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# Effects of organic warm mix asphalt additives on marshall properties

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**Abstract.** Warm mix asphalt (WMA) is a new sustainable technology that gives an economic and environmental beneficial value by means of production temperature decrease of the asphalt mixture by (10-40) °C. The difference between conventional Hot Mix Asphalt (HMA) and WMA mixes were analyzed, in this study, in term of marshall properties which conducted on specimens are produced of: Al-Nibaae source aggregate and Al-Dorah Refinery source asphalt binder (40/50 PEN) modified by two organic additives (Asphaltan A and Asphaltan B). The laboratory tests to determine the mechanical properties of asphalt binder and aggregates are conducted. Two types of aggregate gradation mixtures are designed to perform HMA and WMA preparations using Marshall design method. Doses of 1, 2, and 3% of the additives by total weight of asphalt binder were chosen. WMA mixtures are prepared at 40 °C less than HMA specimens and produced by the same procedure. Many changes on mechanical and physical properties are observed due to the existence of the additives and dosages. The results show that the resulted properties are enhanced by using Asphaltan A and Asphaltan B as WMA additives to the Iraqi asphalt binder.

## 1. Introduction

The first idea of using lower temperature for asphalt binder production was by Prof. Ladis Csanyi in 1956 by using foaming technique [1]. A new ways are invented in recent years to perform temperature reduction by (20-40°C), organic additives are one of them [2]. Usually, the asphalt mixture is produced at high temperatures (150 to 170 °C) and often referred to as HMA [3]. Besides, environmental awareness has been increasing rapidly over the past few years and extensive measures like air pollution reduction targets are set by the European Union with the Kyoto Protocol have encouraged efforts to reduce environmental pollution [4]. At a minimal temperature production, WMA technologies allow the mixing and compaction process of bituminous mixtures by the meaning of decrease the viscosity of the asphalt binder and improving the workability of the mixture. Several benefits are found by decreasing the production temperatures related to reduce the bad emissions and minimize energy consumption [5].

Organic WMA additives are a group of WMA technologies which are based on organic compounds that can modify certain properties of asphalt binder to improve its workability at warm temperatures. They are used to be added to hot asphalt binder and there are many types of them such as: Sasobit®, Asphaltan B®, Asphaltan A® and Licomont BS 100.

Two organic additives are used in this: Asphaltan A and Asphaltan B which produced by Romonta GmbH. The objective of using these additives is to study the effects on the mechanical properties of



210 prepared Marshall specimens and check how the additive type and content can be used to reduce the bituminous mixture production temperature as compared to HMA. Two aggregate design mixtures are adopted: surface and base layer according to Iraq Standards [6]. The modified binder was prepared by using three doses of each additive: 1, 2 and 3% by weight of virgin binder.

## 2. Materials preparation

All the materials used in this study are described in the following paragraphs.

### 2.1. Virgin binder

Asphalt binder of 40/50 penetration grade from Al-Durah refinery in southern of Baghdad is used in the study. This type of binder is widely used in Iraq to produce asphalt pavement mixtures at hot temperatures. The basic properties of virgin asphalt binder are listed in table 1.

**Table 1:** 40/50 asphalt binder physical properties.

Properties	Unit	Test Result	Test Method
Penetration (25°C)	dmm	41	ASTM D5/D5M – 13
Ductility (25°C)	cm	>100	ASTM D113 – 07
Specific gravity (15.6 °C)		1.04	ASTM D70 – 18
Flash Point	°C	326	ASTM D 1310 - 14
Softening Point	°C	51.5	ASTM D36/D36M – 14
percent of weight soluble in C <sub>2</sub> HCL <sub>3</sub>	(%)	0.999	ASTM D2042 – 15

### 2.2 Aggregates

Coarse and fine aggregates were obtained from crushed stones of Al-Nibaae quarry, northern of Baghdad. Aggregates retained on sieve No. 4 are used as coarse aggregate and those passed No. 4 sieve and retained on sieve No. 200 are used as fine aggregate. The physical properties of aggregates which are used in this study are listed in Table 2. The selecting of aggregate gradations is based on Iraqi ‘Standard Specifications for Roads and Bridges’ [6] and is based on the light of the recommendation of Asphalt Institute for base and surface layer [7] as shown in Table 3. Coarse and fine aggregate are sieved and analyzed according to ASTM C136/ C136-14 standards.

