Volumetric Properties Analysis of Reheated Asphalt Mixture

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Abstract

Asphalt mixture hardening has long been considered one of the key causes that may greatly impact the quality of bituminous paving materials. The purpose of this study is to examine the impact of reheating and remolding on the hot mixture of asphalt measured at various cooling times and the impact of temperature on road asphalt surface compaction. The effect of reheating the asphalt mixture after a whole 2, 8, 15, and 20 hours of mixing was studied. 15 samples were mixed and tested by Marshall Method and the best asphalt ratio was obtained which was 5.33%. After that, 12 samples were mixed with optimum asphalt content percentage which was obtained for reheating study where 3 samples for each time. Stability, void mineral aggregate, and void ratio decreased, but they remained within the specification range. Also, flow and density increased and it remains within the specification range. After 20 hours of mixing, stability and void mineral aggregate decreased but it remained within the specification range, but the void ratio was decreased less than the specification range. Also, flow and density increased and it remains within the specification range. There is no high effect of reheating on the asphalt mixture performance. The impact of reheating was compressed by reducing stability, void mineral aggregate and void ratio, while Flow and density increased.

Keywords: Hot Asphalt Mixture, Marshal Method, Mixture Performance.

1- Introduction

The major road network is bituminous pavement roads. This is because the bituminous pavement providing a safe, durable, and good riding surface over a desirable period with minimum maintenance. It is considered an insulating surface that prevents leakage of water and liquids from entering the paving layers, in addition to having the flexibility necessary to bend when it is under the pressure of heavy loads instead of breaking.Asphalt binders are thermoplastic materials with temperature-sensitive properties; as their viscosity increases, they become stiffer and brittle, depending on their heating history and chemical composition (Al- jumaili 2008). Furthermore, before being laid and compacted in the field, the asphalt concrete mixtures are continuously heated and reheated.

The object of this study is to evaluate the effect of re-heating on the performance and volumetric properties of Hot Mixture Asphalt (HMA) mixtures. The marshal method was used in this study to select asphalt content at the desired density, achieving the lowest level of stability and flow. Marshall's test provides us with a measure of sample performance. This research is also divided into two stages: determining the optimal asphalt content and the effect of reheating the mixtures on pavement performance.The Marshall Method computes the best asphalt content percent using 15 samples in the first stage and 12 samples in the second stage, using five different percentages of asphalt content.

2- Literature Review

Shubber (2015) investigated the effects of heating and reheating on the Marshall Properties and indirect tensile strength of asphalt mixtures. The mixture of three asphaltic layer courses (base, binder, and surface) confirmed with Iraqi specifications was subjected to continuous heating for (3, 6) hours, while the other samples were allowed to cool at room temperature for (1, 3) days before being reheated to compaction temperature. When compared to the initial properties recorded, the results showed that heating had a larger defect on mixture properties than reheating. Furthermore, reheating mixtures after 3 days had no effect when compared to reheating mixtures after 1 day.

Al-Qadi et al. (2012)explained if the asphalt mixture is usable after re-heating, dispose of impurities in the mixture, reduce the cost when re-maintenance and increase the efficiency and safety of the road. The impact of reheating asphalt mixture was studied using library tests; semicircular beam fracturing, complex modulus, and loaded wheel track indirect tensile strength on stone-matrix asphalt mixture with different warm-mixing additives. The effect was that the heating process culminated in larger asphalt mixtures. The result was that the heating process resulted in larger mixtures of asphalt. Indeed, the comparatively smallest improvements in the mixture properties due to the reheating were shown when Sasobit was added to the mix. Finally, the warm stone-matrix asphalt (SMA) mixtures displayed differences in special performance characteristics, basing on the hot-mixing additives type and recycled materials, then the control mixture.

