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Investigation of using SBR nanocomposite on moisture damage of HMA using surface free energy theory

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ABSTRACT: Moisture damage is one of the common damages of asphalt mixtures due to the deteriorating effect of moisture on asphalt cement cohesion and asphalt cement-aggregate adhesion. Anti-stripping additives are used to enhance the strength of asphalt mixtures against this damage in order to increase the asphalt cement-aggregate adhesion and asphalt cement cohesion. In the present study, it has been tried to examine the effect of the nano clay/styrene-butadiene rubber (SBR) nanocomposite as asphalt cement modifier on the moisture susceptibility of asphalt mixtures using thermodynamic and mechanical technics. The asphalt specimens were placed under 1, 3, and 5 freeze-thaw cycles in order to simulate environmental conditions. The findings of this study indicated that the application of SBR nanocomposite has led to the improvement of the strength of the asphalt mixtures to moisture damage, particularly in specimens made using granite aggregates. In addition, the results of the surface free energy theory showed that asphalt cement modification using SBR nanocomposite increased and decreased the basic and acidic components of the base asphalt cement, respectively. This improved the adhesion between asphalt cement and acidic aggregates, which are prone to moisture damage. Moreover, the SBR nanocomposite use increased the cohesion free energy, hence increasing the resistance of asphalt film against the cohesion-type rupture. Furthermore, calculations based on thermodynamic concepts revealed that the asphalt cement modification has led to a reduction in the de-bonding energy in the stripping event; this event indicates a decrease in the tendency of the system to stripping from the thermodynamics view.

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1. INTRODUCTION

Moisture damage is regarded as a key effective factor to durability of asphalt pavements. Due to the presence of moisture in the structure of pavement and its destructive effects on adhesion between asphalt binder-aggregate and mastic cohesion, this damage leads to the reduction of mechanical properties of asphalt mixture [1, 2].

According to the previous studies [3-5], losing adhesion between asphalt binder and aggregate has been known as the most common type of the above mechanisms. This shows that "adhesion" problem is of paramount importance in increasing the strength of asphalt mixtures. Therefore, using any method which firstly avoids from penetration of moisture into the asphalt binder-aggregate interface regions and secondly, increases the adhesion between asphalt binder and aggregate can be useful in reducing moisture damage.

2. Surface free energy

The SFE of the aggregate and asphalt binder can be individually obtained using the following equation:

$$\Gamma = \Gamma^{LW} + \Gamma^{AB} \tag{1}$$

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Where, Γ = SFE of the asphalt binder or aggregate; Γ^{LW} = non-polar component of the SFE; and, Γ^{AB} = acid-base polar component of the SFE.

According to the principles of Good [6], the acid-base term is composed of a Lewis acidic parameter and a Lewis basic parameter:

$$\Gamma^{AB} = 2\sqrt{\Gamma^{+}\Gamma^{-}} \tag{2}$$

Where, Γ^{+} = acidic component; and Γ^{-} = base component.

From the thermodynamic viewpoint, the free energy of continuity (ΔGi^{c}) is defined as the required energy to formation of a crack with unit area inside a material. For various materials it can be showed as follows:

$$\Delta G_i^c = 2\Gamma_i^c \tag{3}$$

The free energy of adhesion (ΔGia) has two main components as defined before. Non-polar component (Lifshitz-van der Waals component) and acid-base polar component. The following equations are used to determine the non-polar and polar adhesion between asphalt binder and aggregate:

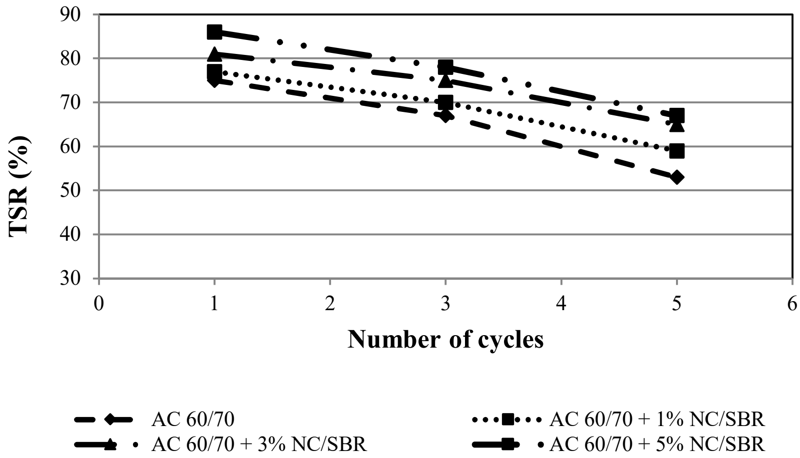

Fig 1. Effects of CBR nanocomposite on TSR in mixtures made with granite aggregate

