International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:6, No:2, 2012

Assessment of Compaction Temperatures on Hot Mix Asphalt (HMA) Properties

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***Abstract*—**Hot Mix Asphalt (HMA) is one of the most commonest constructed asphalts in Iran and the quality control of constructed roads with HMA have been always paid due attention by researchers. The quality control of constructed roads with this method is being usually carried out by measuring volumetric parameters of HMA marshall samples. One of the important parameters that has a critical role in changing these volumetric parameters is “compaction temperature”; which as a result of its changing, volumetric parameters of Marshall Samples and subsequently constructed asphalt is encountered with variations. In this study, considering the necessity of preservation of the compaction temperature, the effect of various temperatures on Hot Mix Asphalt (HMA) samples properties has been evaluated. As well, to evaluate the effect of this parameter on different grading, two different grading (Top coat index grading and binder index grading) have been used and samples were compacted at 5 various temperatures.

***Keywords*—**Compaction Temperature, HMA, Volumetric Parameters, Marshall Method

I. Introduction

ONE of the most traditional constructed asphalts in Iran and across the world is “Hot Mix Asphalt”. Due to its high durability, solid production, temperature control, moisture and quick provision for traffic crossing, it is being still paid attention by many people. Determination of volumetric parameters of HMA samples has vital importance for quality control of constructed roads. The compaction temperature is one of the parameters that can change the HMA volumetric parameters. According to the ASTM D 6926, (standard practice for preparation of bituminous specimens using Marshall Apparatus) the compaction temperature is the temperature in which bituminous should be heated to produce viscosities of 0.28 ± 0.03 pa.s. [1]The compaction temperature is one of the major issues in HMA and also on of important criteria in the process of producing good quality of hot mix asphalt. Also, the temperature is a key factor in the control of bitumen viscosity, which affects its ability to coat and provide adequate lubrication for the aggregates and slides with each other.

II. LABORATORIAL TESTS

A. Aggregates Grading

In this study two mix designs were used and the gradation limit for the aggregates has been shown in the table 1 and their diagrams have come in fig. 1, 2.

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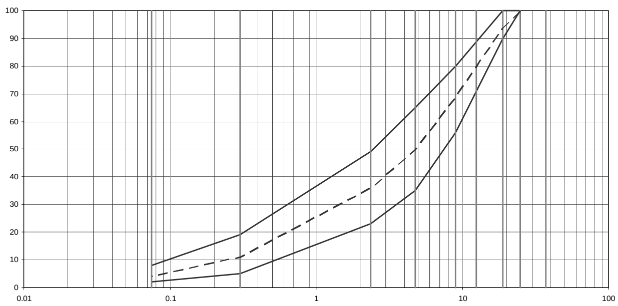

Fig. 1 Gradation Curve of mixing aggregate for binder layer

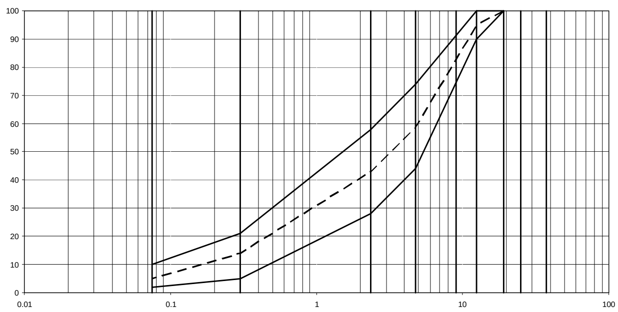

Fig. 2 Gradation Curve of mixing aggregate for top coat layer 0-19 mm

B. Bitumen selection

Considering this fact that the most consuming bitumen in Iran is the bitumen of 60-70, in this study this kind of bitumen was used and figure 3 shows the temperature and viscosity. Table II shows the results of asphalt cement tests.

C. Aggregates Specifications

In the tables III and IV (below), the result of some aggregates’ specification has been shown.

TABLE I
AGGREGATES GRADING USED IN THIS STUDY

sieve size	Limitations of specification aggregate grading	Grading applied for binder index (grading NO.1)	Limitations of specification aggregate grading	Grading applied for top coat index (grading NO.2)
1 in	100	100		
¾ in	100-90	95	100	100
½ in	80-56	69	100-90	94
NO.4	65-35	50	74-44	60
NO.8	49-23	35	58-28	42
NO.50	19-5	10	21-5	12
NO.200	8-2	5	10-2	6

