Vol. 03, No. 01, pp. 12 –17 (2022)
ISSN: 2709-6904

JOURNAL OF CIVIL ENGINEERING FRONTIERS

www.jocivilef.org

Influence of Laboratory Aging on the Engineering Properties of DGAMs Containing Two Different Iraqi Asphalts

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Abstract

The influence of laboratory aging on Marshall stability (MS), Marshall quotient (MQ), indirect tensile strength (ITS) at 25 and 60° C, tensile strength ratio (TSR), resilient modulus (MR), modulus of rupture (MOR), cohesion, and aging index (AI) of dense graded asphalt mixes (DGAMs) containing Baiji (B) and Qayarah (Q) Iraqi asphalt was examined. The results of DGAMs containing B and Q-asphalt showed 46% and 43%, and 37% and 24% higher MS, 132% and 99%, and 111% and 78% higher MQ, 24%, and 20%, and 14% and 10% higher ITS at 25° C, 4%, and 3% and 20%, and 13% higher ITS at 60° C, 27% and 19%, and 26% and 24% higher MOR at 0° C, and 25% and 18%, and 24% and 21% higher MOR at -10° C. For 4 and 8 d aging, TSR was 11% and 7%, and 4%, and 3% higher, MR 52% and 38%, and 38% and 24% higher, cohesion 73% and 58%, and 58% and 44% higher, and AI 1.74 and 1.58, and 1.56 and 1.44 times higher, respectively.

Keywords: *Aging, Asphalt binders, Engineering properties, Moisture damage.*

Received: January 01, 2022/ Accepted: March 01, 2022/Online: March 02, 2022

I. INTRODUCTION

The performance of asphalt mixtures is greatly influenced by moisture and aging [1, 2–6]. Moisture damage in an asphalt mixture results adhesive or cohesive failure, or a combination of both [7]. The extent of moisture damage is influenced by the temperature, type of aggregate and binder used, viscosity, and asphalt film thickness [8]. However, long-term aging offsets the initial variation seen in short-term aging [9,10]. Furthermore, a strong interlink between aging and moisture damage on the performance of asphalt mixture [11–13] highlights the importance of including aging and moisture for evaluation of the performance of dense graded asphalt mixes (DGAMs) containing Baiji (B40) and Qayarah (Q40). Therefore, a clear understanding of moisture damage and aging's influence on tensile characteristics, flexural characteristics, resilient modulus, and cohesion behavior is critical.

For asphalt mixes, the recommended laboratory procedure for long-term aging (LTA) is to place the samples in a forced draft oven for 4 to 8 days at 85°C or 2 to 4 days at 100°C. The LTA conditions representative of older than 3 years mixtures in the field as reported by Bell [14] and Al-Hadidy [15,16]. The 4 to 8 days at 85°C conditions were adopted in this study.

However, the characteristics of DGAMs with B40 and Q40 bitumen subject to the 4 to 8 days at 85°C aging levels were assessed in terms of Marshall stability (MS), Marshall quotient (MQ), indirect tensile strength (ITS) at 25 and 60°C, tensile strength ratio (TSR), resilient modulus (MR) at 25° C, modulus of rupture (MOR) and stiffness modulus (SM) at 0 and -10° C, cohesion at 60° C, and aging index (AI).

