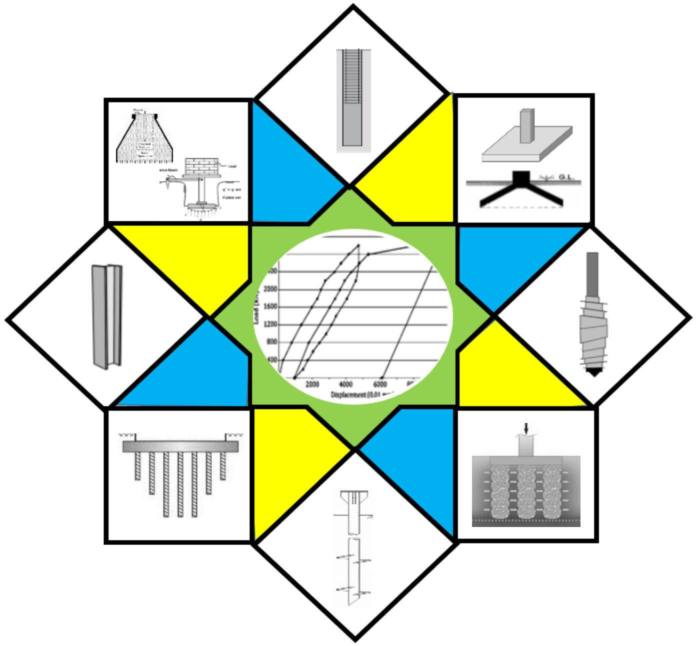
A Unified Approach to Foundation Engineering;
Capacity & Settlement Through Load-Displacement (CaSeLD)

Presented to Prof. Kenichi Soga and the Research Team
University of California, Berkeley



Dr. Abolfazl Eslami and Research Group

May 2026

Outline

1	Background
2	Databases
3	Advancements
4	Prospects

Scope:
Foundation Engineering, The Integration of;
Structural Logic, Geomaterial Reality, and Construction Experience.
Powered by Data. Proven by Performance.

Data Sources

(1) Maps

(2) Aerial Photos

(3) Site Visit

(4) Non-Destructive Tests

(5) Remote Sensing

(6) On-Situ Testing

(7) In-situ Penetration Testing

(8) Boring and Sampling

(9) Laboratory Testing

(10) Physical Modeling

(11) Full-Scale Tests

(12) Instrumentation & Monitoring

***In-Situ Tests;* more pronounced and applicable in Foundation Engineering**

Why In-Situ Testing?

Laboratory Test Limitations

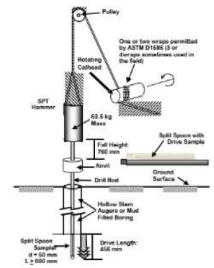
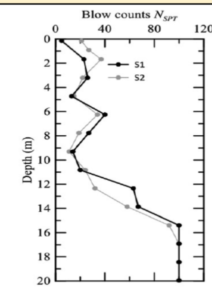
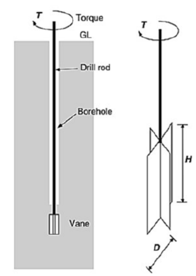
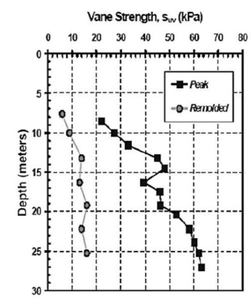
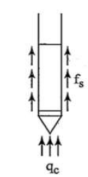
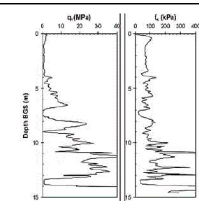
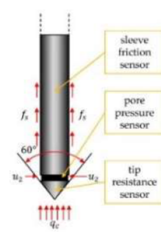
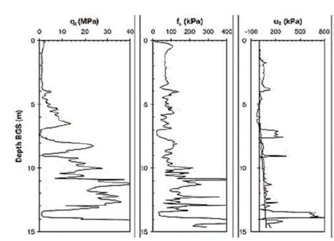
- *Undisturbed Sampling Challenges:* True in-situ soil conditions are hard to preserve.
- *Soil Disturbance & Preservation:* Handling and storage can alter natural properties.
- *Volume Changes:* Shrinkage or swelling may distort laboratory measurements.
- *Inadequate Confinement:* Lab conditions cannot fully replicate field stress states.
- *Scale & Boundary Effects:* Small specimens and boundaries can bias results.

Field Test Advantages

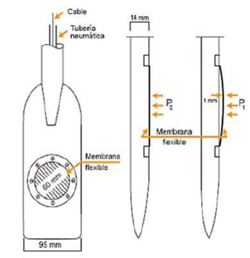
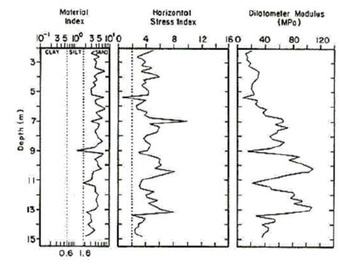
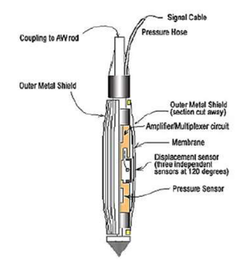
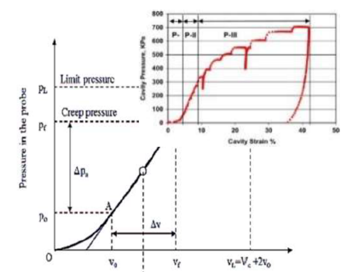
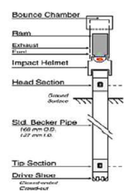
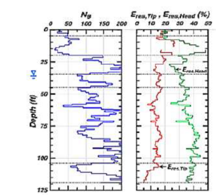
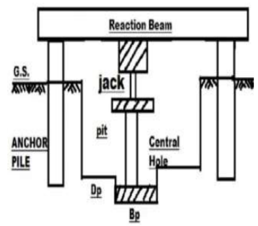
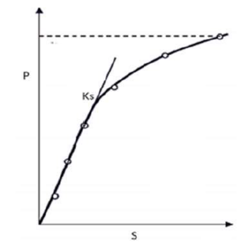
- *Bypasses Sampling Difficulties:* No need for extracting undisturbed samples.
- *Maintains In-Situ Stress State:* Preserves natural soil behavior during testing.
- *Fast and Efficient:* Simple execution with rapid data acquisition.
- *Economical:* Reduces laboratory handling and associated costs.
- *Direct Foundation Relevance:* Data immediately applicable to design and analysis.

Laboratory & In-Situ Tests; Complementary & Interactive

Procedures and Records of Common In-situ Tests (Karakouzian & Eslami, 2026)

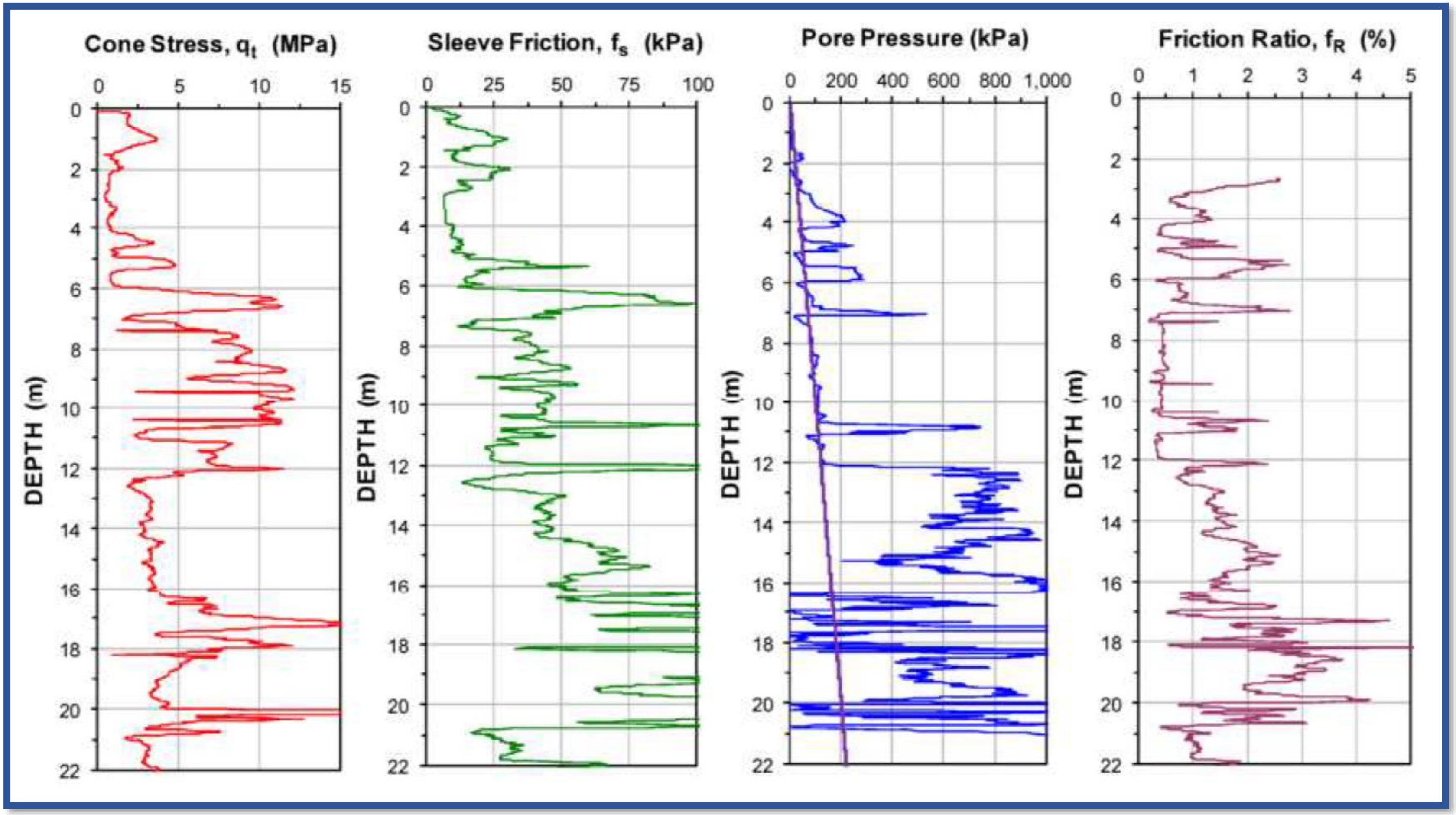
Test and Standard	Suitable Soils	Testing Procedure		Records	
				Graphical Presentation	Numerical Quantity
Standard Penetration Test (SPT) ASTM D1586	Almost all soil types	• Insert an SPT split-spoon sampler into the hole. • Raise a 63.5-kg hammer to a distance of 760 mm and allow it to fall. • Repeat this process until the sampler has penetrated 450 mm. • Record the number of hammer blows required for each 150-mm interval for three intervals.			**N:** The number of blows required to achieve a penetration of 12 inches (300mm)
Vane Shear Test (VST) ASTM D2573	Soft to medium fine grained soils	• Insert a metal vane into the soil. • Rotate the vane at a rate of 6 degree per minute until the soil fails in shear. • Record the maximum torque during the rotation.			$\mathbf{S_u}$: Undrained shear strength $S_u = \frac{6T_{max}}{7\pi D^3}$
Cone Penetration Test (CPT) ASTM D3441	All except gravels	• Cone is pushed continuously by a hydraulic jack at a speed of 20mm/s. • The readings are taken at every 10 to 50 mm.			$\mathbf{q_c}$: Cone point resistance $\mathbf{f_s}$: Sleeve friction
Piezocone Penetration Test (CPTu) ASTM D6067	Fine-grained (very soft to hard) Granular (loose to medium-dense)	• Probe is pushed into the ground at a speed of 2cm/second to reach a predefined depth or the probe cannot be pushed any further due to obstacles.			$\mathbf{q_c}$: Cone point resistance $\mathbf{f_s}$: Sleeve friction $\mathbf{u_2}$: Pore pressure at cone shoulder

Procedures and Records of Common In-situ Tests (Karakouzian & Eslami, 2026)

Test and Standard	Suitable Soils	Testing Procedure		Records	
				Graphical Presentation	Numerical Quantity
Dilatometer Test (DMT) ASTM D6635	Almost all soil types	• A tapered stainless-steel blade with an 18-degree wedge tip that is pushed vertically into the ground at 8-inch (200mm) intervals at a rate of (0.8-inch/s) (20mm/s). • The blade is connected to a readout pressure gauge at the ground surface via a special air-tubing with internal wire pre-threaded through push rods. • A 2.4 in (60mm) diameter flexible steel membrane located on one side of the blade is inflated pneumatically.			I_D: Material index K_D: Horizontal stress index E_D:Dilatometer modulus
Pressuremeter Test (PMT) ASTM D4719	Almost all types of soils and soft rock	• The test is conducted in a prebored hole with a diameter that is between 1.03 and 1.2 times the nominal diameter of the probe. • The most common probe has a diameter of 58 mm and a length of 420 mm. • Probe cells can be expanded by either liquid or gas. • Pressure is applied in increments and the new volume of the cell is measured. The process is continued until the soil fails or the device's pressure limit is reached.			E_p: Pressuremeter modulus P_f: Creep, or yield pressure P_l: Limit pressure **G**: Shear Modulus
Becker Penetration Test (BPT)	Sands through boulders	• Using a small diesel pile-driving hammer and percussion action to drive a 135 to 230 mm (5.5–9.0 in) diameter double-wall steel casing into the ground. • The cuttings are sent to the top by blowing air through the casing.			N_B: The number of blows required to advance the casing 300 mm (1 ft) E_{res}: Residual energies measured at head and tip sections
Plate Load Test (PLT) ASTM D1194	Almost all soil types	• Typical sizes of plates range from 0.15m (6in.) to 0.91m (36 in.). • Plate rests uniformly on the soil; arrange a loading system to provide a sufficient reaction; and provide a means for measuring plate deformation.			K_s: Subgrade reaction E_s: Elastic modulus Q_U: Ultimate bearing capacity of shallow foundation

Soil Profiling: In-Situ Tests

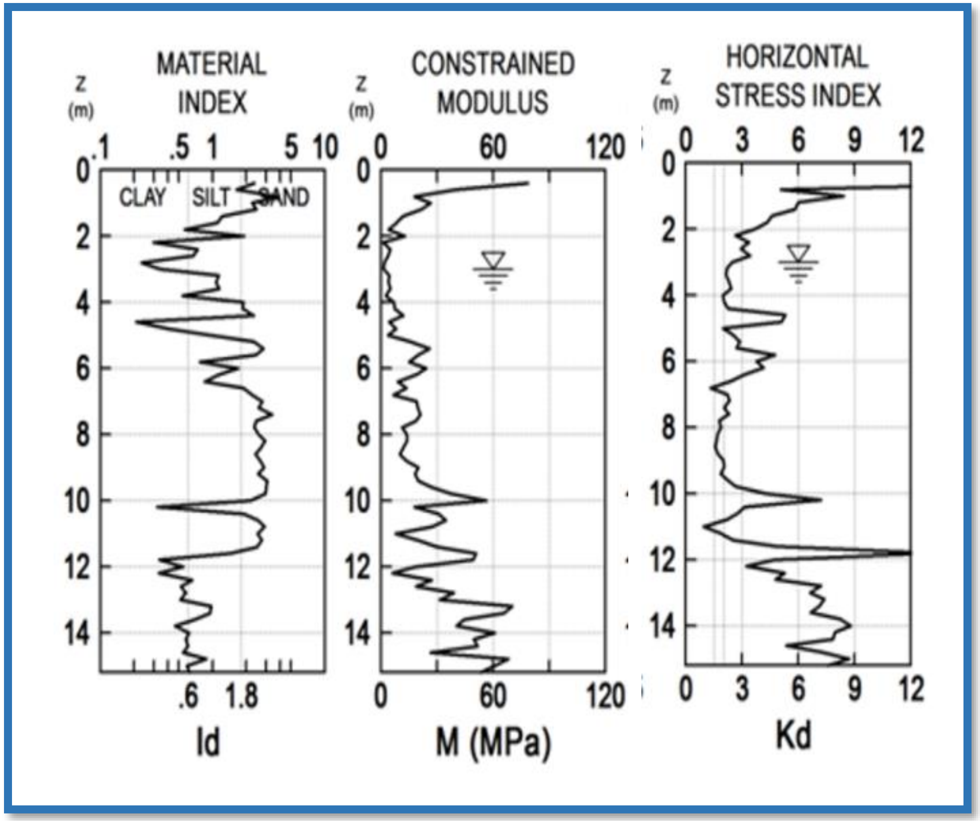
❖ **Bolivian Experimental Site for Testing (B.E.S.T.) (Fellenius et al., 2017)**



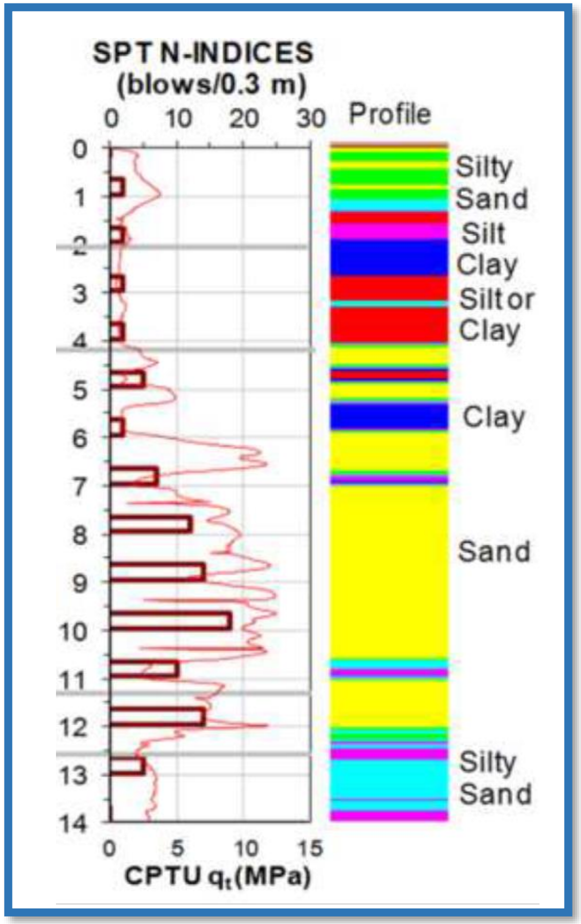
CPTU sounding diagram for BH-E2 (Fellenius et al., 2017)

Soil Profiling: In-Situ Tests

- **Bolivian Experimental Site for Testing (B.E.S.T.) (Fellenius et al., 2017)**



DMT results for BH-B2 (Fellenius et al., 2017)



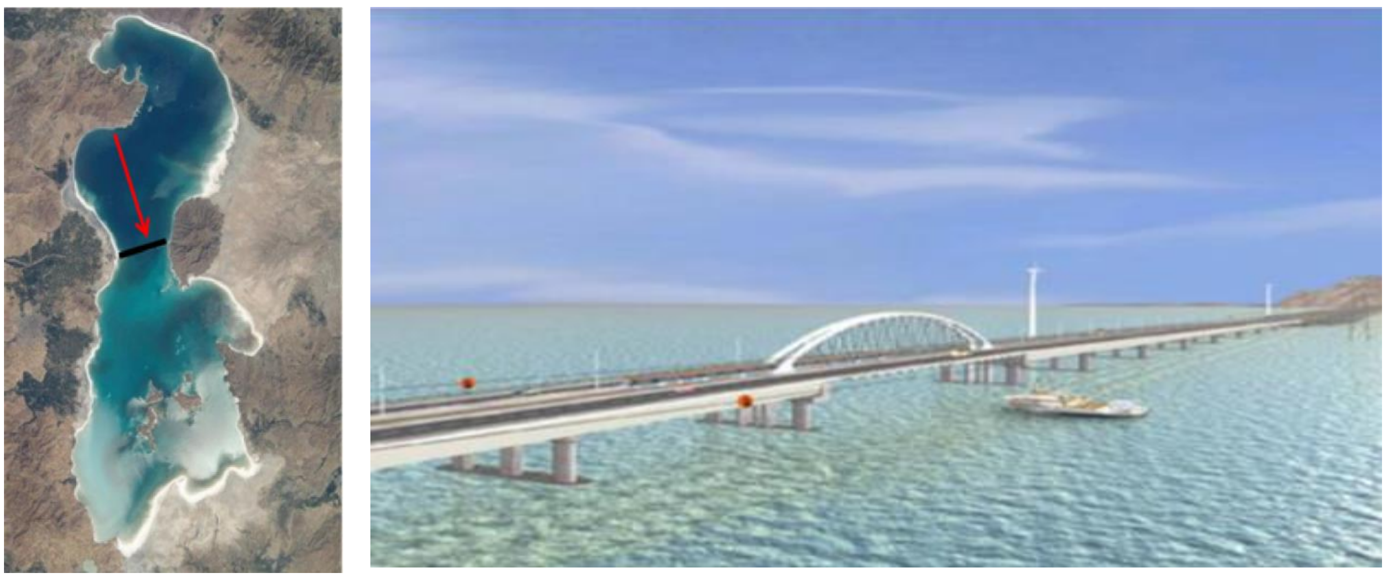
SPT N values for BH-E2 (Fellenius et al., 2017)

