CONSTRUCTION
E-ISSN: 2785-8731
VOLUME 3, ISSUE 1, 2023, 1 – 5
DOI: https://doi.org/10.15282/construction.v3i1.8813

RESEARCH ARTICLE

Influence of Aggregates Shape on Porous Asphalt Mixture

N.S.I. Liew*, C.M. Ng, N.S.N. Mohd Sori, R.P. Jaya and K.A. Masri

Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

ABSTRACT - Porous asphalt (PA) is a porous pavement layer made of an open graded aggregate that has a lot of linked air voids. The technical qualities and performance of PA are heavily influenced by the aggregate shape and surface roughness. Granite aggregate was use in this research to study the effect of aggregate shape on volumetric and mechanical properties of porous asphalt mixture and to evaluate the quality of aggregate shape of porous asphalt mixture (PAM) in relation to aggregate shape. To classify the aggregate size, sieve analysis was carried out and followed by flakiness and elongation index test. Marshall stability test and resilient modulus test were conducted to study the behavior of PAM by replacing different shape of aggregate. Based on the result cubical shaped aggregates are more recommended to be use in PAM, due to the strength is higher than the conventional PA.

ARTICLE HISTORY

Received	:	26th Oct. 2022
Revised	:	04th Jan. 2023
Accepted	:	07th Feb. 2023
Published	:	19th April 2023

KEYWORDS

Porous asphalt,
Aggregate shape,
Elongation index,
Flaky aggregate,
Cubical aggregate,

1.0 INTRODUCTION

One of Malaysia's key economic sectors, the road construction industry is heavily dependent on the quarrying industry for its aggregate needs. The density and packing structure of aggregate blends are significantly influenced by the physical characteristics of the aggregates, such as size distribution, grading zone, and particle density [1]. Asphalt mixtures with flaky stones were discovered to require a larger quantity of asphalt binder, increasing the amount of flaky particles in an asphalt mixture may result in a reduction in the mixture's robust modulus and resistance to permanent deformation [2]. The resilience modulus and creep resistance of asphalt mixtures may be increased by using geometrically cubical particles [3].

An open-grade asphalt mixes also called as porous asphalt mixture has interconnected gaps that let water readily flow through the fabric and into the binder course. It has long been understood that porous asphalt mixes provide advantages in terms of safety and the environment. Porous flexible asphalt is well known for its benefits in lowering riding noise, reducing splashing impacts, and enhancing the skid resistance of pavements during rain. When it rains, the risk of accidents and fatalities is reduced attributable to the use of porous asphalt mixtures that drain surface water while also ensuring that tyres have good contact with the pavement [4].

Porous asphalt typically has a total void percentage between 20 and 25 percent, according to Malaysia Public Works Department [5]. This value is significantly higher than that of traditional hot mix asphalt. Applying an open-graded type of aggregate allows porous asphalt to have a highly connected void content. Additionally, porous asphalt may be a flexible non-structural pavement layer that is expected to have enough strength to resist external loads placed on it by traffic [6].

The objectives of this study are to study the effect of aggregate shape on volumetric and mechanical properties of porous asphalt mixture and to evaluate the quality of aggregate shape of porous asphalt mixture in relation to aggregate shape.

2.0 MATERIALS AND METHODS

2.1 Binder and Aggregate

The grade of bitumen used in this study to create a porous asphalt sample was bitumen grade 60/70. Generally it used as a paving grade, bitumen grade 60/70 is the range of bitumen that falls between 60 and 70 at usual test conditions of penetration value. Because of its thermoplastic nature, bitumen grade 60/70 softens in high temperatures and hardens in cold temperatures. Granite aggregate was the type of aggregate used for this research.

2.2 Sieve Analysis Test

In this study, sieve analysis was utilised to separate aggregates into the desired size of coarse aggregates. It consists of several ranges of sieve which are 19 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 0.600 mm, 0.300 mm, 0.075 mm, and the finest sieve used are pan size as shown in Table 1.

*CORRESPONDING AUTHOR | N.S.I. Liew | ✉ nicole95liew@gmail.com
© The Authors 2023. Published by Universiti Malaysia Pahang Publishing. This is an open access article under the CC BY-NC 4.0 license

Table 1. Aggregate grading for porous asphalt

Sieve size (mm)	Percentage of Passing (%)
19	100
12.500	85-95
9.500	65-75
4.750	20-28
2.360	16-24
0.600	12-16
0.300	12-15
0.075	8-10
Pan	

2.3 Flakiness and Elongation Index Test

It was crucial that this test be carried out on aggregate in the lab. The proportions of flaky and elongated particles in aggregates influenced by their particle shape. A standard thickness gauge and a standard length gauge were the measuring instruments that can be used to determine the thickness and length of aggregate. The elongation test was used to achieve the cubical shape, while the flakiness test was used to obtain the flaky shape. Only three aggregate sizes, namely sizes 12.5 mm, 9.5 mm, and 4.75 mm, had been changed to the appropriate shape.