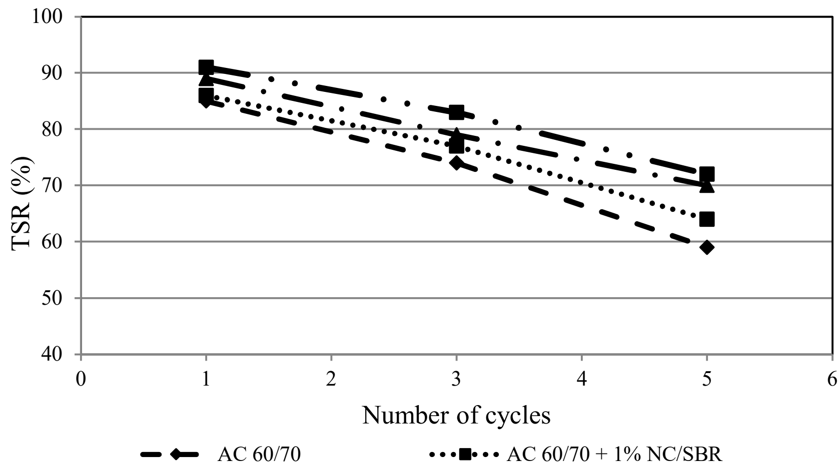

Fig 2. Effects of CBR nanocomposite on TSR in mixtures made with granite aggregate

$$\Delta G_i^a = \Delta G_i^{aLW} + \Delta G_i^{aAB} = 2\left[\left(\sqrt{\Gamma_S^{lw}\Gamma_l^{lw}}\right)+\left(\sqrt{\Gamma_S^{+}\Gamma_l^{-}}\right)+\left(\sqrt{\Gamma_S^{-}\Gamma_l^{+}}\right)\right] \quad (4)$$

Where, ΔGi^a = free energy of adhesion; ΔGi^{aLW} = non-polar or Lifshitz-van der Waals part of adhesion; ΔGi^{aAB} = acid-base or polar part of adhesion; Γ_1^{LW}, Γ_1^{+}, and Γ_1^{-} = SFE components of asphalt binder; and Γ_S^{LW}, Γ_S^{+}, and Γ_S^{-}= SFE components of the aggregate.

The following equation also is used to calculate the adhesion between asphalt binder and aggregate in the presence of water, which the subscripts 1, 2, and 3 represent asphalt binder, aggregate, and water, respectively. If the value of the free energy of adhesion is negative, the two phases of the material tend to bind together, and the more negative values give tendency.

$$\Delta G_{lsw}^a = +\Gamma_{13} + \Gamma_{23} - \Gamma_{12} = \begin{bmatrix} \left(2\Gamma_w^{LW}\right) + \left(4\sqrt{\Gamma_w^+\Gamma_w^-}\right) - \left(2\sqrt{\Gamma_l^{LW}\Gamma_w^{LW}}\right) \\ - \left(2\sqrt{\Gamma_w^+\Gamma_l^-}\right) - \left(2\sqrt{\Gamma_l^+\Gamma_w^-}\right) - \left(2\sqrt{\Gamma_s^{LW}\Gamma_w^{LW}}\right) \\ - \left(2\sqrt{\Gamma_w^+\Gamma_s^-}\right) - \left(2\sqrt{\Gamma_s^+\Gamma_w^-}\right) + \left(2\sqrt{\Gamma_l^{LW}\Gamma_s^{LW}}\right) \\ + \left(2\sqrt{\Gamma_l^+\Gamma_s^-}\right) + \left(2\sqrt{\Gamma_l^-\Gamma_s^+}\right) \end{bmatrix} \quad (5)$$

3. MATERIALS

Two types of aggregate were investigated in this study. The two aggregates (limestone and granite) represent a considerable range of different minerals and the degree of stripping associated with them. Bitumen of 60-70 penetration grade was used.