Soil Profiling: In-Situ Tests

❖ Urmia Lake Causeway (Eslami et al., 2011, 2019 & 2024)

- Reducing the proposed route from 300 km to 120 km,
- Total length of 1260 m
  - ❖ 19 spans
  - ❖ 100 m in length for the main span

Long Piles & Super Soft Deposits

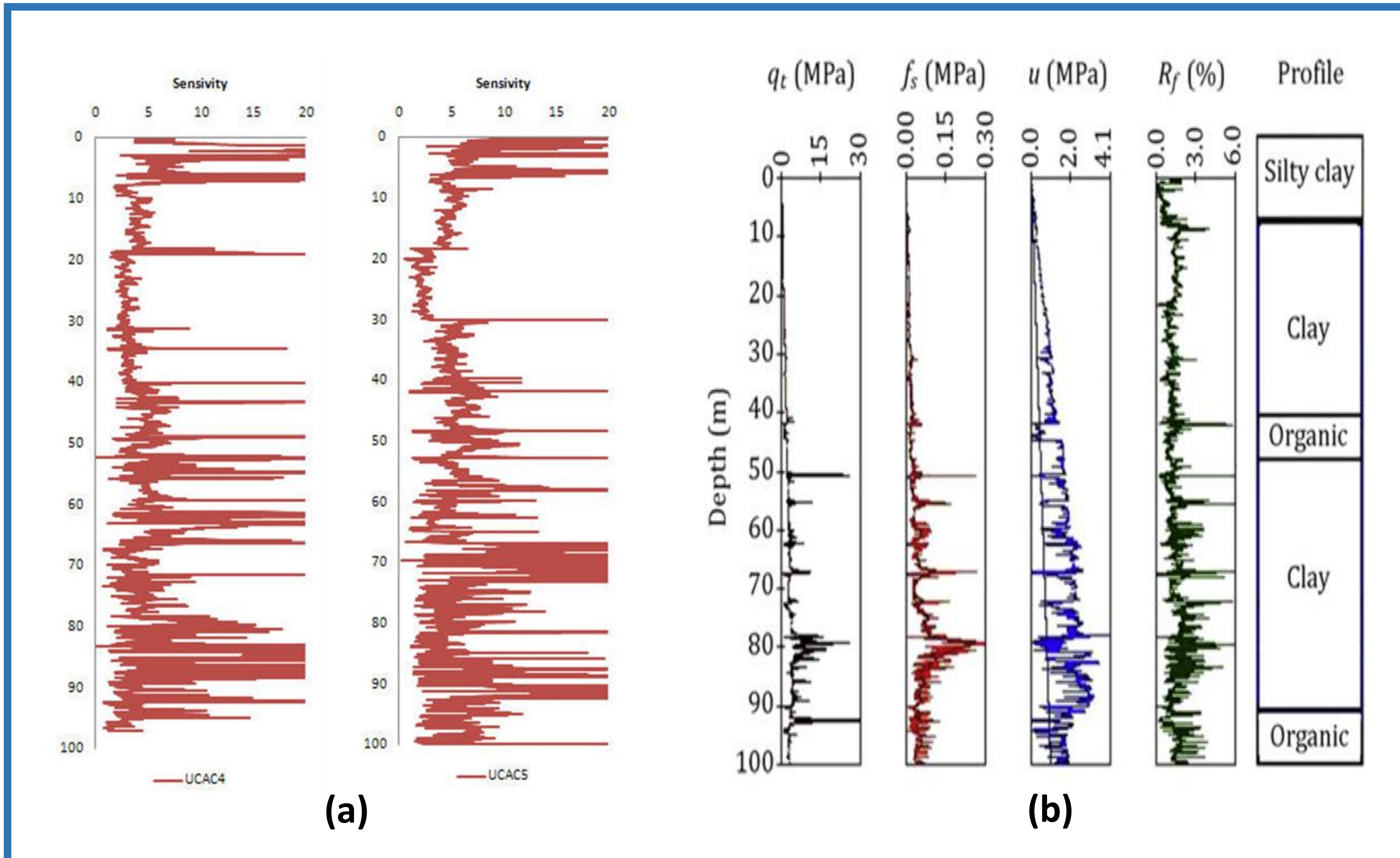


(a) (b)

a) Location, b) Longitudinal view of the causeway

Soil Profiling: In-Situ Tests

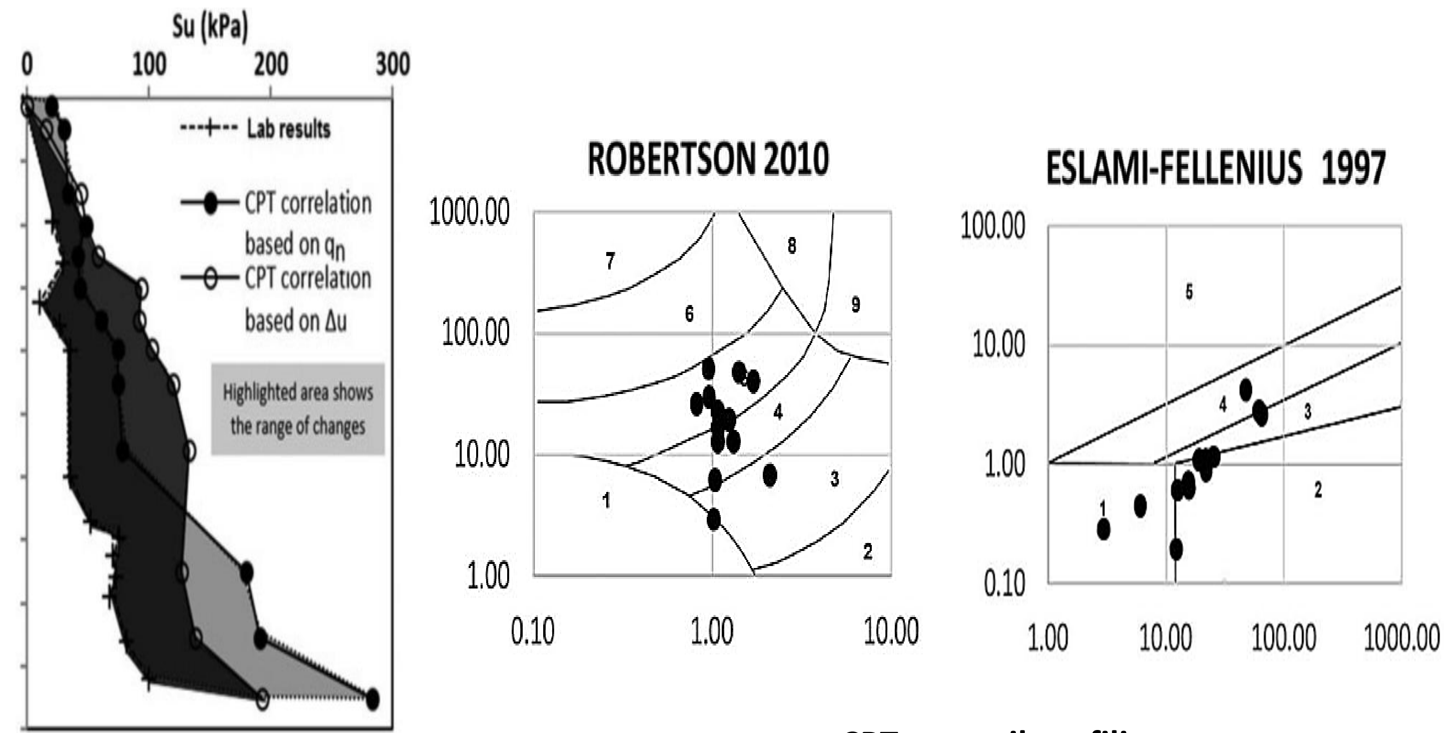
❖ **Urmia Lake Causeway (Eslami et al., 2011, 2019 & 2024)**



a) Sensitivity log, b) Typical CPT logs

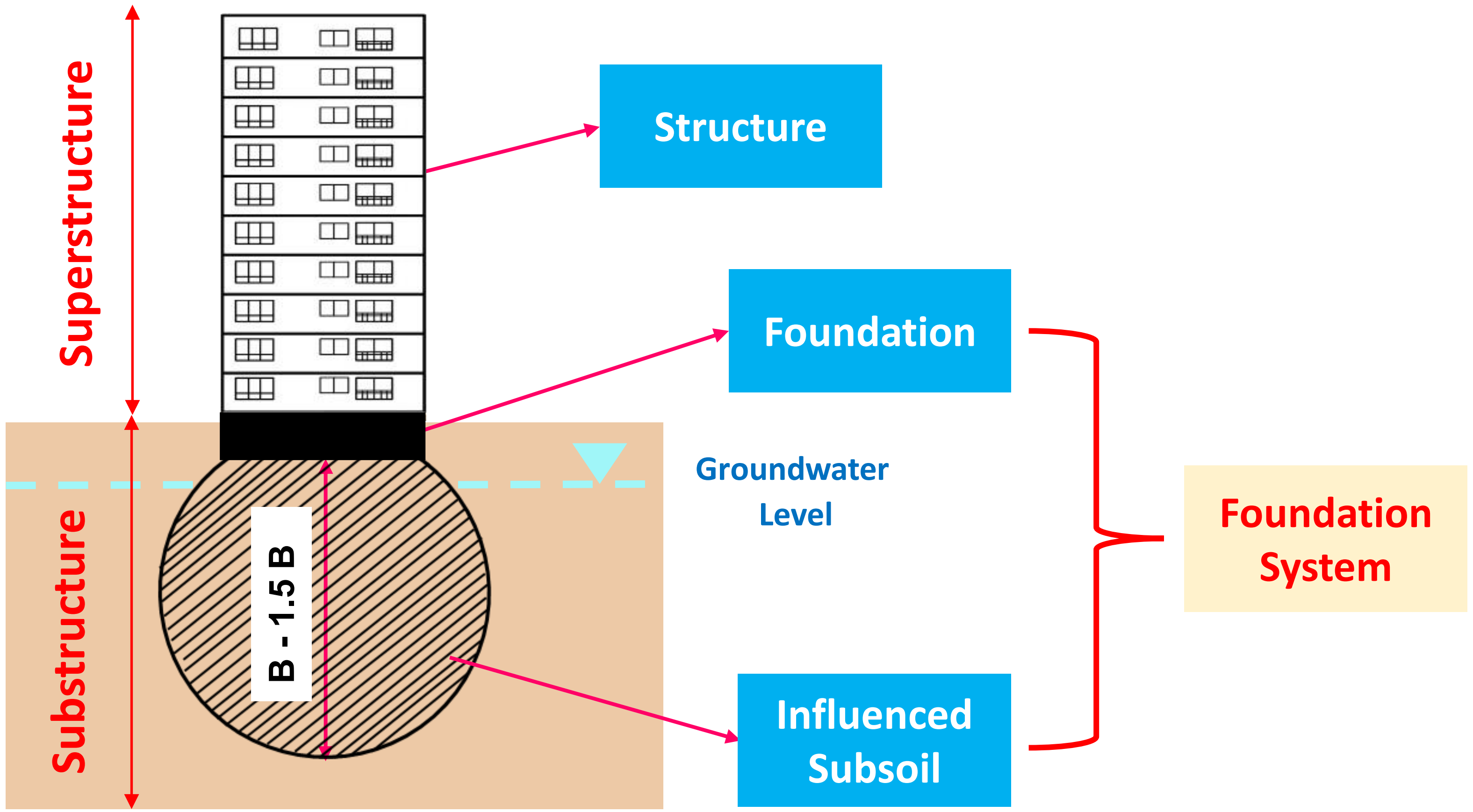
Soil Profiling: In-Situ Tests

❖ Urmia Lake Causeway
(Eslami et al., 2011, 2019 & 2024)

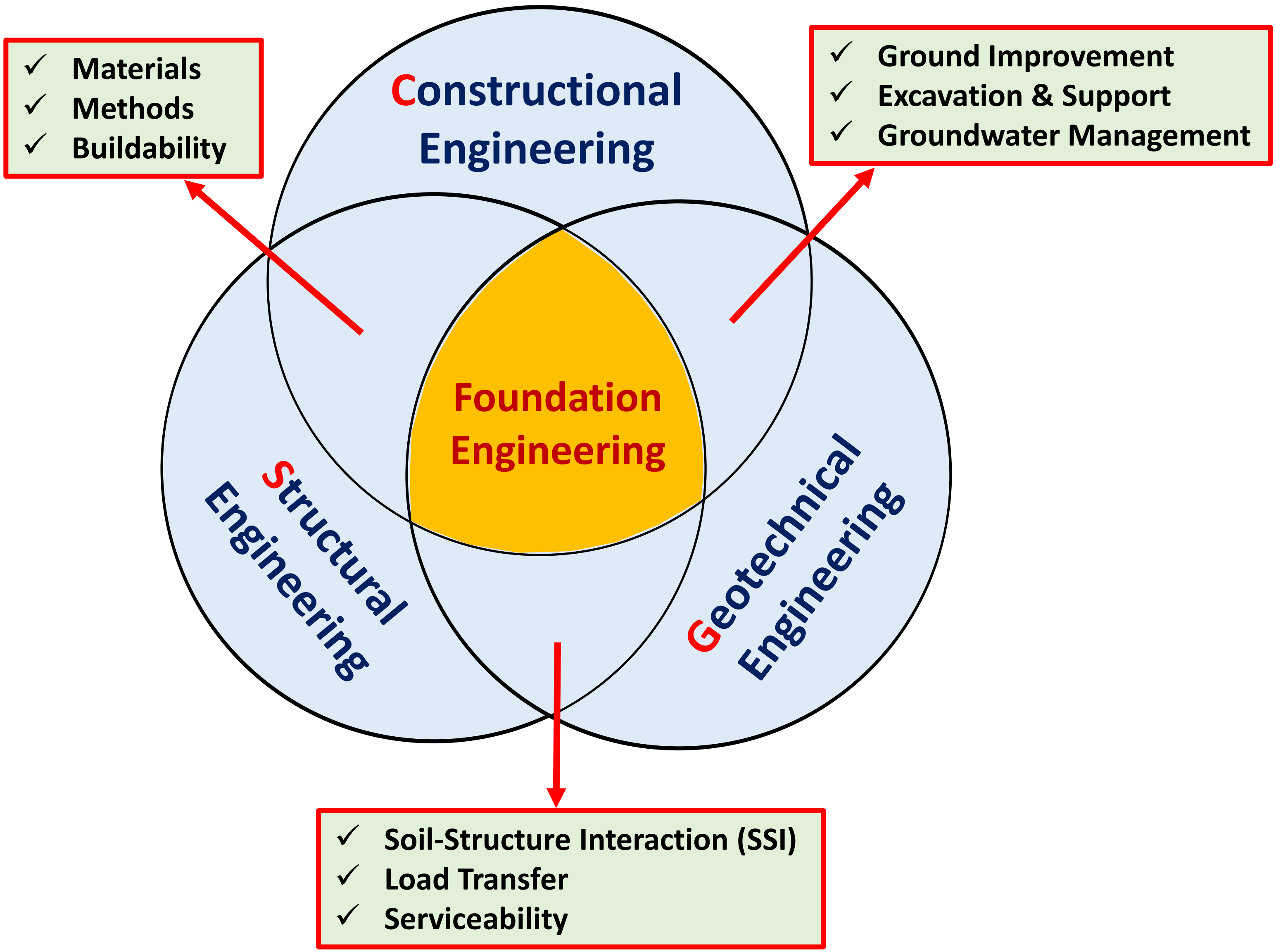


CPT test soil profiling

Interaction of Superstructure & Substructure



Foundation elements or systems are structural units that transfer various load combinations from the superstructure to the underlying geomaterials. Foundation units may tolerate the loads individually or by contribution of other elements such as basement walls, floors, or slabs (Eslami et al., 2020).


Materials
Methods
Buildability
Constructional Engineering
Ground Improvement
Excavation & Support
Groundwater Management
Foundation Engineering
Structural Engineering
Geotechnical Engineering
Soil-Structure Interaction (SSI)
Load Transfer
Serviceability

Major Analysis & Design Requirements

Eslami et al. (2020):

- Bearing Capacity
- Serviceability
- Structural Design
- Stability Control
- Full or Model Scale Testing
- Constructional Aspects
- Durability
- Economic Requirements

Foundation Engineering Tools

Salgado (2008):

- Soil & Rock Mechanics
- Codes & Standards
- Experience & Empiricism
- Publications: Where to Go for Help
- Conferences & Short Courses
- Computers

Fellenius (2015): The analysis and design of foundations are an iterative and interactive, affected by geotechnical capacity, structural capacity and settlement requirements.

Foundations Classification

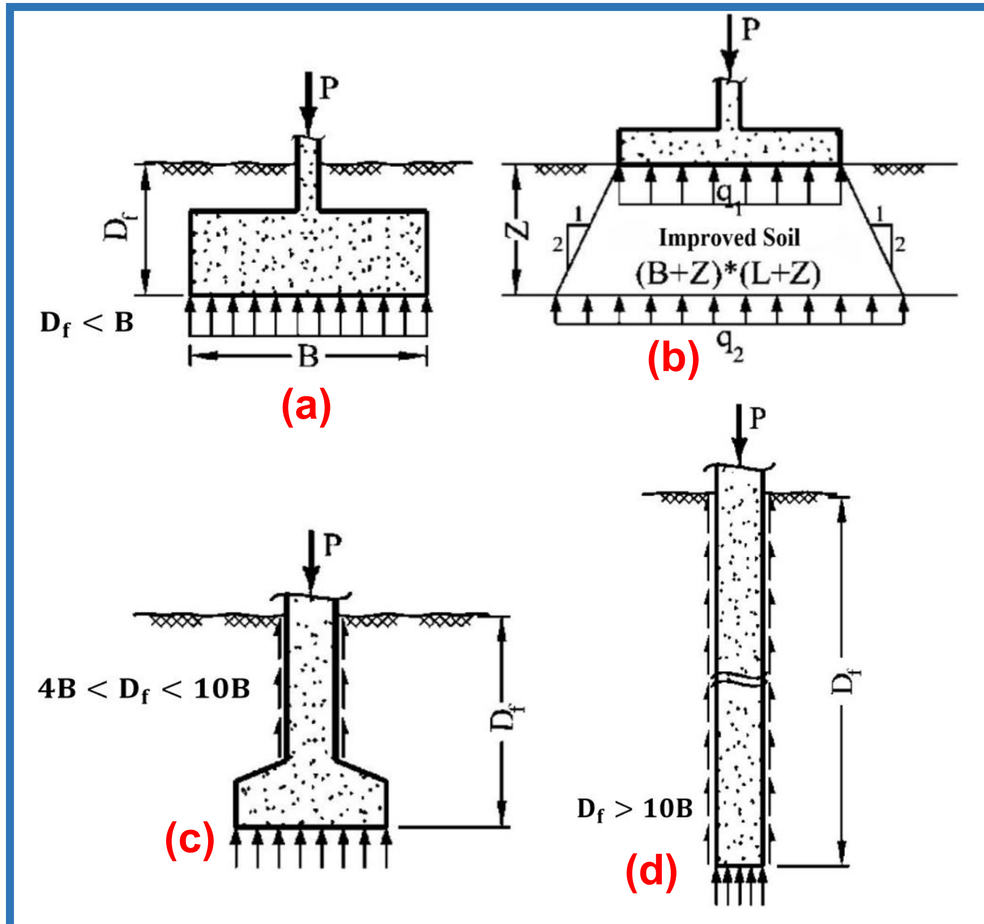
- **Embedment Depth**

✓ Shallow Foundations (a)

✓ Shallow + Soil Improvement (b)

✓ Semi-deep Foundations (c)

✓ Deep Foundations (d)



Current categories of foundations
(Eslami et al., 2020)

