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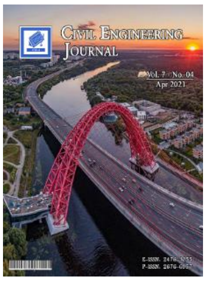

Preloading Model on Soft Soil with Inclusion Thermal Induction Vertical and Incline Types

Maraden Panjaitan [1*], A. R. Djamaluddin [2], Tri Harianto [2], A. B. Muhiddin [2]

[1] *Doctoral Course Student, Department of Civil Engineering, Hasanuddin University, Makassar and 90245, Indonesia.*

[2] *Department of Civil Engineering, Hasanuddin University, Makassar and 90245, Indonesia.*

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Abstract

Soft clay has a relatively low subgrade bearing capacity. The aim is to obtain physical values, mineralogy, mechanical strength values, values for reduction. The research method used is preloading in a test tube measuring 50×70×150 cm. Each cycle of preloading and thermal induction used a fixed load of 0.015 kg/cm². Thermal induction is given vertically and obliquely with temperature variations of 100, 200, 300, and 400 °C. The main observation point is a distance of 15 cm from the center of the induction. At 400 °C inclined induction, the water content is 17.36% (from the initial water content of 59.07%), the soil cohesion is 21.75. kN/m², the value of unconfined compressive strength is 67.72 kN/m², the highest modulus of elasticity is 4593 kN/m², and the decrease is 5.13 cm. XRD, SEM, EDS results before heating showed mineralogy 0 (65.06%), Ca (13.30%), Na (3.64%), Mg (2.15%), Al (6.63%), Si (8.52%), Sn (0.70%) and did not change significantly after heating at 400 °C. The results after heating included 0 (58.39%), Ca (14.09%), Na (0.72%), Mg (1.16%), Al (6.63%), Si (14.72%), Sn (2.54%). The novelty obtained is to change very soft conditions became medium conditions.

Keywords: Thermal Induction; Preloading; Soft Clay; Modulus Elasticity; Mineralogy.

1. Introduction

The main problem of infrastructure development in soft clay is the relatively low bearing capacity of the base soil and the relatively large compaction of the base soil which lasts relatively longer. To overcome the problem of infrastructure development on soft clay soil, it must be improved or ground improvement to make it stronger or gain strength. One of the soil improvement methods, namely the combination method of preloading and thermal induction, is quite an interesting repair method because the method of implementation is simple and still not widely studied in Indonesia at this time. The land used comes from Takalar District, South Sulawesi [1].

The soil improvement methods that have been used today are varied such as preloading, prefabricated vertical drain (PVD), electro-osmosis, vacuum consolidation, lightweight fill, stone column, jet grouting, lime columns, fracture grouting, ground freezing, vitrification, electrokinetic treatment, electro heating, and thermal induction. However, the combination method of preloading and Thermal Induction is a method of repair that is quite interesting and is still not widely studied in Indonesia at this time [2]. The improvement of soft soil by this method is considered very appropriate by considering the factor that soft soil has high water content, with heat induction it can accelerate the drainage rate of

* Corresponding author: panjaitanmaraden179@gmail.com

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water in soft soil. So that the combination of Preloading and Thermal Induction can accelerate the rate of soil compression for infrastructure development purposes. Therefore, this research aims to determine the effect of Thermal Induction with variations in the inclusion of vertical and sloping types with preloading loading on soft soil at the radius where the Thermal Induction rod is embedded [3]. It is expected that from the results of this experimental study, empirical findings and an overall picture of soft soil behavior will be obtained, especially on the influence of soft soil mechanical properties, mineralogical aspects, soil thermo-mechanical [4].

2. Literature Review

2.1. Soft Soil Preloading

The preloading method is the initial loading with the weight of the embankment and equivalents around the weight of the structure used later. Soil conditions vary and are not always the same in each construction area, thus requiring precision in planning and implementing the construction itself. Soil strengthening (gained strength) that occurs due to the gradual preloading process or stage construction, changes in the level of saturation or wetting effect, creep strain, are factors that are often not taken into account in estimating consolidation decline [5]. Preloading aims to increase the shear strength in the soil, reduce the compressibility of the soil and prevent large settlements and possible damage to the building structure. Preloading is generally used on soils with low bearing capacities, such as soft clay soils and organic soils. This type of soil usually has the following characteristics: extreme moisture content, large compressibility, and small permeability coefficient [6, 7].

2.2. Thermal Induction in Clays

The relationship between thermal conductivity and soil properties such as mineral composition, dry bulk density (porosity), pore fluids, degree of saturation, moisture content, and temperature The geometric effect of soil particles on the thermal conductivity of saturated clay .Table 1 lists the thermal conductivity of the mineral (thermal conductivity) in the soil, which is one of the thermal parameters that shows the amount of energy that can be distributed in the soil [8].

