Reducing the Environmental Impact of Asphalt Emulsion Production from Petroleum Bitumen utilizing Buton Island Natural Asphalt in Various Scenarios

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ABSTRACT

By utilizing Buton asphalt as the solid component in the creation of emulsified asphalt, a substantial amount of petroleum bitumen, which is a finite energy resource, can be reduced. Additionally, the utilization of natural mining materials can be decreased, hence lowering the carbon footprint and impact of the emulsified asphalt-producing sector. This research assesses different approaches to mitigate the environmental consequences of manufacturing emulsified asphalt using Buton asphalt as a substitute for petroleum bitumen in the solid phase. Asbuton Indonesia is an asphalt emulsion that employs solid raw materials, particularly the Extracted Bitumen from Buton Rock Asphalt (EBBRA). The solvents in the mixture consist of kerosene, an emulsifier, hydrochloric acid (HC1), calcium chloride (CaCl), and water. The research process involved the EBBRA using a Socklet tool, followed by the production of emulsion asphalt. Subsequently, quality tests were conducted on the emulsion asphalt in the laboratory, and the results of these tests were analyzed to determine the value of the emulsion asphalt quality. The study's findings confirm the suitability of natural asphalt from Buton Island, Indonesia, as a primary ingredient for emulsified asphalt. This involves extracting bitumen from the minerals found in the asphalt. The test results indicate that the E3 sample has a solid phase content of 57.4% EBBRA and 5% kerosene, which aligns with the criteria set by ASTM and SNI-Indonesia. The liquid phase contains an emulsifier at a concentration of 1%, HC1 at a concentration of 0.5%, CaCl at a concentration of 0.1%, and water at a concentration of 36%. This study encompassed five different scenarios for making asphalt emulsion, with each of them utilizing Buton asphalt as the solid phase in variable proportions. Laboratory testing results demonstrate that including Buton asphalt in the production of asphalt emulsion mixtures can yield advantages for the construction industry, waste management sector, and the environment.

Keywords-environmental impact; asphalt emulsion; Buton asphalt; solid phase

I. INTRODUCTION

On a global scale, the excessive use of finite fossil fuels and natural resources, resulting in the release of Greenhouse Gases (GHG) and subsequent alteration of the climate, causes significant apprehension and raising awareness. Authorities are currently enforcing rigorous environmental restrictions to mitigate the exacerbation of climate change. Meanwhile, the deliberate effort to replace the notion of 'end-of-life' with the concept of a circular economy in manufacturing processes is recognized as a crucial strategy for promoting sustainability [1-3]. The construction industry has the potential to make a significant contribution to the sustainable management of natural resources and materials. The construction sector is a major user of materials, accounting for 24% of global material extractions. Furthermore, this extraction process not only depletes resources, but also inflicts damage on the landscape and ecosystems. It leads to contamination of both indoor and outdoor habitats during the many stages of production, processing, maintenance, and demolition. Additionally, it results in the pollution of soil, water, and air throughout the utilization phase [4, 5]. Therefore, sectors that rely heavily on materials must adopt this notion to promote the growth and utilization of more circular products [6]. Researchers have advocated for the asphalt paving sector to adopt technology that significantly reduces energy usage and greenhouse gas emissions [7]. This is particularly vital for asphalt mixtures and pavement courses with a shorter functional lifespan since they are more prone to undergoing regular maintenance and repair activities, such as course wear. Studies have shown that the use of warm mix asphalt technologies can lower mixing and compaction temperatures by 20 °C-30 °C. This leads to a decrease in energy usage and emissions during the manufacturing of traditional hot mix asphalt, while still maintaining the quality of the pavement [8-10].

