests are illustrated in table (1).These experiments were carried out at the General Authority for Roads, Bridges, and Land Transport. The Organic additive used is Sasobit which is type of paraffin, previously explained in the introduction and is shown in figure (1).

Table (1) Show names of the material tests, and number of specifications from AASHTO, and ASTM.

Name of the test	AASHTO	ASTM
Sieve Analysis of fine and coarse aggregates	T 27 T 37	C 136 D 546
Los Angeles test	T 96	C 131
Specific gravity and Absorption of coarse aggregates	T 85	C 127

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Figure (1): Sample of Sasobit, Hurley, and Prowell (2005).

Many tests have been carried out on asphalt binder to identify Penetration, Kinematic Viscosity, Softening Point and Flash and fire Points by Cleveland, this tests are shown in table (2).

Table (2): Show the names of the asphalt binder tests, and the number of specifications from AASHTO, and ASTM.

Name of the test	AASHTO	ASTM
Penetration of Bituminous	T 49	D 5
Kinematic Viscosity	T 201	D 2170
Softening Point of Bitumen (Ring, Ball Apparatus)	T 53	D 36
Flash and fire Points by Cleveland Open Cup test	T 48	D 92

Testing of emissions and gases was divided into two parts according to inorganic gases and organic solvents. The tests aimed to measure carbon dioxide (CO2), nitrogen oxides (NOx) and volatile organic compounds (VOCs). The tests were carried out at the National Center for Safety Studies, Occupational Health, and Environmental Insurance Work. The nitrogen tube, Carbon dioxide tube (Drager), Accuro Manual Pump and Gas chromatograph are illustrated in figure (2).

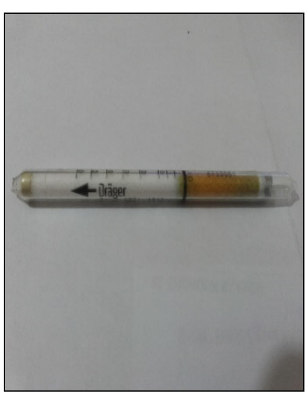

Figure (2) Nitrogen tube, Carbon dioxide tube (Drager), Accuro Manual Pump and Gas chromatograph.

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RESULTS AND DISCUSSION

Sieve analysis of fine and coarse aggregates, Los Angeles, specific gravity and absorption for coarse aggregates have been carried out and the properties of asphalt binder with and without Sasobit are presented in tables (4) and (3) respectively according to AASHTO.

Table (3): The Properties of asphalt binder without Sasobit.

Property	AASHTO	Result	AASHTO Limits	Approval
Softening Point	T 53	50	45-55	ok
Penetration at 25º C, (0.1mm)	T 49	64	60-70	ok
Flash point	T 48	270	≥ 250	ok
Kinematic viscosity	T 201	419	≥ 320	ok

Table (4): The Properties of asphalt binder with Sasobit at different percentages.

Percentages (%)	Property	Softening Point	Penetration at 25º C,(0.1mm)
1 %		76	39
2 %		81.3	34
3 %		+85	30
10 %		+85	21

The percentages of each material from job mix (4C) using (C.D.F) and (L.S.F) are presented in table (5), while table (6) show the gradation of the applied mixture using (C.D.F) and (L.S.F). Marshall properties for each S.C.D.F and S.L.S.F with and without sasobit are presented in table (7) and table (8) respectively, It has been noticed that O.A.C

Slightly changed by adding Sasobit. Also, adding of S.C.D.F or S.L.S.F increased the stability to a peak value and then reduced, while, flow generally decreased by an increase in the Sasobit percentage. The density decreased by an increase in the Sasobit percentage. Also, air voids, voids in mineral aggregates increased by adding Sasobit. O.A.C was slightly affected by adding the Sasobit as presented in tables (7), and (8).

Table (5): The percentages of each material from job mix (4– C) Using (L.S.F) and (C.D.F).

Materials	Percentages (%)
Agg2	20 %
Agg1	42 %
Natural sand	33 %
L.S.F or C.D.F	5 %

Table (6): Gradation of the applied mixture using (C.D.F) and (L.S.F).

Sieve size	Job mix formula	Specification Limits
1 "	100	100
1/2"	98.2	100 / 80
3/4"	87.2	--
3/8 "	75.4	80 / 60
# 4	48.7	65 / 48
# 8	43.0	50 / 35
# 16	37.9	--
# 30	29.6	30 / 19
# 50	14.9	23 / 13
# 100	7.8	15 / 7
# 200	5.8	8 / 3

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Table (7): Marshall Test Results of (C.D.F) with and without sasobit.

