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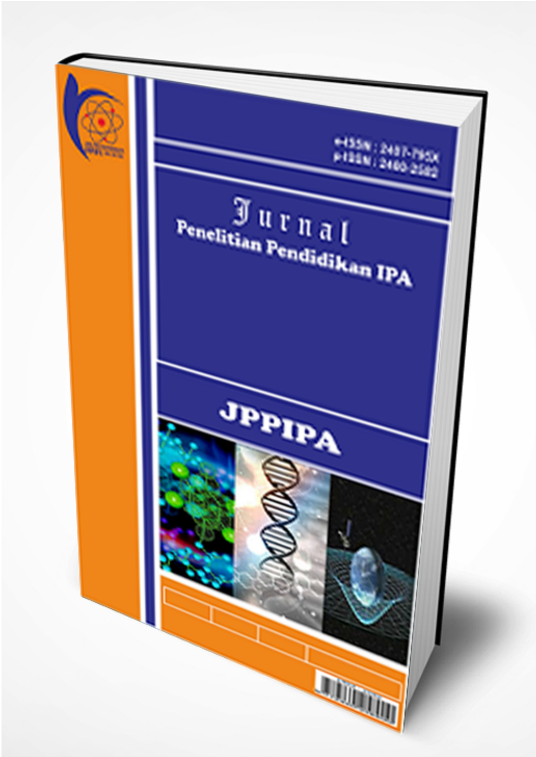

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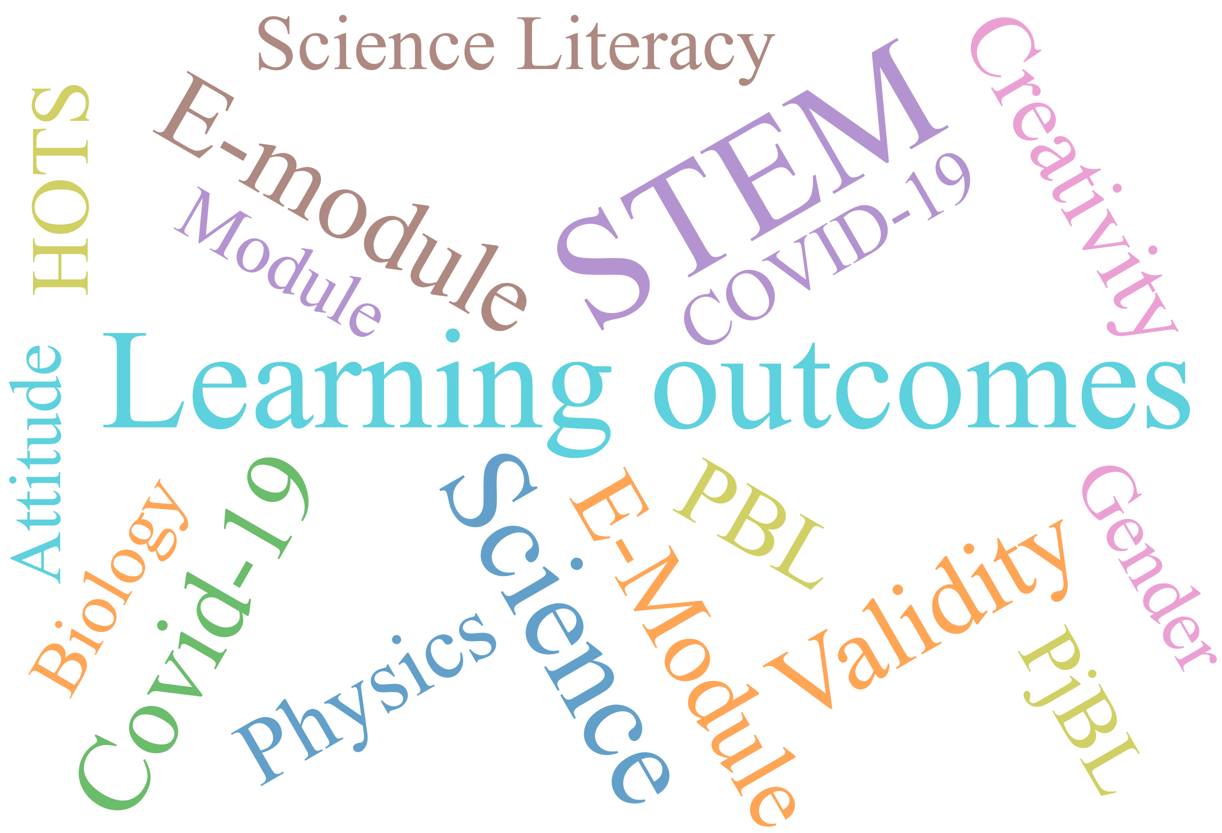

