Popular Scientist

Research Article

Influence of Flakiness and Elongation Index Compliance on Marshall Parameters of Asphalt Mixtures

Siti Mira Maulida*, Ucha Arief Pratama, Rafiqa Muhnita Yusputri, Aulia Rahmad, Aqlima Putri, Yusria Darma, Sofyan M Saleh

Department of Civil Engineering, Faculty of Engineering, Universitas Syiah Kuala, 23111, Banda Aceh, Indonesia

***Corresponding Author:** Siti Mira Maulida (sitimiramaulida@usk.ac.id)

Articles History: Received: 16 May 2025; **Revised:** 5 June 2025; **Accepted:** 16 June 2025; **Published:** 23 June 2025

Abstract

The road pavement layer comprises coarse aggregate, fine aggregate, filler, and asphalt. The increasing demand for aggregate in road infrastructure has become a growing concern. According to Bina Marga, the aggregate flakiness and elongation index in the asphalt-concrete mix is limited to a maximum of 10%, whereas the British Standard and AASHTO in BS 812 set a limit of 25%. This index is assessed only for coarse aggregates with a minimum passing size of 3/8". This study evaluates the Marshall parameters of asphalt concrete mixtures using coarse aggregates that either fulfill or do not fulfill the flakiness and elongation index limits. The coarse aggregates were sourced from two stone crushers in Indrapuri, Aceh Besar, while penetration-grade 60/70 asphalt and Portland cement filler were used. Testing was conducted using the Marshall method at the Highway Laboratory of Universitas Syiah Kuala. The results indicate that mixtures with coarse aggregates exceeding the index limit have an optimum asphalt content (OAC) of 5.85%, while those fulfilling the limit achieve 6.05%. Additionally, asphalt mixtures incorporating compliant aggregates demonstrate superior stability and greater resistance to traffic loads, highlighting the importance of using well-graded coarse aggregates in asphalt concrete mixtures.

Keywords: Aggregate, Asphalt Concrete Mixtures, Flakiness Index, Elongation Index, Marshall Parameters

Introduction

The highway is a critical component of the transportation network, facilitating both population mobility and the flow of goods. Ensuring the durability of this infrastructure is paramount, necessitating robust pavement structures capable of withstanding various potential threats [1,2]. Asphalt concrete pavement is among the most prevalent types of flexible pavement in Indonesia. The development of infrastructure has been shown to have a positive correlation with increased demand for road materials, including asphalt and aggregate [3,4]. The composition of this layer consists of coarse aggregate, fine aggregate, and asphalt. The physical properties of the material, including its shape and surface texture, can contribute to the strength of the asphalt mixture [5-7]. For this study, the flakiness and elongation indices are considered essential factors in the analysis of coarse aggregates [8]. The hypothesis tested in this study is that asphalt mixtures using coarse aggregates that comply with the flakiness and elongation indices will demonstrate superior Marshall performance characteristics compared to those that do not. Aggregate products resulting from stone crushing operations exhibit a wide range of geometric forms, such as round, cubic, flat, oval, and irregular shapes. Aggregates with round or oval shapes exhibit reduced inter-aggregate bonding due to smooth surfaces and tangent contact points, which limit interlocking [9]. Similarly, flat or elongated aggregates, while possibly achieving better orientation, tend to fracture more easily under load, altering the gradation and potentially reducing pavement stability.

According to BS 812 [10,11], the maximum allowable flakiness and elongation index in asphalt concrete mixtures is 25%, while Bina Marga (2020) [12-14] imposes a much stricter limit of 10%. These limits apply only to coarse aggregates with a minimum passing size of 3/8”, with no equivalent limits for fine aggregates [15]. Previous studies have generally investigated the influence of aggregate shape on asphalt mix properties. Still, few have directly compared the performance of mixtures using aggregates within and beyond the strict 10% index limit imposed by Bina Marga. This study addresses that research gap by experimentally comparing the Marshall performance of asphalt concrete mixtures using coarse aggregates that either comply with or exceed the 10% flakiness and elongation index threshold. This comparison is scientifically meaningful because it evaluates the practical implications of stricter national specifications relative to international standards. The findings may support more effective and performance-oriented aggregate specifications in pavement design practices. The objective of this study is to ascertain the characteristics of asphalt concrete mixtures using coarse aggregates that either fulfill or do not fulfill the flakiness and elongation indices, with the expectation that incorporating aggregates that meet these indices will enhance the quality and performance of the asphalt mixture, and vice versa.

