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ANALYSIS OF THE USE OF COAL WASTE (BOTTOM ASH) AS A SUBSTITUTE FOR AGGREGATE IN A THIN LAYER MIX OF ASPHALT CONCRETE

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ABSTRACT

PLTU Tidore produces coal waste in the form of bottom ash or (FABA) which produces an average of 14 tons per day or 5,040 tons per year. To reduce the amount of waste, which can reduce production costs and reduce industrial waste, namely by using bottom ash as a substitute for fine aggregate. The specifications in the implementation of this test refer to the General Bina Marga 2018 specifications. The compaction of the test object is carried out in 2 × 75 collisions assuming that the test is intended for heavy traffic. The test results show that the bottom ash content as an aggregate substitute for fine aggregate produces a stability value of 1437 kg, flow 3.23 mm, MQ 450.11 kg/mm, density 2.377 gr/cm³, and porosity 4.71%. The values of flow, density, stability, MQ, porosity and porosity meet the requirements of the values set in Revision II of Highways (2018). ITS test of hot mixture HRS-BASE with the addition of bottom ash in the optimum asphalt content of 925.39 Kpa

KEYWORDS *Bottom ash; ITS; Lataston*

INTRODUCTION

Asphalt concrete as a material for road construction has long been known and is widely used in road construction. Its use in Indonesia is increasing from year to year (General, 1987). (Ashari, 2020) . This is because asphalt concrete has several advantages compared to other materials, including its relatively cheaper

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price than concrete, its ability to support high vehicle weight loads and can be made from locally available materials and has good weather resistance. (Moses, Airports, & Mampearachchi, 2020) . Asphalt concrete or asphaltic concrete is a mixture of continuously graded aggregate with bituminous materials. (Hawari & Lizar, 2021) (Wahyuri, 2011)

According to Bhattacharya et al, Bottom ash is the residue from coal combustion at the PLTU which is currently not widely used and is only disposed of as waste (Buritatum et al., 2022) . Even though bottom ash coal still has a fairly high calorific value. Biomass generally has a fairly low density, so it will be difficult to handle. In general, biomass densification has a uniform size and quality. (Dou et al., 2017) (Siddique, 2014) .

The technology that is currently being developed is the management of industrial waste to be used as raw materials or construction and infrastructure materials originating from the Tidore PLTU as a power plant with a capacity of 2x7 MW. Where the Tidore PLTU produces coal waste in the form of bottom ash or (FABA) which produces an average of 14 tons per day or 5,040 tons per year (Dou et al., 2017) (Singh & Chaurasia, 2022) .

With the invention of these material innovations, it is hoped that they can replace construction and infrastructure materials so that they can reduce production costs and reduce industrial waste. One of these innovations is to use bottom ash as a substitute for fine aggregate. An idea arose to conduct research on "Analysis of the Use of Bottom Ash Waste as Substitute Aggregate in Mixed Asphalt Concrete Thin Layers"

RESEARCH METHOD

The method used in this study refers to Bina Marga in 2018. This research was conducted at the Road and Asphalt Laboratory, Khairun University, Ternate. In order for this research to run smoothly, the equipment and materials must first be prepared.

A. Tools and materials

The equipment used in the implementation of this research, as follows:

1. Mold of the test object (mold).
2. A compactor having a flat cylindrical impact surface, weighing 4.536 kg (10 lbs), free-falling height of 45.7 cm (18inc).
3. The compactor base consists of wooden beams (teak and similar), measuring approximately 20x20x45cm (12”x12”x1”) and tied to the concrete floor by four angled sections.
4. Scales equipped with hanging specimens with a capacity of 2 kg with an accuracy of 1gr.
5. 250˚C . capacity temperature gauge
6. Jack to remove the test object
7. Vernier calipers
8. Other tools such as pots, stoves, spoons, spatulas, and gloves.

The materials used are as follows:

1. The asphalt used is asphalt with Penetration 60-70
2. Bottom ash used is the result of the burning of the Tidore City PLTU.
3. Coarse Aggregate used comes from Kali Oba

B. Research Stage

1. Material Characteristics Test

This test aims to determine the physical properties of the material used by referring to the specifications/standards that have been determined. The standard used as a reference in this study can be seen in table 1.1

