International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Determination of the acceptable range of mixing and compaction temperatures for modified asphalt mixture with styrene butadine styrene (SBS)

Hasan H. Joni and Ethar K. Shaker*

Building and Construction Engineering Department, University of Technology, Baghdad

Received 06 July 2017, Accepted 06 Sept 2017, Available online 09 Sept 2017, **Vol.7, No.5 (Sept/Oct 2017)**

Abstract

The temperatures of mixing and compaction of modified asphalt mixture are an important factor in the construction process. The temperature should be chosen in the specified range because the increase of the temperature above the limit may cause the drainoff of the asphalt from the mixture. On the other hand , the decreased temperatures lead to poor in coated aggregate particles. This research has been made to predict models for mixing and compaction temperatures for SBS modified asphalt mixture and study the effect of asphalt content, SBS content and filler type on the temperatures. One type of asphalt cement grade (40-50) used and polymer styrene butadiene styrene (SBS) with (3%, 4% and 5%) by weight of asphalt cement. Two types of tests were carried for asphalt mixtures (mix coating test and compaction of asphalt mixture test). From experimental test results, it is observed that the mixing and compaction temperature of the modified asphalt mixture has a negative relationship with asphalt content. On the other hand, the relationship between the temperatures and SBS content is a positive relationship. The mixing and compaction temperature of the modified asphalt mixture with limestone dust has been result more than the mixture with Portland cement.

Keywords: *SBS-polymer, mixing and compaction temperatures, Superpave, modified asphalt mixtures,Ross count method.*

1. Introduction

The modified asphalt mixture with styrene butadiene styrene (SBS) has many advantages like enhance the performance(Ahmadinia, Zargar, Karim, Abdelaziz, & Ahmadinia, 2012), preventing thermal cracking, delaying fatigue cracking and reducing permanent deformation in hot mix asphalt at high temperature (Emery & O'connell, 1999), increase the service life of highway surface(Airey, 1997). the adverse effects of using SBS to modify the asphalt mixture were excessive aging, degradation and toxic fumes release may occur to the bitumen (Azari, McCuen, & Stuart, 2003; Yildirim, 2000; Yildirim, Ideker, & Hazlett, 2006), serious consequences to modified bitumens (oxidation, breakdown of long chain polymers, volatile loss, emissions, odor-causing compounds) (Branco & Pereira, N.D.).Therefor suitable range for mixing and compaction temperatures should be used to avoid these adverse effects. The purpose of this study is to estimate the effects of some variables on the mixing and compaction temperature, developing statically models to predict these temperatures to determine acceptable range.

*Corresponding author's ORCID ID: 0000-0002-6453-9123

2. Material used in the work

Materials were evaluated according to the routine type of tests from the ASTM standard specifications and compared with the SCRB (R/9, 2003) specification requirements.

2.1 Aggregates

In this work the aggregate was selected from al-Nibaie Quarry. The properties of gravels were found by laboratory experiments, and the physical and chemical properties were measured using routine tests as indicated in table (1).

2.2 Asphalt binders

One type of asphalt cement was used in this study AC (40-50) and obtained from AL-Daurah Refinery. Table (2) shows the physical properties of asphalt binder.

Table 1: Physical Properties of Selected Aggregate

Laboratory Test		**ASTM Designation and Specification**	**Results**			
Specific gravity	Coarse aggregate	ASTM C127	Sieve size (mm)	Apparent Gs	Bulk Gs	Abs.%
			19-12.5	2.672	2.650	0.32%
			12.5-9.5	2.593	2.580	0.35%
			9.5-4.75	2.570	2.565	0.22%
	Fine aggregate	ASTM C128	Crashed sand (<#4)	2.67	2.64	0.63%
Angularity for Coarse aggregate		ASTM D 5821 **Min 90%**	93%			
Soundness for Coarse aggregate		ASTM C88 **10-20% Max**	4.3%			
Equivalent sand (clay content)	Crashed(<#4)	ASTM D2419 **Min 45%**	96%			
Flat & Elongation aggregate	Flat	ASTM D4791 **Max 10%**	1%			
	Elongation		4%			
Toughness, by (Los Angeles Abrasion)	Aggregate Size < 25mm	ASTM C131 **35-45% Max**	21.7%			

Table 2: Physical properties and standard limitation of asphalt binder

Test	**Test Conditions**	**Standard**	**Test value**		**SCRB specification**
Penetration	100 gm., 25°C, 5sec., (0.1mm)	ASTM D5	43.6		40-50
Ductility	25°C, 5cm/min	ASTM D113	+115		+100
Specific gravity asphalt	25°C	ASTM D70	1.03		-----
Flash and fire points	.....	ASTM D92	Flash	335°C	> 232 °C
			Fire	339°C	-------
Rotational Viscometer	Pa.sec	ASTM D 4402	0.6625 @ 135ºC 0.2375 @ 165ºC		

2.3 Additives

The additive used in this research was Styrene-butadiene-styrene known as SBS polymer brought from the Ministry of Industrial and Materials/ State Company for Mining Industries as shown in plate (1).

