

# tech notes

“tech notes” are a product of the State Materials Laboratory to share design and construction technology gained from projects done through WSDOT. This issue is from the Pavements Branch discussing the CoreLok® device

## The CoreLok® Device

### Introduction

The CoreLok® device can be used to determine the bulk specific gravity ( $G_{mb}$ ) of compacted hot-mix asphalt (HMA) samples, the maximum specific gravity ( $G_{mm}$ ) of HMA, and the aggregate bulk specific gravity ( $G_{sb}$ ), apparent specific gravity ( $G_{sa}$ ), and absorption. The focus will be on the measurement of  $G_{mb}$ . Research on the CoreLok® device is ongoing and will be evaluated when it becomes available.

Proper measurement of  $G_{mb}$  for compacted HMA samples is critical especially with the introduction of Superpave and volumetrics. The  $G_{mb}$  is the basis for volumetric calculations used during HMA mix design, field control, and construction acceptance. Inaccurate measurement of  $G_{mb}$  can result in erroneous calculations for air voids, voids in mineral aggregate (VMA), voids filled with asphalt (VFA), and correlations for the nuclear density gauge.

### CoreLok® Testing System

The CoreLok® uses a controlled vacuum system to seal samples. Samples are placed inside a polymer bag, which is then inserted into the vacuum chamber. Under vacuum, the bag conforms tightly around the sample, which prevents water from infiltrating the sample (Image 1). The volume of the sample is encapsulated within the bag and considered as the bulk volume. This procedure is similar to the paraffin wax test procedure as outlined in AASHTO T-275, but is quicker and easier to perform.

### Current $G_{mb}$ Determination

AASHTO T-166 Method A for laboratory-compacted samples and Method C for core samples have proved adequate for mixes that utilize fine-graded aggregate structures. However, erroneous  $G_{mb}$  measurements have occurred with the adoption of the Superpave mix design system and the use of stone matrix asphalt (SMA). With the use of Superpave, more coarse-graded mixtures have been utilized and SMA has the properties of a gap-graded mixture.

With these types of mixtures, the internal air voids can become interconnected (Figure 1), which allows water to infiltrate into the sample quickly during the saturation process. However, when measuring the saturated-surface dry (SSD) condition using AASHTO T-166, the water tends to drain quickly from the sample and cannot be measured. The infiltration of water, according to AASHTO T-166, should not exceed 2.0 percent, hence the errors that can be introduced into the measurement of  $G_{mb}$ <sup>1</sup>. If the water absorption exceeds 2.0 percent, AASHTO T-275 (paraffin wax) should be used to seal the sample prior to measuring the  $G_{mb}$ .



Image 1 - Sealed laboratory compacted sample (Courtesy of NCAT).

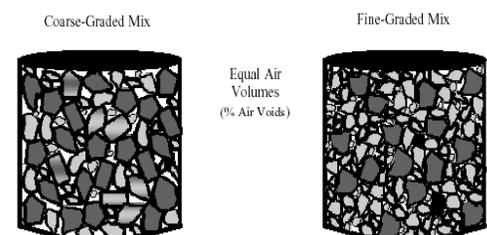


Figure 1 - Illustration of interconnected air voids (Courtesy of NCAT).

1 National Center for Asphalt Technology, Bulk Specific Gravity Round Robin Using the CoreLok Vacuum Sealing Device, NCAT Report No. 02-11.

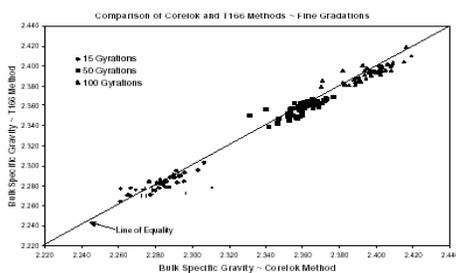


Figure 2 - Fine gradation  $G_{mb}$  comparisons at varying gyration levels (Courtesy of NCAT).

