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International Journal of Pavement Research and Technology xxx (2017) xxx–xxx

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# Effect of Superpave restricted zone on volumetric and compaction properties of asphalt mixtures

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Received 15 October 2016; received in revised form 6 February 2017; accepted 1 March 2017

**Abstract**

The Superpave aggregate criteria originally include a restricted zone that lies along the maximum density line and through which gradations are not recommended to pass. The debate with regard to whether or not such a restriction needs to be imposed has been ongoing and inconclusive. In this study, fifteen different gradations of limestone aggregate having three nominal maximum aggregate sizes (NMAS) of 19.0, 12.5, and 9.5 mm and covering five types: above, below, crossover through, hump through, and through restricted zone (ARZ, BRZ, CRZ, HRZ, and TRZ) were used to investigate the effect of restricted zone on mixture properties. The Superpave gyratory compactor (SGC) was used to produce the asphalt mixture samples according to the Superpave system. Findings of the study showed that the CRZ, HRZ, and TRZ mixtures generally could meet the Superpave voids in mineral aggregate (VMA) criteria easier than the BRZ and ARZ mixtures. Contrary to the expected trend, the VMA values for the BRZ mixtures were found to be higher than those of the ARZ mixtures for the 19.0-mm NMAS. The HRZ mixtures similar to the ARZ and BRZ mixtures had high effective asphalt binder content. ARZ mixtures generally could violate the Superpave criteria for compaction properties (% of maximum specific gravity at the initial number of gyrations, $\%G_{mm}$ at $N_{initial}$, and% of maximum specific gravity at the maximum number of gyrations, $\%G_{mm}$ at $N_{maximum}$). The TRZ mixtures in general provided the highest dust proportion (DP) values, whereas, the BRZ mixtures provided the lowest DP values.



*Keywords:* Restricted zone; VMA; Mixture volumetric properties; Mixtures compaction properties; Aggregate gradation; Superpave

## 1. Background

The restricted zone is that area on the FHWA's 0.45 power chart in Superpave specifications through which aggregate gradations are not allowed to pass through. The restricted zone varies with the Nominal Maximum Aggregate Size (NMAS) for the gradation. The restricted zone is associated with the mixture design. Mixtures with gradations passing through the restricted zone are hypothesized to be susceptible to tenderness and rutting.

In Superpave, it was originally observed that asphalt mixtures closely following the maximum density line on the 0.45 power chart in the finer gradation provided unacceptably low voids in mineral aggregate (VMA) values due to the excess of natural sand. Low VMA values typically lead to insufficient asphalt coating the individual aggregate particles (less effective asphalt binder).

Various previous studies have dealt with the volumetric properties including the VMA and the voids filled with asphalt (VFA) as well as the compaction properties and the factors that impact these properties in asphalt mixtures.

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Peer review under responsibility of Chinese Society of Pavement Engineering.

http://dx.doi.org/10.1016/j.ijprt.2017.03.004

The aggregate gradation, the Superpave restricted zone, and the NMAS are among the important factors that affect the volumetric properties and the compaction properties of asphalt mixtures.

Kandhal and Cooley [1] evaluated the effect of the Superpave restricted zone on permanent deformation of dense-graded asphalt mixtures. Two Nominal Maximum Aggregate Sizes (NMAS's): 9.5 and 19 mm; three compaction levels: 75, 100, and 125 gyrations; and five gradation types: above, below, crossover through, hump through, and through the restricted zone (ARZ, BRZ, CRZ, HRZ, and TRZ) were used. A PG 64–22 asphalt binder, two coarse aggregates (crushed granite and crushed gravel), and ten fine aggregates with fine aggregate angularity (FAA) values between 38 and 50 were used. It was found that the ARZ and CRZ gradations tended to provide higher VMA values; the TRZ gradation provided the lowest VMA values. The TRZ gradations generally provided the lowest VMA values for both the 9.5-mm and 19.0-mm NMAS mixtures. Higher $\%G_{mm}@N_{initial}$ values were generally obtained for finer gradation mixtures (such as ARZ and HRZ) compared with the values of TRZ, CRZ, and BRZ mixtures. Many mix designs in this study exceeded the maximum VFA requirement (75%).

