

Environmental Impact Analysis of Asbuton Utilization in Road Rehabilitation: Potential, Risks, and Mitigation Directions

Bambang Heru Suharyadi¹, Okti Indayani¹, M. Zakiyuddin¹, Hendriani Solihah¹, Senja Madani Anriana¹,
I Dewa Made Alit Karyawan^{1*}

¹Master's Students, Department of Civil Engineering, University of Mataram.

*Corresponding Author

I Dewa Made Alit Karyawan

Master's Students, Department of Civil Engineering, University of Mataram.

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Abstract: The utilization of Buton asphalt (Asbuton) as an alternative material in road rehabilitation represents a strategic step in supporting sustainable infrastructure development in Indonesia. Asbuton, a local resource with high carbon content and superior technical characteristics, offers significant potential to replace petroleum-based bitumen, which has a substantial environmental impact. This article examines the sustainability potential of Asbuton, its associated environmental risks, and the necessary mitigation strategies for its implementation. The findings indicate that Asbuton can reduce carbon emissions, extend pavement service life, and decrease reliance on imported materials. However, several challenges remain, including pollution from chemicals used in the emulsification process, the management of solid waste such as Asphalt Solid Waste (ASW), and social impacts arising from mining activities. Therefore, a comprehensive mitigation strategy is required—one that includes regulatory reinforcement, innovations in waste treatment technology, and an environmental justice approach that prioritizes local communities. Cross-sectoral synergy is essential to ensure that the use of Asbuton contributes meaningfully to the sustainability of Indonesia's road sector.

Keywords: Asbuton, road rehabilitation, sustainability, environmental impact, mitigation, ASW waste.

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1. Introduction

Improving road connectivity has become one of the national infrastructure development priorities in Indonesia. In the context of road rehabilitation, the selection of construction materials is not solely based on technical performance, but also on environmental sustainability. The production and application of petroleum-based asphalt are known to generate significant carbon emissions and high energy consumption, particularly during the binder production stage and fuel combustion in mixing plants. These two activities account for approximately 75% of total greenhouse gas emissions in asphalt mix production, with emission ranges between 20 and 80 kg CO₂-eq per ton of mix (Shacat Richard Willis & Ciavola, 2024). This condition has prompted extensive research on new technologies and the use of more environmentally friendly alternative materials to support sustainable road construction.

One promising local material is Buton asphalt (Asbuton), a natural asphalt found and mined exclusively on Buton Island, Indonesia. This resource is abundant, with estimated reserves reaching 663 million tons, yet only around 0.06% has been utilized. Buton Rock Asphalt (BRA) offers several advantages over petroleum bitumen, such as better resistance to tropical climates, greater flexibility, and durability. Exposure to sunlight and the humid tropical environment gives BRA a denser and more flexible texture, which helps reduce the risk of rutting in road pavements. The mixing process of BRA is also considered more environmentally friendly as it does not involve chemical reactions and is deemed efficient in both construction and maintenance (Nawir & Mansur, 2021).

The use of Asbuton as a base material for asphalt emulsion has demonstrated potential in reducing reliance on petroleum-

based bitumen. According to Israil et al. (2024), utilizing Asbuton as the solid component in asphalt emulsion production can significantly reduce petroleum bitumen consumption, thus lowering the carbon footprint and environmental impact of asphalt emulsion manufacturing. Furthermore, research by Liu et al. (2023), shows that asphalt modified with a combination of BRA and additives such as Sasobit can improve rheological properties and performance at high temperatures, contributing to the development of more durable and sustainable road pavements.

A study by Zhang et al. (2023) also found that BRA enhances fatigue resistance, thermal aging durability, and long-term moisture stability. Additionally, its use can be combined with plastic waste or used diesel oil to improve mixture stability while simultaneously reducing emissions and waste (Gusty et al., 2021; Nawir & Mansur, 2021).

However, the large-scale implementation of BRA still faces technical and environmental challenges. Material segregation and low storage stability of BRA-modified asphalt remain key issues (Su et al., 2022). Moreover, the bitumen extraction process from BRA rocks produces solid waste known as Asphalt Solid Waste (ASW), which contains high levels of hydrocarbons and requires proper waste management (Aulia & Ekaputri, 2024).