Asphalt emulsions are frequently employed as an alternative to traditional techniques, such as dilution. Researchers deploy the direct application of organic solvents through the process of heating asphalt to elevated temperatures, reaching as high as 120 °C. This fast-advancing technology has a broad spectrum of uses, including the construction of roads and the application of surface treatments like waterproofing. Asphalt emulsions are a type of mixture consisting of asphalt and water. These materials are often manufactured using high-shear rate equipment, such as a colloidal mill. Recently, satisfactory results have been produced by adopting advanced approaches, such as static mixers [11]. However, asphalt emulsions can be destabilized by three common mechanisms, like hetero flocculation caused by the introduction of a mineral aggregate [12, 13], water loss due to evaporation of the continuous phase [12, 14], and chemical destabilization resulting from an elevation in pH [12]. Nevertheless, the most frequently followed technique is the introduction of very alkaline material, such as cement particles, to provide a quick increase in pH in road pavement applications. This procedure induces certain physicochemical alterations, facilitating the quick disintegration of the emulsion. Various nations have successfully created asphalt emulsion by utilizing a cold asphalt mixture, as substantiated by multiple studies, such as the one conducted in [13]. It was concluded that asphalt emulsion is a highly efficient method for preserving and maintaining asphalt pavement. Authors in [14] assessed the efficacy of utilizing asphalt emulsion for the purpose of conducting asphalt mixture recycling in real-world scenarios. Authors in [15] explained that the duration required for the curing process while utilizing emulsion is between 10 and 14 days. Authors in [16] proposed a modified technique for mixing cement with asphalt emulsion to improve the stiffness of the asphalt binder and boost its adhesion to the aggregate surface. The introduced method involves using an ideal proportion of cement. Authors in [17] discovered that a cold asphalt mixture has superior mechanical qualities compared to an asphalt mixture. Authors in [18] found that incorporating waste ash into a cold asphalt mixture enhances its water resistance. Furthermore, it exhibits exceptional resilience against weariness. Authors in [19] carried out a study on the compressive strength of cold-mix combinations. The asphalt emulsion utilized was enhanced with polyvinyl acetate (PVAC), a polymer that is added to improve asphalt compressive strength. Authors in [20] investigated the correlation between the rigidity of cold asphalt mixtures and air temperature. They also derived guidelines for predicting the behavior of these mixtures under different conditions.

Asphalt distillation is used as an adhesive in all reported investigations with cold asphalt mixtures. Currently, no alternative to asphalt oil has been discovered to replace it in the production of emulsion asphalt. This is because the demand for asphalt oil in Indonesia is approximately 1.2 million tons per year, while the domestic production capacity of asphalt, oil asphalt, is only around 600 thousand tons per year [21]. Buton asphalt is a type of natural asphalt obtained through mining on Buton Island, located in the Southeast Sulawesi Province of Indonesia. This area has a mining potential that can last for 300 years. Indonesia, like other nations, has successfully produced asphalt emulsion and cold asphalt mixtures. These mixtures utilize asphalt emulsion, obtained from the distillation of asphalt oil, as the adhesive material. Exploring the potential of Buton natural asphalt (Asbuton-Indonesia) as an alternative raw material for asphalt emulsion, with the aim of developing a cold asphalt combination, is highly fascinating. In Indonesia, asphalt emulsion is exclusively utilized for adhesive and impregnating layers. Everyone has implemented multiple strategies to optimize the utilization of Buton-Indonesia asphalt. These include substitutes and additives in the hot asphalt mixture. The granular asphalt material, consisting of around 20% to 30% bitumen, with the remaining portion being lime and silica, presents a challenge to this endeavor due to its suboptimal quality. To address this problem, it is crucial to enhance the efficiency of Buton-Indonesia asphalt by implementing emulsified asphalt. The solid component of the cationic slow setting (CSS-1h) emulsion asphalt consists of EBBRA and kerosene. The liquid component consists of an emulsifier, HC1, CaCl, and water. Typically, studies on emulsified asphalt utilize petroleum asphalt as the primary substance. This study distinguishes itself by utilizing EBBRA as the primary substance for producing emulsified asphalt.

II. SCOPE OF THE STUDY

The objective of this study is to showcase and provide detailed information on the utilization of Buton asphalt as the main ingredient for manufacturing emulsion asphalt. To extract Buton asphalt, the initial stage comprises the separation of bitumen and minerals. Chemical engineers utilize Buton asphalt, which is a solid-phase raw material. This study uses the laboratory as the experimental environment. The objective of this research is to reduce the ecological consequences associated with the utilization of petroleum bitumen as a solid-phase input for emulsion asphalt manufacturing.

