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EXTRACTION BITUMEN BUTON ROCK ASPHALT AS SOLID PHASE IN ASPHALT EMULSION MIXED: STABILITY, FLOW, AND MARSHALL QUOTIENT

Israil[1], *M. Tumpu[2], Hamkah[3], Nursafanah Dzakiyah AlMakassari[4]

[1]Civil Engineering Department, Muhammadiyah University, Indonesia;
[2]Disaster Management Study Program, The Graduate School, Hasanuddin University, Indonesia;
[3]Civil Engineering Department, Ambon State Polytechnic, Indonesia;
[4]Accounting Study Program, Pelita Buana College of Economics, Indonesia

*Corresponding Author, Received: 02 Jan. 2024, Revised: 27 Oct. 2024, Accepted: 28 Oct. 2024

ABSTRACT: This research is part of an effort to advance the use of Buton rock asphalt (EBBRA)—an asphalt emulsion derived from extracted bitumen—as a binder. EBBRA, or extraction bitumen Buton rock asphalt, consists of 70% mineral and 30% asphalt. To produce bitumen emulsion, cationic emulsion, kerosene, hydrochloric acid, calcium chloride, and water are combined with the bitumen extracted from EBBRA. Coarse, fine, and filler aggregates are then mixed with the EBBRA-based asphalt emulsion to create an Asphalt Concrete Wearing Course (AC-WC) mixture. Marshall specimens are used to measure the stability of this EBBRA-containing asphalt emulsion.Test results indicate that bitumen emulsions made with EBBRA deliver asphalt concrete mixes with high stability, satisfactory flow, and a favorable Marshall Quotient (MQ). Moreover, increasing curing time improves stability and reduces flow across all emulsified asphalt mixtures. This study emphasizes the use of environmentally friendly materials, including Buton asphalt and other locally sourced materials from Indonesia. By utilizing Buton asphalt, Indonesia could potentially reduce its reliance on imported petroleum bitumen.

Keywords: EBBRA, Asphalt Emulsion, Solid Phase, Stability, Marshall Quotient

1. INTRODUCTION

A number of nations have created emulsion asphalt by the use of cold asphalt mixtures, which is backed by numerous research. Emulsion asphalt is a useful method for preserving and maintaining asphalt pavement [1-3]. The effectiveness of employing emulsion asphalt in the field for implementing asphalt mixture recycling was discovered [4, 5]. The curing time of emulsion is 10 to 14 days [6]. A modified cement mix method with an emulsion asphalt mixture based on the selection of the optimum amount of cement, which increases the stiffness of the asphalt binder and adhesion on the surface of the aggregate, is part of practical application research [7-9]. Cold asphalt mixtures can reach better mechanical qualities than hot asphalt mixtures [10]. Adding waste ash to a cold asphalt mixture can boost the material's resistance to water sensitivity [11, 12]. In addition, it offers strong fatigue resistance. The compressive strength of cold-mix using emulsion asphalt treated with polyvinyl acetate (PVAC), a polymer modified (blended) with emulsion asphalt to improve the capacity of cold-mix mixtures to receive compression [13, 14]. By analyzing the link between cold asphalt mixture stiffness and air temperature, we were able to anticipate guidelines under other known circumstances [15].

Distilled asphalt oil was employed as an adhesive in a cold asphalt mixture in all of the trials that were discussed. Given that Indonesia needs about 1.2 million tons of oil asphalt annually but only has a domestic production capacity of about 600,000 tons of asphalt (oil asphalt) per year, there has not yet been a substitute asphalt that can be used to make emulsion asphalt [16-18]. On the Indonesian island of Buton, in the Southeast Sulawesi Province, there is natural asphalt that can be mined on-site for up to 300 years [19]. Natural asphalt Buton, also known as Asbuton, has been the subject of research by a number of road pavement construction experts in Indonesia [20–27]. The Buton natural asphalt extraction procedure has also resulted in bitumen in a number of experiments. The results of the study show that the performance of asphalt mixtures, especially stability, is enhanced when Buton natural asphalt is used as a binding ingredient [28, 29]. The notion that Asbuton liquid can be used in place of petroleum bitumen and as a binder to improve the performance of the asphalt mixture is supported by the findings of a study that examined what happened when Asbuton liquid was introduced to a hot asphalt slurry prior to the application of porous asphalt [30].

