

The effects of carbide column to swelling potential and Atterberg limit on expansive soil with column to soil drainage

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Abstract. The expansive soil is soil that has a potential for swelling-shrinking due to changes in water content. Such behavior can exert enough force on building above to cause damage. The use of columns filled with additives such as Calcium Carbide is done to reduce the negative impact of expansive soil behavior. This study aims to determine the effect of carbide columns on expansive soil. Observations were made on swelling and spreading of carbides in the soil. 7 Carbide columns with 5 cm diameter and 20 cm height were installed into the soil with an inter-column spacing of 8.75 cm. Wetting is done through a pipe at the center of the carbide column for 20 days. Observations were conducted on expansive soil without carbide columns and expansive soil with carbide columns. The results showed that the addition of carbide column could reduce the percentage of swelling by 4.42%. Wetting through the center of the carbide column can help spread the carbide into the soil. The use of carbide columns can also decrease the rate of soil expansivity. After the addition of carbide column, the plasticity index value decreased from 71.76% to 4.3% and the shrinkage index decreased from 95.72% to 9.2%.

1. Introduction

The expansive soil is a soil whose clay within has a potential for swelling-shrinking due to changes in water content. This type of soil will experience swelling if the water content is high and shrinking if the water content is low. Swelling and shrinking condition could be very dangerous for the buildings above this kind of soil. Expansive soil is classified as an unstable type of soil which could damage the floor and foundation of the building above. Efforts have been made to improve the expansive soil properties by mixing additives on the soil. But It still creates obstacles in the implementation in the field. This research was conducted to add reference in anticipating the damage of the building caused by expansion of expansive soil. Experiments in this study were conducted by installing carbide columns on expansive soil. The drainage is carried from the column to the soil through a pipe mounted in the center of the carbide column. The results come from observations of swelling and spreading of carbides in the soil.

2. Theoretical Background

2.1 Expansive Soil

Expansive soil is a soil that is susceptible to swelling-shrinking due to changes in water content. This volatile soil is a clay soil containing mainly montmorillonite minerals. These small amount of montmorillonite minerals which contained in the soil could have a strong tensile force against water at any given time. The soil containing montmorillonite is very easy to swell by additional moisture content.



2.2 Identification of Expansive Soil

One common way to identify changes in soil volume is by analyzing the plasticity index (*PI*) or shrinkage index (*SI*). The expansive soil has a relatively large difference ratio between the liquid limit and the plastic limit, the expansive soil with a very high expansionary rate having a plasticity index of > 35%. The relationship of expansion potential and *PI* is shown in Table 1.

Table 1. Expansion Potential Relationships and PI [1]

Plasticity Index (%)	Expansion Potential
> 35	Very High
20 – 55	High
10 -35	Medium
0 -15	Low

The identification of expansive soil can also be determined using the shrinkage index (*SI*) value is the reduction between the liquid limit and the shrinkage limit. The expansive soil with high expansive rate has a shrinkage index of > 60%. Determination of expansive soil based on shrinkage index (*SI*) can be seen in Table 2.

Table 2. Expansiveness Rate by Shrinkage Index

Shrinkage Index (%)	Degree of Expansion
0 – 20	Low
20 – 30	Medium
30 – 60	High
> 60	Very High

2.3 Atterberg Limit

Atterberg (1911), provides a way to illustrate the consistent limits of fine grained soils by considering the moisture content of the groundwater. These limits are liquid limit, plastic limit, and shrinkage limit. The liquid limit (*LL*) is defined as the groundwater content at the boundary between the liquid state and the plastic state, is the upper limit of the plastic area. The liquid limit is usually determined from the Casagrande test, where the percentage of moisture content required to cover the 12.7 mm long slit on the bottom of the plate after 25 strokes is defined as the soil liquid limit [2].

The plastic limit (*PL*) is defined as the moisture content in the position between the plastic and semi-solid areas, ie the percentage of moisture content in which the 3.2 mm diameter cylinders begin to crack when rolled. The shrinkage limit (*SL*) is defined as the water content at the position between the semi-solid and solid areas, ie the percentage of moisture content where subsequent water content reductions do not result in changes in the volume of soil.

The value of the shrinkage limit is obtained from the graphical way suggested by Casagrande in accordance with ASTM D-427. Plasticity index (*PI*) is the interval of moisture content where the soil is still plastic. The plasticity index value is derived from the reduction between the liquid limit and the plastic limit, while the shrinkage index value is obtained from the reduction between the liquid limit and the shrinkage limit.

