Comparative Analysis of Durability and Cost Efficiency Between Hot Rolled Sheet (HRS) and Cold Paving Hot Mix Asbuton (CPHMA) in Road Maintenance

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Abstract

Natural asphalt deposits on Buton Island are estimated to reach 677 million tons, but their utilization remains suboptimal. Additional challenges, such as the increasing number of vehicles and issues related to Over Dimension Over Load (ODOL) on commercial vehicles, contribute to widespread road damage and shortened pavement lifespans. One potential solution for efficient road maintenance is the use of Cold Paving Hot Mix Asbuton (CPHMA), a flexible pavement mixture that is heated during mixing but can be laid at ambient temperatures, thus promoting the utilization of Buton asphalt. This study compares HRS (Hot Rolled Sheet) and CPHMA wich used in routine road maintenance in Malang Raya with laboratory tests and cost analyses.. The HRS materials were sourced from PT. Piranti Utomo Makmur, while the CPHMA materials were provided by PT. Ketahanan Aspal Nasional. Testing confirmed that both the aggregate and asphalt materials meet technical specifications. Marshall test results for CPHMA after a 1x30-minute immersion showed a strength of 576.3 kg, while a 1x24-hour immersion produced a strength of 508.4 kg, resulting in a residual strength index of 88.22%. For HRS, the 1x30-minute immersion yielded a strength of 1,091.2 kg, and the 1x24-hour immersion produced 986.3 kg, with a residual strength index of 90.39%. These results indicate that HRS exhibits better durability compared to CPHMA. From a cost perspective, however, CPHMA proves more economical, with a cost of IDR 245,500.00/m^2 compared to HRS at IDR 248,800.00/m^2. The difference of IDR 3,300.00/m^2 makes CPHMA a more cost-effective option and could be a quicker option for routine road maintenance.

Keywords

Routine road maintenance, hot rolled sheet, cold paving hot mix asbuton. durability, cost efficiency.

INTRODUCTION

The growing mobility of people and goods in today's modern era requires adequate infrastructure, particularly roads that are in good condition and ensure safety. This aligns with the mission [1] to "accelerate the development of road infrastructure to enhance connectivity, improve productivity, efficiency, and the national logistics system, thereby strengthening the nation's global competitiveness with a focus on integrating land and maritime connectivity." Alongside the construction of new roads to support this mission, effective road maintenance is essential to ensure optimal service for road users [2 & 3].

Many national, provincial, and district/city roads experience damage due to repeated increases in traffic loads driven by economic growth in the region. Additional factors contributing to road damage include water infiltration in the pavement layers and inadequate pavement structures [4]. Pavement refers to the layer situated between the subgrade and vehicle tires, designed to support transportation activities by providing a reliable surface. Ideally, it should remain free of significant damage throughout its service life [5]. However, roads subjected to high and repetitive traffic volumes often experience a decline in quality, which is commonly indicated by visible surface damage [6].

Routine road maintenance actions commonly performed by the Public Works Bina Marga include patching or filling potholes. This study focuses on routine maintenance activities involving patching with HRS-WC and CPHMA asphalt [7 & 8]. HRS-WC is a widely used mixture for surface layers, consisting of coarse aggregates, fine aggregates, fillers, and asphalt. These materials are heated and blended at the Asphalt Mixing Plant [9]. The proper integration and quality of these materials, when meeting specifications, result in a well-performing mixture that positively affects the overall pavement construction [10]. On the other hand, CPHMA, or Cold Paving Hot Mix Asbuton, is an asphalt mixture containing Asbuton and other additives. This mixture is pre-blended in the factory and is sold ready to be spread and compacted at ambient temperatures [11 & 12]. It serves as an alternative solution, particularly for road construction in areas where Asphalt Mixing Plants (AMP) are not readily available [13].

Indonesia is home to natural asphalt reserves, particularly Buton asphalt. Buton asphalt (Asbuton) is a type of natural asphalt found in rock deposits on Buton Island and its surrounding areas [14 & 15]. With estimated Asbuton deposits reaching 650 million tons, Indonesia is the largest producer of natural asphalt in the world. Buton asphalt is sourced from multiple mines [16], all located within the same province, Southeast Sulawesi. Notable examples include the Lawele area mine, also known as Lawele Granular Asphalt (LGA), and the Kabungka area mine, known as Buton Granular Asphalt (BGA) [17]. The use of Asbuton is expected to reduce reliance on oil-based asphalt without compromising the quality of the asphalt mixture [18].