Table 1. Soil types and thermal conductivity

Types	Thermal Conductivity (W/m/K)	Thermal Capacity (J/Kg/K)
Clay	0.25 – 4.20	800 – 2,646
Sand	0.15 - 5.03	800 – 1,747
Gravel	4.44	1.175

2.3. Settlement Consolidations

A decrease in consolidation is a condition when the soil layer experiences additional loads, the pore water pressure will suddenly rise. The discharge of pore water goes along with a decrease in soil volume which causes a reduction in the soil layer. In clay soil with low probability, excess pore water stress takes a long time to dissipate, so that the decline in consolidation takes a very long duration. To calculate the consolidation decline using Equation 1 [9].

$$S_c = \sum \left(\frac{C_c \times h}{1+e} \times Log \left(\frac{\sigma_{o+} \Delta_\sigma}{\sigma_o} \right) \right) \tag{1}$$

Where: S_c = Settlement consolidation (m); C_c = Compression Index; H = High layer (m); e = Void; σ_o = Effective Pressure (t/m^2); Δ_σ = Surcharge effective pressure (t/m^2).

2.4. XRD (X-Ray Diffraction) Testing

The analysis method by X-ray diffraction (XRD) can be used to identify clay minerals because it emphasizes the crystal structure aspect of the mineral by referring to Bragg's law and can be used to classify the type of mineral as long as the mineral has a certain crystal form even though its size is very small. Regarding the X-ray diffraction character of a single mineral which can guide the basic properties of the X-ray diffraction pattern for each type of clay mineral. Semi-quantitative XRD analysis was carried out to determine the proportion of montmorillonite, illite, and kaolinite or chlorite clay minerals which are useful for estimating the expansive properties of clay contained in rocks [10].

3. Material and Methods

3.1. Sampling Location

Soft soil for this study was obtained from Takalar, South Sulawesi, Indonesia. The sampling location is shown in Figure 1 below with coordinates 5°26'54.79"S 119°82'85.71" T. The research location is on the Takalar coast, a rice field irrigation area. The sample locations are shown in Figure 1.

