Study of coffee husk ash addition for clay soil stabilization

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Abstract. Industrial solid wastes have become a difficult problem in some developing countries, especially in Indonesia. The environmentally friendly issue regarding how to decrease industrial wastes by reuse or recycling process has become famous in recent years. Coffee husk ashes in this research were attained from burned waste coffee husk which can be considered as solid waste material from the coffee processing industry. In this study, clay soil obtained from Cot Bagie Village, Blang Bintang, Aceh was mixed with coffee husk ashes. Several soil physical properties test was conducted such as specific gravity, Atterberg limit, and grain size distribution by following ASTM standard. The physical parameter of soil was evaluated with the addition of 3%, 6%, 9%, and 12% coffee husk ashes by soil dry weight. The result shows that the physical properties of soil were improved if compared to untreated soil. A further mechanical laboratory test in soil mechanics was suggested for more advanced analysis of effect in soil-coffee husk ashes mixing.

1. Introduction
Indonesia as an archipelago is geographically vulnerable to tsunami natural disasters. Most earthquakes epicenter on the bottom of the Indian Ocean and some of them caused large ocean waves (tsunamis). Environmentally friendly alertness has been increasing nowadays around the world. As a result, efforts in developing and recycling environmentally friendly materials to be reused again is also inclined. Moreover, many studies regarding industrial waste materials for construction have been developed [1] and [2]. In developing countries, industrial solid waste to become problematic recently, which results in a hazard of nature. The geographical position of Indonesia which are prone to earthquake disaster requires the use of good surround material for construction [3].

Stabilizing soil with industrial waste materials to obtain better soil parameter are also conducted by several types of research. Coir fiber as industrial waste material was added to clay soil for pavement construction [4]. The result shows an increment of CBR soil value with the adding percentage of coir fiber. Palm oil clinker as waste material to be used as light material in constructing a floating foundation in soft soil was also experimented [5]. Furthermore, the use of waste marble dust production for cement and concrete production was also introduced by [6]. Several other industrial waste material for soil stabilization was conducted by [7]. They use a recycled tire and fiberglass as substituted material for soil improvement. The use of nanoparticle as soil additive was also conducted by [8]. The research attempts to evaluate the behavior of silty clay geotechnical parameters by adding lime and nano lime. The nano lime presence can give a decent effect on the soil properties. Another
lime-clay stabilization was also performed by [9]. The swelling potential of stabilized soil was reduced by the addition of lime.

Coffee husks are industrial waste material from the coffee industry. Figure 1 shows the fruit coffee structure. The size of the coffee fruit is approximately 10 mm with an oval shape. Nowadays coffee has become a basic need for people and has already become top commodities in the world. According to [10] coffee is the number two most traded goods worldwide after petroleum. Brazil is the number one country in producing coffee which oversees more than 35% of worldwide production in the last 5 years.

Every 1 kg of coffee bean production will result in around 1 kg of coffee husk waste [10]. In Indonesia, twelve million 60 kg bags production yearly as the number four largest coffee-producing countries in the world [11]. Solid waste produces from coffee industries is a coffee husk, coffee silver skin, and spent coffee ground. These wastes have been used for limited applications like livestock feed, compost and fertilizer, and some other which remain a large amount of idle coffee waste. This unused waste will lead to a bad environmental effect on the world.

![Figure 1. The structures of coffee fruit [12].](image)

Several advances used for coffee waste material namely as bioprocessing products, biodiesel, fertilizer, animal feed, thermochemical conversion products, antioxidants, bio sorbents, biodegradable films in food packages, material for construction, and energy storage devices [13].

The use of coffee products in construction was developed by some researches. [12] introduces coffee chaff characterization for material in building applications in terms of environmental purposes. They investigate sound insulation material by coffee chaff in construction. The result shows that coffee chaff is may be suitable for insulation panel material for industry. [14] conducted a study in untreated coffee husk ashes for flux ceramic tiles. The result shows that coffee husk ashes can be used to replaced feldspars for fluxing material in the ceramic industry. Moreover, the use of coffee husk ashes can also reduce waste disposal and consumption of ceramic raw material.

