Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-091

Research Article

Open Access

A Study of Air Voids Variation with Compactive Effort in Asphalt Mixes

Prahallad Bangalore Satyanarayanachar, Jaya Raghuveer Shinganmakki*, Mohan Murugan and Swathi Jayanna

Department of Highway Technology, RASTA-Center for Road Technology, Bengaluru, Karnataka, India

***Correspondence to:**
Jaya Raghuveer Shinganmakki
Department of Highway Technology,
RASTA-Center for Road Technology,
Bengaluru, Karnataka, India.
E-mail: jayars@rastaindia.com

Received: July 28, 2023
Accepted: October 17, 2023
Published: October 19, 2023

Citation: Satyanarayanachar PB, Shinganmakki JR, Murugan M, Jayanna S. 2023. A Study of Air Voids Variation with Compactive Effort in Asphalt Mixes. *Nano World J* 9(S3): S496-S499.

Published by United Scientific Group

Abstract

This paper envisages a comprehensive study on the air voids (Vv) in asphalt-aggregate mix BC Grade-II and effect of varying the compaction levels on the mix performance and air voids. The study dwells on volumetric analysis as carried out on laboratory samples and an attempt is made to measure the percentage air voids at a nano-level by image processing using MATLAB. The motivation to this research work is to understand and determine the % air voids which is one of the most critical physical properties of any asphalt mix design with variation of compactive effort. Three levels of compaction, involving 150, 200, and 250 gyrations each, were adopted in this investigation. It is observed that density and stability peaks at 200 gyrations with voids varying from 3 - 5% which is in the acceptable range of volumetrics. A marginal decrease in the voids as obtained from image processing is observed which could be attributed to method divergence and needs careful consideration.

Keywords

Air voids, Asphalt mix, Gyrations, Marshall stability, Image processing using MATLAB

Introduction

In 1974, Norio Taniguchi of Tokyo University of Science coined the term “nanotechnology,” referring to the exploration and utilization of structures within the 1 nm to 100 nm size range. This field has led to significant advancements in various sectors, including oncology, immunology, and ophthalmology [1, 2]. Compared to bulk materials, nanoparticles exhibit distinct characteristics due to their nanostructure [3-5]. Objectives of the present were: (i) to study the variation of air voids in asphalt mixes at varying compaction levels and (ii) to compare the air voids obtained at a nano-level by image processing using MATLAB.

Materials and Method

The three constituents of HMA are aggregate, asphalt binder, and air voids. All three of the constituents have an effect on performance of the HMA. The results as obtained for aggregates and binder are mentioned as follows in table 1 and table 2, respectively. The physical requirements are meeting standards.

Compactive effort variation

The air voids in the asphalt mix are directly impacted by changing the compactive effort. As a result, in the laboratory, the number of gyrations were varied to bring about a change in the compactive effort imparted to the specimen. The field compaction which resembles a kneading action is replicated by the gyratory compaction process.

Table 1: Physical properties - coarse aggregate for BC Grade-II and their results.

Property	Test	Result	Specification as per MoRT&H for BC	Method of test
Particle shape	Combined index	26.4	Max 35%	IS:2386 Part I
Strength	Los Angeles abrasion value	27.7	Max 30%	IS:2386 Part IV
	Impact value	23.88	Max 24%	IS:2386 Part IV
Water absorption	Water absorption	0.24	Max 2%	IS:2386 Part III
Stripping	Coating and stripping of asphalt aggregate mix	97%	Minimum retained coating 95%	IS:6241
Specific gravity of aggregates	Specific gravity of course aggregates	2.62	-	IS:2386 Part III
	Specific gravity of fine aggregates	2.68	-	IS:2386 Part III

Table 2: Test results and specifications on VG-30.

S. No.	Property	Results	IS: 73-2013 requirement	Test method
1	Penetration at 25 °C 0.1 mm, 5 s, 100 g, min	62.38	45	IS 1203
2	Softening point (R&B) (°C) Min	51.5	Min. 47	IS 1205
3	Flash point °C, Min	300	Min. 220	Is 1209
4	Ductility, cm at 27 °C, Min	58.76	Min. 40	IS 1208
5	Specific gravity	1.02	0.97 to 1.02	IS: 1202
6	Kinematic viscosity at 135 °C, cSt, Min	360	350	IS: 73- 2006

The specifics of the compaction effort are provided as follows: Gyratory compactor: Samples were compacted using gyratory compactor, with following details: Gyratory angle (1.25°), vertical pressure applied (600 KPa) and gyrations rate applied (150, 200, and 250).

The asphalt mixture prepared at optimum binder content (OBC) was placed into a 100 mm-diameter, previously heated mould. A base plate at the bottom and a top plate kept in the mold to ensure confinement while compacting. Throughout the compacting process, the gyratory base revolved at a constant 30 rpm. A representation of the gyratory compactor is shown in figure 1.

