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The Influence of Initial Conditions on the Swelling Potential and Swelling Pressure of Cikarang's Expansive Soil

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ABSTRACT

Expansive soil can cause damage to simple constructions such as roads and houses with loads less than 20 kPa. Damage occurs due to the swelling behavior of expansive soil, due to changes in the moisture content of the soil. This research aims to determine the impact of the percentage of swelling potential and swelling pressure on expansive soil in the Delta silicon, West Java. This expansive soil is known to have very high swelling potential criteria. The samples used had variations in moisture content of 27% and 32%, with variations in initial stress of 16 kPa, 36 kPa, 38 kPa, and 42 kPa. The deformation that occurs due to swelling shows that all samples will continue to increase swelling for 4320 minutes (3 days). The results on the value of swelling potential and swelling pressure are influenced by water content. When a sample with a water content of 27% was compressed with a initial stress of 36 kPa, the swelling potential value increased by a maximum of 11%, and the maximum swelling pressure value was 913 kPa. These test results confirm the presence of very high soil swelling in the test area located in the silicon delta. The results of identification and swelling tests in the laboratory show that the development potential value of this land is high, which causes a high level of damage to simple construction.

Keywords: swelling potential; swelling pressure; soil deformation; oedometer test; expansive soil.

INTRODUCTION

The development town in cikarang is currently developing very rapidly such as roads and houses which makes soil an important material. The simple construction with loads less than 20 kPa. Expansive soil is a designate generally applied to any soil material or rock that is potentially shrinking or swelling due to changing moisture conditions. A soil is called an expansive soil where there is a potential for swelling and the cause of a shrinkage because of a change in water levels. Therefore, the designate expansive soil and swelling potential is generally used universally to refer to a soil that shrinks and swells.

In expansive soil is the main thing that forms the basis of the structure of a building and pavement. The changes in volume that occur are a function of a few variables, including the properties of the soil, the moisture condition (suction) at the time of construction, the amount of change in moisture content, its variation over time and space, and the geometry and stiffness of the structure. The moisture change that generates volume change beneath the structure occurs in unsaturated soils located above the ground water table. The behavior of unsaturated soils is often not fully and/or appropriately analyzed for residential construction where there is a tendency to use more empirically based solutions. Furthermore, with many existing models, small changes in input parameters can lead to dramatic changes in estimated soil response. Conditions in practice and in forensic investigations present engineers with substantial uncertainty for field applications.

In contrast to earlier years, when many problems with expansive soils were incorrectly associated with settlement, the concerns are now correctly diagnosed. Constructions built on expansive soil are susceptible to several forms of damage, like the bending of the bridge's abutment owing to ground movement, the roadway being waved and followed by crackers, and the wavy and cracked floor of the house.

Many issues with expansive soil were incorrectly associated linked to settlement. Constructions built on expansive soil are susceptible to several forms of damage, like the bending of the bridge's abutment owing to ground movement, the roadway being waved and followed by crackers, and the wavy and cracked floor of the house due to the movement of the ground. Expansive soil swelling and shrinkage, and will cause cracks when the conditions of contact with water. The main aspect of the change in soil volume on expansive soil is caused by water and some things such as soil properties (mineralogies), suction and water conditions, variations in water content both temporarily and spatially, and the geometry and rigidity of a structure, especially its foundations [1].

This research aims to determine the impact of the percentage of swelling potential and swelling pressure on expansive soil with construction damage. To recognize this type of expansive soil, it is necessary to carry out geotechnical investigations, namely by taking soil samples in the field and carrying out laboratory tests. This area is now in a state of development especially in terms of construction, so an initial study is needed regarding the swelling behavior of expansive soil, which is expected to provide an initial contribution to the study of the feasibility of construction development in Cikarang, West Java. As a result, more issues were identified accurately, and many issues with expansive soils were mistaken.

For simple buildings such as small houses, schools, or community halls, the presence of expansive soil beneath foundations can lead to multiple problems. Uneven swelling and shrinking across the site frequently cause differential settlement, where one part of the foundation moves more than another. This movement results in cracks on walls, uneven floors, and misaligned openings such as doors and windows [2], [3]. During rainy seasons, the soil may swell significantly and exert upward pressure on shallow foundations, a condition known as heave. Even small amounts of heave are enough to damage rigid masonry walls. In dry seasons, the soil shrinks and leaves voids beneath the foundation, further destabilizing the structure. Over time, these repeated movements increase maintenance costs for homeowners and may shorten the building’s service life [4].

