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The Effect of Nano-Hydrated Lime on the Durability of Hot Mix Asphalt

Hawraa J. Aljbouri[1,*], Amjad K. Albayati[2]

Department of Transportation Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq
hawraa.abbas2001m@coeng.uobaghdad.edu.iq[1]; a.khalil@uobaghdad.edu.iq[2]

ABSTRACT

Recently, some of Iraq's newly constructed asphalt concrete pavements showed premature failures with significant negative impacts on roadway safety and the economy. Using Nano hydrated lime (NHL) in pavement construction could be one of the possible steps to improve pavement durability. This article discusses how NHL affects the durability of hot mix asphalt. NHL was added in two methods to the asphalt concrete mixture for the wearing course. The first is the dry method, i.e., on the aggregate, whereas the second is the wet addition method, i.e., to the bitumen. The percentages were tried for each additional method; 1, 2, and 3% by weight of aggregate for the dry method and 0.5, 1, and 1.5% by weight of asphalt concrete for the wet method. The optimum asphalt cement contents were evaluated using the Marshall procedure. Asphalt concrete mixes were prepared at their optimum asphalt content and then tested to evaluate their durability properties, including moisture damage and permanent deformation. These properties have been evaluated using indirect tensile strength and uniaxial repeated loading tests. The results show that the NHL has improved the permanent deformation characteristics and resistance to moisture susceptibility.

Keywords: Nano Hydrated lime, TSR, Marshall Mix design, Permanent deformation (repeated load).

*Corresponding author
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تاثير النورة المطفأة النانوية على ديمومة الخلطة الاسفلتية الحار

حوراء جعفر الجبوري*، امجد حمد خليل البياتي

قسم هندسة النقل، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

لوحظ في السنوات الاخيرة ان بعض رصفات الخلطة الاسفلتية في بغداد ومدن العراق الاخرى ظهور فشل مبكر مما يترتب عليه من اثار سلبية على الناحيتين الاقتصادية ومستوى امان الطريق. ان استخدام مادة النورة النانوية (NHL) في الخرسانة الاسفلتية لانشاءالرصيف احد الخطوات الممكنة في تحسين ديمومة الرصيف. هذا البحث يدرس تأثير مادة النورة النانوية على ديمومة خليط الاسفلت الحارة. تمت اضافة النورة النانوية بطريقتين الى المزيج الاسفلتي للطبقة السطحية. الاولى هي الطريقة الجافة اي اضافته الى الركام الجاف بينما الطريقة الثانية هي الرطبة اي اضافته الى القيرالحار. تم تجربة ثلاث نسب مئوية لكل طريقة وكالاتي 1و2و3% من وزن الركام بالطريقة الجافة و0.5و 1و1.5 % من وزن الخرسانة الاسفلتية بالطريقة الرطبة.تم تقييم المحتوى الامثل للاسفلت باستخدام طريقة مارشال.تم تحضيير الخلطات الاسفلتية بالاعتماد على المحتوى الاسفلتي الامثل ثم فحصها لتقييم خصائص ديمومتها والتي تشمل الضرر نتيجة الرطوبة والتشوه الدائم. هذه الخصائص تم تقييمها باستخدام فحص مقاومة الشد واختبار الحمل المتكرر. اضهرت النتائج ان مادة النورة النانوية قد حسنت مقاومة التشوه الدائم و تلف الرطوبة.

الكلمات المفتاحية: النورة المطفأة النانوية, نسبة قوة الشد، تصميم خلطة مارشال، تشوه دائم (الحمل المتكرر)

1. INTRODUCTION

Some recently constructed asphalt concrete pavements in Baghdad and other cities across Iraq have prematurely failed in the last five years, detrimental to the economy and the safety of the roads. The primary failure types found in those newly constructed roads frequently include load-associated modes of failure (rutting and fatigue) and sporadically moisture damage in some poorly drained parts. Investigations into the causes of the failure beyond these found that there are two categories: intrinsic and extrinsic. The intrinsic category is limited to the mixture, improper gradients, and excessive use of natural sanitizer. The extrinsic category is caused by the heavy axle loading combined with the relentlessly high summer temperatures (ambient air temperature for nearly three months can reach 50 degrees Celsius, and pavement surface temperature can reach up to 60 degrees Celsius). Using HL could be one of the possible ways to improve the performance of asphalt concrete pavement (**Sebaaly et al., 2006; Al-Tameemi et al., 2016)**. Different fillers can change the physical or chemical properties of the binder in various ways because they have different qualities **(Kavussi and Hicks, 1997).** The following elements play a significant role in this modification process:

(1) Filler type (e.g., limestone powder, fly ash, hydrated lime, etc.)

