CORRELATION BETWEEN AGGREGATE-TO-AGGREGATE CONTACT AND MECHANICAL PROPERTIES OF HMA MIXTURE

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ABSTRACT

The mechanical properties of hot mix asphalt (HMA) mixture are directly related to the internal structure. Earlier studies have suggested that aggregate-to-aggregate contact maybe a significant contributor to the mechanical properties of HMA mixes. In this study, the mechanical properties of HMA mixture, quantified by Marshall Stability, Flow and Marshall Quotient, were related to the internal structure in terms of aggregate-to-aggregate contact. For development of a model, field core samples were taken from Binder and Topeka layers at different sites. A total of 21 different HMA mixes were obtained.

An advanced 2-dimensional Image Processing and Analysis System (i.e., iPas) was used to characterize the internal structure of the cores. The test results indicated that there is a strong correlation between aggregate-to-aggregate contact and mechanical properties of HMA mixture. This is an indication that aggregate-to-aggregate contactis a significant contributor to the mechanical properties of asphalt concrete.

KEY WORDS:

Aggregate contact, Mechanical performance, Image processing

1. INTRODUCTION

The mechanical properties of HMA mixture are directly related to the internal structure indentified by air void distribution, aggregate orientation, and aggregate contact. The concepts of aggregate orientation and air void distribution are not new, as indicated by previous studies[1-3]; however earlier studies have also suggested that aggregate structure (i.e., aggregate-to-aggregate contact) maybe a significant contributor to the mechanical performance of HMA mixes[4-5], however, this aggregate skeleton could not be readily observed. In order to quantify the internal structure characteristics of asphalt mixes such as aggregate contact, air voids, or aggregate orientation; an internal image should be obtained, processed and analyzed. Methods for acquiring an internal image of asphalt mix fall into two categories: destructive and non-destructive methods. Destructive methods require cutting the sample in either the horizontal or vertical direction to reveal an internal structure of the mix, and a picture of the exposed surface is then obtained, while non-destructive methods are based on obtaining the internal structure image(s) by means of X-ray computed tomography (CT). Once an internal structure image is obtained, image processing is required to enhance the quality of the image and allow a clear definition of the image components (air voids, mastic, and coarse aggregates).The last step is to analyze the processed image to obtain meaningful parameters that describe the internal structure of the mix. Parameters such as aggregate size distribution, aggregate orientation, aggregate segregation, aggregate contact points, and air void distribution highlight the main parameters that can be obtained from such analyses.

The main objective of this study is to determine the relation between aggregate-to-aggregate contact and mechanical properties of HMA mixture.

2. MATERIALS & METHODS

For development of a model, field core samples were taken from Binder and Topeka layers at different sites. A total of 21 different HMA mixes were obtained. Each of these mixes differs by aggregate gradation from one another .In this study, specimens were cut with a circular masonry saw into multiple rectangular plane cross sections and also circular sections. The two opposing faces of each cut were then scanned, providing images per specimen for processing and analysis for comparison with the mechanical testing specimens. The images were processed and analyzed using the advanced software (iPas) and the number of aggregate-to-aggregate contact points was obtained. This advanced imaging tool allows for internal structure parameters to be determined, which can then be compared to mechanical properties to determine if a relationship exists.

The Marshall stability and flow tests were carried out following the procedure of the Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus in ASTM D1559. The test covers the measurement of resistance to plastic flow of cylindrical specimens [101.6mm (4 inches) in diameter and63.5mm (2.5 inches) high] of asphalt mixture loaded on the lateral surface by means of Marshall Apparatus.

3. RESULTS

In the following sections, the effects of aggregate-to-aggregate contact on the mechanical properties of HMA mixture are presented in terms of Marshall Stability, Flow, and MQ. Correlations between the number ofn contact points and mechanical properties of HMA mixture are also presented.

3.1.HMA internal structure analysis

An advanced 2-dimensional Image Processing and Analysis System (i.e., iPas) was used to characterize the aggregate structure of the cores. The software (i.e., iPas) includes two main functions: processing of an image and analyzing the image for identification of micro-structural parameters such as number of contact points as shown in Figure 1.