Therefore, this article aims to examine the environmental impacts of Asbuton utilization in road rehabilitation, including its benefits, associated risks, and the mitigation strategies required to support its sustainable implementation.

2. Literature Review

Buton asphalt (Asbuton) is a type of natural asphalt formed through geological processes involving petroleum deposits within limestone rocks, predominantly found on Buton Island, Southeast Sulawesi. Based on geological data, Asbuton reserves in the region are estimated to reach hundreds of millions of tons, with varying bitumen content depending on location (Darsana, 2006). Asbuton is available in several forms granules, blocks, or powder and can be utilized in both hot and cold mixtures for road pavement applications.

Nawir dan Mansur (2021) evaluated the performance of Buton Rock Asphalt (BRA) mixed with plastic waste to produce sustainable pavement in tropical regions. The study found that incorporating plastic waste, such as HDPE or LDPE, into BRA enhances the mixture's stiffness and resistance to plastic deformation, especially under high temperatures typical of tropical climates. This combination not only improves structural performance but also contributes to plastic waste reduction, thereby reinforcing sustainability efforts.

Gusty et al. (2021) investigated the use of BRA combined with used diesel oil in porous asphalt mixtures. Their findings revealed improved stability and pore structure, while simultaneously addressing liquid waste issues by incorporating it as an additive in the mix.

Liu et al. (2023) examined the effects of modifying BRA with Sasobit additives on asphalt's rheological properties. The study concluded that the combination of BRA and Sasobit significantly enhances resistance to plastic deformation and broadens the operating temperature range, making it effective in

extending service life and improving pavement performance in high-temperature regions.

Zhang et al. (2023) studied the long-term durability and moisture resistance of BRA-modified asphalt mixtures. Their research demonstrated that BRA significantly enhances resistance to thermal fatigue and moisture-induced damage, which are key factors in pavement degradation in wet and rainy regions.

Rani Anawai & AzharSaban (2023) highlighted the negative environmental and social impacts of BRA mining activities in Winning Village, Buton Regency. Their study revealed that mining operations cause land degradation, air pollution from heavy machinery, noise pollution, and health issues such as respiratory infections and diarrhea among residents. Additionally, spatial conflicts and reduced quality of life were reported, indicating social stress due to natural asphalt exploitation in residential areas.

Aulia & Ekaputri (2024) reported that Asphalt Solid Waste (ASW), a byproduct of Asbuton extraction, contains hydrocarbon levels reaching 68,911 ppm. Although this concentration can be reduced by mixing ASW with cement, the resulting artificial aggregate still fails to meet ASTM C33 standards due to high water absorption (6.75%) and abrasion loss (57%). This suggests that without further treatment, ASW remains a potentially hazardous waste burdening the environment near production sites.

Israil et al. (2024), found that using Asbuton as the solid component in asphalt emulsion production can reduce dependency on petroleum-based bitumen. This shift positively impacts carbon emission reductions and promotes more sustainable asphalt production. However, they also pointed out that the emulsification process involves chemicals such as HCl and CaCl₂, which, if not properly managed, could lead to contamination of soil and water.

Shacat Richard Willis & Ciavola (2024) noted that binder production and mixing plant operations contribute approximately 75% of total greenhouse gas emissions in the asphalt industry, with emission levels ranging between 20–80 kg CO₂-eq per ton of asphalt mix. These findings underscore the urgency of transitioning toward environmentally friendly materials such as BRA, which originates from local resources and potentially offers lower emissions compared to conventional bitumen.

3. Discussion

3.1 The Potential of Asbuton as a Sustainable Road Infrastructure Material

The utilization of Asbuton as an alternative road pavement material directly supports the principles of sustainable development, particularly by reducing reliance on non-renewable resources such as petroleum-based bitumen. The carbon content in Bitumen Hard Emulsion Asphalt Aspal Buton (BHEAAB), reaching up to 88.8% (Israil et al., 2024) indicates that Asbuton possesses high energy potential even without undergoing the complex refining processes typical of conventional bitumen. This makes Asbuton suitable for partial or full substitution of petroleum bitumen in asphalt mixtures.

From a technical performance standpoint, the chemical properties of Buton Rock Asphalt (BRA) enhance the asphalt mixture's resistance to plastic deformation, especially under high temperatures common in tropical climates. Liu et al. (2023)

demonstrated that BRA modified with Sasobit additives improves rheological properties and rutting resistance, thereby extending pavement service life and reducing the frequency of road rehabilitation.

