Determination of Air Voids in Asphalt Mixes by Image Processing Technique

Prahallad B S, Jaya R Shinganmakki, Mohan M
Department of Highway Technology,
RASTA Center for Road Technology,
Bengaluru, India 560058.

Abstract—**Air Voids plays a vital role in determining the lifespan of asphalt pavement. In this study, percentage of air voids for different asphalt mixes is determined by Image Processing technique. A new approach is used to determine the percentage of air voids using image processing technique based on Color Thresholding of core sample images in MATLAB software. The 3-phase of asphalt mix (bitumen, aggregates and air voids) is calculated and represented for each type of asphalt mixes. The Color thresholding technique along with the basic programming language in the MATLAB software is an effective tool in determining the percentage of air voids and to represent the 3-phase image of the various asphalt mixes.**

I. INTRODUCTION

Roads are one of the largest infrastructures in our country and vitally important to a nation's economic development. The life of Asphalt pavement is mainly affected by the amount of air voids present in the pavement surface. Too much air voids are too less air voids in the pavement layer can drastically affect the performance of the pavement. Extracting the components of bitumen mixture by means of image processing technique helps to study their performance and efficiency. In asphalt mix, there will be three phases namely aggregates, binder and air voids. One of the most important problems in bitumen mixes is to recognize and quantify their volumetric properties. In general, experiments are divided into two parts destructive and non-destructive tests. Image processing technique is an important non-destructive technique. In this particular work, an attempt is made to separate these three phases and measure the value of these phases by digital image processing technique. The microstructure of the asphalt mix is captured by using digital camera. The images that are obtained are then analysed in the MATLAB software using programming language to obtain the percentage air voids in the processed sample images.

II. METHODOLOGY
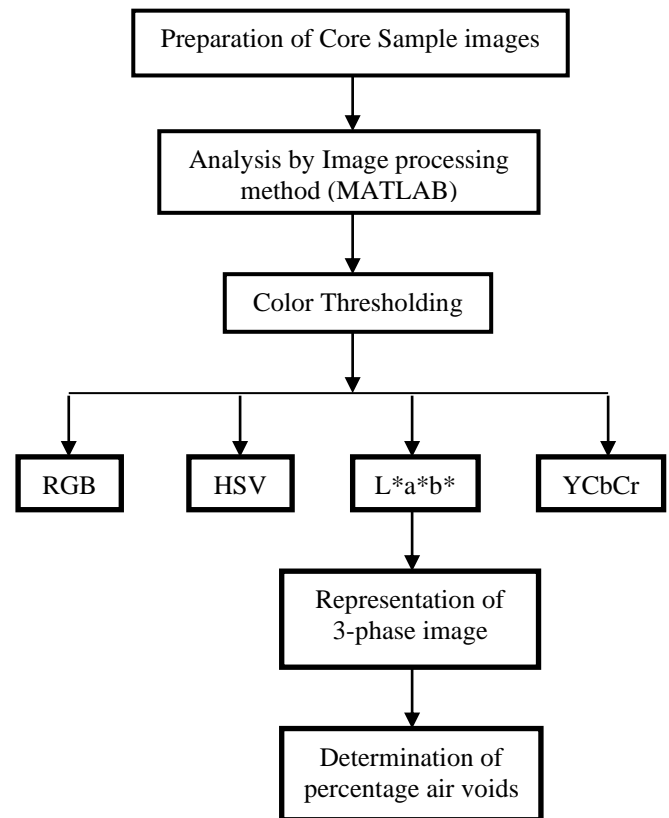
III. ANALYSIS THROUGH IMAGE PROCESSING

A. Material and Methodology

In this study the research was done on asphalt samples. The 24-cylinder samples of 7x 10.1 cm dimension. Different asphalt mixes namely Mix 1, Mix 2 and Mix 3 with varying binder content and varying temperature was prepared for analysis by image processing technique. The percentage air voids of this sample were obtained in the laboratory test. The top surface of the asphalt mixture was then photography scanned perpendicular to the vertical axis at distance of 25 cm. The obtained image is 6016 x 4000 resolutions of a bitumen

mix of 100 mm diameter. To have a unique attribute and to identify the features of the mixture (aggregate, binder and air voids) the original image is transformed to gray scale image. The features of the mix are then separated by using image thresholding technique.

