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A Swastik Pile Foundation: Application of a Roto-reciprocation Mechanism in Pile Foundation

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Abstract

Discovering the optimum pile foundation design in terms of economy and performance is imperative because pile foundations are crucial to geotechnical engineering, as they support high-significance structures like bridges, high-rise buildings, power plant stations, offshore platforms, and museums. Pile foundation costs may surpass 20% of superstructure construction costs, while the quantity of piles needed may surpass several hundred or even thousands. Using design code suggestions as a guide, the topic of identifying the best pile foundation designs is investigated in this paper. The efficiency of the suggested design formulation is evaluated by using the suggested structural optimisation process on two actual situations, both of which are situated in India. In this invention, the recoverable ground anchor that reveals the anchors utilised to support the sheet pile is described. To securely support the sheet pile with a strong soil weight, these anchor pairs are attached to the pile's end that is open in a certain manner. As needed, anchor pairs were opened and closed, and the anchors are open in an upside-down fashion. In general, the current invention deals with the design and implementation of a mechanically assembled pile foundation that makes use of a roto-reciprocation mechanism.

Major Findings: *This paper describes a novel pile foundation featuring a unique anchor device designed to securely fix the pile into the ground, preventing movement and subsidence. The invention, with its specific design for a rotary steel pipe pile and a "Swastik pile foundation" with a roto-reciprocation mechanism and prongs, claims superior load-bearing capacity and enhanced stability compared to conventional methods. It is asserted to significantly reduce construction costs and improve the structural safety factor, particularly beneficial for heavy onshore and offshore structures.*

Keywords: *Anchors, Collapsible Anchors, Load-Bearing Capacity, Pile Foundation, Roto-Reciprocation Mechanism*

1.0 Introduction

In particular, the design of a Swastik pile foundation is the focus of this invention, which generally pertains to the implementation and design of pile foundations using mechanical assemblies that use roto-reciprocation mechanisms. This innovation offers the design and implementation of a Roto-reciprocation mechanism and prongs-based mechanical civil structure element to give strength and stability to the foundation of a heavy structure. A mechanism known as the "Prongs" is positioned in the centre of a hollow pipe in the Swastik pile foundation. All the centre shaft, anchors, and C-pin are part of an anchor mechanism.

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The anchor assembly is fitted to the centre shaft in a plane or zigzag pattern, with the C-pin and anchors connected for effortless movement. With the assistance of the top and bottom supporting systems, an anchor mechanism is inserted into the pipe and held in the middle. The anchor assembly hoisting device is the primary means by which the invention aims to stabilise the superstructure. The mechanical anchor assembly's purpose is to prevent settling and provide the building extra strength. The invention illustrates the benefits of the Swastik pile anchor assembly over the current methods while also pointing out their shortcomings.

1.1 Necessity of Work/ Motivation of the Work

It is difficult to provide massive structures with foundation support in sandy soil and soft black cotton when erecting a building. Friction piles come in a wide variety of forms and compositions. In addition to being expensive initially, concrete piles are challenging to cast into a hole measuring two to two and a half meters. Building also requires a significant amount of labour. Timber friction piles deteriorate quickly. The settling of a vibrating structure can be impacted by composite friction piles, which are weak in joints. The primary engineering difficulty lies in developing a design that is not only cost-effective and time-efficient but also capable of withstanding greater loads and providing stability and vibration resistance.

1.2 The Goals of Research Work

- To make constructions more stable in conditions of loose, sandy, silty black cotton soil.
- To prevent the foundation from settling differently due to small fissures in the subsurface soil.
- To improve the soil's carrying capacity.
- To raise the safety factor for heavily laden constructions.
- To make offshore and onshore constructions stronger.

Further goals, characteristics, and benefits will become clear from the in-depth explanation and the appended claims to the knowledgeable reader in this text.

