

Determination of bearing capacity of fiber-reinforced polymer screw piles via field loading tests

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ABSTRACT

This study investigated the pull-out performance of fiber-reinforced polymer (FRP) screw piles using full-scale field loading tests. FRP screw piles are lightweight, corrosion-resistant alternatives to traditional piles, particularly suited for soft ground (i.e., saline reclamation sites) applications such as solar power structures. The results demonstrate that the screw blade geometry, especially the tip area, affects the pile's load-bearing capacity, with a minimum effective tip resistance area of 785.4 cm² required for optimal performance. The field test results reveal that increasing the number of screws has no impact on the bearing capacity when the blade is sufficiently wide. Additionally, conventional methods for estimating bearing capacity are inadequate for FRP screw piles, necessitating a revised design approach. Based on the test results, optimized specifications for FRP screw piles are proposed to improve their performance for weak ground conditions. This study provides practical insights for the adoption of FRP screw piles in challenging environments where they offer a durable, efficient, and sustainable solution for foundations.

1. Introduction

Foundations are critical for distributing the loads exerted on a structure to the underlying ground during the construction process. Given that most construction structures possess considerable self-weight, foundations are primarily designed to accommodate vertical loads. However, for solar power structures, only the minimum performance requirements need to be met for the adequate support of solar modules. Owing to the relatively lightweight of solar modules and their expansive geometric distribution, wind loads can influence these structures significantly, which means that solar power structures must sufficiently resist not only to vertical loads but also to pull-out forces.

Furthermore, solar power plants typically are constructed within tight timelines, which makes the implementation of wet construction methods, such as reinforced concrete, relatively impractical. As a result, the use of lightweight pile foundations has become predominant in the construction of solar power facilities. Foundation piles are able to resist vertical loads via side friction and tip-bearing capacity, whereas the resistance to pull-out loads relies primarily on side friction, which requires enhanced pull-out performance and rapid installation. In contrast to traditional foundation piles, screw piles leverage distinct mechanisms for their tip-bearing capacity, which is attributable to both the screw component and side friction. Therefore, the interplay among the screw pile's penetration characteristics, bearing capacity, and its structural integrity must be examined carefully.

In South Korea, research into piles constructed from composite materials, especially fiberglass-reinforced polymer (FRP) tubes in

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conjunction with concrete, started in the early 2000s. Notably, Choi et al. [1] performed comparative studies of conventional concrete-filled FRP tubes and FRP-concrete composite piles wrapped with filament winding to examine and compare their compressive strength performance. Additionally, Kim and Chung [2] conducted both analytical and experimental investigations into hollow FRP concrete-filled piles to derive a formula to compute flexural strength. Hwang [3] substantiated the superior bearing capacity of ultra high-strength pre-stressed concrete piles through rigorous loading tests.

International research into FRP materials dates back to the 1960s, with a marked increase in studies of FRP composite piles emerging in the 1980s. Alwalan and Alnuaim [4] used numerical modeling to assess the performance of helical pile groups that featured various structures and configurations, specifically within sandy soil environments. Their findings highlighted that factors such as central pile spacing, quantity of piles, and the helix-to-diameter ratio play a crucial role in determining both group efficiency and the settlement ratio. Shuman [5] conducted a comprehensive numerical investigation into axial compression and tension test programs that targeted large-diameter helical piles installed in both cohesive and non-cohesive soil types. Their extensive study of 21 tests confirmed that noncohesive soils exhibit greater resistance to axial loads and a greater tensile capacity of the piles compared to cohesive soils. Hamad et al. [6] conducted numerical analysis of the seepage rate of concrete dams using various sheet pile increase.

Safdar et al. [7] conducted an in-depth investigation into the settlement behavior and bearing capacity of helical piles and helical pile raft foundations. Their research involved the development of a small-scale model of a helical pile raft foundation, followed by a series of experiments aimed at rigorously evaluating the model's performance. Their findings revealed that a helical pile raft foundation exhibits significantly greater bearing capacity compared to traditional pile raft foundations, particularly when comparing rafts with different numbers of piles. In a complementary study, Fayez et al. [8] conducted comprehensive analysis of the responses measured from single and grouped helical piles subjected to intense ground motion during extensive large-scale shake table tests. Their research focused on evaluating the seismic behavior of helical piles, with particular attention to the performance characteristics of helical pile groups. They investigated aspects such as the pile–pile interaction within groups and the vertical and lateral stiffness of individual piles, which provided valuable insights into the structural performance of piles during seismic events. Tappenden et al. [9] explored the load transfer mechanisms of helical piles installed in both clay and sandy soil. The used hollow circular steel shafts with a diameter of 219 mm to which three helices of 356 mm in diameter were affixed at intervals 1.5 times the helix diameter. Teppended et al. presented comprehensive results, including load distribution curves for five test piles, which serves to deepen the understanding of load behavior in different soil types.