III. LIFE-CYCLE ASSESSMENT

Life-Cycle Assessment (LCA) is a systematic approach used to examine the environmental impact of processes and products throughout their entire life cycle, from the extraction of raw materials to their disposal. Individual items are typically evaluated using a cradle-to-grave study, which requires detailed data on specific processes [22]. It includes every stage of product manufacturing, beginning with the procurement of raw materials, progressing through production, distribution, consumption, and utilization, and concluding with the disposal phases. A life cycle approach encompasses the entire process of acquiring raw materials, manufacturing the product, and disposing of it, with a focus on analyzing energy use, material inputs, and waste production. Examining the complete lifetime is crucial to ensure that reducing the negative effects in one stage does not inadvertently lead to increased negative effects in another stage of the lifecycle. One of the main difficulties in conducting LCA is ensuring that different product studies can be compared accurately, that they may use different methodologies and assumptions. Implementing a standardized procedure can be beneficial in this regard [23]. Moreover, this method requires a significant amount of time and resources [24].

IV. EMULSION ASPHALT

An emulsion is the state in which a liquid is dispersed into another liquid. Emulsion asphalt often refers to asphalt that is capable of being dissolved in water, rather than water that is capable of being dissolved in asphalt. Its composition consists of 40% to 75% solid asphalt, 0.1% to 2.5% emulsifier, 25% to 60% water, and other minor constituents, such as HC1 and CaCl [25]. An emulsifier is a substance that evenly distributes asphalt in water, resulting in the formation of asphalt emulsion. The dispersion of asphalt in water leads to the creation of particles through a solid phase process, which are subsequently mixed in the colloid mill. The composition and production equipment of emulsions has an impact on the different distributions of particle sizes in emulsions. The size and distribution of the particles in these emulsion droplets greatly affect the physical properties of the emulsion, including its viscosity and stability over a 24-hour period. Increasing the average particle size as well as having a wide or bimodal distribution of particle sizes can decrease emulsion viscosity. Emulsion performance is also influenced by the size of the particles. Reducing the size of particles often improves the effectiveness of emulsified asphalt mixtures and makes them easier to use in road pavement construction. Recent advancements in emulsified asphalt focus on controlling the size and distribution of emulsion particles during the emulsification process, which in turn affects the qualities of the emulsion. Macroemulsions are inherently unstable [26]. Over a prolonged duration, ranging from hours to years, the asphalt phase will gradually detach from the water, a crucial constituent in the composition of emulsified asphalt. As the water layer surrounding the floccules becomes thinner, the droplets merge. The process of coalescence is permanent and cannot be reversed. Factors that can lead to droplets merging include decreased gravitational force, evaporation of water, shear, or freezing, which will speed up the process of clumping and melting, while also decreasing the electrical charge on the droplets. Asphalt with a low viscosity will combine more rapidly than asphalt with a high viscosity. This paper's goal is for the emulsified asphalt to be combined with the gravel and create a road surface [27]. Emulsified asphalt offers the advantage of having a reduced viscosity compared to regular asphalt, enabling its application at lower temperatures. Utilizing low-temperature emulsified asphalt combination technology will result in decreased emissions, reduced energy consumption, prevention of asphalt oxidation, less risk of hazards associated with hot mix asphalt processes and enhanced economic and environmental viability. The reactivity of the asphalt emulsion is dictated by the polarity of the droplets. Cationic emulsions consist of droplets that possess a positive charge. Anionic emulsions consist of droplets that carry a negative charge, while non-ionic emulsions consist of droplets that do not carry any positive or negative charge. Non-ionic emulsions are hardly utilized in road paving. Cationic and anionic asphalt emulsions belong to distinct classes. Slow Setting (SS) refers to an emulsion asphalt that undergoes a gradual and consistent binding process. Medium Setting (MS) refers to an emulsion asphalt that undergoes a steady and consistent binding or reaction process. Rapid Setting (RS) refers to an emulsion asphalt that undergoes a fast and consistent binding process. Typically, standard asphalt emulsions, which contain bitumen, belong to the O/W type. The composition consists of asphalt ranging from 40% to 75%, emulsifiers ranging from 0.1% to 2.5%, water ranging from 25% to 60%, and additional minor components. The diameter of the asphalt droplet ranges from 0.1 to 20 microns [28].