Previous research on CPHMA has been conducted by [19], focusing on the comparison of temperatures between the spreading temperature of CPHMA and the optimal temperature for mixing and spreading, which is 90ºC. Another study by [6] compared the characteristics of AC-WC and Cold Paving Hot Mix Asbuton (CPHMA) using experimental methods, including laboratory testing based on the 2018 Bina Marga Specifications. These tests involved abrasion testing, material density, material content weight, bricket making, Marshall testing, and CPHMA extraction [20]. The testing was carried out in two laboratories: the Material Testing Laboratory of Manado State Polytechnic for material property testing and the PT. Dayana Cipta Laboratory for test object preparation and Marshall testing [21]. Based on the comparison of the results, AC-WC Asbuton showed better density and resistance to vehicle loads than CPHMA. CPHMA, on the other hand, exhibited more cavities in the mixture and aggregate compared to AC-WC Asbuton [22; 20; 23].

Based on the previous research, there has been no study that directly compares HRS-WC and CPHMA once they have been laid in the field. Earlier studies focused on various modification options for CPHMA [19]. Therefore, this research aims to provide direct comparative data between HRS-WC and CPHMA after they have been applied in the field. To achieve more accurate results, this study was conducted on the Bts. Malang City - Turen road section, which falls under the jurisdiction of the Malang Road and Bridge Management Technical Implementation Unit, Public Works and Highways Department, East Java Province.

The Malang City - Turen BTS Road Section (link. 020) spans 20.22 km, connecting Malang City BTS (Jln. Kol. Sugiono) to Turen District in Malang Regency. According to data from the Regulation and Control Division of the East Java Provincial Public Works and Highways Service on 2024, traffic on this section is predominantly composed of motorcycles and light vehicles, with a daily traffic volume (LHR) of 54,370 vehicles/day. However, this road is frequently used by trucks carrying excess loads, resulting in a Cumulative Equivalent Single Axle (CESA 5) value of 15,885,467. This heavy traffic has led to frequent road damage, including cracks, sinking, bleeding, and potholes. Additionally, another contributing factor to the damage is the suboptimal drainage system; some sections lack drainage altogether on either side of the road. This section was selected for the study because it has undergone repairs in the form of patching using both hot asphalt HRS-WC and CPHMA.

RESEARCH SIGNIFICANCE

This research is significant as it provides a scientific foundation and empirical data to support decision-making in routine and periodic road maintenance, particularly in selecting the most suitable material based on durability and cost-effectiveness. By comparing the durability of HRS-WC and CPHMA, the government or relevant parties can identify more durable materials, which will help reduce the frequency of repairs and extend the road's service life. Additionally, the budget efficiency analysis offers guidance on maximizing the use of maintenance funds, which is particularly crucial in times of budget limitations. Therefore, this research not only aids in optimizing the use of Buton asphalt but also contributes to more sustainable and cost-effective management of road infrastructure.

METHODOLOGY

A. RESEARCH DESIGN

This study uses CPHMA material from PT. Ketahanan Aspal Nasional (Remalthon) and HRS from PT. Piranti Utomo Makmur, both applied in routine maintenance activities on the Malang City - Turen BTS road section (link 020). In general, the study consists of several key stages, including the preparation of test specimen samples. The Methodology chapter will provide a detailed description of the research steps to offer a clear and comprehensive overview of the research process.

B. PROBLEM IDENTIFICATION

The gap analysis in this study compares the current state with the ideal state. Currently, the use of CPHMA is less common, as it is believed to have lower strength than hot asphalt mixes, and this perception remains widespread among those responsible for road maintenance. However, in practice, various modifications have been made to CPHMA, leading to its growing adoption as a solution for routine road maintenance. On the other hand, hot asphalt mixes heavily rely on the Asphalt Mixing Plant (AMP), which can delay the immediate handling of road damage. The ideal condition is an increased use of CPHMA in routine road maintenance, allowing for quicker repairs. Additionally, the process of spreading and compacting CPHMA should meet the same standards as hot asphalt mixes to achieve equivalent strength.

C. LITERATURE STUDY

The literature study is the stage where various theories are gathered to support and serve as references for this research. The sources of literature include research journals, regulations, thesis reports, dissertation reports, and the results of papers and seminars. Relevant references for this research have been summarized in the Literature Review section.