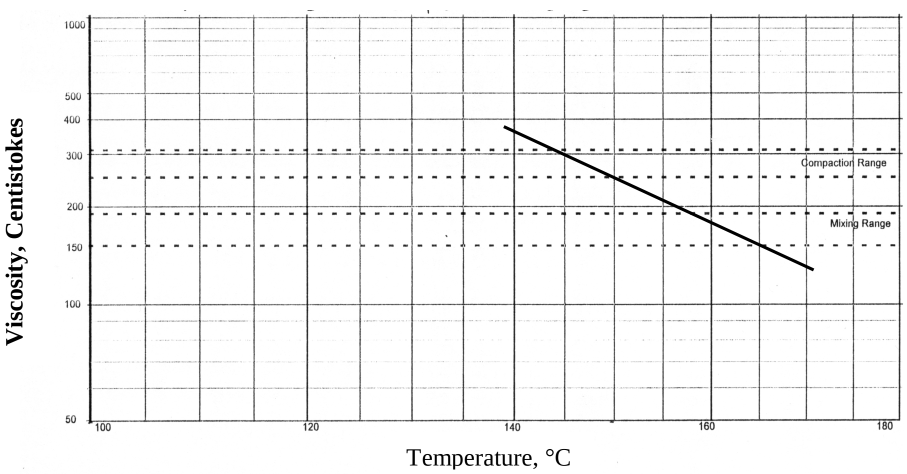

Fig. 3 Viscosity-Temperature bitumen for determination of mixing and compaction temperatures

TABLE II
RESULTS OF ASPHALT CEMENT TESTS

Asphalt cement tests	Test method		Results	Standard specifications	
	ASTM	AASHTO		MIN	MAX
Density @ 25°C	D 70	T 228	1.017	–	–
Penetration of bituminous @ 25°C (100g , 5 sec)	D 5	T 49	64	60	70
Softening point of bitumen (ring and ball)	D 36	T 53	50	49	56
Ductility @ 25°C	D 113	T 51	+100	+100	–
Solubility in trichloroethylene	D 2042	T 44	99.7	99	–
Flash and Fire Points by Cleveland Open Cup	D 92	T 48	296	232	–
Kinematic viscosity @ 120°C	D 2170	T 201	884	–	–
Kinematic viscosity @ 135°C	D 2170	T 201	415	300	–
Kinematic viscosity @ 160°C	D 2170	T 201	172	–	–
A film of bitumen (heated 5 h @ 163°C)	D 1754	T 179	+		

TABLE III
AGGREGATES TEST RESULTS

Properties		Test result binder: Coarse mix	Test result binder: Sand0-6mm	Test result binder: Filler	Test result top coat: Coarse mix	Test result top coat: Sand0-6mm	Test result top coat: filler
Sand equivalent		-	73	-	-	73	-
Los Angeles abrasion loss (aashto T96)	Grading	B	-	-	B	-	-
	Machine revolution	500	-	-	500	-	-
	Abrasion Percent	11			14		
(aashto – T89 , 90)	Plastic index	-	N.P	N.P	-	N.P	N.P
	Liquid limit	-	-	-	-	-	-
	Plastic limit	-			-		
Percent of fractured particles in coarse aggregate(astm-D5821)	One face	100	-	-	100	-	-
	Two face	97	-	-	98	-	-
BS – 812	Flakiness index	21	-	-	19	-	-
	Elongation index	11	-	-	9	-	-
Soundness by use sodium sulfat	Coarse agg		0.58	-		0.61	-
	Fine agg	0.72	-	-	0.74	-	-

TABLE IV
SPECIFIC GRAVITY AND WATER ABSORPTION OF AGGREGATES TEST RESULTS

Top coat			Binder			Properties of Aggregate
Bulk specific gravities and absorptions of aggregates (ASTM – C127,128)			Bulk specific gravities and absorptions of aggregates (ASTM – C127,128)			
Water absorption	Bulk specific gravity (dry)	Apparent specific gravity	Water absorption	Bulk specific gravity (dry)	Apparent specific gravity	
2.1	2.479	2.615	1.9	2.486	2.610	Remained on NO.8
2.4	2.469	2.622	2.3	2.477	2.630	Passed from NO.8 and remained on NO.200
-	2.630		-	2.630		Passed from NO.200
2.484			2.490			Gsb (bulk specific gravity of mix aggregate)

D.Compaction Temperatures Used In This Study

According to the Asphalt Institute Manual series no 2 (MS-2), the temperature of the asphalt cement in tanks during mixing aggregate in mixer of asphalt factory with continuous grading which is being unloaded from factory to the truck, should not be over 163°C. [2]

III. RESULT AND ANALYSIS

A. Analysis of density

Fig. 4 shows the following results:

- Density of binder is slightly higher than top coat.

-Density of binder and top coat is being simultaneously increased with increasing compaction temperature, which is as a result of asphalt cement viscosity due to temperature increase and subsequently, the condition of aggregates location beside each other is in a denser condition.

-The highest density of binder and top coat is being occurred over the temperature of 145 °C.