Hafeez et al.(2014) examined the characteristic of the in situ recycled content that involves the ability of asphalt mixtures for deformation, low-temperature cracking, and fatigue cracking, and the effect on the rheological properties of the asphalt binder of the special technique of in-place hot recycling and rejuvenation. The research developed performance-related specifications of 100% in-place recycled mixtures using one of the on-site recycling techniques in which the intended two-phase ex-works mixtures were recycled.The test showed that after recycling, the rigidity of the asphalt mixtures had improved relative to that previous to recycling. After 20,000 load cycles, specimens displayed a limited permanent deformation potential of 2–3 mm by using the Hamburg wheel-track check. This research showed that in fracture experiments at -12 ° C-12 ° C, the continuous propagation of crack could not be accomplished, indicating the brittleness of the asphalt mixtures at that altitude.To evaluate the effect of the recycling process on the properties of mixtures extracted from samples collected at different stages of growth, asphalt binders and aggregates are characterized. The obtained results from the frequency sweep test of the asphalt mixture show an improvement in the modulus value, which was mostly attributed to the surface layer heating operation. The introduction of the rejuvenator effectively offset this change in the module value of the asphalt binder.

Lemke et al. (2018)illustrated the effects of sample size, method of the furnace, and temperature variability on the outcome of two plant mixture performance tests. The results of the test of the chosen mixture volumetric properties and efficiency using semi-circular bending (SCB-IFIT) tests and the Hamburg wheel tracking indicate that reheating mixtures exposed and in small containers will greatly decrease the time required to reach aged temperature and could make the procedure more effective and reliable. Additionally, the outcome of aging utilizing three different types of furnace shows that the position of the samples inside the furnace suggests differing temperatures within the furnace, which influences the time required to reach the target temperature. The volumetric mixture properties indicate that the influence of specific heating conditions is negligible.

Abdallah et al. (2011)tested two mixtures of Asphalt Warm Mix (WMA) from two testing sections. A foam-based WMA blend was used in the first segment, while a chemical-based WMA blend was used in the second part. The majority of the project needed control of the mixture of hot asphalt. The evaluation included the preparation at two separate temperatures of laboratory specimens: 270 ° F (132 ° C) and 310 ° F (154 ° C) respectively. Three laboratory experiments carried out at 70 ° F (21 ° C) involved the experimental design: indirect tensile strength, dynamic modulus, and the calculation of moisture loss using the testing protocol AASHTOT-283. Related E values for control HMA and foam-based WMA mixtures were shown in the dynamic module E field core experiments at 70 ° F; the E values for the chemical-based WMA mixture were relatively higher. The results of the IDT field core analysis were the same as those of the E examination.

Vo et al. (2019) studied the impact of the forms and age of the asphalt binder on the healing efficiency of the asphalt mixture was adjusted with steel wool fibersby using the induction heating process. The findings showed that the performance grade of the asphalt binder had a minor impact on the healing efficiency of the mixtures owing to the variation in viscosity of the binder. The curing degree of the asphalt mixture was greatly decreased by the age of the asphalt binder. Gallego et al. (2013) documented the technical feasibility of microwave asphalt mixture heating and how microwaves influence the heating process of the various variables involved. Several previous experiments have shown that elevated temperatures promote self-healing during the asphalt mixture's rest periods. Latest experiments have also been carried out on electromagnetic induction heating of asphalt mixtures; graphite additives and steel wool have been introduced into mixtures, improving their conductivity and thereby increasing their susceptibility to electromagnetic induction.

The volumetric and mechanical properties of asphalt mixtures have influenced the application of recycled asphalt pavement (RAP). The 19 mm Super pave mixture containing 0% RAP was used to control the properties of the control (Daniel and Lachance 2005) mixtures containing 15%, 25%, and 40% RAP. Two RAP types were evaluated; RAP was processed, and RAP (grinding) was unprocessed. Two types of RAP were investigated; polished RAP and unprocessed (grinding) RAP. The mineral aggregate (VMA) and asphalt-filled (VFA) voids of the RAP mixtures decreased at 25% and 40% values, and the volumetric materials were also affected by preheating time. The dynamic modulus of the produced RAP mixtures grew from the control point to 15 percent RAP, but in both voltage and compression, the 25 percent and 40 percent RAP mixtures had dynamic modulus curves similar to those of the control mixture. Linked trends were seen in the creep acceptance curve.

Mills-Beale and You (2010)identified the material characteristics of asphalt mixtures with recycled concrete aggregates for low-volume roads (in this case, the corresponding standard axle load is low). In this study, the RCA is supplemented with Michigan trap rock virgin aggregates (VA) in amounts of 25, 35, 50, and 75 in the light traffic volume HMA (control mix). To determine the suitability of the field output or otherwise of the mixture, the Dynamic Modulus (E), the Asphalt Pavement Analyzer (APA), the Tensile Strength Ratio (TSR) for moisture susceptibility, the Indirect Tensile Measure (IDT) for the resilient module, and the Building Energy Index (CEI) are used.

