Potential mixture cold lava sand and volcanic ash as a concrete admixture

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Abstract. Mount Sinabung is a mountain volcano is active that exist in North Sumatra. To minimize the impact that occurs then the ashes of volcanic and sand lava cold can be used as a material replacement in part of cement and aggregate fine. The purpose of this study was to determine the effect of using volcanic ash as a partial substitute for cement and cold lava sand as a partial substitute for fine aggregate on the compressive strength value. Variations of the mixture were made by adding 5%, 7.5%, and 10% at the immersion age of 7 days, 14 days, 21 days, and 28 days. The test object used is a cube with a size of 15 cm x 15 cm x 15 cm. Results of the study showed that the mixture variation 10% by the age of 28 days can be used as an ingredient mixed early concrete because the value of compressive strength approaching normal concrete.

1. Introduction
Mount Sinabung is a volcano in Indonesia precisely in Districts Karo with a height of 2,460 m and is the highest volcano on the island of Sumatra and is included in the category of an active volcano. Mount Sinabung has experienced repeated eruptions, and according to history Mount Sinabung last erupted in 1600. The eruption of Mount Sinabung has continued to increase from August 29, 2010 to June 9, 2019, until now Mount Sinabung is still showing its activity[1].

A lot of material that comes out of the stomach of the volcano after the volcano has experienced a large eruption. These materials include rock, sand, volcanic ash and gas. Some of these materials have not been utilized and when discharged into the river will cause increased sedimentation of rivers and streams that damage through it. Therefore, to minimize the impact by volcanic ash and lava cold it is necessary efforts to use volcanic ash and sand cold lava for use into something useful, one of which is volcanic ash as a partial replacement of cement and sand cold lava as a substitute some of the fine aggregate in the concrete mixture.

Concrete work plays a very important role in the construction industry. Almost every building that is erected, such as multi-story buildings, housing, bridges, roads, irrigation channels, dams, and other buildings, requires concrete work, both as a primary need and as a supporting element. Concrete has many advantages so it is widely used in construction, such as relatively cheap maintenance costs, concrete can carry heavy loads, and is resistant to fire. Due to a large number of uses of concrete, many are carrying out studies that can produce better concrete products. Simply put, concrete is only formed by a mixture of hydraulic cement, coarse aggregate, fine aggregate, and water.

From the explanation regarding the development of normal concrete using volcanic ash as a partial substitute for cement and cold lava sand as a substitute for some of the fine aggregate, it is very necessary to introduce it to the community to build simple houses. This study can find out how many variations of
the mixture of volcanic ash as a substitute for part of cement and cold lava sand as a substitute for some of the fine aggregate to obtain the highest compressive strength. Compressive strength also decreases with increasing laterite content, however, the strength of the concrete will increase with increasing drying age [2]. This research was also carried out to determine how much influence the volcanic ash and cold lava sand of Mount Sinabung had and can the concrete mixture of volcanic ash and cold lava sand provide good compressive strength of concrete.

1.1. Concrete
Concrete is a composite building material consisting of a combination of aggregate and cement binder. The common form of concrete is a mixture of Portland cement and mineral aggregates (gravel and sand) and water.

There are 8 types of concrete [3], which are as follows:

- Normal concrete
- Lightweight concrete
- Non-sand concrete
- Watertight concrete
- Ferro cement
- Fiber concrete
- Cyclone concrete
- Concrete vacuum (Vacuum Concrete)

The properties of concrete are influenced by the following factors [3]:

- Quality of cement, for reinforced concrete construction in general.
- Types of cement that have predetermined conditions are used.
- Comparison of Portland cement mixture, additives (additives) and water.
- How to mix components.
- Coarse aggregate (gravel or crushed stone).
- Care work accuracy.
- Age of concrete, and
- Air temperature mixing time and concrete hardening process time.

As a concrete construction material, it has advantages and disadvantages. The advantages of concrete [4] include:

- The price is relatively cheap.
- Resistant to high temperatures.
- Be able to carry heavy burdens.
- Easily formed according to construction needs.
- Maintenance/maintenance costs are small.