Materials and Methods

This research was conducted at the Highway Laboratory of the Department of Civil Engineering at Universitas Syiah Kuala. The determination of Optimum Asphalt Content was achieved using five asphalt levels based on the estimated asphalt content: 5%, 5.5%, 6%, 6.5%, and 7%. This study utilized these five asphalt content levels, with three specimens prepared for each level, resulting in a total of 15 specimens to determine the Optimum Asphalt Content (OAC). Subsequently, six additional specimens were prepared at the determined OAC to compare the Marshall parameter values between asphalt concrete mixtures using coarse aggregates that both comply with and do not comply with the flakiness and elongation indices. This research employs the Marshall method. The test specimens were compacted with a total of 2x75 blows, followed by Marshall testing to obtain the optimum asphalt content value using the overlapping method, which involves taking the middle value of the asphalt content range that satisfies all Marshall parameters [16-18].

Aggregate

The aggregates used were taken from 2 different locations in the Indrapuri area, Aceh Besar. Prior to use, the physical properties of the aggregates were tested in accordance with the General Specifications of Bina Marga 2018 Revision 2 (2020). The tests conducted included specific gravity and water absorption, unit weight, Los Angeles abrasion, flakiness, elongation index, and impact resistance. Aggregates from the first location met the flakiness and elongation index requirements as specified by Bina Marga 2020, whereas those from the second location did not meet these criteria.

Asphalt

Asphalt pen 60/70 and filler material in the form of Portland cement were tested for their physical properties in accordance with the General Specifications of Bina Marga 2018 Revision 2 (2020). The tests included specific gravity, penetration, ductility, and softening point.

Results

Testing the physical properties of materials

Testing of the physical properties of the aggregates met the Bina Marga 2020 specification; however, at location 2, the flakiness and elongation tests did not fulfill the specification requirement of a maximum of 10%. Fixed aggregates were used because this study reviewed the use of coarse aggregates that did and did not fulfill the flakiness and elongation indices. The results of the testing of the physical properties of the aggregates can be seen in Table 1.

Table 1. Test results of physical properties of aggregates

Testing	Standard	Terms	Unit	Result Location 1	Result Location 2
Specific gravity	SNI 1969-2008	Min. 2,5	-	2.789	2.702
Water absorption	SNI 1969-2008	Max. 3	%	1.044	1.040
Aggregate content weight	AASHTO T-19-74	Min. 1	kg/dm	1.532	1.547
Elongation Index	ASTM D-4791	Max. 10	%	7.924	23.780
Flakiness Index	ASTM D-4791	Maks. 10	%	9.907	30.513
Impact	SNI 03-4426-1997	Max. 30	%	6.480	10.227
Abration	SNI 2417:2008	Max. 40	%	16.440	19.146

In testing the physical properties of pen 60/70 asphalt, it fulfills the Bina Marga 2020 specifications. The results of the asphalt physical properties test can be seen in Table 2.