Plate 1: SBS polymer

2.4 Filler

Two types of filler are used in this work. The first is the limestone dust obtained from lime factory in Karbala and the second is the Portland cement by Mas Company which is supplied from local market. The physical properties of limestone dust are as illustrated in Table (3) for limestone dust while the Physical and chemical properties of Portland cement are shown in Table (4).

Table 3: Physical Properties of Limestone Filler

Property	Test Result
Specific gravity	2.92
%Passing Sieve No.200 (0.075 mm)	96%

Table 4: Physical Properties of Portland cement Filler

Property	Test Result
Bulk specific gravity	3.10
Specific surface area	312.5 m^2/kg
%Passing Sieve No.200 (0.075 mm)	97

3. Experimental testing

3.1 Superpave mixture design

The design of asphalt mixture is included mixing the materials (aggregate, asphalt binder and mineral filler), after making sure it is in accordance with specifications, then preparation the specimens to the compaction processes in the SGC according to ASTM D 6925. The design asphalt binder content is established at 4.0% air voids as demonstrate in figure (1). The optimum asphalt content was found to be (5%) by the total weight of sample. Plate (2) shows the steps of preparation samples of the Superpave gyratory compactor.

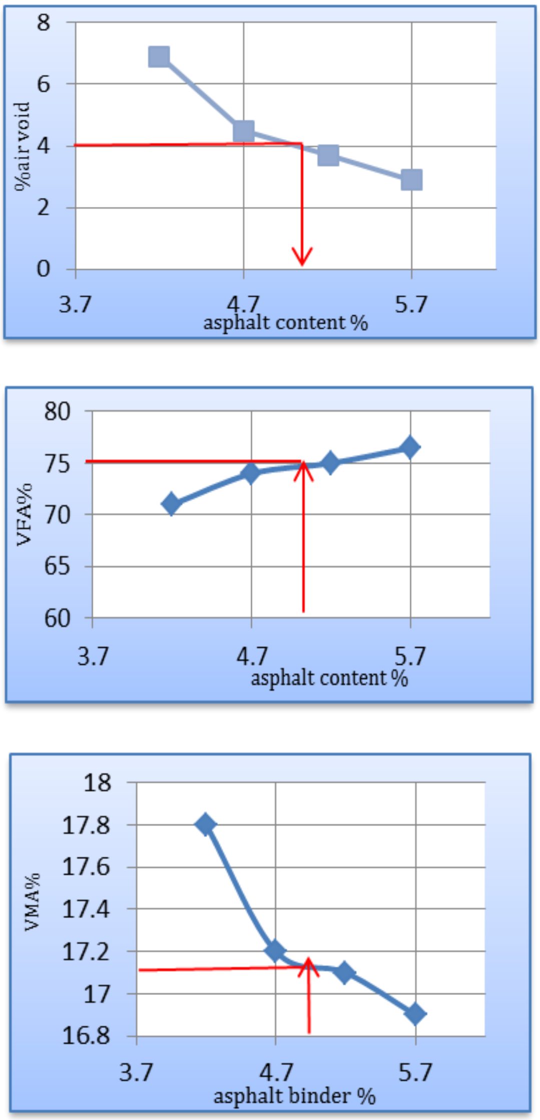

Figure 1: Relation of air void %, VMA%, and VFA% versus asphalt content %.

