International Journal of Scientific & Engineering Research Volume 10, Issue 12, December-2019
ISSN 2229-5518

Study of Interface Behaviour Between Concrete and Clay Shale and Its Effect on The Load Transfer on Bored Pile Foundation

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Abstract — Clay Shale is hard soil type that is very sensitive to water so that at the lag times between the drilling and concreting in bored pile, the condition of the soil was construction exsposed to water. Shear strength of clay shale depend on the length of lag time, where the soil of the clay shale can loss its shear strength (a loss of shear strength capacity).

This research is to study the shear strength capacity on the clay shale. The research was conducted based on published data, soil test in both the field and axially loaded test piles on 2 bor piles that are specifically focused on the scrap yard area of PT. Indocement Tunggal Initiative, TBK, Citeureup, Bogor, West Java. This area belongs to the plains of Jatiluhur Formation (TMJ); where the area is domiciled by the material of napal and mud stone with quartz sandstone inserted or clay shale.

On the foundation of the bor piles embedded in the clay shale soil layer indicates that the behavior of the pile's blanket friction value is relatively low when compared to Clay's previous research results recommended by Reese and Wright (1979) i.e. α = 0.55.

This research is done by the back analysis of 2 axially loaded piles with a variation of piles test. The tests are Kentledge and PDA test. In this study Cu values on the formula of friction formula bor piles: fs = α. Cu is 0.6 NSPT according to the correlation proposed by Terzaghi & Peck, 1967; Sowers, 1979.

The conclusion of the results of this research is the acquisition of α value in the formula FS = α. Cu (Reese & Wright, 1977) for a Shear Strength capacity of bor piles on the clay shale. From the research, the value of α in Formula FS = α. Cu is 0.2 for slaking clay shale (with 30 < NSPT < 70) and 0.35 for fresh clay shale (with NSPT > 70).

Index Terms — A Fragment of Mudstone, Adhesion, Cohesion, Clay, Clay Shale, Clay Shale Behaviour, Interface, Shear Strength of Bored Pile, Indonesia.

1 INTRODUCTION

Bore pile is one type of deep foundation that can receive considerable load depending on the structural and geotechnical capacity. Bored pile foundation is usually used on soil that has a good friction value. The advantages of Bore pile foundation than driven pile foundation are on the friction capacity. Bore pile the friction capacity can use the hard soil layer layer shear strength where in driven pile can't. Driven pile length will stop in the hard soil layer therefore the friction value of the hard soil layer cannot be used and the pile is only going to use the end bearing capacity of the hard soil layer only.

The hard soil layer characteristic determines the value of shear resistance from the soil on bore pile foundation. This study was conducted to determine the value of factor of adhesion multiplier (α) in clay shale. The characteristic of clay shale soil that has a very sensitive nature to water in terms of its slacking properties can make the shear strength capacity of this clay shale decreases drastically.

At the moment the value of factor of adhesion multiplier (α) in shale clay is often considered the same as the value of factor of adhesion multiplier (α) in general. So at the time of verification of the bore pile shear capacity in test test pile like Kentledge/PDA test are often found that the design of bore pile higher than the real shear capacity that found in Kentledge/PDA test results. Or for those who have experienced for bore pile design on shale clay often ignore the shear capacity of clay shale. Kentledge or PDA test is done as design verification in deep foundation.

The purpose of this study is to obtain the adhesion factor (α) value in clay shale for bored pile foundation so that the design can resemble the reality of the actual shear capacity.

2 LITERATUR STUDY

Geological reviews for clay shale of the rock formation are distinguished into three kinds: igneous rocks, sedimentary rocks, and metamorphic rocks.

Clastic Rock or sedimentary rocks consist of mineral particles as material transformation of the weathering or igneous rock erosion, metamorphic, or sediment transmitted by Water (aluvial, Marine), Wind (aeolian), or Erosion (Colluvium /talus) which is experiencing a compressive and/or sementation event (Skinner et al, 1995).

