ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Effects of Heating and Reheating of Hot Mix Asphalts Mixtures on Marshall Properties and Indirect Tensile Strength.

Dr. Khawla H. H. Shubber

Civil Dep. / College of Engineering/University of Kufa/ Najaf/ IRAQ

Manuscript Info

Manuscript History:

Received: 14 October 2015
Final Accepted: 22 November 2015
Published Online: December 2015

Key words:

Hot Mix Asphalt, Marshall Test, Heating, Reheating, Indirect Tensile Strength, short term aging.

Corresponding Author

Dr. Khawla H. H. Shubber

Abstract

Marshall Test is the only hot mix asphalt design method depended in Iraq. Asphalt concrete mixtures subjected to continuous heating starting from asphalt plant to compaction location that may be continuous for many hours. Furthermore, these mixtures may subjected to cooling under its compaction temperature for any reason, when reheating them will be requesting matter. Heating and reheating process have an effect on mixtures properties and durability due to its effect on asphalt viscosity. In addition to that, it's become a major concern for both the state and the contractor to measure these properties. Minor changes in Marshall Properties may be the difference in whether contractor receives full pay or reduced pay for produced mixtures. It is believed that differences in how mixtures are handled and tested have played a role in discrepancies between government agency and contractor test results. The objective of this study was an attempt to evaluate the effects of asphalt mixtures heating and reheating on the Marshall Properties and indirect tensile strength. Mixture from three asphaltic layer (base, binder, surface) courses confirm with Iraqi specification subjected to continuous heating for (3, 6) hr., and another samples leaving to cool in room temperature for (1, 3) day then reheating to compaction temperature. Results showed that the heating of mixtures had a bigger defect on mixture properties than that caused by reheating as compared with initial properties recorded. Furthermore, reheating mixtures after 3 day had no effect as compared with that after 1 day.

INTRODUCTION

In Iraq, as in many international hot weather countries, the main type of pavement structure is flexible pavement. The common type of flexible pavement is asphalt concrete pavement or hot mix asphalt (HMA). That consist from asphalt binder, course& fine aggregate, and filler. These materials combined and mixed at high temperature, range between (150-180) ^{o}C (Prowell et al. 2007). On the other hand, it well known, Asphalt binders are thermoplastic materials and their characteristics are highly sensitive to temperature, where their viscosity increase they become more stiff and brittle according to their heating history and chemical composition (Al-jumaily, 2008). Furthermore, the asphalt concrete mixtures subjected to continuous heating and reheating before laying and compacting in the field. Due to mixing need a specific heating condition, it's adopted in asphalt plant and mixtures transporting at compaction temperature -as soon as possible- to the designed location. The transportation time (i.e. continuous heating of mixture) depend on transportation distance, weather condition, construction condition and working sequence. Over that, quality control and quality assurance methods depend on taking samples from mixture reaching to field before laying, and send them to laboratory for test and compared with designing properties and requirements. Here, different ways in which mixtures are handled prior to testing. Where, samples subjected to reheating after different time period, depending on working sequences and time. This believed to play a role in the variability between governmental agency and contractor measured properties (Huner &Brown, 2004).

There are two reasons for mixtures heating and re-heating before laying and compaction. One reason is a result of mixing and transporting to the laboratory for testing, while the second occurs when either referee or verification samples must be tested. Referee samples are taken and set aside for possible testing when case discrepancies occur between contractor and agency results. These samples will have cooled for hours or even days. In order to compact these mixtures they must be reheated at compaction temperatures. This is represent statement problem of present research, studying and evaluating the effect of heating and reheating asphalt mixtures on Marshall Properties for the control samples tacking for quality control and quality assurance. Indirect tensile strength performed in order to certify the results. Although, there are lot of methods of HMA design, in Iraq, the mixture design and quality control depend on Marshall Test Method only. The evaluation was taken for specific mixtures for surface, binder, and base course layers according to State Corporation for Roads and Bridges specifications (S.C.R.B, 2003). Then standing on the discrepancies reasons between agency and contractor test results.

Background:-

Asphalt binder is a widely used as construction material. It is well known that, asphalt consistencies is range from solid, semisolid to fluid according to chemical composition and its temperature (Al-jumaily, 2008). It is believed by some that discrepancies between agency and contractor test results may be partially related to re-heating mixture samples that have cooled below compaction temperatures. Also, when re-heating mixtures, the compaction temperature, if not closely monitored, could be inaccurate and thus cause more deviation. The effect of these two issues needs to be looked at more closely to determine if they significantly affect sample volumetric properties (Huner & Brown, 2004).