**Table 2:** Aggregate physical properties.

Test	Aggregate Type		Test Method
	Coarse	Fine	
Specific Gravity	2.62	2.618	ASTM C127-15 and C128-15
Water Absorption	0.56%	0.64%	
Los Angeles Abrasion Test	16.7%		ASTM C131/C131M-14
Clay Content NMAS 25 mm		0.01%	ASTM C142/142M - 17
Clay Content NMAS 19 mm		0.19%	

**Table 3:** Aggregate gradation.

Sieve opening mm	Base Layer				Surface Layer					
	Specifications		Restricted zone		Selected	Specifications		Restricted zone		Selected
	Lower	Upper	Lower	Upper		Lower	Upper	Lower	Upper	
37.5	100				100					
25	90	100			95					
19	76	90			83	100				100
12.5	56	80			72	90	100			95
9.5	48	74			62	76	90			83
4.75	29	59	39.5		33	44	74			58
2.36	19	45	26.8	30.8	24	28	58	39.1		34
1.18			18.1	24.1					25.6	31.6
0.6			13.6	17.6					19.1	23.1
0.3	5	17	11.4		8	5	21	15.5		13
0.075	2	8			5	4	10			7

### 2.3 Mineral filler

Dust of Al-Nibaae quarry crushed stones are used as a mineral filler after conducting all the physical tests to find out the properties which are listed in Table 4.

**Table 4:** Physical properties of mineral filler.

Test	Sand Equivalent	Plasticity Index
Result	76%	2.9%
ASTM Designation	D2419 - 14	D4318 - 17e1

### 2.4 WMA additives

The physical properties of organic additives which used in this study is listed in table 5.

**Table 5:** Physical properties of the additives.

Additive type	Property				
	Solidification point °C	Flash point °C	Ignition temperature °C	Viscosity mPa	Solubility in water
Asphaltan A:	133 - 143	> 200	> 300	5-15 at 150 °C	not soluble
Asphaltan B:	95 - 105	> 250	> 300	20 - 200 at 120 °C	not soluble

### 2.5 Marshall specimen preparations

Three percentages (1, 2 and 3%) by weight of additives are added as doses to the 40/50 virgin binder to perform the production of the modified binder which used in the study. A mixer with a fitted propeller with a steel container is used to produce the modified binders. The steel container was exposed to fixed temperature source controlled to  $\pm 1$  °C precise condition. A sample of 1 kg of virgin binder is heated to 150 °C and poured in the preheated steel container. The additive is added carefully to the virgin

binder as quickly as possible and mixed for 10 minutes at 120 rpm so that the whole dosage has been melted into the binder. The modified binder was then removed and let to be cooled for 1 hr at  $25\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ . 210 asphalt cement Marshall specimens are prepared and tested to find the optimum contents of the binder and to evaluate the differences in volumetric properties. For surface layer, the control mix contained virgin binder with five percentages: 4.0%, 4.5%, 5.0%, 5.5% and 6.0% of total weight of mixture, three specimens are prepared for each percentage by performing Marshall procedure. The same number of specimens are prepared for each sample of modified binder. The number of prepared specimens for base layer was equal to that of surface layer and the preparation method is the same except that the five percentages of binder were: 3.5, 4.0, 4.5, 5.0 and 5.5%. Mixture IDs which are selected for this study are described in Table 6. The additives seem to be brown pastilles with weak specific odor. The melting point is  $80 \pm 5\text{ }^{\circ}\text{C}$  as ordered by the manufacturer.

The mixing and compaction temperatures are selected according to SORB specifications. The production temperatures of WMA mixtures are chose to be  $40\text{ }^{\circ}\text{C}$  below that of HMA according to the recommendation of the manufacturer. Mixing and compaction temperatures of control mixtures are found to be  $163\text{ }^{\circ}\text{C}$  to produce a viscosity of  $170 \pm 20\text{ cSt}$  for mixing and  $153\text{ }^{\circ}\text{C}$  to produce a viscosity of  $280 \pm 30$  for compaction [6]. All the mixtures are tested and compared to each other to evaluate the disparity in results due to additive amount differences. The preparation of all the specimens is conducted according to ASTM D6926-16. The specimens of control mixture are prepared by pouring a specified weight of mineral filler and aggregates in a container inside an oven of  $160\text{ }^{\circ}\text{C}$  and adding a heated virgin binder of  $150\text{ }^{\circ}\text{C}$  temperature to the preheated dry mix in the container, **Table 6**. Hand mixing is taken apart as quickly as possible until full aggregate coating appeared. The prepared loose mixture is, then, put into the compaction mold of 101.6 mm diameter. Special attention is taken to maintain the temperature of mixture stable throughout the whole operation. The compaction is done by preheated clean hummer for both surface and base samples with 75 blows a side and a free 450 mm falling distance of 4.5 kg weight from the base of the mold perpendicularly. The compacted specimens are left over the night before removing them from the mold. The same heating and compaction procedure is taken for the other WMA mixes except that the temperature was  $40\text{ }^{\circ}\text{C}$  less than the conventional hot mixes.

