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Original Research Article

Investigation of the Physical Properties of Thin Layer Asphalt Concrete Mixtures using by-Products from Power Plants

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Abstract: Bottom ash is a by-product produced from the process of burning rocks for electricity generation. The bottom ash produced requires a large enough storage area, high transportation costs to move it to a safe final disposal location so that it does not have a negative impact on humans. This research aims to analyze the effect of using bottom ash waste in the HRS WC asphalt mixture. The asphalt mixture is made in the form of a cylinder with a diameter of 101.6 mm and a thickness of 64 mm and is made in a hot mix. The test object was tested using the Marshall test to determine stability. Flow, vim and marshall quotient. The use of 20% BA to substitute sand in the asphalt mixture has a positive impact by increasing the stability value. The flow value meets the specifications required by the ministry of public works and public housing. The VIM value of the asphalt mixture also meets, indicating that the presence of bottom ash with an amount of up to 20% in the asphalt mixture can work optimally in the asphalt mixture.

Keywords: Bottom ash, marsall, asphalt, HRS WC.

INTRODUCTION

Electricity generation in many countries around the world relies on fuel combustion processes. Fossil fuels, such as petroleum and coal, are used as the main source of conventional electricity generation. Green alternative energy generation technology, using biomass, solar and wind power, has succeeded in replacing the use of fossil fuels for energy generation. However, due to the current economic cost advantages of fossil fuels, such as coal, remain the main energy source for electricity generation in many countries, including Indonesia. Coal-fired power plants (PLTUb) produce by-products called bottom ash and fly ash (FABA) [1, 2]. PLTUb is estimated to produce around 25% of bottom ash released from dry boilers and 75% of flyash [3, 4]. Fly ash (FA) is produced from combustion which is carried along with the flue gas and is separated while waiting at the top while bottom ash (BA) is collected at the bottom waiting for combustion [2]. FA and BA have different chemical contents and physical characteristics.

Bottom ash is usually coarse grained, dark gray in color, and has a higher carbon content than fly ash. Bottom ash also contains heavy metal elements such as arsenic, cadmium, chromium, lead, mercury and zinc [5]. Bottom ash can cause soil and groundwater pollution if not managed properly. Bottom ash can also cause corrosion in combustion equipment.

Fly ash is in the form of fine particles, light gray in color, and has a high content of silica, alumina and calcium. Fly ash can be used as an additive to cement, concrete, asphalt, brick and other building materials. Fly ash can increase compressive strength, sulfate resistance, and reduce porosity in concrete. Fly ash can also reduce greenhouse gas emissions from the cement industry [6].

However, fly ash also has potential dangers to human health and the environment. Fly ash can contain radionuclides such as radium, thorium and uranium which are radioactive. Fly ash can also contain organic compounds such as dioxins, furans, and polycyclic aromatic hydrocarbons (PAH) which are carcinogenic [7]. Fly ash can spread through the air and cause respiratory problems, eye irritation, skin and mucous membranes.

Indonesia from 2015 to 2022 has experienced a significant increase in coal consumption of 60% for non-medium electricity generation by 52%. In 2022, Indonesia's coal consumption for electricity will be around 144 million tons, it is estimated that in 2023 it will be 195.9 million tons, in 2025 it will reach 197.9 million tons, a very large number. The amount of coal consumption still excludes non-electricity consumption which is estimated at 69.6 million in 2022[8]. Special consumption for the Tidore PLTUb is estimated to produce around 14 tonnes of FABA waste per day [9], this amount is very large when compared to the land area of Tidore Island which is only around 126.66 KM2 [10].

Pollution from coal-fired power plants consists mostly of harmful smoke and dust emitted during the combustion process. These emissions make a significant contribution to global warming and cause long-term health problems for communities around power plants [11]. To reduce pollution, residue from coal combustion is treated with pollution collection systems, such as precipitators or baghouses, before releasing the treated air into the atmosphere. After the pollution treatment process, the residual by-products are transformed into Coal Combustion Products (CCP) including gypsum, fly ash (FA), and bottom ash (BA). Most power plants in developed and developing countries deal with CCPs, through discharge to landfills and ash ponds. A larger number of landfills and CCP dumps is required, due to the higher demand for power generation capacity, therefore, reclamation and management of landfills is becoming problematic, from an economic and environmental perspective. In addition, toxic leachate contamination from CCP disposal sites causes serious environmental problems in the surrounding areas [11-13].

The study and utilization of FA in construction, especially concrete, has been carried out in America and European countries. The volume of FA utilization is quite large, America for example is estimated to use around 6 million tons/year, Europe around 9 million tons/year and Italy has utilized around 90% of the FA it produces and has had a technical and economic impact, but this does not happen with BA. America uses more BA in construction compared to European countries BA replacement [4], effectively, serves as a green additive to warm asphalt mixes. BA has the potential to increase the mechanical strength of warm mix asphalt.

