Soil-Compost Mixture as Alternative Material for Soil Cover Landfill

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Abstract. One of typical problem in a developing country is the lack of controlling odors, vectors, fires, and litter in the waste landfill. It is known that this problem can be reduced by landfill. However to maintain cover material always available, it is uneasy, especially due to limited budget. This study intends to propose compost-soil mixture as an alternative material using residual soil cover from completed waste landfill. In order to investigate and assess the geotechnical properties of soil-compost mixture as an alternative material, several tests were conducted such as compaction, unconfined compression, and permeability tests. Compaction tests show ed 0.4%, 0.8% and 1.2% of compost in soil mixture results the values of dry density in the range between 1.297 g/cm³ and 1.330 g/cm³, which meet the minimum requirement according to Indiana environmental department USA. Shear strength of compost-soil mixture that derived from results of unconfined compression tests, reduced slightly for additional compost without curing time. However, the values increased sharply for 3 and 7 days of curing time. All the shear strength values of 0.88 kg/cm³ to 34.76 kg/cm³ passed the minimum requirement for cover material according to Environmental Protection Agency (EPA) and Environment Agency. In case of ability of the soil mixture to transmit water, permeability coefficient were 1.5 x 10⁻³ cm/sec, 7 x 10⁻⁴ cm/sec and 3 x 10⁻⁴ cm/sec for 0.4%, 0.8% and 1.2% of compost respectively. Referring to modern sanitary landfill and design, it was shown that, the soil mixtures meet minimum requirement for permeability coefficient. To sum up, compost-soil mixtures with composition tested can be considered as material alternative for soil cover in landfill.

1. Introduction
Inappropriate solid waste management is one of the global issues in the world especially in the case of environmental problem such as soil and ground water contamination, and air pollution [1]. One of the cause of exist problem is amount of waste and number of facilities available are not matched [2], [3], [4]. Another cause is improper structure of waste landfill. Many developing countries still apply open dumping and control open dumping rather than sanitary landfill. Waste disposal plays important role in this issue, since uncontrolled waste disposal can generate serious disease to the human, animal and ecosystem in that area due to heavy metals pollution in water, air and plant [5]. Burning waste openly also can produce CO, CO₂, SOx, NOx, PM10 and other pollutant in the atmosphere [6]. Moreover waste pickers can be exposed to disease while working in open dumping area [7].

Since several decades ago, sanitary landfill has been recommended by government of developed countries to control odors, fires and litter in the waste landfill [8]. Sanitary landfill is a waste landfill concept, where the waste was dumped, buried in the holes underground, compacted, and covered by
material. One of the basic differences between system of conventional waste landfill and sanitary landfill is covering layer. Conventional system is normally designed without properly soil cover while sanitary landfill has regular daily cover [9]. However, providing cover materials every day is not easy, especially due to limited budget.

Tamangapa waste landfill is one of controlled dumping that exists in Indonesia regularly cover almost once a month. Some areas in Tamangapa landfill are inactive, but still can be reused as cover material. Another material that can be used to combine with soil is compost which made from degradation of leaves, trunks and some vegetation in that landfill. The purpose of this study is to evaluate geotechnical properties and possibility of soil-compost mixture use as an alternative cover material in Tamangapa landfill.

2. Methodology

2.1. Sampling Method

Soil sample was taken randomly in landfill of Tamangapa under disturbed condition. This landfill is located at Manggala Tamangapa with coordinate of 5º10’30” LS and 119º 29’36”LE, ±15 km from center of Makassar. The soil samples were covered by material of inactive landfill, at depth of 0-100 cm from surface. For compost, it was provided from the same place of soil sample.

2.2. Sample Preparation

The soil sample that collected from the landfill site by scoop was brought to Soil Mechanics laboratory in Civil Engineering Department UNHAS. Soil sample was screened using 1 cm in diameter of sieve to separate soil from organic waste. Then soil was put in the wide plate to get air dried until dry air condition. Almost the same treatment was done for compost. Sample test was prepared in composition of soil with 0%, 0.2 %, 0.4 %, 0.8% and 1.2% of compost. Then several tests were conducted on these samples such as Atterberg limit tests, grain size analysis, specific gravity, compaction test, unconfined compression test and permeability test.

2.3. Laboratory Tests

Before conducting mechanical properties tests, physical characteristic tests were performed on soil samples, such as moisture content, liquid limit, plastic limit, shrinkage limit and specific gravity tests. For moisture content, the tests were performed according to ASTM D2216-10[10], while other tests such as liquid limit and plastic limit tests referred to ASTM D4318-17[11] and shrinkage limit tests were based on ASTM D4943[12]. For specific gravity, the test was done referred to ASTM D854-14[13]. It was found that soil sample contains 18.10% of water and specific gravity of 2.662 g/cm³.

Another test performed on soil and compost samples was sieving analysis test, which referred to ASTM D 422-63[14]. This test was intended to determine the distribution of fine and coarse aggregate. Five hundred grams of soil samples were used for this test. This experiment used sieve no.4 (7.75mm), 10 (2 mm), 20 (0.84mm), 40 (0.42mm), 60 (0.25mm), 100 (0.15 mm), 200 (0.075), and they were shaken by shaker for 15 minutes.

Standard proctor compaction tests were performed in order to define maximum dry density and optimum moisture content of the soil-compost mixture. Following ASTM D558-96[15], moisture content of sample was increased gradually by pouring water in the sample. Then plot dry density and moisture content in the graph to find optimum moisture content and maximum dry density of the mixture sample.