- High correlation of binder and top coat indicates the strong relationship between density and compaction temperature. (For the top coat aggregate index $R2 = 0.938$ and for the binder aggregate index $R2 = 0.951$).

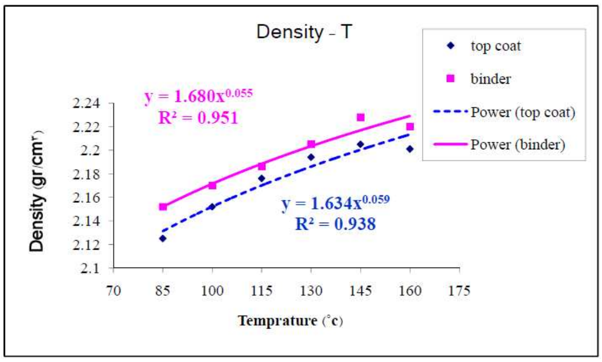

Fig. 4 Density versus compaction temperature

B. Analysis of percent air voids

Percent air voids (Va) of binder aggregate index is higher comparing to the top coat aggregate index. Furthermore, high R2 value for binder and top coat is indicator of the strong relationship between air voids and compaction temperature. (For the top coat aggregate index, $R2= 0.970$ and for the binder aggregate index, $R2= 0.986$)

The higher compaction temperature is behind of the asphalt cement viscosity and more asphalt cement dispersion on the asphalt surface, as well it makes a thin film of bitumen becomes enough for covering the coarse aggregates, and finally since the volume of bitumen is constant, consequently, the temperature increase merely decreases the percent air void.

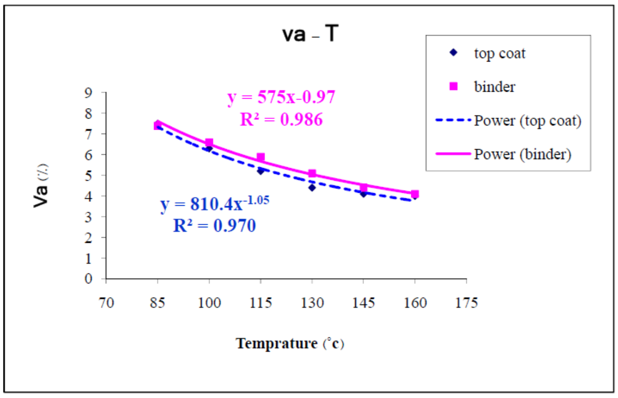

Fig. 5 Air voids versus compaction temperature

C. Analysis of percent voids filled with asphalt

Fig. 6 shows that VFA is simultaneously being increased with the increase of compaction temperature. The amount of VFA in the binder is more than top coat, which is due to the more optimum asphalt content in the top coat, comparing to the binder. But, due to the lack of inequality of air void percent difference of top coat comparing to the binder in different temperatures, the amount of top coat VFA in comparison with binder VFA are not exactly equal with each other. Also, the drawn figures for binder and top coat show an attending move of VFA versus the increase of temperature. This figure also indicates the existence of a strong relationship between VFA and compaction temperature (because of the high correlation of binder and top coat). According to the Iranian highway asphalt paving code NO.234, the authorized limitation for the VFA of top coat must be in the range of 112 °C (VFA = 65) to 163 °C (VFA = 75) and for the binder it must be 129 °C (VFA = 65) to 189 °C (VFA = 75). [2,4]

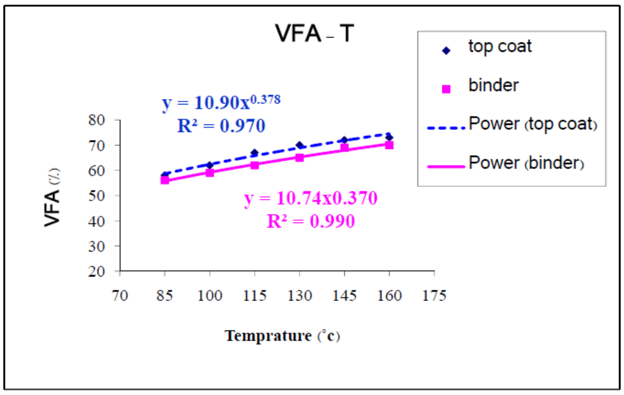

Fig. 6 VFA versus compaction temperature

D. Analysis of stability

As it come in Figure 7, stability of both mix design (binder and top coat) is being increased with the increase of the compaction temperature, but it is being slightly dropped over the temperature more than 145°C.

This figure also indicates the strong relationship between stability and compaction temperature (because of the High R2 value for binder and top coat). Since the size of aggregate in the binder is bigger than the top coat, as a result; stability in binder is also greater than top coat.