All nations, including Indonesia, have created emulsion asphalt and cold mix asphalt with distilled oil asphalt as the adhesive supply. It would be very intriguing if natural Buton asphalt (Asbuton Indonesia) could be investigated in order to develop environmentally friendly technology (green technology) by using Asbuton as one of the alternate raw materials in producing emulsion asphalt with the goal of creating cold asphalt mixtures (cold mix). Although the Public Works Department of the Directorate General of Highways has issued several guidelines for the use of cold asphalt mix works, emulsion asphalt is still only used in Indonesia for adhesive and permeate layers (General Specification of Indonesia 2018, Indonesia requirement (in Indonesian)) [31].

2. RESEARCH SIGNIFICANCE

The goal of this series of studies is to replace petroleum bitumen with Extraction Bitumen Buton Rock Asphalt (EBBRA) as the primary solid-phase material for producing Buton asphalt-based emulsion asphalt. EBBRA-based emulsion asphalt can be used as a binder in the production of Asphalt Concrete Wearing Course (AC-WC) by combining the solid phase (EBBRA and kerosene) with the liquid phase (water, CaCl, HCl, and emulsifier) through an engineered process. This method yields emulsion asphalt with excellent stability characteristics, including stability, flow, and Marshall Quotient (MQ) values.

3. MATERIALS AND METHOD

3.1. Physical Properties of Aggregate

Tables 1 through 3 present the aggregate characteristic testing findings. To ensure that the utilized aggregate meets the requirements set forth by the Indonesian National Standard, we examine aggregate characteristics.

Table 1 Physical characteristics of coarse aggregate

No.	Testing type	Testing result
1	Water absorption (%)	
	Stone crusher 0.5 - 1 cm	2.07
	Stone crusher 1 - 2 cm	2.08
2	Specific gravity	
	Stone crusher 0.5 - 1 cm	
	Bulk specific gravity	2.62
	Saturated surface dry specific gravity	2.68
	Apparent specific gravity	2.77
	Stone crusher 1 - 2 cm	
	Bulk specific gravity	2.63
	Saturated surface dry specific gravity	2.68
	Apparent specific gravity	2.78
3	Flakiness index (%)	
	Stone crusher 0.5 - 1 cm	20.10
	Stone crusher 1 - 2 cm	9.38
4	Abrasion aggregate (%)	
	Stone crusher 0.5 - 1 cm	25.72
	Stone crusher 1 - 2 cm	24.36

The employed aggregate complies with the General Specification of Indonesia 2018 (in Indonesian) for the necessary road materials, as shown by the results of testing the characteristics of coarse aggregate (crushed stone), stone dust, and filler.

Table 2 Physical characteristics of stone dust

No.	Testing type	Testing result
1	Water absorption (%)	2.792
2	Bulk specific gravity	2.449
	Saturated surface dry specific gravity	2.518
	Apparent specific gravity	2.629
3	Sand Equivalent (%)	89.66

Table 3 Physical characteristics of filler

No.	Testing type	Testing result
1	Water absorption (%)	2.283
2	Bulk specific gravity	2.595
	Saturated surface dry specific gravity	2.654
	Apparent specific gravity	2.758
3	Sand Equivalent (%)	69.57

3.2. Extraction Bitumen Buton Rock Asphalt (EBBRA)

The bitumen characteristics of the Buton natural asphalt extraction were tested, and the results are presented in Table 4. According to this Table, the bitumen utilized mostly complies with the General Specification of Indonesia 2018 (in Indonesian) for the necessary emulsion asphalt bitumen. In theory, bitumen must be developed so that it has properties similar to those of oil asphalt (hard asphalt) for road pavement in order for Asbuton to be used in the field of road pavement. Bitumen is extracted from 500 grams of Asbuton, yielding an average of 125 grams per extraction. For every 1000 grams of emulsified asphalt, or 600 grams of extracted Asbuton bitumen, one liter of emulsified asphalt contains 60% extracted bitumen.

