

Optimization of PG70 Asphalt Mixtures Through the Addition of Palm Kernel Shell Ash

Septi Adnan^{1*}, Arya Dirgantara¹, Haerul Purnama¹, Aidhil Saputra Syahwal¹

¹Program Studi Teknik Sipil, Fakultas Sains dan Teknologi, Universitas Sembilanbelas November Kolaka, Jl.Pemuda, Kolaka, 93517, Indonesia

*e-mail: septiadan39@gmail.com

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Abstract

Optimization of PG70 Asphalt Mixtures Through the Assition of Palm Kernel Shell Ash. This study aims to determine the effect of adding palm kernel shell ash to PG70 modified asphalt mixtures using the Marshall method. This study was motivated by the high volume of palm kernel shell ash waste. The study was conducted with variations in palm kernel shell ash content of 0%, 2%, 4%, and 6% by weight of the total aggregate. The parameters tested included stability, flow, VIM, VMA, VFB, and the Marshall Quotient (MQ). The results showed that the addition of palm kernel shell ash increased the stability and density of the mixture. The optimum content was obtained at a 4% ash addition, where the stability value reached its maximum limit, providing a balance between stability, workability, and void content in the mixture. Thus, palm kernel shell ash can be used as an alternative filler material in PG70 modified asphalt mixtures that is more environmentally friendly and economically viable.

Keywords: Filler, Modified Asphalt, Marshall, PG70, Palm Kernel Shell Ash

INTRODUCTION

The expansion of road infrastructure development in Indonesia requires construction materials that are not only high-quality but also sustainable. One of the primary materials in flexible pavement construction is asphalt, which serves as a binder for aggregates to withstand traffic loads and environmental factors. As vehicle volume increases, the performance of conventional asphalt pavement layers often deteriorates due to permanent deformation (rutting) and cracking caused by temperature changes (Oktavia et al., 2022) (Oktaviani et al., 2024). Therefore, efforts are needed to improve asphalt quality through modification with additives that can enhance its mechanical properties. Road infrastructure construction goes hand in hand with the progress of modernization and the ideas of the people who use it, as roads are an essential means for people to reach their intended destinations (Widianto & Faisal, 2020) (Ginting et al., 2023).

PG70 modified asphalt is a type of high-performance asphalt developed to enhance resistance to high temperatures and plastic deformation. This modification is typically achieved by adding polymers or natural materials with pozzolanic properties (Indrawan & Ahmad, 2025) (Stabilitas et al., 2024). Meanwhile, industrial waste from the palm oil industry in Indonesia continues to rise, particularly in the form of palm kernel shell ash produced by burning shells at palm oil mills. This waste has the potential to pollute the environment if not properly utilized. Palm kernel shell ash is a byproduct of the industrial processing of palm oil, and its utilization has not yet been maximized (Pratama & Haratama, 2024). The problem is the increasing volume of palm kernel shell ash waste, making it difficult for palm oil mills to manage this waste issue (Hui et al., 2025).

Several previous studies have examined the use of palm kernel shell ash as an additive in pavement mixtures. Fahmi et al. (2021) found that the use of palm kernel shell ash up to 3% can improve the Marshall stability of asphalt mixtures. Hidayat (2021) demonstrated that an optimal palm kernel shell ash content of 5% improves stability and void content (VIM) in AC-BC layers. Meanwhile, Amin (2022) reported that a combination of palm kernel shell ash and Portland cement can enhance resistance to deformation in AC-WC layers. However, research examining the effect of palm kernel shell ash on PG70 modified asphalt mixtures—which have different characteristics from conventional asphalt—remains limited.

Based on this, this study was conducted to analyze the effect of adding palm kernel shell ash on the Marshall characteristics of PG70 modified asphalt mixtures (Tosi et al., 2024). This study is expected to provide an alternative use

for palm kernel shell ash waste as an environmentally friendly filler substitute while improving the performance of asphalt mixtures. Furthermore, the results of this study are expected to serve as a foundation for the development of more sustainable road construction materials in the future.

METHODS

This study employed a laboratory-based experimental approach to analyze the effect of adding palm kernel shell ash on the properties of PG70 modified asphalt mixtures. The research stages included material preparation, specimen preparation, testing using the Marshall method, and analysis of the results based on applicable national and international standards.