**Table 6:** WMA mixtures studied.

Mixture Name	Type of Mixture	Additive (%)	WMA Additive	Mixing T $^{\circ}\text{C}$	Compaction T $^{\circ}\text{C}$
BC	Base-control-HMA	0	-	163	153
BA1	Base-WMA	1	Asphaltan A	120	110
BA2	Base-WMA	2	Asphaltan A	120	110
BA3	Base-WMA	3	Asphaltan A	120	110
BB1	Base-WMA	1	Asphaltan B	120	110
BB2	Base-WMA	2	Asphaltan B	120	110
BB3	Base-WMA	3	Asphaltan B	120	110
SC	surface-control-HMA	0	-	163	153
SA1	surface-WMA	1	Asphaltan A	120	110
SA2	surface-WMA	2	Asphaltan A	120	110
SA3	surface-WMA	3	Asphaltan A	120	110
SB1	surface-WMA	1	Asphaltan B	120	110
SB2	surface-WMA	2	Asphaltan B	120	110
SB3	surface-WMA	3	Asphaltan B	120	110

### 3. Test methods

All the required tests are conducted according to ASTM specifications and listed in the following paragraphs.

#### 3.1 Bulk density and voids determination

The maximum specific gravity is determined according to ASTM D 2041 - D 2041M – 11. Bulk density in concert with maximum density are necessary to find the void percent of specimens according to ASTM D 3203 - D 3203M - 17. For each combination of aggregate and binder contents, three specimens are prepared and tested together to report the average result of it.

#### 3.2 Marshall Stability and Flow

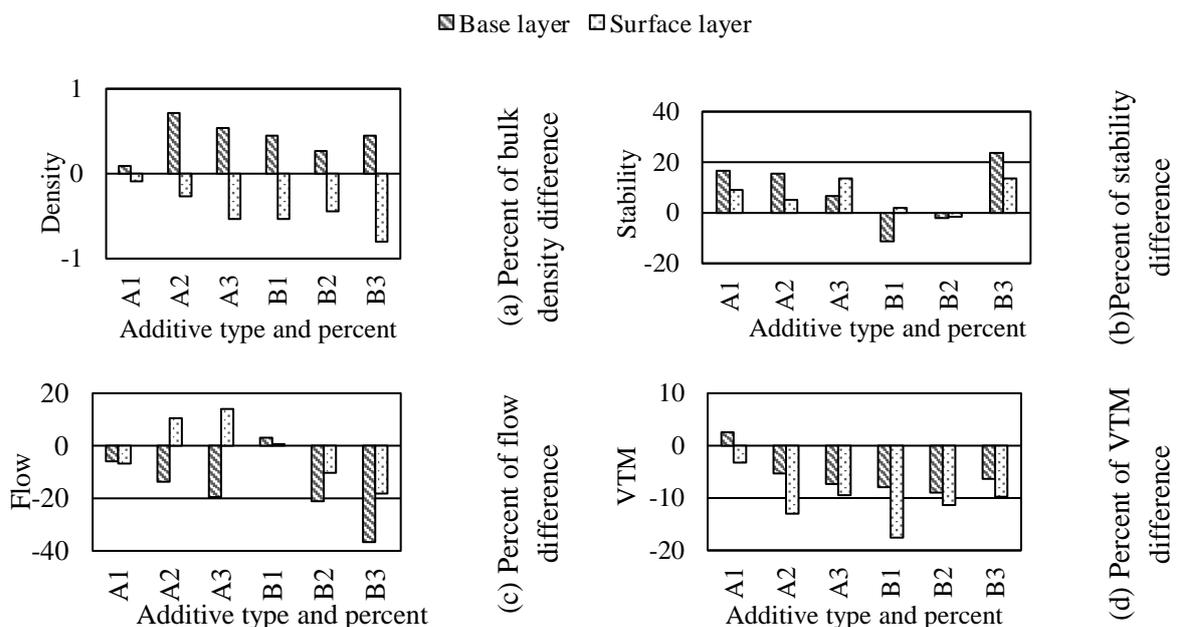
ASTM D6927-15 is the specification according to which the prepared specimens are tested. All the specimens are brought to a  $60 \pm 1.0$  °C water bath and immersed 30-40 minutes. After cleaning the inside surface of testing heads and lubricating the guide rods of stability testing machine, each specimen placed in its position in the assembly and the flowmeter is placed and adjusted to zero. A constant load of 50 mm/min. rate is applied until the maximum reading of load is reached and recorded with the flow reading at the instance of failure. The stability reading is correlated to accommodate the volume of specimen.