In the production of emulsified asphalt, water, CaCl, HCl, and emulsifiers are the liquid-phase raw ingredients, and EBBRA and kerosene are the solid-phase raw materials. The use of EBBRA must be in accordance with the dosage. Engineering accomplishes the combination of solid and liquid phases, with the most crucial objective being to balance the specific gravities of the two phases. The purpose of the Thin Film Oven Test (TFOT) is to assess the longevity of asphalt materials, specifically to detect indications of weathering or hardening in asphalt minerals. The findings of examining EBBRA's properties are displayed in Table 4. Physically, it behaves virtually similarly like petroleum bitumen, particularly in terms of penetration both before and after weight loss. Consequently, EBBRA can be used as the main raw ingredient for making emulsion asphalt, which functions as a binder and is tested with Marshall test items.

Table 4 Physical characteristics of EBBRA

No.	Testing type	Testing result
1	Penetration in 25°C, 100 g, 5 second (0.1 mm)	93.2
2	Soft point (°C)	48
3	Ductility on 25°C (cm)	137
4	Solubility in C_2HCl_3 (% weight)	97.6
5	Flash point (°C)	289.5
6	Specific gravity	1.05
7	Lost weight 163°C (TFOT) (% weight)	0.25
8	Penetration after TFOT (% pure)	145.4
9	Viscocity 170 Cst (cm^2/sec.)	24

3.3. Combined Aggregate Gradation and Mixtures Design

The combined aggregate proportion is calculated by multiplying the value of the plan aggregate composition ratio by the percentage of the value that passed the filter analysis. To get the anticipated combined percentage, sieved analysis is then used to add up the results for all components, including 1-2 cm crushed stone, 0.5-1 cm crushed stone, and rock ash. Additionally, the obtained component of the combined aggregate is adjusted to the specification interval's value. The specification interval and aggregate aggregates are then plotted into a graph, as seen in Figure 1. The mixture design for AC-WC combinations is displayed in Table 5. The aggregate grading combination complied with the specifications for a blend of petroleum bitumen, EBBRA, and cold asphalt AC-WC. Each cylindrical mold had a capacity of 1,200 grams and a diameter of 101.6 mm. The asphalt bitumen and aggregates of all the cold asphalt mixtures were combined at a temperature of 27.5 ± 5ºC. The specimens were compressed using a Marshall compactor as described in SNI 06-2489-1991 [31] with 75 blows to each face.

This research acquired the aggregate for this study straight from a stone crusher, examined its properties using the SNI standard, and discovered that it satisfies Indonesian standards for road construction materials. This is demonstrated in Figure 1 and Table 5, where the gradation aggregates that are produced together reach the ideal condition value. The resultant aggregate combination with a control point value that remains off the aggregate combined line is shown in Figure 1 and Table 5.

With a 0.5% interval, the asphalt content in SNI ranges from 4.5% to 6.5% based on the effective emulsion asphalt content calculation. The description of the aggregate combination for the AC-WC mixture, where the mixture's total weight for one specimen as a Marshall test object is 1200 grams, provides the composition of the mixture.

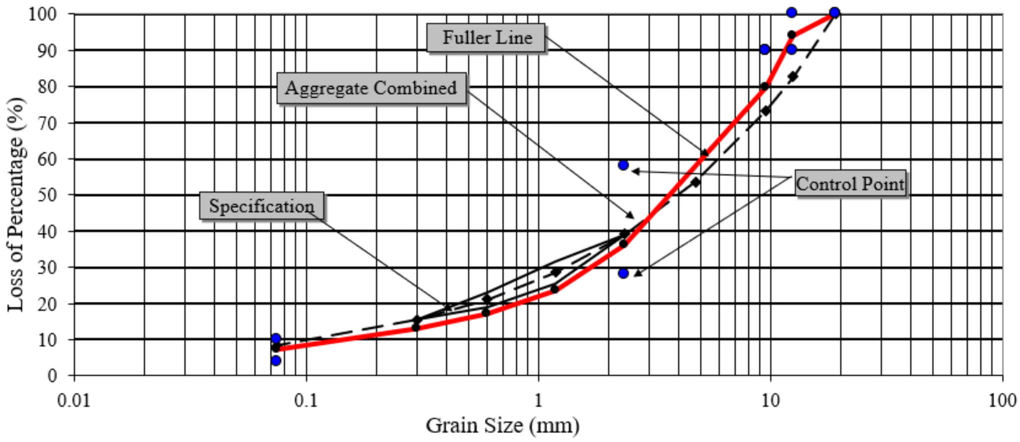

Fig. 1 Combined aggregates gradation

Table 5 Mixtures design of AC-WC mixtures (for 1,200 grams)