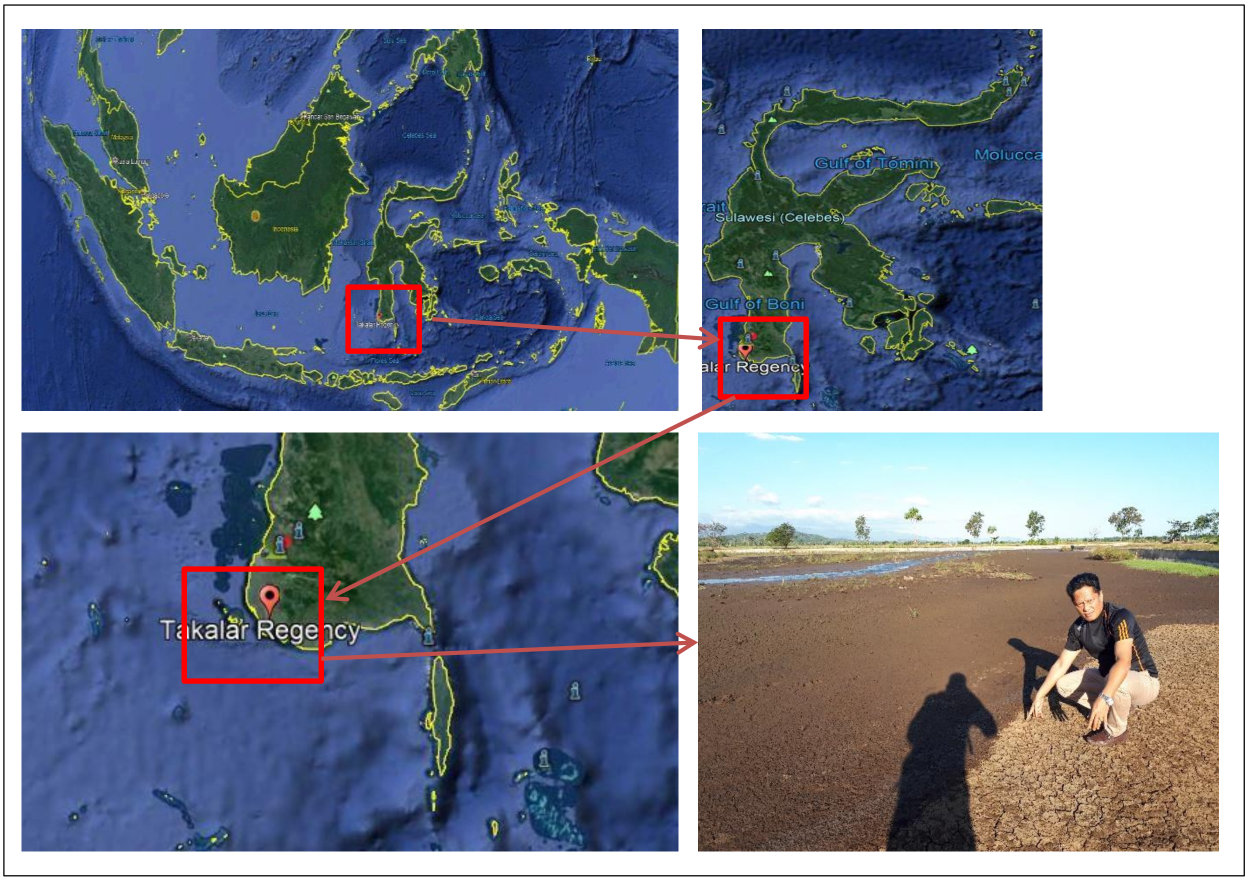

Figure 1. Sampling location, Takalar, South Sulawesi, Indonesia

Initial condition partially due to the drier conditions associated with climate change. The soil thermal conductivity depends on the soil composition, bulk density and especially on the water content. Thus, moisture content might have an insulating effect, decreasing the temperatures reached on the soil after a heating event or might conduct heat pulses more efficiently, resulting in deeper penetration and, perhaps, higher temperature down the soil profile. Therefore, the impact of heating on the physical, chemical and biological soil properties depends, among other factors, on the soil moisture, which can affect both the direct impact of thermal shock and the further survival of soil microorganisms. Increasing heat conditions will make the soil stiff [11-13].

3.2. Model Test Procedure

Modelling the disturbed soil sample is placed in a test tube with the dimensions of the soil sample being tested in a test tube with a length of 150 cm, a width of 50 cm, and a height of 70 cm. The test tube is shown in Figure 3. Besides, the load given is 0.015 kg/cm², this loading is constant at each test temperature variation, where reconstitution is carried out with a mixing water and sediment pattern before thermal induction. The research method is to create a framework and stage flowchart as in Figure 2.