The impact of altering compactive energy was examined through adjustments in gyratory compaction - specimens prepared at the OBC. The gyratory compaction method imitates a kneading process, simulating the rolling process applied at field. This approach is effective in emulating the final density achieved on-site. It provides flexibility in mimicking the tyre pressures of diverse vehicle classes. Furthermore, it allows for the monitoring of sample densification, thereby controlling the preparation of samples. This study focuses on compaction as a variable influencing air void. Mixtures that compact too rapidly are perceived to be vulnerable and unstable.

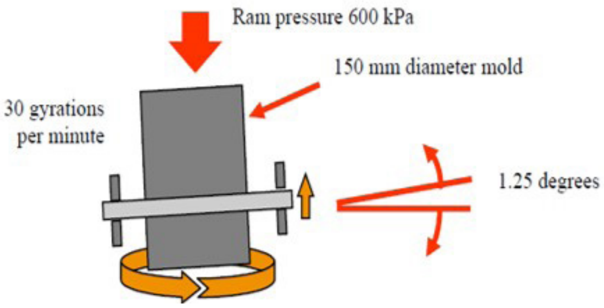


Figure 1: Schematic representation of the gyratory compactor.

Stability analysis

Stability analysis was performed on samples of BC Grade-II, which were densified using gyratory compaction. This analysis aimed to comprehend the impact of compaction. Variations in compaction were introduced by altering number of gyrations to G(150), G(200), and G(250), and these variances displayed in tabular form as indicated below in table 3. The variation of stability, air voids, and bulk density with compaction is shown in figure 2.

Results and Discussion

Indirect tensile strength (ITS) test (Static)

The ITS test (static) is a standard method for determining the tensile strength of bituminous mix. It is a simple test which provides useful information on the material's strength and behavior under tensile loading conditions. The ASTM DD 6931-07 test is used to find the ITS values of asphalt mix. In addition, the test is conducted to assess moisture sensitivity and potential to striping of asphalt mixtures. The obtained results tabulated in table 4.

Fatigue test with varying compaction

A typical laboratory process for evaluating a material's endurance and longevity, particularly in engineering contexts requiring cyclic loads, is the fatigue test. Using stress levels of 20% and 30%, this test was carried out at a temperature of 30 °C to check the effects of compaction on the fatigue perfor-

Table 3: Marshall properties at varying compactive efforts.

	Gyratory effort	Stability (kg)	flow (mm)	Vv (%)	Gb (g/cc)	VFB (%)	VMA (%)
BC Grade-II (Mix-3)	150	1278.08	3.13	5.05	2.37	72.45	18.32
	200	1365.98	3.23	4.23	2.39	76.01	17.61
	250	1242.91	3.43	4.19	2.39	76.24	17.58

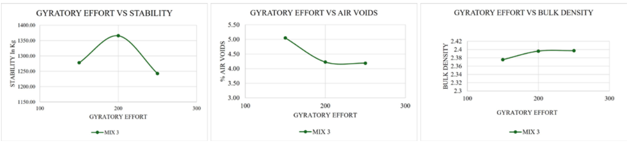


Figure 2: Variation of Marshall volumetric characteristics in response to varying compaction efforts across different mixtures.

mance of mixes using an indigenously fabricated equipment - repeated load testing. The results shown in table 5.

Image processing and voids analysis

For the study, cylindrical samples measuring 7 x 10.1 cm were sliced out by diamond-edge cutting from the Marshall test specimens in the fabrication lab. In a laboratory test, the proportion of air voids in this sample was determined. The top surface of the mix was then photographed and scanned from a constant distance of 25 cm, normal to the vertical axis. The sectional image of the mix specimen with 100 mm diameter that was obtained has a resolution of 6016 x 4000. The original image is then converted to a grayscale image in order to have a distinctive quality and to distinguish the characteristics of the mix (aggregate, mastic, and air voids). Then, using the color thresholding technique in the MATLAB software the mix's features are separated.

To separate the features of the mixture the image undergoes volor thresholding by L*a*b* color space in the MATLAB software. The separated images are then obtained and by using simple MATLAB programming language, the quantities of all three quantities of aggregates, asphalt and air voids are determined. Finally, the air voids, % in the asphalt mixture is determined.

The samples of BC Grade-II at various gyration levels such as G(150), G(200), and G(250) were considered for image processing in the present study. The procedure followed in characterizing the air voids using image processing tool and the editor tab depicting the code written to process the images is shown in figure 3 and figure 4, respectively. All three phases of mixture (aggregates, mastic and air voids) obtained after color threshold for each gyratory compaction of G(150), G(200), and G(250) are shown in figure 5, figure 6, and figure 7, respectively. Calculated individually as displayed in the workspace of the MATLAB interface (Figure 4) The comparison of the air voids thus obtained by image processing and as obtained by volumetric calculations for the specimen are tabulated in table 6.

