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Correlation Between Linear Shrinkage Value and Soil Desiccation Cracking Pattern

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ABSTRACT
Soil is a common material used in construction. However, saturated clayey soils can shrink and crack when subjected to a drying process. Cracks in the soil can reduce the stability and strength; and increase the compressibility and hydraulic conductivity of the soil. Therefore, this study was conducted to determine the relationship between linear shrinkage values and soil cracking patterns in Bandung Raya. Soil crack pattern photos were processed using the Crack Image Analysis System. The crack pattern test was carried out using a 16 cm x 16 cm x 1 cm acrylic mold at 40 °C. This research shows that the soil with the most significant shrinkage and cracking potential is soil with a high plasticity index and a high percentage of fine grains. In addition, although the shape of the cracks on the soil surface looks distinct, the total area of the cracks formed is similar.

Keywords: *linear shrinkage, cracking pattern, plasticity index*

1. INTRODUCTION

Soil is one of the most commonly used materials in construction, yet when experiencing the drying process, water will evaporate, and soil will shrink and form surface cracks. Cracks on the soil surface will begin when the tensile stresses exceed the soil strength (Atique and Sanchez, 2011). Desiccation cracks can modify soil's mechanical and hydraulic properties (Tang et al., 2012). It can reduce strength and stability while increasing soil compressibility and hydraulic conductivity (Yesiller et al., 2000). The hydraulic conductivity can increase five to 500 times to the initial hydraulic conductivity (Albrecht and Benson, 2001). Therefore, the stability and strength of structures built using soil material such as embankments and foundations will be affected when cracking forms on the soil surfaces.

This study investigated the correlation between soil shrinkage behavior, desiccation cracks, and soil parameters such as the percentage of fine grains and soil plasticity index values. Quantification of cracking patterns is one of the essential aspects of the study of soil cracking (Tang et al., 2013). This study uses image processing technology to help quantify the desiccation cracking pattern. Using image processing technology, one can determine the value of soil surface crack ratio (RSC). The RSC value itself is the ratio of the surface area of cracks to the total surface area of the sample (Tang et al., 2011).

2. METHODS

Laboratory tests were conducted to obtain necessary data that can be used to perform the analysis. Soil samples were kaolinite, bentonite, and natural soil from 8 different locations in Bandung Raya. The location of soil sampling in the Bandung Area can be seen in Fig.1.

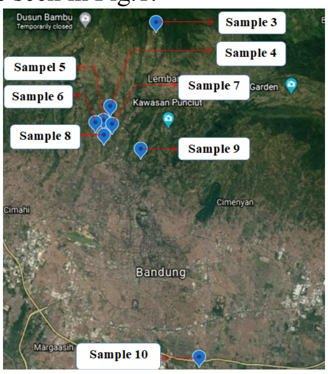

Fig. 1. Soil sampling location in the Bandung Raya area

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2.1. Soil Parameter

Samples are tested to determine the particle size distribution, Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI), and soil classification based on Casagrande's Plasticity Chart (Table 1).

Table 1. The Soil Parameters for Ten Soil Samples from Laboratory Tests

Sample	Particle Size Distribution				LL	PL	IP	Soil Activity, A	Soil Classification
	Clay	Silt	Sand	Gravel					
1	49,64	50,36	0,00	0,00	72	34	38	0,766	CH
2	39,86	49,30	10,84	0,00	96	44	52	1,305	MH
3	11,05	41,32	47,53	0,10	64	43	21	1,901	MH
4	30,33	42,08	27,22	0,37	58	40	18	0,610	MH
5	39,54	41,84	18,45	0,17	63	33	30	0,759	MH
6	17,41	53,09	29,28	0,22	64	47	17	0,961	MH
7	26,11	43,15	30,74	0,00	58	44	14	0,536	MH
8	39,54	47,91	8,91	10,95	58	37	21	0,542	MH
9	68,58	28,32	3,09	0,01	78	42	36	0,525	MH
10	28,98	59,62	10,98	0,43	64	28	36	1,242	CH

2.2 Linear Shrinkage Test

The Linear Shrinkage (LS) test will be carried out according to the procedure from British Standard Part 2 (1990). The dimensions of the mold used in the test are 14 cm long and 2,5 cm in diameter. The soil sample has to pass through no. 40 sieve. Add distilled water until the water content of the soil closes to LL. Then, apply a thin layer of petroleum jelly to its mold and place the sample inside the sample mold. Place the sample in the oven for 24 hours at 105°C.