Despite these challenges, construction on expansive soils is often unavoidable, especially in rapidly growing areas where suitable land is limited. For this reason, builders must take careful precautions before and during construction. Ideally, soil conditions should be investigated before building. Simple observations such as the presence of cracks during dry weather or the sticky texture of wet soil can provide indications of shrink–swell potential. More detailed investigations involve laboratory testing to determine plasticity index, cohesion, and swelling capacity [5], [6]. Once expansive soil has been identified, building designs should adapt to minimize its impact. Foundations need to be constructed in ways that reduce differential movement. For small buildings, wider strip footings or raft foundations can distribute loads more evenly, while reinforced concrete floors tied to walls help resist cracking. Drainage also plays an important role because it prevents excessive moisture variations in the soil. Well-designed surface drainage, sloping ground away from the building, and the installation of gutters can effectively control water infiltration [7].

RESEARCH METHODS

Materials

The soils Figure 1 defines the research’s location as the area with problematic soil and its necessity to investigate the possible construction damage issues. The expansive soil material used is disturbed soil from the delta silicon in Cikarang. The soil material is obtained by dredging soil that cleans the top layer of about 0.2 meters, a depth of about 1.2 meters, and a horizontal width of approximately 0.5 meters that is inserted into a plastic bag.

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Figure 1. The map of the spread of problematic clay in west java [8]

Sample preparation

The expansive soil was saturated, then crushed with a hammer and sieved through a 4.75 mm sieve. There are 12 specimen and two condition of moisture contents samples 27% and 32%. All samples were compacted to the same dry density of 1.31 g/cm3 inside a cylindrical stainless-steel mold by using a stratified sample preparation device. After the compaction, all samples are ready to be tested in oedometer compressed with various initial stresses (16 kPa, 38 kPa, and 42 kPa).

Table 1. All samples tested with the oedometer refer to the [9] method C. Reading and initial recording on the dial already installed with the initial stress. After the sample is in the oedometer, make sure the samples are swallowed with water. Observe the dial read and record the result, control the vertical stress of swelling potential until the samples reach the maximum of swelling pressure.

Table 1. Samples

No.	Sample	Moisture Content (%)	Initial Stress (kPa)
1.	S1	32	16
2.	S2		
3.	S3		38
4.	S4		
5.	S6		42
6.	S7		
7.	S8	27	16
8.	S9		
9.	S9		36
10.	S10		
11.	S11		42
12.	S12		

RESULT AND DISCUSSION

Time Rate of Swelling for Expansive Soils

Defined swelling become two stages. in Figure 2 shows that the behavior of all samples kept swelling for three days (4320 minutes). The curve flow in Figure 2 is characterized by three distinct trends: a rapid increase in percentage swell overtime at first, a slow increase indicated by the creation of a curve, and a very modest increase in swell over time explained by the asymptotic line. The three stages of swelling initial, primary, and secondary have evolved, according to data analysis. The initial stage of swelling occurred in less than four minutes and the primary stage of swelling for 1 to 8 hours (60 to 480 minutes), while the secondary swelling resumed after 8 hours [10].

Defined swelling potential as increased swelling for 2 days. The research [11] shows that secondary swelling occurs at a slower rate than primary swelling and reduces as the amount of moisture content in the solution increases. Previous research by Mehmood defined swelling potential as increased swelling for 2 days. The result of the percent of potential swelling increases greatly, about 11%, while the moisture content is 27% and the initial stress is 36 kPa [12]. Comparison with the previous research by Reddy defined the state of maximum swelling potential, which indicates the sample has been compressed to less than its original volume. In the current research after compressing with the initial stress of 42 kPa (moisture content of 27% and 32%), the maximum percent of swelling decreased. The sample of the swelling potential has been compressed to 42 kPa, almost back to its original height [13].

