CHAPTER I

INTRODUCTION

1.1. Background

Soft soil is one of a common concern in civil engineering area. In Indonesia, soft soil can be found in Java [1]. For instance some places in North Java such as Jakarta, Semarang, and Surabaya mainly consist of soft clay with a very little content of sand [2]. Soft soil especially in the form of clay can be found easily in the marine area. The natural water content of marine clay that is generally higher than the liquid limit creates large void in the soil and thus making marine clay weak [3]. Furthermore, soft marine clays are very sensitive to changes in the stress system, moisture content and system chemistry of the pore fluid [4].

Marine area or deep ocean is considered to be one of an extreme environment [5] where hydrostatic pressure occurs and mineral solute exists. Additionally, marine area is considered as an extreme environment because the seawater is having the possibility to cause corrosion due to harmful chemical contained in it [6]. One of the most aggressive chemicals contained in seawater that affect the long term durability of cemented material is sulfate [7]. Sulfate has 7.7% part out of the whole composition of seawater, and magnesium takes 3.65% portion [8]. Sulfate attack has been reported to be a cause of damage to concrete for over a century, and considered as one of the major deteriorative problems [9]-[10].

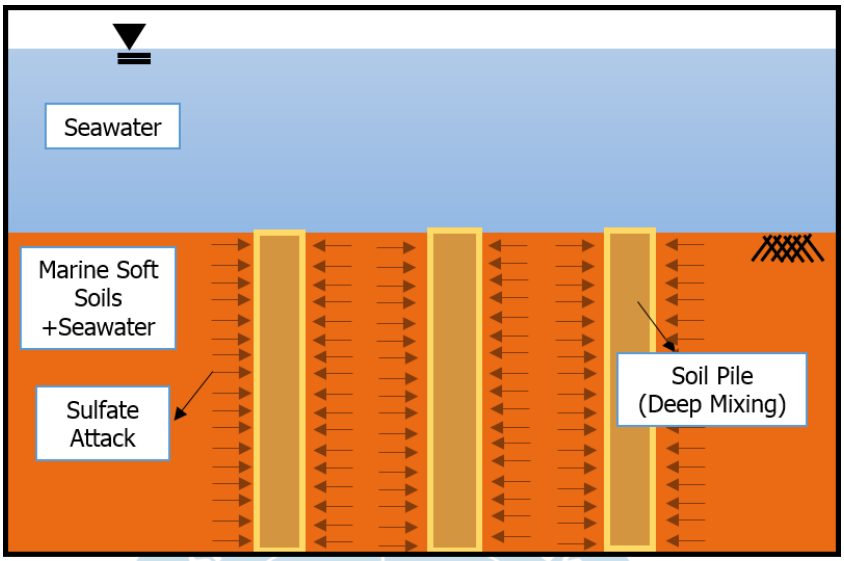

Figure 1. Pile Placement Cross-Section

When a structure is built above weak marine soft soil, the soil will not be able to support the upper structure. Thus, a soil improvement is needed to strengthen the ground. Soil-cement mixed piles are widely used to improve soft subsoil [11]. Soil pile can be erected by deep-mixing the ground. The stabilized soil will have a higher strength, lower permeability and lower compressibility than the native soil [12]. However, in regions with high-salinity groundwater, the soil-cement is susceptible to deterioration [11]. High-salinity is one of marine area indication. Moreover, marine soil at the seabed is mixed with the seawater containing sulfate above it, resulting in the deterioration of the soil pile. Figure 1 shows the cross section of soil pile placement. Seawater above will be infused into the soil below causing the sulfate attack inside the soil occurs radially from every directions. Sulfate attack leads to the redundant of the compressive strength of cement blended material [13]. Furthermore, the deterioration

by sulfate attack is characterized by a swelling of material due to the formation of expansive products, which lead at a long term to decohesion of this material and consequently a degradation of its mechanical properties [14]. Also, the deterioration decreased the effective diameter of the soil-cement pile [15]. And the smaller the pile diameter, the more obvious the difference in bearing capacity between the deteriorated and undeteriorated piles becomes [11]. Thus, soils containing sulfate should not be used for soil-cement stabilization [16].