(2) Concentration of filler in the mix.
The use of hydrated lime in asphalt concrete has been a topic of interest for researchers in t he industry for many years. Studies have shown that adding hydrated lime can improve the performance of asphalt concrete in several ways. **(Mohammad et al., 2000; Kennedy, 1984)** performed a mechanistic assessment of the necessary engineering characteristics of the Marshall-designed bituminous mixes that contain HL as defined by the indirect tensile strength, permanent deformation characteristics, modulus of resilience, and fatigue resistance. The outcomes exhibited that the HL addition as a mineral filler enhanced the permanent deformation characteristics and the fatigue endurance of the asphaltic concrete mixes. Such enhancement especially appeared at the higher testing temperatures with the polymer-modified asphalt and the limestone aggregate mixes. It has been found that using the HL as a reactive mineral filler can increase aggregate binding and matrix strength **(Lesueur et al., 2013; Preti et al., 2021; Khattak and Kyatham, 2008)**. Hydrated lime stiffens the binder above or at room temperature due to its highly tinny nature and high surface area **(Lime, 2010**). **(Hossain and Ullah, 2011)** carried out a study to assess the efficiency of lime as a modifier and a replacement for stone filler used in road paving asphalt concrete mixtures by dry addition method for four different lime percentages (1.0, 1.5, 2.0, and 2.5). Compared to the AC mixes without lime, the results showed that increasing the amount of added lime increased resistance to the adverse effects of water. Increases in the amount of lime are correlated with increases in tensile strength ratio (TSR) and the loss of stability. A study found that adding 2% HL by aggregate weight resulted in the highest stability and strength of asphalt concrete. However, another study by (Albayati et al., 2022)suggested that a dosage of 3% hydrated lime may be more suitable for improving the fatigue resistance of asphalt concrete. Also, they investigated three different hydrated lime (HL) sizes ranging from nano, sub-nano, to microscales. The researcher stated that the efficacy of asphalt concrete against rutting, moisture damage, and the fineness of the HL particles are positively correlated. The authors suggested that 1.5 % of NHL could compensate for the 3% of normal size HL. Because of the above preface, little information exists in the literature about using NHL in asphalt concrete **(Albayati, 2012)**. Therefore, this research attempts to bridge the gap in the literature about the effect of NHL on the durability of asphalt concrete mixes. The environment in Iraq is epitomized by high temperatures in summer coupled with heavy axle loads, which hastens the premature deterioration of asphalt concrete pavement. The primary distress type in newly constructed pavements was moisture damage and accumulation of permanent deformation in the asphalt concrete surface layer **(Mohammad et al., 2008)**.
This study investigated using hydrated lime in a nanoscale to reduce the possibility of performance reduction due to the two types of distress and produce more durable asphalt concrete mixtures.
This work aims to determine the effect of nano-hydrated lime on the durability of a hot asphalt mixture. Two NHL addition methods are considered, dry and wet. The optimum asphalt cement contents shall be evaluated using the Marshall method. Asphalt concrete mixes will then be prepared at their optimum asphalt content and tested to evaluate their durability properties, including moisture damage, resilient modulus, and permanent deformation.

2. MATERIALS

2.1 Asphalt Cement

Concerning the hot mix asphalt, one type of asphalt cement was used for this study. It is produced in the Al-Dura petroleum factory with a penetration grade of (40-50). **Table 1** lists the asphalt cement's physical characteristics. Also, the results are compared to the specifications provided by the State Corporation for Roads and Bridges (SCRB R9, 2003) Asphalt cement fulfills the requirement.

Table 1. Physical Properties of AC 40/50

Test	Unit	Result	Specification limit **(SCRB R9, 2003)**
Penetration at 25°C, 100 gm, and 5 sec	mm	44	40-50
Softening point RandB **(ASTM, D36, 2003)**	°C	52	----
Specific gravity at 25°C **(ASTM, D70, 2003)**	----	1.02	----
Flashpoint	°C	280	Min. 232
Ductility	cm	129	Min. 100
Residue from thin film oven test			
Retained penetration, % of original	%	56	Min. 55
Ductility at 25°C, 5 cm/min, (cm)	cm	86	Min. 25

2.2 Coarse and Fine Aggregate

The aggregate used in this work was crushed quartz obtained from the Amanat Baghdad asphalt concrete mix plant located in Al-Obaidy, east of Baghdad; its source is the Al-Nibaie quarry. This aggregate is widely used in Baghdad city for asphaltic mixes. The coarse and fine aggregates used in this work were sieved and recombined in the proper proportions to meet the wearing course gradation as required by SCRB specification **(SCRB R9, 2003)**. Routine tests were performed on the aggregate to evaluate their physical properties. The results and the specification limits set by the SCRB are summarized in **Table 2**.

Table 2. Physical properties of aggregate

Property	Coarse Agg.	Fine Agg.	**(SCRB R9, 2003)**
The bulk specific gravity (g/cm) **(ASTM C127, 2012; ASTMC128, 2012)**	2.636	2.62	----
The apparent specific gravity (g/cm) **(ASTM C127, 2012; C128, 2012)**	2.646	2.65	----
The water absorption percentage **(ASTM C127, 2012; ASTM C128, 2012)**	0.139	0.52	----
The wear percentage (Los Angeles Abrasion) **(ASTM C 131, 2006)**	18.89		max. 30
The percentage of fractured pieces	96		max. 90
The sand equivalent		53	min.45
The soundness loss by Sodium Sulfate solution percentage	3.5		12 max.

