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STUDY OF CIRCULAR PLATE ANCHOR PILE IN MARINE CLAY UNDER VERTICAL LOAD CONDITION

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ABSTRACT:
This Research paper study the performance of circular plate anchor piles in Marine Clay. It highlights about the Vertical capacity load carrying capacity of the piles with respect to varying embedment depth, failure mechanisms, and soil-structure interaction of anchor piles. The study reviews past experimental and numerical research to identify performance trends and design implications. It also emphasizes the importance of FEA in understanding anchor behavior. The goal is to guide optimal anchor selection for different applications.

KEYWORDS:
Circular Anchor Pile, Helical Anchor Pile, Embedment Depth, Vertical Load Capacity.

1. INTRODUCTION:

Soil anchors are critical in geotechnical engineering for resisting uplift, lateral, and tensile forces, particularly in low-shear-strength soils such as marine clay. These anchors enhance the structural integrity of systems like retaining walls, offshore platforms, and deep foundations by engaging soil through frictional and bearing resistance mechanisms. Among the various types, helical plate anchors and circular plate anchors are emphasized for their application in soft soils. Helical anchors, consisting of a central steel shaft with welded helical plates, are installed via torque, allowing deep penetration with minimal soil disruption and improved load distribution. Circular plate anchors, on the other hand, utilize a flat plate to provide resistance primarily through end-bearing, and while effective in soft soils, they are typically less efficient than helical types due to higher installation disturbance and lower load transfer efficiency.

Driven plate anchors and grouted anchors also serve critical roles in soil stabilization. Driven plate anchors, shaped as flat or fluke-type plates, rely on passive earth pressure and are installed through impact driving, making them suitable for slope stabilization and marine applications. However, their performance in marine clay is constrained by the soil’s poor shear strength. Grouted anchors comprise steel tendons grouted into pre-drilled holes and offer high load-bearing through bond strength between grout and soil or rock, making them reliable in weak soil conditions. These anchors are widely used in infrastructure like bridges and offshore structures. Overall, the selection of anchor type depends on soil characteristics, load requirements, and installation constraints, with finite element analysis (FEA) used to optimize their design and performance.

2. LITERATURE REVIEW

The literature review comprehensively examines the development and comparative analysis of circular and helical plate anchors in soft soils, particularly marine clay, over the past decade and a half.

Early works such as Sakr et al. (2011)[1] experimentally investigated helical piles in cohesionless soils, identifying a direct link between installation torque and axial capacity. In the same year, Mittal et al. (2010)[2] studied screw anchor piles under lateral loading, highlighting the importance of embedment depth and helix number. Hambleton et al. (2014)[3] introduced a torque-based analytical model for predicting the capacity of single-helix piles in clay, while Chen et al. (2014)[4] applied an Eulerian finite element method to simulate uplift behavior of circular plate anchors. Todeshkejoei et al. (2014)[5] utilized 3D numerical analysis to evaluate helix geometry impacts, contributing practical insights for optimizing offshore anchor design.

Progressing to more advanced modeling and field conditions, Chiluwal et al. (2019)[6] investigated helical pile-to-foundation connections under cyclic loads, proposing enhancements for durability. In the same year, Feng et al. (2019)[7] conducted large deformation FEA to study the effect of layered clays on plate anchor performance, while Hao et al. (2019)[8] focused on helix spacing in multi-helix anchors and its impact on tensile strength. Dhatrak et al. (2020)[9] examined anchor performance in clayey soils using FEA to propose optimal design parameters, and Mortazavi et al. (2020)[10] introduced tapered helical piles, proving improved material efficiency and axial performance. Mohammad-Emad et al. (2021)[11] reviewed the limited adoption of helical foundations in developing countries and called for greater awareness and technical education. Xue et al. (2021)[12] demonstrated the superior performance of pile-anchor systems over cantilever piles for excavation stability.

