Amirkabir University of Technology
(Tehran Polytechnic)
Department of Civil and Environmental Engineering

Overview of Physical Modeling (FCV-AUT) and Field Load-Displacement Records for Various Piles

Organized By:

Prof. Abolfazl Eslami

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Outline

1 Physical Modeling in GE

2 Recently Developed FCV (FCV-AUT)

3 Various CPTs in FCV-AUT

4 Piling Testing

5 Field Testing and Scale up

6 Data Bank

1

Physical Modeling in GE

Physical modeling is an intermediate solution between element testing & Full Scale.

Physical Modeling in Geotechnical Engineering

- High Stress
  - Geotechnical Centrifuge
  - Calibration Chamber (CC)
  - Frustum Confining Vessel (FCV)
- 1g

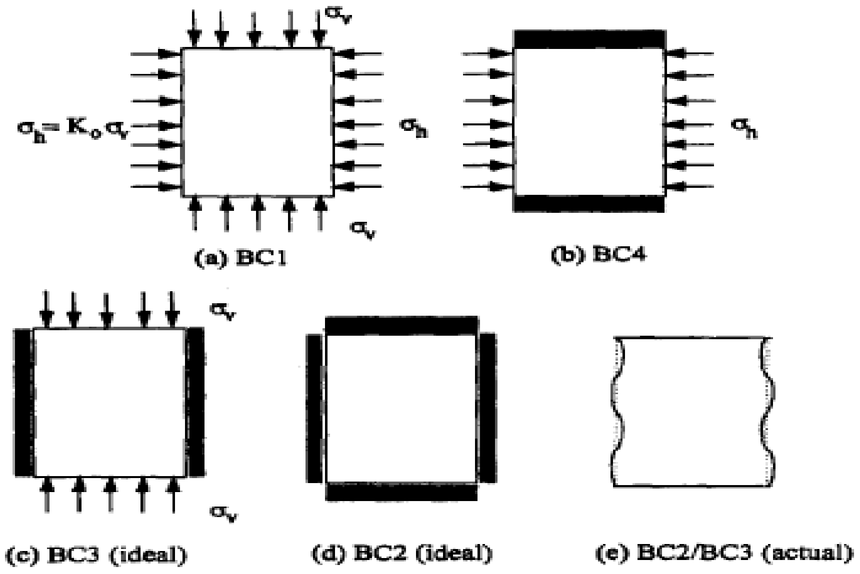
1g Physical Modeling

- One of the most inexpensive and prevailing tests
- Routine samples preparation
- Incompatible stress field with the true overburden stress distribution in reality

1g equipment

CC Physical Modeling

Calibration Chamber in University of New South Wales

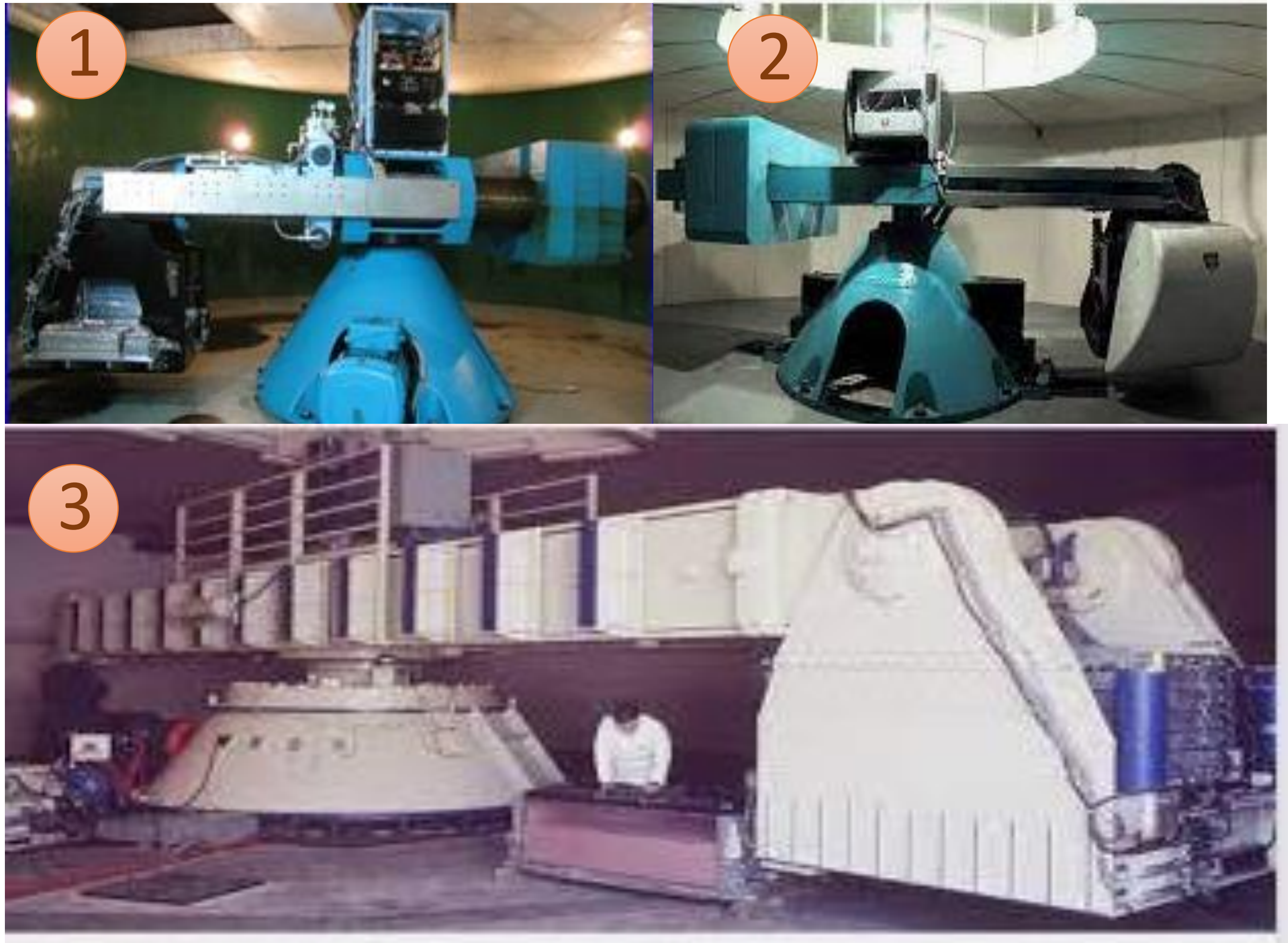


Type of Boundary Conditions	Lateral Boundary Conditions	Top and Bottom Boundary Conditions
BC1	Constant Stress	Constant Stress
BC2	No displacement	No displacement
BC3	No displacement	Constant Stress
BC4	Constant Stress	No displacement

Boundary condition in Calibration Chamber (Ghionna and Jamiolkowski, 1991)

Geotechnical Centrifuge

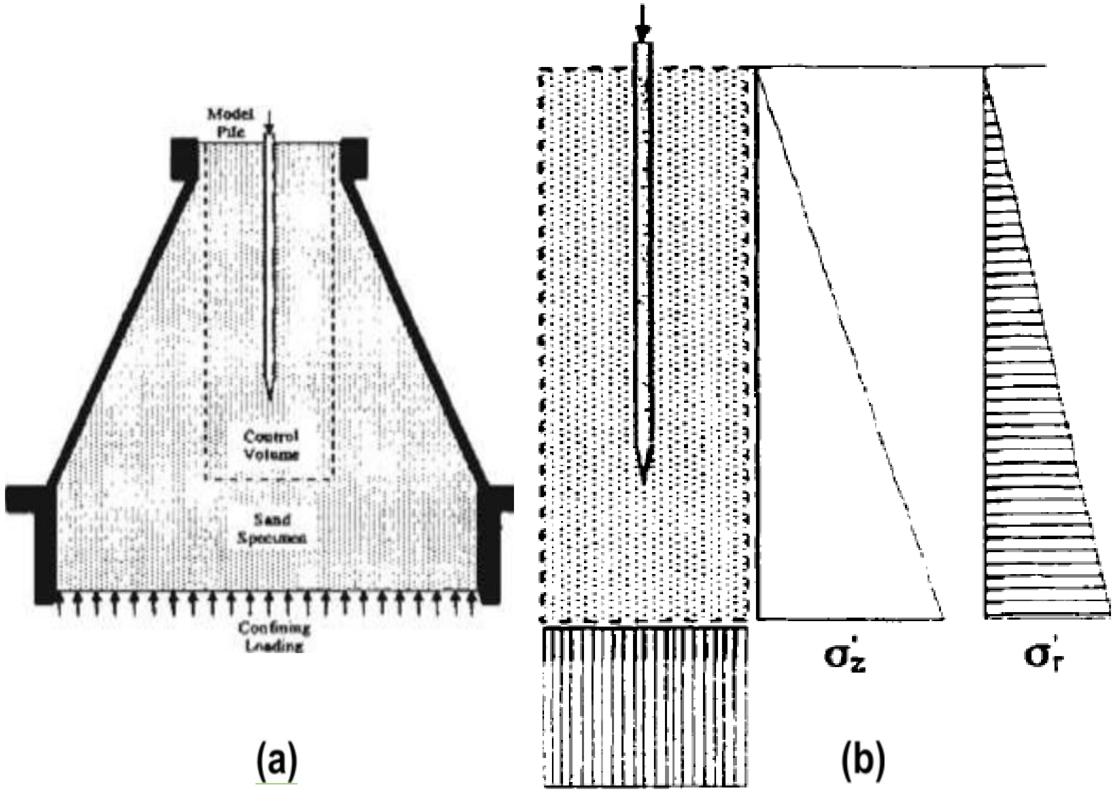
- Recognized as a physical modelling technique in all types of soils
- Increasing the g-forces on the model to made equal stress of field
- Successfully applied to model classical problems



Fu Geotechnical Centrifuge devices 1) NCUCE 2) Tehran University 3) US Devise

Frustum Confining Vessel (FCV)

- Triangular stress distribution throughout the chamber
- Capable of constructing bored model pile in chamber
- Stress gradient changes with the alteration of bottom pressure
- Stress equal to zero on the surface



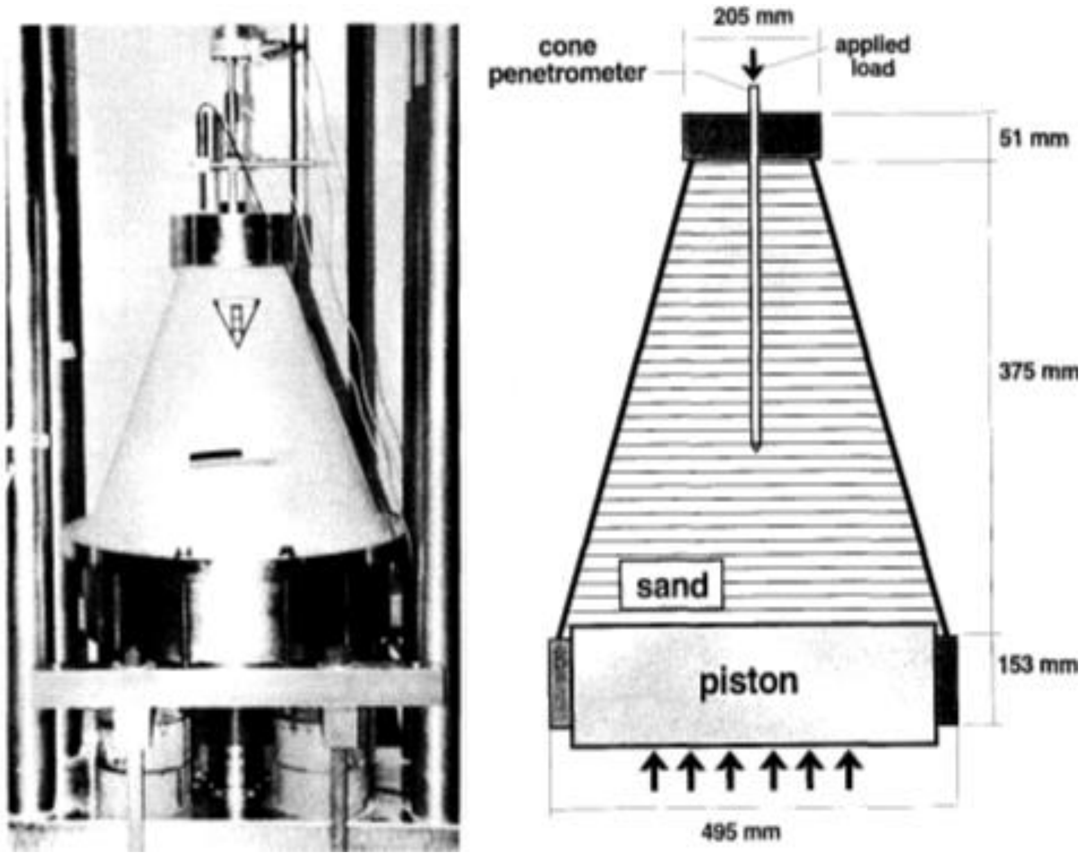
FCV: a) general view b) Stress distribution in control volume (Horvath & Stolle 1996)

FCV device of McMaster University

- The basic idea of FCV configuration was provided by Patrick Bermingham

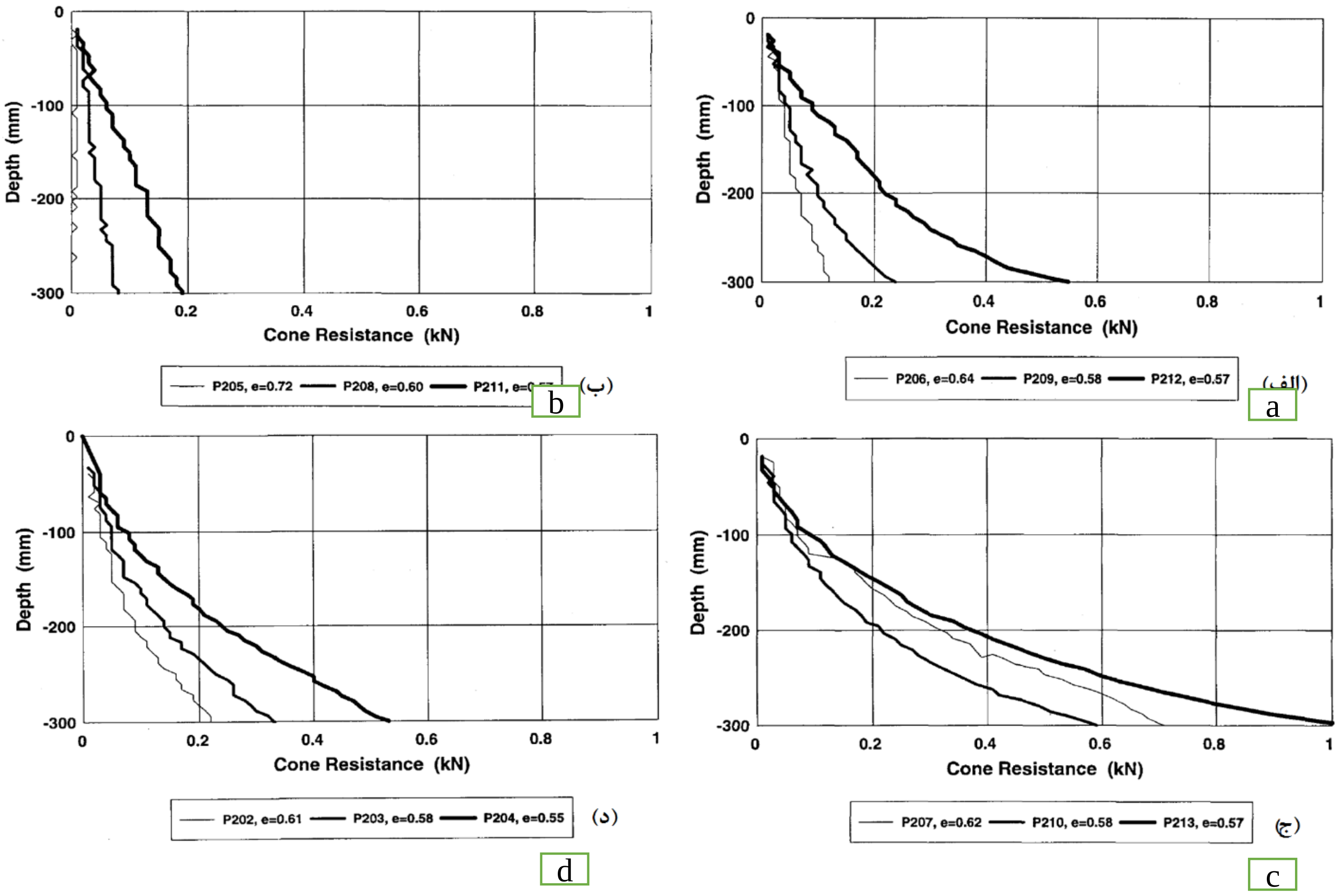
- Fabricated by McMaster University & Birminghammer Foundation Equipment

- 375mm height,
- 152 and 456mm diameters in top and bottom



FCV device of McMaster University (Horvath & Stolle, 1996)

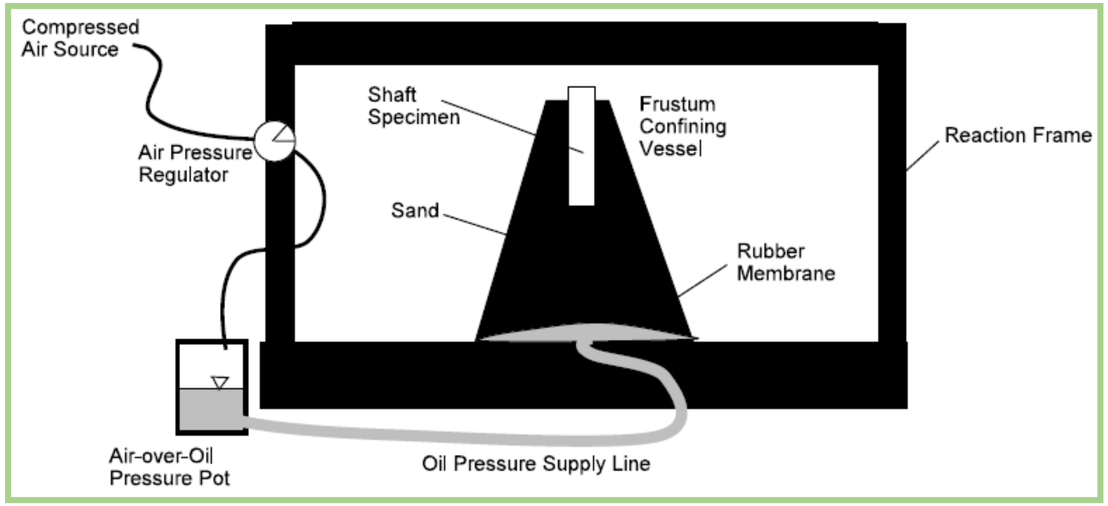
CPT Records in FCV (McMaster University)



a) Bottom pressure 125 KPa b) Bottom pressure 5 KPa c) Bottom pressure 500 KPa
d) Bottom pressure 250 KPa (Horvath and Stolle, 1996)

FCV device of Florida University (Mullins, 2001)

- Another FCV was constructed by University of South Florida in 1999
- This device was utilized in order to investigate the behavior of post-grouted piles



Schematic FCV device of Florida University (Mullins, 2001)

FCV device of Florida University (Mullins, 2001)

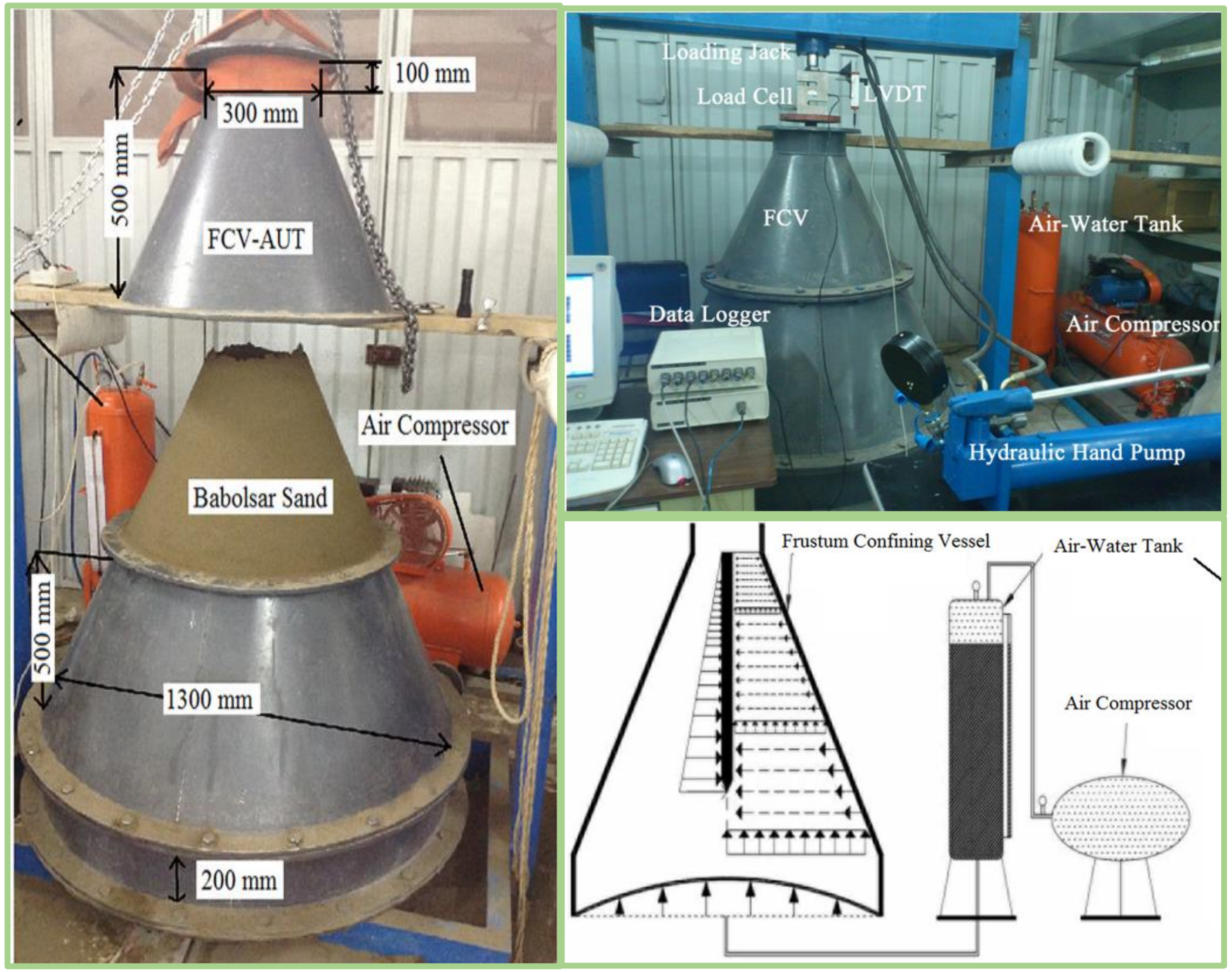
2

Recently Developed FCV (FCV-AUT)

FCV-AUT Development

- In 2012, the largest FCV was constructed at Amirkabir University of Technology.

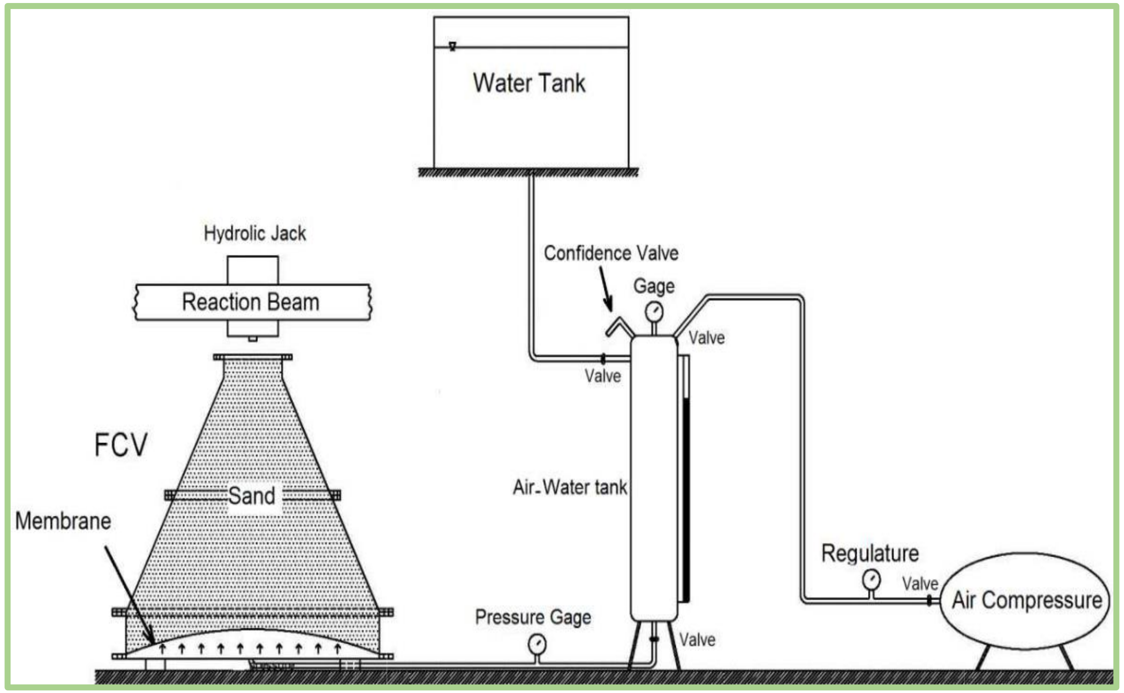
- The FCV-AUT allows modeling of larger piles and reduces boundaries error.