Not much has been done in the way of researching the effect of re-heating on HMA properties. Such sources could be located that made mention of this issue and how it may or may not affect results. In state of Alabama there is a study aimed to compare variability and accuracy in achieving target production values for Marshall and Superpave mixes. Part of the study looked at the possible effect of re-heating on air void in total mix percentages (VTM). Contractors compacted sample sat plant sites, but mix for ALDOT samples required transport to division laboratories where reheating was required prior to compaction. The mean air void in total mix percentage of over 600 contractor measurements and over 300 ALDOT measurements, differed by only 0.01 percent. This difference is insignificant. However, there were several other uncontrolled variables associated with the statistics and more direct comparisons are needed to definitively establish the influence of re-heating (Parker, et. al., 1999).

Because of asphalt cement viscosity changes with temperature, mix compaction temperature is important. However, another study performed at the University of Wisconsin-Madison, NCHRP 9-10 (Bahia & Hanson, 2000), showed surprising data that indicated little change in density with change in compaction temperature. Samples were compacted at temperatures from 80°C and 155°C and measured to determine VTM, VMA, and VFA percentages. These data showed that although the asphalt cement viscosity changed by three orders of magnitude between 80°C and 155°C, compaction temperature had little to no effect on volumetric properties of the compacted samples.

Another research studied effect of temperature on stability and other Marshall test results depend on different bitumen percent used to determine the optimum bitumen content confirm with State Corporation for Roads and Bridges specifications in Iraq requirements (S.C.R.B, 2003) that contain voids ratio, voids in mineral aggregate, percent of voids filled with bitumen, stability, flow. The results showed that value of stability results tested at different temperature increased under temperature of 60°C such as in 30°C, 45°C and decreased over it such as in 70°C test (Abed Al-Hussain, 2009). Effect of weather temperature on asphalt concrete stiffness was investigated in 2011 (Al-Aani & Makki, 2011) by inject a temperature data logger instruments on different depth of pavement layer. The investigation proof that resilient modulus decrease with increasing testing temperature by rate of $8.78*10^3$psi/°C for asphalt concrete wearing courses.

MATERIALS AND METHODS:-

The materials used in this research, namely asphalt binder, aggregate, fillers were characterized by conventional tests and results were compared with specifications in Iraq (S.C.R.B, 2003]. Asphalt cements 40/50 brought from Al-naseryai refinery with physical properties given in Table 1, were used. The crushed quartz aggregate used was obtained from Al-Najaf Sea quarry. Coarse and fine aggregates used were sieved and recombined in the proper proportions to meet the type mixes gradation of surface, binder, base courses as required by specifications (S.C.R.B, 2003). Aggregate gradation and physical properties are shown in figure 1 and Table 2, respectively. The filler is a non- plastic limestone dust that passing sieve No.200 (0.075 mm). Table 3 illustrate the physical properties of limestone dust filler used. Test results show that the chosen materials confirm specifications requirements.

Experimental Program:

After selection the suitable materials confirm with Iraqi specification (S.C.R.B, 2003), and compute the optimum asphalt content according to Marshall Test Method. The experimental work has been conducted using control mixtures that depend on confirming specification for three layers, surface, binder, and base courses, mixed and compacted directly without any delay. And another mixtures subjected to heating and re-heating program as illustrated below where compact mixtures after mixing in one of the following process:

1. Keeping 3 mixture samples of the three layers under continuous heating at compaction temperature for 3 hours (i.e. 0.125 day as will show in results);
2. Keeping 3 mixture samples of the three layers under continuous heating at compaction temperature for 6 hours (i.e. 0.25 day as will show in results);
3. Leaving 3 mixture samples of the three layers to cool at room temperature for 24 hours(1day) then re-heating to compaction temperature;
4. Leaving 3 mixture samples of the three layers to cool at room temperature for 3 days then re-heating to compaction temperature.

Steps 1&2 simulate continuous heating asphalt mixtures that subjected to from asphalt plant to field. While, steps 3&4 simulate that case when either referee samples must be tested, or samples will have cooled then reheated to compaction temperatures.