D. DATA COLLECTION

The preparation stage is the planning phase before conducting the research. The first step in the preparation for this study involves gathering the materials needed to carry out the research.

1. Technical Specification Data for Cold Paving Hot Mix Asbuton (CPHMA)

   To increase Indonesia's independence in road paving, the government has implemented several regulations aimed at maximizing the use of Buton asphalt and reducing reliance on imported oil-based asphalt. These include Government Regulation No. 29 of 2018 on Industrial Empowerment, PUPR Ministerial Regulation No. 18/PRT/M/2018 on the Use of Buton Asphalt for Road Construction and Maintenance, and Law No. 03 of 2014 on Industry. The CPHMA material used in this study is produced by PT Ketahanan Aspal Nasional, a company with over 6 years of experience in the Buton asphalt processing and trading industry, addressing the challenges of road paving in Indonesia. This company actively supplies road paving materials through its premium products, such as REMALTON CPHMA and LGA, with the CPHMA produced meeting the specifications required for road infrastructure development in Indonesia.

2. Hot Rolled Sheet (HRS) Technical Specification Data

   Hot Rolled Sheet (HRS) is an oil-based asphalt produced and compacted at high temperatures. It is commonly used for road construction and repair. The quality of road repairs using HRS is highly dependent on the temperature during production at the Asphalt Mixing Plant (AMP) and during laying. Since it must be produced and laid at high temperatures, careful planning is required to ensure the laying temperature remains optimal. Unlike CPHMA, HRS needs to be applied relatively close to the AMP and compacted immediately to achieve the best compaction quality. In the Malang Raya area, HRS is often supplied by the AMP operated by PT. Piranti Utomo Makmur.

3. Average Daily Traffic Data

   The Average Daily Traffic is a method used to calculate the volume of vehicles passing through a specific road segment or intersection. Average Daily Traffic data has several applications, including serving as a reference for traffic engineering policies, traffic impact analysis, road pavement thickness planning, and the selection of pavement materials for both construction and maintenance. Average Daily Traffic data is gathered through a 7-day field survey on a designated road segment or intersection, aiming to provide a comprehensive overview of the Average Daily Traffic, peak hours, and peak days. In 2022, CV. Dhiratama Cipta Persada conducted this field survey and Average Daily Traffic calculation.

4. Standard Unit Price Data

   Self-Estimated Prices (HPS) are gathered from various sources, including market price surveys, prices in the E-Catalog, and price references outlined in the East Java Governor's Regulation (Pergub) or local regulations. According to Pergub No. 30 of 2023 regarding the Standard Unit Price of Goods for the East Java Provincial Government, the preparation and execution of the Regional Revenue and Expenditure Budget (APBD) must adhere to technical standards and regional unit prices. These standards serve as guidelines for implementing regional expenditures to fund government activities based on the duties and functions of regional authorities in the 2023 Fiscal Year. The Standard Unit Price of Goods includes low, average, and high prices to account for price variations across different areas in East Java Province. Below is the Standard Unit Price (SSH), compiled based on the Pergub and market price surveys within the jurisdiction of the Malang Road and Bridge Management UPT.

5. Cost Calculation Analysis Data

   The cost calculation analysis in this study follows the self-management guideline book issued by the Department of Public Works and Highways of East Java Province. This guideline book outlines various aspects of routine road maintenance tasks, including the maintenance of channels, culverts, right-of-way spaces (rumija), pothole patching, bridge cleaning, and other activities related to routine road and bridge maintenance. The analysis is further concentrated on detailed data regarding cost calculations for patching work.

E. RESEARCH PLANNING

1. Material Preparation

   The materials used in this study were produced by the Asphalt Mixing Plant (AMP) with the following specifications: HRS-type hot asphalt sourced from PT. Piranti Utomo Makmur, with the AMP located in Tajinan Village, Malang Regency, and Cold Paving Hot Mix Asbuton (CPHMA) sourced from PT. Ketahanan Aspal Nasional, located in Pasuruan Regency. Both service providers hold operational feasibility certifications, and the products produced comply with the General Bina Marga Revision 2 Specifications issued in October 2020.

