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Effects of Aging and Moisture Damage on Asphaltic Mixture

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Hot Mix Asphalt
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Indirect Tensile Strength
Resilient Modulus

ABSTRACT

Moisture damage in asphalt mixtures refers to the loss of strength and durability due to the presence of water. Road network is showing severe deterioration such as raveling and stripping because the bond between aggregates and asphalt film is broken due to water intrusion. To minimize moisture damage asphalt mixes are investigated to evaluate the effect of air voids degree of saturation media of attack and the conditioning period. Moisture damage is one of the major issues in asphalt distress. It is due to the adhesive and cohesive failure of the asphalt mixture and it will shorten pavement life. Moisture-sensitive mixtures need to be identified during the course of the mixture design process which fulfil the specified minimum standard. The laboratory testing procedures currently available for compacted Hot Mix Asphalt (HMA) to test the moisture sensitivity were primarily developed to determine the degree of resistance to moisture damage by a particular combination of asphalt and aggregate. These moisture sensitivity tests evaluate the effect of moisture damage in the laboratory by measuring the relative change of a single parameter before and after conditioning (i.e. Tensile Strength Ratio Resilient Modulus Ratio).

تأثير التقادم وأضرار الرطوبة على الخلطات الاأسفلتية

بشير أبواروي

جامعة المرقب ، الخمس ، ليبيا

الكلمات المفتاحية:
اختبار الشد الغير مباشر
اختبار معامل المرونة
الخطات الأسفلتية الساخنة
حساسية الرطوبة.

الملخص

تؤدي الأضرار الناجمة عن الرطوبة في الخلطات الأسفلتية إلى فقدان القوة والمتانة بسبب وجود الماء. وقد ظهرت في شبكات الطرق تدهورًا شديدًا مثل التجريد بسبب فقدان المادة الرابطة (الأسفلت) بين حبيبات الركام والتجريد الذي حصل للأسفلت المغلف للركام بسبب تسرب المياه. ولتقليل ضرر الرطوبة ، يتم اختبار الخلطات الأسفلتية لتقييم تأثير الفراغات الهوائية المشبعة والتي خضعت العدة عوامل من الرطوبة والتقادم حيث يعد التلف الناجم الرطوبة أحد المشكلات الرئيسية في الطرق الأسفلتية وهو ناتج عن الفشل في الالتصاق والتماسك لمكونات الخلطة الأسفلتية يجب الاخذ في الاعتبار حساسية للرطوبة أثناء عملية تصميم الخلطات التي تفي بالمعيار الأدنى المحدد. وقد تم تطوير إجراءات الاختبارات المعملية المتاحة حاليًا للخلطات الساخنة لاختبار حساسية الرطوبة بشكل أساسي لتحديد درجة مقاومة التلف الناتج عن الرطوبة من خلال مزيج معين من الأسفلت والركام. تعمل اختبارات حساسية الرطوبة هذه على تقييم تأثير التلف الناتج عن الرطوبة في المختبر عن طريق اختبار الخلطات باختبار الشد الغير مباشر واختبار تحديد معامل المرونة.

Introduction

Durability is one of the most important properties of a Hot Mix Asphalt (HMA). A key factor affecting the durability of asphalt pavements is moisture damage [1]. Moisture
damage of an asphalt mixture generally called stripping potential is among the most important distresses of asphaltic pavements [2]. Moisture damage can be defined as the loss of strength and durability in asphalt mixtures due to the effects of moisture. Moisture sensitivity is primarily concerned with the potential for loss of adhesion between the binder and aggregate in the presence of moisture commonly called stripping. It is self-evident that stripping can only occur if there is moisture in the pavement although the mere presence of moisture does not necessarily result in stripping [3-5]. This damage can then cause stripping, hydraulic scouring (where fine aggregate particles are transported through the voids in the pavement when a traffic load

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causes positive and negative pore pressures), or by a loss of cohesion in the asphalt binder when the positive pore pressures push the aggregate apart. When the pavement surface is saturated moving vehicle tires first apply a positive pressure then a negative pressure (suction) to the water in surface pores. This compression-tension cycle is likely to contribute to the stripping of the asphalt film from the aggregate surface. In addition, dust mixed with rainwater can enhance the abrasion of asphalt films. It seems that traffic loading plays an important role in developing moisture damage [6]. Moisture can damage HMA in two ways: ① loss of bond between asphalt or mastic and fine and coarse aggregate or ② weakening of mastic due to the presence of moisture[7-9].