The addition of BA reduces carbon monoxide emissions of warm mix asphalt concrete by up to 75%, compared to conventional hot mix asphalt concrete [14]. Apart from coal-fired BA, municipal solid waste incinerator bottom ash (MSWI-BA), can also be used as a road pavement material. MSWI-BA has similar physical properties to coal-fired BA, such as low density and high absorption properties. Apart from its engineering properties, MSWI-BA can effectively reduce the release of alkali metals and heavy metals in hot mix asphalt concrete [15-17].

RESEARCH METHOD

The Marshall test is a testing method used to determine and evaluate the characteristics of hot asphalt mixtures, such as stability, flexibility, durability and workability [18]. Asphalt stability is the ability of an asphalt mixture to overcome plastic deformation or permanent shape changes under traffic loads and operational temperatures. Stability measures the resistance of an asphalt mixture to plastic deformation that can occur due to vehicle loads and other environmental factors. Stability measurements are carried out in the Marshall test to measure the quality and durability of the asphalt mixture. Marshall testing is carried out by compacting a cylindrical test object with a diameter of 101.6 mm and a height of 64 mm, then measuring the stability and flow experienced by the test object when loaded at a temperature of 60°C [19]. The Marshall test can help determine the optimum asphalt content in accordance with Bina Marga standards [18]. The Marshall test can also be used for hot asphalt mixes with a maximum aggregate size of 25 mm [20].

Compaction of asphalt mixtures in the laboratory generally uses a Marshall compactor with 2x75 impacts for each 4 inch diameter test object. If the test object used is 6 inches in diameter, compaction is carried out 2x600 impacts. Marshall compaction is a method for testing the quality of a hot asphalt mixture in a laboratory using a heavy pounder that falls from a certain height. The number of impacts used to make Marshall test specimens affects the properties of the asphalt mixture, such as stability, flow, density and air voids. According to the 2010 Bina Marga Technical Specifications revision 3, the number of collisions specified for making marshall test specimens on AC-WC and AC-BC mixtures is 2 x 75 times [21]. This number of collisions is based on research results which show that the number of collisions can produce asphalt mixture properties that meet technical specifications and approach compaction conditions in the field. If the number of impacts is less than 75 times, the asphalt mixture will have too many air cavities, thereby reducing the strength and durability of the pavement. If the number of impacts is more than 75 times, the asphalt mixture will have too few air cavities, thereby increasing the risk of bleeding or asphalt coming out of the pavement surface Figure 1. Asphalt mixture specimen for the Marshall test, and Figure 2 shows the Marshall test set up test.

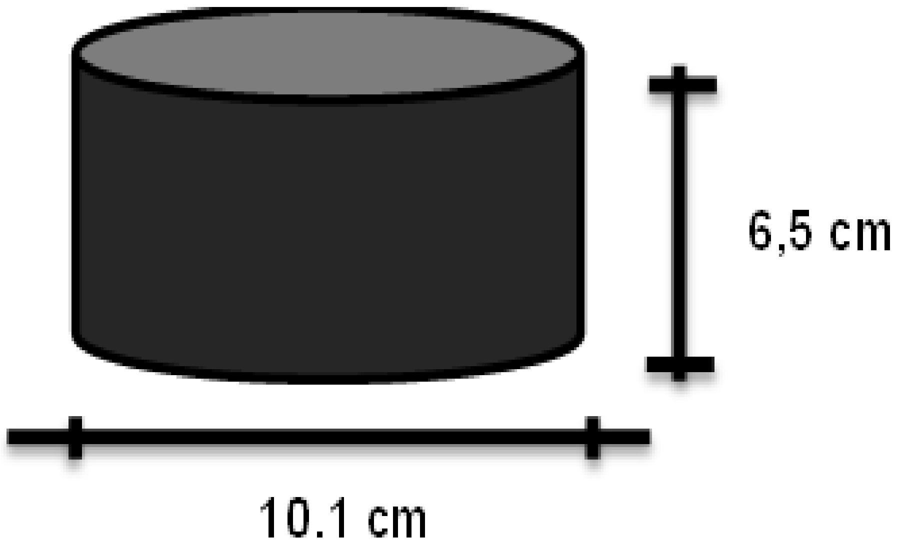

Figure 1: Asphalt mixture specimen for the Marshall test

Figure 2: Set up stability and flow test layout

RESULTS AND DISCUSSIONS

Stability marshall

In laboratory tests using the Marshall test, Marshall stability values and flow values were obtained from dial readings. The VMA, VFB and VIM values are obtained based on the aggregate, asphalt and stability and flow characteristic values. The physical property values from the Marshall test are as follows:

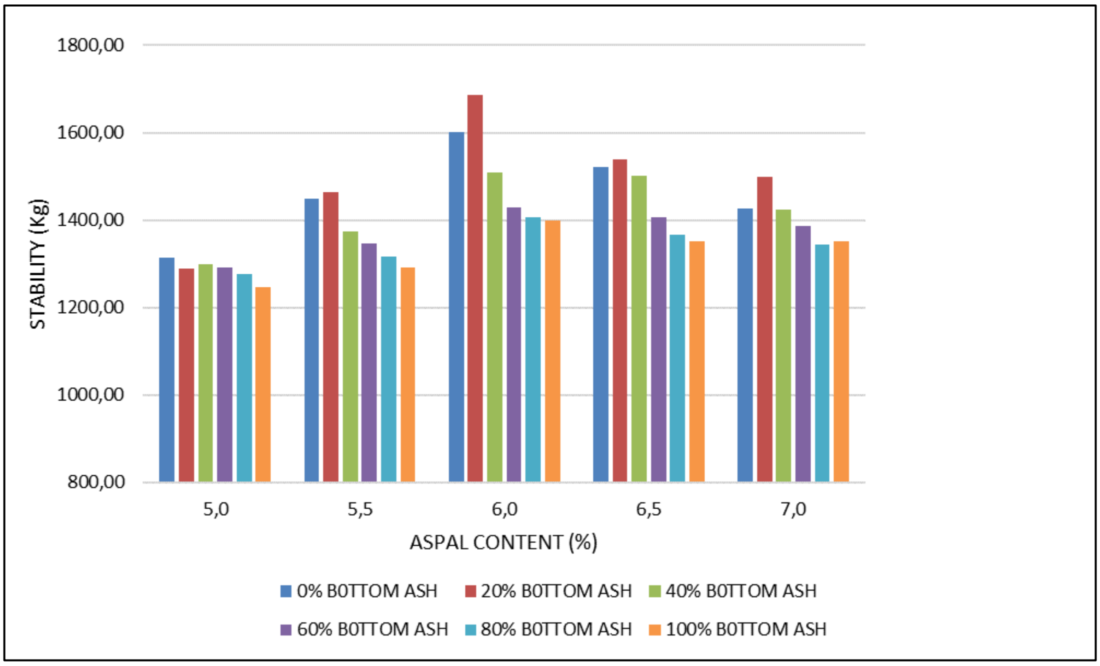

Figure 3: Relationship between asphalt content and stability value

Figure 3 shows that with the substitution of fine sand with coal BA, the marshall stability value generally increases at 20% BA substitution but 40% - 100% substitution tends to show a decreased stability value. A high increase was shown at 6% asphalt content. At 5% and 5.5% asphalt content, the marshall stability of asphalt mixtures without BA tends to be higher than mixtures with BA but is still smaller when compared to BA substitution of 20%.

Flow

Figure 4 shows that the flow value of the mixture without BA is higher when compared to the asphalt mixture using BA. BA in the asphalt mixture has an impact on decreasing the flow value, this is due to the higher absorption value compared to sand. The flow value of an asphalt mixture with a BA of 20% reflects that the asphalt mixture can flow without experiencing cracking or permanent damage under traffic loads. This is important because excessive plastic deformation can cause cracks and permanent deformation of the road surface, reducing the service life of the road and the comfort of road users.

