The Effect of Mahakam Sand on the Mechanical and Durability of Porous Concrete Paving Blocks

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Abstract: The high price of Palu aggregate and the reduced catchment area in East Kalimantan have encouraged the improvisation of local materials as materials for infrastructure development. Porous Concrete Paving Block (PCPB) is an alternative to overcome this problem. PCPB can absorb water into the soil but has a low compressive strength. To increase the compressive strength of PCPB by adding sand. This study aims to determine the effect of Mahakam sand on the compressive strength, flexural strength, permeability, and porosity of porous paving. This study used the addition of 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% sand. The test results indicated that Mahakam sand has significantly affected the compressive strength and permeability of porous paving. The compressive strength of porous paving increases with the addition of Mahakam sand. However, the porosity value decreases with increasing sand content. The optimum sand content that can be used is 7.5%, with compressive strength of 17.13 MPa.

1 INTRODUCTION

Porous Concrete Paving Block (PCPB) is a ground cover using a material that can seep water flow into the soil layer below it. PCPB are alternatives to the traditional pervious asphalt and concrete pavement (Hidayah et al., 2014). Porous pavers are suitable for roads with low traffic volumes, bicycle lanes, sidewalks, playgrounds, and terraces in front yards (Manan et al., 2018), (Wijaya and Ekaputri, 2014). In this porous paver, there is a space for the flow of water and air. This space causes rainwater to enter the paving and seep into the ground so that the porous paver has a higher permeability than conventional paving. Runoff water from the road will be absorbed into the soil and can reduce water discharge in drainage channels by being applied to the road surface.

Porous concrete pavement is rarely used in infrastructure development but looks at porous concrete usefulness as multifunctional concrete, especially to respond to green engineering issues. Porous concrete can be considered worthy of being one of the lightweight construction materials that will play an essential role in the future. Therefore, research is needed to optimize porous paving to produce PCPB with high strength and permeability. PCPB generally has cavities in the concrete ranging from 15 – 35% (ACI 552R-10, 2010; Alam et al., 2019; Huang et al., 2016).

In general, PCPB has lower strength when compared to conventional paving because PCPB has voids in the concrete. Increasing the strength of PCPB can be done by using additives. In previous studies use fly ash to improve the strength of PCPB, such as studies conducted by (El-maaty, 2016; Gpcc et al., 2016; Roshni J John, 2015; Jonbi and Fulazzaky, 2020; Mali and Abraham, 2016; Hossiney et al., 2020; Aoki et al., 2012; Malliga and Moorthy, 2019). Abd Halim et al., 2018, used different aggregate sizes

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to determine the effect on compressive strength and porosity. From the results of his research, PCPB with CA 8 – 10 gave better results in permeability and was more suitable to be applied in areas with high surface runoff. In this study, used of Mahakam sand to increase the strength of PCPB. The addition of sand will certainly increase PCPB strength but will reduce permeability.

This paper aimed to evaluate the effect of Mahakam sand on the strength and permeability of Porous Concrete Paving Blocks (PCPB).

2 METHODS

This research uses experimental methods in the laboratory. PCPB mix design refers to the ACI 522R-10 to determine the material composition. The variation of Mahakam sand content used is 0%, 2.5%, 5%, 7.5%, and 10%. The parameters to be tested in this research are porosity, permeability, compressive strength, and flexural strength. For the porosity parameters obtained using equation (1):

$$\text{Porositas} = \frac{B-C}{B-A}\ x\ 100\% \qquad (1)$$

Where:
A: Sample weight in water (gram)
B: Sample weight SSD (gram)
C: Oven-dry sample weight (gram)

Then, the permeability parameter can be obtained using equation (2):

$$\frac{dq}{A.dt} = k\frac{dh}{L} \qquad (2)$$

Where:
$\frac{dq}{dt}$: Water flow rate (m^3/dtk)
A : Section of area (m^2)
dh : Falling water height (m)
L : Penetration depth (m)
k : Permeability coefficient (m/dtk)

Compressive strength test was carried out according to the SNI 03-1974-1990 (Badan Standardisasi Nasional, 1990) standard to evaluate the compressive strength after the desired curing period used universal testing machine. Load at the failure divided by area of specimen gives the compressive strength of concrete. The compressive strength (f'c) can be calculated from the equation (1):

