International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Effect of Aging on the Performance of Asphalt Concrete

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Abstract:
One of the main issues that asphalt encounters over its service life is aging, which causes the material to change from a flexible to a solid condition and increases its susceptibility to breaking and fissures. Asphalt ages due to the oxidation of the asphalt and the evaporation of volatile components. This paper's primary objective is to investigate the impact of aging on the site-modified asphalt mixture. Asphalt pavements usually age due to the binder's lighter and the asphalt's oxidizing evaporating. After being prepared, asphalt concrete mixtures were aged over an extended period. For Marshall compacted specimens, the process entails long-term aging periods for the asphalt within a year of its service. At its ideal asphalt concentration, the effects of varying aging durations on the Marshall Properties, The combination becomes stiffer as it ages longer, which raises Marshall Stability and the robust modulus, which raises the mixtures' resistance to irreversible deformation. Compared to the control mixture, the one-year long-term aging increases the Marshall stability and resilient modulus by 35.33% and 28.59%, respectively.

Keywords: Aging, asphalt core, stability, compaction ratio, short-term aging, long-term aging.

1. Introduction:

Asphalt pavement is the term used to describe any asphalt-surfaced paved road. The composition of hot mix asphalt (HMA) is around 95% gravel, sand, or stone combined with asphalt cement, a byproduct of crude oil. In an HMA facility, heated aggregate is blended and mixed with asphalt cement. The finished hot mix asphalt is put into trucks and driven to the location of paving. The hoppers in front of the paving equipment are where the trucks dump the hot mix asphalt. Once the asphalt has been put out, a big roller compacts it. Generally, As soon as the pavement cools, cars are allowed on it. As a result of constant loading from traffic and environmental factors like heat, wind, rain, or UV radiation, asphalt layers gradually disintegrate.

Each of these influences the mixture's mechanical and rheological properties. Their behavior changes as a result, becoming brittle instead of ductile. Aging-related bitumen hardening is the result of multiple processes coming together. It can be explained by physical and chemical aging or steric hardening. Steric hardening results from a structural rearrangement and is reversible, while chemical processes such as volatilization and oxidation are irreversible. There are two stages to aging—both immediate and delayed aging. The hot mix is laid down and manufactured during the short-term aging process. The combination undergoes rapid volatilization and oxidation during this stage, taking hours. Long-term aging happens during the service life of the mixes and is solely related to environmental degradation. In this instance, oxidation results from a reaction between the molecules on the pavement surface and the surrounding environment. This procedure is slower than the first step, and its consequences take time to become apparent.

2. Background:

Numerous studies have been conducted on the aging of bituminous binders in asphalt mixtures since it impacts the binder's mechanical performance and the pavement's longevity. The rheological properties of the binder will also vary since the aging process alters the chemical composition, and the chemical constitution influences some of the most significant rheological aspects of bitumen (Simpson et al., 1961). When the long-term step was extended from 4 to 8 days, Jamieson and Bell (1995) discovered a significant link between aged road mixtures from 14 to 19-year-old pavements. According to their findings, depending on the climate, the long-term oven aging (LTOA) technique might be equivalent to up to 15 years, while the short-term oven aging (STOA) method could be comparable to 0–2 years. In 1997, Harvey and Tsai conducted a controlled-strain loading laboratory study to determine how long an oven-aged sample would age before experiencing fatigue. They only employed one kind of aggregate and two sources of asphalt AR-4000. Their results show that aging can be influenced by the type of asphalt used and that a beam's fatigue life is not always shortened by an increase in stiffness caused by aging. Aging extended the fatigue life of the pavement structure, according to an analysis of thick and thin pavement sections utilizing beam fatigue and stiffness data. The Pressure Ageing Vessel (PAV) test by Korsgaard et al. (1996) was a component of the SHRP research program. It was utilized to make oxidized compacted mix specimens (1.1–5.8% air gaps, 5% bitumen) that were allowed to oxidize at 100°C and 2.1 MPa of air pressure for 72 hours. Measurements were made of the extracted bitumen's penetration and softening point. According to their research, the combination's bitumen oxidized at a rate that was likely 3.2 mm, which is four times slower than pure bitumen. Dense mix slabs were created by Hachiya et al. (2003), crushed, and then cut into 20 x 40 x 250 mm beams. After oxidizing the mix for up to eight hours at 70°C in an oven, they measured its flexural strength, strain at failure and stiffness at -10° to 30°C. They also investigated oxidation at 60°C in an oxygen-only atmosphere for up to 20 days. Similar tendencies, albeit with quantitative differences, were observed in the data from laboratory testing and samples exposed to the elements for up to five years. These findings suggested that combining the two oxidation processes would be most suitable. Their findings showed that test temperature had a more significant effect on the examined flexural properties than oxidation duration, even though the authors do not prove a connection between laboratory oxidation length and field aging period.