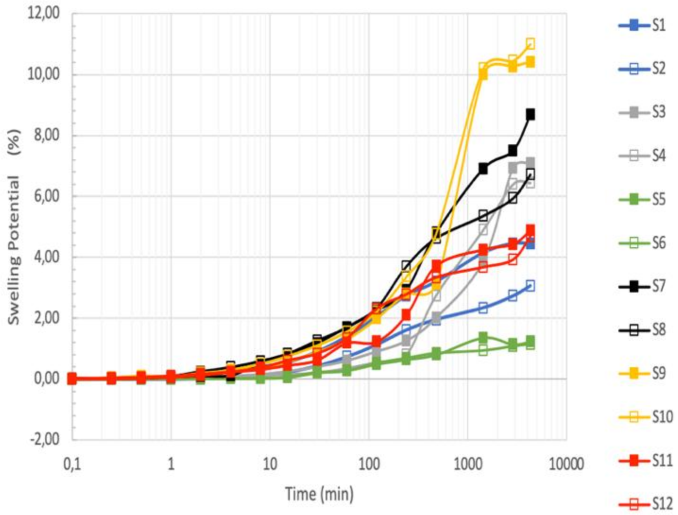

Figure 2. Swelling potential with time

Swelling Behavior of Expansive Soil

Table 2 shows the relationship between swelling potential and moisture content. The condition of the swelling potential is compressed with the same initial stress, but the moisture content is different. The value of the swelling potential is 11% with the moisture content of 27% being the maximum percentage of swelling potential. The lowest percentage value of swelling potential is 4,68% with the same moisture content. In comparison when the moisture content is 32% the swelling potential percentage is about 7,09% and the lowest percentage is 1,15%.

Table 2. Experimental result

Sample	Swelling Potential (%)	Swelling Pressure (kPa)
S1	4,45	203
S2	3,06	184
S3	7,09	497
S4	6,45	540
S6	1,23	155
S7	1,15	497
S8	8,70	595
S9	6,72	780

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Sample	Swelling Potential (%)	Swelling Pressure (kPa)
S9	10,42	873
S10	11,00	913
S11	4,87	626
S12	4,68	575

The behavior of swelling potential with moisture content shows changes increasing the swelling potential followed by decreasing moisture content. The relationship between swelling pressure and moisture content is shown in Figure 3. It shows the value of swelling pressure turned to a maximum of 913kPa when the moisture content was 27% but decreased to 155 kPa when the moisture content was 32%. The result shows that the behavior of swelling pressure change is caused by moisture content.

The expansive soil's initial moisture content condition will have an impact on the potential for swelling behavior [14]. On the other hand, a comparable condition with swelling pressure increases with decreasing moisture content and the phenomenon called the fatigue of swelling. This result shows that the moisture content below the optimum moisture content usually indicates a bad condition caused by high swelling potential and swelling pressure. The expansive soil could absorb water about twice as much as the moisture content percentage, and the expansion could cause structural damage [15].

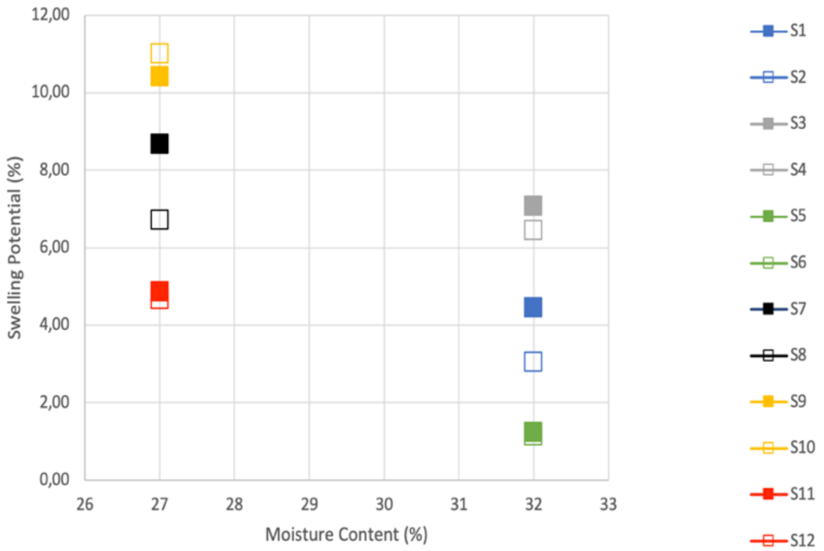

Figure 3. Swelling potential with moisture content

The behavior of swelling potential with moisture content shows changes increasing the swelling potential followed by decreasing moisture content. The relationship between swelling pressure and moisture content is shown in Figure 4, It shows the value of swelling pressure turned to a maximum of 913 kPa when the moisture content was 27% but decreased to 155 kPa when the moisture content was 32%. The result shows that the behavior of swelling pressure change is caused by moisture content.

