**Title:** Comprehensive Investigation of Aggregates in Asphalt Mixture Designs and Relationship to Compaction (Idea 138)

**Date:** June 27, 2017  
**Prepared for:** Omar Fateh  
**Prepared by:** Marilee Tuite, x3797

**Resources searched:** MnDOT Library catalog, TRID, RiP, Transport, ASCE Civil Engineering database

**Summary:** Results were found using terms from the proposed work in the Ideascale description: *aggregates, asphalt mixture, compaction, aggregate gradation, pavement performance, scanning, X-ray, CT/computed tomography.* They are divided into most relevant and less relevant.

**Most Relevant Results:**

**Title:** Evaluation of the effects of gyratory and field compaction on asphalt mix internal structure  
**Source:** Materials and Structures, vol. 49, no. 1-2, pp. 665-676 (2016)  
**Abstract:** This study investigates the effect of gyratory and field compaction on the internal structure of asphalt mixtures. For this purpose, three new full-scale pavement test sections with different HMA mixes were selected for sampling loose material and field cores. Loose material was compacted using the gyratory compactor and adjusting several parameters, namely the gyration angle, compaction temperature and specimen geometry. Internal structure of the gyratory and field compacted specimens was quantified in terms of the aggregate contact points, orientation and segregation by means of 2-D image analysis. From the laboratory investigation it was demonstrated that the gyration angle and specimen geometry significantly affected the internal structure. The results also indicated that the field compaction produced similar internal structure in asphalt pavements and, especially, compaction with gyration angle of 1.45° best simulated the internal structure of field cores.  
Full text: Contact the library to obtain full text.

**Title:** Compaction characteristics of asphalt mixture with different gradation type through Superpave Gyratory Compaction and X-Ray CT Scanning  
**Abstract:** To determine the appropriate compaction parameters of different asphalt mixtures (AC13, AC16, AC20 and SMA13) in Shaanxi Province and to study their micro-
structural characteristics, SK70# and SK90# matrix asphalt and limestone were used in this study to prepare asphalt mixtures via Superpave Gyratory Compaction (SGC) and X-Ray CT Scanning. The compaction characteristics of these specimens were tested at three temperatures (120 °C, 140 °C and 155 °C), and the slope of the compaction curve $K_1$, as an evaluation index, was statistically analyzed. The test specimens prepared using the appropriate compaction parameters were scanned by X-ray Computed Tomography (X-ray CT) and the air void distribution was analyzed by the Volume Graphics (VG) Studio MAX, which is for X-ray CT analysis that is used to calculate the volume distribution of the voids of an asphalt mixture. The results show that the SMA13 mixture exhibits a better compaction performance and temperature stability than the AC13 mixtures regardless of the asphalt binder type; The AC13 asphalt mixture has better temperature stability and compaction performance than the AC16 and AC20 asphalt mixture at the same number of gyrations, which with SK70# asphalt binder. The compaction temperature recommendations in Shaanxi Province are 140 °C for the AC13 mixtures whatever with SK70# or SK90# asphalt binder, 155 °C for the AC16 and AC20 gradation types with SK70# asphalt binder, 140 °C for the AC16 gradation types with SK90# asphalt binder, and 155 °C for the SMA13 mixtures with SK70# asphalt binder. Asphalt binder viscosity has a visible influence on the compaction level and VMA when the same gyration numbers are applied. For each recommended mixture, the volume of the majority of the air voids fell into the 0–150 mm$^3$ range, and most of these voids are concentrated in the 0–50 mm$^3$ volume range.

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ray computed tomography (CT) and the characteristics of the images are analysed. Using the image analysis technique, the aggregate particles are separated from the mixture and the orientation and distribution in the compacted specimen are characterised. It was found that aggregates near the edge of a specimen tend to form circumferential alignment while the aggregates near the centre of the specimen are randomly oriented. Aggregate gradations show that coarse particles are mostly concentrated at the bottom compared to the top of a specimen.


Less Relevant Results:

Title: Improved Image Unevenness Reduction and Thresholding Methods for Effective Asphalt X-Ray CT Image Segmentation
Abstract: The internal structure of asphalt mixture revealed by X-ray computed tomography (CT) images provides useful information in a variety of civil engineering applications. This paper studied two image processing issues commonly encountered in asphalt X-ray CT images: image intensity unevenness caused by beam hardening effect and unrealistic image segmentation. Inspired by nonuniform illumination correction techniques, a grayscale morphological method is proposed to solve image intensity unevenness. Two modified multilevel thresholding methods are developed to effectively divide the asphalt CT images into three phases—air voids, binder, and aggregates. The comparisons of existing multilevel thresholding methods with the ones developed in this study indicate that the proposed methods provide more consistent, robust, and accurate results. Moreover, the developed thresholding objective functions enable a user to easily adjust thresholds to match visual examination or laboratory test results through modifying a single parameter. The developed methods help improve the analysis of asphalt CT images for various engineering applications.

