



# Analysis of the Bearing Capacity of Screw Piles with the Addition of Liquid Cements to Sand

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**Abstract:** Foundations are crucial for the strength of a building's structure. With the advancement of technology, market demand for foundation materials is increasingly seeking those that are more economical, easy to work with, and easy to accommodate. Along with the development of technology, the use of foundation piles is also accompanied by research examining the advantages of certain materials for application as foundation piles. One such example is foundation piles made from screw piles made from rust-resistant galvanized iron pipes. The process is quite simple: rotating the pipe in the direction of the screw shape will force the pile into the ground. This became the background for researchers to test screw piles by applying test loads plus the addition of a cement slurry around the screw pile. Tests were conducted on screw piles with diameters of 7.5 and 10 cm, both non-grouted and grouted. This resulted in an increase in ultimate bearing capacity of 1 to 1.2 times the load for screw piles with a diameter of 7.5 cm and 1.2 to 1.36 times the load for screw piles with a diameter of 10 cm. So, the addition of cement liquid (grouting) to the screw piles installed in the sand significantly increases the bearing capacity.

**Keywords:** Bearing Capacity, Screw Piles, Cements, Sand, Grouting.

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## 1. Introduction

A foundation is the part of a structure that transmits the load from the structure to the underlying soil or rock (Das, 2021). Foundation types: Shallow Foundation, if the ratio of foundation depth to width ( $D_f/B$ ) is  $\leq 1$ , Examples: footings, mat foundations, etc. And Deep Foundation, if  $D_f/B > 4$ , Examples: piles, caissons, drilled shafts, etc.

The issue of soil bearing capacity is a major challenge in constructing structures on sandy soils. Sand, as a non-cohesive soil, has limitations in supporting vertical loads, especially for buildings with high loads. Therefore, foundation solutions are needed that can increase the bearing capacity of this soil.

One widely used type of foundation is the screw pile, which offers the advantages of fast installation, no vibration, and minimal environmental disturbance. However, in loose sandy soil

conditions, screw piles still face limitations in optimally supporting vertical loads.

To address this, the method of adding cement mortar (grouting) to the sandy soil around the screw pile has been introduced. Grouting strengthens the soil by increasing intergranular cohesion and reducing deformation under load. This approach has been proven to increase the bearing capacity of piles based on various experimental studies.

However, to date, there has been limited research specifically evaluating the effect of grouting on screw piles in sandy soil through laboratory experiments. Therefore, this study was conducted to provide a deeper understanding of the effect of cement mortar addition on the bearing capacity of screw piles in sand.

Grouting is a flexible and highly effective technique for improving local soil beneath foundations. The choice of grouting



method depends on the soil type, engineering objectives, and site construction limitations Sitharam & Govindaraju (2021).

Watanabe et al. (2011) demonstrated that pressure grouting through a one-way valve in screw piles can significantly increase the bearing capacity (Watanabe et al., 2011). Zhao et al. (2024) found that grouting pressure and helix configuration influence the axial performance of piles in sandy soil (Zhao et al., 2024). Lee & Kim (2014) developed a prebored screw pile method, where screw piles are inserted into cement-filled holes. This method has been shown to increase foundation strength in sandy soil (Lee & Kim, 2014).

Chen et al. (2020) stated that screw geometry, pitch, and screw section length significantly influence the bearing capacity of piles (Chen et al., 2020). Research results from Wahyuni et al (2023), the mixture of CCR and RHA was proven effective in increasing the bearing capacity of the soil, it resulted in increased shear strength and reduced soil deformation, and the optimum mixture composition provided the most significant reinforcement results compared to the unreinforced condition.

The helix diameter configuration of a screw pile significantly affects its bearing capacity. Selecting the right helix design can improve foundation performance and construction efficiency, especially in areas with soft or disaster-prone soil conditions (Amalia et al., 2023).

## 2. Literature Review

Foundation is the interface between the structure it supports and the soil or rock that supports it. The function of a foundation is to transfer the structural loads safely into the ground according to Coduto (2016).

A spun pile is a sub-foundation structure that functions to continue, move or transfer loads from the upper structure to deep layers of hard soil (Purba et al., 2017). Types of piles based on the method of load transfer, namely Point bearing piles (end bearing piles) and Friction piles.