Many variables affect the amount of moisture damage which occurs in an asphalt mixtures mixture. Some of these variables are related to the materials forming HMA such as aggregate and bitumen. Others are related to mixture design and construction (air void level film thickness permeability and drainage) environmental factors (temperature pavement age freeze–thaw cycles and presence of ions in the water) traffic conditions and type and properties of the additives [8, 10]. Moisture damage can be understood as the progressive deterioration of asphalt mixes by loss of adhesion between asphalt binder and aggregate surface and/or loss of cohesion within the binder primarily due to the action of water [3, 5, 11].

Cohesive failure in asphalt mixtures cohesion is described as the overall integrity of the material when subjected to load or stress. It is determined primarily by the attraction within the asphalt binder and influenced by factors such as viscosity of the asphalt film. Water can affect cohesion through saturation and expansion of the void system due to freeze-thaw cycles under temperature changes. Adhesion Failure for asphalt mixtures it is an objective of mix design to coat all aggregate surfaces with a film of asphalt to form a cemented composite material. The attraction between asphalt films and aggregate surfaces is defined as adhesion and water can destroy adhesion [3, 11]. Figure 1 shows the types of failure in asphalt mixture.

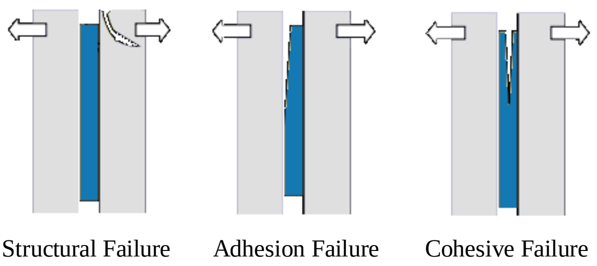


Fig. 1: Types of failure in asphalt mixture

The essential problem was how water penetrated the asphalt film and/or interfaces between asphalt and aggregate. Some of the major moisture damage mechanisms are the development of pore water pressure in the mixture voids due to the repetition of wheel loads. Thermal expansion and contraction produced by ice formation and temperature cycling above freezing freeze-thaw. The direct result of moisture effect is weakening or loss of bond strength within asphalt mixes and composite stiffness of the mix which is the basis of most desired pavement performance so many distresses will show up due to moisture damage such as fatigue cracking rutting ravelling and bleeding [11].

Warm mix asphalt (WMA) technologies are capable of significantly reducing the production and compaction temperatures of asphalt mixes. This temperature reduction results in saving energy cutting emissions extended paving season in cold climates and significant cuts in production costs. Despite WMA advantages over the conventional HMA its ability to resist moisture-induced damage is uncertain. [12]. WMA technique has been found to be more promising for cold weather paving and recycling with high percentage of reclaimed asphalt pavement (RAP). WMA with high percentage of RAP exhibited higher rut resistance better moisture damage resistance and better fatigue performance when compared with HMA containing RAP [13].

Material and Method

This places the design in traffic category from 3 to 30 million ESALs. Traffic level is used to determined design requirement such as number of design gyrations for compaction aggregate physical property requirements and mixture volumetric requirements. The conventional virgin 80/100 asphalt binder used was obtained from Shell Bitumen Company Singapore and used as the control binder. Granite aggregate used in the preparation of all the mixtures were supplied by Kuad Kuari in Penang. The crushed granite was used in the mix design for Asphaltic Concrete mixture AC14 wearing course mix according to the Malaysian Public Works Department Local Specifications. Aggregates and asphalt binder with properties similar to those used by Aburawi [14] were also utilized for this study. A mechanical mixer was used to blend the aggregate and binder at the mixing temperature 160°C. After mixing the loose mixtures were poured into the heated metal trays and conditioned in the oven at 150°C a temperature equal to the mixture's specified compaction temperatures for two hours. The mixtures were compacted using the Servopac gyratory compactor (SGC) as shown in Figure 2 at 30 gyrations per minute at a compaction angle of 1.25° for 100 gyrations.