Title: 3D Voxel-Based Approach to Quantify Aggregate Angularity and Surface Texture
Abstract: In this study, a three-dimensional (3D) approach is proposed to determine the angularity index (AI) and surface texture index (STI) of aggregates, namely the 3D Sobel-Feldman operation, which has not been well used in civil engineering. First, aggregate particles are subjected to X-ray scanning to obtain cross-sectional images, which are then processed and stacked to construct the 3D voxel-based images. Then the gradient vector of each voxel on the surfaces is calculated based on the 3D Sobel-Feldman operation, which was derived and verified in this study based on the 2D Sobel-Feldman operation. The results showed that the 3D Sobel-Feldman operation derived in this study is correct and feasible to be used to determine the 3D AI of aggregates. The AI is determined by the accumulative change of gradient vectors of some selected surface voxels. A pretreatment (dilation followed by erosion) is used to reduce the effect of surface texture on the AI calculation. The surface texture index is determined by the
relative loss of voxels after a morphological opening (erosion followed by dilation) operation on the 3D image. User-written coding was used to deal with the massive calculation. A total of 15 aggregate particles were used as case study to investigate the feasibility of the proposed approach to measure the 3D AI and STI. Some factors that affect the AI and STI values were also discussed to find the optimum approach. The 3D STI results were also compared to the 2D results to justify the benefits of the 3D approach.

Full-text PDF: http://ascelibrary.org/doi/10.1061/%28ASCE%29MT.1943-5533.0001872

Title: Study on Aggregate Size Distribution in Asphalt Mix Using Images Obtained by Different Imaging Techniques
Originally presented at 11th Transportation Planning and Implementation Methodologies for Developing Countries (TPMCD 2014) in Mumbai, India
Abstract: The present paper deals with the application of imaging technique to estimate the aggregate size distribution in asphalt mix. Aggregate size in asphalt mix typically varies by several orders of magnitude. Thus, it may become difficult to use a single imaging technique to assess the entire spectrum of aggregate size distribution. In the present study, different imaging equipment namely, camera, scanner and scanning electron microscope (SEM) are used to capture images of asphalt mix. Each equipment has a upper and a lower size limit within which the aggregates are distinguishable. The images are analyzed to derive information on aggregate size distribution. Performance of the individual imaging techniques on an asphalt mix sample of known aggregate gradation is studied.

Full-text: http://dx.doi.org/10.1016/j.trpro.2016.11.105

Title: Investigation of warm-mix asphalt using Iowa aggregates
Source: Iowa State University Institute for Transportation (2011)
Abstract: The objectives of this study are to test the binder and mix properties of WMA technologies for both field- and laboratory-produced mixes to determine the performance of WMA compared to traditional HMA. Field- and laboratory-produced mixes were studied. The laboratory-produced mixes compared HMA control mixes with WMA mixes that had the same mix design. The WMA technologies used for the laboratory study were Advera, Sasobit, and Evotherm. The field study tested four WMA field-produced mixes. Each of the four mixes had a corresponding control HMA mix. The WMA technologies used in the field study included: Evotherm 3G/Revix, Sasobit, and Double Barrel Green Foaming. The three main factors for this study were WMA/HMA, moisture-conditioned/not moisture-conditioned, and reheated/not reheated….The conclusions of this study are as follows: (1) Reduced mixing and compaction temperatures were achieved. (2) Statistical differences were found when comparing tensile strength ratio (TSR) values for both laboratory- and field-produced mixes. In the laboratory, none of the WMA additives performed as well as the HMA. For the field mixes, all TSR values passed Iowa’s minimum specification of 0.8 but, on average, WMA is lower compared to HMA TSR values. (3) Dynamic modulus results show that, on average, HMA will have higher dynamic modulus values. This means the HMA exhibits stiffer material properties compared to WMA; this may not necessarily mean superior performance in all cases. (4) Flow number results show that WMA has
reduced flow number values compared to HMA. The only exception was the fourth field mix and weather delayed production of the control mix by nine days. The laboratory mixes showed that flow number values increased significantly with the addition of recycled asphalt pavement (RAP). (5) In the laboratory study, Advera reduced TSR values. Given that Advera is a foaming agent, the increase in moisture susceptibility is likely attributed to the release of water necessary for the improvement of the workability of the asphalt mixture.