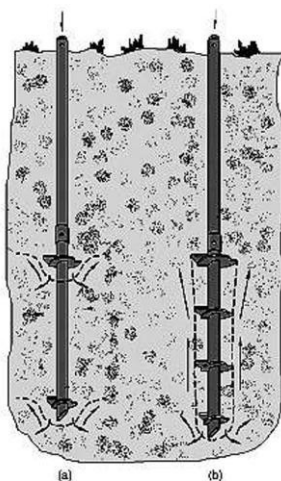


Figure 1. Individual Bearing Method (a) and Cylindrical Shear Method (b)

For a shallow foundation under vertical loading on homogeneous soil, Terzaghi proposed the following general formula for ultimate bearing capacity:

$$q_{ult} = cN_c + \gamma D_f N_q + 0.5 \gamma B N_{\gamma}$$

Where:

$q_{ult}$  : ultimate bearing capacity of soil (kN/m<sup>2</sup> or psf)

$c$  : cohesion of the soil (kN/m<sup>2</sup>)

$\gamma$  : unit weight of soil (kN/m<sup>3</sup>)

$D_f$  : depth of foundation (m)

$B$  : width of foundation (m)

$N_c, N_q, N_{\gamma}$ : bearing capacity factors, dependent on the internal friction angle  $\phi$

Determining the ultimate bearing capacity ( $Q_{ult}$ ) using this method is done by adding the tip bearing capacity ( $Q_b$ ) of the lowest screw pile, the pile cover bearing capacity ( $Q_s$ ), and the cylinder bearing capacity ( $Q_{cyc}$ ).

$$Q_{ult} = Q_b + Q_s + Q_{cyc}$$

Where:

$Q_{ult}$  : Ultimate bearing capacity (KN)

$Q_b$  : Bottom screw pile tip bearing capacity (KN)

$Q_s$  : Pile cover bearing capacity (KN)

$Q_{cyc}$ : Screw plate cylinder bearing capacity (KN)

To determine the ultimate bearing capacity ( $Q_{ult}$ ) using this method, add the end bearing capacity of each helix plus the pile cover bearing capacity.

$$Q_{ult} = \sum Q_b + Q_s$$

Where:

$Q_{ult}$ : Ultimate bearing capacity (KN)

$Q_b$  : End bearing capacity of the lowest screw pile (KN)

$Q_s$  : Pile cover bearing capacity (KN)

Data processing can be carried out using a data interpretation analysis approach according to previous researchers. The data interpretation analysis method is one way to determine the ultimate bearing capacity of screw piles by analyzing data from field load tests. Three data interpretation analysis methods were used in this research: the Davisson method, the de Beer method, and the Chin method.

## 3. Methodology

The results of this research will determine the effect of thread diameter, thread spacing, thread configuration, and the addition of cement in increasing the ultimate bearing capacity of screw piles. This research was conducted using a laboratory experiment method, using a test box as the testing medium and a screw pile model as the test object. The research took place at the Soil Mechanics Laboratory of Sriwijaya University, Indralaya, Province South Sumatera.

The preparation phase is a step before beginning the load testing process. This phase includes sand preparation and testing instruments. The sand to be used, from Tanjung Raja, Ogan Ilir, Province South Sumatera as the testing medium, must first be dried and sieved using a No. 10 sieve to separate the sand from the gravel.





Figure 2. Sand Preparation Process

The dried and sieved sand was then sampled for laboratory testing to determine its properties and characteristics. Testing was conducted according to ASTM standards. The laboratory tests performed included: (1) Moisture content (ASTM D 2216-80); (2) Specific gravity (ASTM D 854-23); (3) Volumetric gravity (ASTM D4532-R03); (4) Sieve analysis (ASTM D-442); (5) Vane shear (ASTM D-3080-04).

This research was conducted on a laboratory scale. The dimensions of the test box were designed based on the failure diagram proposed by Livneh and Nagggar. The test box was 200 cm long, 100 cm wide, and 100 cm high, and was made of wood.

For variations and illustrations of test objects, see Table 1 and Figure 3. To find out how much the bearing capacity of screw piles is, apart from being obtained using empirical calculation methods, load-settlement tests are also carried out on screw piles that have been inserted into sand. The instruments used in this test are explained in the Figure 4.