Note that research into composite material piles has advanced significantly in other countries, with a timeline of approximately

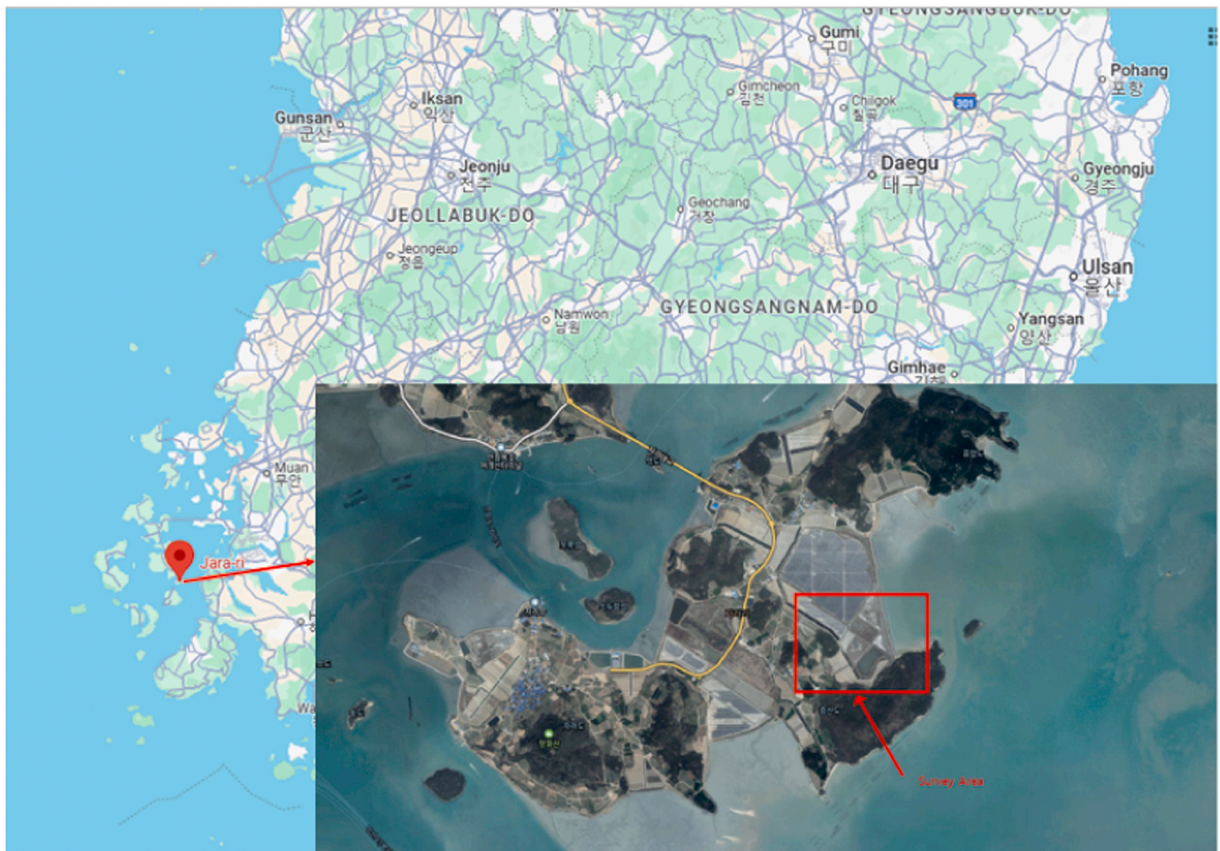


Fig. 1. Field loading test location in Sinan-gun County, Jeollanam-do Province, South Korea.

30–40 years ahead of South Korea. Nevertheless, most of this research has focused predominantly on FRP concrete composite piles, whereas investigations into the performance and application of FRP screw piles in soft ground contexts remain markedly limited.

To fill this gap in the literature, we developed FRP piles that are especially suitable for construction in soft ground. We based our work on domestic and international data and conducted field loading tests and pull-out tests. Fig. 1 shows the site in Sinan-gun County, Jeollanam-do Province, South Korea that is designated specifically for the construction of solar power structures. We installed innovative screw piles, developed by Joo et al. [10] and Kim et al. [11], at this site. Our research confirms the bearing capacity of FRP screw piles and proposed specifications that enhance their load resistance performance.

2. Materials and methods

2.1. Screw piles

Screw piles are a type of foundation pile that are characterized by helical blades attached to slender steel pipes. These helical blades facilitate the pile's penetration into the ground through a rotational motion that transfers torque from above ground to the helical blades. This torque is subsequently converted into penetration force, allowing the screw pile to effectively penetrate the soil. Compared to traditional cast-in-place piles, screw piles offer the advantage of requiring compact drilling equipment for their installation, thus eliminating the need for driving or excavation. This unique and efficient method also significantly reduced noise and vibration during the installation process. Furthermore, using torque machines, piles can be embedded to the depths necessary to ensure adequate bearing capacity, making screw piles particularly suitable for underpinning techniques that reinforce or establish new foundations beneath existing structures. Fig. 2 illustrates the design of the FRP screw piles employed in this study.

A filament winding technique was used to manufacture the FRP screw piles to a diameter of 150 mm and a wall thickness of 6 mm. This design provides torsional characteristics that are comparable to those of conventional steel screw piles. According to Kim et al. [11], a screw, being a critical component for rotational penetration and ground bearing, should be designed with a diameter twice that of the pile body (300 mm) and a pitch of 100 mm. Fig. 3 is a photograph of the test specimens utilized during the trial construction phase in this study. Correspondingly, Table 1 lists the specifications of these specimens.

2.2. Trial construction

The trial construction for this study took place at an occupied site, with the dual objectives of verifying the deformation characteristics of the screw and assessing any potential damage to the pile body that may have resulted from the rotational penetration and subsequent extraction of the newly developed FRP screw pile. Fig. 4(a) through (d) respectively show the trial construction process that is comprised of four critical stages: (a) penetration with specialized equipment, (b) rotational penetration, (c) completion of the penetration, and (d) extraction of the screw pile to evaluate its structural integrity.