B. Computation by using MATLAB Software

MATLAB software is specially developed for researchers and engineers containing several built-in applications that can be used to analyze and develop structures in various engineering fields. The most important part of MATLAB software is its programming language, a simple language based on arrays and matrix makes the mathematical computations easier.

a) Image processing by Color Thresholder

Under several apps in MATLAB, image processing is done by Color Threshold. The color image which is the image of the core sample in our study is fed into the Color Thresholder app where the color spaces in the thresholder app fragments the core image into different color channels.

This fragmentation of the color image results in binary segmentation of the sample image i.e., the color sample image is converted into black and white image. Fragmentation of the image is done by four unique color spaces. When the image is loaded into Color Thresholder app, the image is displayed under different color spaces. By selecting suitable color space, analysis is done where each color space have three different color channels and the pixel values of the image is represented in a 3-D space frame as points.

b) Choosing the suitable Color Space

In the Color threshold segment suitable image of the asphalt samples to be analysed is loaded to the threshold as shown in *Fig. 1*. The Color Threshold contains 4 different Color Spaces namely:

1) RGB 2) HSV 3) YCbCr 4) L*a*b*

c) Image thresholding by L*a*b*

The process of Color thresholding is done by L*a*b* color space, the L* channel denotes black at 0 and white at 100. That is the intensity of white increases towards the increase in frequency in L* color space. The a* axis represents the green–red component colors, with green having negative values and positive values toward red. The b* axis represents the blue–yellow components, with blue having negative numbers and yellow having positive numbers.

The three phases of asphalt sample can be processed by using L*:

The mastic or bitumen content is usually represented within the frequency range 0 to 30, aggregate content in the frequency range 30 to 80 and air voids content in the range of 90 to 100 of L* color channel.

The a* channel is used to eliminate or vary green or red component colors in the image within or outside the core boundary. The b* channel is used to eliminate or vary blue or yellow component colors in the image within or outside the core boundary.
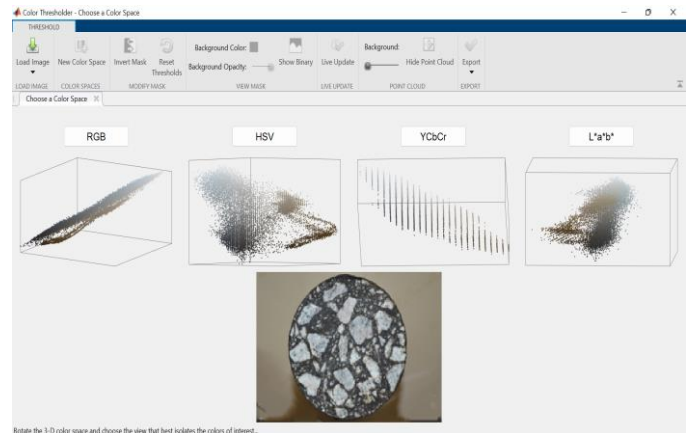

Fig. 1. Choosing a Color Space in MATLAB software

d) Determination of Percentage Air voids by coding or programming

In the editor tab of MATLAB, a new script is created by adopting a code or programming to determine percentage air voids for the processed image.

The code which has been developed to determine percentage air voids is as follows:

```
I=imread("E:\MATLABresultphotos\BC-I\R304AV.JPG");

imshow(I)

AVprops = regionprops("table",I,"Area");

AVareaPixels = sum (AVprops.Area);

AVpix2mm = (902/101)^2;

AVareammsq = round(AVareaPixels*AVpix2mm);


A=imread("E:\MATLABresult photos\BC-I\R304A.JPG");

imshow(A)

MAprops = regionprops("table",A,"Area");

MAareaPixels = sum (MAprops.Area);

MApix2mm = (902/101)^2;

MAareammsq = round(MAareaPixels*MApix2mm);


B=imread("E:\MATLAB result photos\BC-I\R304B.JPG");

imshow(B)

Bprops = regionprops("table",A,"Area");

BareaPixels = sum (Bprops.Area);

Bpix2mm = (902/101)^2;

Bareammsq = round(BareaPixels*Bpix2mm);


PercentageAirvoids=(AVareammsq/(AVareammsq+MAaream
msq+Bareammsq))*100;
```

'Imread' is the MATLAB syntax used to read the processed image in a particular location in the computer. 'Imshow' is the syntax used to display or show the image that

has been read by the MATLAB interface. 'Regionprops' is the syntax used to determine the region properties of the processed image which can be either the area or perimeter that needs to be calculated and displayed in the desired format (table). 'Sum' is the syntax used to add all the area of individual segments which may be aggregates, mastic or air voids in a processed image.