V. MATERIALS AND METHODS

A. Testing the Results of EBBRA

The extraction procedure is performed by utilizing a Socklet instrument to separate Asbuton bitumen from its minerals. Natural asphalt is inserted into a tube containing samples. Trichloroethylene (TCL), a solvent, is added to the solvent tube at a proportion of 1/3 of the volume of the solvent. To ensure the solvent remains at the desired temperature and to prevent any damage, it is necessary for the condenser to be consistently replenished with flowing water during the extraction process, while the solvent is heated. TCL evaporates from Buton natural asphalt, causing the bitumen and minerals in the sample to gradually separate. The separation between bitumen and its minerals is indicated by the purification of minerals from the evaporated and reconstituted asphalt covering, referred to as TCL. The process of isolating bitumen and its components continues until all the natural asphalt is fully separated from Buton in the sample. Table I displays the procedure and findings of EBBRA investigation. Upon examining Table I, which depicts the physical characteristics of the extracted bitumen, it becomes evident that most of these features satisfy the criteria for 80/100 penetration oil asphalt. At a temperature of 25 °C, with a mass of 100 grams, and a duration of 5 seconds, the penetration measurement is 93.2 units, with each unit representing 0.1 mm. The chemical composition EBBRA is shown in Figure 1. The outcome bears a resemblance to that in [29, 30], which has an 85 rating. It also aligns with the penetration value of EBBRA in the Lawele zone I2 area (penetration = 75) and Lawele zone E13 (penetration = 120) [27]. The penetration value of the EBBRA result (93.2) is different from the research results of Furqon A (penetration value = 43.6), which categorize the bitumen's penetration as 40/50. Upon examining the melting temperature, flash point, ductility at 25°C, specific gravity, solubility in

C_2HCl_3, weight loss, and penetration after TFOT, it has been determined that these characteristics closely resemble to those of BHEAAB with 80/100 bitumen [7]. The BHEAAB result comprises bitumen [7]. Typically, bitumen consists of carbon (82%-88%), hydrogen (8%-11%), sulfur (0%-6%), and nitrogen (0%-1%) according to The Shell Bitumen Handbook, 1990. The EDS analysis of BHEAAB reveals that it mostly consists of carbon (88.8%), sulfur (S) (3.9%), and oxygen (O2) (7.3%). The physical features and chemical composition of BHEAAB indicate that it can be included in the solid phase during the manufacturing of emulsified asphalt [31].

TABLE I. INSPECTION RESULTS OF THE CHARACTERISTICS OF EBBRA

Types of Testing	Method	Results
Penetration at 25°C, 100 g, 5 sec (0.1 mm)	SNI 06-2456-1991	93.2
Softening point (°C)	SNI 06-2434-1991	48
Ductility at 25°C (cm)	SNI 06-2432-1991	37
Solubility in C_2HCl_3 (% weight)	SNI 06-2438-1991	97.6
Flashpoint (°C)	SNI 06-2433-1991	289.5
Specific gravity	SNI 06-2441-1991	1.05
Weight loss 163°C (TFOT) (% weight)	SNI 06-2440-1991	0.25
Penetration after TFOT (% original)	SNI 06-2456-1991	145.4
Viscosity 170 CST		4

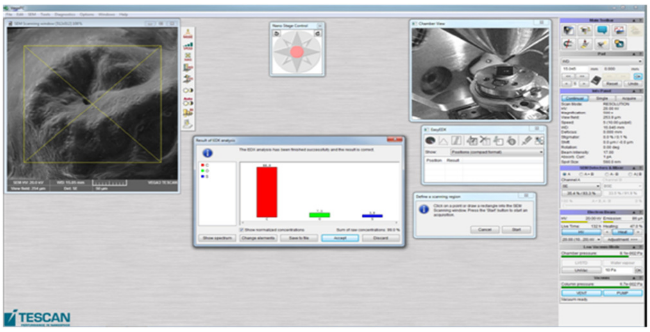

Fig. 1. SEM and EDS Results of EBBRA.

