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Effects of Hydrated Lime on Moisture Susceptibility of Asphalt Concrete

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ABSTRACT

Moisture damage is one of the most critical distresses affecting asphalt pavement. The use of mineral fillers such as hydrated lime can increase the moisture resistance of the asphalt mixtures. In this study, the effects of hydrated lime (HL) and nano hydrated lime (NHL) were investigated on the moisture susceptibility of modified asphalt mixtures. The asphalt mixtures were modified using HL and NHL with varying percentages of each additive. The indirect tensile strength (ITS) test was performed to investigate moisture susceptibility. This test was carried out with three types of asphalt mixtures including, normal asphalt mixture without additives, modified asphalt mixture with HL, and modified with NHL. The results showed that the addition of HL and NHL as mineral fillers enhanced the performance of the mixtures against moisture damage. The highest increase in ITS value under dry conditions was observed in the modified mixtures with 20% HL and 20% NHL, and under wet conditions it was observed at 30% HL and 20% NHL. The results also indicated that the addition of 20% HL and 30% NHL increased the value of tensile strength ratio (TSR) by 78.6% and 70.6%, respectively.

Keywords: modified asphalt mixture; nano hydrated lime; indirect tensile strength; tensile strength ratio; moisture damage

INTRODUCTION

Safe, comfortable, functional, and economical road network infrastructure is a priority for every developed country. Flexible asphalt pavement is the most commonly used due to quick construction, repair work is fairly easy, and No joints required during installation. Flexible asphalt mixtures are visco-elastic materials where the rate of load application and temperature have a great influence on their behaviour. In the flexible asphalt mixtures where good quality aggregates and asphalt cement materials were used, the main contributing factors to the pavement distresses may be the environment (e.g., temperature, water, and air) and traffic loading. These factors commonly cause distresses such permanent deformation (rutting), moisture damage, thermal cracking, and fatigue cracking. In general, conventional asphalt mixtures have a limited capacity under a wide range of traffic loads and temperatures. Therefore, asphalt mixtures are usually modified to face load and temperature challenges. Modified asphalt mixtures can bring a real advantage in road construction, by improving pavement performance as well as extending the pavement life.

Nano-materials enhance the properties of asphalt mixtures in terms of supporting these against common pavement distresses. Nano-materials having a very high specific surface area, which creates a strong network in bitumen and this often increases fatigue resistance, rutting resistance, and resilient modulus of asphalt mixtures (1–4). The effects of Nano-materials on the performance of asphalt concrete have been investigated by many researchers such as (5–10).

Taherkhani and Tajdini (9) investigated the effect of Hydrated Lime (HL) and Nano-Silica (NS) on the mechanical properties of asphalt mixtures. The study showed that both additives improve the indirect tensile strength (ITS), resistance to freezing thaw, and resistance to fatigue cracks of the mixtures. The study also showed that more improvement was achieved with NS than with HL. However, other studies have found that additives such as HL and Nano-hydrated lime (NHL) are very effective to protect the asphalt concrete against moisture damage, stripping, and rutting (3, 4, 11–15). Gilani, Hosseinian (12) found that the NHL increased the resistance of asphalt concrete to fatigue and moisture damage. Moreover, the highest increase in fatigue life and indirect tensile strength (ITS) was observed in modified asphalt mixtures. Razavi and Kavussi (16) investigated the performance of the modified asphalt mixtures after adding HL and NHL. The results concluded that the use of 20% HL and 4% NHL had great resistance against damage caused by moisture and the values of tensile strength ratio (TSR) had increased to 60%.

The main objective of the current study is to investigate and evaluate the effects of HL and NHL in improving the resistance of asphalt mixtures against pavement distresses such as moisture damage. For this objective, the indirect tensile strength test was performed on asphalt mixtures. This test was carried out with three types of asphalt mixtures including, normal asphalt mixture without additives, modified asphalt mixture with HL, and modified with NHL.

MATERIALS AND METHODS

Materials

In this research, the asphalt cement with a 60/70 penetration grade was adopted, which had been provided from the Jordan petroleum refinery corporation. In order to characterize the properties of the asphalt cement, a number of laboratory tests such as specific gravity test, penetration test, softening point test, flash point test, and ductility test were performed. The specifications of the asphalt cement are presented in Table 1. Natural crushed coarse and fine aggregates were used in this research. Table 2 shown the final gradation chosen for the aggregate mixture. Also, Figure 1 shows the gradation of the chosen aggregate and the specification band. The grading curve of the chosen aggregate mixture indicates that the gradient of this mixture conforms to the specified limits.