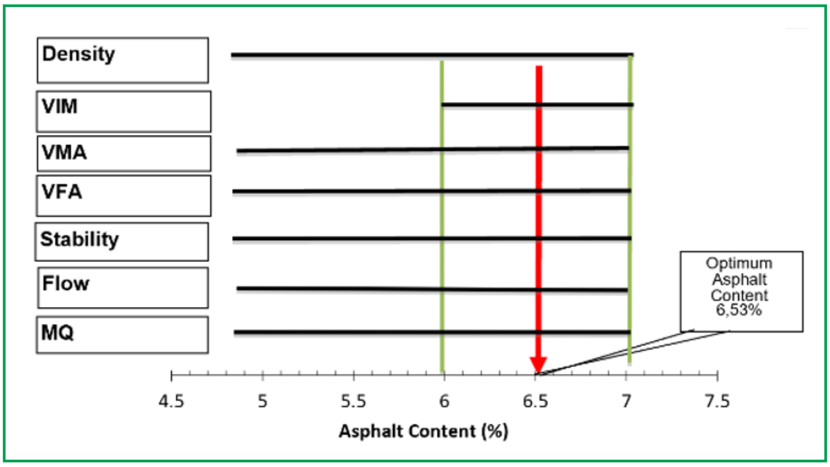
https://doi.org/10.70028/sgm.v2i1.41

Table 2. Test results for physical properties of asphalt

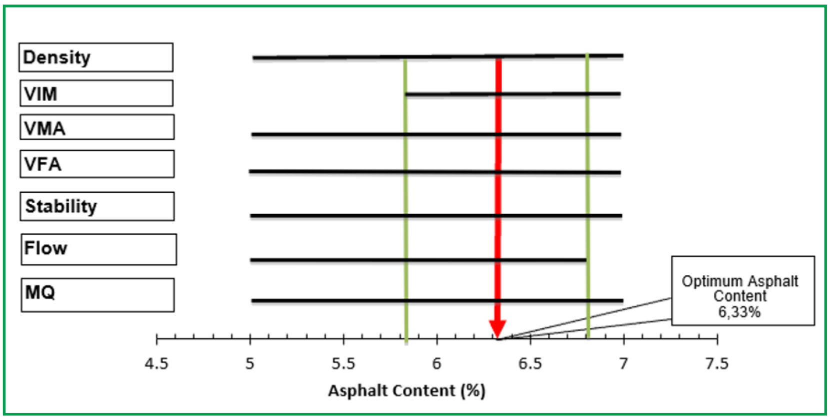
Testing	Standard	Terms	Unit	Result
Specific gravity (25 C)	SNI 2441:2011	≥1	-	1.031
Penetration (25 C; 5 sec; 0,1 mm; 100 gr)	SNI 2456:2011	60-70	(0,1 mm)	65
Ductility (25 C; 5 cm/sec	SNI 2432:2011	≥100	cm	>120
Softening Point; C	SNI 2434:2011	≥48	C	48

Asphlat content

The optimum asphalt content was obtained using the overlapping method. From the distribution of data obtained, non-linear regression was determined to be the most suitable for the relationship pattern between asphalt content and Marshall parameters. The Marshall test results obtained Marshall parameters, namely stability, flow, density, VIM, VMA, VFA, and MQ. The graph of optimum asphalt content values of asphalt concrete mixtures with coarse aggregate that fulfill and do not fulfill the flakiness and elongation index can be seen in Figure 1.



(a)



(b)

Figure 1. Optimum asphalt content graph (a) 6.53%, (b) 6.33%

https://doi.org/10.70028/sgm.v2i1.41

For more details about the Marshall test results, see Table 3. Comparison of the results of Marshall parameter values on asphalt concrete mixtures. From the results of the Marshall test, it is found that the Marshall parameter values of asphalt concrete mixtures with coarse aggregates fulfill the flakiness elongation index better than those of asphalt concrete mixtures with coarse aggregates that do not fulfill the flakiness and elongation index. The comparison results can be seen in Table 3.

