Evaluation of Bore Pile Foundation for Landslide Management in Tenggarong, Kutai Kartanegara, East Kalimantan, Indonesia

Abstract. Bore pile foundations are an effective solution to improve structural stability in areas with unstable geotechnical conditions, such as in the landslide-prone Tenggarong District. This study using the Bageman method aims to analyse the bearing capacity of bore pile foundations in supporting vertical loads on retaining wall structures. The ultimate capacity of the pile group design, the calculation of the group ultimate capacity (Qu_group) reached 48,459.393 kN, with a permit capacity of 4,845.939 tonnes. The calculation results show that the bore pile foundation with a depth of 12 metres and a diameter of 300 mm can bear considerable loads, ensuring safety and efficiency in the retaining wall structure. In addition, the use of longitudinal and spiral transverse reinforcement in the piles provides additional strength against lateral forces and structural stability, thus meeting the design needs with long-term stability assurance, which is very important in landslide-prone sites.

Keywords: Bore pile foundation, pile bearing capacity, soil stability, capacity calculation, retaining wall

INTRODUCTION

The condition of one of the roads in Tenggarong Sub-district faces the challenge of serious damage due to landslides, especially in high slope areas. In this context, bore pile foundations have become a reliable solution to improve the stability of soil structures. Bore piles offer significant bearing capacity, especially in areas with clay and silty soils, where soil structures are often unstable due to high moisture and vehicle dynamic loads (Unaibayev et al., 2021; Zhang et al., 2023).

Piles can be either driven or cast in place. Piledriving is achieved by: impact dynamic forces fromhydraulic and diesel hammers; vibration or jacking.Drivenpiles which tend to displace a large amount of soil dueto the driving process are called full-displacementpiles. Cast-in-place (or bored) piles do not cause anysoil displacement, therefore, they are non-displacement piles.One type of pile foundation ispile foundation, where the strengthbearing capacity is determined based onend resistance (end bearing) and attachmentwith the soil (friction), thus thisthus this type of foundation is very suitableused on soft soils where the hard soil is located far away from thesurface of the ground (Poulos & Davis, 2017; Mahmudi, 2023; Liliwati et al 2024).

The bore pile method not only provides stability but also shows high sustainability in geotechnical practice. Recent studies have shown that the use of bore piles with silicate protection technology can increase bearing capacity up to 2.5 times compared to conventional methods. This approach also reduces the risk of cracking or structural deformation in soils subjected to high lateral pressure (Unaibayev et al., 2021; Kumar et al., 2022).

In addition, a more integrated bore pile design approach is now being applied, including probabilistic analyses to ensure safety against complex soil conditions. This approach allows for more informed and applicable planning, especially in meeting the requirements of technical standards in landslide-prone areas such as Tenggarong (Kumar et al., 2022; Zhang et al., 2023).

MATERIALS AND METHODOLOGY

Soil mechanics data is directly taken at the research site located at Jalan Ikip Mekar Sari, Tenggarong District, Kutai Kartanegara by using bore pile. The results of the soil description can be seen in Figures 1, 2 and 3.

