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Prefabricated and Prestressed Bio-Concrete Piles: Case Study in North Jakarta

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Abstract

In this research, we will talk about Prefabricated and Prestressed Concrete piles in general and their types, what they are manufactured and developed over the years and how much they cost according to international standards and their usefulness in overcoming soil problems and pre-construction problems, then we will talk specifically about Prefabricated and Prestressed Bio-Concrete piles and the difference between them and ordinary piles. The research will also present the opinions of people who have delved into and discussed this topic and the opinions of all engineers, economists and specialists in general. In the end, this research will conclude with a complete and simplified summary of Prefabricated and Prestressed Bio- Concrete piles and all the information related to them in foundation engineering and other points that the engineer or specialist has not encountered before.

Keywords :
Bio-concrete piles, Engineering Study, Foundation, Prefabricated, Prestressed

1. Introduction

Prefabricated and Prestressed Concrete piles are used in the construction of many civil engineering and building structures. It's customizable via the pile trimmer, and is suitable across a wide range of applications and ground conditions. Push supports are created by driving piles into the soil to a depth of more than 40 meters, using adjustable hydraulic or diesel hammers. It is considered a versatile option, suitable for a variety of ground conditions and a pile of this type can be used as the basis for engineering structures. Prefabricated and Prestressed Concrete piles substrates are suitable when dry layers overlap with fine sediments. They also do well in aggressive or polluted soils.

In construction, Prefabricated and Prestressed Bio-Concrete piles are usually square or hexagonal tubes or tube sections. Features solid cross-section designs for short and medium length units. They are also built with light, by hollowing out the interior in hexagonal, circular or octagonal sections. The result is a section of tubes that saves weight and can stand up to high pressure and the interior of each pile can also be filled with concrete. This adds structure for better overall reinforcement and weathering resistance. This is especially important when the piles are exposed to severe frost, as it helps prevent them from cracking. Drainage holes can also be created to prevent water from accumulating in the hollow interior portions of the tubes themselves (Thomas, 2020). It also works well with the horizontal moments of any additional material but in the case of prefabricated substrates, the reinforcement inherent in their structure gives additional strength (Hamakareem, 2021).

2. Literature Review

2.1. Prefabricated and Prestressed Bio-concrete Piles

Prefabricated and Prestressed piles can range in length from 4m and increase by 1m to standard lengths of up to 14m. They are cast in square sections ranging from 200 mm to 450 mm and to benefit from the use of piling joints, precast concrete pilings can be pushed to lengths longer than 30 m. Prefabricated and Prestressed Bio-Concrete piles can often be pushed to a depth of 30 meters, however, in special circumstances, such as offshore projects, the piles can be pushed to a maximum depth of 150 meters (Crawshaw, 2018).There is no specific depth for concrete piles; There is no simple way to determine the appropriate depths. Instead, there is a very wide range of foundation types and depths suitable for different applications, depending on many considerations such as the nature of the load requiring support, ground conditions, presence of water, space availability, accessibility, sensitivity to noise and vibration, and other considerations important to determining the depth of the concrete pile and are installed with hammers. Vibratory impact piles (piling device) at a specific depth depends on what was previously mentioned of important considerations to determine the depth of concrete piles. There are many different types of pile driving methods, including hydraulic hammer, pneumatic hammer, vibrator, hydraulic pressure and others (Warrington, 1989).

Figure 1. Various types of bio bacterial concrete

2.2. Engineering View on Prefabricated and Prestressed Bio-concrete Piles

Driven Prefabricated and Prestressed Bio-Concrete piles are created by hammering them into the soil to a depth of greater than 40m by hydraulic or diesel hammer and are widely used due to their versatility and suitability for most ground conditions (Hamakareem, 2021). These piles can be used to establish all types of engineering structures under almost every soil condition. Prefabricated and Prestressed Bio-concrete Piles are particularly suitable where the foundation layer is covered with soft sediments and aggressive or contaminated soils. The piles are manufactured in factories under high quality control, and consist of sectional lengths of reinforced concrete sections with lengths ranging from 3 m to 15 m with the required or standard cross-section (V. Modeer, 2022). The sequence of production of Prefabricated and Prestressed Bio-Concrete piles is as follows: It is first poured in factories and then tensioning work begins in the case of the pre-stressed substrate, then it is cured and released in the case of the tension pile, then it is finished and finally handled and stored.