Test results show that the chosen aggregate met the SCRB specifications. The gradation for the aggregate is presented in **Table 3.**

Table 3. Selected gradation for wearing course

Sieve size		Wearing course	
Inch	mm	Selected gradation	Specification limit **(SCRB R9, 2003)**
¾	19	100	100
½	12.5	95	100-90
3/8	9.5	83	79-90
No. 4	4.75	59	44-74
No. 8	2.36	37	28-58
No. 50	0.3	13	5-21
No.2 00	0.075	7	4-10

2.3 Mineral Filler

Local ordinary Portland cement, which is compatible with the requirements of SCRB specification (SCRB, R9 2003), was used for this research work. The physical properties of Portland cement, a non-plastic material passing through sieve No. 200 (0.075 mm), are presented in **Table 4.**

Table 4. Physical characteristics of the natural Portland cement

Property	Result of test
The bulk specific gravity	3.20
Passing sieve No.200 (0.075mm)	97%

2.4 Additive (Nano Hydrated lime)

Hydrated Lime ($Ca(OH)_2$) is a dehydrated powder mostly comprised of Calcium Hydroxide Ca(OH)2. It's determined by the hydration of Quicklime (principally Calcium Oxide, CaO) utilizing particular hydration equipment. CaO is produced by the combustion of limestone of too high purity (prepared from Calcium Carbonate, $CaCO_3$) at temperatures of about (900°C) into the devoted kilns according to the National Lime Association (NLA) **(NLA, 2003)**, the usual HL grades appropriate for most chemicals objectives possess (85%) or more that passes throughout the sieve no. 200, where for special uses, it may be determined as fine as (99.5%) that passes the sieve no. 325. And the below chemical equation evinces the HL formation from the limestone **(Boynton, 1980; Crossley, 1999)**

$$CaCO_3 \rightarrow CaO \rightarrow Ca(OH)_2$$

NHL has acquired a substantial appreciation as a beneficial additive to improve asphalt pavement performance. It's added to specific low-grade aggregates rendering them appropriate in asphalt mixture for use in a highway building. Occasionally, it's hard to coat a definite aggregate with asphalt due to its acidic or siliceous surface. Adding NHL often improves the coating ability and ponding properties of asphalt of this aggregate **Table 5**. shows the Physical and Chemical properties of hydrated lime on a nanoscale.

Table 5. Physical and Chemical properties of Nano hydrated lime.

Material property	NHL
Average particle size (nm)	93.4
Surface area to volume ratio	85.5
200 Mesh (75μm) passing	100
% CaO	56.1
%SiO_2	1.38
%Al_2O_3	0.72
%Fe_2O_3	0.12
%MgO	0.13
%SO_3	0.21
%L.O.I.	40.65

3. EXPERIMENTAL WORK

The present section comprises the conducted tests depiction for mix design as well as evaluating the HMA mixtures durability for the wearing course utilizing NHL in two various methods: Dry method (dry lime supplemented to the dry aggregates) and Wet method (dry lime supplemented to the asphalt cement) before the asphalt blending in three different contents for each method; for the first one (1.0, 2.0 and 3.0%) by the aggregate weight as a cement feller substitution **(Albayati and Mohammed, 2016)** and for the second one (0.5%,1%, and1.5%) by weight of mixture to introduce NHL for the asphalt cement the asphalt binder, heated at 150°C, and blended by a shear mixer device set at 12000 rpm for 20 min, as displayed in **Fig. 1.** Asphalt concrete mixtures were produced using the optimum amount of asphalt cement according to the Marshall method for mix design. They were then tested for moisture susceptibility employing the Indirect Tensile Strength (ITS) as well as for permanent deformation utilizing uniaxial repeated load test.

(a) **(b)**

Figure 1. Hydrated lime and mixing device, a) Hydrated lime, b) Mixing device

3.1 Marshall Mix Design

Using the graduation requirements listed in **Table 2**, various aggregate fractions were retained on sieves no.12. 3/8, no. 4, no. 8, no. 50 and no. 200, and the mineral filler was combined into an (1150 g) batch. Then, the aggregate blend was heated in a container to roughly (150°C) for (2 hr.). To accomplish a (170 c.St) viscosity, asphalt cement was also heated separately for (2 hr.) at a controlled temperature of (155°C). The mixture was then precisely blended for two min at (155°C), while a precise asphalt binder quantity was added to it by the prescribed percentages (4.0, 4.3, 4.6, 4.9, and 5.2 % by weight of the mixture). As soon as the mixture was prepared for compacting, it was then located in a furnace at a controlled temperature (146°C) of compaction (matching to a (280 c.St) viscosity) for ten min. After that, they were dispatched into cylindrical specimens having a diameter of 101.6 mm (4 inches) and a height of 63.5 mm (2.5 in), as well as compacted utilizing (75) blows per face by the Marshall Compactor. After overnight, the specimen was extracted from the mold, and volumetric test parameters (i.e., weight and dimension) were determined. Then, it was submerged in water at 60°C for (30-45 min.) before testing for stability and flow.