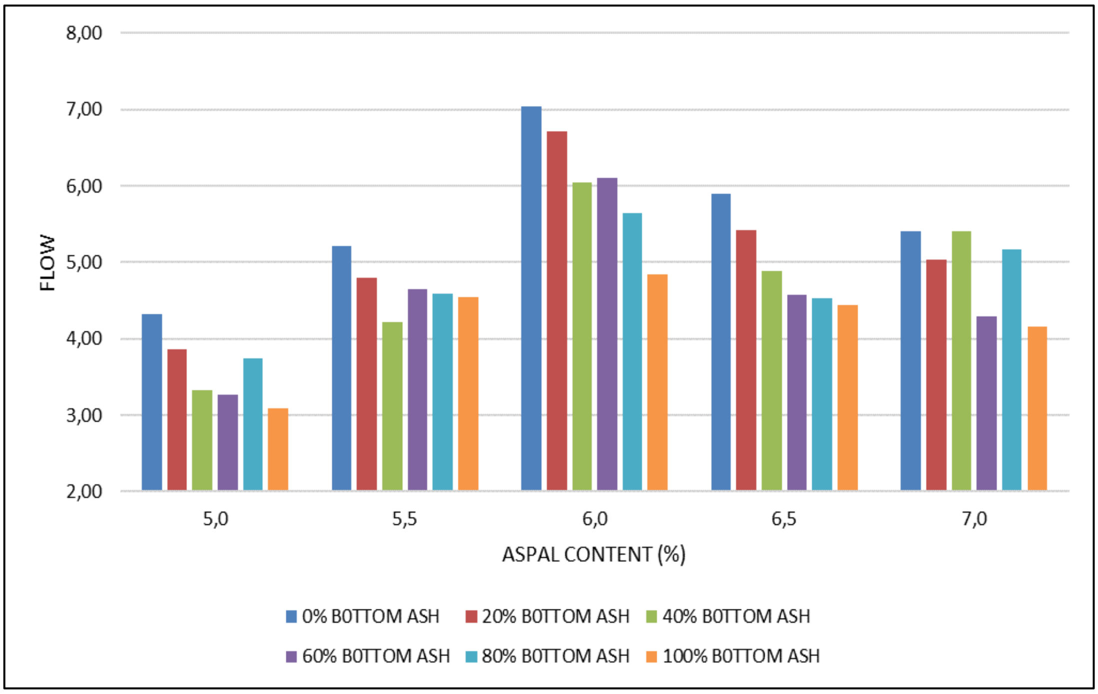

Figure 4: Relationship between asphalt content and flow

Void In Mix (VIM)

The void value of a 20% BA asphalt mixture has a significant impact on the quality, durability and performance of the asphalt mixture. Management of voids in asphalt mixtures is an important factor in road construction and maintenance. This shows that the asphalt mixture has a good density which occurs due to the materials interlocking well, the asphalt can fill the voids in the asphalt mixture.

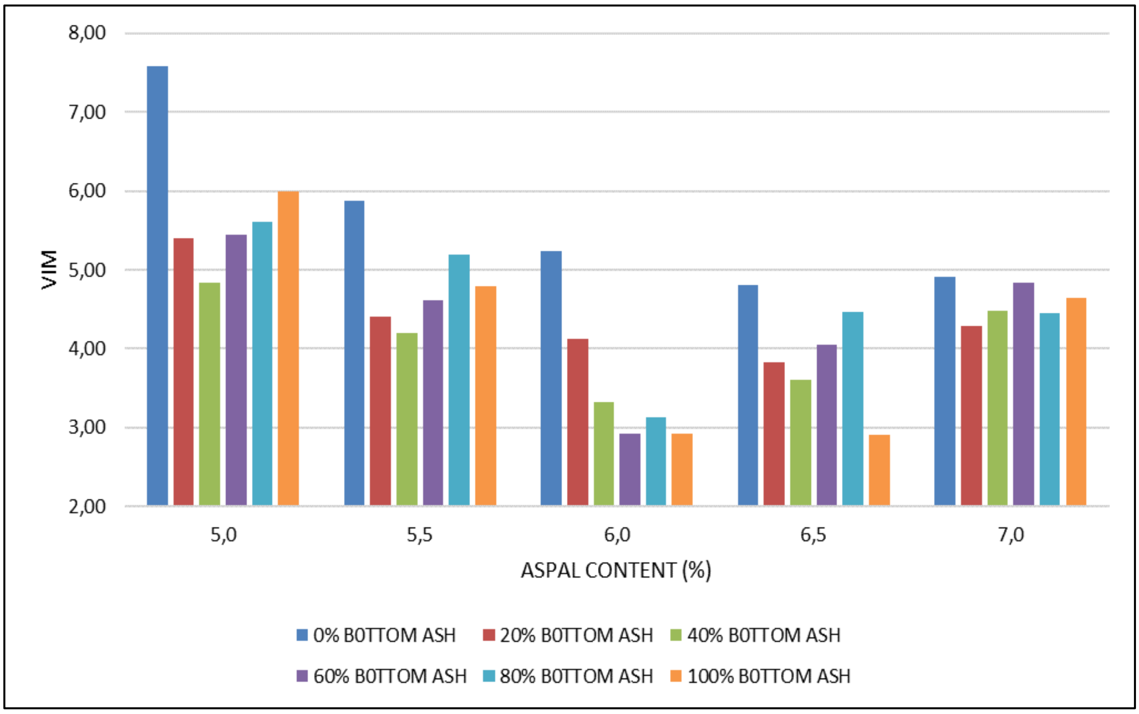

Figure 5: Relationship between asphalt content and VIM

CONCLUSIONS

Based on the discussion on the use of BA in HRS WC asphalt mixtures, the following conclusions are drawn: 1. The use of bottom ash of 20% in the HRS WC asphalt mixture provides better marshall characteristics and the optimum asphalt content is the use of BA of 20%, with an asphalt content of 6% for substitution of 40% to 100 BA which has a negative impact in the asphalt mixture. 2. The highest marshall stability value is given by adding 20% BA to the asphalt mixture, while the flow value decreases, this indicates that the stiffness of the asphalt mixture increases and so does the strength of the asphalt mixture.

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