The Utilization of Lapindo Powder as a Material for High Strength Concrete

As’at Pujianto\textsuperscript{*}, Hakas Prayuda\textsuperscript{1}, Fanny Monika\textsuperscript{1}, Martyana Dwi Cahyati\textsuperscript{1} and Fernanda Zulviandika\textsuperscript{1}

\textsuperscript{1} Department of Civil Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta. Kasihan, Tamantirto, Bantul, Yogyakarta, 55183, INDONESIA
*Corresponding author: pujiantoasat@umy.ac.id

Abstract. This study discusses the utilization of Lapindo powder for pozzolan material in the manufacture of high-quality concrete. The existence of Lapindo mud is one of the disasters that destroy many residential areas. This mud is still increasing in volume without being able to be utilized by the community. In terms of its chemical properties, Lapindo mud, processed into a powder, it has no hydration properties when mixed with water, but it can harden naturally. This research has investigated the characteristics of high-quality concrete by utilizing the mud of Lapindo as additional material. The examinations are workability, compressive strength, tensile strength, moisture content, water absorption, and porosity. The specimens were made in a cylindrical shape with a 75 mm diameter with a height of 150 mm. The test results show that Lapindo powder can be used as additional material to manufacture high-quality concrete. The composition suggested through this study is 10% of the weight of cement. The compressive strength for 10% Lapindo content is 45 MPa at 28 days.

1. Introduction

In recent years, the manufacture of infrastructure in a considerable number is significant enough. It makes concrete construction is in high demand. Besides the easy to be conducted, the concrete is also relatively cheaper to be obtained. The fundamental constituent of concrete consists of water, cement, coarse aggregates, fine aggregates, and reinforced concrete, often called reinforced concrete. In this regard, conventional concrete with normal quality standards becomes less desirable among construction workers. In addition to its long-time finishing, good quality construction needs are also growing the obstacles in making concrete.

The increasing concentration on weather changes due to excessive cement use is one reason the concrete becomes environmentally unfriendly [1]. Concrete made of waste is becoming an issue because it will produce green construction. The use of industrial waste and plantation waste in the making concrete makes concrete more environmentally friendly and economical [2]. High-quality concrete has many advantages, i.e., accelerating construction projects and having a tremendous environmental impact [3]. The construction of high-rise buildings also requires material properties, especially good quality concrete [4].

Making high-quality concrete using additional waste materials has been done a lot before. Some studies use residual plantation waste such as oil palm plantation waste [5], Sugar Cane Plantation Waste [6-7], Rice husk ash [8-10], and various other wastes.

The Lapindo mud eruption was one of the disasters in Sidoarjo, Jawa Timur, Indonesia, in 2006 [11]. This mud contains a composition of 55% SiO\textsubscript{2} [2]. This research will use processed powder from
the Lapindo mud eruption from Sidoarjo in making concrete. The research aims to know the effect of using Lapindo mud as additional material in concrete. The inspection of compressive strength and tensile strength with variations in the size of grain sludge that has been processed into powder will be carried out. The composition of the Lapindo powder used also varies.

2. Materials and Research Method

This research used basic ingredients for making concrete, and it was added with Lapindo powder. The primary material for making concrete consists of cement, water, coarse aggregates, and fine aggregates. The cement used in this study was type 1 Portland cement. The coarse aggregates came from Clereng, Kulon Progo Indonesia. The test result is presented in Table 1. The density of coarse aggregate produced is 2.63, and the results of the aggregate abrasion test show a yield of 33.11%, it meets the aggregate specifications in the manufacture of concrete.

The fine aggregate in this study was from Merapi Indonesia. Table 1 shows the result of testing properties of fine aggregates. The test results indicate that the density is 2.45, and the unit weight is 1.48 gr/cm³. Based on the test results, it can be concluded that this aggregate can be used as a concrete constituent.

| Parameter                  | Fine Aggregate | Coarse Aggregate |
|----------------------------|----------------|------------------|
| Specific Gravity           | 2.45           | 2.63             |
| Water Content (%)          | 7.89           | 2.31             |
| Water Absorption (%)       | 2.45           | 0.92             |
| Mud Content (%)            | 2.95           | 0.66             |
| Bulk Density (gr/cm³)      | 1.48           | 1.53             |
| Aggregate Abrasion (%)     | -              | 33.11            |

As mentioned in Table 2, Lapindo mud has been heated at 800°C for 4 hours. It can be seen that Lapindo mud particles do not have hydration properties such as cement. However, since it has the main content of silica-dioxide (SiO₂), then at ordinary temperatures, it can react chemically with calcium hydroxide (Ca(OH)₂) and forms calcium-silicate-hydrate compounds (CSH gel). Therefore, it can increase the strength of concrete. Also, the existence of mud powder in fine size can fill the concrete pores better, so that the concrete with lower porosity is obtained. The test results of Mud Powder show that there is a specific gravity of 2.08 gr / cm³, water absorption of 0.60%, and moisture content of 1.01%. The results of the chemical material of Lapindo mud both before and after it has burned are presented as follows.