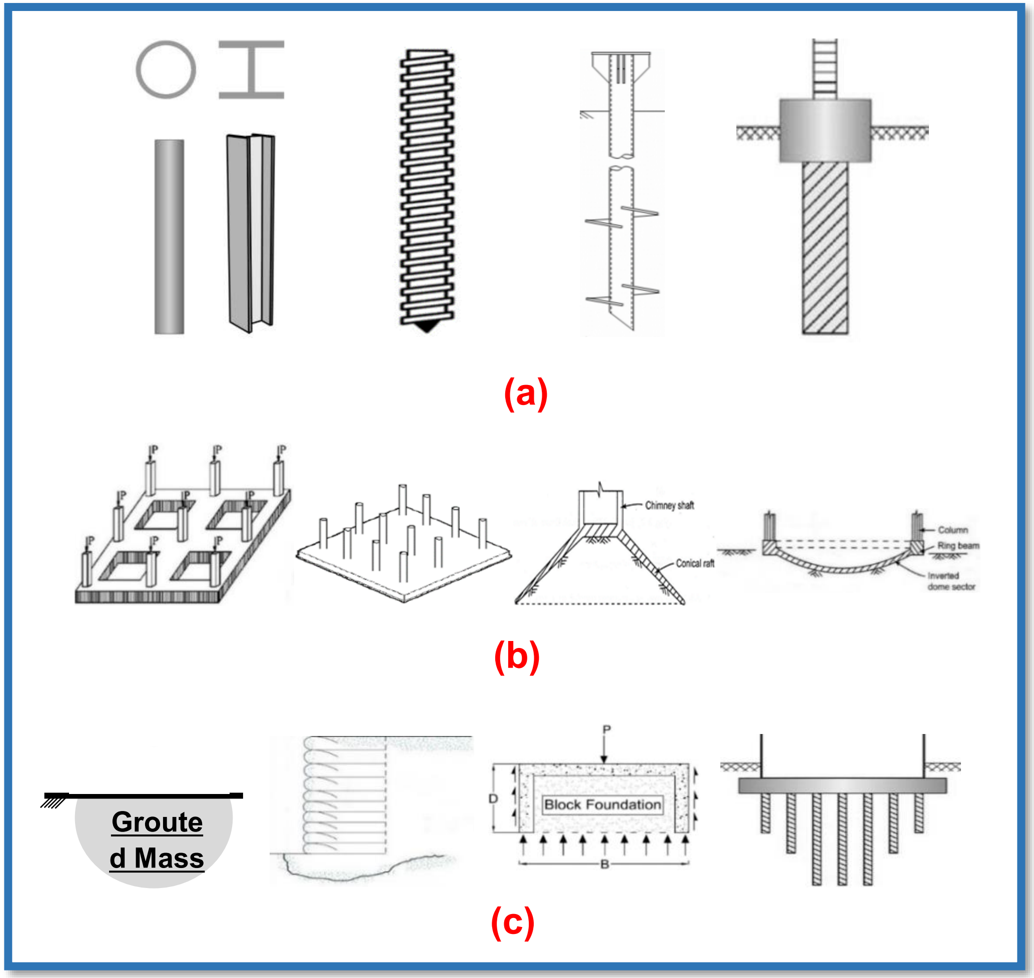
Foundations Classification

- **Form & Function**

✓ **Linear (1D) Foundations (a)**

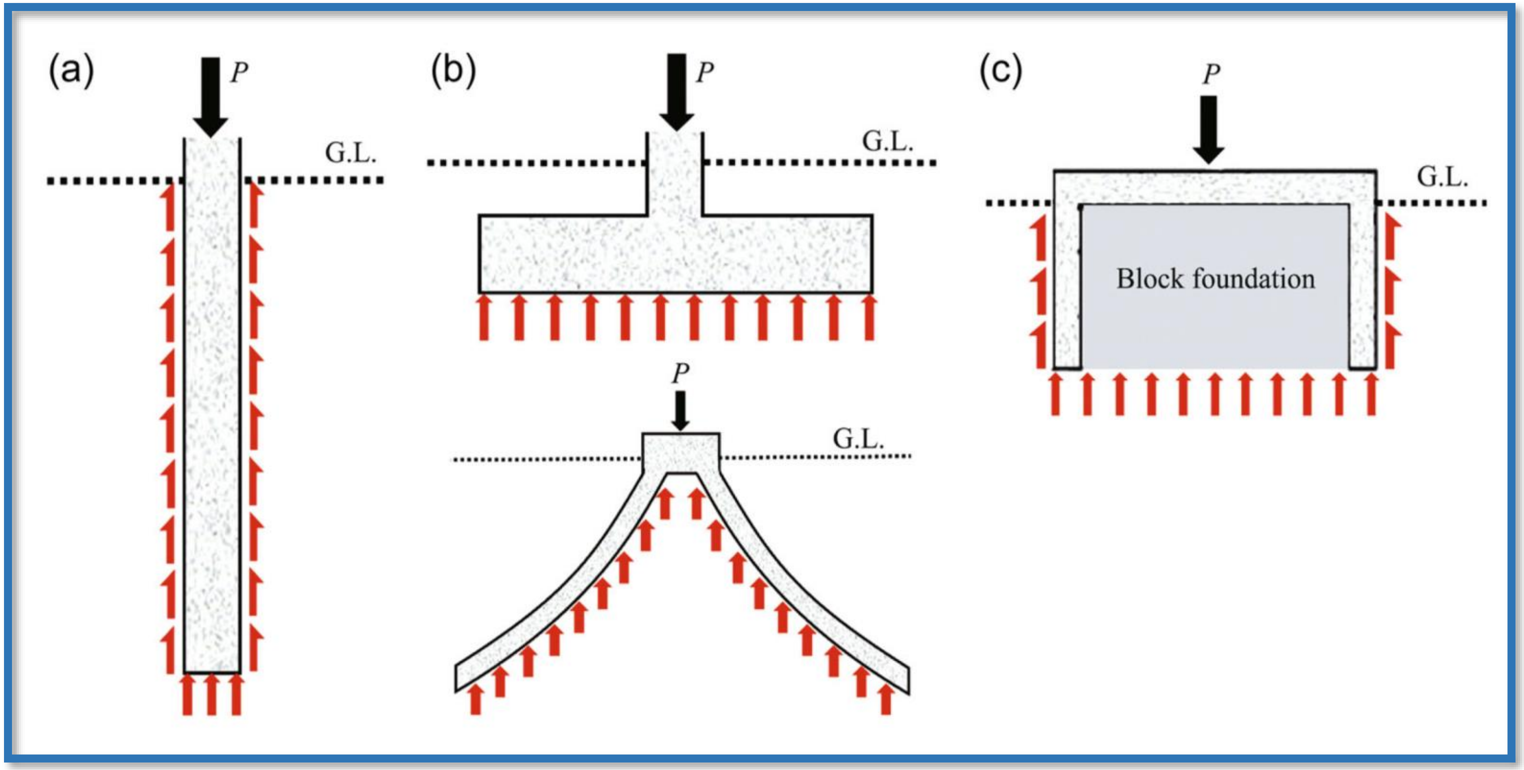
✓ **Planar (2D) Foundations (b)**

✓ **Volumetric (3D) Foundations (c)**



(Eslami et al., 2025)

Prevailing External Load Transfer Mechanism (Eslami et al., 2025)

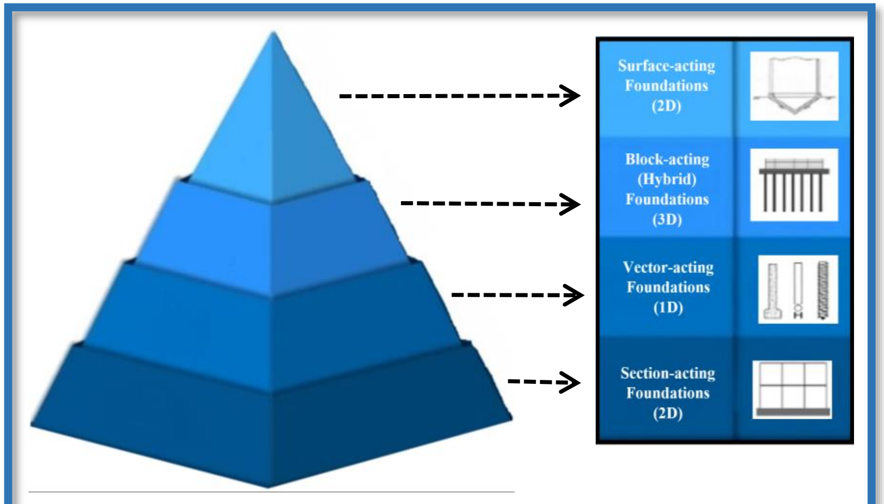


Prevailing external load transfer mechanism of various types of foundations regarding form: (a) linear, (b) planar, and (c) Volumetric (Eslami et al., 2025)

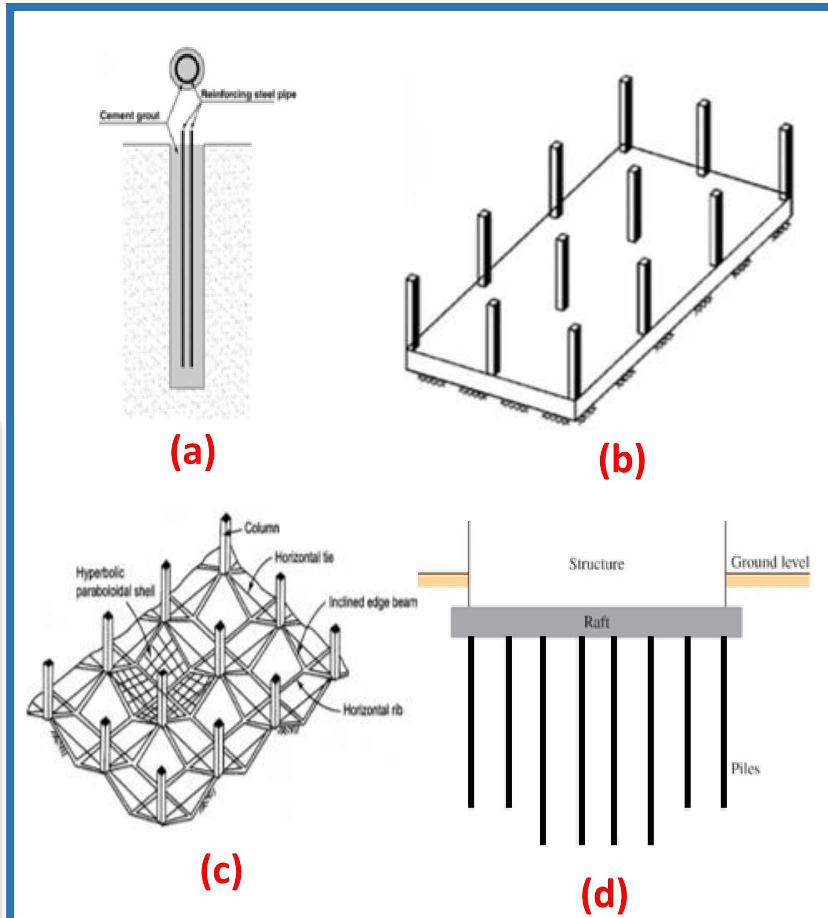
Foundations Classification

- **Load Transfer System**

- Vector-acting Foundations (a)
- Section-acting Foundations (b)
- Surface-acting Foundations (c)
- Block-acting (Hybrid) Foundations (d)

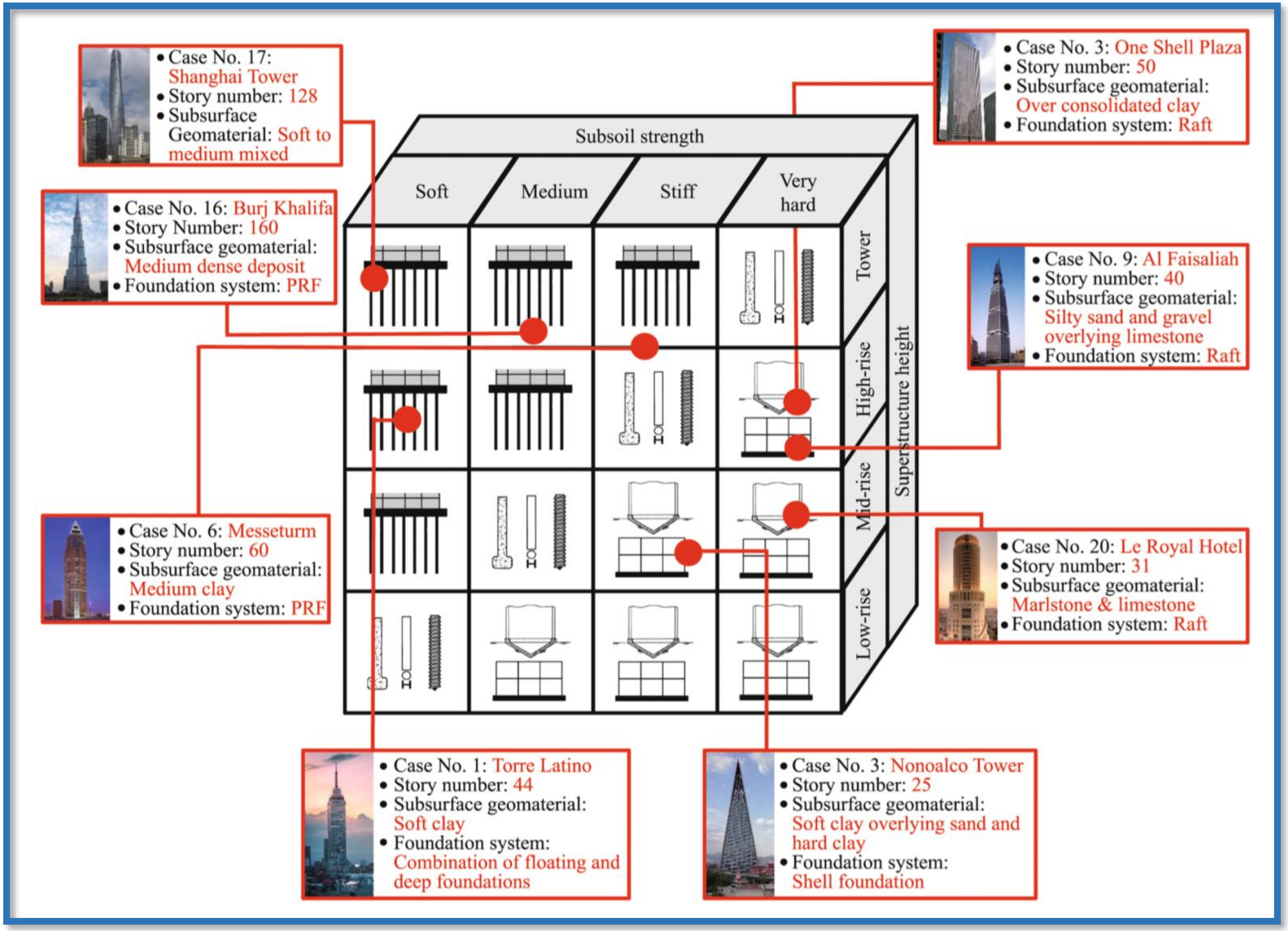


Foundations Frequency
(Eslami et al., 2025)



(Eslami et al., 2025)

Case-Based Implementation (Eslami et al., 2025)



Common Approaches for Bearing Capacity of Deep Foundations

1. Static Analysis

2. In-Situ Tests Application

3. Static Load Test

4. Dynamic Analysis & Load Test

5. Numerical & Laboratory Modeling

Static Analysis: Unified Pile Design (CFEM)

$$R_t = r_t . A_t \qquad R_u = R_t + R_s$$

$$R_s = r_s . A_s . D_f \qquad P_a = \frac{R_u}{FS}$$

$$\mathbf{r_t = N_t \times \sigma'_{Z=D_f}}$$

$$\mathbf{r_s = \beta \times \sigma'_{Z-avg}}$$

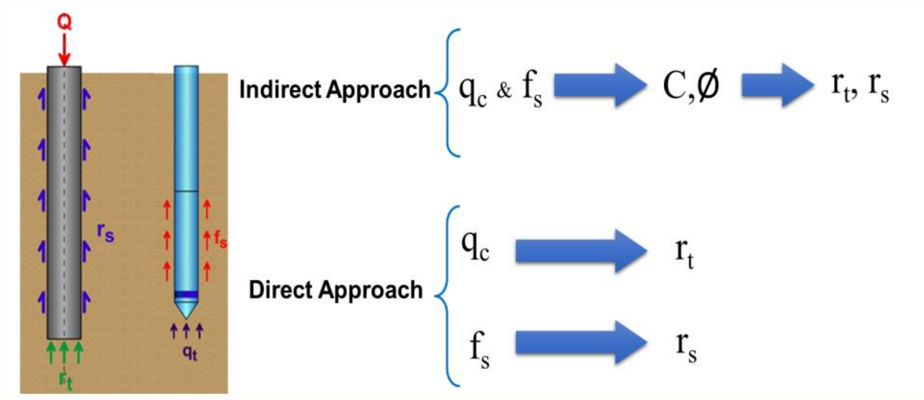
$\sigma'_{Z=D_f}$ is the effective vertical stress at depth $Z = D_f$

The values of β and N_t are as given in Table

Soil type	Soil friction angle	Drilled Shafts		Driven Piles	
		β	N_t	β	N_t
Clay	25-30	0.25-0.32	3-10	0.25-0.32	3-10
Silt	28-34	0.2-0.3	10-30	0.3-0.5	20-40
Loose sand		0.2-0.4	20-30	0.3-0.8	30-80
Medium sand	32-42	0.3-0.5	30-60	0.6-1	50-120
Dense sand		0.4-0.6	50-100	0.8-1.2	100-120
Gravel	35-45	0.4-0.7	80-150	0.8-1.5	150-350

Capacity: In-Situ Tests (CPT/CPTu)

List of common CPT- and CPTu-based methods for pile bearing capacity



No.	Method/ Reference	No.	Method/ Reference
1	Begemann (1963, 1965, 1969)	15	Fugro-05 (Kolk et al. 2005)
2	Meyerhof (1956, 1976, 1983)	16	UCD-05 (Gavin and Lehane 2005)
3	Aoki and Velloso (1975)	17	ICP-05 (Jardine et al. 2005)
4	Nottingham (1975), Schmertmann (1978)	18	UWA-05 (Lehane et al. 2005)
5	Penpile (Clisby et al.1978)	19	NGI-05 (Clausen et al. 2005)
6	Dutch (de Ruiter & Beringen 1979)	20	Cambridge-05 (White & Bolton 2005)
7	Philipponnat (1980)	21	Togiliani (2008)
8	LCPC (Bustamante & Gianeselli 1982)	22	German (Kempfert and Becker 2010)
9	Cone-m (Tumay & Fakhroo 1982)	23	UCD-11 (Igoe et al. 2010, 2011)
10	Price and Wardle (1982)	24	V–K (Van Dijk and Kolk 2011)
11	Gwizdala (1984)	25	SEU (Cai et al. 2011, 2012)
12	UniCone (Eslami & Fellenius 1997)	26	HKU (Yu and Yang 2012)
13	KTRI (Takesue et al. 1998)	27	UWA-13 (Lehane et al. 2013)
14	TCD-03 (Gavin and Lehane 2003)	28	Modified UniCone (Niazi and Mayne 2016)

Single Pile Settlement (Vesic, 1977)

$$S_e = S_{e1} + S_{e2} + S_{e3}$$

Elastic shortening of the pile

$$s_{e1} = \frac{(Q_{wp} + \xi Q_{ws})L}{A_p E_p}$$

Q_{wp} = working load at pile toe

Q_{ws} = working load along the pile shaft

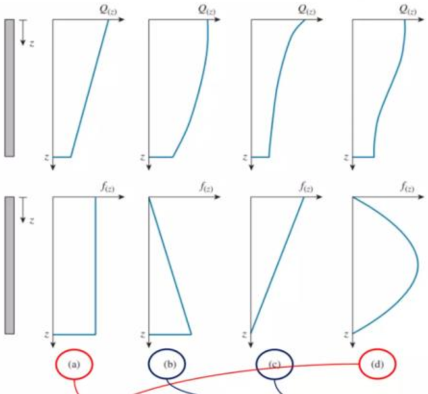
A_p = cross section of pile

E_p = elasticity modulus of the pile material

L = pile length

ξ = a constant in the range of 0.50–0.67

Variation of pile load Q and skin friction with depth.
(Braja M. Das,(2019), Principles of Foundation Engineering)



(uniform or parabolic) $\xi = 0.5$

(increasing or decreasing) $\xi = 0.67$

$$S_e = S_{e1} + S_{e2} + S_{e3}$$

Settlement of pile along the pile shaft

$$s_{e3} = \left(\frac{Q_{ws}}{pL}\right)\frac{D}{E_s}(1-\mu_s^2)I_{ws}$$

p = perimeter of the pile

L = embedded length of pile

I_{ws} = influence factor

$$I_{ws} = 3 + 0.35\sqrt{\frac{L}{D}}$$

Settlement of pile along the pile shaft (a semi- empirical method)

$$s_{e3} = \frac{Q_{ws}C_s}{Lq_p}$$

q_p = ultimate point resistance of the pile

C_s = an empirical constant

$$C_s = \left(0.93 + 0.16\sqrt{\frac{L}{D}}\right)C_p$$

$$S_e = S_{e1} + S_{e2} + S_{e3}$$

Settlement of pile at pile toe

$$s_{e2} = \frac{q_{wp}D}{E_s}(1-\mu_s^2)I_{wp}$$

D = width or diameter of pile

q_{wp} = stress at the pile toe

E_s = elastic modulus of soil below the toe

μ_s = Poisson's ratio of soil

I_{wp} = influence factor = 0.85

Settlement of pile at pile toe (a semi- empirical method)

$$s_{e2} = \frac{Q_{wp}C_p}{Dq_p}$$

q_p = ultimate point resistance of the pile

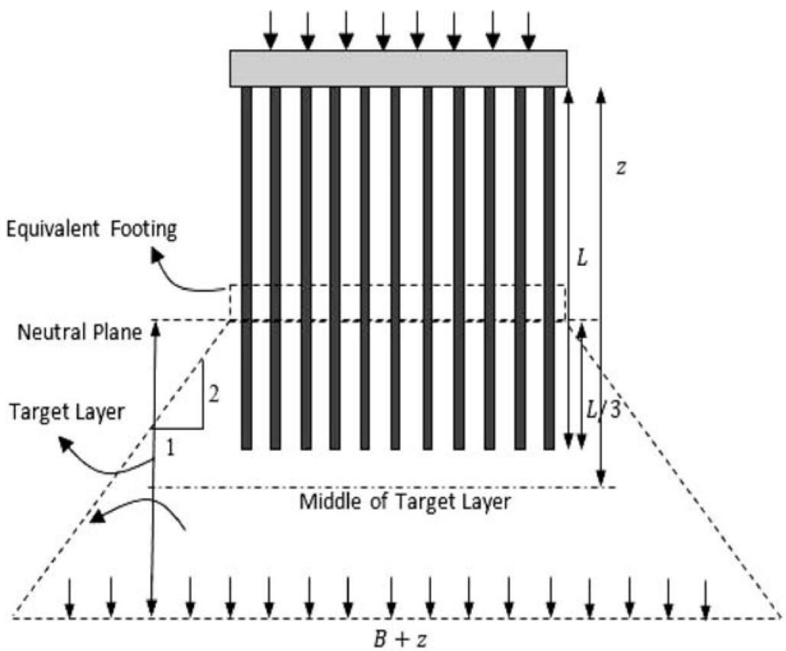
C_p = an empirical coefficient.

