Volumetric Properties of Hot Mix Asphalt Containing Subnano-Sized Hydrated Lime (SNHL)

J. Shen, W. Brazell, J. Pankiw & T. DeKalb
Department of Construction Management and Civil Engineering Technology, Georgia Southern University, Statesboro, GA, 30458, USA

B. Tang
Chongqing Jiaotong University, No. 66, Xuefu Road, Nan'an District, Chongqing, 40007, P.R. China

G. Fu
Jiangsu Transportation Research Institute Co. Ltd, 223 Shui xi men st. Nanjing, China, 210017, P.R. China

ABSTRACT: Fine hydrated lime (HL) that has more surface area may increase the chemical bond between asphalt cement (AC) and aggregate, leading to an improved anti-stripping performance of hot mix asphalt (HMA) added with HL. The purpose of this study is to investigate the influence of the different percentages of a subnano-sized hydrated lime (SNHL) of 660 nanometers on the volumetric properties of the HMA. A commercially available HL was broken down into the subnano-sized particles by using a LA abrasion machine. The SNHL was then introduced into mixtures at 0.5, 1.0, and 1.5%. Optimum asphalt contents (OACs) were obtained for the asphalt mixtures designed with the various amounts by Marshall Method. Indirect Tensile Strengths of HMA samples prepared at the OACs were obtained. HMA samples added with conventional HL at 1.0% were tested as controls. Results from this study indicated: 1) The OACs of the HMA containing SNHL was about 8% less than that containing the controls; 2) The ITS and TSR of the samples containing 0.5% SNHL were even better than the controls containing 1.0% of conventional HL.

KEYWORDS: HMA, anti-stripping, lime, nano, size

1. INTRODUCTION

The practice of including additives within HMA is an idea that has been around since it was first created (Button, et al., 1987). The purpose behind this is to improve the properties of HMA, including the physical and mechanical outcomes of stripping, crack and rutting. Stripping is one of the severe problems that HMA is unable to resist failures, mainly due to moisture that is trapped in the mix and inhibits the mix from performing at its expected potential. Introducing HL in a mix plant for the production of asphalt mixtures is a prominent solution to improving this failure. The HL that is added to the mix was first intended to improve the resistance to moisture and eliminate the possibility of stripping failure, however, it has other benefits that have since been discovered including the resistance of fatigue, rutting, and cracking (Tunnicliff and Root, 1981). HL has essentially improved the overall quality of HMA by acting as mineral filler.

Researches available have released the mechanism for the HL added in HMA to work as an anti-stripping agent. When the mix is made, the HL enhances the bonds between asphalt binder and aggregate. After the HMA is finished, the HL becomes an anti-stripping agent by reacting with highly polar molecules inhibiting the formation of water-soluble soaps that cause stripping. The reaction between the lime and polar molecules creates an insoluble salt that repels water.

The effectiveness of the application of HL into a HMA on the properties of HMA is dependent on, but not limited to, the amount of HL, the type of binder and aggregate, and the way the HL is introduced. The optimum percentage of HL to be added is practically between one and two percent by weight of the mix, according to the specifications proposed by most of the Department of Transportation in USA. In addition, the size of the particles of HL may expect a large impact on the properties of HMA. The finer the HL, the more the reaction will be between the binder and the aggregate, since a finer particle has more surface and more active. Many state departments of transportation (DOTs) require the HL satisfy the ASTM C 1097, i.e., a minimum passing percentage of 85 is specified for sieve No. 200 (75 micrometer), for the production of HMA mixtures. Knowing this, it is hypothesized that HL with decreased particles will perform better than regular HL that is used currently in USA. HL currently used in mix plant is largely in the range of a micrometer size. The subnano or nano-sized HL will have a surface area larger than the regular lime, leading to an increased reaction between the aggregate and the binder thus strengthening the bond between the two.

A previous study investigated the influence of subnano-hydrated lime (660 nanometers) (SNHL) on the anti-stripping properties of HMA by adding 1% of the SNHL (Shen, et al., 2009). The ITS increased averagely 10% for the samples added with SNHL more than those with normal HL.

The objectives of this research are

1) To investigate the influence of different percentages of SNHL on the volumetric properties of the HMA;
2) To determine Indirect Tensile Strength (ITS) and Tensile Strength Ratio (TSR) of asphalt mixtures added with various percentages of SNHL.