To confirm the assumptions made during the design of a pile foundation, a load test is necessary. In this research, the load test conducted to determine the test specimen's ability to withstand compressive loads followed the ASTM D1143-81 procedure.

Table 1. Variations in Thread Diameter, Thread Spacing, and Thread Configuration of Test Specimens

Thread Spacing (S)(cm)	Thread Diameter (cm)			Pipe Diameter (cm)	Symbol
	Top	Middle	Bottom		
5	7,5	7,5	7,5	2,54	D5-(7,5)G
5	7,5	7,5	7,5	2,54	D5-(7,5)NG
5	10	10	10	2,54	D5-10G
5	10	10	10	2,54	D5-10NG
10	7,5	7,5	7,5	2,54	D10-(7,5)G
10	7,5	7,5	7,5	2,54	D10-(7,5)NG
10	10	10	10	2,54	D10-10G
10	10	10	10	2,54	D10-10NG
20	7,5	7,5	7,5	2,54	D20-(7,5)G
20	7,5	7,5	7,5	2,54	D20-(7,5)NG
20	10	10	10	2,54	D20-10G
20	10	10	10	2,54	D20-10NG



Figure 3. Test Specimen of Threaded Pile



Figure 4. Test Object

The loading procedure used in this study was the Quick Maintained Load Test (QML). This method is relatively fast compared to other methods required by ASTM, with a total test time of approximately 3 to 5 hours. The theoretical estimated bearing capacity of the screw pile, calculated using empirical methods, is used as the design load to determine the load increase. In the QML test, the load increase is carried out in 5% increments of the design load until failure is achieved. The load increase is maintained for a minimum of 4 minutes but not more than 15 minutes. Recording is carried out in 5-minute increments. The load test in this study was carried out until the pile fails. ASTM D 1143 states that the test is stopped if the load reaches 1.5 to 2 times the design load.

The data generated from the load testing is then processed to determine the ultimate bearing capacity of each test object. The test results, which are the output of this test, are displayed as a load-settlement relationship curve. Interpretation of the test data to obtain the ultimate bearing capacity value uses several graphical



methods, including the De Beer Method, the Chin Method, and the Davisson Method.

### 4. Results and Discussion

#### Results of Identification of Sandy Soil Parameters

Laboratory sand testing results provide the parameters of sandy soil. These values are used to calculate the design bearing capacity using theoretical calculations. The required sand parameters are both physical and mechanical. A summary of the laboratory test results for the sand used in this study can be seen in Table 2.

Table 2. Summary of Sand Laboratory Testing Data

Parameter	Value
Specific Gravity (Gs)	2,639
Grain Gradation (Cu, Cc)	Cu = 2,6 dan Cc = 1,6
Volume Weight (γ, KN/m <sup>3</sup> )	15,39
Water Content (w̄, %)	3,7%
Friction Angle (φ̄, °)	32,5°

The Cu value is 2.592 and the Cc value is 1.556. Sandy soil with Cu or uniformity coefficient of 2.592 is categorized as having poor gradation because it does not meet the requirements of Cu>6, however, sandy soil with Cc value or curvature coefficient of 1.556 can indicate that the sand is well graded because it meets the requirements of 1<Cc<3. After the investigation stage is completed, the next step is to calculate the estimated bearing capacity of the pile using the empirical method.

#### Empirical Ultimate Bearing Capacity Results of Screw Piles Based on the Cylindrical Shear Failure Method

Table 3 shows the results of the recapitulation of empirical ultimate bearing capacity of piles using the cylindrical shear failure method (non-grouting piles). And Table 4 shows the results of summary of empirical ultimate bearing capacity of piles using the cylindrical shear failure method (grouting screw piles).