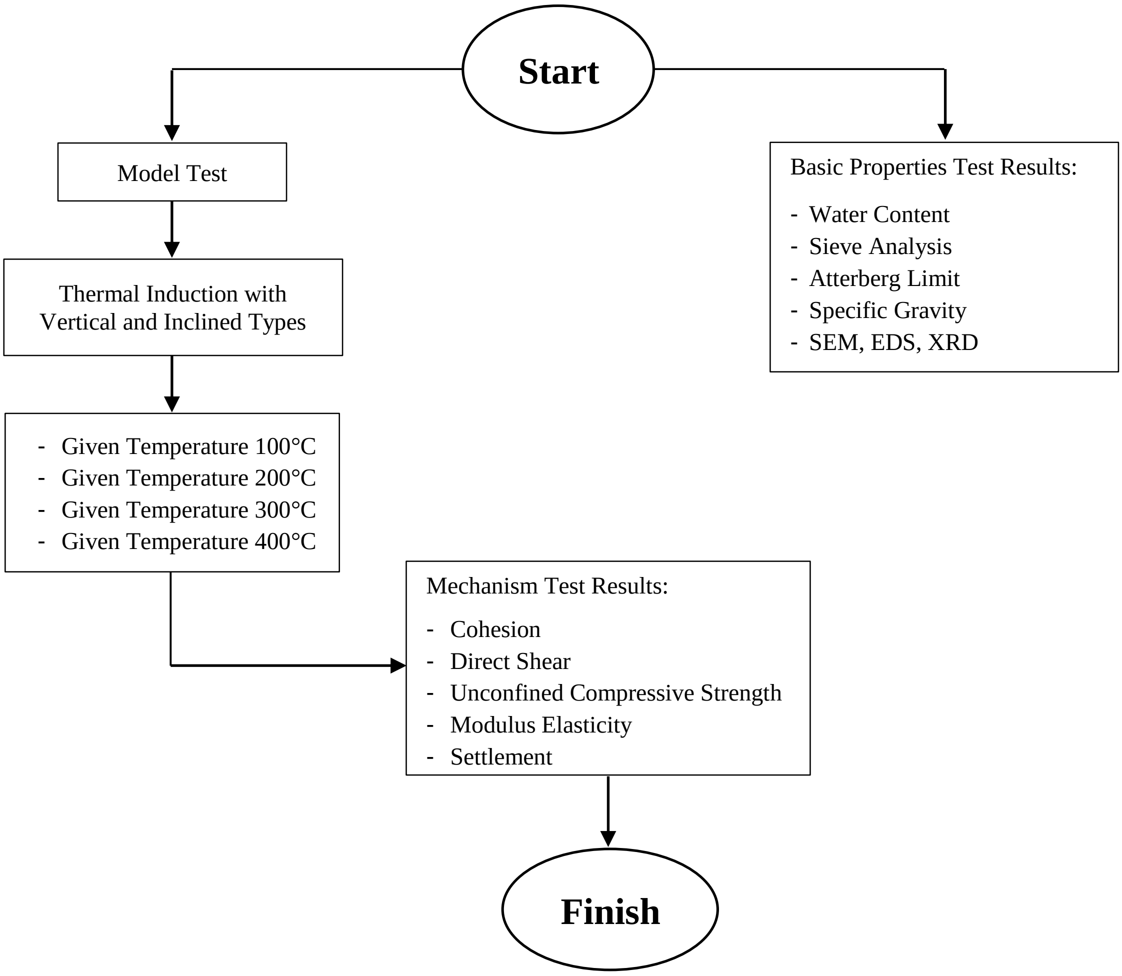

Figure 2. Flowchart of the research methodology

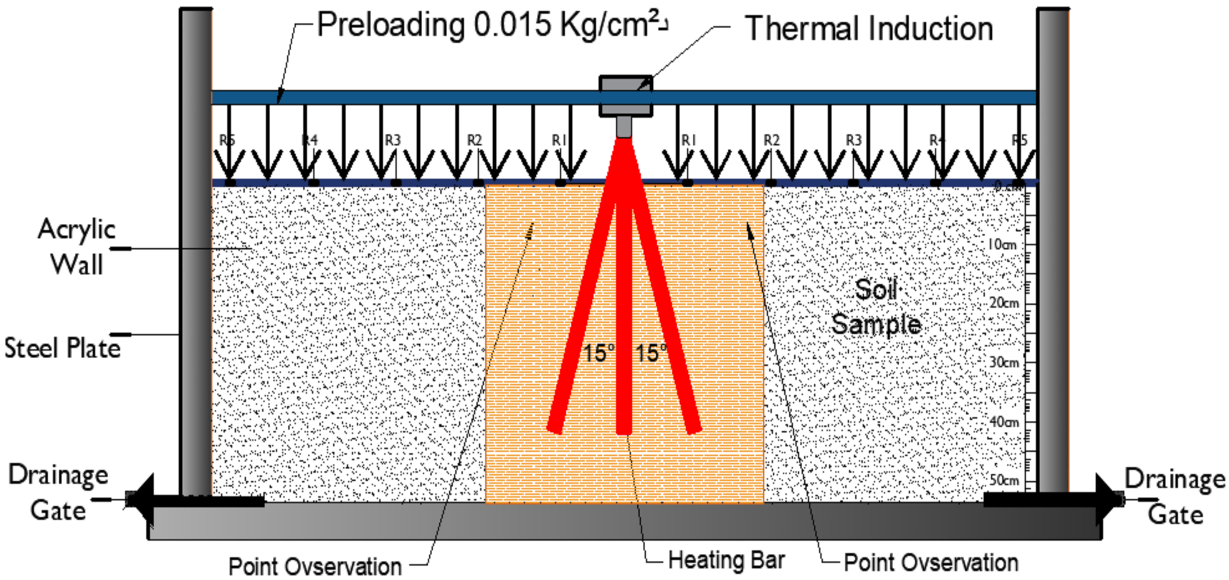

Figure 3. Testing model

Observations are made at the radial zone (R1) or 15 cm from the thermal point as shown in Figure 3 which has a significant impact on the thermal effect. This observation is in the form of physical, chemical, and mechanical changes of the test sample [14, 15]. Physical test is carried out through of a property test which includes specific gravity, grade, water, Atterberg limit. Mineralogical testing was carried out by SEM, EDS, and XRD tests to see changes before and after thermal application. Mechanical testing was carried out to determine changes in the values of shear strength, free compressive strength, and modulus of elasticity [16].

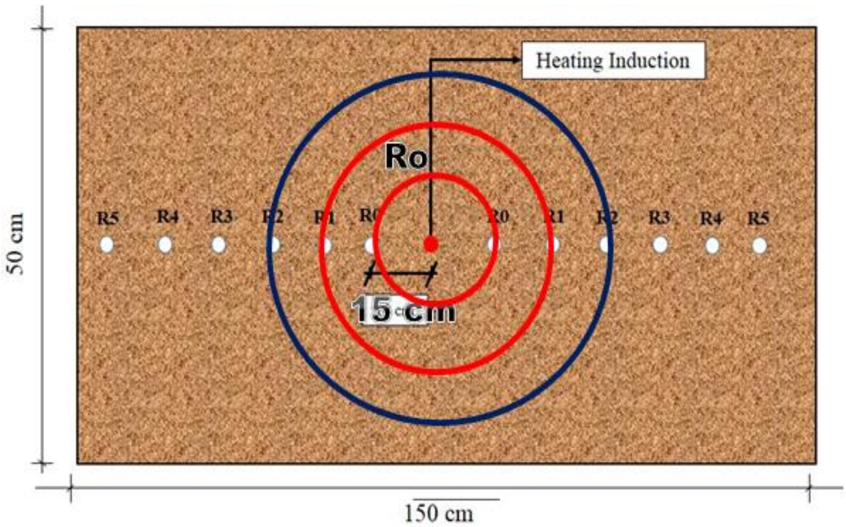

Figure 4. Physical, chemical and mechanical radial zone (R1) observations

4. Results and Discussion

Testing the physical and mechanical characteristics of the soil was carried out to classify the type of soil used in the study. Based on the test results in the laboratory, the physical characteristics data were obtained which are shown in Table 2.

