
Influence of Laboratory Ageing on Volumetric Properties and Durability of Asphalt Concrete

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ABSTRACT

Ageing process of asphalt concrete throughout its service life can alter the durability and serviceability of the pavement. In the present assessment, asphalt concrete mixtures were subjected to short-term ageing. Marshall Specimens were prepared practiced long-term ageing process. The changes in volumetric properties among ageing were investigated. The durability parameters in terms of temperature susceptibility and resistance to moisture damage were assessed before and after the ageing processes. It was observed that the bulk density and voids content changes significantly after ageing process. The temperature susceptibility and the tensile strength ratio of asphalt concrete declines after practicing the ageing processes. At optimum binder content, the temperature susceptibility declines by (40, and 50.8) % while the Tensile Strength Ratio TSR values declines by (23.1, and 57.5) % after short and short and long-term ageing respectively as compared with the control mixture. The ageing processes exhibit a positive influence on the asphalt concrete from the temperature susceptibility point of view. However, the Voids Filled with Asphalt VFA % of asphalt mixtures decline by (9.7, and 23.6) % and the bulk specific gravity declines by (1.7, and 3.4) % while the Volume of Voids V_v % increases by (36.5, and 97.5) % after short and short and long-term ageing processes respectively as compared with the control mixture.

Keywords: Volumetric Properties, Asphalt concrete, Ageing, Moisture damage, Temperature Susceptibility

INTRODUCTION

The quality of asphalt concrete usually declines throughout its service life due to loss of binder volatiles and reduction in flexibility. Al-Khateeb and Alqudahaims, [1] investigated the influence of laboratory ageing process on the fatigue behaviour of asphalt concrete. The mixtures had practiced short and long-term ageing processes, then tested for fatigue life using repeated indirect tensile stresses at various initial strain levels. It was revealed that the short-term ageing process had increased the fatigue life. Almeida et al., [2] studied the influence of moisture and temperature on the complex modulus and fatigue resistance of asphalt mixture. It was concluded that it was possible to evaluate the effect of the action of water and temperature on the graphical representation of the complex modulus and on the reduction in the fatigue life of the asphalt mixture. Sarsam and Alwan, [3] revealed that the fatigue life decreased by 70 percent after subjecting the asphalt concrete specimen to the moisture damage process. For microstrain level ranges from 400 and 250, the fatigue life decreases by 87 percent when compared with the reference mixture. Cui et al., [4] investigated the residual fatigue properties of asphalt concrete pavement after practicing the long-term field service. The fatigue behaviour of asphalt pavement specimens with different traffic loads, failure types, and service time were assessed. It was concluded that surface layer practices longer fatigue life under small stress levels, but shorter fatigue life under large stress levels. Longer