According to BS 1377, 1990, the value of LS can be calculated using equation (1).

$$LS = \left(1 - \frac{L_D}{L_O}\right) \times 100 \quad (1)$$

with L_D is the length of the oven-dried sample (in mm) and L_O is the original length of the sample (in mm).

2.3 Desiccation Cracking Pattern Test

The desiccation cracking pattern test will be conducted using an acrylic mold with dimensions 16 cm x 16 cm x 1 cm. To perform the test, first, the soil must be filtered using sieve no. 40 and then mixed with distilled water until it is homogenous and the water content is near LL. Put the sample into the acrylic mold and place the sample into the oven at 40 °C for 24 hours. After the sample comes out from the oven, a photo will be taken using a digital camera and processed using Crack Image Analysis System (CIAS) developed by Liu et al. (2013).

3. RESULTS AND DISCUSSION

3.1. Linear Shrinkage Results

According to Altmeyer (1956), the LS value can be an indicator that can describe the shrinkage behavior of the soil. Altmeyer divides the classification of soil shrinkage behavior into three classes, as shown in Table 2. The LS value from 10 soil samples ranges from 6,43% to 23,93% (Table 3 and Figure 2).

Table 2. Soil shrinkage behavior according to Altmeyer (1956)

Linear Shrinkage (%)	Shrinkage Behavior
> 8 %	Critical
5 % - 8 %	Marginal
< 5 %	Non - critical

From Table 3, in general, soils are most classified as critical. Based on the results of the shrinkage behavior classification, soil sample no. 3 is the material that has the lowest shrinkage potential. The soil material can be used as material for embankment or cover for waste containment facilities with minimal shrinkage and cracking potential.

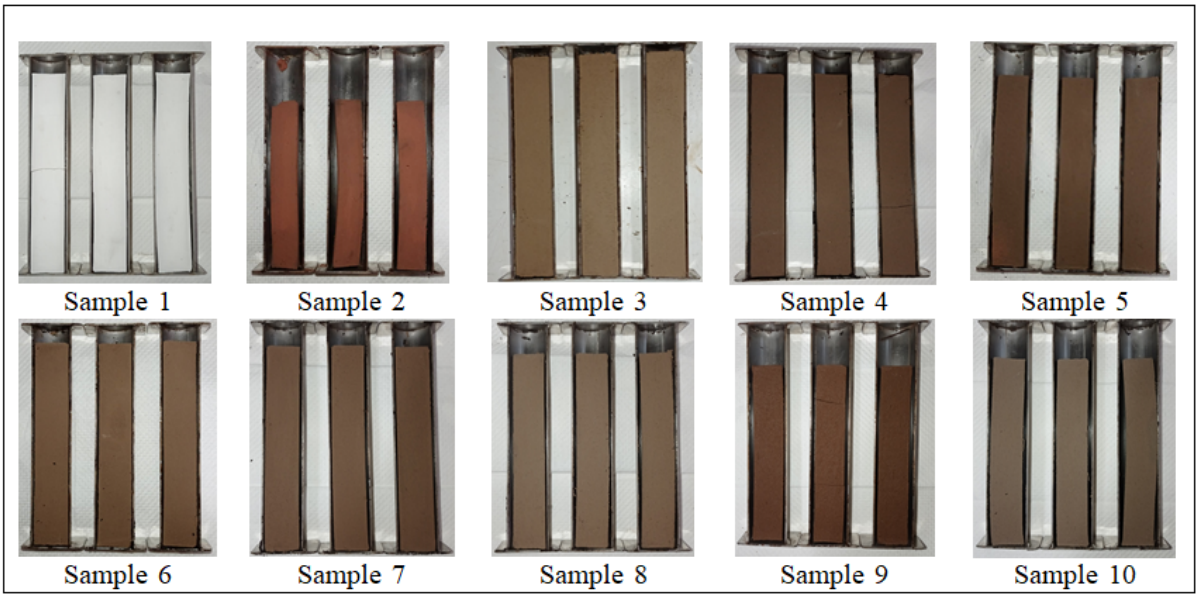

Fig. 2. Linear shrinkage test results

Table 3 Linear shrinkage value, the initial water content (ω), and soil shrinkage behavior classification according to Altmeyer (1956) for the ten soil samples from laboratory test