B. Design of Solid and Liquid Phases of Asphalt Emulsion

The method of extracting bitumen-based emulsion asphalt from EBBRA is guided by the Technical Guidelines for Making Cationic Emulsion Asphalt, as specified in the Decree of the Director General of Highways-Indonesia number 76/KPTS/Db/1999. The extraction procedure mentioned earlier causes the asphalt to emulsify [32]. Kerosene, a solid phase material and emulsifier, produces Buton natural asphalt, while HCl, CaCl, and water act as liquid phase materials. A lab mill, or colloid mill, is the apparatus utilized in the manufacturing process of emulsified asphalt. A lab mill, also known as a colloid mill, separates the solid phase and liquid phase before their combination in a container. The solid phase is formed by the removed granular Ashburton asphalt, which complies with the AASHTO M-20-1990 standards. Subsequently, kerosene is incorporated into the mixture until the penetration level attains a value of 180/200. The kerosene concentration varies between 2% and 4%. The extracted Asbuton asphalt comprises 57% of the overall emulsified asphalt. The aqueous phase comprises emulsifying agents, HCl, and CaCl that are dissolved in water [14].

C. Determination of the Optimum Composition of the Asphalt Emulsion Mixture of Ashburton

The independent variable in this case is the solid phase bitumen concentration obtained from the extraction of Buton Natural Asphalt. Kerosene is the dependent variable, while the liquid phase, consisting of the emulsifier, HC1, and CaCl, is also a dependent variable. It is mixed with water to achieve a mixture that has been previously determined and investigated, with a composition of 100%. The kerosene content is currently the independent variable. The ideal bitumen content was derived from the results of the Buton Natural Asphalt Extraction, where it was used as the dependent variable. Researchers combine the emulsifier, HC1, and CaCl with water to obtain a mixture that matches the composition previously calculated and examined, reaching 100% accuracy. The emulsifier stage is considered a dependent variable because previous research has established that HC1, CaCl, and water are used at this stage. The emulsified asphalt typically contains an emulsifying substance, known as an emulsifier, which is present in a concentration ranging from 0.25% to 1.5%. Laboratory experiments can inform the development of emulsifiers and HCl. In the laboratory, the concentration of HCl is initially evaluated at values both higher and lower than the emulsifier concentration that was previously determined. The emulsifier and HC1 composition test uses the one-day sedimentation test, with sieve number 20 retaining the measured value. The one-day sedimentation value is used to evaluate the ideal amount of emulsifier and HC1. The test is conducted using a sieve with a number 20, and the smallest value obtained indicates the point at which the mixture of emulsifier and HC1 does not result in excessive foaming in the emulsified asphalt. Optimization is performed once the composition of the solid phase, EBBRA and kerosene, and liquid phase, emulsifier, HCl, and CaCl, has been determined.

D. Asphalt Emulsion Test

Table II demonstrates the application of the SNI 4798:2011 testing requirements for cationic emulsion asphalt in the manufacturing process of asphalt emulsion.

TABLE II. STANDARD TESTING REQUIREMENTS FOR ASPHALT EMULSION (SNI 4798:2011)

No.	Testing Type	Testing method	Specification	Unit
1	Viscosity of say bolt furol at 25°C	SNI 03-5721-2002	20-100	sec.
2	24-hour storage stability	SNI 03-5828-2002	Maks. 1	%
3	Retained sieve analysis no. 20	SNI 03-3643-1994	Maks. 0.1	% Getaway
4	Residue content distillation, %	SNI 03-3642-1994	Min. 57	%
5	Penetration, 77 F(25°C), 100 g, 5 sec	SNI 06-2456-1991	40-90	0.1 mm
6	Residual ductility, cm	SNI 06-2432-1991	Min. 43	cm
7	Solubility of residue in C_2HCl_3	SNI 06-2438-1991	Min. 97.5	%
8	The electric charge of particles	SNI 03-3644-1994	Positive	

This study employs the CSS-1h variant of emulsion asphalt. The test findings were analyzed according to the guidelines outlined in the Indonesian National Standard (SNI) 4798:2011 for cationic emulsion asphalt and the testing requirements specified by ASTM [33] for emulsion asphalt produced from petroleum asphalt raw materials.