In geotechnical engineering, [15] already studied about expansive soil behavior of compressibility and strength after stabilized with coffee husk ash. The results specify the good strength parameter of soil after treated by coffee husk ashes. Furthermore, the indication of hydrates particle formation and cementitious compound show after stabilization leads to the possible use of coffee husk ashes as stabilization material and subsequently. The chemical properties of coffee husk ash are shown in Table 1. Potassium oxide (K₂O) was the dominant chemical properties with 46.46%.
Table 1. Chemical properties of coffee husk ashes (CHA) [15].

| Chemical Properties          | Composition (%) |
|------------------------------|-----------------|
| Silica (SiO$_2$)             | 1.24            |
| Alumina (Al$_2$O$_3$)        | 0.58            |
| Iron oxide (Fe$_2$O$_3$)     | 0.56            |
| Calcium oxide (CaO)          | 17.7            |
| Magnesium oxide (MgO)        | 4.51            |
| Sodium oxide (Na$_2$O)       | 0.14            |
| Potassium oxide (K$_2$O)     | 46.46           |
| Manganese oxide (MnO)        | 0.06            |
| Titanium dioxide (TiO$_2$)   | 0.08            |
| Phosphorpentoxid (P$_2$O$_5$)| 3.85            |
| Sulphur oxide (SO$_3$)       | 3.75            |
| Loss on ignition (LOI)       | 21.07           |

2. Experimental method
The soil used for the experiment was obtained from the local site of Cot Bagie Village in Blang Bintang, Aceh Province. This site has been used as a quarry for construction projects for around Banda Aceh area recently. Disturbed soil was collected from around 0.5 m below ground surface and taken to the Soil Mechanics Laboratory of Universitas Syiah Kuala. The soil was cleared from all roots and stones, then dried in an oven for 24 hours in 105°C temperature and then sieved. The Cot Bagie soil is classified as OH and A-7-5 for USCS and AASHTO methods respectively. The gradation curve of the soil is given in Figure 2 where 67.42 % of original soil particles are pass sieve #200.

![Figure 2. Grain sizes distribution for untreated soil.](image)

The soil was mixed with 3%, 6% 9%, and 12% of coffee husk ashes by the dry weight of soil. The coffee husk was collected from the local coffee farm area in Bathin Weh Pongas Village, Bener Meriah, Aceh, then burned into ashes grey in color. Figure 3 shows the coffee husk ashes use in this study.
The mixing percentage was chosen according to some previous research. Untreated samples (0%) were also prepared for comparison purposes. Some physical tests i.e., specific gravity, Atterberg limit, and grain size distribution were carried out in this study by using the American Society for Testing and Material (ASTM) standard.

3. Result and discussion
Table 2 shows the recapitulation of the physical properties of soil mix with coffee husk ashes for different percentage of addition. The test parameter analyze are specific gravity, liquid limit, plastic limit, plasticity index, and sieve passing #200. Generally, the plastic limit of treated soil showed good decrement with the increasing percentage of coffee husk ashes. The specific gravity value of untreated soil is 2.32, then there is a slight decrease with and addition of coffee husk ashes from 3% to 12% until 2.11.

| No | Test Parameter       | Mixing Percentage |
|----|----------------------|-------------------|
|    |                      | 0%    | 3%    | 6%    | 9%    | 12%   |
| 1  | Specific Gravity (SG)| 2.32  | 2.29  | 2.20  | 2.12  | 2.11  |
| 2  | Liquid Limit (LL) (%)| 63.00 | 59.00 | 58.00 | 55.40 | 52.2  |
| 3  | Plastic Limit (PL) (%)| 41.76 | 41.80 | 42.41 | 41.37 | 44.11 |
| 4  | Plasticity Index (PI) (%)| 21.24 | 17.20 | 15.59 | 14.03 | 8.09  |
| 5  | Sieve Passing #200 (%) | 67.42 | 71.39 | 69.53 | 61.75 | 55.22 |
Figure 4. Effect of coffee husk ashes on Atterberg limit.