Generally fossils or shells are found in sedimentary rocks. To get the sedimentary particle size range is required grain

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size gradation information. A rock is called a poor gradation when it has a very large size range. In addition, gradation can be attributed to weight and rock durablity. Clastic sedimentary rocks derived from the Greek classifications which means fragmented/broken is the sedimentary rock in which the minerals are tied to one another due to the sementation process.

This type of rock is classified according to the dominant grain size, conglomerate, sandstone, siltstone, and shale. For each type, the size or by the source is equivalent in a row, gravel, sand, silt, and clay. The size is also determined by the speed of transportation. If the transportation process is faster, the particle size is even larger.

Shale is the deposition of material in quiet water. Sedimentary rocks occur as a result of changes in temperature, abrasion, or the penetration of plant roots. Large variations of the thematic changes cause the stone to be disintegrated because they are unable to withstand a changing style of drag and style. Abrasion occurs as a result of erosion by wind or water. Plant roots can damage the rock pores or can enlarge the cracks that have occurred before.

Shale as clastic sediment rock is a formation of clay-sized particles that have a smaller diameter of 2 µm (ASTM). The item's constituent tektur is a fine particle that is smaller than 0.074 mm. This rock is easily fragmented in the form of fragment layered when experiencing direct contact with the outside air. The dominant components of the shale are quarts, feldspar, calcite, and clay. Because the size of granular from the shale is very small, should be used method of X-ray diffraction in determining mineral composition of the formation.

Based on the formed processes, the shale is divided into two kinds: the embedded Shale (Cementation Shale) This type consists of particles bound with the embedded material (e.g. silica and calcium carbonate); the mechanical shale (Compaction/interlocking Shale) is a form of material composition tied to the style of its constituent molecular attraction. The mechanical shale is relatively less stable due to weathering when compared to the embedded shale

Embedded shale and mechanical shale can occur process of desintegration when exposed to the outside air in a long period of time. The influence of such air can be indicated by the mechanical shale due to the sementation bond between particles. As a result, the rock generally has lower isotropic properties when compared to mechanical shale (Peck et. Al, 1974). The original shale is a sedimentary rock which can be a residual soil when the shale is re-disintegrated into the silt or clay.

Shale is one of the argillaceous material in which the main constituent material is clay. The argillaceous Material in addition to clay shale includes mudstone, Claystone, and Siltstone (Morgenstern & Eigenbrod, 1974). Clay Shale is the result of weathering or transportation of mechanical type sedimentation with the main constituent material is the size of the clay. In analyzing the clay shale can be treated as clay mainly in determining the behavior and gradation of the clay.

The differences between clay and clay shale are clay shale formed as a result of the diagenesis process of soil sedimentation into a stone where the constituent material is experiencing compaction process as well as compressions and fragmented layer by layer. Therefore, the clay shale has anisotropy properties with material content because of that, the shale has anisotropy properties with the content of the constituent material that is the size of the clay. Clay is a product of the clay shale. The process of diagenesis is the process of change in the sedimentation material at the end of its deposition at which moment the deposition can turn into sedimentary rock. The term diagenesis is the same as lithification.