To this end, a commercially available HL with an average particle size of 1.38 micrometers was used for the production of the SNHL particles. A particle size of 660 nanometers of the SNHL was produced by using LA abrasion machine in laboratory. That is the finest size that could produce using the LA abrasion machine. A currently-used dense graded HMA mixture in the state of Georgia, GA, USA, was designed by Marshall Method for this study. The HMA mixtures containing 0.5, 1.0 and 1.5 % of SNHL were employed to determine the volumetric properties. Optimum asphalt content was obtained from the mixtures for each % of SNHL. Further, asphalt samples were produced with the OACs for each SNHL content. The indirect tensile strength test and TSR were obtained to evaluate the moisture sensitivity. HMA containing 1% of conventional HL was investigated as a control.

2. MATERIALS AND TEST METHODS USED

2.1 Materials:

- Coarse and fine granite aggregates labeled as 089, M10, &W10 were used to blend into a normal maximum size of 9.5mm gradation of aggregate, that is currently used in the State of Georgia.
- Asphalt Binder with grade of PG67-22 was used.
- HL used for the production of SNHL is a commercially available one used in the mix plants for the Department of Transportation in the state of Georgia, USA. The average size of the HL was measured to be 1.38 microns, a value corresponding to rotation zero in Table-1.The SNHL used was produced using a LA abrasion machine under the condition that rotations of 500 were applied for the drum filled with 12 steel balls and 500 grams of HL. The size of the lime particles took from the LA abrasion machine after 500 rotations was measured using a powerful microscope and found to be 660 nanometers, which is actually a subnano-sized hydrated lime (abbreviated as SBHL in the research). That is the tinniest particles that could be created using the LA abrasion machine (Shen, et al., 2009).

Table 1. HL size with the rotations of LA abrasion drum (after Shen, et al., 2009)

Rotation	0	250	500	1000	2500
Average microns	1.38	1.35	0.66	0.61	0.60
STDEV	0.56	0.54	0.35	0.32	0.25

2.2 Test Methods:

ITS test method: Four different mixture types were used for the production of hot-mix asphalt (HMA) with the OAC obtained from the Marshall Method. Of the four mixture types, one was produced with conventional HL while the other three employed the varying quantities of SNHL, i.e., 0.5, 1.0 and 1.5%. Six HMA samples were produced for each mixture type. Two subsets with three samples each were made for the purpose of dry and wet conditioning before testing. The subset for dry condition was stored at room temperature 77°F (25°C) while the subset for wet conditioning was placed into a 140°F (60°C) water bath and allowed to soak for 24 hours. After 24 hours the wetted samples were removed from the bath and placed into another water bath at 77°F (25°C) for one hour.

To determine the indirect tensile strength (ITS) of the samples, both wet and dry subsets were removed from the water baths and tested within one minute from removal. The samples were placed into the testing machine and aligned such that the load was applied directly along the diameter of the specimen. The testing machine provided a constant rate of movement of two inches (50mm) per minute. The load was continuously applied until a vertical crack appears along diameter of sample. The maximum load was recorded for each sample and applied to the indirect tensile strength.

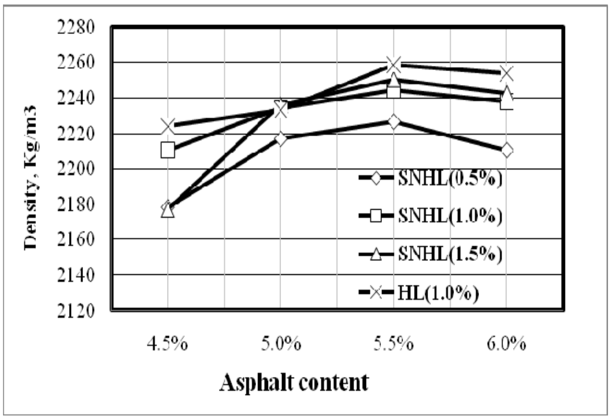
3. RESULTS AND DISCUSSIONS

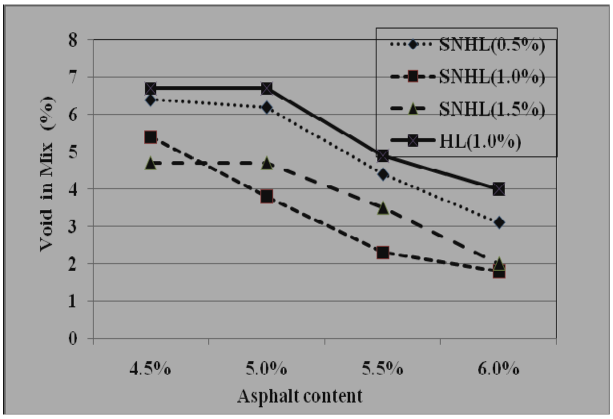
3.1 Density, void, VMA, stability of mixtures

