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Compressive Strength of Concrete with Malang Sand as Fine Aggregate Substitute

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Abstract

Malang sand has small and rough grains with a sharp surface, it can easily absorb water and adhere to cement. It is very suitable for use as fine aggregate in concrete to improve the quality and durability of concrete. As sand from a volcano, Malang sand has similar characteristics to sand from cold lava resulting from volcanic eruptions. In another study, concrete with sand from cold lava of Sinabung volcano was reported to have the highest compressive strength in a mixture variation of 60-70% of Sinabung sand at the age of 14 days. This study focuses on investigating the compressive strength of concrete with the addition of Malang sand as partly replacement of 50-70% of the fine aggregate material. The concrete design method uses practical guidelines for designing concrete mixes according to Indonesian standard (SNI), and for testing the compressive strength of concrete using ASTM C-39. The percentage of sand used in this study is 50%, 60%, and 70% as a substitute for fine aggregate with a concrete age of 28 days. Based on the study results, the maximum average compressive strength is achieved for the concrete with Malang sand of 70% (MSC 70%) with a compressive strength of 31.89 MPa or an increase 4.32% compared to normal concrete. In this study indicated that the trend of compressive strength is increase with the increase of Malang sand content in the concrete.

Keywords: Malang sand, concrete, cold lava aggregate, compressive strength, mechanical properties

1. Introduction

Concrete is the most common construction material used in various construction projects such as buildings, roads, bridges and other infrastructure. As a construction material, concrete has the advantages of having high strength and durability, design flexibility and a long service life [1]. As a material for simple structures to facilitate transportation, sometimes lightweight concrete material is also needed by replacing some of the fine aggregate with lightweight material [2]. Partial replacement of fine aggregate is generally carried out with material that has characteristics similar to fine aggregate, such as material that has a high silica content.

The use of materials containing high silica content as concrete binders and fillers in green concrete as well as uses for waste materials has been reported in the literature. As a concrete binder, fly ash which has high silica content is reported to be used as a fully substitute of cement as a concrete binder, thereby producing green Geopolymer concrete [3-4]. As a partial replacement for cement, waste cementitious materials in powder sizes that are grained to micron meter size such as glass powder have also been used [5-8]. On the other hand, partial replacement of fine aggregate with a function as concrete filler is carried out using waste materials such as rice husk ash [9], volcanic ash [10] or cold lava aggregate [11-12] and waste bottle glass powder [13-15].

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This study will focus on the use of sand from cold lava called Malang sand which contains high silica as a partial substitute filler for fine aggregate in concrete. As a basis for this study, several reports in the literature regarding sand from cold volcanic lava such as Merapi sand and Sinabung sand can be useful information for this study because they have similar characteristics to Malang sand. Regarding Merapi cold lava sand, it is widely reported to have the potential function as a concrete filler [16-17]. Merapi sand grains have the sharper shape of the particle pattern of is what improves the interaction between Merapi sand and cement paste in concrete [18]. The mineral content of the Merapi sand is dominated by silica more than 60%, alumina of 17%, and other contents such as iron, calcium, and magnesium in very modest concentrations [19]. Meanwhile, cold lava sand from the Sinabung volcano is also reported to function very well as a filler for concrete to replace some of the fine aggregate. The results of the study of Sinabung sand show that the use of Sinabung sand as a partial replacement of fine aggregate of 60-70% provides the highest compressive strength of concrete [20]. Based on the study report for Merapi and Sinabung sand, the Malang sand proposed in this study is assumed to have the same potential as a concrete filler in increasing the compressive strength of concrete.

In this study, Malang sand which functions as a concrete filler is used to replace some of the fine aggregate content with variations of 50%, 60%, and 70%. Malang sand was refined to the size of fine aggregate by passing a 2.26 mm sieve. The coarse aggregate material used was passing 9.5 mm and retained at 4.75 mm sieve. The objective of this study is to investigate the influence of Malang sand on the compressive strength of Malang Sand concrete compared to normal concrete. Furthermore, as part of environmental concerns, this study is expected to contribute to reducing Malang cold lava material waste through the function of partial substitution of fine aggregate in concrete.