doi: 10.38094 /jocef30143

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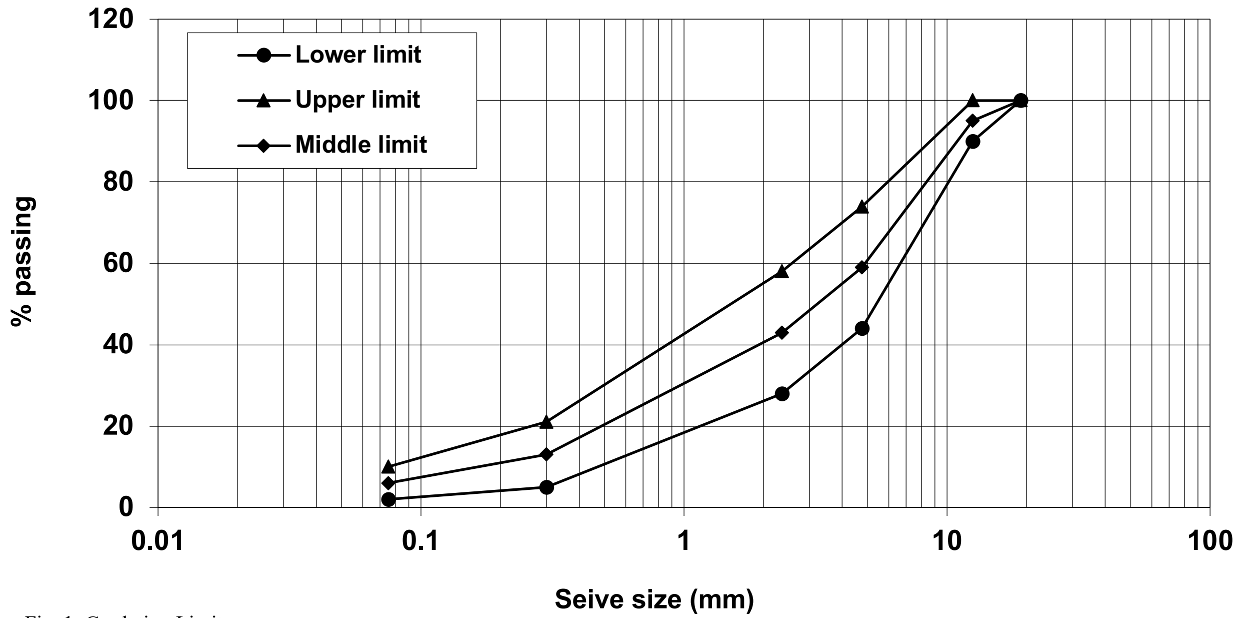

Fig. 1. Gradation Limits

II. Experiments

A. Asphalts and Aggregate

Baiji (B40) and Qayarah (Q40) Iraqi bitumen were utilized in preparing the bituminous mixes. The basic properties of B40 as per ASTM [17] are: asphaltenes, 11.2%; penetration, 42dmm; ductility, 150+cm; specific gravity, 1.051; softening point: 58°C; flash point, 275°C; and loss on heat and air (aging), 0.375%, whereas, these characteristics for Q40 were found to be 6.7%, 41 dmm, 150+cm, 1.049, 52°C, 263°C, and 0.386%, respectively.

Sand and gravel were utilized as aggregate. Fig. 1 depicts the gradation per ASTM D3515 limits [17]. The aggregate source and consensus characteristics are reported in Table 1. Calcium carbonate (CaCo3) with Sp.gr. of 2.731was utilized as a filler.

TABLE 1 SOURCE AND CONSENSUS PROPERTIES OF AGGREGATE

Property	Coarse Aggregate	Fine Aggregate
Bulk sp.gr.	2.652	2.541
Apparent sp.gr.	2.693	2.592
Angularity,%	99	47.00
Toughness,%	19	-----
Soundness,%,Na2SO4	0.968	0.664

B. Mixture Design and Test Specimen Preparation

Marshall testing apparatus according to ASTM D1559 [6] and Asphalt Institute MS-2 [18] was adopted to determine the B40 content for the aggregate blends. A content of 5.0% was obtained for the B40 and Q40 mix; its design properties are summarized in Table 2. The optimum asphalt content for the B40 and Q40 mixtures was found to be 5.0% at 4% air voids. Then, two groups (G1 and G2) of samples were mixed with 5% B40 and Q40 and at a mixing temperature of 150-160°C. G1 and G2 were aged at 85°C, and at two aging levels, between 4 and 8 d, following procedures described in [14]. These conditions simulate the aging during the first 1–3 years of service life.

Each group was tested in triplicate for Marshall stability (MS) at 60°C, indirect tensile strength (ITS) at 25°C and 60°C, flexural strength at 0°C and -10°C, resilient modulus (MR) at 25°C, and cohesion at 60°C accordance with the ASTM standard [17].