The weaknesses of concrete [4] include:

- Concrete has a low tensile strength, so it is easy to crack.
- The shape that has been made is difficult to change.
- Great sound reflectivity.
- The execution of work requires high accuracy.
- Hard concrete is completely impermeable to water.
1.2. Volcanic Ash as a Cement Substitute

Volcanic ash is a volcanic rock mineral including glass material which has the size of sand and gravel with a diameter of approximately 2 mm (1/2 inch) which is the result of volcanic eruptions. These tiny ash particles can have a cross-section smaller than 0.001 mm which is soft and fine, such as the result of burning wood, leaves or paper. The compressive strength value of concrete with volcanic ash is close to the compressive strength of normal concrete [5]. A mixture of 10% bottom ash or less can be used as a substitute for sand to produce significant compressive strength values for concrete [6].

Volcanic ash is insoluble in water and has very hard properties so that it is slightly corrosive and very abrasive and can conduct electricity when it is wet.

The increase and decrease in compressive strength is due to variations in the replacement of volcanic ash from Mount Merapi for cement in the concrete mixture. The increase occurred because it was caused by fine volcanic ash grains and the cavities between the aggregate grains were filled with volcanic ash grains which could minimize the existing pores.

Some of the properties of volcanic ash are:

1.2.1. Chemical Properties.

Chemically, the elements contained in volcanic ash are Al, Mg, Si, and Fe in a high enough percentage. The elements and chemical compounds found in volcanic ash are shown in the Table 1:

| Compound | Content Percentage |
|----------|--------------------|
| SiO₂     | 54.56 %            |
| Al₂O₃    | 18.37 %            |
| CaO      | 8.05 %             |
| Na₂O     | 2.95 %             |
| MgO      | 2.92 %             |
| K₂O      | 1.70 %             |
| Fe₂O₃    | 8.33 %             |
| TiO₂     | 0.71 %             |
| MnO      | 0.16 %             |
| P₂O₅     | 1.12 %             |

1.2.2. Physical Properties.

Some of the physical properties of volcanic ash are based on shape, color, appearance and size as well as absorption. It can be seen in the Table 2:
Table 2. Physical Properties of Volcanic Ash

| Physical Properties | Volcanic Ash          |
|---------------------|-----------------------|
| Shape               | Fine / granular particles |
| Color               | Reddish gray          |
| Display             | Like fine sand        |
| Size                | 0.01-0.001 mm         |
| Specific Graphite   | -                     |
| Absorption          | -                     |

1.3. Mount Sinabung Cold Lava to Replace Fine Aggregates

Cold lava is formed due to the accumulation of volcanic material at the peak during the eruption which forms a lava dome and can slide downward at times when it rains. The cold lava flow has great lunge and carrying capacity and flows together with large rocks following the flow of water, causing damage along with the cold lava flow. From the research results, cold lava sand contains two elements, namely major elements (aluminum, silica, potassium, and iron) and minor elements (iodine, magnesium, manganese, sodium, phosphorus, sulfur, and titanium).

Table 3. Elemental content of Mount Sinabung Cold Lava

| Element | Concentration (%) |
|---------|-------------------|
| SiO₂    | 80.7              |
| Fe₂O₃   | 2.72              |

Based on Table 3, cold lava sand has a high silica content and contains iron content. The higher the silica (SiO₂) content, the higher the compressive strength of the concrete than the concrete with a lower silica content [7].

2. Research Methods

The research sample consisted of volcanic ash and cold lava sand taken from Mount Sinabung in North Sumatra. The tests carried out as the initial stage of the research are sieve analysis, aggregate density, slump test, and abrasion test (Figure 1). The variation of the concrete mixture used is 5%, 7.5%, and 10%, which is a mixture of cold lava sand as a substitute for part of river sand and volcanic ash as a partial substitute for cement, with concrete ages of 7 days, 14 days, 21 days, and 28 days.
3. Results and Discussion

3.1. Slump Test
Figure 2 shows the relationship between the percentage of volcanic ash and cold lava sand with the reduction value of the concrete mixture. The decreasing value of the concrete mixture increases with the increasing percentage of the mixture of cold lava sand and volcanic ash. The increasing decrease occurs due to a mixture of cold lava sand, which has a lower water absorption rate than river sand.