The HL, calcium hydroxide [$Ca(OH)_2$], additive was obtained from locally available resources, while NHL additive was produced from HL in the laboratory using a planetary ball mill. Based on the results of previous researches, the HL and NHL additives quantity were chosen as 5%, 10%, 20%, and 30% by the weight of bitumen. To mix the additives (i.e HL and NHL filler) and asphalt binder, the asphalt binder was heated to fluid condition

Table 1. Properties of asphalt cement base

Test	Specification	Unit	Results	Specification limits
Specific gravity at 25 ºC	ASTM D70	-	1.02	1.01–1.06
Penetration at 25 ºC, 100 g, 5s	ASTM D5	0.1 mm	64	60–70
Softening point	ASTM D36	ºC	51	49–56
Flash point	ASTM D92	ºC	265	250 (min)
Ductility at 25 ºC, 5 cm/min	ASTM D113	cm	100	-

* Tested in laboratory of Civil Engineering Dept./ Tafila Technical University.

Table 2. Selected gradation of aggregate

Sieve size mm (inch)	Specification limits (%)	Passing by weight (%)
19 (3/4”)	100	100
12.5 (1/2”)	80–100	87
9.5 (3/8”)	70–90	75
4.75 (No.4)	50–70	63
2.36 (No.8)	35–50	45
0.60 (No.30)	18–29	19.5
0.15 (No.100)	8–16	9
0.075 (No.200)	4–10	5.2

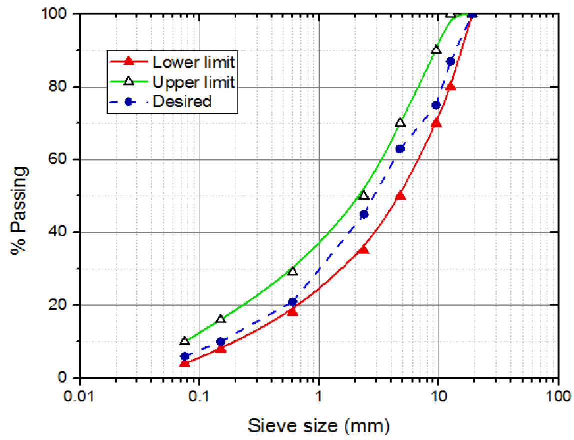

Figure 1. Aggregate gradation curve

(150–160 °C) then the additive was slowly poured into a high-speed shear laboratory mixer with 2500–3000 rpm for 1 hour to ensure uniform distribution of additive in asphalt binder (3, 17).

The indirect tensile strength test

The indirect tensile strength (ITS) test was conducted according to AASHO T 283 method to examine the performance of modified asphaltic mixtures against damage caused by moisture. In order to perform the test, eighteen samples were made in wet conditions and eighteen in dry conditions. The asphalt mixture samples included two without additives, eight with different proportions of HL, and eight with different proportions of NHL. Two samples were used in each test condition. In total, 36 samples were made in this research. In the ITS test, loading was performed at a constant rate of 50.8 mm/min (2 in/min) vertical deformation at 25 ^{o}C until the samples break. The amount of loading was recorded at the moment of failure. The ITS value in kPa was estimated using the following equation (9):

$$ITS = \frac{2000F}{t\pi d} \tag{1}$$

where: F is the vertical load at the moment of failure in N, t is asphalt sample thickness in mm, and d is diameter of asphalt sample in mm.

Moisture susceptibility of the compacted samples is estimated by tensile strength ratio (TSR) using the following equation (9, 18):

$$TSR = \frac{ITS_{wet}}{ITS_{dry}} \times 100 \tag{2}$$

where: ITS_{wet} is the average value of the ITS in a wet condition (kPa), and ITS_{dry} is the average value of the ITS in a dry condition (kPa).