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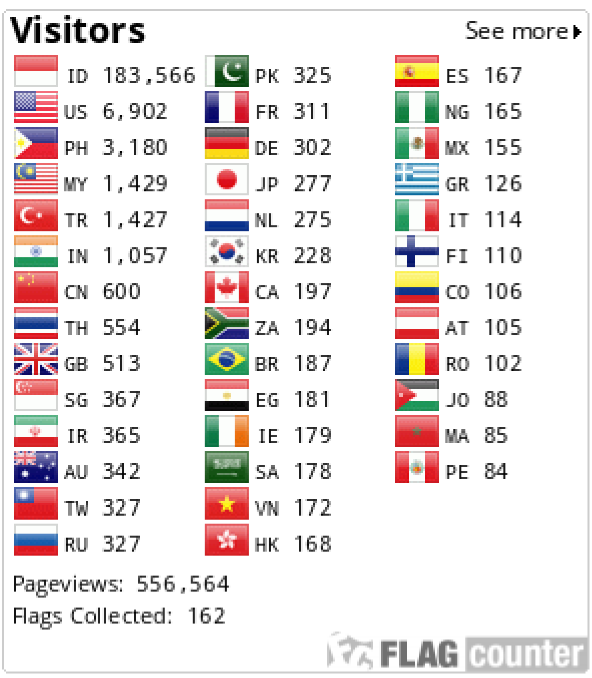

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Performance of Artificial Compared to Natural Coarse Aggregates as Road Pavement Materials

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Abstract: Aggregates are the main material for road pavement made of natural stone. The availability of this natural stone will decrease because the stone is a non-renewable resource. The use of artificial aggregates can be an alternative to natural aggregates. The promotion of the use of waste as an artificial aggregates is starting to develop, especially with fly ash. Aggregates road materials must be tested to determine their characteristics by methods according to applicable standards. In this study, it can be seen that the aggregates of all quarries can be used as pavement materials, but the aggregates of the KB quarry show a poor flakiness index value. The test results of geopolymer-made aggregates made from fly ash showed that the abrasion and absorption values were not good. However, in general, it has good characteristics as road materials, so further research is needed to obtain geopolymer-made aggregates that meet the abrasion and absorption requirements for use as road materials.

Keywords: Natural aggregates; Artificial aggregates; Geopolymer fly ash; Road pavement

Introduction

The current development of road infrastructure has led to an increase in aggregates demand. As is known, 60%-75% of road pavement materials based on the volume of the mixture are aggregates (Yuliana et al., 2019). Aggregates used as road materials are generally obtained from the nearest quary to the location of road works. Aggregates are made by breaking natural rock in a quarry with a stone crusher machine. Aggregates from natural rock must be tested before being used as road pavement materials. Then do the production to meet the needs of the job. Continuous use results in the availability of natural aggregates being increasingly limited, even in certain areas it is difficult to obtain them. Therefore, it is necessary to develop artificial aggregates as an alternative to natural aggregates.

The basic ingredients of artificial aggregates are generally waste, including: fly ash, paper pulp, municipal solid waste, solid waste from power plants, sawdust, rice husk ash, granite powder, and charcoal dust (Srinivasan et al., 2016). The use of processed artificial aggregates from industrial waste as a substitute for natural aggregates can significantly reduce the cost of concrete production (Perumal & Anandan, 2014). Research on the use of fly ash as a waste product of coal combustion has been carried out. The performance of spherical fly ash-based geopolymer aggregates qualifies as road pavement materials if they are made with a granulator slope of 50^0 (Yuliana et al., 2019). The variation in the composition of the alkali ratio as an activator of 2.5 between sodium sulfate and sodium hydroxide is a research development to get better results (Karyawan et al., 2020; Karyawan et al., 2019).

Aggregates performance can be known based on its characteristics. Aggregates shape properties, such as angularity and surface texture, greatly affect the performance of hot mix asphalt (HMA). For example, interlocking between particles produces grooves that are related to the angularity and shape of the aggregates (Bessa et al., 2015). Other properties that affect the performance of HMA are the level of rock abrasion, brittleness index, resistance to fragmentation, water absorption, dust content, adhesion to bitumen binders, density and health tests.

Characteristics of artificial aggregates and natural aggregates need to be obtained by testing. Based on these characteristics, it can be seen whether the

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aggregates can be used as a road pavement material. In this regard, the purpose of this study is to determine the characteristics of natural aggregates and artificial aggregates and to compare the test results of artificial aggregates with natural aggregates.