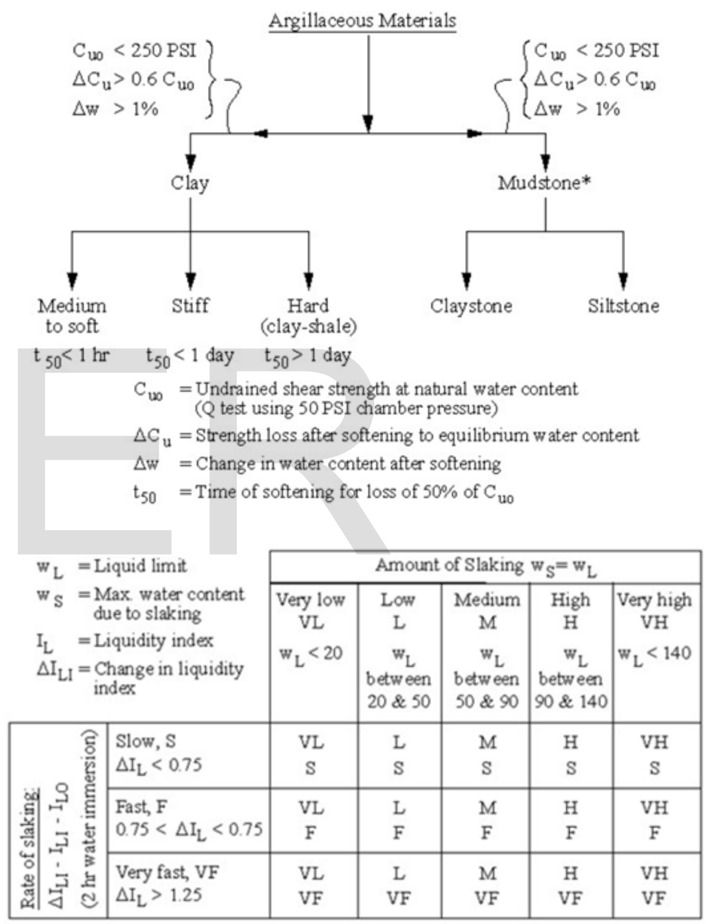

Figure 1. Two part classification scheme based on minimum 50% clay sized particles (after Morgenstern and Eigenbrod. 1974)

Sedimentary rocks are classified by their deposition mode, grain size, mineralogy, mode and litification level and the relationship between the particle grain sizes. Sedimentary rocks are separated into two main categories, Clastic or chemical, depending on their precipitation mode. The basic classification system for sedimentary rocks is shown in the table for the classification and identification of sedimentary rocks.

Table 1. Weathering Criteria (Shale)

Type of Shale	Typical

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		N_{SPT}
WEATHERED	a. Greater than 50% Mixed, (not in-place); - clayey shale with foreign material inter-mixed. (For < 50% shale, use soil description with indication of presence of weathered shale).	<30
	b. Disturbed (not in-place) (1) Disturbed clayey shale*- fragments or bedding plane remnants that are not horizontally oriented. Bedding plane remnants are frequently difficult to see.	<30
	(2) Disturbed fractured shale** - fragments or small pieces of relatively firm to hard fresh shale with bedding planes that are not horizontally oriented.	30-70
	c. In-place (top of weathered bedrock) (1) In-place clayey shale -has not been moved. Bedding plane remnants are horizontal.	<30
	(2) In-place fractured shale - fragments or small pieces of relatively fresh horizontally oriented shale. Essentially similar to fresh shale below, except for blow count	30-70
Fresh Shale (Top of Bedrock)	Dense, fractured, somewhat brittle. Bedding planes are horizontal.	>50/0.7

Notes:
Transitional forms between categories are likely to be encountered.
* Shale type material which is generally quite plastic, uniform in texture, and has physical properties similar to clay.
** When a sample is broken open, small cubic or rectangular pieces of rather firm shale are evident. The pieces bounded by fracture planes are relatively unweathered, thus less plastic and more firm in contrast to clayey shale.

The adhesion factor (α) is an empirical factor used to seek connection or correlation with the shear forces of the soil under undrained conditions Cu. The (α) value is always used in design planning. Conventional formulae for the comfort of the sliding resistance are generally based on an undrained shear force or in a condition that has been in this conventional method. The adhesion factor value between the bore pile and the soil is given in the equation:

Ca = α. Cu (Equation 2.1)

Where:
Ca : adhesion along the pole
α : adhesion factor
Cu : undrained shear forces between soil and bore pile.

The (α) values commonly found in the literature are generally used for the foundation of the stake. One of the most popular ones is given by Tomlinson (1957)

