Effect of trass substitution in sand on the compressive and flexure strength of concrete

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Abstract. The existence of limitations in the supply of sand as a concrete material requires an alternative. On the other hand, the potential trass in Rembang is quite abundant and has not been utilized optimally. This study utilizes the potential of trass ex. Rembang is a substitution of sand in concrete with compressive and flexural strength as test parameters. Concrete with a design quality of 33 MPa is made from the split, cement, water, and sand substituted with trass 0, 20, 40, 50, 60, 80, and 100% of the weight of sand in cylinders 15/30 cm and beams 15x15x60 cm. The concrete was treated with wet burlap and tested at the 3, 7, 14, 28, and 90 days in compression also 7 and 28 days in flexure. The test results show that the presence of trass in the concrete reduce the concrete compressive strength by 17% until 42% of the concrete compressive strength without trass. Moreover, the flexural strength decreases by 7% to 23%.

Concrete using a fine aggregate in the form of trass (100% trass) has increased compressive strength with increasing age of the concrete, but with a compressive strength of 36% lower than the compressive strength of concrete with sand as the fine aggregate.

1. Introduction

Along with the development of road construction in Indonesia from year to year, the use of concrete material has become very popular because concrete is easy to make and has a fixed shape when it has reached a certain time. Concrete constituent materials consisting of cement, fine aggregate, coarse aggregate, and water are often additionally added with certain ratios. One of the additives that can be used in the concrete mix is trass. Trass can be assessed for its performance on concrete pavements [1].

The use of trash can be considered as a mixture in the manufacture of concrete such as to reduce the use of sand. Trass can be used in partially substituted concrete mixes with fine aggregate [2]. The use of trash can develop the economic value of the community because it can reduce the amount of sand used. The percentage of using trass as a partial substitute for fine aggregate needs to be considered [3].

In the area of Rembang Regency, precisely in Terjan Village, Kragan District, many trass materials that can be used as added ingredients in concrete mixtures, so that the natural potential in the area can be developed. Trass is a mineral containing silica oxide (SiO2) that has been weathered [4], which hardens easily when in contact with water. The content of silica oxide compounds (SiO2) and alumina oxide (Al2O3) which when mixed with water will have cement-like properties. Pozzolan reaction, material gradation, and morphology (physical properties) are the main factors in determining the effectiveness of the mixture [5].
The trass weathering process is caused by the presence of water which results in the escape of most of the basic components such as CaO, MgO, and NaO contained by the minerals of the original rock. The CaO compound undergoes the first process, followed by the next compound according to the rock-forming minerals. With the occurrence of this process, SiO2 compounds. Active A12O3 will determine the quality of trass deposits that occur in the next period [6]. Trass is resistant to sulphate salts and acid water, because the chemical reaction of SiO2 and A12O3 in the formed trasses is acidic. The characteristics of the trass can be used in cement mixtures [7]. Natural pozzolan or trass can affect cement properties [8]. In its utilization, trass can be used as the basic capital for the development of the local economy of the community [6]

Several studies on trasses have been carried out for different areas to determine the properties, mechanical properties, and utilization of trasses for construction materials. The trass of the Samigaluh Kulon Progo area for mortar mix were studied [9] and [10] examined the effect of adding two different types of trass to clinker with trass from the Turkey region. Research [11] tested water-permeable concrete using some of the trass for the concrete mix. Treatment of concrete with a trass mixture is more effective for a minimum of 14 days so that the strength of the concrete can be optimal [12]. The increase in compressive strength occurs in concrete that is given a trass substitution of 20% of the proportion of sand [2], an increase of 5% compared to concrete without a trace. While in the research of [3] and [13] it was shown that the split tensile strength increased by 16.56% and 17.40%, respectively, in the concrete treated with 10% of the fine aggregate proportion. [13] also noted that 10% of the trass to sand will produce optimum compressive and tensile strength.

In developing the economic factors of the people in the Rembang area, trass can be used as an alternative step as an ingredient in the manufacture of concrete mixtures, namely as an added material to replace fine aggregate (sand). This study aims to determine the effect of trass substitution on the sand in planning the manufacture of concrete in terms of compressive strength and flexural strength of the concrete by utilizing the potential of trass from the Rembang Regency area.

2. Material and experiment work
This study uses a research method through a testing process in the laboratory with the test object in the form of a 150/300 mm concrete cylinder for compression testing and a concrete beam measuring 150x150x600 mm for flexural testing as shown in Figure 1.

![Figure 1. Cylinder and concrete block](image)

2.1. Materials. Concrete constituent material in the form of fine aggregate sand ex. Muntilan, trass from Rembang Regency, coarse aggregate (split) ex. Karang Jati, OPC Type I cement for general use, as well as water that meets the requirements for concrete. All materials used are in an as-is condition which then passes a properties test before mixing. Properties tests carried out include sieve test [14], water absorption [15], fine grain content test through filter no. 200 [16].

