Usage of power plant waste for airport pavement surface

N Widayanti and E Ahyudanari
Department of Civil Engineering, Faculty of Civil, Environmental, and Geological Engineering, Institut Teknologi Sepuluh Nopember (ITS), Kampus ITS Sukolilo, Surabaya, 60111, Indonesia.
ervina@ce.its.ac.id

Abstract. A research has been conducted to analyze usage of power plant waste and characteristics of asphalt concrete mixture for airport pavement using artificial aggregate. The artificial aggregate was made of power plant wasted related to waste energy that has not been fully utilized. This testing method used to determine the marshall stability and flow values of asphalt concrete, and to measure how much fly ash from power plant waste can be reduce to utilized as airport pavement surface. The result of marshall testing provides the new material that made of power plant wasted was eligible to used as a replacement material for airport pavement and the mixed compositions can be applied for airport runway pavement which is using artificial aggregate was expected to reduce power plant wasted.

1. Introduction

As infrastructure development in Indonesia, the need for natural aggregate as a base material for pavement is increasing. Previously, the fulfillment of aggregate needs has been obtained from quarry spread in Indonesia. The need is so great that the resources obtained from nature are depleting. If excessive aggregate exploitation is carried out, it is possible that Indonesia will experience a shortage of natural aggregate as a base material for pavement. On the other hand, this behavior can also threaten environmental sustainability. For this reason, there needs to be an effort to find alternatives so that the use of natural aggregates can be reduced, one of which is by utilizing waste.

Based on PLN data, the trend of FABA (fly ash and bottom ash) production in Java Island until 2027 will reach 11.18 million tons per month, which consists of PLN 6.5 million tons and Independent Power Producers (IPP) of around 4.6 million tons. In 2016, ash production has reached 4.6 million tons per month, consisting of ash from PLN of 3.26 million tons and IPP of 1.33 million tons [1]. Related to the data, there is waste that has not been fully utilized. Many studies have been conducted to find alternative uses of the waste. One of them is the processing/recycling of fly ash into a useful product. According to previous research, fly ash-based geopolymer is potentially used as an artificial aggregate material for as a replacement aggregate in a concrete asphalt mixture [2].

The main differences in design considerations for highway and airport pavements arise from the characteristics of traffic using them. An airport pavement may have to be designed to withstand equivalent single wheel loads (ESWL) of the order of 50 t (approximately 50 tons), whereas the maximum single wheel load allowed on the road pavement by most highway authorities is about 10 t (approximately 10 tons). Furthermore, the wheel tire pressure of an aircraft of about 1200 kPa (175 psi) is nearly twice the value of a normal truck tire. These differences greatly influence the material requirements for the pavements [3].
Along with the development of technology, the increasing mobility of the Indonesian people in the use of air transportation is one of the important considerations in determining the type of aircraft based on its capacity. The weight of an aircraft or the wheel load carried by the airport runway pavement is also greater based on the type of aircraft used. The weight of the load carried by the pavement that continues to increase will have an impact on the quality of a pavement. Changes in aircraft characteristics, especially aircraft dimension shown as follows [4]:

- Gear geometry:
  B777 – Tridem; Combo gears A380-800 tandem/tridem
- A/C Loadings:
  Boeing 747 (1995) – 833,000 lb vs. A380-800 (2017) – 1.24x10^6 lb
- Wheel Load:
  B777-300 (1995) - 57,000 lb versus A350-900 (2017) – 70,000 lb
- Higher tire pressures:
  215 psi (1995) vs. 241 psi (2017)

Tire Pressures may be restricted on asphaltic concrete, depending upon the quality of the asphalt mixture and climatic conditions. Tire pressure effects on an asphalt layer relate to the stability of the mix in resisting shearing or densification. A poorly constructed asphalt pavement can be subject to rutting due to consolidation under load. The principal concern in resisting tire pressure effects is with stability or shear resistance of lower quality mixtures [5]. An airport has a flexible (asphalt-surfaced) pavement runway having the operating gross weights and tire pressure shown in Table 1.

