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Implementation of Mini Piles and Retaining Wall in the Construction of the North Kalimantan Provincial DPRD Building in Bulungan Regency

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Abstract – Piles are used as the foundation for a building's construction when the underlying soil beneath the structure lacks sufficient bearing capacity to support the weight of the construction and its load, or when hard soil with enough bearing capacity lies at a significant depth. Retaining walls are a type of civil construction built to withstand the lateral active pressure of soil or water. Therefore, the construction of a retaining wall must be planned and designed to safely counter potential forces that could cause structural failure. The purpose of this writing is to understand the implementation of mini pile foundations and retaining walls concerning the stability control of the retaining wall against sliding, overturning, and soil-bearing capacity. The observational method used involves collecting secondary and primary data. The mini pile foundations are driven to a specified depth, with each pile segment being 4.0 meters long, and this piling activity aligns with the plan. The retaining wall used is a cantilever retaining wall with concrete quality K-300 f'c 25 MPa, where the successive heights, upper width, and bottom width of the retaining wall are 4.5 m, 0.3 m, and 2.7 m, respectively.

Keywords: mini pile, retaining wall, bearing capacity

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1. Introduction

Today, technology continues to advance with the passage of time. Technological advancements in the field of building construction have experienced rapid growth, including technology within the realm of geotechnical engineering. Geotechnical engineering constitutes its own field of study, focusing on the application of civil engineering and issues related to the mechanical properties of soil and rock [1] [2]. Soil is the Earth's dynamic surface layer, and changes in soil are influenced by several factors such as air, water, and the shifting of tectonic plates. One consequence of these changes is the formation of slopes [3]. Slopes are surfaces of the Earth that form a certain angle with the horizontal plane. They can occur naturally due to geological processes or can be man-made. Naturally occurring slopes include hillsides, riverbanks, etc., while man-made slopes consist of excavations, embankments for roads, dams, railways, river embankments, etc. Slopes can undergo shifts leading to instability due to various forces, ultimately causing landslides [4].

The construction of the North Kalimantan Provincial DPRD building is situated in an area with unstable soil slopes. Land improvement is necessary for soil stabilization, slope stabilization, and soil-bearing capacity enhancement, especially in soils with technical weaknesses, such as those prone to expansion and contraction, or soils with expansive characteristics [5]. To maintain the stability of these slopes, retaining walls (DPT) equipped with reinforced mini-pile foundations are constructed. Retaining walls are essential structures for buildings with differing contours or elevations. In essence, a retaining wall is a structure built to hold back a mass of soil. Retaining walls are commonly constructed using timber, stone, steel, and concrete. They are designed to withstand lateral soil forces, mitigating the risk of potential landslides. Mini-piles, also known as piles, are used to stabilize slopes. Slopes are portions of the earth's surface that form inclines or steepness and can be found in various environments, from hills and mountains to uneven or contoured surfaces. Stability of slopes is influenced by external forces that counteract the shear strength of the soil material itself [6] [7], as in the case of retaining walls.When planning mini-pile foundations for the stability of these retaining walls, they are engineered to withstand bearing capacity, shear stability, and overturning forces.

In the construction project of the North Kalimantan Provincial DPRD Building, for the embankment work, a retaining wall is constructed with a type suitable for the project's needs, known as a cantilever retaining wall. A cantilever retaining wall is a type of retaining wall supported by beam structures and piles embedded in the ground. These retaining wall constructions are often applied in sloped or varied elevation terrains [8].

To address the strength of the foundation of a retaining wall supporting a structural building erected on soil with poor bearing capacity, and considering that using standard-sized pile foundations might be less economical, one alternative offered is the utilization of mini-pile foundations deemed sufficiently strong and cost-effective.

The construction of a retaining wall must be able to withstand forces such as overturning moments, self-weight, active-passive lateral soil/water forces, sliding forces, and uplift forces [9]. The design of a retaining wall often involves highly precise technical calculations, including thorough structural and soil analyses. Therefore, planning a retaining wall construction must be designed to withstand these forces.

In the construction project of the North Kalimantan Provincial DPRD building, a retaining wall is needed due to its location on a hillside. To maintain the stability of this slope, a retaining wall is constructed to support the buildings above it [10]. This project is located in the North Kalimantan Province, specifically in Bulungan Regency, Tanjung Selor District, as shown in Figure 1.

Figure 1 Location of the Provincial DPRD Building Construction Project
Source : Google maps, 2023

2. Methods

2.1 Primer Data Collection

Direct observation of activities taking place in the field and studying them firsthand by participating in the field research activities. Capturing documentation in the form of photos during each stage of the project and utilizing them as attachments in the article [11].