Sample	ω (%)	LS (%)	Shrinkage Behavior	Sample	ω (%)	LS (%)	Shrinkage Behavior
1	74,4	8,86	Critical	6	63,3	8,35	Critical
2	94,1	23,93	Critical	7	58,9	10,31	Critical
3	63,2	6,43	Marginal	8	56,8	13,38	Critical
4	55,5	10,38	Critical	9	80,9	18,69	Critical
5	62,1	14,12	Critical	10	66,5	16,16	Critical

3.2 Soil Desiccation Cracking Pattern

To determine the relationship between soil parameters, linear shrinkage values, and soil desiccation cracking pattern in this study, the surface crack ratio (R_{SC}) value obtained with the CIAS program will quantify the soil crack pattern. Images obtained from the laboratory test were processed using image processing technology. The desiccation cracking images can be seen in Fig. 3, and the value of R_{SC} can be seen in Table 4.

Calculation of the R_{SC} value uses the CIAS program. The maximum R_{SC} value difference between the two samples is 1,75 %. This result shows that even though the crack pattern seems different, the soil's surface crack area tends to be similar. This phenomenon can occur because both soil samples contain the same soil material with the same soil properties and under the same drying conditions. If the soil samples consist of the same material but under different drying conditions, the R_{SC} value will differ.

A few factors that influence the cracking behavior of soils are temperature and soil thickness. According to Tang et al. (2008), the higher the experimental temperature, the length, and width of the cracks that appear on the soil surface will increase. However, in this study, we use one constant number of temperatures.

3.3 Correlation Between Linear Shrinkage and Desiccation Cracking

The relationship between LS and R_{SC} values can be seen in Fig. 5. The higher the LS value, the higher the R_{SC} value. During the drying process on saturated soil, water will evaporate, and soil will shrink. This relation indicates that soil with a higher shrinkage will become more vulnerable to cracking during the drying process.

Shrinkage will create tensile stresses on the soil surface, and cracks will occur when the tensile stresses exceed the soil's tensile strength. Soil with a high LS value will experience significant volume shrinkage, and when cracks are formed, the soil will continue to shrink, creating a larger cracking area on the soil surface.

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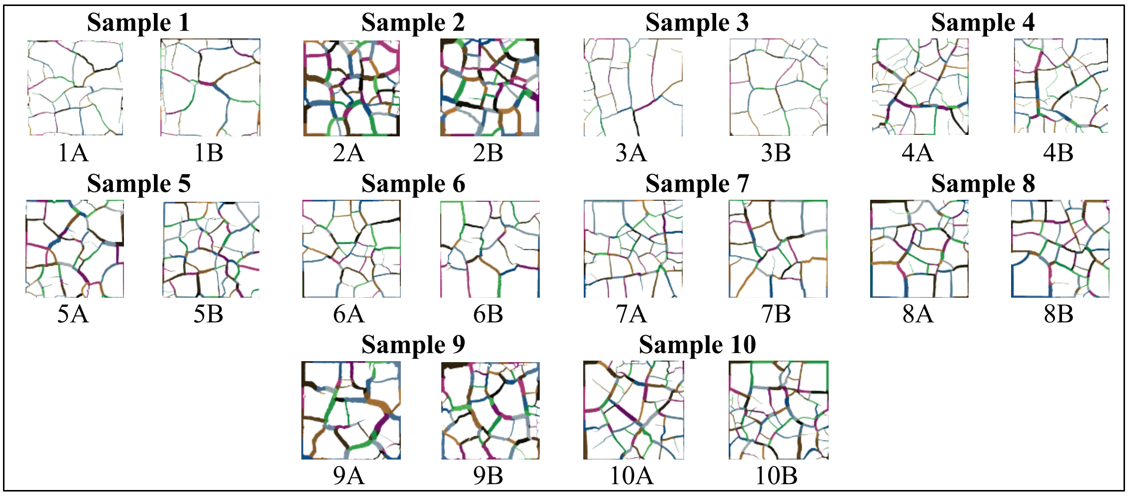
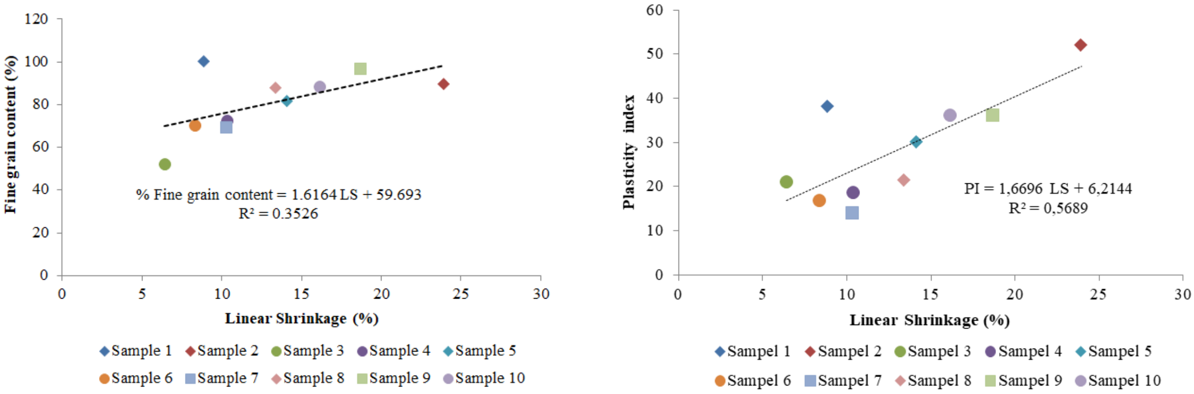