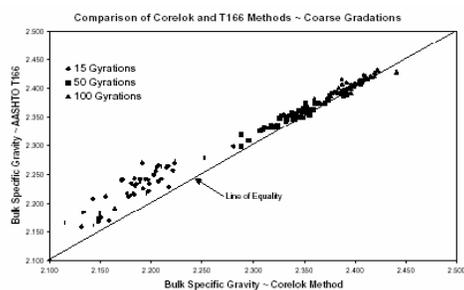


Figure 3 - Coarse gradation  $G_{mb}$  comparisons at varying gyration levels (Courtesy of NCAT).

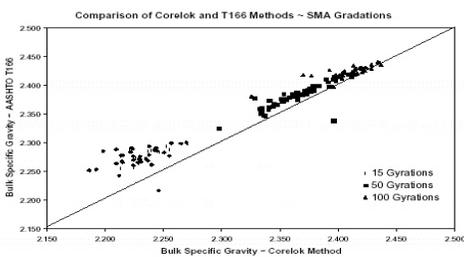


Figure 4 - SMA gradation  $G_{mb}$  comparisons at varying gyration levels (Courtesy of NCAT).

## NCAT Round Robin Testing

The National Center for Asphalt Technology (NCAT) conducted round robin testing to evaluate the CoreLok® device for repeatability and reproducibility along with its ability to accurately determine  $G_{mb}$ . Testing was broken into three categories: fine-graded (gradations passing near or above the maximum density line), coarse-graded (gradations passing below the maximum density line and the restricted zone), and SMA (gap-graded mixtures filled with mastic). Within each of these categories, three gyration levels were tested: 15, 50 and 100. All mixes utilized the same aggregate type and binder grade.

For the fine-graded mixes, testing showed the CoreLok® method to be similar to AASHTO T-166 for the  $G_{mb}$  measurements as well as the absorptions. All the absorption values were well below the 2 percent threshold as outlined in AASHTO T-166. Figure 3 shows  $G_{mb}$  results for fine-graded mixes for the CoreLok® and AASHTO T-166. For all three gyration levels tested, the majority of the results fall below the line of equality, which means that the CoreLok® method tends to measure the  $G_{mb}$  slightly lower than AASHTO T-166.

The results shown in Figure 2 (fine-graded mixes) suggest that the CoreLok® method does provide a good estimation of  $G_{mb}$  when compared to AASHTO T-166 (i.e. when absorptions are well below 2 percent).

For coarse-graded mixes, the  $G_{mb}$  measurements indicate a significant difference between the gyration levels (i.e. the amount of interconnected voids at or near the surface of the sample). At 15 gyrations, the mean  $G_{mb}$  difference between AASHTO T-166 and CoreLok® was 0.041, which equates to 1.6 percent difference in air voids. At 50 gyrations, the results were closer to the line of equality, but still had a mean  $G_{mb}$  difference of 0.012 (approximately 0.5 percent air voids). At 100 gyrations, the results are very close to the line of equality (mean  $G_{mb}$  difference was 0.008) and had an air void difference of about 0.4 percent (Figure 3).

The  $G_{mb}$  results for the SMA mix were very similar to the coarse-graded mix (Figure 4). For instance, the samples at 15 gyrations showed the mean  $G_{mb}$  difference as 0.045, which equates to approximately 1.8 percent air voids. The 100 gyration level results were much closer to each other with an air void difference of 0.5 percent.

The coarse-graded and SMA mixtures had higher water absorptions, especially at the lower gyration levels, which showed a significant difference in the  $G_{mb}$  measurements between AASHTO T-166 and the CoreLok®. From these observations, it appears that the CoreLok® device provides more accurate measures of  $G_{mb}$  at high levels of water absorption and/or high air voids levels. An evaluation of water absorption for the coarse-graded and SMA mixtures showed that the air void content diverged at 0.4 percent water absorption. Therefore NCAT recommends that the CoreLok® method be used during mix design and construction of SMA and coarse-graded Superpave mixes (it is expected that a significant portion of design samples would exceed 0.4 percent absorption for mixes below the maximum density line).