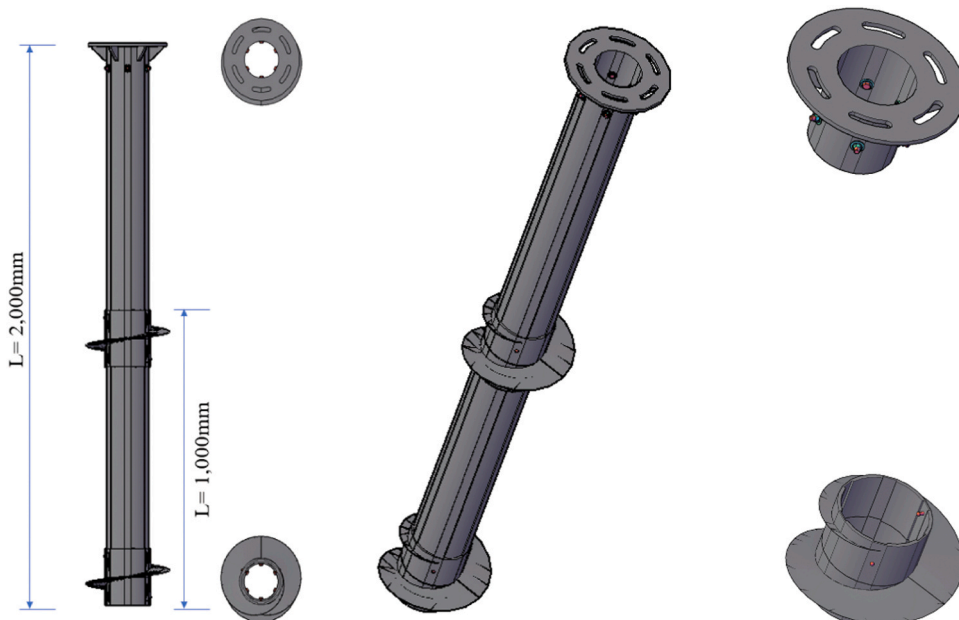


Fig. 2. Fiber-reinforced polymer Screw Pile.



Fig. 3. Fiber-reinforced polymer Screw Pile Specimens.

Table 1

Specifications and dimensions of FRP screw pile prototype.

Category	Outer Diameter (mm)	Length (mm)	Body Thickness (mm)	Screw Thickness (mm)	Number of Bolts (ea)	
					Head	Screw
FRP-6-1	150	2000	6	5	12	8
FRP-6-2	150	2000	6	5	12	N/A
FRP-6-3	150	2000	6	5	8	8
FRP-6-4	150	2000	6	5	8	6
FRP-8-1	150	2000	8	5	12	8
FRP-8-2	150	2000	8	5	12	N/A
FRP-8-3	150	2000	8	5	8	8
FRP-8-4	150	2000	8	5	8	6



(a)



(b)



(c)



(d)

Fig. 4. Trial construction of FRP screw pile. (a) Penetration equipment (b) Rotational penetration; (c) Penetration complete (d) Extraction.

2.3. Results of trial construction of FRP screw pile

Upon completion of the trial construction and extraction of the FRP screw pile, we conducted a comprehensive examination of the screw portion of the pile to identify any damage. Fig. 5(a) shows no observed damage at the bolt connections between the reinforcing jig located at the pile head and the pile body during the full penetration phase. However, Fig. 5(b) and (c) show significant deformation at the screw portion of the pile. Furthermore, Fig. 5(d) indicates that the pile tip experienced damage during the installation of FRP piles without screws. During the rotational penetration process, soil accumulated on the FRP screw, which greatly increased its resistance, causing the screw to deform. This damage is attributed to the exceptionally hard ground conditions encountered at the trial site.

2.4. Analysis of trial construction results for FRP screw piles

The excessive deformation of the prototype screws during the trial construction can be attributed to the small screw pitch, which caused soil to clog between the screw blades. The piles fitted with dual screws encountered significant resistance due to the soil being trapped between the two screws, which presented formidable challenges during the rotational penetration phase. Additionally, the screws, which were made with steel plates, demonstrated a tendency to deform in the out-of-plane direction under stress.

During both the rotational penetration and extraction phases, the pile body efficiently transmitted energy to the tip screw. Notably, no deformation or damage in the pile head reinforcement or the screw connections could be observed throughout the testing. Based on these experimental findings, we modified the FRP screw pile using the specifications of the revised prototype described in Table 2. Fig. 6 presents the design of the two type of modified and improved FRP screw piles. Fig. 6(a) illustrates the single screw configuration and Fig. 6(b) illustrates the configuration with two screw.

Fig. 7 demonstrates the trial installation of the improved FRP screw piles using penetration equipment at the unoccupied site. Fig. 8 (a) shows the extraction of a test specimen. We thoroughly inspected both the screws and the pile bodies post extraction. Fig. 8(b) shows the inspection results that confirm the absence of any damage across all specimens.

Moreover, the soft ground conditions prevalent at the saline site significantly influenced the resistance of the piles, indicating that the resistance was dependent more on the surrounding ground conditions than on the structural performance of the piles themselves. However, in these ground conditions, the larger screw areas tended to exhibit a greater pull-out capacity. In addition, the resistance of the FRP screw pile was difficult to predict, as a traditional, cylindrically shaped mechanism designed for soil cannot be expected to resist soft ground conditions.