2.0 Literature Review

Regardless of rigid cap assumptions, the thickness of the pile cap is often approximated during the primary stage of pile cap design by engineering expertise. Consequently, it makes sense that a thicker pile cap would behave rigidly. The behaviour of thick pile caps was investigated, along with a comparison of several design approaches for pile cap thickness, by Sabnis and Gogate[1], to research how the pile cap's thickness behaves. The experimental research conducted by Adebar *et al.*[2] was verified using the ACI building code for pile cap design. Eventually, a straightforward design process was created to determine the shear strength of thick pile tops while taking the maximum bearing load into account[3]. Based on a single pile cap unit, the simplified approaches were presented by Randolph[4], Clancy and Randolph[5], Poulos[6], and Ai *et al.*[7]. These approaches, however, did not take the interaction between the pile and the cap into account. Despite the foregoing, the thickness of the cap, which represents its rigidity, is thought to have a significant impact on the pile cap system's performance[8]. It was recommended by IRC 112[9] that the thickness of the cap should be at least 1.5 times the diameter of the pile. Thumb guidelines for rigid foundation are provided by ACI 351.3R-04. A foundation is deemed rigid if its thickness is greater than 1/5 of its shorter dimension, 1/10 of its longer dimension, 0.6 m, and 1/30 of the span plus 0.6 ft. If this thumb rule is followed, the thickness will be extremely large and not cost-effective[10]. But, due to its weight, an overly hard cover could put additional strain on the piles. On the pile inside the pile cap, however, a flexible cap could result in an uneven distribution of column load.

Numerous studies have continued to explore the pile-cap interaction and its effect on structural performance. For instance, Thangavel and Ramakrishnan[11] emphasised the significance of cap rigidity on load dispersion in multi-pile foundations. Sinha and Babu[12] used finite element modelling to highlight the importance of cap thickness in reducing differential settlements. Additionally, Reese and Van Impe[13] provided guidelines on optimising pile cap stiffness in seismic zones. Das[14] offered insights into soil-structure interaction beneath pile caps of varying thickness. Horvath[15] and Davis, and Selvadurai[16] studied the flexural behaviour of thick caps under eccentric

loading. Experimental evaluations by Lee *et al.*[17] showed that pile cap depth considerably affects punching shear strength. A series of dynamic load tests by Fleming *et al.*[18] confirmed the need for cap stiffness in energy dissipation. Kuwabara and Akiyama[19] discussed the enhancement of cap performance through high-performance concrete in thicker caps. Analytical work by Bowles[20] and field tests by Meyerhof[21] further demonstrated that rigid caps exhibit lower bending stresses and improved moment transfer.

A combined analytical-experimental study by Zhang *et al.*[22] and design charts proposed by Berardi and Lancellotta[23] allowed engineers to rapidly estimate appropriate pile cap dimensions based on pile group geometry. Studies by Rollins and Kim[24], Prakash and Sharma[25], and Poulos and Davis[26] all highlighted that increasing cap thickness improves performance but reaches diminishing returns beyond a certain ratio relative to pile spacing and layout. According to Hemsley[27], thicker caps can absorb irregular pile loading more effectively. Eurocode 7[28] and IS 2911[29] also support provisions for increasing cap thickness depending on column size, pile layout, and anticipated lateral loads.

Recent numerical studies by Al-Shukur and Al-Shaarbaf[30] support the view that optimising cap depth can enhance overall pile group efficiency under varying axial and lateral load scenarios. Furthermore, Goh and Teh[31] used 3D finite element simulations to show that overdesigning cap thickness leads to minimal structural benefit and poor material economy. To bridge theory with practice, practical guidelines were provided by Tomlinson and Woodward[32], who suggested that site conditions, pile type, and column eccentricity should all be factored into cap thickness determination. Bhattacharya and Madabhushi[33] presented centrifuge test results showing how thicker pile caps respond better to liquefaction-induced lateral spreading. The observations of Terzaghi[34], and later Peck, Mesri, and others[35], further contributed to understanding how rigid caps mitigate differential movement in layered soils. Finally, Gopalakrishnan and Kameswara Rao[36] showed that empirical rules alone are insufficient for complex pile group designs and must be supplemented with numerical simulations and physical model testing.