Preparation of Materials and Equipment

The primary materials used consist of coarse aggregate, fine aggregate, and stone dust filler obtained from the *stone crusher* at PT. Satria Jaya Sentosa. The binder used is PG70 modified asphalt obtained from PT. Kartika Prima Abadi. Palm kernel shell ash as an additive was obtained from the Palm Oil Mill in Popalia Village, Tanggetada Subdistrict, Kolaka Regency.

Before use, all materials were tested in accordance with **SNI** and **AASHTO** standards, including SNI 1969:2008 for aggregate specific gravity, SNI 2417:2008 for the Los Angeles abrasion test, and SNI 2434:2011 for the asphalt softening point. Asphalt characteristic testing was conducted to ensure the material meets the 2018 General Specifications for Road Construction, Revision 2.

Mixture Design and Variations in Palm Kernel Shell Ash Content

Mix design uses the **Marshall** method (SNI 2489:2018) with variations in palm kernel shell ash content of 0%, 2%, 4%, and 6% by weight of total aggregate. The planned asphalt content was set at 4.5%, 5.0%, 5.5%, and 6.0% of the mix weight. The mix was heated to a temperature of 155°C–165°C, then compacted using a *Marshall Compactor* with 75 blows per side of the test specimen.

The observed test parameters included stability, plastic flow, density, void content in the mixture (VIM), void content between aggregate minerals (VMA), and asphalt-filled void content (VFB). These values were calculated using the basic Marshall formula as follows:

$$VIM = (1 - Gmb / Gmm) \times 100\% \dots\dots\dots \text{eq. (1)}$$

Notes:

Gmb = bulk density of the compacted mixture (g/cm³)

Gmm = maximum density of the mixture (g/cm³)

$$VMA = [1 - (Gmb \times Ps / Gsb)] \times 100\% \dots\dots\dots \text{eq. (2)}$$

Notes:..

Ps = percentage of aggregate relative to the total mixture weight (%)

Gsb = bulk density of aggregate (g/cm³)

Data Analysis

Test results for each variation were compared against the Bina Marga (2018) specification limits to determine the palm kernel shell ash content that provides the best performance. The analysis was conducted using descriptive-quantitative methods, taking into account the balance between stability, flow, and air void values. The optimum asphalt content (OAC) was determined from the intersection of the relationship curve between asphalt content and Marshall characteristics that met the specification criteria.

Thus, this research methodology is expected to yield a comprehensive understanding of the influence of variations in palm kernel shell ash on the Marshall characteristics of PG70 modified asphalt mixtures and their potential application in sustainable road construction.