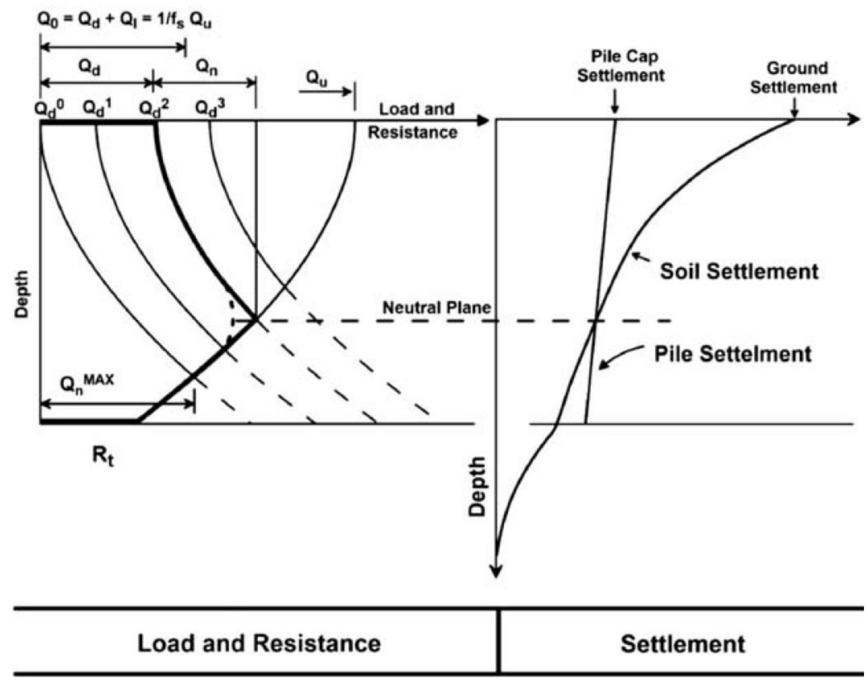
Type of soil	Driven pile	Bored pile
Sand (dense to loose)	0.02–0.04	0.09–0.18
Clay (stiff to soft)	0.02–0.03	0.03–0.06
Silt (dense to loose)	0.03–0.05	0.09–0.12

Typical Value of Cp based on "Design of Pile Foundations," by A. S. Vesic. Synthesis of Highway Practice by American Association of State Highway and Transportation, 1977.

(Braja M. Das, (2019) Principles of Foundation Engineering)

Settlement & Resistance Distribution; Pile Group





Simple model to estimate pile group settlement proposed by Terzaghi and Peck (1948)

Unified approach: load, resistance, and settlement distribution along depth (Fellenius, 2015)

A Few Latest developed Databases on Foundations

- **Briaud and Tucker (1988)** ❖ 98 cases of steel and concrete piles
- **Alsamman (1995)** ❖ 95 records of axial load testing on bored piles
- **Eslami and Fellenius (1997)** ❖ 102 cases from 40 sites and 13 countries
- **Abu-Farsakh & Titi (2004)** ❖ 35 cases of prestressed square concrete piles
- **UWA (Lehane et al., 2005)** ❖ 77 records of driven piles in sands
- **Eslami & Gholami (2006)** ❖ 27 cases of PLT and Footings with CPT records
- **Kempfert & Becker (2010)** ❖ 1000 records of deep foundations (German Method)
- **Eslami & Valikhah (2019)** ❖ 46 cases of testes spread footings and CPT profiles

Unicone Database (Eslami & Fellenius, 1997)

- Total of 150 records of pile tests and adjacent CPT/CPTu profiles
- 102 Cases for method development

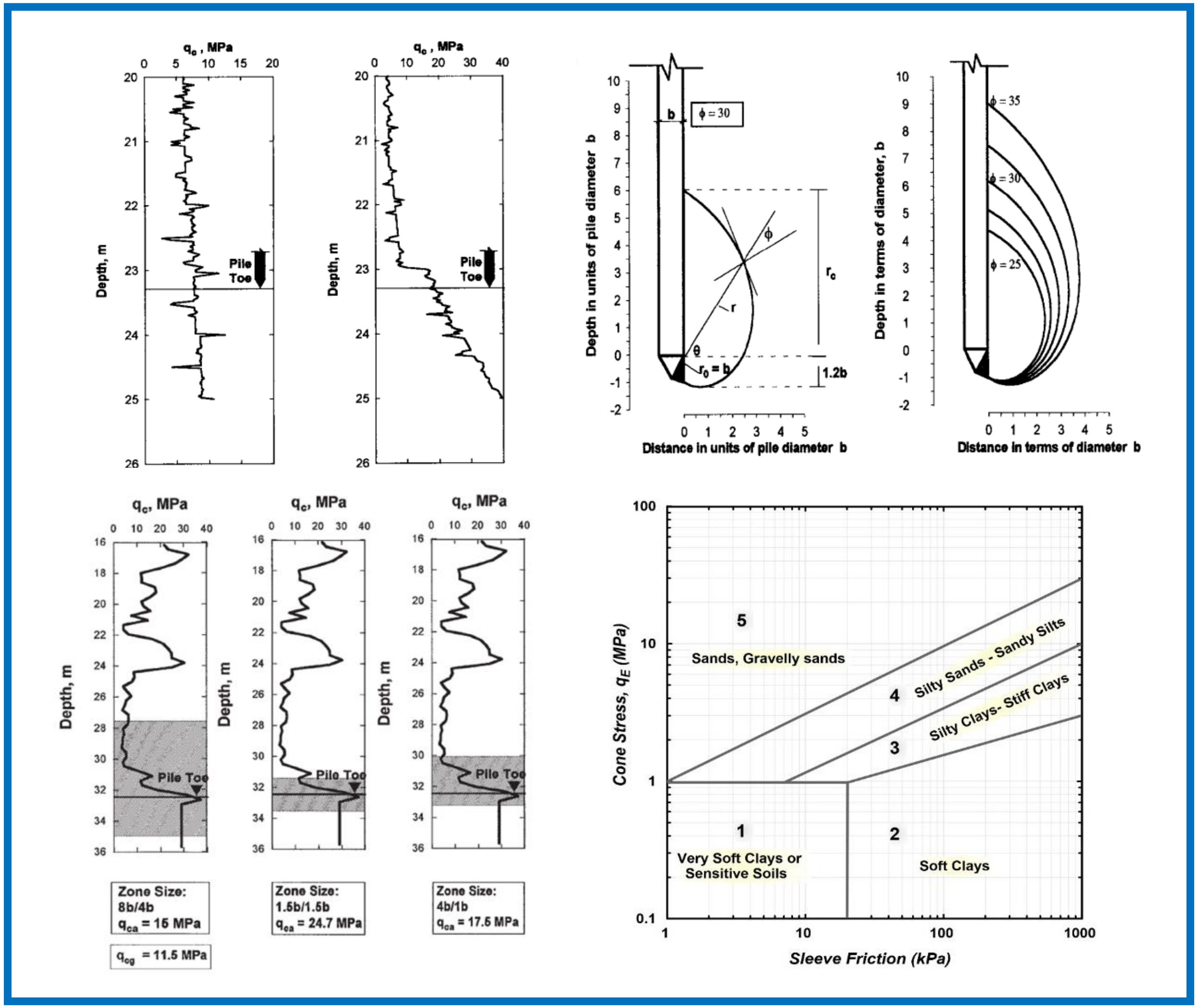
Pile capacity by direct CPT and CPTu methods applied to 102 case histories

Abolfazl Eslami and Bengt H. Fellenius

Abstract: Six methods to determine axial pile capacity directly from cone penetration test (CPT) data are presented, discussed, and compared. Five of the methods are CPT methods that apply total stress and a filtered arithmetic average of cone resistance. One is a recently developed method, CPTu, that considers pore-water pressure and applies an unfiltered geometric average of cone resistance. To determine unit shaft resistance, the new method uses a new soil profiling chart based on CPTu data. The six methods are applied to 102 case histories combining CPTu data and capacities obtained in static loading tests in compression and tension. The pile capacities range from 80 to 8000 kN. The soil profiles range from soft to stiff clay, medium to dense sand, and mixtures of clay, silt, and sand. The pile embedment lengths range from 5 to 67 m and the pile diameters range from 200 to 900 mm. The new CPTu method for determining pile capacity demonstrates better agreement with the capacity determined in a static loading test and less scatter than by CPT methods.

Key words: cone penetration test, pile capacity, toe resistance, shaft resistance, soil classification.

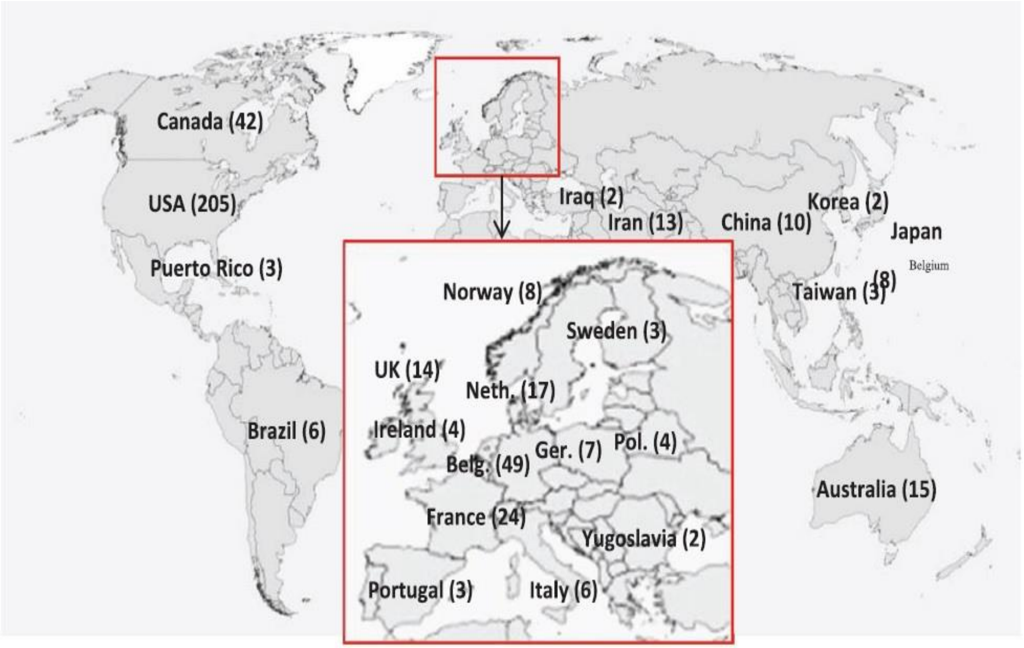
Unicone Database (Eslami & Fellenius, 1997)



AUT:Geo-CPT&Pile Database (Eslami et al., 2015 - 2025)

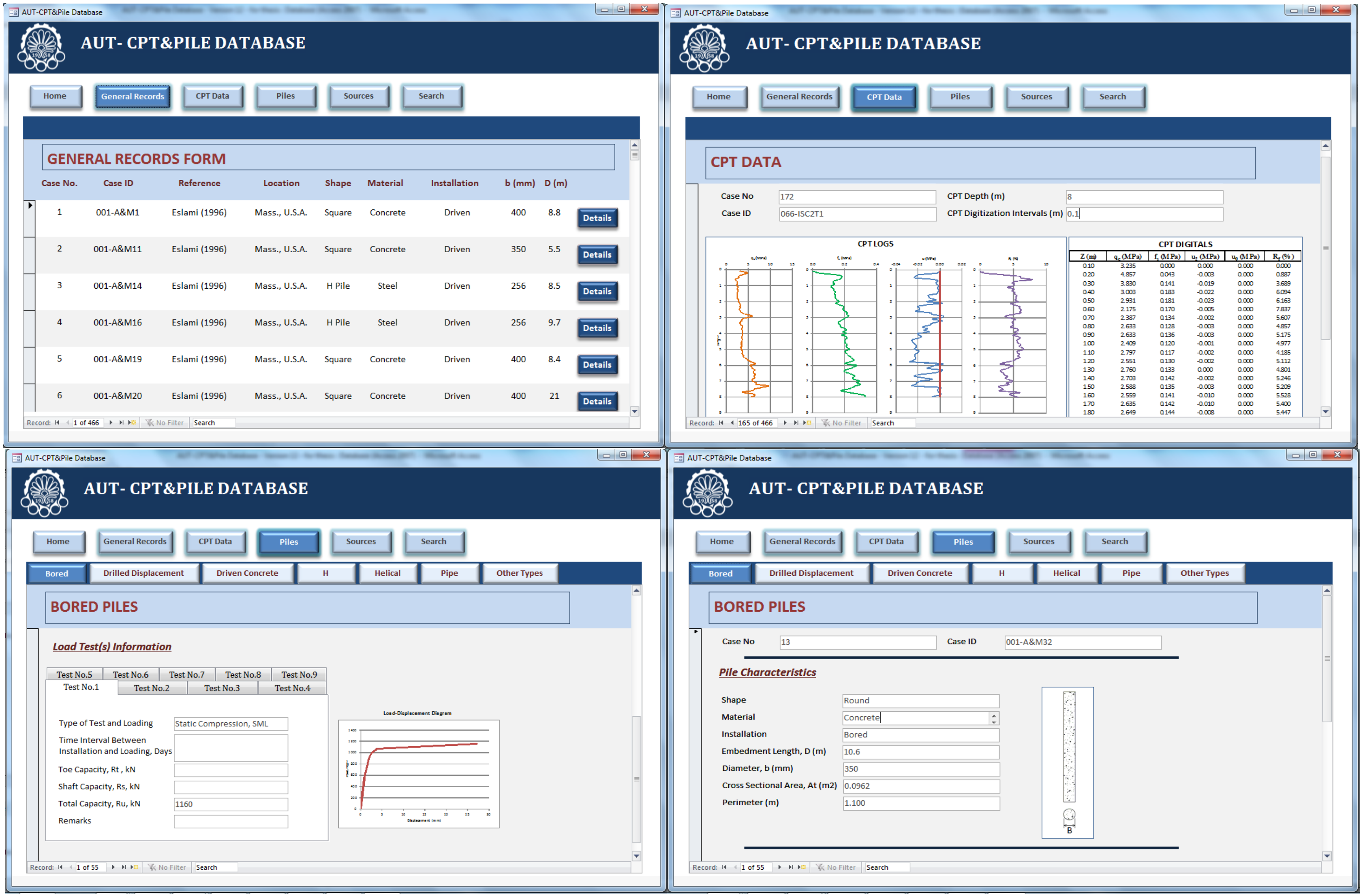
GEOTECHNICAL INFORMATION, CPT AND CPT$_U$ DATA AND PILE LOADING TESTS RECORDS

- **600 Records of pile axial loading tests along with adjacent CPT/CPTu profiles**
- **Digitizing load-displacement diagrams derived from loading tests and CPT**
- **Soil Properties**
  - **Includes a wide range of clayey, silty and sandy soils.**
  - **Classified within three categories: Sandy, Clayey and Mixed soils**



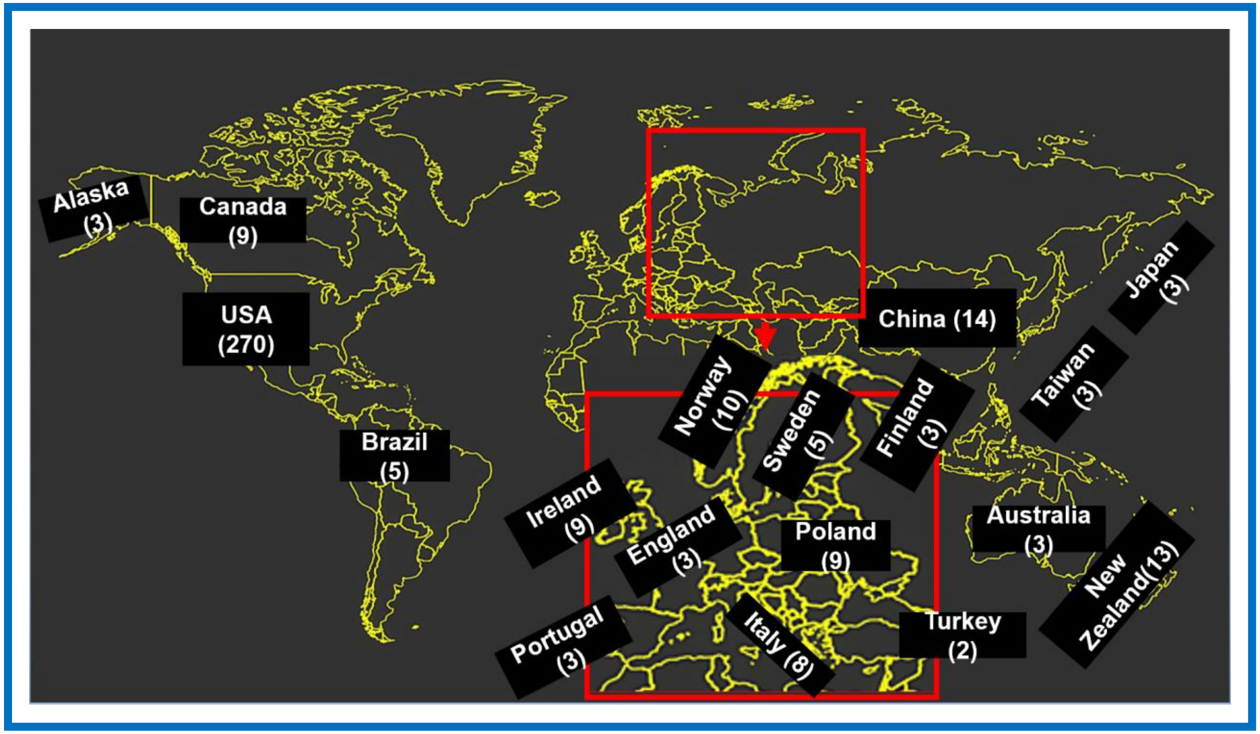
Geographical Distribution

AUT:Geo-CPT&Pile Database (Eslami et al., 2015 - 2025)

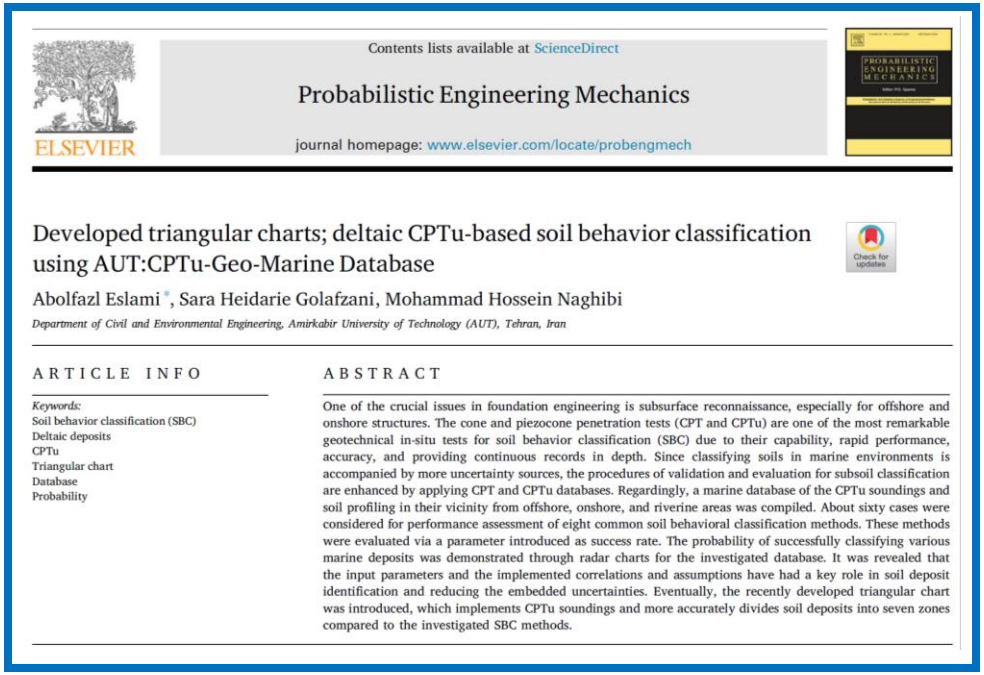


AUT: Geo-Marine Database (AUT: GMD) (Eslami et al., 2021 - 2023)

- 385 Records of CPT/CPTu profiles from 58 sites in 18 countries
- 7000 m of soil profile
- Records from 60 documented sources
- Sites: Onshore, Offshore and Riverine
- Deposits: Sensitive, Clay, OC Clay, Sand-Gravel & Mixed



