IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Compressive strength of laterite soil stabilized with rice straw ash and fly ash based geopolymer

IOP Conf. Series: Earth and Environmental Science **419** (2020) 012026 doi:10.1088/1755-1315/419/1/012026

Compressive strength of laterite soil stabilized with rice straw ash and fly ash based geopolymer

P R Rangan[1], R Irmawaty[1], A A Amiruddin[1], and B Bakri[1]

[1]Department of Civil Engineering, Faculty of Engineering, Universitas Hasanuddin, Makassar, Indonesia

E-mail: inersia.structure@gmail.com

Abstract. This study discusses the use of rice straw ash, fly ash and alkali activators (NaOH) to bind laterite soils, where the hardening process is carried out at room temperature to form geopolymers. Comparison of the binder composition used consisted of straw ash: fly ash: laterite soil that is 0.417: 0.167: 0.417 based on weight ratio, using a base activator (NaOH). Flow testing on new geopolymers shows that all materials are well bound and there is no segregation. The specimens are curing until 3, 7 and 28 days old. There are two curing methods used, which are keep in the room temperature and immersed in fresh water, to observe the resistance of the specimens to environmental. Experimental results show that laterite soil with straw ash-fly ash based geopolymer can provide sufficient compressive strength.

1. Introduction

Fly ash is produced from power plants that use coal as fuel. The residue from coal combustion is fly ash and bottom ash. The consumption of electrical energy continues to increase from year to year resulting in an increase in the amount of fly ash and bottom ash. Fly ash is rich in silica and alumina, thus it can be mixed with Portland cement type I (Ordinary Portland cement, OPC) to produce concrete that has low-medium hydration and good durability. In addition, fly ash has been used in conjunction with the Portland cement clinker to produce blended cement [1]. However, Portland cement clinker production requires large quantities of raw materials in the form of limestone and soil. Limestone is a non-renewable resource. Continuous exploitation will damage the environment around limestone mining sites. Currently, there is still a lot of fly ash and bottom ash being dumped into the disposal ponds and only a small amount is reused as cement and concrete [2].

Geopolymers have become a suitable material for reusing fly ash which is rich in silica and alumina [3]. Indonesia is one of the rice producing countries. Every harvest, a number of husk ash, straw ash which is the result of burning rice husk and straw ash are wasted, then research is needed to utilize abundant rice husk ash and straw ash as building material or soil stabilization. From some related literature, rice husk ash contains silica, alumina and lime, thus it can be used as material to make cement [4][5]. A number of studies have also shown that husk ash can be used in geopolymer manufacturing [6][7].

There are a number of areas which are mostly covered by laterite soils and it is difficult to find suitable building or roads materials. Several attempts to increase the strength of laterite soils have been made, so that it is expected to become a better building material by mixing cement or geopolymers [8][9].

This study aimed to use rice straw ash, fly ash, Na (OH) to improve compressive strength of laterite soil.

2. Materials

2.1. Fly Ash (FA)
Fly ash used in this study was collected from waste of Jeneponto coal-fired power plant, South Sulawesi, Indonesia. All fly ash particles pass the sieve No. 200 (0.075 mm). Fly ash has a specific gravity of 2.65. From the sieve analysis, it is obtained the percentage value of fly ash that passes the sieve No. 200 more than 50%, with a grain diameter ranging from 0.00277 - 0.07522 as presented in Table 1.

Table 1. Physical properties of fly ash.

Characteristics	Value
Specific gravity	2.65
Water absorption	26.42 %
Sieve analysis test	> 50 % pass sieve No. 200

2.2. Laterite Soil (LS)
Laterite soil was obtained from fields in the Gowa area, South Sulawesi, Indonesia. Laterite soil must be crushed to pass the sieve No. 8 (2.36mm). Engineering properties of laterite soil is shown in Table 2. This soil is classified as heavy clay (CH) according to Unified Soil Classification System (USCS) [10].

Table 2. Engineering properties of laterite soil.