Sarnowski et al. (2019) investigated the properties of non-modified and SBS polymer modified bitumen. For 1 hour, temperatures of 200 C, 250 C, and 300 C were used. The asphalt mixtures were then heated to the same temperatures. Based on the developed Overheating Degradation Index (ODI), polymer-modified bitumens were found to have higher overheating sensitivity than non-modified bitumen, as confirmed by mixture test results. T(ODI) values for overheating limits were determined for polymer-modified bitumens, which ranged between and 20 degrees Celsius lower than non-modified bitumen. When the temperature exceeds T (ODI), the loss of the material loses its viscoelastic properties, which results in a loss of resistance to fatigue cracking, among other things.

3- Methodology

The marshal method was used in this study to select asphalt content at the desired density, achieving the lowest level of stability and flow. Marshall's test provides us with a measure of sample performance. This research was divided into two stages: determining the optimal asphalt content and determining the effect of reheating the mixtures on pavement performance.

The marshalmethod computes the best asphalt content percent using 15 samples in the first stage and 12 samples in the second stage and five different percentages of asphalt content. The weight of aggregate (gravel, sand, and filler) was calculated using the job mix formula. Determine the weight of bitumen in the mix for each asphalt content percentage using the following equation:

Bitumen weight = weight of mix (1200g) * used asphalt content percent.

The total weight of the mix ingredients, aggregate and bitumen, was (1200g) for each mould and asphalt content percentage. The aggregate was heated to (175–190) degrees Celsius, the bitumen to (135–160) degrees Celsius, and the mould to (105–125) degrees Celsius. The aggregate and bitumen were prepared and mixed before the weight was calculated. When all of the aggregate grains were covered with bitumen, the mixing was stopped. The oven was used to heat the mould before it was oiled and filled with filler paper. Finally, the mix was rammed into the mould from a distance of 50 cm, with 75 blows on each side of the mould and the mix. It was removed from the mould and left in the laboratory for 24 hours. The weight of the sample was recorded (A), and it was then placed in the water bath for 3 minutes before being dried to measure the weight (B), which will be saturated surface dry.Following that, the weight of the sample was recorded using a water balance while the sample was submerged in water (C). The sample was placed in a water bath at 60° C for 30–40 minutes. The Marshal test measures each sample's stability and flow value. The bulk specific gravity of aggregate (GA), the maximum specific gravity of the mix (max GA), the specific gravity of bitumen (Gs), and the effective specific gravity of aggregate were all calculated. Then, for each sample, the unit weight, void ratio, and void mineral aggregate were calculated. The following relationships were plotted: stability vs. asphalt content percent (AC percent), flow vs. AC percent, unit weight vs. AC percent, void ratio vs. AC percent, and void mineral aggregate vs. AC percent.The best asphalt percentage was chosen using the following criteria: stability vs. AC, unit weight vs. AC percent, asphalt percent at maximum unit weight value, and void ratio vs. AC percent. The best asphalt content was the average.

In stage two of this study, the mix properties determined the percentage of asphalt content. The best asphalt content percentage was used to mix the 12 samples. Before reheating, the samples were left for 2, 8, 15, and 20 hours, with three samples for each period. The marshalling procedure is then repeated, and the samples are tested for stability, flow, void ratio, unit weight, and void mineral aggregate. Then, plot the numbers for stability versus hours, flow versus hours, unit weight versus hours, void ratio versus hours, and void mineral aggregate versus hours. Finally, the reheating effect on the asphalt mixture was discussed.

4- Calculation and Results

4-1 Percentage of Aggregate size

According to the retained percentage table, for coarse aggregate with aggregate size greater than 4.75 mm, the cumulative percentage for each sieve larger than 4.75 mm equals 50%. According to the retained percentage table, the cumulative percentage for each sieve less than (4.75 mm) and greater than (0.075 mm) is 45 percent. The percentage will be equal to 5% for filler with a size less than 0.075 mm.

