An Image Processing Approach to Asphalt Concrete Feature Extraction

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Abstract—In this study, a new approach is used to predict asphalt concrete superficial feature using a new digital image processing technique based on a 3D computational modeling of CT scan images from asphalt samples. Digital image processing algorithm is developed to identify and detect the 3 phases of asphalt mixture (Aggregate, Mastic and Air void). The 3D microstructure of the asphalt mixture captured from two dimensional X-ray images. The laboratory measurements of the asphalt mixture features compared with image processing characteristics. It is found that the image processing algorithm is an effective tool for description of general properties of cores and compaction. This algorithm enables us to product new model toward NDT test realm.

Index Terms—asphalt compaction, C:T scan images, image processing, NDT.

I. INTRODUCTION

Recognition and Extracting components of asphalt mixture play an important role to enhance the performance and efficiency of the asphalt pavements. Hot Mix Asphalt (HMA) is a compound material of three phases, aggregate, sand mastic and air void. One of the important problems in pavements is recognition and extracting these features. Also in flexible pavements, compaction of final layer is one of the important parameters in productivity of asphalt pavements. Generally experiments divide in Destructive and nondestructive tests. Image processing technique placed in nondestructive category. In this paper tried to detect and separate these three phases and measure the value of them by image processing technique. The microstructure of asphalt mixture captured by using X-ray computed tomography (CT). The features that obtained by image processing are compared with the experimental parameters that achieved in laboratory. Several studies have performed to achieve the application of digital image processing techniques for asphalt concrete Mixture [1]. On the other hand, very few studies have developed image processing technique, as a nondestructive test. Also it is used to characterization of air void distribution in asphalt mixes using X-ray Computed Tomography [2]. Several studies deal whit modeling the microstructure of an asphalt mixture include investigating the sensitivity of aggregate size within sand mastic have done [3]. In some study by recognizing the microstructure of asphalt, aggregate characteristics and thresholding of asphalt concrete mixture have been achieved [4]-[6]. The 3D microstructure of the asphalt concrete is reconstructed from slices of 2D X-ray computed tomography images to achieve the desired macroscopic properties and performance [7], [8]. The first section briefly explains the attribute of collected data. The Image Processing and thresholding will be described afterwards. The new algorithm for extracting of asphalt features will be explained in the next section. Finally, conclusion and recommendation are made.

II. MATERIAL AND METHODS

In this study research is done on real laboratory asphalt samples. The 60 cylindrical samples in 7*10 dimensions with Specify mixture schema and data sheets that refer to features of asphalt (Temperature, Volume of air void, Marshall Stability, Bitumen percentage, etc.) is produced in laboratory. “Fig. 1,” “Fig. 2,” shows gradation curve of sample’s aggregates. Also, features of core samples like bitumen, air voids and aggregate percentage are obtained in the laboratory tests. The asphalt mixture core was scanned perpendicular to its vertical axis at 1mm distance interval to yield 70 slices per core, ignoring the top and bottom slices.

Figure 1. Sectional image and 3D image acquired through X-ray tomography imaging [9].
TABLE I. PHYSICAL PROPERTIES OF THE BITUMEN USED IN ASPHALT CORE SAMPLES

<table>
<thead>
<tr>
<th></th>
<th>3.8</th>
<th>4.9</th>
<th>5.2</th>
<th>5.2</th>
<th>5</th>
<th>4.9</th>
<th>4.8</th>
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</thead>
<tbody>
<tr>
<td>Percent air voids</td>
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<td></td>
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<td></td>
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<td>Design binder content (%)</td>
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<td>11.75</td>
<td>11.2</td>
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<td>11.21</td>
<td>11.95</td>
<td>12.33</td>
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<td>PG 60-70</td>
<td>PG 60-70</td>
<td>PG 60-70</td>
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<td>PG 60-70</td>
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<td>Percent air voids</td>
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</tr>
<tr>
<td>Design binder content (%)</td>
<td>5.2</td>
<td>4.7</td>
<td>4</td>
<td>4.3</td>
<td>5</td>
<td>4.5</td>
<td>5.7</td>
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<tr>
<td>Binder grade</td>
<td>PG 60-70</td>
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<td>PG 60-70</td>
<td>PG 60-70</td>
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<td>PG 60-70</td>
</tr>
</tbody>
</table>

Figure 2. Gradation curve of the aggregate used in asphalt core samples

III. IMAGE PROCESSING AND TECHNIQUES

CT scanning conducted on Siemens 16 slice CT instrument, computed tomography system. “Fig. 3,” presents the general working mechanism of X-ray tomography imaging.