Additional studies by Zhang and Yung[37] and Zhao *et al.*[38] explored the impact of varying cap material properties on crack resistance and flexural behaviour. Li and Xu[39] introduced cap reinforcement techniques that significantly enhanced rigidity in lightweight designs. Nakashima and Morikawa[40] emphasised earthquake resilience in thick cap systems using time-history analysis. Park and Kim[41] used vibration monitoring to assess dynamic performance of varying cap geometries. Sheta and Helmy[42] provided data on cost-effective thick cap layouts for offshore foundations. Recent AI-driven design optimisation tools by Ahmed *et al.*[43] also support better prediction of cap performance. Finite difference analysis by Singh and Chowdhury[44] further affirmed the need to balance stiffness and soil-structure interaction. Case histories compiled by Long and Bozozuk[45] indicated real-world examples where cap depth was critical in load transfer efficiency. Finally, the parametric study by Wu *et al.*[46] concluded that ideal cap thickness varies considerably with pile group shape and boundary conditions.

3.0 Construction of Work

In the paper, a rotary steel pipe pile made of steel pipe is described. The first blade in the pile has a helical shape and is fitted on the steel pipe near the distant end. The central angle of the first sectional gap creates the circumference direction. The second blade is then placed and has a helical shape. The steel pipe is kept closer to the rear end than the first blade, and in that central angle, a second sectional gap forms in the circumferential direction. The first and second sectional gaps are fixed at the point where they do not overlap in the circumstantial direction. In comparison to the first sectional gap, the central angle is designed to be narrower. Once the pile has been positioned correctly in the ground, the anchors are thrust into the soil using a twisting machine that twists the centre shaft to allow for anchor opening.

The anchors, C-pins, bottom and top supporting systems, centre shaft, and external casing are the primary components of the preferred embodiment.

The Major Components of Research Work are Listed Below

The cross-section of the Swastik pile foundation is shown in Figure 1, and the names of its components are listed in Table 1.

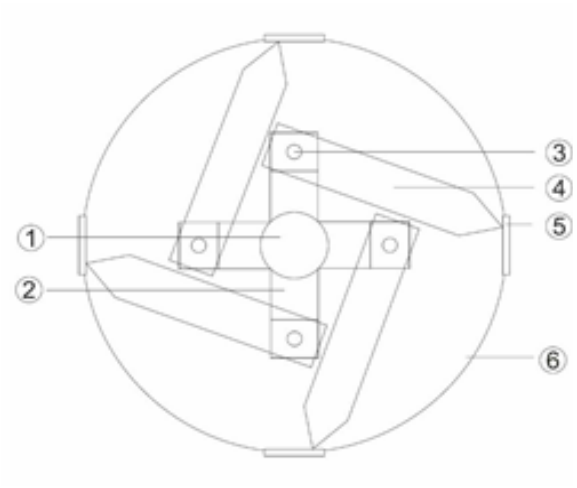


Figure 1. Cross-section of the Swastik Pile Foundation.

Table 1. Components of the Swastik Pile Foundation Assembly in cross-section

Component number	Component name
1	Central shaft
2	C-Pin
3	Anchor pin
4	Anchor (Prong)
5	Perforation on casing for anchor
6	External casing

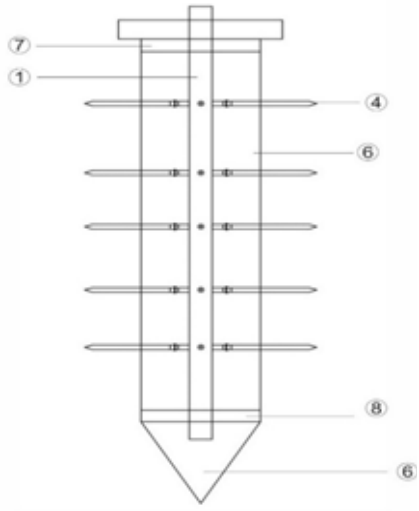


Figure 2. Sectional front view of the Swastik Pile Foundation.

Figure 2 shows the sectional front view of the Swastik pile foundation, and its components are given in Table 2.