Table 2. Physical and mechanical characteristics of soft soil before and after heating

Characteristics	Units	Test Results Initial Condition	Test Results After Heating
Specific gravity (Gs)	-	2.70	2.69
Initial water content (ω)	(%)	59.07	17.36
Soil unit weight	kN/m^3	15.32	16.60
Dry soil unit weight	kN/m^3	9.75	14.00
Degree saturation	(%)	90.32	51.59
Plasticity Index (PI)	(%)	36.60	34.30
Gravel fraction	(%)	0.00	0.00
Sand fraction	(%)	5.20	5.20
Silt fraction	(%)	41.36	41.36
Clay fraction	(%)	53.44	53.44
USCS		CH	CH
Unconfined compressive strength	kN/m^2	Very soft	67.22
Elasticity modulus	kN/m^2	Very soft	4593.00
Cohesion	kN/m^2	Very soft	21.75
Internal Friction Angle	Degree (°)	Very soft	23.00
Permeability	cm/second	0.00068	0.00015

Soil consistency shows the resistance to cohesion or adhesion of soil grains with other objects. This is indicated by the resistance of the soil to forces that will change its character [17, 18]. Soil conditions that are often a constraint and are relatively common are the soil that has non-uniform swelling and shrinkage properties as well as fairly high soil plasticity. The plasticity index is an important parameter as a measure of soil stability as a subgrade. Figure 4 shows that the consistency of illite clay soil.

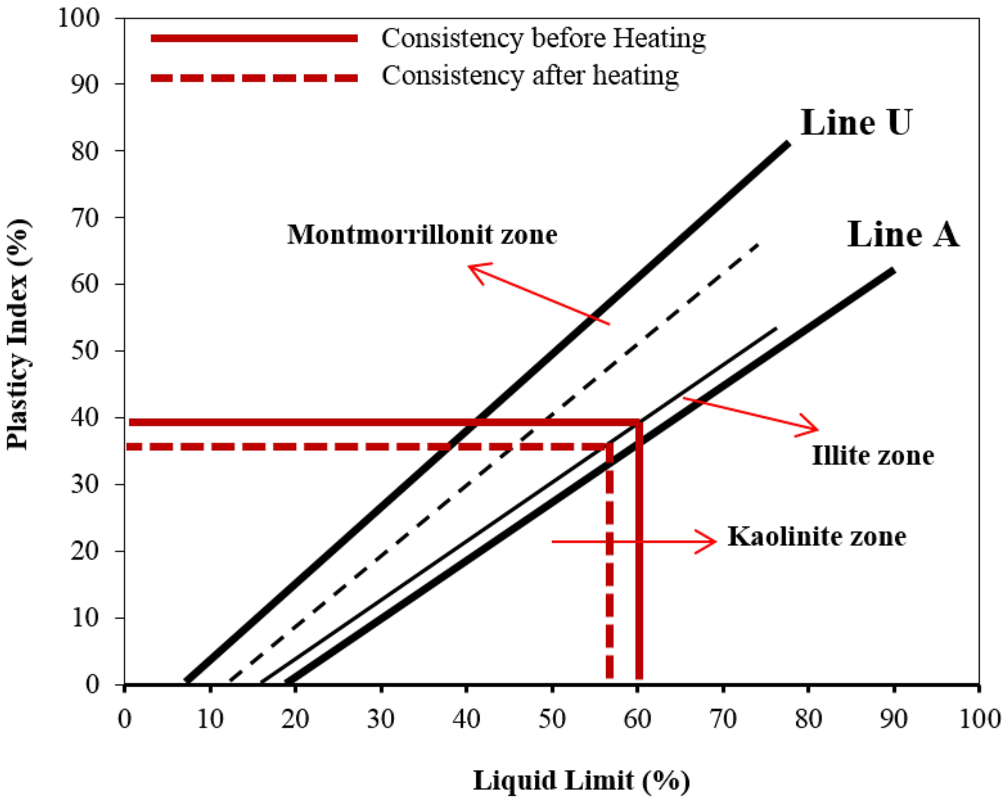

Figure 5. Consistency of the Casagrande soil plasticity index

The XRD (X-Ray Diffraction) results as shown in Figure 5 show the type of illite clay minerals, with X-Ray Diffraction (XRD), Chemical Composition, and Surface Morphology knew with an integrated system of Energy Dispersive Spectroscopy (EDS) and Polycrystalline Scanning in the Hexagonal system with the following lattice parameters. Substituted in the illite equation: $H_2KAl_3O_{12} = Al_2O_34SiO_2H_2O + H_2O$.