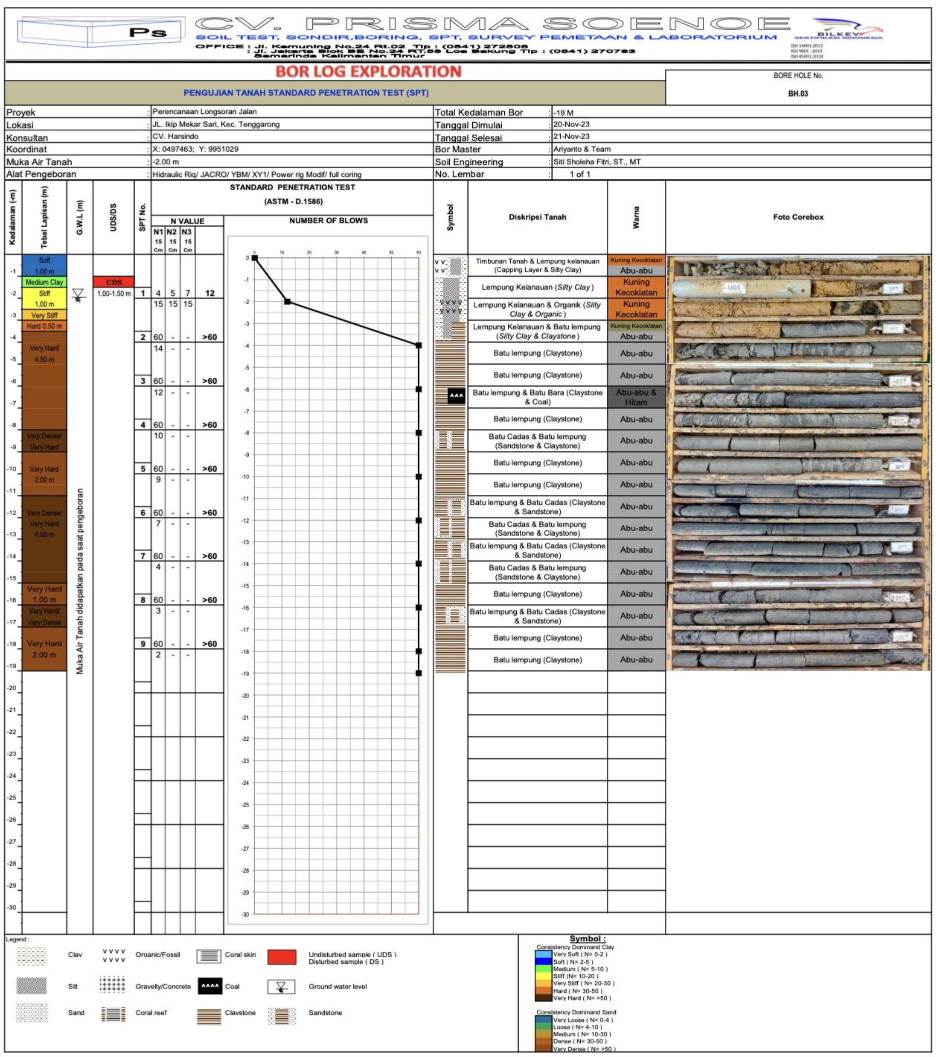

Figure 1: Results of Soil Investigation BH.01

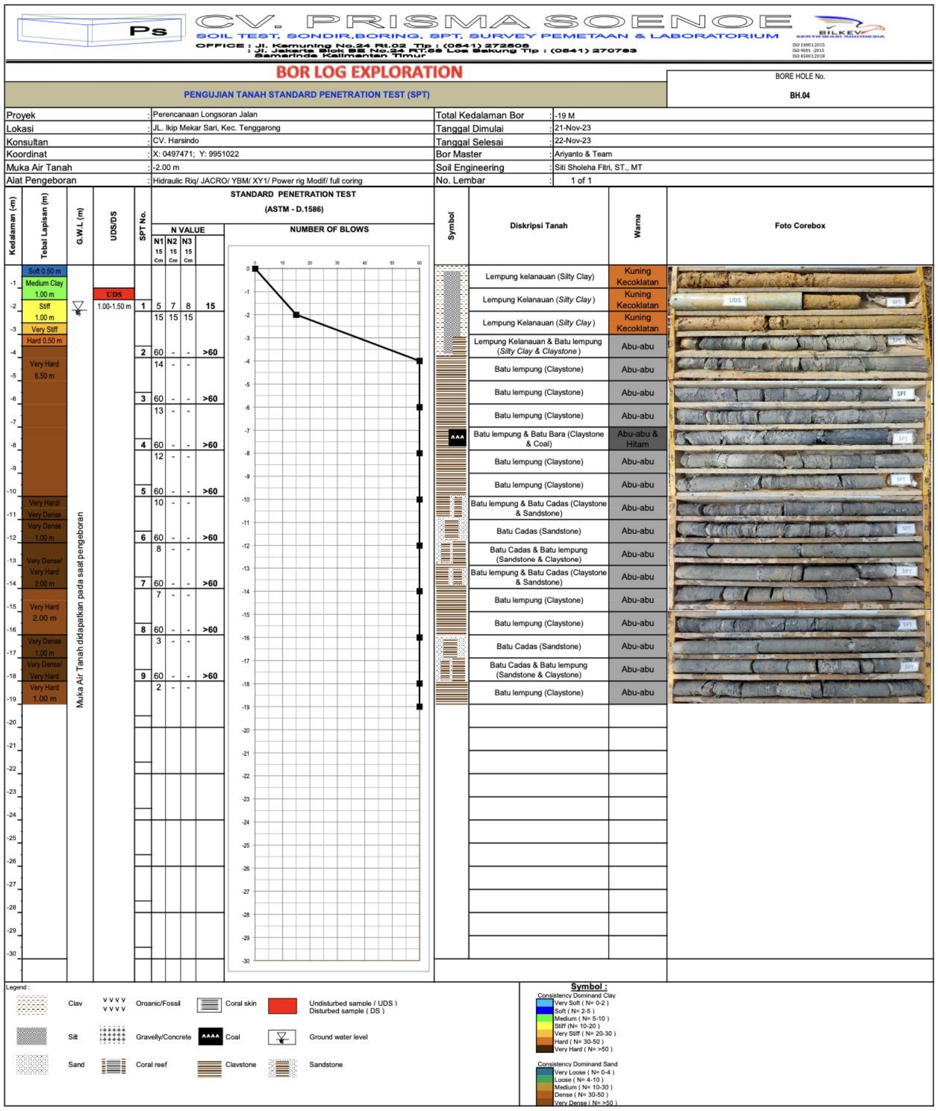

Figure 2: Results of Soil Investigation BH.02

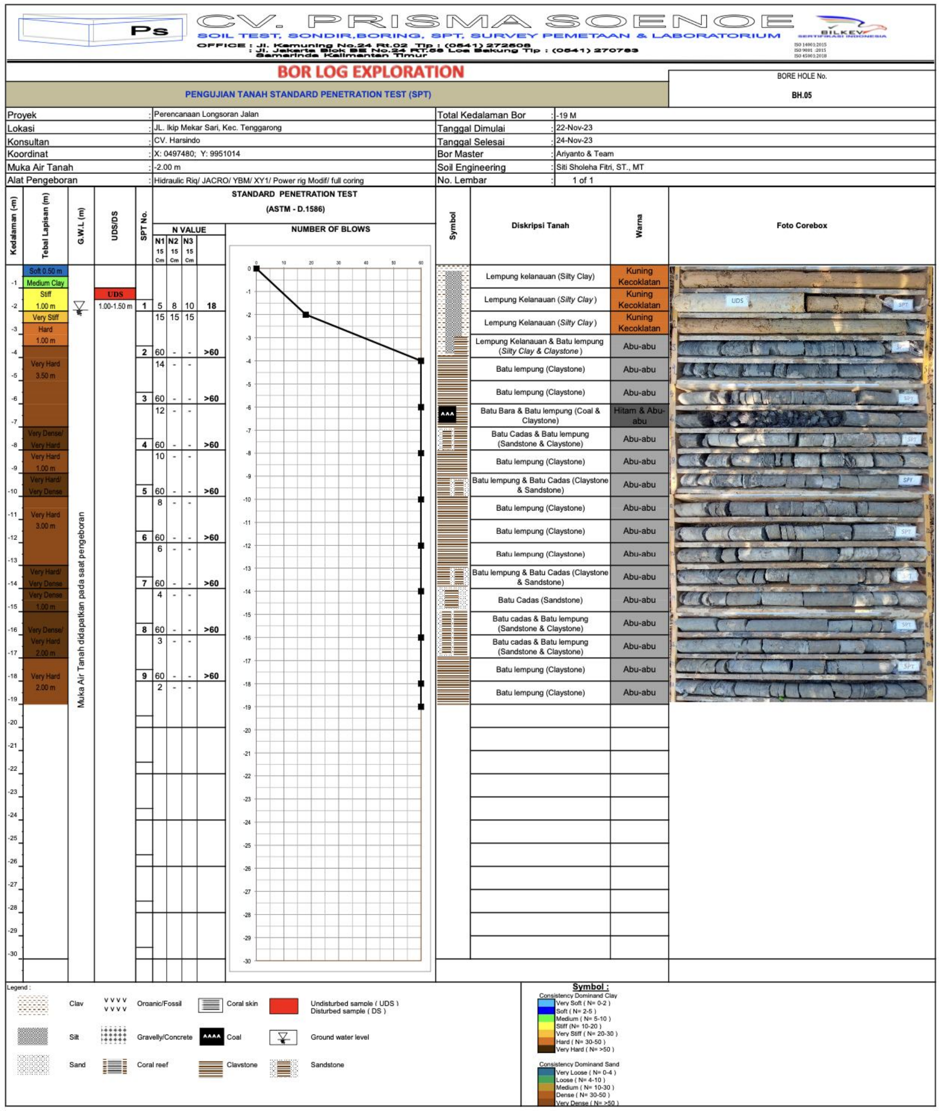

Figure 3: Results of Soil Investigation BH.03

RESULT AND DISCUSSION

Interpretation Based on Location shows

a. The soil at BH.03 tends to be denser with a higher bulk density, low pore number, and fine grain distribution, suitable for sites that require high stability soils.
b. The soil at BH.01 is more saturated and porous, indicating a soil condition that may be softer and requires more attention in foundation design.

Figures 1 and 2 show the results of the soil investigation at the borehole point. This location has a drilling depth of up to 19 metres with Standard Penetration Test (SPT) testing as per ASTM D-1586. The data shows that the soil layers consist of clay, claystone and sandstone combinations with varying N values that increase with depth, indicating increasing density. Coring results visually show changes in soil stratigraphy, supporting the evaluation of foundation bearing capacity for bore pile design.

