Influence of groundnut shell ash on compressive and tensile strengths of concrete

Samsunan1*, I Y Salena1, Rosiana2 and Ruslaini2

1 Department of Civil Engineering, Faculty of Engineering, Teuku Umar University, Alue Peunyareng street, Ujong Tanoh Darat, Meureubo, Aceh Barat, Aceh 23615, Indonesia

2 Students of Civil Engineering, Faculty of Engineering, Teuku Umar University, Alue Peunyareng street, Ujong Tanoh Darat, Meureubo, Aceh Barat, Aceh 23615, Indonesia

*Email: samsunan@utu.ac.id

Abstract. Research objectives are to determine the effect of groundnut shell ash used as partial cement replacement on concrete compressive strength. Groundnut shell ash obtained from the combustion results and passed sieve No. 200. Design mix is 21.7 MPa, with different variation percentage of groundnut shell ash in the order of 0%, 5%, 7.5%, 10% and 12.5% as partial replacement of cement for mixes. Total of 60 concrete specimens with 150 mm in diameter and height of 300 mm and tested for compression and tensile strength in 14 and 28 days. The result according to variations percentages in compression strength test on average at the age of 14 respectively were 18.495; 19.250; 20.382; 22.647 and 20.005 MPa. Whereas 28 days respectively were 18.495; 19.250; 20.382; 21.703 and 22.741 MPa. The results in tensile strength at the age of 14 respectively were 2.218; 2.029; 1.746; 1.557 and 1.463 MPa and 28-day age concrete respectively were 1.934; 2.029; 2.123; 2.029 and 1.840 MPa. The highest compressive and tensile strength in days 14 were 22.647 and 2.218, and in days, 28 were 22.741 and 2.123. It was observe that the strength has increased and groundnut shell ash seems promising material in concrete production.

Keywords: Compressive strength, Groundnut shell ash, tensile strength and normal concrete

1. Introduction

Groundnut (Arachis hypogea) is widely cultivated in Indonesia, but groundnut shells only become waste [1]. The Government of West Aceh District in 2019 developed 4,000 hectares of groundnut plants with a total harvest of 1.25 tons per hectare [2]. The results of the chemical properties test in Baristan [3] show that the peanut shell contains groundnut SiO2 (19.06%), CaO (7.53%), K2O (5.55%), Al2O3 (4.6%), ferrous oxide (1.59%), MgO (0.18%), Na2O (2.71%). Lakshmi and Sagar [4] state that the silica content in groundnut shells, so that it can be used as a building material for concrete construction and used as an alternative for conducting research as a partial substitute for cement. Groundnut shell ash is composed of ferrous oxide, aluminium oxide, magnesium oxide, calcium oxide, sodium oxide, potassium oxide and silica so that it has the potential as agent concrete.
Portland cement is an inorganic binder, which is mix with water as a hydraulic binder. Tjokrodimuljo [5] states that Portland cement combines fine aggregate and coarse aggregate so that it hardens into concrete. The raw material components for Portland cement are; Limestone (CaO) = 60 - 67%; Silica sand (SiO2) = 17-25%; Alumina (Al2O3) = 0.3 - 0.8%; Magnesia (MgO) = 0.3 - 0.8% and sulfur (SO3) = 0.3 - 0.8%. SNI 15-2049-2015 defines Portland cement as hydraulic cement produced by grinding Portland cement slag mainly consisting of calcium silicate, which is hydraulic in nature and milled together with additional materials in the form of one or more crystalline forms of calcium sulphate compounds and may be add with other additives [6]. The use of groundnut shell ash as a partial substitute for cement in concrete can reduce costs and prevent environmental pollution. It is also expected to be able to cover the cavities or pores between the aggregate particles, by filling the cavities it will increase the area of the concrete so that the ability of the concrete to withstand loads can be perfect.

2. Materials and Methods

This research was conducted at the Laboratory of the Department of Civil Engineering, Teuku Umar University. Concrete forming materials consist of coarse aggregate, fine aggregate, cement, water and groundnut shell ash (AKKT). This research begins with material preparation, equipment preparation, processing of peanut shells, checking the physical properties of the aggregate, planning the concrete mix (mix design), working on the concrete mix, testing fresh concrete (slump test), making the test object, treating the test object, and testing.

2.1. Materials

The materials used are coarse aggregate / gravel, fine aggregate / sand, cement, water and groundnut shell ash. Coarse aggregate in the form of crushed stone (split) from one of the stone crushers at Nagan Raya district. The sand used comes from the Krueng Meurubo River, of Aceh Barat district. Groundnut shells come from Pante Ceureumen, Aceh Barat district. Coarse aggregate and fine aggregate are for physical properties checked to meet the quality of the material according to ASTM standards. Examination of aggregates is in the form of sieve analysis, bulk density, specific gravity and absorption. The cement has checked for the integrity of the package and only seen visually for the lump and smoothness of the cement. Water is not be checked because it meets the water quality requirements for concrete mixtures. The ash from the peanut shells checked for chemical elements according to the chemical content in cement.

| Number | Composition            | Percentage |
|--------|------------------------|------------|
| 1      | Silica oxide (SiO)     | 19.06 %    |
| 2      | Potassium oxide (K$_2$O) | 7.53 %   |
| 3      | Calcium oxide (CaO)    | 5.55 %     |
| 4      | Aluminium oxide (Al$_2$O$_3$) | 4.6 %   |
| 5      | Sodium oxide (Na$_2$O) | 2.71 %     |
| 6      | Ferro oxide (FeO)      | 1.59 %     |
| 7      | Magnesium oxide (MgO)  | 0.18 %     |

Table 1 indicates that the groundnut shell ash contains a lot of silica oxide and Calcium Oxide also which is mostly contained in cement.