4-2 Specific Gravity for Aggregate and Bitumen

Using a mould with dimensions of 5cm*5cm*5cm, take the weight for coarse, fine, and filler. The bulk specific gravity of coarse, fine, and filler aggregate is 2.85, 2.93, and 2.87, respectively. The bulk specific gravity of PG 60/70 was 1.019.

4-3 Marshall Properties

Table (1) shows the mass of each sample in air and water, stability, flow, and the maximum specific gravity of each paving mixture.

Table 1. The mass of each sample in air and water, stability, flow, and the maximum specific gravity of each paving mixture.

	No. of specimen	Asphalt % by weight of total Mix				
		4	4.5	5	5.5	6
Mass in Air (g)	1	1200.15	1198.40	1197.94	1200.07	1196.87
	2	1200.09	1198.75	1196.29	1198.91	1198.34
	3	1200.23	1198.60	1197.32	1197.40	1200.16
	Average	1200.15	1198.58	1197.18	1198.79	1198.46
Mass in Water (g)	1	747.26	761.03	772.38	755.60	734.76
	2	739.40	758.07	776.54	751.55	733.87
	3	733.17	753.85	778.68	745.67	715.48
	Average	739.94	757.65	775.87	750.94	728.04
Stability (Kg)	1	1151	1254	1405	1451	1319
	2	1167	1283	1427	1445	1384
	3	1143	1241	1432	1454	1326
	Average	1153.67	1259.33	1421.33	1450	1343
Flow (mm)	1	1.85	2.43	2.55	3.19	3.51
	2	2.01	2.15	2.94	3.24	3.91
	3	1.76	2.35	2.91	3.70	3.95
	Average	1.87	2.31	2.8	3.38	3.79
Maximum specific gravity ofpaving Mixture		2.898	2.941	2.976	2.792	2.632

4-3-1Maximum specific gravity of paving Mixture

Table (2) summarizes the mass of dry sample in the air (A), the mass of dry sample in water (B), the maximum specific gravity of the paving mixture, which is calculated by the bowl method (Gmm), the effective specific gravity of aggregate (Gse), and the maximum specific gravity of the paving mixture (Gmax).

Table 2.Specific gravity for paving mixture

Asphalt % by weight of total Mix	A (g)	C (g)	G_{mm}	G_{se}	G_{max}
4	1423.25	820.43	2.361	2.498	2.898
4.5	1452.41	830.39	2.335	2.486	2.941
5	1509.36	853.97	2.303	2.467	2.976
5.5	1448.28	773.09	2.15	2.29	2.792
6	1417.19	711.77	2.01	2.14	2.632

4-3-2Bulk Specific gravity for compacted mixture

Bulk specific gravity for compacted mixture and bulk density for compacted mixture have been calculated for the samples shown in table (3).

Table 3. Bulk specific gravity and bulk density for compacted mixture

	No. of specimen	Asphalt % by weight of total Mix				
		4	4.5	5	5.5	6
Bulk Specific gravity for compacted mixture	1	2.65	2.74	2.82	2.71	2.59
	2	2.60	2.72	2.85	2.68	2.58
	3	2.57	2.695	2.86	2.65	2.47
	average	2.61	2.718	2.84	2.68	2.55
Bulk Density for compacted mixture (g/cm^3)		2.61	2.718	2.84	2.68	2.55

4-3-3Void mineral aggregate (VMA) and Void ratio%

Void mineral aggregate and voidratios have been calculated for each sample as shown in table (4).

Table 4. VMA% and Void ratio%

	No. of specimen	Asphalt % by weight of total Mix				
		4	4.5	5	5.5	6
VMA %	1	14.93	9.43	7.43	11.36	15.76
	2	13.57	10.09	6.28	12.34	16.05
	3	14.6	10.91	5.95	13.29	19.63
	average	14.37	10.14	6.55	12.33	17.15
Void ratio %	1	8.56	6.83	5.41	2.94	1.67
	2	10.25	7.51	4.24	4.01	1.98
	3	11.32	8.36	3.9	5.05	6.16
	average	10.04	7.567	4.52	4	3.27