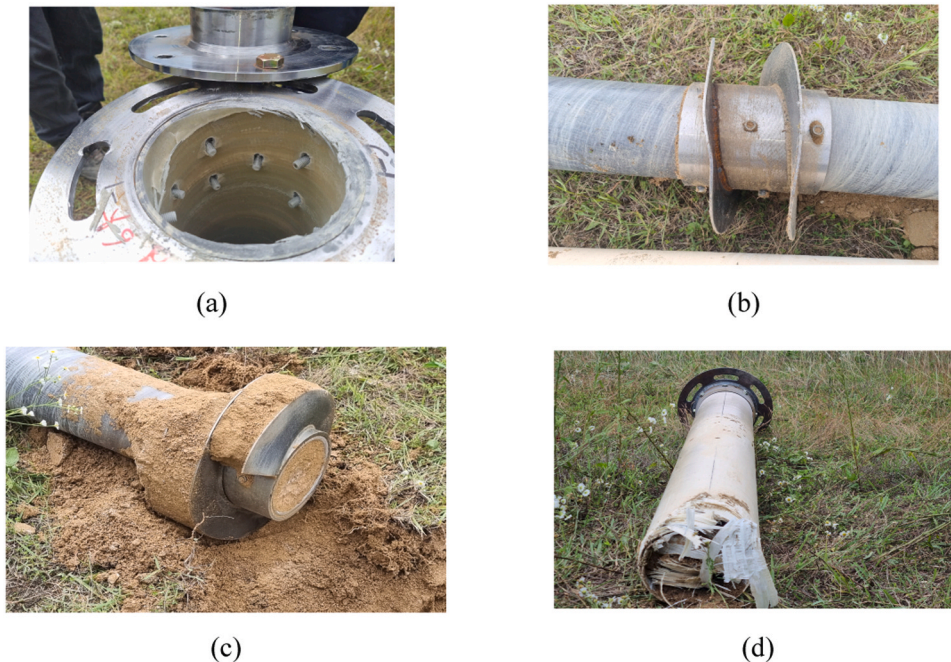


Fig. 5. Damage patterns of specimens after trial construction. (a) Pile head (b) Screw at central section (c) Screw at pile tip (d) Driving test specimen.

Table 2
Specifications of improved prototype FRP screw piles.

Specimen Number	Body Thickness (mm)	Screw (mm)			Bolts (ea)		
		Blade Width	Pitch	Thickness	Number	Head	Screw
FRP-200-1	4.5	50	200	6	1	10	5
FRP-200-2	4.5	50	200	6	2	10	5
FRP-150-1	4.5	50	150	6	1	10	5
FRP-150-2	4.5	50	150	6	2	10	5

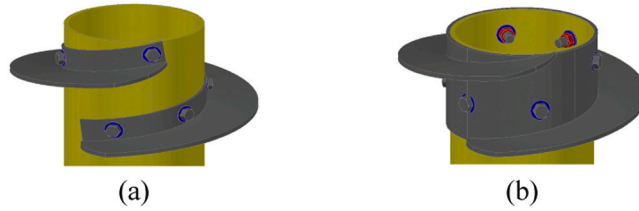


Fig. 6. Improved screw piles. (a) Case with one screw (b) Case with two screws.

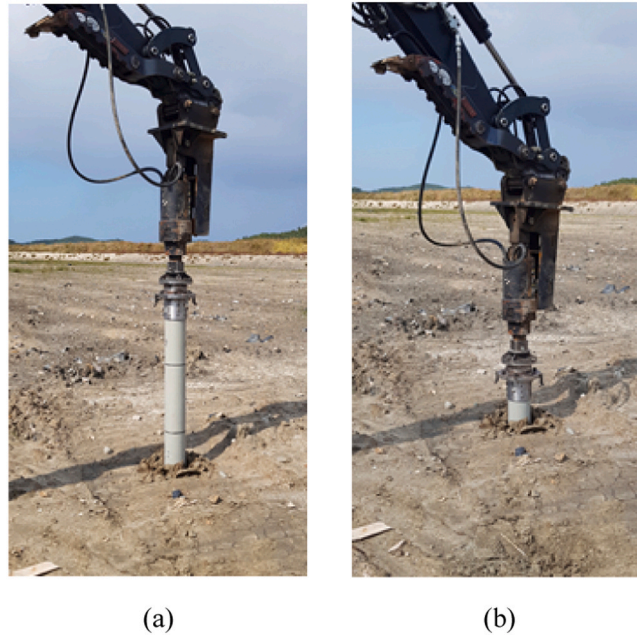


Fig. 7. Trial construction of improved FRP screw piles. (a) Rotational penetration (b) Penetration complete.



Fig. 8. Results of trial construction of improved FRP screw piles (a) Extraction (b) Failure mode.

3. Field loading test

3.1. Experimental plan

We conducted field loading tests at the designated site shown in Fig. 1, where the construction of a solar power plant is anticipated. Informed by analyses of prior trial constructions, we identified the width of the FRP screw as a key variable. In conventional commercial screw products, the diameter of the screw typically measures approximately double that of the pile body diameter. For the FRP screw piles, we established a pile body diameter of 150 mm and a thickness of 4.5 mm, a specification that reflects the inherent characteristics of the winding process employed. We categorized the dimensions of the screws into two widths: 110 mm and 55 mm. Accordingly, we determined the screw diameters to be 370 mm and 260 mm, corresponding to ratios of 1.73 and 2.7 times the pile body diameter, respectively.