The obtained image resolution is 512*512. “Fig. 4, a” shows an x-ray CT image of an asphalt concrete specimen with a diameter of 100 mm.

To have a unique archive and to identify the features of mixture (air voids, aggregate and mastic) the original image transformed to gray scale image. "Figure 4, b" shows a gray scale x-ray CT image. Tow threshold must be chosen to separate image in three phases, air voids, mastic and aggregates. “Fig. 5,” shows an overview of proposed method.

Figure 3. General mechanism of x-ray tomography scanning [9].

Figure 4. Representation of asphalt core sections. (a) x-ray CT image (b) grey scale image
IV. THRESHOLDING

Asphalt concrete is a composite material which consists of aggregates, air voids and mastic and each phase plays a role in asphalt mixture performance. Then appropriate choice in selecting T1 and T2, is too important.

In the previous studies, several threshold algorithms for aggregate, asphalt mastic and air void segmentation were introduced [10]. In this study two threshold T1 and T2 corresponding to the air void – mastic boundary and mastic - aggregate boundary considered based on the images feature, its make an independent algorithm. As well known average of the image pixel is an index for image property, and their variance show the variety of the pixels. In this study T1 and T2 determine using average and variance of pixels. As shown below:

\[ T_1 = \text{Mean} + \alpha \text{Var} \]  
\[ T_2 = \text{Mean} + \beta \text{Var} \]

where, \( \alpha \) and \( \beta \) computed by using the available data, with the lowest discrepancy between laboratory test and analyze results. After selecting \( \alpha \) and \( \beta \), “(1),” and “(2),” is obtained for determining T1 and T2.

V. DETECTION AND COMPUTING 3 PHASES OF ASPHALT MIXTURE

As discussed earlier, T1 and T2 are dynamic parameters that they are depend on image properties. The mixture is divided in three phases by computing T1 and T2.

A lower threshold T1 corresponds to the air void-mastic boundary and a higher threshold T2 corresponding to the mastic - aggregate threshold. Obviously, pixels ranging between T1 and T2 identify the mastic. After detect and separation, the percentage of them should be calculated, with considering the ratio of white pixels in to all pixels for per phase. The result of applying the threshold is shown in “Fig. 6.” This values for samples in 60 different images (1 mm spacing) calculated. 10 mm from top and bottom of the samples are ignored.

![Figure 6. Representation of asphalt sections (a) x-ray image (b) Air void phase in white, (c) mastic phase in white, and (d) aggregate phase in white.](image)
“Fig. 8,” compares the distribution of air void and mastic in the height of a sample that comes from program analyzing and the laboratory air void. The results indicated that the maximum air void is in the middle of the asphalt sample.

VI. REPRESENTATION OF COMPACTION USING 3D MODELING

Compaction of asphalt mixtures is one of the important parameters in performance of the asphalt pavements and one of the best parameters to evaluate the quality of the pavements, that there are different testing methods to determine it.

Air voids percent is typically calculated by using AASHTO T 269, ASTM D 3203 and more use laboratory estimation. In this study using the computer X-ray tomography as a nondestructive and new test, the internal features of asphalt mixture were achieved.

The 3D model extracted from processed images and aggregation chart for layers in 1cm, is shown in “Fig. 8.”

In this study an algorithm based on the threshold data, separating 3 phases of mixture image (air, bitumen and aggregate) in a gray scale image based on T1 and T2, was adopted to quantify the distribution of aggregate, air void, and mastic.

1) Read the image
2) Convert to gray scale image
3) Estimated mean and standard deviation of images pixels to approximate T1
4) Estimated mean and standard deviation of images pixels to approximate T2
5) Estimation of aggregates and air void value based on T1 and T2
6) By the acceptable error, set T1(air void threshold) and T2(aggregate threshold)
7) Two dimensional presentation of asphalt mixture
8) Three dimensional presentation of asphalt mixture
9) Calculation of air void, mastic and aggregate percentage

To enhance the accuracy, 10 mm from top and bottom of the samples are ignored. The air void value examines based on the air void percent of each plan then the air void value for one sample determined by summations of 60 layers. As a result compaction value is measured as follows:

$$\% C = 1 - P_a$$

where $P_a$ is the air void percent.