The volumetric properties of HMA mixtures with different percents of 0.5, 1.0 and 1.5% SNHL were calculated on the samples made by Marshall Method, see Figures 1 a) to f). Those of the controls with 1% conventional HL were also presented in the same Figures 1 a) to f) for comparison purpose. In genearal, the densities of the HMA mixtures with SNHL were increased and the void ratioes of the mixtures were decreased as the % of SNHL was increased from 0.5 to 1.5%. This finding may indicate the fact that the SNHL worked more likely as a liquid in the mixtures during the mixing process and compaction, resulting in the difference of the compaction degree. A proper amount of SNHL, a value at which a mimimum void and maximum density was achived, was found as 1% in this research for an example. The asphalt content was still a predomnt factor to the density and void ratio of HMA mixtures with vairous of the % SNHL, as can be found that a high % of SNHL added in the mixture produced a high density and a low void. This was aslo true for controls.

The densities of controls were higher than those of the HMA mixtures added with SNHL, whileas, the void of the controls were higher than those of the HMA mixtures. A high density of a mixture should have a less void. This was not the cases for the HMA added with normal HL and SNHL. The reason for this finding could be resulted from the difference of the mastics of the mixtures added with SNHL and HL. Obviously, in the reseach, mastics of binder and SNHL was problabely lighter.

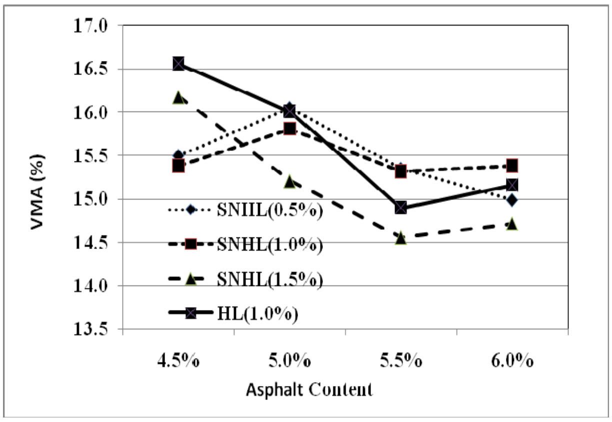
The VMA of the HMA added various SNHL in general decreased as the % of asphalt content was increased. However, the results did not indicate any distinct trend of the influence of the percentage of SNHL on the VMA. Moreover, there was no obvious evidence that can tell the influence of the size of HL on the VMA.