TABLE 2. DESIGN PROPERTIES OF B40 AND Q40 MIXES

Property	B40	Q40	SCRB [19]
Stability, kN	13.15	11.80	8 min.
Flow, mm	3.15	3.05	2-4
Bulk density, kg/m3	4.20	4.10	3-5
Air voids, %	2373	2365	-----
Voids in mineral aggregate, %	14.1	14.65	14 min.
Voids filled with asphalt, %	70	69	65-85
Asphalt, %	5.0	5.0	4-6

III. Results and Discussion

A. Marshall Characteristics

The MS, flow, Marshall quotient (MQ), and air voids (AV) characteristics of B40 and Q40 mixes are depicted in Fig. 2. The results of DGAMs containing B40 and Q40-asphalt showed 46% and 43%, and 37% and 24% higher MS, 132% and 99%, and 111% and 78% higher MQ for the 4 and 8 d

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aging levels, respectively. This illustrates that aging improves the performance of DGAMs mix containing B40 and Q40-asphalt in resisting rutting.

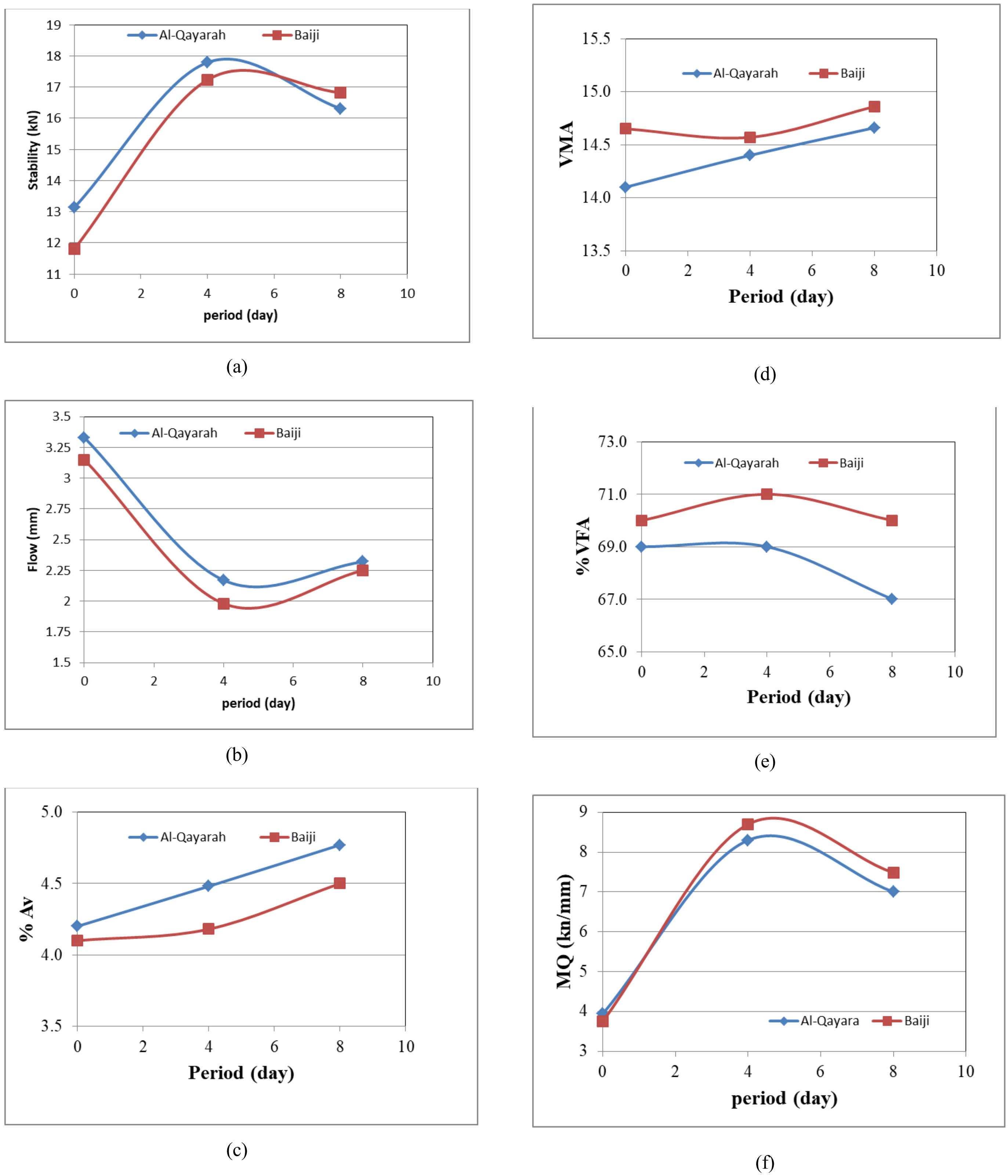


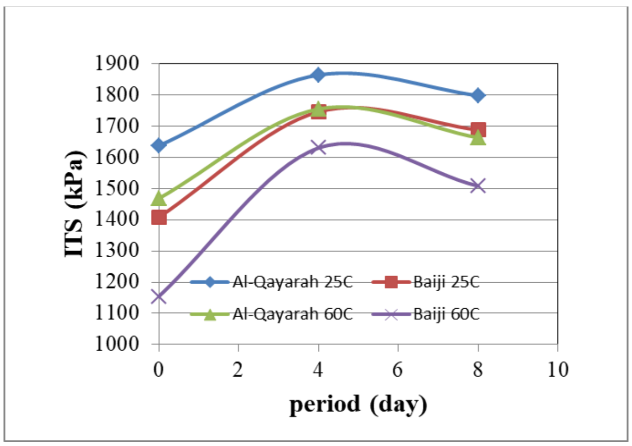
Fig. 2. Marshall properties of DGAMs (a- stability, b- flow, c- air voids, d- VMA, e- VFA &, f- MQ)

B. Static ITS