The measured area of the processed image done by MATLAB is in square pixels that have to be converted to square mm. A suitable 'conversion factor' is developed for this conversion of area from square pixels to square mm, this factor is the square of the ratio of diameter of the core sample in pixels to the diameter of the core sample in mm.

Conversion factor = (dia of core sample in pixels/ dia of core sample in mm) ^2. This conversion factor is multiplied with the area of core sample in square pixels to get area of the core sample in square mm. 'Imtool' is the syntax used to measure the diameter of the core sample in terms of pixels. The diameter was found to be 902 pixels and the diameter of

the standard core sample measured in laboratory is 101 mm. Similarly, area of all three phases (aggregates, mastic and air voids) are calculated individually and is displayed in the workspace of the MATLAB interface.

Finally, Percentage of air voids is calculated by,

Percentage of air voids = (area of air voids/ (area of air voids + area of aggregates + area of binder))*100

C. Results from the Analysis

In this study, non-destructive method was used to detect and evaluate the value of each phase of asphalt mixture. The images shown in the below tables are the image processing results for different asphalt mixes. Where, Image (a)= Image of the core, Image (b)= Image of segmented aggregate, Image (c)= Image of binder and Image (d)= Image of segmented voids.

TABLE I. IMAGE ANALYSIS OF MIX 1 AT VARYING BITUMEN CONTENT
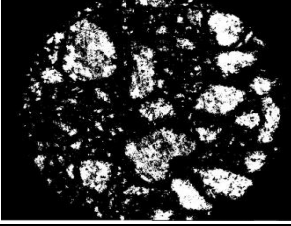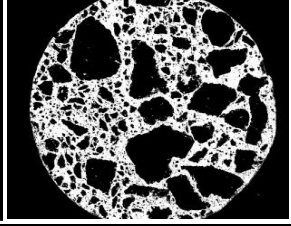
5				
	Image (a)	Image (b)	Image (c)	Image (d)

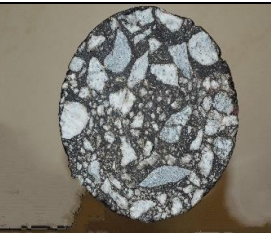TABLE II. IMAGE ANALYSIS OF MIX 3 AT VARYING BITUMEN CONTENT
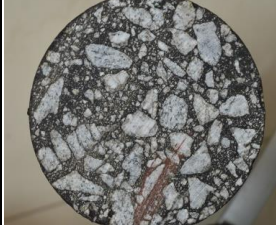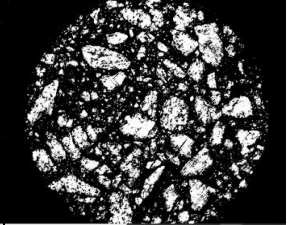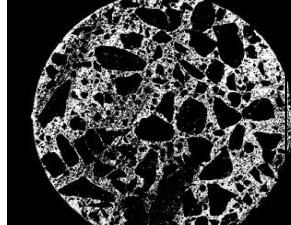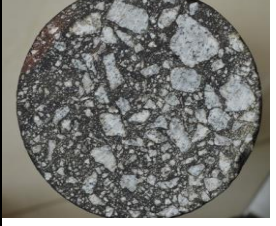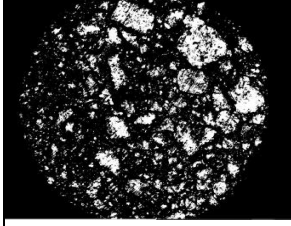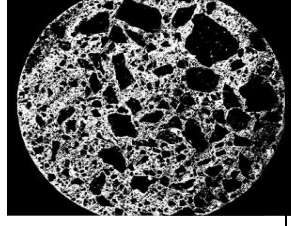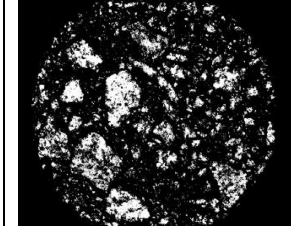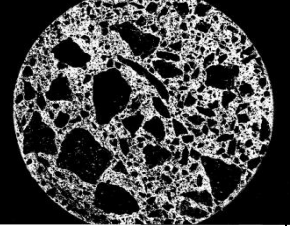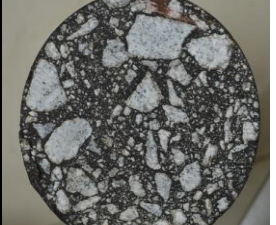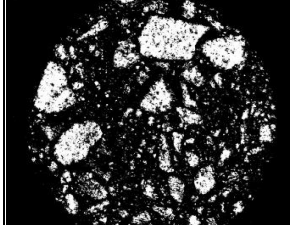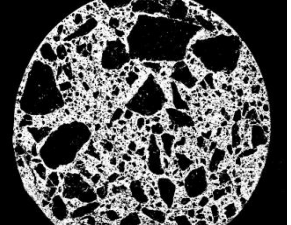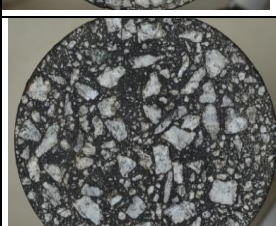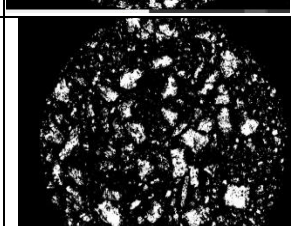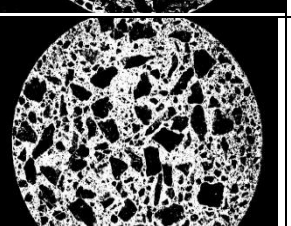
1				
2				
3				
4				
5				
	Image (a)	Image (b)	Image (c)	Image (d)