The samples were conditioned at 85°C for 5 days according to AASHTO PP2 (AASHTO 2001) procedures. Figure 3 shows the oven draft used for simulating the long-term aging.

Fig. 2: Servopac gyratory compactor

Fig. 3: Oven Draft Used for Simulating the Long-Term Aging Process

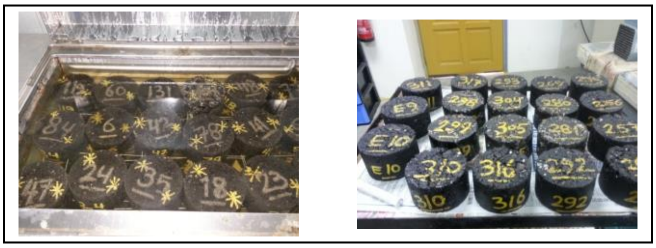
Moisture Conditioning Process

Moisture conditioning was performed in the laboratory to evaluate the effects of accelerated water conditioning through the freezing-thawing cycle on compacted asphalt mixtures. The conditioning of all the compacted samples was performed according to ASTM D4867 (ASTM 2006c) procedures with the only modification made using sodium carbonate Na2CO3 solution added at 6.62 gm per litre concentration to the distilled water. Water with Na2CO3 was used to increase the pH to enhance the stripping rate/damage inside the asphalt samples. Sodium carbonate was used in chemical immersion tests to evaluate the moisture damage in the asphalt mixture. This type of test consists of coating aggregate with asphalt binder and then soaking in solutions containing various concentrations of sodium carbonate. The concentration of the sodium carbonate solution at which stripping was first observed was used as a measure of adhesiveness [15]. The samples were immersed in the solution and vacuumed for 15 min to achieve saturation levels between 55% and

80% as shown in Figure 4 (a). These samples were subsequently exposed to freezing condition at -18±3°C for 16 h as shown in Figure 4 (b) and thawing at 60°C for 24 h as shown in Figure 4 (c).

(a) Vacuum Saturation

(b) Freezing Conditioning



(c) Thawing Process

Fig. 4: Moisture Conditioning of Samples

Three sets of samples unconditioned dry conditioned one freeze–thaw cycle (1 F-T) and three freeze–thaw cycles (3 F-T) were produced. The samples were to be compacted to achieve 7% ± 1% air voids.

The samples were prepared in the laboratory. These samples have air void range from 6.0% to 8.0%. They were divided into 5 sets to be tested under the proposed test procedure with replication. Moisture conditioning protocol summarized in the Table 1.

Table 1: Moisture conditioning protocol

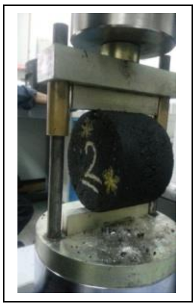
1	Un aging + aging + aging
2	Aging + Vacuum 30 min at 25°C + Aging
3	Aging + Vacuum 30 min at 25°C + Freezing -18°C 24 hr. Thawing 60°C 24 hr. + Aging
4	Aging + Vacuum at 25°C 30 min and merged in Water 3 days + Aging
5	Aging + Vacuum at 25°C 30 min and merged in Water 14 days + Aging

Mixture Performance Tests

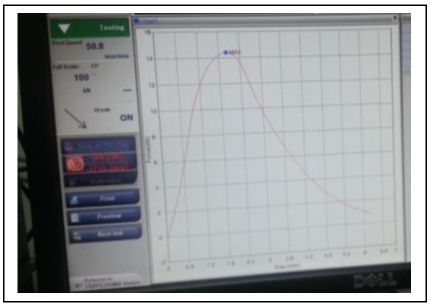
Indirect Tensile Strength (ITS)

ITS test is used to indicate the moisture susceptibility of mixtures and in some cases the cracking potential of mixtures. The mixture that exhibits high ITS is generally better to resist cracking. The sample was placed in the controlled temperature chamber at 15°C for at least 24 hours prior to testing. A low temperature of 15°C was used to test the samples. Itis well established that asphalt mixture becomes brittle under low temperatures and as a consequence is easy to disintegrate when subjected to any external loads. Therefore, the low temperature condition ensures asphalt concrete achieves near elastic properties.