RESULTS AND DISCUSSION

The average loading values obtained from every two samples under the same condition were recorded at the moment of failure as shown in Table 3. These were utilized to estimate the ITS values for control asphalt mixtures (without additives) and modified asphalt mixtures. Figure 2 shows the ITS values on the wet and dry conditions with different additive proportions. As can be seen, the addition of 20% HL and 20% NHL (by weight of bitumen) to the mixture resulted in increase ITS values of asphalt mixtures, in dry condition, by 22.3% and 30.4% respectively. Similarly, the addition of 30% HL and 20% NHL (by weight of bitumen) to the mixture resulted in increase ITS values of asphalt mixtures, in wet condition, by 33.3% and 59.4% respectively. These results may be attributed to the increasing

Table 3. Laboratory testing results of ITS for wet and dry conditions

Content	Thickness (mm)	Diameter (mm)	Failure load at dry condition (N)	Failure load at wet condition (N)
No additive	62.0 64.5	100 100	5566.0	3578.1
5% HL	64.0 61.5	100 100	5817.8	3796.4
10% HL	63.0 64.0	100 100	6286.5	4191.0
20% HL	62.5 60.5	100 100	6620.0	4590.5
30% HL	63.0 64.0	100 100	6785.4	4789.7
5% NHL	63.5 63.0	100 100	6013.3	4323.6
10% NHL	62.5 63.0	100 100	6656.0	4979.7
20% NHL	61.0 61.5	100 100	7026.3	5524.8
30% NHL	63.5 62.0	100 100	7149.0	5571.3

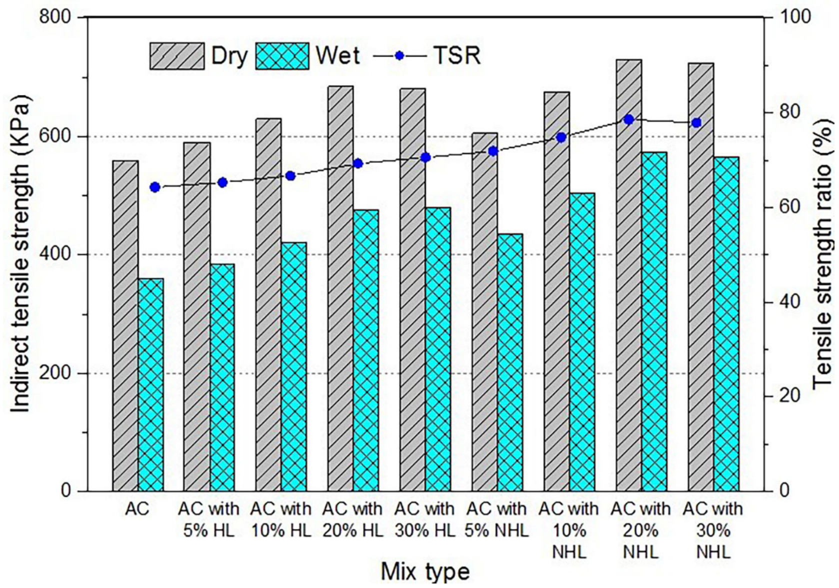

Figure 2. ITS and TSR results of mixtures with and without additives at wet and dry conditions

adhesion between asphalt cement (bitumen) and aggregate particles after adding these fillers. On the other hand, the results showed that increasing NHL content to 30% did not significantly affect the ITS values. This result was expected because more amount of NHL, which has a larger specific surface area, leads to insufficient amount of asphalt binder to coat it.

The values of TSR are also introduced in Figure 2 based on additive content. As shown in Figure 2, the use of HL and NHL as bitumen modifier in asphalt mixtures leads to increase TSR values. The TSR values for all modified asphalt mixtures are higher than TSR values for control mixtures (with no additives). The TSR values of 70.6% and 78.6% were obtained by adding 30% HL and 20% NHL, respectively. Whereas, TSR value of 64.3% was obtained for control mixture. These results indicate that the resistance of asphalt mixtures to the harmful effect of water increases with increasing HL and NHL. The results also indicated that the NHL was highly effective in improving the performance of asphalt mixtures against harmful moisture, as compared to control and HL modified mixtures.

CONCLUSIONS

The performance of asphalt mixtures modified with HL and NHL mineral fillers was investigated based on the ITS results. The following brief conclusions were drawn based on the experimental results, which valid over the test conditions and the range of additives used in this study.

1. The results showed that asphalt modifiers such as HL and NHL helps the asphalt mixture to resist moisture damage under the wet condition.
2. The ITS values of the modified mixtures containing HL or NHL in the dry conditions were higher than for wet conditions.
3. The addition of 20% of HL and 20% of NHL to bitumen increased ITS values of asphalt mixtures, in dry conditions, by 22.3% and 30.4% respectively.
4. The addition of 30% HL and 20% NHL to bitumen increased ITS values of asphalt mixtures, in wet conditions, by 33.3% and 59.4% respectively.
5. The resistance of the NHL modified mixtures against moisture damage was higher compared to mixtures containing HL. The TSR values of 78.6% and 70.6% were obtained by adding 20% of NHL and 30% of HL, respectively.
6. Upon increasing NHL in mixtures at more than 20%, the trend of TSR values showed decreased. This can be attributed to introducing higher amount of NHL material, which has a larger specific surface area, resulting to insufficient amount of binder in mixture. As a result, stiffness of the asphalt mixture increases, air voids content increases, and the compaction of the asphalt mixtures become more difficult.