Sustainability is also reflected in the production process. BRA can be used in asphalt emulsion formulations without requiring high-temperature heating, which significantly lowers energy consumption and carbon emissions. The study by Israil et al. (2024) showed that substituting petroleum bitumen with BRA in asphalt emulsions reduces dependency on mined materials and contributes to a lower carbon footprint in the road infrastructure sector. These findings align with the report by Shacat Richard Willis & Ciavola (2024) which stated that 75% of greenhouse gas emissions in asphalt mix production come from heating and binder production, with emissions ranging between 20–80 kg CO₂-eq per ton of mix.

Moreover, sustainable innovation is evident through the integration of waste materials into Asbuton-based mixtures. Gusty et al. (2021) found that BRA modified with used diesel oil enhances Marshall stability and results in porous asphalt mixtures with promising mechanical characteristics. This integration expands Asbuton's potential as part of a circular economy approach in road construction.

Nevertheless, the application of Asbuton remains suboptimal. Its effectiveness is highly dependent on material quality consistency, mixing methods, and industry readiness to adopt this technology. Without proper quality control and implementation procedures, the technical and environmental benefits of Asbuton may be diminished. Therefore, a comprehensive implementation strategy is essential—not only in material development but also in application systems, standard policies, and the preparedness of human resources within the road construction sector.

3.2 Environmental Risks and Management Challenges of Asbuton Risiko

Despite its technical potential and sustainability benefits, the utilization of Asbuton also presents several environmental risks that must be carefully managed. One of the primary concerns is the environmental impact of mining activities, particularly in Buton Island, which is the only site of Asbuton mining in Indonesia. Research by Rani Anawai & AzharSaban (2023), revealed that mining operations in Winning Village have led to vegetation degradation, air pollution from heavy machinery, and noise disturbances. Residents also reported increased cases of respiratory infections and diarrhea due to dust exposure and deteriorating air quality. Spatial conflicts, diminished quality of life, and disrupted community mobility have also emerged as significant social consequences.

At the downstream level, Asbuton production and application also pose potential pollution risks. In the production of Asbuton-based asphalt emulsion, Israil et al. (2024) noted the use of chemical agents such as HCl and CaCl₂ during the mixing phase. Without proper wastewater treatment, residues of these chemicals may contaminate soil and water, potentially posing long-term risks to local ecosystems. While these chemicals are effective in breaking down solid materials, their usage necessitates the

implementation of strict waste treatment systems, as well as further studies on safe dosages and residue management.

In addition, the use of solid waste derived from Asbuton processing—commonly referred to as Asphalt Solid Waste (ASW)—presents its own challenges. Studi Aulia & Ekaputri (2024) reported that ASW contains hydrocarbon concentrations of up to 68,911 ppm. Although this can be reduced by blending with cement, the resulting artificial aggregates still fail to meet ASTM C33 standards, due to a water absorption rate of 6.75% and an abrasion resistance of 57%. This indicates that without advanced post-treatment processes, ASW remains a potentially hazardous waste product that burdens the surrounding environment.

Further challenges lie in the unpreparedness of local industrial systems and regulatory frameworks. Sustainable utilization of Asbuton demands consistent material quality and process control—from extraction and processing to field application. However, in practice, not all producers are equipped with adequate quality control systems or equipment. The lack of standardization, minimal environmental monitoring, and absence of integration between industry actors and regulatory bodies exacerbate the risk of environmental degradation throughout Asbuton's life cycle.

Moreover, the transition toward alternative materials like Asbuton also faces social and economic barriers. In several regions, communities have not been actively involved in planning or monitoring mining activities, leading to social resistance or even horizontal conflicts. This highlights that Asbuton's sustainability is not solely a technical issue, but also a matter of governance, social inclusion, and transparency in decision-making processes.

Thus, while Asbuton offers numerous advantages in terms of technical performance and energy sustainability, its utilization must be approached cautiously. Advancements in technology and the establishment of effective environmental management policies are crucial and cannot be overlooked. A comprehensive evaluation of its life cycle, environmental risk assessments, and the strengthening of regulatory frameworks and monitoring capacities will be key to addressing these challenges.