FCV-AUT (Zare & Eslami, 2014)

Steps of Applying Bottom Pressure

- Base pressure provided by air compressor
- The water is injected to rubber membrane
- The soil subjected to pressure from rubber
- Creation Triangular shape pressure



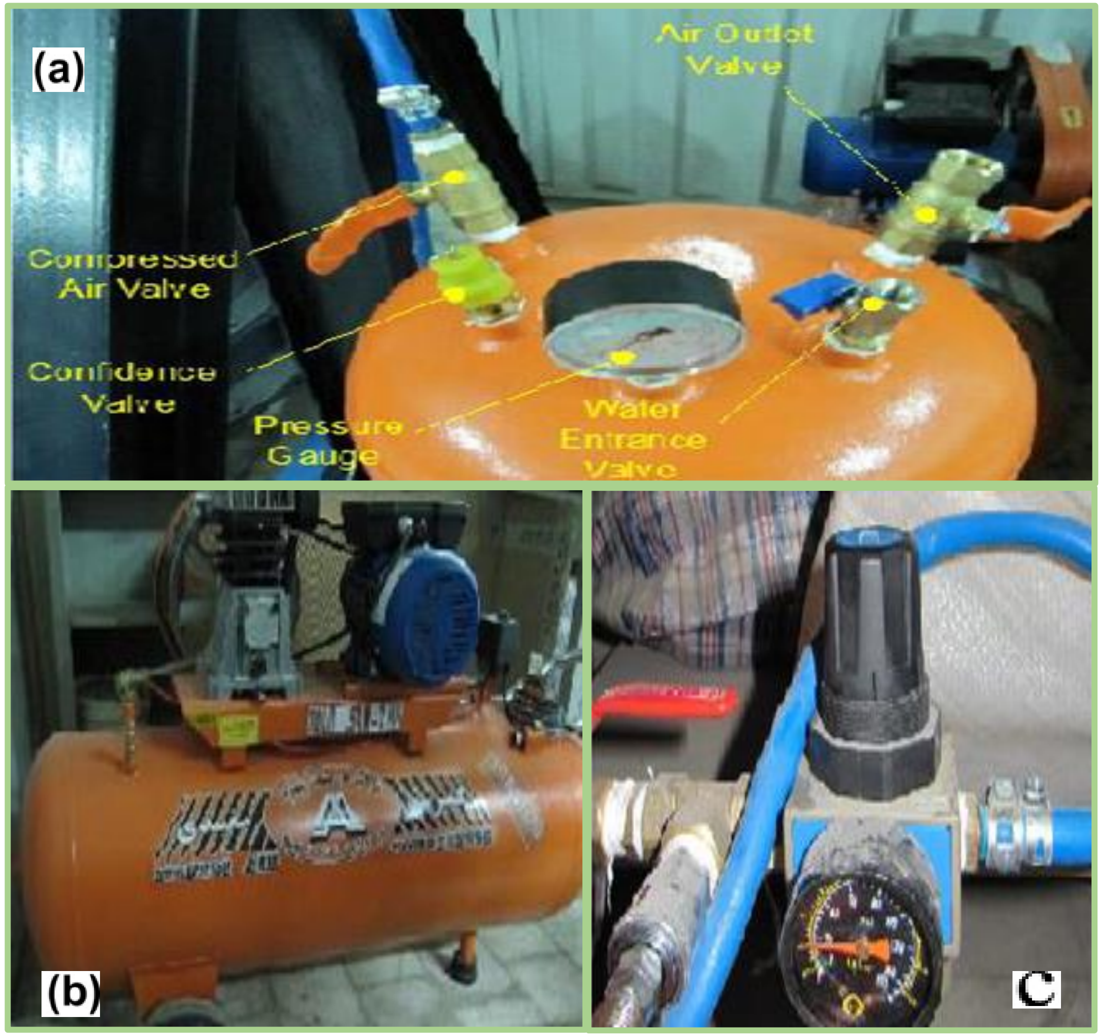
Schematic view of the FCV-AUT (Zare & Eslami, 2014)

Reservoir of water-air & Air Compressor

- Painting surfaces for corrosion resistance
- Water-air tank capacity: 75 Liter

Properties of Air Compressor:

- Capacity: 110 Liter
- Max pressure level : 10Bar
- Power: 1.5Hp



Pressure vessel a) Cylindrical tank a) installed equipment
b) Compressor c) regulator

Loading System

1. Mechanical jack:
   Capacity: 50kN; Course: 300mm

2. Hydraulic jack:
   Capacity: 100kN; Course: 1000mm

3. Hydraulic jack:
   Capacity: 150kN; Course: 150mm

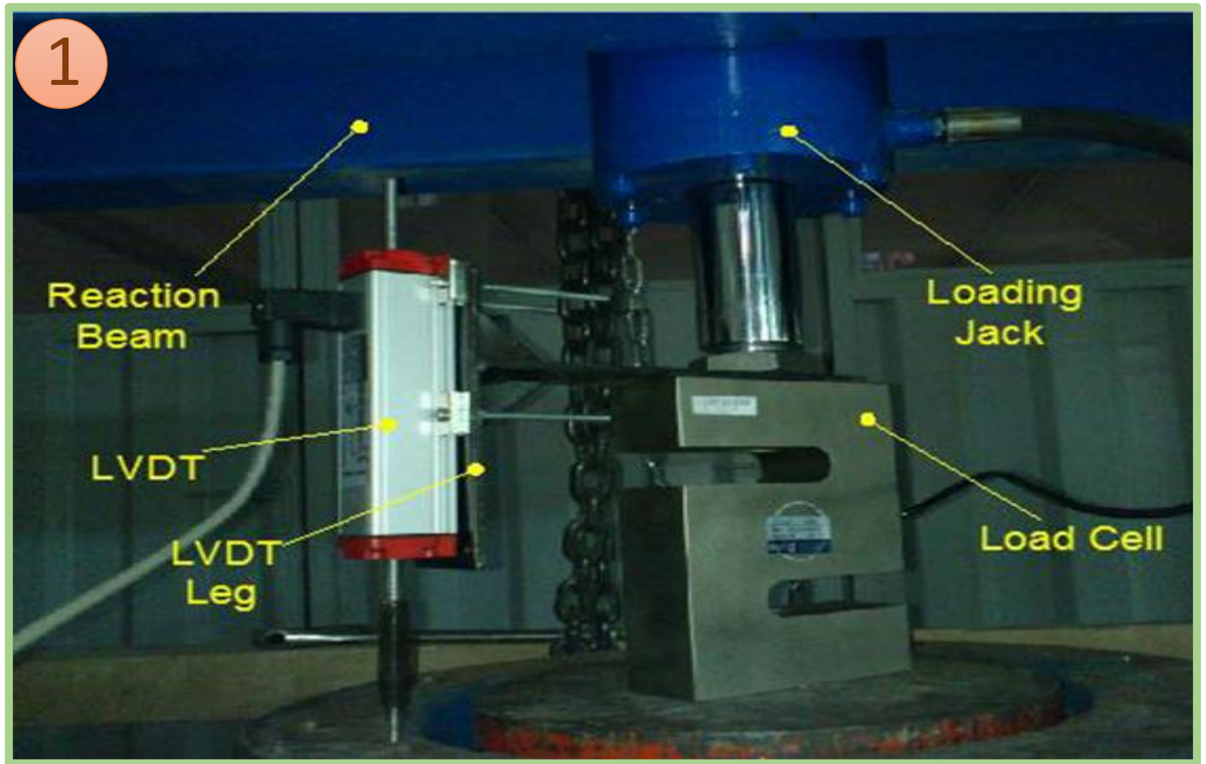
4. Pneumatic jack:
   Capacity: 15kN; Course: 125mm

Loading System & Data Recording Instrument

1. Sensors: 10 tons of S-shaped load cell and a LVDT with 50mm courses

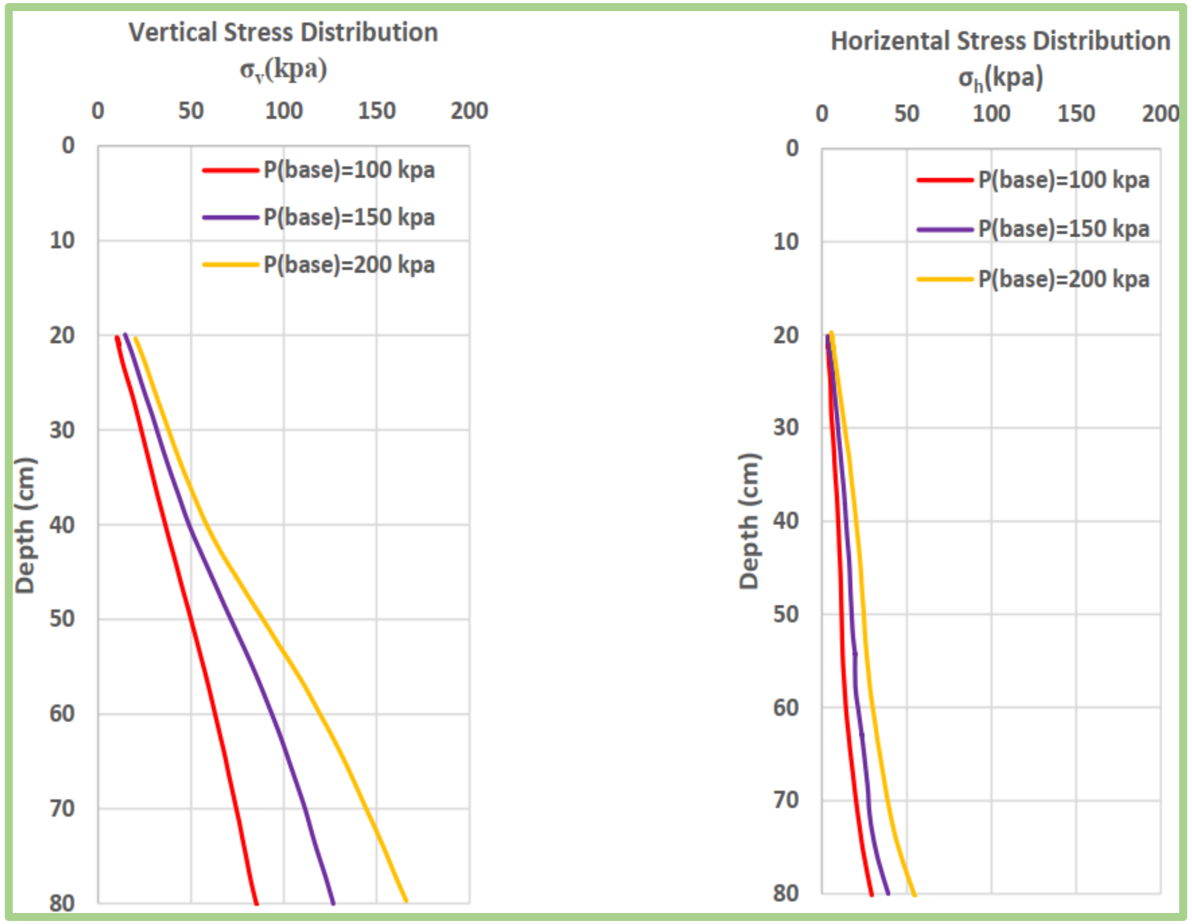
2. Data Logger

3. S-shaped load cells with 2 tons capacity



Soil Pressure Cells

- Five number
- Capacity: 1000kPa
- Measuring amount & distribution of stress

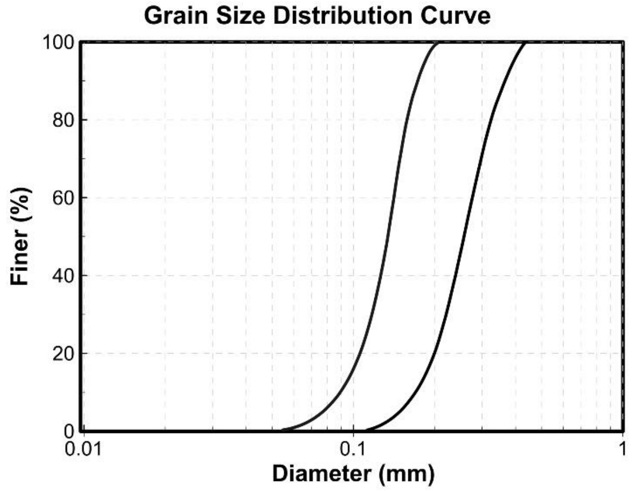


Stress distribution in FCV (Zare & Eslami 2014)

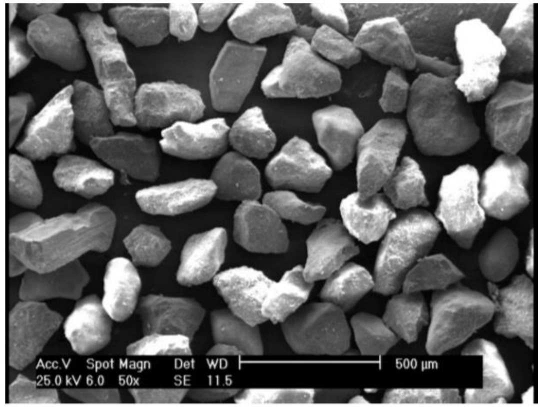
Sand Deposit used for Testing

- Babolsar sand specification

Parameter	Value
D_{50}	0.18
$e_{\max}$	0.876
$e_{\min}$	0.637
$\gamma_{d,\max}\,(kN/m^3)$	17
$\gamma_{d,\min}\,(kN/m^3)$	14.82
G_s	2.78
C_u	1.22
C_c	1.67
$\omega_{opt}\,(\%)$	11



(a)



(b)

a) Soil distribution curve b) Scanning electron Microscope (SEM) image

Preparation of Soil Sample

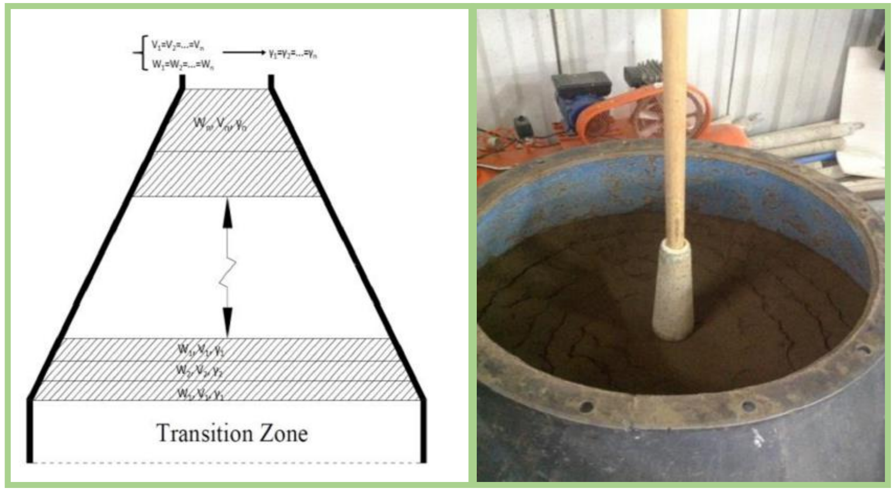
Sample Preparation

- Wet tamping

  Dr = 4-8%, 17-22% and 35-40%

- Dry Deposition

  Dr = 20-25%, 40-45%, 60-65% and 80-85%

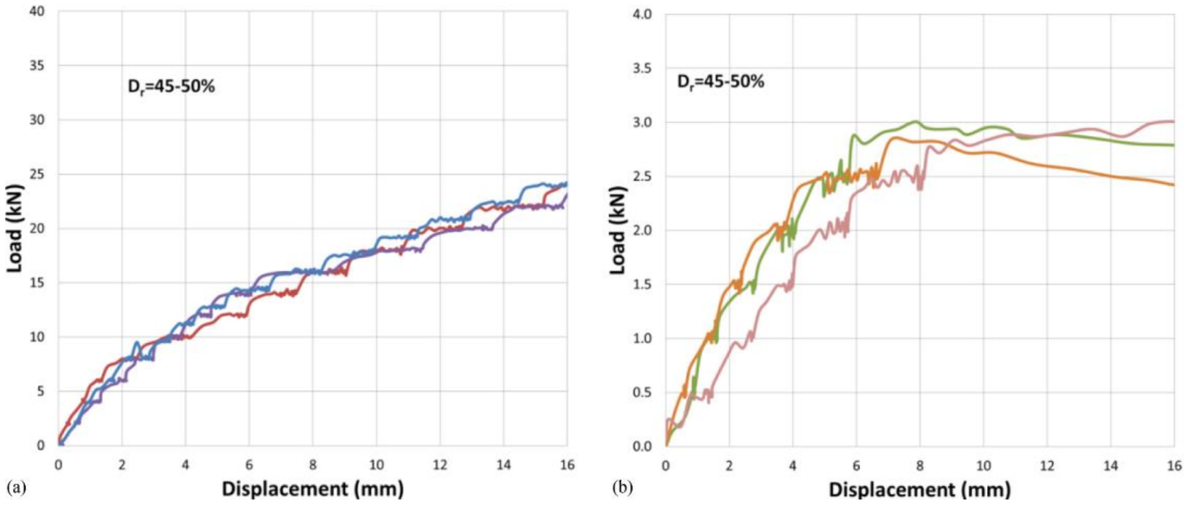


Wet tamping (Zarrabi & Eslami 2016)

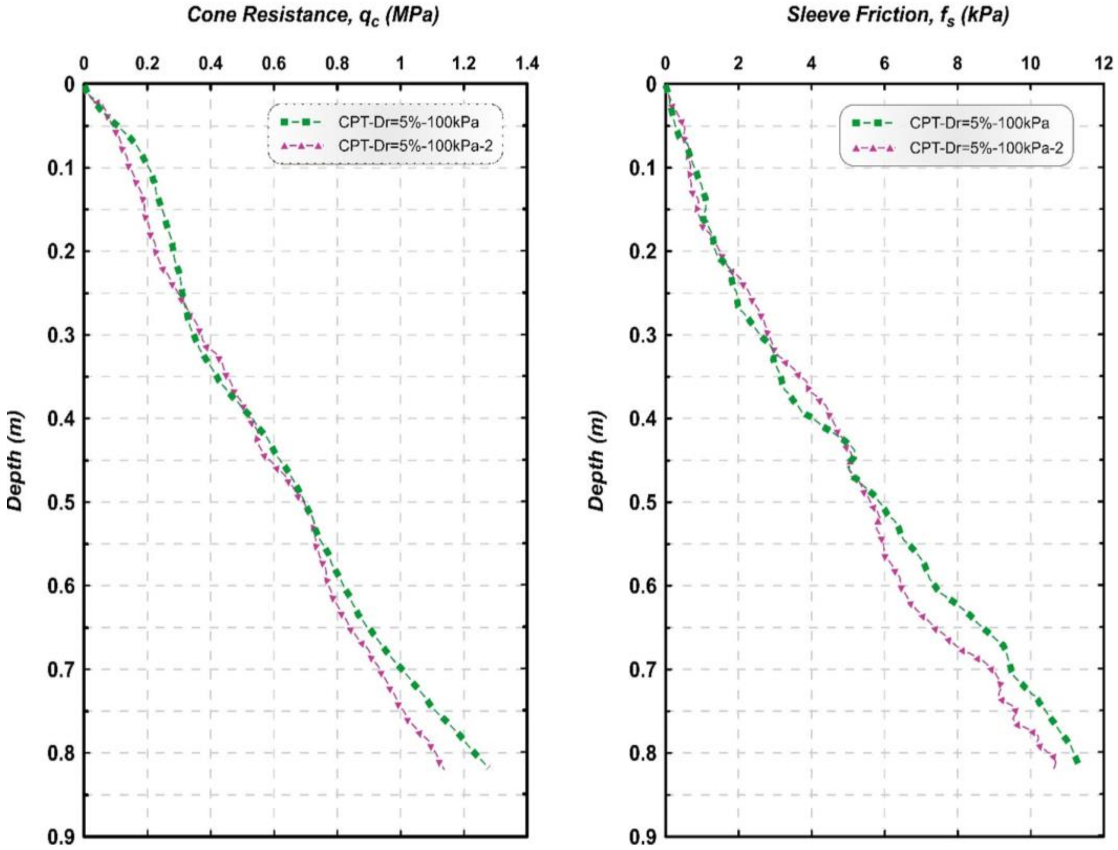
Dry Deposition (Esmailzade et al. 2022)

Repeatability

- Concrete drilled pile in FCV-AUT
- CPT result in FCV-AUT



Load–displacement curves (a) compression; (b) tension (Zarrabi & Eslami, 2016)



CPT Result a) cone resistance b) sleeve friction

(Esmailzade & Eslami, 2022)

Zare, M. and Eslami, A. (2014)

Study of deep foundation performances by frustum confining vessel (FCV)

M. Zare, A. Eslami,

Abstract

Physical modeling for study of deep foundations can be performed in simple chambers (1g), calibration chambers (CC), and centrifuge apparatus (ng). These common apparatus face certain limitations and difficulties. Recently, Frustum Confining Vessels (FCV) have been evolved for physical modeling of deep foundations and penetrometers. Shaped as the frustum of a cone, this device applies steady pressure on its bottom and creates a linear stress distribution along its vertical central core. This paper presents the key findings in FCV, as developed in AUT. The FCV has a height of 1200 mm, with top and bottom diameters of 300 and 1300 mm, respectively. By applying bottom pressure up to 600 kPa, the in-situ overburden stress conditions, equivalent up to 40 m soil deposits, become consistent with the embedment depth of commonly used piles. Observations indicated that a linear trend of stress distribution exists, and this device can create overburden stress in the desired control volume along the central core. Moreover, a couple of compressive and tensile load tests were performed on steel model piles driven in sand with a length of 750 mm, and different length to diameter (L/D) ratios between 8-15. Comparison between measured and predicted ultimate capacity of model piles performed in FCV demonstrate a suitable conformity for similar confinement conditions in the field. Therefore, the FCV can be considered as an appropriate approach for the investigation of piling geotechnical behavior, and the examination of construction effects.

Keywords: Deep foundation, Axial capacity, Physical modeling, Frustum confining vessel (FCV).

3

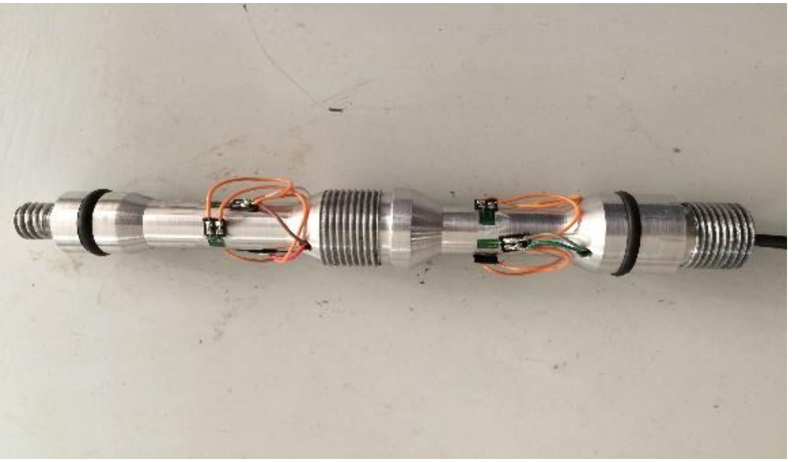
Various CPTs in FCV-AUT

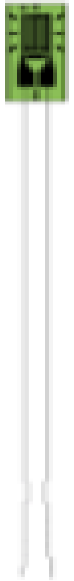
Properties of CPTs

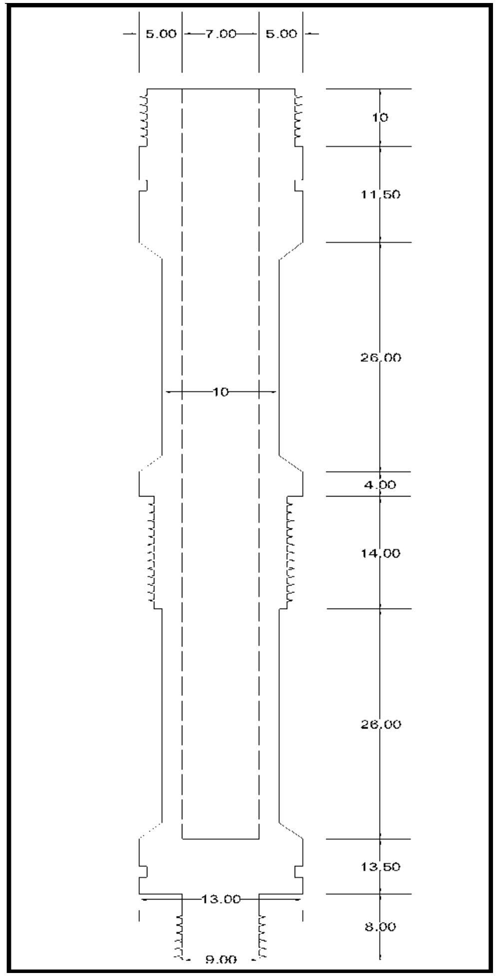
CPT TYPE	Diameter (cm)	Area (cm^2)	Tip Angle (Degree)	Sleeve friction height (cm)	Sleeve friction Area (cm^2)
CPT	3.57	10	60	13.38	150
Mini CPT	2.4	4.52	60	9.00	67.86
DCP	2	3.14	60	-	-

Properties of CPTs

- Made of Aluminum 7075
- Sensor of FLA-1-350-23







CPT& DCPT

1 Installed strain gauges

2 Consist of CP

3 Sleeve friction

4 Close up of CP, miniCP

Test Condition

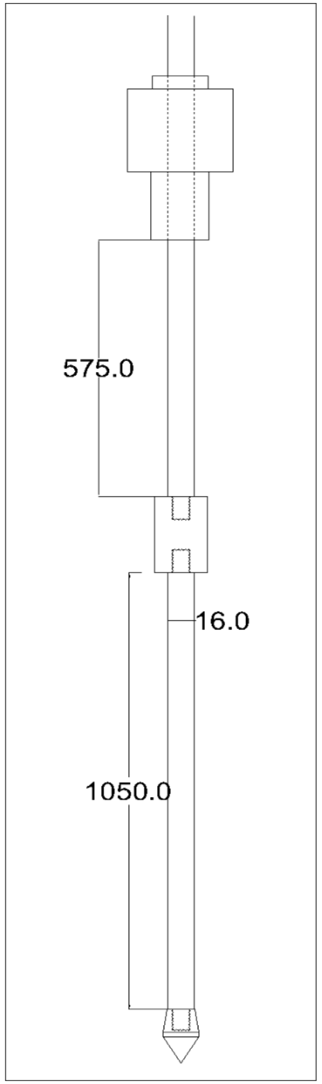
- Depth of 850mm
- Penetration rate of 3 – 10mm/s
- Bottom pressure of 0, 100, 200 kPa

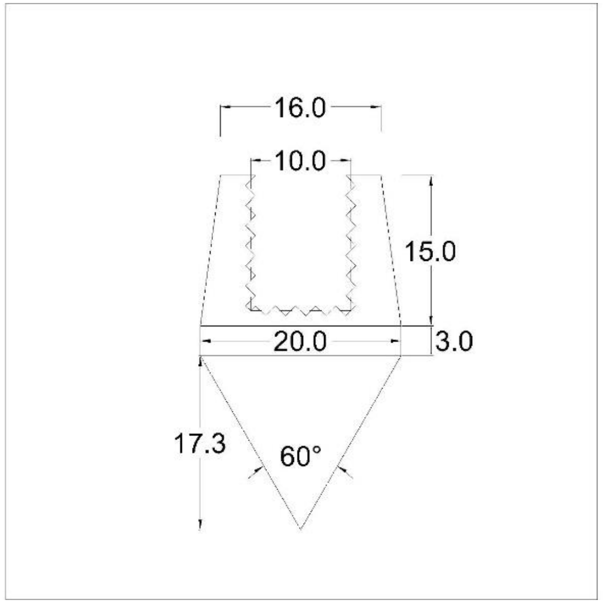
Properties

- Hammer Weight = 8kg
- Drop Height = 575 mm
- Cone diameter =20 mm
- Cone Angle = 60˚

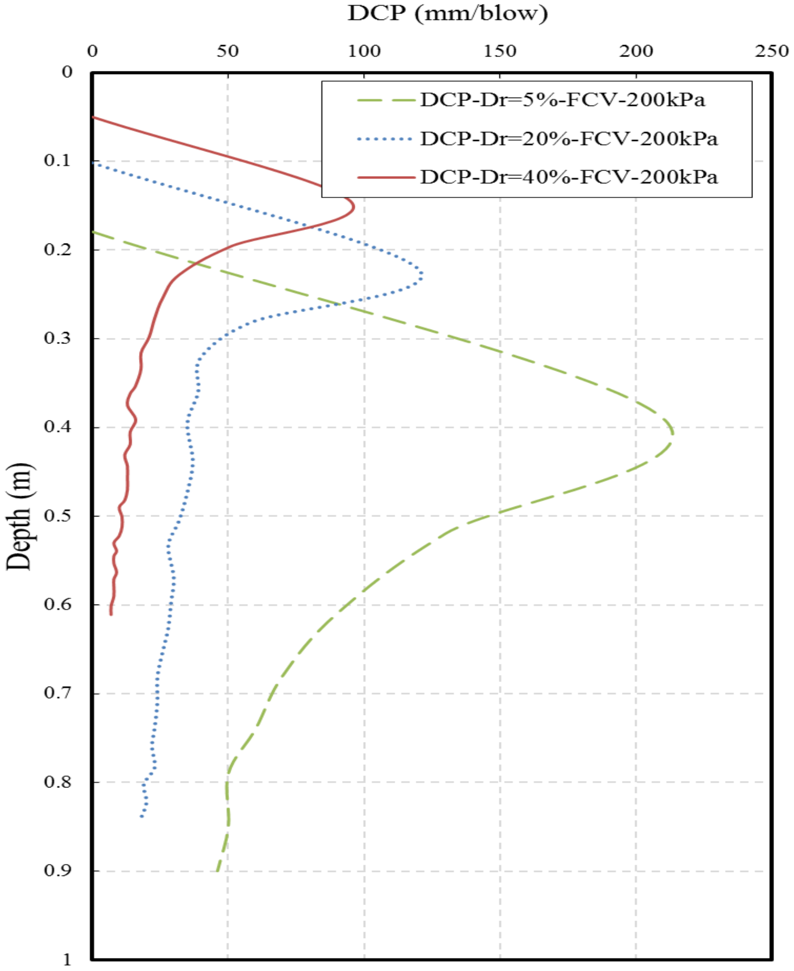
Output

$$PDI = \frac{P_{i+1} - P_i}{B_{i+1} - B_i} \qquad ({}^{mm}/_{blow})$$

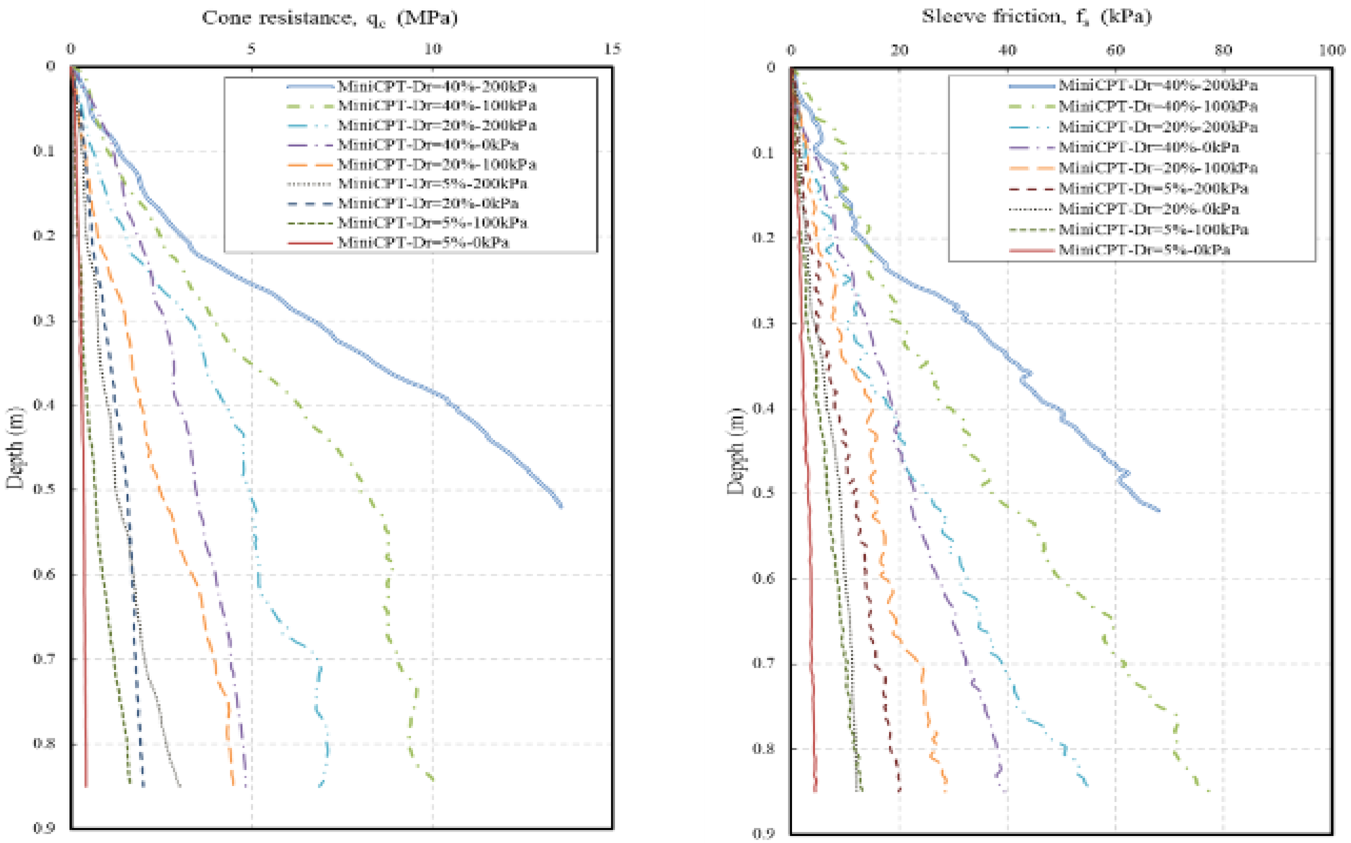




CPT Results



DCP Result at FCV-AUT



CPT Result at FCV-AUT

Esmailzade, M., Eslami, A., Nabizadeh, A., Aflaki, E. (2022)