4-4 Asphalt optimum content

The best asphalt percentage was selected from the figure of stability vs. AC%, take asphalt percent at maximum stability value, from the figure of unit weight vs. AC%, take asphalt percent at maximum unit weightvalue, from the figure of void ratio vs. AC%, take asphalt percent at 4% value of the void ratio. The best asphalt content percent is the average of them. This percent of asphalt content controls the mix properties as shown in the following figures (1-5). Optimum asphalt content= (5+5.5+5.5)/3=5.33 %. Depended on the optimum asphalt content (5.33%), optimum Stability (Kg) equal 1445kg, Optimum flow (mm) equal 3.15mm, optimum VMA% equal 10%, optimum Void ratio % equal 4.1% and Optimum density equal 2.763 g/cm3.

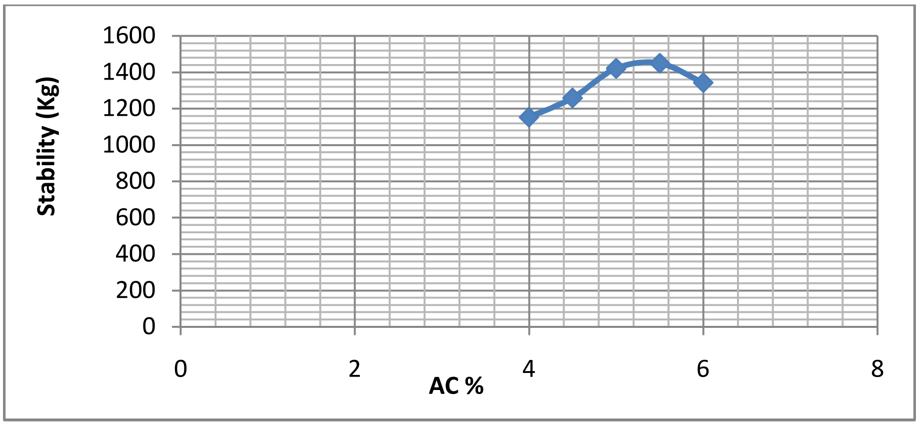