Table 1 Standard Specification

Material Type	Test	SNI Standard
Coarse Aggregate	Specific gravity	SNI 1969:2016
	Water absorption	SNI 1969:2016
	Aggregate Wear	SNI 2417:2008
	Sieve Analysis	SNI ASTM C 136:2012
	Specification	SNI 03-6819-2002
Fine Aggregate	Specific gravity	SNI 1970:2016
	Water Absorption	SNI 1970:2017
	Sieve Analysis	SNI ASTM C 136:2012
	Specification	SNI 03-6723-2002
Filling Material	ductility	SNI 2432:2012
	Penetration	SNI 2456:2011
	Softening Point	SNI 2434:2011
Asphalt	Flash point and burn point	SNI 2433:2011
	Losing Weight	
	Specific gravity	SNI 06-2440-1991
		SNI 2441:2011

2. Test Object Making

The specimens made are cylindrical in shape with an average diameter of 10.16 cm (4") and an average height of 7.62 cm (3") for Marshall and ITS specimens, while for UCS specimens, the diameter and height of the UCS specimens are 10 cm, each variation made 3 test objects.

Table 2 Making Test Objects

No	Test	Number of Samples						Unit
		% *Bottom Ash* to fine aggregate						
		0	20	40	60	80	100	%
1	Mashal	3	3	3	3	3	3	Fruit
2	*ITS*	3	3	3	3	3	3	Fruit
3	*UCS*	3	3	3	3	3	3	Fruit
Total Sample		54						Fruit

RESULTS AND DISCUSSION

A. Aggregate Inspection Results

In this case the inspection of aggregates for wear using the Los Angeles machine, apparent density and water absorption indicate that the aggregates used have met the specified requirements (Dou et al., 2017) (Zhou et al., 2022) . The results of the aggregate examination are presented in table 1.3

Table 3. Aggregate Inspection Results

No	Inspection	Results	Specification Min	Specification Max	Unit
1	Aggregate Density				
	A. Coarse Aggregate				
	- Bulk Type Weight	2.46	2.50	3	Gr
	- SSD Type Weight	2.52			
	- Pseudo Type Weight	2.60			
	B. Medium Coarse Aggregate				
	- Bulk Type Weight	2.47	2.50	3	Gr
	- SSD Type Weight	2.51			
	- Pseudo Type Weight	2.57			
	C. Stone Ash				
	- Bulk Type Weight	2.23	2.50	3	Gr
	- SSD Type Weight	2.26			
	- Apparent Specific Gravity	2.30			
2	Water Absorption				
	Rough	2.20	-	3	%
	Medium Rough	1.55			
	Ash Rock	1.53			
3	Aggregate Wear	32.55	-	40%	%
4	Flatness Index	22	-	25%	%
5	Mud and Clay Content				
	Rough	3.25	-	5	%
	Medium Rough	4.25			
	Ash Rock	4			

B. Asphalt Characteristics Inspection Results

The asphalt used in this research is hard asphalt with 60/70 penetration. Asphalt inspection was carried out at the Road and Asphalt Laboratory, Khairun University, Ternate. From the results of the inspection that has been carried out, the asphalt still meets the specifications set by Bina Marga based on the Asphalt Concrete Thin Layer Instructions (Lataston) No.16.1/SE/Db/2020.

C. Filler Inspection Results

This study uses rock ash filler from the Oba River which has been examined at the Road and Asphalt Laboratory, Khairun University, Ternate. The stone ash filler examination carried out is testing the specific gravity value. The examination that has been carried out has resulted in the specific gravity value of the rock ash filler being 2.30 gr/cc.

D. Determination of Optimum Asphalt Content

The optimum asphalt content can be determined by performing the Marshall test or what is often referred to as the Asphalt Institute method. In determining the optimum asphalt content , the researcher used the data results based on the report from the Public Works and Spatial Planning Department, UKPBJ Tidore Islands (2021) with the package name for the Kahoho – Tayawi Road Section Improvement (DAK).

From these values, it can be determined the best mixed properties or the optimum asphalt content produced is 6.5 % which is then used as the basis for making the next test object.

After knowing the value of the optimum asphalt content , then determine the need for aggregate. To clarify the calculation, the following is an example of calculating JMD for marshal and ITS specimens with a bottom ash content of 0% and an asphalt content of 6.5% of the total weight of the mixture.

Table 4 Composition of aggregates for Masrhal and ITS . specimens

Calculation of Material Requirements					
No	Material	Asphalt Level	% Of Aggregate	Aggregat e Rate	Sample Weight (Gr)
1	Rough	6.50%	35%	93.5%	359.98
2	Medium Rough		40%		411.40
3	Ash Rock		25%		257.13
4	Liquid Asphalt		71.5		71.50
	Mold Capacity		1100		1100

For the filler, the researcher added cement that passed the #200 sieve at 0.07% of the total weight of fine aggregate.

Before carrying out the Marshal Test, first carry out a volumetric test which includes measuring the thickness of the test object, the weight of the test object in a dry state, the weight of the test object in the SSD state and the weight of the test object in water (Hawari & Lizar, 2021) .