Trass used from Rembang Regency are yellowish-white to brownish white. In the visual Scanning Electron Microscopy (SEM) magnified 1000x and 3000x, it can be seen that the shape of the trace particles is irregular, in the form of flakes, dispersion packing as in Figures 2 and 3, while the chemical components that make up the trace are the results of the X-Ray Fluorescence (XRF) test for the Rembang area shown in Table 1.
Table 1. XRF test result of trass Rembang

| Component | Result | Unit  |
|-----------|--------|-------|
| Al2O3     | 5.8843 | mass% |
| SiO2      | 42.0383| mass% |
| P2O5      | 0.236  | mass% |
| K2O       | 4.6124 | mass% |
| CaO       | 3.1196 | mass% |
| TiO2      | 0.3437 | mass% |
| MnO       | 0.1173 | mass% |
| Fe2O3     | 3.5104 | mass% |
| Rb2O      | 0.0123 | mass% |
| SrO       | 0.1657 | mass% |
| ZrO2      | 0.0261 | mass% |
| BaO       | 0.1716 | mass% |
| Balance   | 39.7625| mass% |
| Total     | 100.0002| mass% |

Source: Integrated Laboratory of UNDIP

2.2. Mix Proportion. The design of the comparison of the composition of the concrete mixture must pay attention to the factors of viscosity, durability, strength, and economy so that the planned compressive and flexural strength of the concrete can be achieved. The planned composition of the concrete mix $f'_{c} = 33$ MPa using the Design of Experiment (DOE) method with a water-cement factor of 0.42. The proportion of sand obtained is then replaced with trass with a proportion of 0; 20; 40; 50; 60; 80; and 100% of the required amount of sand. The composition of the ratio of each cubic meter of concrete mix with traces is stated in Table 2.

2.3. Experimental works. The specimens made are 150/300 mm concrete cylinders for compression testing and 150x150x600 mm concrete blocks for bending tests. For each variation of the mixture, the workability test was carried out with the slump test as shown in Figure 3. The test object that had been made was then treated by covering it with a wet sack until it was close to the testing time.
| Variation of trass (%) | Proportion / m3 | Cement (kg) | Sand (kg) | Coarse Aggregate (kg) | Water (kg) | Trass (kg) |
|-----------------------|----------------|-------------|-----------|-----------------------|------------|------------|
| 0 (control)           |                | 405         | 601.0     | 1249                  | 170        | 0          |
| 20                    |                | 405         | 480.8     | 1249                  | 170        | 120.2      |
| 40                    |                | 405         | 360.6     | 1249                  | 170        | 240.4      |
| 50                    |                | 405         | 300.5     | 1249                  | 170        | 300.5      |
| 60                    |                | 405         | 240.4     | 1249                  | 170        | 360.6      |
| 80                    |                | 405         | 120.2     | 1249                  | 170        | 480.8      |
| 100                   |                | 405         | 0.0       | 1249                  | 170        | 601.0      |

The compressive strength test of cylinder concrete [17] was carried out when the concrete was 3, 7, 14, 28, and 90 days for all variations, while the flexural strength test was carried out when the concrete was 14 and 28 days. For each variation and test, 3 (three) test objects are made each. The value of the compressive strength of a concrete cylinder can be calculated using Equation 1, where \( f'_c \) is the compressive strength (N/mm\(^2\) or MPa), \( P \) is the maximum compressive force (N), and \( A \) is the area of the compression area (mm\(^2\)).

\[
f'_c = \frac{P}{A} \text{ (MPa)}
\]

(1)

As for the flexural test, the beam test specimens were tested for the flexural strength of the concrete which was directly loaded with a distance between supports of 450 mm [18]. The flexural strength is calculated using Equation 2 where \( f_{lt} \) is the flexural strength (MPa), \( L \) = the span length between the two support blocks (mm), \( b \) = the average beam width at the collapse section (mm), and \( d \) is the average beam height, flat on the collapsing section (mm). Tests of compressive strength and flexural strength are shown in Figure 6 and Figure 7.

\[
f_{lt} = \frac{3PL}{2bd^2} \text{ (MPa)}
\]

(2)
3. Result and discussion

The results of the sieve analysis on the aggregates used in this study indicate that the sand belongs to zone 1 group [14], which is coarsely graded with a Fineness Modulus (FM) value of 3.18 and the fine grains pass sieve no 200 of 6.98%. Split belongs to the split group with a maximum size of 40 mm with FM = 7.31 and fine grains of 0.35%, while the trass belongs to the zone 3 group, which is somewhat finely graded with FM = 2.09 and the fine grains pass the 200 sieves of 17.59%. Absorption for split, sand, and trass were respectively 0.94; 1.84; and 3.21% while the specific gravity value is 2.63; 2.49 and 2.39. The sieve analysis curves are shown in Figures 8 to 10.
The combination of sand gradation and split for the planned concrete mix results in the proportion of sand in each m³ of concrete is 601 kg and the split is 1,249 kg. This proportion of sand is substituted with trass as much as 0, 20, 40, 50, 60, 80, and 100% of the weight of the sand. Finer trass grains mixed with coarser sand grains produce different workability and density for each variation, as shown in Figure 11.