2. Preparation and Collection of Test Specimens

   The test specimens in this study consisted of two treatments: the creation of test specimens using HRS and CPHMA materials, and core drilling at the road repair site. The specimen preparation process begins by heating the sample from the AMP to a temperature range of 150ºC-170ºC, then placing it into a mold that has been cleaned and preheated to a temperature of 93.3ºC-148.9ºC. The mixture is compacted in the mold by pounding it 75 times on each side, using a drop height of 45.7 cm. The test specimens are then measured for height and diameter, with thicknesses ranging from 3-5 cm for routine maintenance and 4-7 cm for periodic maintenance. After the process is complete, the specimens are removed from the mold and left on a flat surface for 24 hours at room temperature.

3. Density Testing

   Pavement density is a key factor in determining the quality and durability of the road, and it is calculated as a percentage of the Job Mix Formula (JMF). Test samples, in the form of intact and undamaged cylindrical core drills, are taken after the asphalt layer has been compacted to the design thickness specified in the JMF. The field density is then tested in the laboratory to ensure it meets the planned value in the Job Mix Design, with a minimum standard of 98% of the Job Standard Density, as per SNI 03-6757-2002. This test is conducted after the asphalt layer has been compacted to the design thickness through a compaction process.

4. Marshall Testing

The asphalt mixture was tested using the Marshall Test to determine the resistance (stability), flow, and optimum asphalt content of the asphalt-aggregate mixture. The test specimen, in the form of a cylinder with a diameter of 101.6 mm and a height of 63.5 mm, was compacted with 75 poundings per side. After compaction, the specimen was stored for 24 hours and weighed to determine the bulk density. The specimen was then soaked at 60ºC for 30 minutes or heated in an oven if liquid asphalt was used. Subsequently, the specimen was tested for stability and flow by applying a load until the maximum load was reached, and the flow value was recorded at the point of maximum load. The 20 specimens used–five specimens of each material were soaked for 30 minutes and 24 hours. The Marshall test was conducted with two immersion variations: 30 minutes and 24 hours–this is in accordance with the Marshall test procedure to assess short-term and long-term conditions.

5. Extraction Testing

The purpose of the extraction test is to determine the actual asphalt content in the asphalt mixture sample. The procedure for the extraction test is explained in detail in the Literature Review. The results of this test are crucial for assessing the durability of asphalt, particularly if the detected asphalt content differs from the Design Mix Formula (DMF).

F. DATA ANALYSIS

1. First Durability Index Analysis

The First Durability Index (IDP) is defined as the successive slopes of the durability curve, which illustrates the sensitivity of stability loss in the test specimen relative to immersion time. The IDP value, calculated using a specific equation, indicates that a more gradual decrease in the IDP value corresponds to less strength loss, while a steeper decline in the IDP value signifies greater strength loss or increased sensitivity to immersion. A positive "r" value indicates a reduction in stability, meaning a loss of strength, whereas a negative "r" value suggests an increase in stability, indicating a gain in strength [24].

2. Residual Strength Index Analysis

The Residual Strength Index (RSI), or Residual Stability Index, is a comparison of the stability of the test specimen after immersion with the stability of a standard test specimen, expressed as a percentage. The RSI is used to evaluate the sensitivity of asphalt concrete strength to water damage. The test specimen is prepared using the optimum asphalt content determined by the Marshall method, and after immersion, it is soaked for 24 hours at 60ºC. The stability of the soaked specimen is compared to that of the standard specimen, and the result, expressed as a percentage, is referred to as the Residual Stability Index (RSI).

3. Cost Efficiency Calculation

After the work is completed, the fieldwork volume data is processed using the Basic Unit Price (HSD) and analysis for hotmix work. For Burda work, a trial-and-error composition is conducted to determine the appropriate analysis. The results of the needs analysis are then calculated using HSD to estimate the repair costs for Burda. This study's cost analysis includes: 1) Basic Material Price, which covers the cost of materials and wages in the production process; 2) Efficiency and Flexibility of Spreading Time, which includes labor costs and equipment rental for the spreading process; 3) Total Cost Difference Analysis, which compares the cost differences incurred during the spreading of each research object.

RESULTS AND DISCUSSIONS

This chapter will present the research results and data analysis that have been obtained. The discussion will cover the process of collecting asphalt samples from the Asphalt Mixing Plant (AMP), creating test specimens, conducting Marshall testing and extraction, and calculating the cost estimate.