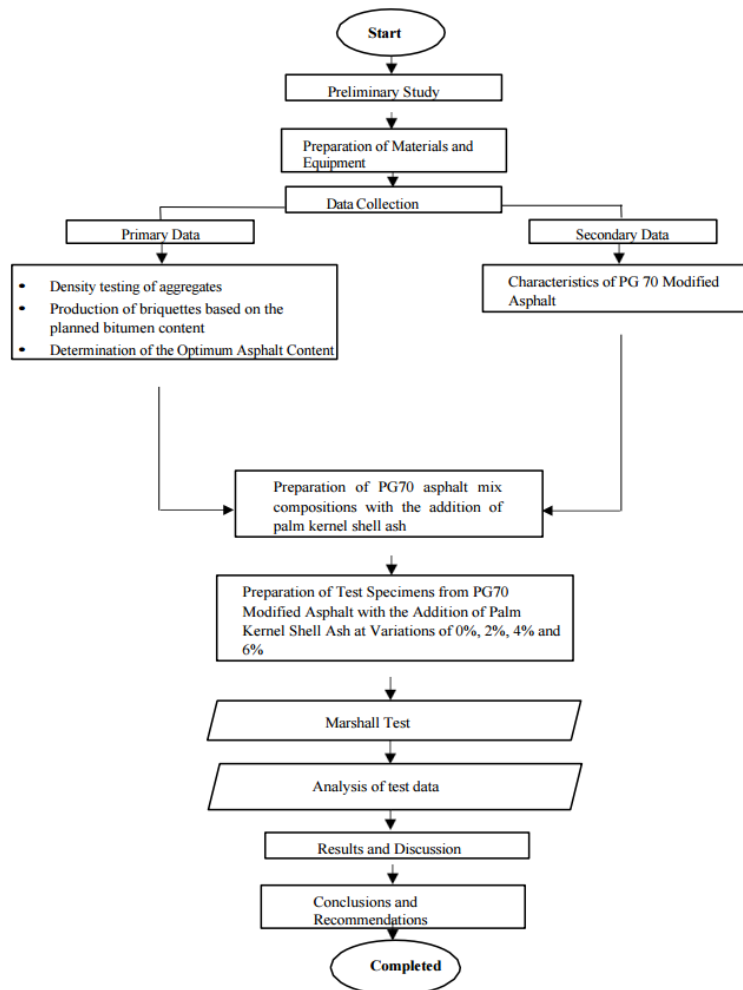


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

This study aims to determine the effect of adding palm kernel shell ash on the properties of PG70 modified asphalt mixtures using the Marshall method. The test results include stability, plastic flow, density, void content in the mixture (VIM), void content between aggregate minerals (VMA), and asphalt-filled voids (VFB). The test data are presented quantitatively in Table 1 and visualized in graphical form as shown in Figure 2 to illustrate the trends in characteristic changes resulting from variations in the palm kernel shell ash content. Tests were conducted using palm kernel shell ash content variations of 0%, 2%, 4%, and 6% by weight of the total aggregate. The summary results of the Marshall test are shown in Table 1 below.

Table 1. Marshall Test Results for PG70 Modified Asphalt Mixtures

Variation of ash content (%)	Stabilitas (kg)	Flow (mm)	VIM (%)	VMA (%)	VFB (%)	Density (gr/cm ³)
0	1620	3.5	4.6	15.2	69.7	2.32
2	1815	3.2	4.3	15.6	72.4	2.35
4	1968	3.0	4.0	15.8	74.7	2.38
6	1795	3.8	4.8	15.5	68.9	2.33

Analysis of the Relationship Between Marshall Parameters

Test results show that increasing the palm kernel shell ash content to 4% resulted in a 21.4% increase in mixture stability compared to mixtures without ash, indicating that the fine particles of palm kernel shell ash act as an active filler that enhances interlocking between aggregate particles and strengthens the asphalt-aggregate bond.

The *flow* value shows a decreasing trend as ash content increases up to 4%, indicating that the mixture becomes stiffer and more resistant to plastic deformation. However, at a 6% content, the *flow* value increases again due to an excess of filler, which causes uneven asphalt distribution and reduces the mixture’s flexibility.

Figure 1 illustrates the relationship between ash content and Marshall stability values. The significant increase in stability up to a 4% content is attributed to the pozzolanic reaction of the silica (SiO₂) content in the palm kernel shell ash, which helps fill the voids between aggregate minerals, resulting in higher density. Beyond this content, the filling effect becomes saturated, leading to a decrease in stability.

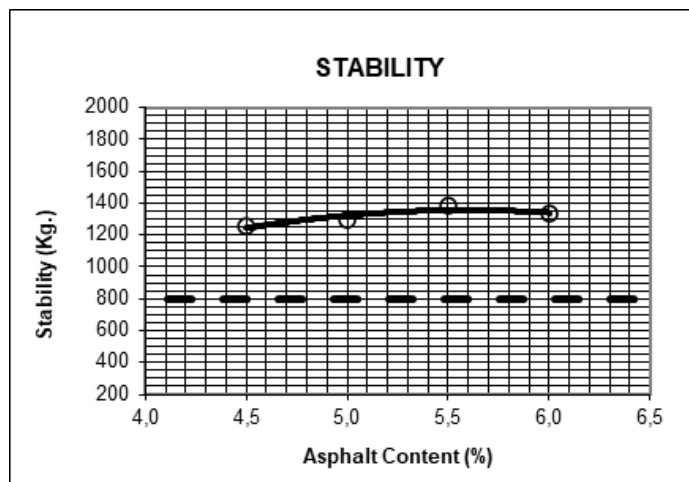


Figure 2. Graph of the Relationship Between Palm Kernel Shell Ash Content and Stability Values (2025)

The obtained *VIM* and *VFB* values show an inverse relationship. At an ash content of 4%, *VIM* decreased to 4.0%, while *VFB* increased to 74.7%, indicating a more efficient distribution of asphalt filling the voids in the mixture. This indicates that the mixture has good density and resistance to rutting and deformation caused by traffic loads.