Figure 11 shows concrete without trass substitution (0% trass) has higher slump and density values than concrete substituted with trass. Substitution of trass 40 and 50% of the weight of the sand for the same phase value resulted in the same lowest slump value of 30 mm, while the substitution of trass 80 and 100% (concrete without sand) had a slump value of 35 mm. The specific gravity of concrete for all variations that use trass is in the range of 2255 to 2323 kg/m³ which is lower than concrete without trass with a density of 2362 kg/m³.

The compression test of the concrete cylinder was carried out at the age of 3, 7, 14, 28, and 90 days on all variations using a compression test tool. The results are shown in Table 3 and Figure 12 are the average values of the three test objects for each variation in the age of the concrete test. The compression test showed that the concrete with the trass substitution experienced a decrease in the compressive strength in all variations compared to the concrete without the trass substitution. The percentage of trass 80% was the most significant decrease, which was 42.43% compared to concrete without a trass when the concrete has aged 28 days. The percentage of trass 40% produces the highest compressive strength for concrete with a trass substitution, however, the value is 17.30% lower when compared to concrete without trass. The same slump values at the substitution of 40 and 50% resulted in nearly the same compressive strength on the compressive strength curve. The concrete mixture in which all the sand was replaced by trass had a lower compressive strength of 36.73% than the concrete mixture which used sand as the fine aggregate.

Table 3. Compressive strength of concrete in all variations

| Age (Days) | Substitution of trass | Compression strength (MPa) | % Trass | Slump (mm) | Density (kg/m³) |
|------------|-----------------------|----------------------------|---------|------------|-----------------|
|            | 0 20 40 50 60 80 100 |                            |         |            |                 |
| 3          | 20.30 15.27 21.41 18.91 13.88 12.12 15.05 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |
| 7          | 26.16 20.20 23.88 23.62 15.48 14.27 16.66 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |
| 14         | 29.72 22.66 26.73 23.68 19.85 17.24 18.27 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |
| 28         | 33.27 23.90 27.52 26.08 19.89 19.19 21.05 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |
| 90         | 33.87 24.93 27.48 27.69 22.71 20.46 23.64 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |

| decrease in 28 days (%) | 0 28.16 17.30 21.61 40.22 42.32 36.73 | 0 20 40 50 60 80 100 | 55 50 30 30 40 35 35 | 2362 2283 2323 2301 2260 2235 2255 | 2362 2283 2323 2301 2260 2235 2255 |
In Figure 12 it is shown that all variations experience an increase in strength with increasing age of concrete. From the age of 28 to 90 days of concrete, the strength of the concrete is relatively stable, although the addition of strength is not significant anymore. As for the flexural strength that was tested when the concrete blocks were 7 and 28 days old as shown in Figure 13, it can be seen that when the concrete mixture was treated with trass 20% of the weight of the sand showed higher flexural strength than concrete without trass both at the age of 7 and 14 days. Trass percentage 40% shows the same flexural strength as concrete without the trass at 28 days but the difference is 3 MPa when it is 7 days old. The lowest flexural strength of 7 days of age for concrete with trass substitution is at 80% trass substitution, which is 2.1 MPa, but at 28 days, 100% trass substitution (concrete without sand) shows the lowest flexural strength of 2.9 MPa. The concrete, where all fine aggregate was replaced by trass (100% variation) experienced a decrease in flexural strength of 23.68% when compared to concrete using sand as fine aggregate, from 3.8 MPa to 2.9 MPa at 28 days.

Based on the results of these studies, it can be said that the substitution of trass in the concrete mixture as a substitute for sand reduces the compressive strength and flexural strength of the concrete, the difference in properties between sand and trass both in fineness, specific gravity and absorption is a contributor to the decrease. If in the research of Salassa et al. [2] and Mongisidi et al. [13] it is stated
that the substitution of trass as a substitute for sand increases the compressive strength, in contrast to this study which showed a decrease in the compressive strength, as happened in the study of Ghahari et al. [1] and Lukar et al. [19] who also stated that the trass did not increase the compressive or tensile strength. In [1] research it was also stated that the compressive strength of concrete decreased up to 35% compared to plain concrete, while in this study a decrease in compressive strength occurred in the range of 17 to 42% and a decrease in flexural strength to 23% when the concrete was 28 days old due to the substitution of trass.

4. Conclusion
The use of trass from Rembang Regency as a substitute for sand in the concrete mixture reduces the compressive and flexural strength of the resulting concrete, although for the percentage of trass 20% the flexural strength is slightly increased compared to concrete without a trass. Utilization of trass 40-50% of the weight of sand is possible to get the most optimal compressive and flexural strength for concrete by substitution of trass by considering the decrease in compressive strength of 17-21% and 8% for flexural strength.

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