Figure 1. Stability (kg) vs. AC%

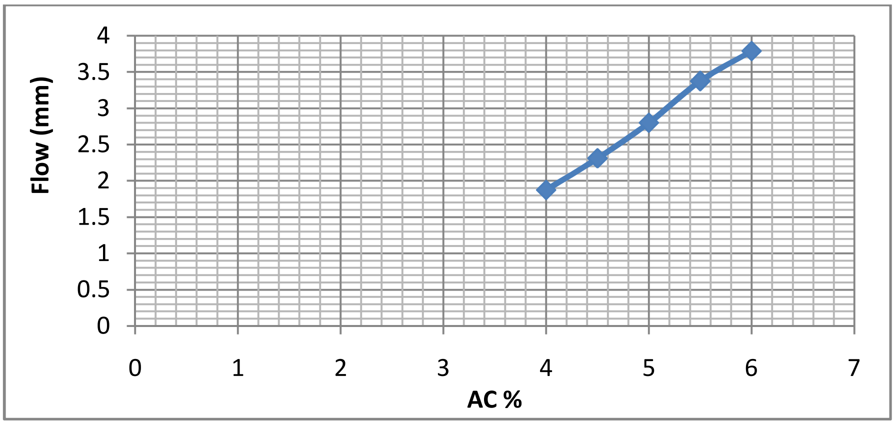

Figure 2. Flow (mm) vs. AC%

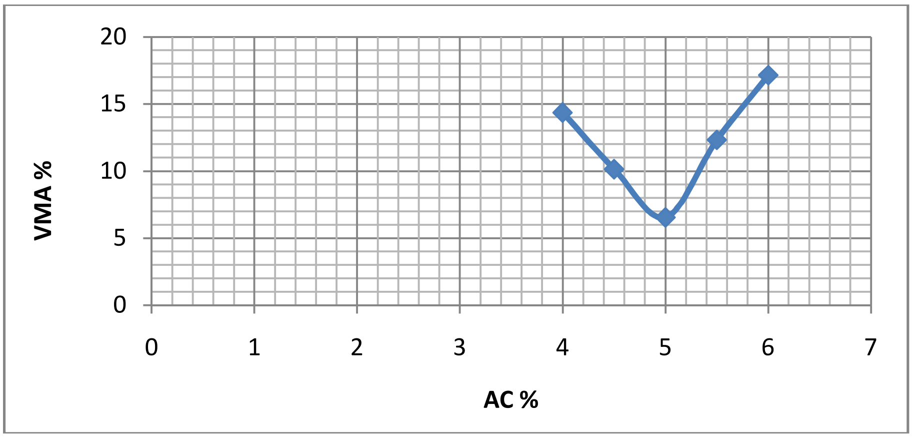

Figure 3. VMA% vs. AC%

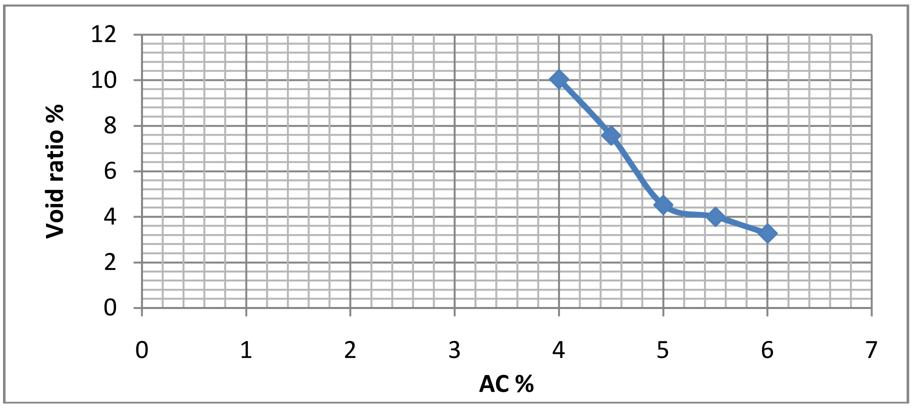

Figure 4. Void ratio% vs. AC%

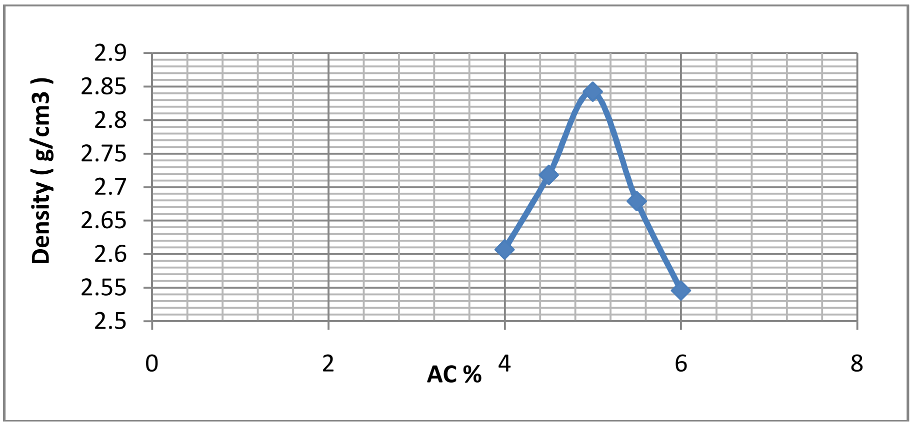

Figure 5. Density (g/cm3) vs. AC%

.5 After reheating calculations

4-5-1 Stability and flow after reheating

New 12 samples with 5.33% bitumen were prepared and allowed to cool at different times. After that, they were reheated in the oven at 150–160 C° and re-applied the same tests on them. Table (6) shows the stability, flow, and mass of samples in air and water after 2, 8, 15, and 20 hours of mixing. Also, figures (6) and (7) explain the stability and flow during the number of leave hours of the samples.

