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## Properties of debris flow deposits in Masamba, South Sulawesi, Indonesia

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**Abstract.** On 13 July 2020, a huge landslide-induced debris flow struck Masamba city and its vicinity, providing a massive amount of sedimentation materials. The landslide-induced debris flow was triggered by heavy rainfall, causing damages such as life and property losses, traffic disruption. Landslide-induced debris flow is a sudden natural hazard in mountain regions characterized by fast velocity, huge impact area, large scale, and often causes disastrous accidents. This study aims to investigate the properties of the debris flow materials including the soil size distribution, density, shear strength and bearing capacity. The results showed that the sedimentation material at landslide sites containing a large amount of sand which is classified as a poorly graded sand (SP). The engineering properties such as density, cohesion, internal friction angle and the value California Bearing Ratio (CBR) were also discussed.

4

### 1. Introduction

Landslide is a general term used to describe the downslope movement (displacement) of soil, rock and other organic materials under the effect of gravity. An event of landslide-induced debris flow is a sudden geological hazard in a mountain region characterized by fast velocity, huge impact area, large scale, and often causes disastrous accidents [1]. A debris-flow is a very rapid flow of saturated debris in a steep slope and hazardous phenomenon in mountainous areas [2-3]. Furthermore, the landslide-debris deposit can cause a secondary disaster, such as another landslide-debris flow, which could expand the scope of disaster impact [4-5]. In recent years, the investigation of post-earthquake debris flow hazards is widely conducted due to the high occurrence frequency, catastrophic damage and long activity duration [6-9]. The landslide-induced debris flow characteristics with high flow velocities, long travel distance, and high impact force can cause catastrophic damage to infrastructure such as bridge, road and settlements.

Numerous studies reported the utilization of sediment from mountain areas as construction material [10-11]. Many attempts have been made to increase the quantity and quality of re-usable debris flow sediment material as a construction material while protecting the environment [12]. It is necessary to evaluate the characteristics of post-landslide debris flow in order to avoid catastrophic events. The comprehensive study is needed to characterize the debris flow material properties for mitigation countermeasures. The current study was conducted to investigate the basic and engineering properties of debris flow sediment material at several locations. These parameters (i.e., density, shear



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strength, and bearing capacity) could be used as preliminary data in order to apply this material for future utilization as a construction material.

## 2. Material and Methods

The soil samples were collected at three location by method of disturbed sampling collection as shown in Figure 1. Each soil sample was collected in the depth of 0-50 cm from the surface. The debris flow material were transported to laboratory in sealed bags to maintain the humidity.



**Figure 1.** Locations of soil sampling

The soil sample preparation was conducted by air-dried the samples for one day prior to testing to simulate the field condition. The basic and engineering properties of the soil samples were determined in accordance with the American Society for Testing and Materials (ASTM). The soil classification determined according to the Unified Soil Classification System (USCS) and Association of State Highway and Transportation Officials (AASHTO) to describe the texture and grain size of a soil. The compaction test was conducted to obtain the value of maximum dry density ( $M_{4D}$ ) and optimum moisture content (OMC) of the soil samples. The shear strength characteristics were obtained by conducted direct shear test. The shear strength parameter such as cohesion ( $c$ ) and internal friction angle ( $\phi$ ) of soil samples was collected from the direct shear test. Furthermore, to evaluate the bearing capacity of each sample, the California Bearing Ration test (CBR) was conducted in unsoaked condition.

## 3. Results and Discussion

### 3.1. Soil classification

Soils with similar properties might be classified into groups and subgroups based on their engineering behaviour. At the present time, the grain-size distribution of soil is obtained by two classification system (USCS and AASHTO). The soil collected at three locations classified as a sand according to the sieve analysis result as shown in Figure 2. The USCS system classified the soil samples as a poorly graded sand (SP) and AASHTO system classified the soil samples as an A-3 (mostly poorly graded fine sand with few fines). The A-3 soil are relatively free draining and possess desirable strength characteristics, but this type of sand somewhat difficult to compact due to their uniformity.