2.4 Soil Stabilization by Column Method

Soil stabilization is one effort that can be done to anticipate the losses caused by expansive soil behavior. Soil stabilization is carried out in an effort to change or improve the technical properties of the soil such as the carrying capacity, compressibility, permeability, ease of use, expansion potential, and sensitivity to changes in water content so as to meet certain technical requirements.

The use of columns is one of the methods in soil stabilization. The method is done by making a hole in the soil and filling it with additives. The additive inside the column is allowed to seep into the soil, causing a reaction between the soil and the additive. Hardiyatmo [3] states that the use of column methods can reduce the potential for changes in the volume of soil. This is because the column can make the soil move in the lateral direction into the hole thereby reducing the movement toward the vertical.

2.5 Carbide

Previous studies have used carbide waste as a stabilizing agent. Carbide waste is the waste material from the process of making acetylene gas (acetylene), in the form of high calcium lime (calcium lime). This material has properties such as limestone, so as with lime outages, carbide wastes include hydraulic bonding material, but the quality is not as high as portsoil cement. Because the properties are almost equal to this limestone so that carbide can function as one of the alternative materials in soil stabilization. The chemical soil stabilization carried out in this study used carbide as a stabilizing agent. Carbide or Calcium Carbide is a chemical compound with CaC_2 formula. Carbide usually contains only about 80-85% CaC_2 while the rest are CaO , Ca_3P_2 , CaS , Ca_3N_2 , SiC , and others.

3. Research Method

7 pieces of carbide columns with diameter of 5 cm and depth of 20 cm. The distance between columns is 8.75 cm. Wetting is done periodically for 20 days through a pipe mounted in the center of the column. Observations were made on swelling that occurred on expansive soil without carbide columns and expansive soil with carbide columns. Observations were also conducted on X-Ray Fluorescence (XRF) testing, UCS testing, and Atterberg limit test on expansive soil before and after addition of carbide columns. XRF test is done to determine the soil contents due to the addition of carbide columns as well as to know the spreading of carbide in the soil. The UCS test was performed to determine the strength of the soil after the addition of carbide columns on the expansive soil. Swelling observation was done in 4 areas: area I, area II, area III, and area IV. Testing sketches and location of observations are shown in Figures 1 and 2.

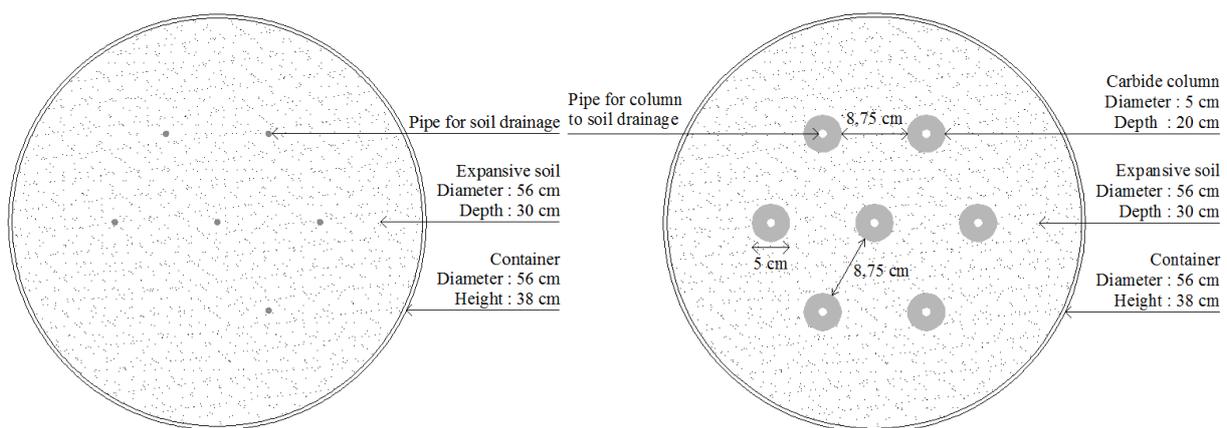


Figure 1 Sketches of Expansive Soil Testing without and with Carbide Columns.