AUT: Geo-Marine Database (AUT: GMD) (Eslami et al., 2021 - 2023)



Contents lists available at ScienceDirect

Probabilistic Engineering Mechanics

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

Developed triangular charts; deltaic CPTu-based soil behavior classification using AUT:CPTu-Geo-Marine Database

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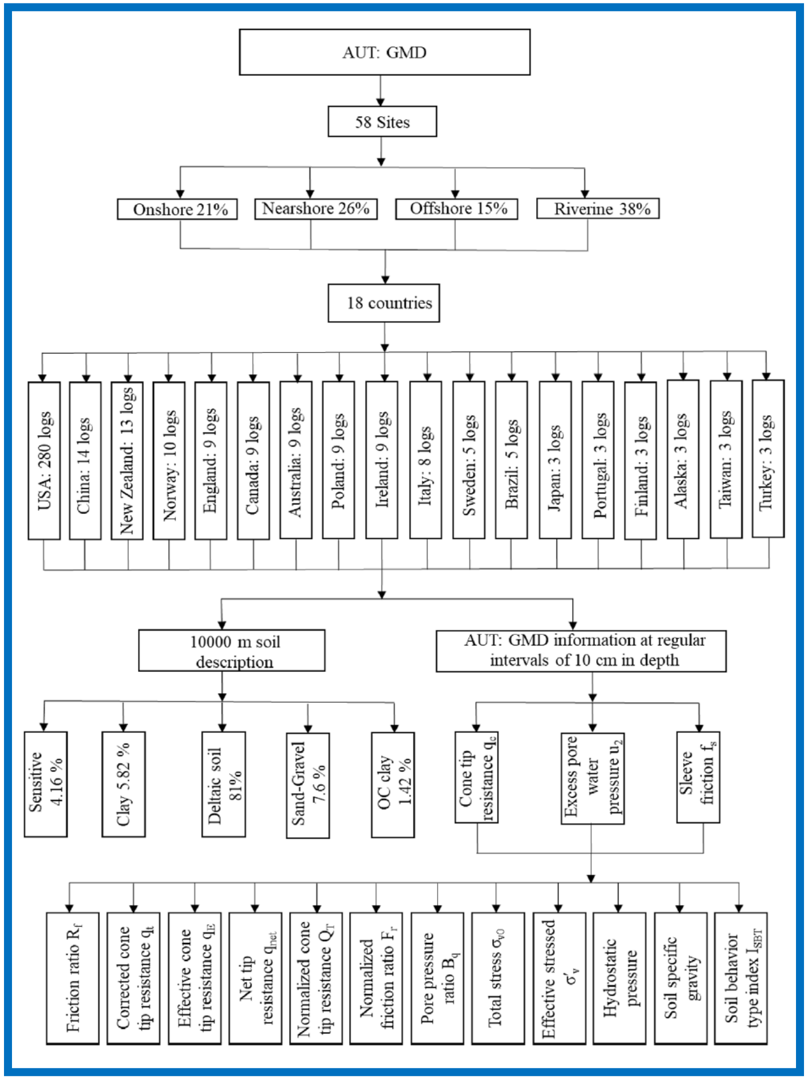
ARTICLE INFO

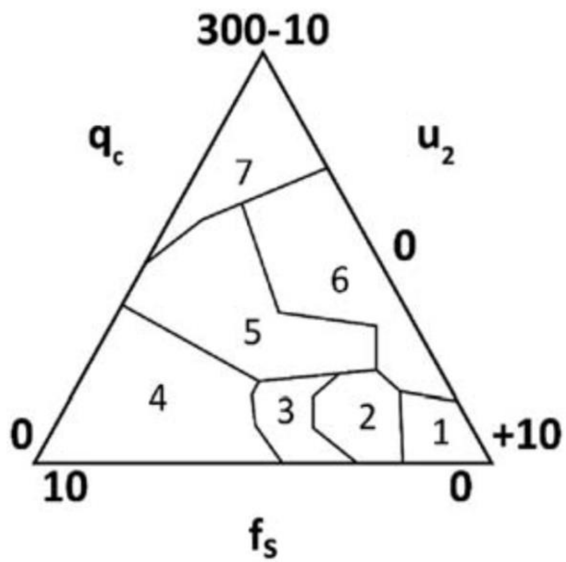
Keywords:
Soil behavior classification (SBC)
Deltaic deposits
CPTu
Triangular chart
Database
Probability

ABSTRACT

One of the crucial issues in foundation engineering is subsurface reconnaissance, especially for offshore and onshore structures. The cone and piezocone penetration tests (CPT and CPTu) are one of the most remarkable geotechnical in-situ tests for soil behavior classification (SBC) due to their capability, rapid performance, accuracy, and providing continuous records in depth. Since classifying soils in marine environments is accompanied by more uncertainty sources, the procedures of validation and evaluation for subsoil classification are enhanced by applying CPT and CPTu databases. Regardingly, a marine database of the CPTu soundings and soil profiling in their vicinity from offshore, onshore, and riverine areas was compiled. About sixty cases were considered for performance assessment of eight common soil behavioral classification methods. These methods were evaluated via a parameter introduced as success rate. The probability of successfully classifying various marine deposits was demonstrated through radar charts for the investigated database. It was revealed that the input parameters and the implemented correlations and assumptions have had a key role in soil deposit identification and reducing the embedded uncertainties. Eventually, the recently developed triangular chart was introduced, which implements CPTu soundings and more accurately divides soil deposits into seven zones compared to the investigated SBC methods.

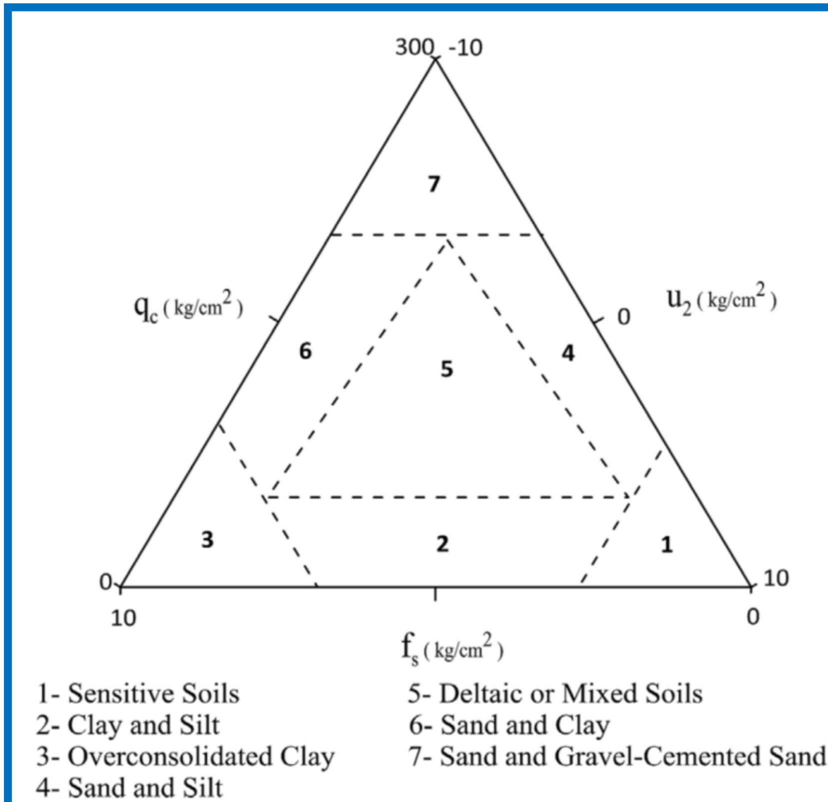


AUT: Geo-Marine Database (AUT: GMD) (Eslami et al., 2021 - 2023)



1	2	3	4	5	6	7
Sensitive Soil	Clays	Silts	Over Consolidated Clay	Mixed Soil (Clayey silt to sandy silt)	Sands	Very Dense Sand

The axes and zones for the triangular chart (Eslami et al., 2016)



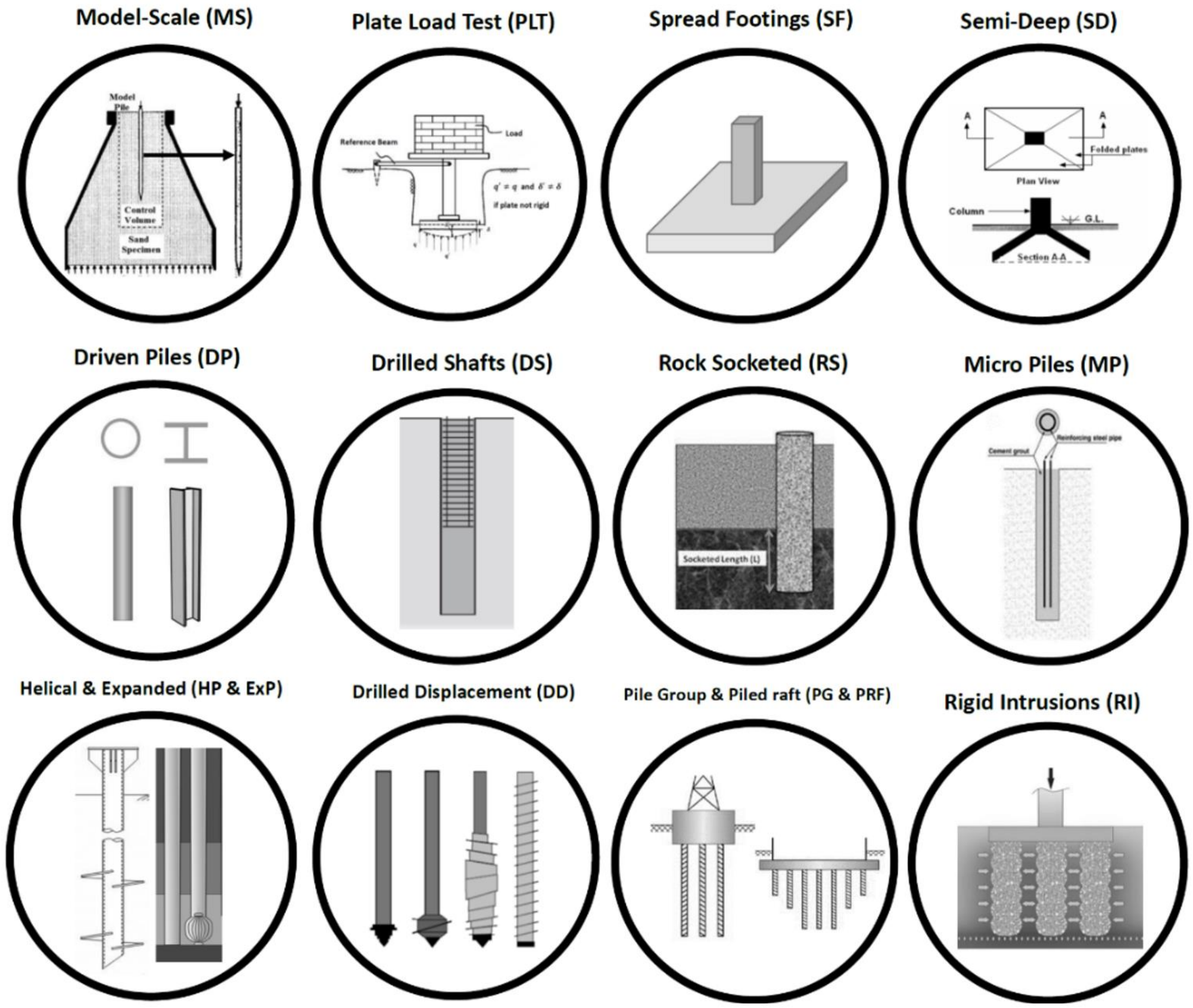
The delineated zones for developed triangular chart using deltaic deposit (Eslami et al., 2022)

FELADD: Field Engineered Load And Displacement Database

Foundation Categories for Database Arrangement

Categories		Foundation Types		Acronym
A	Physical Modeling	I	Model-Scale	MS
		II	Plate Load Test (PLT)	PLT
B	Shallow & Semi-deep Foundation	III	Spread Footings	SF
		IV	Semi-Deep	SD
C	Deep Foundations	V	Driven Piles	DP
		VI	Drilled Shafts	DS
		VII	Rock Socketed	RS
D	Special Deep Foundations	VIII	Micro Piles	MP
		IX	Helical & Expanded Piles	HP & ExP
		X	Drilled Displacement Piles	DD
E	Block & Massive Foundations	XI	Pile Groups & Piled Raft Foundations	PG & PRF
F	Rigid Intrusions	XII	Stone Columns, Deep Mixing & Jet Grouting	RISC, RIDM or RIJG

Foundation Categories



Foundation Categories for Integrated Package

Recent Add-ons

Pads:
50 Cases

Footings:
100 Cases

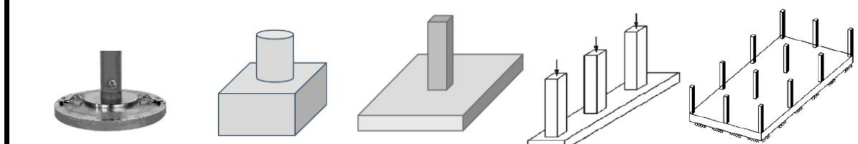
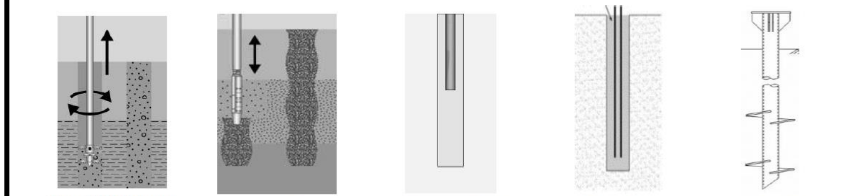
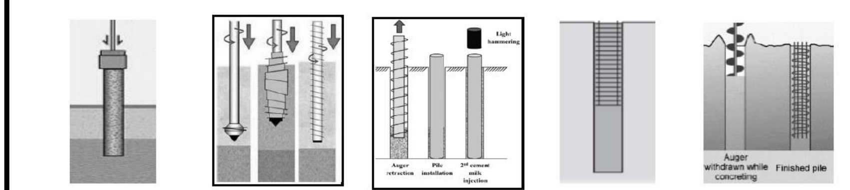
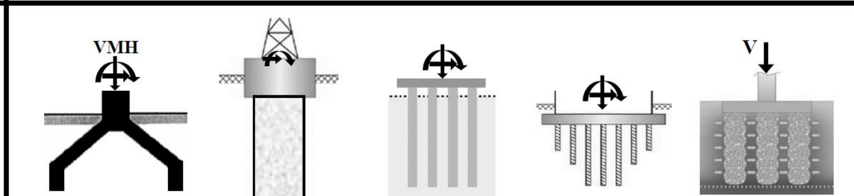
Helical Piles:
120 Cases

DSM & Stone Column:
90 Cases

Drilled Shafts:
50 Cases

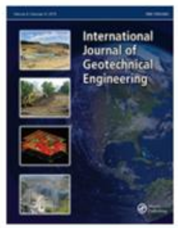
DD Piles:
60 Cases

CFA Piles:
50 Cases

#	Categories	Foundations
I	**Shallow Foundations** • PLT • Pad • Footing • Strip • Mat	 Plate Load Test · Pad · Footing · Strip · Mat
II	**Ground Modification & Reinforcement** • DSM • SC • CDSM • Micro Pile • Helical Pile	 Deep Soil Mixing or Jet Grouting · Stone Column · Composite DSM · Micro Pile · Helical Pile
III	**Deep Foundations** • DP • DD • PPP • DS • CFA	 Driven Pile · Drilled Displacement · Prebored Precast Pile · Drilled Shaft · Continuous Flight Auger
IV	**Hybrid Foundations (Block)** • Semi-Deep • Mega Pile • PG • PRF • MT	 Semi-Deep · Mega Pile or Caisson · Pile Group · Piled Raft Foundation · Massive Treatment

Study No.1

Piles Ultimate Capacity Criteria
(Moshfeghi & Eslami, 2015)



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International Journal of Geotechnical Engineering

ISSN: 1938-6362 (Print) 1939-7879 (Online) Journal homepage: http://www.tandfonline.com/loi/yjge20

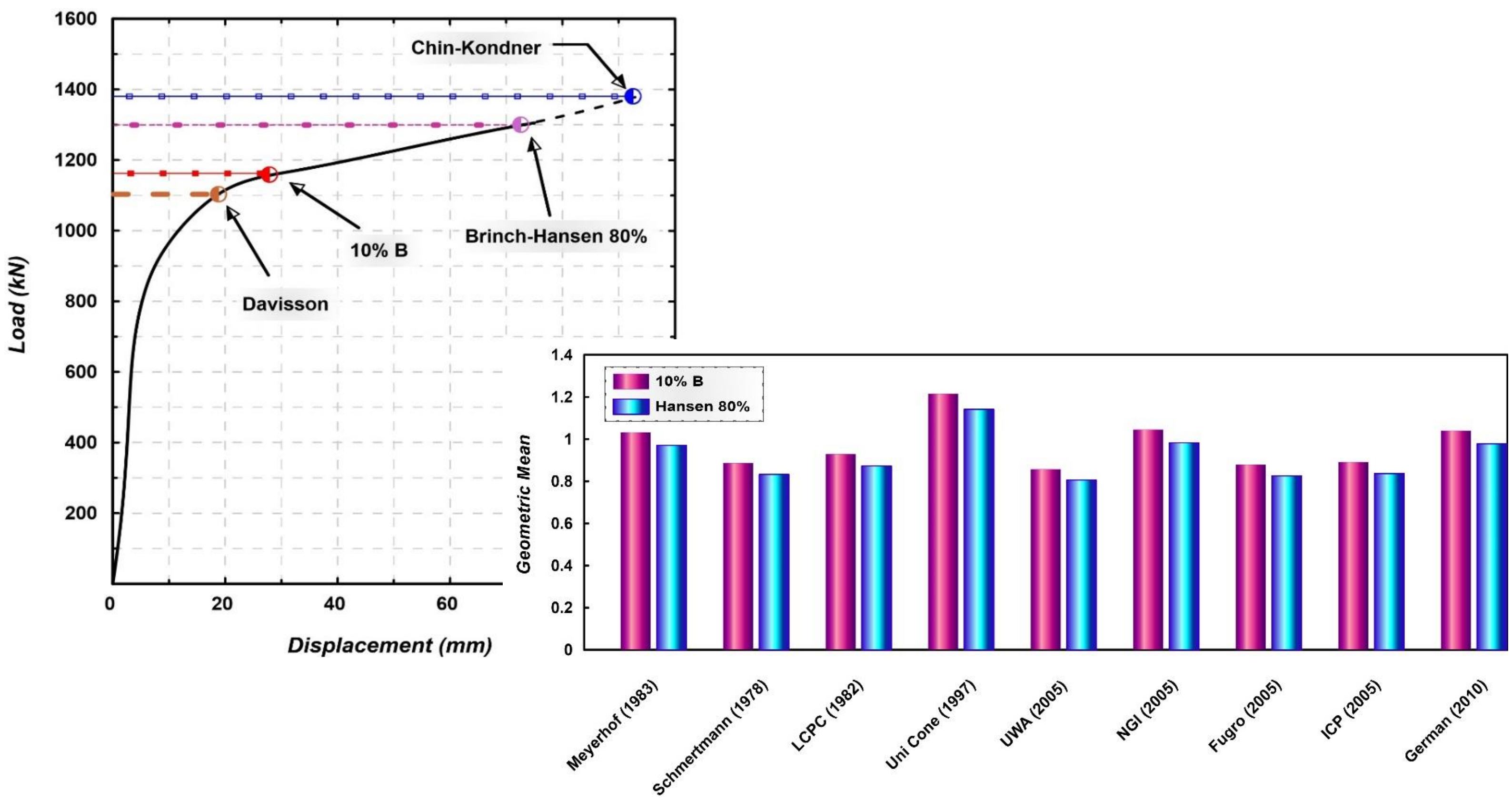
Study on pile ultimate capacity criteria and CPT-based direct methods

Sara Moshfeghi and Abolfazl Eslami*

Due to the variety of current Cone Penetration Test (CPT)-based methods of estimating the pile bearing capacity, for optimum design, it is necessary to evaluate the performance of such methods in various geotechnical conditions. Geotechnical databases including piling and *in situ* testing records have been recognised as useful tools for analysis, design and economical construction. In order to evaluate current CPT-based pile bearing capacity methods, AUT-CPT and Pile database has been compiled including 450 full scale pile load tests and CPT sounding records. This database consists of different pile types with a relatively wide range of geometries and various soil conditions. Forty-three records of piles driven in sand deposits were then employed to evaluate effects of ultimate capacity interpretation criteria from load displacement diagrams. The Brinch Hansen 80% criterion and the load at the displacement of 10% of the pile diameter were compared to estimated capacities from 10 CPT-based design methods currently used in practice. The Brinch Hansen 80% criterion and the load at the displacement of 10% of the pile diameter lead to reasonable results, the Brinch Hansen 80% criterion showed less scatter. For evaluating the accuracy and the precision of CPT-based methods, the results were compared to estimated capacities. Methods with the best performance are introduced. Generally, comparisons indicate that the CPT-based methods mainly predict the pile capacity with reasonable accuracy.