Recent studies from 2022 onward focused on application-specific improvements. Kong et al. (2022)[13] analyzed cyclic loading effects on marine aquaculture anchor piles, while Venkatesan et al. (2022)[14] examined mono helical piles under combined loading, emphasizing helical configuration's role. In (2023)[15], Ling et al. assessed the effect of prestressing on displacement reduction in pile-anchor systems, and Alnmr et al. compared granular and helical anchor piles, favoring granular anchors for expansive soils. Wang et al. (2023)[17] highlighted the contribution of the pile shaft to uplift resistance, and Jerin Joseph et al. (2024)[18] reaffirmed granular pile anchors' superior performance under uplift in loose sands. Collectively, these studies from 2010 to 2024 advance the understanding of anchor pile behavior, encourage the use of numerical modeling tools like FEA, and offer guidelines for improved foundation performance in complex soil conditions.

3. Methodology & Parameters

This section discusses the development of a finite element model for a circular plate anchor using the FEM software program MIDAS GTS NX 3D. The analysis conducted in this study involves modeling a circular plate anchor with a single plate embedded in marine clay soil at varying embedment depths. The ultimate vertical load capacities under vertical loading conditions were determined. The properties of the circular plate anchor used in the analysis are presented in Table 3.1, while the soil properties are listed in Table 3.2. For each model, the shaft diameter and plate diameter were taken as 0.4 m and 2.4 m, respectively, with a plate thickness of 0.1 m. The failure criterion was defined as 5% of the plate diameter. Vertical load analyses are carried out for each configuration, and the results are evaluated.

Table 3.1 Properties of Circular Plate Anchor (Wang *et. al*. 2013)

Young's Modulus(kN/m^2)	**Density (kg/m^3)**	**Poisson's Ratio**
2.1x10^8	7800	0.25

Table 3.2 Properties of Marine Clay (Wang *et. al*. 2013)

Young's Modulus(kN/m^2)	**Undrain Cohesion (kN/m2)**	**Unit Weight (kN/m3)**	**Poisson's Ratio**	**Angle of Internal Friction**
12.75x10^3	12.75	16	0.4	0

Table 3.3 Circular Plate Anchor Pile Models w.r.t Embedment Depth of Plate From Ground Surface

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Single Plate Circular Plate Anchor	
Model Configrations	**Embedment Depth of Plate from G.L**
A	2.65
B	6.25
C	9.85

4. Result

Vertical load test is carried out on three model anchor's A, B & C on marine clay and following results are drawn mentioned as per case below.

Case I:- Result of model "A" with embedment depth 2.65m shown in Fig. 4.1 and Fig 4.2.