2. Material and Method

Malang sand as a result from the Malang cold lava has small and rough grains with a sharp surface, therefore, it can easily absorb water and adhere to cement paste. The grain form of Malang sand is very suitable for use as an aggregate filler in concrete to improve the quality and durability of concrete. Malang sand is cold lava from volcanic eruptions whose mineral content has a high silica content, so the material is very good as a building construction material. Malang sand is the result of an eruption from an active volcano which is spread through the ashfall process, and the factors that influence the distance the particles are distributed are influenced by their geometric size and geometric shape [21]. Based on research using the SEM-EDX method, it is known that the chemical content of Malang sand is O at 45.71%, Na at 5.18%, Mg at 0.89%, Al at 9.04%, Si at 23.87%, Cl of 1.39%, K of 2.56%, Ca of 4.69%, and Fe of 6.67%. The concentration components in Malang sand through XRF analysis are A12O3 at 11%, SiO2 at 42.7%, K2O at 4.66%, CaO at 13.2%. It is known that the silica content in Malang sand is 42.7% [22].

In this study, the mechanical property of concrete is investigated such as the compressive strength of the Malang sand concrete (MSC) and normal concrete (NC) at age of 28 days. The percentage of use of Malang sand as a partial substitute for fine aggregate is varied by 50%, 60%, and 70%. The aim of investigation is to check the performance of the compressive strength of Malang sand concrete compared to the normal concrete. All specimens are cured with water immersion curing before tested in compressive strength at age of 28 days [23]. The methodology of this study is shown in Fig. 1.

A brief explanation of the main concrete materials applied in this study is as follows [24-26]. The main materials for normal concrete (NC) are cement, coarse aggregates, fine aggregates, and water. The cement used as a binder for the concrete mixture is Portland Composite Cement (PCC) Type I, the coarse aggregate uses crushed stone (Fig. 2) with gradation of passing 9.5 mm and retained at 4.75 mm sieve and its fineness modulus (FM) is 6.025%, and the fine aggregate uses Cikarang local sand (Fig. 3) that passes a 2.36 mm sieve where its fineness modulus, FM is 2.32%. Meanwhile, for Malang sand concrete (MSC), Malang sand is applied as a partial replacement for the fine aggregate with its fineness modulus, FM is 2.35%. The Malang sand used in this study passes a 2.36 mm sieve ranging between 0.075 mm and 0.150 mm (Fig. 4). The coarse and the fine aggregate are tested for specific gravity and absorption, mud levels, aggregate gradation, and aggregate moisture. The mix design of normal concrete and Malang sand concrete can be seen in Table 1. The concrete specimens used in this study are cylinders with a diameter of $Ø$ = 150 mm and height of h = 300 mm (Fig. 5) and the curing type used the immersion curing (Fig. 6). The compressive strength test setup is shown in Fig. 7.