Study No.1

Piles Ultimate Capacity Criteria
(Moshfeghi & Eslami, 2015)



Study No.2

Reliability Assessment of DD Piles
(Moshfeghi & Eslami, 2018)

MARINE GEORESOURCES & GEOTECHNOLOGY
https://doi.org/10.1080/1064119X.2018.1448493

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Reliability-based assessment of drilled displacement piles bearing capacity using CPT records

S. Moshfeghi and A. Eslami

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

ABSTRACT

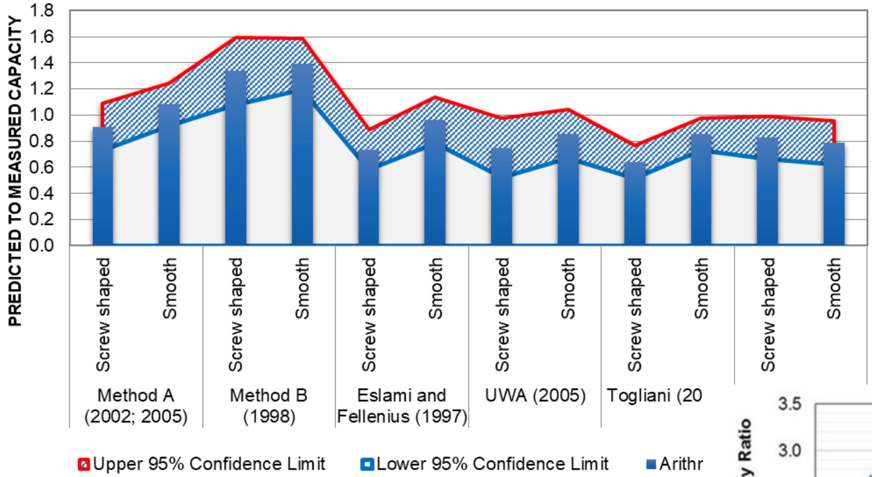
Drilled displacement piles (DDPs) are known as an alternative to conventional foundations in coastal areas, given the elimination of environmental impacts and difficulties caused by installation process of driven piles and more consistency with environment. Despite increasing employment of these piles, the extent of research works does not yet suffice the requisites to reach a routine design. This paper aims to analyze six cone penetration test (CPT)-based methods of determining the bearing capacity of DDP. The statistical and reliability-based approaches were used in two parts of assessing performance of the methods with respect to soil–pile characteristics followed by evaluating reliability of the prediction outcome. A database is compiled including 65 DDP load tests with adjacent CPT profiles. Performance of the methods are analyzed. Finally, a reliability parameter, i.e., confidence interval, is introduced to demonstrate a more realistic insight into the evaluations by expressing performance of the methods in terms of a range for possible average values of the predictions ratios, rather than simply an arithmetic mean. The study reveals that the commonly used CPT-based methods which have not been specifically developed for DDP show great potential for design. The results indicate that the investigated methods can have promising performance if some modifications are applied.

ARTICLE HISTORY
Received 10 November 2017
Accepted 1 March 2018

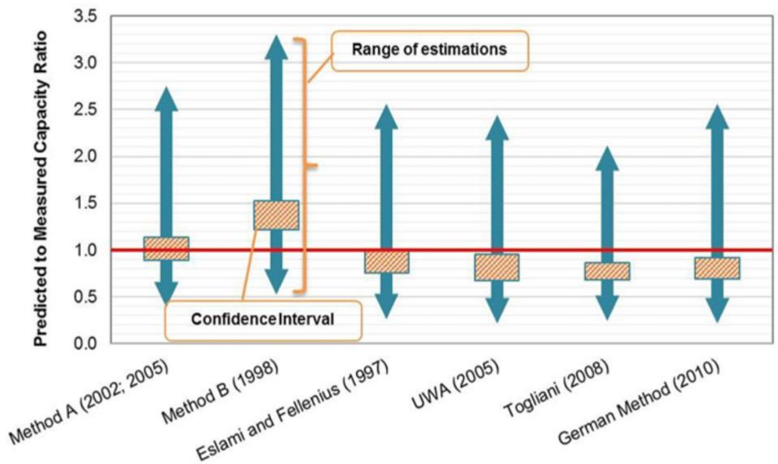
KEYWORDS
Bearing capacity; confidence interval; CPT methods; drilled displacement pile (DDP); reliability-based evaluation

Study No.2

Reliability Assessment of DD Piles
(Moshfeghi & Eslami, 2018)



Evaluation results of CPT-based methods based on shaft shapes



Study No.3

CPT-Based Load-Displacement of Footings
(Valikhah & Eslami, 2019)

Arabian Journal for Science and Engineering
https://doi.org/10.1007/s13369-019-04034-y

RESEARCH ARTICLE - CIVIL ENGINEERING

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CPT-Based Nonlinear Stress–Strain Approach for Evaluating Foundation Settlement: Analytical and Numerical Analysis

Fatemeh Valikhah[1] · Abolfazl Eslami[1]

Received: 9 May 2019 / Accepted: 16 July 2019

Abstract
Due to complexities in soil–foundation interaction and nonlinear behavior of subsoil, considerable uncertainty is involved in the foundation settlement evaluation. In the present paper, a new analytical approach is proposed to estimate the foundation settlement based on soil behavior classification charts developed from CPT records. The approach is founded on the Janbu nonlinear stress–strain method. However, instead of using fixed parameters in the Janbu method, the variable coefficients are used depending on geomaterial properties. Also, in the proposed approach, the scale effect is taken into account for foundation width considering soil stiffness. The proposed procedure is calibrated and verified by a data bank containing 46 case histories including 22 square, 17 circular and 7 rectangular foundations with widths varying between 0.3 and 2.4 m in conjunction with CPT data. Furthermore, the numerical finite difference analysis using a CPT-based stress characteristics method is carried out to validate the proposed approach for the prediction of foundation settlement. The accuracy of the calculations done by the proposed and some available common methods is investigated. Comparisons based on statistical and probabilistic methods apparently reveal that the proposed approach calculates the foundation settlement promisingly.

Study No.3

CPT-Based Load-Displacement of Footings
(Valikhah & Eslami, 2019)

$$\varepsilon = \frac{\Delta H}{H} \qquad \varepsilon = \frac{1}{mj}\left[\left(\frac{\sigma_0' + \Delta\sigma'}{100}\right)^j - \left(\frac{\sigma_0'}{100}\right)^j\right]$$

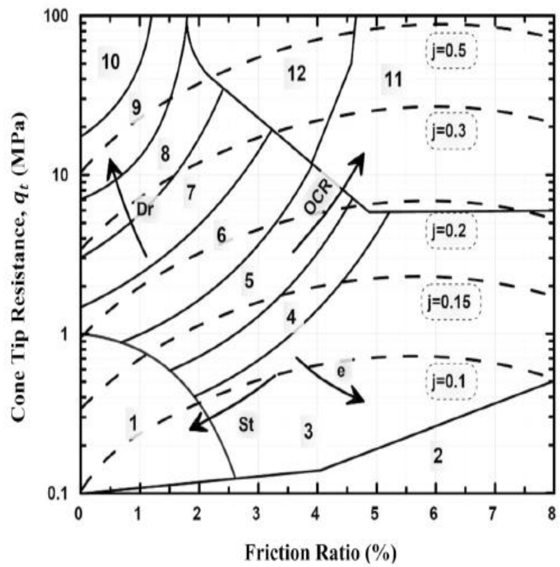
$$m = \alpha q_c$$

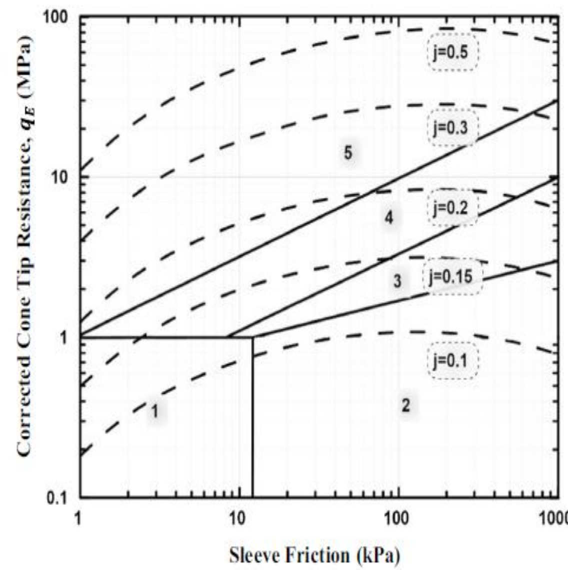
$$\alpha = 0.25b \times \left(\frac{2B+1}{3B}\right)^3$$

$$j = \frac{q_c}{x + yq_c}$$

$$x = 0.02R_f + 0.5$$

$$y = 7.53(\sigma_0')^{-0.25}$$





Study No.4

Reliability Appraisal of Static, SPT & CPT Methods for Piles Capacity

(Heidarie, Jamshidi, Eslami , 2019)

GEORISK
https://doi.org/10.1080/17499518.2019.1628281

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Reliability based assessment of axial pile bearing capacity: static analysis, SPT and CPT-based methods

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[a]Department of Civil Engineering, University of Guilan, Guilan, Iran; [b]Department of Civil and Environmental Engineering, Amirkabir University of Technology (AUT), Tehran, Iran

ABSTRACT
Since piles are one of the major geotechnical foundation systems, estimation of their axial bearing capacity is of great importance. Employing different design methods, resulting in a wide range of bearing capacity estimations, complicates the selection of an appropriate design scheme and confirms the existence of model error along with the inherent soil variability in bearing capacity prediction. This paper tends to evaluate different predictive methods in Reliability-Based Design (RBD) framework. In this regard, different static analyses, SPT and CPT-based methods are considered to evaluate which approaches collectively and which method individually, have more reliable predictions for compiled data bank. In order to assess reliability indices and resistance factors, two approaches have been considered, i.e. First Order Second Moment method (FOSM) and First Order Reliability Method (FORM). To investigate the reliability indices for different methods in both RBD approaches, various safety factors and loading ratios have been considered. Also, the Load and Resistance Factor Design (LRFD) resistance factors are calibrated for different target reliability indices and loading ratios. Results show that CPT-based methods are more reliable among other methods. Furthermore, the estimated efficiency ratio, i.e. the ratio of resistance factor to resistance bias factor, confirms this agreement.

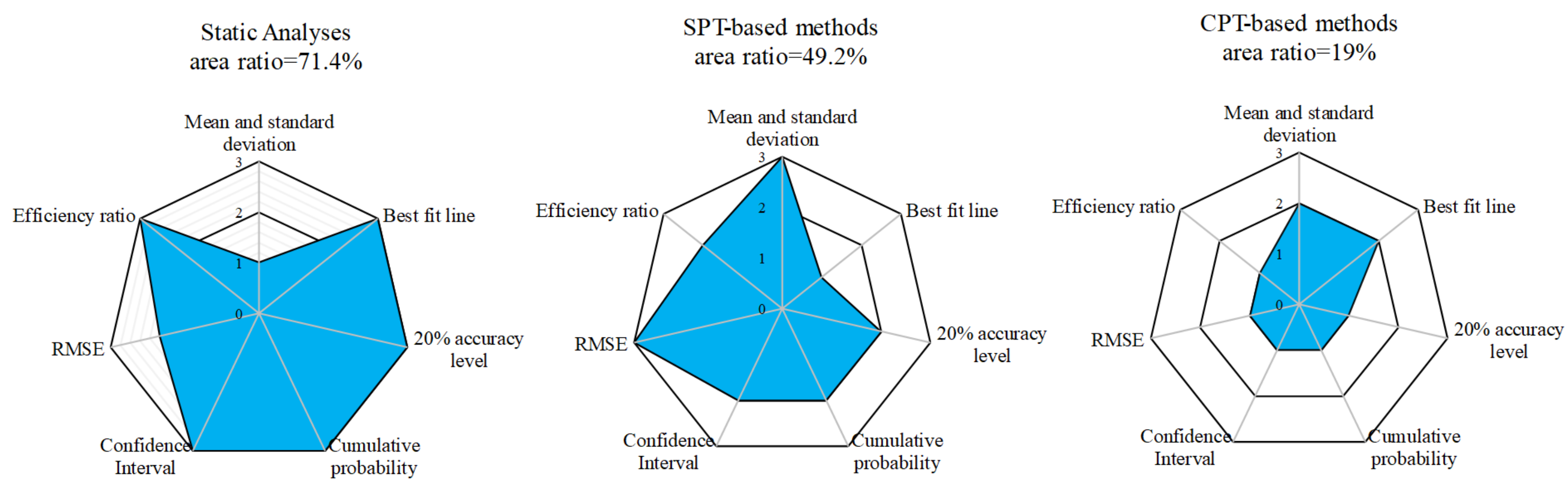
ARTICLE HISTORY
Received 11 November 2018
Accepted 2 June 2019

KEYWORDS
Axial pile bearing capacity; CPT; LRFD; pile foundation; reliability based design

Study No.4

Reliability Appraisal of Static, SPT & CPT Methods for Piles Capacity

(Heidarie, Jamshidi, Eslami , 2019)



Comparison of Errors

Study No.5

Database Approach for Helical & Expanded Piles
(Rahimi, Eslami & McCartney, 2024)

Geotechnical Engineering

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

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John S. McCartney PhD, PE
Professor, Department of Structural Engineering, University of California, San Diego, USA

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

Study No.5

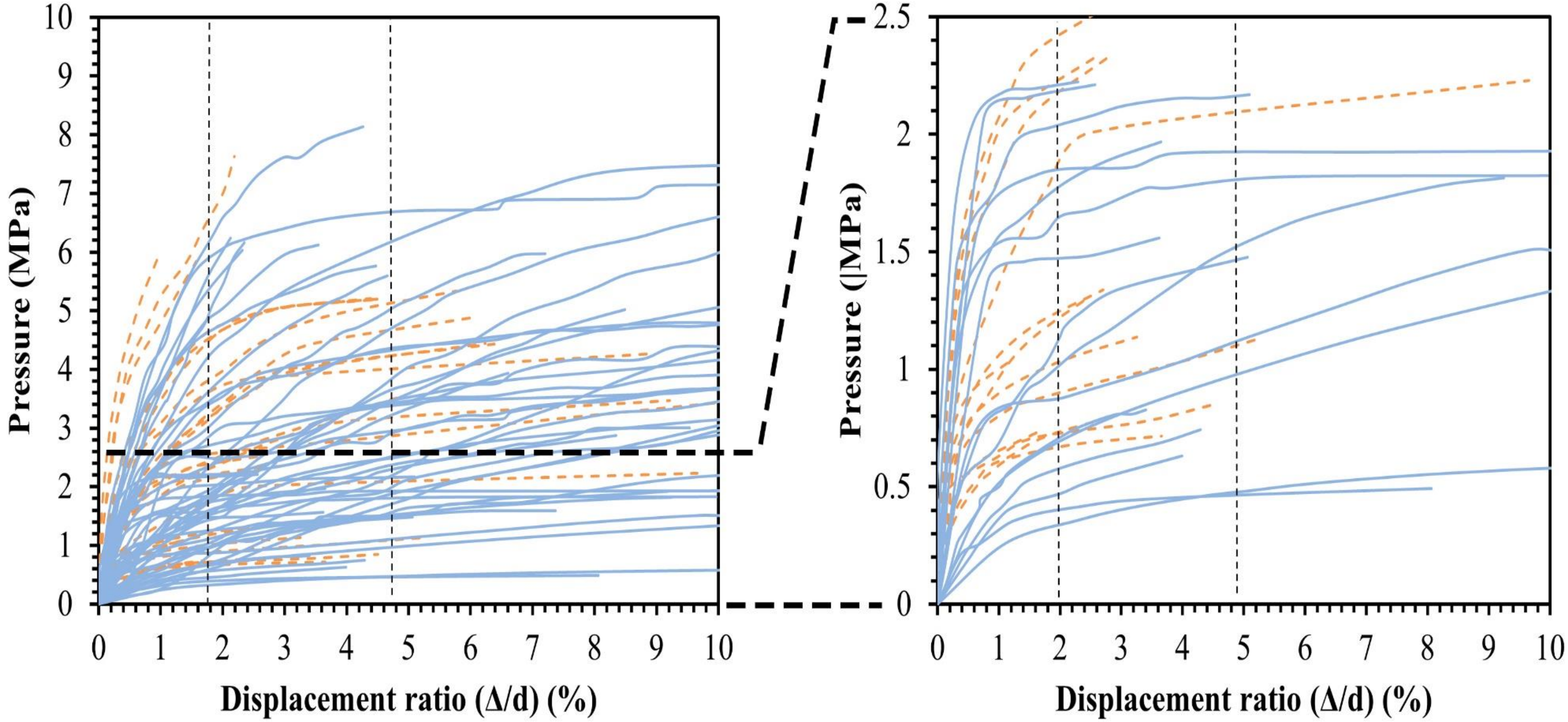
Database Approach for Helical & Expanded Piles
(Rahimi, Eslami & McCartney, 2024)

	ID	Country	Soil type[a]	Pile type[b]	Height: m	NEA[c]	Shaft dia.: mm	D_{mH} or D_{mEP}: 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

Study No.5

Database Approach for Helical & Expanded Piles
(Rahimi, Eslami & McCartney, 2024)

- **Depth:**
  - **1- Helicals: 3 to 16 m**
  - **2- Others: 8 to 22 m**
- **Diameter:**
  - **1- Helicals: 300 to 900 mm**
  - **2- Others: 600 to 1500 mm**

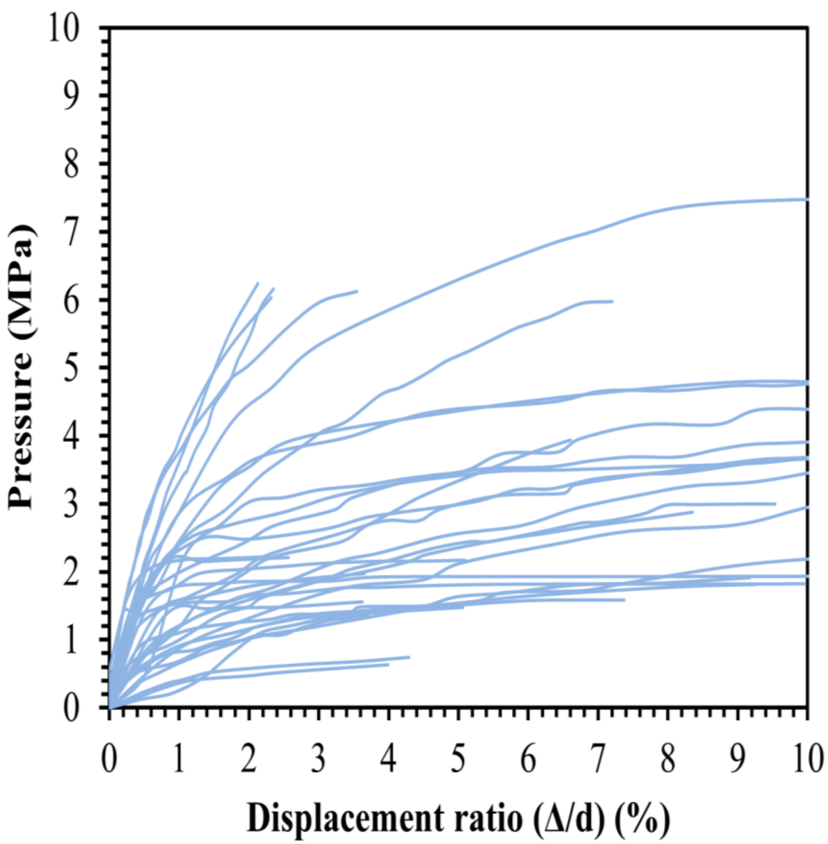


Pressure – S/B for helical and expanded piles

Study No.5

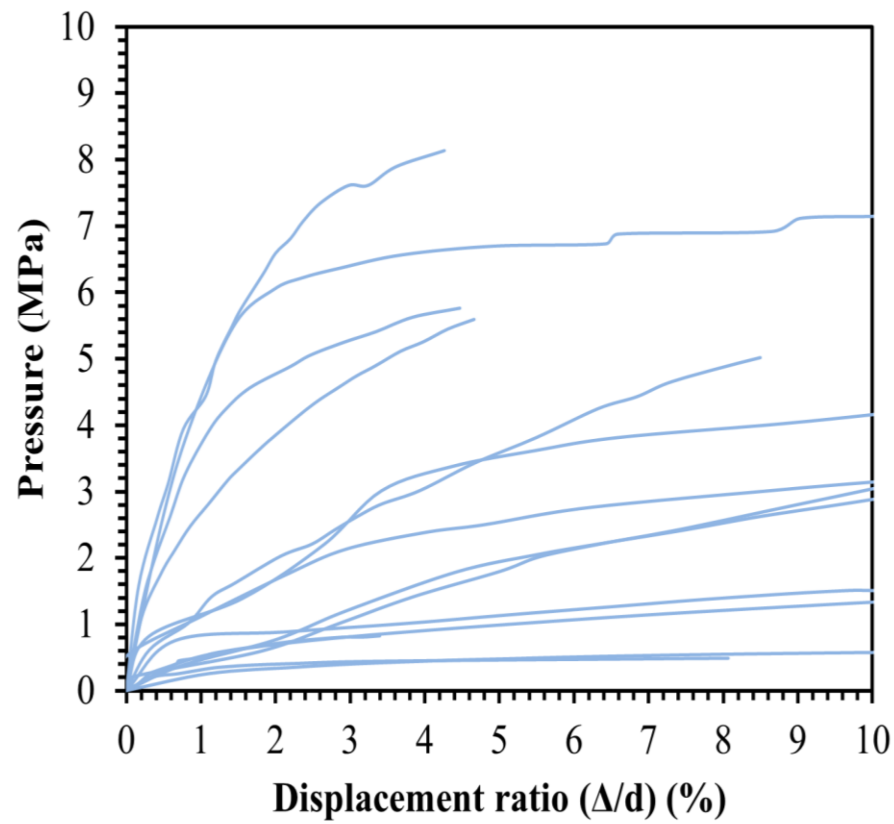
Database Approach for Helical & Expanded Piles
(Rahimi, Eslami & McCartney, 2024)

Helical Piles: 3 to 6 m



Pressure – S/B for helical piles (3m < Df < 6m)

Helical Piles: 6 to 12 m



Pressure – S/B for helical piles (6m < Df < 12m)

Study No.6

Soil-Cement Columns Load-Displacement
(Arjmand & Eslami, 2024)

MARINE GEORESOURCES & GEOTECHNOLOGY
https://doi.org/10.1080/1064119X.2024.2380530

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Appraisal of soil-cement columns load displacement behavior through full-scale tests database

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[a]School of Civil Engineering, University of Tehran, Tehran, Iran; [b]Civil and Environmental Engineering Department, Amirkabir University of Technology, Tehran, Iran

ABSTRACT

Soil-cement columns are implemented in coastal areas to improve the capacity of loose, soft, and dredged soils, reduce settlement, and mitigate liquefaction effects. Static load testing is used for quality control and the verification of design assumptions. Given the greater reliability of full-scale testing results compared to physical and numerical modeling results and the lack of a database for soil-cement columns, 42 full-scale loading records on these columns were compiled to assess the behavior of these columns and identify the most influential factor in their behavior. The database contains columns ranging in length from 5 to 19 meters with diameters ranging from 40 to 120 cm, as well as soil profiles ranging from clay to sand and mixed soil. Their behavior was evaluated using a hyperbolic relationship. The results indicate that component materials, influenced by implementation technique, in-situ soil properties, and reinforcing, more significantly influence the behavior of columns than the columns' length. The columns are categorized into three separate groups, which are separated due to their different equivalent unconfined compressive strengths and shapes. These categories allow for the prediction of the load-displacement ratio diagram range of the column based on initial information such as the column diameter, length, and properties of in-situ soil. The upper and lower bounds of categories were validated by the loading results of five soil-cement columns implemented in Iran coastal line.