For fine-graded mixes, AASHTO T-166 may be used when the water absorption is less than 2 percent, which matches the current criteria within AASHTO T-166. Based on this study, it appears that the CoreLok® is a viable method for determining the bulk specific gravity of compacted HMA.

Further, the findings show that repeatability of AASHTO T-166 was slightly better than that of the CoreLok® device although the within- and between-lab standard deviations are similar in value. The slight increase

in variability was likely caused by the lack of experience with the CoreLok<sup>®</sup> method. Data also indicates that the type of mix or gyration level affects AASHTO T-166 measurements more than measurements from the CoreLok<sup>®</sup><sup>1</sup>.

### Operator Variability for Measuring $G_{mb}$

An examination of operator variability for measuring the  $G_{mb}$  of HMA was conducted at the University of Arkansas<sup>2</sup>. Comparisons were performed between AASHTO T-166, CoreLok<sup>®</sup>, and AASHTO T-269 (dimensional analysis). With the use of AASHTO T-166 as the main test method for determining the  $G_{mb}$  of HMA, it has been noted, especially since the introduction of coarse-graded mixes, that there is a tendency for different operators to obtain dissimilar results when performing testing on the same material with the same equipment using the same procedures.

AASHTO T-166 (or the SSD method) has recently been criticized with the increased use of SMA and coarse-graded mixes. Therefore, the University of Arkansas performed testing on 144 lab-compacted HMA samples to determine the variability of the SSD, dimensional analysis, and the CoreLok<sup>®</sup> methods. All testing was performed with Superpave 12.5 mm (½ inch) HMA from 6 different projects within Arkansas. Each project had a different mix design, aggregate type, and optimum asphalt content. The range of air voids tested was 2.5 to 9.5 percent.

The results show that the multi-operator variability increased with each of these methods: CoreLok<sup>®</sup>, dimensional analysis, and then AASHTO T-166. Simply by changing the method of measuring the  $G_{mb}$ , an air void difference of 0.36 to 0.90 percent and a difference in VMA of 0.31 to 0.79 percent can be obtained. From a construction (or volumetric analysis) perspective, these reported differences in air voids and VMA are significant even though no physical changes in the mix had occurred.<sup>2</sup>

### WSDOT Use of CoreLok<sup>®</sup> Device

The WSDOT Materials Laboratory conducted testing on 96 core samples that were obtained from seven projects in Washington. The cores were tested using the CoreLok<sup>®</sup> and AASHTO T-166. Findings show that the difference in air voids between the two methods can vary significantly. This difference in air voids varied for the Class A, Superpave ½ inch and Superpave ¾ inch mixes that were tested. The Class A gradations follow the maximum density line (i.e. fine-graded), while the Superpave gradations (both the ½ and ¾ inch) fall below the maximum density line and restricted zone (i.e. coarse-graded).

The density results show that the Class A mixes on average, follow the line of equality (Figure 5), but around 12 percent air voids, the CoreLok<sup>®</sup> tends to have higher results than AASHTO T-166. The Superpave ½ inch mixes, shown in Figure 6, begin to deviate from the line of equality around 8 percent air voids and the Superpave ¾ inch mixes (Figure 7) are all above the line of equality (i.e. the CoreLok<sup>®</sup> results are always higher than the AASHTO T-166 results).