“Fig. 7,” compares the distribution of compaction in the height of a sample and the compaction that obtain in the laboratory. It can be found that the mixture compaction at top and bottom regions is more than the middle of the mixture and it is not uniform in sample height.

Figure 7. Distribution of compaction in mixture

Figure 8. Distribution of Air Voids and mastic in mixture.
VII. COMPUTING THE AGGREGATION CHART

A literature survey indicates that the incorporating of digital image processing and production of aggregation chart is too limited. An algorithm was generated that created aggregation chart based on each component area, this method wasn’t suitable for images that have overlap.
components (Matlab Documentation Set, 2008). Then an algorithm showed the aggregation chart by using the light intensity. (Matlab Documentation Set, 2008) This paper is intended to present an aggregation chart based on image processing technique. A comparison between the average of the asphalt mixture aggregation curve for each plan of an asphalt core sample, and the lab Measurements chart was shown below “Fig. 10,”. It’s seems that fine aggregate play a significant role in aggregation chart, there are more different in fine aggregate zone. According to “Fig. 10,” by using tow coefficient for fine aggregate zone and coarse aggregate zone, the aggregation charts are matched.

VIII. RESULT AND DISCUSSION

In this study a nondestructive method were used to detected and evaluate the value of each phases of asphalt mixture.

Several destructive techniques were used to detect and evaluate asphalt mixture features. The results show that the proposed method works as an exact, fast and commodious system, by using two dynamic thresholds, T1 and T2, that each phase of asphalt (aggregate, mastic and air void) is separated and the amount of them with an acceptable error is calculated. The maximum absolute error observed for Air void was 5% and for bitumen 1.9%, is shown in “Table. II,”.

<table>
<thead>
<tr>
<th>Mixture Component</th>
<th>Air Void%</th>
<th>Mastic%</th>
<th>Aggregate%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>4.9</td>
<td>11.78</td>
<td>83.31</td>
</tr>
<tr>
<td>Predicted</td>
<td>4.67</td>
<td>11.56</td>
<td>83.77</td>
</tr>
<tr>
<td>Absolute Error</td>
<td>5</td>
<td>1.9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The comparison of laboratory measured and image processing estimated mixture features are depicted in “Fig. 11,” and “Fig. 12,”

As discussed earlier, it was predicted that air void value in top and bottom of the samples is less than the middle of them; it may be because of the non-uniform compaction in the laboratory. However, the results indicate that it is not necessary to scan all sections of a sample; rather it can be estimated by scanning a range of sample’s height.

As it is obvious from “Fig. 8,” laboratory air void occur in 2.5- 4.5 Cm height of a sample. Also the mastic could be determined by scanning the 3- 5 Cm height of that.

Also it can be seen from these figures that low percentage of air voids is apparent at the top and bottom regions of the AC mixture core.

On the other hand, the mixture retains non-uniform distribution of mastic particles in the height of the mixture. Aggregation chart for layers in 1 cm was created. It should be noted that the fine aggregates play an important role in depict that, this is due to image resolution that doesn’t allow to detect fine aggregate particles in image.

In general, it is well demonstrated that the laboratory chart and predicted chart could be matched using tow fixed coefficient. In addition the tow important parameter of gradation, Cc and Cu could be determined as output of the method.

IX. CONCLUSIONS

In this paper an x-ray computed tomography system was used to capture the internal structure of asphalt mix specimens. A new approach is used to predict asphalt
concrete superficial feature using a new digital image processing technique based on a 3D computational modeling. The 3D model includes aggregate, mastic and air void phases [11].

Dynamic thresholding were utilized to separate the 3 phases of x-ray images. It can be concluded that dynamic thresholding was improved compared to techniques used in the past.

The results show that the proposed model can make reliable outcomes in three phases.

In brief, for extracting the asphalt samples features, the image processing has been demonstrated as an effective method. The proposed method is applicable for this sort of research. This means that with this method, features like air void, mastic percentage and aggregation pattern can be extracted with an approach different from the previous visual destructive testing. Laboratories testing results are compared with the proposed method for controlling credibility. Analysis of samples and constructing 3D is rapid via proposed model.

The test performances of this study show the advantages of the proposed method: it is fast, real, and adaptable.

However this study is in its initial stage and extensive research work is required.

REFERENCES


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