TABLE III. IMAGE ANALYSIS OF MIX 2 AT VARYING BITUMEN CONTENT
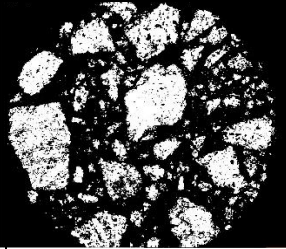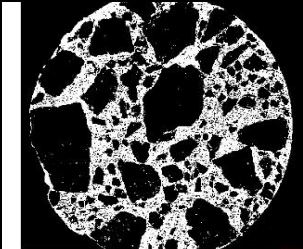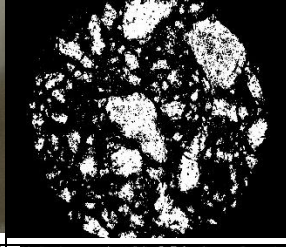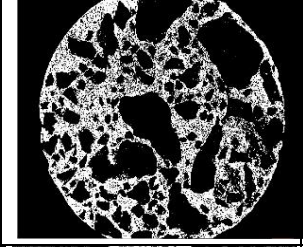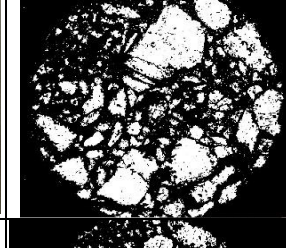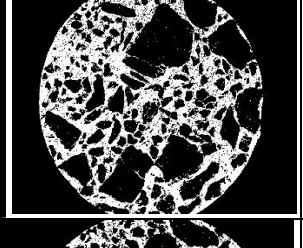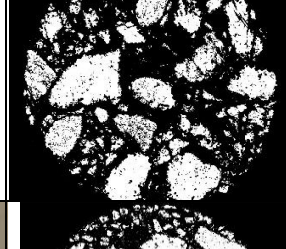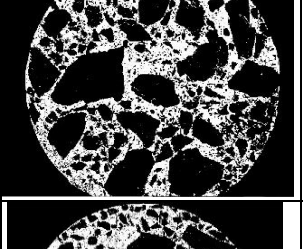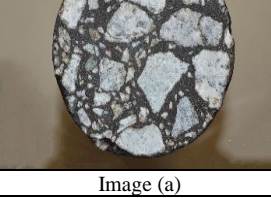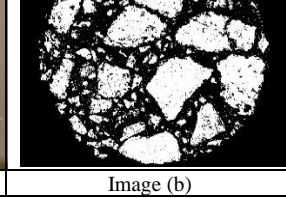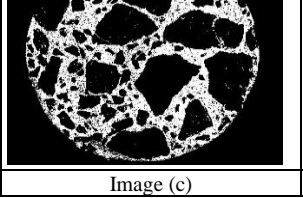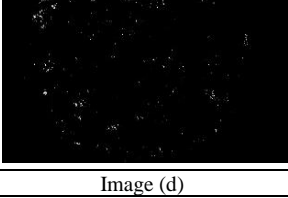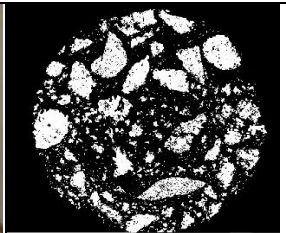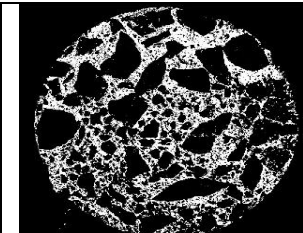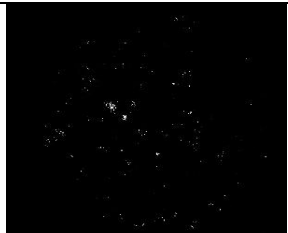
| | Image (a) | Image (b) | Image (c) | Image (d) |