Materials and Methods:

3.1 Asphalt Cement:

A composite substance called asphalt cement is frequently used to surface parking lots, embankment dam cores, highways, and airports. Since the early 1900s, asphalt mixtures have been used to create pavement.[9] It comprises layers of compacted mineral aggregate linked with bitumen, commonly called asphalt. For this examination, asphalt cement with a penetration grade of (40–50) was used. It comes from the oil refineries in Al-Doura, Baghdad, and Al-Naesria, Syria. These two varieties of asphalt cement have the same properties as SCRB (2003) specified. Both varieties' physical attributes and specifications are displayed in the tables below.

Table 1. Physical Properties of Asphalt Cement for Al-Doura oil refinery

Test	Test condition	ASTM Designation	Units	Test results	Specification Limit
Penetration Test	**5 sec,100gm, 25˚c, 0.1mm**	**D5**	**1/10 mm**	**45**	**(40 – 50)**
Ductility	**25˚c,5cm/min**	**D 113**	**Cm**	**135**	**100 (Min)**

Flash Point (c)	**Cleave land open cup**	**D 92**	**˚c**	**263**	**230 (Min)**
Softening Point	**(ring &ball)**	**D 36**	**˚c**	**57**	**---**
Specific Gravity	**25 ˚c**	**D 70**	**gm /cm3**	**1.04**	**---**

Table 2. Physical Properties of Asphalt Cement for AL-Naesria Oil Refinery

Test	Test condition	ASTM Designation	Units	Test results	Specification Limit
Penetration Test	**5 sec,100gm, 25˚c, 0.1mm**	**D5**	**1/10 mm**	**41**	**(40 – 50)**
Rotational Viscometer	**135 ˚c**	**D4402**	**Pa.sec**	**0.82**	**3 (Max)**
Ductility	**25˚c,5cm/min**	**D 113**	**Cm**	**>100**	**100 (Min)**
Flash Point (c)	**----**	**D 92**	**˚c**	**275**	**230 (Min)**
Softening Point	**----**	**D 36**	**˚c**	**62**	**---**
Specific Gravity	**25 ˚c**	**D 70**	**gm /cm3**	**1.04**	**---**

3.2 Coarse and Fine Aggregates:

Aggregates are generally obtained from Badra District and Sheikh Saad (Ghariba) quarries in Wasit Governorate. As for coarse aggregate, the selection mechanism depends on the type of asphalt layer to be worked with. Everything that passes through the 37.5 mm sieve and remains on the No. 4 sieve is considered coarse aggregate. Sieve No. 4 is considered the dividing line between coarse and fine aggregate. Everything is regarded as fine aggregate if it goes through filter number 4 and stays on sieve 200. The tables below list the fine and coarse aggregate's physical characteristics.