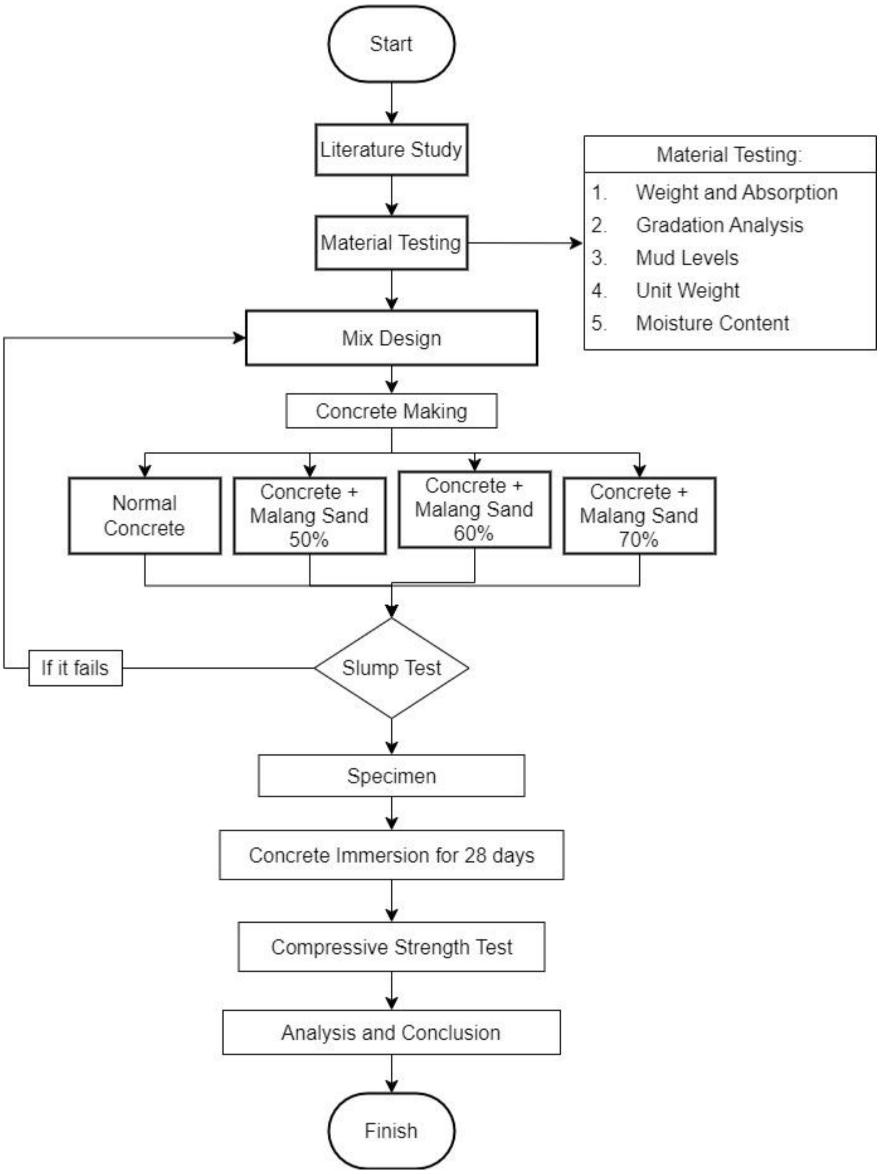

Fig. 1 Study methodology

Table 1 Mix design

Concrete type	Specimen	Volume (1 specimen) (m^3)	Material compositions				
			Cement (kg)	Fine aggregate		Coarse aggregate (kg)	Water (kg)
				Sand (kg)	Malang Sand (kg)		
NC	3	0.00556	7.259	9.062	-	15.596	3.276
MSC 50%	3	0.00556	7.259	4.531	4.531	15.596	3.276
MSC 60%	3	0.00556	7.259	3.625	5.437	15.596	3.276
MSC 70%	3	0.00556	7.259	2.719	6.344	15.596	3.276
Total	12		29.037	19.937	16.312	62.383	13.105


Fig. 2 Coarse aggregate

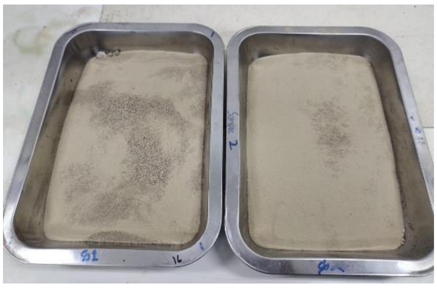
Fig. 3 Fine aggregate


Fig. 4 Malang sand


Fig. 5 Concrete specimens


Fig. 6 Concrete curing

Fig. 7 Compressive strength test and a tested specimen

3. Results and Discussion

The slump tests in Fig. 8 indicated the results that all slump values in Malang sand concrete and normal concrete in this study have an average value of 10.22 cm ~ 10.33 cm and this is in accordance with the design slump target which is in the range of 120 mm. The average compressive strength (f_c') test results on the Malang sand concrete and normal concrete specimens are shown in Table 2. Based on the average compressive strength test results shown in Table 2 and Fig. 9, it shows that the compressive strength of Malang sand concrete increases with increasing the content of Malang sand.

The compressive strength of concrete with 70% of Malang sand content (MSC 70%) showed the highest increase of 4.32% with the value of 31.89 MPa compared to the normal concrete (NC) compressive strength of 30.57 MPa at age of 28 days. The concrete with Malang sand content showed the increase in the range of 1.24 ~ 4.32% with the value of 30.95 ~ 31.89 MPa compared to normal concrete. The results showed that the use of Malang sand in this study was quite reasonably good as a partial replacement for fine aggregate of Cikarang local sand in term of the concrete compressive strength.

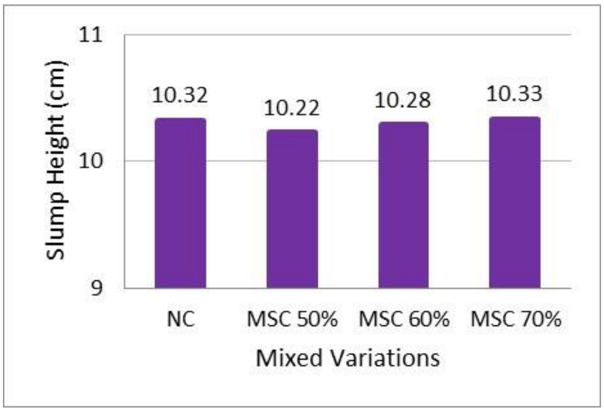

Fig. 8 Slump value of Malang sand concrete and normal concrete

Table 2 Compressive strength tests result of Malang sand concrete and normal concrete