Asphalt content (%)	Aggregate (gram)				Asphalt (gram)	Total (gram)
	Stone crusher 1-2 cm	Stone crusher 0.5-1 cm	Stone dust	Filler		
4.5	217.7	412.6	492.8	22.9	54.0	1200
5	216.6	410.4	490.2	22.8	60.0	1200
5.5	215.5	408.2	487.6	22.7	66.0	1200
6	214.3	406.1	485.0	22.6	72.0	1200
6.5	213.2	403.9	482.5	22.4	78.0	1200

4. RESULTS AND DISCUSSION

4.1 Marshall Stability Characteristic

Figure 2 depicts the correlation between emulsion asphalt content and stability based on the outcomes of the Marshall test. The test findings demonstrate that as emulsion asphalt content rises, so does the stability value until it reaches a desirable level.

The stability value of the mixture is highest when the emulsion asphalt content is at the optimal emulsion asphalt content, and it gradually decreases as it approaches the optimal emulsion asphalt content in the figure, just like an asphalt mixture made with petroleum bitumen. The stability value achieved fell short of the General Specification of Indonesia 2018's (in Indonesian) requirements for the weight of the necessary road materials, which is 550 kg.

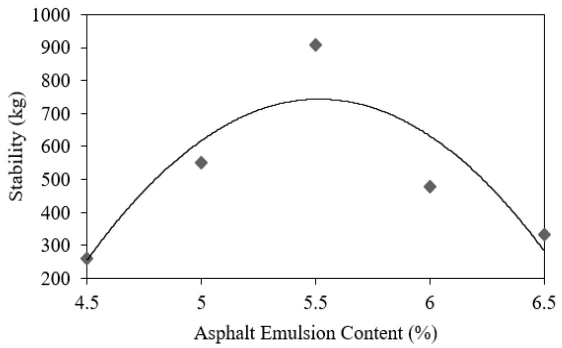

Fig. 2 The relationship between emulsion asphalt content and stability

Having an emulsion asphalt concentration of 4.5%, the mixture with the lowest stability value has a stability value of 261.14 kg, while the mixture with the highest stability value has a 5.5% emulsion asphalt content and a stability value of 908.9 kg. A mixture with a 6.5% emulsion asphalt content has a stability value of 333.59 kg, which is less stable than a mixture with a 6% emulsion asphalt content (477.60 kg), a 5% emulsion asphalt content (551.77 kg), and a mixture with a 5.5% emulsion asphalt content (which had the highest stability value among the four mixture variations). As a result, we can observe that 5.5% emulsion asphalt content is the ideal level. 4.5%, 6%, and 6.5% of emulsion asphalt composition did not meet requirements.

The thicker coated aggregate and the huge flow that results in the low stability of the emulsion asphalt mixture will ultimately lower the binding capacity between the aggregates in the mixture when it is loaded. The stability of the mixture is decreased by less bonding between the particles. The water content of the emulsion asphalt will likewise grow as the amount of emulsion asphalt increases. The water content will cause a fine cavity in the mixture to reach its ideal level after evaporating, allowing it to become more flexible. However, the stability value may drop due to an increase of cavities between the mixtures. The stability rating illustrates how well the asphalt concrete mixture holds up and resists alterations in fixed shapes like waves, grooves (rutting), and bleeding. The performance of the mixture in supporting the load on the wheels of the vehicle decreases as the mixture's stability value decreases.

4.2 Marshall Flow Characteristic

Figure 3 depicts the correlation between emulsion asphalt content and flow based on the outcomes of the Marshall test. Emulsion asphalt composition and flow have a close correlation. It is clear that the mixture's lowest flow occurs at the ideal asphalt content, or 5.5%, when the asphalt content is at its highest.