Permeability test was conducted with falling head test method. The test aimed to find coefficient of permeability of soil-compost mixture. Experiments were done following ASTM D2434-68[16]. Unconfined compression test was conducted to determine unconfined compression strength values then they were derived into shear strength by following ASTM D2166-00 [17].
3. Results and Discussion

3.1. Laboratory Tests

3.1.1. Basic Properties. Several basic properties of soil and compost were defined from physical properties as mention in earlier. The tests were conducted to these materials separately. Results of the tests are shown in Table 1.

| Soil Properties               | Value  |
|-------------------------------|--------|
| Liquid limit (%)              | 73.62  |
| Plastic limit (%)             | 34.29  |
| Index Plastic (%)             | 39.33  |
| Shrinkage limit (%)           | 16.14  |
| Specific gravity (g/cm³)      | 2.662  |
| Water content of soil (%)     | 18.10  |
| Water content of compost (%)  | 39.25  |

3.1.2. Sieve Analysis Tests. From sieve analysis tests, it found that 81.10 % of soil (> 50%) passed sieve no. 200, which consisted of 19.40 % of sand, 9.80 % of silt, and 71.30 % of clay. It was concluded that soil sample was clay soil with high plasticity. Furthermore, it was found also various size of compost particle that is 0.18 % of compost was bigger than 4.75 mm-diameter, 2.82 % was bigger than 2 mm and more than 81 % was smaller than 0.075 mm as seen in Table 2. According to SNI 19-7030-2004 [18] the sample was categorized as organic compost.

| No. Sieve | Diameter (mm) | Passed (%) |
|-----------|---------------|------------|
| 4         | 4.75          | 99.81      |
| 10        | 2             | 97.17      |
| 20        | 0.84          | 91.71      |
| 40        | 0.42          | 87.15      |
| 60        | 0.25          | 84.55      |
| 100       | 0.15          | 82.89      |
| 200       | 0.075         | 81.83      |
| PAN       | -             | 0          |

3.1.3. Standard Proctor Compaction Tests of Soil-Compost Mixture. Compaction tests were conducted on four variant samples, 0%, 0.2%, 0.4%, 0.8% and 1.2% based on procedures were mention above. Dry density varied between 1.32 g/cm³ and 1.3 g/cm³ as shown in Table 3.

| No. | Variation (%) | Optimum water content (ωopt) % | Dry density (γdry max) gr/cm³ |
|-----|---------------|-------------------------------|-----------------------------|
| 1   | 0%            | 33.77                         | 1.316                       |
| 2   | 0.4%          | 33.92                         | 1.330                       |
| 3   | 0.8%          | 33.82                         | 1.297                       |
| 4   | 1.2%          | 33.79                         | 1.300                       |
3.1.4. **Permeability Tests.** Falling head test was conducted to determine permeability coefficient of the soil compost mixture. Similar to compaction test, four variants of samples were also tested on these tests. Result of the tests is shown in Figure 2. From result tests, it can be seen that permeability coefficient tend to reduce as percentage of compost increasing. It might be happened because the particles of compost filled in pore leading to reduction of empty spaces in soils.

3.1.5. **Unconfined Compression Tests.** As can be seen in the graph below, unconfined compression strength (qu) increased as percentage of compost in soil mixture increased. In case of variation of curing time, it found that qu of 3 and 7 days of curing time increased from 20 up to 40 times than 0 day. Similar trend was happened on shear strength in Figure 3.
3.2. Test Results Analyses to the Alternative Daily Cover Requirement

Three type of composition of soil-compost mixture have been tested, 0%, 0.4%, 0.8% and 1.8% to assess possibility of soil-compost to become cover material alternative. In this case zero percent of compost was also tested just for comparison to other variants.

3.2.1. Liquid Limit and Plastic Limit. Since there was small part of sand in compost tested so value of liquid limit and plastic limit of soil-compost tested were not available but it will refer to liquid and plastic limit of soil cover tested. According to [19] and [4] liquid limit of cover material in landfills should be within the range of 20% to 90%. Plasticity index should be in the range of 7% to 65%.
Table 1 shown that the liquid limit and plastic limit meet the requirements as alternative cover liner material.

3.2.2. Grain Size Distribution. Referring to [4], soil cover material should contain at least 10% of clay, which makes the soil tested suitable for using as cover material since the soil content 71.30% of clay.

3.2.3. Bulk Density. Result of standard compaction test shown that all soil-compost tested meet requirement of cover material. As stated by Indiana department of environmental management USA 2013 [14], minimum bulk density of material should be at least 1 g/cm$^3$. Table 3 show the bulk density of all soil-compost tested were about 1.3 g/cm$^3$.

3.2.4. Coefficient of Permeability. Referring to [20], alternative cover material should have permeability coefficient between $10^{-2}$ and $10^{-5}$ cm/sec. Result of falling head tests shown that permeability coefficient of all soil-compost tested were ranging $2.7 \times 10^{-3}$ to $3.0 \times 10^{-4}$ cm/sec means meet requirement.

3.2.5. Shear Strength. Derived from unconfined compression strength, value of shear strength of soil compost was defined. From these results, it shown that shear strength of sample tested meet minimum requirement which ranging from 10 kg/cm$^3$ to 67 kg/cm$^3$.

4. Conclusion
Based on study above it can be concluded that soil sample which taken from Tamangapa waste landfill and then mixed with compost can be used as alternative cover material. Value of liquid limit, plasticity index, clay fraction, bulk density, coefficient of permeability and shear strength meet minimum requirement of cover material in landfill area. Increasing composition of compost in sample tested tend to reduce coefficient of permeability. Similar tendency also for shear strength value, it tends to increase as percentage of compost was added. Even the value can be increased when the sample was cured about 3-7 days.

Acknowledgments
The authors would like to thank to Engineering Faculty of Hasanuddin University for providing financial support via LBE Development System.

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