Furthermore, the compressive strength parameters can be obtained using equation (3):

$$f'c = \frac{P}{A} \qquad (3)$$

Where:
f'c : Compressive strength (MPa)
P : Maximum load (N)
A : Section area (mm^2)

The flexural test of PCPB, according to the Indonesian Standard SNI 03-4154-1996 to evaluates the compressive strength. For measuring flexural strength, the typical standard size of specimens 150×150×500 mm was used. Equal loads were applied at the distance of one-third from both of the beam supports. The maximum tensile stress reached called "flexural strength" is computed from equation (4):

$$f_{lt} = \frac{3PL}{2bd^2} \qquad (4)$$

Where:
f_{lt} : flexural strength (MPa);
L : beam span between supports (mm);
d : depth of beam (mm);
b : width of the beam (mm), and
P : rupture load (N).

3 RESULT

3.1 Materials

The basic materials tested in this study were coarse aggregate and fine aggregate, and cement. The results of testing the material properties of fine aggregate and coarse aggregate are shown in table 1 and table 2.

Table 1: Fine aggregate test results.

Test type	Result	Standard	Conclusion
Bulk density	1.34 gr/cm^3	Min. 1.3 gr/cm^3	Qualify
Bulk specific gravity SSD	2,51	2.5-2.7	Qualify
Sludge content	3.9 %	Max. 5 %	Qualify
Absorbtion	0.76 %	Max. 3 %	Qualify
Water content	1.88 %	Max. 2.5 %	Qualify

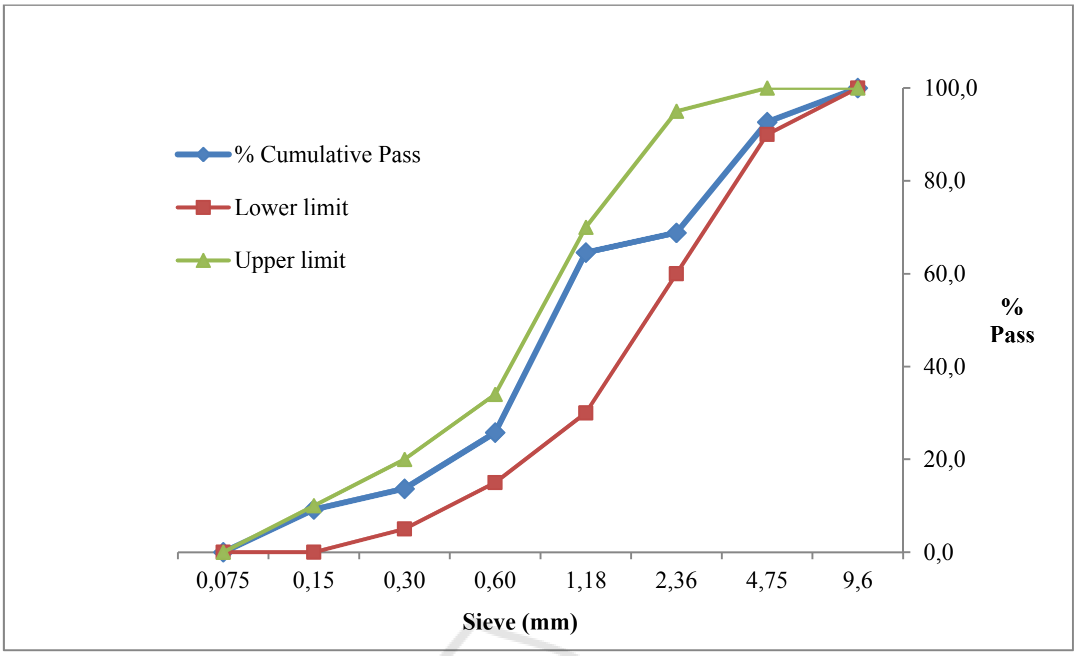

Figure 1: Gradation graph of coarse aggregate.

Table 2: Coarse aggregate test results.

Test type	Result	Standard	Conclusion
Bulk density	1.54 gr/cm^3	Min 1.3 gr/cm^3	Qualify
Bulk specific gravity SSD	2.69	2.5-2.7	Qualify
Sludge content	0.82%	Max. 1%	Qualify
Absorbtion	1.94%	Max 3%	Qualify
Abration	22.35%	Max. 40%	Qualify
Water content	0.45%	Max. 2.5%	Qualify

Figure 1 describes the fine aggregate gradation test results that still meet the boundary requirements of ASTM C-33. From the graph, Mahakam sand is included in the first zone. Tests on uniform coarse aggregate 1-2 cm in size (crushed stone) carried out in this study included testing specific gravity, abrasion, and coarse aggregate gradation.