The influence of aggregate shape properties was evaluated by utilising aggregates in three shapes, namely cubical, blade, and disk. The form characteristics of the aggregates were quantified using three shape factors, namely sphericity, shape factor, and roundness.

There are two sieving procedures in the test. To divide the sample into different particle size fractions during the first operation, sieve analysis are applied. After that, bar sieves are used to separate each of the fractions. For both the entire sample and each fraction within it, the flakiness index can be determined. The total mass of particles passing through the bar sieves, represented as a percentage of the total dry mass of the entire sample, is used to determine the overall index.

2.4 Aggregate Crushing Value (ACV)

When a compressive stress is gradually applied to an aggregate, the aggregate crushing value test measures how resistant it is to crushing. The aggregate crushing value is the weight-per-percentage of crushed material achieved when test aggregates are subjected to a specific load under standard conditions, and the strength of aggregate used in road construction is indicated by a numerical index.

2.5 Aggregate Impact Value (AIV)

On the basis of aggregate effect value, their suitability for road construction can be evaluated. The term "toughness" describes a substance's capacity to withstand impact. As a matter of fact of vehicle movement on the road, aggregates are exposed to impact, which causes them to disintegrate into smaller pieces. As a result, the aggregates must be robust enough to withstand disintegration due to impact.

2.6 Marshall Stability Test

Marshall mixed design is a method to prepare a specimen of porous asphalt, the compaction for each sample was carried out in 50 blows. To evaluate the bituminous mix's performance prediction, the Marshall stability test was carried out. The process includes determining the characteristics of mix, Marshall stability, flow analysis, and finally determining the ideal bitumen content. The specimens were heated to the required temperature for the stability test by immersing them in a water bath set at 60°C ± 1°C for 45 minutes. After that, it was put inside the Marshall Stability testing device and loaded continuously up until the maximum load was attained. The Marshall testing apparatus reported the stableness result in kN.

2.7 Resilient Modulus Test

The resilient modulus test can be used to measure the stiffness of materials under various circumstances, such as wetness, density, and stress level. When evaluating how the pavement mix responds to traffic loading, resilient modulus tests are frequently used. According to ASTM D 4123, the resilient modulus measured in the indirect tensile mode accurately captures the elastic characteristics of asphalt mixtures under repeated loads [7].

Utilizing a Universal Material Testing Apparatus (UMATTA), the test was performed to determine the indirect strength under repeated loading or pulse. Each specimen performed a test at 25°C after four hours of conditioning, with test protocols following ASTM D4123 guidelines [7]. The samples were initially put through five condition pulses, after which a 1200N peak load was applied along the sample's vertical diameter. For this test, 3000ms and 100ms of pulse width with a 50ms rise time were used.

2.8 Dynamic Creep Test

To determine the rutting potential of asphalt mixes, the dynamic creep test was performed. According to ASTM D4123's instructions, this test was carried out with the Asphalt Universal Testing Machine, MATTA [7]. The dynamic creep test was done at 40°C, 0.1MPa of applied stress, and 3600 seconds of loading period. The temperatures of 45°C will be used for testing.

3.0 RESULT AND DISCUSSION

3.1 ACV

Table 2 shows the result of ACV for aggregate. The percentage of loss in ACV is less than or equal to 25% [8]. Table 1 shows that the percentage of loss for aggregate was 9.83%, where it is less than 25%. Thus, it is suitable to use for porous asphalt.

Table 2. Aggregate crushing value test result

Sample	Percentage of Loss	Requirement Values [5]
Aggregate (14mm – 10mm)	9.38%	<25%

3.2 AIV

Table 3 shows the result of AIV for aggregate. The percentage of loss in AIV is between 20% to 30% [8]. Table 3 shows that the percentage of loss for aggregate was 22.10%, where it falls within the range of 20% to 30%. Based on Table 3, it is satisfactorily for road surfacing, and it is suitable to use for porous asphalt.

Table 3. Aggregate impact value test result

Sample	Percentage of Loss	Requirement Values [5]
Aggregate (14mm – 10mm)	22.10%	20% - 30%

3.3 Marshall Stability

The results as shown in Figure 1 showed that porous asphalt mixture with cubical shaped aggregates had the best Marshall Stability. The usage of cubical aggregates enhances porous asphalt mixture stability in comparison to flaky aggregates. Cubical aggregates are more resistant to breakage due to its strong aggregate interlocks and internal friction, which is the primary source of stability [1]. Flaky aggregates break easily during mixing and compaction [9].