This test aims to determine the characteristic value of the test object using bottom ash (Gaus, Tjaronge, Ali, & Djamaluddin, 2015) . This test is carried out using the Marshall test tool. From this test, marshall characteristics will be obtained, namely the value of stability, flow, voids filled with asphalt (VFB), voids in aggregate (VMA), voids in the mixture (VIM), and Marshall Quotient

(MQ) (Irfansyah, Setyawan, & Djumari, 2017) (Zhu, Zhao, Zhao, & Gupta, 2020) .

Table 5 Volumetric and Marshall Calculation Recapitulation

Bottom Ash	BJ. BULK CAMP.	VIM	VMA	VFB	STABILITY	*FLOW*	MQ
0	2,387	4.31	17.09	77.44	1190.00	3.43	347.94
20	2.380	4.58	17.32	76.33	1240.00	3.40	366.79
40	2.380	4.60	17.34	76.24	1309.57	3.37	419.72
60	2.377	4.71	17.44	75.77	1437.52	3.23	450.11
80	2.386	4.36	17.13	77.28	1408.55	3.30	426.74
100	2.386	4.34	17.11	77.39	1337.03	3.40	394.56

(Source: 2022; Road and Asphalt Laboratory, Khairun University, Ternate.)

From the recapitulation results for each percentage of bottom ash content , a relationship can be made to obtain the optimum bottom ash content as shown in Figure 1-4.

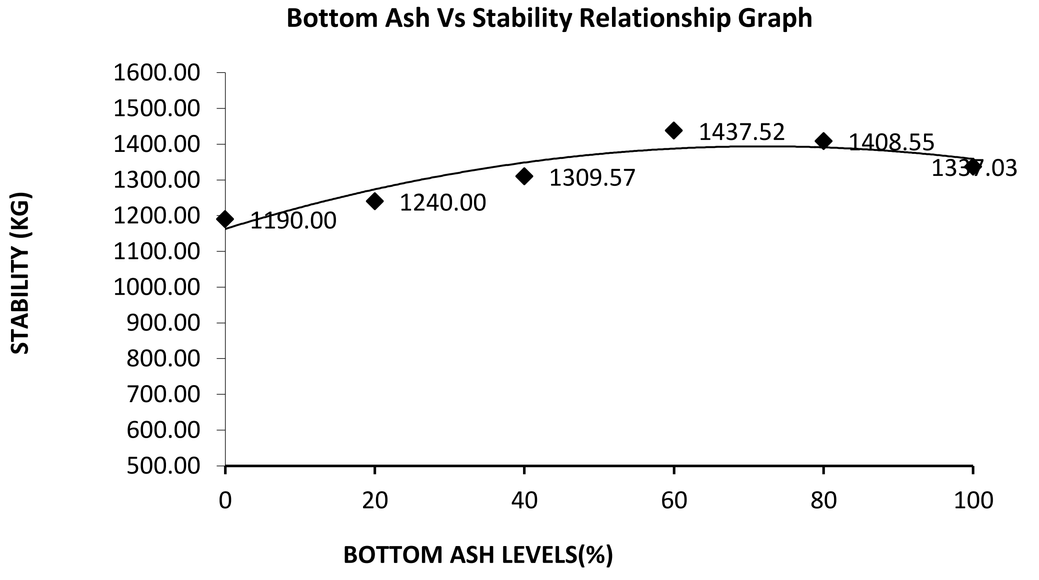

Figure 1. Graph of the relationship between bottom ash content and stability

The addition of bottom ash into the asphalt mixture greatly affects the stability value produced. The greater the percentage of bottom ash in the asphalt mixture, the higher the stability value produced, but greater than the minimum stability value