2.3. Prefabricated and Prestressed Bio-concrete Piles construction procedures

Before starting the pile hammering process, ways to protect the pile head from collapse must be determined. This can be determined from the requirements of the final bearing and driving conditions. It must be ensured that the pile has gained its full strength before construction begins. The Prefabricated and Prestressed Bio-concrete concrete Piles are then placed in the specified location and driven into the ground with a hammer.

Special wooden packing or synthetic cushion block protection should be noted. Sufficient for pile head while driving because with the driving because with the drive control that is achieved by gauge, the pile is pushed into the resistive soil layer to a depth equal to once the diameter of the pile (P: 501-844-4210). The most important applications of Prefabricated and Prestressed Bio-concrete Piles are masonry foundations, heavy loads, soft soils, tall buildings more susceptible to seismic loading, industrial buildings with horizontal or curved stresses, underground tank foundations, wind turbines, towers, river bridge foundations and piers supports, marine construction as well as dam supports and walls Small and micro projects, heavy floored warehouses, power plants and other applications (Burman, 2020).

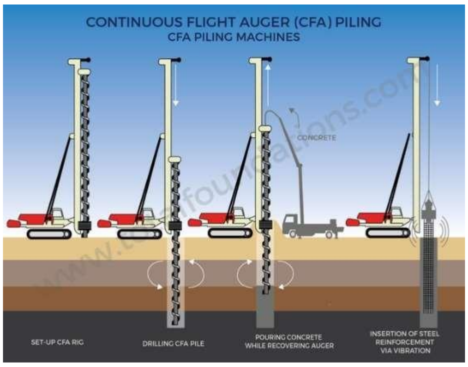

Figure 2. (CFA) Piling machines, Continuous Flight Auger group

2.4. Economic Studies Regarding Prefabricated and Prestressed Bio-concrete Piles

Prefabricated and Prestressed Bio-Concrete piles, when compared to ordinary concrete piles, require less amount of concrete and about 1/5 to 1/3 the amount of steel. For example, steel and prestressed concrete piles need high strength and high quality. Unit costs for this steel and/or concrete are higher than the cost of materials required to construct regular concrete piles. Formwork may be more expensive, and the additional cost of the prestressing process itself must be considered. However, in general, there is not much difference between the initial costs of prestressed concrete piles and ordinary concrete piles, provided that a large number of prestressed units are required. On the other hand, the indirect savings which accrue from pre- stress are often significant and should be fully taken into account.

