MECHANICAL PROPERTY TESTING OF CONCRETE USING MOUNT MARAPI VOLCANIC SAND AS FINE AGGREGATE

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Abstract. *Infrastructure development in Indonesia mostly uses concrete as a construction material. The eruption of Mount Marapi in West Sumatra which occurred on December 3, 2023, spewed material in the form of sand and volcanic rocks. Mount Marapi volcanic sand is sand obtained from nature and has different qualities that affect the strength of the concrete. This study aims to obtain the properties of concrete-forming materials by using volcanic sand as a fine aggregate in the laboratory. The method used in this study is experimental. A cube-shaped concrete sample measuring 15 cm x 15 cm x 15 cm was made with a variety of concrete using volcanic sand from Mount Marapi and tidal sand. The concrete was then tested for compressive strength at 28 days. The results showed that concrete with a mixture of volcanic sand provided a higher compressive strength of 20,662 Mpa compared to concrete with tidal sand of 20,788 Mpa.*

Keywords: *Concrete, Compressive strength, Volcanic sand*

1. INTRODUCTION

In Indonesia, with the advancement of structural engineering technology, concrete is still the main choice as a construction material such as the construction of buildings, bridges, dams, and so on. The manufacture of concrete can be done by mixing components such as Portland cement, coarse aggregate, fine aggregate, water, and additives. The widespread use of concrete and the increasing development show how high the demand for concrete is in the future, thus demanding innovation regarding materials for concrete mixtures (Susanti et al., 2022).

Previous research conducted by (Wawan & Kusdian, 2021) with the title Comparative Analysis of Concrete Compressive Strength Using Mount Merapi Ash Sand Yogyakarta Province With Daily Estimation Variations, It can be concluded that the effect of concrete compressive strength using Mount Merapi ash sand in Yogyakarta province on concrete can change the compressive strength to be higher when compared to normal concrete.

Mount Marapi, which is in West Sumatra, experienced an eruption on December 3, 2023. One of the areas affected by the eruption is the Sungai Pua area, Agam Regency. The eruption of Mount Marapi released materials in the form of volcanic sand and rocks. Fine aggregate material (sand) is one of the materials that make up concrete, the quality of the concrete produced is influenced by the quality of the material used.

Based on the description above, a study of the material properties of Mount Marapi was carried out in the form of volcanic sand mixed in concrete as a construction material. This study aims to obtain the properties of concrete-forming materials by using Mount Marapi volcanic sand as fine aggregate in the laboratory.

2. LITERATURE REVIEW

2.1 Beton

Based on (SNI 2847:2013), concrete is a mixture of materials in the form of coarse aggregate, fine aggregate, and Portland cement or other hydraulic cement, and water or without additives that form a solid period. The types of concrete according to the

strength of the puzzle are divided into 3, which are as follows:

a. Low-strength concrete having a compressive value below 20 Mpa, this quality is usually used for residential building structures.
b. Medium-strength concrete has a compressive strength value of 20 to 40 Mpa, this quality is commonly used for multi-story building structures.
c. High-strength concrete is quality concrete that has a compressive strength above 40 Mpa, commonly used in skyscrapers or High-rise buildings.

According to (Putrianti et al., 2021) Concrete has advantages and disadvantages.
The advantages of concrete are as follows:

a. Concrete includes materials that have high compressive strength, as well as properties that are resistant to rust or decay and resistant to fire.
b. Concrete is relatively cheap because it uses basic materials that are easy to get except Portland Cement.
c. Fresh concrete can be easily transported or molded in the desired shape.
d. High compressive strength, when combined with reinforcing steel can be used on heavy structures.
e. Fresh concrete can be pumped so that it is possible to pour it in places where the position is difficult.
f. Wear- and fire-resistant, so maintenance costs are relatively cheap.

Concrete also has the following disadvantages:

a. Low tensile strength on concrete so that concrete is easy to crack.
b. Fresh concrete hardens and shrinks when changes occur in temperature.
c. Concrete is difficult to be perfectly waterproof, so it can always be watered and water-carrying salt can damage the concrete reinforcement.
d. Concrete is brittle so it must be carefully calculated and detailed so that it is combined with reinforcing steel to become ductile.

2.2 Properties of Concrete

Concrete is a material that is very strong in resisting compressive force. Related to its strength, the properties of concrete are highly dependent on the ratio of water-cement paste mixture, the type of aggregate, and the casting and treatment process of concrete. Therefore, the characteristics of concrete are highly dependent on the internal structure of the concrete constituents (Supriadi & Romadhon, 2020).

Concrete is composed of 15% cement, 8% water, 3% air, and the rest is coarse aggregate and fine aggregate. These mixtures after hardening have different properties depending on the process of making, comparing, mixing, transporting, molding, compacting, treatment, and others that will affect the properties of the concrete (Erlina et al., 2023). The importance of knowing the properties of concrete to get the expected quality of concrete.