Properties	Value
Specific gravity	2.65
Plastic limit (PL)	33.90 %
Liquid limit (LL)	65.46 %
Plastic index	31.57 %

2.3. Rice Straw Ash (RSA)
Locally available Rice straw ash (RSA) was collected from open-field burning in locally small heaps, in Toraja, South Sulawesi, Indonesia. Rice straw was incinerated in tin box furnace under controlled conditions for production of RSA. After burning at 800 - 900^{o}C for one hour, then RSA is pulverized in the ball mill until the average particle size passes the sieve No. 50 (0.3mm) and 10% pass the sieve No. 100 (0.6 mm). The physical characteristics of RSA are shown in Table 3.

Table 3. Physically characteristic of RSA.

Characteristics	Value
Specific gravity	2.36
Fine Aggregate water absorption	172.78%
Sieve analysis	< 10 % pass sieve no.100

2.4. Liquid Alkaline Activator
Liquid alkaline activator was sodium hydroxide (NaOH) solution with a concentration of 12 Molar.

2.5. XRF Analysis
XRF analysis was conducted to determine the chemical composition of laterite soil, fly ash and RSA.

2.6. Laterite Soil-Rice Straw Ash-Fly Ash
Geopolymers in this study are a mixture of laterite soil, RSA, FA and NaOH activators. The FA content was fixed at 41.66% of the total mix weight. LS: RSA: FA ratios were 41.66: 16.66: 41.66. From the initial trial mixed, geopolymer composition was obtained, as presented in Table 4. The method of mixing fly ash, laterite soil, NaOH and water is shown in Figure 1. The amount of water used was also calculated to obtain optimal laterite soil compaction.

Table 4. Geopolymer mortar mixtures (1 m3).

Materials	Weight (Kg)
Water	125.690
NaOH	60.392
Rice straw ash	60.392
Fly ash	150.979
Laterite soil	150.979

2.7. Mixing Procedure
Mixing method used in this research as follows:
- Laterite soil + fly ash + rice straw ash, mix in dry conditions for 1 minute (slow speed).
- Put the alkali activator (NaOH) that has been dissolved in water, mix for 2 minutes.
- Blend manually for 1 minute.
- Laterite soil, fly ash and rice husk ash, activator solution and water, mix with mixing machine (high speed) for 10 minutes. Total mixing time is 14 minutes.

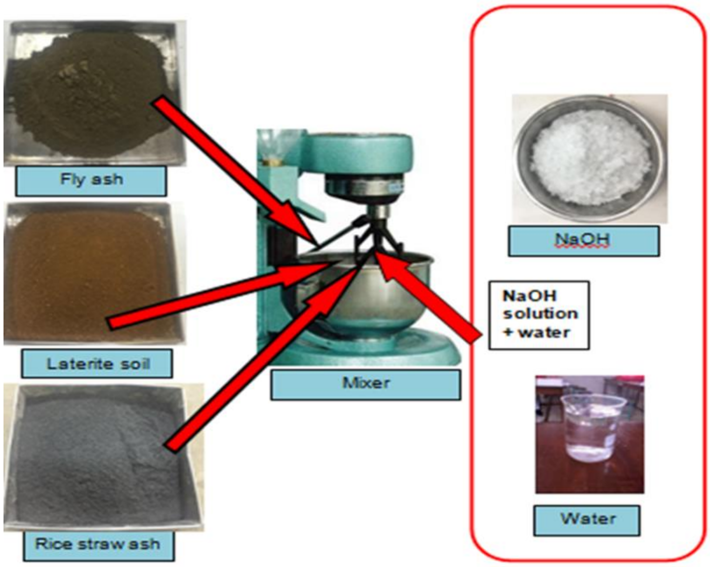

Figure 1. Mixing geopolymer.

2.8. Consistency
Flow or consistency of the mixture is conducted based on SNI 03-6825-2002 [11]. In this research used water to solid ratio of 0.35, with flow equal to 110 ± 5% of fresh mortar. The value of flow or consistency is then maintained for each mix design performed as an indication that the mixture used has the same condition.

2.9. Compaction and Curing Method
This study was designed on a mortar geopolymer with a cylindrical specimen diameter of 50 mm and height of 100 mm. The specimen cured at room temperature of 20o C. The specimens were cured until the age of compressive strength testing was carried out.