TABLE IV. IMAGE ANALYSIS OF MIX 1 AT VARYING TEMPERATURE
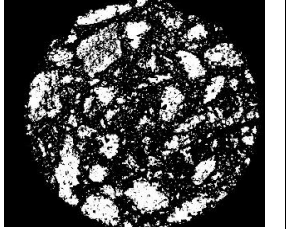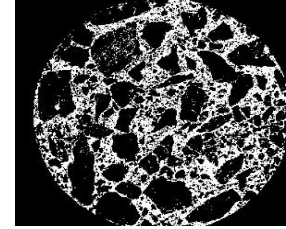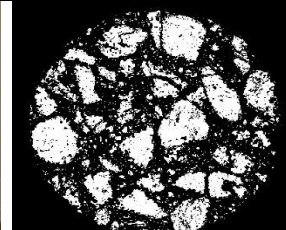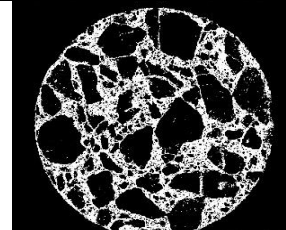
2				
3				
4				
	Image (a)	Image (b)	Image (c)	Image (d)

TABLE V. IMAGE ANALYSIS OF MIX 3 AT VARYING TEMPERATURE
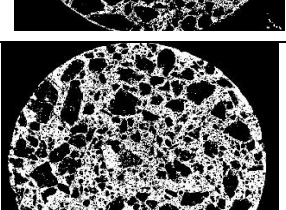
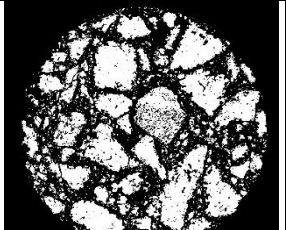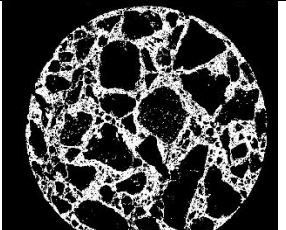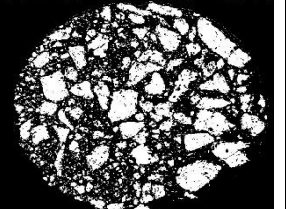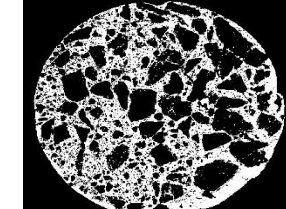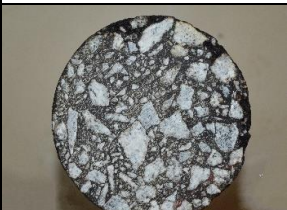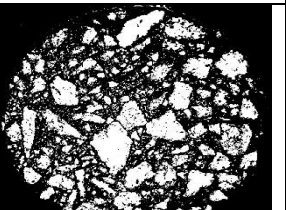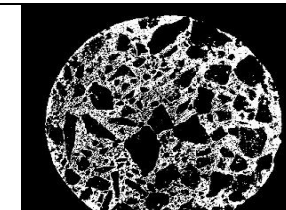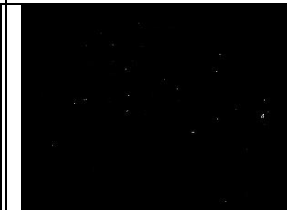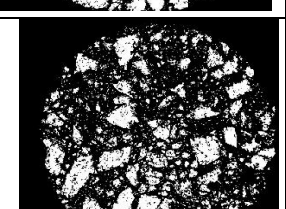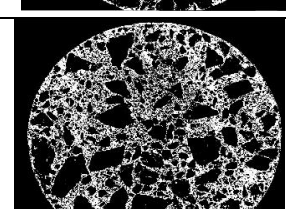|				
1				
2				
3				
4				
	Image (a)	Image (b)	Image (c)	Image (d)