As a result, the angular pebbles made the porous asphalt sample less workable. The coarse aggregate's angularity, which provided a stiffer and stronger mixture, was a major factor in the porous asphalt's resistance to permanent deformation. [10] The sample that had a significant amount of angular aggregates performed better against permanent deformation. As a result, the angular pebbles made the porous asphalt sample less workable. The angularity of the coarse aggregate had a significant impact on how resistant porous asphalt was to permanent deformation, resulting in a stiffer and more robust combination.

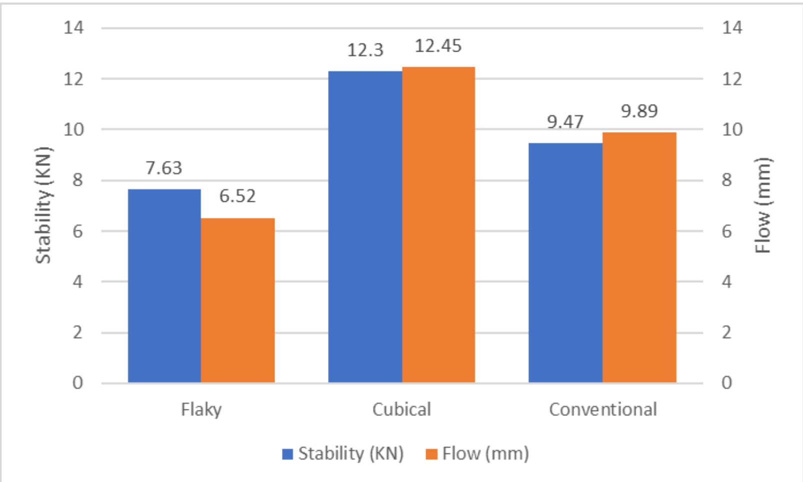

Figure 1. Result of Marshall Stability test

3.4 Resilient Modulus

Based on the resilient modulus results as shown in Figure 2, the result at temperature 25°C is more efficient and higher for porous asphalt mixture as compared to the test results at temperature 40°C. At both temperatures, the cubical aggregates sample has a greater elasticity modulus. By referring to Figure 2, when the load applied, the stress and strain increased. When the stress reduced, the strain lowered as well, but not all of the strain is recovered after the stress is removed.

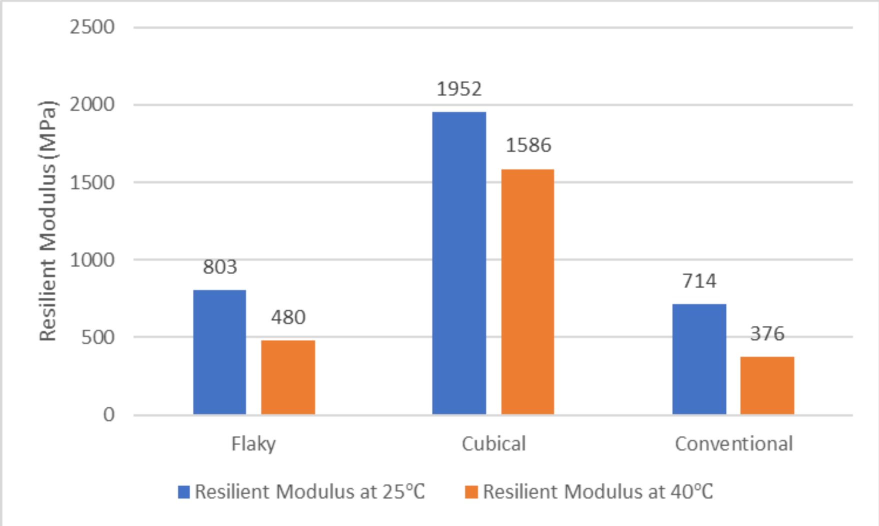

Figure 2. Result of Resilient Modulus test

3.5 Dynamic Creep

The overall outcomes in Figure 3 showed the benefits of using aggregates with a geometrically cubic shape. The Wheel Tracking Machine (WTM) tool is used for the dynamic stability testing in order to evaluate how well the mixture will hold the wheel tracks and any form changes that the pavement structure will experience. One of the crucial mechanical characteristics utilised to build asphalt pavement constructions is dynamic stability with Wheel Tracking Machine (WTM). Testing is conducted utilising 45°C temperatures [11].