Temp º C	Specimens	O.A.C (%)	Stability (lb)
155	C.C.D.F	5.70	1950
120	1% S.C.D.F	6.12	1020
	2% S.C.D.F	5.75	1090
Specification limits of Light Traffic		4 – 7.5	Min 750
120	3% S.C.D.F	5.73	1240
	10% S.C.D.F	5.75	1500
	15% S.C.D.F	5.75	1585
Specification limits of Medium Traffic		4 – 7.5	Min 1200
120	18% S.C.D.F	5.74	1890
	19% S.C.D.F	5.70	1980
	20% S.C.D.F	5.70	2070
	21% S.C.D.F	5.65	1930
Specification limits of Heavy Traffic		4 – 7.5	Min. 1800

Table (8): Marshall Test Results of (L.S.F) with and without sasobit.

Temp º C	Specimens	O.A.C (%)	Stability (lb)
155	C.L.S.F	5.60	1980
120	0.5% S.L.S.F	5.77	1830
	1% S.L.S.F	5.72	1900
	1.5% S.L.S.F	5.72	2000
	2.5% S.L.S.F	5.67	2050
	3.5% S.L.S.F	5.71	1990
Specification limits of Light Traffic		4 – 7.5	Min. 1800

A comparison between Marshall properties for (C.C.D.F), (C.L.S.F) at 155º C, and (20%S.C.D.F), (2.5%S.L.S.F) at 120º C was illustrated in figure (7), while figure (6) shows a comparison between Marshall stability for (S.C.D.F), and (S.L.S.F) at 120º C.

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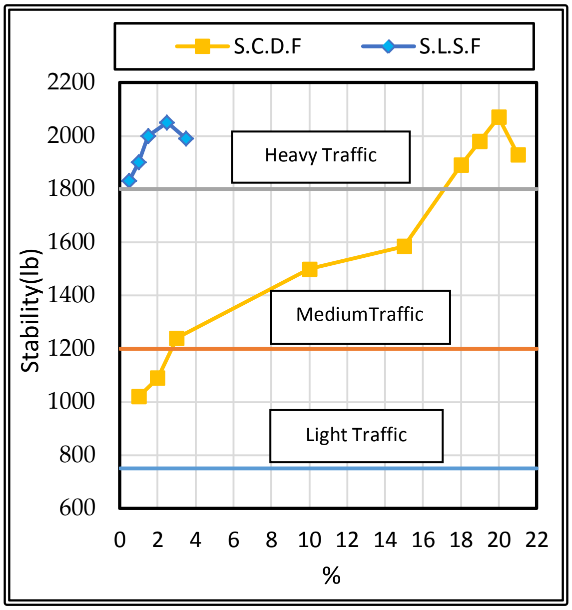
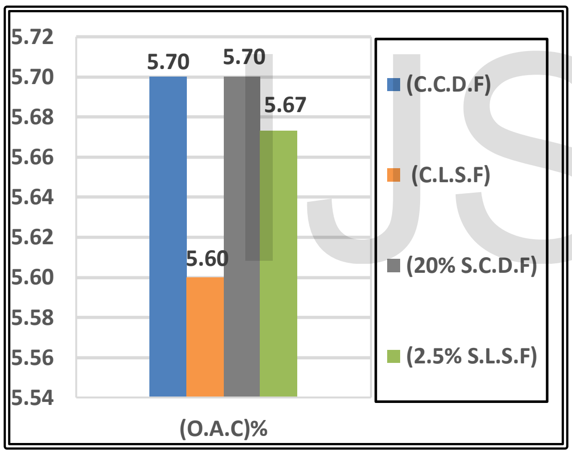
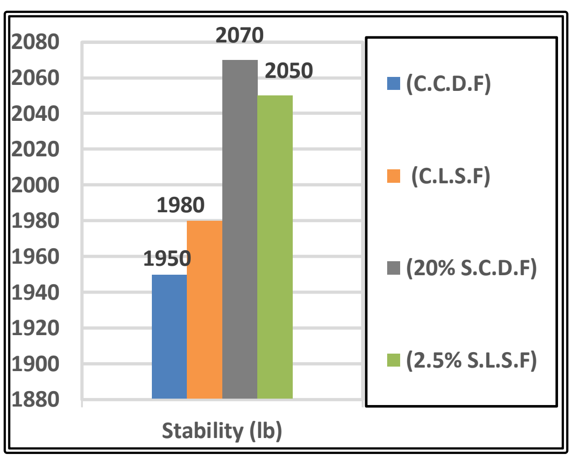
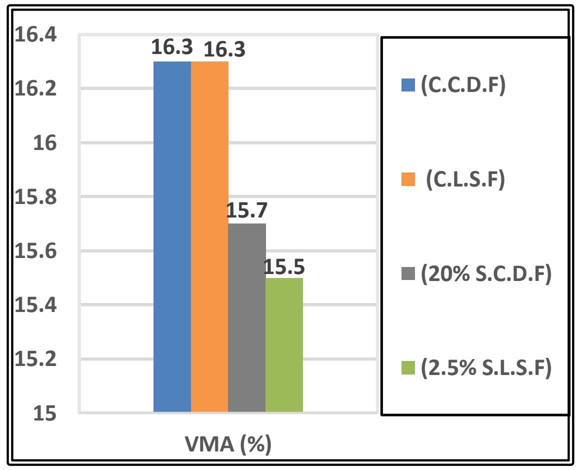
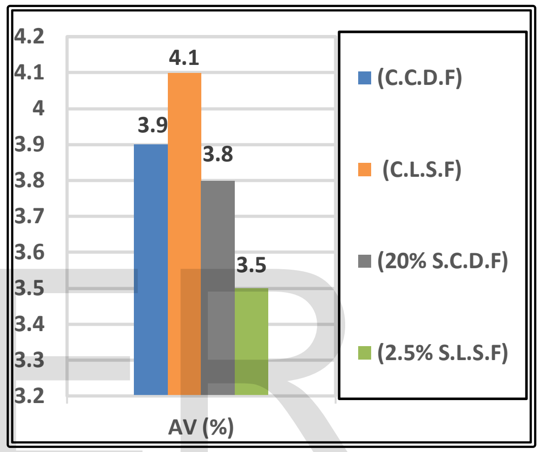