TABLE VI. IMAGE ANALYSIS OF MIX 2 AT VARYING TEMPERATURE

| | Image (a) | Image (b) | Image (c) | Image (d) |

TABLE VII. PERCENTAGE OF AIR VOIDS OF DIFFERENT ASPHALT MIXES COMPUTED BY IMAGE PROCESSING TECHNIQUE.

Asphalt Mix	Percentage Air voids (%) at varying bitumen				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Mix 1	3.33	3.03	3.96	3.93	1.77
Mix 3	1.98	2.86	0.39	0.83	2.196
Mix 2	2.82	3.25	0.72	2.49	3.81
Percentage Air voids (%) at varying temperatures					
Mix 1	2.32	2.99	1.19	2.82	-
Mix 3	4.55	0.6	2.92	0.91	-
Mix 2	0.99	1.51	1.77	0.85	-

D. *Discussion and Conclusion*

- The core sample images of different asphalt mixes are processed to get 3-phase image of the asphalt (binder, aggregates and air voids) by Color Thresholding of core images in MATLAB software. The amount or area of binder, aggregates and air voids of processed image is calculated.

- Percentage air voids at different binder contents of Mix 1 ranges from 1.77% to 3.96%, Mix 3 ranges from 0.83% to 2.86% and Mix 2 ranges from 0.72% to 3.81% when the analysis is carried out by image processing technique.