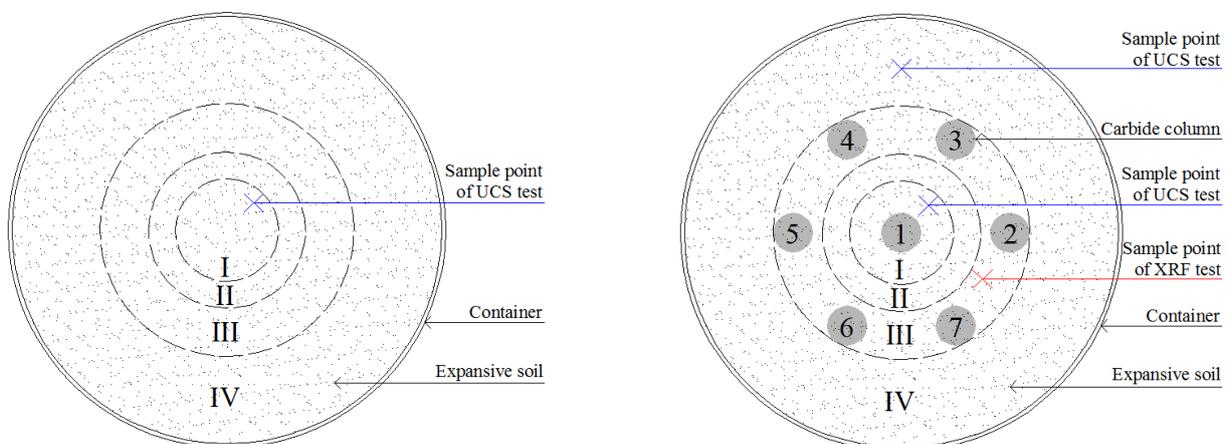


Figure 2 Point of Swelling Observation and Sample Point of XRF Test and UCS test

4. Result and Discussion

4.1 Testing X-Ray Fluorescence (XRF)

This test is carried out twice before and after the addition of carbide column on the expansive soil. XRF test produces data in the form of percentage of compounds contained in the soil. The data can show how large the mineral content with the potential to expand in the soil. The XRF test results also determine whether the soil that has been taken is considered expansionary and can be continued to subsequent tests.

The second X-ray Fluorescence (XRF) test was performed after the swelling and wetting process were completed. The sample is taken at a predetermined point. The amount of carbide compounds in the soil can be seen through this test. The amount of carbide compounds present in the soil can be thought to represent the spread of carbons in the soil. Comparison of XRF test results before and after addition of carbide column is shown in Table 3.

Table 3 Comparison of XRF Test Results

Before the Addition of Carbide Columns		After the Addition of Carbide Columns	
Name of Compound	Percentage (%)	Name of Compound	Percentage (%)
SiO ₂	33.83	CaO	54.78
Fe ₂ O ₃	20.84	SiO ₂	11.56
Na ₂ O	12.97	Fe ₂ O ₃	10.74
CaO	10.57	Na ₂ O	9.29
Al ₂ O ₃	9.66	Al ₂ O ₃	4.43
MgO	3.41	SO ₃	2.84
TiO ₂	1.75	MgO	2.09
Another Compounds	3.15	Another Compounds	4.27

Table 3 shows that in the XRF test results after addition of carbide column there is CaO as the largest percentage compound. CaO compounds have a percentage of 54.78% of all soil contents. The percentage of CaO compound increased significantly from 10.57% to 54.78% after the addition of carbide column. It is thought to have occurred due to the reaction of carbides with water. The SiO₂ and Al₂O₃ compounds commonly found in montmorillonite minerals have percentage of 33.83% and 9.66% to only 11.56% and 4.43% after the addition of carbide columns.

CaO is one of the constituents of carbide. The carbides having the general formula CaC₂ are produced by heating Calcium Oxide (CaO) and Carbon (C) in an electric furnace with carbon dioxide as byproducts. Nafisah [4] states that CaO is also a dominant compound in lime and cement commonly used in clay stabilization. CaO compounds are needed in a chemical process with clay soils that will produce high calcium ions. These high calcium ions can bind around the clay soil particles so as to reduce the pull on the water. It can be seen in Table 3 that CaO compounds are more dominant than other compounds. It indicates that the carbide content has seeped into the soil through streaming through the center of the column.

4.2 Swelling Test

The swelling test is performed on 4 predefined observation areas. The percentage ratio of swelling across observation points that occur between expansive soil with carbide columns and without carbide columns after 20 wetting days is shown in Table 4.