2.5. Previous Literary Reviews

1. Based on Li & Zheng (2020) Loading tests of bio grout-improved and unimproved concrete model piles were conducted to evaluate the performance of bio grout to enhance the toe bearing capacity of precast concrete piles. The total bearing capacity of the precast concrete pile with a bio grouted toe was 4.4 times as large as that without bio grout. A series of index tests were performed using a penetrometer to estimate the spatial distribution of strength of bio cemented sands below the pile toe. It was found that the average strength of the bio cemented sand below the bio grouted pile toe gradually decreased with increasing vertical distance or lateral distance from the pile toe. The novel application of bio cement to treat bearing sands following pile installation represents a promising method to increase pile capacity.
2. Based on Dolati et al. (2022) Establishing a bridge foundation when there is a top layer of weak soils normally requires the application of deep foundations such as piles. Driving prestressed-precast concrete piles (PPCP) is one of the options among various types of piles and installation methods. However, it often happens that shipping and transportation constraints limit the length of precast prestressed pile segments that can be delivered to the bridge site. Therefore, the length of pile segments may be smaller than the length required to establish adequate resistance, and splicing of pile segments becomes necessary.
3. Based on Li & Zheng (2020) the carbon emissions of construction machinery reached 73% of the total carbon emissions during the construction of precast concrete piles, and the carbon emissions of pile drivers are more than half of the carbon emissions of construction machinery. And there is a strong linear relationship between the area of pile foundation, the cost of pile foundation and the number of pile foundation and the total carbon emission during the construction of precast concrete piles.
4. Based on Dolati et al. (2022) The use of piles is a common method for establishing deep foundations for bridges where there is a top layer of weak soil. Among various types of pile and installation methods, driving prestressed-precast concrete piles (PPCP) is a durable and economical option compared with the alternatives. Also, since the method employs pile segments prefabricated in precast plants and delivered to the site for installation, it conforms to the principles of Accelerated Bridge Construction (ABC) and provides a rapid alternative to other methods. However, often because of limitations on shipping and transportation, the length of precast prestressed pile segments that can be delivered to the bridge site has to be reduced. Also, headroom limitations for pile driving may limit the length of pile segments such that establishing adequate resistance may not be achieved with one segment. Therefore, splicing of pile segments has to be performed at the site to produce longer lengths.
5. Based on Zhou et al. (2020) the frictional capacity of precast pipe pile–cemented soil interface is largely dependent on the cemented soil strength, and the peak skin friction of the interface increases from 7.58 to 204 kPa with the cemented soil strength increasing from 65 to 1500 kPa. An adhesion factor is proposed to correlate the peak skin friction of the precast pipe pile–cemented soil interface and cemented soil strength. The adhesion factor is found to range from 0.116 to 0.141 corresponding to the range of cemented soil strength from 65 to 1500 kPa. It was also noted the failure at the pile– cemented soil interface is brittle. The scale effect also exists in the pile–cemented soil interface shear test, and the scale effect factor is 1.9 when the pile diameter decreases from 85 to 37 mm. Accordingly, the design of PGP pile should avoid approaching the frictional capacity of the pile–cemented soil interface.
6. Based on Wang et al. (2018) increasing the subsoil shear modulus can significantly improve the bearing performance of the reinforced PC piles that are subjected to axial loading. The ultimate bearing capacity of the reinforced PC pile increases by approximately 20% for every 100 mm increase in the diameter of outer cement-treated soil. Moreover, the pile-head displacement reduction is generally proportional to the increase in the elastic modulus and the diameter of the inner PC pile.
7. Based on Marcos & Chen (2018) Round piles exhibited a more elongated load displacement response than square piles especially in uncut loading. The amplitude ratios (Qx/QCHIN) in depleted loading were slightly higher than in non-minimized loading.
8. Based on Benmokrane et al. (2021) Marine, coastal structures, and bridges deteriorate prematurely due to corrosion. Numerous failures have occurred in substructure members of these structures, such as piles, leading to very high repair and replacement costs. Problems related to corrosion could be resolved through the use of noncorroding materials such as fiber-reinforced polymer (FRP) bars.
9. Based on Thusoo et al. (2021) The use of steel-encased precast concrete (SC) piles has risen rapidly for the construction of earthquake-resilient foundation systems for buildings in Japan and Southeast Asia. SC piles are used near the pile-pile cap connection owing to their increased ductility, and resistance against large bending moments and axial forces, compared to the other precast concrete piles. However, there are no official guidelines available for the design of SC piles in severe earthquakes, except for a proposed draft by the AIJ committee for the determination of bending capacities.