Method

Materials

Artificial aggregates (AA) were tested for characteristics compared to natural aggregates made with a mixture of geopolymers based on fly ash. Natural materials as a comparison tested were coarse aggregates, fine aggregates, and filler sourced from 4 quarry construction companies, namely: 1) Aggregates MLU, 2) Aggregates SJU, 3) Aggregates PAR, and 4) Aggregates KB. Figure 1 shows an artificial aggregates made from fly ash geopolymer and natural aggregates from four mines on Lombok Island.

Aggregates AA Aggregates MLU Aggregates SJU Aggregates PAR Aggregates KB

Figure 1. Natural and artificial coarse aggregates

Types and methods of testing

Tests on coarse aggregates are carried out to obtain aggregates performance parameters. Based on these parameter values, it can be seen how the performance of the aggregates as road pavement materials. The tests performed are:

- Abrasion test. This abrasion test is intended to measure the level of rock abrasion. Laboratory test for characterization of toughness/abrasion resistance (Wu et al., 1998).
- Flakiness index. Flakiness index (IF) is the percentage of materials that passes through a certain sieve size, which is expressed as a percentage of the total weight of the sample (Gayathri, 2019). IF is one of the most prominent criteria governing the behavior and performance of aggregates in asphalt mixtures. The flakiness index of aggregates used in road construction should be less than 15% and usually not exceed 25%.
- Aggregates shapes. Aggregates shape properties, such as shape, angularity, and surface texture, greatly affect the performance of hot mix asphalt. The angular shape of the aggregates particles provides a good bond between the aggregates (aggregates interlocking) which can withstand the displacement of the aggregates that may occur. The combination of particle shape, angularity, and surface texture produces asphalt mixtures that are good for aggregates stability (Chen et al., 2005).
- Resistance to fragmentation. The measure to characterize the durability/hardness of the aggregates that determines the resistance to impact is known from the impact test results. Aggregates must have sufficient toughness to resist disintegration due to the impact of vehicle movement on the road. The collision causes the aggregates to break into smaller parts (*Standard Test Procedures (Chapter 7 - Tests For Aggregates And Bricks)*, 2001)(*Aggregate Impact Value Test Apparatus, Procedure and Uses*, 2019).
- Water absorption. The amount of asphalt added to the mixture to produce the desired mix quality is influenced by the absorption of the aggregates, therefore it is necessary to know the amount. High water absorption causes a lot of asphalt to be absorbed by the aggregates, so the effective asphalt content will decrease so that the bond film is thinner (Speight, 2016). Thus, there is less asphalt on the aggregates surface which functions as a binder of aggregates particles so that it will produce a thin asphalt film (Ji et al., 2021).
- Dust content. Dirty aggregates will adversely affect the performance of hot mix asphalt pavements. This is due to the reduced bond between asphalt and aggregates. Several types of damage can occur, such as raveling, rutting, stripping, and segregation, decreasing long-term pavement performance (Akbulut et al., 2014).
- Adhesivity to bituminous binders. Adhesion is defined as the attractive force of molecules in the contact area between adhesive materials and a dissimilar substrate that acts to hold the objects together. In the context of asphalt mixtures, adhesion is used to refer to the amount of energy required to break the adhesive bond between asphalt and aggregates (Jakarni, 2012). The test of Adhesivity to bituminous binder is intended to determine the adhesion of aggregates to asphalt.

- Density. Density is needed because it has a significant effect on the performance of asphalt mixture pavement (Yinping et al., 2016).
- Soundness test. Soundness is the term usually given to the characteristic of resistance to weathering of aggregates. For each aggregates size reported, determine the mass loss (in percent)("Durability and Soundness," n.d.)(Ioannou et al., 2013).

Parameters of aggregates characteristics as road pavement materials are obtained by testing methods and with the requirements as in Table 1.

Table 1. Requirements and Methods of Testing Coarse

Parameter	Unit	Value	Test Method
Abration test	%	<40	ASTM C 131-76 / AASHTO T 96-87
Flakiness index	%	≤ 10	ASTM 4791-10
Aggregates shape	%	≤ 15	ASTM C136/ AASHTO T 27
Resistance to fragmentation (Impact Test)	%	≤ 30	ASTM D5874-16
Water absorption	%	≤ 1	ASTM C-127-68/ AASHTO T-85-74
Dust content	%	≤ 1	ASTM D 2419-74 / AASHTO T 176-86
Adhesivity to bituminous binder	%	≥ 95	ASTM D 1664/ AASHTO T-182
Density	kN/m^3	26.5+30	C 29/C 29M – 07/ AASHTO T19
Soundness test	%	≤ 10	ASTM C88/ AASHTO T104

Result and Discussion

The test result data were analyzed by the method based on each type of test (Table 1). The data retrieval of flakiness index, dust content, and adhesion on the asphalt binder test is shown in Figure 2 and the results of the analysis of the test data are shown in Fig. 2.