Based on the results of tests carried out on fine and coarse aggregate materials, it shows that both types of materials meet the determined Indonesian National Standards (SNI).

3.2 Compressive Strength

The compressive strength of concrete is the ability of concrete to withstand compressive forces per unit area. The compressive strength test was carried out when the specimens were 7, 14, 21, and 28 days old using a compression testing machine to get the maximum load, namely the load when the concrete was crushed when it received the load (Pmax). Compressive strength is generally considered to be the most important property of concrete. This usually gives an overall picture of the quality and performance of the concrete. From Figure 2, it can be seen that the compressive strength of PCPB with a sand content of 7.5% has a higher compressive strength than PCPB with other sand content. This is due to the lower void content in PCPB compared to other PCPB specimens. The results also show that the addition of 7.5% sand can increase the compressive strength of PCPB by 36.28%.

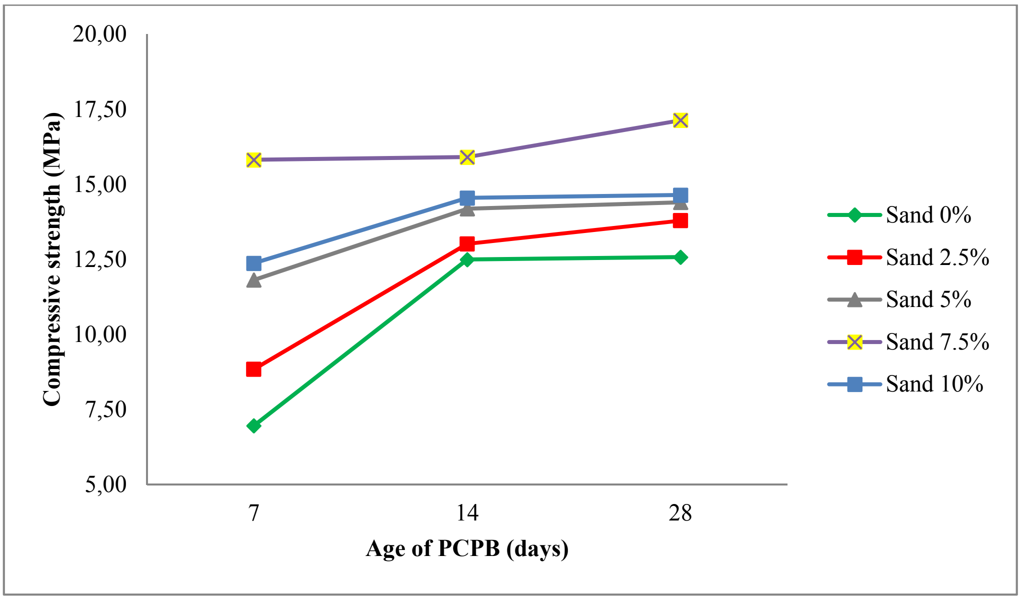

Figure 2: Compressive testing porous paving graphs.

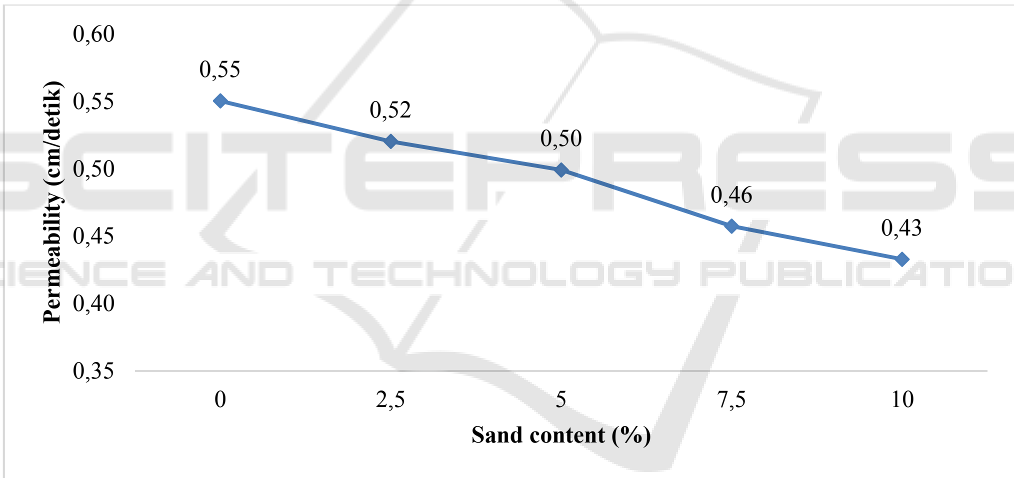

Figure 3: Porous paving permeability testing graph.