Table 3. Summary of Empirical Ultimate Bearing Capacity of Piles using Cylindrical Shear Failure Method (Non-Grouting Piles)

Sample	Ultimate Bearing Failure Method (KN)				
	Empirical		Analysis		
	Cylindrical	Individual	De Beer	Davisson	Chin
D7,5-5 NG	0.714	-	5.00	2.18	2.86
D7,5-10 NG	0.716	-	5.20	2.00	3.70
D7,5-20 NG	-	1.335	5.80	2.20	6.21
D10-5 NG	1.299	-	5.90	2.20	7.69
D10-10 NG	1.396	-	5.00	2.40	4.93
D10-20 NG	-	-	6.10	2.60	7.48

Table 4. Summary of Empirical Ultimate Bearing Capacity of Piles using the Cylindrical Shear Failure Method (Grouting Screw Piles)

Sample	Ultimate Bearing Failure Method (KN)				
	Empirical		Analysis		
	Cylindrical	Individual	De Beer	Davisson	Chin
D7,5-5 G	-	-	8.60	5.42	6.60
D7,5-10 G	-	-	6.20	4.60	6.53
D7,5-20 G	-	-	7.70	5.62	7.44
D10-5 G	-	-	8.90	7.90	9.41
D10-10 G	-	-	6.70	6.57	8.83
D10-20 G	-	2.501	7.80	6.20	8.95

From the empirical calculations above, it can be seen that Qb in the cylindrical method is significantly influenced by thread diameter and not by spacing, where the larger the diameter, the greater the resulting end bearing capacity. Meanwhile, QS is only influenced by the spacing between threads, with QS being inversely proportional to the increase in spacing. QCyc is influenced by both diameter and spacing, but the spacing between threads has the most significant effect on QCyc.

#### Empirical Ultimate Bearing Capacity of Piles Based on the Individual Bearing Failure Method

Summary of the results empirical ultimate bearing capacity of piles based on the individual bearing failure method can be seen in the Table 5 and Table 6.

Table 5. Summary of Ultimate Bearing Capacity Ratio of 7,5 cm Piles

Test Pieces	Ultimate Carrying Capacity, Qult (KN)					
	Empirical		Load Testing Data Interpretation Analysis			
	Cylindrical	Individual	The Bear	Davisson	Chin	
D7.5-5 NG	0.714	-	5,00 (7,00)	2,18 (3,05)	2,86 (4,01)	
D7.5-10 NG	0.716	-	5,20 (7,26)	2,13 (2,97)	3,70 (5,17)	
D7.5-20 NG	-	1.335	5,80 (4,34)	2,20 (1,65)	6,21 (4,65)	
Average Ratio			(6,20)	(2,56)	(4,61)	
D7.5-5 G	-	-	5,80	4,20	6,60	
D7.5-10 G	-	-	5,50	4,40	6,53	
D7.5-20 G	-	-	5,90	4,60	7,44	
Average Ratio ( )						

Table 6. Summary of Ultimate Bearing Capacity Ratio of 10 cm Piles

Test Pieces	Ultimate Carrying Capacity, Qult (KN)				
	Empirical		Load Testing Data Interpretation Analysis		
	Cylindrical	Individual	The Bear	Davisson	Chin
D10-5 NG	1.299	-	5,40 (4,16)	2,25 (1,73)	7,69 (5,92)
D10-10 NG	1.306	-	5,20 (3,98)	2,40 (1,84)	4,93 (3,77)
D10-20 NG	-	2.501	6,10 (2,44)	2,60 (1,04)	7,48 (2,99)
Average Ratio			(3,53)	(1,54)	(4,23)
D10-5 G	-	-	6,00	4,42	9,41
D10-10 G	-	-	6,20	4,65	8,86
D10-20 G	-	-	6,40	4,80	8,95
Average Ratio ( )					



**Results of Uniform Screw Pile Loading Tests**

Loading tests on screw piles are carried out to predict the interaction behavior between the soil and the screw pile against the given compressive load which is described through the loading- settlement curve.

Figures 5, 6, 7 and 8 respectively show the load-displacement curves of test objects D7.5-5 NG, D7.5-10 NG, D7.5-20 NG; load-displacement curve of test objects D10-5 NG, D10-10 NG, D10-20 NG; load-displacement curve of test objects D7.5-5 G, D7.5-10 G, D7.5-20 G; and load-displacement curves for test objects D10-5 G, D10-10 G, D10-20 G.