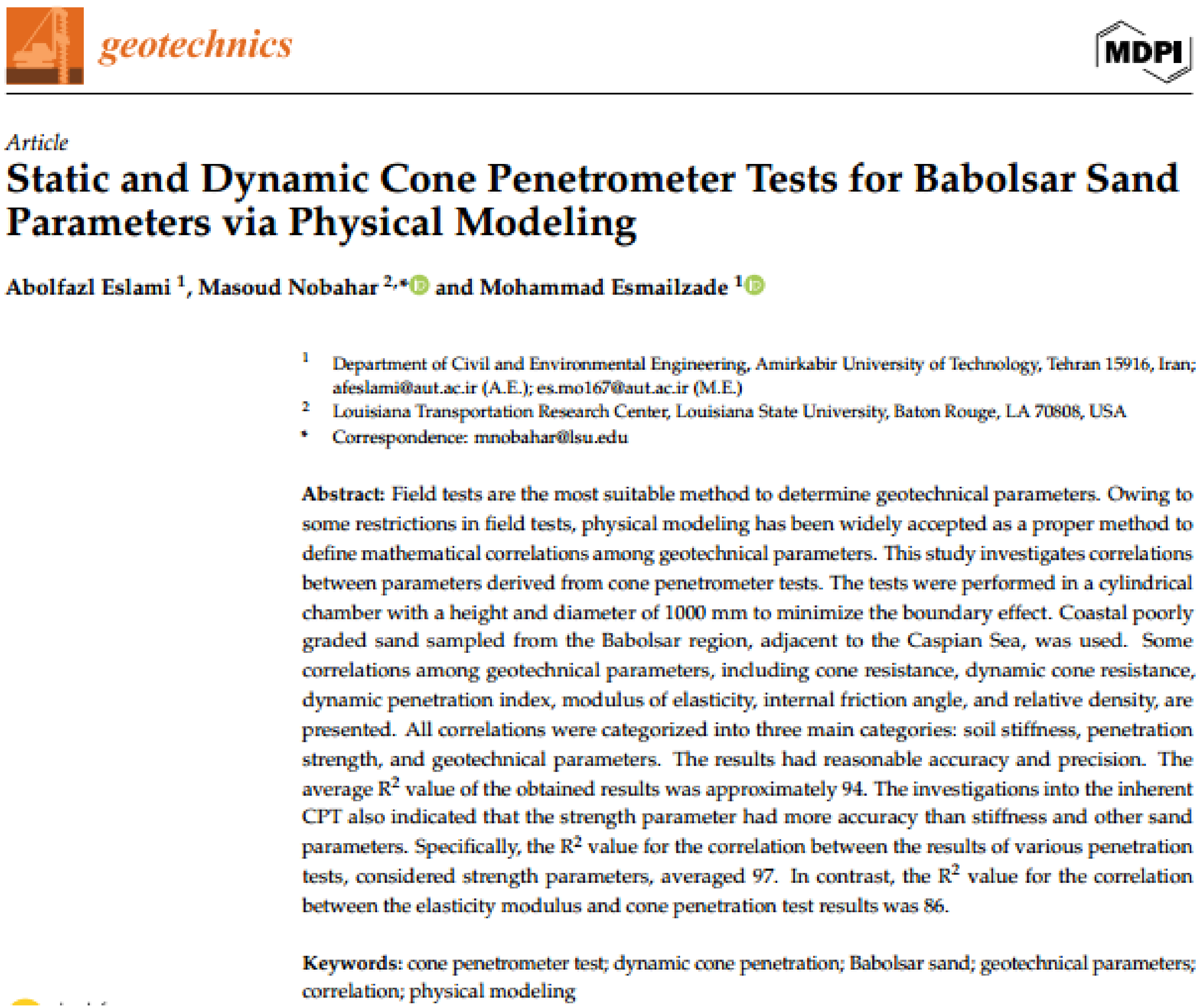
Effect of Cone Diameter on Determination of Penetration Resistance Using a FCV

Mohammad Esmailzade[1] · Abolfazl Eslami[1] · Ali Nabizadeh[2] · Esmail Aflaki[1]

Abstract

The cone penetration test (CPT) and dynamic cone penetration test (DCPT) are the most two efficient in-situ tests in geotechnical practice. Due to experimental test limitations, it is sometimes impossible to use cone penetrometer (CP) with standard dimensions via physical modeling, and the use of smaller size of CP is needed. The objective of this study has been to investigate the size effect of CPT on penetration resistance. The sand material collected from a coastal area of the Caspian Sea in Babolsar city. Frustum confining vessel (FCV) was used due to its ability in high stress physical modeling and forming approximately linear distributed stress in depth, which makes it one of the most suitable physical modeling apparatus for investigating DCP and CPT. In this research, two different CPs, a standard dimension (35.7 mm) and a smaller size (24 mm in diameter), and one standard DCP were employed to be tested in Babolsar sand. Results demonstrate that the cone resistance (qc) and sleeve friction (fs) values are greater in the miniCP compared to the standard cone. This trend goes more notable when either of relative density or vertical effective stress increases. However, the ratio of cone resistance or sleeve friction, for MiniCPT to standard CPT is constant with various values of vertical effective stress or relative density. Accordingly, the cone resistance and sleeve friction ratio for MiniCPT in comparison to CPT are greater almost 1.23 and 1.18, respectively. Also, the correlation values between qc with sand parameters, obtained from laboratory tests, relative density (Dr), porosity (e), and with dynamic cone penetration index (DPI) have been investigated and presented.

Eslami, A., Nobahar, M., & Esmailzade, M. (2024)


geotechnics
MDPI

Article

Static and Dynamic Cone Penetrometer Tests for Babolsar Sand Parameters via Physical Modeling

Abolfazl Eslami [1], Masoud Nobahar [2,*] and Mohammad Esmailzade [1]

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[2] Louisiana Transportation Research Center, Louisiana State University, Baton Rouge, LA 70808, USA
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Abstract: Field tests are the most suitable method to determine geotechnical parameters. Owing to some restrictions in field tests, physical modeling has been widely accepted as a proper method to define mathematical correlations among geotechnical parameters. This study investigates correlations between parameters derived from cone penetrometer tests. The tests were performed in a cylindrical chamber with a height and diameter of 1000 mm to minimize the boundary effect. Coastal poorly graded sand sampled from the Babolsar region, adjacent to the Caspian Sea, was used. Some correlations among geotechnical parameters, including cone resistance, dynamic cone resistance, dynamic penetration index, modulus of elasticity, internal friction angle, and relative density, are presented. All correlations were categorized into three main categories: soil stiffness, penetration strength, and geotechnical parameters. The results had reasonable accuracy and precision. The average R^2 value of the obtained results was approximately 94. The investigations into the inherent CPT also indicated that the strength parameter had more accuracy than stiffness and other sand parameters. Specifically, the R^2 value for the correlation between the results of various penetration tests, considered strength parameters, averaged 97. In contrast, the R^2 value for the correlation between the elasticity modulus and cone penetration test results was 86.

Keywords: cone penetrometer test; dynamic cone penetration; Babolsar sand; geotechnical parameters; correlation; physical modeling

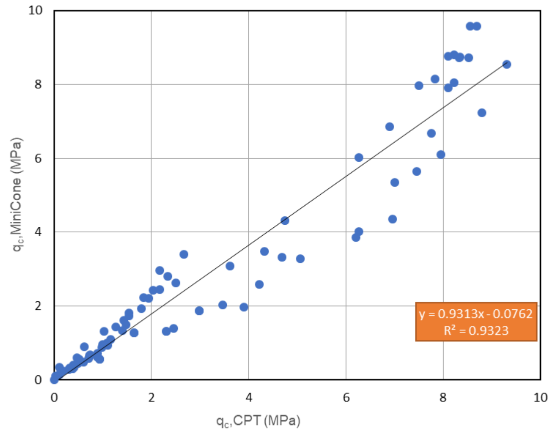
CPT & MiniCone

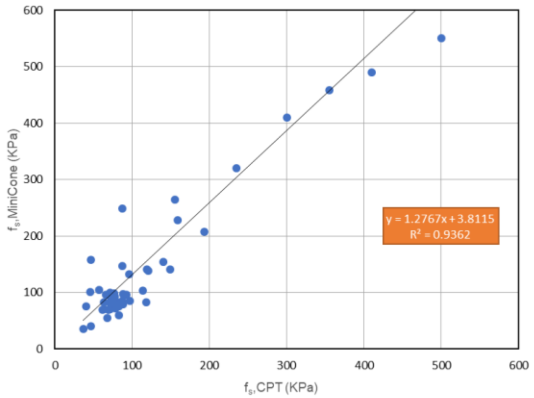
Cases study records summary

No.	Reference	Institution and Site	Cone diameter (mm)	Soil profile	Chamber type / Field	Measurement depth (m)	Research topics
1	Kerisel (1958)	Mexico	4.2, 11, 21.6	Sand	Field	7	Scale and Density
2	Lunne (1997)	North Sea, Norway	35.7, 43.7	Silty Sand	Field	40	Scale effect
3	Walid Khaled Eid (1987)	Virginia Polytechnic Institute, USA	23.2, 35.7, 43.7	Monterey Sand	CC	1.4	Boundary Condition
4	Abedin (1995)	The University of Newcastle, England	10	Sandy Clay	triaxial compression cell	0.2	Penetration Rate
5	Tumay (2001)	Highland Road Site, Louisiana, USA	15.9, 35.7	OC Clay	Field	10	Scale effect
6	Hird (2003)	University of Sheffield, England	11.2, 25.2	Kaolinite + Silt + Fine Sand	Flexible lateral boundary	0.4	Scale effect
7	Tufenkjian (2010)	Port Hueneme, USA	15.9, 35.7	Golden Flint Sand	Rigid Side Wall	1	Scale and Density
8	Khamehchiyan (2012)	Tarbiat Modares University, Iran	15.9, 35.7	Sand + Silt	CC	0.9	Scale and Density
9	Kim (2014)	Kongju University, South Korea	7, 10, 13	Silty Sand	Centrifuge	0.3	Scale effect
10	Eslami (2018)	AUT, Iran	15.9, 35.7	Babolsar Sand	FCV-AUT	0.9	Scale and Density

Eslami, A,. Karakouzian, M,. Shirani, S,. Ebrahimipour, A

MiniCone, CPT and Pile Correlations on Scale Effect Factors: Databased Approach

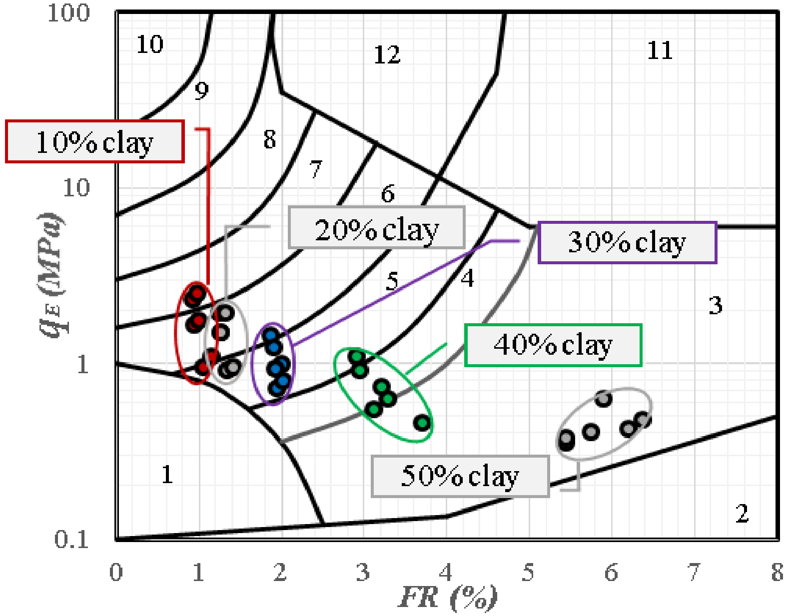




ABSTRACT

The Cone Penetration Test (CPT) contributes to pile design and analysis regarding geometry, installation effect and capacity components, including shaft and toe resistance. MiniCone, as an alternative to CPT sounding, has been used for performing in the field and laboratory investigations via physical modeling. More tests can be practically implemented through moderate equipment and soil mass, involving less error caused by boundary conditions. Furthermore, it can be used for on-situ testing, such as quality control, assessment of ground improvement and subgrade characterization. Using a database comprising MiniCone and CPT records in the field and physical modeling with a variety of cone diameters, the case study records have been obtained from 140 tests compiled from 26 sources reporting data. The sources include the results of 20 physical modelings and the field data from six sites in 10 countries. The data comprises MiniCone and CPT measurements (q_c and f_s). The different cones are performed in sandy, silty sand and clayey soils via simple chambers (1g), calibration chambers (CC) and frustum confining vessels (FCV). Also, correlations extended through the machine learning (ML) approach between penetration records regarding scale effect, physical modeling type, cone diameter, penetration rate and soil density. First, 40% of the data were utilized for training the machine, and then the others were used to provide the correlations. Appropriate correlation coefficients smaller than unity are also used to relate q_c and f_s to pile toe and shaft capacities, respectively. Correlations and scale effects in geotechnical practices between MiniCone, CPT and Pile have been reviewed and discussed.

Soroush, S., Eslami, A., & Nobahar, M. (2024)



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TECHNICAL PAPER

Various Approaches for Assessment of Crude Oil Mixed Soil Behavior Using Cone Penetration Test Records

Alireza Soroush Hagh[1] · Abolfazl Eslami[1] · Masoud Nobahar[2]

Accepted: 14 August 2024 / Published online: 18 November 2024

Abstract
The study proposed a new classification index, the Crude Oil Classification Index, to detect changes in soil behavior due to crude oil, water, and clay. The index was calculated based on water and oil composition. The small cone tests and physical modeling techniques were used. Data from cone tests were compared with observations from physical modeling methods. Significant changes in soil properties including density, cohesion, and deformation resistance were observed due to crude oil. The research classified soil mixed with crude oil and evaluated trends in cone tip resistance and sleeve resistance parameters. The results indicated a decrease in soil strength and stiffness with increasing crude oil content.

Keywords Crude oil mixed soils · Physical modeling · Soil Behavior Classification Index (I_c) · Mini cone

4

Piling Testing

Special Piling Testing via FCV-AUT

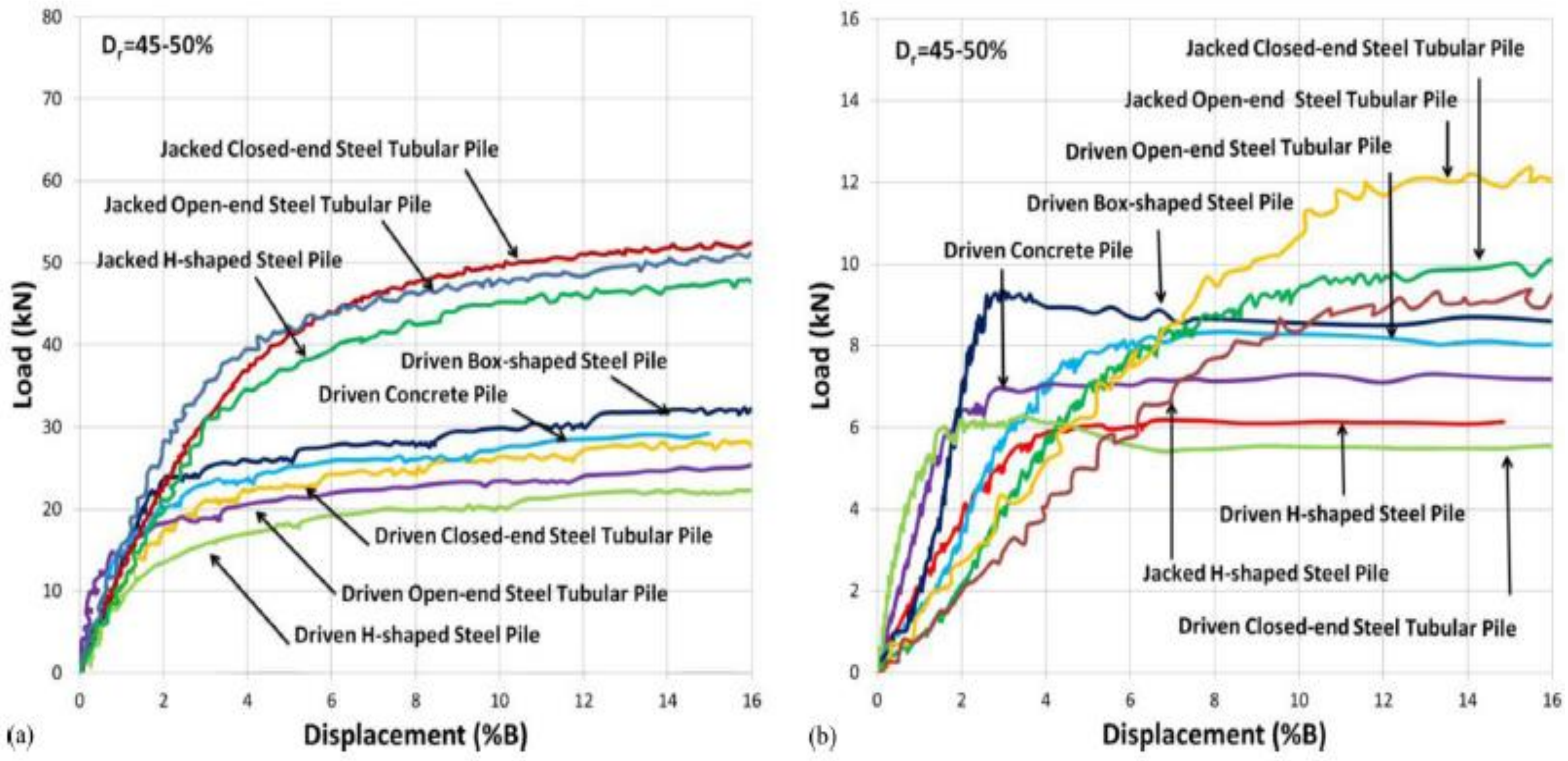
- Drilled Displacement Piles (DDP)
  - DeWaal
  - Tsubasa
- Post Grouted Piles (PGP)
  - Tip Post Grouted
  - Shaft Post Grouted
- Unconventional Piles
  - Self Expanded Piles
  - Wing Piles
  - Bubble Piles
- Helical Piles

Conventional Piles

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

a) drilled shaft; (b) precast-in-place pile; (c) precast pile; (d) box-shaped pile; (e) H-shaped pile; (f) closed-ended pile; (g) open-ended pile; (h) helical pile (S/D = 3); (i) helical pile (S/D = 2); (j) helical pile

Conventional Piles



Load-displacement diagrams of jacked-in and driven piles: (a) Compression; (b) Pullout

Zarrabi, M. and Eslami, A. (2016)

Behavior of Piles under Different Installation Effects by Physical Modeling

Mohammad Zarrabi & Abolfazl Eslami

Abstract

Many factors influence the axial bearing capacity and performance of deep foundations embedded in sand deposits. Among these factors, the installation method is of great importance. The objective of this study was to investigate the construction effects on pile performance via physical modeling. The frustum confining vessel of Amirkabir University of Technology (FCV-AUT) was employed for this purpose. Six different installation methods were studied: jacking, drilling and grouting, driving, screwing, drilling and placing, and post-grouting. Up to 30 axial compressive and tensile load tests were carried out on different piles on Babolsar sand, from the northern coast of Iran, with relative densities of 45% to 50% within the FCV-AUT. Experimental results show that among different pile installation methods, jacked and precast-in-place piles had the greatest and lowest capacities, respectively. Moreover, the performance results of the different pile types in the FCV-AUT indicate that the axial bearing capacity of piles can be boosted by modification of the installation method. These modifications result in a reduction of the number and size of piles, and consequently result in savings in construction costs and time requirements.

keywords: Deep foundations; Installation effects; Physical modeling; Axial bearing capacity; Frustum confining vessel (FCV).

Tip Post-grouted Piles

- There are several method accomplished to decrease the effect of installation procedure and increase bearing capacity.

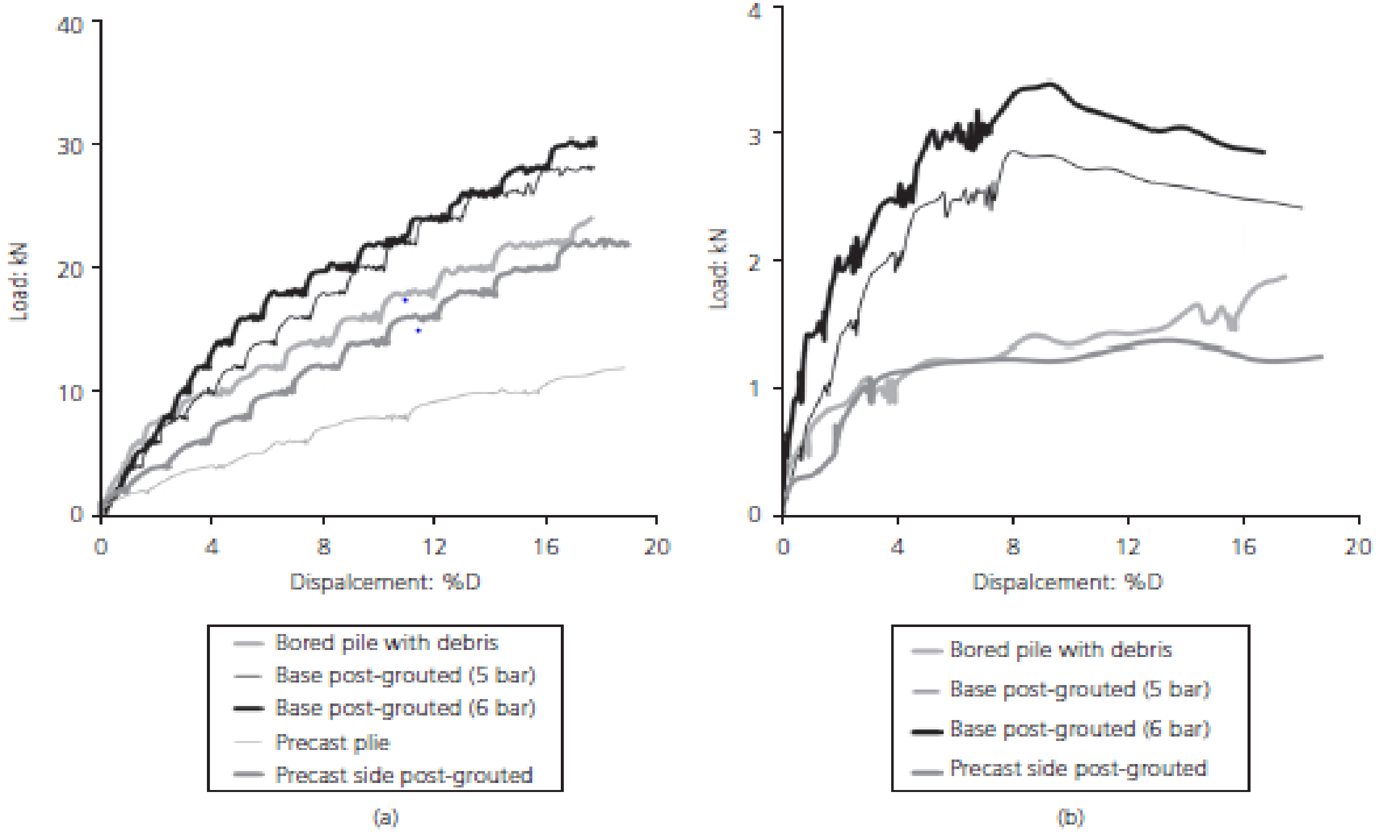
Formed Bulb Height (mm)	Formed bulb Diameter (mm)	Bottom Pressure (Bar)	Pile displacement (mm)	Injected Volume Grout (cc)	Injection Pressure (Bar)	Pile Name
-	-	2	-	-	4	PG4
45	115	2	14	600	5	PG5
50	110	2	5.17	600	6	PG6-1
50	110	2	10	600	6	PG6-2
40	120	2	17	600	6	PG7

Shaft Post-grouted Piles

Bottom pressure (Bar)	Injected Volume Grout (cc)	Injection Pressure (Bar)	Type pile
2	-	2 - 4	PGS1
2	-	4	PGS2
2	-	4 - 9	PGS3
2	1500	4	PGS4
2	6000	2	PS

Shaft post-grouted precast-in-place pile

Post-grouted Piles Results



Load–displacement graph of post-grouted piles: (a) compression test and (b) tension test

Karimi, A.H. & Eslami, A., (2017)

Physical modelling for pile performance combined with ground improvement using frustum confining vessel

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ABSTRACT

Piles were physically modelled using a frustum confining vessel device made in Amirkabir University of Technology, to examine the effect of density and soil improvement from grouting on piles. Piles scales were ranged from 13 to 19. The results of pile tests on Babolsar sand under different compaction (density) states were used to study the effects of soil improvement on pile performance. Increasing the soil pile interaction by post-grouting of the base and sides of the piles also improved the soil capacity. Post-grouting of the base was applied for bored piles and post-grouting of the side was applied for precast concrete piles. According to the results by soil densification, capacity increase from loose to medium state is more than from medium to dense soils. Bored concrete piles showed a greater increase in bearing capacity than steel piles under compression testing as the capacity reduction factors due to installation were minimized. In tensile tests, the capacity increase of open-ended steel piles is more than that of concrete piles because of more surfaces of soil–pile interaction. Post-grouting increased bored and precast concrete pile performance by enhancing soil–pile interaction and soil densification around the pile.

Karimi, A.H., Eslami, A., Zarrabi, M. & Khazaei, J. (2017)

Study of pile behavior by improvement of confining soils using frustum confining vessel

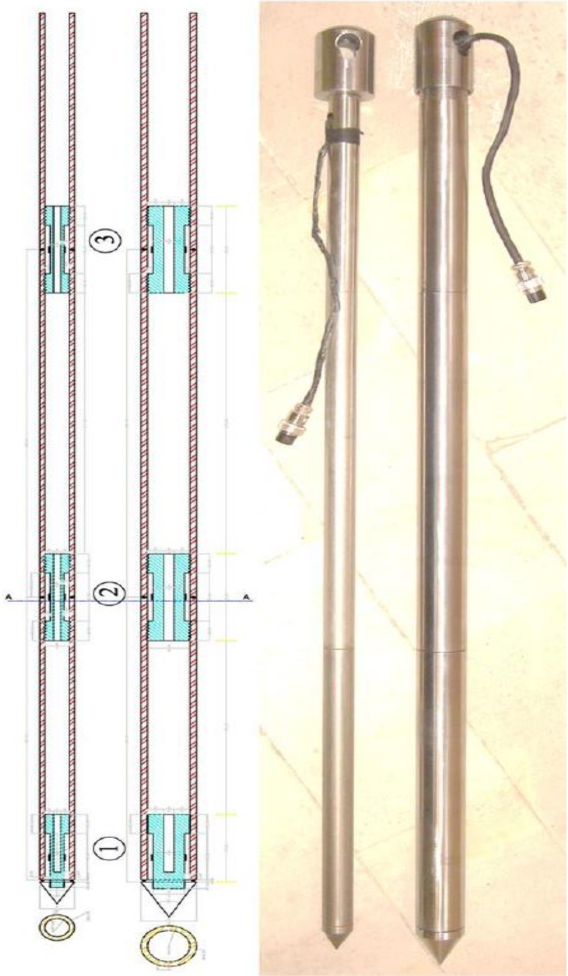
A.H. Karimi, A. Eslami, M. Zarrabi and J. Khazaei

Abstract

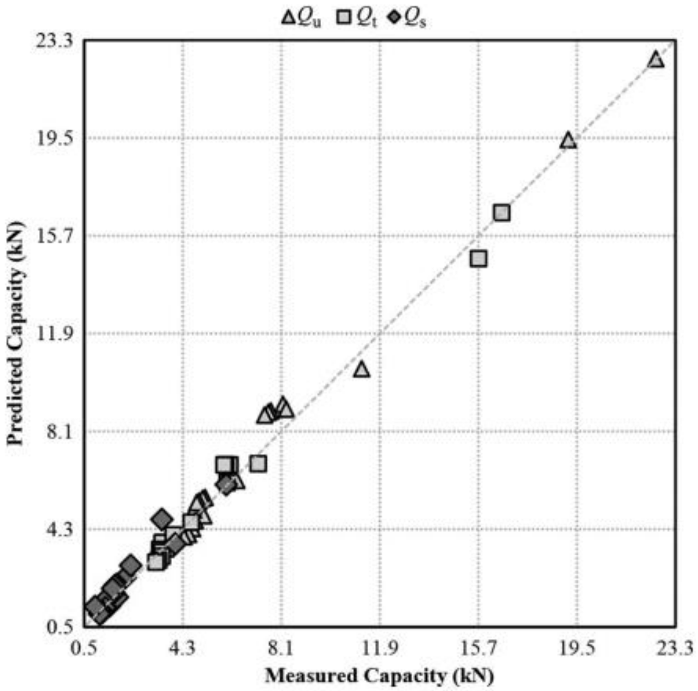
A physical modeling apparatus made at Amirkabir University of Technology (FCV-AUT), called Frustum Confining Vessel, is employed to determine the effects of soil improvement on piles performance. The FCV-AUT is capable of linearly modeling the existing overburden stresses in the eld. Three types of Babolsar sand with relative densities between 20% and 70% were examined in these tests. Results of compression and tensile load tests on seven piles, with the embedment length to diameter ratio (D/B) of 9, were used to evaluate the effects of soil improvement methods of soil densification as well as post-grouting on the piles performance. The results show that the increased bearing capacity by soil compaction from loose to medium state is greater than that of the medium to dense state. This increase has been observed to be a function of pile construction methods and pile tip conditions. Also, tip and/or side post-grouting enhanced the performance of bored and concrete precast piles by increasing soil-pile interaction and its bearing capacity. The results of pile load tests carried out on the FCV-AUT have been observed to be well-aligned with the static bearing capacity calculations based on the API method.