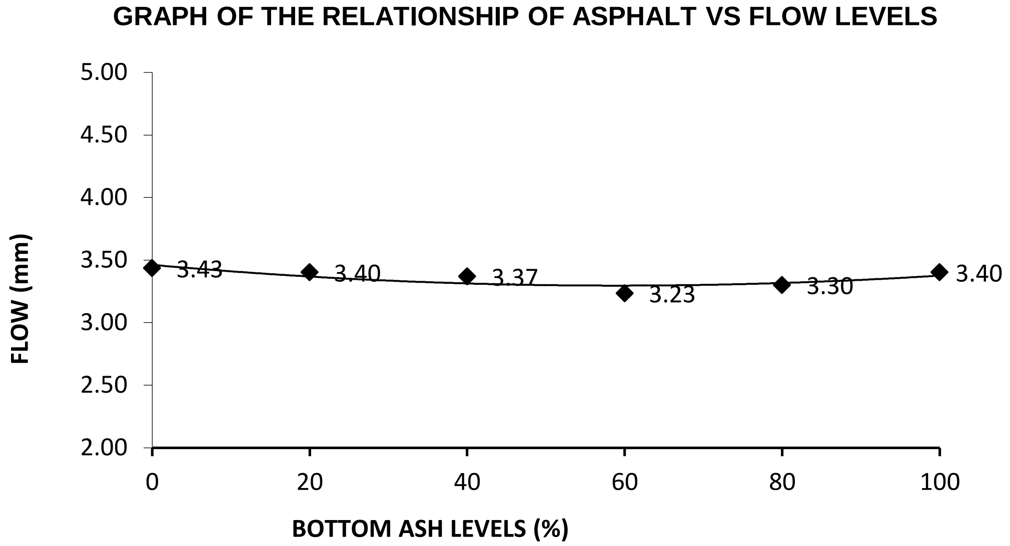

Figure 2. Graph of the relationship between bottom ash content and flow

The flow value produced in this study does not meet the standard because it is outside (2-4 mm). The resulting flow value is less than 2 mm on average, this is caused by the addition of bath ash into the mixture asphalt can increase the stiffness of the asphalt mixture (Ksaibati & Sayiri, 2006) .

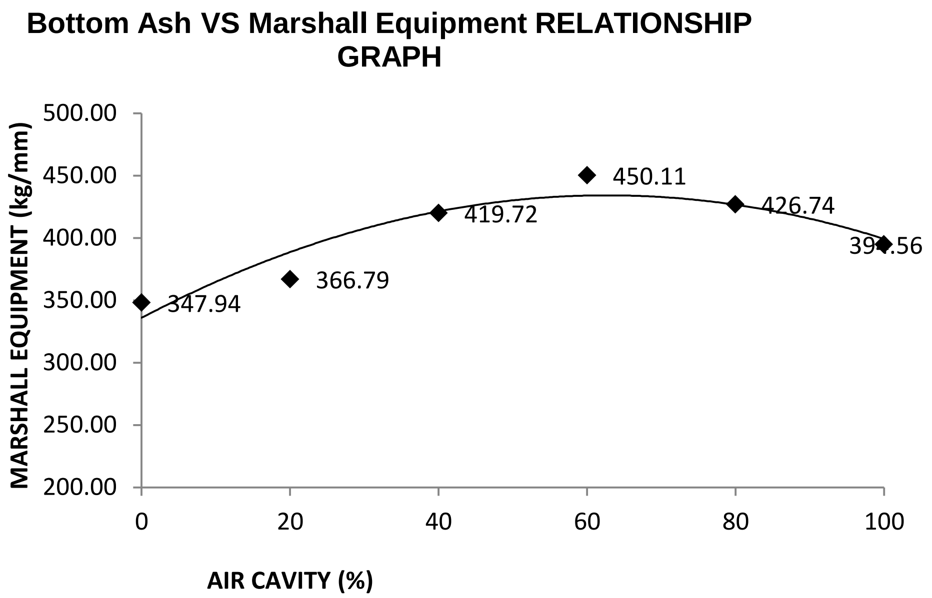

Figure 3. Graph of the relationship between bottom ash content and Marshall Quotient

The use of bottom ash filler can be concluded that the test object has rigid properties caused by the material having a higher asphalt absorption than rock ash (Lu et al., 2020)