Table 5: Repeated load - Fatigue test results at varying compaction.

Compaction effort, Gyrations	Load cycles, Nos.		Gradation
	20% stress	30% stress	
150	4380	1040	BC Grade-II (Mix 3)
200	4460	921	
250	4245	1963	

Conclusions

- Stability and density reach peak at 200 gyrations as shown in figure 2, which represents the optimal compaction effort in this investigation. Air voids, on the other hand, tend to decrease gradually with an increase in the number of gyrations or the compaction effort. Furthermore, as the gyratory effort increases, the flow value is noted to rise.
- The outcomes regarding air voids for all mixtures exhibit a reliable consistency with minimal divergence from the intended targets. Air void percentages fall uniformly within 3% to 5%, meeting the stipulated specifications satisfactorily. Improved results in terms of ITS and, consequently, TSR are observed with the employment of 200 gyrations.
- At a nano level, the air voids were analyzed by image processing using MATLAB (2% - 3%) and was learnt to be lesser than those obtained volumetrically in the laboratory studies (3% - 5%) as seen from table 6. This marginal difference necessitates the careful consideration of test methods to characterise the air voids in asphalt mixes.
- The quantity of air vodis in HMA depends on the level of compaction effort, and therefore, inadequate compaction leads to increased susceptibility to moisture damage and fatigue.
- Compaction is a densification process in which air voids are minimized by closely packing aggregates together.

Table 4: ITS results at varying compactive effort.

Compaction effort	Mix	OBC (%)	ITS conditioned in (KPa)	ITS unconditioned in (KPa)	TSR (%)	Required
G(150)	BC Grade-II (Mix 3)	4.9	1132	1189	95.2	80% Min
G(200)			1191.5	1260.3	94.54	
G(250)			1174	1235	95.06	

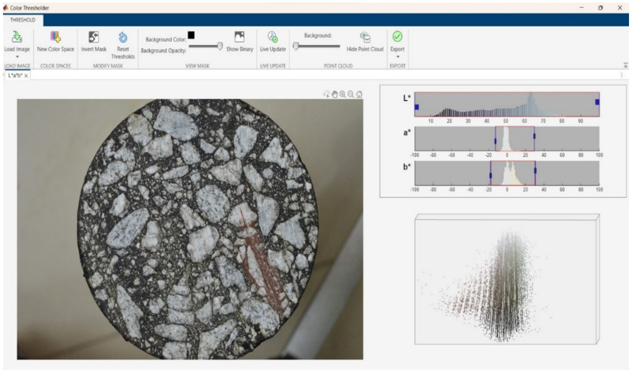
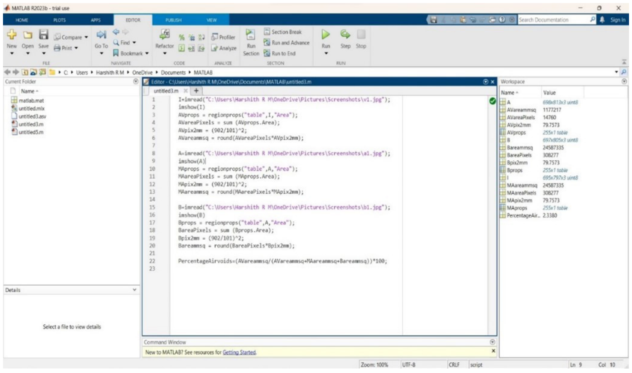