KEYWORDS: Pile behavior; Ground improvement; Physical modeling; Frustum confining vessel; Soil compaction; Post-grouting.

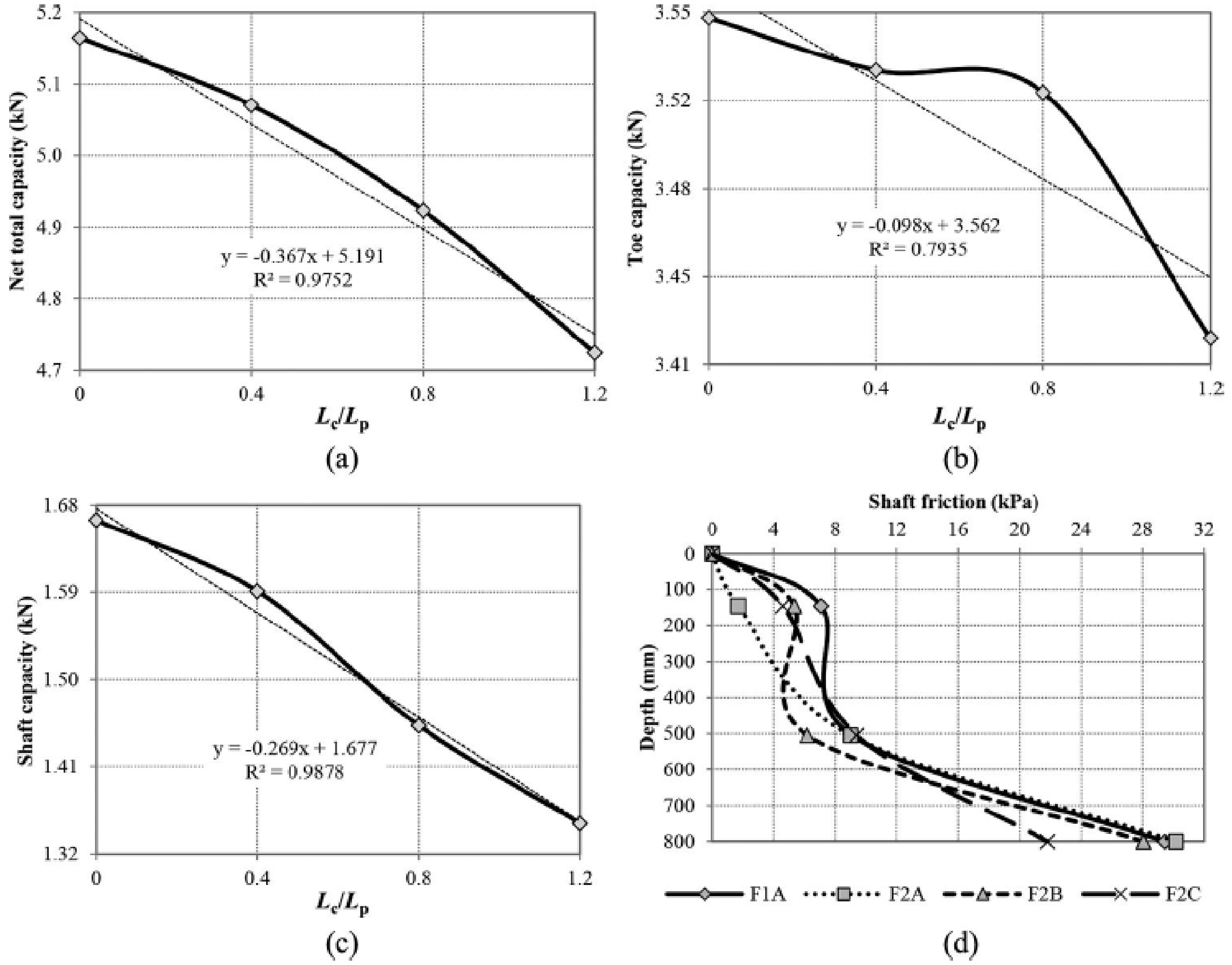
Piles in oil-contaminated



Piles in oil-contaminated



Comparison between calculated and measured bearing capacities of pile



Mohammadi, A., Ebadi, T., Eslami, A. (2019)

Axial compressive bearing capacity of piles in oil-contaminated sandy soil using FCV

Amirhossein Mohammadi, Taghi Ebadi, Abolfazl Eslami, and Sjoerd E. A. T. M. van der Zee

Abstract

Oil and its derivatives contaminate many soils and not only affect their chemical and biological properties but also their geotechnical properties. As oil contamination may deteriorate the functioning of piles, this paper addresses the effects of oil contamination on soil–pile interactions. Axial compressive bearing capacities of two close-ended, instrumented piles were investigated in different oil-contaminated sand using frustum confining vessel. Three different oils (gasoil, crude oil, and used motor oil) at different contamination levels were considered and using some strain gauges, the toe, shaft, and the net total bearing capacity of piles, as well as load distributions along the pile length, were derived. The results show that the presence of oil between soil particles has considerable adverse effects on bearing capacities of model piles, especially the shaft bearing capacity. The oil viscosity and percentage, as well as the contaminated sand bed thickness around the piles, are the most influential parameters. The higher the oil viscosity and oil content, the lower the values of the piles' bearing capacities in comparison to the uncontaminated sand. With some modifications on the bearing capacity parameters of CFEM method, a good agreement was observed between measured and calculated bearing capacity values.

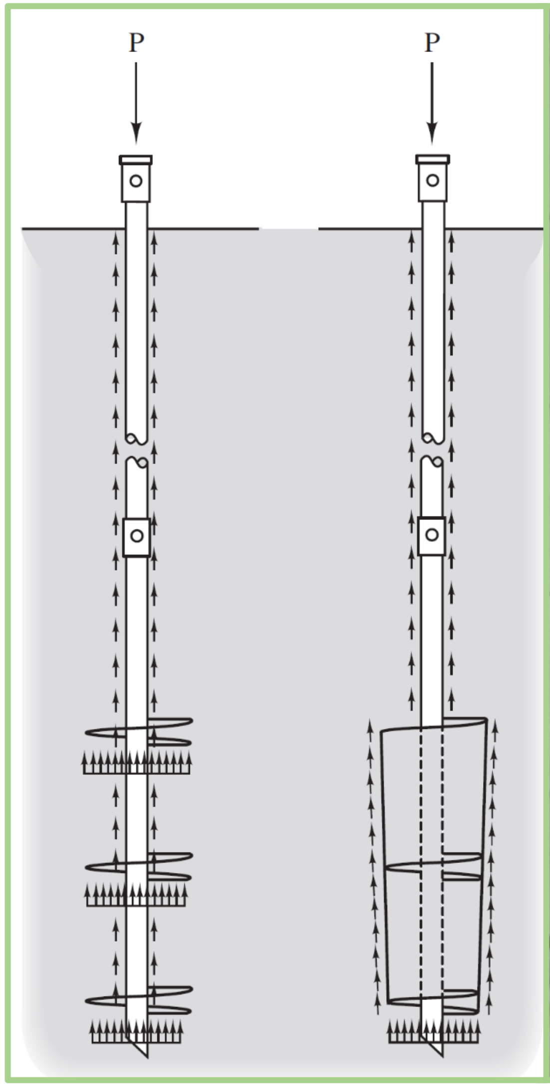
Keywords:

Axial bearing capacity; frustum confining vessel; oil-contaminated soil; pile; sand

Helical Piles

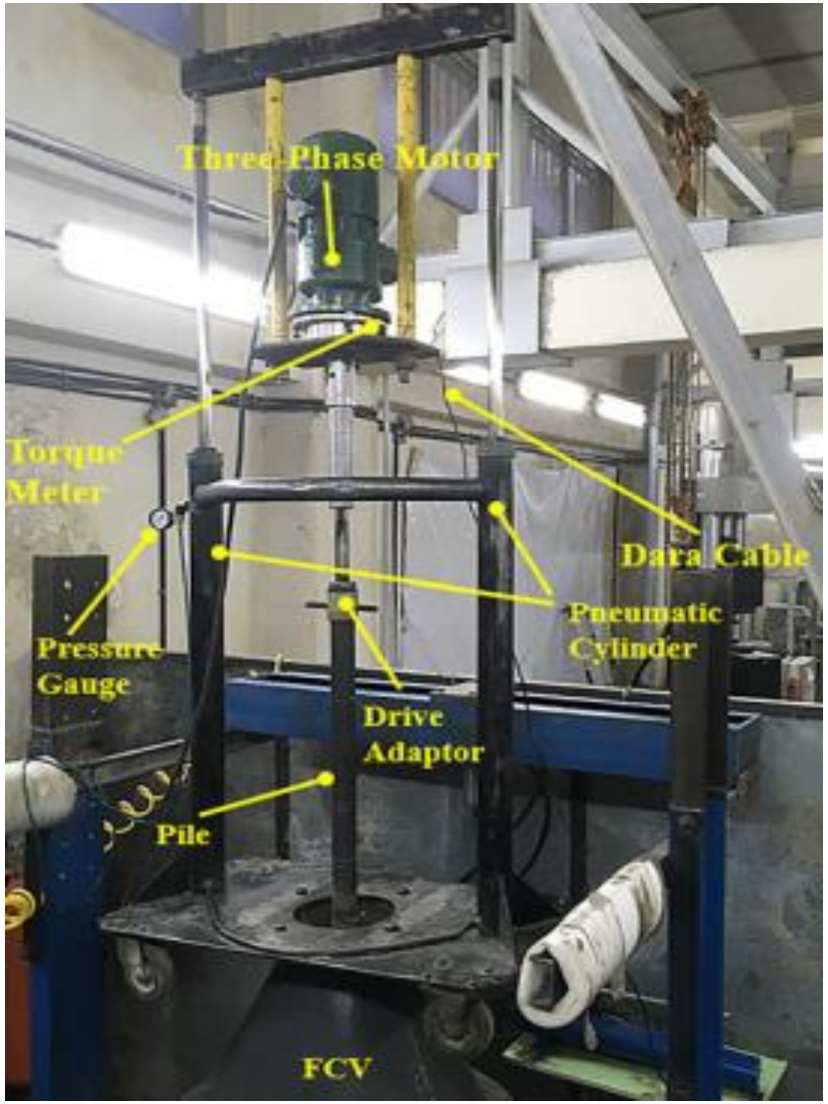
Failure mechanisms:

- Individual
- Cylindrical

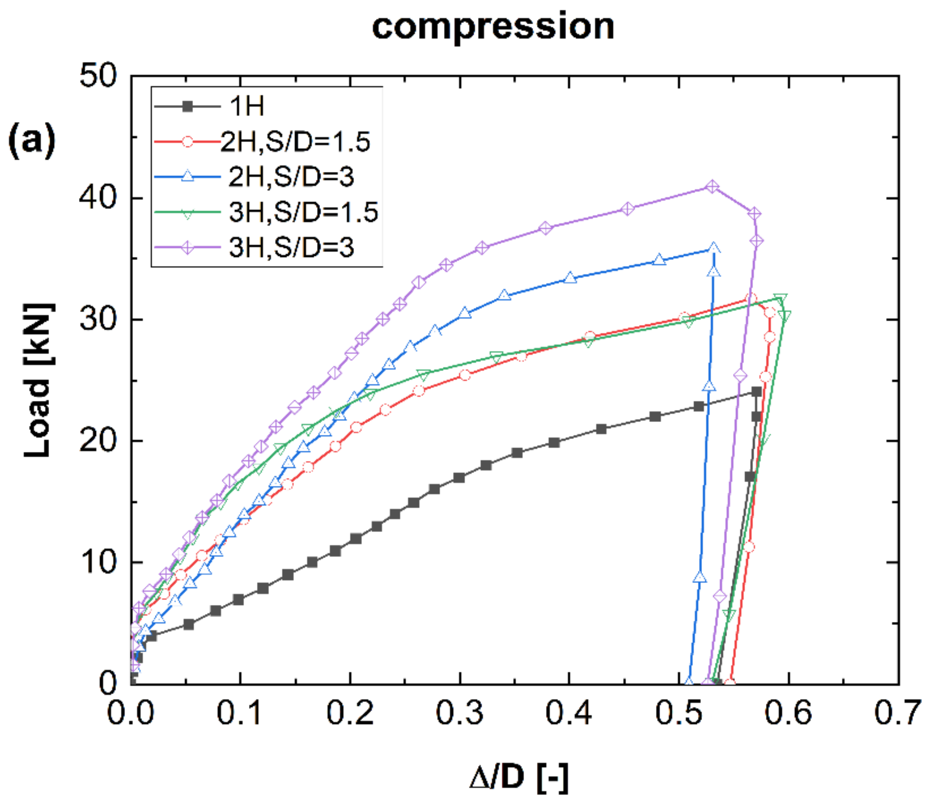


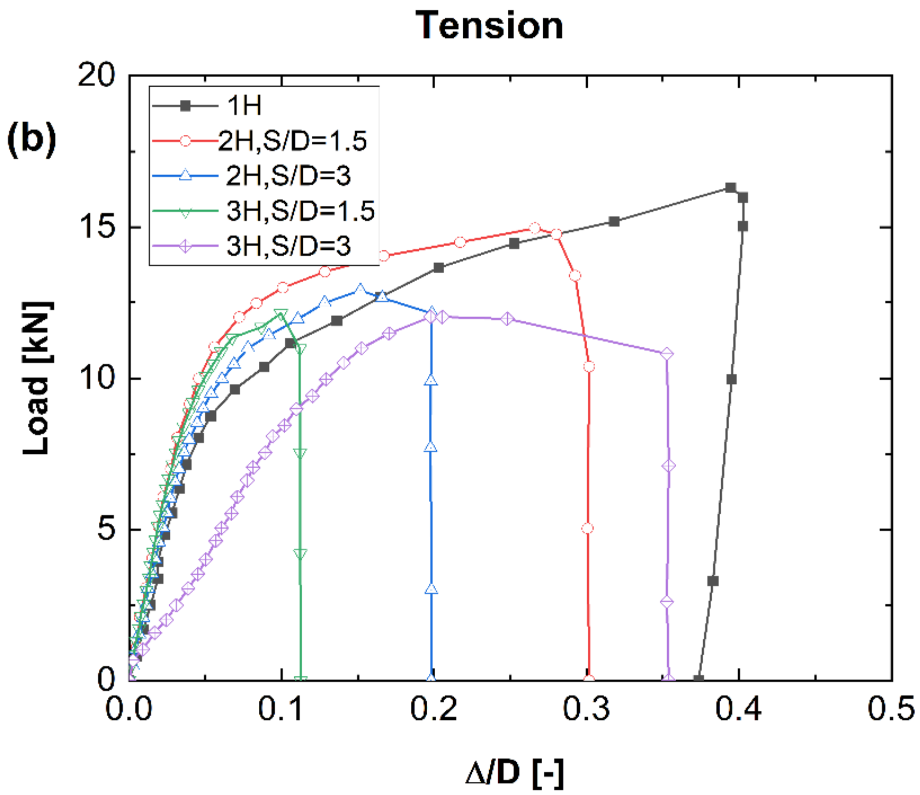
Helical Piles Installation

- Design and construction of torque motor



Helical pile's Results





Load- displacement curve of helical pile in different number and space ratio

Khazaei, J. & Eslami, A. (2016)

Advances in Science and Technology
Research Journal
Volume 10, No. 31, Sept. 2016, pages 8–22
DOI: 10.12913/22998624/64113

Research Article

BEHAVIOR OF HELICAL PILES – AS A GEOENVIRONMENTAL CHOICE – – BY FRUSTUM CONFINING VESSEL

Javad Khazaie[1], Abolfazl Eslami[1]

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Published: 2016.09.01

ABSTRACT

Helical piles are environmentally friendly and economical deep foundations that, due to environmental considerations, are excellent additions to a variety of deep foundation alternatives available to the practitioner. Helical piles performance depends on soil properties, the pile geometry and soil-pile interaction. Helical piles can be a proper alternative in sensitive environmental sites if their bearing capacity is sufficient to support applied loads. The failure capacity of helical piles in this study was measured via an experimental research program that was carried out by Frustum Confining Vessel (FCV). FCV is a frustum chamber by approximately linear increase in vertical and lateral stresses along depth from top to bottom. Due to special geometry and applied bottom pressure, this apparatus is a proper choice to test small model piles which can simulate field stress conditions. Small scale helical piles are made with either single helix or more helixes and installed in fine grained sand with three various densities. Axial loading tests including compression and tension tests were performed to achieve pile ultimate capacity. The results indicate the helical piles behavior depends essentially on pile geometric characteristics, i.e. helix configuration and soil properties. According to the achievements, axial uplift capacity of helical model piles is about equal to usual steel model piles that have the helixes diameter. Helical pile compression bearing capacity is too sufficient to act as a medium pile, thus it can be substituted other piles in special geoenvironmental conditions. The bearing capacity also depends on spacing ratio, S/D, and helixes diameter.

Keywords: helical pile, environment, geoenvironment, frustum confining vessel, physical modeling, bearing capacity.

Khazaei, J. & Eslami, A. (2016)

International Journal of Geography and Geology
2016 Vol. 5, No. 9, pp. 167-181
ISSN(e): 2305-7041
ISSN(p): 2306-9872
DOI: 10.18488/journal.10/2016.5.9/10.9.167.181

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GEOTECHNICAL BEHAVIOR OF HELICAL PILES VIA PHYSICAL MODELING BY FRUSTUM CONFINING VESSEL (FCV)

Javad Khazaei[1] --- **Abolfazl Eslami**[2]†
[1]*Ph.D. Candidate, Dept. of Civil and Environmental Engineering, Amirkabir University of Technology (AUT), Tehran, Iran*
[2]*Associate Professor, Dept. of Civil and Environmental Engineering, Amirkabir University of Technology (AUT), Tehran, Iran*

ABSTRACT

Helical piles including central shaft and helices performance depends on soil properties, soil-pile interaction and the pile geometry. Failure due to helical piles axial loading can occur either in individual helix vicinity or cylindrical shear surface. So, the failure type can affect on piles behavior and also their capacity. Static analysis, in-situ testing records and also static or dynamic tests can be used for calculating of helical piles capacity. In this study we focused on an experimental method that carried out by frustum confining vessel (FCV) to investigate geotechnical behavior of helical piles. The FCV has been used because of its special geometry that makes a linear distribution of vertical and lateral stresses along its vertical line. Thus, it can simulate field conditions as well. Accordingly, several tests performed on small scale helical piles are made of 4 mm thick steel plate with 750 mm length, 32 mm shaft diameter and 64 to 89 mm helices diameter. According to the achievements, helical piles behavior essentially depends on pile geometric characteristics and in addition test results demonstrated the bearing capacity of helical model piles depends on spacing ratio, S/D, and helices diameter. Results also, indicated helical model piles can bear axial uplift loads about equal of usual steel model piles that have the helices diameter and in compression their bearing capacity is too sufficient to act as a medium pile.

Keywords: Helical pile, Frustum confining vessel (FCV), Physical modeling, Bearing capacity, Geotechnical behavior, Deep foundation.

Hejazi, S., Ghareh, S,. Eslami, A. & Ghanjiyan, N. (2021)

The experimental investigation of the behavior of executed piles model with applied torque in Frustum Confining Vessel (FCV-AUT)

Saeed Hejazi Rad, Soheil Ghareh, Abolfazl Eslami, Navid Ganjian

Abstract

A deep foundation is applied to transfer the load of tall and large structures to the underlying soil layers with a sufficient strength. Over the last few decades, a new type of piles has been executed in developed countries using torque with the development of hydraulic devices which can create high torques. Due to the new emergence of these deep foundations, the scope of studies in this regard are limited. Thus, studying the behavior of these foundations can increase the breadth of their application in other countries while creating a better understanding of their behavior. In the present research, some models of this type of pile have been made and studied using laboratory equipment and static loading. Execution of drilled displacement and helical piles in the FCV-AUT device as well as running static compression and tension load tests were done according to ASTM D1143 and ASTM D3689 standards. Experiments on the executions have been studied in two modes of density, a) relative density of 20 to 25% and b) relative density of 45 to 50%. Accordingly, drilled displacement pile has a good performance in terms of compression and tension bearing capacity compared to other piles, while the required installation torque for this pile shows higher values.

Keywords: Deep foundation behavior – drilled displacement pile - helical pile – Installation torque - Physical modeling

Hejazi, S., Ghareh, S,. Eslami, A. & Ghanjiyan, N. (2021)

Innovative Infrastructure Solutions (2021) 6:188
https://doi.org/10.1007/s41062-021-00557-2

TECHNICAL PAPER

Check for updates

Experimental and field studies on the behavior of drilled displacement piles

Saeed Hejazi Rad[1] · Soheil Ghareh[2] · Abolfazl Eslami[3] · Navid Ganjian[1]

Received: 17 March 2021 / Accepted: 29 May 2021 / Published online: 17 July 2021

Abstract

Piles or deep foundations are elements for transferring the load of structures to the substructure and soil layers with more suitable conditions to guarantee the stability of the structure and provide proper service by them. In this regard, the driven and bored piles are commonly used, but high noise and vibration of the driven piles, as well as difficulties and limitations in implementation of the bored piles, have led to the use of a new alternative type of piles installed in the soil using torque and a small amount of compressive axial force. Helical and drilled displacement piles can be mentioned as new types of these piles. Considering the increasing use of these piles, still a few studies have been conducted on them and there is a need for further research on their behavior in different soils and conditions. Therefore, in the present study, in two field and experimental sections, behavior of these piles was evaluated by performing tensile and compressive loading tests. Three models of helical, Tsubasa, and drilled displacement pile were implemented and loaded in experimental section in the frustum-confining vessel of the Amirkabir University of Technology (FCV-AUT) and were compared with the previous works in field section. Our results revealed that drilled displacement pile had better performance than other piles under tension and compression, and it had harder behavior and better capacity than the other two piles in both experimental and field conditions. Also, the required torque of this pile had higher values compared to other piles.

Keywords Drilled displacement piles · Helical piles · Physical modeling · Static loading · Frustum-confining vessel of the Amirkabir University of Technology (FCV-AUT)

Safikhani, H., Eslami, A. & Ganjian, N. (2021)

Laboratory Study of the behavior of Helical piles under tension and pressure loading Using the FCV

Hossein SafiKhani [1], Abolfazl Eslami [2] *, Navid Ganjian [3], Amin Bahmanpour [4]

1- Ph.D. student of Geotechnical Engineering, Islamic Azad University, Science and Research Branch, Tehran, Iran
2. Professor, Amirkabir University of Technology, Tehran, Iran
3- Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran
4- Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran

ABSTRACT

In recent years, the use of Helical piles has become prevalent in the foundation of marine structures exposed to the reciprocal waves of seawater. Moreover, these foundation systems have received particular attention due to several influential parameters, including the limited required time for installation and the ability to be immediately loaded after it. The present study investigates the behavior of three different helical piles under tensile and compressive loading via Frustum Confining Vessel available at Amirkabir University of Technology (FCV-AUT). The under-study piles were single, double, and triple-helix with diameters of 70 and 90 mm and distance ratios of 1.5 and 3. These piles were installed in Bandar Anzali sand, regarding two loose and medium densities by adding 4% humidity. The applied bottom pressure of FCV-AUT was 200 kPa. The results indicated that the helical pile bearing capacity was increased due to soil improvement and densification during its special installation procedure. However, the repeated compressive and tensile loading reduced the capacity of helical piles.

ARTICLE INFO

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Revise Date: 17 November 2020
Accept Date: 19 January 2021

Keywords:
Helical piles
FCV physical modeling
Bearing capacity
Tension loading
Compression loading
Reciprocal loading

Numerical Modeling

Bearing capacity of tested tri-helix pile

Test no.	Soil condition	Relative density (Dr)		Measured bearing capacity (kN)	Numerical estimation (kN)	Ratio
State 1						
1	Moist sand $W=4\%$	Loose	20–25%	23.5	16.9	0.72
2		Medium	45–50%	36.1	32.2	0.89
3		Dense	65–70%	50	45.8	0.92
State 2						
4	Saturated sand	Loose	20–25%	6.3	4.3	0.68
5		Medium	45–50%	14.9	18.1	1.21
6		Dense	65–70%	20.2	24.6	1.22

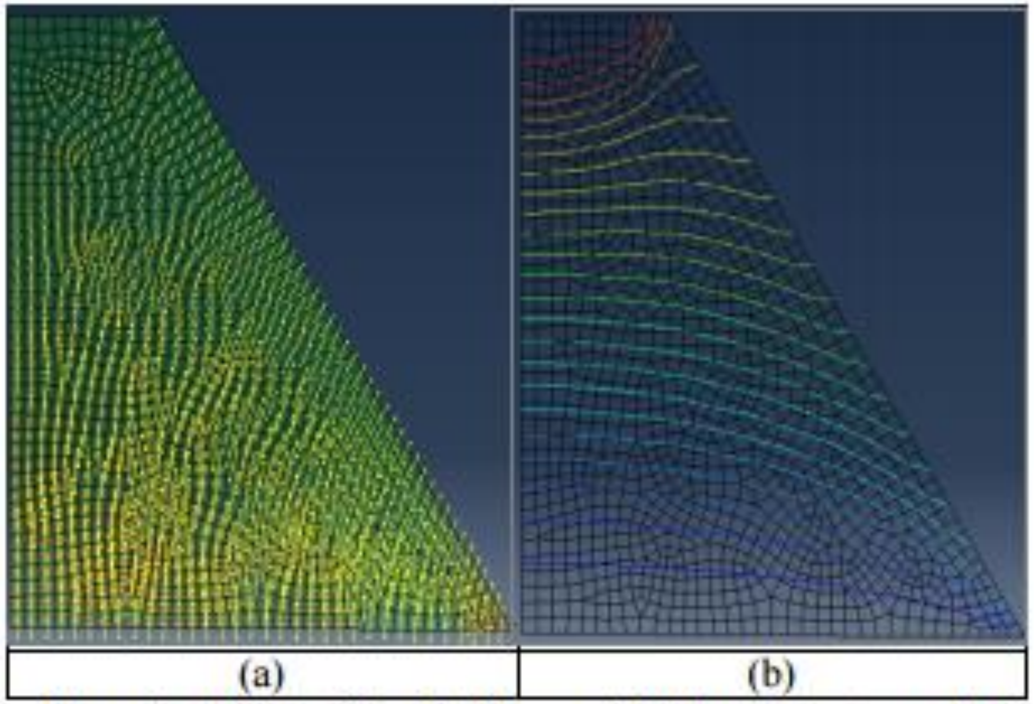

Figure 3: (a) Max. Principle Stress and (b) Isosurface stress plot for new FCV apparatus

Jassim, A., Ghanjiyan, N. & Eslami, A. (2022)

Innovative Infrastructure Solutions (2022) 7:280
https://doi.org/10.1007/s41062-022-00877-x

TECHNICAL PAPER

Check for updates

Design and fabrication of frustum confining vessel apparatus for model pile testing in saturated soils

Ali Jassim[1] · Navid Ganjian[1] · Abolfazl Eslami[2]

Received: 19 November 2021 / Accepted: 18 June 2022

Abstract
Offshore and marine engineering has developed rapidly, mainly due to the growing demand from the oil and gas industry for research and construction in deep-sea areas. Consequently, the need for research on the behavior of piles in saturated and partial saturated soils has also arisen. Frustum confining vessel (FCV) is a relatively new device for physical modeling, which was first introduced in 1996. In this research, a comprehension study was conducted on the optimum dimensions of the FCV apparatus with the aim of considering fabrication. To assess the performance of the models, ABAQUS software was adopted. By comparing the performance of the generated models, the optimum dimensions were selected and the apparatus was fabricated. All the flange connections were sealed to be able to conduct pile tests in saturated soils. The present apparatus is the first FCV device built with the capability of testing in saturated soils, to the best of the author's knowledge. Finally, to assess the performance of the device, the axial bearing capacity of a multi-helix pile in both moist and saturated conditions with different relative density was studied through experiments. Results indicate that the present FCV apparatus could effectively model the scaled condition of the soil and is capable of testing in saturated conditions. Results indicate that the saturation condition affects both the bearing capacity of pile and the initial slope of the load–displacement curve.