To determine the ITS the conditioned sample was placed on the bottom strip and the top loading strip was mounted on the sample. The load was then applied until the sample failed. The test was performed using the Marshal Stability apparatus but with two steel loading strips with concave surfaces as shown in Figure 5 (a). Figure 5 (b) shows the load versus deformation curve.



(a) ITS Sample



(b) Curve of Load Versus Deformation

Fig. 5: Indirect tensile test

The maximum load required to break the sample was recorded and used in determining the ITS which was calculated using Equation (1):

$$ITS=\frac{2000F}{\pi\, h\, d} \qquad (1)$$

Where:

ITS = Indirect tensile strength (kPa)

F = Maximum applied load (N)

h = Sample thickness (mm)

d = Sample diameter (mm)

Resilient Modulus (M_R)

The Resilient Modulus(M_R) is a significant property in mechanistic-empirical pavement design as it is being used as an input for multilayer elastic theories or finite element models to compute structural response under traffic loading. The resilient modulus test for mixtures was carried out in accordance with ASTM D4123 (ASTM 2006d) procedures. The test was carried out using the universal testing machine (UTM-25) equipped with an environmental chamber for sample conditioning as shown in Figure 6.

Fig. 6: UTM-25 Set Equipped with an Environmental Chamber for MR Test

Samples were kept in the universal testing machine (UTM-25) conditioned at 40°C for at least four hours. A direct compressive load was applied to a 12 mm wide loading strip along the vertical diameter of the samples. For each sample the test was repeated by rotating the sample through 90°.

Results and discussion

Results of studies on the effect of various moisture conditioning and its incorporation with aging on properties of asphalt mixtures.

Indirect Tensile Strength (ITS) Test

ITS test results of asphalt mixtures under aging and different moisture conditioning are presented in Figure 7. From the figure aging increased the ITS of the asphalt mixtures while the moisture conditioning reduced the ITS of the asphalt mixtures. The results showed that the moisture conditioning state exhibit a noticeable effect on the value of ITS. For example, moisture conditioning using (Aging + Vacuum 30 min at 25°C + Freezing -18°C 24 hr. Thawing 60°C 24 hr. + Aging) exhibited the lowest ITS while moisture conditioning using only vacuum saturation showed the highest ITS for asphalt binder.