service time exhibit greater sensitivity to loading stress, while heavier traffic results in shorter fatigue life. Sarsam and AL-Lamy, [5] addressed that fatigue is a process of cumulative damage in asphalt concrete layer and it is one of the major causes of cracking in asphalt concrete pavement. It was reported that the traditional fatigue approach assumes that damage occurs in a specimen from dynamic repetitive loading that leads to fatigue failure of the specimen. The number of load repetitions to failure equal to the fatigue life, and can be calculated based on stress, or strain. Molenaar et al., [6] assessed the influence of ageing process on the mechanical characteristics of the asphalt binders in asphalt concrete. The results showed that the ageing process had increased the indirect tensile strength of the asphalt concrete while decreases the strain at break. Hamzah and Omranian, [7] assessed the influence of short-term ageing on the asphalt binder viscosity at high temperature. The test results revealed that ageing process had increased the asphalt binder's viscosity; however, increasing the testing temperature had decreased the corresponding value of viscosity. It was concluded that ageing process impact differs and depend on the aging process conditions, testing temperatures, and binder types. Sarsam, [8] prepared Marshall specimens using different binder sources from asphalt concrete mixture after practicing the short-term ageing process. The prepared Marshall specimens have practiced the long-term ageing before determination of its indirect tensile strength. The volumetric properties variations of the asphalt concrete specimens were determined throughout the short- and long-term ageing process. It was concluded that the binder from Erbil shows low indirect tensile strength and low value of temperature susceptibility of while it exhibits the highest degradation in asphalt concrete flexibility when compared with Dourah and Nasiriyah binders. Huner and Brown, [9] revealed that the demand for accurate measurement of the asphalt concrete mixtures' volumetric properties has gained attention due to their significant influence on the design of mixtures and evaluation of the final product. Sarsam, [10] investigates the influence of short and long-term ageing of laboratory beam specimens, asphalt percent, and testing temperature on fatigue life of asphalt concrete wearing course. It was concluded that the fatigue-life decreases by (85 and 97) %, (87.5 and 97.4) %, and (71.4 and 95.2) % after increasing the applied microstrain from (250 to 400 and 750) for control mixture and for mixtures subjected to short-and long-term ageing processes respectively. Omranian et al., [11] assessed the influence of short-term ageing process on compactibility and volumetric properties of asphalt concrete mixtures. Three different binders were utilized to prepare asphalt concrete mixtures. Ageing duration, and ageing temperature are recognized as the independent variable, while volumetric properties and compactibility are considered as the dependent variable. The test findings revealed that there is a significant influence of ageing duration and ageing temperature on the compactibility, air voids, voids in mineral aggregates, and voids filled with asphalt. Understanding the influence of ageing process on the volumetric properties of asphalt concrete is considered as the utmost important as revealed by Sadek et al. [12]. It was reported that an equivalent level of volumetric properties of plant-produced mixtures can be captured using corresponding lab-produced mixtures. Grilli et al., [13] investigated the impact of ageing on mechanical properties of a paving grade asphalt binder. The results showed that the stiffening effect of ageing can be reduced or restored by using rejuvenator. In addition, the ageing process affects the rejuvenated bitumen as well as it does for paving grade bitumen. Do ET AL., [14] stated that asphalt binder aging in asphalt mixtures can have a very significant impact on moisture damage susceptibility. Sarsam, [15] studied the influence of three binder sources on temperature susceptibility of asphalt concrete and revealed that the temperature susceptibility of asphalt concrete increase after practicing long-term ageing by a rate of (31, 52.4, and 55) % for Erbil, Doura, and Nasiriya binders respectively. It was recommended that the selection of a proper asphalt cement for paving must be based on evaluation of rheological properties such as temperature susceptibility and environmental

conditions rather than the present practice of considering the physical properties only. Sirin et al., [16] stated that asphalt binder aging is a complex phenomenon and affects the performance of asphalt concrete pavement by exhibiting functional damage to asphalt layer. It is generally defined as the change in the rheological properties of asphalt binder or mixtures due to the changes in the chemical composition during the construction and throughout its service life period. The aim of the present investigation is to assess the influence of laboratory short and long-term ageing processes on the volumetric properties of asphalt concrete. The impact of ageing process on the durability parameters in terms of resistance to moisture damage and temperature susceptibility of asphalt concrete will also be evaluated.

MATERIALS AND METHODS

The materials implemented in this investigation are locally available and obtained from the currently used materials in road construction in Iraq.

Asphalt Cement

Asphalt cement binder of 40-50 penetration graded was obtained from Dora Refinery; the physical properties of asphalt cement are listed in Table 1.

Table 1. Physical properties of asphalt binder as per ASTM, [17]

Property	Testing condition	ASTM Designation	Test results
Penetration	25°C, 100gm, 5 Seconds	D-5	41
Softening point	Ring and ball	D-36	49
Ductility	25°C, 5 Cm/Minutes	D-113	>150
Specific gravity	25°C	D-70	1.04
Flash point	Cleveland open cup	D-92	275 °C
Properties after thin film oven test as per ASTM D-1754			
Retained penetration of residue	25°C, 100gm, 5 Seconds	D-5	60 %
Ductility of residue	25°C, 5 Cm/Minutes	D-113	85 Cm
Loss of weight	163 °C, 50 gm, 5 hours	-	0.3

Coarse and Fine Aggregate

Crushed coarse aggregate and crushed sand were obtained from AL-Nibae quarry. The physical properties are listed in Table 2.