A. COLLECTION OF TEST OBJECTS

The test specimens used in this study were obtained from the Asphalt Mixing Plant (AMP), commonly used for road maintenance within the jurisdiction of the Malang Road and Bridge Management Technical Implementation Unit. Hot Asphalt of the Hot Rolled Sheet (HRS) type was sourced from PT. Piranti Utomo Makmur, while Cold Paving Hot Mix Asbuton (CPHMA) was supplied by PT. Ketahanan Aspal Nasional. The collected asphalt samples were then processed into test specimens with thickness variations of 3–5 cm, in line with the patching plan for routine road maintenance, and 5–7 cm for re-coating in periodic road maintenance. A total of 20 test specimens were used in this study, with each variation consisting of 5 test specimens.

B. MATERIAL INSPECTION

After acquiring a sufficient volume of asphalt samples for the research, the next step is to conduct material inspections, including asphalt and aggregate testing. This stage is intended to ensure that the road paving materials used comply with the established standards, namely SNI and the Technical Specifications of the Directorate General of Highways.

1. Aggregate Inspection

The materials used in this study, including coarse aggregate, fine aggregate, and filler, were sourced from samples at AMP PT. Piranti Utomo Makmur. Aggregate testing was conducted to determine the characteristics of the materials and compare them with the relevant standards. Additionally, the inspection and sampling of aggregates at the AMP were intended to ensure the cleanliness of the aggregates before the mixing process with hot asphalt. The results of the aggregate tests are presented in Table 1.

Table 1 Aggregate Test Results

Test Parameters	Coarse Aggregate	Fine Aggregate	Filler
Aggregate Impact Value	8.86		
Angularity Number	3.79		
Aggregate Content Weight	1.49	1.44	1.85
Aggregate Specific Gravity	2.61	2.56	2.71
Coarse Aggregate Wear	18.22		
Flatness	19.91		

The aggregate test results indicate that the aggregate material from PT. Piranti Utomo Makmur meets the requirements outlined in the General Specifications of the Directorate General of Highways (2018). Additionally, aggregate testing was conducted on CPHMA material samples from PT. Ketahanan Aspal Nasional. The complete test results are shown in Table 2. The technical specifications for aggregates in both HRS and CPHMA are similar, with the primary difference being in the aggregate gradation.

Table 2 CPHMA Aggregate Test Results

Test Parameters	Unit	Test Results
Soundness Test		
Coarse Aggregate	%	2.47
Abrasion Test	%	17
Aggregate Adhesion to Asphalt	%	> 96
Coarse Aggregate Specific Gravity Check		
Coarse Aggregate (12-19)	-	2.75
Medium Aggregate (5-12)	-	2.73
Fine Aggregate Specific Gravity Inspection	-	2.76
Material Passing Sieve No. 200	%	1.3
Fine Aggregate Sludge Content Testing		
Coarse Aggregate (12-19)	%	0.86
Medium Aggregate (5-12)	%	0.95
Medium Aggregate (0-5)	%	1.45
Sand Equivalent Test	%	87.38

The results of the CPHMA aggregate test show that the material meets the specified technical specifications. Therefore, the aggregate is deemed suitable for use in asphalt mixture planning and the field application process. The HRS asphalt test results are presented in Table 3, while the asphalt test results for CPHMA are shown in Table 4.

Table 3 HRS Asphalt Characteristics Test Results

Asphalt Parameters	Results
Penetration	64.4
Penetration After TFOT	62.4 (96.89% from the beginning)
Specific gravity	1.015
Soft Point	53
Flash Point and Burn Point	304 ºC Flash Point 309 ºC Burn Point
Ductility	> 100
Ductility After TFOT	> 100
Weight Loss (Thin Film Oven Test/TFOT)	0.543

Table 4 CPHMA Asphalt Characteristics Test Results

Asphalt Parameters	Results
Penetration 25 ºC (0.1 mm)	111
Asphalt Content	7.05 %
Soft Point (ºC)	41.2
Ductility in 25 ºC	138

Based on the test results, the asphalt material meets the specified requirements and is considered suitable for use. The material testing indicates that both the material from PT. Piranti Utomo Makmur and the CPHMA material from PT. Ketahanan Aspal Nasional comply with the 2018 Bina Marga General Specifications, making them suitable for road maintenance and construction work.

C. ASPHALT MIXTURE TESTING

The test specimen samples used in the experiment were asphalt mixture materials ordered by the Malang Road and Bridge Management Unit for routine and periodic road maintenance purposes. The CPHMA test specimen samples, on the other hand, were ordered in bulk, packaged in 25 kg sacks.