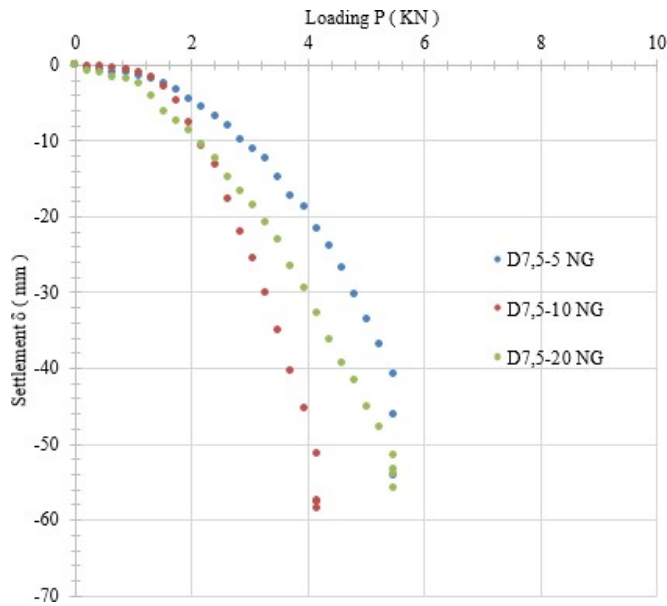


Figure 5 Load-Displacement Curve for Test Objects D7.5-5 NG, D7.5-10 NG, D7.5-20 NG

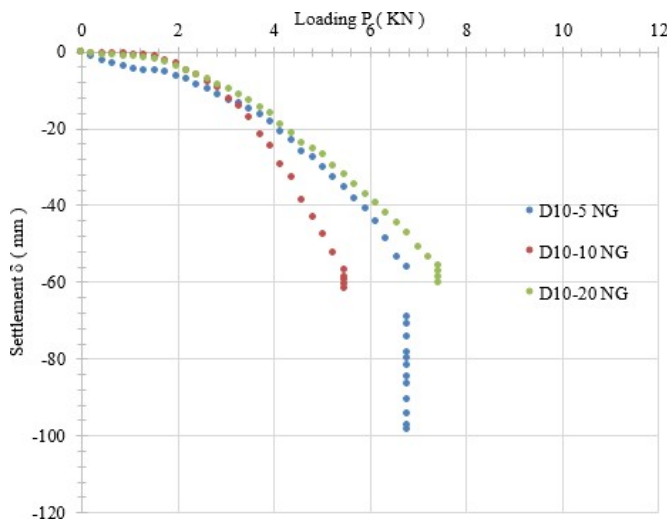


Figure 6. Load-Displacement Curve for Test Objects D10-5 NG, D10-10 NG, D10-20 NG

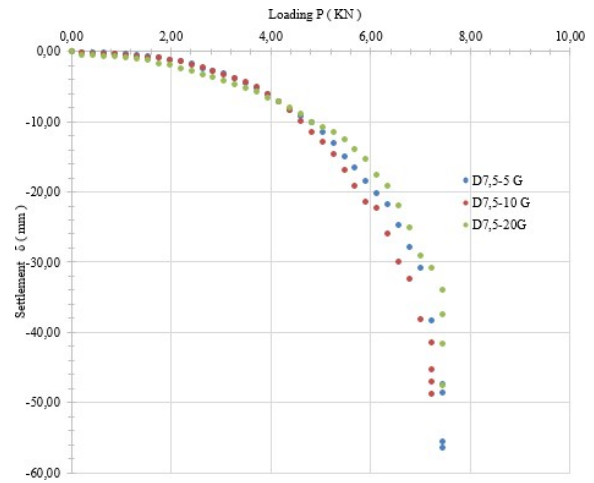


Figure 7 Load-Displacement Curve for Test Objects D7.5-5 G, D7.5-10 G, D7.5-20 G

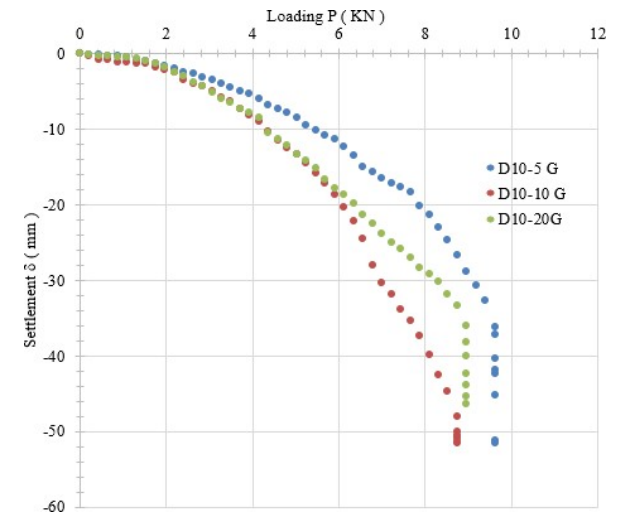


Figure 8 Load-Displacement Curves of Test Specimens D10-5 G, D10-10 G, D10-20 G

Determination of the ultimate bearing capacity using the three methods above for all uniform pile test specimens will be shown in the appendix, while a recapitulation of the ultimate bearing capacity values obtained from the three data interpretation analysis methods can be seen in Table 7.