10. Based on Dolati et al. (2022) Prestressed precast concrete pile (PPCP) is the most common type of pile currently practiced for establishing bridge foundations because it provides for a rapid, economical, and durable method of construction. For various reasons, including unpredictable soil conditions and shipping as well as transportation limitations, it is preferable or imperative to cast PPCPs with shorter lengths and connect them at the site to achieve longer lengths. Accordingly, various splice systems have been implemented over the decades for connecting PPCPs. However, current splice methods have shortcomings that have limited their applications.
11. Based on Zhang et al. (2020) Precast concrete elements in accelerated bridge construction (ABC) extends from superstructure to substructure, precast pile foundation has proven a benefit for regions with fragile ecological environment and adverse geological condition. There is still a lack of knowledge of the seismic behavior and performance of the precast pile foundation.
12. Based on Do & Lam (2022) The demand for housing has increased rapidly in the major cities of Vietnam in particular, and in the world in general, the means of transport have also increased significantly, and the standard of living is very high, leading to a series of service activities appearing while the construction area was narrow. With high-rise buildings and many basements, construction works are increasingly designed, and this design makes sense in making use of building land as well as increasing the efficiency of building use. There are currently some construction methods for building houses with basements, such as pile construction method is done, then dig the soil to the bottom of the foundation and then build the house from the bottom up, or build according to the soil wall method (barrette wall), or the top-down method, semi-top down methods, etc. Each methodology has its own advantages and disadvantages.
13. Based on Kocherzhenko et al. (2020) The considered design and technological solutions allow to reduce the power of hammering the piles, while increasing their bearing capacity. Some of these innovative structural and technological solutions for precast piles, which significantly increase their bearing capacity: a convertible pile and a pile with “pockets” (cavities) on the side surface for use in loose soil. In the first case, in the manufacture of precast reinforced concrete piles in the center, cruciform-cone-shaped brake details are placed 0.75 of the length of the pile, into which after hammering the piles a destructive non-explosive material is poured, which increases in volume in 2-3 times, turns Prismatic stack to pyramid. In the second case, when making precast concrete piles, they provide for the arrangement along the side faces of the “pockets” (recesses). The liquid hardening compound in the “pockets” penetrates the pile soil during the driving process and secures it, which significantly increases the lateral friction force and bearing capacity of the pile and reduces the pile sinking energy.
14. Based on Hassanli et al. (2021) Epoxy resin can greatly speed up and simplify construction procedures because of its operability in addition to its high early strength and non-shrink properties, its thickness and low modulus of elasticity greatly affected the performance of the sine joint. Jib joints can be used for GFRP-reinforced precast concrete elements; however, they must be carefully designed to take into account the low stiffness of GFRP reinforcement. Also, to avoid premature failure and to achieve higher capacity of the jib joints, it is recommended to use the material used for the jib to fill the gap between the shaft and the beam to have a higher modulus of strength and flexibility compared to surrounding precast concrete.
15. Based on Jialin Zhou & Oh (2021) Pile foundation is a long structural element that cooperates with soil to resist the loading transferred from the upper structure. It can be primarily categorized into cast-in-place and precast pile based on the piling construction condition.

3. Research Methodology

3.1. Research method and sample

Jakarta faces limited land resources due to its location surrounded by water from several directions and also being the capital of the country and an economic destination for many companies around the world. Therefore, many high-rise buildings are being constructed to solve this problem and provide accommodation for a large number of foreigners and Jakarta residents, who number approximately 10 million according to the census Therefore, Prefabricated and Prestressed Bio-Concrete piles are commonly used as the basis for high-rise buildings, especially in the north of the city, which are close to the sea and in that area precipitation of deep loose soil prevails.

Katulik Parahyangan University in Bandung has carried out some field studies aimed at characterizing the soil properties for the analysis of 600 mm diameter prestressed concrete substrates in the coastal area of North Jakarta based on Standard Penetration Test (SPT-N) values. The project contains 11 towers located in the north coast of Jakarta region, known as Dadap, and it is dominated by thick and soft soil. This study focused on a spun pile, specifically A1204, embedded in Tower 1 area and pushed approximately 44.5 m below ground level, with a diameter of 600 mm and a compressed strength of 45 Mpa. Soil samples and their stratification information. The SPT-N test was followed by the ASTM-D1586 test, also known as Borehole 01 (BH-01).

Table 1. Prefabricated and Prestressed Bio-Concrete Spun Pile Input Materials

Properties	value
Poisson ratio (v)	0.2
Unit Weight (y)	24KN/m3
Modulus of Elasticity (E)	3E+07KN/m2

3.2. Method of data collection and analysis

Background analyzes were performed by the finite element method to obtain a stable load settlement curve and a well-documented static substrates load test using the kentledge system. Moreover, the effect of the strength of the inter face between the substrate and the soil on the load-settling curve was investigated and also, several parameters of soil geotechnical engineering, such as unlined shear strength and effective youth modulus, were established using data from the in-situ soil site investigation and experimental correlations with SPT-N.