We standardized the pile length at 2000 mm, which represents the most prevalent dimension utilized in solar power plant installations. We determined the screw pitch to be 100 mm based on the trial construction results that indicated efficient penetration rates during the rotational installation in soft soil conditions. To mitigate any potential deviation of the pile from its intended installation position during the rotational penetration process, the screw at the base of the pile body was situated 180 mm above the bottom of the pile. Fig. 9 describes the configuration of the test specimens. Fig. 9(a) presents the pile body without screws. Fig. 9(b) depicts a pile body with a length of 2000 mm and a screw located 180 mm from the bottom. Fig. 9(c) depicts the installation of screws at intervals of 600 mm to evaluate the resistance performance relative to the number of screws employed. Fig. 9(d) shows a pile body that is 1500 mm in length. Fig. 9(e) is a photograph that provides an overview of the specimens utilized in the field loading test. Table 3 presents the experimental variables pertinent to the field loading test.

3.2. Field loading test

We performed the field loading test of the FRP screw pile as pull-out test in accordance with KCS 11 50 40 [12]. These pull-out test used penetration equipment (Fig. 7) to achieve rotational penetration, followed by the extraction of the pile. Fig. 10(a) presents a schematic representation of the pull-out test set-up and Fig. 10(b) shows photo of the experimental test set-up that incorporates a hydraulic tension jack rated at 30 tons and a displacement gauge with a precision of 50 mm/mm affixed to the foundation pile. During the test, the load was increased incrementally until the maximum load was reached, thereby allowing the research team to assess the maximum pull-out load generated by the adhesion forces between the FRP screw pile and the surrounding soil.

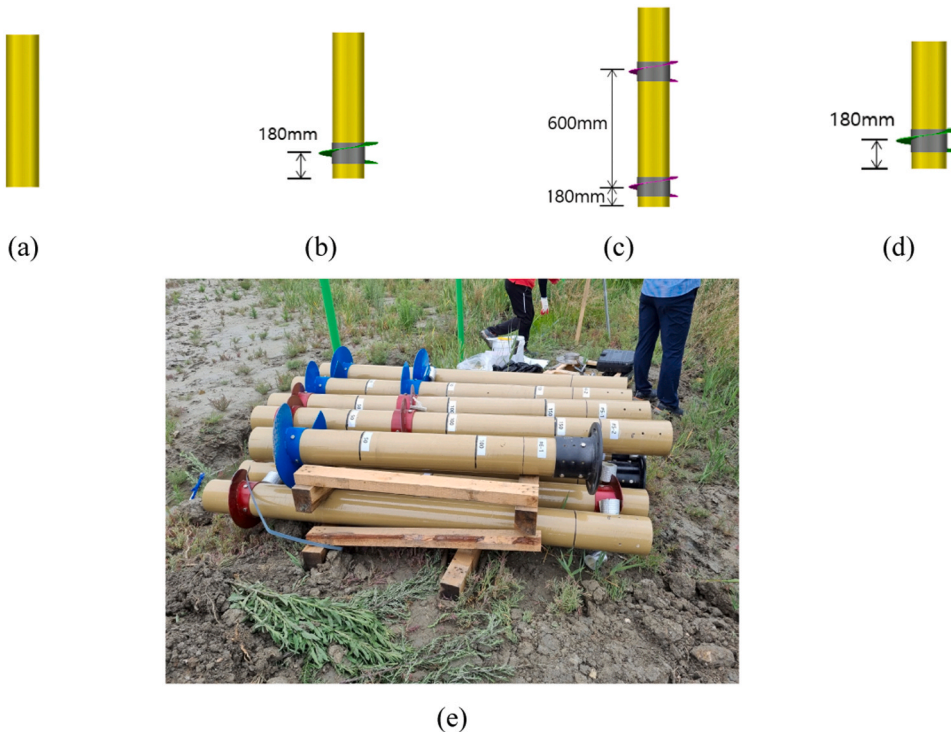
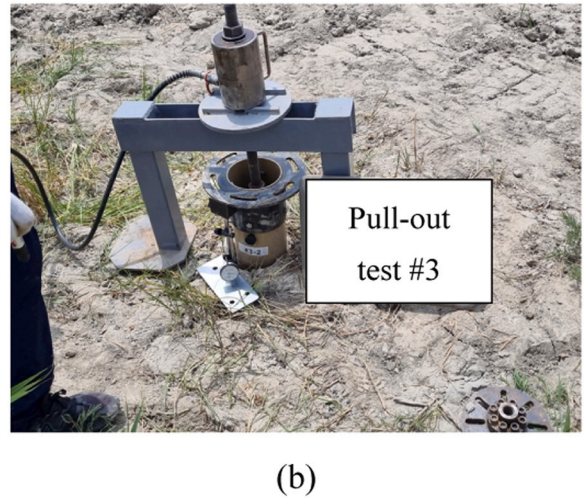
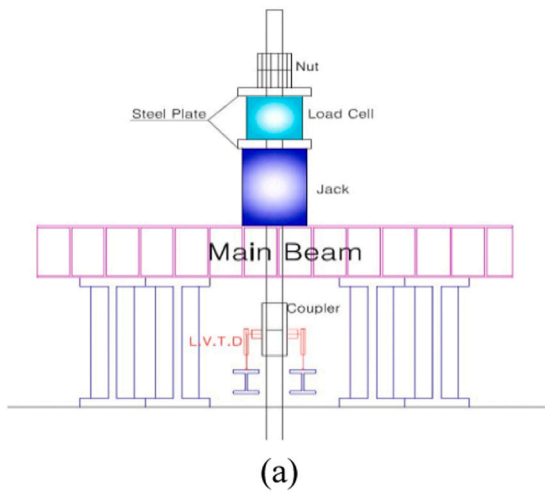
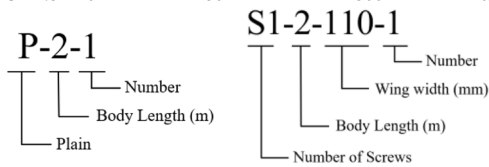


Fig. 9. Test specimens. (a) Pile body (b) One screw with a pile body length of 2000 mm (c) Two screws with a pile body length of 2000 mm (d) One screw with a pile body length of 1500 mm (e) Overview of test specimens.