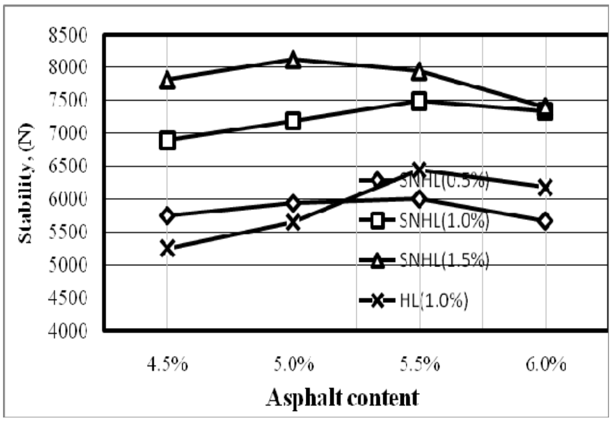


a) Density

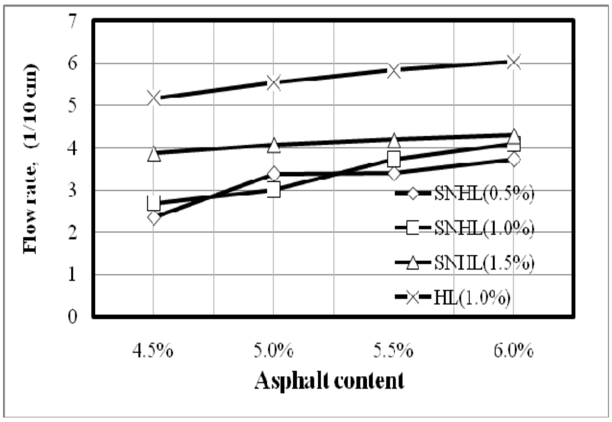
b) Void



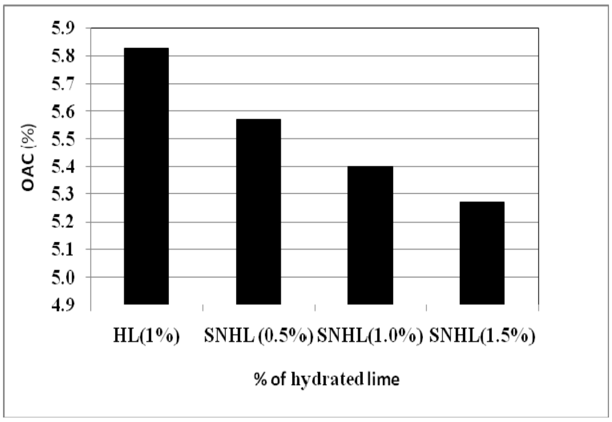
c)VMA



d) Stability



e) Flow



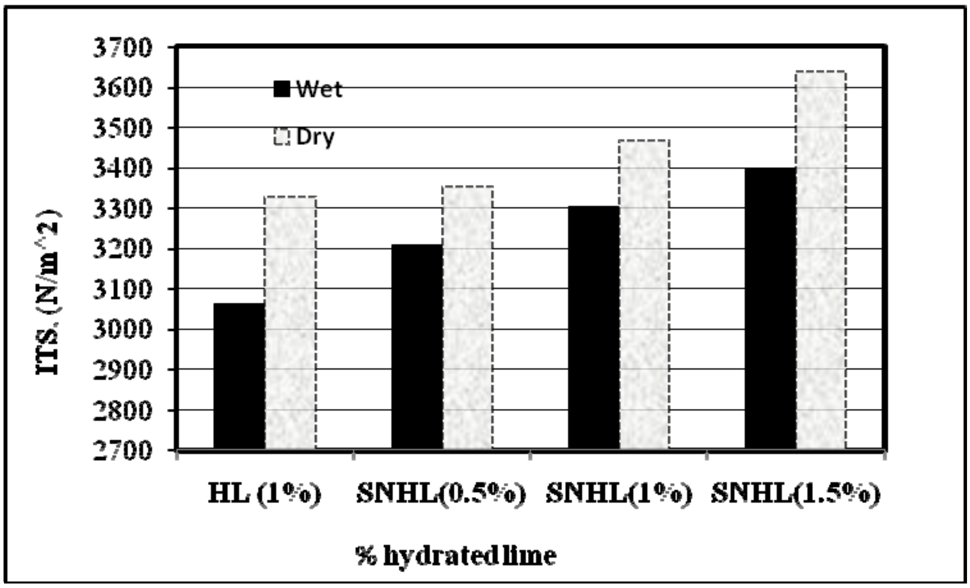
f) OAC

Figures 1 a) to f), Volumemetric Properties of HMA mixtures containing vaiouse of SNHL: a) density; b) void; c) Stability; d)VAM; e) flow; f) OAC