Table 2. Physical properties of aggregates as per ASTM, [17]

Property	Test result	ASTM Designation	Test result	ASTM Designation
Coarse aggregates			Fine aggregates	
Bulk specific gravity	2.584	C-127	2.604	C-128
Apparent specific gravity	2.608	C-127	2.664	C-128
Water absorption %	0.57	C-127	1.419	C-128
% Wear	13.08	C-131	--	---

Mineral Filler

Ordinary Portland cement was obtained from Badosh cement plant and implemented as a mineral filler; the physical properties of cement are shown in Table 3.

Table 3. Properties of Mineral Filler

Property	Test result
Bulk specific gravity	3.14
Percent passing sieve No. 200	96

Selection of Aggregate Gradation

The selected gradation in this study follows the SCRB, [18] specification for wearing course with 12.5 mm nominal maximum size of aggregates as demonstrated in Table 4.

Table 4. Grain size distribution for wearing course

Sieve size mm	19	12.5	9.5	4.75	2.36	0.3	0.075
Selected gradation	100	95	83	59	43	13	7
SCRB Limitations	100	90-100	76-90	44-74	25-58	5-21	4-10

Preparation of Asphalt Concrete Specimens

The optimum binder content was selected using four percentages of asphalt cement (4, 4.5, 5, and 5.5 %) based on Marshall Method. The testing program was conducted on specimens constructed at optimum asphalt content and at asphalt contents of 0.5 percent above and below optimum. Three groups of asphalt concrete mixture were prepared; the first group was the reference mix; the second group was prepared by subjecting the loose asphalt concrete mix to short-term aging.

Loose asphalt concrete mixture was heated to 130°C, then spread in shallow trays with 3cm thickness and subjected to one cycle of accelerated aging process by storage inside an oven at 135°C for 4 hours (Short-term aging) as per SHRP, [19] procedure. Marshall Specimens were constructed from the aged asphalt concrete mixture after heating the material to 150°C using Marshall Method. The third group was prepared by subjecting the loose asphalt concrete to (short-term aging) then compacted in accordance with ASTM D1559, [17] method and subjected to (long-term aging) for five days as per SHRP, [20] procedure. The temperature of the asphalt concrete mixture immediately prior to compaction was 150 ° C.

The Marshall mold assembly was placed on the compaction pedestal and 75 blows on the top and the bottom of specimen were applied. Details of specimen preparation could be found in Sarsam and AL-Zubaidi, [21]. The specimens were subjected to the Marshall volumetric properties determination, then tested for indirect tensile strength at (25, 40, and 60)°C, at conditioned and unconditioned states. The durability properties of asphalt concrete were determined in terms of resistance to moisture damage and temperature susceptibility. A group of the specimens was subjected to moisture damage by conditioning the specimens in water bath at 25° C for two hours, the air in the voids was evacuated using a compressor with a vacuum of 3.74 kPa applied for 10 minutes to obtain 80 % saturation. The asphalt concrete specimens were then placed in a deep freeze at (-18°C) for 16 hours. The frozen specimens were then moved to a water bath and stored for 24 hours at (60°C). Then they were dried and placed in the testing chamber for two hours at 20° C before testing for indirect tensile strength.

RESULTS AND DISCUSSIONS

Influence of Ageing Process on Volumetric Properties of Asphalt Concrete

Figure 1 exhibits the influence of ageing processes on the volumetric properties of asphalt concrete including bulk specific gravity, volume of voids V_v %, and voids filled with asphalt binder VFA %. It can be noticed that the V_v % of asphalt concrete increases significantly after practicing the ageing processes regardless of the binder content. At optimum asphalt binder of 4.7 %, the V_v % increases by (36.5, and 97.5) % after short and short and long-term ageing processes respectively as compared with the control mixture. Such behaviour will degrade the quality of the asphalt mixture and make it more prone to moisture damage and oxidation. The voids filled with asphalt of the asphalt concrete declines after practicing the ageing processes. This may be attributed to the reduction in the volume of binder after evaporation of its volatiles. At optimum binder content, the VFA % of asphalt mixtures decline by (9.7, and 23.6) % after short and short and long-term ageing processes respectively as compared with the control mixture. Finally, the bulk specific gravity of asphalt concrete mixture declines after practicing the ageing processes. This may be attributed to the loss of volatile oils by evaporation throughout the ageing processes. At optimum binder content, the bulk specific gravity of asphalt concrete declines by (1.7, and 3.4) % after short and short and long-term ageing processes respectively as compared with the control mixture. Similar behaviour was reported by Huner and Brown, [9] and Omranian et al., [11].