Table 3

Experimental variables and quantities of test specimens.

Category	Body Dimensions			Blade Width Dimensions (mm)	Number of Bolts		Quantity
	Outer Diameter (mm)	Length (mm)	Thickness (mm)		Head	Screw	
P-2-1	150	2000	4.5	N/A	–	–	1
S1-2-110-1	150	2000	4.5	110	8	5	2
S1-2-110-2	150	2000	4.5	110	8	5	2
S1-2-55-1	150	2000	4.5	55	8	5	2
S1-2-55-2	150	2000	4.5	55	8	5	2
S2-2-110-1	150	2000	4.5	110	8	5	2
S2-2-110-2	150	2000	4.5	110	8	5	2
S2-2-55-1	150	2000	4.5	55	8	5	2
S2-2-55-2	150	2000	4.5	55	8	5	2
S1-1.5-110-1	150	1500	4.5	110	8	5	1

**Fig. 10.** Pull-out test. (a) Schematic description (b) Equipment.

3.3. Field test results and analysis

Fig. 11(a) through (j) present the load–displacement curves that correspond to each specimen used in the pull-out tests. Notably, the maximum load for each curve is the peak value observed in the displacement region, where further increases in the load did not result in additional displacement, despite the hydraulic jack applying greater loads.

Table 4 presents a summary of the pull-out test results, including the maximum load and displacement measured for each specimen. The pull-out capacity is defined as the maximum load recorded by the testing instrument, and displacement refers to the movement observed at the point of maximum load. The infill depth is specified as the vertical height of soil within the pile body, measured from the top of the pile to the uppermost layer of soil. Based on the infill depth, we could determine the adhesion area, which is the interface between the soil and the pile body, both internal and external. The adhesion area was 3.32–3.33 m², which was similar for all specimens.

Analysis of the load–displacement relationships for each specimen indicated that the FRP screw piles demonstrated a linear behavior up to the point of maximum load. However, we noted considerable discrepancies in the maximum loads attained by the various specimens. For instance, Fig. 11(a) shows that specimen P-2-1, which was designed without a screw and featured a circular body, achieved a maximum pull-out capacity of approximately 0.5 tonf, accompanied by a displacement of 3.14 mm. Consequently, we calculated the frictional resistance between the soil and the FRP body to be 1.342 Pa.

A comparative evaluation of the results presented in Fig. 11(b) and (c) versus (d) and (e) corroborate that an increase in the area of