Table 7. Summary of Ultimate Bearing Capacity Based on the Load Test Data Interpretation Analysis Method

Sample	Ultimate Bearing Capacity, Qult (KN)		
	De Beer	Davisson	Chin
D7,5-5 NG	5.00	2.18	2.86
D7,5-10 NG	5.20	2.00	3.70
D7,5-20 NG	5.80	2.20	6.21
D10-5 NG	5.90	2.20	7.69
D10-10 NG	5.00	2.40	4.93



D10-20 NG	6.10	2.60	7.48
D7,5-5 G	8.60	5.42	6.60
D7,5-10 G	6.20	4.60	6.53
D7,5-20 G	7.70	5.62	7.44
D10-5 G	8.90	7.90	9.41
D10-10 G	6.70	6.57	8.83
D10-20 G	7.80	6.20	8.95

**Results of Non-Grouting Screw Pile Loading Tests**

In this research, in addition to the poles being modified with a uniform diameter thread configuration, the poles were also modified by reducing and increasing the thread diameter or a non- uniform configuration.

The analysis of the bearing capacity was carried out on the ultimate Grouting and Non-Grouting screw piles using the data interpretation method. There are 12 types of test objects that will be discussed this time, namely D7.5-5NG, D7.5-10NG, D7.5- 20NG, D10-5 NG, D10-10 NG, D10-20 NG, D7.5-5 G, D7.5-10G, D7.5-20 G, D10-5 G, D10-10 G and D10-20 G.

Determination of the ultimate bearing capacity using the above method for all uniform pile test specimens will be shown in the appendix, while a recapitulation of the ultimate bearing capacity values obtained from these three interpretation analysis methods (the De Beer Method, the Chin Method, and the Davisson Method) can be seen in Table 8.

Table 8. Summary of Ultimate Bearing Capacity based on the Results of the Non-Grouting Load Test Data Interpretation Analysis Method

Sample	Ultimate Bearing Capacity, Qult (KN)		
	De Beer	Davisson	Chin
D7,5-5 NG	5.00	2.18	2.86
D7,5-10 NG	5.20	2.00	3.70
D7,5-20 NG	5.80	2.20	6.21
D10-5 NG	5.90	2.20	7.69
D10-10 NG	5.00	2.40	4.93
D10-20 NG	6.10	2.60	7.48

**Results of Grouting Screw Pile Loading Tests**

This plain pile loading test aims to compare whether threading the pile increases its bearing capacity. The diameters of the plain piles tested are the same as those of the threaded piles, namely 7.5 cm and 10 cm. Determination of the ultimate bearing capacity for grouted screw piles using the three methods above for all uniform pile test specimens will be shown in the appendix, while a recapitulation of the ultimate bearing capacity values obtained from these three interpretation methods can be seen in Table 9.

Table 9. Summary of Ultimate Bearing Capacity of Grouted Piles Based on the Results of the Analysis Method for Interpretation of Grouting Load Test Data

Benda Uji	Ultimate Bearing Capacity, Qult (KN)		
	De Beer	Davisson	Chin
D7,5-5 G	8.60	5.42	6.60
D7,5-10 G	6.20	4.60	6.53
D7,5-20 G	7.70	5.62	7.44
D10-5 G	8.90	7.90	9.41
D10-10 G	6.70	6.57	8.83
D10-20 G	7.80	6.20	8.95

**Comparison of Bearing Capacity of Grouted Screw Piles and Non-Grouted Screw Piles**

The uniform screw pile sizes used were 7.5 and 10 cm. The graphs below, Figures 9 and 10, show the differences in ultimate bearing capacity of the piles under non-grouted and grouted conditions. This was done to determine the difference in bearing capacity and which configuration provides the greatest bearing capacity.