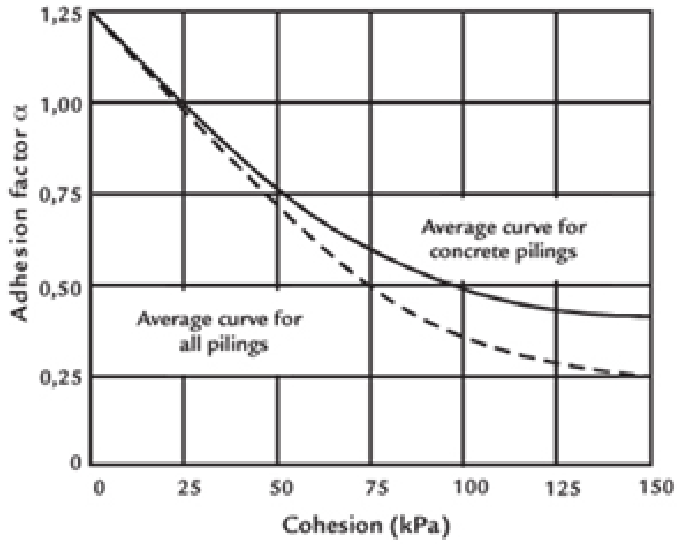

Figure 2. Adhesion Factor (α) Vs Undrained Shear Strength (Cu) for piles (Tomlinson, 1957).

Soil in geotechnical terms is generally classified as a cohesive soil and non-cohesive soil. The method of calculating the axial capacity for both types of soil is also different due to differences in soil properties.

Though the method of calculating the axial capacity for both types of soil is different, the load transfer mechanism on pile foundation can be explained as follows:

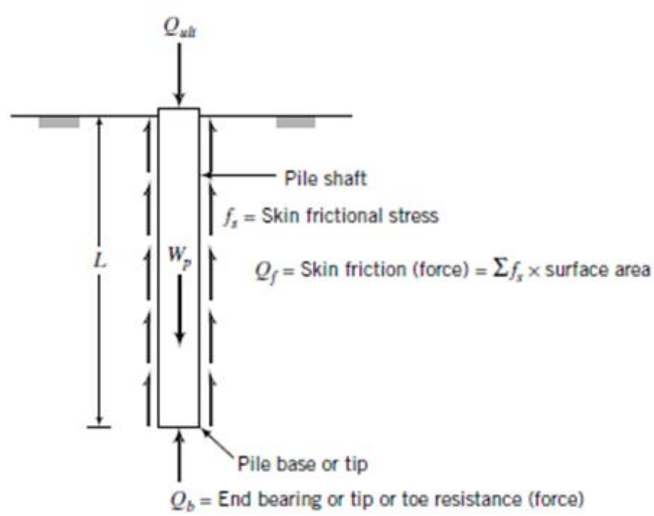

Figure 3. Axial Load Transfer Mechanism in piles (Budhu Muni, 2011)

When the pile receives the load from the upper structure, the pile will pass the received load into the ground layer through the friction along the pile blanket and the bottom end of the pile. Transfer Load Mechanism of the foundation into

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the ground is quite complex. To understand the mechanism, the following illustrations are given as shown in the Figure 4

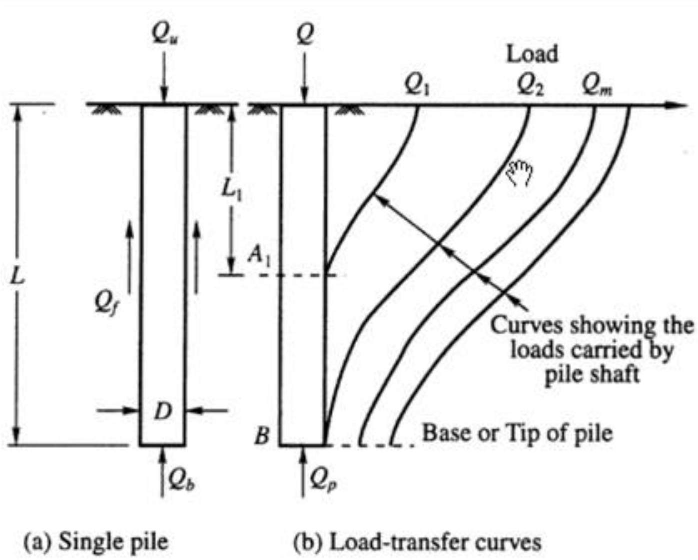

Figure 4. Load Transfer Mechanism on pile blanket (Tomlinson, 1986)

On the chart it was seen that a portion of the load was received by a pile blanket and partly received by the pile tip. If the load is continuously improved, then both the load of the pile blanket and pile tip will increase as well. The blanket load will reach the maximum load when the load value is Qm and will not increase anymore even though the load has exceeded the Qm value, but at the pile tip the load will be increased until the ground eventually will experience collapse. The condition was put forward by Van Wheele in 1957, where the Qp at the pile tip increased linearly to elastic compression.