### 3.2. Compaction properties

The result of standard and modified proctor test is shown in Figure 3. Generally, the density of sample location 1 is lower than other locations. The density of the modified proctor test is higher than the standard proctor test. The higher moisture content signifies the plastic condition of the sample. Many variables are affected to the soil densification. The most influence is the type of soil, moisture content

and compaction energy. This condition is due to the present of various particle sizes from fine to coarse-grained soil size. The coarse-grained soil will attain a density for given compaction energy. For sand soil, the dry unit weight (density) has a general tendency first to decrease as increasing of moisture (water) content. Subsequently the increasing of moisture content will increase the density of soil until reach its optimum moisture content. The initial decrease of sand density with increase of water content can be attributed to the capillary tension effect. At lower water content, the capillary tension in the pore water inhibits the tendency of the soil particles to move around and be densely compacted.

Maximum dry density (MDD) will increase with the increase of compaction energy. Increasing compaction energy, the maximum dry density increased while the optimum moisture content (OMC) decreased. In general, for all the soil compaction results, the modified compaction test showed the curve is shifted to the left part in the graph and going upward compared to a standard proctor compaction test. The increase of MDD is accompanied by a decrease of OMC.

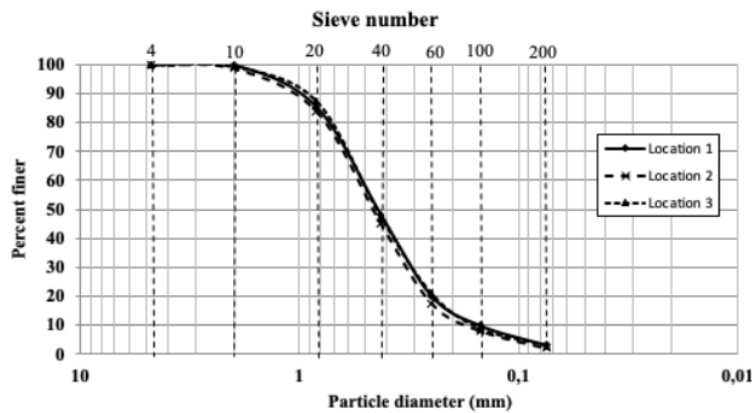
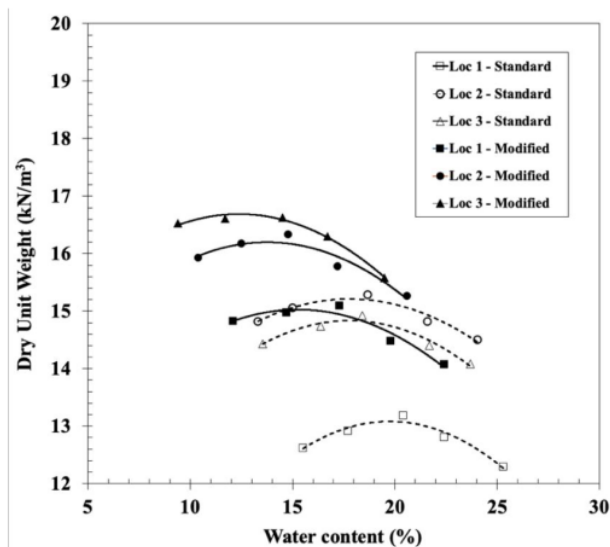


Figure 2. Soil size distribution curve



1 Figure 3. Variation of soil density with different compaction energy

### 3.3. Shear strength characteristics

The value of cohesion ( $c$ ) and the internal friction angle ( $\phi$ ) depends on the density of the soil and the testing method. Figure 4 shows the variation of the shear strength properties at three different location. Typically, the value of cohesion of sand (granular material) is very small. In dense sand, the resisting shear stress increases with shear displacement until it reaches a failure stress. After failure stress is attained, the resisting shear stress gradually decreases as shear displacement increase until it reaches a constant value (ultimate shear strength).

Since the permeability of sand is quite high, the excess pore water pressure generated due to normal and shear loading is dissipated quickly. However, for ordinary loading rate, essentially full drainage condition exist. The friction angle ( $\phi$ ) obtained from a drained direct shear test of saturated sand will be the same as that for a similar specimen of dry sand. The water between sand particle form a layer of water film which plays an important role in lubrication process. Increasing water content of the sand, the angle of internal friction decrease during the shearing process. On the other hand, the sand has a larger particle size compare to clay soil, and with poor water retention and water content of variable interval is quite small. Therefore, the water content of sand particle has a little effect on the angle of internal friction. The average value of internal friction angle of the debris flow material can be accepted for the application in the field. The cohesion of unsaturated sand is affected with the variations of water content significantly.