2.2. Method

This research uses normal concrete with concrete quality $f'c = 21.7$ MPa. Planning is based on the method of comparing the weight and volume of the concrete forming material. The percentage of groundnut shell ash (GSA) used as a partial substitute for cement is 0%, 5.0%, 7.5%, 10.0% and 12.5%.
The test is at 14 days and 28 days of age in the form of a compressive test and tensile test. The number of test specimens is 30 cylindrical Ø15 cm, H = 30 cm with variations in the percentage of groundnut shell ash is 3 pieces.

Table 2. Research design

| Specimens code | Proportion of groundnut shell ash | Number of specimen by Testing method and age of testing |
|----------------|----------------------------------|------------------------------------------------------|
|                |                                  | Compressive test                                      |
|                |                                  | 14 day      | 28 day      | 14 day      | 28 day      |
| GSA0           | 0 %                              | 3           | 3           | 3           | 3           |
| GSA 5          | 5.0 %                            | 3           | 3           | 3           | 3           |
| GSA 7,5        | 7.5%                             | 3           | 3           | 3           | 3           |
| GSA 10         | 10.0 %                           | 3           | 3           | 3           | 3           |
| GSA 12.5       | 12.5%                            | 3           | 3           | 3           | 3           |
| Summary of age’s testing |       | 15          | 15          | 15          | 15          |
| Summary of method |     | 30          | 30          |
| Summary of specimen | | 60          |

The tests are carrying out after the test object is first remove from the soaking tub the day before the test is carry out after the treatment process. Then let stand for 24 hours until the test object is surface dry, then weighed to get the weight per specimen. Compressive tests and split tensile tests were carrying out at the age of 14 and 28 days using a compression tested machine.

3. Results and Discussions

3.1. Result of materials properties

3.1.1. Physical aggregate properties

The results of the examination of the physical properties of coarse and fine aggregates are in the form of bulk density, specific gravity saturated surface dry, specific gravity oven dry, absorption and fineness modulus (FM) of aggregate, as shown in the table 3.

Table 3. Result of materials properties

| Material Checked | Bulk density | Specific Gravity | Absorption | Fineness Modulus (FM) |
|------------------|--------------|------------------|------------|-----------------------|
|                  | Unit         | Sat. Surface Dry| Oven Dry   | (%)                   | (%)                   |
| Coarse Aggregate | Result       | 1.98             | 2.663      | 2.602                 | 2.348                 | 6.695                 |
| Requirement      | 1.6 – 1.9    | 1.60 – 3.20      | 1.60 – 3.20| 0.2 – 4.0             | 5.5 – 8.5             |
| Reference        | ASTM         | ASTM             | ASTM       | ASTM                  | ASTM                  |
| Fine Aggregate   | Result       | 1.817            | 2.473      | 2.426                 | 1.956                 | 3.049                 |
| Requirement      | >1.445       | 1.60 – 3.20      | 1.60 – 3.20| 0.2 – 2.0             | 2.2 – 3.1             |
| Reference        | Orchard      | ASTM             | ASTM       | ASTM                  | ASTM                  |

The results of physical properties checked of the aggregate show that all material checks have met the requirements. Only the results of the examination of the bulk density coarse aggregate are higher than required.
3.1.2. Result of slump test
The results of the slump test indicate that the use of groundnut shell ash as a substitute for part of the cement in the concrete mixture can reduce the slump test value, as shown in Figure 1 below.

![Slump Test Chart](image)

**Figure 1.** Value of slump test chart

Fig. 1 shows that the more the percentage of groundnut shell ash, the thicker the concrete, but it is still within the planning boundary between than 7.5 - 10 cm.

3.1.3. Weight of specimen
The substitution of groundnut shell ash (GSA) for cement in concrete affects the density of the concrete as shown in Figure 2 below.

![Weight of Sample Chart](image)

**Figure 2.** Weight of sample

From the figure 2 above, it shows that the more addition of groundnut shell ash causes the concrete to become lighter. Based on the age of the concrete, the test at the age of 28 days is lighter than the concrete at the age of 14 days.
3.1.4. **Result of compression test**

The results of the concrete compressive test indicate that the use of groundnut shell ash in the concrete mixture can increase the compressive strength of the concrete. The results of the concrete compression test of 14 days and 28 days of age are in Figure 3 below.