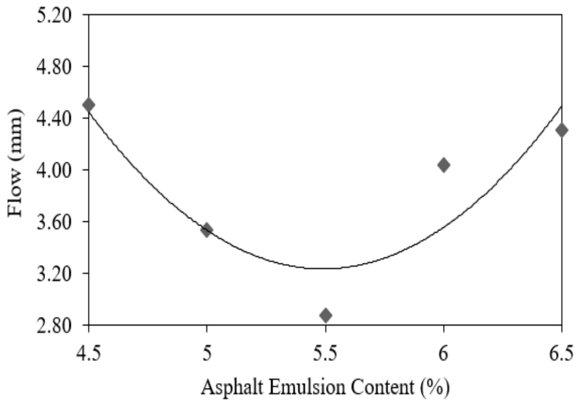

Fig. 3 The relationship between emulsion asphalt content and flow

The obtained flow values fell short of all the requirements set forth in the General Specification of Indonesia 2018 (in Indonesian) for the necessary road materials, namely 2 mm to 4 mm. The mixture with an emulsion asphalt content of 5.5% has the lowest flow value (2.90 mm), and the combination with an emulsion asphalt content of 4.5% has the highest flow value (4.50 mm). A mixture with a 6.5% emulsion asphalt content had a flow value of 4.30 mm, which was significantly higher than mixtures with 6% and 5% emulsion asphalt contents, which had flow values of 4.00 and 3.50 mm, respectively. The mixture with a 5.5% emulsion asphalt content had the lowest flow value among the four mixture variations. Although the enlarged cavity between the mixture and the usage of high emulsion asphalt content can cause the plastic melt value (flow) to grow, the water content will produce a fine cavity in the mixture to increase to the ideal level, giving it the potential to be more flexible (flexibility).

4.3 Marshall Quotient Characteristic

Figure 4 depicts the correlation between emulsion asphalt content and the Marshall Quotient based on the findings of the Marshall test.

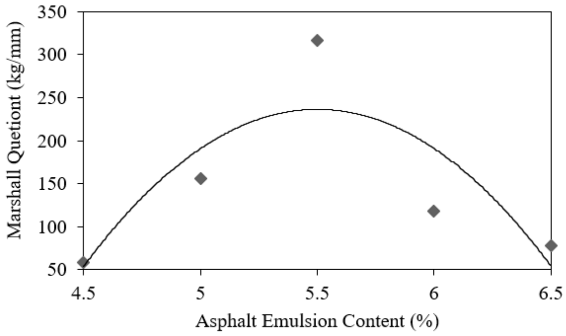

Fig. 4 The relationship between emulsion asphalt content and Marshall quetiont

The Marshall Quotient values were not within the range of 200 kg/mm to 350 kg/mm required by the General Specification of Indonesia 2018 (in Indonesian), which specified the requirements for the necessary road materials. The Marshall Quotient value of the asphalt emulsion combination with a 4.5% percentage is 58.00 kg/mm, whereas the value of the mixture with a 5.5% asphalt emulsion content is 317.10 kg/mm. This indicates that the Marshall Quotient value, which shows a correlation with the stability and flow values, is significantly influenced by the asphalt emulsion content. Aggregate bleeds when there is a high asphalt emulsion content; a small asphalt emulsion content keeps the asphalt from covering the aggregate entirely. This is so because water and asphalt make up asphalt emulsion. In order to allow the water in the mixture to evaporate, cold asphalt mixtures that employ asphalt emulsion as a binder need to consider the drying time.

A mixture with a 6.5% emulsion asphalt content has a Marshall Quotient value of 77.50 kg/mm, which is relatively lower than mixtures with 6% emulsion asphalt content and 118.40 kg/mm, 5% emulsion asphalt content and 156.20 kg/mm, respectively. The mixture with the optimal emulsion asphalt content of 5.5% had the highest Marshall Quotient value among the four variations of the mixture.