Table 2. Components of the Swastik Pile Foundation Assembly in front view

Component number	Component name
1	Central shaft
2	C-Pin
3	Anchor pin
4	Anchor (Prong)
5	Perforation on casing for anchor
6	External casing
7	Top supporting system
8	Bottom supporting system

Figure 3 shows the cross-section of the anchor assembly, and its components are given in Table 3.

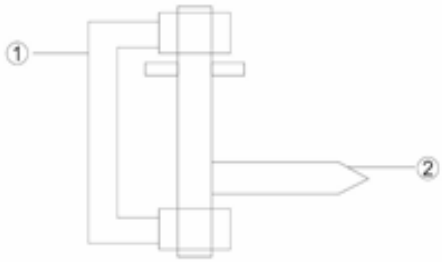


Figure 3. Cross-section of the anchor assembly.

Table 3. Components of the Swastik Pile Foundation cross-section of the anchor assembly

Component number	Component name
1	C-Pin
2	Anchor (Prong)

Figure 4 shows the sectional front view of the anchor assembly, and all its components are given in Table 4.

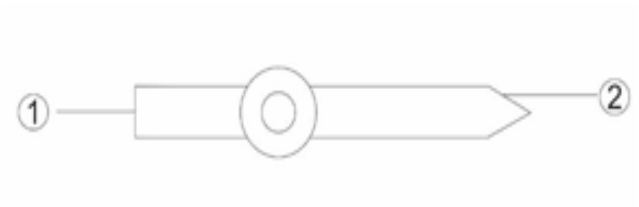


Figure 4. Sectional front view of the anchor assembly.

Table 4. Components of the Swastik Pile Foundation, front view of the anchor assembly

Component number	Component name
1	C-Pin
2	Anchor (Prong)

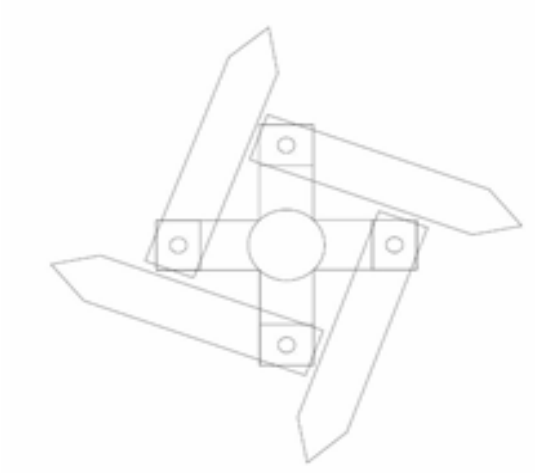


Figure 5. Internal mechanism.

Figure 5 shows the Internal mechanism of the assembly.

A more detailed explanation of the invention, which is represented in the attached drawing, will be provided to explain how the aforementioned benefits and other inventive objects are achieved. The invention will be detailed with more specificity and details using the accompanying figure, keeping in mind that these drawings simply show typical embodiments of the invention and should not be interpreted as restricting its scope.

3.5 Detailed Description

The whole project is divided into:

A) Supporting system
B) Internal mechanism
C) Outer casing
D) Anchor assembly

A) Supporting System

a) Top supporting system
b) Bottom supporting system

a) Top Supporting System: It helps to hold the central shaft at the top in exact central position, which is aligned with the bottom supporting system in outer casing.

b) Bottom Supporting System: Bottom supporting System helps to hold the central shaft at the exact central position of outer casing, and it bears the total load of internal assembly. Top supporting system helps to rotate the central shaft easily at 90-120 degrees. Due to which anchors will rotate in Roto-reciprocation motion, and anchors will easily go outside of the outer casing through drilled holes.

B) Internal Mechanism

It is the most important part of the invention of swastika pile foundation internal mechanism consists of the anchor assembly connected to the central shaft, which provides the strength and stability to lift heavy structures.

C) Outer Casing

It is the External cover which covers the internal mechanism and takes the complete load of structures from superstructures.

D) Anchor Assembly

It is the complete set of C-pin And Anchors (Prongs), which is flexibly interconnected. The anchors, which give more stability, strength to hold the heavy structures

3.3 Best Method of Performance of the Invention

1. Selection of steel pipe as an external casing of Swastik pile foundation.
2. To drill the holes on external casing.
3. Cast the anchor assembly from the foundry shop.
4. Selection of the central hollow shaft.
5. Fitting of the anchors on central shaft as per drilled holes on external casing.