Table 3. Physical Properties of Fine Aggregates for Ghariba quarries

Field No. (Date of Sample)		Not Specified	Specification Limits
Sieve Size			
(Inch)	(mm)	Percentage of Passing	
3/4"	19	100	100
1/2"	12.5	92	90-100
3/8	9.5	86	76-90
No.4	4.75	55	44-74

No. 8	2.36	47	25-58
No.50	0.3	15	5-21
No.200	0.075	5	4-10
Specific Gravity gm /cm3		2.73	Not Specified
Soundness,5, cycles, MgSo4,%		N. A	Max 18
Percent Deleterious material		1.54	Max 3
Sand Equivalent Test		60	Min 45
Plasticity Index, %		N . P	Max 4

Table 4. Physical Properties of Coarse Aggregates for Ghariba quarries		
Field No. (Data of Sample)	Not Specified	Specification Limits
Percent Fractured Pieces	90	Min.90%
Soundness, five cycles, MgSo4	4.35	Max 18%
Flat & Elongated Ratio (5:1)	2.6	Max 10%
Percent Wear, Los Angeles Abrasion	18.4	Max 30% Wearing Max 35 % Binder
Percent Deleterious material	0.70	Max 3 %
Sand Equivalent Test	N.P	Min 45
Plasticity Index, %	N.P	Max 4

3.3 Mineral Filler:

The filler used is divided into two types of fillers: either limestone, which is obtained from gravel crushers from Badra district in Wasit Governorate, or ordinary Portland cement (OPC), which is used according to Specification Limits (SCRB, R/9, 2003). Table 5 shows the characteristics of the filler used.

Table 5.Physical Properties of Mineral Filler for Ghariba quarries			
Property	Limestone	Cement	SCRB specification
Specific gravity	2.722	3.14	
%Passing sieve No.200	88	96	70-100

3. Preparation of Asphalt Concrete Mixture:

Clean aggregate, both coarse and fine, is prepared and placed in its cold storage tank. Through it, the materials are pulled through the conveyor belt to the dryer at a temperature of 170°C. The dust it generates is drawn into storage rooms as a filling material. Then, the dried aggregate is transported to the sites of special sieves supported by a good vibrator. The grades are then separated into extraordinary chambers for each grade, known as "Hopman chambers", which contain gates used to lower the aggregate and filler after weighing it according to its equation into the unique mixer. After that, the bitumen is calculated at a temperature of 150°C and lowered into the mixer until the mixture is homogeneous. Finally, it is reduced into the vacuum chamber and then into Vehicles designated for transportation 2.4. Preparation of Asphalt Concrete Mixture

3.1 Preparation of Aged Mixture:

Aging of the combination complied with AASHTO, SP2 2002. To simulate the effects of construction and plant-mixing on the mixture, The mechanical property testing process takes advantage of long-term mixture conditioning to mimic the aging the compacted mixture will experience throughout seven to ten years of use.

3.1.1 Short- term aging:

The control mixture was prepared using the same process, but after it was ready, the loose mix was placed in a pan and leveled to a uniform thickness of 25 to 50 mm. The mixture in the pan was conditioned for four or eight hours at 135 °C in the conditioning oven to provide uniform conditioning. Every sixty minutes, the loose mixture was mixed. Marshall Hammer uses the same method as the virgin sample to condense the conditioned mixture.

3.1.2 Long-term aging:

Marshall-sized compacted specimens made from mixtures exposed to short-term aging were placed in a forced-draft oven at 85°C for (48,120) hours. Aging of HMA that happens during the pavement service life. After the aging times are over, the oven is turned off and the specimens are taken out once it has cooled to room temperature. The samples weren't analyzed until at least twenty-four hours after being removed from the oven.

4. EXPERIMENTAL WORK:

Using the Marshall mix design approach, the optimal asphalt content for each asphalt concrete mix was determined to commence the experimental work. Table 4 displays the performance parameters and the optimal amount of asphalt (OAC.)