These three figures illustrate the difference in air voids that can occur when different test methods are used for fine- and coarse-graded mixes. The results directly relate to the amount of interconnected voids present in the different types of mixes over a wide range of air voids. For instance, when the air voids are less than 8 percent, the difference between the

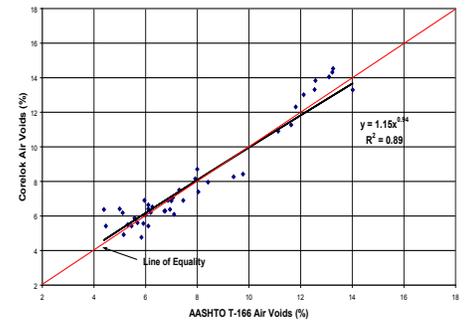


Figure 5 - Class A comparison of AASHTO T-166 and CoreLok<sup>®</sup> air voids.

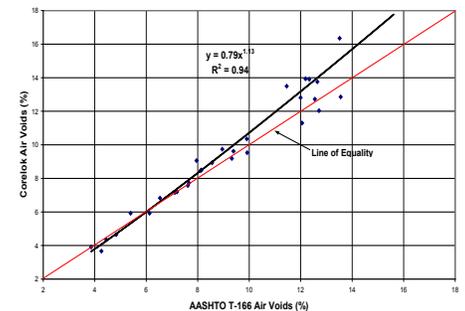


Figure 6 - Superpave 1/2 inch comparison of AASHTO T-166 and CoreLok<sup>®</sup> air voids.

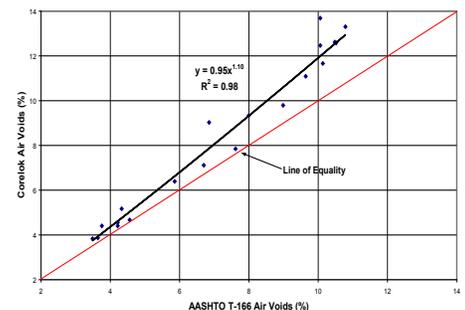


Figure 7 - Superpave 3/4 inch comparison of AASHTO T-166 and CoreLok<sup>®</sup> air voids.

<sup>2</sup> TRR1761, Examination of Operator Variability for Selected Methods for Measuring Bulk Specific Gravity of Hot-Mix Asphalt Concrete, K.D. Hall, et al.

**Table 1. Average Difference between CoreLok® and AASHTO T-166 Air Voids.**

Air Voids	Class Mix		
	A	½ inch	¾ inch
<8 %	0.11	0.08	0.55
8 - <12%	-0.37	0.45	0.69
≥ 12 %	0.79	1.69	1.99

CoreLok® and AASHTO T-166 air voids are very similar for the Class A and Superpave ½ inch mixes, while the Superpave ¾ inch mixes differ by about a half percent (Table 1). When the air voids are 12 percent or greater, the results show that, on average, the Superpave ¾ inch mixes can vary by 2 percent depending on the test method used. Again, the amount of interconnected voids and surface voids can drastically affect the SSD testing within AASHTO T-166. Of the 96 cores sampled, 46 were tested for absorption, and 85 percent of these core samples (which had air voids ranging from 4.5 to 15.6 percent) exceeded 2.0 percent absorption.

**Summary of Findings**

NCAT<sup>1</sup>:

- AASHTO T-166 can be used for fine-graded mixes with less than 2.0 percent water absorption.
- CoreLok® should be used for coarse-graded and SMA mixes when the absorption exceeds 0.4 percent.
- Repeatability for the CoreLok® and AASHTO T-166 are similar, but AASHTO T-166 is slightly better.

University of Arkansas<sup>2</sup>:

- CoreLok® had a lower multi-operator variability than AASHTO T-269 and T-166.
- The choice of G<sub>mb</sub> test method can produce a 0.36-0.90 percent air void difference and a 0.31-0.79 percent difference in VMA.

WSDOT:

- For the core samples, a larger difference between AASHTO T-166 and CoreLok® was seen with increasing air voids and coarse-graded mixes.
- The CoreLok® better represents the G<sub>mb</sub> at higher air void levels due to the incorrect use of AASHTO T-166 (water absorption greater than 2.0 percent).

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