6. Manufacturing and fitting of the top and bottom supporting system on external casing.
7. Fitting of anchor assembly with central shaft in external casing as per alignment.
8. Install the Swastik pile in a soft soil and rotate the anchor assembly.
9. Make the required mixed proportion of the concrete and fill the concrete in the Swastik pile.
10. Testing of Swastik pile on dynamic loading.
11. Taking a test of a 50-ton load in a plate load test.
12. Taking a test of a 100-ton load in a plate load test.
13. Taking a test of 150 tons load in plate load test.
14. Swastik pile is tested on various loading tests.

4.0 Working

This invention pertains to a steel pipe that is driven into the ground and stays there. The slime layer has a cross-section that is wide at the top and narrows at the bottom, and it connects the main steel pipe pile by means of a driving shoe. The frictional steel pipe's lower end can be driven into the foundation quickly, increasing the front-end power and reducing pile subsidence. The invention describes the opening bottom portion of a steel pipe pile that is made up of a main frame that is no shorter than two meters. The steel pipe pile is driven into the foundation and rests on the lower part of the punch hole by rotating power.

For the frictional steel pile to drive easily into the foundation at the lower part of the punch hole, the driving shoe is kept or fixed to connect the main frame of the pipe and also the lower end of the pile. The driving shoe is made or created like a ring shape with an open centre, where both cross sections of the ring are wide-tapped and narrow-bottomed like a U or V shape. The frictional steel pipe and the main frame of the steel pipe pile are installed on both ends of the driving shoe's upper surface.

5.0 Methodology

To accomplish the stated goal, the current study has used the following technique as shown in Figure 6.

For most geological and geotechnical jobs, the user-friendly GEO5 software suite has an answer. From the exploration of geological sites to the development of sub-

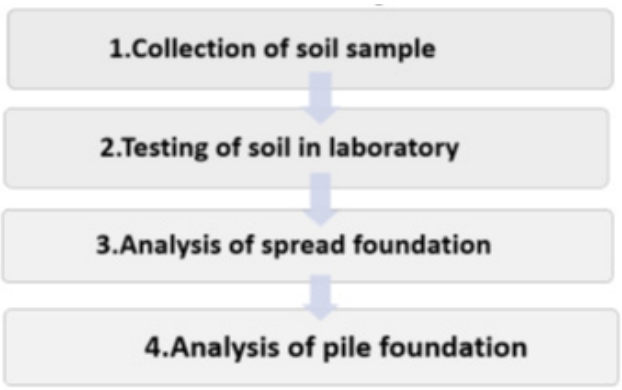


Figure 6. Techniques.



Figure 7. The GEO5 design method.



Figure 8. GEO 5 Program.

base models to a broad variety of assessments, including foundation designs, deep excavation, and slope stability. It is possessed through excellent software. The procedure is given in Figure 7. GEO 5 is depicted in Figure 8 and is a useful technique for foundation design to suit



Figure 9. GEO5 Design tools..

actual circumstances, which will improve structural stability.

Numerous numerical methods (software) have been created during the past ten years for the study and design of the foundation for any construction, including Plaxis, Geo Studio, Abacus, Ansys, Geo5, and others. GEO 5 software is utilised in the current work to analyse and construct a few foundations. The GEO5 software is a very user-friendly and intuitive application. Most of the time, users can operate with applications with confidence in a matter of minutes without the need for a lengthy lesson. However, if necessary, you can make use of a range of training and documentation resources. The GEO5 programs' fundamental geotechnical methods are applicable everywhere in the world. However, most nations establish their laws and customs. GEO5 provides a novel approach to applying standards that greatly streamlines a designer's job. Refer to Figure 9.

6.0 Case Study

The GEO5 software's foundation analysis results are examined for both shallow and deep foundations.

6.1 Spread Foundation

The GEO5 software's foundation analysis results for shallow foundations are given in Table 5 and Figure 10.