Plate 2: Superpave Gyratory Compactor Samples Preparation

3.2 Asphalt mixture test

Asphalt Mixture tests were performed to analyze the effects of temperature and binder consistency on aggregate coating, lubrication and shear resistance during laboratory compaction. Each of The mix coating and compaction of asphalt mixture tests were done using (72) specimens with different condition as present in table (5)

Table 5: variables that include in the study

Variable	Characterization	No
Asphalt content	Optimum	3
	optimum+0.5	
	Optimum-0.5	
Filler	Limestone	2
	Portland cement	
SBS content	3%	3
	4%	
	5%	

3.2.1 Mix coating test

The Ross count method ASTM D2489 was used to evaluate the Percentage of coated aggregate particles as shown in plate (3). The minimum temperature suitable for mixing should be based on how well the binder coats the aggregate. The percentage of coated aggregate tests were done for (72) specimens of different conditions. The mixing temperatures are (150, 170, and 190). Symbols from A to X represents 24 different cases, each case depend on specific variable (type of filler, SBS percentage, and asphalt content as illustrated in the table (6). For each case, the coating percentages were related to mixing temperatures using Sigmoid functions (West, Watson, Turner, & Casola, 2010) of the form:

$$C = \frac{1}{1+a*e^{-b*T}} \tag{1}$$

Table (6) demonstrates the predicted mixing temperature for equivalent coating and the value of the constant (a and b) for each case which is produced from the regression analysis.

3.2.2 Compaction of asphalt mixture test

The 72 specimens were compacted at 140, 160, and 180 by SGC as demonstrate in plate (4). %Gmm was calculated for each specimen at 25 gyrations (West et al., 2010). The compaction temperature was predicted for each case by using the linear equation that result from linear regression. Linear regressions were established between %Gmm and compaction temperature for each case from A to X as demonstrate in table (7).

Plate 3: Mix coating test

Plate 4: Compacted specimen

Table 6: The regression result and the predicted mixing temperature

Symbol	Mixing temperature	a	b	temperature
A	**3% SBS+cement+optimum**	2.2317	0.02	166
B	**4%SBS+cement+optimum**	4.158	0.022	168
C	**5% SBS+cement+optimum**	4.085	0.02	170
D	**unmodified+cement+optimum**	0.65	0.017	164
E	**3% SBS +cement + (optimum+1/2)**	11.796	0.032	165
F	**4% SBS+cement+ (optimum+1/2)**	4.721	0.024	166
G	**5% SBS+cement + (optimum+1/2)**	3.406	0.02	169
H	**Unmodified +cement + (optimum+1/2)**	0.796	0.021	163
I	**3%sbs+cement + (optimum-1/2)**	1.001	0.012	168
J	**4% SBS +cement + (optimum-1/2)**	0.694	0.009	174
K	**5% SBS+ cement + (optimum-1/2)**	0.582	0.006	176
L	**Unmodified +cement + (optimum-1/2)**	0.874	0.016	166
M	**3% SBS +lime+optimum**	12.092	0.028	168
N	**4% SBS +lime+optimum**	1.841	0.015	170.4
O	**5% SBS +lime+optimum**	1.594	0.012	171
P	**unmodified+lime+optimum**	1.802	0.02	165
Q	**3%SBS+lime+ (optimum+1/2)**	4.816	0.025	166
R	**4% SBS+lime+ (optimum+1/2)**	1.465	0.015	168
S	**5%SBS+lime+ (optimum+1/2)**	0.65	0.009	170
T	**unmodified+lime+ (optimum+1/2)**	33.177	0.04	163
U	**3%SBS+lime+ (optimum-1/2)**	5.318	0.022	170
V	**4%SBS+lime+ (optimum-1/2)**	2.707	0.016	172
W	**5% SBS+lime+ (optimum-1/2)**	2.659	0.014	173
X	**unmodified+lime+ (optimum-1/2)**	1.092	0.016	166

Table 7: The summary of compaction test result

Symbol	Regression Equation	R^2	C
A	%Gmm=90.158+0.012T	0.949	161
B	%Gmm=89.762+0.019T	0.795	162
C	%Gmm=86.22+0.031T	0.68	164
D	%Gmm=88.125+0.005T	0.96	159
E	%Gmm=92.757-0.005T	0.94	158
F	%Gmm=86.959+0.022T	0.996	161
G	%Gmm=86.345+0.034T	0.971	162
H	%Gmm=83.696+0.038T	0.626	158
I	%Gmm=87.488+0.018T	0.776	162
J	%Gmm=96.230-0.026T	0.961	166
K	%Gmm=91.755+0.004T	0.757	168
L	%Gmm=65.527+0.154T	0.989	160
M	%Gmm=90.683+0.009T	0.921	161
N	%Gmm=91.158+0.011T	0.857	163
O	%Gmm=89.414-0.001T	0.691	166
P	%Gmm=94.912-0.018T	0.6	160.4
Q	%Gmm=84.950+0.038T	0.747	159
R	%Gmm=79.56+0.074T	0.792	161
S	%Gmm=89.840+0.01T	0.9	165
T	%Gmm=87.295+0.038T	0.879	158
U	%Gmm=89.265+0.019T	0.93	162.5
V	%Gmm=87.98+0.021T	0.633	164
W	%Gmm=90.11+0.009T	0.848	167
X	%Gmm=97.863-0.037t	0.808	161