Fig. 3. Desiccation cracking pattern

Table 4 Rsc value and the initial water content (ω) for ten soil samples

Sample	Rsc (%)	ω (%)	Rsc value difference (%)
1A	9,37	74,03	1,75
1B	11,12	72,65	
2A	38,23	95,92	1,49
2B	39,72	95,32	
3A	8,08	67,50	0,72
3B	8,80	67,18	
4A	16,86	56,25	0,29
4B	16,57	55,86	
5A	20,09	61,98	0,57
5B	20,66	62,13	
6A	15,94	63,92	0,84
6B	15,10	64,56	
7A	17,02	59,40	0,91
7B	17,93	64,56	
8A	21,22	56,99	0,41
8B	20,81	57,40	
9A	29,71	78,75	0,55
9B	30,26	81,07	
10A	24,59	64,24	0,69
10B	25,28	63,25	



5(a) 5(b)

Fig. 4. Correlation between linear shrinkage, fine grain content, and plasticity index

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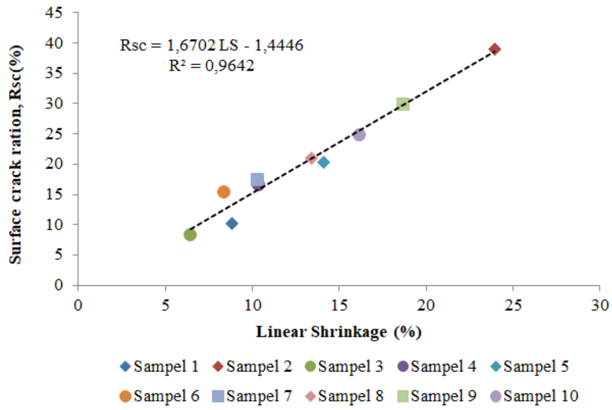

Fig. 5. Correlation between linear shrinkage value and surface crack ratio

4. CONCLUSIONS

Although the desiccation cracking pattern on the soil surface seems different, the surface crack ratio on the soil is similar to each other. It can occur because the sample consists of the same material and experience the same drying condition. Linear shrinkage value is influenced by the plasticity index value and particle size. As plasticity index value and fine grain content in soil increase, linear shrinkage value will also increase. Then, the soil will experience more considerable volume shrinkage and have a higher surface crack ratio value along with the increase of linear shrinkage value. Soil with a high plasticity index and high fine grain content has characteristics susceptible to shrinkage and forming cracks on the soil surface. One of the limitations of this study is that there is no data on the mineral content of the soil sample.

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