3.2 The Repeated Load

The cylindrical specimens used in this study have a diameter of 101.6 mm (4 in) and a height of 203.2 mm (8 in). The aggregate fractions were divided into coarse and fine groups, and the aggregates retained on the pan were discarded and replaced with mineral filler (Portland cement). The aggregates were combined into a batch of 3800 g and heated in a temperature-controlled oven to 150°C. A container containing asphalt was likewise heated to a temperature between 145 and 150°C for 2 min, and the bowl contents were completely blended manually on a hot plate. The bowl and its contents were placed in an oven and heated to 140 °C for 10 minutes to guarantee a consistent compaction temperature 101.4 mm (4-inch) paper disk was added to cover the mold base plate after the compaction mold was heated to 100°C. To make it easier to remove the specimen, the internal edge of the mold was greased with a brush. Then, in the laboratory of Materials of the Department of Civil Engineering at Baghdad University, a hydraulic compression machine was used to compact the specimen using the double plunger method while applying a weight of 65000 lb (29491 kg) **(Kakade et al., 2018)**. The weight was applied to both ends of the specimens for one minute. A hydraulic extractor was used to carefully remove the specimens from the molds after they were cooled overnight at 25°C and had the ideal amount of NHL. The samples were classified and stored in bags. **Fig. 2** exhibits the repeated loading device and specimen.
The permanent strain (εp) is computed as:

$$\varepsilon_p = \frac{P_d \times 10^6}{h} \qquad (1)$$

where:
ε_p is an axial permanent microstrain
P_d is permanent axial deformation
h is the height of the specimen
This investigation's permanent deformation test results are illustrated in Eq.2 **(Monismith et al., 1975; Barksdale, 1971)**.

$$\varepsilon_p = aN^b \tag{2}$$

where ε_p is a permanent strain, N is the stress application number, a is the coefficient of intercept, b is the coefficient of Slop

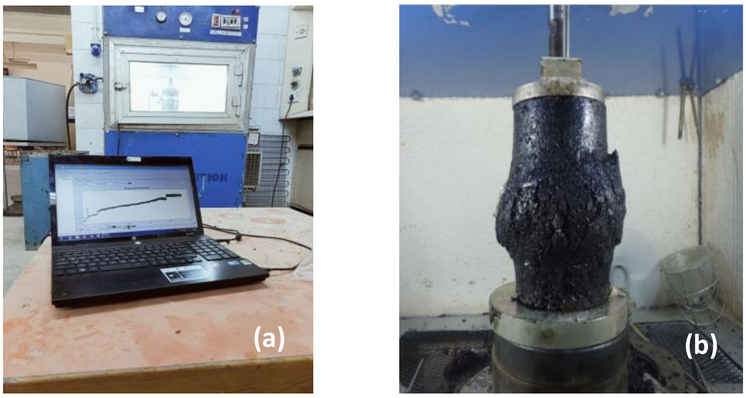

Figure 2. Repeated loading device and cylindrical specimen (a) Repeated loading device and (b) cylindrical specimen

3.3 Moisture Susceptibility Test

The susceptibility of the moisture of the asphalt concrete mixes was assessed according to the **(ASTM, D 4867-14,2009)** for the indirect tensile strength (ITS) **(Hicks, 1991; Hadi, 2017;** . Specimens of every mixture were prepared according to the Marshall technique and compacted at the two ends to achieve a (7±0.5%) air void content. Also, 6 specimens were prepared for every mixture. Then, they were divided into two groups: 3 for the control were straightly tested at a temperature of (25°C), and the other 3 for the conditioned were exposed to a cycle of freezing as well as thawing experience at (−18±2°C) (16 hr), pursued by another at (60±1°C) for (24 hr), before the tensile test at (25°C). In the ITS test, a compressive load was applied alongside the cylindrical specimens' diametric axis at a (50.8 mm/min) rate. **Fig. 3** exhibits the device and specimen of the ITS test.

$$ITS = \frac{2P}{\pi t D} \tag{3}$$

$$TSR = \frac{ITS_c}{ITS_d} \tag{4}$$

where ITS is Indirect tensile strength, P is the Ultimate exerted load, t is the specimen's thickness, D is the specimen's diameter. The other factors are well-defined earlier.

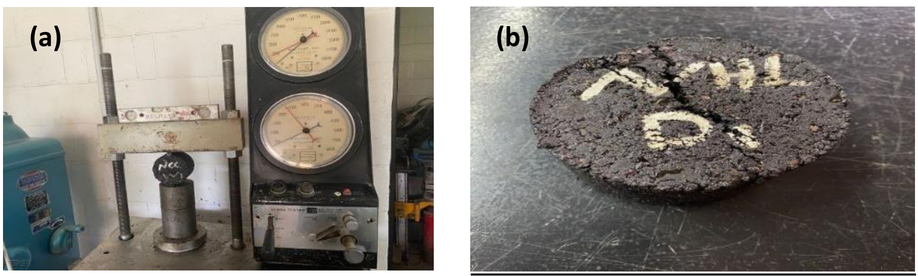

Figure 3. ITS device and the specimen, a) ITS device, b) specimen

4. RESULTS AND DISCUSSION

The tests conducted are to design the mixes and evaluate the durability of HMA mixes for wearing courses using two additional methods of nano-hydrated lime (dry and wet) and the content. Following the Marshall method for mix design, asphalt concrete mixtures with the optimal amount of asphalt cement were prepared and then tested for moisture susceptibility using Indirect Tensile Strength (*ITS*) and permanent deformation using a uniaxial repeated load test.