2.2 Secondary Data Collection

Secondary data collection involves obtaining indirect data regarding the project within this article. Examples include test result data, work plan drawings, quantity lists, implementation schedules, execution methods, and related data necessary for this article [12].

3. Result and Discussion

3.1 Observed Work

The research, which commenced on July 1, 2023, had reached approximately 70% progress in fieldwork and concluded on September 8, 2023. The discussion will encompass various aspects, including the work on mini-pile foundation and retaining wall as the upper structure of the mini-pile foundation.

3.2 Implementation of Mini Piles

Mini piles are a type of pile foundation used to support various structures such as buildings, bridges, docks, retaining walls, and more [13]. If compared to other pile-driving tools, especially diesel hammers, the Drop Hammer pile-driving tool is more effective [14]. Typically, mini piles have a smaller diameter compared to conventional piles and can be placed using smaller equipment as well. The development process of mini piles may involve further analysis related to the type of soil to be penetrated, the most effective installation method, and ensuring optimal strength and bearing capacity. Additionally, the implementation of new construction technologies or methods can be applied to enhance the efficiency and reliability of mini piles in supporting structures.

The execution of mini-pile foundations for the Retaining Wall (DPT) involves several observed work items, including.

1. Clearing or preparing the area for the retaining wall's location.
2. Determining the plan for pile points. Following the clearing of the area, the plan for pile points is established. To ensure that the pile points align with the working drawings, tools such as theodolites and measuring tapes are used in the field. The pile plan and side view of the 4-meter depth mini pile can be seen in Figure 2 and Figure 3.
3. Installation of iron stakes according to the pile point plan.

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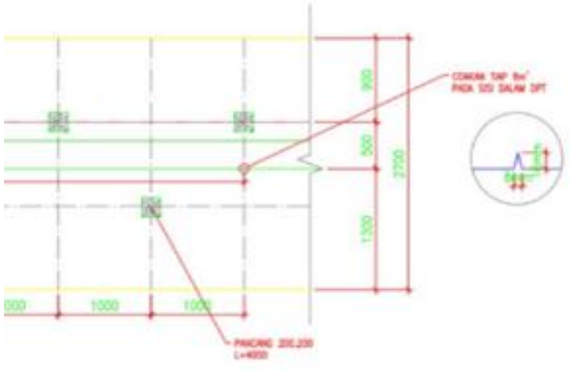

Figure 2 Section of the Mini Pile Pile Point Plan - Top View of Retaining Wall
Source : PT. Permata Anugerah Yalapersada

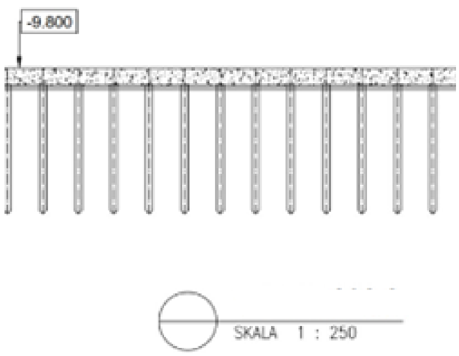

Figure 3 Side View of the 4-Meter Depth Mini Pile
Source : PT. Permata Anugerah Yalapersada

After obtaining the pile point plan, the next work item is staking or installing iron stakes at the planned pile points, as shown in Figure 4.

Figure 4 Work of Installing Iron Stakes After Receiving Pile Point Locations
Source : Documentation, 2023

4. Preparing the drop hammer equipment for the installation of mini pile foundations. The working principle of the Diesel Hammer DD-35 is to use a pile-driving tool with a hammer head weight of 3.5 tons [15]. After installing the iron stakes at the planned pile points, the next work item is preparing the drop hammer equipment with an excavator for installing the Mini Pile foundations. The field conditions can be

seen in Figure 5 as follows.

Figure 5 Preparation of the Drop Hammer Equipment at the Pile Points Where Iron Stakes Have Been Installed
Source : Documentation, 2023

5. Installation of mini pile foundations. After preparing the Drop Hammer equipment, the next step is to prepare the pile points. For this retaining wall, the pile foundations use mini pile types. The implementation method of installing the pile foundations begins with preparing the mini pile by fitting a helmet on the top before striking it. The mini piles are driven to the specified depth. Each section of the pile is 4.0 meters long; if the depth requires more than the length of each section, sections are joined. However, during observation, the piling activity aligns with the planned depth. Pile driving stops when the end of the pile reaches the desired depth, followed by a control check. A hammer with a 1.0-meter fall height strikes the top of the pile ten times. Pile driving can cease if the settlement of the pile over these ten strikes does not exceed the predetermined final set. The process and results of the piling can be seen in Figure 6 and Figure 7.