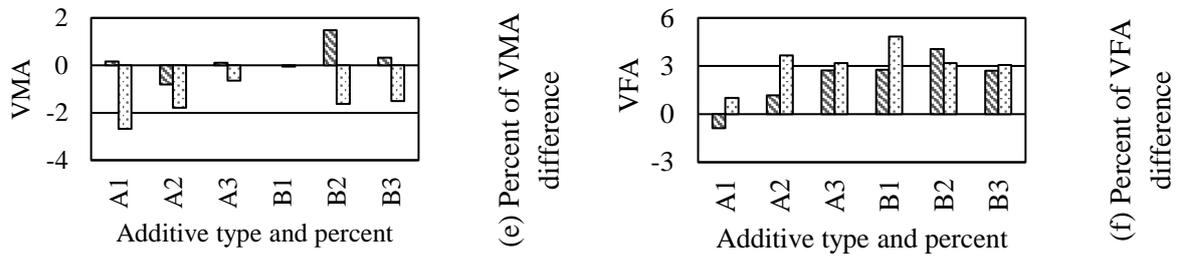
### 4. Results and discussions

Marshall test results of the fourteen bituminous mixtures are illustrated in the following figures. The six Marshall test results indicated many effects and the present of WMA additives caused valuable enhancements. At the point of optimum content of binder for each mix, the values are outlined and discussed.

#### 4.1 Marshal density

The highest increase in densities were that of BA2 mix by 0.36 % more than BC mix for base layer and SB3 has the highest by 0.4 % lesser than SC for surface layer. As shown in **Figure 1**, a little difference in densities is found for all the mixtures, but surface layer mixtures have a little higher of difference than those of base layer. With this result, the conclusion could be trends toward that A2 is improved in term of compatibility.