Table 2. Soil stratification of BH – 01

%	Load (kN)	Settlement (m)
0	0	0.00000
25	350	0.00163
50	700	0.00376
75	1050	0.00591
100	1400	0.00806
125	1750	0.01026
150	2100	0.01265
175	2450	0.01504
200	2800	0.01768
225	3150	0.02086
250	3500	0.02517

Table 3. Pile A1204 Tower loading test results

Elevation Depth (m)	Soll Type	USCS Symbol	SPT-N
0.0 – 1.0	Very soft – Silty Clay	CL	2
1.0 – 7.0	Loose - Sand	SW	8
7.0 – 31.0	Very soft – Silty Clay	CL	2
31.0 – 39.0	Dense - Sand	SW	32
39.0 – 69.0	Hard – Silty Clay	CL	26
69.0 – 80.0	Dense – Sand	SW	27

Several parameters of soil geotechnical engineering, such as unpaired shear strength and effective modulus, were achieved using data from the in-situ soil-site investigation and experimental relationships with SPT-N. Simulations of a 2D finite element model to predict final pile capacity have been validated in this study. The results showed that the substrate load test was successfully simulated using finite element analysis. The calculated load adjustment curve is generally close to the measured data. Moreover, the experimental correlation was developed according to the SPT-N values to obtain the Undrained shear strength and the effective young modulus. The effective soil modulus for clay was estimated as E′ = 1350 NSPT (kPa) and E′ = 2625 NSPT (kPa) for sand, while the unlined shear strength (Su) was estimated as 5.5 NSPT and 6 NSPT.

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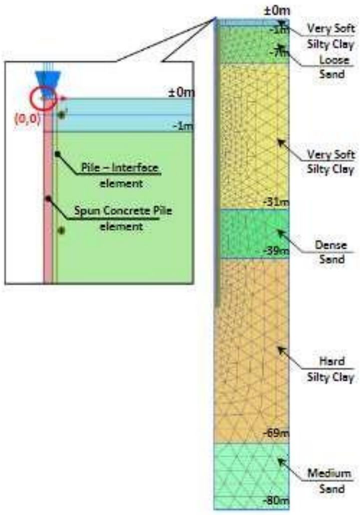

Figure 4. Prefabricated and Prestressed Bio-Concrete Element Model for analysis (PLAXIS 2D 2019) Stage Construction

4. Discussion and Results

4.1. Pile loading test

Axial load capacity is an important geotechnical requirement for deep foundation design because it is used for support. Therefore, this led to the development of various methods for evaluating the axial load of the piles by geotechnical engineers, such as the static full load test (Coduto, 2001). There are two types of substrate load tests, continuous penetration rate (CRP) and continuous load (ML) tests. According to Tomlinson (1994), ICE's pilingborders boundary rate decreases when movement is above 0.25 mm/hr. This indicates that it is important to ensure more time at each load to obtain a similar degree of soil cohesion because the slower the loading rate, the lower the final failure. This test sequence includes loading, unloading and reloading to working level.

The load pressure cell was used to regulate the hydraulic pressure in the lifting system. In general, this system is more stable and less prone to breakdown, although it is expensive and cumbersome. Geometric sides used cylinder conditions, and the lower borders were fixed. The physical behavior of soil layers was used to simulate the perfectly elastic plastic Mohr-Coulomb constitutive law. Then, the interaction of the pile structures with the surrounding soil was determined using an interface agent (Rint) along the substrate column. Facades are connected elements added to plates or geogrids to allow proper modeling of soil structure interaction. It is also used to simulate the thin zone of intense material engagement at the contact between the plate and the surrounding soil (Dandagawhal, 2018).

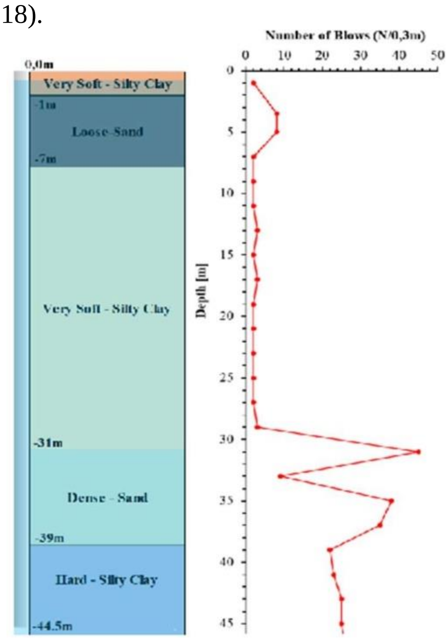

Figure 5. Soil stratification and SPT-N value of BH-01

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4.2. Soil modulus and correlation of shear strength properties