No	Concrete type	Day	Specimen	f'_c (MPa)	Average f'_c (MPa)
1	NC	28	1	30.57	30.57
			2	30.01	
			3	31.14	
2	MSC 50%		1	32.27	30.95
			2	31.14	
			3	29.44	
3	MSC 60%		1	32.27	31.71
			2	32.84	
			3	30.01	
4	MSC 70%		1	32.84	31.89
			2	31.71	
			3	31.14	

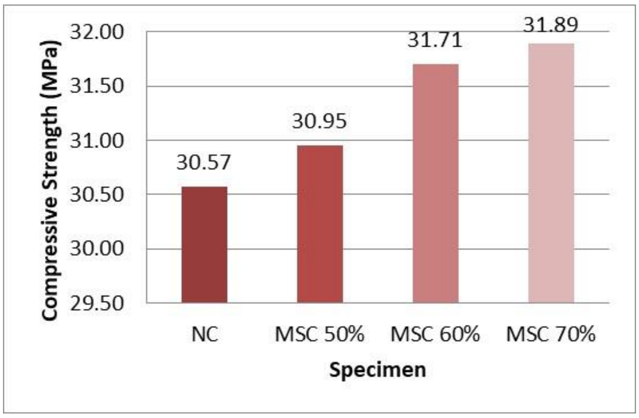

Fig. 9 Enhancement in the compressive strength of concrete

4. Conclusions

The investigation of the influence of Malang sand as a partial replacement for fine aggregates with a percentage of 50%, 60%, and 70% in the compressive strength of concrete at 28 days has been conducted in this study. Based on the test results, conclusion can be obtained as follows. The average compressive strength for concrete with 70% of Malang sand content (MSC 70%) showed the highest strength with the increase of 4.32% compared to normal concrete (NC). In this study, Malang sand concrete has an influence that tends to increase the compressive strength of concrete. These results indicate that Malang sand is quite reasonably good as a filler material to replace fine aggregate of Cikarang local sand in concrete. Apart from that, it can reduce the environmental impact due to waste material from Malang cold lava sand.