| Chemical Content | Before Burned (%) | After Burned (%) |
|------------------|-------------------|------------------|
| SiO₂             | 56.68             | 53.08            |
| Al₂O₃            | 20.47             | 18.27            |
| Fe₂O₃            | 7.92              | 5.61             |
| Na₂O             | 2.27              | 2.97             |
| SO₂              | 3.21              | 2.96             |
| MgO              | 1.96              | 2.89             |
| CaO              | 2.96              | 2.07             |
| K₂O              | 1.81              | 1.44             |
| TiO₂             | 0.91              | 0.57             |

This study provides some research on variation in the amount of Lapindo powder composition and variation in the size of sludge grains. The variation of Lapindo powder composition was 0%, 10%,...
20%, 30%, 40%, 50% and 60%. This composition was taken to replace the weight of cement. Meanwhile, the grain size was granules that pass filter No. 80, 100, 120, 140, 180, and pass filter No. 200. The entire variation will be tested by compressive strength, tensile strength, water absorption, and porosity test. The specimen in this study was concrete, with a 70 mm diameter and a height of 150 mm. In the concrete mix design planning, the compressive strength planned at 28 days old concrete is 35 MPa, while the composition of each variation can be seen in Table 3 below. The variation in the size of granular powder particles, using a variation of 10%.

| Powder Variation | Material (kg) | Water | Sand  | Gravel | Cement | Lapindo Powder |
|------------------|---------------|-------|-------|--------|--------|----------------|
| 0%               |               | 204.9 | 628.1 | 942.1  | 499.8  | 0.0            |
| 10%              |               | 204.9 | 628.1 | 942.1  | 449.8  | 50.0           |
| 20%              |               | 204.9 | 628.1 | 942.1  | 399.8  | 100.0          |
| 30%              |               | 204.9 | 628.1 | 942.1  | 349.9  | 149.9          |
| 40%              |               | 204.9 | 628.1 | 942.1  | 299.9  | 199.9          |
| 50%              |               | 204.9 | 628.1 | 942.1  | 249.9  | 249.9          |
| 60%              |               | 204.9 | 628.1 | 942.1  | 199.9  | 299.9          |

3. Result and Discussion

The initial examination that needs to be done when the concrete is still not hardened is slump flow. This examination aims to know the level of workability of the concrete mixture that has been made. Based on the result of Figure 1, it can be seen that the highest slump flow is on the specimen with the Lapindo powder content of 0% with a slump value of 14.2 cm. The addition of 10% of Lapindo powder produces a slump value of 13.4 cm. The smallest slump value is found in the specimen with additional Lapindo powder as much as 60% with a 7.9 cm slump.

The percentage increase in Lapindo powder use can reduce the value of workability in fresh concrete, but is still in a reasonable condition. The evidence is in Figure 1; there is a phenomenon, i.e., the more the Lapindo powder composition increases, the smaller the slump value produced. The condition of Lapindo powder, which is quite dry, causes this material to absorb enough water. This water absorption is one reason for the decrease in slump value as the composition of the Lapindo powder increases.

![Figure 1. Slump flow of fresh concrete](image-url)

Testing of water absorption is carried out when the concrete has hardened. The aim is to find out the water content absorbed in concrete using additional ingredients, i.e., Lapindo powder. Lapindo 0%
powder mixture produces an absorption value of 3.94%. Increasing the amount of Lapindo powder can improve the absorption value in concrete but a relatively small percentage. The variations of 10% to 40% only produce water absorption values ranging from 4.30% to 4.32%. The highest water absorption in the specimen occurs in the percentage of Lapindo powder of 60%, namely 5.13%. The results shown in Figure 2 show that the increasing amount of Lapindo powder content will increase the absorption value. The absorption value produced is still in a reasonable condition so that all of this mixture can be used as a base for making concrete.

In addition to using the powder percentage in the concrete content, the Lapindo powder size was also examined to find out the best results. Through this study, it can be seen in Figure 3 the maximum size of Lapindo powder grain for the absorption of water produced. The specimen with the maximum grain size passed the filter No. 80 produces the highest absorption value of 5.23%. Meanwhile, the smaller grain size, the absorption value will decrease. The size of the granules passed filter No. 200 produces the lowest water absorption value that is equal to 2.75%.