| Airplane   | Operating Weight, lbs | Tire Pressures (psi) |
|------------|-----------------------|----------------------|
| B727-200   | 185,000               | 148                  |
| B737-300   | 130,000               | 195                  |
| A319-100   | 145,000               | 196                  |
| B747-400   | 820,000               | 200                  |
| B767-300ER | 370,000               | 190                  |
| DC8-63     | 330,000               | 194                  |
| A300-B4    | 370,000               | 205                  |
| B777-200   | 600,000               | 215                  |

The performance of asphalt mixtures can be tested using a Marshall tool. The testing is intended to determine the resistance (stability) of asphalt concrete mixtures to the flow of the mixture of asphalt and aggregate. Flow is a state of changing the shape of an asphalt concrete mixture that occurs as a result of a load to a failure limit in mm or 0.01”. The correlation of the stability value with the tire pressure can determining the loading that can bear by asphalt mixture from the aircraft wheel.

In this study, the test results can be used as a consideration for the potential utilization of waste as an alternative to asphalt mixtures for airport runway and it can be seen the pavement capacity in resisting the load. Furthermore, this research is part of author’s thesis. To meet the element need to be considered for pavement (fatigue resistance), therefore, the results of Marshall testing on this research are needed for fatigue testing as material for subsequent authors' research [6].
2. Materials and Methods

2.1. Materials

In this study, the gradation of the mixture of asphalt met the requirements for Federal Aviation Administration 2014 (Table 2) as illustrated in Figure 1. The median gradation was selected as the target gradation.

| Sieve Size (mm) | Percentage by Weight Passing Sieves |
|-----------------|-------------------------------------|
|                 | Gradation 2                          |
| 1"              | 25                                   |
| 3/4"            | 19                                   |
| 1/2"            | 12                                   |
| 3/8"            | 9                                    |
| No. 4           | 4.75                                 |
| No. 8           | 2.36                                 |
| No. 16          | 1.18                                 |
| No. 30          | 0.600                                |
| No. 50          | 0.300                                |
| No. 100         | 0.150                                |
| No. 200         | 0.075                                |

The materials used for this research include coarse fraction of natural and artificial aggregates, fine aggregates, filler, and bitumen. The coarse and fine aggregates were collected from Laboratorium
Transportasi dan Perhubungan ITS. The mineral fillers used are the crushed stone dust (CSD). The 60/70 penetration grade bitumen was chosen for the study.

Fly ash which is used for the artificial aggregates were collected from Paiton Power station, Probolinggo, East Java. Procedure for making artificial aggregates follows the procedure in the previous study [8]. The artificial aggregate is shown in Figure 2.

![Artificial Aggregates](image)

**Figure 2. Artificial Aggregates**

2.2. Methods

The specification of the asphalt mixture met the requirements for Federal Aviation Administration (FAA) 2014. The specification is shown in Table 3.

| Test Property                          | Pavement Design for Aircraft Gross Weights of 60,000 Lbs (27216 kg) or more or Tire pressures of 100 psi or more |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Number of blows                        | 75                                                                                                           |
| Stability, pounds (Newtons) minimum    | 2150 (9560)                                                                                                   |
| Flow, 0.01 inch. (0.25 mm)             | 10-16                                                           |
| Target air voids (percent)             | 3.5                                                             |
| Percent Voids in Mineral Aggregate (minimum) | 15%                             |

This study evaluates the characteristics on the Marshall stability and flow of airport surface course. This was achieved by preparing asphalt mixtures with natural aggregate and artificial aggregate to Marshall test. Based on previous research, optimum stability of ratio for artificial and natural aggregate is 25% : 75% [9]. The mixture composition of the airport pavement surface is shown in Table 4.