The tests performed on the asphalt mixture include Marshall, extraction, and field density tests. Marshall testing is conducted to assess the quality parameters of the asphalt mixture, extraction testing is used to determine the asphalt content in the mixture, and field density testing measures the density of the asphalt mixture once applied in the field.

1. Extraction Testing

One of the methods used to test the asphalt content in the mix design is the extraction method based on the AASHTO test procedure (T-164-74). This extraction test plays a key role in quality control, aiming to assess the asphalt content in the mixture applied in the field and compare it with the optimum asphalt content specified in the Job Mix Formula (PUPR, 2018). In this study, the extraction test was conducted four times, including two CPHMA samples and two HRS samples.

Important parameters in asphalt mixture analysis include stability, flow, VIM, VMA, VFB, and the Marshall Quotient (MQ). Stability measures the resistance of the mixture to vertical loads, while flow indicates the flexibility of the mixture under load at a specific temperature, such as 60°C. Voids in the mixture (VIM) represent the volume of air remaining after compaction, providing an indication of the mixture's density. Voids in the mineral aggregate (VMA) measure the space between aggregates for the asphalt to fill, supporting adhesion. Voids filled with asphalt (VFB) indicate the percentage of empty space occupied by asphalt, which contributes to strength and durability. Finally, the Marshall Quotient (MQ) reflects the balance between strength and flexibility, ensuring the mix can withstand traffic loads without excessive deformation.

2. CPHMA Testing

Marshall testing for CPHMA was performed at the East Java Regional Road and Bridge Engineering Laboratory, which is operated by the East Java – Bali National Road Implementation Center of the Ministry of Public Works, Directorate General of Highways. The Marshall test was conducted with two immersion variations: 30 minutes and 24 hours. This variation was used to assess the residual strength of the CPHMA sample. The results of the Marshall test with CPHMA material are shown in Table 5.

Table 5 Marshall CPHMA Test Results

Types of Testing	Result V1	Result V2	Specification Limits
ASPHALT MIX			
Maximum Specific Gravity	2.420	2.420	
Extraction (%)	7.050	7.050	5.5
MARSHALL TEST			
Cavity In Mixture (VIM) (%)	8.49	8.62	
Cavity Against Aggregate (VMA) (%)	21.27	21.38	
Density (gr/cm^3)	2.215	2.212	2.25
Asphalt Filled Cavity (VFB) (%)	60.20	59.73	
Melting (Flow) (mm)	3.76	3.70	
Marshall Quotient (kg/mm)	153.50	139.20	
Effective Asphalt Content (%)	6.02	6.02	
Stability (Kg)	576.30	508.40	
Percentage of Stability Decrease (%)	88.22	88.22	

The Marshall test results conducted on five test samples with 30-minute immersion and five samples with 24-hour immersion showed that the CPHMA material from PT. Ketahanan Aspal Nasional met the specifications outlined in the General Bina Marga Specifications Rev. 2 of 2018. In this experiment, additional parameters such as the Durability Index and Residual Strength Index were also calculated, with the Residual Strength Index reaching a value of 88.79%. Based on these results, it can be concluded that CPHMA material is suitable for use on low-traffic roads or for road maintenance work, particularly in repairing wearing layers.

3. HRS Testing

Marshall testing for HRS was carried out at the Construction Testing Laboratory of the Public Works Department of East Java Province. The testing involved two immersion variations: 30 minutes and 24 hours. These variations were used to determine the residual strength of the HRS sample. The results of the Marshall test with HRS material are presented in Table 6.

Table 6 Marshall HRS Test Results

Types of Testing	Result V1	Result V2	Specification Limits
ASPHALT MIX			
Maximum Specific Gravity	2.420	2.420	
Extraction (%)	5.900	5.900	5.5
MARSHALL TEST			
Cavity In Mixture (VIM) (%)	4.65	4.70	
Cavity Against Aggregate (VMA) (%)	17.40	17.45	
Density (gr/cm^3)	2.360	2.359	2.28
Asphalt Filled Cavity (VFB) (%)	73.30	73.07	
Melting (Flow) (mm)	2.92	2.74	
Marshall Quotient (kg/mm)	373.30	359.80	
Effective Asphalt Content (%)	5.58	5.58	
Stability (Kg)	1091.20	986.30	
Percentage of Stability Decrease (%)	90.39	90.39	

Marshall testing on five samples with 30-minute immersion and five additional samples with 24-hour immersion showed that the CPHMA material from PT. Ketahanan Aspal Nasional met the standards specified in the General Specifications of Bina Marga Rev. 2 of 2018. Furthermore, the calculated values for the Durability Index and Residual Strength Index were 90.39%. Therefore, CPHMA material is recommended for use on roads with light to moderate traffic and for road maintenance work, particularly in repairing worn layers.