4.1 Optimum Asphalt Content in the Mixture

The optimal content of the asphalt of the Bituminous mixes is obtained depending on the mean values that fulfill the needs groups for the Marshall Stability, Marshall Flow, voids of air, VMA, and VFA. According to the Marshall approach, a comprehensive mix design process was carried out **(ASTM D6926., 2010)**. The three asphalt cement contents that produce the best stability values were averaged to determine the OAC, unit weight, and air voids of 4%. As a result of averaging the asphalt cement concentration over the three properties described above, the OAC is 4.9%. As presented in **Fig. 4**

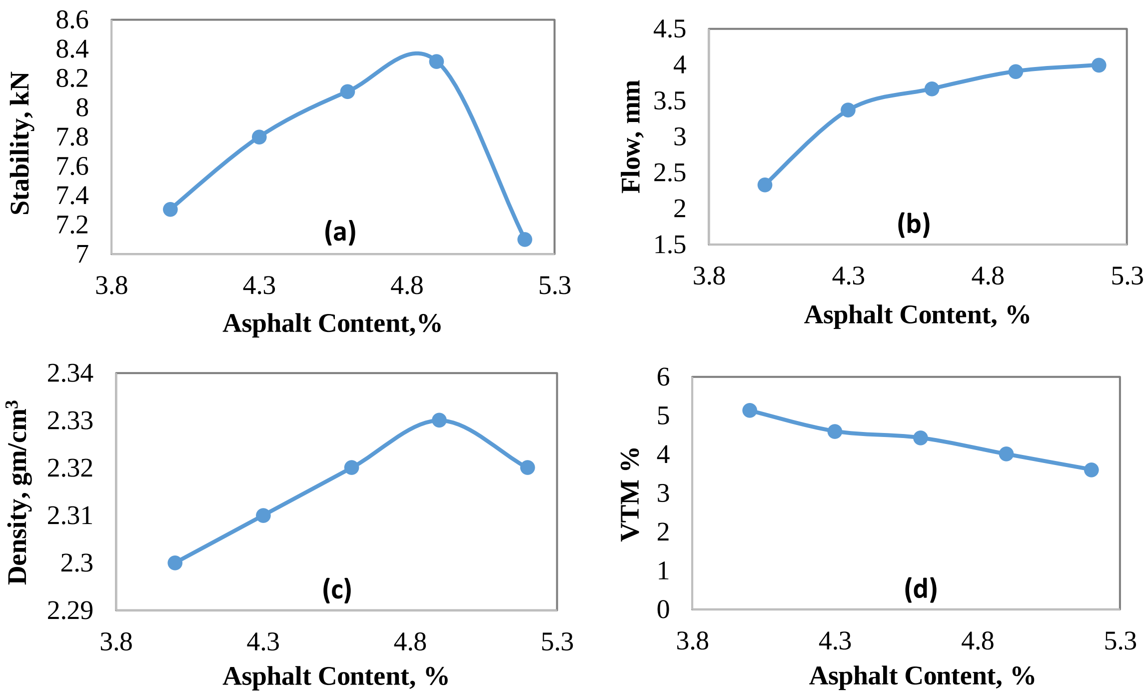

Figure 4. Relationship between asphalt content and Marshall properties, a) Stability, b) Flow, c) Density, d) VTM

4.2 Optimum Nano Hydrated Lime Content

Marshall Stability and Flow tests were carried out on specimens prepared using three percentages of nano-hydrated lime for both dry and wet methods at the OAC of 4.9. The optimum contents were 1.5% for the hydrated lime wet method and 3% for the hydrated lime dry method. According to the comprehensive outcomes of the measured Marshall characteristics (Marshall Stability and Flow) **(Blažek et al., 2000; Yardim et al., 2019)**, which can be seen in **Figs. 5 and 6**, the content of hydrated lime continuously increases over the investigated content of NHL with stability. The highest content of NHL was chosen as the optimum content, which produced the best results.

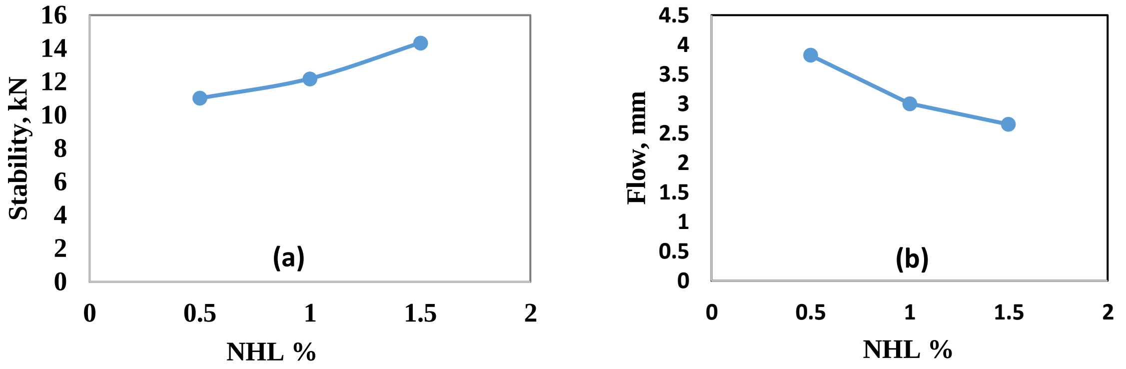

Figure 5. The effect of NHL (wet method) on stability and flow, a)The effect of NHL (wet method) on stability, b) The effect of NHL (wet method) on flow