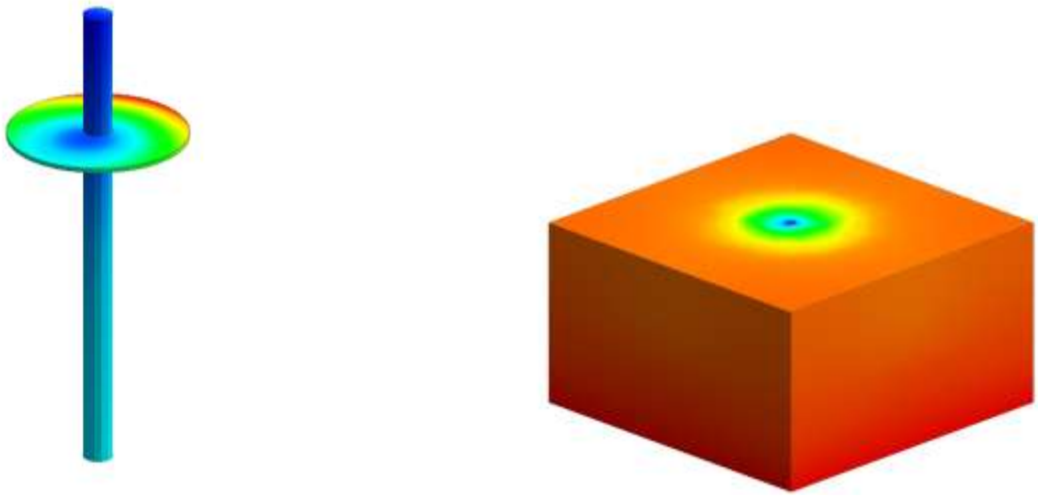

Figure 4.1: Failure Surface of Model "A" and Soil Profile

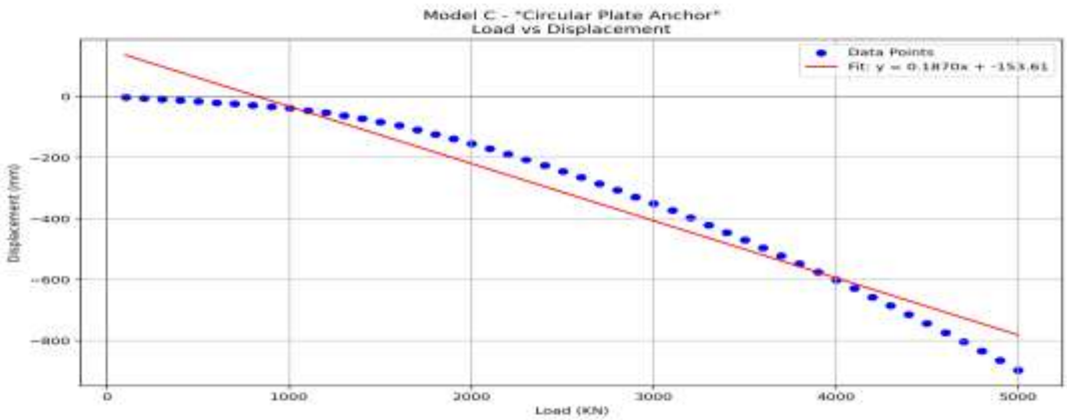

Figure 4.2: Load vs Settlement Curve of Model "A"

Case II:- Result of model "B" with embedment depth 6.25m shown in Fig. 4.3 and Fig 4.4.

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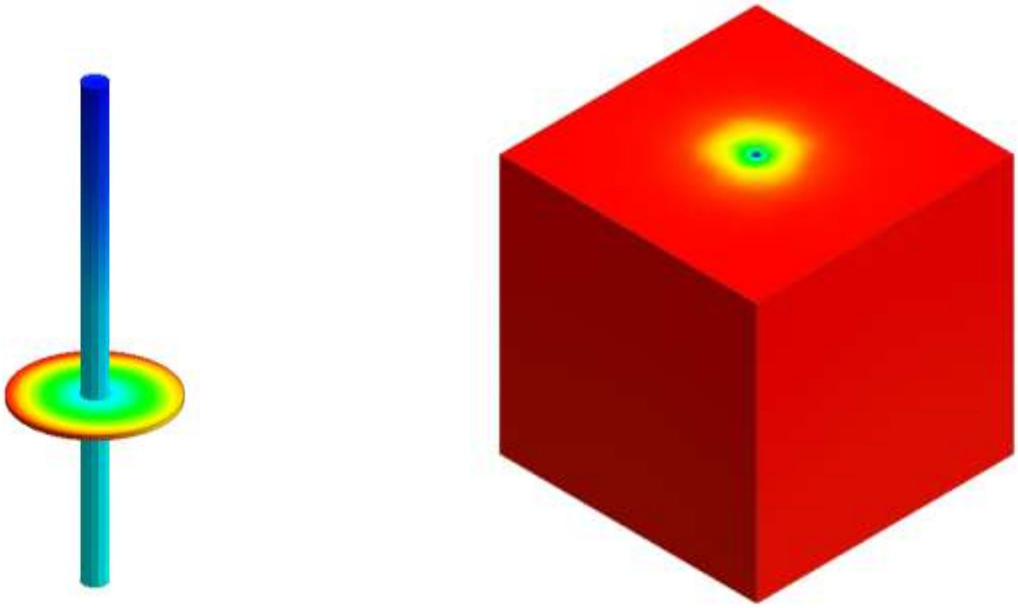