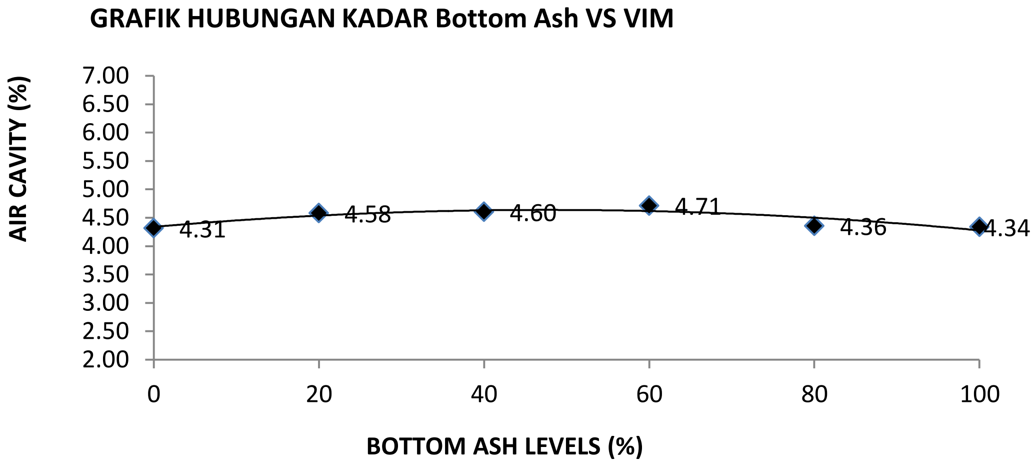

Figure 4. Graph of the relationship between bottom ash and porosity

The greater the percentage of addition of bottom ash in the asphalt mixture, the greater the voids in the resulting mixture, this is due to the nature of the pozzoland (Lynn, OBE, & Ghataora, 2016) . The pozzoland nature of bottom ash causes the filler to agglomerate so that compaction is more difficult to do.

E. ITS Test Results (Indirect Tensile Strength)

From testing the test object using the ITS tool, the tensile strength is obtained in lb units, then the tensile strength value is calculated in Kpa units. Where previously the unit conversion was carried out from kg/m2 to Kpa. The following is an example of unit conversion :

Test object code = 0%
The result of reading tensile strength = 50 lb = 50 x 0.454 kg = 22.70 kg
The result of calibrated tensile strength = 22.70 x 30.272
= 687.14 kg

The magnitude of the tensile strength is corrected according to the formula 1.1. are as follows:

ITS = (2 X Pi)/(π xdxh)

$$= \frac{2\ x\ 20802{,}14}{3{,}14\ x\ 0{,}06 \text{ x } 0{,}10}$$

= 72948 ,45 kg/ ^{m2}

Conversion kg/ ^{m2} → kPa = 1137.9958 x 9.81 x 10 $^{-3}$ = 715.62 Kpa

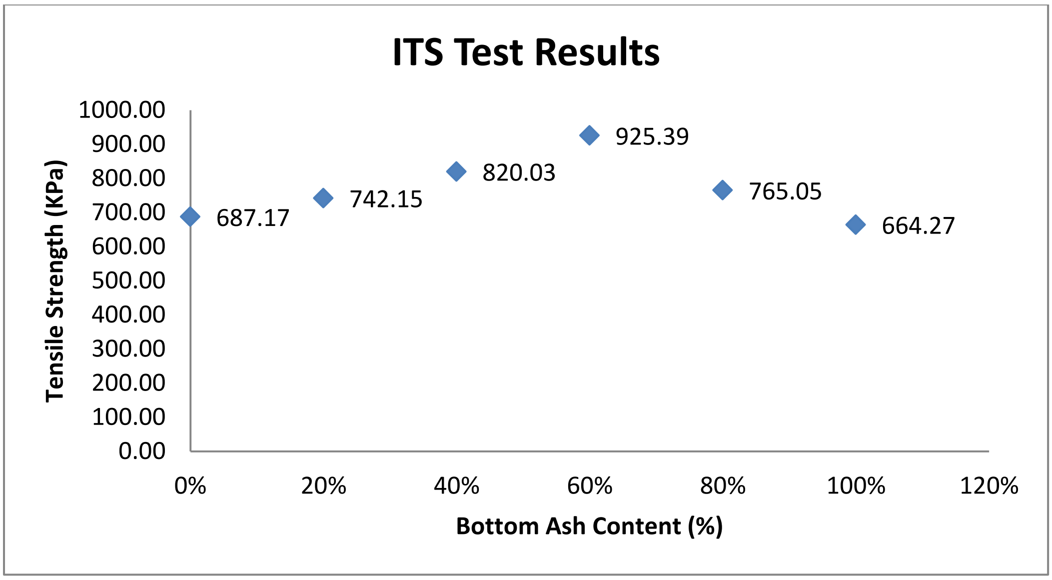

Figure 5. ITS Test Graph

From figure 5. it can be seen that after the test, the test object only experienced cracks and did not split into two parts. This shows that the actual test object has a good adhesion value. Based on graph 5, it shows that the bottom ash content of 60% has a higher tensile strength.

CONCLUSION

From the results of research and data analysis that has been carried out, it can be concluded that; Marshall hot asphalt mixture when used for HRS-BASE using bottom ash content as a substitute for fine aggregate produces a stability value of 1437 kg, flow 3.23 mm, MQ 450.11 kg/mm, density 2.377 gr/cm³, and porosity 4.71%. The values of flow, density, stability, MQ, porosity and porosity meet the requirements of the values set in Revision II of Highways (2018). So overall the Lataston mixture with the addition of bottom ash has met the requirements for use as a road pavement layer; ITS testing of hot mixture HRS-BASE with the addition of bottom ash in the optimum asphalt content of 925.39 Kpa .

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