The flakiness of the aggregates is expressed in terms of the flakiness index. The natural aggregates flakiness index value in Fig. 3 shows varied and significant results. This can be seen from the high aggregates value of KB (15.8%) and the lowest in the SJU aggregates (6.1%), indicating a gap of up to 61%, from 4 different quarries on Lombok Island. The higher the flakiness value, the more easily the aggregates will break if exposed to traffic loads. The flakiness index value of artificial aggregates (AA) < natural aggregates of KB, indicates that artificial aggregates are more resistant than natural aggregates. While the flakiness index value of artificial aggregates > natural aggregates MLU, SJU, and PAR, indicates that the artificial aggregates is easier to crack, but still meets the requirements for road pavement materials.

Flakiness index Dust content Adhesivity to bituminous binder

Figure 2. Sample testing for flakiness index value, dust content, and adhesivity on bituminous binder

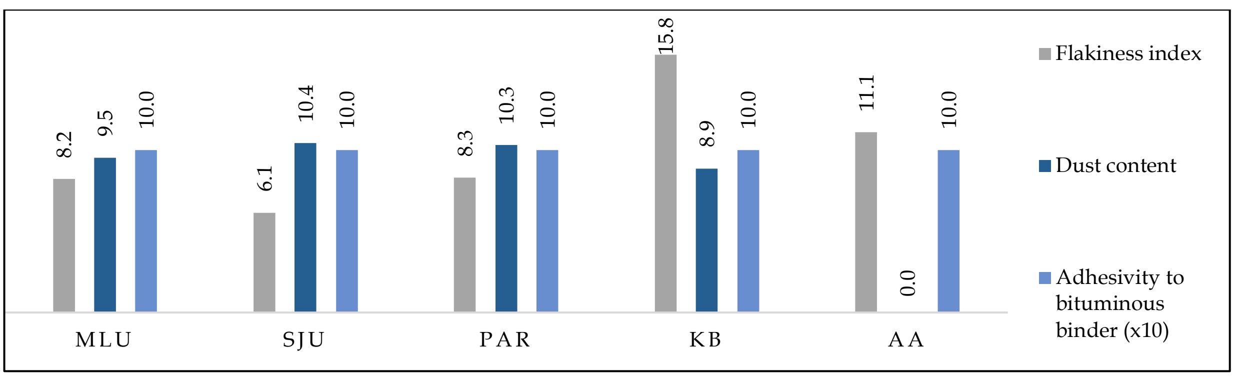

Figure 3. Value of flakiness index, dust content, and adhesivity to bituminous binder

In Fig. 3 it can be seen that all the natural aggregates tested have a dust content value of >1%. However, the dust content value of the artificial aggregates is <1% because it is made and stored in the laboratory so that it is protected from adhering dust. Adhesivity to bituminous binder is carried out visually based on the test method, which shows that almost the entire asphalt surface is covered with asphalt. This occurs in all types of aggregates. So, if it is used as a road pavement material, it is so that the use of asphalt more effective.

The data retrieval of resistance to fragmentation (impact test), water absorption and maximum density are shown in Fig. 4 and the results of the test data analysis are shown in Fig 5. Artificial aggregates are less capable of receiving impact loads than natural aggregates (see Fig. 5). This is linear with the value of water absorption. A high value of water absorption indicates a large pore in the aggregates, so it is easier to crumble if given a shock load. Likewise, the low-density value due to the large pores in the artificial aggregates.