Keywords Frustum confining vessel · Saturated soil · Model pile · Helical pile · Fabrication

Jassim, A., Ghanjiyan, N. & Eslami, A. (2023)

Numerical Methods in Civil Engineering

Axial bearing capacity of helical piles in moist and saturated conditions using frustum confining vessel (FCV)

Ali Jassim [1], Navid Ganjian [2*], Abolfazl Eslami [3]

ARTICLE INFO

Article history:

Received:

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Keywords:

Helical Pile

Axial Bearing Capacity

Physical Modeling

FCV Apparatus

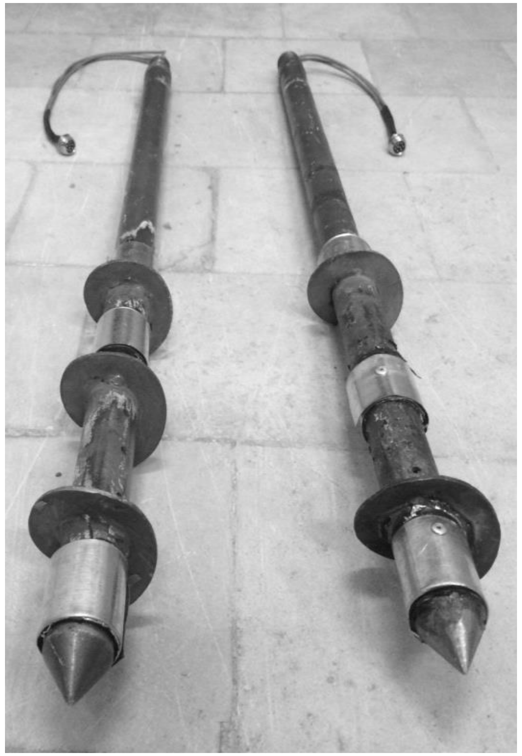
Anzali Sand

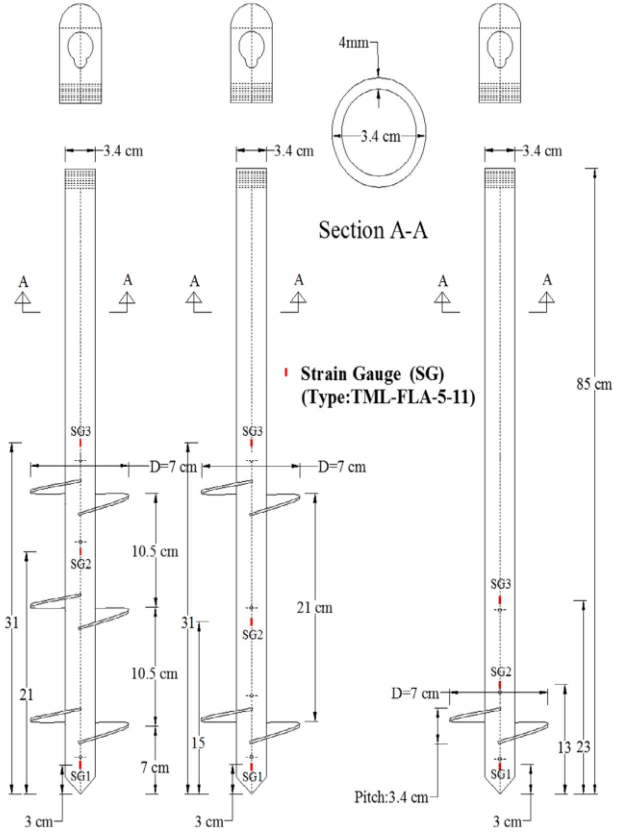
Abstract:

Due to the increasing demand in construction and use of different types of piles on the one hand, and the high cost of conducting large-scale tests on different types of piles, on the other hand, new methods have been proposed to study the behavior of different types of piles. Physical modeling provides the researcher the capability of studying model piles in the scaled environment at low costs. Among the different methods of physical modeling, the use of frustum confining vessels (FCV) have gained attraction in recent years. FCV is a cone-shaped vessel that can produce a stress distribution similar to the idealized linear stress distribution in depth. Helical piles are common types of deep foundations which their first usage dates back to about 200 years ago. Helical piles are driven to the soil by applying a torque to the end of piles, in the presence of vertical loads. Their quick and noise-free installation method, the minimal disturbance during the installation, and their environmental compatibility make them popular for working in urban areas. In this research, using finite element method the optimal dimensions of FCV apparatus was selected and the FCV apparatus with optimal dimensions were constructed. A total of 18 compression tests were performed on Anzali sand in different relative densities and moisture contents using single-helix and three-helices piles. Results indicate that increasing the number of helices and soil relative density increases the pile and sand contact and causes higher bearing capacity for helical piles. Soil saturation, on the other hand, significantly reduces the ultimate strength.

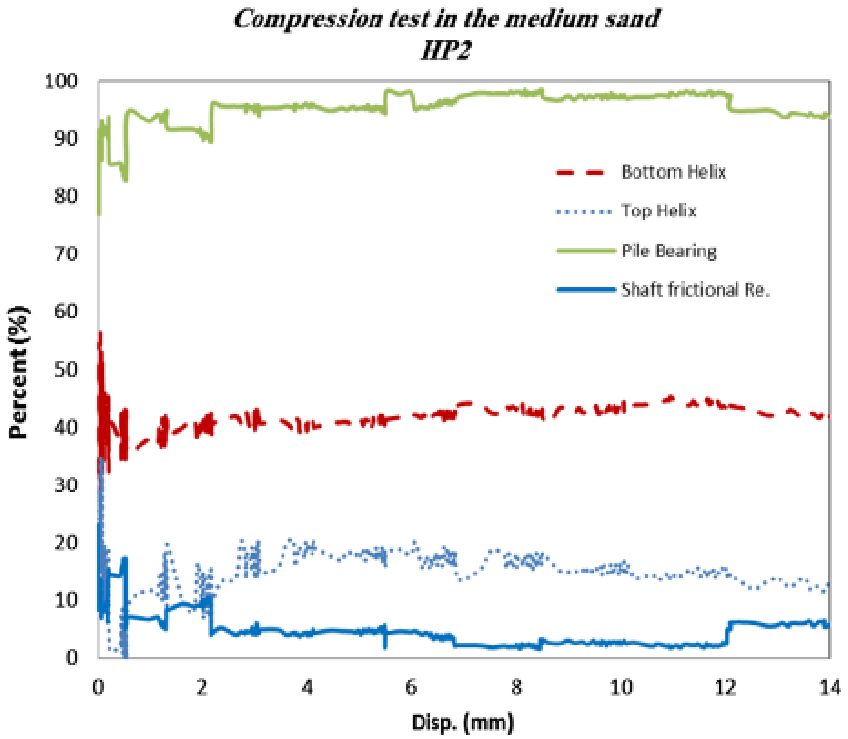
Helical Piles Installation

- Several sensors were accomplished in different points in order to separate the bearing capacity of tip and each of helix

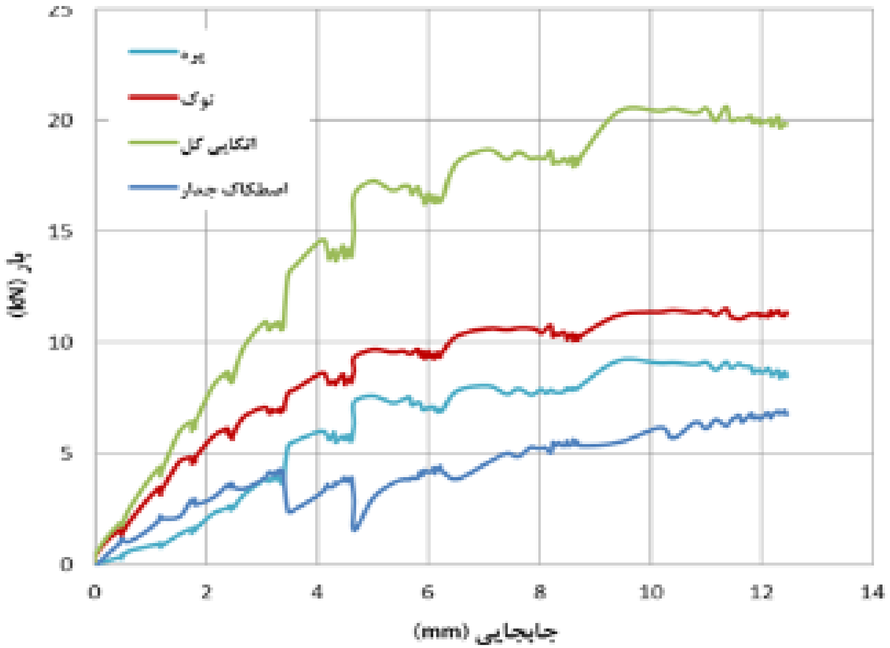




Helical Piles Results



Percentages distribution of resistances during compression tests in medium density for double helices pile



Askari Fateh, A.M., Eslami, A., & Fahimifar, A. (2018)

A study of the axial load behaviour of helical piles in sand by frustum confining vessel

Abstract

Helical piles as screwed piles are a popular solution for removable or recyclable foundations that support road or offshore structures. In this study, the frustum confining vessel developed at the Amirkabir University of Technology (FCV-AUT) is used to study the axial behaviour of helical piles as the physical modelling of their apparatus. Three models of helical piles are made of hollow galvanised iron pipes (diameter of 34 mm and length of 85 cm), to which single-, double- and triple-helical plates (diameter of 70 mm) are welded. The influences of the number of helices and the geometry of the piles on failure mechanism are studied at two different densities of Babolsar sand by conducting 12 tensile and compressive loading tests in FCV-AUT. The piles are instrumented using strain gauges in order to study internal axial load distribution during pile loading. Two static analysis methods are used to verify the experimental results. The results have shown that the FCV has good performance in modelling the behaviour of helical piles under compression tests. It is also known that the shear resistance parameters of the surrounding soil are more affected by three- or multi-helix piles with higher relative densities.

Askari Fateh, A.M. & Eslami, A., & Fahimifar, A. (2017)

Study of Soil Disturbance Effect on Bearing Capacity of Helical Pile by Experimental Modelling in FCV

Amir Mansour Askari Fateh, Abolfazl Eslami & Ahmad Fahimifar

ABSTRACT:

Helical piles as deep foundations are a traditional solution for supporting structures such as residential construction, communication tower installations, static or seismic structural retrofitting and reconstruction. Two mechanisms of failure during helical pile loading occurred depending on pile geometry and soil strength as individual or cylindrical failure. Commonly, soil disturbance effects during pile driving by torque mechanism are not considered in conventional static analysis methods for determine bearing capacity of the helical pile toe or helices plates, while this disturbance can influence the bearing resistance of the pile. Present study considered the behavior of three models of instrumented helical piles in two densities of Babolsar Sand by the frustum confining vessel developed at Amirkabir University of Technology (FCV-AUT) as the physical modeling apparatus. Bearing capacity of the pile toe and helices plates in addition to axial capacity of the pile are measured and controlled during pile compression load test. Two static analysis methods (CFEM, 2006 and Vesic, 1977) are used in order to verify the experimental results and deriving the coefficient of bearing capacity for promotion of the conventional static analysis to predict axial capacity of helical piles with more accuracy. The axial capacities of twenty-one full scale helical piles are predicted by the new approach and compared with measured capacity from static pile load test. The results of comparison have shown that by using the new approach errors in helical pile capacity estimation have been lowered almost 43%. Therefore it can be realized as an alternative in static analysis of helical pile design.

Askari Fateh, A.M. & Eslami, A., & Fahimifar, A. (2017)

Study of Soil Disturbance Effect on Bearing Capacity of Helical Pile by Experimental Modelling in FCV

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ABSTRACT:

Helical piles as deep foundations are a traditional solution for supporting structures such as residential construction, communication tower installations, static or seismic structural retrofitting and reconstruction. Two mechanisms of failure during helical pile loading occurred depending on pile geometry and soil strength as individual or cylindrical failure. Commonly, soil disturbance effects during pile driving by torque mechanism are not considered in conventional static analysis methods for determine bearing capacity of the helical pile toe or helices plates, while this disturbance can influence the bearing resistance of the pile. Present study considered the behavior of three models of instrumented helical piles in two densities of Babolsar Sand by the frustum confining vessel developed at Amirkabir University of Technology (FCV-AUT) as the physical modeling apparatus. Bearing capacity of the pile toe and helices plates in addition to axial capacity of the pile are measured and controlled during pile compression load test. Two static analysis methods (CFEM, 2006 and Vesic, 1977) are used in order to verify the experimental results and deriving the coefficient of bearing capacity for promotion of the conventional static analysis to predict axial capacity of helical piles with more accuracy. The axial capacities of twenty-one full scale helical piles are predicted by the new approach and compared with measured capacity from static pile load test. The results of comparison have shown that by using the new approach errors in helical pile capacity estimation have been lowered almost 43%. Therefore it can be realized as an alternative in static analysis of helical pile design.

Akbari Zare, A.M. & Eslami, A. Razmkhah, A., & Vosoughifar, H., (2017)

Investigation of the Load-Displacement Behavior of Helical Piles in Sand through Novel Instrumentation

Ali Akbari Zare[a], Abolfazl Eslami[b,*] (Corresponding Author), Arash Razmkhah[c] and Hamidreza Vosoughifar[d]

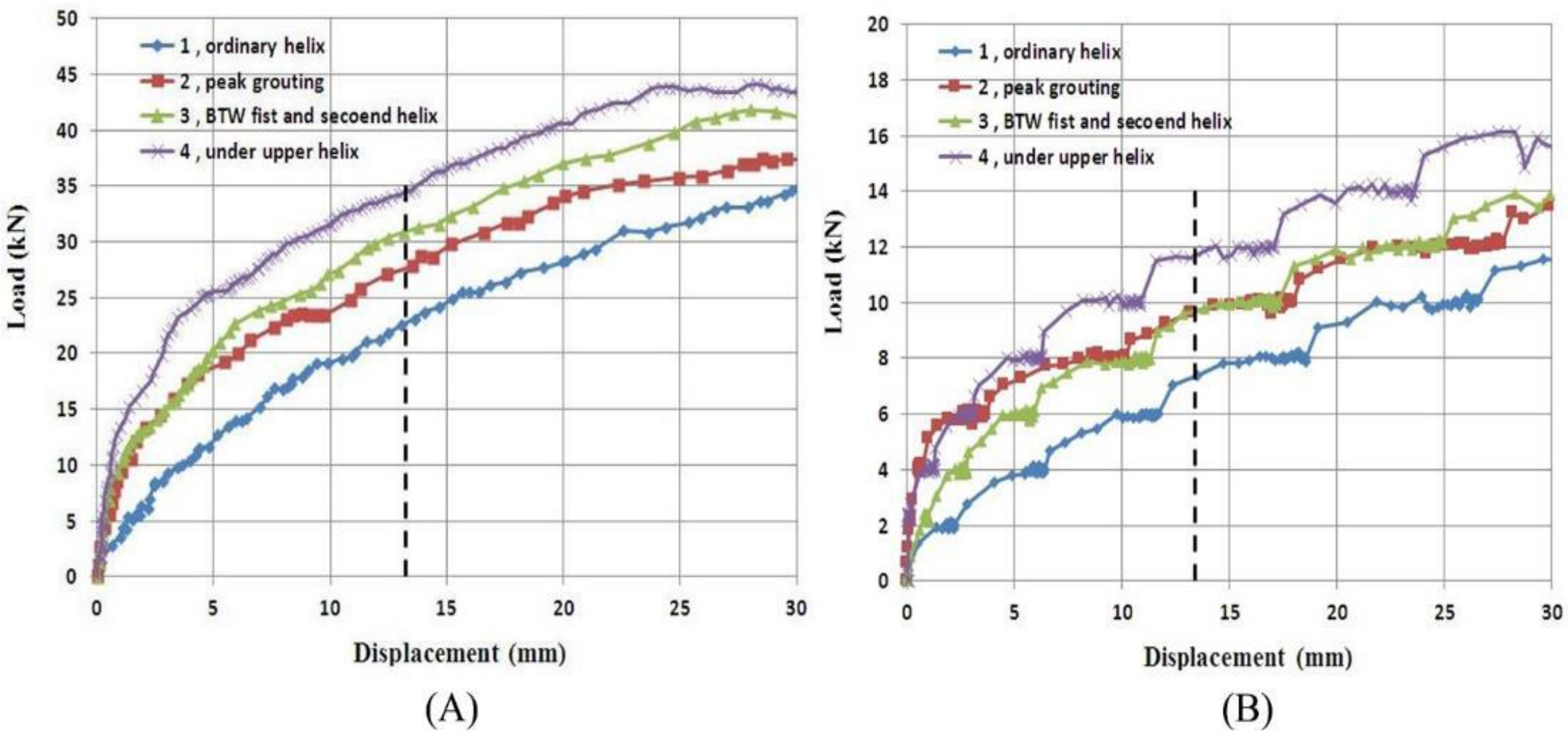
Abstract

Considering the economic and environmental advantages of using helical piles and the limited number of field load tests, examining the performance and load-bearing capacity of helical pile components is highly beneficial. The objective of this study is to investigate the load-displacement behavior of helical piles using FCV physical modeling and to determine the load-bearing capacity of the pile tip, blades, and shaft through novel instrumentation. For this purpose, axial compression loading tests were conducted on samples of moist sand with 4% moisture content in a physical modeling apparatus with a relative density of 40-45%, under pressures of 100 and 200 kPa, and with different blade diameters (D = 90, D = 70, and D = 60 mm). By examining the slope of load-displacement changes (dQ/dρ) in the load-displacement curves of helical piles, it was observed that this ratio varies with changes in blade diameter and pile height at a constant relative density. The behavior of the load-displacement curves transitions from nearly linear to nonlinear as the blade diameter increases. Analysis of the load-displacement curves of the instrumented piles showed that the overall slope of the load-displacement curves follows the slope of blade loading, particularly the bottom blade, and the load-bearing capacity of the bottom blade is more pronounced compared to the top blade.

Post-grouted helical

- The post-grouted method is performed to decrease the prevalent problem of disturbed soil in installation procedure of helical pile

Post-grouted Helical Results



Post grouted helical model piles performance, a) Compression tests, b) Tension tests.

Khazaei, J. & Eslami, A. (2017)

Post-Grouted Helical Piles Behavior via Physical Modeling by FCV

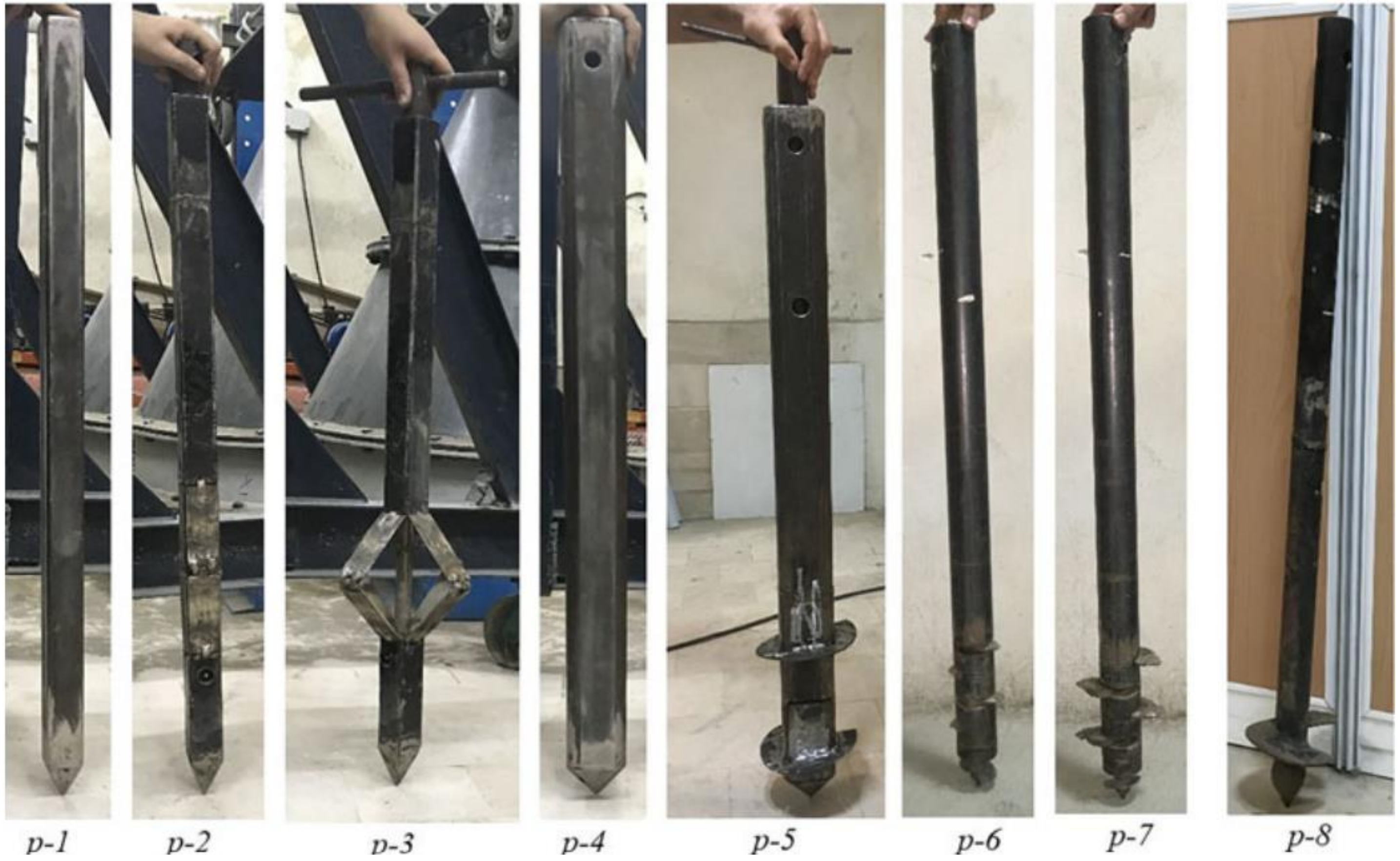
Javad Khazaei & Abolfazl Eslami

Abstract

Piling procedure may disturb the surrounding soil, due to the installation particularly for cast-inplace piles. It causes a reduction in the soil strength parameters and consequently, pile capacity. To overcome shortcomings and also for improving piles capacity, post grouting as a compensation method is recognized and more developed in recent years. Helical piles, those are used widely in marine and land projects, although are driven by torque implementation, but soil disturbance is noticed where number of the helices becomes up to three and more. In this paper, an experimental study program carried out by frustum confined vessel (FCV) to investigate bearing capacity of model helical piles and also post grouted cases performance. FCV has been used because of its linear distribution of vertical and horizontal stresses from zero at top to maximum at bottom which simulates real field stress conditions. Via experimental study, small scale helical model piles were made from 4 mm thick steel plate and have been used with length of 750 mm. The shaft and helices diameters of model piles have been 32 mm and 89 mm, respectively. So, the helix-to-shaft ratio (wing ratio) was about 2.8. The helical model piles installed in fine-grained sand as a surrounding soil, then axial loading tests before and after grouting performed to achieve ultimate pile capacity. Results indicated post grouting can improve both ratios of toe and frictional soil-pile interactions including upgrading β and Nt factors. In addition, the post grouting phenomena can change the pile geometry due to treated soil bond, resulting better functioning. Therefore, it is a proper method to improve helical piles performance and compensate installation effects in capacity mobilization.

Keywords: frustum confining vessel (FCV), helical pile, installation effects, physical modeling, post-grouting, static analysis

Expanded pile



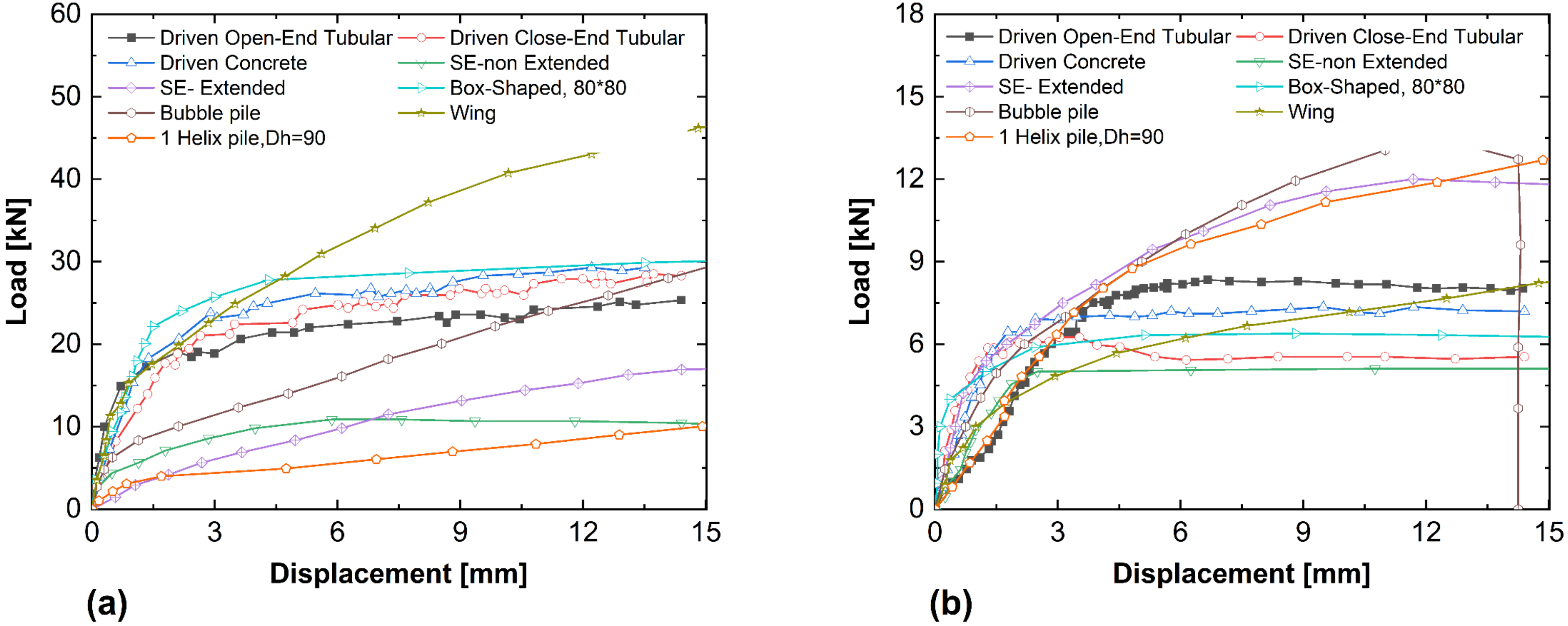
(p-1) Box-shaped steel piles; (p-2) Bubble pile without extension; (p-3) Bubble pile with extension; (p-4) Box-shaped steel pile; (p-5) Wing pile without extension; (p-6) Self-Expanded pile (SE) without extension; (p-7) Self-Expanded pile (SE) with extension; (p-8) Helical pile.

Expanded pile

(a) (b) (c)

After expansion condition : a) Bubble pile b) Wing pile c) Self-Expanded pile

Expanded pile



Expanded model piles performance, a) Compression tests, b) Tension tests.

Shojaei, E., Eslami, A. & Ghanjian, N. (2019)

Self-expanded piles: A new approach to unconventional piles development

Ebrahim Shojaei, Abolfazl Eslami and Navid Ganjian

Abstract

In onshore and offshore fields of ocean engineering, piles are used as foundation systems for various structures. Piles are classified into different types depending on their materials, geometries, and particularly, installation methods, which have advantages or limitations. Companies and engineers have developed a new group of piles, because of necessity to improve their performance in terms of increasing the bearing capacity, reducing impacts of traditional installation procedures, implementing by low- torque power equipment, and utilizing them in widely different ground conditions, including in a marine environment. In the present study, three different models of a new pile with an expander body are introduced to increase the shaft and pile-toe diameters and its self-expansion in the embedment depth under the titles of the Bubble pile (BP), Self-Expanded pile (SEP) and Wing pile (WP). The main subject of this research is to achieve increased bearing capacity, reduced installation effects, and decreased required installation torque. The frustum confining vessel of Amirkabir University of Technology (FCV-AUT) was employed for this purpose. Up to 14 axial compressive and tensile load tests were carried out on different model piles on sand collected from Anzali shore located on the northern coast of Caspian Sea in Iran, with relative densities of 45% to 50% within FCV-AUT. Comparing the performance of introduced pile with traditional pile corresponding to the same characteristics, the results indicated a significant increase in the axial bearing capacity and reduced disturbance effect of the pile. Also, a lower installation torque of the SE pile was required compared to the helical pile. The test results also demonstrated that the new pile could resist considerable compressive and uplift loads, and could be a possible alternative to traditional piles in the onshore sector.