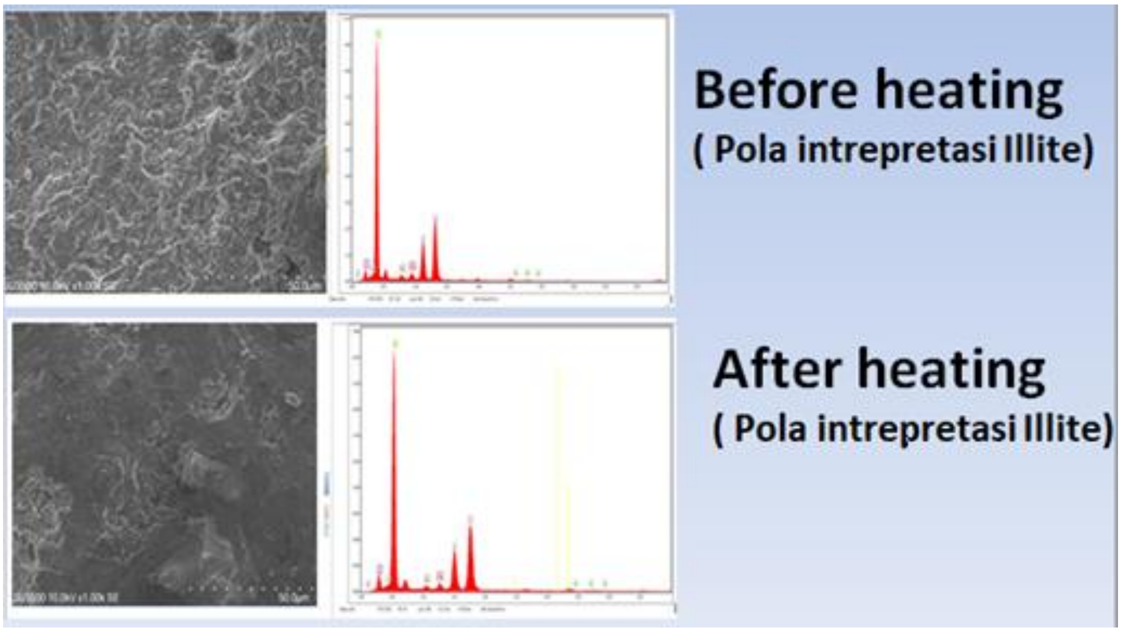

Figure 6. SEM, EDS and XRD test patterns

The geometric effect of soil particles on the thermal conductivity value of clay can experience soil properties such as mineral composition, dry bulk density (porosity), fluid-pore, degree of saturation, moisture content, and temperature Figure 6.

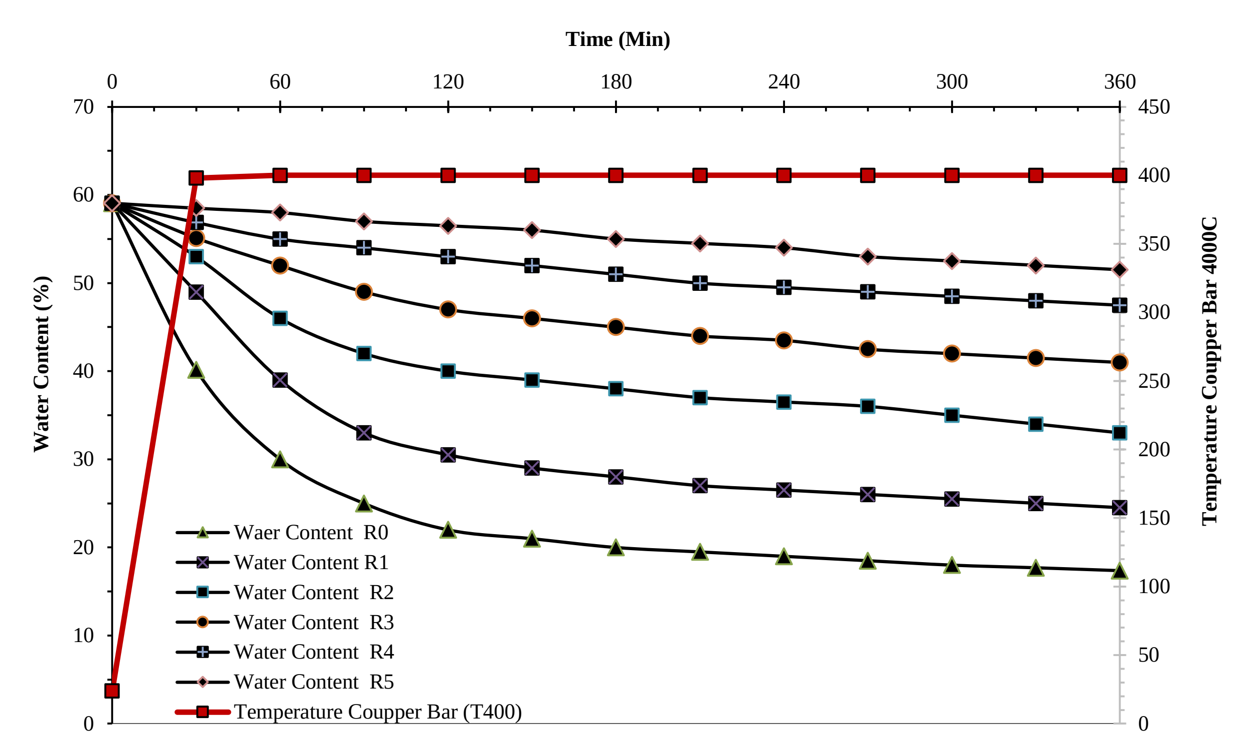

Figure 7. Thermal Relationship of Copper bar with Water Content at Temperature 400⁰C

Identification of soil characteristics after the effect of thermal induction with the addition of free compressive strength (q_u). The unconfined compression test is one of the most common soil tests performed on clay soils. From the results of this test, it will be known that the failure stress parameter (q_u) is shown in Figure 7.