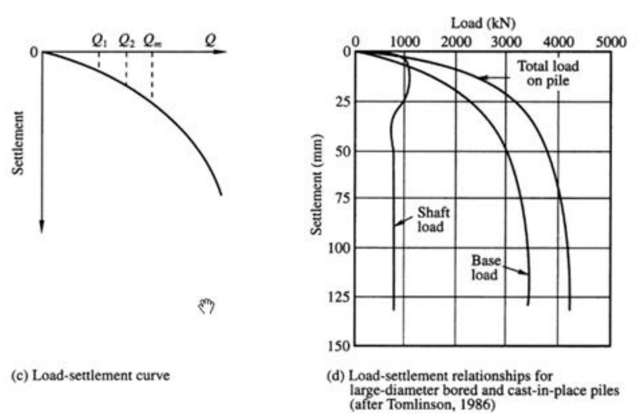

Figure 5. Load Transfer Mechanism at end pile (pile tip) (Tomlinson, 1986)

The amount of load received by the blanket and pile tip proportionally depends on the shear strength and elasticity of the soil. In general, the vertical movement of the pile needed to mobilize/mobilize the full end settlement is greater than that required by the pile blanket. On the foundation of the pile to mobilize the blanket load of the pile in full in general occurs at a decrease of between 0.5% – 1% of the diameter of the pile. Meanwhile to mobilize the maximum load at the pile tip will occur at a settlement of 10%-20% of the pile diameter.

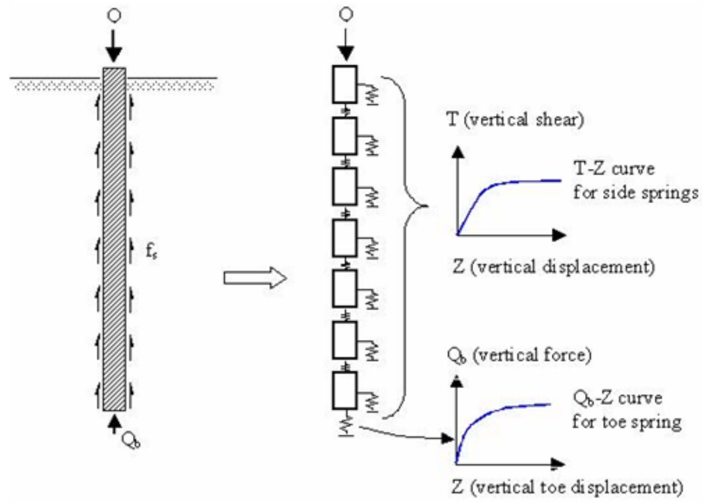

Figure 6. Foundation Model with Axial Load illustration (Download: Reese & Associates)

The behaviour of the T – Z curve according to Seed and Reese (1981) is influenced by the pile foundation factors and the soil in which the foundation resides. Factors include: pile diameter, pile stiffness, pile length, strength distribution and soil stiffness along the pile.

For the Q – Z curve, a maximum value of q is obtained by one of the following methods:

Q = Q' (Nq), for non-cohesive soils

Q = 9Cu, for a cohesive soils

3 Research Methodology

Basically scientific researches need to be drafted steps-working steps to achieve the purpose of the research. In this chapter, the steps or outline of the problem begins with the study of the literature, followed by preliminary studies and ending with the conclusion of the study. Preliminary studies will be known as background problems that exist on the foundation in particular on the foundation of the bore pile, especially with regards to the foundation behavior of bore pile behaviour on clay shale soil.