Anderson and Bahia [2] discussed the Superpave mixture design process and various methods of increasing the VMA within mixtures and evaluated four different mixture gradations using crushed granite except for one blend that had 20 percent of natural sand. A PG 64–22 asphalt binder was used for mixtures, which were compacted to $N_{design}$ of 109 gyrations. It was found that the gradation passing through the restricted zone produced a mixture with low or intermediate potential for rutting. The gradation passing through the restricted zone also met the Superpave requirements for percent theoretical maximum specific gravity at the initial number of gyrations (($\%G_{mm}$ @ $N_{initial}$), VMA, and VFA. The gradation below the restricted zone with no natural sand showed the highest potential for rutting.

Mallick et al. [3] evaluated the effect of the restricted zone on volumetric properties of SGC-compacted specimens. They tested six different mixtures: three with 100-percent crushed granite aggregate and three with 80-percent crushed granite and 20-percent natural sand. For each aggregate blend type, three 19.0-mm NMAS gradation types were studied: above, through, and below the restricted zone (ARZ, TRZ, and BRZ). A traffic level of 3–10 million ESALs and a temperature of less than 39 °C were used in the design of asphalt mixtures. The volumetric properties of the mixtures at optimum asphalt content were determined and then compared. It was concluded that none of the mixtures containing natural sand met all Superpave requirements for volumetric and gyratory properties. Only two mixtures; the TRZ and BRZ mixtures containing all crushed material, met all volumetric requirements. The TRZ mixture with all crushed material had better volumetric properties than did the BRZ mixture with 20-percent natural sand.

Coree and Hislop [4] assessed the effect of aggregate-related factors on the VMA for Superpave asphalt mixtures. Three maximum aggregate sizes (9.5, 12.5, and 19.0 mm) with dense, fine, and coarse aggregate gradations were used in their study. Combinations of natural and manufactured coarse and fine aggregates were also used. Based on the analysis and results of the study, they proposed a new method to volumetric mixture design that takes into account aggregate gradation, shape, and texture.

Zhang et al. [5] in their study concluded that the below restricted zone (BRZ) mixtures provided much higher VMA values than did the through restricted zone (TRZ) and the above restricted zone (ARZ) mixtures. Against the trend (that BRZ mixtures tend to have lower VMA values), the BRZ mixtures had approximately 1.5 percent higher VMA than the TRZ mixtures, and 0.9 percent higher VMA than the ARZ mixtures. Because the gradation of the TRZ mixtures is closer to the maximum density line, they provided the lowest VMA values.

Nukunyaet al. [6] used dense-graded asphalt mixtures produced using both angular and non-angular aggregates to study the effect of restricted zone on permanent deformation (rutting) of asphalt mixtures. The findings of the study (contrary to what was determined by the Superpave) showed that the BRZ mixtures are not rutting resistant due to the higher asphalt binder, which causes potential problems to achieve the minimum VMA requirement.

Sebaaly et al. [7] performed an analysis of data collected from laboratory performance tests and field test sections. It was concluded from the study that the TRZ mixtures performed better than the coarse-graded mixtures that generally included BRZ mixtures. The TRZ mixtures were also found to have higher stiffness than the BRZ mixtures produced from same materials.

## 2. Objective

The major objective of this study is to investigate the effect of the Superpave restricted zone of the aggregate gradation on the volumetric properties and compaction properties for asphalt mixtures with crushed limestone aggregate. Aggregate gradations above, below, crossover through, hump through, and through the restricted zone for three NMAS's: 9.5, 12.5, and 19.0 mm were used in the study to achieve this objective.

## 3. Materials and methodology

### 3.1. Asphalt binder

A 60/70-penetration grade asphalt binder having a Superpave performance grade of PG 64–16 was used in the study. The asphalt binder was evaluated using the Superpave asphalt binder tests. The test results are summarized in Table 1. Based upon the Superpave test results, the

Please cite this article in press as: G.G. Al-Khateeb et al., Effect of Superpave restricted zone on volumetric and compaction properties of asphalt mixtures, Int. J. Pavement Res. Technol. (2017), http://dx.doi.org/10.1016/j.ijprt.2017.03.004