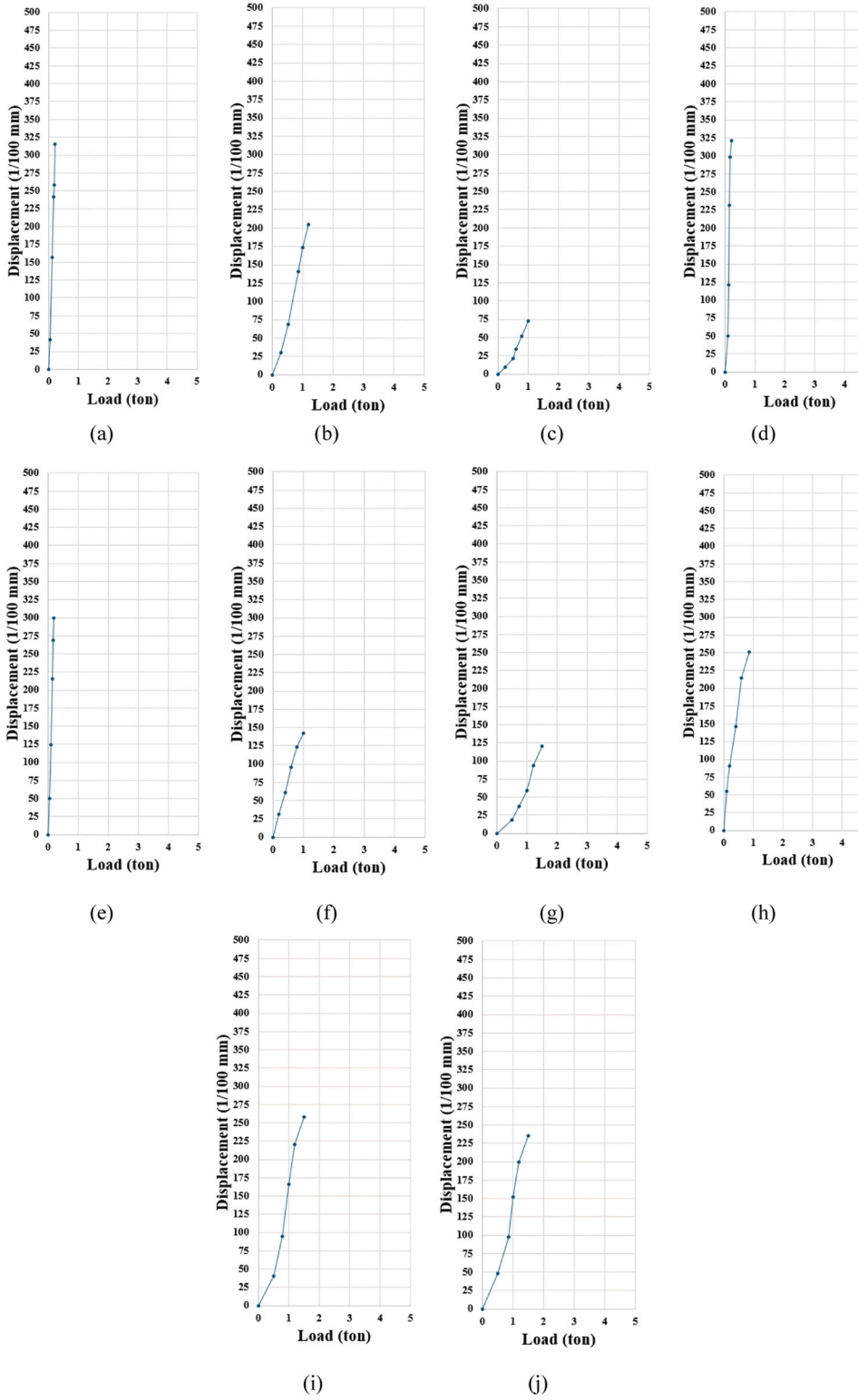


Fig. 11. Load–displacement relationships derived from field pull-out test results. (a) P-2-1 (b) S1-2-110-1 (c) S1-2-110-2 (d) S1-2-55-1 (e) S1-2-55-2 (f) S2-2-110-1 (g) S2-2-110-2 (h) S2-2-55-1 (i) S2-2-55-2 (j) S1-1.5-110-1.

Table 4
Pull-out test results.

Category	Maximum Load (tonf)	Displacement (mm)	Infill Depth (cm)	Adhesion Area (m ²)
P-2-1	0.5	3.14	68	3.314
S1-2-110-1	1.5	2.05	48	3.332
S1-2-110-2	1.5	0.74	80	3.303
S1-2-55-1	0.2	3.21	80	3.303
S1-2-55-2	0.2	3.00	40	3.339
S2-2-110-1	1.0	1.43	74	3.309
S2-2-110-2	1.5	1.20	34	3.344
S2-2-55-1	1.0	2.51	46	3.333
S2-2-55-2	1.5	1.72	43	3.336
S1-1.5-110-1	1.5	1.72	68	3.314

the screw blade substantially improves the pull-out capacity of the pile, which highlighting the influence of our design modifications on performance. However, in the case of the single screw with a blade width of 55 mm, the pull-out capacity is similar to that of specimens without screws, indicating that small blade widths do not significantly affect the pile's pull-out capacity.

Furthermore, as illustrated in Fig. 11(f) and (g), the maximum load achieved with a screw blade width of 110 mm reached 1.5 tonf. This observation suggests that an increase in blade width notably increases the tip resistance area, which posed the most pronounced impact on overall resistance in our tests. Figure (h) and (i) show that the specimens that feature two screws with a blade width of 55 mm, namely S2-2-55-1 and S2-2-55-2, demonstrated maximum loads of 1.0 tonf and 1.5 tonf, respectively. This improvement in performance can be attributed to the larger tip area created by the dual screw configuration. However, a comparison between specimens S1-2-110 and S2-2-110 indicated that increasing the number of screws has only a minimal effect on resistance when the blade width is fixed at 110 mm.

Fig. 11(j) shows that, in the case of specimen S1-1.5-110-1 with the shorter pile body length, the maximum load recorded is notably high at 1.5 tonf. This result led to the conclusion that the pull-out resistance of FRP screw piles is influenced predominantly by the screw tip area, and the friction between the pile body and the surrounding soil is negligible. Furthermore, post-test observations of specimens S2-2-110-1 and S2-2-110-2 revealed that no typical soil bulbs formed between the screws, reinforcing the notion that tip resistance is the key determinant of performance in these configurations. Thus, under soft ground conditions, the resistance of screw piles is controlled more by the individual screw tip areas than by the cylindrical shear methods. The tip resistance area must be designed to be no less than 785.4 cm².

3.4. Performance analysis of FRP screw piles

The most reliable method of determining the axial ultimate compressive bearing capacity of the soil is to construct piles and perform pile load tests [13]. The ultimate bearing capacity of the pile tip is generally calculated using the modified formula developed by Meyerhof, which is a refinement of the original equation proposed by Terzaghi. Utilizing Meyerhof's formula, the tip bearing capacity for each pile can be represented as shown in Eq. (1) [12].

$$q_{ult} = cN_c s_c d_c + q'N_q s_q d_q + 0.5\gamma BN_r s_r d_r \quad (1)$$

where

c : cohesion

q' : effective overburden pressure

B, L : width and length of pile foundation ($D = B$)

γ : unit weight of soil

N_c, N_q, N_r : bearing capacity factor due to internal friction

s_c, s_q, s_r : shape factor of the foundation

d_c, d_q, d_r : depth factor

To evaluate the performance of screw piles, we compared the predicted bearing capacity of the pile with the results from the field loading tests. Table 5 is a summary of the predicted and recorded resistance capacity of the FRP screw piles.