2.3 Concrete Composition Materials

1. Portland Cement

Cement is a fine powder used as a hydraulic binder of fine aggregates and coarse aggregates that can be chemically activated after mixing with water. Pasta semen (water and cement mixture), Mortar is a mixture of cement paste with fine aggregate, if combined with coarse aggregate after hardening it will become concrete. (Imam et al., 2023).

Based on (SNI 15-2049-2004), portland cement is divided into lima according to its type and use:

a. Type I Portland cement is for general use and does not require special requirements like other Portland cement.
b. Type II is Portland cement that requires resistance to sulfate or moderate hydration heat.
c. Type III is a Portland cement that requires high strength at the stage after bonding occurs.

d. Type IV is Portland cement requiring low hydration heat.
e. Type V is a Portland cement that requires high resistance to sulfates.

2. Aggregate

There are 2 types of aggregates, namely coarse aggregates and fine aggregates. Aggregate serves as a filler in concrete mixtures. According to (SNI 03-2847- 2002) aggregate is a natural material in the form of gravel, crushed stone, sand, and incandescent furnace crust which is used together with hydraulic cement binding materials.

A. Fine aggregate

According (SNI 03-2847:2002), pasir alami hasil disintegrasi alami batuan atau hasil batuan yang di produksi oleh industri pemecah batu dengan ukiuran maksimal 5,0 mm. Fine aggregate serves as a filler material in the concrete mixture. The use of fine aggregate in concrete mixtures must meet the requirements by the Decree of (SK SNI S 04-1989-F) as follows:

a. Fine aggregates has sharp and hard grains.
b. Fine aggregate grains are permanent and do not crumble or break by weather factors.
c. It does not contain more than 5% sludge.
d. It does not contain too much organic matter.
e. The grain variation according to the grading standard and the fineness modulus ranged from 1.5 to 3.8.

B. Coarse aggregate

According to the Indonesian National Standard (SNI 03-2847:2002), coarse aggregate is the main material in concrete formation that has a size larger than 5mm to 40mm, or grains that are held in a sieve of 4.75mm. Coarse aggregate in the form of gravel is obtained from the natural disintegration of crushed rocks or crushed stones using machines or broken (stone crushers) manually. The requirements for coarse aggregate for concrete mixtures according to (SK SNI S0 4-1989-F) concerning Building Material Specifications are as follows:

a) The aggregate is composed of hard, non-porous granules.
b) The gravel contains grains and the length must not be more than 20% of the total aggregate weight.
c) It does not break or be destroyed by weather factors.
d) It does not contain more than 1% sludge.
e) It does not contain substances that can damage concrete.
f) The grain variation is according to the grading standard and the fine modulus of the grain is between 6 to 7,1.
g) The maximum size of the grain is not more than 1/5 of the smallest distance between the side planes of the mold, 1/3 of the thickness of the plate, and 3/4 of the net distance between the rebar or the rebar.

3. Water

Water is a mixing material and mixer of aggregates and cement. In general, potable water meets the requirements of concrete mixing water, this water must be free from suspended solids or too much-dissolved solids, and free from organic materials (Wawan & Kusdian, 2021). According to (SNI 03 – 2847 – 2002) water that can be used for concrete mixtures must meet the following conditions:

1) Water must be clean and free from destructive substances containing salt, oil, alkhalic acid, organic matter, or other materials that are detrimental to concrete or reinforcement.
2) Especially for prestressed concrete, water must not contain chloride with harmful

amount of chloride.

3) If the water is not drinkable, the selection of the concrete mixture must be based on the concrete mixture that uses water from the same source.

2.4 Compressive Strength

According to (SNI 03-1974-1990), the compressive strength of concrete is a broad union load that causes the concrete test piece to collapse when loaded with a certain compressive force, which is generated by the press. The stronger the desired structure, the greater the compressive strength required (E. Susanti, 2014). The compressive strength of concrete can use the equation (2.4)

$$\text{Compressive strength of concrete} = \frac{P}{A} \qquad (2.4)$$

Information:
p = Maximum load (N)
A = Cross-sectional area of the test piece (mm2)

Factors that affect the compressive strength of concrete are as follows:

a. Cement water factor (FAS)
   FAS is the comparison of the value between the weight of water and cement in a concrete mixture. The comparison of moisture content in the concrete mixture must be in sufficient and balanced proportions. The greater the FAS value used, the lower the quality of concrete strength. The function of FAS enables chemical reactions for bonding and hardening processes and ease of concrete work.
b. Concrete age
   The compressive strength of concrete is stated at the age of 28 days while the concrete does not rise again after the age of 28 days. The longer the life of the concrete, the greater the compressive strength, and vice versa, the faster the age of the concrete, the stronger the pressure will drop.
c. Concrete density
   A parameter that affects the strength of concrete is the density of concrete. The strength of the concrete will be weak if the hardness of the concrete is reduced.
c. Amount of Cement
   The amount of cement content in concrete will affect the strength of the concrete if there is too little cement and the concrete mixture is difficult to compact. Excess moisture and cement content in concrete results in concrete containing pores which results in low concrete.
d. Aggregate Properties
   There are 2 types of aggregates, namely coarse aggregate (broken stone/gravel) and fine aggregate (sand). Water content, specific gravity, fine modulus of grain, aggregate hardness, aggregate gradation, and aggregate retention are aggregate properties that affect the quality of concrete.