D. BUDGET COST CALCULATION

In road and bridge maintenance and construction projects, the budget calculation phase is always a critical component. The purpose of this calculation is to determine the required budget so that the owner or the PU Bina Marga Service can plan the budget allocation effectively. A well-structured budget calculation enhances the efficiency of budget utilization, making the maintenance process more effective and efficient. Additionally, thorough calculations help minimize discrepancies between the Owner's Estimate and the outcomes of negotiations with the Service Provider. The price reference used for preparing this budget is based on the unit price from the Malang Road and Bridge Management UPT.

1. CPHMA Budget Costs

   The budget calculation is based on the Routine Maintenance Analysis of the Public Works and Highways Agency for 2024, with adjustments made according to field conditions. In patching work using CPHMA/DGEM, several technical provisions apply: the area to be repaired must be square with vertical walls and a flat base; the surface of the base layer and the walls of the hole must be sprayed with tack coat; and then the DGEM/CPHMA material is spread and compacted until the patch surface is level with the existing road surface. Based on these provisions, the unit price for patching holes using DGEM/CPHMA is calculated. The cost per m^2 for CPHMA is IDR 1,862,316.67.

2. HRS Cost Budget

   The budget calculation is based on the Routine Maintenance Analysis of the Public Works and Highways Agency for 2024, with adjustments made to account for field conditions. The technical provisions for patching work using Hot Asphalt Mixture (CAP) include shaping the repair area into a square with vertical walls and a flat, clean, and dried base, spraying tack coat on the base surface and walls of the hole, spreading and compacting the hot asphalt mixture until the patch surface is level with the existing road surface, and allowing traffic after the hot asphalt mixture has cooled. Based on these steps, a unit price calculation is performed for patching work using CAP. The cost per m^2 for HRS is IDR 2,170,020.65.

   The calculation results for the Unit Price of Work for both CPHMA and HRS highlight several important points: if Civil Servants (ASN) are used, the unit price for labor is left blank, and for equipment use without operator wages, if ASN labor is involved, the cost is excluded. If the equipment is rented, the rental price covers all associated costs. The labor wages already include the cost for tools and safety equipment (K3), which accounts for 6% of the base unit price for labor. Additionally, the prices for wages, materials, and equipment have taken into account overhead costs for procurement involving service providers. However, these prices do not include mobilization and demobilization costs.

3. Cost Budget Efficiency

   Budget efficiency is assessed by comparing the unit prices of work between CPHMA and HRS. The calculation of the unit price undergoes several adjustments based on field conditions. These adjustments include changes in the number of personnel required for the work, the daily work volume, and the latest fuel prices. From the price calculations, it can be concluded that the unit price for CPHMA work is IDR 1,862,316.67 per m^2, while for HRS work it is IDR 2,170,020.65 per m^2. The price difference between the two is IDR 307,703.98 per ton. Therefore, it can be concluded that the budget cost for CPHMA is lower than for HRS.

E. DISCUSSION OF RESEARCH RESULTS

In this study, Extraction and Marshall testing were conducted on CPHMA and HRS materials. Asphalt was chosen because the road maintenance projects conducted by the PU Bina Marga Office of East Java Province predominantly use this material. The asphalt samples used in this study were directly sourced from the service providers: CPHMA from PT. Ketahanan Aspal Nasional and HRS from PT. Piranti Utomo Makmur.

The results of the aggregate tests conducted on the two samples indicate that the aggregates used in the asphalt mixtures meet the standards set in the General Specifications for Bina Marga Rev. 2 of 2018. In addition to aggregate testing, asphalt testing was also carried out. CPHMA uses Asbuton B50/30 (LGA), while HRS uses Pen 60/70 Asphalt. The results of the asphalt tests show that the asphalt samples meet the required specifications and are suitable for use in asphalt mixtures.