References

[1] H. Du and K. H. Tan, “Properties of High-Volume Glass Powder Concrete,” Cement and Concrete Composites, vol. 75, pp. 22–29, 2017.
[2] I. Bali, J. Widjajakusuma, G. P. Ng, and R. Tjahjono, “High Early Strength Foamed Concrete Design for Structural Precast Concrete,” IOP Conference Series: Earth and Environmental Science, vol. 1195 (012022), pp.1-8, 2023.
[3] A. P. Bayuseno, S. A. Widyanto, and J. Juwantono, “Sintesis Semen Geopolimer Berbahan Dasar Abu Vulkanik dari Erupsi Gunung Merapi,” Rotasi, vol. 12, no. 4, 2010. (In Indonesian)
[4] J. Widjajakusuma, I. Bali, G. P. Ng, and K. A. Wibowo, “An Experimental Study on the Mechanical Properties of Low-Aluminum and Rich-Iron-Calcium Fly Ash-Based Geopolymer Concrete,” Advances in Technology Innovation, vol. 7, no. 4, pp. 295-302, 2022.
[5] W. Kushartomo, I. Bali, and B. Sulaiman, “Mechanical Behavior of Reactive Powder Concrete with Glass Powder Substitute,” Procedia Engineering, vol. 125, pp. 617-622, 2015.
[6] I. Bali, W. Kushartomo, and Jonathan, “Effect of In-Situ Curing on Compressive Strength of Reactive Powder Concrete,” MATEC Web of Conferences, vol. 67 (03013), pp. 1-6, 2016.
[7] I. Bali and W. Kurnia, “The Curing Method Influence on Mechanical Behavior of Reactive Powder Concrete,” International Journal on Advanced Science, Engineering and Information Technology, vol. 8, no. 5, pp. 1976-1983, 2018. [Online]. Available: http://dx.doi.org/10.18517/ijaseit.8.5.4197.
[8] N. Hanafiah, Pengaruh Penambahan Bubuk Kaca sebagai Bahan Pengganti Sebagian Semen dengan Variasi 2%, 4%, 6% dan 8% terhadap Kuat Tekan dan Nilai Slump, Teknik Sipil, Universitas Muhammadiyah Yogyakarta, Yogyakarta, 2011. (In Indonesian)
[9] I. Bali and A. Prakoso, “Beton Abu Sekam Padi sebagai Alternatif Bahan Konstruksi,” Jurnal Sains dan Teknologi EMAS, vol. 12, no. 29, pp. 75-81, 2002. (In Indonesian)
[10] I. Bali and F. Sitorus, “Merapi Volcanic Ash as an Eco-Material of Concrete Filler,” The 8th International Symposium on Lowland Technology, Bali, Indonesia, 2012.
[11] I. Bali and O. Sitorus, “The Effect of Cold Lava Aggregate as a Filler Material of Concrete,” The 3rd International Conference of European Asian Civil Engineering Forum (EACEF), Yogyakarta, Indonesia, 2011.
[12] T. T. C. P. Bungalolon and I. Bali, “Compressive Strength of Concrete Containing Merapi Cold Lava Sand,” PRESUNIVE Civil Engineering Journal, vol. 2, no. 1, pp. 38-44, April 2024.
[13] B. P. Nugraha, E. T. Sudjatmiko, and I. Bali, “Compressive Strength of Concrete Containing Recycled Glass Powder,” PRESUNIVE Civil Engineering Journal, vol. 1, no. 1, pp. 8-12, April 2023.
[14] R. H. Geovenerdy, I. Bali, and E. T. Sudjatmiko, “The Effect of Steam Curing on the Early Compressive Strength of Glass Powder Concrete,” PRESUNIVE Civil Engineering Journal, vol. 1, no. 2, pp. 48-53, October 2023.
[15] I. M. Tatanka, I. Bali, and E. Sudjatmiko, “Mechanical Properties of Concrete with Recycled Bottle Glass Powder Substitute,” PRESUNIVE Civil Engineering Journal, vol. 2, no. 1, pp. 1-7, April 2024.
[16] S. Choiriyah and D. Pertiwi, “Kuat Tekan Beton dengan Menggunakan Pasir Gunung Merapi Ditinjau dari Manajemen Kwalitas,” Seminar Nasional Sains dan Teknologi Terapan IV, 2016. (In Indonesian)
[17] Lasino, B. Sugiharto, and D. Cahyadi, “Pemanfaatan Pasir dan Debu Merapi sebagai Bahan Konstruksi dalam Mendukung Pembangunan Infrastruktur dan Meningkatkan Nilai Guna Lahar Vulkanik,” Prosiding PPI Standardisasi, 2011. (In Indonesian)
[18] D. Pertiwi, B. Wibowo, E. Kasiati, Triaswati, and A. G. Sabban, “Perbandingan Penggunaan Pasir Lumajang dengan Pasir Merapi terhadap Kuat Tekan Beton,” Jurnal APLIKASI, vol. 9, no. 2, 2011. (In Indonesian)

[19] Sudaryo and Sutjipto, “Identifikasi dan Penentuan Logam pada Tanah Vulkanik di Daerah Cangkringan Kabupaten Sleman dengan Metode Analisis Aktivasi Neutron Cepat,” Seminar Nasional V SDM Teknologi Nuklir, 2009. (In Indonesian)
[20] R. D. Susanti, A. Waruwu, D. Endriani, and I. Lesmana, “Potensi Penggunaan Pasir Lahar Dingin Gunung Sinabung sebagai Campuran Beton,” Techno, vol. 23, no. 2, 2022. (In Indonesian)
[21] C. M. Riley, W. I. Rose, and G. J. S. Bluth, “Quantitative Shape Measurements of Distal Volcanic Ash,” Journal of Geophysical Research, vol. 108, no. B10, 2504, 2003. doi:10.1029/2001JB000818
[22] D. Ramadhanty, K. A. Reksatama, and E. Kurniati, “Sintesa dan Karakteristik Adsorben dari Abu Vulkanik,” Journal of Chemical and Process Engineering, vol. 2, no. 2, pp. 52-56, 2020. (In Indonesian)
[23] American National Standards Institute, Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM C-39, USA: Annual Books of ASTM, 1993.
[24] Badan Standardisasi Nasional, Persyaratan Beton Struktural untuk Bangunan Gedung, SNI 2847:2013, Jakarta, 2013. (In Indonesian)
[25] Badan Standardisasi Nasional, Tata Cara Pembuatan Rencana Campuran Beton Normal, SNI 03-2834-2000, Jakarta, 2000. (In Indonesian)
[26] Badan Standardisasi Nasional, Spesifikasi Bahan Bangunan Bagian A (Bahan Bangunan Bukan Logam), SK. SNI S-04-1989-F, Bandung: Lembaga Penyelidikan Masalah Bangunan, 1989. (In Indonesian)