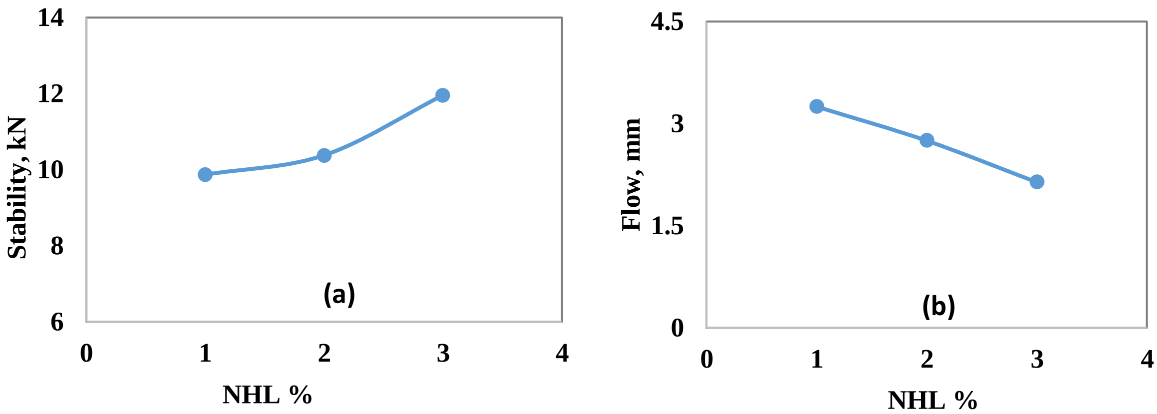

Figure 6. The effect of NHL (dry method) on stability and flow, **a)**The effect of NHL (dry method) on stability, b) The effect of NHL (dry method) on flow

4.3 Influence of Optimum Hydrated Lime Content on Marshall Properties.

The addition of slaked lime as an additive to asphalt increased the Marshall Stability by 1.5% by the wet method, i.e., by adding NHL to the asphalt cement, and by 3% by the dry method, i.e., by adding NHL to the aggregate by the filler replacement method, as observed in **Fig. 7**. The maximum increase in Marshall Stability was 72% for the wet method and 43% for the dry method. The increment was escorted by a reduction in flow values by 28% for the wet and 42% for the dry methods. The air voids decreased by 22.7% for the wet method and by 17.8% for the dry method. All values were within the allowable range. Conversely, the NHL addition raises the asphalt cement's viscosity **(Kim et al., 2003; Little and Petersen, 2005; Zeng and Wu, 2008; Sebaaly et al., 2002).** These results can be explained by the fact that the NHL addition augmented the fine materials in the mixes of asphalt, and as a result, the air voids decreased while these materials absorbed more asphalt. The increase in bulk density caused by the decrease in the air void values leads to an obvious increase in Marshall Stability **(Nataadmadja et al., 2020)**. **Table 6** includes the test results.