The Relationship Between Asphalt Content and VIM (Voids IN Mix)

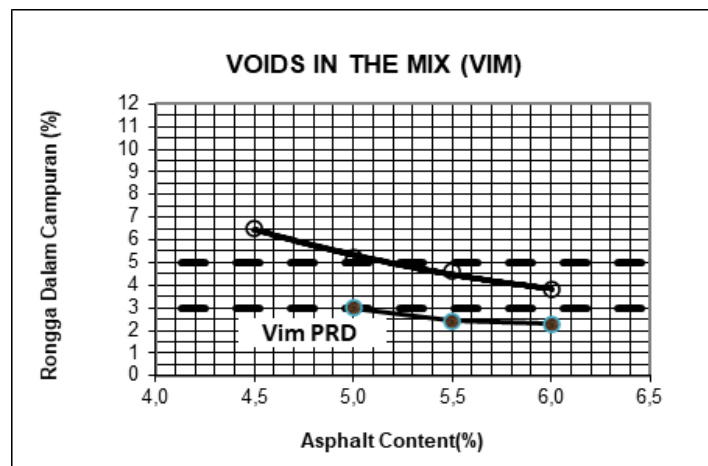


Figure 3. Voids in the Mix (VIM) Chart (Data Processing, 2025)

Relationship Between Asphalt Content and VMA (Voids in Mineral Aggregate)

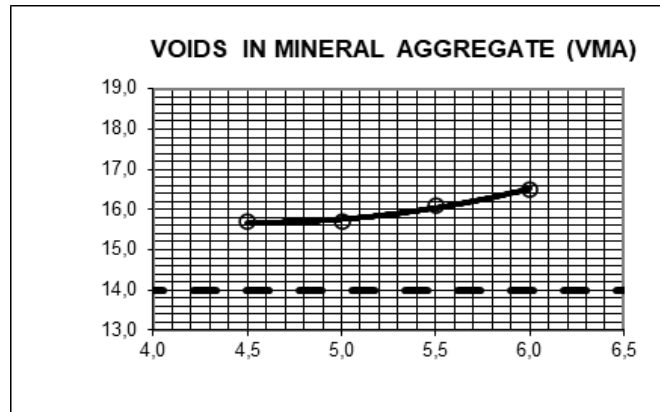


Figure 4. Voids in Mineral Aggregate (VMA) Chart (Data Processing, 2025)

Relationship Between Asphalt Content and VFB (Voids Filled Bitumen)

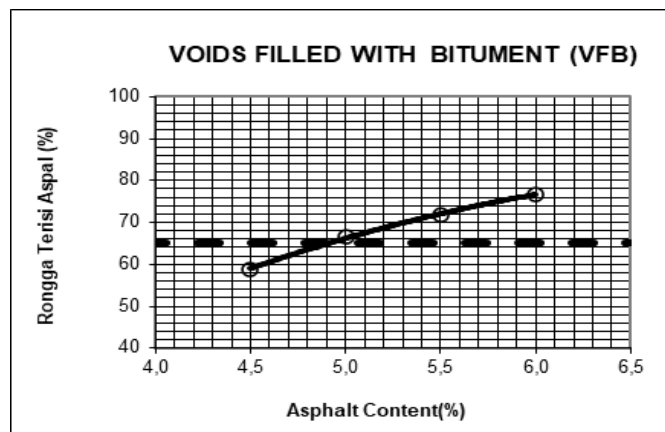


Figure 5. Voids Filled With Bitumen (VFB) Charts (Data Analysis Results, 2025)

Discussion of the Results of Palm Kernel Shell Ash Addition at 0%, 2%, 4%, and 6%

The results of palm kernel shell ash addition to the PG70 modified asphalt mixture are shown in the following table 2.