Table 4. The Mixture Composition

| Sieve Size | Lower Spec (%) | Median Spec (%) | Upper Spec (%) | Percentage by Weight Passing Sieves (%) | Rasio Aggregate 25% : 75% |
|------------|----------------|----------------|----------------|------------------------------------------|---------------------------|
|            | in mm          |                |                |                                           | AA : NA                   |
| 3/4        | 19             | 100            | 100            | 100                                      | 0.0 : 0                   |
| 1/2        | 12             | 79             | 89             | 99                                       | 11.0 : 132                |
| 3/8        | 9              | 68             | 78             | 88                                       | 11.0 : 132                |
| No.4       | 4.75           | 48             | 58             | 68                                       | 20.0 : 240                |
| No.8       | 2.36           | 33             | 43             | 53                                       | 15.0 : 180                |
| No.16      | 1.18           | 20             | 30             | 40                                       | 13.0 : 156                |
| No.30      | 0.6            | 14             | 22             | 30                                       | 8.0 : 96                  |
| No.50      | 0.3            | 9              | 15             | 21                                       | 7.0 : 84                  |
| No.100     | 0.15           | 6              | 11             | 16                                       | 4.0 : 48                  |
| No.200     | 0.075          | 3              | 4.5            | 6                                        | 6.5 : 78                  |
| Pan        | 4.5            | 54             | 54             | 54                                       | 4.5 : 54                  |
| Jumlah     | 100            | 1200           | 171            | 1,029                                    |                           |

2.2.1. Marshall Test. Marshall Test aims to determine the optimum bitumen content, then determine the stability and flow of asphalt mixture. The method used to make airport pavement surface will be follow Marshall procedure of AASTHO T 245-74, or ASTM D 1550-E27.

The specimen is asphalt mixture with a diameter of 101.6 mm (4 inches) and a height of 76.2 mm (3 inches). Compaction for the Marshall test is done by blows 75 times per field using a compactor. After the test object is compacted, then stored at room temperature for 24 hours, then the objects are weighed in air, in the water and in saturated surface dry (SSD) conditions to obtain bulk specific gravity. Then soaked at a temperature of 60±1°C for 30-40 minutes and ready to conduct stability and flow testing. The Marshall stability machine is shown in Figure 3.

Figure 3. Marshall Testing Machine
3. Results and Discussions

3.1. Marshall Test

The optimum bitumen content was found to be 5.10%. The result of marshall testing can be seen in Table 5. The results show that the stability increases with increasing bitumen content up to the optimum bitumen content and thereafter decreases.

| Properties               | Specification | Bitumen Content (%) |
|--------------------------|---------------|---------------------|
|                          |               | 4.50    | 5.00    | 5.50    | 6.00    | 6.50    |
| Stability                | 2150 lbs      | 3128    | 3797    | 3917    | 3969    | 3932    |
| Flow                     | 10-16 inch    | 12      | 11.6    | 11.2    | 13.6    | 16.8    |
| Target Air Voids (%)     | 3.5           | 5.80    | 3.82    | 2.89    | 1.06    | 0.77    |
| Voids In Mineral Aggr. (%) | 15%           | 18.50   | 17.74   | 17.89   | 17.30   | 18.01   |

The stability value met the FAA specifications requirements. The increase in stability can be attributed to improved adhesion between the aggregate and bitumen. However, more tests like the indirect tensile fatigue test would be carried out in future studies to confirm this. The Marshall test result are shown in Figure 4.

![Figure 4. Marshall Characteristics](image-url)
The flow values of the asphalt mixtures against bitumen content are shown in Figure 5. It can be seen from the results that the flow value inversely proportional with stability. All of variation of bitumen content meet the requirements except in 6.5%. This shows that the bitumen content is a state of asphalt which has flow value in resisting changes in the shape of a mixture when receiving a load.

From Table 5 it can be seen that voids in mineral aggregate (VMA) meet the specification requirements, but the values of target air voids (VIM) only meets the requirements in bitumen content of 5.0%. This indicates there is a part of the asphalt mixture which is not filled by aggregate or by bitumen. The higher the VIM value, the easier the asphalt to be oxidized so that it causes reduced adhesion between the aggregate granules so as to enable revelling and stripping. The VIM value also affects the durability of the pavement layer, the higher the VIM value shows the greater the cavity in the mixture so that the mixture is porous. To improve the VIM value, modifications can be made to the penetration of bitumen or compaction temperature.