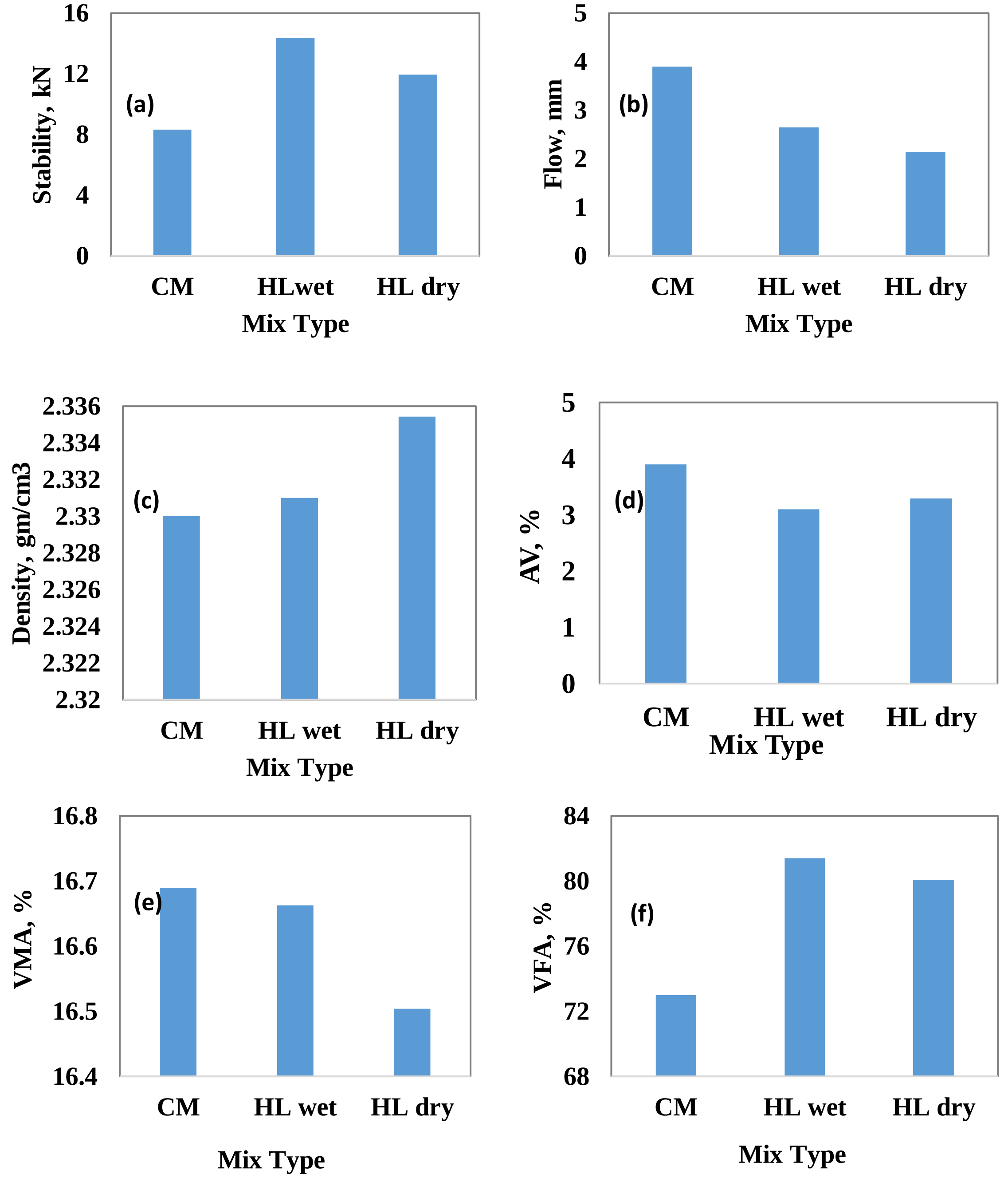

Figure 7. Effect of mix type on the Marshall Property: a) Stability, b) Flow, c) Density, d) AV, e) VMA, f) VFA

Table 6. The Influence of mix type on the Marshall properties for the Asphalt grade

Mixture	Stability kN	Flow mm	Density (gm/cm^3)	AV %	VMA %	VFA %
CM	8.31	3.71	2.330	4.01	16.69	73
NHL wet method (1.5%)	14.33	2.65	2.331	3.09	16.66	81
NHL dry method (3%)	11.96	2.14	2.335	3.28	16.50	80

4.4 Influence of NHL on Tensile Strength and Moisture Susceptibility

The NHL addition to the asphalt mixtures improves tensile strength outcomes for the two additional methods, i.e., dry and wet. As a result, the values of TSR for the two mixture kinds were higher, while the ultimate increase of the wet method happened at an NHL content of 1.5%. Also, the ultimate value of TSR was augmented by 11.7% above the control mix; the results are in agreement with **(Ismael and Ahmed, 2019)**. Similarly, the ultimate value of TSR for the dry method at 3% of lime was higher by 20.16% than the control mix. And, the Ca inclusion into the lime material strengthened the bond among the aggregates. According to the scientific interpretation, the asphalt cement's surface texture and the film may have had a chemical reaction that improved the moisture damage resistance **(Behbahani et al., 2020; Al-Marafi, 2021)**. **Fig. 8** portrays the influence of NHL (dry and wet) on the conditioned and unconditioned ITS, while **Fig. 9** demonstrates the influence of NHL (dry and wet) on TSR.

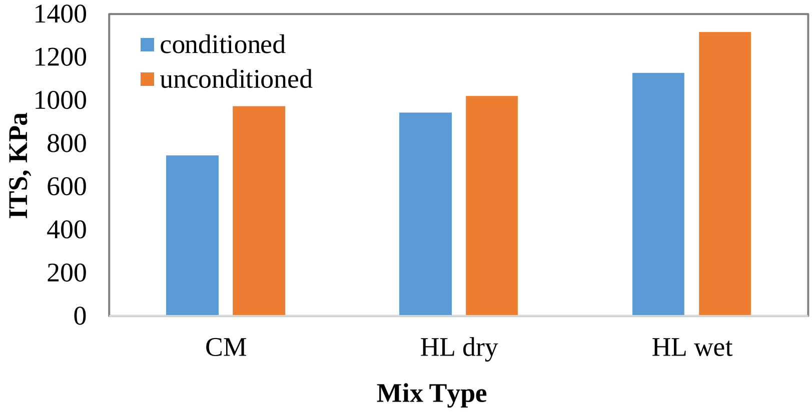

Figure 8. Effect of mix type on conditioned and unconditioned ITS

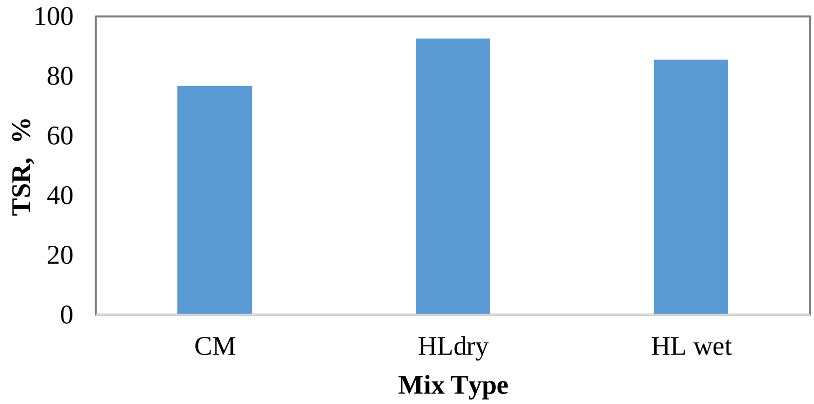

Figure 9. Effect of mix type on TSR

4.5 Influence of NHL on the Permanent Deformation

Fig. 10 depicts the test results of the permanent deformation measurement under the repeated uniaxial load (schemed on a log-log scale). By employing Eq. 2 for representing the relationship, two parameters, i.e., the intercept and the slope, are linked to the potential of material deformation. **Table 7**. compares the fitting lines' slope and intercept parameters.