Table 2. Results of Palm Kernel Shell Ash Addition

Palm shell ash content (%)	Density (gr/cm ³)	Stability (kg)	VIM (%)	VMA (%)	VFB (%)	Flow (mm)
0	2.356	1355.99	3.921	15.377	74.506	3.117
2	2.356	1395.71	3.351	14.875	77.545	3.167
4	2.393	2912.25	2.417	14.052	82.84	3.400
6	2.393	4124.03	2.415	14.050	83.09	3.517
Spesification	-	Min 1000	3-5	Min 14	Min 65	2.0-4.0

Based on the results of adding 2% palm kernel shell ash, the stability value obtained was 1350.24 kg (minimum specification: 1000 kg), the VIM value was 3.351% (minimum specification: 3%–5%), a VMA value of 14.875% (minimum specification 14%), a VFA value of 77.545% (minimum specification 65%), a flow value of 3.167 mm (specification 2.0–4.0 mm), and a density value of 2.370 g/cm³. At a 2% addition rate, it meets the 2018 Rev. II road construction specifications. For a 4% addition of palm kernel shell ash, the stability value is 2,912.25 kg (minimum specification 1,000 kg), VIM 2.417% (minimum specification 2%), a VMA value of 14.052% (minimum specification 14%), a VFA value of 82.84% (minimum specification 65%), a Flow value of 3,400 mm (minimum specification 2.0–4.0

mm), and a density of 2.393 g/cm³. At a 4% content addition, the requirements of the 2018 Bina Marga Specifications Rev. II were not met because the VIM value did not meet the requirements based on the specified data. At a 6% addition, the 2018 Bina Marga Specifications Rev. II were not met, with a stability value of 4124.03 at a 6% content (minimum specification 1000%), the VIM value of 2.415% (minimum specification 2%), the VMA value of 14.050% (minimum specification 14%), the VFA value of 83.09% (minimum specification 65%), the Flow value of 3.517 mm (minimum specification 2.0–4.0 mm), and a density value of 2.393 g/cm³.

Theoretical Discussion

Theoretically, the increase in Marshall stability is related to the increase in shear strength between aggregate particles and the adhesive strength of the asphalt. Palm kernel shell ash functions not only as a filler but also as a pozzolanic material that strengthens the bonds between the aggregate and binder phases. The silica (SiO₂) and alumina (Al₂O₃) content in the ash can react with the polar components in the asphalt, producing a chemically more stable layer.

An optimal ash content of 4% indicates a balance between stability and plastic flow. Excessively high stability values can result in a brittle mixture, while excessive *flow* values reduce resistance to permanent deformation. Therefore, based on the results and analysis, a PG70 modified asphalt mixture with a 4% addition of palm kernel shell ash is recommended as the optimal composition that meets the criteria of the 2018 Revision 2 General Specifications of the Ministry of Public Works. Thus, it can be concluded that the moderate addition of palm kernel shell ash is capable of improving the Marshall characteristics of the PG70 modified asphalt mixture both physically and mechanically, as well as supporting the concept of utilizing palm oil industry waste in sustainable road construction.

CONCLUSION

The addition of palm kernel shell ash as a filler has a significant effect on the performance of PG70 modified asphalt mixtures. The main advantage of this material is its ability to improve the stability and density of the mixture through the fine-particle filling effect, which strengthens the bonds between aggregates. However, adding ash beyond the optimum content leads to an increase in air void content (*VIM*), which reduces the mixture's resistance to deformation. The recommended optimum content of palm kernel shell ash is 2% by weight of total aggregate.

At this content, improved stability and *density* are achieved without compromising the mixture's flexibility. The Optimum Asphalt Content (OAC) obtained at 5.6% meets the 2018 General Specifications for Road Construction (Revision II), with a stability of 1,307 kg, *flow* of 3.45 mm, *VIM* of 4.53%, *VMA* 16.00%, *VFB* 71.69%, and residual stability after immersion of 91.86%. The strength of this study lies in the use of industrial waste as an environmentally friendly and economical filler substitute. Its limitation is that the scope of the study is still confined to the laboratory scale, thus requiring field validation to ensure consistent performance.

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