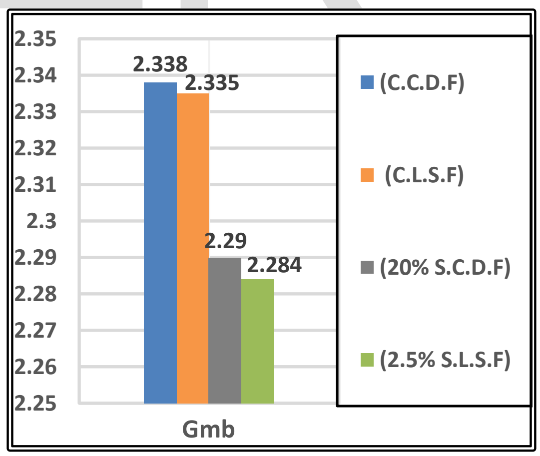
Figure (6): Comparison between Marshall Stability values for (S.C.D.F), and (S.L.S.F).











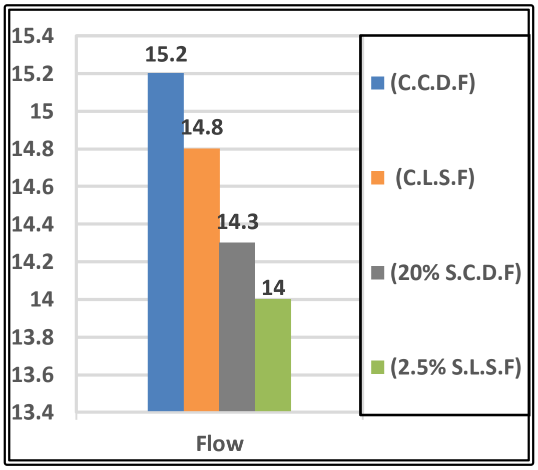


Figure (7): Comparison between Marshall Properties for HMA andWMA.

The costs of preparing 1 ton of HMA or WMA as a function of type of mixer, and number of liters of solar are presented in table (9). Generally, it was found that the cost increased by an increase in the number of liters of solar. Table (9) shows the type of mixer, number of litres and the cost to prepare 1 ton of HMA at 155º C. Cost of preparing 1 ton using (20%S.C.D.F), (0.5%S.L.S.F), and (2.5%S.L.S.F) using furnace with fan is illustrated in tables (10).

Table (9): Number of liters and the cost to prepare 1 ton of HMA at 155 º C.

Type of Mixer	**Automatic**	**Normal**	**Local**
Number of Liters to prepare HMA at 155 º C (lit/ton)	7.5	15	20
Cost of solar (L.E/lit)	1.80		
Cost of solar to prepare 1 ton of HMA at 155 º C (L.E/ton)	13.5	27	36
Average cost of solar to prepare 1 ton at HMA (L.E/ton)	24.75		
Cost of 1 ton of HMA at 155 º C (L.E/ton) , Assume (1 ton = 0.5m³)	250.0		

Table (10): Calculation of the cost of 1 ton using (20%S.C.D.F), (0.5%S.L.S.F), and (2.5%S.L.S.F) by using furnace with fan.