![Figure 2. The relationship between slump value and volcanic ash](image)

3.2. Results of the Compression Strength of Normal Concrete
The compressive strength of the concrete is used as a cube shaped printer with a size of 15cm x 15cm x 15cm. The value of the compressive strength of concrete can be obtained with the average value of each variation for 7, 14, 21, and 28 days of age. After getting all the compressive strength values for each variation of the mixture, the comparison of the results for each age of the concrete made can be grouped as in the Table 4.
### Table 4. Normal Concrete Compressive Strength Value

| No. | Value of Concrete Compressive Strength |
|-----|---------------------------------------|
|     | 7 Days | 14 Days | 21 Days | 28 Days |
| 1   | 17.52  | 17.52   | 17.98   | 18.44   |
| 2   | 16.60  | 15.57   | 16.33   | 17.08   |
| 3   | 17.15  | 15.49   | 15.59   | 15.68   |
| Average | 17.09 | 16.19   | 16.63   | 17.07   |

In Table 4 it can be concluded that the compressive strength of normal concrete has a compressive strength that increases from 14 days, 21 days, to 28 days.

#### 3.3. Results of the Compression Strength of Volcanic Ash

The concrete compressive strength test was carried out with a specimen of a cube of size 15 cm x 15 cm x 15 cm with the immersion age of the concrete for 7 days, 14 days, 21 days, and 28 days, and variations of 5%, 7.5%, and 10%. That way there will be a comparison of each variation to get a good compressive strength value for concrete.

The relationship between concrete age and concrete compressive strength from the test results for all test schemes can be seen in Figure 3. Test the compressive strength of the concrete using a cube shaped printer with a size of 15 cm x 15 cm x 15 cm. The compressive strength of concrete is obtained from the compressive strength of the average values taken at the age of the concrete test, 7 days, 14 days, 21 days, and 28 days. From this research, it can be seen that the results obtained in the compressive strength test of concrete with the addition of volcanic ash and cold lava sand of 5%, 7.5%, and 10% on each specimen produce different compressive strength. With the addition of volcanic ash and cold lava sand of Sinabung by 5%, the age of 28 days produces a concrete compressive strength that is close to normal concrete.

The compressive strength of concrete at 7 days, 14 days, 21 days, and 28 days is below normal compressive strength, but at 28 days of concrete, 10% variation can be used as the recommended composition for concrete mixtures.

### Table 5. Compressive strength values

| Variation (%) | Results of Compressive Strength (Mpa) |
|---------------|--------------------------------------|
|               | 7 Days     | 14 Days    | 21 Days    | 28 Days    |
| 5             | 15.28      | 15.62      | 16.29      | 15.28      |
| 7.5           | 13.65      | 15.86      | 15.02      | 15.68      |
| 10            | 13.59      | 15.55      | 14.73      | 16.02      |

The results of the concrete compressive strength test with volcanic ash as a partial substitute for cement and cold lahr sand as a substitute for some of the fine aggregate are shown in Figure 3 as follows:
3.4. Effect of Volcanic on Compressive Strength

In Figure 4 you can see the effect of volcanic ash and cold lava sand on the compressive strength of concrete. It can be seen from the figure that at 10% variation and 28 days of age, the compressive strength of concrete is close to normal compressive strength, and variations of 7.5% and 10% are constant strength values. At the age of 7 days, 14 days, 21 days, and 28 days at a variation of 5%, 7.5% and 10% the compressive strength values tend to be below normal concrete compressive strength. However, the use of volcanic ash as a partial substitute for cement and cold lava sand as a substitute for some of the fine aggregate can be considered for concrete mixtures, because besides the relatively cheap price it can also minimize environmental problems for non-structural concrete needs.

From the addition of volcanic ash as a partial substitute for cement and cold lava sand as a substitute for some of the fine aggregate with a variation of 5%, 7.5%, and 10%, it will produce compressive strength on different specimens and produce a compressive strength lower than normal compressive strength. However, the use of these mixtures can still be used even in a small percentage.

From the experiment of volcanic ash as a partial substitute for cement and cold lava sand as a partial replacement for fine aggregate, it can be seen in Table 5 that the 10% variation fulfills the planned compressive strength requirements of 16.78 with a compressive strength of 16.6. Meanwhile, 7.5% and 10% have not met the compressive strength requirements planned.
4. Conclusion
Based on the results and discussion, several conclusions were drawn including:

- Replacement of cement with part of volcanic ash and fine aggregate with part of cold lava sand with variations of 5%, 7.5%, and 10% with concrete ages of 7 days, 14 days, 21 days, and 28 days results in lower compressive strength of concrete normal.
- The addition of volcanic ash as a partial substitute for cement and cold lava sand as a substitute for fine aggregate does not qualify do to the lack of influence of volcanic ash and cold lava sand, but it can still be used as a mixture of concrete and can be used by local residents for non-structural concrete.

5. References
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