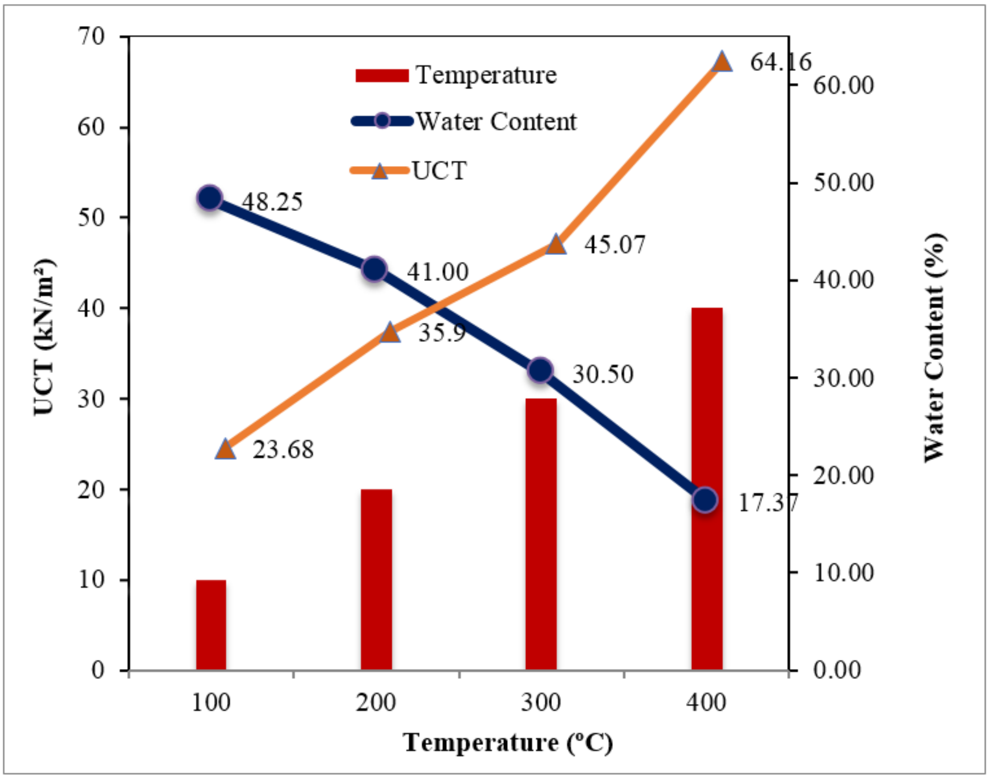

Figure 8. Graph of relationship temperature and water content with free compressive strength

Thermal addition to the soil can cause the soil layer underneath to experience compression, resulting in deformation of soil particles, particle relocation, discharge of water or air in the pores, settlement caused by loading. The results of this test model show that in Figure. 7 there is a decrease due to the addition of temperature with static loading. The prediction of a decline in the Asaoka method occurs as Figure 8.