The background of the problem of this study was the adhesion factor (α) of the Bore Pile Foundation on Clay Shale soil. Back analysis is done to get the adhesion factor (α) from the instrumentation test results on bore pile will be obtained decreased data of each segment, which is then sought by the size of the settleement blanket and after the detention of the blanket will be obtained the value of adhesion (α). The research object in this study is an instrumented bore pile located at the indocement site, Citeureup.

The load transfer curve vs settlement indicates a relationship of magnitude reduction due to the axial load given on the top pile that was according to the load plan. Elastic deformation is indicated by a graph that returns to its original state without leaving strain after unloading. In this condition means the whole load is withheld by a pile blanket. The resistance of pile blankets will resist the load on pile top first until ultimate then followed by pile tip resistance. When load transfer curve vs settlements is seen as a small recovery or leave a strain after unloading, it indicates the presence of a plastic deformation. In this condition, the capacity of the blanket friction is fully mobilized and the pile tip resistance is already works.

For maximum test load each cycle is depicted a mobilized blanket relationship and its relative switching. Thus the magnitude of the blanket is mobilized and the relative switching of each segment can be known. The friction is mobilized blanket is measured along with its equipment compared to the friction of theoretical maximum blanket.

The calculation step to determine the transfer of load at the end of the pole is equal to the pile blanket, except at the magnitude of the mobilized end prisoner, namely the same as the mobilized tip style divided by the broad cross section of the pile. On-instrumented pile strain data is obtained from each load test cycle at the level where the instrumentation is installed. By determining the modulus of concrete elasticity, the axial force at the depth of instrumentation can be calculated.

The maximum axial force of each loading test cycle can be described into the load-transfer curve shape. The axial force difference at the top of a segment minus the lower axial force of a segment is a blanket friction style value. And the accumulation of the style of blankets from each segment along the pole is the value of the power to support the blanket friction. The typical load transfer curve Plot can be seen in Figure 4.

The adhesion factor (α) is important in the calculation of the shear capacity of the bore pile blanket resistance capacity. Once the maximum blanket friction value is known, and the shear value of the soil investigation data is known, it will be known the value of adhesion factor. The value of the blanket friction capacity equals with the value of adhesion factor (α) multiplied by a value of undrained shear strength of cohesive soil.

$Qs = fs. As$

$fs = \alpha. Cu$ (Equation 3.1)

Where:

As = obtain from pile blanket friction area
fs = obtained from instrumentation analysis results
Cu = obtained from the results of soil investigation
α = obtained from Equation 3.1

4 Research Methodology

Description of Research Location that became the research place is area P-14 Soil Investigation Cement Plant Factory and the facilities area located at PT. Indocement Tunggal Prakarsa, TBK, Citeureup, Bogor, West Java. The owner plans to make one factory area consisting of a coal warehouse, an open yard around a coal warehouse, batching plant and scrap area.

In the analysis and discussion of this thesis is specifically review the tests result in the area of BH-22 and BH-31, where the tested pile done was PDA test & Kentledge test with an-instrument of VWSG. In addition, the soil data from the BH-22 and BH-31 is located in a fairly adjacent location in the scrap area where the planned foundation and test are carried out is a bore pile foundation.

The problems discussed on this thesis are in the bore pile axial capacity design on the clay shale soil. In specific is in determining α value at the time of determining the blanket resistance of the formula: $fs = \alpha. Cu$.