Since there is little stability, there is a lot of flow, and the covered aggregates are thicker, the Marshall Quotient coefficient of the emulsion asphalt mixture is low. As a result, there is less binding capacity between the covered aggregates when the mixture is loaded. The mixture's stability will decrease due to the aggregates' reduced bond strength, increasing the flow value. The water content of the emulsion asphalt will likewise grow as the amount of emulsion asphalt increases. The water content will induce a small cavity in the mixture to attain its ideal size after evaporating, making it more flexible. However, the use of high emulsion asphalt content and the expanded cavity between the mixture might raise the plastic melt value (flow). The emulsion asphalt mixture can be utilized for flexible pavement if the curing time is 1 day at the ideal asphalt concentration of 5.5%, according to the Marshall Quotient value.

Studies on the behaviour of cold asphalt mixtures with EBBRA as the source material for the solid phase show that EBBRA improves the behaviour of these combinations. Because the basic ingredient for the petroleum bitumen-based emulsified asphalt combination has less adhesion than EBBRA, several earlier trials that used this type of asphalt performed poorly. This is because the primary components of asphalt, asphaltenes, maltenes, carbon, and aromatics, are highly concentrated in EBBRA [32-35].

4.4 Physical Appearance of Specimens

The physical form of cold asphalt mixture test objects with EBBRA-based emulsified asphalt as the solid phase raw material is depicted in Figures 5 through 9. Emulsion asphalt is a form of cold asphalt composed of a liquid phase (emulsifier, water, HCl, and CaCl) and a solid phase (kerosene and EBBRA). The test item shown is the Marshall test object with emulsified asphalt contents of 4.5%, 5.0%, 5.5%, 6.0%, and 6.5%, both before and after testing. The results of testing are indicated by the cracking pattern of the Marshall test item [36, 37]. The crushed stone and the asphalt binding it together are damaged, as seen in the destruction pattern image. The strength to bind between the aggregates is also diminished if we use too little asphalt.

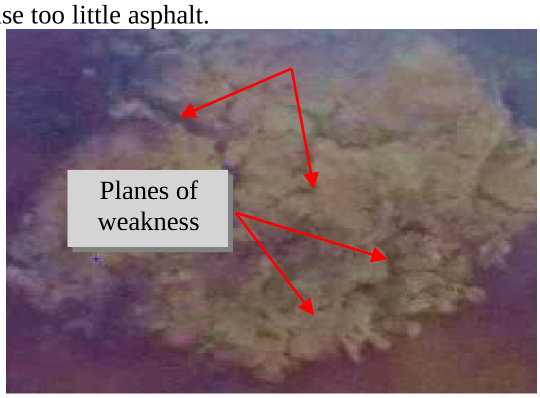

Fig. 5 Physical appearance of 4.5% asphalt emulsion content

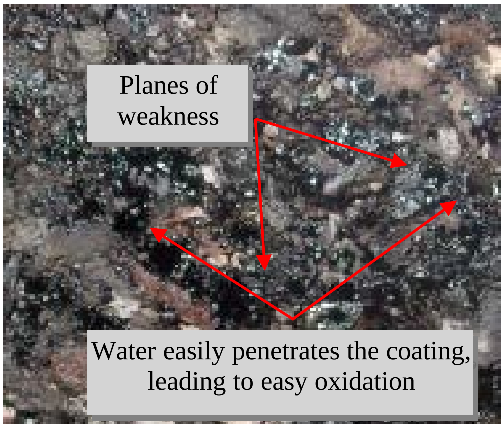

Fig. 6 Physical appearance of 5.0% asphalt emulsion content

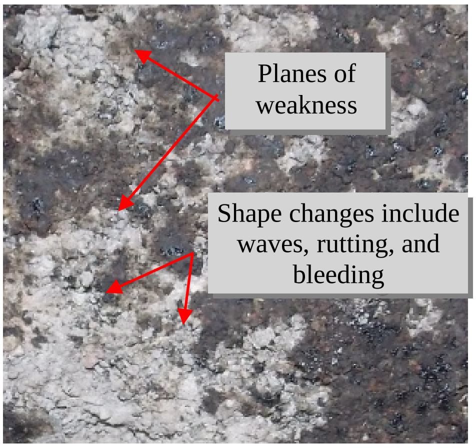

Fig. 7 Physical appearance of 5.5% asphalt emulsion content

This may cause the layer to become more easily permeable to water, accelerate oxidation, and produce low stability. Furthermore, the pavement is more prone to damage because of the composition of the emulsified asphalt, which is made up of water, emulsifying chemicals, and asphalt particles. This happens when the content of asphalt emulsion drops below the ideal range of 4.5% and 5.0%.