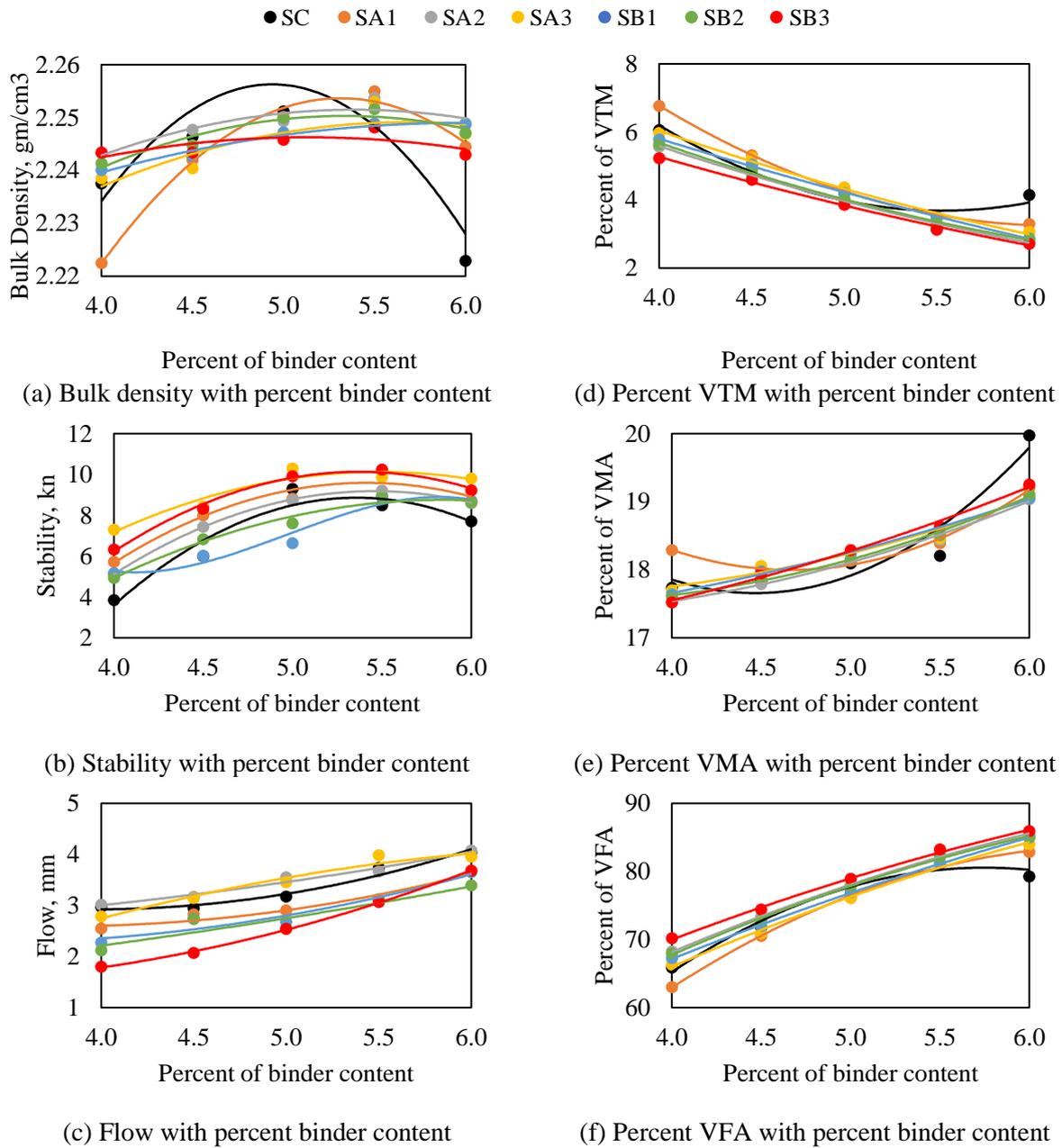




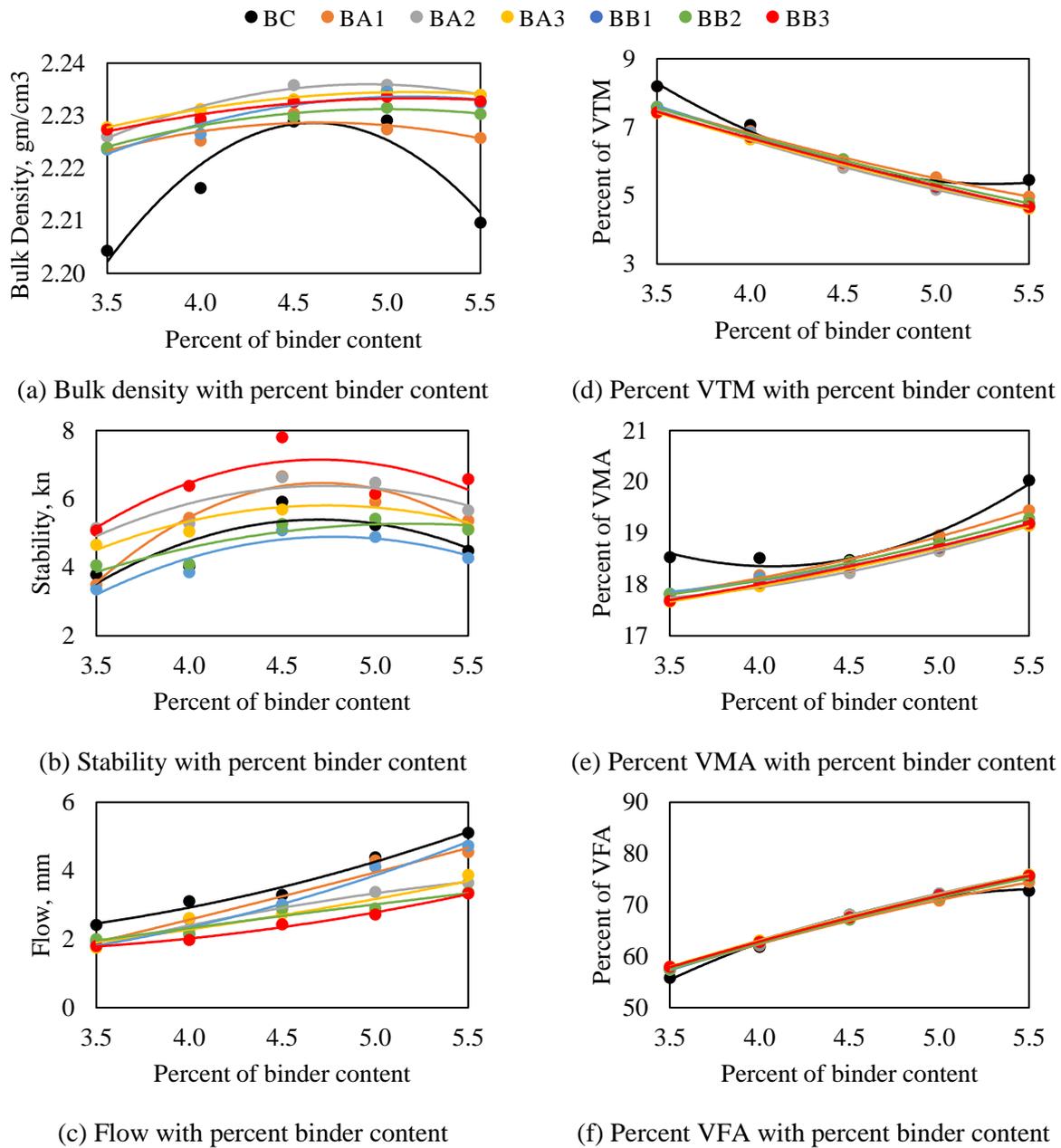
**Figure 1:** Percent of difference of Marshall properties with control mix.