Table 3. Comparison of Marshall parameter values

Marshall Parameter Value		
Marshall Parameter	**Asphalt Concrete Mix**	
	fulfill the Index of Flakiness and Elongation	**Does not fulfill the Index of Flakiness and Elongation**
Asphalt Content	6.53	6.33
Stability	1321.78	1254.65
Flow	3.53	3.6
Density	2.39	2.4
VIM	4.67	4.81
VMA	19.81	19.51
VFA	76.43	75.46
MQ	375.79	348.08

Discussion

Based on the results of the research conducted, the best asphalt content in asphalt concrete mixtures is obtained at an asphalt content of 6.05% with coarse aggregate fulfilling specifications and at an asphalt content of 5.85% with coarse aggregate not fulfilling specifications (Figure 2). Based on the review of the Marshall parameters, the values obtained have met the Bina Marga 2018 Revision 2 (2020) specifications. However, the comparison of the two asphalt concrete mixtures shows that the results of the Marshall parameters on the asphalt concrete mixture with coarse aggregates fulfill the flakiness and elongation index are better than those of the asphalt concrete mixture with coarse aggregates that do not fulfill the flakiness and elongation index. This is also influenced by the aggregate used in the mix and the strength of the asphalt concrete mix.

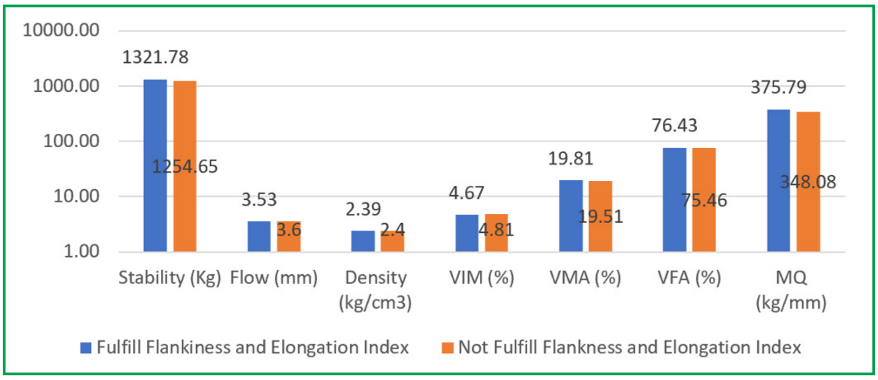


Figure 2. Marshall parameter values

Based on the Marshall test results, the VMA value of the asphalt concrete mixture with coarse aggregate fulfills the specification of 19.81%. This states that the pore content between aggregates in the asphalt concrete mixture is sufficient. Sufficient VMA is a requirement for the stability value obtained, because the VMA value is the limit so that the density of asphalt concrete is not excessive. In the case of asphalt concrete mixtures with coarse aggregates that do not fulfill the flakiness and elongation index, the VMA value is 19.51%. Based on Figure 3, it is found that the VMA value of asphalt concrete mixtures with coarse aggregates that do not fulfill specifications is lower than that of asphalt concrete mixtures with coarse aggregates that fulfill specifications. This occurs because while flat and elongated aggregates may achieve better particle orientation, they inherently exhibit poor interlocking behavior. Furthermore, their reduced thickness makes them more susceptible to crushing under applied loads. This can be seen in the decreasing stability values and increasing flow/melting with the use of coarse aggregates that do not fulfill the flakiness and elongation index. The stability value of asphalt concrete mixtures with coarse aggregate fulfills the flakiness and elongation index, which is 1321.78 kg. Meanwhile, the asphalt concrete mixtures with coarse aggregate did not fulfill the flakiness and elongation index of 1254.65 kg. This value indicates that the asphalt mixture is strong enough to withstand traffic loads. This represents an increase of approximately 5.35% in stability when using aggregates that comply with shape indices, demonstrating a measurable performance improvement. Additionally, the Marshall quotient (MQ) increased by about 7.96%, indicating better stiffness and load-bearing capacity. The flow of asphalt concrete mixtures using coarse aggregate fulfills the flakiness and elongation index, which is 3.53 mm. Meanwhile, the asphalt concrete mixtures with coarse aggregate did not fulfill the flakiness and elongation index of 3.6 mm. This indicates good flexibility properties of asphalt concrete.