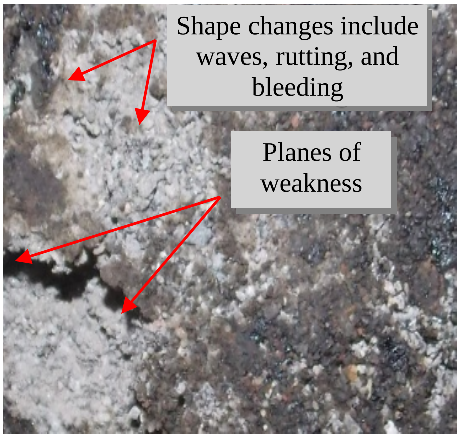

Fig. 8 Physical appearance of 6.0% asphalt emulsion content

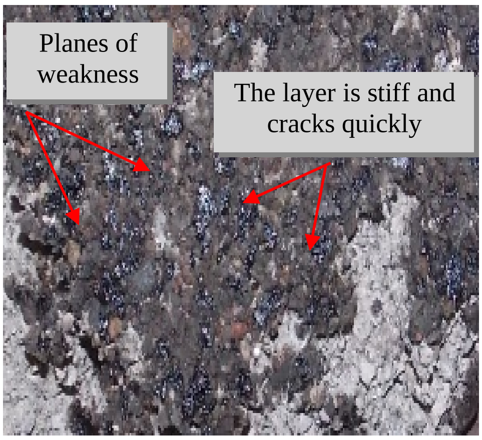

Fig. 9 Physical appearance of 6.5% asphalt emulsion content

However, because of Indonesia's high temperatures and frequent traffic, using too much asphalt could cause the layer to become fat. This may result in rutting, bleeding, waves, grooves, or other morphological alterations in the layer. This happens when the content of asphalt emulsion is higher than the ideal range of 6.0% and 6.5%. Theoretically, the stability of the pavement layer is based on its capacity to withstand traffic pressures without undergoing morphological alterations like rutting, bleeding, or waves. But it's important to watch out that the stability doesn't get too high, as this could cause the layer to harden and fracture quickly.

The Marshall stability performance of asphalt mixtures with the hot-mix hot process was tested in the field, along with the stability performance of asphalt mixtures with the hot-mix hot process using oil asphalt as an adhesive in the lab. Finally, the stability performance of asphalt mixtures with the Asbuton transformation emulsion asphalt as a binder with the cold mix method cold process was also looked at. This type of asphalt is made from bitumen extracted from Buton Natural Asphalt (EBBRA).

5. CONCLUSIONS

The study's findings, based on the summary above, include:

1. Due to the similarity in properties between the bitumen derived from Buton rock asphalt (EBBRA) and petroleum bitumen grades 80 or 100, EBBRA can be used as a solid phase in emulsion asphalt production.
2. The optimal asphalt content was determined to be 5.5%, based on the relationship between emulsion asphalt content and stability.
3. The stability values obtained did not meet the General Specification of Indonesia 2018 requirement for road materials, which specifies a minimum of 550 kg. Similarly, the flow values were below the specified range of 2 mm to 4 mm, and the Marshall Quotient values fell outside the Bina Marga standard range of 200 kg/mm to 350 kg/mm. However, at 5.5% asphalt emulsion content, the mixture showed sufficient flow, stability, and Marshall Quotient values. There was minimal evidence of deterioration or bleeding, particularly noted from the crack pattern.
4. The findings support the feasibility of using ebbra-based emulsion asphalt. This could potentially reduce the need for hot mix asphalt produced in an amp (asphalt mixing plant), making cold mix asphalt applications more practical and accessible.

6. ACKNOWLEDGMENT

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