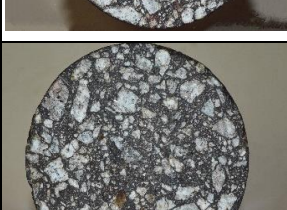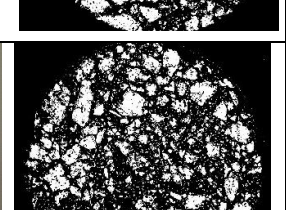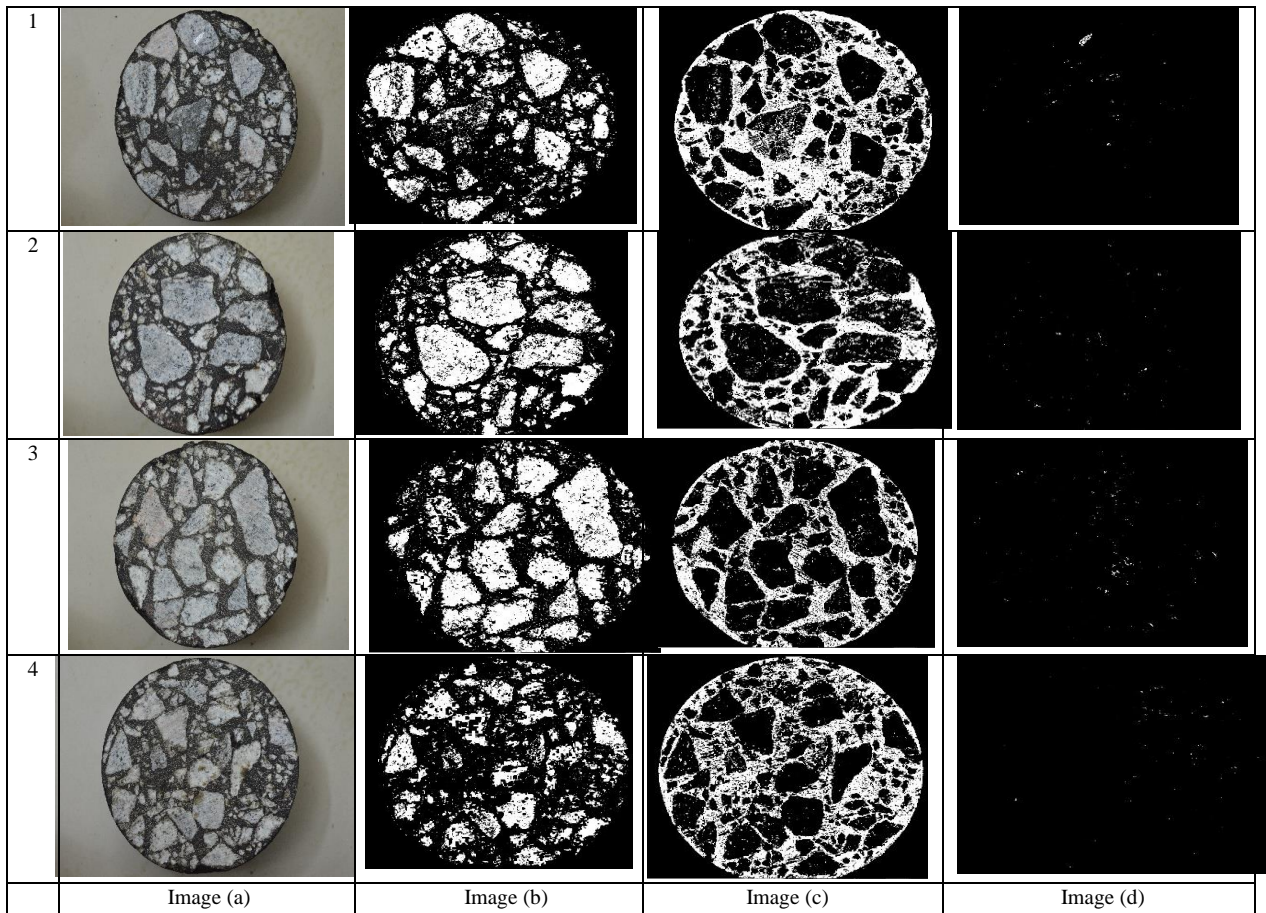- Percentage air voids at varying mixing temperatures of Mix 1 ranges from 1.2% to 2.82%, Mix 3 ranges from 0.6% to 4.55% and Mix 2 ranges from 0.85% to 1.77% when the analysis is carried out by image processing technique.

- The present study is an initial attempt to quantify the air voids of the mix by image processing technique and hence the variation of other parameters are not highlighted with voids.

- Analysis of Percentage air voids by MATLAB software is easier and is an effective tool compared to analytical method due to its flexibility such as 3-phase imaging and area calculation of all three components (binder, aggregates and air voids).

REFERENCES

[1] Fereidoon Moghadas Nejad, Farah Zare Motekhases, Hamzeh Zakeri and Ahmed Mehrabi, "An Image Processing Approach to Asphalt Concrete Feature Extraction", Journal of Industrial and Intelligent Information Vol. 3, No.1, March 2015.

[2] Zanqi Wang, Jianguang Xie, Lei Gao, Yanping Liu and Kuan Li, "Study on Air Void Characteristics and Hydraulic Characteristics of Porous Asphalt Concrete Based on Image Processing Technology", Hindawi Geofluids Volume, 2021.

[3] Adhikari Sanjeev, You Zhan-ping, Hao Pei-wen and Wang Hai-nian, "Image analysis of aggregate, mastic and air void phases for asphalt mixture", Journal of Traffic and Transportation Engineering, Vol. 13, No. 2, April 2013.

[4] Augusto Cannone Falchetto, Ki Hoon Moon, Michael P. Wistuba, "Microstructural analysis of asphalt mixtures containing recycled asphalt materials using digital image processing", 6th Eurasphalt & Eurobitume Congress, June 2016.

[5] HU Jing, Qian Zhendong, LIU Yang and XUE Yongchao, "Microstructural Characteristics of Asphalt Concrete with Different Gradations by X-ray CT", Journal of Wuhan University of Technology, June 2017.

[6] Ambika Kuity and Animesh Das, "Study on aggregate size distribution in asphalt mix using images obtained by different imaging techniques", Transportation Research Procedia, 2016.

[7] Ali Mohamed Zaltuom, "A Review Study of the Effect of Air Voids on Asphalt Pavement Life", Proceedings of First Conference for Engineering Sciences and Technology", September 2018.

[8] The MathWorks, Inc. © 1994-2022.