2.10. Compressive Strength and Modulus of Elasticity
Based on SNI-03-6825-2002, a compressive strength test is to provide a continuous monotonic static load at a constant rate on the test specimen that creates compressive stress. Two test specimens were used for the compressive strength test. A compressive strength test was performed using a Universal Testing Machine, two LVDT 10 mm mounted vertically and a set of data logger tools connected to a set of computers. LVDT is placed to measure the displacement that occurs when receiving a compressive load, the value of change or decrease that is analysed to obtain strain due to the compressive load.

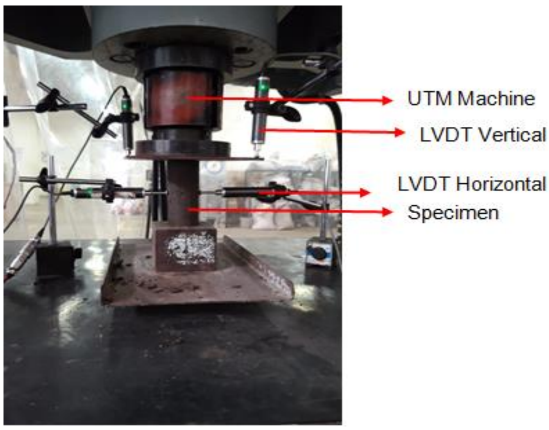

Figure 2. Set up compressive strength.

3. Results and Discussion

3.1. Chemical Content of Fly Ash, Rice Straw Ash and Laterite Soil
Table 5 shows the oxide content of fly ash and laterite soil. The fly ash used in this study is categorized as class F because it has a total content of Fe_2O_3, Al_2O_3, and SiO_2 greater than 70%. The density of fly ash is 2.65 gr/cm3 and laterite soil is 2.65 gr/cm3. The rice straw ash used containing SiO_2, P_2O_5, $CaCO_3$ and K_2O.

Table 5. Oxide content of fly ash, rice straw ash and laterite soil (XRF result).

Oxide Content	Concentration (%)		
	Fly ash	Rice straw ash	Laterite soil
Fe_2O_3	19.96	2.31	12.49
Al_2O_3	19.16	-	49.38
SiO_2	34.63	70.80	34.81

MnO	0.25	-	0.10
TiO_2	1.26	-	1.39
K_2O	1.33	15.89	0.35
CaO	12.74	5.34	0.85
P_2O_5	-	3.61	0.44
V_2O_5	-	-	0.06
ZrO_2	-	-	0.05
SrO	0.13	-	0.03
Cr_2O_3	0.07	-	0.02
CuO	-	-	0.02
ZnO	-	-	0.011
MgO	8.1	-	-
SO_3	1.80	-	-
CoO	0.05	-	-
BaO	0.21	-	-
Pr_6O_{11}	0.05	-	-
Nd_2O_3	0.07	-	-

3.2. Flow Testing

Flow of fresh mortar geopolymer is 112.50 mm, the volume weight when it is fresh is 1901.3 kg/m3. Mixed geopolymer mortar is able to bind the laterite so that the fresh mortar geopolymer can flow and spread evenly without any accumulation in the middle of the circle and without any bleeding. Figure 3 shows the flow of fresh mortar geopolymer.

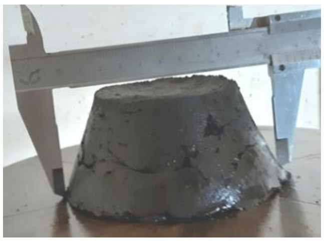

Figure 3. Flow of fresh mortar geopolymer.

3.3. Compressive Strength

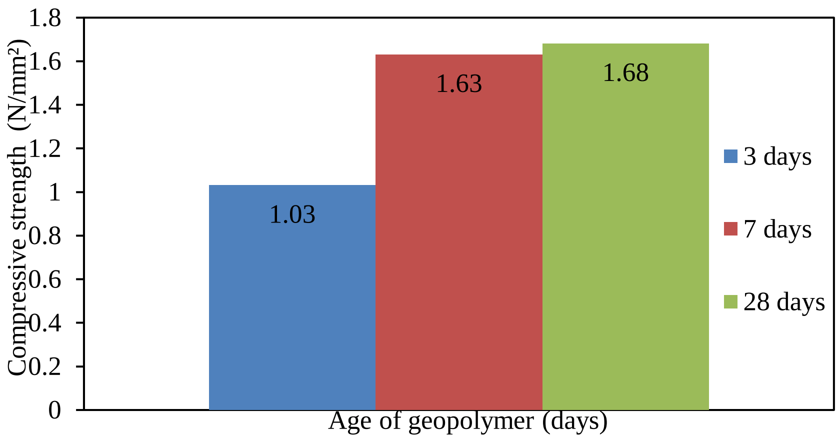

Figure 4. Stress average of geopolymer.