Several experimental error operations were used to determine the correct input parameters for the curve fitting process. This technique is known as background analysis and consists of soil parameters with significant influences on the load and stability curve results, such as the strength of the unexploited soil (Su) and the effective youth modulus (E'). Several iterations changed two soil parameters based on background analysis until the computed results for field measurement were closed.

The uncast slurry shear strength (Su) from experimental correlation was achieved by posterior analysis, which connects Su to NSPT, as shown in the following equations:

$Su = 5.5\ NS(kPa)$

$Su = 6\ NS(kPa)$

The previous two equations are used to form Su clays with a very fine, hard to hard clay consistency. Figure 6 compares the Su profile calculated from the above equation and the actual depth of the soil profile. The value of Su obtained from these two equations depends on the value of SPT-N for each soil layer.

Layer	Soil Type	S_u (kN/m²)	E' (kN/m²)
1.	Very Soft – Silty Clay	$5.5 \times N_{SPT}$	$1350.0 \times N_{SPT}$
2.	Loose – Sand	-	$2625.0 \times N_{SPT}$
3.	Very Soft – Silty Clay	$5.5 \times N_{SPT}$	$1625.0 \text{ x } N_{SPT}$
4.	Dense – Sand	-	$1562.5 \times N_{SPT}$
5.	Hard – Silty Clay	$6 \times N_{SPT}$	$1538.5 \times N_{SPT}$
6.	Medium – Sand	-	$1666.7 \times N_{SPT}$

Figure 6. Su and E’ Correlation based on SPT-N DataBorehole 01

The effective soil modulus (E′) is also an essential property of soils to predict its deformational properties. The effective soil modulus for clay was estimated as E′ = 1350 N (kPa) and E′ = 2625 N (kPa) for sand. Like the determination of Su values, the effective soil modulus (E’) is also related to the SPT-N value of each layer. For practical purposes, the proposed correlation equations between SPT-N values with non-wet soil strength (Su) and effective Young's modulus (E') used in the Mohr-Coulomb model are summarized.

4.3. Soil Constitutive Model

The spun pile is a linear elastic material, where the model represents Hooke's law of resistance to linear elasticity. According to the geotechnical field investigation, the groundwater discharge was located at a depth of 0.5 m below ground level, while the spun substrate used in this study was classified as Class A1 concrete. Moreover, the pile was modeled using mass, and the linear elastic material was used to determine the stiffness of the concrete material, such as modulus of elasticity (E), Poisson's ratio ($\boldsymbol{\nu}$), and concrete unit weight (C). The model, a common elastic linear plastic model, was used as the first approximation of soil behaviour, with constant mean stiffness to predict soil stratification. This model includes 4 basic soil parameters, namely modulus of elasticity (E) Poisson's ratio ($\boldsymbol{\nu}$), angle of friction (φ), and cohesion (C). Mud and sand were simulated with unaccompanied and filtered behaviour, respectively. The main difference between these two behaviors was the increase in pore pressure due to loading. In the case of immersion, excess pore pressure is created, while in the case of drainage, it remains zero. In this analysis, clay and silt adopted uncoated B model which consisted of effective hardness parameters and uncast shear strength (CU). During this process, uniformity analysis after non-extreme calculation is not required due to increased pore pressure.

4.4. Load Settlement Curve

The results indicated that the spun strut was not tested until failure, while finite element analysis was used to extrapolate the load flatness curve to evaluate the maximum capacity of the tested material. The results showed that the calculated curve correctly fits the measured data. Therefore, it can be concluded that the FE model and the input parameters were valid and verified. According to Mazurkiecwicz's theory, the final pile capacity was 4110 kN. Interpretation of the final heap capacity (Rinter = 1) was carried out using Mazurkiewicz and Davisson method after obtaining the extrapolated load flattening curve using PLAXIS 2D software 2019. Calculation and determination of the final capacity is shown in Figs 6 and 7. The final capacity is smaller than Mazurkiewicz with a difference of 5%.

