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Retaining Wall Design in Addressing the Waterlogging Problem in Tambaklorok

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ABSTRACT

North Semarang is a densely populated area. Several villages are located not only on the North Coast of Java but also at the mouth of the Semarang River, and these villages are often hit by inundation floods. One of the causes of flooding in Tambak Lorok, Semarang is land subsidence and high tide or ROB. To handle the inundation that occurs, a study of the calculation of the retaining wall structure to hold back the inundation so that it does not enter the Old GIS Switchyard of Tambak Lorok Substation Semarang. The retaining wall planned with a total height of 1.8 m and a bottom width of 0.85 m is stable to the bearing capacity of the soil and safe against overturning and sliding. The bearing capacity of 18 drill pile foundation points with a diameter of 40 cm at a depth of 14 meters is sufficient to withstand the retaining wall and the load above it (350,424 tons > 264,384 tons).

Keywords: *Retaining Wall; Drilled Pile Foundation; Foundation Bearing Capacity*.

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INTRODUCTION

Semarang City has a strategic role in economic growth and infrastructure in Central Java, supported by the presence of ports, land transportation networks, and air transportation that become regional transportation nodes. However, the increasing development in Semarang poses various environmental challenges, one of which is land degradation and land subsidence, especially in the lower Semarang area. This problem is exacerbated by the annual increase in population, which puts more pressure on the city's environment and infrastructure [1].

North Semarang Sub-district is one of the most densely populated areas with significant environmental challenges. Several urban villages in the area are located on the edge of Java's North Coast and at the mouth of the Semarang River, making them subject to frequent inundation flooding. One of the affected locations is the Old GIS Switchyard of Tambak Lorok Substation, which experiences inundation due to a combination of land subsidence and sea tides (rob). Therefore, a technical solution is needed to overcome this problem in order to maintain the sustainability of the electrical infrastructure function in the area [2].

Based on this background, the problems faced in this study are how the geological conditions in the Old GIS Switchyard area of the Tambak Lorok Substation affect the phenomenon of land subsidence and inundation flooding, how to design an optimal retaining wall to overcome inundation in the area, and how to analyze the stability of the retaining wall in resisting lateral pressure and ensuring adequate soil bearing capacity [3].

Several previous studies have discussed soil improvement with reinforcement methods using retaining walls and bored piles. Hardiyatmo (2018) explained that lateral soil pressure is the main factor that must be taken into account in the design of retaining walls. In addition, Reese and O'Neill (1989) developed a model for calculating the bearing capacity of drilled piles that can be used in designing foundations in soils with weak characteristics [4]. The stability of retaining walls must consider safety factors against sliding, overturning, and the bearing capacity of the subgrade (Tomlinson, 1977 in Hardiyatmo, 2020) [5]. Therefore, a comprehensive analysis of geotechnical and hydrological parameters is necessary to ensure the long-term reliability of the structure [6].

This study aims to analyze and design retaining walls that can overcome inundation due to land subsidence and sea tides in the Old GIS Switchyard of Tambak Lorok Substation.The study involved geological condition evaluation, lateral earth pressure analysis, and foundation bearing capacity calculation.The proposed solution includes the design of a cantilever-type retaining wall by considering the stability of the structure against static and dynamic loads acting on the retaining system.

This research makes a novel contribution to the planning and design of retaining walls in areas with unique geological characteristics.The main innovation offered is the application of a more accurate calculation method to consider the combined impact of lateral soil pressure and tidal influence on structural stability.In addition, the design approach used will consider material efficiency and environmental sustainability in mitigating inundation problems in coastal areas. With this research, it is expected to provide a more effective and sustainable solution in dealing with the problem of inundation flooding and land subsidence in the coastal area of Semarang, especially in the Old GIS Switchyard area of Tambak Lorok Substation.

METHOD

This research begins with collecting data. The soil data obtained consists of data from field tests (CPT-1 and CPT-2) and laboratory tests [7]. From the data, interpret the soil data and calculate the design structure of the retaining wall that can be used and meet the safety requirements with analytical calculations.The analytical calculation step begins with calculating the self-weight and moments acting on the retaining wall and then proceeds to calculate active soil pressure and passive soil pressure, as well as calculating stability against shifting, overturning, and collapse of soil bearing capacity.