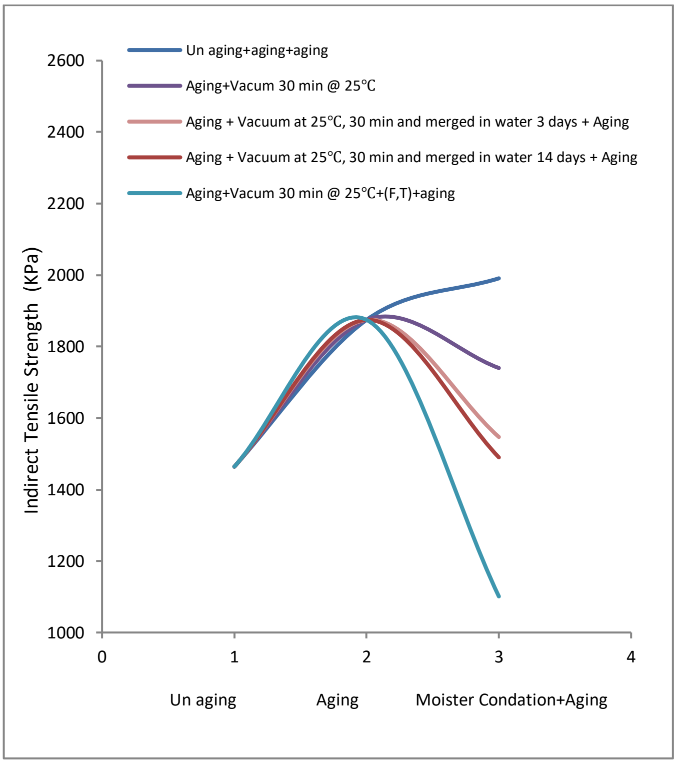


Fig. 7: Effect of Aging and Different Moisture Conditioning on the value of ITS for Asphalt Mixtures

Resilient Modulus (M_R) Test

Figure 8 presents the effect of aging and different moisture conditioning on the resilient modulus of asphalt mixtures. As can be seen moisture conditioning reduced the stiffness of asphalt mixtures due to aging in terms of resilient modulus. For instance, the effects of moisture conditioning using (Aging + Vacuum 30 min at 25°C + Freezing -18°C 24 hr. Thawing 60°C 24 hr. + Aging) were greater than the effect of other types of conditioning on the resilient modulus of asphalt mixtures.

6 Conclusion

Moisture damage, occurring in several forms, can cause deterioration of asphalt pavements leading to a shortened service life of the pavement. Water or water vapour can affect the asphalt mixtures through the general `theory' of water susceptibility (sensitivity) behaviour loss of adhesion (bond) between the aggregate surface and the asphalt cement; loss of cohesion softening and reduction in strength and stiffness of the asphalt mixtures; and/or fracture of individual aggregate particles with freezing.

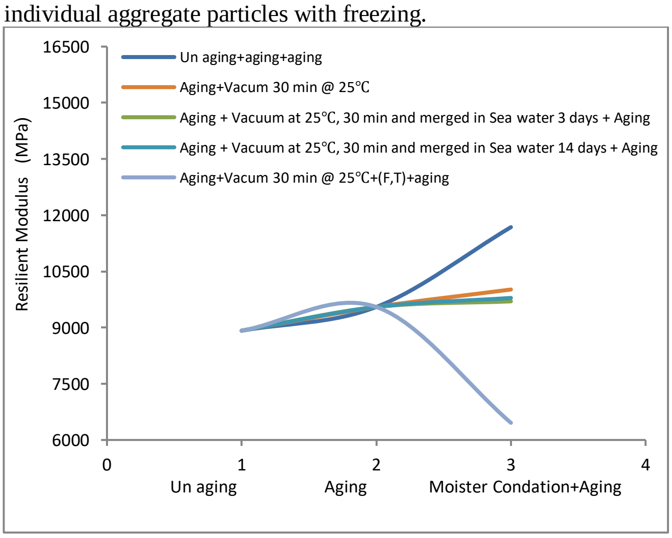


Fig. 8: Effect of Aging and Different Moisture Conditioning on the Resilient Modulus for Asphalt Mixtures

In conclusion this paper shows an incorporating effects of aging and moisture conditioning on the stiffness properties of 80/100 binder were investigated at various conditioning in terms of resilient modulus and ITS. In addition, the test results showed that aging and moisture conditioning have opposing effects on the stiffness properties of HMA. Conditioning in the chemical environment showed greater effects on the ITS of asphalt mixtures compared to samples conditioned in distilled water.

Keeping the moisture out or least controlling the degree of moisture in the asphalt to avoid critical levels of saturation is a fundamental requirement. Design air voids and compacted density (insitu air voids) are important factors in the permeability of the asphalt mix. Grading and nominal size can also be contributing factors. Asphalt is rarely completely waterproof so some level of moisture is inevitable. Relative permeability of adjacent pavement layers can have a significant effect on development of critical levels of moisture saturation in particular layers. Factors that affect moisture sensitivity of the mixture itself include the nature and condition of aggregates and the type and proportion of filler and binder. Manufacture to the extent of achieving good coating of bitumen and aggregates can also be a contributing factor. These factors are largely controlled by the selection and testing of component materials as well as tests applied to the final mixture.

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