Figure 4 shows the effect of coffee husk ashes in addition to the soil in terms of the Atterberg limit parameter. The liquid limit of untreated soil is 63.0%, with the addition of coffee husk ashes, the liquid limit value then decreases up to 52.2%. On the other hand, the plastic limit value increases slightly from 41.76% for original soil to 44.11% in 12% addition, even though there is a slight decrease from plastic limit 6% is 42.41% to 8% addition at 41.37%. The index plasticity parameter decreases constantly from 21.24% of untreated soil to 8.09% for 12% of coffee husk ashes. Commonly the Atterberg limit trend of treated soil showed good results with the cumulative percentage of coffee husk ashes. These results are like the literature studies of general solid waste materials which also found that the decrease of plasticity index with an increase of additive materials.

4. Conclusion

This article presents laboratory results from work done at Universitas Syiah Kuala (UNSYIAH) for coffee husk ash application for soil improvements. Coffee based waste is readily available in huge amount, therefore it is also natural, economical, and environmentally friendly materials which can be used as an alternative material for construction purposes. From obtained results, the combinations of coffee husk ashes and soil enhance the physical properties of soil and are potential materials to be used for soil stabilization. For example, the index plasticity of treated soil exhibits a good reduction at 8.09 for 12% of coffee husk ashes compared with 0% soil at 21.24%. It can be expected that with further laboratory tests in soil mechanics, more soil parameters can be improved with the soil-coffee husk ashes mixing.

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References

[1] Aamir M, Mahmood Z, Nisar A, Farid A, Khan T A, Abbas M, Ismaeel M, Adnan S, Shah R, Waseem M 2019 Processes, 71–16.
[2] Thirumalai R, Babu S S, Naveenayak V, Nirmal R, Lokesh G 2017 Engineering, 9 1008–1017.
[3] Munirwansyah M, Munirwan R P, Yunita H 2018 International Journal on Advanced Science Engineering Information Technology, 8(3) 870–875.
[4] Munirwan R P, Munirwansyah, Marwan, Ramadhansyah P J, Kamchoom V 2020 IOP Conf. Ser. Mater. Sci. Eng., 712(1) 012009.
[5] Sulaeman A, Fulazzaky M A, Haroen M, Bakar I 2018 KSCE Journal of Civil Engineering, 22 2232–2240.
[6] Aliabdo A A, Elmoaty A, Elmoaty M A, Auda E M 2014 Construction and Building Materials, 50 28–41.
[7] Ahmad F, Yahaya A S, Safari A 2016 IOP Conf. Ser. Mater. Sci. Eng., 136(1) 012003.
[8] Taha M R, Govindasamy P, Alsharef J 2019 E3S Web Conference, 11005 1–6.
[9] Munirwansyah, Munirwan R P 2016 International Conference of Engineering and Science for Research and Development, 1(1) 63–68.
[10] Carvalho F De, Srinivas K, Helms G L, Isern N G, Cort J R, Roberto A, Kjaer B 2018 Bioresource Technology, 257 172–180.
[11] Banu J R, Kavitha S, Kannah R Y, Kumar M D, Atabani A E 2020 Bioresource Technology, 302 122821.
[12] Ricciardi P, Torchia F, Belloni E, Lascaro E, Buratti C 2017 Construction and Building Materials, 147 185–193.
[13] Massaya J, Prates A, Mills-lamptey B, Benjamin J, Chuck C J 2019 Food Bioproducts Processing, 118 149–166.
[14] Acchar W, Dultra E J V, Segadães A M 2013 Applied Clay Science, 75 141–147.
[15] Atahu M K, Saathoff F, Gebissa A 2019 Journal of Rock Mechanics And Geotechnical Engineering, 11 337–348.