Sample preparation:

Marshall Test was performed through present research according to the (ASTM Designation: D 1559-89) (ASTM, 2004). This test is performed at a deformation rate of 51 mm/min (2 inch/min) and a temperature of 60 ºC. The properties obtained from this test are Marshall Stability, flow and volumes properties. The Marshall stability of HMA is the maximum load the material can carry when tested in the Marshall apparatus. The Marshall flow is the deformation of the specimen when the load starts to decrease. Stability is reported in (KN), flow is reported in (mm) of deformation, and volumes properties in percentage. Average of three tested specimens were reported and used in the analysis.

According to the research program, the optimum asphalt content found according to Marshall Test Method, for the three asphaltic pavement layers (base, binder, surface), aggregate gradations used as shown in figure 1, and three asphalt percent were selected within the range of specifications for three samples from each layer (S.C.R.B, 2003). These percent are (3, 4, 5) % for Base course, and (4, 5, 6) % for binder & surface courses. Totally, 27 samples were prepared according to Marshall Test Method. Marshall properties computed (density, stability and flow, air voids, VMA), from which the optimum asphalt contents found to be 3.9% for base course, 4.9% for binder course, and 5.1% for surface course. Three Marshall Specimens were prepared for each layer with optimum asphalt content, for each selected heating and reheating process and tested to find average Marshall Properties. Totally 45 specimens prepared.

The indirect tensile strength test was performed through research according to the (ASTM Designation: D 6931), (ASTM, 2004). The tensile characteristics of bituminous mixtures are evaluated by loading the Marshall specimen along a diametric plane with a compressive load at a constant rate acting parallel to and along the vertical diametrical plane of the specimen through two opposite loading strips. The deformation rate is 51 mm/min and a temperature of 25 ºC. The compressive load indirectly creates a tensile load in the horizontal direction of the sample. The peak load is recorded and it is divided by appropriate geometrical factors to obtain the split tensile strength using the following equation:

$$\mathrm{IDT} = \frac{2p}{\pi\, tD} \qquad \ldots\ldots(1)$$

Where: IDT: indirect tensile strength, (MPa), p: maximum load, (N), t: specimen height immediately before test, (mm), D = specimen diameter, (mm). Another 45specimens prepared for indirect tensile strength for the three layers, at optimum asphalt content, and heating and reheating research program.

RESULTS AND DISSCASIONS:

After implementing the experimental works according to research testing program, five results have been obtained for Marshall Test Results shown below. All the following figures are plotted for time of heating in days (0.125day= 3hr, 0.25 day=6hr) and time of reheating (1day &3day). Firstly, Figure 2 indicates the average results of effect of heating and reheating on mix density (g/cm^3) for the surface, binder, and base course mixtures. In general, the continuous heating reduce density in high rate from 0.125 day (3hr) to 0.25 day (6hr), and the reduction was in rapid rate than the reheating causes. Furthermore, the reheating after one day as compered by that after 3 day had little effect on density. In addition to that, density reduction from heating and reheating are approximate. Base course mixture are relatively dense than other mixtures for all cases. While, surface course was the most effected form heating and reheating due to high percent of asphalt and finer gradation aggregate.

Figure 3 shows the average test results of Marshall Stability. Curves in figure illustrate that continuous heating (for 3& 6hr) decrease the stability in relatively high rate (decreasing percent is around 6%). While, the reheating of the mixture (after 1 &3 days) had less effect on stability. This may be return to keeping asphalt its properties in the mixture due to single cycle of heating. On the other hand, the heating and reheating decreasing the mixture stability values. Ordinary, the higher stability combined with the higher percent of asphalt and finer aggregate (i.e. surface course).

The average Marshall Flow results conducted from the experimental work represented in figure 4 below. It's clear that the continuous heating for 3 & 6 hours increase flow in relatively high rate and the highest effect was for the surface course mixture because of high asphalt content. This behavior also may be return to the higher asphalt content in these mixtures. The reheating process decreasing flow in less rate than that caused by continuous heating. Furthermore, the effect of reheating after 3day is approximate to that effect from reheating after 3day.

As a result of changing density of mixtures shown in figure 2 above, figure 5 illustrate the effect of heating and reheating process on void in total mix. The same trend appear in behavior of mixtures for the three layers types. Base course appear higher effect from heating process (in about 16% increasing from initial void in total mix). This may be caused by lower asphalt content in the mixture. Also, reheating mixtures after 1day had approximately same increasing effect when compared with reheating after 3 day. This mixtures behavior improve that cooling the mixtures for time and reheating for one cycle had little effect on void in total mix.