Figure 4.3: Failure Surface of Model “B” and Soil Profile

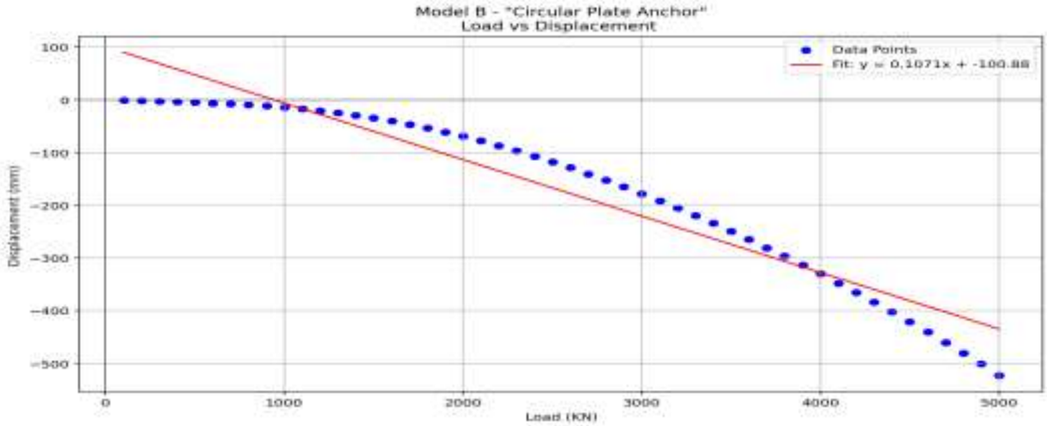

Figure 4.4: Load vs Settlement Curve of Model “B”

Case III:- Result of model “C” with embedment depth 9.85 m shown in Fig. 4.5 and Fig 4.6.