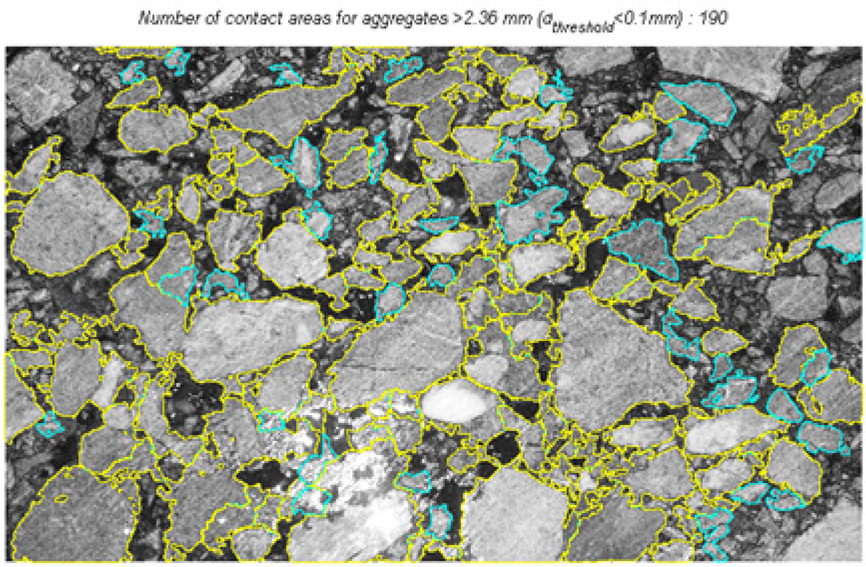

Figure1. Number of contact points by iPas software

3.2.Correlation between Marshall Stability and internal structure

It can be seen in figure 2& figure 3 that a good positive coefficient of correlation was found between Marshall Stability and number of contact points. There is a relationship between HMA strength resistance and the number of contact points. This is an indication that the aggregate structure acts as the load bearing component of HMA. A higher aggregate contact pointsis indicative of a supportive matrix/skeleton provided by the aggregate that can lead to higher load capacity.

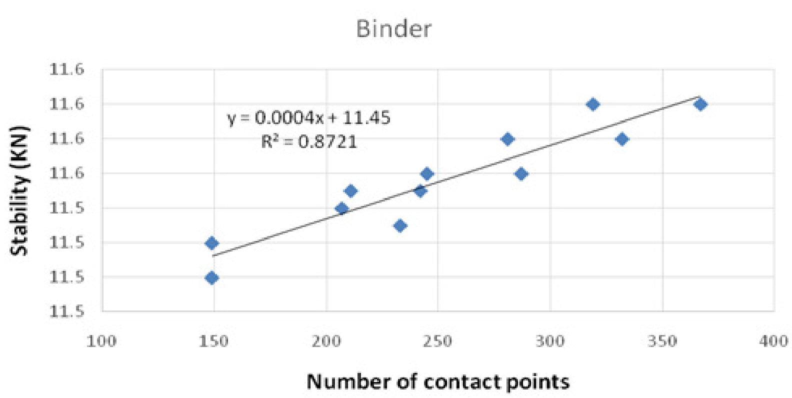

Figure2. Correlation between stability and number of contact points for binder mixtures

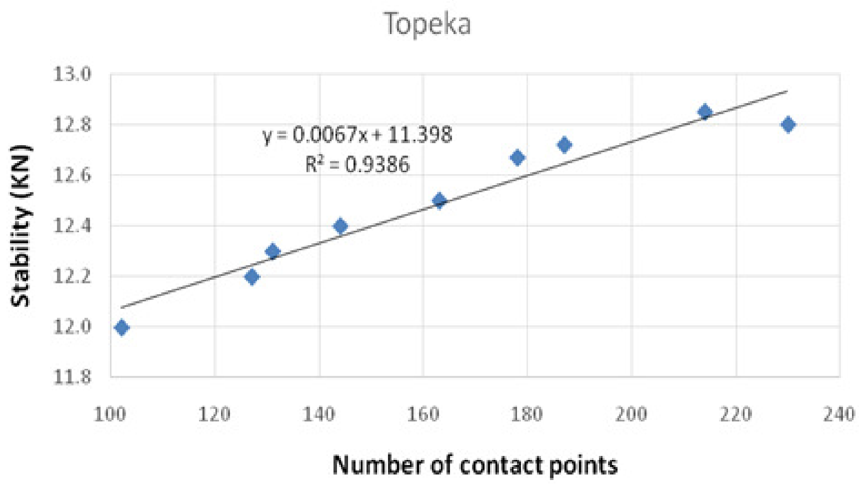

Figure 3. Correlation between stability and number of contact points for topeka mixtures

3.3. Correlation between Flow and internal structure

The coefficient of correlation was high as shown in Figure 4&5, so there is a strong correlation between measured Flow and number of contact points indicating that a greater number of contact points relates to a greater resistance to plastic flow.