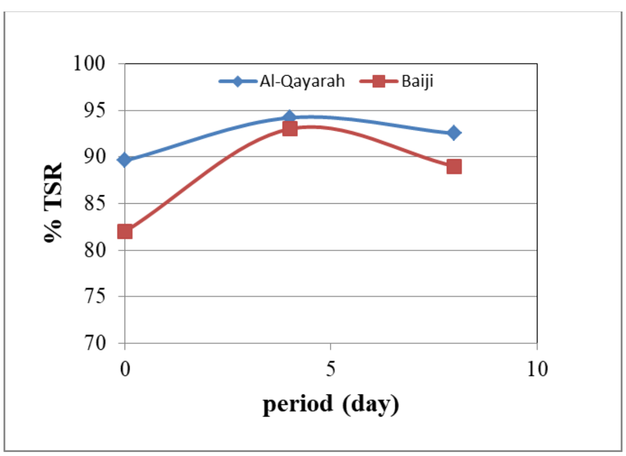
ITS and TSR tests of DGAMs mix containing B40 and Q40-asphalt at 25 and 60°C are depicted in Fig 3. The results of DGAMs containing B40 and Q40-asphalt showed 24%, and 20%, and 14% and 10% higher ITS at 25°C, 4%, and 3%, and 20% and 13% higher ITS at 60°C. Whereas, TSR was 11% and 7%, and 4% and 3% higher for the 4 and 8 d aging levels, respectively. This illustrates that aging improves the performance of DGAMs containing B40 and Q40-asphalt in resisting water damage.

C. Resilient Modulus

The resilient modulus at 25°C was determined using an ITS test as described in ASTM D4123 [17]. MR is illustrated in Fig. 4. The results of DGAMs containing B40 and Q40-asphalt showed 52% and 38%, and 38% and 24% higher ITS at 25°C for the 4 and 8 d aging levels, respectively. This indicated that the MR of DGAMs containing B40 and Q40-asphalt improved with aging.



(a)



(b)

Fig. 3. Tensile strength properties of DGAMs ((a) tensile strength & (b) % TSR).

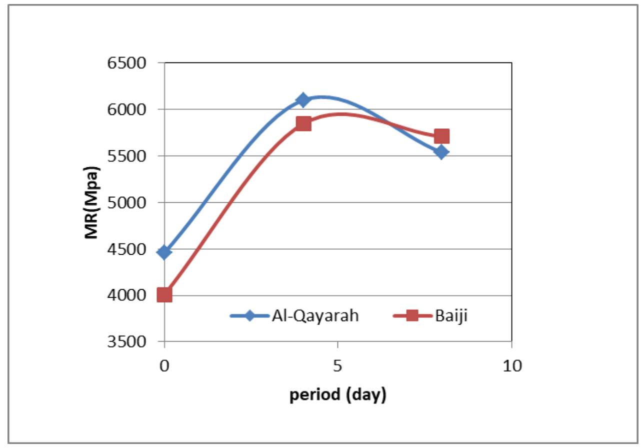
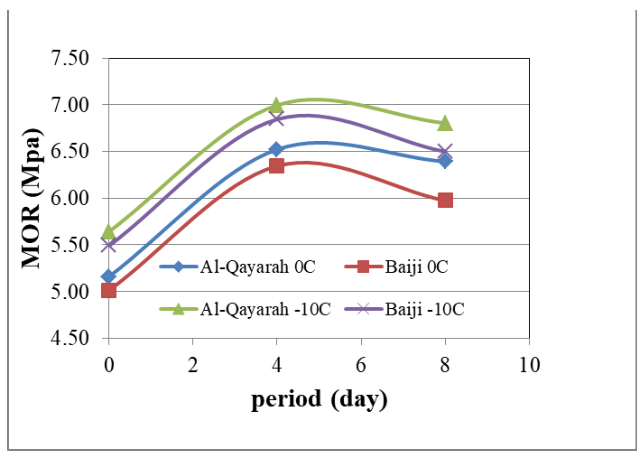