![Figure 3. Compressive strength test](image)

Figure 3 above, shows that the concrete test of age 14 shows an increase in the compressive strength of the concrete, with a composition of GSA content up to 10%, but decreases at 12.5%. The maximum compressive strength is obtained at the composition of 10% GSA, with value of linear regression of $y = 0.6417x + 18.231$. Whereas in the 28 day age test, the greater the use of GSA, the higher the results of the concrete compressive test with a linear regression of $y = 1.0945x + 17.231$. In this study, the maximum concrete compressive strength test results occurred at a composition of 12.5%.

3.1.5. **Result of split tensile test**

The results of the split tensile test at the age of 14 days and 28 days with the percentage of peanut shell ash aged 14 days at a variation of 0%; 5.0%; 7.5%; 10.0% and 12.5% by weight of cement, respectively (MPa) is 1.580; 1.895; 1.679; 1.356 and 1.329 MPa. The results of the split tensile test aged 28 days were 1.761; 1.891; 1.895 and 1.840 MPa. More details can be seen in Table 4 the increase or decrease in the tensile strength of concrete at the age of 14 and 28 days as follows:

| Age’s     | Tensile strength (MPa) |
|-----------|------------------------|
|           | 0%   | 5.0% | 7.5% | 10.0% | 12.5% |
| 14 days   | 1.580| 1.895| 1.679| 1.356 | 1.329 |
| 28 days   | 1.749| 1.761| 1.891| 1.895 | 1.840 |

The results of the split tensile test at the age of 14 days showed that the use of soil skin ash reduced the tensile strength of the concrete. The optimum tensile strength of 14 days at 5.0% is 1.895 MPa and the lowest is at 12.5% which is 1.329 MPa. While the results of the split tensile test at the age of 28 days have increased with the optimum value at 10.0% variation, namely 1.895 MPa and the lowest at the percentage of 5.0% at 1.761 MPa. The results of the comparison of the tensile strength of concrete at the age of 14 and 28 days shown in Figure 4 below.
From Figure 4 shown that the split tensile test at age 14 decreased the split tensile strength due to the use of GSA based on the equation \( y = -0.1982x + 2.3972 \) with a value of \( R^2 = 0.9756 \). Meanwhile, in the 28-day test, there was also a decrease in split tensile strength with the equation \( y = -0.0188x + 2.0474 \), where the value of \( R^2 = 0.0762 \).

3.2. Discussion
The effect of substitution of GSA as a partial substitute for cement can affect the performance of concrete and the strength of the concrete. The use of GSA can cause the concrete to become thicker by decreasing the slump test value. The use of GSA also affects the density of concrete, where the more GSA composition, the lighter the concrete. This occurs because the density of GSA is much lighter than the density of cement. So that it can use be as an alternative use in mixing lightweight concrete. Based on the age of concrete, the weight of concrete at 28 days is lighter than that of 14 days. The longer the life of the concrete, the lighter it will be.

The results of the concrete compressive test show that the use of GSA can increase the compressive strength of concrete. The 28-day-old concrete test showed a more significant increase in the compressive strength of the concrete compared to the 14-day. The use of GSA in the split tensile test was not able to increase the results of the split tensile test. In the 14 days test, the split tensile strength decreased due to the substitution of GSA in the concrete mixture. At 28 days of age testing, there was an increase in the tensile strength of the split to 10% composition, but at larger compositions, the split tensile strength decreased. This can be show based on the linear regression value which is negative, as in a good agreement with others [5,6].

4. Conclusions
The results of the slump test show a decrease in the slump value, the higher the percentage of peanut shell ash the higher the water absorption in the concrete mixture. The weight of the concrete is lighter by substituting GSA as a partial substitute for cement in the concrete mixture. The results show that partial substitution of GSA in the concrete mixture can increase the compressive strength of concrete. The split tensile test results are not able to increase the split tensile strength with the use of GSA in the concrete mixture.
Acknowledgements

We thank you for the participation of all parties, especially the Civil Engineering Laboratory of Teuku Umar University. We thank too for the leaders of the civil engineering department, and the leaders of the engineering faculty at Teuku Umar University.

References

[1] Sumarno 1986, Teknik Budidaya Kacang Tanah, Penerbit Sinar Baru, Bandung.
[2] Safrizal., 2019, https://aceh.antara.news.com/berita/197370/aceh-barat-kembangkan-4000-hektare-tanaman-kacang-tanah, Aceh Barat.
[3] Baristan., 2019, Komposisi Kimia Abu Kulit Kacang Tanah, Balai Riset dan Standarisasi Kementerian Perindustrian, Banda Aceh.
[4] Lakshmi, N.V., dan Sagar, P.S., 2017, Study on Partial Replacement of Groundnut Shell Ash With Cement, Challenge Journal of Concrete Research Letters 8 (3) (2017) 84–90, GMR Institute of Technology, Razam, Andhra Pradesh 532127, India.
[5] Tjokrodimuljo,K., 1996, Teknologi Beton, Biro Penerbit Universitas Gadjah Mada, Yogyakarta.
[6] Badan Standarisasi Nasional, 2015, SNI 2049-2015, Semen Portland, Badan Standarisasi Nasional, Jakarta.