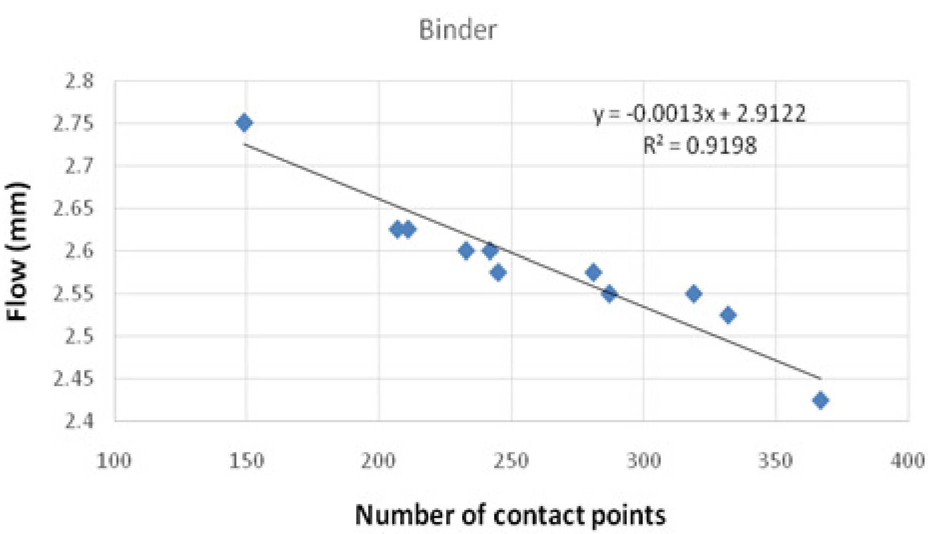

Figure4. Correlation between flow and number of contact points for binder mixtures

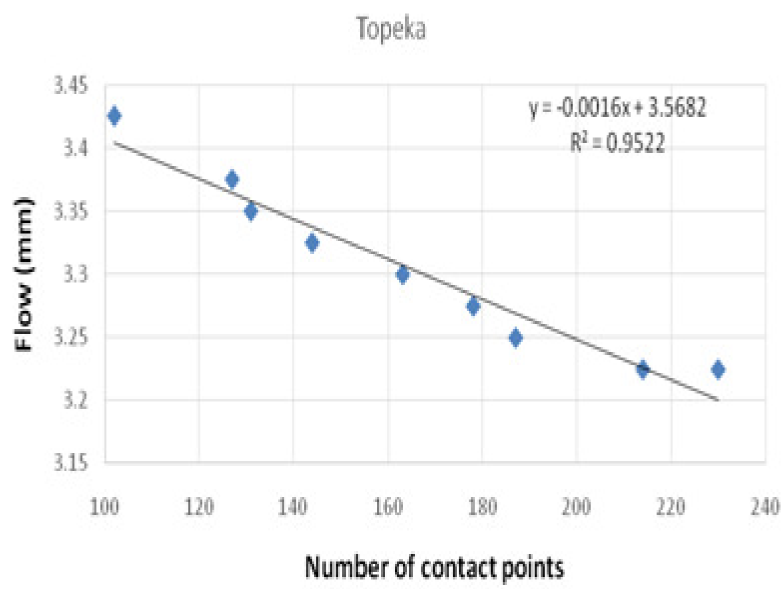

Figure 5. Correlation between flow and number of contact points for topeka and binder mixtures.

3.4 Correlation between Marshall Quotient and internal structure

The Marshall Stiffness or Marshall Quotient (MQ), calculated as the ratio ofstability to flow and thereby representing an approximation of the ratio of load todeformation under the particular conditions of the test, can be used as a measure ofthe material's resistance to permanent deformation in service [6]. A higher stability to flow ratio shows a stiffer mixture and hence, indicates the mixture is likely more resistance to permanent deformation. It can be seen in Figure 6&7 thata high correlation was obtained between Marshall Stiffness and number of contact points. This implies that HMA mixture resistance to permanent deformation is more dependent on aggregate-to-aggregate contact.