3.3 Permeability

Permeability testing in this study used laboratory-scale testing. The test object used for permeability testing is pervious concrete with a length of 20, a width of 10 cm, and a height of 8 cm. The variation of the test object is based on the sand content. The results of the permeability test are presented in graph 3.

Figure 3 shows that the highest permeability value was obtained at 0% sand variation with a value of 0.55 cm/second. Meanwhile, the lowest permeability value is found in the 10% sand variation with a value of 0.43%. This result indicates that PCPB permeability decreases with increasing sand content.

3.4 Porosity

Porosity (Void in mix) is the volume of pores in the compacted mixture or the number of air voids in the porous concrete mixture. The composition of the weight of each aggregate can be seen in Table 3. In the porous paving porosity test results, the highest porosity value was obtained at 0% sand variation with a value of 18.27%. Meanwhile, the lowest porosity value is found in the sand variation of 10%, with a porosity of 9.78%. PCPB porosity decreases with the addition of sand. Sand fills the voids in the porous paving, thereby reducing porosity.

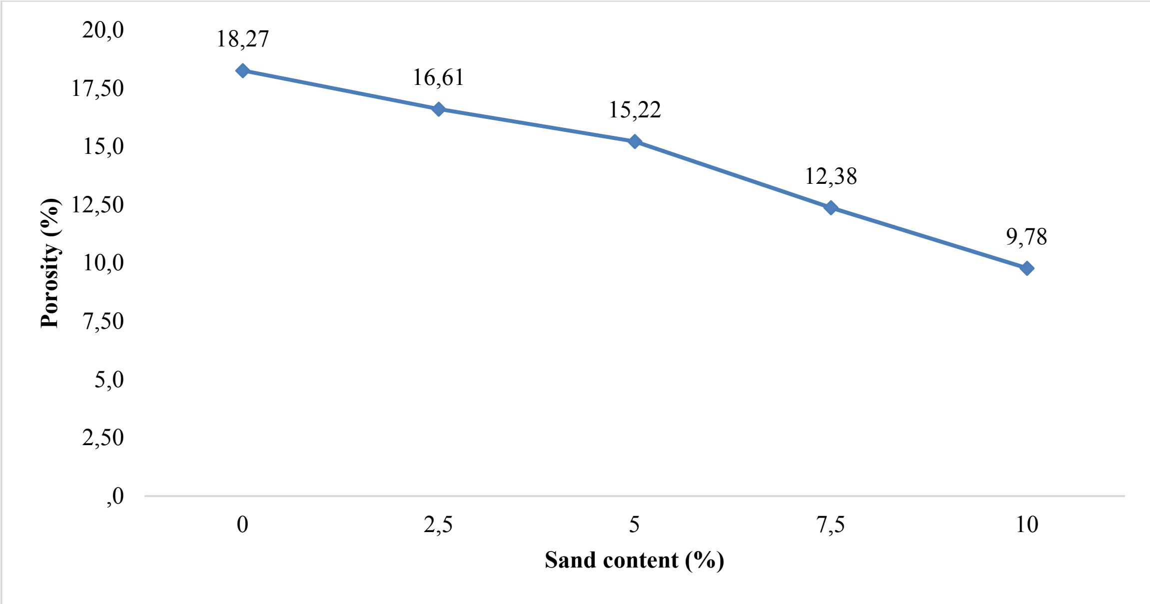

Figure 4: Porous paving porosity testing graph.