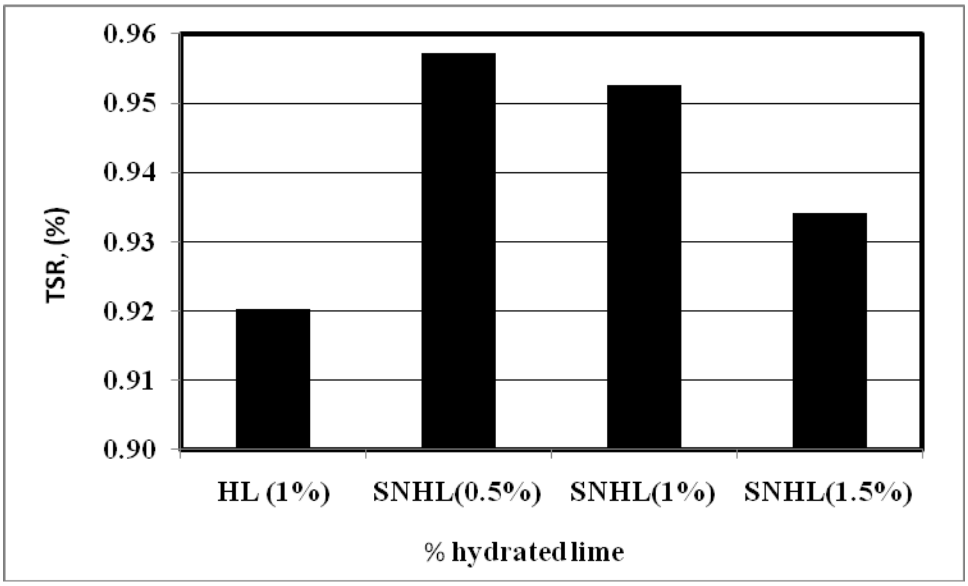
The stability and flow of the samples added with various of % SNHL were also presented in the Figures 1. In general, the stablity of the samples increased signifcantly with the % of SNHL. In addition, the stability of the HMA mixtures with SNHL reached a maximum value for the range of asphalt contents discussed. Generally, the stablity of the HMA samples containing 0.5 % SNHL was changed with the asphalt contents in the same range of the stability of the controls. The flow values of the samples with various of % SNHL increased generally as the % of SNHL increased. This increase was especially obvious when a low asphalt content was added. The flow value of the controls was much larger than that of the mixtures added with SNHL.

Optimum asphalt contents of the mixtures added with various of SNHL and the control was presented in Figure 1 f). In general, a trend was found that OAC of the mixtures added with SNHL was less than the control. Moreover, the OAC of the mixtures decreased with the increase of the % of SNHL. A 8% of OAC was reduced for the mixture added with 1% of SNHL comparing with the control.

3.2 Indirect Tensile Strength tests for ITS and TSR values



a) ITS



b) TSR

Figures 2 a), b) ITS and TSR of HMA mixtures added various of SNHL: a) ITS; b)TSR

Figures 2 a), b) present the Indirect Tensile Strength and Tensile Strentn Ratio (TSR) of the mixtures added with SNHL at various % and the controls as well. The ITS of both the dry and wet samples added with SNHL increased as the percentage of SNHL increased and, although the increase is higher for dry samples than wet samples. The TSR of the samples decreased as the amoutn of SNHL increased, but this decrease was slight. It may be noted that the ITS and TSR of the samples with 0.5 % of SNHL were even a little bit higher than those of controls.

4. SUMMARY AND CONCLUSIONS

This project was completed with the purpose of improving the anti stripping properties of HMA with an addition of a finer HL into the asphalt mixture. Lab work was conducted to break down by a LA abrasion machine the lime into much smaller, subnano-size (660 nanometers) (SNHL), and then added the SNHL to make HMA. The results are:

- The volumetric properties of the HMA mixtures changed with the % of SNHL added, regardless of the asphalt content. Density of the mixture was increased, while void ratio in general decreased as the content of the SNHL was increased from 0.5 to 1.5%. The SNHL worked more likely as a liquid than normal HL.
- The stability of the HMA mixture added with SNHL was bigger and flow value was smaller than the mixture added with tradition lime.
- Results from the HMA using Marshall Design method indicated that OAC of the HMA containing SNHL is about 8% less than that containing conventional HL.
- The ITS and TSR of the sample containing 0.5% subnano-sized hydrated lime are about the same as those of the samples containing 1.0% conventional HL.
- The influence of true nano-sized HL on the properties should be further studied.

ACKNOWLEDGEMENT: The research was supported financially by a Faculty Committee Award for FY10, Georgia Southern University, GA. USA.

MAIN REFERENCES

Shen, J., Huang, B., Shu, X. and Tang, B. (2009), *Influence of Nano-sized Hydrated Lime (HL) on Selected Properties of HMA*, in press, International Journal of Pavement Research and Technology

Button, J., Little, D.N., Kim, Y., Ahmed, J. (1987), *Mechanistic evaluation of selected asphalt additives*, Proceeding of AAPT, p.62-90.

Tunnicliff, D. and Root, R. E. (1981), *Antistripping Additives in Asphalt Concrete State-of-the-Art* , Proceeding of AAPT, V.51-82, p.293.