Table 4 Percentage of Swelling Comparisons

Area	Percentage of Swelling (%)		
	Without Carbide Columns	Using Carbide Columns	Reduction
I	38.94	35.22	3.72
II	39.58	35.42	4.15
III	38.12	33.90	4.19
IV	35.83	30.19	5.63
Average	38.12	33.69	4.42

Based on table 4 can be formed into graphs as follows:

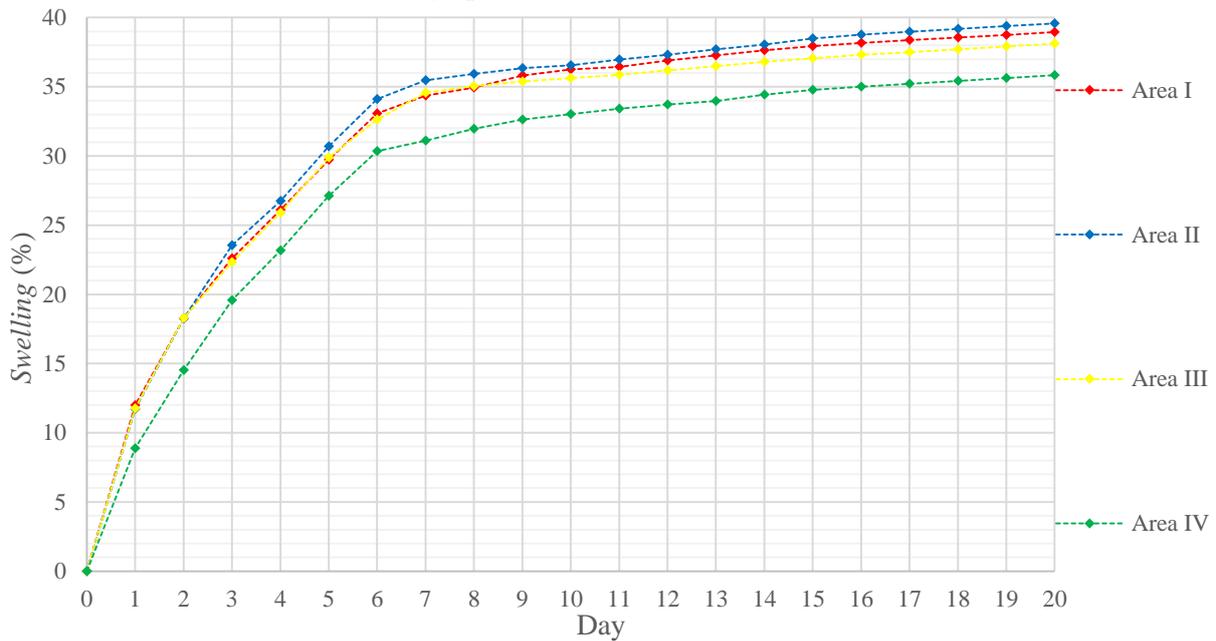


Figure 3 Swelling Graph on Expansive Soil without Carbide Columns

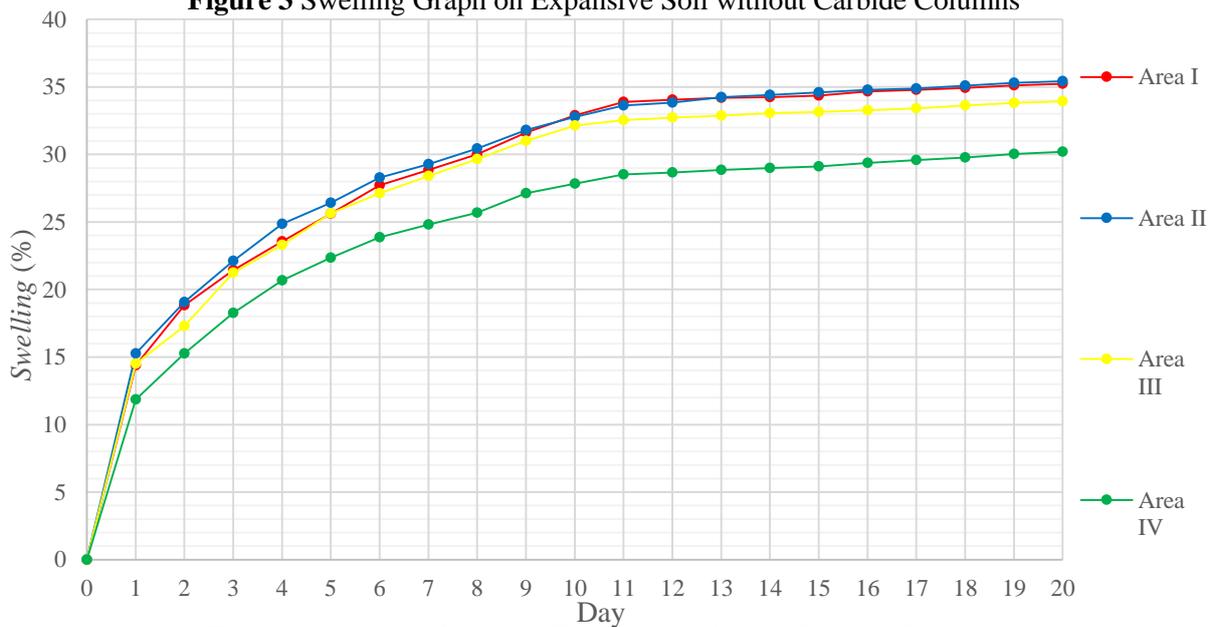


Figure 4 Swelling Graph on Expansive Soil with Carbide Columns

The swelling test results show that all observation points on the expansive soil with carbide columns undergo a lower swelling of expansive soil without carbide columns. The largest reduction of swelling occurred at area IV which experienced a reduction of 5.63%. The smallest swelling reduction occurs at area I at 3.72%. Based on the test results, the addition of carbide column on average can reduce swelling by 4.42%. The mixture between carbide and water is thought to produce positive ions (cations) that can bind expansive negative ion (anions) so that they can reduce the attraction of water. This can reduce the potential for swelling on expansive soil with carbide columns. The event is in accordance with Hardiyatmo [3] which states that the reaction of additives such as carbide with soil components forms a new chemical. The two main components of the soil that react with the additive are alumina and silica. Expansion potential and expansion pressures are significantly reduced by the addition of additives in the soil. Reduced expansion characteristics are generally followed by a reduction in the attractiveness of water.

4.3 Unconfined Compression Strength Test (UCS)

UCS test in this study use three kinds of samples. One sample is taken from expansive soil without carbide columns. Two other samples were taken from the expansive soil with carbide columns in the area I and area IV. UCS test results are shown in Table 5.

Table 5 Comparison of UCS Test Results

Result of UCS Test	Without Carbide Column (kN/m ²)	Using Carbide Column (Area IV) (kN/m ²)	Using Carbide Column (Area I) (kN/m ²)
Cohesion (<i>C_u</i>)	3.47	3.48	4.32
Unconfined Compression Strength (<i>q_u</i>)	6.94	6.96	8.64