4 CONCLUSIONS

From the results of research and data analysis and discussions that have been carried out, conclusions can be drawn as follows:

1. The addition of Mahakam sand causes a decrease in the porosity of the PCPB. The highest porosity occurred in the variation of the addition of 0% sand, which was 18.27%.
2. The highest infiltration velocity is found in the filling of the cavity with the addition of 0% sand content, which is 0.55 cm/second for the lowest air infiltration speed at 10% sand content variation, which is 0.43 cm/second.
3. The addition of Mahakam sand can increase the compressive strength of PCPB when compared to that without cavity filling, which is 17.3 MPa. So that porous concrete can be used as pavement for low traffic such as sidewalks, parks, and gardens.
4. The addition of Mahakam sand can increase the compressive strength but reduce the porosity and permeability of PCPB.

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REFERENCES

Abd Halim, N. H. et al. 2018. "Permeability and Strength of Porous Concrete Paving Blocks at Different Sizes Coarse Aggregate." *Journal of Physics: Conference Series* 1049(1).

ACI 552R-10. 2010. *Report on Pervious Concrete, American Concrete Institute.*

Alam, Taufiqul et al. 2019. "A Comparison of Three Types of Permeable Pavements for Urban Runoff Mitigation in the Semi-Arid South Texas, U.S.A." *Water (Switzerland)* 11(10).

Aoki, Y, Sri Ravindrarajah, and H Khabbaz. 2012. "Properties of Pervious Concrete Containing FLy Ash." *Road Materials and Pavement Design* 13(1): 1–11. http://www.tandfonline.com/loi/trmp20%0AProperties

Badan Standardisasi Nasional. 1990. "SNI 03-1974-1990 Metode Pengujian Kuat Tekan Beton." *Badan Standardisasi Nasional Indonesia.*

El-maaty, Ahmed Ebrahim Abu. 2016. "Establishing a Balance Between Mechanical and Durability Properties of Pervious Concrete Pavement." 1(2): 13–25.

Gpcc, Gsrgpc, Prof Ashok W Yerekar, Rajabhau S Londhe, and Vikram Khajekar. 2016. "Mix Design of

Geosynthetically Reinforced Geopolymer Concrete." 13(6): 129–38.

Hidayah, Nur A.H., Md Hasanan, and P. J. Ramadhansyah. 2014. "Effect of Coarse Aggregate Sizes on Properties of Porous Concrete Paving Blocks." *Advanced Materials Research* 911: 433–37.

Hossiney, Nabil et al. 2020. "Geopolymer Concrete Paving Blocks Made with Recycled Asphalt Pavement (RAP) Aggregates towards Sustainable Urban Mobility Development." *Cogent Engineering* 7(1).

Huang, Jian, Caterina Valeo, Jianxun He, and Angus Chu. 2016. "Three Types of Permeable Pavements in Cold Climates: Hydraulic and Environmental Performance." *Journal of Environmental Engineering* 142(6): 04016025.

Jonbi, Jonbi, and Mohamad Ali Fulazzaky. 2020. "Modeling the Water Absorption and Compressive Strength of Geopolymer Paving Block: An Empirical Approach." *Measurement: Journal of the International Measurement Confederation* 158: 107695. https://doi.org/10.1016/j.measurement.2020.107695.

Mali, Basil M, and Renjan Abraham. 2016. "Study on Geopolymer Concrete Used for Paving Blocks." *International Journal of Innovative Research in Advanced Engineering* 09(3): 2349–2763.

Malliga, P, and J Ashthava Moorthy. 2019. "Paver Blocksby Using Fly Ash and GGBS (Geopolymer Concrete)." *International Journal of Engineering Research & Technology (IJERT)* 7(11): 1–4.

Manan, Aneel et al. 2018. "Experimental Investigation of Compressive Strength and Infiltration Rate of Pervious Concrete by Fully Reduction of Sand." *Civil Engineering Journal* 4(4): 724.

Roshni J John, Husain N Hamdulay,. 2015. "Effect of Aggregate Grading and Cementitious By-Product on Performance of Pervious Concrete." *International Journal of Innovative Research in Science, Engineering and Technology* 4(8): 6890–97.

SNI 03-4154-1996. 1996. Badan Standar Nasional Indonesia *Metode Pengujian Kuat Lentur Beton Dengan Balok Uji Sederhana Yang Dibebani Terpusat Langsung*. Jakarta.

Wijaya, Yulia Putri, and Januarti Jaya Ekaputri. 2014. "Paving Geopolimer Dari Coal Ash Limbah Pabrik." *Jurusan Teknik Sipil FTSP ITS, Surabaya* (June): 33–42.