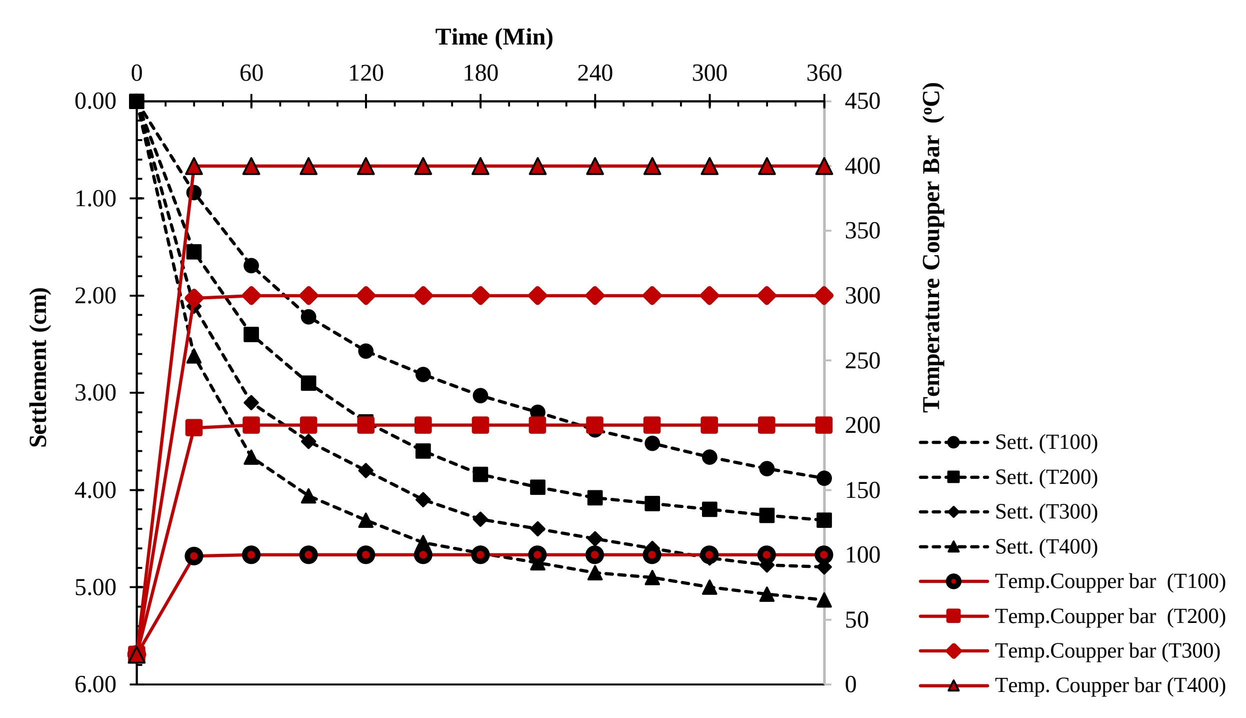

Figure 9. Graph of settlement all radial zone areas

The increase in the modulus of elasticity was due to the addition of the thermal induction value. The combination of these values tended to be directly proportional to the results of the free compressive strength test. The relationship between the unconfined compression test and temperature values is as shown in Figure 9.

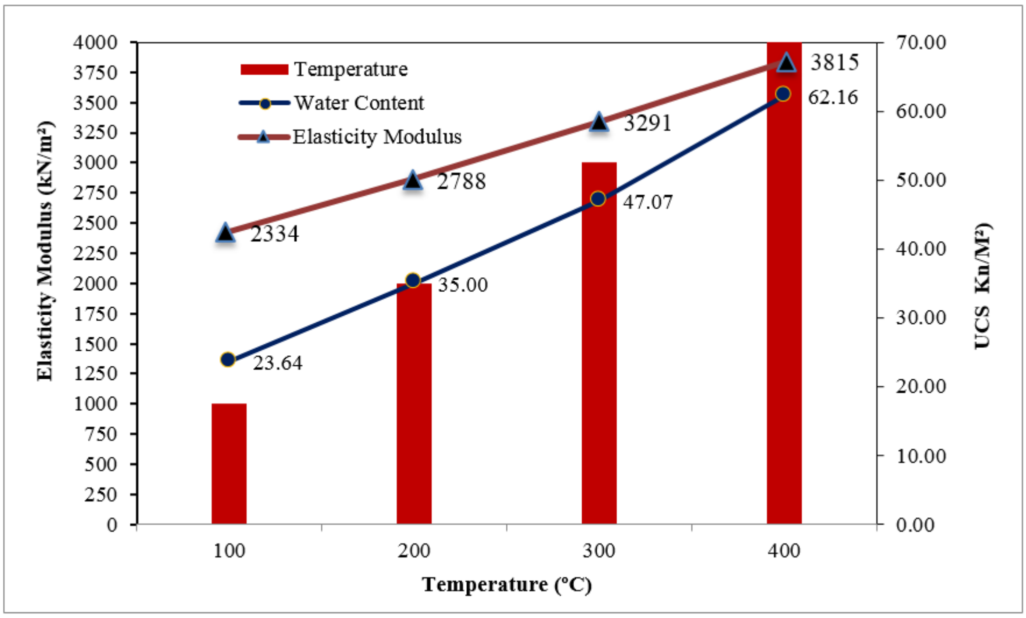

Figure 10. Graph temperature and modulus of elasticity from the results of the free compressive strength test

5. Conclusion

A significant reduction in water content occurs in the radius closest to the heater (R1) or 15 cm. The higher the temperature given, the water content will decrease. The farther from the heater, the effect of smaller the temperature with the intention the water content does not change significantly. The main observation point is a distance of 15 cm from the center of the induction. At the induction it tends to be 400 C, the water content is 17.36% from the initial water content of 59.07%, the soil cohesion is 21.75. kN/m², the value of free compressive strength is 67.72 kN/m² and the highest modulus of elasticity is 4593 kN/m², the decrease is 5.13 cm. XRD, SEM, EDS results before heating showed mineralogy 0 (65.06%), Ca (13.30%), Na (3.64%), Mg (2.15%), Al (6.63%), Si (8.52%), Sn (0.70%) and did not change significantly after heating at 400 °C. The results after heating included 0 (58.39%), Ca (14.09%), Na (0.72%), Mg (1.16%), Al (6.63%), Si (14.72%), Sn (2.54%). The novelty obtained is to change very soft conditions became medium conditions.

6. Declarations

6.1. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.2. Funding and Acknowledgements

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6.3. Conflicts of Interest

The authors declare no conflict of interest.

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