4.1.Marshall Test Method:

This method (ASTM D 1559) tests the resistance of cylindrical bituminous paving mixture specimens loaded on the lateral surface to plastic flow using the Marshall apparatus. Marshall Every specimen was tested for stability and flow. The cylindrical specimen was placed into the testing device and pressed at a constant rate of 50.8 mm/min on the lateral surface until the maximum load (failure) was obtained after 30 minutes in a water bath at 60 ˚C. The maximum load resistance and corresponding flow value were recorded. The bulk specific gravity, density, and theoretical (maximum) specific gravity of the void-less mixture were determined in accordance with ASTM (D 2041). The percentage of air voids was then calculated.

4.2 Determining the effect of aging on the properties of asphalt using the asphalt core test:

The aging process is one of the most significant issues that asphalt faces both before and after paving since it makes the material brittle and harder, leaving it vulnerable to various failures, including (cracks, grooves, etc.). This research used several methods with known previous data to perform an in-situ asphalt core examination. At various levels, including highways, urban roads, and other rural roads, it was found that most of the properties of asphalt change and that the change occurs according to several criteria, including the bitumen purification process (Al-Dora, Nasiriyah, Erbil), the materials used, the asphalt equation used, and the most significant effects on the properties**.**

International Journal of Multiphysics
Volume 18, No. 3, 2024
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Figure 1. Illustrations of taking test samples from the site

5. RESULTS AND DISCUSSION:

5.1 Effects of Aging Time on Marshall Properties:

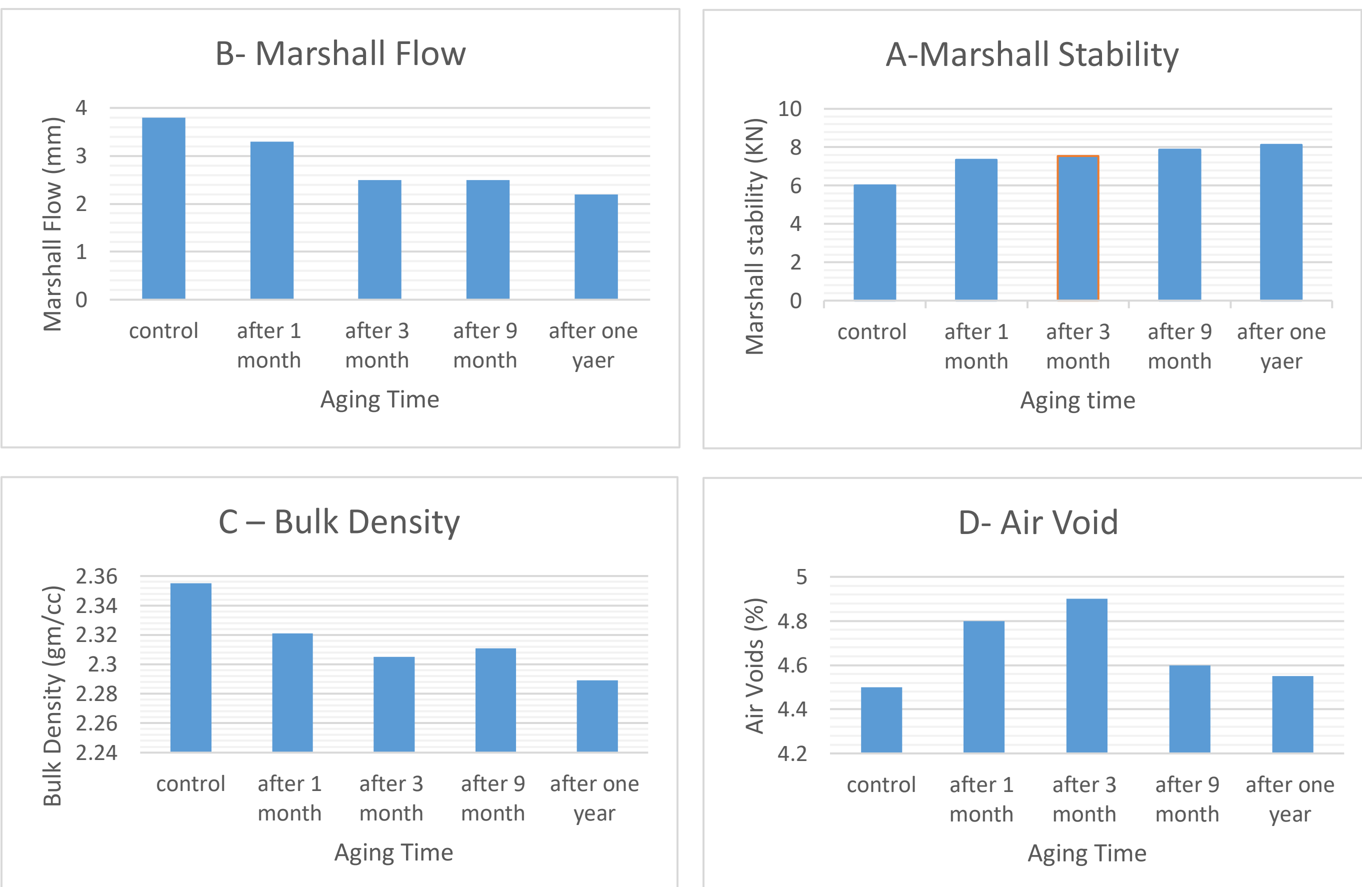
Based on the information in Table 6, Fig. 2 illustrates how Marshall Properties change with age. A high Marshall Stability rating denotes enhanced Marshall Stiffness. Marshall Stability measures the asphalt mixture's resistance to persistent deformation. The impact of one-month to one-year intervals on the Marshall Stability of an asphalt mixture is depicted in Figure (2-a), and it is evident that the Marshall Stability values rise with the asphalt mixture's long-term aging. After aging for one month, the Marshall stability is 22.167% more than the control mixture. Compared to the control combination, the stability increased by 35.33% after a year of long-term aging. The loss of volatiles, which increases the stiffness and resistance to deformation of asphalt concrete, may be the cause. The impact of long-term aging on Marshall Flow asphalt mixture, ranging from one month to one year, is depicted in Figure (2-b).