The test specimen with a maximum size of 100 produces absorption of 4.30%, while the specimen with a maximum grain size of 120, 140, and 180 provides the same absorption value, which is equal to 3.39%. It shows that water absorption has no significant effect on these sizes or will produce a similar water absorption value. The finer the size of the Lapindo mud powder, the smaller the absorption value produced. Therefore, the grain size is very affecting. It means the finer the granules, the better the process of the concrete making. The absorption value can be one of the benchmarks in making concrete. If the concrete is very easy to absorb water, then the concrete quality will be effortless to decrease. When using reinforced concrete, the steel reinforcement in the concrete is very easily corroded, especially in constructing buildings directly related to the natural area. Based on the absorption results in all samples, Lapindo mud powder can be used in extreme field conditions such as ports, bridges, or buildings exposed to high Sulphate levels.
Porosity testing was also carried out on each variation of the test object. Figure 4 shows the results of the relationship between the percentage of Lapindo mud powder and porosity value. The specimen without using Lapindo powder produces a porosity value of 5.90%. For a specimen without using Lapindo powder, the value of porosity is 5.90%. Further, the specimen with the percentage of Lapindo mud powder of 10, 20, and 30% produce a similar porosity value of 6.45%. However, the increase of the Lapindo powder content up to 40% lead to the rise of porosity value become 6.49%. A specimen with the Lapindo mud powder content of 50% produces the porosity value of 6.69%. Meanwhile, the specimen with the highest porosity with Lapindo mud powder content of 60% cement weight. The specimen with 60% Lapindo mud powder content delivers a porosity value of 7.69%.

The increase of porosity value in the concrete shows that the content of the cavity in the concrete is increasing too. It indicates that the use of Lapindo mud powder in the concrete making process can increase the value of porosity of concrete. In the concrete making process, the porosity value can be decreased by making the material has a size that is more complex or in various shape or size. The use of Lapindo mud powder in this study still uses the inappropriate grain size, such as cement, produced well. Also, the grain size of coarse and fine aggregates should meet the specified specifications so that the size of each grain is more complex and smaller and allows the presence of cavities in the resulting concrete.

![Figure 3. Water absorption testing based on variations in test specimens with the grain size of Lapindo mud powder](image3)

The porosity testing was also conducted by varying the size of Lapindo mud powder. Figure 5 presents the relationship between the testing results of the porosity value with the passed size of the Lapindo mud powder used. The specimen with the grain size passed filter No. 80 produces a porosity
value of 7.45%, while the specimen with grain size passed filter No 100 and 120 provide the porosity value of 6.20% and 6.11%. The specimen with grain size passed the filter. No 140 produces a porosity value of 5.56%. The specimen created the smallest porosity value with the grain size passed filter No 200 is 3.59%.

Based on the previous discussion, it can be concluded that the used grain size of Lapindo mud powder affects the porosity value. The finer the used powder, the smaller the porosity value. However, the grain size of Lapindo powder cannot become the main standard for determining the quality of concrete, especially the value of porosity. Besides the grain size of powder, the grain size of fine and coarse aggregate also affects the quality and cavities volume of the concrete. Moreover, the casting process and the accuracy level of the workers also affect the number of cavities produced. During the casting process, fresh concrete should be stirred evenly and meet the rules specified in the applicable regulations. In this study, the moving process was uniformly and tried to be as homogeneous as possible.

The value of porosity is closely related to the concrete’s compressive strength and absorption in water. The more cavities in the concrete lead to the decrease of the concrete strength. Therefore, porosity testing for every study utilizing a new material for concrete making needs to be examined. Besides, the use of water also affects porosity value. The amount of water will make each constituent material difficult to blend and react, then the stirring is not perfect and causes cavities in the concrete. The use of excessive amounts of water can trigger the formation of cavities in the concrete. This phenomenon was caused by the occurrence of bleeding on the concrete, which causes the cavities. The presence of cavities was generated by the evaporates water.

**Figure 5.** Porosity on concrete based on the size of Lapindo mud powder

Figure 6 shows the relationship between water absorption and porosity. Based on the data that were obtained previously, it can be seen that the higher the porosity value, the more water absorption will be produced. Therefore, it can be concluded that the increasing value of porosity will not be suitable for quality in concrete, especially for long-term use.
Figure 6. The relationship between water absorption, porosity, and the additional materials of Lapindo mud powder

The compressive strength testing was done when the concrete is 28 days and to the specimen with cylinder shape and diameter of 70 mm, the length of 150 mm. In each variation of Lapindo mud powder consists of three specimens. Figure 7 describes the relationship between the compressive strength of concrete and the composition of the additional ingredients Lapindo mud powder as a substitute for cement. When the concrete was made without Lapindo mud powder (0%), the concrete produced 35.53 MPa compressive strength. This is following the compressive strength of a normal concrete plan, which is equal to 35 MPa. The composition variation of 10% Lapindo mud powder produces a compressive strength of 44.50 MPa. This thing shows that the additional Lapindo mud powder of 10% potentially increases the concrete compressive strength.