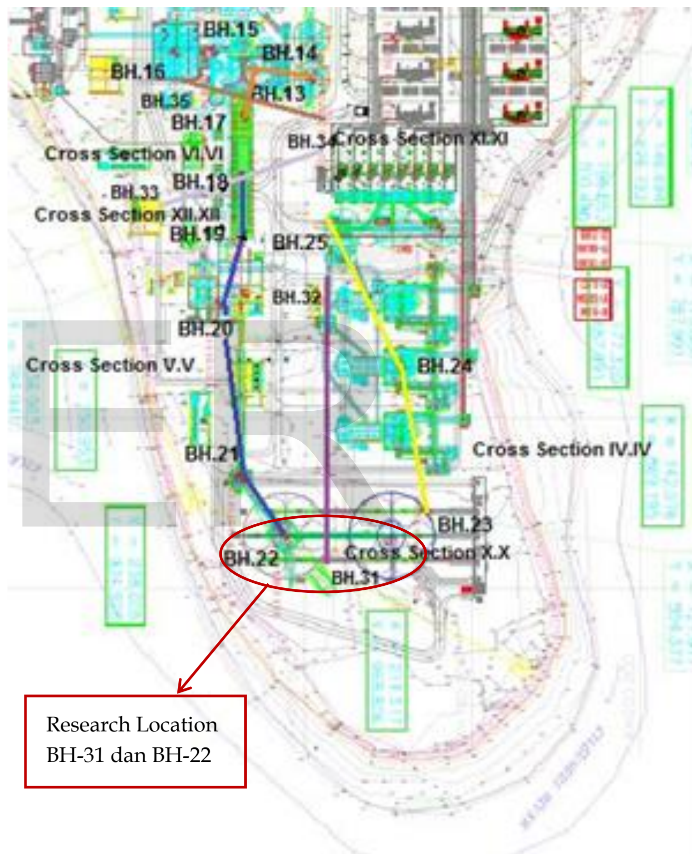

Figure 7. Research Location in scrap area of Cement Plant Factory, PT. Indocement Tunggal Prakarsa, TBK.

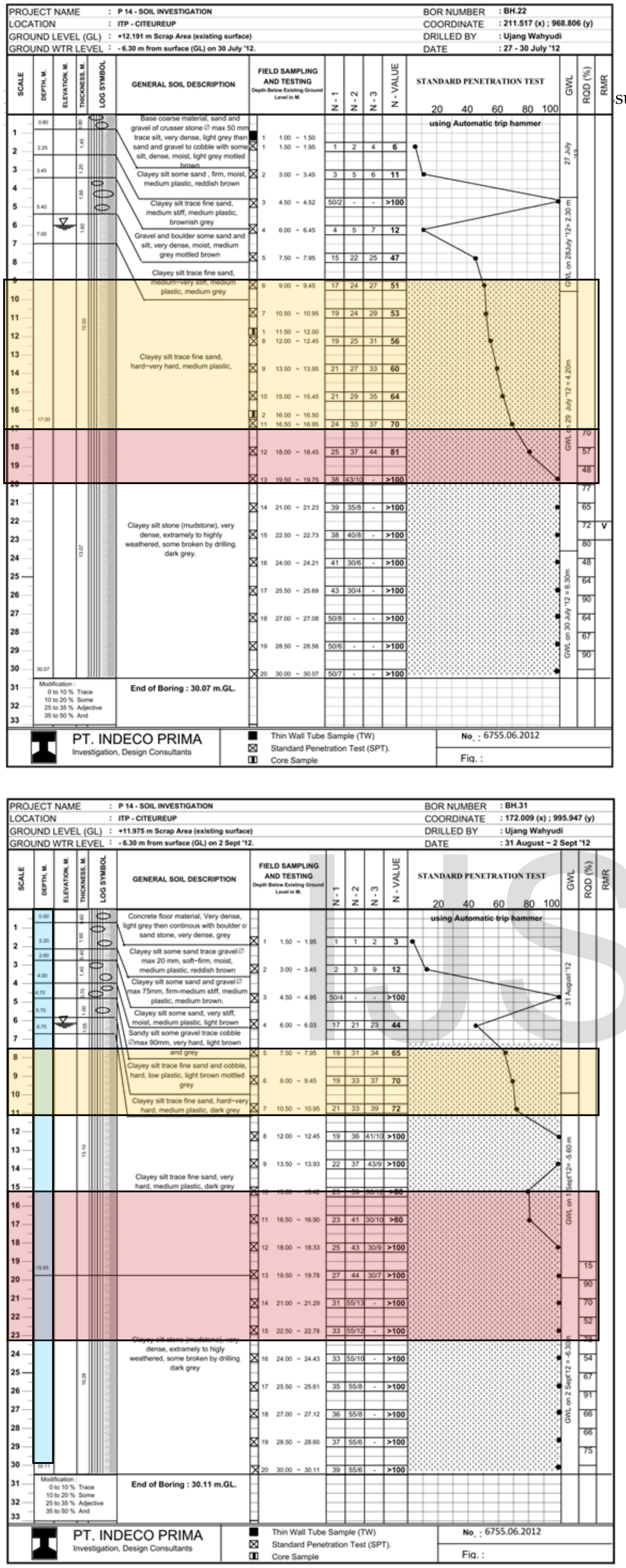

Figure 8. Soil Data og BH-22 and BH-31.