Table 5 shows that the addition of carbide columns can improve the cohesion value and the free compressive strength of expansive soil. The cohesion value on the soil near the carbide column of 4.32 kN/m² is higher than that of cohesion on the soil without carbide column of 3.47 kN/m². The addition of carbide columns can also improve the compressive strength of expansive free pressure. The free compressive strength value of the soil near the carbide column of 8.64 kN/m² is higher than the free compressive strength value without the carbide column of 6.94 kN/m².

The distance to the carbide column also influences the magnitude of the cohesion and the compressive strength of the soil. Table 5 shows that the cohesion at the point near the carbide column of 4.32 kN/m² is higher than the point cohesion away from the carbide column of 3.48 kN/m². The soil free compressive strength value near the carbide column is also higher than that located far from the carbide column of 8.64 kN/m² compared to 6.96 kN/m². It is also supported by Budi [5] study which states that the addition of a single column of carbide waste can increase the expansive soil around it.

4.4 Atterberg Limit Testing

This test was conducted to determine the comparison of Atterberg limit values of soil before and after the addition of carbide column. Grain size analysis test is done to know the soil classification. Initial condition of soil has gravel percentage 0.75%, sand 8.87%, silt 34.95%, and clay 54.44%. Atterberg limit test results are shown in Table 6.

Table 6 Comparison of Atterberg Limit Test Results

Test	Before the addition of carbide columns (%)	After the addition of carbide columns (%)
Liquid Limit (<i>LL</i>)	114.05	65.02
Plastic Limit (<i>PL</i>)	42.49	60.73
Plasticity Index (<i>PI</i>)	71.76	4.3
Shrinkage Index (<i>SI</i>)	95.72	9.2

Table 6 shows that the liquid limit value fell from 114.05% to 65.02%. It is suspected that the positive ion (cation) of carbide binds negative ions (anions) from the soil so that there is an interesting attraction between the cation and the anion. When the soil and carbide are watered, some of the soil tends to bind the carbides so that the soil will bind the water a bit. The water originally absorbed by the soil will be replaced by carbide and the moisture content in the soil will decrease.