3.2. Utilization of Power Plant Waste

To measure how much fly ash from power plant waste can be reduce to utilized as airport pavement surface, the method is calculated the volume asphalt mixture of airport runway pavement such as the following:

The needs calculation of artificial aggregate is 171 gram per sample [6].

Geometric standard design of airport pavement surface [10] :

- Thickness : 4 inch = 0.102 m (HMA Surface Course)
- Runway Width : 45 m
- Runway length : 2000 m

- Pavement volume \( (V_p) \)
  \[ V_p = \text{width} \times \text{length} \times \text{thinkness} \]
  \[ V_p = 45 \times 2000 \times 0.102 \text{ m}^3 \]
  \[ V_p = 9180 \text{ m}^3 \]

- Sample volume \( (V_s) \)
  \[ V_s = \pi \times r^2 \times t \]
  \[ V_s = 3.14 \times 0.05 \times 0.0694 \text{ m} \]
  \[ V_s = 0.0108958 \text{ m}^3 \]

- Multiplier factor \( (F_p) \)
  \[ F_p = \frac{V_p}{V_s} \]
  \[ F_p = 9180 \text{ m}^3 \div 0.0108958 \text{ m}^3 \]
  \[ F_p = 842,526.5 \]

Then, to find out how much power plant wasted (fly ash) needed per standard design of airport pavement surface can be seen such as the following:

- Fly ash reduction
  \[ \text{Fly ash} = \frac{\text{Total weight of fly ash per sample}}{\text{Fp}} \times \text{Fp} \]
  \[ = 171 \text{ gr} \times 842,526.5 \]
  \[ = 144,072,027.8 \text{ gr} \]
  \[ = 144,072 \text{ ton} \]

So, the amount of fly ash that can be reduce from power plant wasted for runway airport pavement is equal to 144.072 ton per standard design of airport pavement surface.
4. Conclusions
From research conducted can be concluded as follows:

- The Asphalt mixture using artificial aggregate-fly ash geopolymer is potential to used as an alternative mixture pavement for airport pavement surface.
- The asphalt mixture of artificial aggregates has a fairly high value of stability.
- The test result indicate that the specimen of asphalt mixture with artificial aggregate for airport pavement surface met the value of the specification requirements in stability, flow (except in 6.5% bitumen content) and voids in mineral aggregates. While the values of target air voids (VIM) only meets the requirements in bitumen content of 5.0%.
- The amount of fly ash can be used in runway airport pavement is equal to 144.072 ton per standard design of runway.

References
[1] Adi 2016 PLN Minta Dipermudah Regulasi Pemanfaatan Limbah FABA PLTU http://petroenergy.id/article/pln-minta-dipermudah-regulasi-pemanfaatan-limbah-faba-pltu [Online]
[2] Karyawan I D M A, Ahyudanari E and Ekaputri J J 2017 Potential Use of Fly Ash Base-Geopolymers Aggregate Substitution in Asphalt Concrete Mixtures Int. J. Eng. Technol. 9 issue 5 pp 3744–52
[3] Fwa T F 2003 Highway and Airport Pavement Design (Singapore: CRC Press LLC) chapter 62
[4] Roesler J 2017 Airport Pavements: Reflection on 20 Years of Design Material and Construction Innovations
[5] Federal A A 2005 Advisory Circular in AC 150/5335-5A I pp 2–4.
[6] Widayanti N 2019 Fatigue Analysis of Flexible Pavement of Asphalt Concrete Mixture With Artificial Aggregate Made Using Fly Ash Geopolymer Thesis Teknik Sipil Institut Teknologi Sepuluh Nopember
[7] Federal A A 2014 Advisory Circular in AC 150/5370-10G pp. 217–256.
[8] Yuliana H A, Karyawan I D M A, Murtiadi S, Ekaputri J J and Ahyudanari E 2019 The Effect of Slope Granulator on The Characteristic of Artificial Geopolymer Aggregate Used in Pavement J. Eng. Sci. Technol. 14 issue 3
[9] F Teknik 2018 Thesis Teknik Sipil Universitas Mataram [Unpublished]
[10] Federal A A 2016 Airport Pavement Design and Evaluation AC 150/5320-6E pp 1