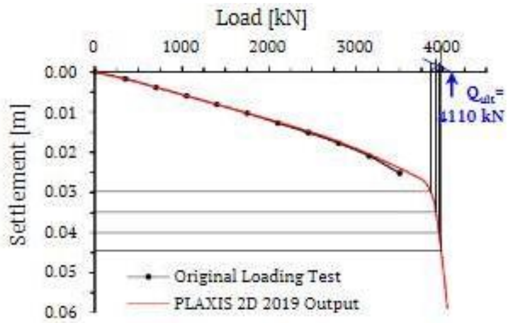

Figure 7. Mazurkiewicz Method

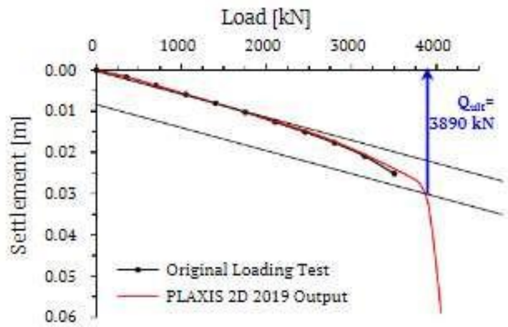

Figure 8. Davisson's Method

4.5. Influence of the Interface Coefficient

To study the effect of interface values, a single axially loaded stack was modeled. Therefore, the interface value was used to reduce the friction between the structure (pillar foundation) and adjacent soil to reduce the friction between structures with sandy or clay soils (Dr., 2022).

4.6. Inline heap length effect

Another parametric study was performed with different lengths of the embedding piles, such as 35 m and 47.50 m. Figure 8 shows the result of the load adjustment curve. The final capacity of the 35m substrate is 47.5m smaller due to skin friction.

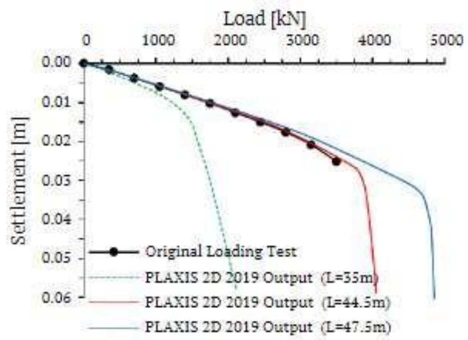

Figure 9. Load adjustment curves for A1204 substrate with variations in pile length

4.7. Summary and Conclusion

Engineers will select prefabricated and prestressed bio-concrete piles. This is done for many reasons, but is basically less expensive for two main reasons: One is the need for prestressed and precast bio-concrete piles to have precast reinforcement in order to withstand any bending or tensile issues that may occur during curing. There is more than one reason for designing and forming standard reinforced concrete piles. For more strength or flexibility, models can also be pre-stressed or post-stressed and pre-stressed. Regular reinforced concrete piles tend to be preferred in any project where all that is required is a fairly small number of piles. When the cost of a full stress on-site production line is not justified, these units are also more economical.

Background analyzes were performed by the finite element method to obtain a constant load settlement curve and a well-documented static substrates loading test using the kentledge system. Moreover, the influence of the interface strength between the substrate and soil on the load stabilization curve was studied, and several parameters of soil geotechnical engineering, such as unlined shear strength and effective youth modulus, were also determined using data from the site soil investigation and experimental correlations with SPT-N.

Several parameters of soil geotechnical engineering, such as the non-paired shear strength and effective modulus, were achieved using data from the in-situ soil-site investigation and experimental relationships with SPT-N. Simulations of a 2D finite element model to predict the final substrate amplitude have been validated in this study. The results showed that the substrate load test was successfully simulated using finite element analysis. The calculated load adjustment curve is generally close to the measured data.

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References

Benmokrane, B., Mohamed, H. M., Mousa, S., Elsafty, A., & Nolan, S. (2021). Design, Construction, Testing, and Behavior of Driven Precast Concrete Piles Reinforced with GFRP Bars and Spirals. Journal of Bridge Engineering, 26(8). https://doi.org/10.1061/(ASCE)BE.1943-5592.0001755

Burman, G. (2020). Applications of prestressed concrete. Structures Insider.