3. RESEARCH METHODS

The method used in this study is an experimental method conducted in the laboratory of the Faculty of Civil Engineering, University of Muhammadiyah West Sumatra, for sampling, namely in the Sungai Pua area, Agam Regency. The total test pieces made were 6 pieces, 3 pieces for normal concrete and 3 pieces for concrete using volcanic sand as a fine aggregate on the concrete mixture.

3.1 Concrete Forming Materials

In this study, the material used is Portland Composite cement (Padang), coarse aggregate (gravel or broken stone) comes from Palembayan, tide sand fine aggregate comes from Palembayan, and Mount Marapi volcanic sand is used for the concrete mixture.

3.2 Testing Tools

- Digital Scales
- The test piece is in the shape of a cube 15cm x 15cm x 15cm.
- Ovens are used to dry test specimens
- Shieve shake machine
- Stirring machine
- CTM
- Abrams cones are used to test slumps on fresh concrete.
- Mistar

3.3 Test Material Properties

a. Coarse aggregate

- Gross aggregate volume weight
- Coarse aggregate sludge content inspection
- Coarse aggregate fineness modulus analysis
- Specific gravity analysis and coarse aggregate absorption
- Moisture content check on fine aggregates

b. Fine aggregate

- Sludge content check-in
- Inspection of materials passed No.200
- Specific gravity analysis and fine aggregate absorption.
- Fine modulus analysis of fine aggregate granules
- Inspection of organic substances in fine aggregates

c. Cement

- Cement-specific gravity check

4. RESULTS AND DISCUSSION

4.1 Material Properties Test Results

Table 1 Coarse Aggregate Test Results

No	Types of Testing		Result	Unit
1	Aggregate Volume Weight	Dense	1,6095	Kg/lt
		Loose	1,4498	Kg/lt
2	Moisture Content		1,236	%
3	Fine Modulus of Granules		4,55	
4	Spesific Gravity	Apparent Specfic Gravity	2,189	
		Bulk Specific Gravity (Dry)	2,054	
		Bulk Spesific Gravity (SSD)	2,114	
		Water Absorption Percentage	2.961	%

Source: Personal Data, 2024

Table 2 Fine Aggregate Test Results

No	Types of Testing	Result		Unit
		Sand Tide	Volcanic Sand	

1	Aggregate Volume Weight	Dense	1,371	1,634	Kg/Lt
		Loose	0,935	1,017	Kg/Lt
2	Sudge content		4,90	5,56	%
3	Passed Sieve No.200		3,080	6,8	%
4	Modulus of Fineness		3,261	2,234	
5	Spesific Gravity	Apparent Specfic Gravity	2,509	2,650	
		Bulk Specific Gravity (Dry)	2,184	2,304	
		Bulk Spesific Gravity (SSD)	2,312	2,428	
		Water Absorption Percentage	0,059	0,0539	%

Source: Personal Data, 2024

Based on Table 2, shows that the volcanic sand mud content of Mount Marapi does not meet the requirements because it exceeds the limit requirement of 5%. Mount Marapi volcanic sand has a high mud content, so the sand must be washed before use. The sludge content in the fine aggregate will affect the compressive strength of the concrete produced.

Based on the test results, the modulus of fineness of volcanic sand was obtained at 2.234 which showed that the volcanic sand met the requirements, and the grading standard, and the modulus ranged from 1.5 to 3.8.

4.2 Mix Design Beton

Table 3 Results of Mix design concrete

Composition of Concrete Mixtures	Result	Unit
Cement	1,263	Kg
Water	0,682	Ltr
Fine aggregate	1,827	Kg
Coarse aggregate	3,151	Kg

Source: Personal Data, 2024

Concrete mix design aims to find out how much composition is from cement, water, coarse aggregates, and fine aggregates. In Table 3, the results of the concrete mix design are obtained after a concrete mechanical property test with the planned concrete quality is fc 20.75 Mpa.

4.3 Concrete Curring

Concrete Curing is done to speed up the hydration process or not lose water in concrete too quickly. The cube test piece that has been opened from the mold, the next process is to carry out the concrete treatment. Concrete treatment is carried out by immersing the test piece in water.