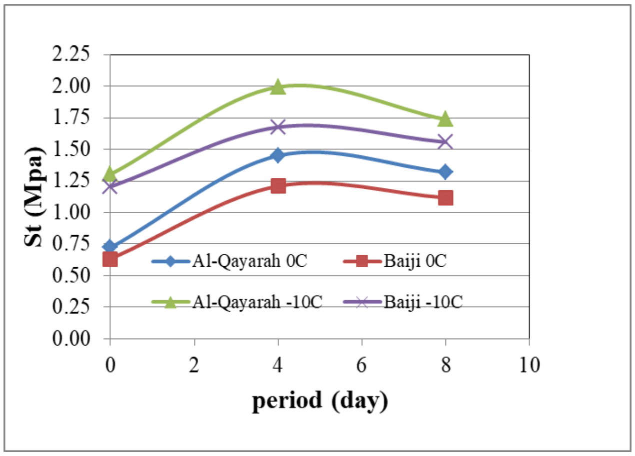
Fig. 4. Resilient Modulus of DGAMs

D. Flexural Strength

Flexural strength at 0°C and -10°C was determined as per ASTM D78 [17]. Modulus of rupture (MOR) and stiffness modulus (SM) are illustrated in Fig. 5. The results of DGAMs containing B40 and Q40-asphalt showed 27% and 19%, and 26% and 24% higher MOR at 0°C, and 25% and 18%, and 24% and 21% higher MOR at -10°C for the 4 and 8 d aging levels, respectively. Whereas, DGAMs with B40 and Q40 showed 91% and 76%, and 101% and 83% higher SM at 0°C, and 28% and 29%, and 53% and 33% higher MOR at -10°C. This indicated that the MR and SM of DGAMs with B40 and Q40-asphalt improved with aging.



(a)



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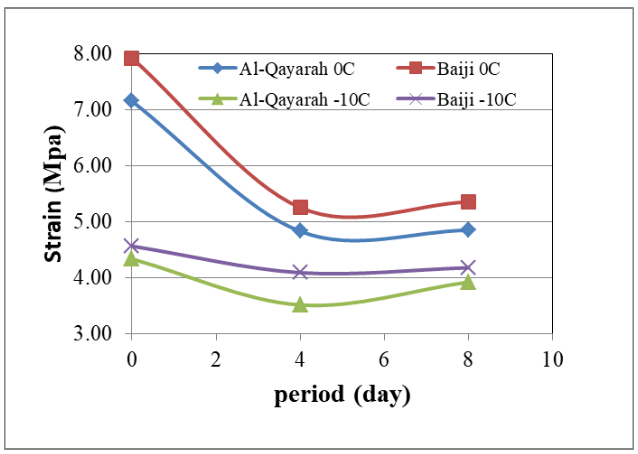

(c)

Fig. 5. Flexural strength properties of DGAMs (a-Modulus of rupture, b-Stiffness modulus, and c-strain)

E. Cohesion Test

Cohesion at 60 ± 3°C was determined as per ASTM D-1560 [17]. Cohesion is illustrated in Fig. 6. The results of DGAMs with B40 and Q40-asphalt showed 73% and 58%, and 58% and 44% higher cohesion at 60 ± 3°C for the 4 and 8 d aging levels, respectively. This indicated that the cohesion of DGAMs with B40 and Q40-asphalt improved with aging.