ARTICLE HISTORY
Received 24 April 2024
Accepted 30 June 2024

KEYWORDS
Soil-Cement column; load displacement; database; Full-Scale testing; hyperbolic function

Study No.6

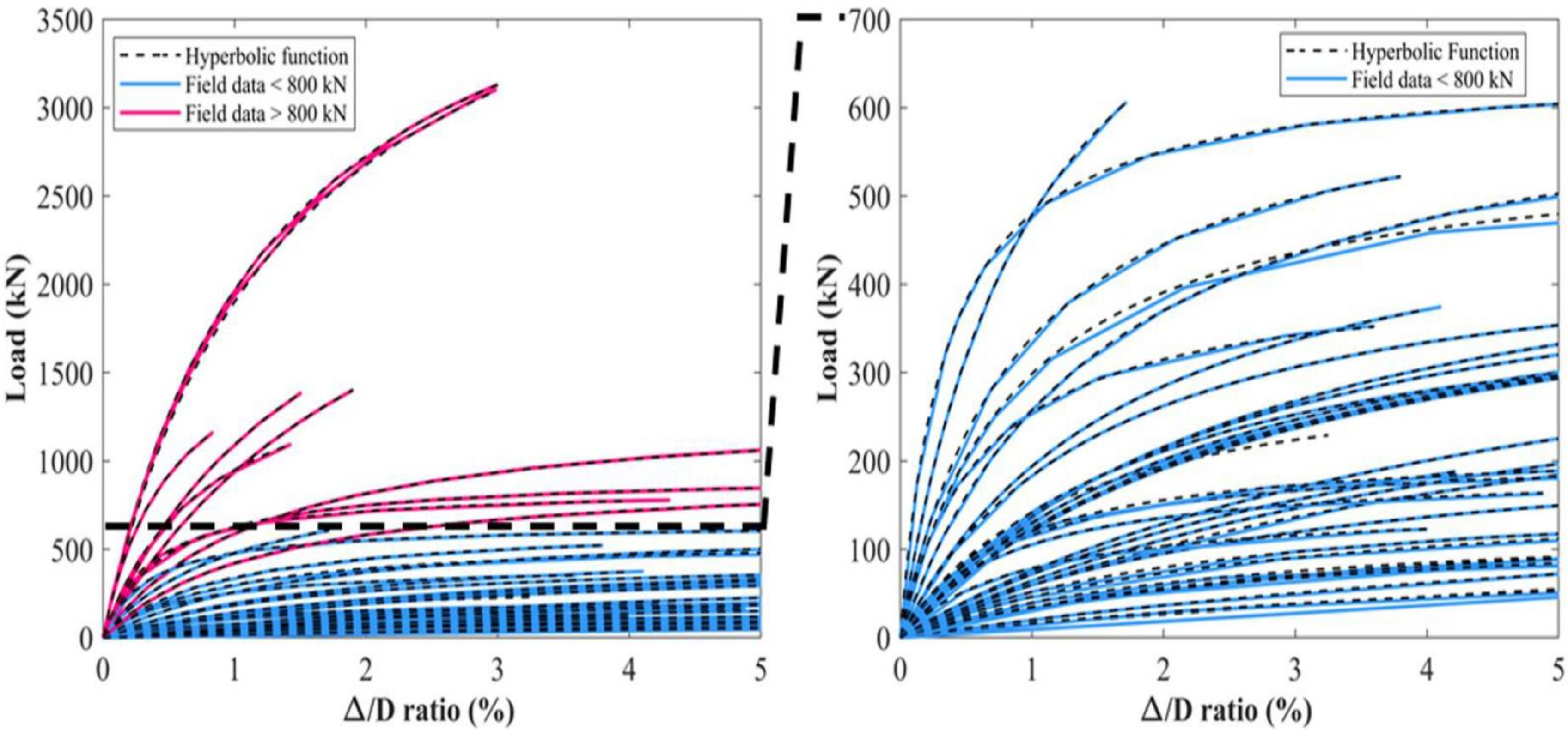
Soil-Cement Columns Load-Displacement
(Arjmand & Eslami, 2024)

No	Site Location	Reference	Adjacent Waterbody	Column Type	Length (m)	Diameter (mm)	Soil Type
1	Da Nang, Vietnam	(Do and Pham 2018)	East Vietnam Sea	DSM	12	800	Sand
2	Bangkok, Thailand	(Wonglert et al. 2018)	Chao Phraya River	DSM	10	500	Clay
3	Bangkok, Thailand	(Wonglert et al. 2018)	Chao Phraya River	SDSM	10	500	Clay
4	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	DSM	7	600	Clay
5	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	DSM	7	600	Clay
6	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
7	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
8	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
9	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
10	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
11	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
12	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
13	Bangkok, Thailand	(Jamsawang, Bergado, and Voottipruex 2010)	Chao Phraya River	SDSM	7	600	Clay
14	Zhejiang, China	(Duan 2004)	East China Sea	DSM	15	500	Clay
15	Zhejiang, China	(Duan 2004)	East China Sear	DSM	12.5	500	Clay
16	Da Nang, Vietnam	(H. D. Do et al. 2020)	East Vietnam Sea	DSM	7.5	600	Mixture soil
17	Antwerp, Belgium	(Maertens and Maekelberg 2001)	Scheldt River	Jet Grouting	7	510	Sand
18	Antwerp, Belgium	(Maertens and Maekelberg 2001)	Scheldt River	Jet Grouting	7	550	Sand
19	Bojszowy, Poland	(Modoni, Bzowka, and Pieczyrak 2010)	–	Jet Grouting	7	1000	Sand
20	Bojszowy, Poland	(Modoni, Bzowka, and Pieczyrak 2010)	–	Jet Grouting	7	1000	Sand
21	Fujian, China	(Lin and Wong 1999)	Taiwan Strait	DSM	8.6	500	Clay
22	Fujian, China	(Lin and Wong 1999)	Taiwan Strait	DSM	9.6	500	Clay
23	Hai Phong, Vietnam	(An and Vu 2016)	Gulf of Tonkin	Jet Grouting	8	600	Clay
24	Hai Phong, Vietnam	(An and Vu 2016)	Gulf of Tonkin	Jet Grouting	8	600	Clay
25	Ca Mau, Vietnam	(An and Vu 2016)	South China Sea	Jet Grouting	10	600	Clay
26	Ca Mau, Vietnam	(An and Vu 2016)	South China Sea	Jet Grouting	10	600	Clay
27	Vernouillet, France	(Grzyb-Faddoul 2014)	Seine River	DSM	5	400	Mixture soil
28	Suzhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	16.5	1000-500	Clay
29	Suzhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	16.5	1000-500	Clay
30	Suzhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	16.5	1000-500	Clay
31	Suzhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	16.5	1200-600	Clay
32	ChangZhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	19	1000-600	Clay
33	ChangZhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	19	1000-600	Clay
34	ChangZhou, China	(Yi et al. 2017)	Taihu Lake	T-Shape DSM	19	800-600	Clay
35	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	5	500	Clay
36	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	7	500	Clay
37	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	9	500	Clay
38	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	11	500	Clay
39	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	11	500	Clay
40	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	13	500	Clay
41	Bangkok, Thailand	(Warapot 2004)	Chao Phraya River	DSM	13	500	Clay
42	Van, Turkey	(Maghsoudloo and Can 2014)	Van Lake	DSM	9	800	Clay

Study No.6

Soil-Cement Columns Load-Displacement
(Arjmand & Eslami, 2024)

- 42 Cases of Soil-Cement Columns



Visualization of the adapted hyperbolic relation depicting load- Δ/D (%) graphs for soil-cement columns from the database

Study No.7

Ultimate Capacity of Helical Piles via ML
(Eslami, Rahimi & Nobahar, 2024)

GEOMECHANICS AND GEOENGINEERING
https://doi.org/10.1080/17486025.2024.2438077

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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.

ARTICLE HISTORY
Received 17 June 2024
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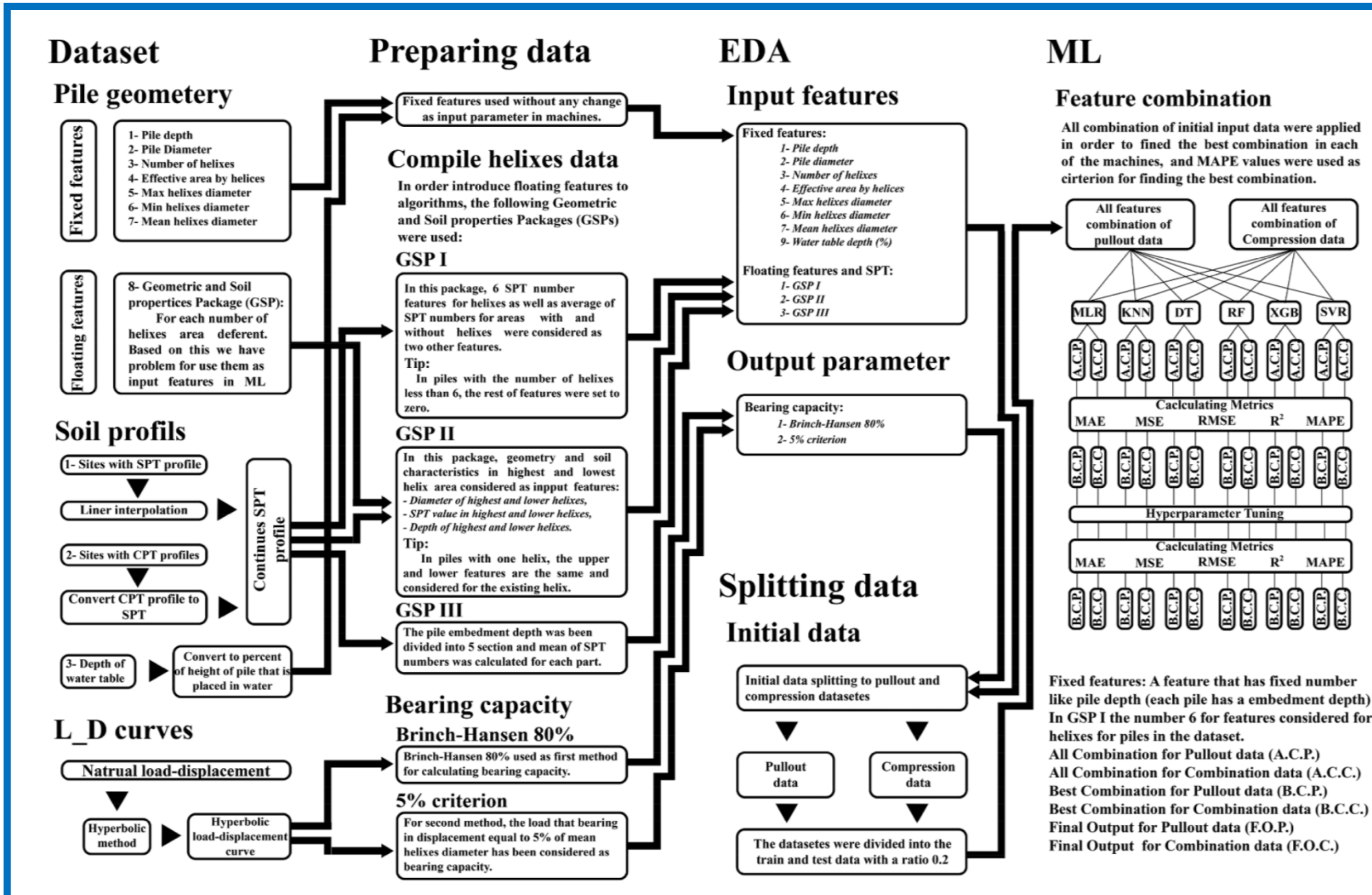
KEYWORDS
Ultimate load criteria; predictive model; machine learning-based algorithms; helical Piles

Study No.7

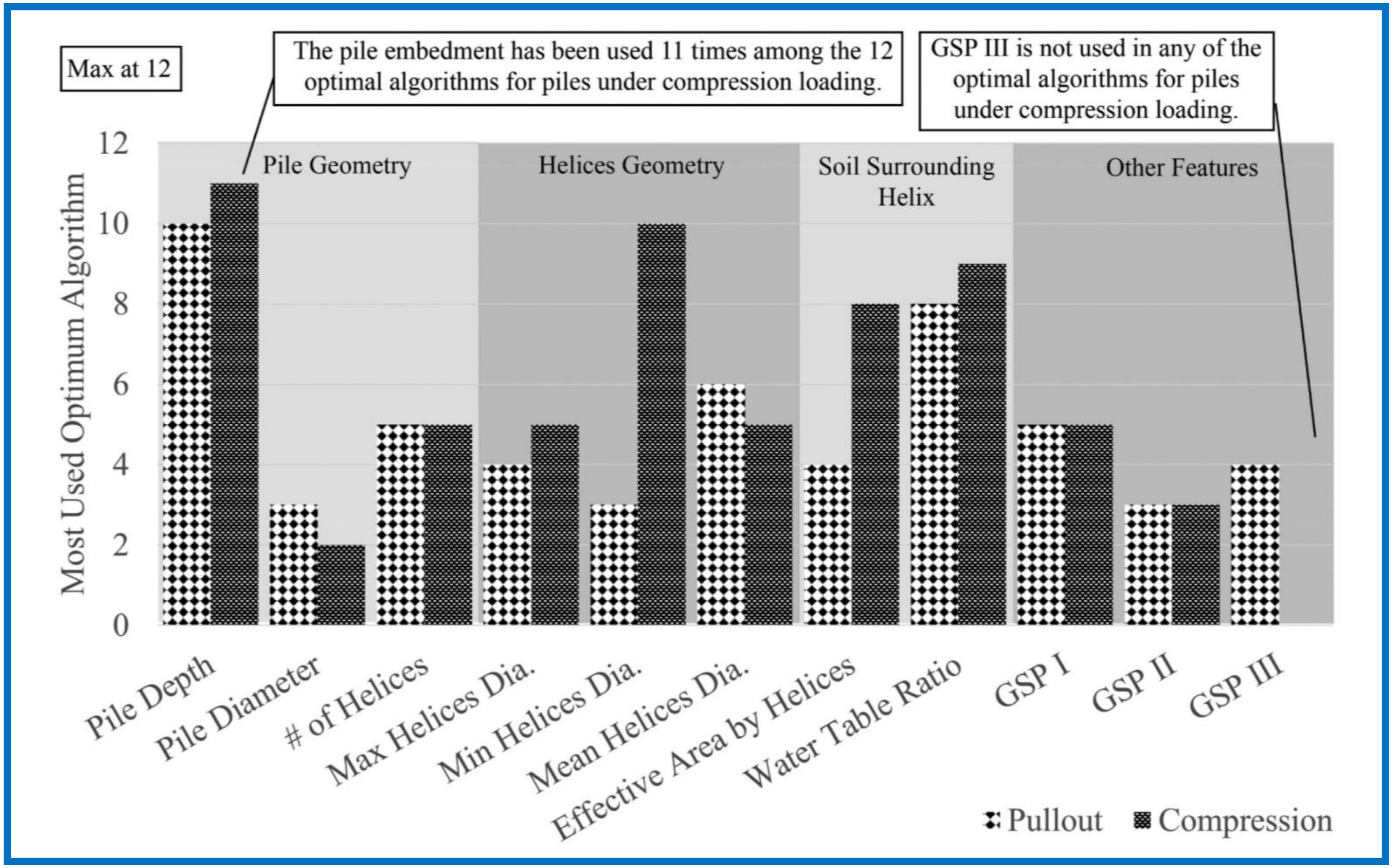
Ultimate Capacity of Helical Piles via ML
(Eslami, Rahimi & Nobahar, 2024)



Study flow guideline for predicting ultimate load bearing of helical piles

Study No.7

Ultimate Capacity of Helical Piles via ML
(Eslami, Rahimi & Nobahar, 2024)



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

Study No.8

Data-Centric Approach for Granular Columns

(Arjmand, Eslami, Ebrahimian, Heidari & Ebrahimipour, 2025)

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Ocean Engineering

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ELSEVIER

Research paper

Appraisal of load-displacement behavior of granular Columns: Data-Centric approach

Ali Arjmand [a], Abolfazl Eslami [b,*], Parinaz Ebrahimian [a], Sara Heidarie Golafzani [b], Amirhossein Ebrahimipour [b]

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A R T I C L E I N F O

Keywords:
Load-displacement
Granular column
Data-centric
Full-scale test
Soil-cement columns
Marine sediments

A B S T R A C T

Granular columns are widely used in nearshore and offshore projects to improve soft marine sediments. Several factors, including column geometry, encasement, and the properties of the surrounding soil and replacement material, influence the load-displacement behavior of granular columns. To assess the effect of each factor on the load-displacement behavior of the granular column, a database of 44 full-scale loading tests was compiled. The hyperbolic function and two data analysis algorithms were then employed. The adjusted K-means algorithm was applied to cluster the columns based on initial stiffness and limit load, as determined by the hyperbolic function. A classification tree was used to identify the most effective factor. The results demonstrate that the column diameter and the properties of the surrounding soil are the dominant factors that simultaneously influence both the initial stiffness and the limit load. Moreover, the threshold limit of the load-displacement range for granular columns was defined based on in-situ test records, and the applicability of the results was validated using two additional case studies and numerical simulations. Finally, a comparative study was conducted between granular and soil-cement columns, leading to the development of a practical guideline for selecting the optimal column type based on project requirements.