The Soil Test data between BH-22 and BH-31 are very similar. Detail research data per location is shown in Table 2.

Table 2. Research data in BH-22 and BH-31

Research Data List	BH-22	BH-31
Bore Pile data:	D = 1.2 m	D = 1.2 m
- Pile diameter (D) - Pile length (L)	L = 20 m	L = 20 m
Test Pile Type	PDA Test	PDA Test & Kentledge with VWSG test
Weathered Clay Shale Review (depth in m)	9.00–17.00	7.00–11.00
Fresh Clay Shale Review (depth in m)	17.00–20.00	16.00–24.00

In this research the parameter of Cu are derived from N_{SPT} value follow Terzgahi chart as in Figure 9.

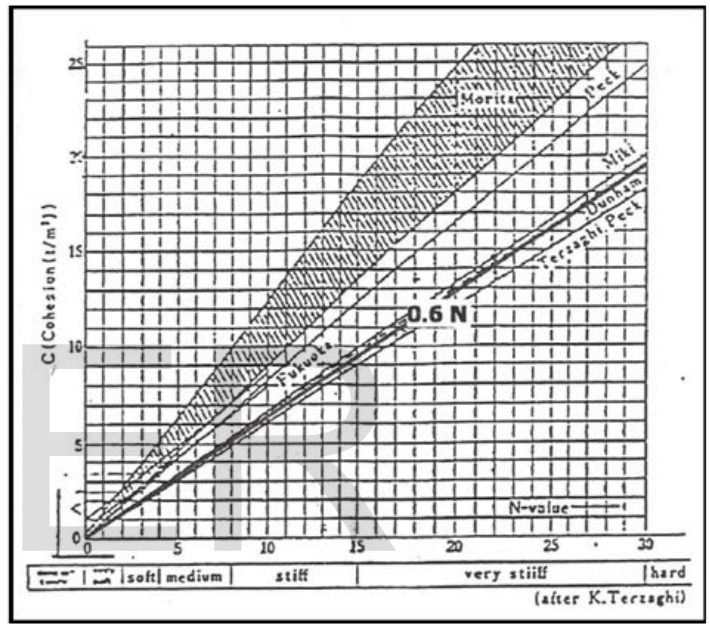

Figure 9. The relationship between cohesion (Cu) and N_{SPT} value for cohesive soil (Terzaghi,1943).

5 Conclutions

5.1 Conclusion

The results of the above studies can be concluded:

1. The total settlement of test pile TP-2 (BH31) diameter 600 mm with a pile length of 30 m at a maximum load of 700 tons is 30.80 mm, the residual decrease in the pole is 15.00 mm. at a load of 175% of the Design Allowable load.
2. From the analysis of this study to L/D is worth 50, indicating that the drill pole behaves as a friction pile on the planned workload.
3. In the calculation of the value of Cu = 0.6 x N_{SPT} used the average N_{SPT} value that has been calculated linearly for N_{SPT} value of the result of soil test in situ to the value of N_{SPT} in penetration of 6 inch/30 cm.
4. Adhesion factors of α in pile to Mudstone soil – Clay Shale In this study can be seen in table 5.1.

Table 3. Result of Back Analysis in this Research

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Average of N_{SPT} in Clay *Shale*	Analysis Result of α value from Test Pile Data		
	PDA (BH-22)	PDA - TP-2 (BH-31)	VWSG - TP-2 (BH-31)
30 < N_{SPT} < 70	0.25	0.12	0.18
70 < N_{SPT}	0.19	0.38	0.32

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