Table 6. Stability, flow and mass in air and water

Duration of re heating after mixing	No. of specimen	Stability (Kg)	Flow (mm)	Mass in Air (g)	Mass in Water (g)
2-Hours	1	1439	3.16	1198.77	764.59
	2	1443	3.09	1191.46	761.80
	3	1440	3.25	1197.61	765.10
	Average	1440.667	3.17	1195.95	763.83
8-Hours	1	1435	3.29	1197.14	764.65
	2	1438	3.24	1190.15	760.96
	3	1434	3.32	1192.05	762.09
	Average	1435.667	3.28	1193.11	762.57
15-Hours	1	1431	3.35	1191.34	762.49
	2	1422	3.29	1189.63	760.32
	3	1426	3.42	1187.22	759.39
	Average	1426.333	3.353	1189.39	760.73
20-Hours	1	1425	3.39	1186.51	759.86
	2	1418	3.44	1186.27	759.25
	3	1421	3.48	1180.7	755.22
	Average	1421.333	3.43	1184.49	758.11

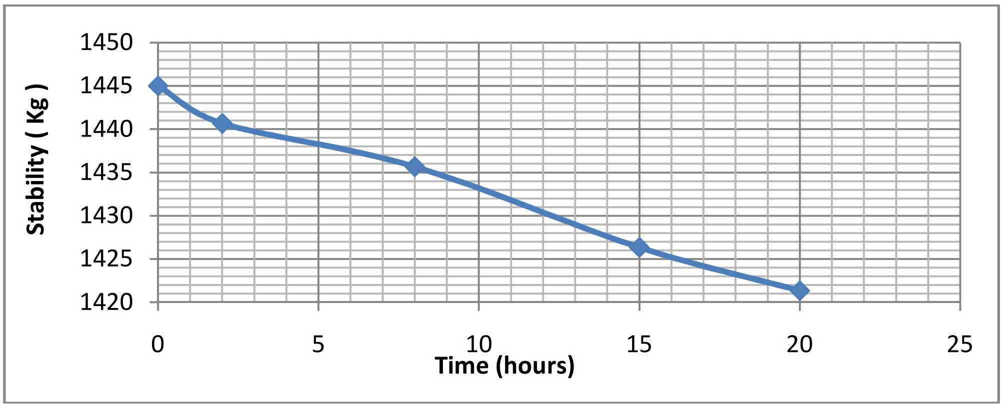

Figure 5. Stability vs. Time

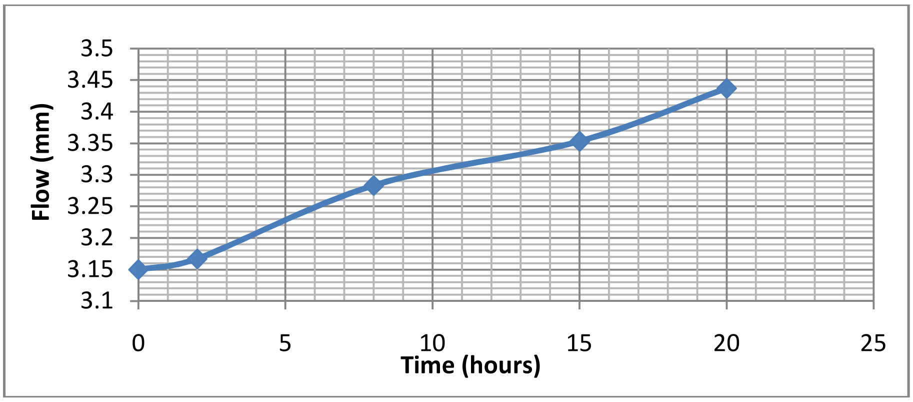

Figure 7. Flow vs. Time

4-5-2 Bulk Specific gravity for reheated compacted mixture

The bulk specific gravity and bulk density for the compacted mixture increased from 2.76g/cm3-2.84g/cm3for the samples after the time of re-heating as shown in fig (8).

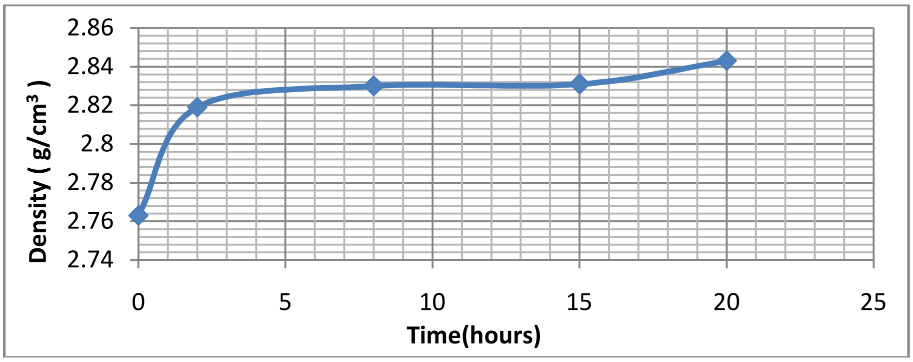

Figure 8. Density vs. Time

4-5-3 Void mineral aggregate (VMA) after reheating

VMA decreased with increasing time, as shown in fig (9). The samples recorded 8.93 after 20 hours and 2.93 after 2 hours.