Keywords:

Expanded piles; traditional piles; bearing capacity; soil disturbance effect; physical modeling; FCV

Shojaei, E., Eslami, A. & Ghanjiyan, N. (2021)

Experimental and comparative investigations of a new self-expanded steel pile behaviour via physical modelling (FCV-AUT)

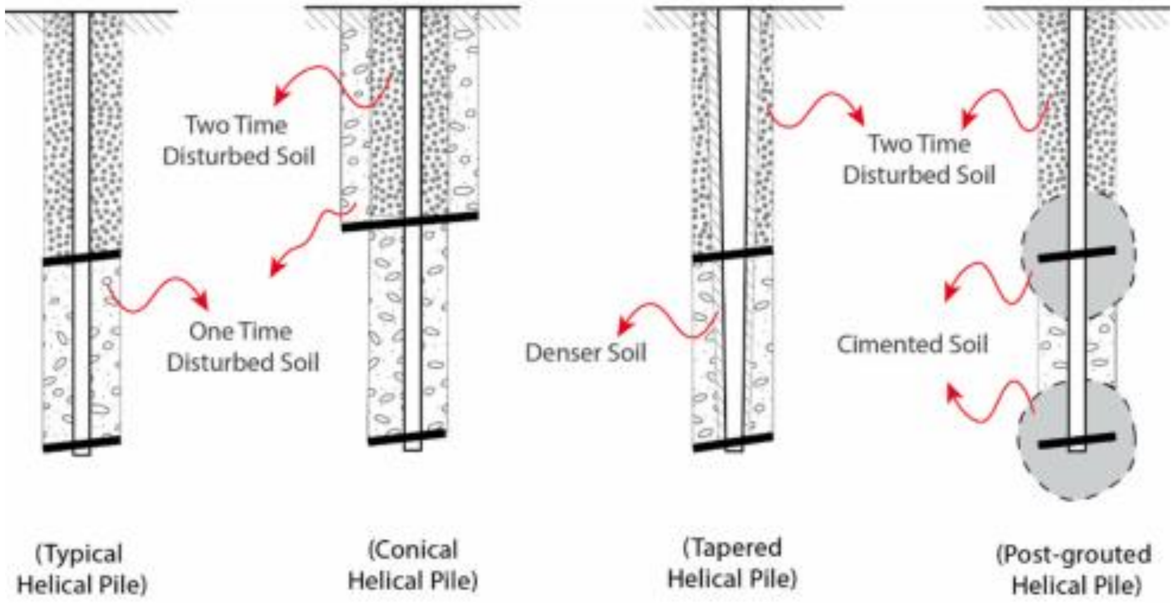
Ebrahim Shojaei, Abolfazl Eslami, Navid Ganjiyan

Abstract

Engineers have used conventional piles such as driven, jacked or cast in place piles in onshore or offshore construction for several years. In recent decades, there is a need to define a new generation of piles. Achieving high bearing capacity, high performance and soil disturbance reduction due to pile driving are the main objectives of the development of unconventional piles. In this study, two new models of self-expanded piles are introduced under the titles of Bubble pile (BP) and Wing Pile (WP) in order to reduce the relatively limited features and disadvantages of common piles and improve their performance. These piles were studied in two different relative densities of sandy soil by frustum confining vessel that developed at Amirkabir University of Technology (FCV-AUT). In order to compare their behavior and performance with traditional piles, 32 tensile and compression static load tests have been conducted. The test results revealed that the new piles could resist considerable tensile and compressive loads and could be a possible alternative to traditional piles in both onshore and offshore sectors.

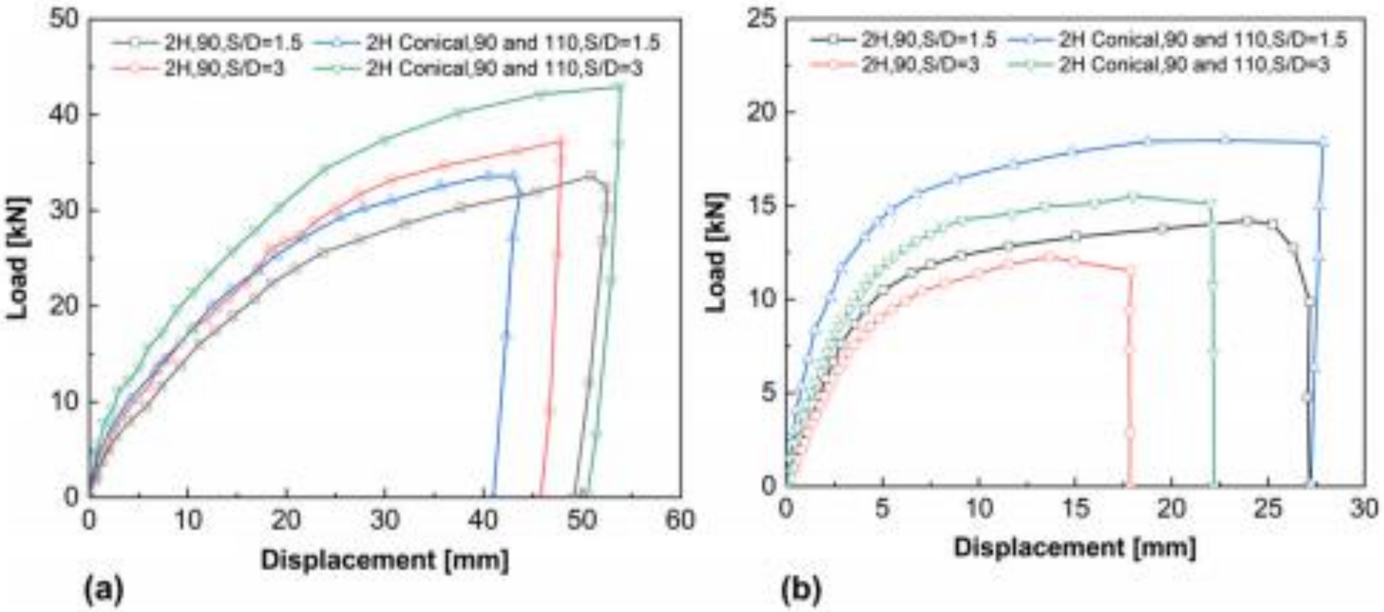
Keywords: Self-expanded steel pile; Conventional piles; Physical modelling, FCV-AUT; Bearing capacity.

Enhanced Helical

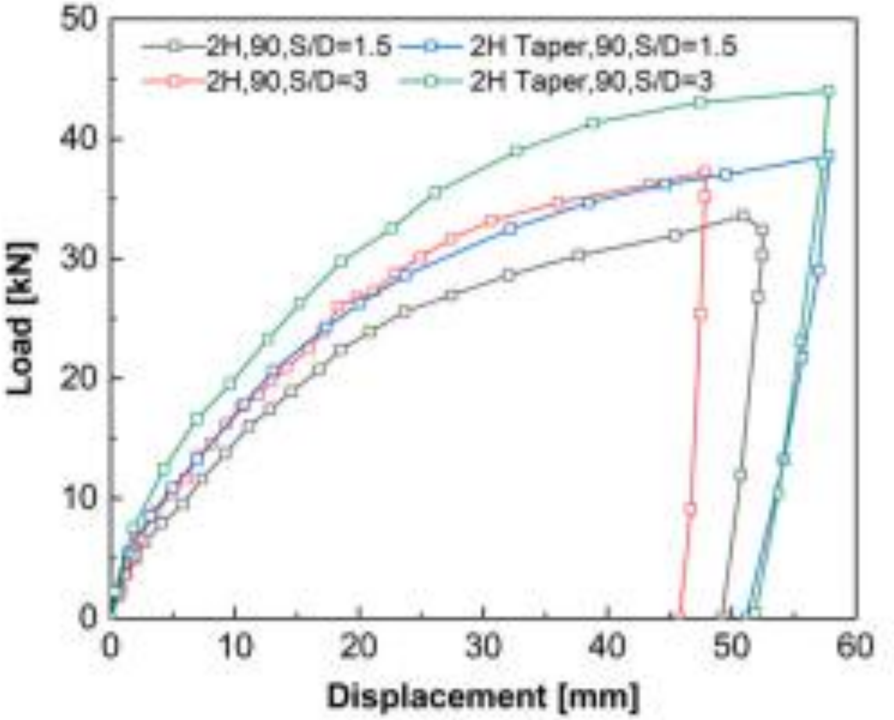


Schematic illustration of soil disturbance around various helical piles

Conical Helical Results



Load-displacement diagram of typical and conical helical piles a) Compression b) Pullout.



Load-displacement behavior of typical and tapered helical piles under Compression loading

Esmailzade, M. & Eslami, A. (2025)

Ocean Engineering 324 (2025) 120624

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

ELSEVIER

Research paper

Experimental study on performance and enhanced methods of helical piles using Frustum Confining Vessel in Anzali Sand

Mohammad Esmailzade, Abolfazl Eslami *

Civil and Environmental Engineering Department, Amirkabir University of Technology, Tehran, Iran

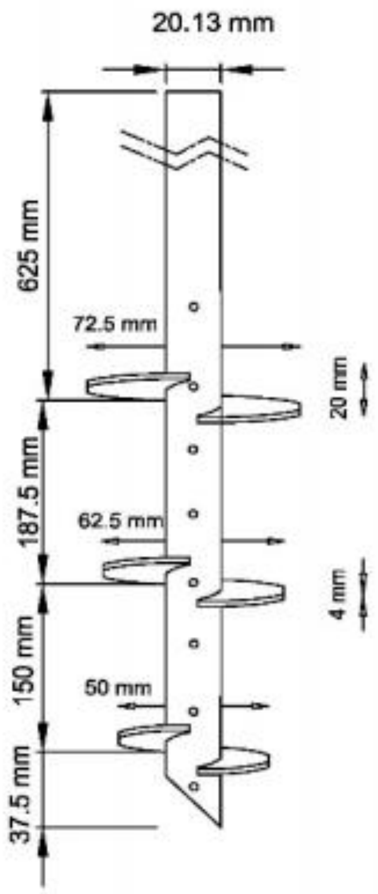
ARTICLE INFO

Keywords:
Helical pile
Conical
Tapered
Post-grouted
Load-displacement
Physical modeling

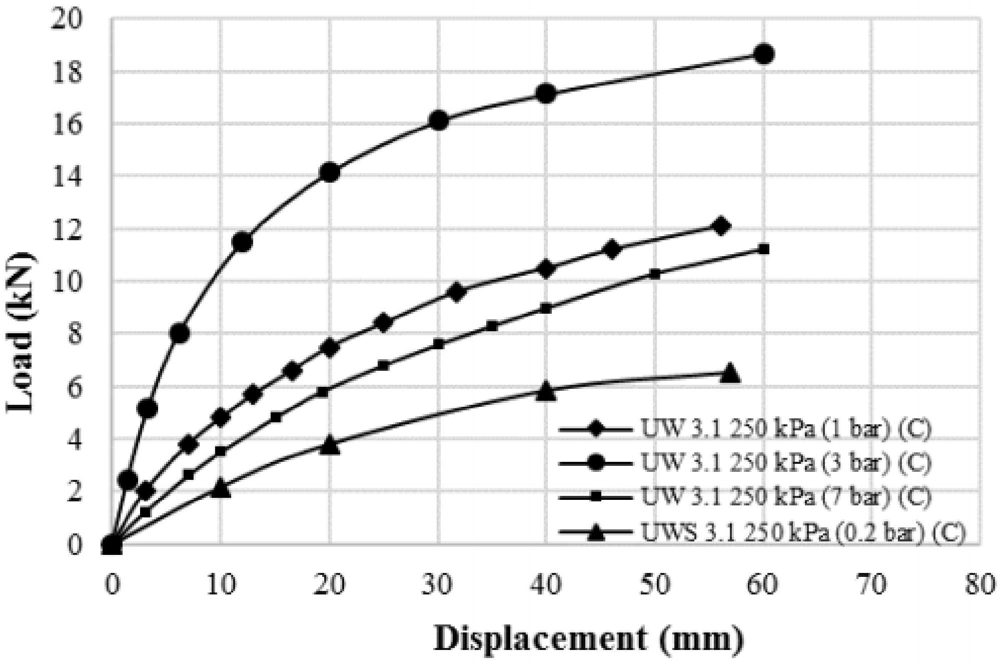
ABSTRACT

Recently, helical piles have been recognized as a viable alternative to conventional piles, particularly in marine environments. The main issue is soil disturbance during installation and solutions to mitigate impacts and enhance performance. The load-displacement of helical piles with varying geometries is examined to find the best geometry in Anzali Sand. The tested helical piles included 1 to 3 helices, 60- and 90-mm diameters, spacing ratios of 1.5 and 3, and embedded length of 750-mm. Three alternatives are proposed: conical helical, tapered, and post-grouted. Overall, 28 pullout and compression tests were conducted on 14 piles using the Frustum Confining Vessel (FCV) device. Increase in the helix space ratio and number has resulted in greater compression capacity, while an increase in the spacing ratio has led to a decrease in pullout capacity. The torque required for conical and tapered helical piles increased by 18%. However, their compression capacity increased by 20%. Additionally, the pullout capacity of conical and post-grouted piles increased compared to typical helical piles. Finally, piles were compared from various geotechnical and practical perspectives, including cost, bearing capacity, manufacture, and installation torque. Conical and post-grouted helical piles exhibit superior performance compared to the others based on the appraisal.

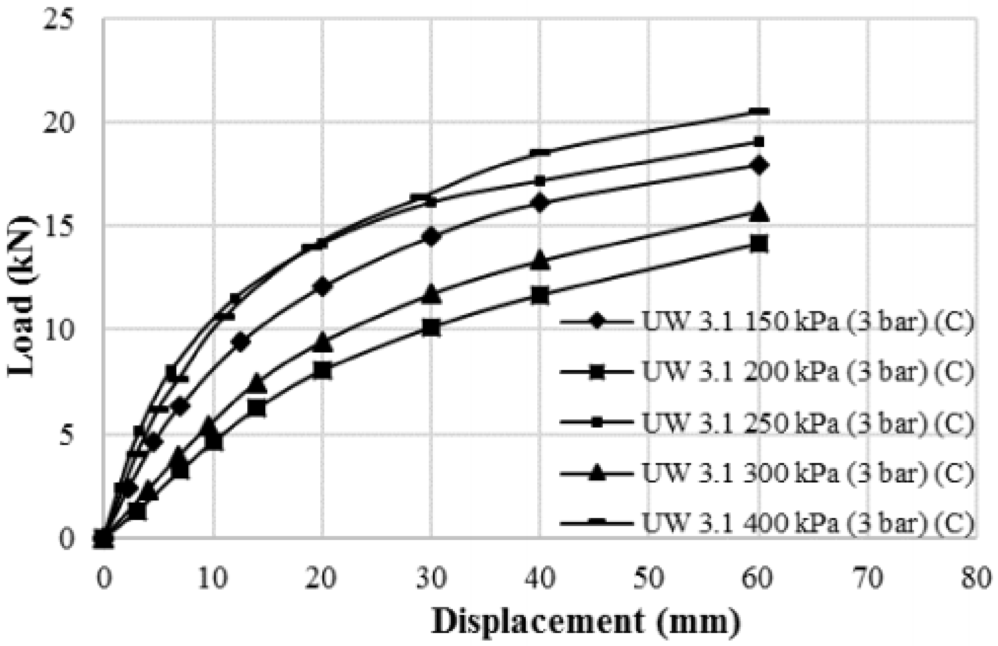
Helical in Loess



Helical in Loess

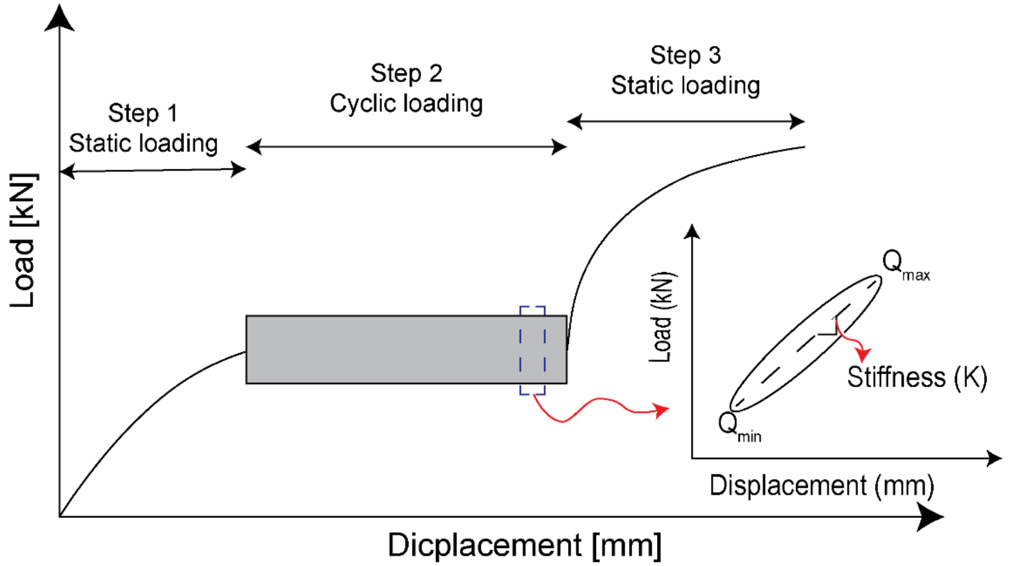


1 helix piles performance in different Injection pressure



1 helix piles performance in Different axial installation loading

Helical Pile under Cyclic Loading



Schematic image of loading process

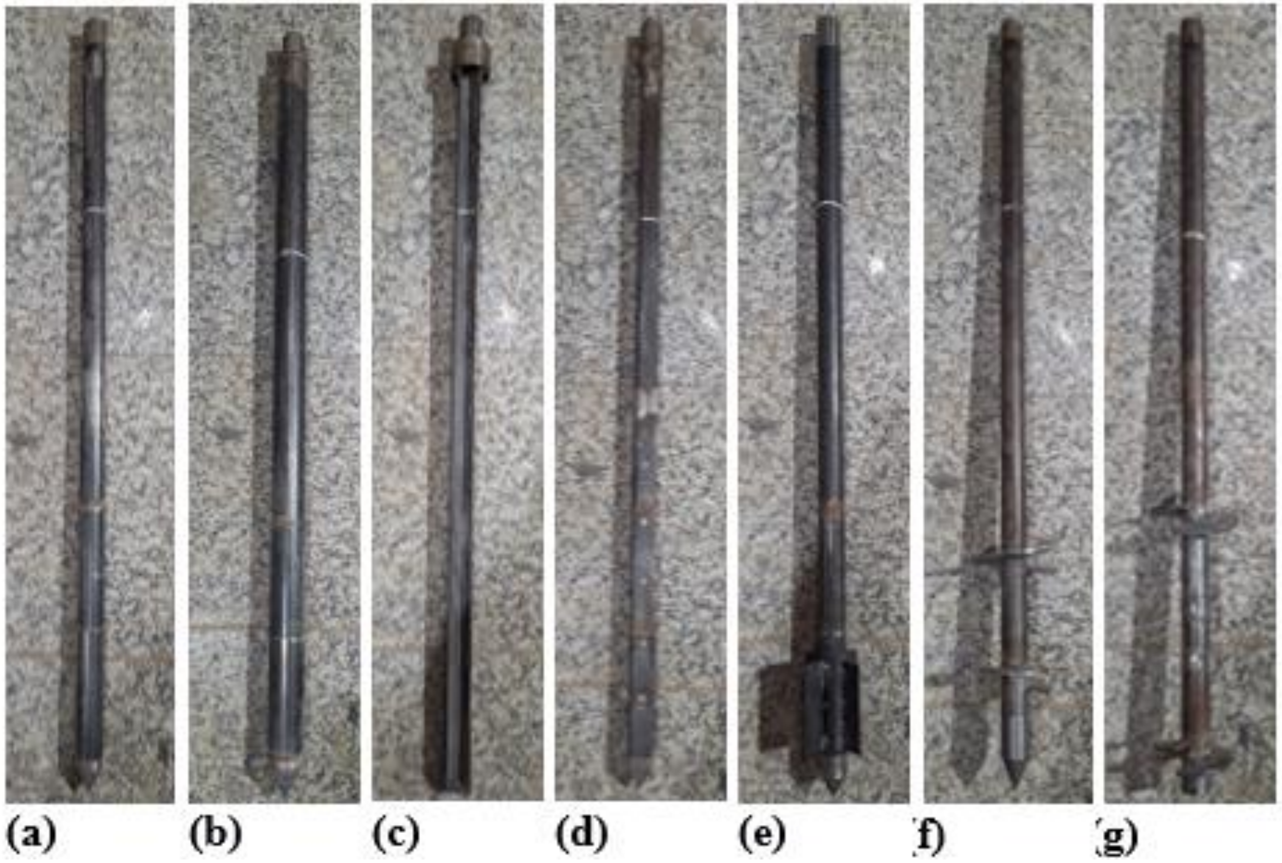
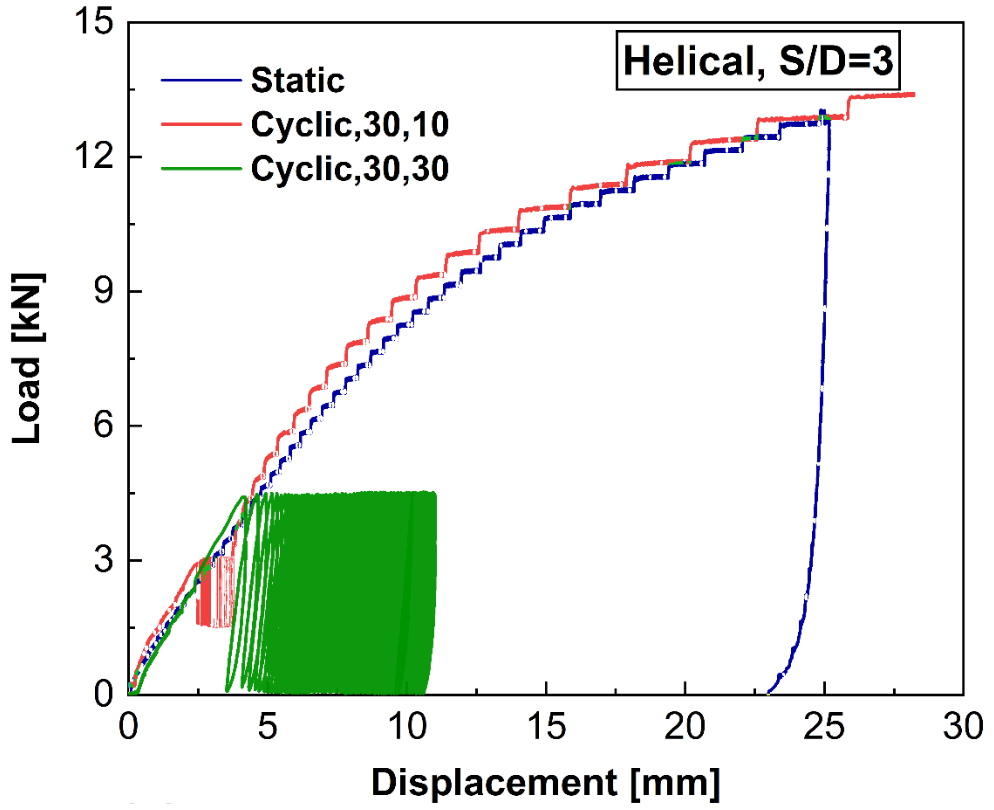
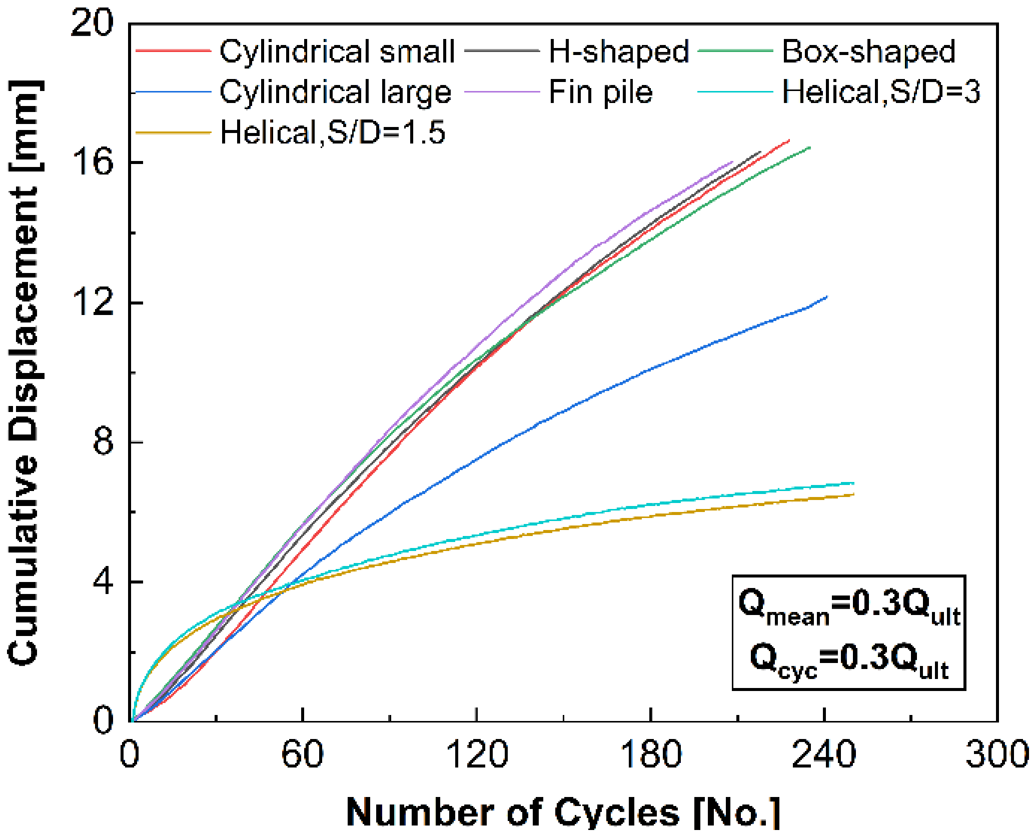


Image of various geometry piles tested in FCV device; a) Small cylindrical; b) Large cylindrical; c) H-shaped; d) Box-shaped; e) Fin; f) Helical, s/d=1.5; g) Helical, s/d=3

Helical Pile under Cyclic Loading



Load-displacement diagram for various pile under static under cyclic loading for helical pile, S/D=3



Displacement versus number of cycles diagram under amplitude equal 30%

Esmailzade, M. & Eslami, A.
(Under Preparation)

Static and Cyclic Load-Displacement Behavior of Various Geometry Piles via Physical Modeling

Abstract

Deep foundations are now the preferred choice for supporting marine and offshore structures. However, the complexity of marine environments and the impact of cyclic loading make selecting the most suitable pile type a critical challenge. his study investigates the load-displacement behavior and performance of various pile types with differing geometries and installation methods under static and cyclic loading using the Frustum Confining Vessel (FCV) physical modeling device. A total of 21 static and cyclic loading tests were conducted, with cyclic amplitudes of 10% and 30% of bearing capacity. For conventional piles, the 10% diameter and offset limited methods yield similar results, while Brinch Hansen 80% and Chin-Kondner overestimate. For helical piles, the 10% method is most accurate, while the offset limited method underestimates. Helical piles exhibited greater initial settlement under low-amplitude loading due to soil disturbance but stabilized as cycles progressed. However, under high-amplitude loading, helical piles outperformed conventional piles, showing reduced settlement rates and greater stability over extended cycles. Although initial stiffness was higher in conventional piles, helical piles exhibited superior improvements in tangential stiffness after cyclic loading. The stiffness ratio for helical piles with spacing ratios of 1.5 and 3 reached 2.7 and 2.8, compared to 2.0 for small cylindrical piles. Finally, piles were compared from various geotechnical and practical perspectives, including cost, bearing capacity, manufacture, and Cyclic behavior. Helical piles exhibit superior performance compared to the others based on the appraisal.