#### 4.2 Marshal stability

BB3 stability recorded as the highest beneficiary of base layer mixtures with 24% larger stability than BC. In surface layer, SA3 and SB3 have the highest percent difference with 14% larger than SC. **Figure 1** illustrates the effects of WMA additives and percentages on the different mix types. The conclusion is that all the mixtures have been improved in term of compressive strength, except WMA mixes: BB1, BB2 and SB2.



**Figure 2:** Marshal properties for surface layer



**Figure 3:** Marshall properties for base layer

*4.3 Marshall flow*

As an indication of resistance to plastic deformation, the flow values for BB3 mixture shows the highest improvement with 37% reduction from control mixture. A brief look at **Figure 1** assures that BA3 and BB2 have less benefit: 20% and 21%, respectively.

#### 4.4 Marshall voids

The voids of bituminous specimens are limited by all the specifications to ranges due to the effects that will be played by the voids and its influence on the performance of pavement, like: durability, moisture sensitivity, squeezing, skid-resistance and other important properties. The percent differences of VTM, VMA and VFA of WMA mixes are illustrated in **Figure 1** which show the following facts: SB1 shows the most affected mixture in term of VTM property by -18% with respect to SC. By looking at VFA property, SB1 is the most affected by 5% with respect to SC, that is an advantage for the mix which indicates higher effective binder content and, in turn, high particles bonding.

#### 5. Conclusions

1. BB3 stability recorded as the highest beneficiary of base layer mixes with 24% larger stability than BC. In the surface layer, SA3 and SB3 have the highest percent difference with 14% larger than SC. All the mixes have been improved in terms of compressive strength, except: BB1, BB2 and SB2.
2. The flow values of BA2, BA3, BB2, BB3, SB2 and SB3 showed the highest improvement as an indication of resistance to plastic deformation with -14%, -20%, -21%, -37%, -10% and -18% of percent difference with control mixes, respectively.
3. SB1 and SB2 showed the most affected mixes in term of VTM by 18% and 11%, respectively, with respect to SC. Both, Asphaltan A and Asphaltan B, made a little change in VMA for both, base and surface layers.

#### References

- [1] Button J, Estakhri C, Wimsatt A. *Evaluation of Warm-Mix Asphalt New Technology*. 2007.
- [2] EAPA. *The use of warm mix asphalt*. In: *Position paper*. 2010.
- [3] Silva HMRD, Oliveira JRM, Ferreira CIG, et al. 2010 Assessment of the performance of warm mix asphalts in road pavements. *Int J Pavement Res Technol*; **3**: 119–127.
- [4] McKeon B. *Aspha-min in Warm Asphalt Mixes*. In: *51st Annual Convention of the National Asphalt Pavement Association*. Lanham, Maryland, 2006.
- [5] Xu S, Xiao F, Amirakhanian S, et al. 2017 Moisture characteristics of mixtures with warm mix asphalt technologies – A review. *Constr Build Mater*; **142**: 148–161.
- [6] SORB. *Standard Specification for Roads and Bridges*. Baghdad, Iraq, 2003.
- [7] Asphalt Institute. *Superpave Mix Design, Superpave Series No. 2 (SP-2)*. Lexington, KY, USA, 2001.