RESULTS AND DISCUSSION

Calculation of retaining walls based on flood water level conditions with cantilever retaining walls using drilled pile foundations with the following calculations:

Planning of retaining wall under flood water level condition

The planned retaining wall is a cantilever type retaining wall.
Planning Data (tried with dimensions):

Total Height (H+D)	= 1,80 m
Retaining Wall Height (H)	= 1,6 m
Bottom Width	= 0,35 m
Top Width	= 0,12 m
Foundation Depth (d)	= 0,8 m
Foundation Width (B)	= 0,85 m

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Active Earth Pressure Coefficient

$$Ka = \frac{1 - \sin\phi}{1 + \sin\phi} = \tan^2(45^\circ - \frac{\varphi}{2})$$

$$Ka = \tan^2(45^\circ - \frac{17{,}51^\circ}{2})$$

$$Ka = 0{,}537$$

Active Ground Pressure

$$PA1 = \frac{1}{2}\gamma\ H2^2\ Ka$$

$$PA2 = \gamma\ H2^2\ Ka$$

$$PA3 = \frac{1}{2}\gamma\ H2^2\ Ka$$

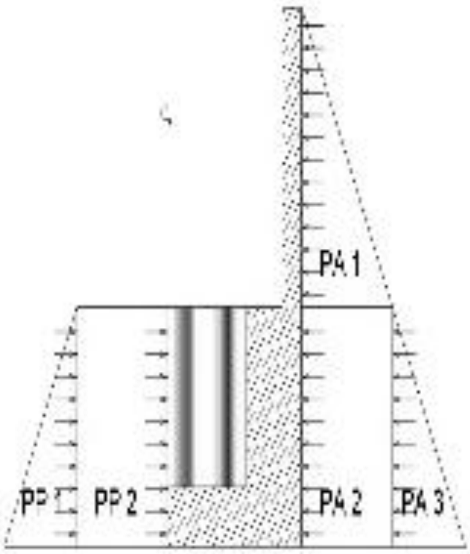

Figure 1. Active and Passive Ground Pressure

Table 1. Active Ground Pressure Calculation Results

Field	Pa (kN)	Rolling distance (m)	Moment (kNm)
PA1	2,64	1,3	3,43
PA2	4,54	0,4	1,82
PA3	1,69	0,267	0,45
Σ Pa	8,86	Σ Ma	5,69

Passive Earth Pressure Coefficient

$$Kp = \tan^2(45^\circ + \frac{\varphi}{2})$$

$$Kp = \tan^2(45^\circ + \frac{17{,}51^\circ}{2})$$

$$Kp = 1{,}86$$

Passive Earth Pressure

$$PP1 = \frac{1}{2}\gamma\ H1^2\ Kp$$

$$PP2 = \gamma\ H2^2\ Kp$$

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Table 2. Passive Earth Pressure Calculation Results

Field	Pa (kN)	Rolling distance (m)	Moment (kNm)
PP1	5,84	0,267	1,56
PP2	15,72	0,4	6,29
Σ Pp	21,56	Σ Mp	7,85

Construction Self-Weight Calculation

The material used in making the retaining wall will affect the retaining wall's own weight. This retaining wall is planned with reinforced concrete material with a concrete volume weight of 24 kN/m3. Own weight can be calculated by multiplying the area of the pias by the volume weight of reinforced concrete.

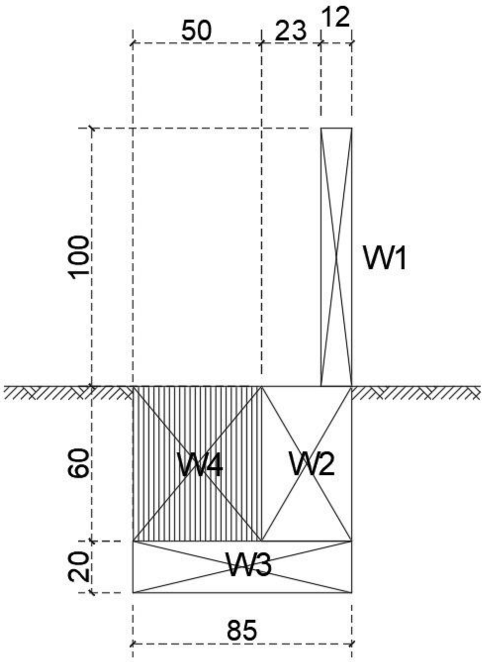

Figure 2. Construction Self-Weight

Table 3. Self-weight Moment Calculation Results

Field	Pa (kN)	Rolling distance (m)	Moment (kNm)
W1	2,88	1,1	3,168
W2	5,04	0,5	2,52
W3	4,08	0,1	0,408
W4	7,2	0,5	3,6
Σ W	19,2	Σ M	6,096

Stability to soil bearing capacity:

$\Sigma M \quad = 6{,}096$ kNm

$V = \Sigma W \quad = 19{,}2$ kN

$e \quad = \frac{1}{2} \cdot B - \frac{\Sigma M}{\Sigma W}$

$= \frac{1}{2} . 0,85 - \frac{6,096}{19,2}$

$= 0,108$

e ijin $= 1/6 . B = 1/6 . 0,85 = 0,142$

σ max $= \frac{2\ v}{3\left(\frac{B}{2}\right) - e}$

$= \frac{2\ .\ 19,2}{3\left(\frac{0,85}{2}\right) - 0,108}$

$= 32,89\ kN/m^2 \quad < qa\ 39,73\ kN/m^2$

Stability to shear

SF $= \frac{(v\ .f) + \left(\frac{2}{3}.c.B\right) + (Pp)}{Pa}$

$= \frac{(19,2\ .\ 1) + \left(\frac{2}{3}.\ 0,06\ .\ 0,85\right) + (21,56)}{8,86}$

$= 4,6 > 1,5$ (Safe)

Stability against rolling

Σ Ma = 5,69 kNm

Σ Mp = 7,85 kNm

Σ M = 6,096 kNm

SF $= \frac{\Sigma M + \Sigma Mp}{\Sigma Ma}$

$= \frac{6,096 + 7,85}{5,69}$

$= 2, 45 > 1,5$ (Safe)

The planned retaining wall is 135 meters long, so the total self weight of the 135 meters long retaining wall can be calculated as follows:

W DPT 135 m = 19,2 kN/m x 135 m

= 2592 kN

= 264,384 ton

Sondir Penetration Test Results

The results of the sondir testing were carried out at 2 points, namely CPT-1 and CPT-2.

Tabel 1. Sondir Test Results

Sondir Point	Depth (m)	Conus Resistance /CR (Kg/cm2)	Total Sticky Resistance (TSF) (Kg/cm)
CPT-1	14.00	45	880
CPT-2	20.00	65	2460

According to Mayerhoff, the bearing capacity of pile foundation soil using sondir tools can be calculated as follows:

$$Q_a = \frac{CR\,.\,Ab}{3} + \frac{TSF\,.\,F}{5}$$

Where :

Q_a = Bearing capacity of the single pile plan (ton)
CR = Cone Resistance (ton/m^2)
TSF = Total Skin Friction (ton/m)
Ab = Cross Section Area of Pile (m^2)
F = Perimeter of Pile (m)

Data from Table 1 is taken from CPT-1, representing a depth of 14 meters. The calculation of the single pile bearing capacity with a planned diameter of 40 cm can be seen in Table 5.

Table 5. Bearing Capacity of Pile with 40 cm Diameter

Depth (m)	CR (ton/m2)	TSF (ton/m)	Qb (ton)	Qs (ton)	Qult (ton)	Qa (ton)
1	275,58	25,35	31,4	14,44	45,84	13,36
2	1322,77	30,86	150,72	3,14	153,86	50,87
3	220,46	36,38	25,12	3,14	28,26	9,00
4	165,35	41,89	18,84	3,14	21,98	6,91
5	165,35	47,40	18,84	3,14	21,98	6,91
6	165,35	52,91	18,84	3,14	21,98	6,91
7	165,35	58,42	18,84	3,14	21,98	6,91
8	220,46	63,93	25,12	3,14	28,26	9,00
9	385,81	69,45	43,96	3,14	47,10	15,28
10	385,81	74,96	43,96	3,14	47,10	15,28
11	385,81	80,47	43,96	3,14	47,10	15,28
12	496,04	85,98	56,52	3,14	59,66	19,47
13	496,04	91,49	56,52	3,14	59,66	19,47
14	496,04	97,00	56,52	3,14	59,66	19,47

The planned bored pile foundation will be installed at 18 points, each with a depth of 14 meters. The total bearing capacity of the planned piles at 18 points, with a spacing of 7.5 meters per point, is:

Total allowable Q = 19,47 tons x 18 points
= 350,424 tons

CONCLUSION

Based on the results of calculations and analysis, the cantilever-type retaining wall with a total height of 1.8 meters and a bottom width of 0.85 meters is proven to be stable in terms of soil bearing capacity and safe against potential overturning and sliding. The cone penetration test results indicate that the bored pile foundation with a circular cross-section diameter of 40 cm has an allowable bearing capacity (Qa) of 19.47 tons per single pile. With a total of 18 bored pile points at a depth of 14 meters, the overall bearing capacity reaches 350.424 tons, which is sufficient to support the retaining wall along with the load above it (350.424 tons > 264.384 tons).

The results of this study show that the design of the retaining wall can be applied to similar conditions with appropriate soil characteristics. To enhance the reliability of the structure, additional tests such as direct shear tests or laboratory compression tests are recommended to obtain more accurate soil parameters. In addition, long-term monitoring of the retaining wall's performance after construction can be carried out to ensure its stability under operational conditions.

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