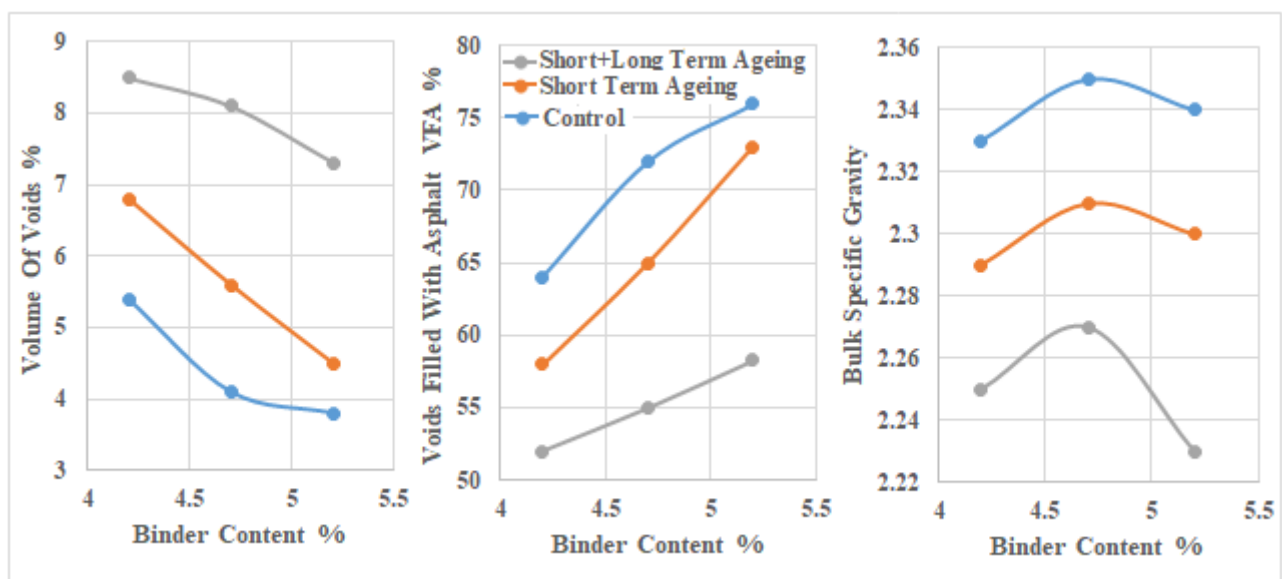


Fig. 1. Influence of Ageing on Volumetric Properties of Asphalt Concrete

Influence of Ageing Process on Durability Parameters of Asphalt Concrete

Figure 2 demonstrates the influence of ageing process on the durability parameters of asphalt concrete. The first durability parameter is the temperature susceptibility. The proper asphalt concrete shall exhibit low susceptibility to the variation in the environmental temperature. It can be noticed that the temperature susceptibility of asphalt concrete mixture declines after practicing short-term ageing process while the temperature susceptibility of asphalt concrete specimens further declines after practicing long-term ageing process regardless of the asphalt binder content. This could be attributed to the loss of binder's volatiles throughout the ageing process and reduction in the flexibility of the mixture. At optimum binder content of 4.7 %, the temperature susceptibility declines by (40, and 50.8) % after short and short and long-term ageing respectively as compared with the control mixture. It can be concluded that the

ageing processes exhibit a positive influence on the asphalt concrete from the temperature susceptibility point of view. On the other hand, Figure 2 also demonstrates the impact of ageing process on the resistance of asphalt concrete to moisture damage. The second durability parameter is the tensile strength ratio TSR which represent the resistance of the asphalt mixture to moisture damage. High TSR of 80 % as a minimum limit is recommended by SCRB, [18] specification for asphalt concrete mixtures. Figure 2 shows that the control mixture exhibits acceptable TSR percentages regardless of the binder content. However, the ageing processes exhibits significant decline in the TSR values. This may be attributed to the increase in voids content of asphalt concrete after practicing the ageing processes. At optimum binder content of 4.7 %, the TSR values of asphalt concrete declines by (23.1, and 57.5) % after practicing short and short and long-term ageing respectively as compared with the control mixture. It can be addressed that the ageing process exhibits negative influence on the resistance of asphalt concrete to moisture damage. Such findings agree with the work reported by Almeida et al., [2].