Most sites that are earmarked for the construction of solar power plants in saline regions consist of reclaimed and sedimentary layers. In these environments, the ground conditions often are characterized by looseness and inferior quality, which results in the bearing capacity of screw piles being significantly more influenced by the geometry of the pile than by the interaction between the soil and the pile. Importantly, the data from the field loading tests in this study demonstrate that the resistance was mobilized when the tip

Table 5
Resistance capacities of FRP screw piles.

Category	Predicted Resistance (tonf)	Field Loading Test (tonf)
Bearing Capacity	10.02	1.5

resistance area of the screw reached approximately 785.4 cm^2 or greater. As established, increasing the tip area of the screw blade significantly increased the bearing capacity of the FRP screw piles, regardless of the number of screws installed.

Based on the design formula for FRP screw piles proposed by Kim et al. [11], if the screw attached to the pile body is assumed to act as a cantilever beam, the resistance area of the screw can be expressed as that in Eq. (2).

$$A_s = \pi d_p B \geq 785.4 \text{ cm}^2 \quad (2)$$

Fig. 12 presents the final dimensions of the screw pile that were established under the premise that all loads exerted on the pile body are effectively transferred to the screw.

Table 6 presents the screw dimensions that we determined based on the magnitude of the load transmitted from the pile body.

4. Conclusions

Saline reclamation sites present a challenging combination of humid and saline conditions that render traditional steel foundations vulnerable to corrosion, thereby increasing the risk of structural failure for solar power plants. In this study, we assessed the performance of FRP screw piles, which are recognized for their superior corrosion resistance, through field loading tests executed at a site earmarked for solar power plant development. To examine the possibility of developing the proposed basic-shaped FRP screw pile, we enhanced the basic cross-section design based on field test results.

The ground conditions at saline reclamation sites typically are characterized as very loose, with the resistance performance of the screw piles being influenced more by the geometry of the pile and screw than by the interaction between the soil and the pile. Additionally, we observed that conventional methodologies for estimating the bearing capacity of screw piles pose significant challenges in their application. Therefore, we determined the minimum tip resistance area of the FRP screw pile via field tests to confirm the bearing capacity of the FRP screw pile.

The field loading test results indicate a recommended minimum tip resistance area of 785.4 cm^2 for the screw. Furthermore, under the assumption that all loads transmitted to the pile body are indeed transferred to the screw, we propose dimensions for screw piles that correspond to various diameters of the pile body. The field loading test results confirm the durability of the FRP screw piles in demanding humid and saline environments typical of the study site. In future research, further study of FRP screw piles is necessary to meet the various on-site conditions where solar power plants are installed and to achieve more economical designs.

Institutional review board statement

Not applicable

CRediT authorship contribution statement

Kim Sun-Hee: Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Choi Wonchang:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis.

Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

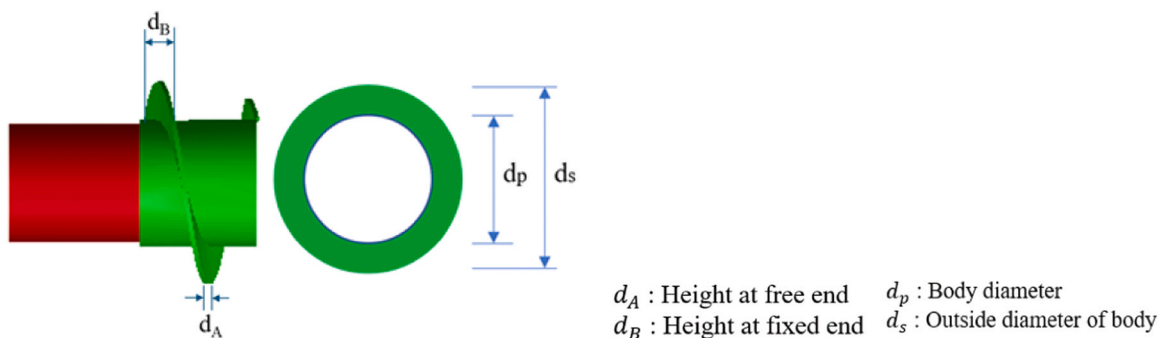


Fig. 12. Recommended dimension of screw pile.

Table 6

Screw dimensions considering load resistance performance.

Required Performance kN (tonf)	Body Diameter (d_p , mm)	Blade Width (b_s , mm)	Area (mm^2)	d_A (mm)	d_B (mm)
9.81 (1.0)	75	125	785.4	1.0	10.2
	100	116	787.2	1.0	9.3
	125	108	790.6	1.0	8.5
	150	100	785.4	1.0	7.8
	200	88	796.2	1.0	6.6
19.6 (2.0)	75	125	785.4	1.0	14.4
	100	116	787.2	1.0	13.1
	125	108	790.6	1.0	12.0
	150	100	785.4	1.0	10.9
	200	88	796.2	1.0	9.3
29.4 (3.0)	75	125	785.4	1.0	17.7
	100	116	787.2	1.0	16.1
	125	108	790.6	1.0	14.6
	150	100	785.4	1.0	13.4
	200	88	796.2	1.0	11.4
39.2 (4.0)	75	125	785.4	1.0	20.4
	100	116	787.2	1.0	18.5
	125	108	790.6	1.0	16.9
	150	100	785.4	1.0	15.5
	200	88	796.2	1.0	13.2

Data availability

Data will be made available on request.

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