



Project Summary

Texas Department of Transportation

0-5268: Role of Coarse Aggregate Point and Mass Strength on Resistance to Load in HMA

Background

The performance of hot mix asphalt (HMA) mixtures is greatly influenced by the properties of the aggregate blends such as gradation and strength. The ever-increasing truck traffic volume and higher tire pressures exert greater stress on asphalt pavements which are manifested in the form of pavement distresses such as rutting and fatigue cracking. To address these issues, coarse-graded Superpave mixtures, Stone Matrix Asphalt (SMA) and Porous Friction Course (PFC), which rely more on stone-on-stone contact for a stronger coarse aggregate skeleton, are used more frequently in Texas. Current laboratory protocols to characterize aggregate quality do not seem to correlate well with aggregate toughness and strength requirements during handling, construction, and service. Specifications should ensure that aggregate particles possess the necessary strengths to avoid degradation during handling, construction, and trafficking.

To address these issues, the characteristics of aggregates have to be considered in a multifaceted way, considering the geological, geotechnical, mix design, and construction aspects. The geological aspects consist of characterizing the hardness and nature of rock mass. The geotechnical aspects are necessary to optimize the gradation, to consider the shape and size of the aggregates in the mix and to assess the strength of the aggregates. A proper HMA mix is needed to ensure the adequate durability, structural capacity, and performance after the gradation is optimized. The construction aspects should consider the best way of compacting a layer without excessively crushing the aggregates.

What the Researchers Did

Six aggregate types were selected from six TxDOT districts. Four mix types (PFC, Superpave-C, CMHB-C, and Type D) were investigated for the six aggregate sources. The same asphalt binder (PG 76-22) and fine aggregates were used for all mixes to minimize the impact of the binder properties on the results.

The geological nature of each aggregate was studied first by visiting the quarries and carrying out petrography analysis of the rocks to be crushed to aggregates. Several field tests on the rocks, such as the Schmidt Hammer and ultrasonic pulse velocity, were performed on the rocks as well. Laboratory tests, such as compressive strength and indirect tensile strength tests, were also performed on the cores extracted from the representative rocks to further characterize the crushing potential and to calibrate the models.

The second series of activities consisted of estimating the strength and hardness of the aggregates produced from the rocks. In addition to traditional tests routinely carried out by TxDOT, two tests included in the British standards were evaluated and adapted for TxDOT use. These two tests were the Aggregate Crushing Value (ACV) and the Aggregate Impact Value (AIV).

The third series of activities consisted of creating the traditional mix design for each aggregate source to obtain the optimum asphalt content and other relevant information. Numerous samples were prepared for each aggregate source and mix type for evaluating the performance of the mixes. Performance tests, such as rutting potential with the Hamburg Wheel Tracking Device, indirect tensile, complex and ultrasonic modulus, and flow time were carried out.

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Representative samples from each mix type and aggregate source were subjected to X-Ray imaging. The X-Ray images were converted to realistic models to be used in a micromechanical analysis. The discrete element model provided powerful insight into the influence of mix design and aggregate properties on resistance to fracture. It also allowed evaluation of the internal forces in the HMA mixtures, which cannot be accomplished by the conventional experimental methods.

Based on the activities above, extensive correlation analysis was carried out to evaluate which of the tests on the rock or aggregates best correlate to the performance indicators of the HMA mixes and the crushing of the aggregates.

Based on the success of the original study, an additional task was added to investigate how the blending of two aggregates from different sources would impact the performance and crushing of the mixes. Two blends were selected: 1) soft absorbent aggregates blended with hard aggregates, and 2) a blend of two reasonably hard but similar aggregates. The activities above were carried out on these blends as well.

What They Found

1. Current aggregate index tests are reasonable but do not provide a complete picture of the performance of the mixes made from them.
2. Several simple tests are proposed for estimating the quality of aggregates. These include:
 - Schmidt Hammer in the quarry for estimating the strength of rock before crushing,
 - Aggregate Crushing Value (ACV) and Aggregate Impact Value (AIV) for characterizing the crushing potential of aggregates,
 - Micro-Deval tests for continuity of the current methods of estimating the durability of the aggregates, and
 - Aggregate Imaging System (AIMS) for quantifying the roughness and angularity of aggregates before and after the Micro-Deval tests.
3. Micromechanical models, when calibrated with parameters from proposed aggregate and rock tests, provide powerful insight into understanding the behavior of a given aggregate in a given mix. They can realistically capture the influence of aggregate variability on mixture performance and selection of the appropriate aggregate type for a given mixture design.
4. The impact of aggregate blending on strength, stiffness, and performance of all mixes seems to follow a linear trend. Increase in the percentage of soft aggregates in a blend negatively impacts the strength, stiffness, and performance, especially for coarser mixes.
5. The optimum asphalt content increases with an increase in the percentage of softer aggregates in the blend for coarser mixes. This was not the case for a Type-D mix.

What This Means

Even though coarser mixes require higher quality aggregates, lower quality aggregates can be successfully used if applied in the proper mix type. With the high cost of binders, the economical viability of using higher quality aggregates in coarser mixes should be balanced with the asphalt content demand. It is recommended that the new tests, such as the ACV/AIV, be implemented by TxDOT for possible adoption. These observations are preliminary since the number of aggregates used was rather small.

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