Key words: *Deep Foundation, Geometry, Load-Displacement, Cyclic Loading, Stiffness, Physical Modeling*

5

Field Testing and Scale up

Site 1, Anzali Port

بندر انزلی

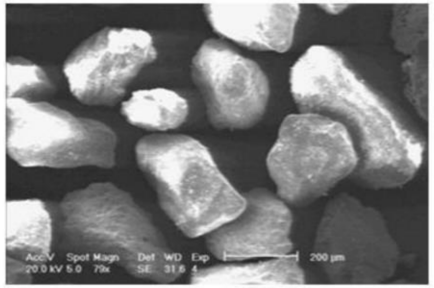
Anzali Port

محدوده اسکله

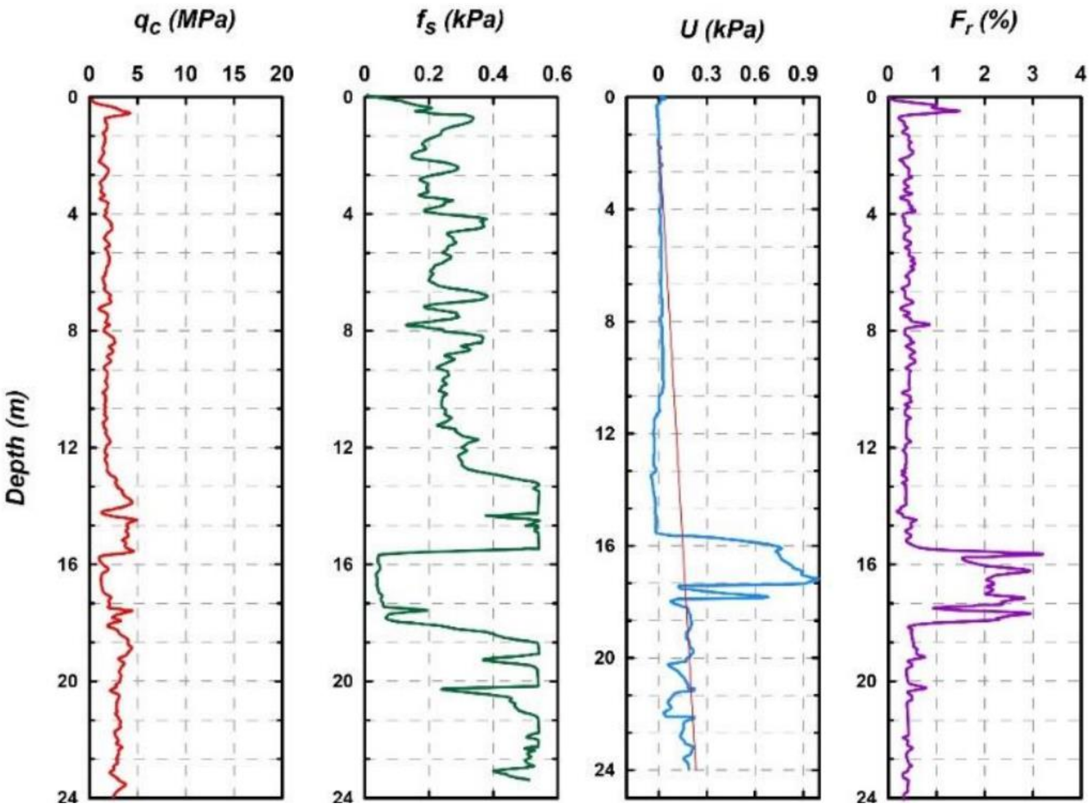
Site 2

سایت تحقیقاتی

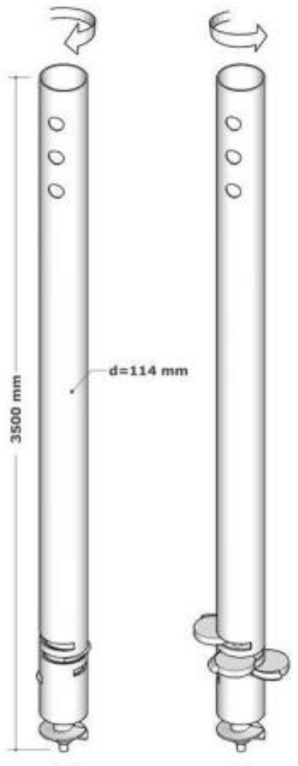
Site 2



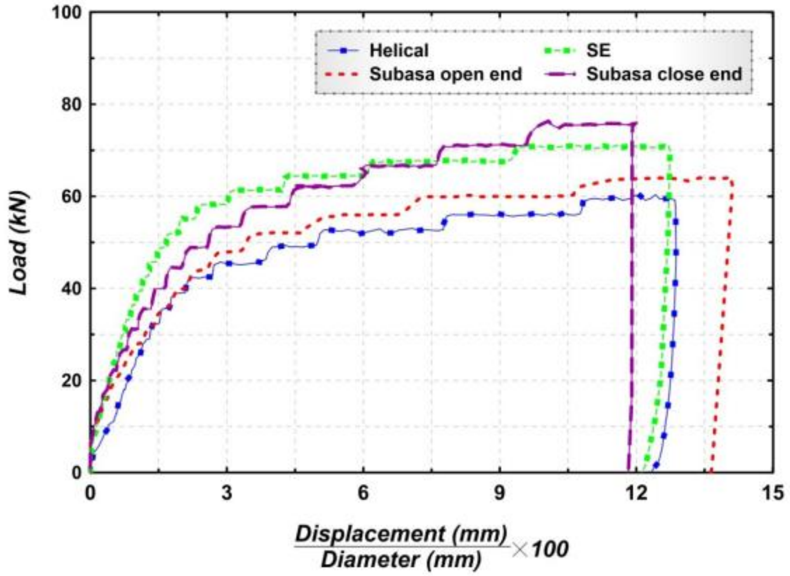
شکل شماره ۵-۲۸: تصویر میکروسکوپی از شکل دانه‌های ماسه انزلی [۹۳]



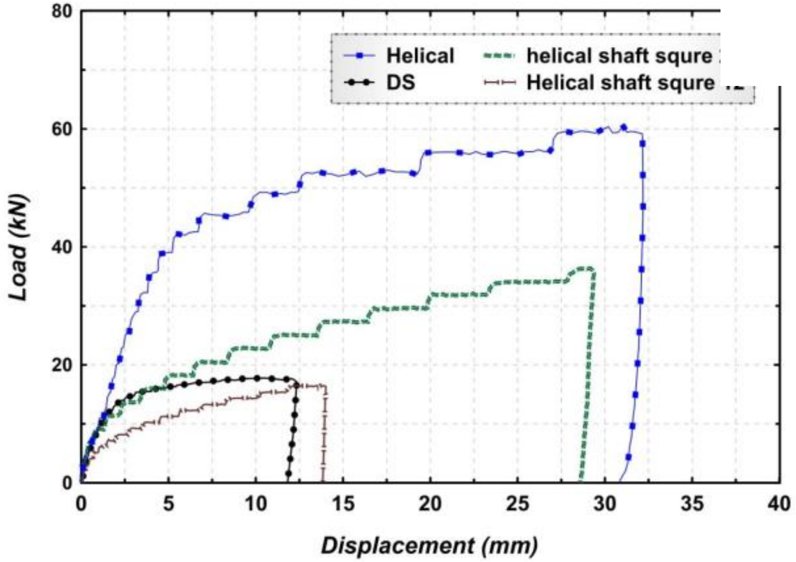
Site 1, Anzali Port



Expanded pile (SE model)

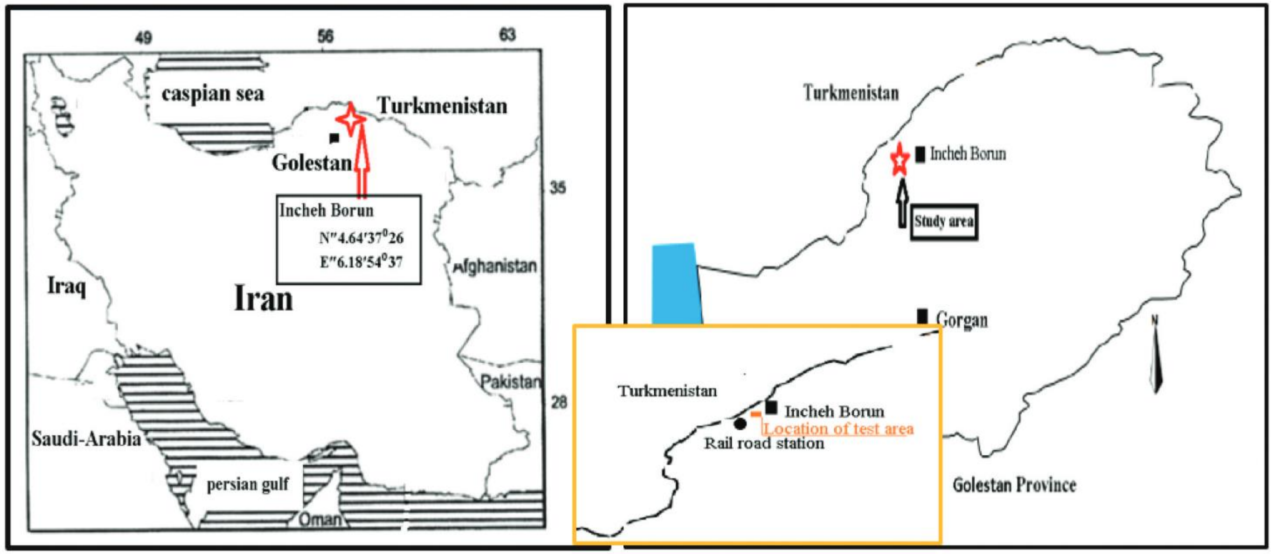


Load-displacement curve of expanded and helical piles

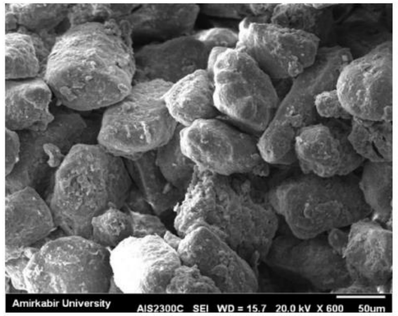


Load-displacement curve of helical piles

Site 2, Golestan



Study site near the north border of Iran and Turkmenistan.



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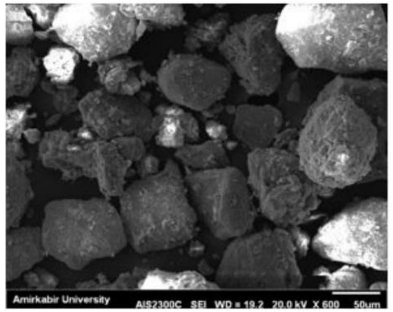


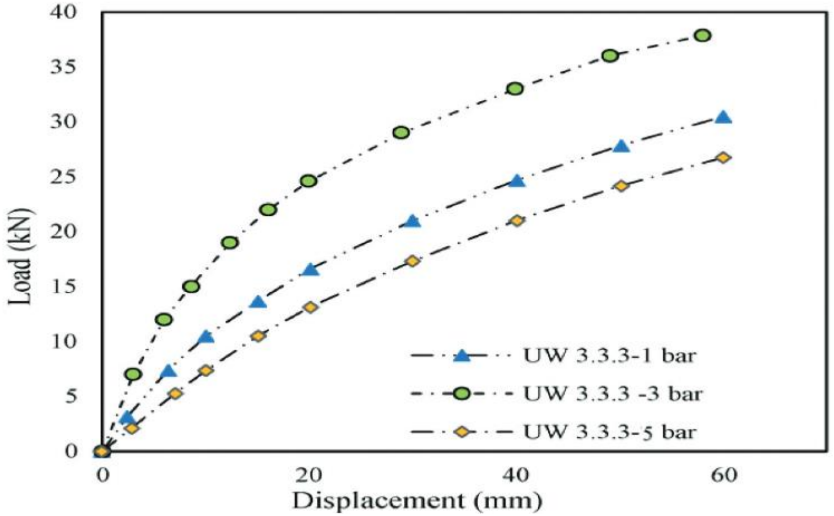
الف

Golestan loess soil properties (Incheh-Borun area).

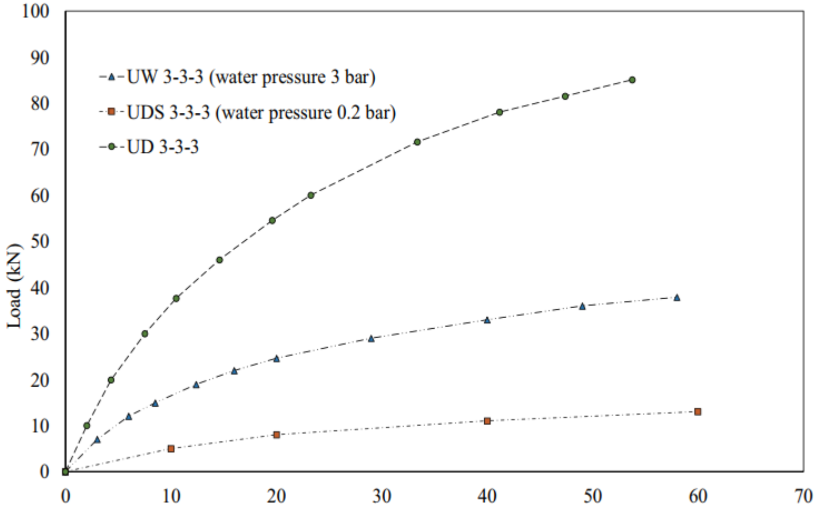
Properties	value	Properties	value
Soil type[a]	ML	Natural friction angle, (φ°)[b]	19°
Natural cohesion,C (kPa)[b]	15	Saturated friction angle,(φ′ °)[b]	8°
Saturated cohesion,C′ (kPa)[b]	4	Liquid limit, LL (%)[h]	28.5
Natural water content (%) [c]	5	Plasticity Index, PI (%)[h]	12.8
Specific gravity [d]	2.68	Plastic limit, PL (%)[h]	15.7
Initial void ratio[l]	1.097	Collapse index (%)[k]	21
Density (gr/cm3)[d]	1.28	[1]N_{SPT}[n]	16

[a] (ASTM D422-63e2 2007), [b](ASTM D3080/D3080M-11 2011), [c](ASTM D2216-19 2019), [d](ASTM D792-20 2020), [l](ASTM D2435/D2435M-11 2020), [h] (ASTM D4318-17e1 2017), [k] (ASTM D5333-03 2003), [n](ASTM D1586/D1586M-18 2018). [1]N_{SPT} =(Standard penetration number or N-SPT value)

Site 2, Golestan

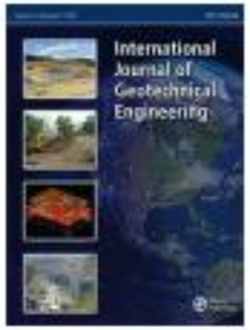


Effect of water pressure in wet installation method on compressive capacity of helical piles tested



Effect of water pressure on load displacement diagram of helical piles installed in Golestan loess

Arabameri, M. & Eslami, A. (2022)



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International Journal of Geotechnical Engineering

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/yjge20

Wet and dry installation effects on the capacity of helical piles in loess deposits

Mohammad Arabameri & Abolfazl Eslami

To cite this article: Mohammad Arabameri & Abolfazl Eslami (2021): Wet and dry installation effects on the capacity of helical piles in loess deposits, International Journal of Geotechnical Engineering, DOI: 10.1080/19386362.2021.1981650

To link to this article: https://doi.org/10.1080/19386362.2021.1981650

Arabameri, M. & Eslami, A. (2023)

International Journal of Civil Engineering
https://doi.org/10.1007/s40999-021-00602-2

RESEARCH PAPER

Microstructure and Strength Effect on Bearing Capacity of Helical Piles Installed in Golestan Loess

Mohammad Arabameri[1] · Abolfazl Eslami[1]

Received: 4 August 2020 / Revised: 12 November 2020 / Accepted: 5 January 2021

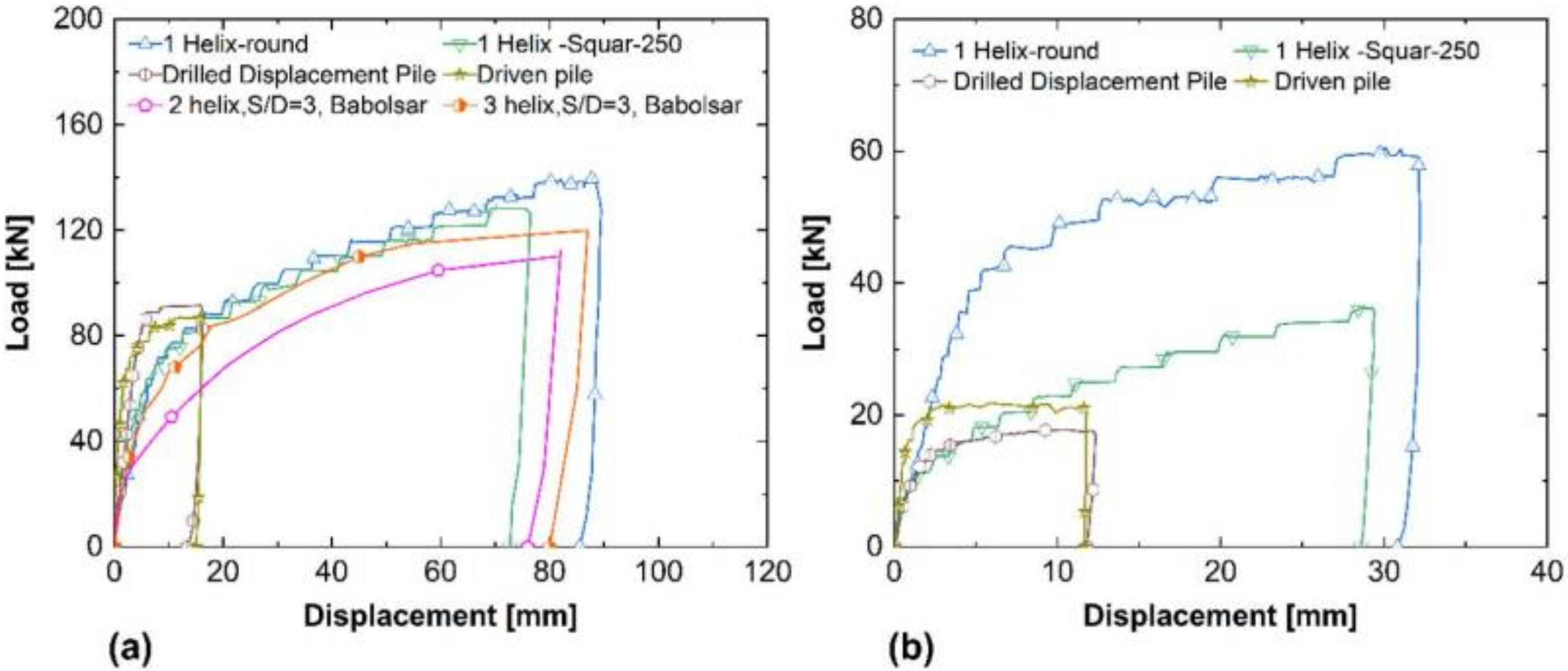
Abstract

Loess soils cover approximately 10% of the Earth's land surface. Due to its honeycomb structure, this soil collapses under pressure and immediately settles when exposed to moisture. Using moisture and loading conditions prior to construction can have positive effects on the geotechnical properties of the soil and help to reduce its settlement. This study aims to investigate the effect of different installation methods of helical piles on microstructure of loess soils. A total number of 16 full-scale helical piles including single helix and double helix piles with spacing to diameter ratios of 1.5 and 3 were installed via wet and dry installation methods. These 3-m-long piles were installed at the site of Inche Borun, Golestan province, northeastern Iran. Pile static load tests were performed on a set of these piles to compare the effect of different installation methods. Furthermore, the behavior of Golestan loess was investigated by removing the soil in front of the other set of helical piles for element testing and SEM imaging. The results suggested that the combination of compressive installation load and water pressure increases the shear strength parameters of Golestan loess and accordingly, the bearing capacity of the installed helical piles.

Keywords Golestan loess · Helical pile · Microstructure · Mechanical property · Bearing capacity · Full-scale test

Site 3, Babolsar

Site 3, Babolsar



Load-displacement curves of different full-scale piles in Anzali and Babolsar sites under:
(a) compression loading; (b) pullout loading

Nazmi, M. & Eslami, A.
(Under Review)

Conical Helical Piles Behavior Appraisal through Physical Modeling and Field Testing

Mostafa Nazmi, Abolfazl Eslami[1]

Civil and Environmental Engineering Department, Amirkabir University of Technology, Tehran, Iran.

Abstract

Helical piles have been recognized as an efficient and reasonable option for onshore and offshore structures. However, soil disturbance during the installation procedure constrains the provided axial geotechnical capacity. Conical helices are among the recently developed enhancement solutions. Considering associated challenges and uncertainties, conical helical piles behavior requires a more meticulous and comprehensive investigation. Therefore, the current study evaluates the performance of conical helical piles under pullout and compressive loading through two distinct and complementary approaches: physical modeling in the Frustum Confining Vessel and field testing. The number of load tests under each loading direction has been eight and three for model- and full-scale piles, respectively. All load tests have been performed in Babolsar Sand, originating from a particular coastal research site. The studied parameters are helix spacing (S) to helix diameter (D) ratio (1.5 and 3) and enhancement in helix geometry. The results represent the more favorable response of conical helical piles compared to typical ones under pullout (28% for model-scale and 36% for full-scale) and compressive (18% for model-scale and 35% for full-scale) loads. Moreover, the field installation torque of conical helical piles has been higher than typical ones (29%). Also, S/D=1.5 has led to more field installation torque than S/D = 3 in conical helical piles (20%). Current research findings are toward a more cost-effective and efficient installation and design.

Keywords:

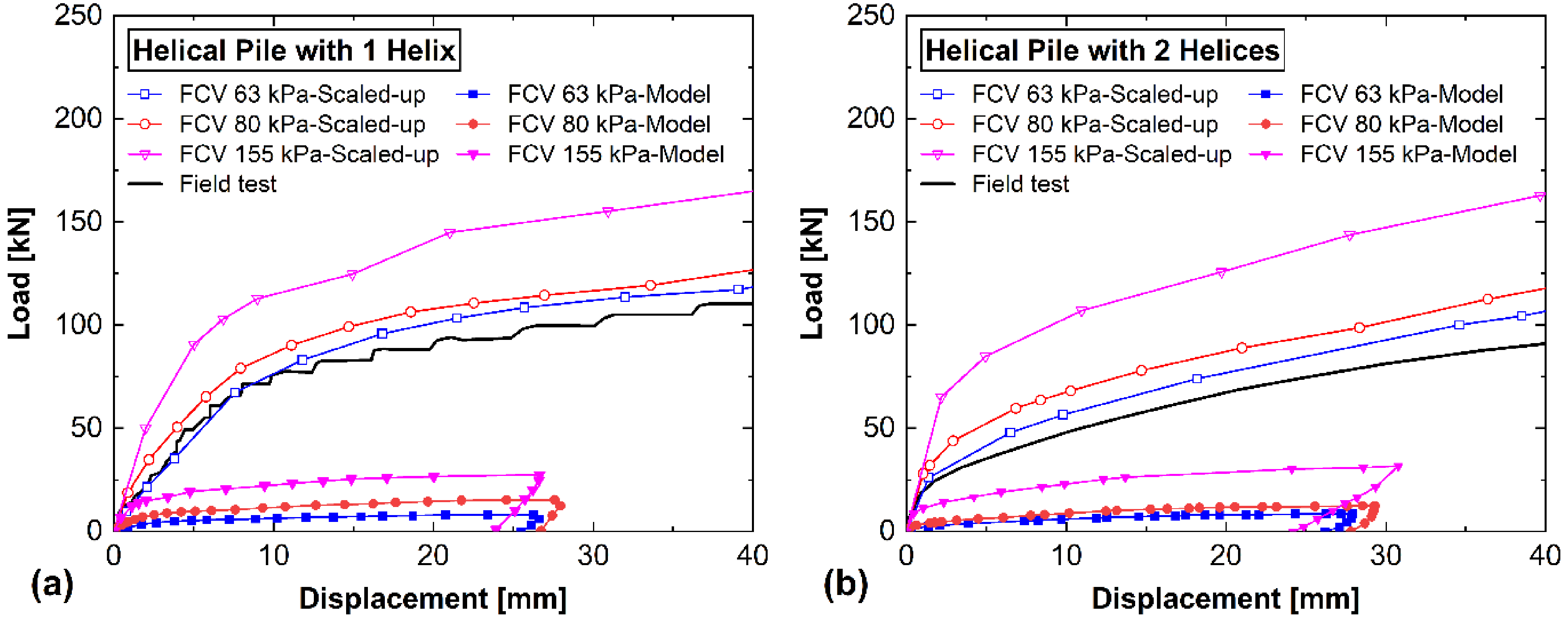
Conical Helical Piles, Frustum Confining Vessel (FCV), Field Testing, Axial Capacity, Babolsar Sand

Scale-up Theory

$$f\begin{pmatrix} \frac{L_D}{L_l}, \frac{C\times T_d^2}{L^2\times\rho}, \frac{E_s\times T_d^2}{L^2\times\rho}, \frac{E_P\times T_d^2}{L^2\times\rho}, \frac{\gamma\times T_d^2}{\mathrm{L}\times\rho}, \frac{\sigma\times T_d^2}{L^2\times\rho}, \\ f\times T_d, \frac{g\times T_d^2}{\mathrm{L}}, \frac{V\times T_d}{L}, \frac{T\times T_d^2}{L^5\times\rho}, \frac{F\times T_d^2}{L^4\times\rho}, \frac{\Delta}{L} \end{pmatrix}=0$$

	If $\lambda_\sigma = 1$
$\frac{L_m}{L_P} = \lambda_L$	$\frac{L_m}{L_P} = \lambda_L$
$\lambda_c = \frac{\lambda_L^2 \times \lambda_\sigma}{\lambda_L^2}$	$\lambda_c = 1$
$\lambda_{E_s} = \frac{\lambda_L^2 \times \lambda_\sigma}{\lambda_L^2}$	$\lambda_{E_s} = 1$
$\lambda_a = \frac{\lambda_L \times \lambda_\sigma}{\lambda_L^2}$	$\lambda_a = \lambda_L^{-1}$
$\lambda_V = \frac{\lambda_L \times \lambda_\sigma^{0.5}}{\lambda_L}$	$\lambda_V = 1$
$\lambda_T = \frac{\lambda_L^5 \times \lambda_\sigma}{\lambda_L^2}$	$\lambda_T = \lambda_L^3$
$\lambda_F = \frac{\lambda_L^4 \times \lambda_\sigma}{\lambda_L^2}$	$\lambda_F = \lambda_L^2$
$\lambda_\Delta = \lambda_L$	$\lambda_\Delta = \lambda_L$

Scale-up Theory



Comparison of load-displacement curves for model, field test, and predicted prototype piles for helical piles with: (a) 1 Helix at the Anzali site; (b) 2 Helices at the Babolsar Site

Esmailzade, M., Eslami, A. & McCartney, J.S. (2024)

MARINE GEORESOURCES & GEOTECHNOLOGY
https://doi.org/10.1080/1064119X.2024.2330003

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Check for updates

Comparison of frustum confining vessel (FCV) and full-scale testing for helical and expanded piles geotechnical performance

Mohammad Esmailzade[a], Abolfazl Eslami[a,b] and John S. McCartney[b]

[a]Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran; [b]Department of Structural Engineering, University of California San Diego, San Diego, California, USA

ABSTRACT

This study focuses on investigating the compression and pullout load-displacement characteristics of various pile types using a frustum confining vessel at Amirkabir University of Technology (FCV-AUT) and full-scale tests. The FCV-AUT provides a versatile platform for physically modeling reduced-scale deep foundations in a laboratory setting, accounting for flexible geometric and stress factors, and the full-scale load tests took place at two research sites situated along the southern coastline of the Caspian Sea. A comprehensive dataset comprising 40 model-scale and 15 full-scale load tests on different pile configurations (including conventional, helical, and expanded piles) installed in sands has been compiled to facilitate a geotechnical performance evaluation. Conventional piles, encompassing cast-in-place drilled shafts, H piles, pipe piles, and box piles, were considered in the analysis. Helical piles with one to three helixes and various expanded piles, including self-expanded, bubble, and wing piles, were also examined. Notably, among the tested piles, those installed through jacking and expanded piles displayed the highest resistance to compression. Conversely, helical piles and expanded piles demonstrated superior pullout performance when compared to conventional piles. Comparisons between physical model-scale tests and full-scale tests validate the suitability of FCV-AUT for assessing the geotechnical performance of diverse pile types in sand under realistic stress conditions.

ARTICLE HISTORY
Received 26 November 2023
Accepted 26 February 2024

KEYWORDS
Frustum confining vessel (FCV); helical and expanded piles; sand; load-displacement records; scale up

6

Data Bank

Helical and CPT

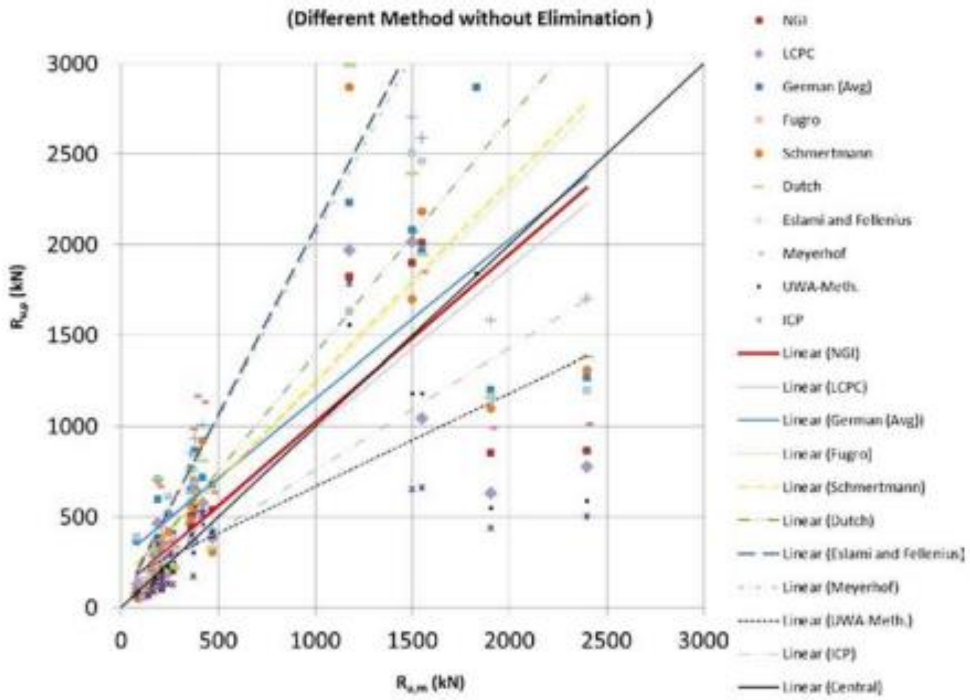

Table 1. Description and geometry of helical piles cases.