Finally, for Marshall Test results, figure 6 represents the effect of heating and reheating on the voids in mineral aggregate (VMA). The same effect had been appear her, i.e. the continuous heating for (3 &6) hr. had relatively increasing the VMA in all mixtures types in higher rate than the reheating caused. Reheating mixtures, also, had little effect on VMA, and it can be say that, there is no effect on returning to reheating mixtures after one or 3 day. When comparing all Marshall Properties obtained from all asphaltic mixtures with their specification requirements (S.C.R.B, 2003), it can be say that, all results still within the acceptable required ranges. Form all above, it can be say that the keeping of mixtures in required compaction temperature for specific time before testing them, caused reduction in all Marshall Properties. On the other side, and although the releasing the mixtures cool and reheating mixtures cause reduction in all Marshall Properties, but have less effect as compared with keeping them at compaction temperature.

In order to confirm the results conducted for Marshall Test, indirect tensile strength test performed, average values of these results shown in figure 7. The general, trend of curves (for surface, binder, and base courses) are the same for Marshall Property's curves. But, reheating mixtures had less or zero effect on initial indirect tensile strength, and there is no different between strength after 1 day and 3 day of reheating.

Fig. 1 Granular Mix Gradation for Base and Binder Course Layers with their limitation.

A- Base Coures **B- Binder Course**

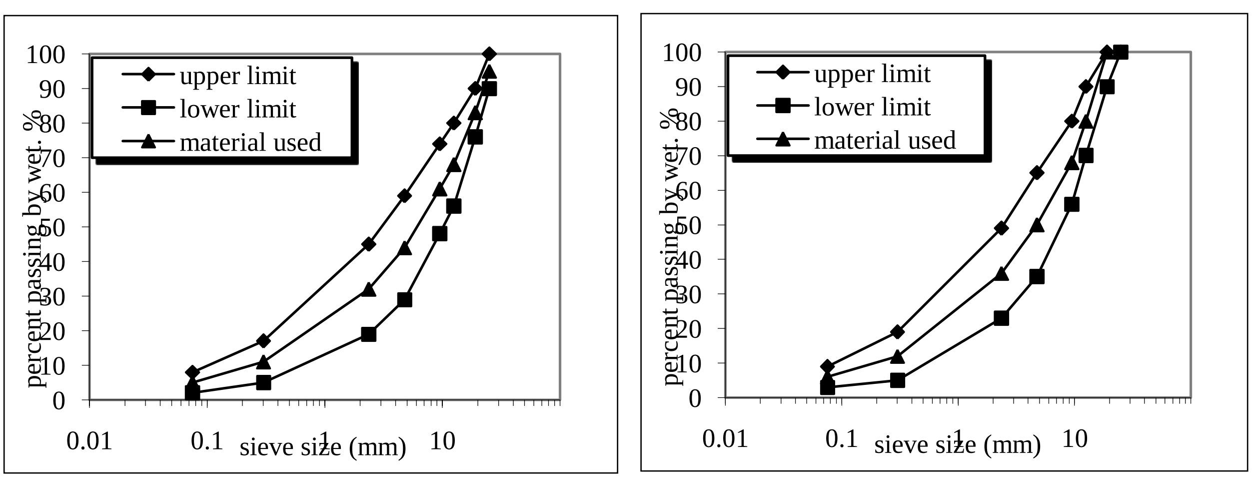

Fig. 1 Continued Granular Mix Gradation for Surface Course Layer with their limitation.

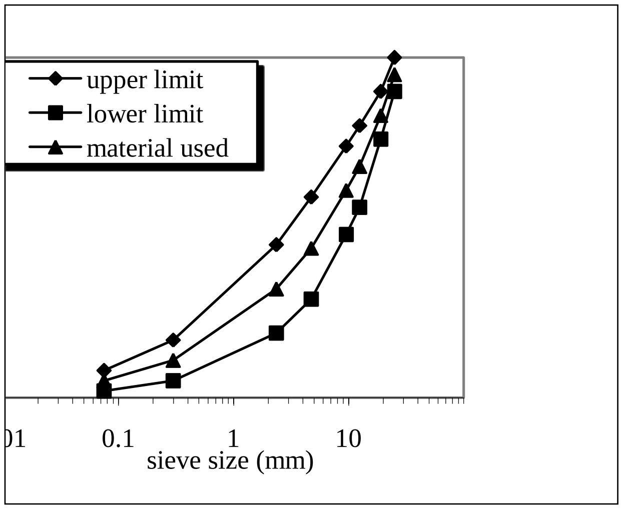

Fig. 2 Density of Asphaltic Mixture Verses Time of Heating and Reheating.