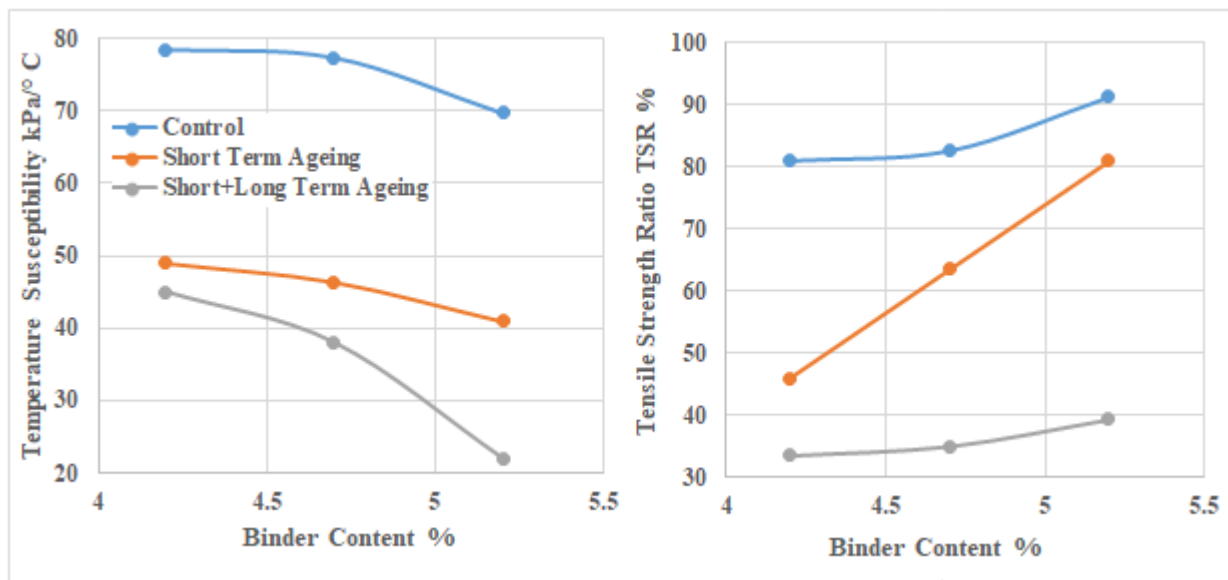


Fig. 2. Influence of Ageing on Durability Parameters of Asphalt Concrete

CONCLUSIONS

Based on the materials implemented and the limitations of the testing program, the following conclusions can be addressed.

- 1) At optimum asphalt binder, the Vv % increases by (36.5, and 97.5) % after short and short and long-term ageing processes respectively as compared with the control mixture.
- 2) At optimum binder content, the VFA % of asphalt mixtures decline by (9.7, and 23.6) % after short and short and long-term ageing processes respectively as compared with the control mixture.
- 3) At optimum binder content, the bulk specific gravity of asphalt concrete declines by (1.7, and 3.4) % after short and short and long-term ageing processes respectively as compared with the control mixture.
- 4) At optimum binder content, the temperature susceptibility declines by (40, and 50.8) % after short and short and long-term ageing respectively as compared with the control mixture. The ageing processes exhibit a positive influence on the asphalt concrete from the temperature susceptibility point of view.

- 5) At optimum binder content, the TSR values of asphalt concrete declines by (23.1, and 57.5) % after practicing short and short and long-term ageing respectively as compared with the control mixture. The ageing process exhibits negative influence on the resistance of asphalt concrete to moisture damage.

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