Figure 3: Original core image subjected to L*a*b* color space.



```
I=imread("C:\Users\Harshith R M\OneDrive\Pictures\Screenshots\v1.jpg");
imshow(I)
AVprops = regionprops("table",I,"Area");
AVareaPixels = sum (AVprops.Area);
AVpix2mm = (902/101)^2;
AVareammsq = round(AVareaPixels*AVpix2mm);

A=imread("C:\Users\Harshith R M\OneDrive\Pictures\Screenshots\a1.jpg");
imshow(A)
MAprops = regionprops("table",A,"Area");
MAareaPixels = sum (MAprops.Area);
MApix2mm = (902/101)^2;
MAareammsq = round(MAareaPixels*MApix2mm);

B=imread("C:\Users\Harshith R M\OneDrive\Pictures\Screenshots\b1.jpg");
imshow(B)
Bprops = regionprops("table",A,"Area");
BareaPixels = sum (Bprops.Area);
Bpix2mm = (902/101)^2;
Bareammsq = round(BareaPixels*Bpix2mm);

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

Name	Value
A	698x813x3 uint8
AVareammsq	1177217
AVareaPixels	14760
AVpix2mm	79.7573
AVprops	255x1 table
B	697x805x3 uint8
Bareammsq	24587335
BareaPixels	308277
Bpix2mm	79.7573
Bprops	255x1 table
I	695x797x3 uint8
MAareammsq	24587335
MAareaPixels	308277
MApix2mm	79.7573
MAprops	255x1 table
PercentageAir...	2.3380

Figure 4: Editor tab containing code to perform analysis.

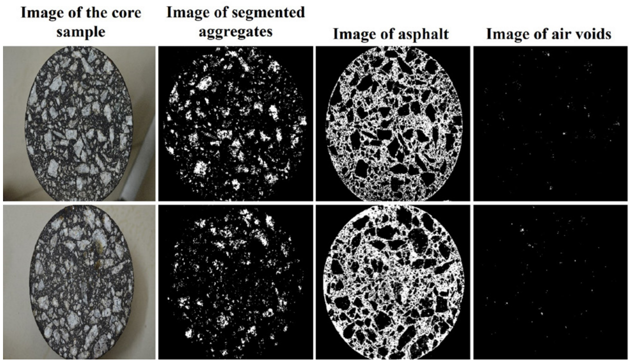


Figure 5: Image processing analysis of asphalt mixes at 150 gyrations.

The air void levels achieved after a specific number of gyrations were observed to closely align with the desired target of 4% air voids for all aggregate gradations in the current research.

- The proper compaction quality significantly impacts asphalt pavement performance. In general, when assessing the mix, air voids are often considered the most crucial parameter.

Acknowledgements

The author acknowledges the valuable contribution of all co-authors and Institute facilities and management support, RASTA Center for Road Technology, Bengaluru (Karnataka, India), throughout the research work.

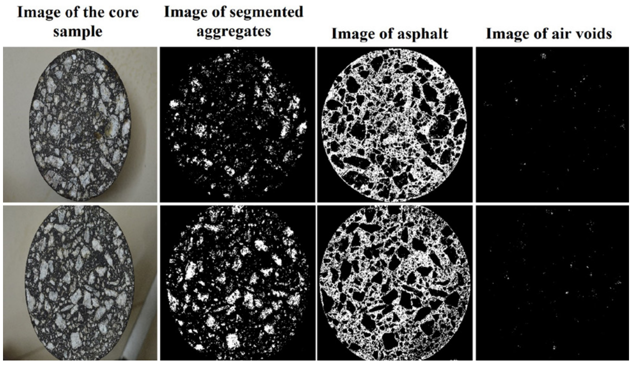


Figure 6: Image processing analysis of asphalt mixes at 200 gyrations.

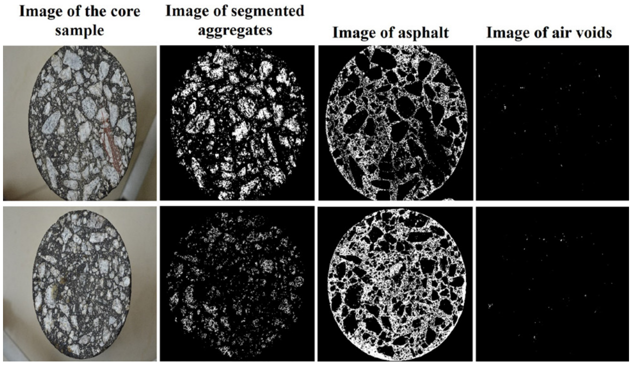


Figure 7: Image processing analysis of asphalt mixes at 250 gyrations.

Table 6: Percentage of air voids of asphalt mix at different gyration computed by image processing technique.

Gyration	Percentage air voids, Vv (%) – Image processing			Percentage air voids, Vv (%) - Lab studies
	Sample 1	Sample 2	Average, Vv	
150	3.62	2.85	3.24	5.05
200	2.80	2.68	2.74	4.23
250	2.33	2.01	2.17	4.19

Conflict of Interest

None.

References

1. Goldsmith DR, Wellington K. 2005. Naftidrofuryl: a review of its use in the treatment of intermittent claudication. *Drugs Aging* 22: 967-977. https://doi.org/10.2165/00002512-200522110-00006
2. Bhatia S. 2016. Natural Polymer Drug Delivery Systems: Nanoparticles, Plants, and Algae. Springer.
3. Joshi SK. 2014. On application of image processing: study of digital image processing techniques for concrete mixture images and its composition. *Int J Eng Res* 3(3): 1137-1146.
4. Keymanesh MR, Nasrollahtabar A, Shahryari N. 2018. Internal structure features of asphalt mixture for field samples. *J Rehab Civ Eng* 6(1): 10-20.
5. Hu J, Liu P, Wang D, Oeser M. 2018. Influence of aggregates' spatial characteristics on air-voids in asphalt mixture. *Road Mater Pavement Des* 19(4): 837-855. https://doi.org/10.1080/14680629.2017.1279072