VI. RESULTS AND DISCUSSION

A. Initial Trials to Determine Solid Phase and Liquid Phase

Table III presents the penetration and specific gravity data obtained during the initial effort to identify the solid phase. To achieve consistent and specific values for penetration, the solid phase is determined by seeking. The pH and specific gravity results from the initial test to determine the liquid phase are presented in Table IV. To ascertain the liquid phase, it is necessary to get pH and specific gravity measurements that are tightly correlated. The objective of this preliminary experiment is to create a cohesive mixture of solid and liquid phases, allowing them to be efficiently combined and produce an emulsified asphalt of the Oil-in-Water (O/W) type, as outlined in the original concept [1-3]. The material composition of bitumen is determined by analyzing the specific gravity values in both the solid and liquid phases. This analysis includes natural bitumen extraction, kerosene, emulsifier, HC1, CaCl, and water in the emulsified asphalt. The specific gravity value is balanced, or equal to 1.03, as shown in Table III for the solid phase, and Table IV for the liquid phase. The initial mixing test was conducted to determine the optimal value for the solid component, specifically EBBRA while using kerosene as a variable that may be adjusted freely. The emulsifier, HCl, CaCl, and water, which constituted the liquid component, were established as constant variables. Therefore, this research successfully produced an emulsion asphalt.

TABLE III. PENETRATION VALUES AND SPECIFIC GRAVITY OF SOLID PHASE EXPERIMENTS

Material composition		Inspection	
EBBRA (%)	**Kerosene (%)**	**Penetration**	**Specific gravity**
99	1	175	1.040
98	2	180	1.038
97	3	184	1.033
96	4	186	1.031
95.5	4.5	188	1.031
95	5	190	1.030
94.5	5.5	192	1.030
94	6	196	1.029
93.5	6.5	201	1.029

TABLE IV. PH VALUE AND SPECIFIC GRAVITY OF LIQUID PHASE EXPERIMENT

No.	**Material type**	**Ingredient composition (%)**				
1	Emulsifier	0.5	0.75	1	1.25	1.5
2	HCl	0.3	0.4	0.5	0.6	0.7
3	CaCl	0.06	0.08	0.1	0.12	0.14
4	Water	39.74	37.87	36	34.13	32.26
No.	**Testing**	**Testing results**				
1	pH	3.0	2.7	2.5	2.3	2.1
2	Specific gravity	1.029	1.03	1.03	1.03	1.031

B. Optimization of EBBRA Content in Emulsion Asphalt

Table V presents the various steps involved in improving the BHEAAB content in emulsified asphalt. The current BHEAAB content varies between 55.4 and 59.4, with an interval of 1% rise. The fixed variables in this stage include kerosene, emulsifier, HCl, and CaCl. The concentrations of kerosene, emulsifier, HCl, and CaCl are 5%, 1%, 0.5%, and 0.1%, respectively. Water is utilized to precisely regulate the quantity of emulsified asphalt to a full 100%. The results of optimizing the EBBRA content in emulsified asphalt are presented in Table VI. The bitumen content was varied according to the requirements specified in SNI 4798:2011 for emulsified asphalt. Researchers conducted this optimization to determine the optimal composition of EBBRA, which can be used as the main ingredient for the solid phase of emulsified asphalt [4-6].