Figure 6 Installation of Mini Pile Foundations Using a Drop Hammer Tool
Source : Documentation,2023

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Figure 7 The Installed Mini Pile Foundation Viewed From Above
Source : Documentation,2023

3.3 Implementation of Retaining Wall

A retaining wall is a structure built to hold materials such as sand, natural stones, and soil behind it. A cantilever retaining wall is made of reinforced concrete consisting of a vertical wall and a floor slab [16]. Retaining walls are constructed to prevent these materials from sliding due to additional loads like road pavement, vehicles, bridges, and more. Retaining wall structures may become unstable due to the insufficient load-bearing capacity of bored piles to withstand dynamic loads [17]. Generally, every retaining wall aims to confine the soil, preventing substantial lateral pressure from the materials behind it [18].

The executing party employed a cantilever retaining wall type, characterized by a thicker stem compared to usual standards. This choice is due to the cantilever retaining wall design, where the stem is positioned perpendicular to withstand lateral loads on the soil. The specifications for the retaining wall used in this project are Concrete Quality K-300 f'c 25 MPa, with a height of 4.5 meters, an upper width of 0.3 meters, and a bottom width of 2.7 meters. The procedures for the retaining wall work include.

a) Preparation for the retaining wall work involves preparing the tools and materials for use in the retaining wall construction.

b) Cleaning the designated site area. Initial cleaning is performed using an excavator, followed by soil mounding to facilitate equipment access to the work location, as shown in Figure 8

Figure 8 Site Area Cleaning
Source : Documentation, 2023

c) The image and data related to the retaining wall can be seen in Figure 9.

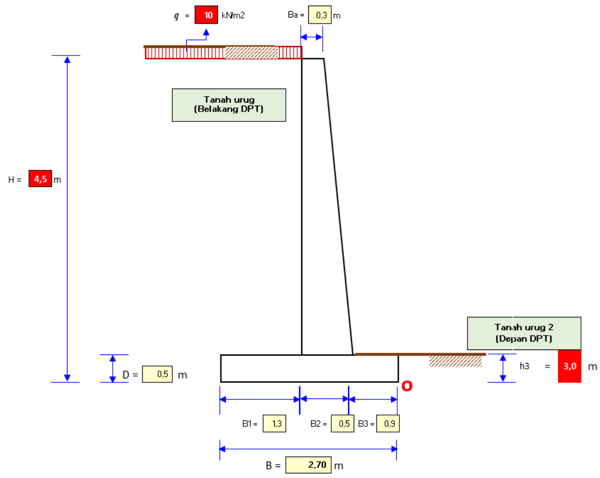

Figure 9 Details of the Retaining Wall Calculation Drawing
Source : PT. Benantin Surya Cipta

d) The strength of the retaining wall is described by the following calculations.
Based on the details in Figure 9, the vertical force and moment at the front foot (point 0), total active soil pressure and moment at the front foot (point 0), total active soil pressure and moment at the front foot (point 0), total passive soil pressure and moment at the front foot (point 0), stability check of the retaining wall against sliding and overturning, and stability against soil bearing capacity, In accordance with the foundation calculation analysis [19].

1. Soil data

Backfill soil data 1 (behind the retaining wall):
a. Unit weight of backfill soil 1 (γ_1) = 16,8 kN/m3
b. Shear angle of backfill soil 1 (Ø 1) = 20^0
c. Cohesion of backfill soil 1 (c_1) = 15,47 kN/m2
d. Backfill soil coefficient (Ka1) = 0,490

Backfill soil data 2 (in front the retaining wall)
a. Unit Weight of backfill soil 2 (γ_3) = 16,8 Kn/m3
b. Shear angle in backfill soil 2 (Ø 3) = 20^0
c. Cohesion of backfill soil 2 (c_3) = 15,47 kN/m2
d. Backfill soil coefficient (Kp1) = 2,040

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2. Concrete, reinforcement steel, and loading data
   a. Concrete unit weight (γ_{beton}) = 24,9 Kn/m3
   b. Planned concrete compressive (fc') = 24,9 Mpa
   c. Tensile strength of steel (fy) = 380 Mpa
   d. Live load factor (LL) = 1,6
   e. Dead load factor (DL) = 1,2

3. Calculation of vertical force and moment at the front foot (point 0): The calculation of the vertical force and moment at the front foot is carried out by calculating the weight of the construction, dividing it into 5 areas, and computing the uniform load. The result from the 5 construction areas and the uniform load is then multiplied by the dead load factor, and finally by the distance from 0 to obtain the moment at 0. The calculation for the vertical force and moment at the front foot (point 0) can be seen in Table 1.