Coduto, D. P. (2001). Foundation Design: Principle and Practices (2nd ed.). Upper Saddle River.

Crawshaw, R. (2018). Beyond Emotion: Empathy, Social Contagion and Cultural Literacy. Open Cultural Studies, 2(1), 676–685. https://doi.org/10.1515/culture-2018-0061

Dandagawhal. (2018). Settlement Analysis of Pile Foundation Using Plaxis.

Do, T. M. D., & Lam, T. Q. K. (2022). Using Prestressed Reinforced Concrete Piles as Basement Walls for High-Rise Buildings (pp. 193–207). https://doi.org/10.1007/978-981-16-5543-2_16

Dolati, K., Saman, S., & Mehrabi, A. (2022). FRP sheet/jacket system as an alternative method for splicing prestressed-precast concrete piles. Case Studies in Construction Materials, 16, e00912. https://doi.org/10.1016/j.cscm.2022.e00912

Dr., T.-L. G. (2022). Deep Excavation Failures, Can They Be Prevented? International Symposium on Sustainable Geosynthetics and Green Technology for Climate Change.

Hamakareem, M. I. (2021). Fibre Reinforced Polymer (FRP) in Construction, Types and Uses. The Constructor Building Ideas.

Hassanli, R., Vincent, T., Manalo, A., Smith, S. T., Gholampour, A., & Gravina, R. (2021). Large-scale experimental study on pocket connections in GFRP-reinforced precast concrete frames. Structures, 34, 523–541. https://doi.org/10.1016/j.istruc.2021.08.009

Kocherzhenko, V., Suleymanova, L., & Kolesnikov, M. (2020). Innovative structural and technological developments of pile foundation engineering. IOP Conference Series: Materials Science and Engineering, 945(1), 012035. https://doi.org/10.1088/1757-899X/945/1/012035

Li, X.-J., & Zheng, Y. (2020). Using LCA to research carbon footprint for precast concrete piles during the building construction stage: A China study. Journal of Cleaner Production, 245, 118754. https://doi.org/10.1016/j.jclepro.2019.118754

Marcos, M. C. M., & Chen, Y. J. (2018). Applicability of Various Load Test Interpretation Criteria in Measuring Driven Precast Concrete Pile Uplift Capacity. International Journal of Engineering and Technology Innovation, 8(2), 118–132.

Thomas, L. (2020). Cross-Sectional Study | Definition, Uses & Examples.

Thusoo, S., Obara, T., Kono, S., & Miyahara, K. (2021). Design models for steel encased high-strength precast concrete piles under axial-flexural loads. Engineering Structures, 228, 111465. https://doi.org/10.1016/j.engstruct.2020.111465

V. Modeer, R. K. B. (2022). Innovative Bridge Design Handbook (Second Edition) (2nd ed.).

Wang, A., Zhang, D., & Deng, Y. (2018). A Simplified Approach for Axial Response of Single Precast Concrete Piles in Cement-Treated Soil. International Journal of Civil Engineering, 16(10), 1491–1501. https://doi.org/10.1007/s40999-018-0341-9

Warrington, D. (1989). Vibratory and Impact-Vibration Pile Driving Equipment. https://doi.org/10.13140/RG.2.2.15745.51044

Zhang, X., Chen, X., Wang, Y., & Ding, M. (2020). Quasi-static test of the precast-concrete pile foundation for railway bridge construction. Advances in Concrete Construction, 10(1), 49–59. https://doi.org/http://dx.doi.org/10.12989/acc.2020.10.1.049

Zhou, Jiajin, Yu, J., Gong, X., El Naggar, M. H., & Zhang, R. (2020). The effect of cemented soil strength on the frictional capacity of precast concrete pile–cemented soil interface. Acta Geotechnica, 15(11), 3271–3282. https://doi.org/10.1007/s11440-020-00915-x

Zhou, Jialin, & Oh, E. (2021). Full-Scale Field Tests of Different Types of Piles: Project-Based Study (1st ed.). Springer.