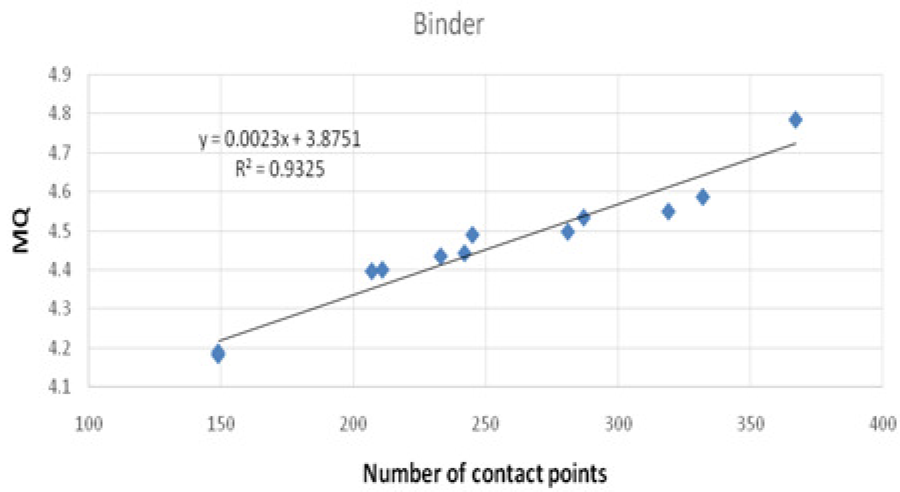

Figure 6. Correlation between MQ and number of contact points for binder mixtures

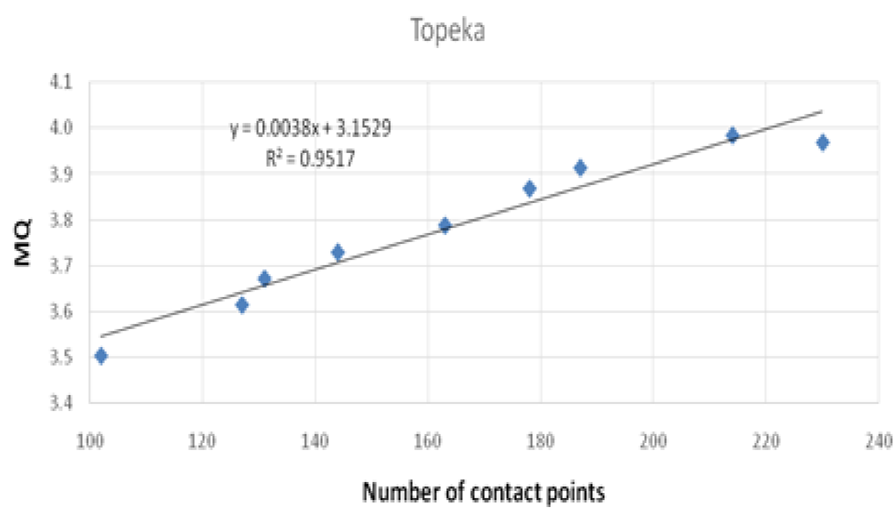

Figure 7. Correlation between MQ and number of contact points for topeka mixtures

CONCLUSION

The test results indicated that there is a strong correlation between aggregate-to-aggregate contact and mechanical properties of HMA mixture. This is an indication that aggregate structure (i.e., aggregate-to-aggregate contact) is a significant contributor to the mechanical properties of HMA mixture. A high level of connectivity is indicative of a supportive matrix/skeleton provided by the aggregate that can lead to higher load capacity and resistance of permanent deformation.The point-to-point contact between individual aggregates is claimed to directly affect mechanical properties of HMA mixture.

REFERENCES

1. Arasan, S., et al. Correlation between Shape of Aggregate and Mechanical Properties of Asphalt Concrete: Digital Image Processing Approach. Road Materials and Pavement Design, 2011. 12(2): p. 239-262.
2. Moon, K.H. and A.C. Falchetto. Microstructural investigation of Hot Mix Asphalt (HMA) mixtures using Digital Image Processing (DIP). KSCE Journal of Civil Engineering, 2015. 19(6): p. 1727-1737.
3. Zelelew, H. and A. Papagiannakis. A volumetrics thresholding algorithm for processing asphalt concrete X-ray CT images. International journal of pavement engineering, 2011. 12(6): p. 543-551.
4. Hamzah, M., W. Von, and N. Abdullah. Effects of Compactor types on Aggregate Orientation in Asphalt mixtures. International Journal of Engineering Transactions A: Basics, 2013. 26(7): p. 677-684.
5. Bessa, I.S., V.T.C. Branco, and J.B. Soares. Evaluation of different digital image processing software for aggregates and hot mix asphalt characterizations. Construction and Building Materials, 2012. 37: p. 370-378.
6. Whiteoak, O. Handbook of shell asphalts. London: Shell Bitumen, UK, 1991. 48.