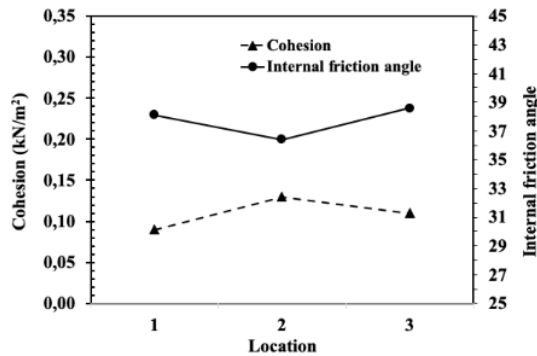


Figure 4. Variation of shear strength at three different location

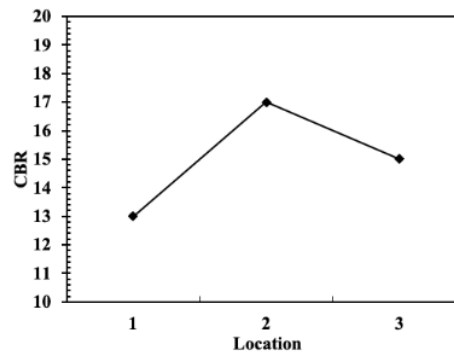


Figure 5. Variation of CBR value at three different location

### 3.4. California bearing ratio

The CBR is an indirect measurement which indicates comparison between strength of subgrade material and the strength of standard crushed rock presented in percentage values. In the design of road projects, the thickness of the pavement layer is based on the soil's strength. Prior to the application, soil tests are generally carried out to estimate the strength of the soil, which in designing CBR test results are often used. Variation of the CBR value of debris flow materials are shown in Figure 5. The CBR value of debris flow materials indicated that the CBR value still in range of application for subgrade. This indicate that the debris flow material has a potential using as a road construction material.

CBR values generally decrease as water content increases and density decreases. However, for the same CBR specimen, if immersed for four days, the CBR peak value occurs at its optimum moisture content or when the soil density reaches its maximum. This is due to absorption and expansion at the time of immersion. Some compacted soils at lower moisture content will expand more with a decrease in strength than those compacted at higher moisture content. It is important in planning, the problem of decreasing soil strength due to wetting depends on the water content supplied, compaction energy and soil type.

The properties summary of debris flow material is shown in Table 1. A variation value obtained from 3 different locations indicated that the debris flow material could be mixed with other fine material during transported to the site location.

**Table 1.** Characteristics of debris flow material

Properties	Unit	Location 1	Location 2	Location 3
Specific Gravity (Gs)	-	2.7	2.7	2.6
<b>Grain Size :</b>				
• Gravel	%	0.2	0.3	0.3
• Sand	%	96.6	96.7	96.6
• Silty & Clay	%	3.2	3.0	3.1
<b>Soil Classification :</b>				
• USCS		SP	SP	SP
• AASHTO		A-3	A-3	A-3
<b>Compaction :</b>				
• Standard Proctor				
Maximum dry density (MDD)	kN/m <sup>3</sup>	13.2	15.3	14.8
Optimum moisture content (OMC)	%	20	18	17
• Modified Proctor				
Maximum dry density (MDD)	kN/m <sup>3</sup>	15.1	16.3	16.7
Optimum moisture content (OMC)	%	15	14	13
<b>Direct Shear :</b>				
• Cohesion	kN/m <sup>3</sup>	0.09	0.13	0.11
• Internal friction angle	( $\phi$ )	38.1	36.4	38.6
California Bearng Ratio (CBR)	%	13	17	15

#### 4 Conclusion

This study was preliminary work to investigate the basic and physical properties of debris flow material shall be considered in engineering practice. The sedimentation material at landslide sites containing a large amount of sand which is classified as a poorly graded sand (SP). The density of the modified proctor test is higher than the standard proctor test. The higher moisture content signifies the plastic condition of the sample. Many variables is affected to the soil densification. The most influence is the type of soil, moisture content and compaction energy. This condition is due to the present of various particle sizes from fine to coarse-grained soil size. Typically, the value of cohesion of sand (granular material) is very small. In dense sand, the resisting shear stress increases with shear displacement until it reaches a failure stress. After failure stress is attained, the resisting shear stress gradually decreases as shear displacement increase until it reaches a constant value (ultimate shear strength). The CBR value of debris flow materials indicated that the CBR value still in range of application for subgrade. This indicate that the debris flow material has a potential using in the practical engineering construction (road construction material).

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