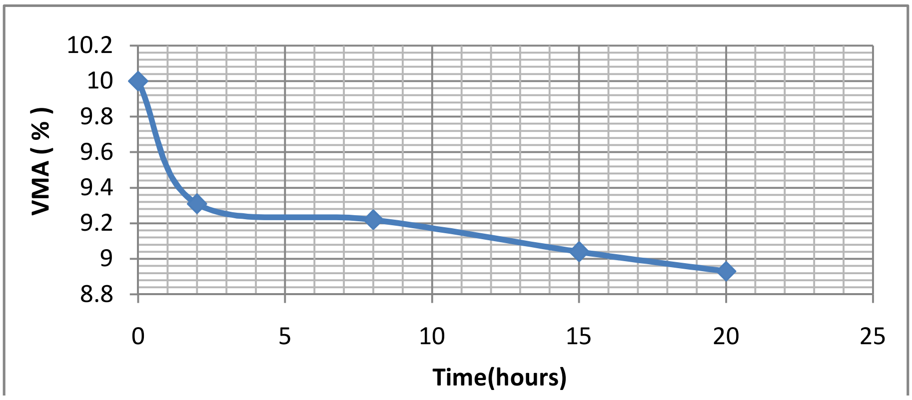

Figure 9. VMA vs. Time

4-5-4 Void ratio %

The void ratio decreased from 4.1% to 2.94% after 20 hours of reheating,as shown in fig (10).

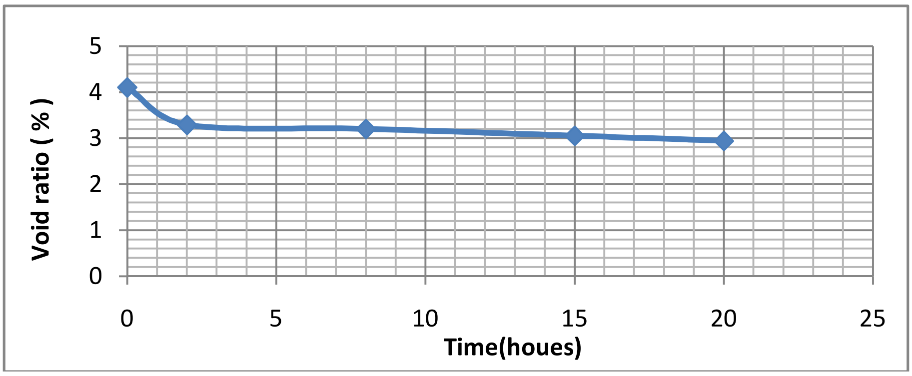

Figure 10. Void ratio % vs. Time

5- Conclusions

The stability declines with the rise, leaving hours to reheat the samples, leading to a reduction in the aggregate grain volume provided by bitumen. The aggregate expansion during reheating allows the sample to have a small load-in which the sample will carry. On the other hand, flow increases with the increase of leaving hours on the sample before reheating it because the stability will decrease when reheating the sample, which leads to more deflection. The density rises with the rise of the sample before reheating them, while the volume of the mixture falls with the same mass during the reheating phase that creates bitumen and the aggregate expansion that contributes to the dissociation of the mixture. The void ratio is inversely proportional to the time left of the samples before reheating them, as the mixture would be loose. When aggregate grains are disassociated, the consumed bitumen is raised by percent and the void ratio is increased, which increases the void mineral aggregate. There is no strong reheating effect on the efficiency of the asphalt mixture. The result of reheating is reduced by the stability, VMA, and air ratio while the flow and density rise. Stability and void mineral aggregate decreased after 20 hours of mixing, but they remained within the specification range. The void ratio decreased less than the specification range after 20 hours of mixing. This also increased flow and density and stayed within the specification range.

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