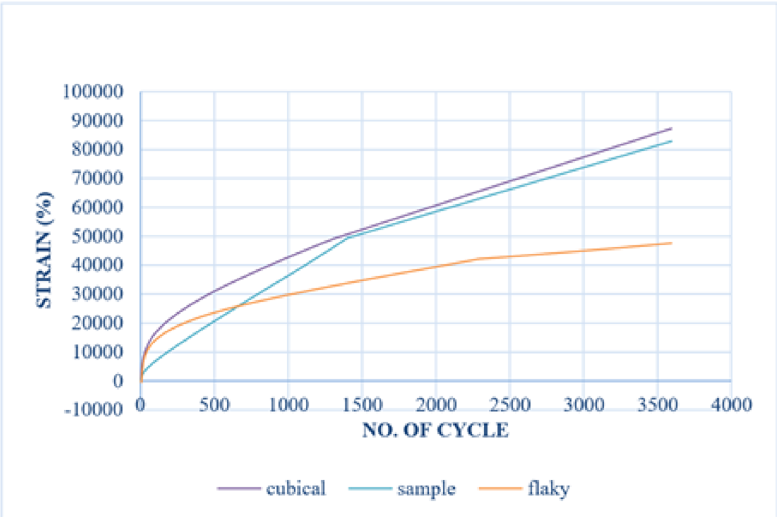

Figure 3. Result of Dynamic Creep test at 45°C

4.0 CONCLUSION

Cubical aggregates porous asphalt mixture is more recommended to be use, due to the strength is higher than the conventional porous asphalt. The rough surface of cubical aggregates is easier to bond with bitumen. Flaky aggregates tend to break easily during mixing and compaction.

5.0 AUTHOR CONTRIBUTIONS

Nicole Liew Siaw Ing.: Data curation, Writing- Original draft preparation.

Ng Cui Ming.: Conceptualization, Methodology, Software.

Nur Syamimi Nabilah Mohd Sori.: Methodology, Investigation.

Ramadhansyah Putra Jaya.: Writing- Reviewing and Editing, Supervision.

Khairil Azman Masri.: Supervision, Visualization.

All authors have read and agreed to the published version of the manuscript.

6.0 FUNDING

This research was funded by Universiti Malaysia Pahang: PGRS210376.

7.0 DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article.

8.0 ACKNOWLEDGEMENT

The support provided by Malaysian Ministry of Higher Education and Universiti Malaysia Pahang in the form of a research grant for this study is highly appreciated.

9.0 CONFLICTS OF INTEREST

The authors declare no conflict of interest.

10.0 REFERENCES

[1] D. M. Kusumawardani and Y. D. Wong, "The influence of aggregate shape properties on aggregate packing in porous asphalt mixture (PAM)," *Construction and Building Materials*, vol. 255, 2020.

[2] M. Z. H. Mahmud, H. Yaacob, R. P. Jaya, and N. A. Hassan, "Laboratory investigation on the effects of flaky aggregates on dynamic creep and resilient modulus of asphalt mixtures," *Jurnal Teknologi*, vol. 70, no. 4, 2014.

[3] R. P. Jaya, N. A. Hassan, M. Z. H. Mahmud, M. M. A. Aziz, M. O. Hamzah, and C. N. C. Wan, "Effect of aggregate shape on the properties of asphalticconcrete AC14," *Jurnal Teknologi*, vol. 71, no. 3, 2014.

[4] J. S. Chen and C. H. Yang, "Porous asphalt concrete: A review of design, construction, performance and maintenance," *International Journal of Pavement Research and Technology*, vol. 13, no. 6, 2020.

[5] Jabatan Kerja Raya (JKR), "JKR/SPJ/2008-S4 Standard Specification for Road Works - Section 4: Flexible Pavement," *Standard Specification for Road Works - Section 4: Flexible Pavement*. 2008.

[6] N. Abdul Hassan *et al.*, "Laboratory evaluation on the effect of clogging on permeability of porous asphalt mixtures," *Jurnal Teknologi*, vol. 76, no. 14, 2015.

[7] ASTM D4123, "Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous," *Annual Book of American Society for Testing and Materials Standards*, vol. 82, no. Reapproved, 1995.

[8] JKR/SPJ/2008-S4, *Standard Specification for Road Works Part4 Flexible Pavement*, vol. 07, no. Reapproved. JKR Specification for Road Works Part 4 Flexible Pavement, 2008.

[9] W. R. Vavrik, R. J. Fries, and S. H. Carpenter, "Effect of flat and elongated coarse aggregate on characteristics of gyratory compacted samples," *Transportation Research Record*, no. 1681, 1999.

[10] N. L. Siaw Ing, R. Putra Jaya, and K. A. Masri, "Performance of Porous Asphalt Mixture Containing Seashell as Aggregate Replacement," *Construction*, vol. 1, no. 1, pp. 18–28, 2021.

[11] F. N. M. Sianturi and S. Sulaiman, "Performance analysis of a porous asphalt mixture with the use of concrete waste as a coarse aggregate and the addition of gilsonite materials," in *IOP Conference Series: Materials Science and Engineering*, vol. 732, no. 1, 2020.