TABLE V. PROCESS OF OPTIMIZING EBBRA CONTENT IN EMULSIFIED ASPHALT (AS A VARIABLE)

No	**Type of Material (%)**	**Experiment composition (E)**					**Note**
		E1	E2	E3	E4	E5	
1	EBBRA	55.4	56.4	57.4	58.4	59.4	Solid phase
2	Kerosene	5					
3	Emulsifier	1					Liquid phase
4	HCl	0.5					
5	CaCl	0.1					
6	Water	38	37	36	35	34	
Total (%)		100					

TABLE VI. OPTIMIZATION RESULTS OF EBBRA CONTENT IN EMULSIFIED ASPHALT

Types of Testing	**Results of Testing**				
	E1	E2	E3	E4	E5
Viscosity of say bolt furol at 25°C	15	20	24	60	106
24-hour storage stability	0.40	0.60	0.70	0.90	1.10
Retained sieve analysis no. 20	0.01	0.02	0.02	0.06	0.08
Residue content distillation, %	58.60	60.20	64.70	70.60	75.40
Penetration, 77 F(25°C), 100 g, 5 sec	92.00	87.00	83.00	81.00	79.00
Residual ductility, cm	42.00	43.00	44.00	47.00	48.00
Solubility of residue in C_2HCl_3	98.40	97.83	97.70	97.70	97.50
The electric charge of particles	Positive				

As the EBBRA increases, the viscosity value of say bolt furol at 25 °C increases. The stability of the substance remains consistent over 24 hours, as does its capacity to pass through a sieve with a mesh size of 20. Additionally, the residue content after distillation and the flexibility of the residue are also maintained. However, the penetration value and solubility in C_2HCl_3 of the residue diminish while extracting more bitumen from Buton Natural Asphalt. This indicates that they have an inverse relationship with the increase in bitumen. An augmentation in the asphalt content in the EBBRA results in a rise in the number of particles in the asphalt emulsion, a decrease in the space between particles, and a decline in the water content in the resultant asphalt emulsion [12-17]. It is evident that the EBBRA results are 55.4% and 56.4%, measured by say bolt furol viscosity at 25°C, and 59.4%, measured by say bolt furol viscosity at 25°C and 24-hour storage stability. These percentages do not meet the criteria for emulsified asphalt, as specified in SNI 4798:2011. The Buton Natural Asphalt Extraction results have a bitumen percentage of 57.4% and 58.4%, which produces emulsified asphalt that satisfies the parameters stated in the requirements for emulsified asphalt SNI 4798:2011. During the optimization phase, researchers determined that the ideal proportion of EBBRA content in emulsion asphalt is 57.4%. This content allows us to preserve EBBRA and manufacture emulsion asphalt that fulfills the specifications of SNI 4798:2011.

C. Optimization of Kerosene Content in Emulsion Asphalt

Table VII depicts the several phases involved in adjusting the kerosene concentration in emulsified asphalt. The emulsified asphalt mixture consists of varying amounts of kerosene, ranging from 4% to 6%, with increments of 0.5%. The mixture is subsequently adjusted to a 100% alignment by incorporating EBBRA, emulsifier, HCl, CaCl, and water as constant factors. The emulsified asphalt consists of 57.4% EBBRA, 1% emulsifier, 0.5% HCl, and 0.1% CaCl. Various experiments were conducted on emulsion asphalt derived from EBBRA, and the outcomes are presented in Table VIII.

TABLE VII. THE PROCESS OF OPTIMIZING THE CONTENT OF KEROSENE IN EMULSIFIED ASPHALT (AS A VARIABLE)

No	Type of Material (%)	Experiment composition (E)					Note
		E1	E2	E3	E4	E5	
1	EBBRA	57.4					Solid phase
2	Kerosene	4	4.5	5	5.5	6	
3	Emulsifier	1					Liquid phase
4	HCl	0.5					
5	CaCl	0.1					
6	Water	37	36.5	36	35.5	35	
Total (%)		100					

TABLE VIII. OPTIMIZATION RESULTS OF KEROSENE CONTENT IN EMULSIFIED ASPHALT

Types of Testing	Results of Testing				
	E1	E2	E3	E4	E5
Viscosity of say bolt furol at 25°C	28	26	24	22	20
24-hour storage stability	1.2	1.10	0.70	0.62	0.54
Retained sieve analysis no. 20	0.08	0.05	0.02	0.02	0.01
Residue content distillation, %	70.4	68.20	64.70	56.60	55.80
Penetration, 77 F(25°C), 100 g, 5 sec	60.00	72.00	83.00	86.00	90.00
Residual ductility, cm	44.00	45.00	44.00	43.00	42.00
Solubility of residue in C_2HCl_3	98.20	97.80	97.70	97.50	97.60
The electric charge of particles	Positive				