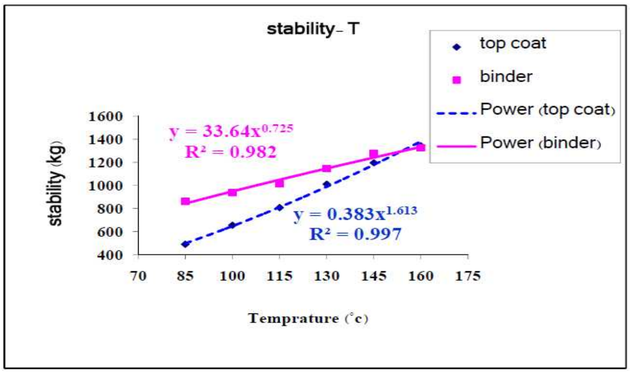

Fig. 7 Stability versus compaction temperature

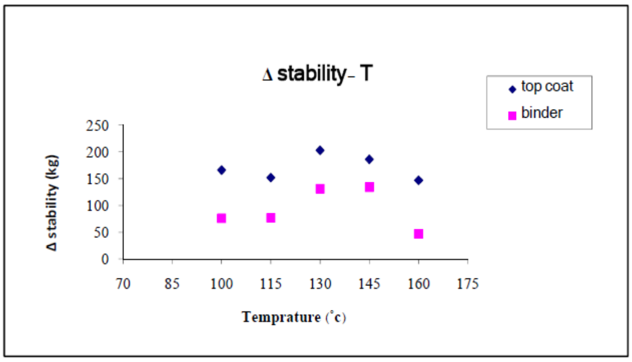

Fig. 8 **Δ** stability versus compaction temperature

The graph of variation satiability (Δ stability) versus compaction temperature shows that the maximum increasing rate of stability is happened in the distance of 115 °C - 130°C and also the distance of 130°C - 145°C, while the mentioned rate is insensible over the distance of 145°C - 160°C.

Although, some believe that high stability means quality of the asphalt, extra stability mostly causes less durability and vice versa. To attain asphalt with high stability and durability, the grading and asphalt content should be selected with high exactness.

E. Analysis of flow

The quantity of Marshall Flow in top coat and binder is being simultaneously increased with the increase of compaction temperature. The fig. 9 indicates that the rate of difference between top coat flow and binder becomes greater in higher temperatures. This figure is also indicator of a strong relationship between flow and compaction temperature (because of the High R2 value for binder = 0.966 and 0.989 for top coat).

According to the mentioned minimum and maximum authorized quantity for flow in the MS-2 (2-3.5mm), seeing the Fig. 9 shows that all of the attained flow quantities for top coat and binder are in the authorized limitation.

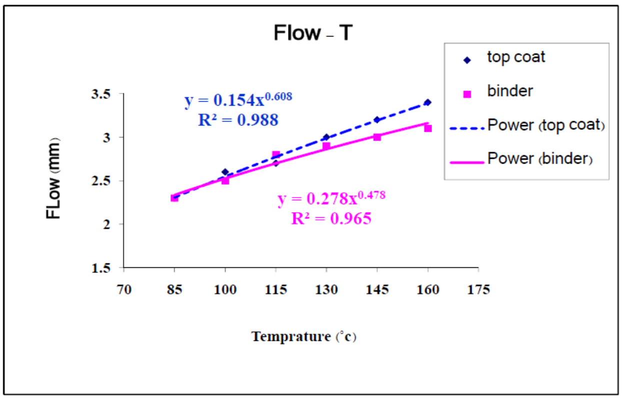

Fig. 9 Flow versus compaction temperature

IV. Conclusion

- This study indicates that the temperature has significant impression on hot mix asphalt properties. From the discovered high correlation value (R2 over 0.9) in the drawn figures, we can realize that there is a strong relation between various parameters of Marshall Samples and compaction temperature. So, observing the compaction temperature during the performing hot mix asphalt, can help us to avoid from considerable changes which there are in the asphalt specifications.
- Increasing compaction temperature makes density to be increased, but there is a limitation for this increase and afterwards density will be decreased. (in this study, this limitation is 145 °C).
- Considering the mentioned minimum and maximum for Va and VFA in MS2 and other references, the amount of authorized temperature parallel with them can be achieved.
- increasing the temperature makes stability to be increased, but the maximum rate of increase in this investigation is being occurred over the distance of 115°C - 130°C and 130°C - 145°C.
- There can be found a golden temperature for each mix design asphalt, which its Marshall sample has got best performance. (For this investigation, the temperature is about 145°C, in which viscosity of consuming bitumen equals with 280 centistokes, cSt)

Acknowledgment

Hereby, all kinds of the contributions of the Technical Soil &Mechanics Laboratory of the Ministry of Roads of the provinces Iran are being kindly appreciated.

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