4.4 Compressive Strength Test Results of Concrete

The concrete compressive strength test is carried out after the test piece is 28 days old, using a CTM tool until the test piece cracks or is destroyed. Based on the results of the compressive strength test, it can be seen in Tables 4 and 5 that fine aggregate in the form of volcanic sand can increase the compressive strength of concrete with the

same composition. The compressive strength of normal concrete uses tidal sand of 20,662 while it uses volcanic sand from Mount Marapi of 23,876 Mpa.

Table 4 Results of Normal Concrete Compressive Strength Test

Sample	Sample weight (Kg)	Area mm^2	Compressive Strength (Mpa)	Average compressive strength (Mpa)
1	7,327	225000	21,634	20,876
2	7,011	225000	19,866	
3	7,113	225000	21,129	

Source: Personal data, 2024

Table 5 Results of Compressive Strength Testing of Concrete Using Volcanic Sand from Mount Marapi

Sample	Sample weight (Kg)	Area (mm^2)	Compressive Strength (Mpa)	Average compressive strength (Mpa)
1	7,443	225000	23,745	23,662
2	7,526	225000	21,220	
3	7,443	225000	26,018	

Source: Personal Data, 2024

CONCLUSION

Based on the research that has been carried out from testing material properties to testing the compressive strength of concrete, the following conclusions can be drawn:

1. The average compressive strength test results of Mount Marapi volcanic sand are 23,662 Mpa while normal concrete is 20,876 Mpa.
2. Mount Marapi volcanic sand can increase the strength of concrete with the same composition as normal concrete using tidal sand.

REFERENCES

Erlina, Krisyanto, H., & Zulfikar, M. D. (2023). Perbandingan Mutu Beton K-250 Dengan. *Perbandingan Mutu Beton K-250 Dengan Menggunakan Pasir Putih Dari Darat Dan Pasir Bekas Galian Bauksit*, *V*(1), 1–10.

Imam, Lukman, H., & Artiningsih, T. P. (2023). Analisa Perbandingan Kuat Tekan Beton Dengan Menggunakan Agregat Halus Pasir Citarik (Sukabumi) Dan Pasir Jebrod (Cianjur). *Jurnal Online Mahasiswa (Jom) Bidang Teknik Sipil*, *1*(1), 1–14.

Putrianti, P. R., Setiawan, A. A., Studi, P., Sipil, T., & Jaya, U. P. (2021). *Karakteristik Uji Propertis Dan Campuran Beton Normal Pratika*. *5*.

Supriadi, & Romadhon, Eri S. (2020). Optimalisasi Penggunaan Abu Batu Sebagai Pengganti Pasir Dalam Campuran Beton. *Optimalisasi Penggunaan Abu Batu Sebagai Pengganti Pasir Dalam Campuran Beton*, *19*(1). Https://Doi.Org/10.54564/Jtsa.V19i1.35

Susanti, E. (2014). Studi Perbandingan Nilai Kuat Tekan Dan Modulus Elastis Beton Yang Menggunakan Pasir Merapi Dan Pasir Lumajang. *Jurnal Prosiding Seminar Nasional Aplikasi Teknologi Prasarana Wilayah (Atpw)*, 1–6.

Susanti, R. D., Waruwu, A., Endriani, D., & Lesmana, I. (2022). Potensi Penggunaan Pasir Lahar Dingin Gunung Sinabung Sebagai Campuran Beton. *Techno (Jurnal Fakultas Teknik, Universitas Muhammadiyah Purwokerto)*, *23*(2), 95. Https://Doi.Org/10.30595/Techno.V23i2.11018

Wawan, A., & Kusdian, R. D. (2021). Analisis Perbandingan Kuat Tekan Beton Dengan Menggunakan Pasir Abu Gunung Merapi Propinsi Yogyakarta Dengan Variasi Penekanan Harian. *Sistem Infrastruktur Teknik Sipil (Simteks)*, 20–33.

SNI (1989). SN SNI S 04-18989-F : Spesifikasi Bahan Bangunan Bagian A (Bahan Bahngunan Bukan Logam). *Badan Standardinasi Nasional.* Bandung.

SNI (1990). SNI 03-1974-1990: Metode Pengujian Kuat Tekan Beton. *Badan Standardisasi Nasional.*

SNI (2002). SNI 03-2847-2002 : Tata Cara Perhitungan Struktur Beton Untuk Bnagunan Gedung.

Badan Standardidasi Nasional. Bandung.
SNI (1989). SNI 15-2049-2004: Semen Porthland. *Badan Standardisasi Nasional.* Jakarta.
SNI (2013). SNI 2847-2013 : Persyaratan Beton Struktur Untuk Bangunan Gedung. *Badan Standardisasi Nasional.* Jakarta.