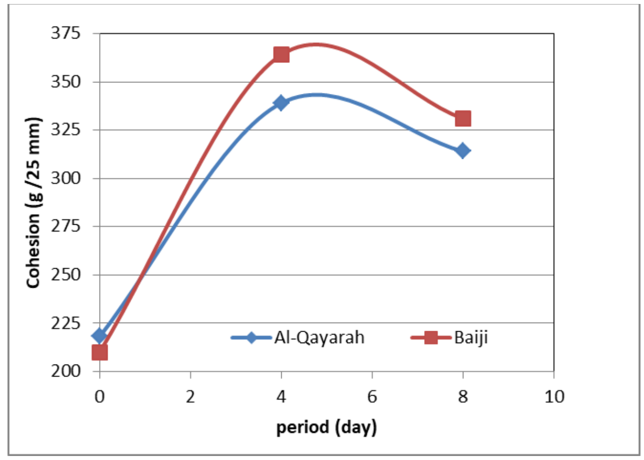

Fig. 6. Cohesion of DGAMs

F. Aging Susceptibility

AI was determined by dividing the cohesion of aged mixes by the cohesion of unaged mixes. Fig. 7 depicts that the AI of the mixes increased for the 4 and 8 d aging levels. This was due to the increase in bonds between bitumen and aggregates. Testing indicated that the DGAMs with B40 and Q40 showed 1.74 and 1.58, and 1.56- and 1.44-times higher AI values for the 4 and 8 d aging levels, respectively.

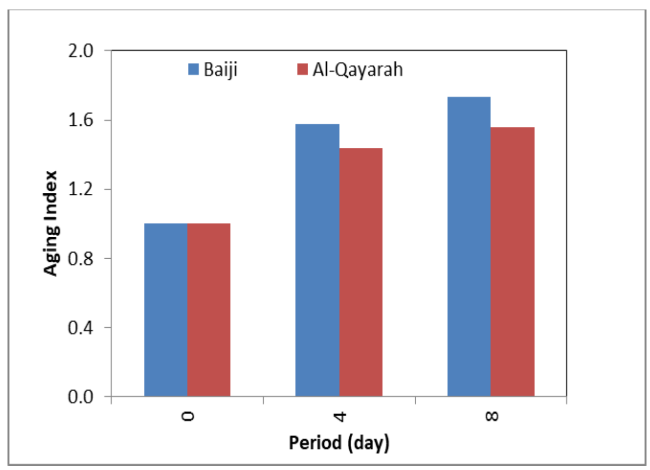

Fig. 7. Aging index of DGAMs

IV. Conclusions

Based on the testing and analysis the following conclusions may be made:

1) DGAMs with B40 and Q40 show 46% and 43%, and 37% and 24% higher MS, 132% and 99%, and 111% and 78% higher MQ for the 4 and 8 d aging levels, respectively. This illustrated that aging improves the resistance of DGMs to rutting.

2) DGAMs with B40 and Q40 shows 24% and 20%, and 14% and 10% higher unconditioned ITS, 4%, and 3% and 20%, and 13% higher conditioned IT'S for 4 and 8 d aging levels, respectively.
3) DGAMs with B40 and Q40 show 11% and 7%, and 4%, and 3% higher TSR for 4 and 8d aging levels, respectively.
4) DGAMs with B40 and Q40 show 52% and 38%, and 38% and 24% higher MR for 4 and 8 d aging levels, respectively. This indicates that the MR of the DGAMs improved after aging.
5) DGAMs with B40 and Q40 shows 27% and 19%, and 26% and 24% higher MOR at 0°C, and 25% and 18%, and 24% and 21% higher MOR at -10°C for 4 and 8 d aging levels, respectively. This indicates the aging process improves the resistance of DGAMs to cracking.
6) The 4 and 8 d-aged DGAMs with B40 and Q40 shows 1.74 and 1.58, and 1.56 and 1.44 times higher AI, respectively. This is due to the increasing bonds between bitumen and aggregate.
7) DGAMs with B40 and Q40 show 73% and 58%, and 58% and 44% higher cohesion at 60°C for 4 and 8 d aging levels, respectively.
8) It was found that DGAMs with B40 bitumen perform better than DGAMs with Q40, especially in the case of moisture damage and flexural strength properties.

ACKNOWLEDGMENTS

The writer wishes to extend his appreciation to the Materials Laboratory, Mosul Municipality, R.P. Iraq for technical assistance, as well as to the various companies that provided the materials used in this study.

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