4. Test result analysis and discussion

4.1 Effect of asphalt content

The relationship between the temperatures (mixing and compaction) for the modified asphalt mixture for different SBS content versus asphalt content is shown in figures (2), (3), (4) and (5). Popularly, the figures demonstrate that the mixing and compaction temperature decreased with increased the asphalt content. This trend is related to that the increase in asphalt content leads to lubricate aggregate particles and make aggregate rearrangement under load easier therefore the necessary temperature for mixing and compaction decreased with increased asphalt content.

4.2 Effect of SBS content

Figure (6) compares the mixing temperature of modified asphalt mixtures over a range of SBS content. A closer look at the figure reveals that the mixing temperature of the modified asphalt mixture increased with increased the SBS content. The same behavior was found in the figures (7), (8), and (9), this behavior is related to that the increase in SBS content leads to increase in the viscosity of the modified asphalt mixture therefor the necessary temperature for mixing and compaction increased.

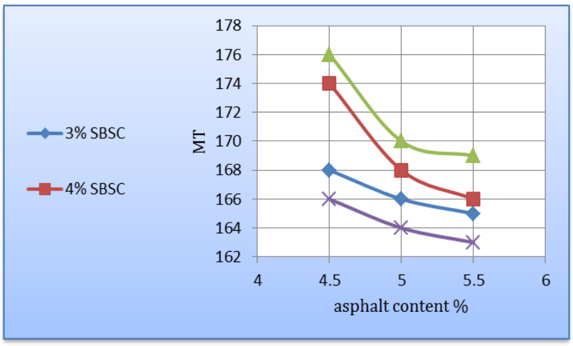

Figure 2: Relationship between mixing temperatures and AC %for Portland cement

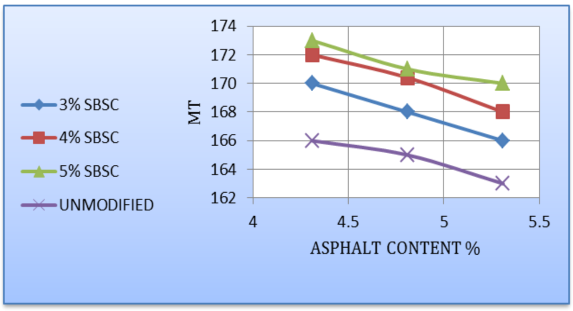

Figure 3: Relationship between mixing temperatures and AC %for limestone dust.

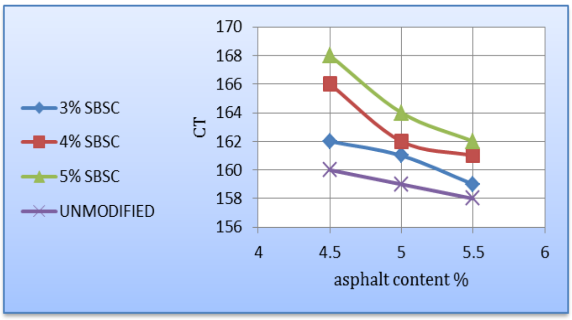

Figure 4: Relationship between compaction temperatures and AC %for Portland cement

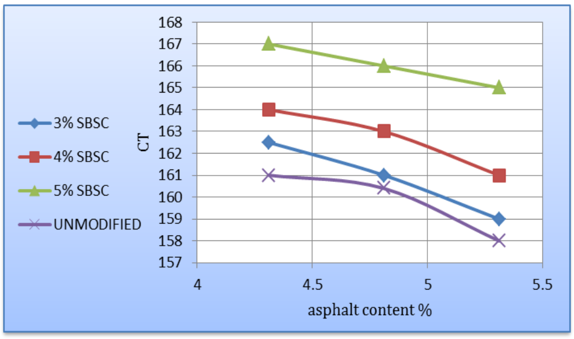

Figure 5: Relationship between compaction temperatures and AC %for limestone dust