3.3 Implications and Mitigation Strategies

The utilization of Asbuton in the road sector carries broad implications—not only in technical and environmental dimensions but also in social and governance aspects. On one hand, the potential substitution of petroleum-based bitumen with Asbuton supports national material independence and energy efficiency. On the other hand, the success of this utilization greatly depends on how effectively the associated risks along its supply chain are mitigated.

From a policy standpoint, Asbuton utilization must be accompanied by reforms in mining management systems. Rahmawati (2018) noted that current Asbuton governance policies have not been fully grounded in principles of rationality and sustainability. Unregulated mining activities may lead to environmental degradation and social conflict; thus, stricter oversight and permitting processes are essential. Moreover, involving local communities in planning and decision-making processes is vital for fostering social legitimacy and environmental justice.

On the technical side, facilities producing Asbuton-based asphalt emulsions must be equipped with integrated waste treatment systems. The use of chemical agents such as HCl and CaCl₂ in the emulsification process may cause pollution if not properly neutralized before discharge (Israil et al., 2024). Therefore, implementing chemical neutralization units and environmental control systems should become standard procedures in the industry.

In addition to liquid waste, managing solid waste such as Asphalt Solid Waste (ASW) also presents a distinct challenge. The development of recycling technologies, including thermal stabilization or binding additives, can serve as viable solutions for enhancing ASW quality as artificial aggregate. Research by Aulia & Ekaputri (2024), indicates that such approaches can simultaneously reduce waste and expand the applicability of alternative materials in construction.

The social implications of Asbuton projects must also be incorporated into mitigation schemes. Asbuton-producing regions, such as Buton Regency, should receive benefits that are proportionate to the burdens they bear. Principles of environmental justice can be realized through increased regional revenue from mining activities, inclusive development of basic infrastructure, and strengthened social services around mining areas.

Overall, mitigating the environmental and social impacts of Asbuton utilization cannot rely solely on technical or material-based solutions. A more systemic, evidence-based, and cross-sectoral approach is required. Rigorous environmental assessments, inter-agency collaboration, and the formulation of science-based regulations with public participation are essential foundations to ensure that Asbuton genuinely becomes part of a sustainable pavement solution.

4. Conclusion and Recommendations

4.1 Conclusion

The utilization of Asbuton as an alternative material in road rehabilitation presents significant potential to support sustainable infrastructure development. Its high carbon content, local availability, and ability to enhance asphalt mixture performance position Asbuton as a promising substitute for petroleum-based bitumen. Beyond improving energy efficiency and reducing carbon emissions, its use also contributes to strengthening national resource independence.

Nevertheless, several challenges warrant serious attention. The risk of environmental contamination due to chemical residues in emulsion asphalt production, solid waste issues such as Asphalt Solid Waste (ASW), and the environmental and social impacts of mining activities require comprehensive mitigation strategies. Limitations in mining management systems, underdeveloped waste treatment technologies, and insufficient community involvement indicate that sustainability aspects have not yet been fully integrated into field practices.

To ensure that Asbuton utilization genuinely contributes to environmentally friendly and sustainable infrastructure, a multidisciplinary approach is essential. This includes strengthening environmentally based regulations, advancing eco-friendly technologies, implementing integrated waste management systems, and ensuring fair distribution of benefits to communities in mining

regions. With effective cross-sectoral collaboration, Asbuton can become a strategic solution to address the sustainability challenges of future road infrastructure.

4.2 Recommendations

- a. Strengthening regulations for Asbuton mining management is necessary to ensure that exploitation activities run in accordance with sustainability principles. Local and central governments need to update policies by integrating aspects of environmental protection and the involvement of local communities.
- b. The industry producing Asbuton-based asphalt emulsion is encouraged to adopt environmentally friendly technologies for liquid and solid waste treatment. The addition of chemical neutralization units and the development of recycling methods for Asphalt Solid Waste (ASW) should become standard in factory operations.
- c. Further research is needed to evaluate the long-term environmental impact potential of chemical residues and the use of BRA, as well as to develop optimal asphalt mixture formulations in terms of both technical and ecological aspects.
- d. Increasing the capacity of local industry and workforce is important so that the utilization of Asbuton is not only technically efficient but also provides economic added value for the region of origin.
- e. The implementation of environmental justice approaches needs to be strengthened through fair redistribution policies of mining revenues, development of basic infrastructure in Asbuton-producing areas, and protection for affected communities.

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