A linear SBR copolymer prepared through a solution polymerization technique with 33% of styrene was employed. In addition, an organically modified montmorillonite nanoclay (MMNC) was used in this study.

4. ITS TEST

Loading of the ITS test is carried out at a loading rate of 5.08 cm (2 inches) per minute until the sample is ruptured. The amount of load is recorded at the rupture moment. Then the ITS value of the samples is obtained using equation 6.

$$ITS = \frac{2F}{t\pi d} \quad (6)$$

where ITS is the indirect tensile strength (kPa), F is the peak value of the applied vertical load (kN), t is the mean thickness of the test specimen (m), and d is the specimen diameter (m).

The average ITS value of dry (three samples) and wet (three samples) samples is calculated separately. The moisture susceptibility or the stripping potential for asphalt mixture samples is obtained by the ratio of the average ITS value of the wet to dry samples (in percent).

$$TSR = (\frac{ITS_{Wet}}{ITS_{Dry}}) \times 100 \quad (7)$$

which, TSR is the indirect tensile strength ratio, ITSWet is the average ITS value of the wet set samples that are subjected to freeze-thaw cycles, and ITSDry is the average ITS value of the dry set samples.

5. RESULTS AND DISCUSSION

TSR values for control and the modified mix with 3% and 5% modifier after three different number of freeze-thaw cycles for two types aggregate are presented in Fig 1 and 2.

According to Fig 1 and 2, using CBR nanocomposite cause an increase in the TSR values of HMA. Two main reasons can interpret this change: firstly in bitumen modified with NC/CBR, aggregate-bitumen adhesion will be increased and secondly the increase in SFE of bitumen will decrease the rupture potential in the mastic. Considering the increase in TSR value for modified samples as compared to control samples, NC/CBR can be used as a modifier to prevent the reduction of aggregate-bitumen adhesion and bitumen cohesion in water presence.

6. CONCLUSIONS

The objective of the researchers in the present study was to strengthen asphalt mixtures to moisture damage using NC/CBR as asphalt cement modifier. Therefore, the mechanical and thermodynamic methods have been used to investigate the effect of the additive used in this study. The most important results obtained in this study are as follows:

- Using NC/CBR causes an increase and decrease in a basic and acidic component of modified bitumen, respectively. Therefore, adhesion SFE of modified bitumen in surfaces in contact with an aggregate increase in water presence.
- The addition of NC/CBR to bitumen decreases de-bounding energy in water presence. So moisture susceptibility potential of the asphalt mixture containing this bitumen is reduced.
- The moisture resistance of modified HMA is increased by the NC/CBR addition. Since the TSR value of modified HMA were larger than control samples, significantly.
- Applying three different freeze-thaw cycles on the asphalt mixture show that modified HMA with NC/CBR has more resistance as compared to control samples.

REFERENCES

[1] Moghadas Nejad, F., Hamedi, G.H., Azarhoosh, A., 2012. "Use of surface free energy method to evaluate effect of hydrate lime on moisture damage in hot-mix asphalt". *Journal of Materials in Civil Engineering*, 25(8), pp. 1119-1126.

[2] Khodaii, A., Khalifeh, V., Dehnad, M., Hamedi, G.H., 2013. "Evaluating the effect of zycosoil on moisture damage of hot-mix asphalt using the surface energy method". *Journal of Materials in Civil Engineering*, 26(2), pp. 259-266.

[3] Abandansari, H.F., Modarres, A., 2017. "Investigating effects of using nanomaterial on moisture susceptibility of hot-mix asphalt using mechanical and thermodynamic methods". *Construction and Building Materials*, 131, pp. 667-675.

[4] Moghadas Nejad, F., Azarhoosh, A., Hamedi, G.H., Azarhoosh, M., 2013. "Influence of using nonmaterial to reduce the moisture susceptibility of hot mix asphalt". *Construction and Building Materials*, 31, pp. 384-388.

[5] Arabani, M., Hamedi, G.H., 2010. "Using the surface free energy method to evaluate the effects of polymeric aggregate treatment on moisture damage in hot-mix asphalt". *Journal of Materials in Civil Engineering*, 23(6), pp. 802-811.

[6] Van Oss, C.J., Chaudhury, M.K. Good, R.J., 1988. "Interfacial Lifshitz-van der Waals and polar interactions in macroscopic systems". *Chemical Reviews*, 88(6), pp. 927-941.

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