Table 5. Results for shallow foundations

Parameter	Value
Design bearing capacity	776.86 kN
Structural dimensions	
Length	2m
Width	1.6m
Depth	0.4m

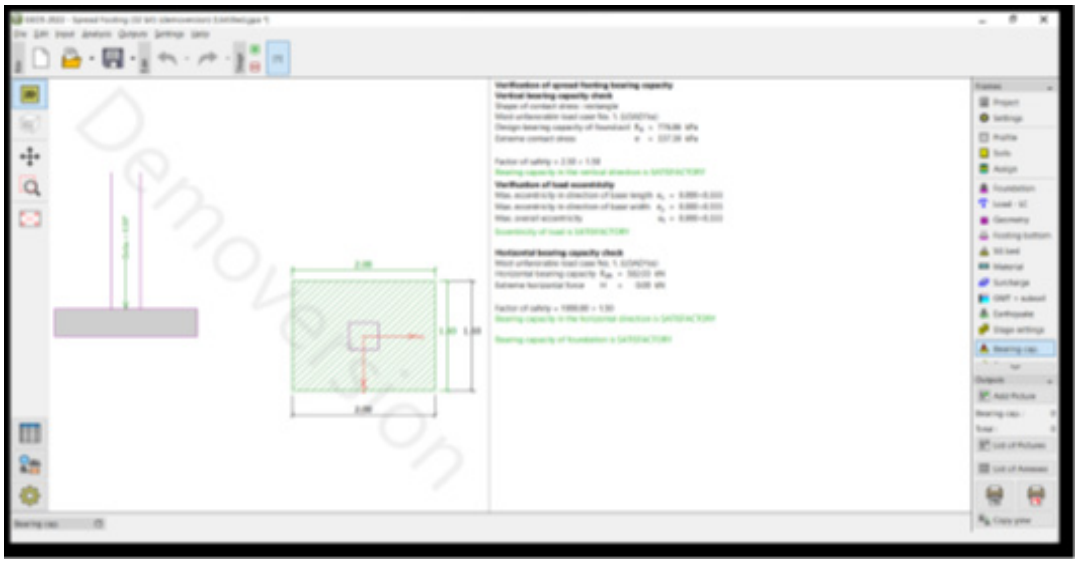


Figure 10. Bearing capacity of spread footing.

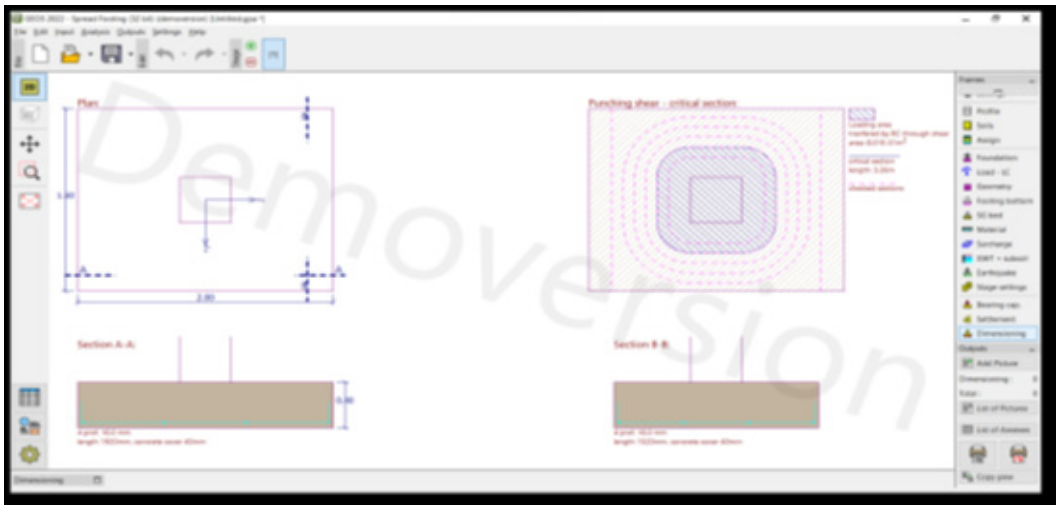


Figure 11. Foundation drawings.