Impact test Water absorption Density

Figure 4. Sample testing for impact value, water absorption, and density

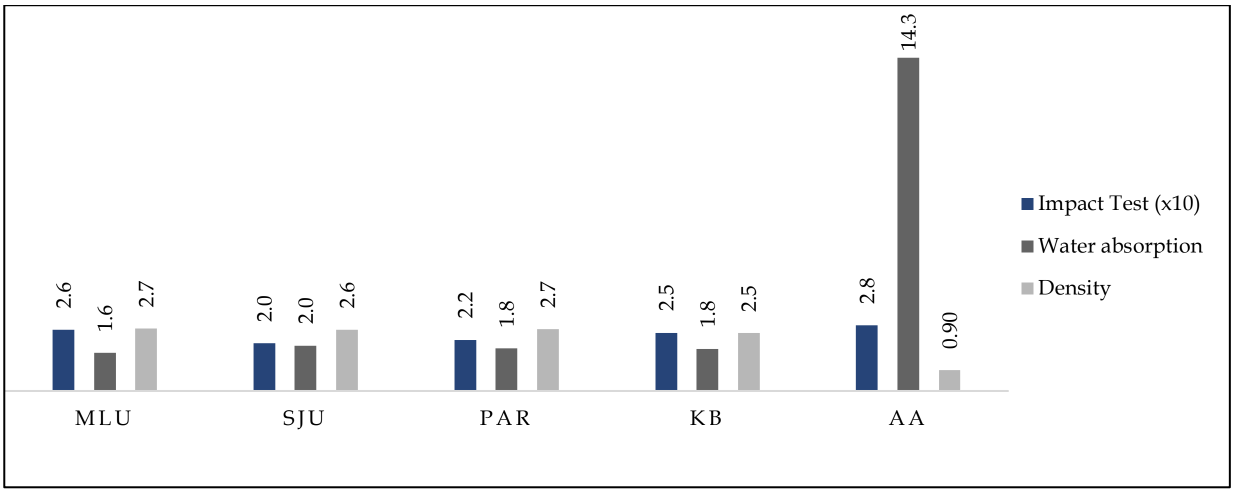

Figure 5. Value of impact, water absorption, density

Abration test Aggregates shape Soundness test

Figure 6. Sample testing for abration value, aggregates shape and soundness

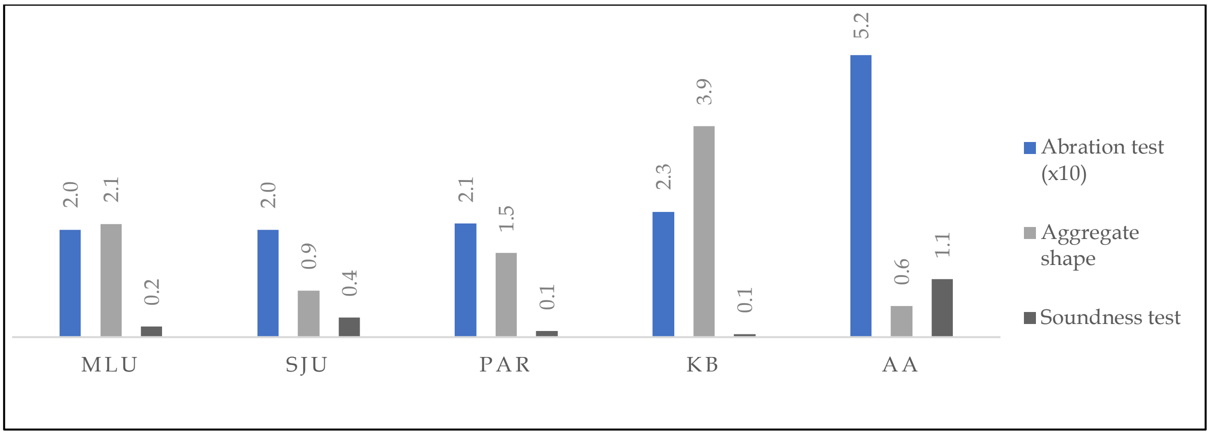

Figure 7. Value of abration, aggregates shape dan soundness

The data retrieval of Abrasion test, Los Angeles 500 rounds, Aggregates shape and Soundness test are shown in Fig. 6 and the results of the test data analysis are shown in Fig 7. Abrasion test results show that natural aggregates from 4 quary has wear resistance. However, the man-made aggregates have a lower ability (Fig. 7). This is related to another characteristic, namely density with a low value. Figure 7 also shows that the aggregates shape characteristics of all natural and artificial aggregates show good results. Generally, have more than one side of the plane that is broken. Because all aggregates are made through the process of breaking. Resistance to environmental conditions is sought through a soundness test. In the test, the percentage of crushed aggregates is sought, the higher the percentage, the more crushed (the higher the value, the easier it is to decompose). Figure 7 shows that all aggregates have good resistance, as can be seen from the percentage of aggregates that are resistant to weathering

Conclusion

The properties of natural aggregates indicate that the aggregates of all mines on the island of Lombok are good as road pavement materials. However, the KB quarry aggregates is not good in its flakiness index. Geopolymer artificial aggregates based on fly ash have good characteristics as road materials, except for high abrasion and absorption values. It is recommended for further research to try to find proportions or other materials as precursors so that geopolymer artificial aggregates meet the requirements for use as road materials.

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