Salt-rich soft soils have not only general characteristics of common soft soils, but also contain high contents of Mg^{2+}, Cl^{-}, and SO_4^{2-} [17]. Hara [18] identified that the most deteriorative content of seawater is magnesium sulfate. However, magnesium sulfate does affect unconfined compression strength of specimens. UCS value reaches the peak value when the $MgSO_4$ content is 4.5g/kg [19]. Otherwise, as the content gets higher than 4.5g/kg, the UCS value decreases. Therefore, to know the severity, $MgSO_4$ is used as the deteriorative substances and the effect is studied in this paper. In order to tell about deterioration severity, penetration test is done. The output of the test is in the form of Tip or Cone Resistance (R) vs Penetration Depth (d).

1.2. Problem Statement

Marine area is considered as one of extreme environments that is having a soft ground. One of a major content of seawater is sulfate. It can cause corrosion especially to cement-mixed material. Thus, soil below seabed that is infused with seawater will also contain sulfate in it. However, when cement-mixed soil or soil pile is exposed to

sulfate environment, it will be deteriorated and the effective diameter will be reduced. Whereas the sulfate attack inside the ground will be occur from every direction. Also, a research stated that soils containing sulfate should not be used for soil-cement stabilization.

1.3. Objective

The objective of this research is to know about the influence of water content (w_c) and cement content (c_c) towards the strength of soil pile that is exposed to sulfate environment. And also to know about the deterioration depth -penetration depth on which the tip resistance is close to zero d_n - of pile cylinder that is tested based on the variation of curing times. The tip resistance -specimen resistance towards the tip or cone of penetration needle R - is also investigated using the penetration test.

1.4. Limitations

1. Lumpur Sidoharjo is used as the soft clay.
2. Soil binder used is OPC (Ordinary Portland Cement)
3. $MgSO_4$ (Magnesium Sulfate) solution is used as corrosive agent
4. Degradation depth is tested using Penetration Test
5. Specimens are placed without controlling the temperature

1.5. Research Benefits

The result of this final project is expected to ease the estimation of curing time of soil pile so that although it is exposed to sulfate environment, it has the best strength to

support structure above. Furthermore, it is also expected that the optimum w_c and c_c can be noted as a reference in order to achieve the adequate strength.

1.6. Originality of Final Project

Reference [16] is discussed about the influence of the chemical properties of a clay on its strength when stabilized with cement. It is stated that the principal factors affecting the strength appeared to be the clay, sulfate, and organic contents of the samples. The result is that the strength of a clay-cement mixture was reduced by more than 50% when immersed in aqueous sulfate solutions of 0.20% concentration. Also, loss in strength was due to the interaction of the sulfate and the cement from the soil-cement, and salts which did not react with cement did not seriously affect the strength of soil-cement when it was immersed in water. Reference [20] discussed about the sulfate resistance of some hardened blended Portland cement pastes. It used 10% $MgSO_4$ solution under some different condition. It resulted that the replacement of Portland cement with SF did not show a significant improvement in sulfate resistance hardened cement pastes. Also, exposure to sulfate solution at 60 degree Celsius with drying– immersion cycles can be considered an accelerated method for sulfate attack. Reference [10] searched about the effect of magnesium sulfate attack on OPC mortars, by all means, the cracks and reactions. Reference [21] observed about the results of a laboratory investigation made to determine the effect of the presence of sulfate ions in soils on the durability of cement- and Ume-stabilized soils. Reference [13] describes

the investigation results conducted on the evaluation of the resistance to magnesium sulfate solution (MgSO4) of limestone mortars containing simultaneously; limestone filler, blast furnace slag and natural pozzolan. Moreover, reference [22] studied the effect of magnesium-sodium sulfate environment on the performance of two plain and three blended cements and to elucidate the sulfate attack mechanisms on these cements in the mixed magnesium and sodium sulfate environment. Above all the researches that have been done, none of them discussed about the deterioration rate in every stage of curing time which is 7, 14, 28, and 56 days.