6.2 Pile Foundation

The GEO5 software's foundation analysis results for pile foundations are given in Table 6 and Figure 12, while Figure 11 gives the foundation plan adopted.

Table 6. Results for pile foundations

Parameter	Value
Design bearing capacity	15360 kN
Structural dimensions	
Length	12m
Diameter	0.5m

7.0 Major Findings and Discussion

The purpose of this paper is to describe an anchor device that is screwed into the ground to anchor the movement of an above-ground, upright cylindrical shape drive shaft. It is constructed with an upper cylindrical housing portion made of ¼ inch rolled steel that matches the inside and outside diameter of the upright connection of the upper housing portion by a conical portion with a slope of less than 20 degrees that typically ranges from 5 to 10 degrees. When driving in soil to screw the anchor device into the ground, the device spins to fix the screw thread to the



Figure 12. Pile foundation bearing capacity.

section, and the housing apex diameter is equal to or less than the diameter of the upper housing portion.

The conical section compresses the disturbed soil outward during the flightiness process. The tightly compressed soil created by the outwardly compressed dirt usually has the same diameter as the upper housing portion of the shaft because the surrounding soil is not disturbed. An elongated flexible element with first and second ends is used in this invention, which relates to a round anchor that can be used to reinforce rock. The rock anchor is made up of a tube that acts as a load washer where the cable is located, a wedge that locks the cable to the tube, and a cable with a hollow core that has an expansion mechanism at one end.

A longitudinally extending hollow core is formed by removing the form cable extension of multiple helically wound wires by the centrally positioned core wire. The hollow core can be formed in any way. In the preferred embodiment, the hollow core is formed by removing the form cable extension of multiple helically wound wires. First end forms an anchor expansion mechanism. Extension of the second end into a tubular barrel locking system is made inside the barrel. This prevents movements in which elements in the first direction of locking of the element while elements move in the second direction to the barrel, opposing the first direction in the barrel.

8.0 Outcomes of Research Work

The current invention discusses steel pipe piles that are well-suited for work and can support force characteristics independent of ground parameters. It improves the bearing capacity. When it comes to installing and removing piles, a spiral-bladed steel pipe is highly workable and has sufficient bearing capacity to withstand pulling and pushing forces.

On the outer periphery of the pile main body, spiral blades 4a, 4b, and 4c are installed at roughly consistent intervals starting at the tip end section and working their way upward. At the tip of the pile body, a steel strip is looped around the cone. With a diameter of the largest control spiral blade 4b. Using spiral blades 4a and 4c at the bottom and top, respectively, reduces the outer diameter. Around 1.5–2 times the steel pipe of shaft diameter D1 pile body is the outer diameter of each spiral blade.

8.1 Inventive Step of Our Invention

1. Above said pile foundation takes more load than as compared to others.
2. It will drastically reduce the cost of construction.
3. It gives more strength and stability to the structure.

8.2 Industrial Application

1. Onshore and offshore structures.
2. Beach structures.
3. For heavy bridges, piers, etc.
4. Heavy buildings, towers, etc.
5. Heavy sheds.

As a result, the invention's more general application is not restricted to the particulars and exemplary implementations that are illustrated and discussed in this document. As a result, several adjustments can be performed without compromising the spirit or breadth of the overall invention concept as specified by the appended claims and their equivalents.

9.0 Conclusions

The current invention relates to collapsible anchors that resemble ship anchors that hold ships at seashores and similarly assist in securely holding piles. These anchors are attached to iron chains and have a centrally rotating pair that is embedded in the ground. The screw pile described in these inventions has an angled end that creates an aperture for communication with the outside of the hollow from the inside. The grouting holes on the side that create a spiral shape and look in the spiral section formed along the longitudinal direction of the portion of rods and joints or attached to the outer circumferential surface of the rod, allow for penetration at a specified distance along the circumferential direction. As a result, it allows for the reduction of the time needed for the drill screw to operate, which is necessary for effectively drilling ground and improving the drilling job's workability conditions.

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