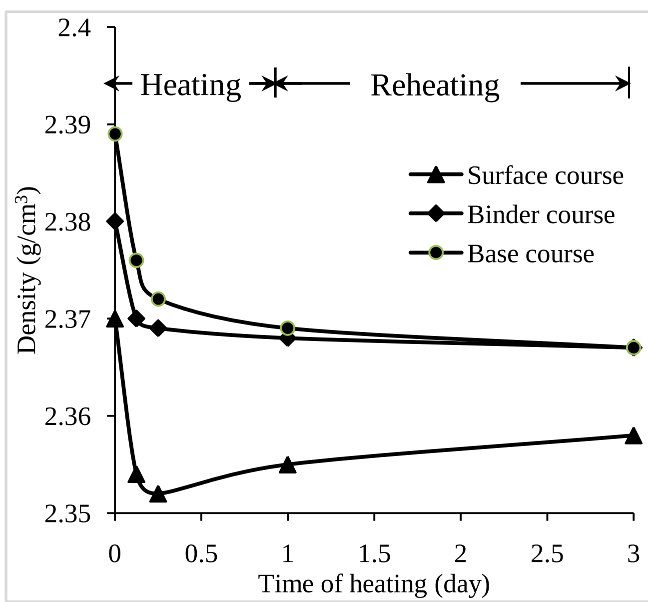

Fig.3 Effect of Heating and Reheating Time on Marshall Stability (KN).

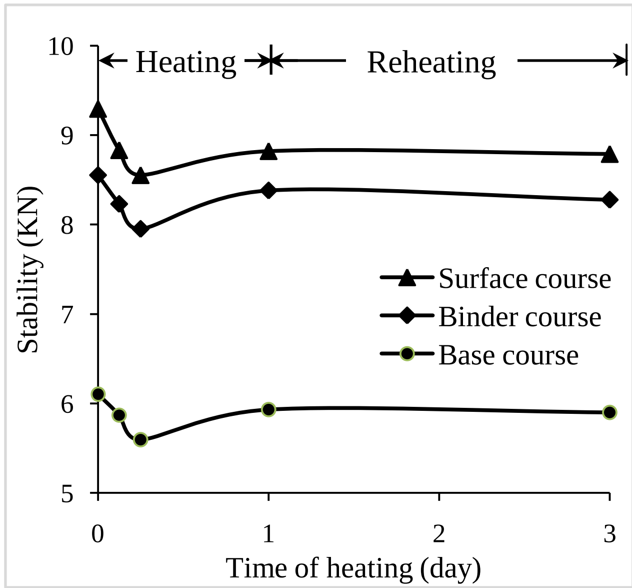

Fig.4 Effect of Heating and Reheating Time on Marshall Flow (mm).

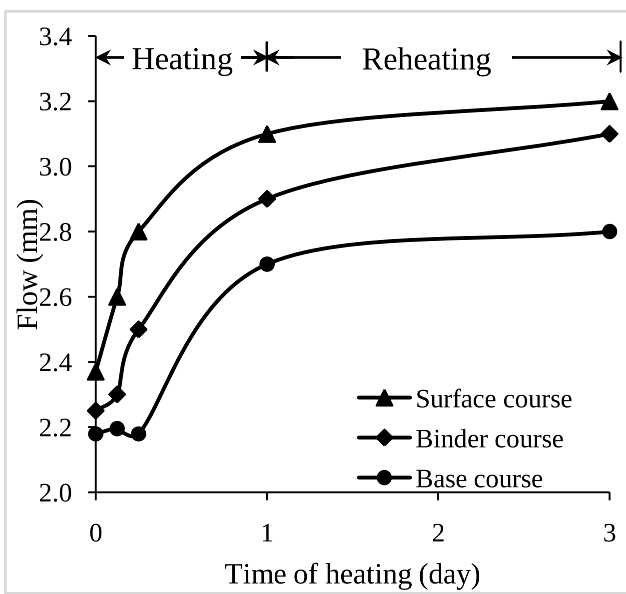

Fig.5 Effect of Heating and Reheating Time on Void in total mix %.