The outcomes revealed that adding hydrated lime on a nanoscale enhanced the asphalt concrete's rutting resistance. Utilizing the nano-sized particles made the uppermost enhancement, and at the content of hydrated lime of 1.5% wet method, the lowermost slope and intercept values at 3% for dry method being greatly lesser than the optimal, respectively. It was noted that the intercept and the slope values for the dry method at the content of hydrated lime of 3% were (31.4%) and (13.2%), respectively, and were substantially lower than the control mix's optimal values. The percentage of slope for the wet method at 1.5% HL was the lowest by (29.3%) from the control mix, while the intercept value for the wet method at 1.5% HL was the greatest by (33.7%) when compared to the unmodified mixture for the control mixture. The mean decrease in the permanent strain experienced after 10,000 load repetitions was about (14.7% and 63.9%) for dry and wet mixes, respectively. The main outcomes evinced the better performance of the NHL in generating a high-stiffness asphalt concrete as well as raising the contact of stone-stone, which caused an effective spreading and a decrease in the strains and stresses placed on the structure of pavement by the loading of traffic, thus also decreasing the likelihood of a high temperature rutting distress in asphalt concrete pavement **(Kakade et al., 2018)**.

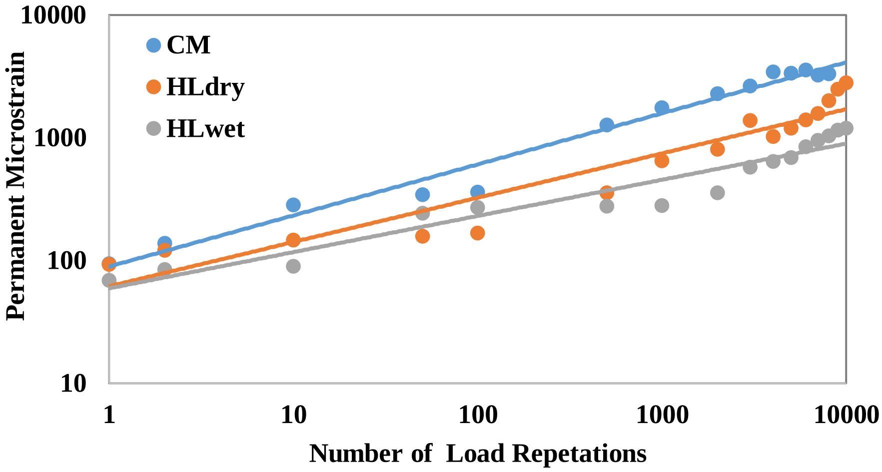

Figure 10. The effect of mix type on the permanent deformation

Table 7. Effect of the mix type on the coefficient of permanent deformation

Mixture	coefficient of permanent deformation at 40 °C		
	a	b	(ε_p) at N=10,000
CM	89	0.416	3290*
Hydrated Lime (dry)	61	0.361	2805
Hydrated Lime (wet)	59	0.294	1185

*CM failed at N=8020

5. CONCLUSIONS

This study aims to determine the effect of hydrated lime on a nanoscale on the durability of the asphalt concrete mixture. Two additional methods were adopted, dry and wet. Three percentages of NHL content for each addition method were investigated. Marshall properties and durability properties were evaluated. The durability of the asphalt concrete mixtures was evaluated regarding moisture susceptibility using indirect tensile strength (ITS) and permanent deformation using the uniaxial repeated load test. The following conclusions can be drawn based on the limited test results obtained in this study.

1- As compared with the conventional asphalt mixture, both NHL addition methods increased the Marshall Stability by 43% and 72% for dry and wet methods, respectively,
2- Marshall flow outcomes were reduced by (28% and 42%) for (dry and wet) methods, respectively, compared with the conventional asphalt mixture.
3- The nano-hydrated lime addition reduces air voids in the asphalt mixes. The reduction value was 22.7% for AC (40-50) for the wet method and 17.8% for the dry method compared to the conventional asphalt mixture.
4- Nano-hydrated lime greatly improved tensile strength ratio results. The percentages of the NHL of 1.5% for wet and 3% for dry produced the highest results. The improvement in TSR results is 11.7% and 20.16% for the mixes with dry and wet addition methods compared to conventional asphalt.
5- At relatively high temperatures (40°C), the influence of nano-hydrated lime addition is more pronounced in resistance to permanent deformation. It can be inferred that 1.5% for the wet method and 3% for the dry method of hydrated lime content will achieve an optimum mixture with the highest resistance to rutting. The slope for the wet method at 1.5% HL was lower by (29.3%) from the control mix, whereas the corresponding reduction for the dry method is 13.2 %.
6- The use of NHL significantly improved the performance of asphalt concrete; it also provides the possibility of producing more durable mixtures with higher resistance to distress in terms of moisture damage and permanent deformation.

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