The Marshall Flow values decreased as the asphalt mixture aged over time. These reductions could be attributed to the combination being stiffer over time compared to the control mixture, as well as to the asphalt binder's improved interlocking with the reduced fluidity of the Predicting the features and performance of the asphalt mixture over the pavement's service life is made possible by the correlation between the mixture's percentage of air voids and durability. As a result, the mixture's air void becomes an important parameter. The Figure shows the effect of long-term aging on the percentage of voids in the total mix (VTM) for the asphalt mixture that is being studied. (2-d). The Figure shows that the air void increases with aging time and that aging for three months has a higher VTM than aging for a year. This could be connected to the decrease in asphalt volume and volatiles lost.

Table 6: Overview of asphalt concrete combinations at optimal asphalt conditions, Marshall Properties

Getting Older	KN Marshall Equilibrium	Marshall flow measurement (mm)	Density in Bulk (gm/cm3)	VTM (%)
In charge	6	3.8	2.355	4.5
One month	7.33	3.3	2.321	4.8
Three month	7.54	2.5	2.305	4.9
Nine-month	7.88	2.5	2.311	4.6
One year	8.12	2.2	2.280	4.55

Figure 2 shows how Marshall Properties change with age.



5.2 Effect of Aging on Resilient Modulus Test:

It was discovered that as people aged, their resilient modulus increased; this finding may have something to do with people becoming stiff. Increased robust modulus values will lead to an increase in the asphalt pavements' resistance to rutting.

Table 7 shows how robust modulus value is affected by aging time.

ageing period	regulating blend	After one month	After three month	After nine month	After one year
Mr (psi)	31822	33465	35823	37031	40891

6. CONCLUSIONS:

1. Ageing of asphalt concrete mixtures results in changes to the mixture parameters; Marshall stability and resilient modulus rise by 35.33% after a year of aging compared to control mixtures.

2. The qualities of asphalt concrete are equally affected by the nine-month long-term aging process as they are by the one-year long-term aging process.

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