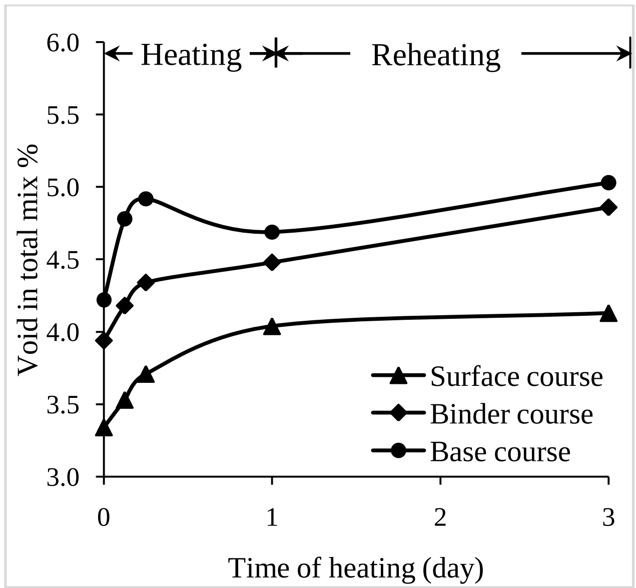

Fig.6 Effect of Heating and Reheating Time on VMA %.

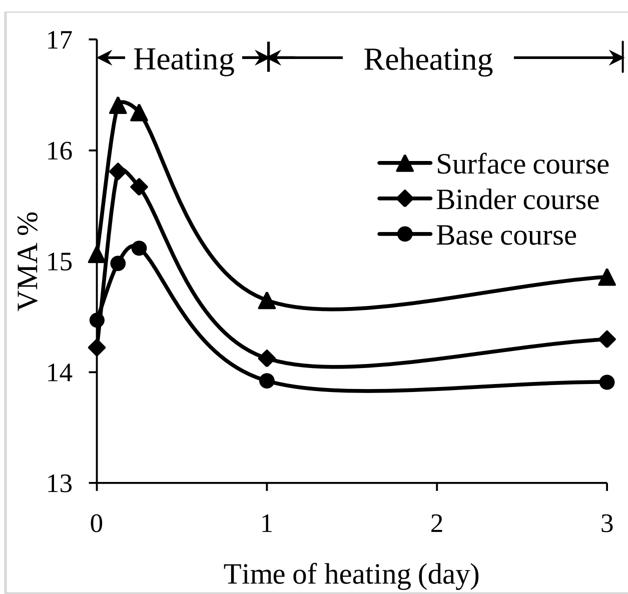

Fig.7 Heating and Reheating Time effect on Indirect Tensile Strength (MPa).

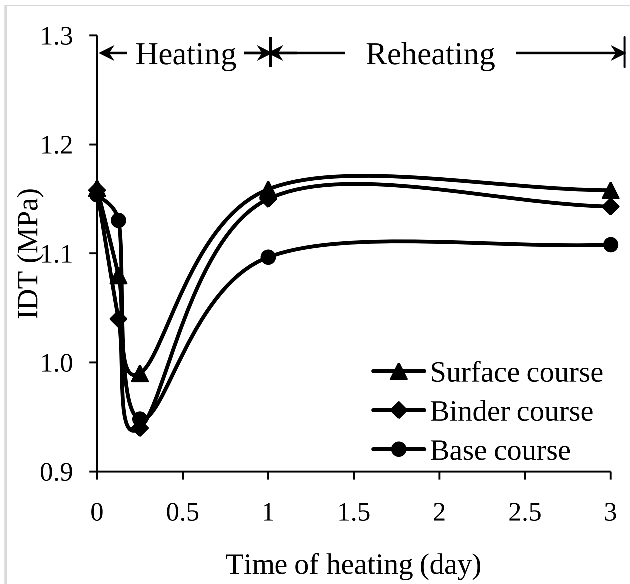

Table 1: Properties of used grade (40/50) asphalt cement

Property	ASTM	Test Results	Requirements*
1. penetration at 25ºC, (0.10 mm)	D5	46	40-50
2. Ductility at 25ºC, (cm)	C113	110	>100
3. Specific gravity at 25ºC,	D70	1.03	---
4. flash point, (ºC)d92	D92	275	>232
5. Solubility in trichloroethylene, (%wt.)	D2042	99.7	>99
6.Residue from thin –film oven test	D1754		
- Retained penetration , % of original	D5	68	>55
-Ductility at 25 ^{o}C, (cm)	D113	57	>25