Testing on asphalt mixtures included Extraction and Marshall Testing. Extraction testing aims to determine the asphalt content in the sample so that the suitability between the field asphalt content and the optimum asphalt content (KAO) can be assessed. The Extraction test results showed that the asphalt content in the CPHMA field was 7.05%, while the KAO was 6.0%, and for HRS, the field asphalt content was 5.9%, with the KAO at 5.58%. It can be concluded that the field asphalt content exceeds the KAO, which affects the strength of the asphalt mixture, preventing it from reaching the optimal point.

Marshall testing was performed with two immersion methods: immersion for 1x30 minutes and immersion for 1x24 hours. This method was used to determine the residual strength index of the asphalt mixture. The Marshall test results for CPHMA showed 576.30 kg for 1x30-minute immersion and 508.4 kg for 1x24-hour immersion, giving a residual strength index value of 88.22%. Marshall testing on HRS samples with the same treatments showed 1091.2 kg for 1x30-minute immersion and 986.3 kg for 1x24-hour immersion. The residual strength index for HRS was 90.39%. Based on these results, it can be concluded that, in terms of durability, HRS asphalt performs better than CPHMA. This is due to the wide gradation of CPHMA aggregates, which lowers its strength. However, with slight modifications, particularly in the aggregate gradation, CPHMA could potentially match or exceed HRS durability.

The next analysis focuses on the budget efficiency of routine road maintenance using CPHMA and HRS asphalt. The budget calculation is based on the unit price used by the Malang Road and Bridge Management UPT, the material prices in the e-catalog, and the realization of field work. From the price calculation results, it can be concluded that the unit price for CPHMA work is IDR 245,500.00 per m^2, while for HRS work, it is IDR 248,800.00 per m^2. The price difference between the two materials is IDR 3,300.00 per m^2, meaning the budget cost for CPHMA is lower than for HRS. This is because, according to the service provider prices in the e-catalog accessed on December 17, 2024, CPHMA asphalt is cheaper than HRS. A summary of the positive and negative aspects of both materials can be seen in Table 7.

Table 7 Comparison between CPHMA and HRS

Aspect	CPHMA	HRS
Distribution to consumers	CPHMA is packaged in 25 kg cement sacks, making it easier to distribute to consumers.	HRS is distributed in bulk and transported using dump trucks to deliver the material to consumers.
	The distribution process can use pickup trucks (for small-scale purchases) and dump trucks (for large-scale purchases), and the material must be covered with tarpaulin to protect it from rain.	The material must be distributed using dump trucks, and purchases must be on a large scale. The tarpaulin used should be able to prevent evaporation to maintain the asphalt's temperature.
Storage	It should be stored in a dry, enclosed space. Avoid exposure to direct sunlight or damp areas. It can be stored according to the expiration date on the packaging.	It cannot be stored because HRS asphalt must be applied immediately upon arrival at the work site.
Work Process	Laying asphalt tends to take longer because the asphalt has to be removed from the packaging first.	The spreading tends to be faster, in addition to the faster material loading process, HRS asphalt must be spread immediately to keep the temperature hot.
Durability	Durability based on Marshall testing obtained an average value of 576.3 Kg. Residual strength index 88.22%	Durability based on Marshall testing obtained an average value of 1091.2 Kg. Residual strength index 90.39%
Budget	The price of patching work with CPHMA is IDR 1,862,316.67	The price of patching holes with HRS is IDR 2,170,020.65

CONCLUSIONS

This study aims to evaluate the durability and budget efficiency of using Hot Rolled Sheet (HRS) asphalt and Cold Paving Hot Mix Asbuton (CPHMA) asphalt by conducting an analysis based on secondary data collection in the form of routine maintenance work history in 2023-2024 and control of the East Java Province Bina Marga Public Works

Based on the results showed that HRS asphalt has an advantage in terms of durability, with a residual strength index value of 90.39%, which is higher than the CPHMA value of 88.22%. This indicates that HRS is more resistant to soaking and has better durability for making it suitable for use on roads with moderate to heavy traffic or on main roads used by heavy good vehicles.

However, in terms of budget efficiency, CPHMA is more cost-effective, with a price of IDR 245,500.00 per m^2, lower than HRS which costs IDR 248,800.00 per m^2, so there is a price difference of IDR 3,300.00 per m^2. It can therefore be concluded that CPHMA is suitable for use on roads with low traffic volumes and as well as for use in emergency situations.

In conclusion, material selection should consider the balance between durability and budget efficiency, based on the specific needs of the project. Authors also recommend further research to improve the composition of CPHMA materials and to develop effective construction methods to enhance the stability od CPHMA.

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