The VIM value obtained based on Figure 3 in the asphalt concrete mix with aggregate roughness fulfills flakiness and elongation index is lower at 4.67% compared to the asphalt concrete mix with aggregate roughness not fulfilling flakiness and elongation index at 4.81%. This is because the aggregates are better arranged, so there are fewer empty spaces in the mix, and the asphalt can fill the spaces between the aggregates more effectively. The volume of pores between aggregate grains filled with asphalt (VFA) in the asphalt concrete mix with coarse aggregate fulfilling the flakiness and elongation index of 76.43% was higher than that of the asphalt concrete mix with coarse aggregate not fulfilling the flakiness and elongation index of 75.46%. Although this study did not directly evaluate durability through moisture susceptibility or aging tests, the improvements in Marshall stability and quotient suggest better resistance to permanent deformation, which is often associated with improved long-term durability. These findings provide practical insights for pavement design, supporting the inclusion of flakiness and elongation index compliance (≤10%) as a material specification to ensure enhanced stability and performance in high-traffic pavement applications. This shows that index-compliant mixes have slightly more voids filled by asphalt, which can affect the durability of the pavement.

Conclusion

Based on the results of this research, the following conclusions can be drawn:

1. Coarse aggregates that fulfill the flakiness and elongation indices produce asphalt concrete mixtures with better Marshall parameters, especially in terms of stability, compared to mixtures using aggregates that do not meet the indices.
2. Mixtures with aggregates that fulfill the specifications show higher stability and better resistance to traffic loads. In contrast, mixtures with aggregates that do not fulfill the indices tend to exhibit decreased interlocking, reduced stability, and increased flow values.
3. Although mixtures using aggregates that do not fulfill the flakiness and elongation indices still hold together adequately, their overall performance is inferior to those made with aggregates that meet the specifications.
4. The study demonstrates that coarse aggregates complying with flakiness and elongation indices limits significantly enhance the stability, strength, and durability of asphalt mixtures, underscoring their importance in sustainable pavement design.

Acknowledgement

The authors gratefully acknowledge the Department of Civil Engineering, Universitas Syiah Kuala, for providing the necessary laboratory facilities and technical support to carry out this research work.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Siti Mira Maulida: conceptualization, methodology, software, writing-original draft preparation. **Ucha Arief Pratama:** data curation, visualization. **Rafiqa Muhnita Yusputri:** investigation, conceptualization, data curation. **Aulia Rahmad:** conceptualization, visualization. **Aqlima Putri:** conceptualization, software. **Yusria Darma:** conceptualization, validation, writing-reviewing and editing. **Sofyan M Saleh:** conceptualization, methodology, writing-reviewing and editing.

Data Availability Statement

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

References

[1] Asrol, S. M. Saleh, and M. Isya, “Karakteristik Campuran Aspal Beton AC-WC Dengan Substitusi Buton Rock Asphalt Terhadap Rendaman Air Berlumpur,” Jurnal Arsip Rekayasa Sipil dan Perencanaan, vol. 1, no. 3, pp. 39–45, 2018, doi: http://dx.doi.org/10.24815/jarsp.v1i1.11760

[2] A. Hanif, F. M. Suryani, and M. Isya, “Penggunaan Aspal Penetrasi 60/70 dan Plastik Polypropylene terhadap Campuran Beton Aspal AC-WC dengan Perendaman Produk Minyak Bumi,” Journal of The Civil Engineering Student, vol. 4, no. 3, pp. 267–273, Dec. 2022.

[3] G. Sugiyanto, A. Harmawan, and B. Mulyono, “The Characteristics of Asphalt Concrete Binder Course (AC-BC) Mixture with Bottom Ash as Aggregate Substitute,” Civil Engineering Dimension, vol. 17, no. 1, Mar. 2015, doi: http://dx.doi.org/10.9744/ced.17.1.29-37

[4] N. A. M. Radzi et al., “Stability and Resilient Modulus of Porous Asphalt Incorporating Steel Fiber,” in IOP Conference Series: Materials Science and Engineering, Institute of Physics Publishing, Jan. 2020. doi: http://dx.doi.org/10.1088/1757-899X/712/1/012027

[5] R. Alfiansyah, M. Isya, and F. M. Suryani, “Pemanfaatan Limbah Plastik Jenis Polyethylene Terephthalate (Pet) Terhadap Kinerja Campuran Laston Lapis Aus (Ac-Wc) serta Penggunaan Filler Abu Tempurung Kelapa dengan Cara Kering,” Journal of The Civil Engineering Student (JoCES), vol. 7, no. 1, pp. 36–42, Mar. 2025.