The calculation of pile capacity using the Bagemann method aims to determine the ability of the pile to withstand loads based on geotechnical parameters and structural design. In this calculation, a plan diameter of 0.3 metres and a depth of 9 metres were used, which is a common configuration for piles in multi-storey building or infrastructure projects. The analysis results show the ultimate capacity (Qu) and permit capacity (Qa) values, which serve as a reference in determining the safety and efficiency of pile design.

Table 1. Pile Capacity Using the Bagemann Method

Approach Method	**Diameter Plan (m)**	**Depth Plan (m)**	**Ultimate Capacity of Pole (Qu) (kN)**	**Allowable Capacity of Pole (Qa) (ton)**
Bagemann	0,3	9	4851,108	485,111

From Table 1, the ultimate capacity of the pile (Qu) reached 4851.108 kN. This value represents the maximum load that the pile can withstand before structural or geotechnical failure. This capacity was then converted to a permit capacity (Qa) of 485.111 tonnes, taking into account the safety factor. The difference between Qu and Qa demonstrates the importance of applying a reduction factor to ensure long-term stability and safety in pile operations. The selection of a depth of 9 metres also reflects an attempt to achieve a more stable soil layer to increase the bearing capacity of the piles.

The results of this analysis indicate that a pile configuration with a diameter of 0.3 metres and a depth of 9 metres is capable of meeting the design requirements with a considerable permit capacity. The obtained permit capacity values are also in line with standard practice in geotechnical engineering. For further optimisation, additional studies such as analysing the effect of depth or diameter variations can be conducted to suit the specific needs of the project.

Table 2. Pile Capacity with Number and Efficiency of Piles

Approach Method	**Diameter Plan (m)**	**Depth Plan (m)**	**Ultimate Capacity of Pole (Qu) (kN)**	**Allowable Capacity of Pole (Qa) (ton)**
Bagemann	12	0,832	48459,393	4845,939

The calculation results show that the ultimate capacity of the pile group (Qu) is 48,459.393 kN, while the permit capacity of the pile group (Qa) is 4,845.939 tonnes. These values reflect the total ability of the pile group to withstand loads after multiplying by the group efficiency of 0.832. An efficiency value of less than 1 indicates a reduction in capacity due to inter-pole interaction effects, such as the effect of overlapping soil stress zones. However, with the efficiency value still high enough, this pile group can provide adequate stability to support the structural loads as designed.

The allowable capacity of nearly 4,846 tonnes indicates that a pile group of 12 with an efficiency of 0.832 is an effective and safe solution for the structural design requirements. Adjustments to the group efficiency can be made by adjusting the spacing between piles to reduce the effect of negative interactions. These results also confirm the importance of pile number selection and efficiency evaluation in pile group planning to achieve a balance between bearing capacity and economic use of materials. Overall, the Bagemann method provides a sound basis for the analysis of piles in group configuration.

The analysis shows that the planned bore pile foundation configuration iseligible to support the retaining wall structure. In this plan, piles with a depth of 12 metres and a diameter of 300 mm were used.

The choice of 12 metres depth ensures the piles reach the soil layer with adequate bearing capacity, while the 300 mm diameter provides the appropriate structural capacity to withstand the load. In addition, the use of 12D19 as longitudinal reinforcement increases the axial capacity of the piles, while P12-100 spirals provide additional strength against lateral forces and stability against buckling in the pile core. The calculation results also show that the foundation of this pile group is capable of supporting all vertical loads, thus providing assurance for the structural performance of the retaining wall.

Based on the foundation bearing capacity analysis, it can be concluded that the bore pile foundation planning has been optimally designed to carry the load of the retaining wall. With the appropriate combination of dimensions, reinforcement and depth, the foundation ensures the transfer of load from the structure to the ground without risk of failure. As a follow-up step, field supervision during drilling and pile installation is necessary to ensure that soil conditions are in accordance with the calculation assumptions, so that the quality and safety of the structure are maintained.

CONCLUSION

From the results of the analyses conducted, it can be concluded that the use of bore pile foundations is an effective solution in improving the structural stability of roads in Tenggarong District that are prone to landslides. This foundation is designed by considering the geotechnical conditions of the soil consisting of clay, loam, and rock, which require high bearing capacity. The pile reinforcement was designed using 12D19 longitudinal reinforcement and P12-100 transverse spiral reinforcement. The combination provides sufficient strength and stability to resist the internal forces acting on the retaining wall. Thus, the planning and implementation of this bore pile foundation guarantees optimal structural performance and safety for buildings or infrastructure in landslide prone areas.

Disclaimer (Artificial intelligence);

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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