No	Weight (W) (Kn)	W (kN) (that has been multiplied by load factor)	Distance from 0 (m)	Momen ke 0 (Kn.m)
1	0,5 x 0,2 x 4,0 x 25 = 9,96	11,95	1,1	13,5
2	0,3 x 4,0 x 25 = 29,88	35,86	1,3	44,82
3	1,3 x 4,0 x 16,8 = 87,31	104,77	2,1	214,78
4	2,7 x 0,5 x 24,9 = 33,62	40,34	2,1	82,69
5	0,9 x 2,5 x 16,8 = 37,78	45,33	0,5	20,40
6	1,3 x 10 = 13,00	20,80	2,1	42,64
		W = 259,05		ΣMu =418,48

Table 1 Calculation of Vertical Force and Moment at the Front Foot

4. Calculation of total active soil pressure and moment at the front foot (point 0). The active soil calculation can be computed with Pa1 and Pa2. After obtaining the active soil pressure results from calculations Pa1 and Pa2, they are multiplied by the live load factor and then added together. The active soil pressure multiplied by the live load factor is then multiplied by the distance from 0 to obtain the moment at 0. The calculation for the total active soil pressure and moment at the front foot (point 0) can be seen in Table 2.

Total active soil pressure, Pa (kN)	Pa (kN) (that has been multiplied by load factor)	Distance from 0 (m)	Momen ke 0 (kN)
Pa1 = q x h1 x Ka1 = 22,06	35,30	2,25	79,43
Pa2 = $1/2$ x y_1 x $h1^2$ x Ka1 = 83,35	100,02	1,50	150,03
	ΣPa = 135,32		ΣMql=229,45

Table 2 Total Active Soil Pressure and Moment at the Front Foot (Point 0)

5. Calculation of total passive soil pressure and moment at the front foot (point 0). The calculation of passive soil pressure can be computed with Pp1. After obtaining the results of passive soil pressure from the calculation Pp1, it is multiplied by the dead load factor and then added together. The passive soil pressure multiplied by the dead load factor is then multiplied by the distance from 0 to obtain the moment at 0. The calculation for the total passive soil pressure and moment at the front foot (point 0) can be seen in Table 3.

   Total weight (W) = 259,05 kN
   Total weight momen (Mu)= 418,48 kN.m
   Total soil pressure (P) = - 49,60 Kn`
   Total momen due to soil pressure (Mql)=75,35 kN.m

Total active soil pressure, Pa (kN)	Pp (kN) (that has been multiplied by load factor)	Distance from 0 (m)	Momen ke 0 (kN)
Pp1 = $1/2$x $_3$ x h_3^2 x Kp urug2= 154,10	184,92	1,00	154,10
	Σ Pp = 184,92		ΣMql= 154,10

Table 23 Total Pasive Soil Pressure and Moment at the Front Foot (Point 0)

e) The reinforcement work for the upper part of the retaining wall involves using horizontal reinforcement with a diameter of 16 at intervals of 200mm, long rods with a diameter of 19 at intervals of 250-320mm, and short rods with a diameter of 19 at intervals of 320mm. For the foundation part of the retaining wall, vertical reinforcement with a diameter of 16 at intervals of 200mm is used, along with short rods with a diameter of 19 at intervals of 250mm. The reinforcement work can be seen in Figure 10.

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(1)

(2)

Figure 10 (1) Reinforcement Work (2)Reinforcement Detail
Source : Documentation, 2023

f) Formwork installation is conducted after the reinforcement is completed. Before installation begins, the formwork is initially constructed in the field according to the planned dimensions. The formwork activity involves cleaning the plywood, then moving the formwork to the designated working location, and installing it as per the specified positions. The formwork installation work can be seen in Figure 11.

Figure 11 Formwork Installation Work
Source : Documentation, 2023

g) Slump testing is a method used to determine the consistency or stiffness level of a concrete mix [20]. The obtained slump value is 11 cm, and the slump test can be seen in Figure 12.

Figure 12 Slump Test
Source : Documentation, 2023

h) The observation during the pouring of the retaining wall, spanning 50 meters with a configuration of 51 mini-pile columns, took approximately 45 days. Each day, the pouring was carried out 3-5 times. The pouring of the mix design lasted around ±30 minutes per interval, utilizing a truck mixer. The pouring work

process is shown in Figure 13

Figure 13 Pouring Work
Source : Documentation, 2023

4 Conclusion

Based on the conducted research, several conclusions have been drawn.

1. The mini-pile columns were driven to the specified depth, with each section's length being 4.0 meters. The piling activity adhered to the planned depth.
2. The retaining wall used was a cantilever retaining wall, with the stem positioned perpendicular to support lateral loads on the soil. The specifications for this retaining wall in the project include Concrete Quality K-300 f'c 25 MPa, a wall height of 4.5 meters, an upper wall width of 0.3 meters, and a lower width of 2.7 meters.

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