Pile name	Loading	Location	Soil type	Depth (m)	Shaft diameter (cm)	Number of helix	Helical diameter (cm)					Helical area (m^2)					Space Ratio (S/D)
							D1	*D2*	*D3*	*D4*	*D5*	*H1*	*H2*	*H3*	*H4*	*H5*	
C1	Compression	Edmonton, Alberta-No.1	Clay	5	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
C2	Compression			3	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
C3	Compression			5	21.9	2	35.6	6	—	—	—	995	619	—	—	—	3
T1	Tension			5	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
T2	Tension			3	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
T3	Tension			5	21.9	2	35.6	6	—	—	—	995	619	—	—	—	3
C6	Compression	Bruderheim, Alberta-No.2	Sand	5	21.9	2	35.6	6	—	—	—	995	619	—	—	—	3
C4	Compression			5	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
C5	Compression			3	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
T6	Tension			5	21.9	2	35.6	6	—	—	—	995	619	—	—	—	3
T4	Tension			5	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
T5	Tension			3	21.9	3	35.6	6	6	—	—	995	619	619	—	—	1.5
C10	Compression	Lamont, Alberta-No.4	Sand	9.3	24.4	2	45.7	8	—	—	—	1640	1173	—	—	—	3.2
C11	Compression	Ruth Lake-No.5	Sand	5.90	27.30	1	76.2	—	—	—	—	4560	—	—	—	—	—
C12	Compression			6.00	27.30	2	76.2	2	—	—	—	4560	3975	—	—	—	3.00
T7	Tension			5.90	27.30	1	76.2	—	—	—	—	4560	3975	—	—	—	—
T8	Tension			6.00	27.30	2	76.2	2	—	—	—	4560	3975	—	—	—	3.00
T9	Tension	Dover-Fort McMurray, Alta-No.6	Sand	4.9	40.6	1	76.2	—	—	—	—	4560	3266	—	—	—	—
C16	Compression	Farmland—John B.C.-No.9	Clay	5	11.4	2	45.7	7	—	—	—	1640	1538	—	—	—	3.3
C17	Compression			4	11.4	1	45.7	—	—	—	—	1640	1538	—	—	—	—
C7	Compression	Saskatchewan, Alberta-No.10	Sand	4.6	17.8	1	46	—	—	—	—	1662	—	—	—	—	—
C8	Compression			4.6	21.9	1	46	—	—	—	—	1662	—	—	—	—	—
C9	Compression			5.5	17.8	2	46	51	—	—	—	1662	1413	—	—	—	3.1
CTP1	Compression	Colebrook	Sensitive clay	8.5	8.9	3	35.5	5	5	—	—	990	928	928	—	—	3
CTP2	Compression			8.5	8.9	5	35.5	5	5	5	5	990	928	928	3	3	1.5
S1	Compression	Ponoka, Alberta,Canada	Silt and clay	9	32.4	2	76.2	2	—	—	—	4560	3736	—	—	—	3
S2	Compression			9	32.4	2	76.2	2	—	—	—	4560	3736	—	—	—	4.5
S3	Compression			9	32.4	2	76.2	2	—	—	—	4560	3736	—	—	—	1.5
S4	Compression			9	32.4	1	76.2	—	—	—	—	4560	—	—	—	—	—
S10	Compression	UMass-Amherst–UMAC	Clay	3.7	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S15	Compression			3.7	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S5	Compression			3.7	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S12	Compression			5.5	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S14	Compression			5.5	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S4	Compression			5.5	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S7	Compression			5.5	7.3	3	2	4	5	—	—	324	282	689	—	—	3
S9	Compression			5.5	7.3	3	2	4	5	—	—	324	282	689	—	—	3

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Direct CPT and CPTu methods for determining bearing capacity of helical piles

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ABSTRACT

Helical piles are structural deep foundation elements, which can be categorized as torque-driven piles without any limitations to implement in marine situations. Different methods are used to predict the axial capacity of helical piles, such as static analysis, but have some limitation for this type of piles on marine conditions. In situ testing methods as supplement of static analysis have been rarely used for helical piles. In geotechnical engineering practice, the most common in situ tests particularly applicable for coastal or offshore site investigation are cone penetration test (CPT) and piezocone penetration test (CPTu). The CPT is simple, repeatable, and prepares the continuous records of soil layers. In this paper, a data bank has been compiled by collecting the results of static pile load tests on thirty-seven helical piles in ten different sites including CPT or CPTu data. Axial capacities of thirty-seven helical piles in different sites were predicted by direct CPT methods and static analysis. Accuracy estimation of ten direct CPT methods to predict the axial capacity of helical piles was investigated in this study. Comparisons have been made among predicted values and measured capacity from the pile load tests. Results indicated that the recently developed methods such as NGI-05 (2005), ICP-05 (2005), and UWA-05 (2005) predicted axial capacity of helical piles more accurately than the other methods such as Meyerhof (1983), Schmertmann (1978), Dutch (1979), LCPC (1982), or Unicone (1997). However, more investigations are required to establish better correlation between CPT data and axial capacity of helical piles.

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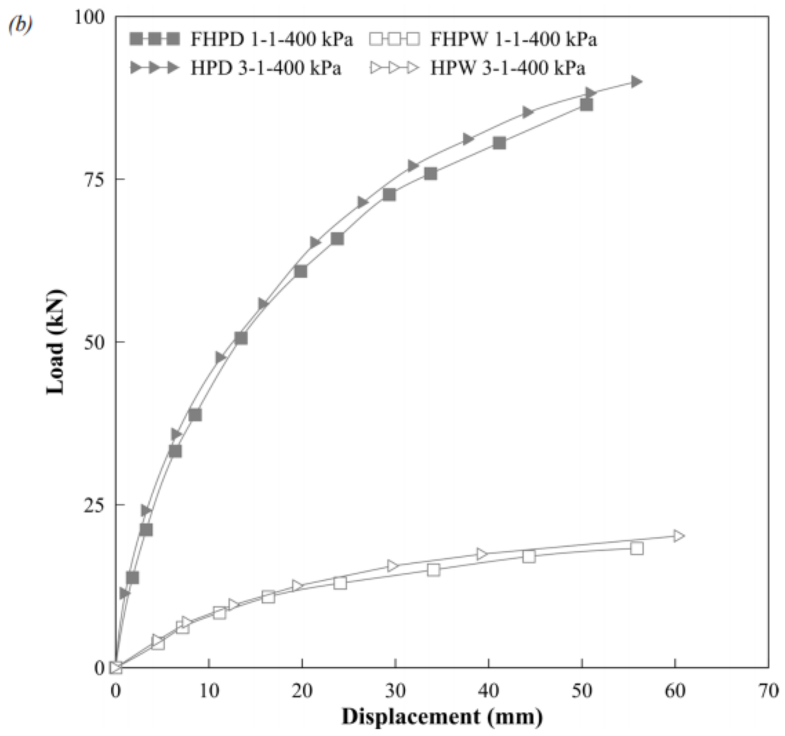
KEYWORDS
Bearing capacity; direct CPT and CPTu methods; helical pile; pile load test; static analysis

Helical in Loess Deposits



Eslami, A., Rostami, F., Heidari Golafzani, S., & Arabameri, M. (2023)

DEEP FOUNDATIONS INSTITUTE DFI

Research Paper

Experimental Investigation of Helical Pile Performance for Loess Deposits Improvement

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Abstract: Collapsible loess is classified as problematic soil found on most continents. The loess immediately collapses under stresses induced by axial compressive loading or the soil weight when exposed to moisture. In Iran, vast areas of the Golestan province are covered with Aeolian loess deposits. This paper investigates whether the simultaneous effect of inundation and pre-loading in helical pile installation is operative and effective in improving Golestan loess. The effect of installation conditions on loess collapsibility is studied via two main approaches, i.e., field investigations and physical modeling. The experimental studies include the installation of ten single and triple helix piles in the Amirkabir University of Technology Frustum Confining Vessel, i.e., FCV-AUT. Also, ten single and double helix piles with embedment depth of 3 to 6 m and a helix diameter of 250 mm were installed in Golestan province, and full-scale pile static loading tests were performed. The results indicated that the simultaneous application of crowd loading and water pressure during the installation of helical piles results in collapsibility potential reduction due to the soil treatment. Moreover, high or low crowd loads accompanied by water pressure during pile installation bring about similar load-displacement behavior of model piles installed in FCV-AUT and full-scale helical piles. Eventually, it was illustrated that the applied improvement technique is effective on loess soils since it uses the least amount of material, machinery, and equipment while attaining the highest possible bearing capacity ratio regarding sustainability.

Keywords:* *Golestan Loess, Helical Pile, Wet & Dry Method, FCV-AUT, Full-Scale Testing, Ground Improvement

Helical Data Base

Table 1. Continued

	ID	Country	Soil type[a]	Pile type[b]	Height: m	NEA[c]	Shaft dia.: mm	D_{min} or D_{max}: mm	Load direction[d]	MML: kN	Maximum displacement: mm
Zhang (1999)											
44	254	Canada	FG	H	3.05	3	219	356	C	158	36
45	255	Canada	FG	H	5.18	3	219	356	C	182	38
46	256	Canada	FG	H	5.18	3	219	356	C	193	70
47	257	Canada	FG	H	5.18	2	219	356	C	216	32
48	259	Canada	FG	H	3.05	3	219	356	T	155	59
49	260	Canada	FG	H	5.18	3	219	356	T	220	71
50	261	Canada	FG	H	5.18	2	219	356	T	221	35
51	264	Canada	S	H	3.05	3	219	356	C	459	50
52	265	Canada	S	H	5.18	3	219	356	C	482	68
53	266	Canada	S	H	5.18	2	219	356	C	391	40
54	267	Canada	S	H	3.05	3	219	356	T	196	46
55	268	Canada	S	H	5.18	3	219	356	T	367	58
56	269	Canada	S	H	5.18	2	219	356	T	384	50
Dos Santos Filho and Cavalcanti Tsuha (2019)											
57	294	Brazil	FG	H	10.50	4	88.9	318	T	224	72
58	298	Brazil	FG	H	9.00	6	88.9	331	T	364	78
59	300	Brazil	FG	H	11.50	4	88.9	318	T	463	79
60	302	Brazil	FG	H	13.50	4	88.9	318	T	501	46
61	304	Brazil	FG	H	12.00	6	88.9	331	T	499	30
62	308	Brazil	FG	H	13.50	4	101.6	318	T	601	36
63	309	Brazil	FG	H	11.00	6	101.6	331	T	502	72
64	311	Brazil	FG	H	13.00	6	101.6	331	T	599	67
65	317	Brazil	FG	H	11.50	4	88.9	318	T	499	66
66	318	Brazil	FG	H	8.00	4	101.6	318	T	185	80
67	333	Brazil	FG	H	16.00	4	101.6	318	T	702	42
Tappenden (2007)											
68	338	Canada	S	H	9.30	2	244	457	C	1169	23
69	339	Canada	FG	H	5.90	1	273	762	C	1023	89
70	340	Canada	FG	H	6.00	2	273	762	C	1368	80
71	341	Canada	FG	H	5.90	1	273	762	T	828	84
72	342	Canada	FG	H	6.00	2	273	762	T	1309	98
73	343	Canada	S	H	4.90	1	406	762	T	1793	50
74	344	Canada	FG	H	7.50	1	219	400	C	1022	18
75	345	Canada	FG	H	10.40	2	324	914	C	542	31
Elsherbiny and El Naggar (2013)											
76	355	Canada	FG	H	7.20	3	178	610	C	144	49
Monteiro et al. (2021)											
77	358	Brazil	FG	XBO	8.80	1	300	600	C	1002	67
78	360	Brazil	FG	XBO	10.00	1	300	600	C	1206	53
79	362	Brazil	FG	XBO	10.00	1	250	600	T	980	55
80	363	Brazil	FG	XBO	8.00	1	250	600	T	630	58

	ID	Country	Soil type[a]	Pile type[b]	Height: m	NEA[c]	Shaft dia.: mm	D_{min} or D_{max}: mm	Load direction[d]	MML: kN	Maximum displacement: mm
Yu et al. (2020)											
1	2	China	FG	XBA	16.00	1	800	1500	T	7860	93
2	3	China	FG	XBA	16.00	1	800	1500	T	7860	95
3	5	China	FG	XBA	22.00	1	850	1500	T	8646	90
4	6	China	FG	XBA	22.00	1	850	1500	T	9432	86
Xu et al. (2009)											
5	7	China	FG	XBA	18.70	1	500	1200	T	840	21
6	8	China	FG	XBA	18.70	1	500	1200	T	887	33
7	9	China	FG	XBA	18.70	1	500	1200	T	806	44
8	10	China	FG	XBA	22.10	1	500	1200	T	1289	39
9	11	China	FG	XBA	22.10	1	500	1200	T	1179	15
10	12	China	FG	XBA	22.10	1	500	1200	T	1280	63
Sakr (2009)											
11	103	Canada	S	H	5.20	1	178	406	C	798	10
12	104	Canada	S	H	5.00	2	178	406	C	808	9
13	105	Canada	S	H	5.10	1	178	406	T	792	14
14	106	Canada	S	H	5.10	2	178	406	T	780	9
15	109	Canada	S	H	5.30	1	178	406	C	1255	52
16	110	Canada	S	H	5.30	2	178	406	C	1575	40
17	111	Canada	S	H	5.10	1	178	406	T	619	43
18	113	Canada	S	H	5.20	2	178	406	T	973	48
Sakr (2013)											
19	122	Canada	FG	H	9.00	1	324	762	C	2549	36
Gavin et al. (2014)											
20	123	Ireland	S	H	2.57	1	110	400	C	588	69
21	124	Ireland	S	H	2.57	1	110	400	T	241	72
Fahmy and El Naggar (2017)											
22	128	USA	S	H	2.40	1	150	390	C	509	90
23	130	USA	S	H	2.75	1	200	390	C	471	52
Elkasabgy and El Naggar (2015)											
24	133	Canada	FG	H	6.00	2	324	610	C	1745	44
25	137	Canada	FG	H	9.00	1	324	610	C	2087	62
Beim and Luna (2012)											
26	140	USA	FG	H	3.70	3	73	254	C	108	15
27	141	USA	FG	H	5.50	3	73	254	C	46	14
28	145	USA	FG	H	5.50	3	73	254	C	54	14
29	146	USA	FG	H	3.70	3	73	254	C	110	14
Weech and Howie (2012)											
30	156	Canada	FG	H	8.50	5	89	356	C	63	90
Gao et al. (2007)											
31	206	China	FG	XBO	24.00	3	620	1333	C	3897	38
32	207	China	FG	XBO	24.00	3	620	1333	C	3610	37
33	208	China	FG	XBO	24.00	3	620	1333	C	3610	40
Piao and Qu (2012)											
34	218	China	FG	XBO	19.00	3	700	1500	C	6284	74
Cui and Wang (2012)											
35	219	China	FG	XBO	8.90	2	600	1100	C	959	54
Yin et al. (2017)											
36	220	China	FG	XBO	17.30	2	700	1400	C	11748	31
37	221	China	FG	XBO	17.30	2	700	1400	C	9020	13
38	222	China	FG	XBO	17.30	2	700	1400	C	8994	22
Dehong et al. (2017)											
39	224	China	FG	XBO	16.70	1	600	1400	C	2010	35
40	225	China	FG	XBO	16.70	1	600	1400	C	2060	38
Zhang et al. (2018)											
41	238	China	FG	XBO	36.80	2	700	1400	C	7986	62
42	239	China	FG	XBO	36.80	2	700	1400	C	8007	61
43	240	China	FG	XBO	36.80	2	700	1400	C	8007	64

Helical Data Base

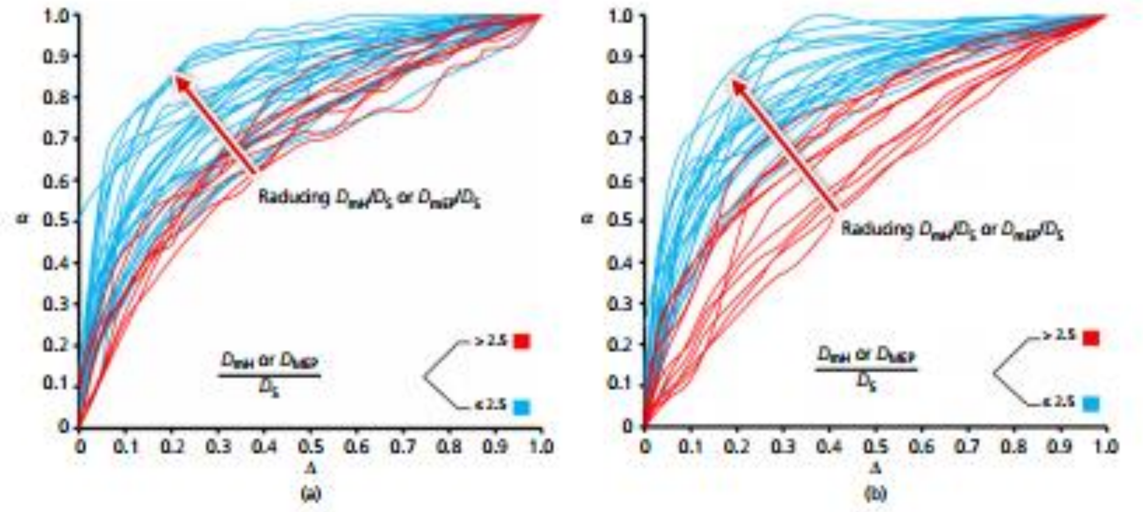

Figure 17. Effect of change in D_{mH}/D_S or D_{mEP}/D_S: (a) compressive tests; (b) tensile tests

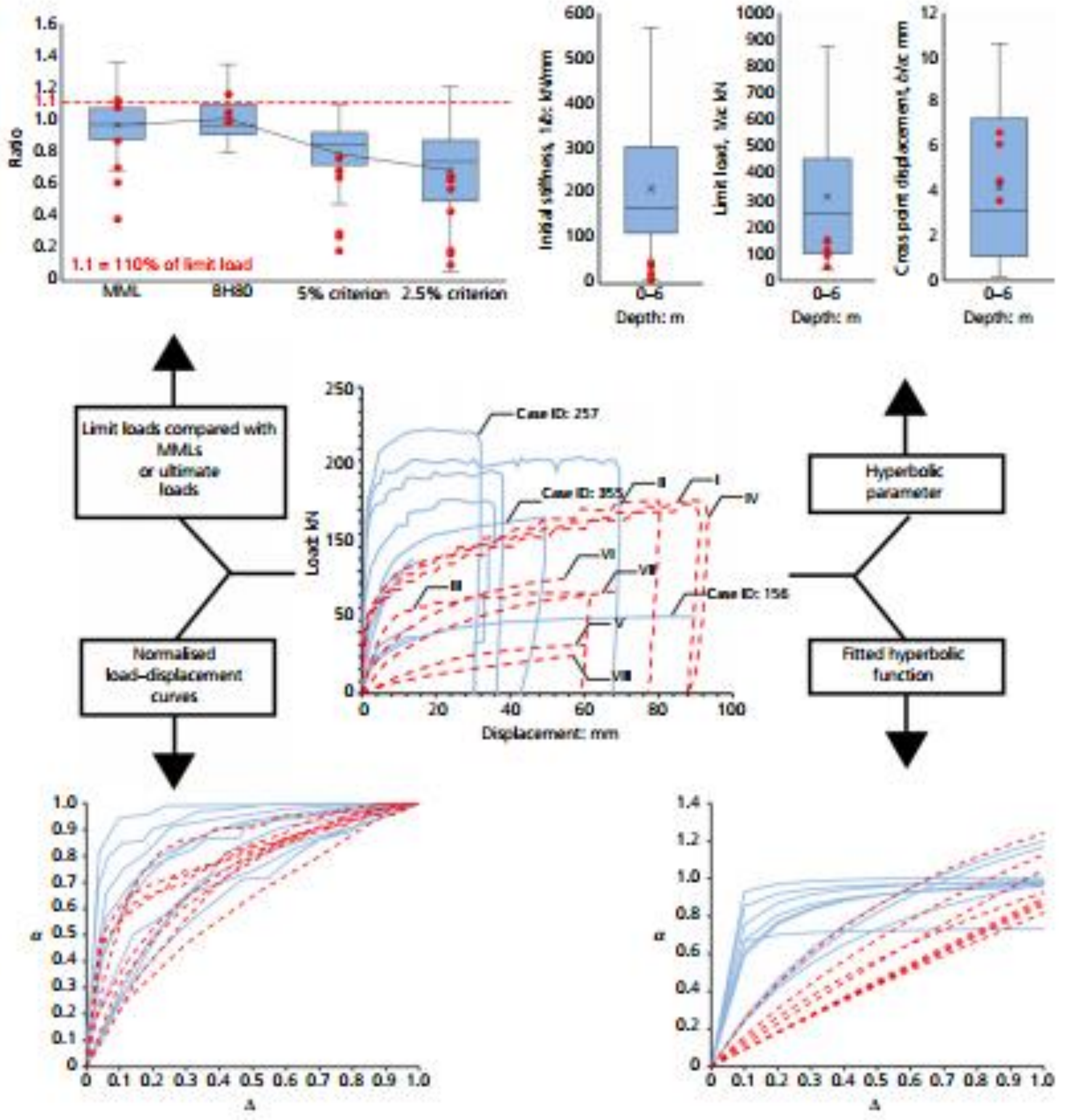

Figure 19. Comparison of load–displacement behaviour from pile tests and from the database

Rahimi, A.H., Eslami, A. & McCartney, J.S. (2024)

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Hyperbolic load–displacement analysis of helical and expanded piles: database approach

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Recent years have witnessed a focus on improving geotechnical systems by implementing and constructing new deep foundations such as helical and expanded piles. In this study, the effects of parameters such as embedment depth, pile geometry and axial loading direction on the load–displacement behaviour of these piles were examined. To this end, a database was compiled consisting of 80 axial loading test records for different piles. The embedment depth of the piles was in the range 2.4–36.8 m and the diameter of the helices (D_H) or expanded parts (D_{EP}) was in the range 254–1500 mm. The ultimate load of the piles was determined using the 2.5% and 5% displacement ratio criteria and the Brinch Hansen 80% method. Hyperbolic functions were fitted to the load–displacement curves, allowing for consistent estimation of the limit load and the initial tangent modulus. Analysis of the results from the database revealed that the dominant factors influencing the ultimate load, limit load, maximum measured load, initial stiffness and load–displacement behaviour were the ratio of D_H or D_{EP} to the shaft diameter, the shaft area and the toe area, and the load direction. Correlations derived from the database were validated using measurements from eight full-scale helical and expanded piles.

Keywords: database/helical and expanded piles/hyperbolic function analysis/load–displacement/piles & piling/pull-out testing/ultimate load

Helical Machine Learning

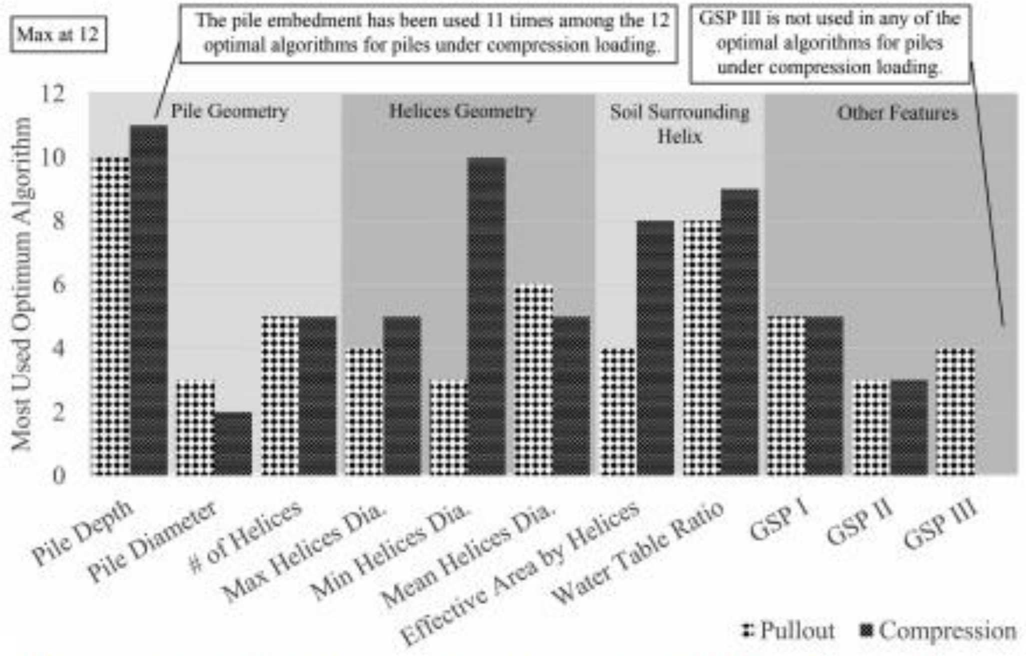

Figure 13. Sensitivity analysis of different machine-based algorithms of test data (features in optimum algorithms).

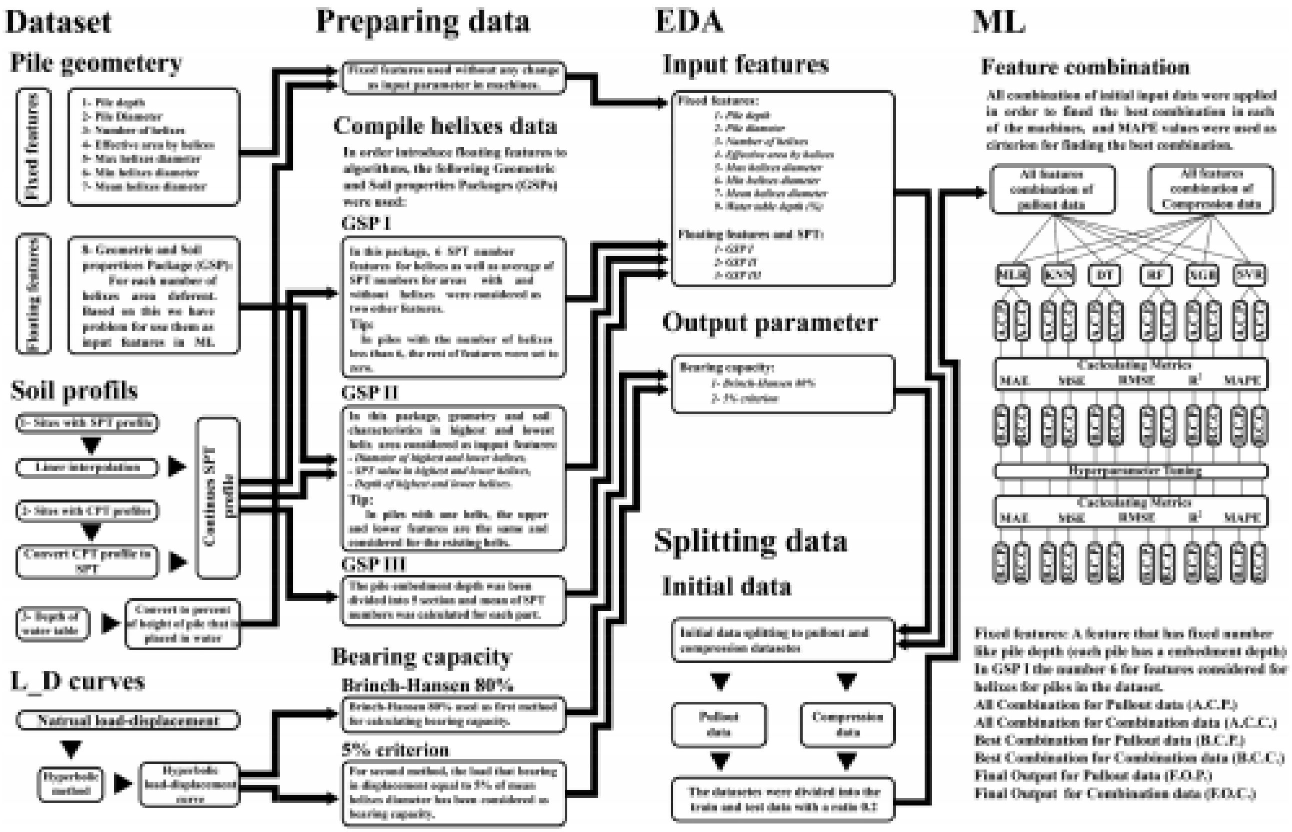

Figure 1. Study flow guideline for predicting ultimate load bearing of helical piles.

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Ultimate load bearing of helical piles prediction and evaluation using machine learning-based algorithms

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ABSTRACT

This study aims to predict the Ultimate Load-Bearing (ULB) capacity of Helical Piles (HP) using six Machine Learning Algorithms (MLA) on an in situ-based 110 pile load tests including a wide range of pile properties: shaft diameters (73–406 mm), helix diameters (254–762 mm), helix spacing (300–1000 mm), number of helices (1–6), pile lengths (2.4–16 m), and helix thicknesses (6–12 mm). The measured axial ULB is analysed using the Brinch-Hansen 80% criterion and 5% criterion of the average diameter of the helices. Load-displacement curves were fitted using the Hyperbolic Function. MLA including Multi Linear Regression (MLR), K-Nearest Neighbors (KNN), Decision Tree (DT), Random Forest, eXtreme Gradient Boosting, and Support Vector Regression were optimised to grid search for hyperparameters like neighbour count, tree depth, learning rate, and kernel type. Input parameters were categorised into Geometric and Soil Properties packages. Results indicate that the DT algorithm excelled in pullout loading, KNN in compression loading, and MLR for Brinch-Hansen 80% criterion estimations. The input parameters related to the soil surrounding the pile helices have the most impact on the ULB prediction of HP. This study enhances HP foundation design by enabling data-driven decisions for optimal pile selection and configuration.

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KEYWORDS
Ultimate load criteria; predictive model; machine learning-based algorithms; helical Piles

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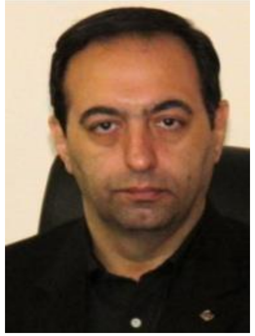
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