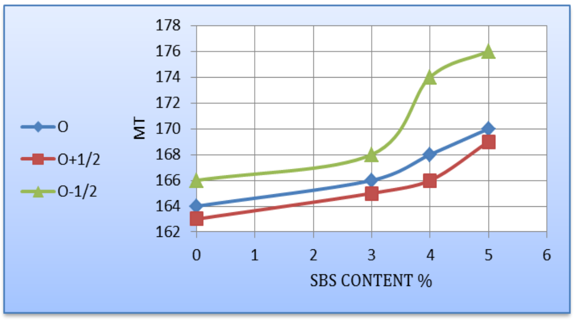

Figure 6: Relationship between mixing temperatures and SBSC %for Portland cement

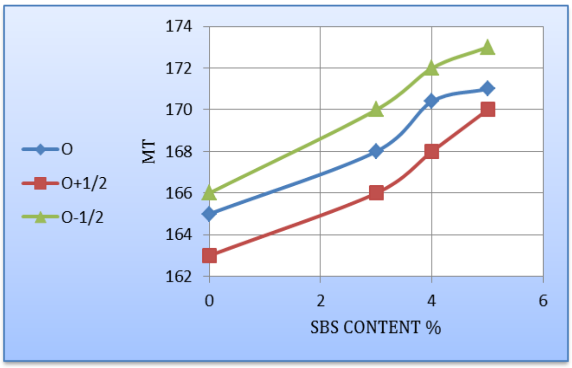

Figure 7: Relationship between mixing temperatures and SBSC %for limestone dust

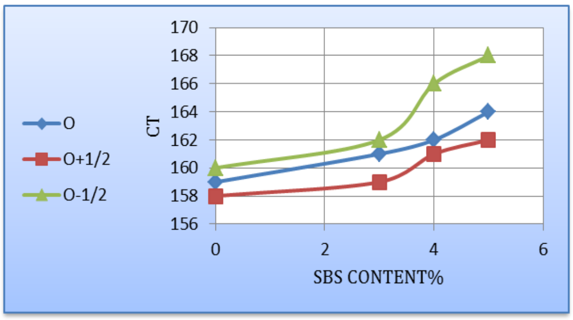

Figure 8: Relationship between compaction temperatures and SBSC % of Portland cement

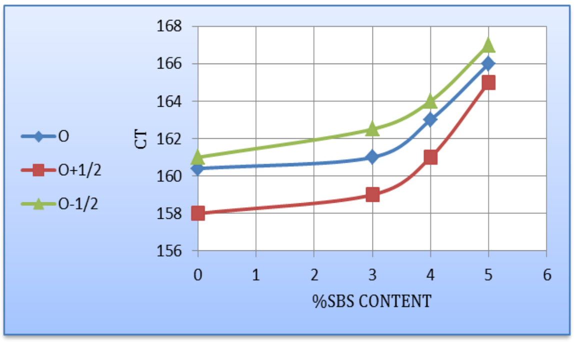

Figure 9: Relationship between compaction temperatures and SBSC % of limestone dust

4.3 Effect of filler type

The mixing temperatures for modified bitumen with Portland cement and limestone dust in the mixture containing different SBS content is demonstrated in the bar chart (10). A glance at the data reveals that mixing temperature of the modified asphalt mixture that containing limestone dust is higher compared with Portland cement. It is obvious that the same behavior was found in figure (11). This is because the highest viscosity for the filler-bitumen mixture when use limestone dust, and show superior stiffening properties when mixed with the binder compared to all other filler types (Cross & Brown, 1992).

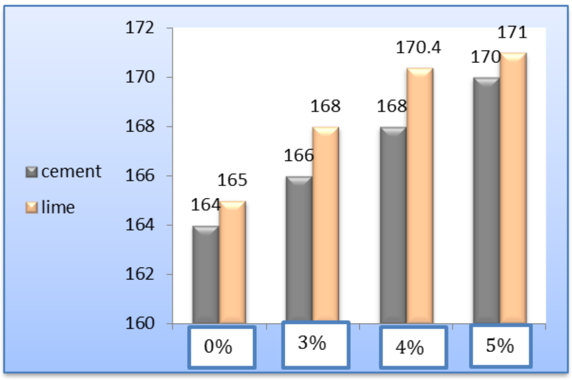

Figure 10: Change of mixing temperatures with SBSC for limestone dust and cement

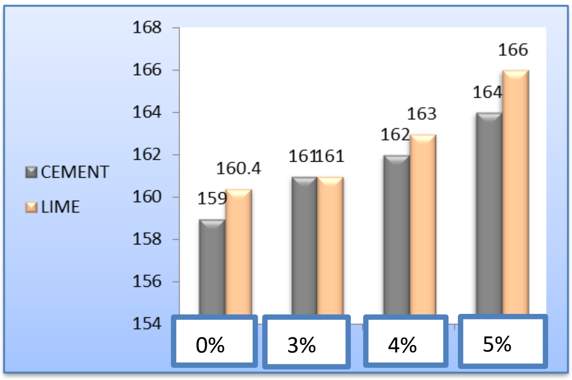

Figure 11: Change of CT with SBSC for limestone dust and cement

Conclusion

Based on the experimental work findings within the limitations of materials as presented in table (8) and testing program used, the following points are concluded:

Table 8: The limitation of data used for mixing and compaction model

	AC%	Filler	SBSC %
max	5.5	3.1	5
min	4.31	2.72	3
mean	4.905	2.91	4

1) Two models were predicted in this work by using SPSS software (Statistical Package for the Social Sciences) version 22 and Microsoft excel software as presented below:

a) Model for mixing temperature for SBS modified asphalt mixture (MT) based on mix coating test results and can be seen as follows:

$$MT = 183.586 - 4.88 * (AC) + 0.311 * (F) + 2.24 * (SBSC)$$

b) A model for compaction temperature of SBS modified asphalt mixture (CT) based on compaction of asphalt mixture test result as presented below.

$$CT = 170.123 - 4.294 * (AC) + 1.818 * (F) + 2.094 * (SBSC)$$

Where,
CT=compaction temperature, Cº
MT=mixing temperature, Cº
Ac=asphalt content, %
F=type of filler (limestone dust 2.9; Portland cement 3.1)
SBSC =SBS content, %

2) The relation between mixing and compaction temperature of modified asphalt mixture and asphalt content is negative relationship.
3) A decrease in SBS polymer content for modified mixture leads to decrease in mixing and compaction temperatures of modified asphalt mixtures. In contrast, an increase in percent of SBS polymer results in increase of mixing and compaction temperatures. The relationship between them and SBS content is a positive relationship.
4) The mixing and compaction temperature of the modified asphalt mixture with limestone dust is more than mixture with Portland cement.

References

ASTM D 4402-03, (2010), Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer, West Conshohocken, USA.
ASTM D 2493, Standard Viscosity-Temperature Chart for Asphalts, West Conshohocken, USA.
ASTM D 6925, Standard Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor, West Conshohocken, USA.
ASTM D2489, Standard Test Method for Estimating Degree of Particle Coating of Asphalt Mixtures, West Conshohocken, USA.
Ahmadinia, E., Zargar, M., Karim, M. R., Abdelaziz, M., & Ahmadinia, E. (2012). Performance evaluation of utilization of waste Polyethylene Terephthalate (PET) in stone mastic asphalt. *Construction and Building Materials*, *36*, 984–989.
Airey, G. D. (1997). *Rheological characteristics of polymer modified and aged bitumens.* University of Nottingham.
Azari, H., McCuen, R. H., & Stuart, K. D. (2003). Optimum compaction temperature for modified binders. *Journal of Transportation Engineering*, *129*(5), 531–537.
Branco, F., & Pereira, P. S. (n.d.). LP (2006)'Pavimentos rodovi{á}rios'. *Coimbra, Edi{ç}{õ}es Almedina*.
Cross, S. A., & Brown, E. R. (1992). Selection of aggregate properties to minimize rutting of heavy duty pavements. In *Effects of aggregates and mineral fillers on asphalt mixture performance*. ASTM International.
Emery, S. J., & O'connell, J. (1999). Development of a high performance SBS modified binder for production. In *Proc. 7th Conf. on Asphalt Pavements for Southern Africa, CAPSA*.
SCRB / R9, (2003). General Specifications for Roads and Bridges, Section R/9 , Hot Mix Asphalt Concrete Pavement, Revised Edition. State Corporation of Roads and Bridges, Ministry of Housing and Construction, Republic of Iraq.
West, R. C., Watson, D. E., Turner, P. A., & Casola, J. R. (2010). *Mixing and compaction temperatures of asphalt binders in hot-mix asphalt.*
Yildirim, Y. (2000). *Mixing and compaction temperatures for superpave mixes.*
Yildirim, Y., Ideker, J., & Hazlett, D. (2006). Evaluation of Viscosity Values for Mixing and Compaction Temperatures. *Journal of Materials in Civil Engineering*, *18*(4), 545–553. https://doi.org/10.1061/(ASCE)0899-1561(2006)18:4(545)