		20%S.C.D.F	2.5%S.L.S.F	0.5%S.L.S.F
Time (min)	HMA	51	53	
	WMA	39	40	
% Reduction in time		22.0	24.5	
Average cost of solar of 1 ton at WMA (L.E/ton)		19.31	18.68	
Reduction in the solar cost (L.E/ton)		- 5.45	- 6.06	
No.of kilograms of sasobit used (Kg)		11.5	1.4	0.28

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Cost of Sasobit (L.E/Kg)	20		
Cost of Sasobit of 1 ton at WMA (L.E/ton)	+ 230	+ 28	+ 5.75
Total cost of 1 ton of WMA (L.E/ton)	474.5	271.9	249.7

It can be concluded that the percentage of reduction in time using the furnace with fan is 24.5% as shown table (6) using (0.5%S.L.S.F) as minimum requirements in (L.S.F). The advantages of using (0.5%S.L.S.F) are; either decrease in the energy of production by 24.5% or decrease in the time of shift by 24.5%. Also, the reduction in production time by 24.5% leads to increase in the life time of the mixers and accessories by 24.5%, decreasing the maintenance cost and spare parts of the working tools and mixers by 24.5% and reducing the used electric energy by 24.5%. The emissions as a function of temperature are presented in table (11). Generally, it was found that the emissions increased by an increase in temperature. A Comparison between emissions when using (20%S.C.D.F), and (2.5%S.L.S.F) at temperature 155 º, and 120º C was illustrated in table (11), while table (12) shows the emissions reduction measured for (20%S.C.D.F), and (2.5%S.L.S.F).

Table (11): Comparison between emissions for (20%S.C.D.F), and (2.5%S.L.S.F) at temperature 155 ºC, and 120 ºC.

	20%S.C.D.F		2.5%S.L.S.F		Limit through 8 work (PPm)
	155	120	155	120	
CO_2	15.6	13.4	15.4	13.1	< 25
NOx	0.82	0.56	0.79	0.53	< 3
VOCs	7.3	6.9	7.1	6.4	---

Table (12): Emissions Reduction Measured from (20%S.C.D.F), and (2.5%S.L.S.F).

	20%S.C.D.F	2.5%S.L.S.F
Reduction (CO_2) %	14.10	14.94
Reduction (NOx) %	31.71	32.91
Reduction (VOCs) %	5.48	9.86

CONCLUSIONS

This research compare the effect of adding (S.C.D.F), and (S.L.S.F) at 120º C to asphalt binder with HMA at 155º C. The program consists of two stages, the first stage was adding (S.C.D.F), while the second stage was adding (S.L.S.F) to the specimens after obtaining (O.S.C) for (C.D.F) and (L.S.F) at 120º. The test results were compared with control specimens (C.C.D.F) and (C.L.S.F). The main conclusions can be summarized as;

1. Maximum stability was achieved by adding 20% of (S.C.D.F)which increased stability from 1020 to 2070 Ib and then decreased at 21%.
2. Maximum stability was achieved by adding 2.5 % of (S.L.S.F) which increased stability from 1830 to 2050 Ib and then decreased at 3.5%.
3. The Flow decreased with the increase of (S.C.D.F) and (S.L.S.F) percentages.
4. The Air Void percentage for WMA increased with the increase of (S.C.D.F) %, while it decreases with the increase of (S.L.S.F)%.

5. The VMA decreased with the increase of (S.C.D.F) and (S.L.S.F) percentages.
6. The total cost of 1 ton of WMA was found 474.55 and 271.94(L.E/ton) for (20%S.C.D.F) and (2.5%S.L.S.F) respectively, but using (0.5%S.L.S.F) cost 249.68(L.E/ton) which is almost the same cost of HMA.
7. The percentages of reduction in Carbon dioxide (CO2), Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs) were 14.10, 31.71 and 5.48% respectively at the optimum percentage of (S.C.D.F), while percentages of reduction were 14.94, 32.91 and 9.86% respectively at the optimum percentage of (S.L.S.F).
8. Using WMA decreases the gas emissions and produces a better working environment with almost the same cost of HMA

From the previous discussed results and the mentioned above conclusions, it is highly recommended to use (0.5 %S.L.S.F) as an optimum dose of chemical additive to produce WMA.

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