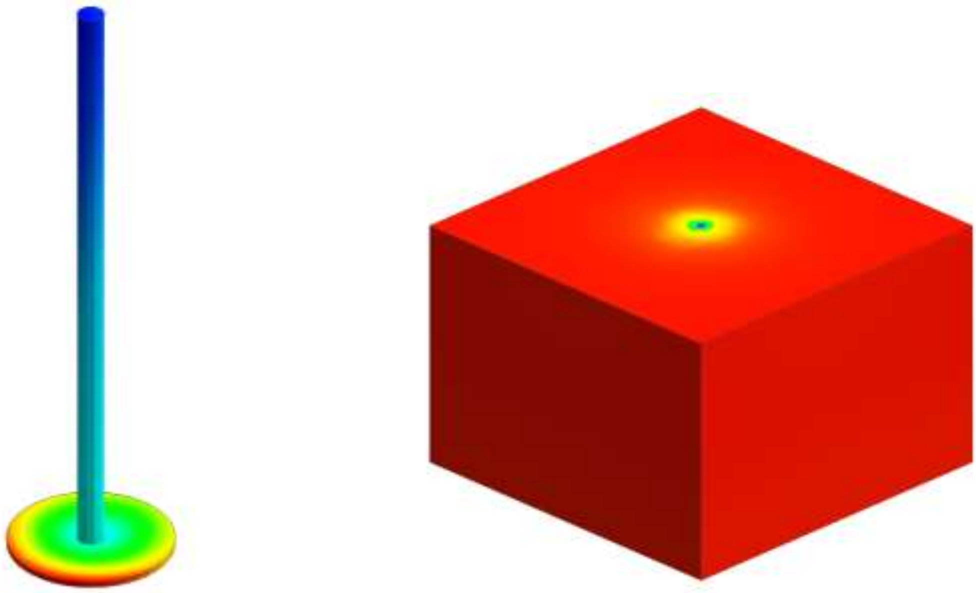

Figure 4.5: Failure Surface of Model “C” and Soil Profile

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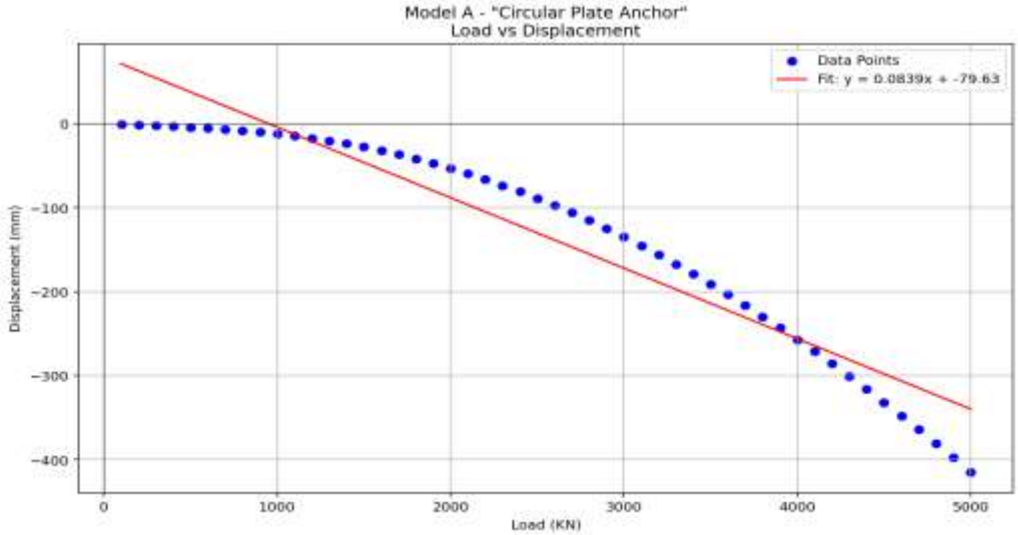

Figure 4.6: Load vs Settlement Curve of Model "C"

5. Discussion

Comparative analysis of vertical load bearing capacities of circular plate anchor pile is shown in Table 5.1 & Fig. 5.1.

Table 5.1 : Ultimate Vertical Load Bearing Capacity of All Model Anchors

Models	Ultimate Vertical Load Bearing Capacity (kN)
A	2849.37
B	2523.63
C	1774.42

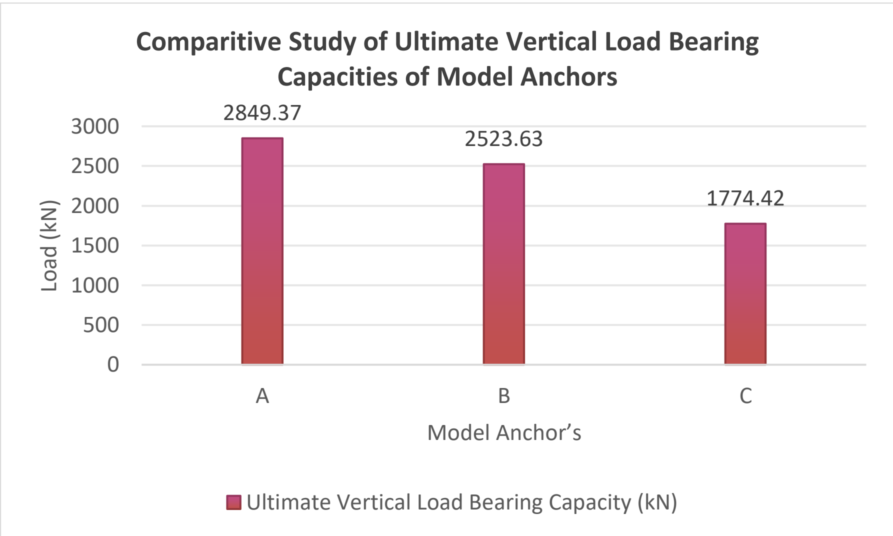

Figure 5.1: Comparitive Study of Ultimate Vertical Load Bearing Capacities of Model Anchors

6. Conclusion

Based on the analysis, it was observed that the ultimate vertical load carrying capacities of Model Anchors "A", "B", and "C" were 2849.37 kN, 2523.63 kN, and 1774.42 kN, respectively. The results clearly indicate that the vertical load capacity of a circular plate anchor increases with an increase in embedment depth. This increase can be attributed to the enhanced confinement effect provided by the surrounding soil and the mobilization of higher shear resistance along the failure surface. As the embedment depth increases, the soil experiences greater overburden pressure, leading to improved passive resistance, which collectively contributes to the higher load-bearing capacity of the anchor. Among all the configurations analyzed, Model Anchor "A" was found to be the most efficient in marine clay, demonstrating superior performance under vertical loading conditions and making it the most suitable design for use in soft cohesive soils.

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