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REFERENCES

1. You Z., Mills-Beale J., Foley J.M., Roy S., Odegard G.M., Dai Q., et al. Nanoclay-modified asphalt materials, Preparation and characterization. Construction and Building Materials, 2011, 25(2), 1072-1078.
2. Kavussi A., Barghabani P. The influence of nano materials on moisture resistance of asphalt mixes. Study of Civil Engineering and Architecture, 2014, 3, 36-40.
3. Das A.K., Singh D. Influence of Nano size hydrated lime filler on rutting performance of asphalt mastic. Road Materials and Pavement Design, 2019, 1-21.
4. Lesueur D., Petit J., Ritter H-J. The mechanisms of hydrated lime modification of asphalt mixtures, a state-of-the-art review. Road materials and pavement design, 2013, 14(1), 1-16.
5. Kavussi A., Qorbani M., Khodaii A., Haghshenas H. Moisture susceptibility of warm mix asphalt, a statistical analysis of the laboratory testing results. Construction and Building Materials, 2014, 52, 511-517.
6. Crucho J.M.L., das Neves J.M.C, Capitão S.D., de Picado-Santos L.G. Evaluation of the durability of asphalt concrete modified with nanomaterials using the TEAGE aging method. Construction and Building Materials, 2019, 214, 178-186.
7. Hamedi G.H., Esmaeili N. Investigating of the Effects of Nano-materials on the Moisture Susceptibility of Asphalt Mixtures Containing Glass Cullets. AUT Journal of Civil Engineering, 2019, 3(1), 107-118.
8. Behbahani H., Hamedi G.H., Gilani V.N.M. Predictive model of modified asphalt mixtures with nano hydrated lime to increase resistance to moisture and fatigue damages by the use of deicing agents. Construction and Building Materials, 2020, 265, 120353.
9. Taherkhani H., Tajdini M. Comparing the effects of nano-silica and hydrated lime on the properties of asphalt concrete. Construction and Building Materials, 2019, 218, 308-315.
10. Sezavar R., Shafabakhsh G., Mirabdolazimi S. New model of moisture susceptibility of nano silica-modified asphalt concrete using GMDH algorithm. Construction and Building Materials, 2019, 211, 528-538.
11. Shen J.N., Xie Z.X., Xiao F.P., Fan W.Z. Evaluations of nano-sized hydrated lime on the moisture susceptibility of hot mix asphalt mixtures. Applied Mechanics and Materials, 2012. Trans Tech Publ.
12. Gilani V.N.M., Hosseinian S.M., Behbahani H., Hamedi G.H. Prediction and pareto-based multi-objective optimization of moisture and fatigue damages of asphalt mixtures modified with nano hydrated lime. Construction and Building Materials, 2020, 261, 120509.
13. Mansour F., Vahid V. Effect of Liquid Nano material and hydrated lime in improving the moisture behaviour of HMA. Transportation Research Procedia, 2016, 17(21), 34-39.
14. Behbahani H., Hamedi G.H., Moghaddam Gilani V.N. Effects of asphalt binder modifying with nano hydrated lime on moisture susceptibility of asphalt mixtures with thermodynamically concepts. Petroleum Science and Technology, 2020, 38(4), 297-302.
15. Mohammad L.N., Abadie C., Gokmen R., Puppala A.J. Mechanistic evaluation of hydrated lime in hot-mix asphalt mixtures. Transportation Research Record, 2000, 1723(1), 26-36.
16. Razavi S-H., Kavussi A. The role of nanomaterials in reducing moisture damage of asphalt mixes. Construction and Building Materials. 2020, 239, 117827.
17. Das A.K., Singh D. Investigation of rutting, fracture and thermal cracking behavior of asphalt mastic containing basalt and hydrated lime fillers. Construction and Building Materials, 2017, 141, 442-452.
18. Gorkem C., Sengoz B. Predicting stripping and moisture induced damage of asphalt concrete prepared with polymer modified bitumen and hydrated lime. Construction and Building Materials, 2009, 23(6), 2227-2236.