Figure 9 shows a comparison of the bearing capacity between D7.5 and D10 screw piles under non-grouted conditions with spacings of 5 cm, 10 cm, and 20 cm. The ultimate bearing capacity shown in Figure 4.23 represents the ultimate bearing capacity derived from data interpretation analysis using the Davisson Method. The Davisson Method produces more consistent results than other methods. The figure shows that if the screw piles are spaced the same as the thread diameter, the bearing capacity is lower than that of screw piles with a thread diameter larger or smaller than the thread spacing. Based on the image, it can be seen that the D10-20 NG screw pile has the greatest ultimate bearing capacity, namely 2.60 kN.

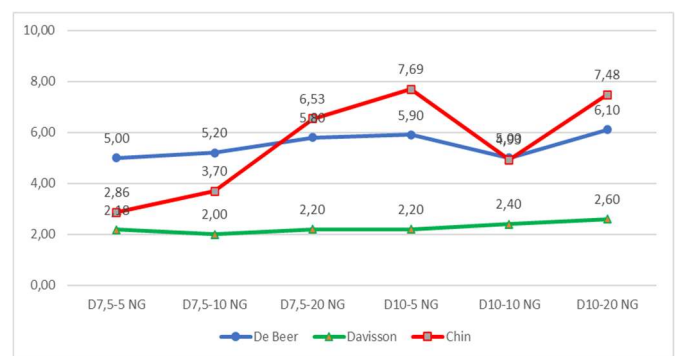


Figure 9. Comparison of Ultimate Bearing Capacity D7.5 and D10 in Non-Grouting Conditions



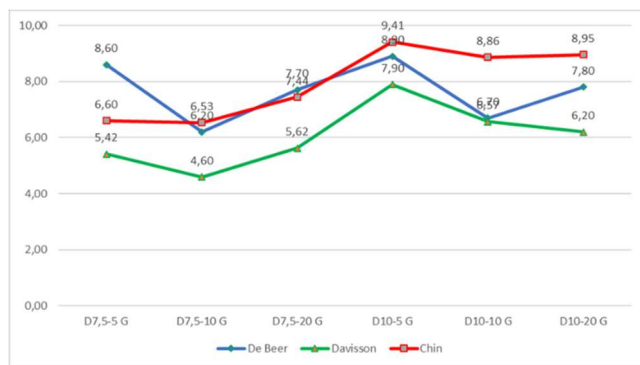


Figure 10. Comparison of Ultimate Bearing Capacity of D7.5 and D10 Under Grouting Conditions

Figure 10 shows the comparison of bearing capacity between D7.5 and D10 screw piles under grouting conditions with a distance of 5 cm, 10 cm and 20 cm. From the figure it can be seen that if the screw pile is spaced the same as the thread diameter, the bearing capacity value becomes lower than the screw pile that has a thread diameter that is larger or smaller than the thread distance. Based on the figure, it can be seen that the D10-5 NG screw pile has the greatest ultimate bearing capacity, namely 7.90 kN. So, from this analysis it can be concluded that the application of the thread diameter configuration is effective because it is able to increase the ultimate bearing capacity of the pile while still being able to save material usage.

## Conclusion

The following conclusions can be drawn based on the analysis of the test data:

1. The difference in Thread Diameter D7.5 and D10 can provide an average ultimate load bearing capacity difference of 13.79% for conditions without cement fluid and an average difference of 4.55% for conditions given cement fluid.
2. The thread spacing factors of 5cm, 10cm and 20cm affected the difference in the average ultimate load bearing capacity of 5.49% for conditions without being given cement liquid and the average difference of 4.43% for conditions given cement liquid.
3. Of several data processing methods to find the Ultimate load, namely: Chin, De Beer, Davisson, then it can be sorted based on the ultimate carrying capacity value obtained from the smallest value to the largest value, namely the method; Davisson, of Beer Chin. The method that is close to the ultimate load value in the test is the Davisson Method.
4. The addition of cement slurry with a W/c ratio = 0.68 can increase the ultimate load by 10% to 20%. The addition of cement liquid resulted in an increase in the ultimate bearing capacity of the threaded pole which was close to the same value for threaded poles with different configurations of both thread diameter and thread spacing.

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