Based on Table 6 and on Figure 4 above, the test sample on 3 days water curing has average compressive strength value of 1.03 N/mm2 while 7 and 28 days water curing gave 1.63 N/mm2 and 1.68 N/mm2 of average compressive strength. It increased about 58.25% and 63.10% from 3 days curing. The sodium hydroxide (NaOH) leaches the silica and alumina in amorphous phase and act as a binder. Besides that, it shows that the test sample for 3 days, 7 days and for 28 days, the compressive strength increased without oven curing. This caused by the presence of rice straw ash in this mortar mixture contributes to the heat, hence without the curing of oven temperature, the fly ash geopolymer mortar with this laterite soil material can still provide strength. This result also indicated that compressive strength increased without oven curing similar because the oxide content of rice straw ash, laterite soil and fly ash SiO_2 able to bind well and produce amorphous silica.

4. Conclusion

1) In fresh condition the mortar geopolymer is able to bond well without segregation and bleeding.
2) Compressive strength development of geopolymer mortar remains can provide desired compressive strength values.

Acknowledgements
The authors wish to acknowledge the support of Eco-material and concrete laboratory, Civil Engineering Department, Universitas Hasanuddin Makassar for the work reported herein and providing the technical resources requires for this study.

References

[1] Tjaronge, M. W. 2012. Teknologi Bahan Lanjutan Semen dan Beton Berongga. CV. Telaga Zamzam. Makassar.
[2] Assi, Lateef, et. al. 2016. Improvement of The Early and Final Compressive Strength of Fly Ash-Based Geopolymer Concrete at Ambient Conditions. Construction and Building Materials 123 : 806-813.
[3] Davidovits, J., 1994,Chemistry of Geopolymer System, Terminology. Paper presented at the Geopolymer '99 International Conference, Saint-Quentin, France.
[4] Hardjito, D. and B. V. Rangan. 2005. Development and Properties of Low-Calcium Fly Ash-Based Geopolymer Concrete. Curtin University of Technology ; Perth, Australia.
[5] Faris Matalkah, Parviz Soroushian, Anagi Balchandra, Amirpasha Peyvandi (2016). Characterization of Alkali-Activated Nonwood Biomass Ash-Based Geopolymer Concrete. Journal of Materials in Civil Engineering, 04016270-1-8.
[6] Prinya Chindaprasirt, Chai Jaturapitakkul, Wichian Chalee, Ubolluk Rattanasak (2008). Comparative Study on characteristic of fly ash and bottom ash geopolymers. Journal of Waste Management 29, 539-543.
[7] Jian He, Yuxin Jie, Jianhong Zhang, Yuzhen Yu, Guoping Zhang (2012). Synthesis and characterization of red mud and rice husk ash-based geopolymer composites. Journal of Cement & Concrete Composites 37, 108-118.
[8] Lemougna, Patrick N., et. al. 2011. Laterite Based Stabilized Products for Sustainable Building Applications in Tropical Countries : Review and Prospects for The Case of Cameroon. ISSN 2071-1050.
[9] Wangsa F.A, M..W Tjaronge, A.R. Djamaluddin and A.B Muhiddin, 2017. Effect of hydrated lime on compressive strength mortar of fly ash laterite soil geopolymer mortar, GCoMSE2017 IOP Publishing IOP Conf. Series: Materials Science and Engineering.
[10] ASTM D3080. Standard Test Methods for Direct Shear Test of Soils under Consolidated Drained Conditions, ASTM International (2011), West Conshohochen, PA. Available online: www.astm.org .
[11] Badan Standardisasi Nasional. 2002. Standar Nasional Indonesia (SNI) 03-6825-2002 Metode

Pengujian Kekuatan Tekan Mortar Semen Portland untuk Pekerjaan Sipil. Jakarta : Dewan Standardisasi Nasional.