The plastic limit increased from 42.49% to 60.73% after the addition of carbide column. Soil mixed with carbide and given water will be easier to crack when rolled compared to the soil without carbide. The rise of the plastic limit value is suspected because the carbides added to the soil will be hydrated causing the soil to dry quickly and crack before the roll reaches 3.2 mm in diameter. Water should be added more so that the rolls crack at 3.2 mm in diameter. This indicates that the addition of carbide column causes the plastic limit value to rise.

The decrease of the liquid limit value and the rise of the plastic limit value after the addition of carbide columns is supported by Fauziah's [6] study which states that the more waste of carbide soil in the soil the liquid limit value decreases and the plastic limit value increases. Changes in soil properties can certainly affect the level of soil expansion. Result of soil classification test before and after addition of

carbide column compared to know how difference of expansion level of soil happened by addition of carbide column. The comparison of expansivity rates of soil before and after the addition of carbide columns is shown in Table 7.

Table 7 Comparison of Soil Expansory Rates Before and After the addition of Carbide Columns

Test	Carbide Column					
	Before Addition			After Addition		
	Result (%)	Requirement (%)	Expansory Rates	Result (%)	Requirement (%)	Expansory Rates
Plasticity Index	71.76	> 35	Very High	4.3	0-15	Low
Shrinkage Index	95.72	> 60	Very High	9.2	0-20	Low

Table 7 shows that the addition of carbide column causes the plasticity index value to decrease from 71.76% to 4.3% and its expansion rate is low. The addition of carbide column also affected the decrease of shrinkage index value which previously was 95.72% to 9.2% and expansive level was low.

5. Conclusion

Based on the results of research and discussion, it can be concluded as follows:

- The addition of carbide column can reduce the percentage of swelling by 4.73%.
- The addition of carbide column can increase the cohesion value from 3.47 kN/m² to 4.32 kN/m² and Unconfined Compression Strength value from 6.94 kN/m² to 8.64 kN/m².
- The addition of carbide column can reduce the percentage of Liquid Limit (*LL*) from 114.05 % to 65.02 %.
- The addition of carbide column can increase the percentage of Plastic Limit (*PL*) from 42.49 % to 60.73 %.
- The addition of carbide column can reduce the percentage of Plasticity Index (*PI*) from 71.76 % to 4.3 %.
- The addition of carbide column can reduce the percentage of Shrinkage Index (*SI*) from 95.72 % to 9.2 %.
- The use of the carbide column method by streaming through the center of the column can spread the carbide into the soil. This is evidenced by X-Ray Fluorescence (XRF) test results. XRF test results stated that the soil samples contain one compound carbide composition is Calcium Oxide (CaO) of 54.78%.

Chen, Y.L., 1988. Foundations on Expansive Soils. Elsevier Science Publishing Co., Inc., New York.

6. References

- [1] Chen, Y.L., 1988. Foundations on Expansive Soils. Elsevier Science Publishing Co., Inc., New York.
- [2] Hardiyatmo, H., C., 2010, *Mekanika Tanah 1*, Yogyakarta: Gajah Mada University Press.
- [3] Hardiyatmo, H., C., 2014, *Permasalahan dan Penanganan Tanah Ekspansif*, Yogyakarta: Gajah Mada University Press.
- [4] Nafisah, A., dan Gunawan, H., 2013, Pemanfaatan Limbah Karbit untuk Meningkatkan Nilai CBR Tanah Lempung Desa Cot Seunong (172G), *Surakarta: Universitas Sebelas Maret*
- [5] Budi, G., S., 2003, Penyebaran Kekuatan dari Kolom yang Terbuat dari Limbah Karbit dan Kapur, *Dimensi Teknik Sipil Volume 5 Nomor 2: Universitas Kristen Petra*.
- [6] Sanusi, 2012, Durabilitas Campuran Aspal Beton Menggunakan Filler Semen Portland, Limbah Karbit, dan Limbah Batu Bara, *Surakarta: Universitas Sebelas Maret*.
- [7] Fauziah, N., 2017, Pengaruh Penambahan Limbah Karbit terhadap Potensial *Swelling* pada Tanah Lempung Ekspansif di Daerah Driyorejo Gresik, *Jurnal: Universitas Negeri Surabaya*