The kerosene content was fine-tuned as a variable. The optimization technique utilizes kerosene concentrations of 4%, 4.5%, 5%, 5.5%, and 6%. The objective of optimization is to ascertain the most favorable kerosene concentration that satisfies the specified emulsion asphalt criteria as stated in SNI 4798:2011. The say bolt furol viscosity value at 25 °C, 24-hour storage stability, retained sieve analysis no. 20, and the distillation of residual content all exhibited a reduction as the kerosene level increased, suggesting an inverse correlation between the two variables. Conversely, the penetration value increased in proportion to the amount of kerosene present. There is a clear relationship between the increase in the kerosene content of emulsion asphalt and the corresponding increase in the EBBRA. Kerosene can alter the specific gravity measurement of the resulting asphalt, according to The Shell Bitumen Handbook, 1990.

The results indicate that emulsion asphalt, when subjected to a 24-hour storage stability test with a kerosene concentration of 4% and 4.5%, fails to meet the specified requirements of emulsion asphalt SNI 4798:2011. Nevertheless, emulsion asphalt, when subjected to testing with kerosene contents of 5%, 5.5%, and 6%, satisfies the specified requirements of emulsion asphalt SNI 4798:2011. During the investigation to determine the optimal kerosene percentage in emulsion asphalt derived from EBBRA, a kerosene content of 5% was identified as the most favorable amount. This decision was reached because, at this level, a small amount of kerosene can be efficiently utilized in the emulsion asphalt produced from EBBRA, while still satisfying the requirements outlined in the SNI 4798:2011 criteria [7, 14, 27, 30-32].

VII. CONCLUSIONS

This study is one of several carried out to ascertain, examine, and expound upon the application of Buton asphalt as the primary component of the solid phase in the production of emulsion asphalt. Currently, the solid component of emulsion asphalt is made with petroleum bitumen. To make CSS-1H emulsion asphalt, this solid component is combined with kerosene, the liquid component, namely calcium chloride (CaCl), hydrochloric acid (HCl), water, and an emulsifier. Nonetheless, the current study unequivocally shows that, in addition to the engineering procedure conducted, the extraction findings of Buton natural asphalt as the primary raw material may be used in the production of emulsion asphalt. Emulsion asphalt, a byproduct of Extracted Bitumen from Buton Rock Asphalt (EBBRA), is the term used to describe the study's findings.

1. The natural asphalt found on Buton Island in Indonesia has been successfully utilized as a raw material for creating emulsified asphalt. This process involves extracting bitumen from its components. The experiment that adheres most closely to the ASTM and SNI-Indonesia standards (E3) involves a mixture concentration of solid phase utilizing 57.4% EBBRA and 5% kerosene. The liquid phase contains an emulsifier at a concentration of 1%, HC1 at a concentration of 0.5%, CaCl at a concentration of 0.1%, and water at a concentration of 36%.
2. The inclusion of EBBRA has a significant impact on the quality of emulsion spall. It leads to an increase in the number of particles and a decrease in the distance between them, resulting in improved quality. The moisture level will also drop. As a result, the particle size of EBBRA increases.
3. A robust correlation exists between kerosene and the caliber of emulsified asphalt. Kerosene is included in the

solid phase that effectively dissolves EBBRA. The quantity of kerosene present in this phase is intricately connected to the penetration and specific gravity of EBBRA.

4. The study's findings can facilitate the utilization of emulsion asphalt derived from EBBRA. This will enable the utilization of cold mix asphalt and reduce the reliance on hot mix asphalt produced in an Asphalt Mixing Plant (AMP).
5. The efficient exploitation of solid phase materials as a substitute for EBBRA has the potential to be advantageous for both the flexible pavement infrastructure and the environment. The literature review of this work has substantiated the positive impacts of the investigated wastes on several aspects of asphalt emulsion and mixes.

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