When using the variation of 20% Lapindo mud powder, the compressive strength was 32.86%. This phenomenon shows that using more than 10% powder will reduce the compressive strength of the concrete, even the results obtained are smaller than concrete without using additional ingredients of Lapindo mud powder. Successfully using additional ingredients of Lapindo mud powder up to 60% makes the compressive strength of the concrete continue to decline. The primary factor that affects the compressive strength in this study was curing in the concrete. Further studies should conduct the curing process for more than 28 days. The properties of Lapindo powder, which do not directly bind when mixed with water, or commonly known as pozzolanic properties.

Figure 7. Relationship between Lapindo mud powder composition with concrete compressive strength

Figure 8 explains the relationship between the grain size of Lapindo powder against the compressive strength produced. Based on the data that were obtained from the concrete with the grain
size passed the filter No 80, the compressive strength was 30.41 MPa. The concrete with the maximum grain size passed the filter. No 100 produces a compressive strength of 31.89 MPa. It shows that there was an increase in the compressive strength even though in a small amount.

The concrete with the grain size passed the filter. No 120 produces a compressive strength of 38.71 MPa. This result has no significant difference to the concrete with grain size passed the filter no 140 mm is 38.92 MPa. This phenomenon proves that the variation of grain size produced the highest compressive strength value passed the filter No 200, i.e., 41.53 MPa. In this test, there was a standard deviation value or difference between the compressive strength results among specimens that considerably vary. Therefore, it needs to carry out further studies on the grain size of aggregate to obtain results with smaller and more similar standard deviations.

![Figure 8](image1.png)

**Figure 8.** Relationship between the size of Lapindo powder grain to the tensile strength of the concrete

The tensile strength testing on the concrete was also done to know whether Lapindo mud powder can increase the tensile strength on the concrete. Moreover, Figure 9 shows the relationship between Lapindo mud powder composition against the tensile strength produced. Concrete without additional Lapindo mud powder material produced the tensile strength of 2.25 MPa when the concrete was 28 days. By adding 10% Lapindo mud powder, the tensile strength was becoming 2.97 MPa. This thing shows that when 10% of powder was added, the tensile strength increased. This occurrence also happened on concrete compressive strength testing. When using the variation of 20% powder, the tensile strength was decreasing up to 2.30 MPa. Furthermore, in the variation of 30% up to 60% powder, the tensile strength was continuously declining. This phenomenon shows that the increase in powder makes the binding capacity diminish. The optimal use of Lapindo powder was 10% of the cement weight.

![Figure 9](image2.png)

**Figure 9.** Relationship between Lapindo mud powder composition to the tensile strength of concrete
Tensile strength testing was also done to the variation in the maximum grain size of Lapindo powder. Figure 10 shows the relationship between the maximum grain size of Lapindo powder against the concrete produced tensile strength. The use of powder passed the No. 80 filter resulted in tensile strength of 1.91 MPa. The use of powder passed the filter. No 100 produced the increased tensile strength of 2.06 MPa. The maximum grain size passed the filter. No 120 produced the tensile strength of 2.32 MPa. The increase of tensile strength continuously occurred until the highest tensile strength on the concrete with the aggregate grain size passed filter No. 200. This thing shows that the grain size affected the tensile strength on the concrete even though the increase is not significant enough. The finer the grain size, the easier the powder will cover the concrete pores that are not covered by fine and coarse aggregates.

**Figure 10.** Relationship between the maximum grain size of Lapindo mud powder against the tensile strength of concrete

This research shows that the utilization of Lapindo mud powder can produce high strength concrete because it can provide a tensile strength of more than 40 MPa. For further studies, it is better to use fiber as additional material to increase the tensile strength of this high-quality concrete.

### 4. Conclusion

Based on the result and discussion above, the conclusion can be presented as follows:

a. When testing the compressive strength and tensile strength in the concrete with the additional material of Lapindo powder produces an optimum powder composition of 10% to the weight of cement.

b. The finer the size of grain powder can increase the compressive strength and tensile strength of the concrete, but the strength produced does not increase significantly.

c. The addition of powder can increase water absorption and porosity. The application of powder needs special attention.

d. The finer the Lapindo powder used will reduce the value of water absorption and porosity. As a consequence, the grain size of the powder becomes a very influential thing in the process of making concrete.

e. Concrete with a 10% Lapindo mud powder composition can be categorized as concrete with high compressive strength because it produces compressive strength above 40 MPa.

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