[6] N. Shafiya Iswandi, Y. Darma, and S. M. Saleh, “Perendaman Produk Minyak Bumi Terhadap Campuran Beton Aspal (AC-WC) dengan Menggunakan Styrofoam sebagai Substitusi Aspal Pen 60/70,” Journal of The Civil Engineering Student, vol. 5, no. 3, pp. 281–287, Sep. 2023.

[7] N. R. Tahtayusmar, S. M. Saleh, and F. Mita, “Penggunaan Filler Abu Serabut Kelapa dan Kombinasi Limbah Plastik pada Aspal Pen. 60/70 Terhadap Stabilitas dan Durabilitas Campuran Beton Aspal,” Journal of The Civil Engineering Student (JoCES), vol. 7, no. 1, pp. 75–83, Mar. 2025.

[8] Sumiati and A. Hasan, “VARIASI AGREGAT PIPIH TERHADAP KARAKTERISTIK ASPAL BETON (AC-BC),” PILAR Jurnal Teknik Sipil, vol. 7, no. 2, pp. 50–56, Sep. 2012.

[9] S. Sukirman, Campuran Aspal Beton. Jakarta: Yayasan Obor Indonesia, 2007.

[10] Anonim, Testing aggregates, BS 812., vol. Part 3. London: British Standards Institution, 1975.

[11] AASHTO, Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 15 th Edition., vol. Part 1 Specification. Washington USA: AASHTO Publication, 1990.

[12] Direktorat Jendral Bina Marga, Spesifikasi Umum Untuk Pekerjaan Konstruksi Jalan dan Jembatan Revisi 2. 2020.

[13] N. Anshar, S. M. Saleh, and J. Fisaini, “Karakteristik Campuran Aspal Beton Menggunakan Coal Bottom Ash dengan Persentase 0%, 5%, dan 10% sebagai Substitusi Agregat Halus,” Journal of The Civil Engineering Student, vol. 5, no. 1, pp. 85–91, 2023.

[14] M. Haekal, S. M. Saleh, A. Salmannur, and A. Putri, “Karakteristik Campuran Aspal Beton Menggunakan Coal Bottom Ash Dengan Persentase 0%, 10%, Dan 15% Sebagai Substitusi Sebagian Agregat Halus,” Journal of The Civil Engineering Student, vol. 5, no. 1, pp. 120–126, 2023.

[15] Bukhari, Saleh M.S, and Isya M, Rekayasa Bahan Dan Tebal Perkerasan. Banda Aceh: Fakultas Teknik Universitas Syiah Kuala, 2007.

[16] S. Firyal, F. M. Suryani, and A. Salmannur, “Studi Pemakaian Plastik LDPE Sebagai Substitusi Aspal dan Penentuan Kadar Aspal Optimum pada Lapisan AC-WC,” Journal of The Civil Engineering Student, vol. 6, no. 2, pp. 92–98, Jun. 2024.

[17] I. Al -Muzakkir, M. Isya, and R. Faisal, “Kajian Penambahan Limbah Low Density Polyethylene (LDPE) Pada Campuran Laston Lapis Pengikat dengan Rendaman Air Laut,” Journal of The Civil Engineering Student, vol. 5, no. 1, pp. 36–42, Apr. 2023.

[18] W. R. Nasution, M. Isya, and F. M. Suryani, “Analisis Kinerja Campuran Laston Lapis Aus (AC-WC) Dengan Penggunaan Polypropylene (PP) dan Abu Tempurung Kelapa,” Journal of The Civil Engineering Student (JoCES), vol. 7, no. 1, pp. 69–74, Mar. 2025.

https://doi.org/10.70028/sgm.v2i1.41