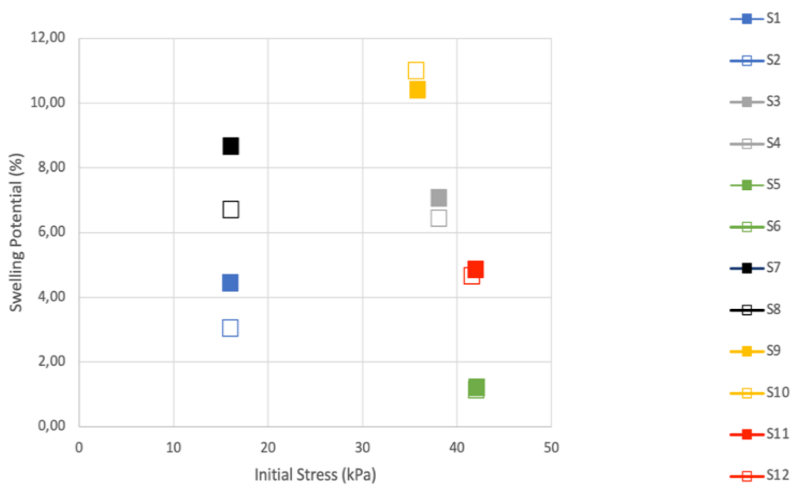

Figure 4. Swelling Potential with Initial Stress

The result of the value at a maximum of about 11% on swelling potential behavior is shown in Figure 4 while compressed with initial stress 36 kPa. It decreased by about 1,15% at the initial stress 42 kPa.

Defined a despite the compression stress and volume, swelling had a limit whenever the samples were in a wetted cycle with the same initial stress. Once this limit was reached, no more volume change was able to occur. The condition with the result related to the research defined that the initial stress of compressing most of the initial damage of soil-related fissures was closed but new fissures could form and propagate [15].

The value of about 913 kPa is the swelling pressure maximum behavior as shown in Figure 5 while compressed with initial stress at 36 kPa, but the swelling pressure behavior changed to decrease to 155 kPa while the initial stress is 42 kPa. Upon testing, the hydrated clay fraction's swelling along the fissure surfaces and the deformation of macropores resulting from initial stress would either increase or decrease the volume change during the process. Because the simple construction's existing load was less than the swelling pressure, the influence of swelling potential could have been causing destruction.

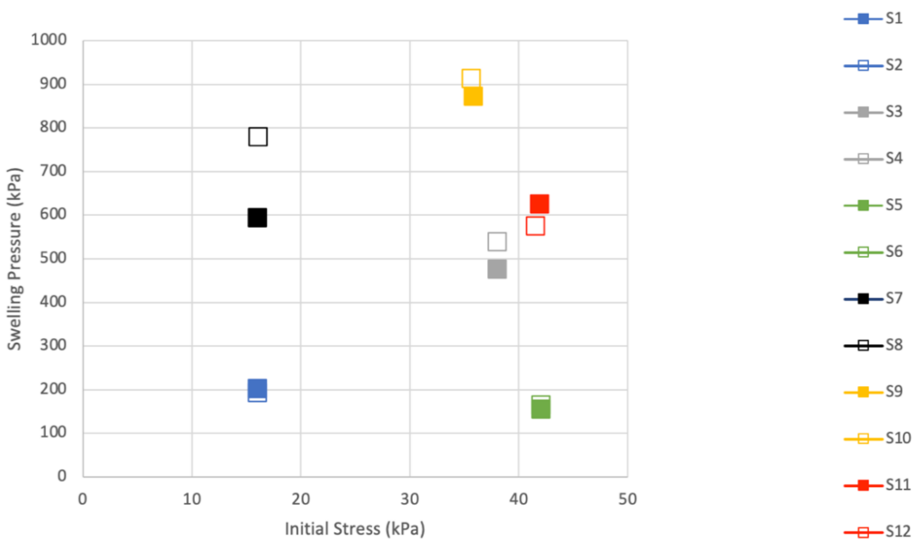

Figure 5. Swelling Pressure with Initial Stress

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CONCLUSION

The destruction of infrastructures caused by expansive soil is very important to observe. Expansive soil in delta silicon was necessary to identify because the location is one of the problematic clay zones in West Java. The swelling potential will keep increasing for 3 days. The sample after compressed 42 kPa swelling potential decreased and it almost back to the original height. The behavior expansive soil could absorb water about 2 times from the moisture content percentage. It showed that swelling potential and swelling pressure decreased while the moisture content increased. The wetted cycle from the samples compressed with the same initial state had a limit in swelling and after reaching this limit no further volume change. As a result of the swelling potential behavior at a moisture content of 27% at a initial stress of 36 kPa, there is a maximum increase and a return to decrease contraction at the initial stress increase to 42 kPa. The soil in Delta silicon had criteria of expansive soil and the behavior of the soil could cause damage to the structure with a small surcharge load.

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