*** Requirements according to** State Commission of Roads and Bridges (SCRB/R9), [S.C.R.B, 2003].

Table 2: Physical properties and specification of aggregates

Property	ASTM Designation	Test results	S.C.R.B* specifications
Course aggregate			
Bulk specific gravity	C127	2.614	--
Apparent specific gravity	C127	2.686	--
Percent wear by Los Angeles abrasion, %	C131	22.7	30 Max
Soundness loss by sodium sulfate solution,%	C88	3.4	12 Max
Flat and elongated particles ,%	C4791	5	10 Max
Fine aggregate			
Bulk specific gravity	C127	2.664	--
Apparent specific gravity	C127	2.696	--
Clay lumps and friable particles %	D142	1.06	3 Max

*** Requirements according to** State Commission of Roads and Bridges (SCRB/R9), [S.C.R.B, 2003].

Table 3: Physical Properties of limestone dust filler

Specific gravity	Surface area (m^2/kg)	% Passing sieve No.200(0.075mm)
2.41	244	94

CONCLUSIONS:

The following points are drawn from the heating and reheating testing program carried out on Marshall Test and indirect tensile strength for surface, binder, and base course asphalt mixtures. As mentioned earlier, heating process were for continuous 3& 6hr after mixing the contents at the same mixing temperature. While, the reheating were after leave mixtures cooling in room temperature for 1&3 day then reheating them to mixing temperature:

1. Heating asphaltic mixtures for continuous 3&6hr reduce density and stability of base, binder, surface course layers in relatively higher percent than that caused by reheating;
2. Heating asphaltic mixtures for continuous 3&6hr increase Marshall Flow in lower percent from that resulting from reheating for base, binder, surface course layer mixtures;
3. Heating asphaltic mixtures for continuous 3&6hr increase voids in total mix and VMA for base, binder, surface course layers as well as reheating cause but in different rate;
4. Marshall Test Properties affected by heating rapidly than reheating. On the other words the reheating had slightly effect on these properties;
5. Although, all test results keep the mixture within the range of acceptable specific requirements, checking the new mixture properties in pavement design still important;
6. Heating asphaltic mixtures for continuous 3&6hr decrease IDS for base, binder, surface course layers. While reheating these mixtures after 1&3days achieve slight reduction;
7. Binder course mixtures were the least one effected by heating and reheating process;
8. Reheating asphalt mixture effect Marshall Properties and IDS less than that continuous heating cause.

REFERENCES:

Abed Al-Hussain F. K., 2009: The Stability Behavior of An Asphaltic Concrete Road Surface Layer During Variation of Various Temperature Degree In Marshal Test, technical journal, Baghdad, Iraq, vol. 22, No. 3, pp 1-16.

Al-Aani H. M. & Makki M. S., 2011: Influence of Ambient Temperature on Stiffness of Asphalt Paving Materials, journal of Engineering, Iraq, vol. 17, No. 5, pp. 1090- 1108.

Al-jumaily, M. A. (2008): Chemical Composition of Asphalt Cement as Related to its Physical Properties, Proceeding of the First Conference for Pure & Applied Sciences, University of Kufa, Iraq, pp.145- 161

ASTM Standards, (2004): Roads and Paving Materials. Annual Book of the American Society for Testing and Materials Standards, Section 4, Vol. 04-03.

Bahia, H.U. and D.I. Hanson, 2000: A Project NCHRP 9-10 Superpave Protocols for Modified Asphalt Binders, Draft Topical Report (Task 9), Prepared for: The National Cooperative Highway Research Program, Transportation Research Board, National Research Council.

Huner h. &Brown E. R., 2004: Effects of Re-Heating and Compaction Temperature on Hot Mix Asphalt Volumetric, NCAT, Auburn University, NCAT repot 01-04

Parker, Frazier and Shabbir Hossain., 1999: Collection and Analysis of QC/QA Data for Superpave Mixes. National Center for Asphalt Technology, April.

Prowell, B., Hurley, G., and Crews, E., 2007: Field Performance of Warm-Mix Asphalt at National Center for Asphalt Center for Asphalt Technology Test Track. Transportation Research Record: Journal of the Transportation Research Board, No. 1998, pp. 96-102.

State Commission of Roads and Bridges (SCRB/R9), 2003: General Specification for Roads and Bridges. Republic of Iraq, Ministry of Housing and Construction, Department of Planning and Studies, Baghdad, Revised Edition, Addendum No.3.