Study No.8

Data-Centric Approach for Granular Columns
(Arjmand, Eslami, Ebrahimian, Heidari & Ebrahimipour, 2025)

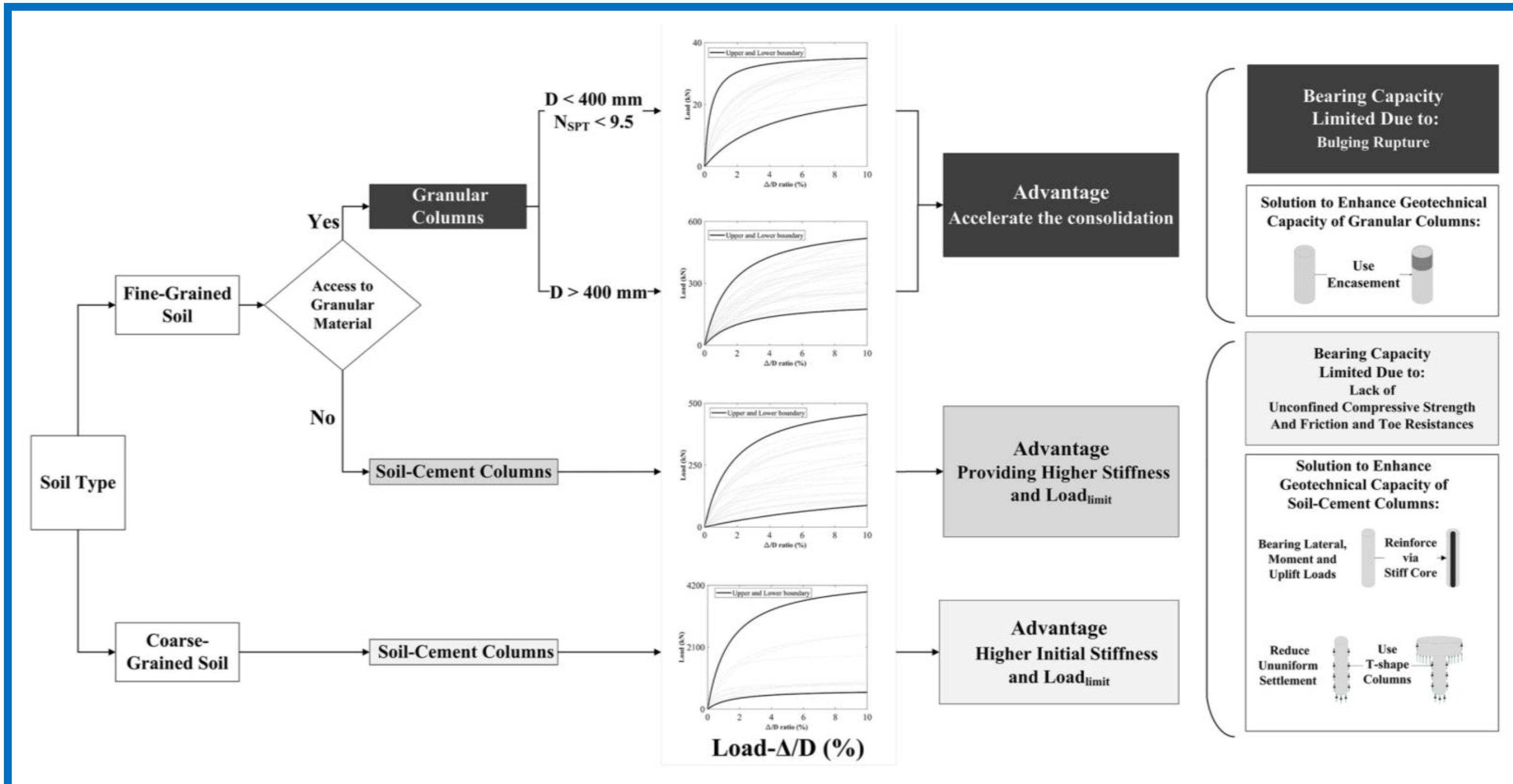
No	Site Location	Reference	Column Type	Length (m)	Diameter (mm)	Soil Type
Granular Columns						
1	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-20Blow[a]	8	300	Clay
2	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-20Blow	8	300	Clay
3	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-20Blow	8	300	Clay
4	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-15Blow	8	300	Clay
5	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-15Blow	8	300	Clay
6	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-15Blow	8	300	Clay
7	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-10Blow	8	300	Clay
8	Bangkok, Thailand	Bergado and Lam (1987)	Sand Column-10Blow	8	300	Clay
9	Bangkok, Thailand	Bergado and Lam (1987)	Gravel + Sand Column-15Blow	8	300	Clay
10	Bangkok, Thailand	Bergado and Lam (1987)	Gravel + Sand Column-15Blow	8	300	Clay
11	Bangkok, Thailand	Bergado and Lam (1987)	Gravel Column-15Blow	8	300	Clay
12	Bangkok, Thailand	Bergado and Lam (1987)	Gravel Column- 15Blow	8	300	Clay
13	Yozgat, Turkey	Bal and Cetin (2012)	RAP[b]	10	500	Clay
14	Yozgat, Turkey	Bal and Cetin (2012)	RAP	9	500	Clay
15	Yozgat, Turkey	Bal and Cetin (2012)	RAP	10	500	Clay
16	Yozgat, Turkey	Bal and Cetin (2012)	RAP	9	500	Clay
17	Gimhae, S.Korea	Yoo and Lee (2012)	Geogrid Encased Column-3D	5.5	760	Mixed soil
18	Gimhae, S.Korea	Yoo and Lee (2012)	RAP	5.5	760	Mixed soil
19	Pohang, S.Korea	Yoo and Lee (2012)	Geogrid Encased Column-2D	8	760	Clay
20	Pohang, S.Korea	Yoo and Lee (2012)	Geogrid Encased Column-4D[c]	8	760	Clay
21	Pohang, S.Korea	Yoo and Lee (2012)	RAP	8	760	Clay
22	Washington, U.S.A.	Fox and Edil (2001)	RAP	4	760	Clay
23	Oregan, U.S.A.	Fox and Edil (2001)	RAP	4.2	760	Clay
24	Oregan, U.S.A.	Fox and Edil (2001)	RAP	4.3	760	Clay
25	Amherst, U.S.A.	Lillis et al. (2004)	RAP	3	610	Clay
26	Texas, U.S.A.	Stuedlein and Holtz (2012).	Vibration-Well Gradation	4.57	760	Clay
27	Texas, U.S.A.	Stuedlein and Holtz (2012).	Vibration-Well Gradation	3.05	760	Clay
28	Texas, U.S.A.	Stuedlein and Holtz (2012).	Vibration-Well Gradation	4.57	760	Clay
29	Texas, U.S.A.	Stuedlein and Holtz (2012).	Vibration-Well Gradation	3.05	760	Clay
30	Texas, U.S.A.	Stuedlein and Holtz (2012).	Tamping- Uniform Gradation	3.05	760	Clay
31	Texas, U.S.A.	Stuedlein and Holtz (2012).	Tamping- Uniform Gradation	3.05	760	Clay
32	Texas, U.S.A.	Stuedlein and Holtz (2012).	Tamping- Uniform Gradation	4.57	760	Clay
33	Texas, U.S.A.	Stuedlein and Holtz (2012).	Tamping- Uniform Gradation	4.57	760	Clay
34	Lowa, U.S.A.	Pham and White (2007)	RAP	2.79	760	Clay
35	Lowa, U.S.A.	Pham and White (2007)	RAP	5.1	760	Clay
36	Gaziantep, Turkey	(kurt and Kemaloglu, 2011)	RAP	7	500	Clay
37	Gaziantep, Turkey	(kurt and Kemaloglu, 2011)	RAP	7.5	500	Clay
38	Lowa, U.S.A.	Wissmann et al. (2007)	RAP	2.4	760	Clay
39	Lowa, U.S.A.	White et al. (2002)	Vibro Column	5	910	Clay
40	Lowa, U.S.A.	White et al. (2002)	RAP	5.4	760	Clay
41	Pittsburgh, U.S.A.	Engelhardt and Golding (1975)	Vibro Column	10.7	1100	Mixed soil
42	Pittsburgh, U.S.A.	Engelhardt and Golding (1975)	Vibro Column	10.7	1100	Mixed soil
43	Surat, India	Tandel et al. (2014)	Sand Column	6	300	Clay
44	Surat, India	Tandel et al. (2014)	Geogrid Encased Column-Full	6	300	Clay

Study No.8

Data-Centric Approach for Granular Columns

(Arjmand, Eslami, Ebrahimian, Heidari & Ebrahimipour, 2025)

- **44 Cases of Stone Columns**



Practical guideline for selecting the best column types under vertical static load and improving their performance according to project requirements

Study No.9

Load-Displacement Prediction of Helical Piles
(Nobahar, Rahimi & Eslami, 2025)

TRR
JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

Research Article

Transportation Research Record
1–23

DOI: 10.1177/03611981251341335
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Predicting and Evaluating Load-Displacement Trends of Helical Piles Using Machine Learning–Based Algorithms

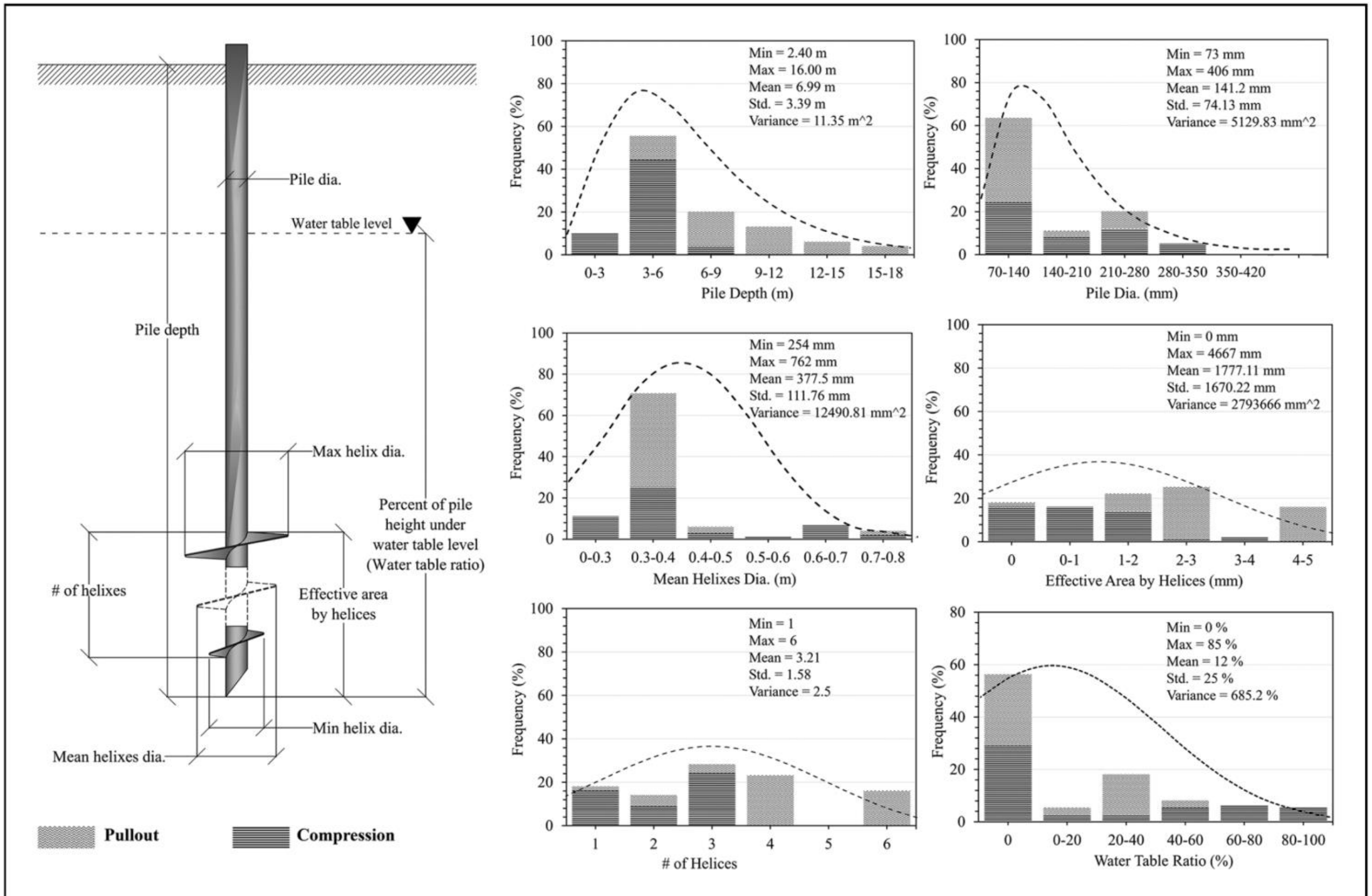
Masoud Nobahar[1], Amirhossein Rahimi[2], and Abolfazl Eslami[2]

Abstract

Evaluating the load-displacement trend of helical piles is essential to meet strength and serviceability standards for pile analysis and design. While pile load tests are the most accurate method, their cost and time constraints often lead in practice to the routine use of load transfer methods. This study aims to explore the feasibility of employing various machine learning–based algorithms to assess the load-displacement trend of axially loaded helical piles, using an existing database. Multiple machine learning models, including multi linear regression, K-nearest neighbors, random forest (RF), extreme gradient boosting (XGB), and artificial neural networks, were developed using data from 98 helical piles with a depth of 2.4 m to 16 m from 14 separate sites and corresponding in situ test data. Statistical evaluation was conducted to assess the performance of these models, comparing their predictions to measured curves from pile load tests. Based on the predictive analysis results, the average area under the regression error characteristic curve for XGB and RF was 0.035 and 0.043, respectively. The performance errors for XGB and RF were 0.01 and 0.05, respectively. The root mean squared error (RMSE) values for XGB and RF on the training data set were 0.083 and 0.1, respectively, while the RMSE values on the testing data set are 0.08 and 0.12.

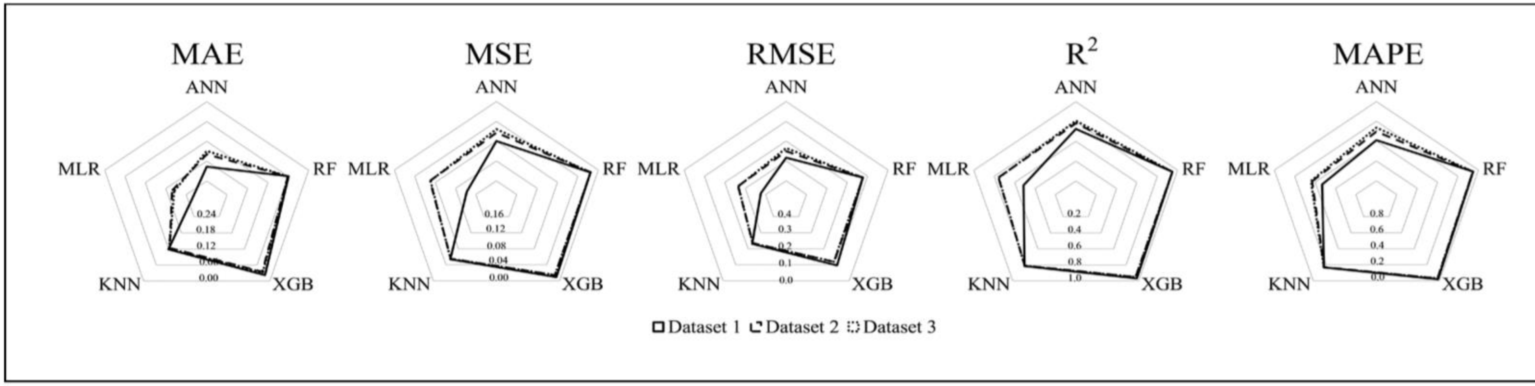
Study No.9

Load-Displacement Prediction of Helical Piles
(Nobahar, Rahimi & Eslami, 2025)

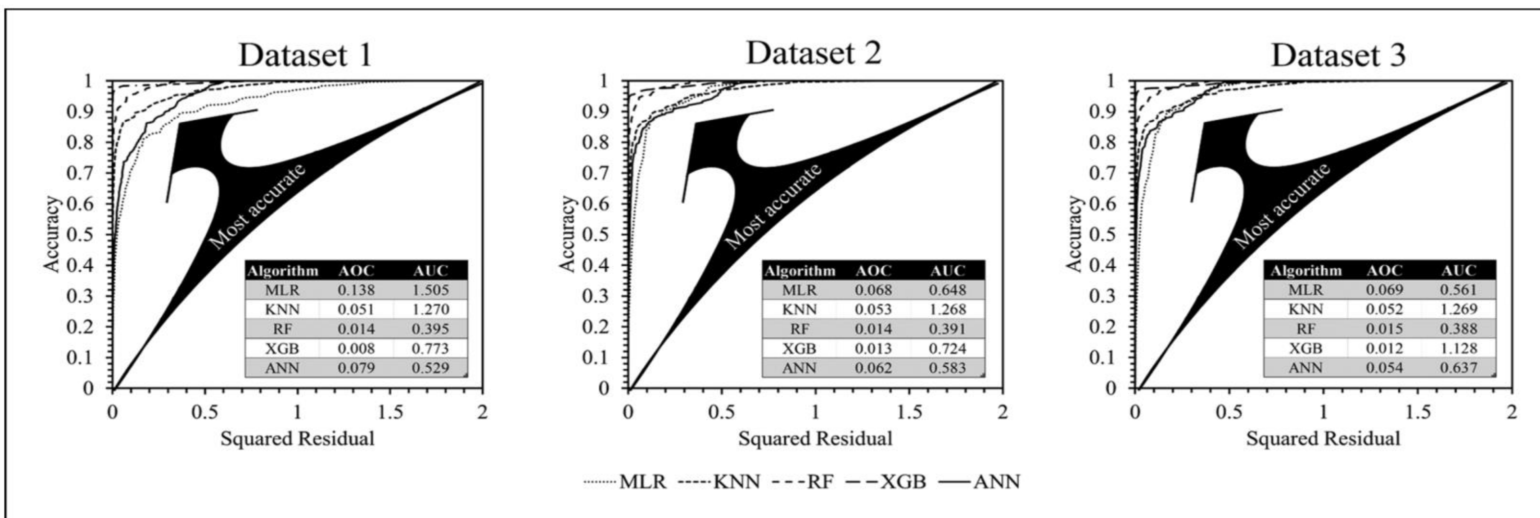


Study No.9

Load-Displacement Prediction of Helical Piles
(Nobahar, Rahimi & Eslami, 2025)



Results of predictive model performance metrics



Dataset 1:

Algorithm	AOC	AUC
MLR	0.138	1.505
KNN	0.051	1.270
RF	0.014	0.395
XGB	0.008	0.773
ANN	0.079	0.529

Dataset 2:

Algorithm	AOC	AUC
MLR	0.068	0.648
KNN	0.053	1.268
RF	0.014	0.391
XGB	0.013	0.724
ANN	0.062	0.583

Dataset 3:

Algorithm	AOC	AUC
MLR	0.069	0.561
KNN	0.052	1.269
RF	0.015	0.388
XGB	0.012	1.128
ANN	0.054	0.637

Regression error characteristic (REC) for best feature combination in all MLA

Study No.10

Piling in Marine Challenging Conditions
(Ebrahimipour & Eslami, 2024)

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Research paper

Analytical study of piles behavior for marine challenging substructures

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A R T I C L E I N F O

Handling Editor: Prof. A.I. Incecik

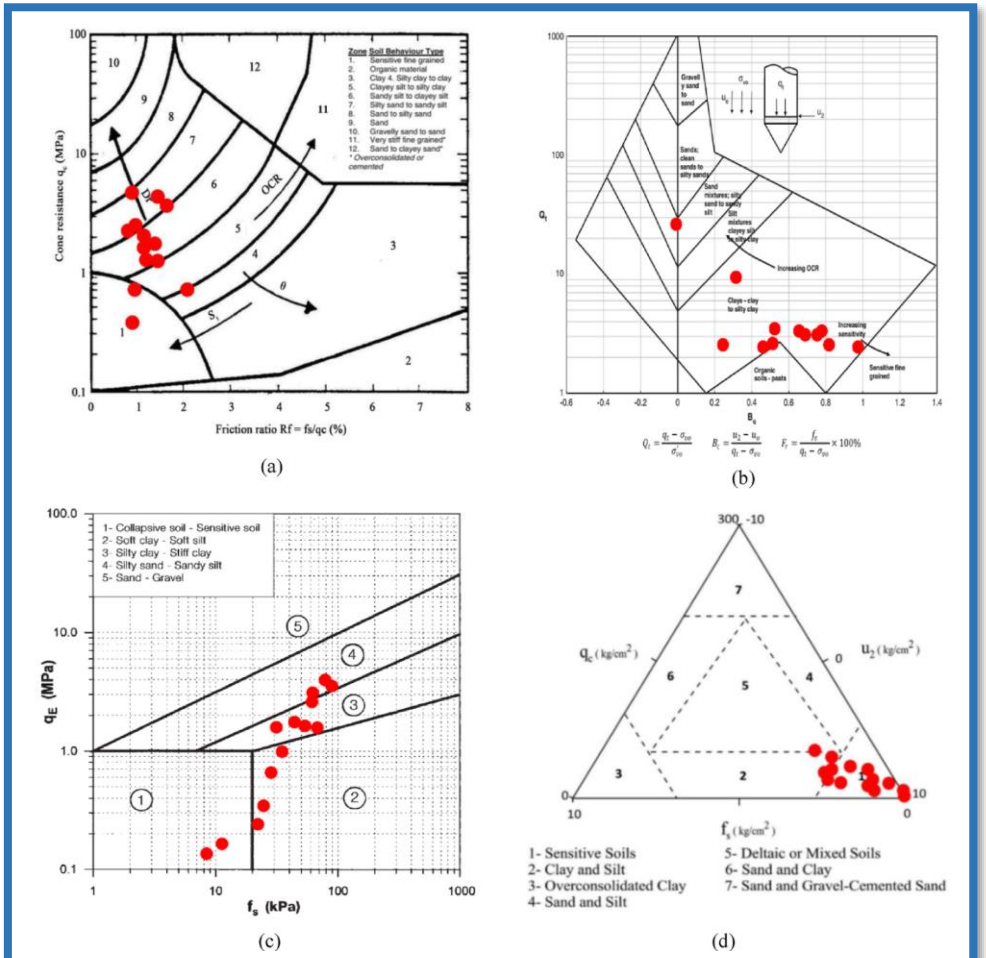
Keywords:
Analytical study
Pile behavior
Challenging deposits
CPT & CPTu
Neutral plane
Downdrag force

A B S T R A C T

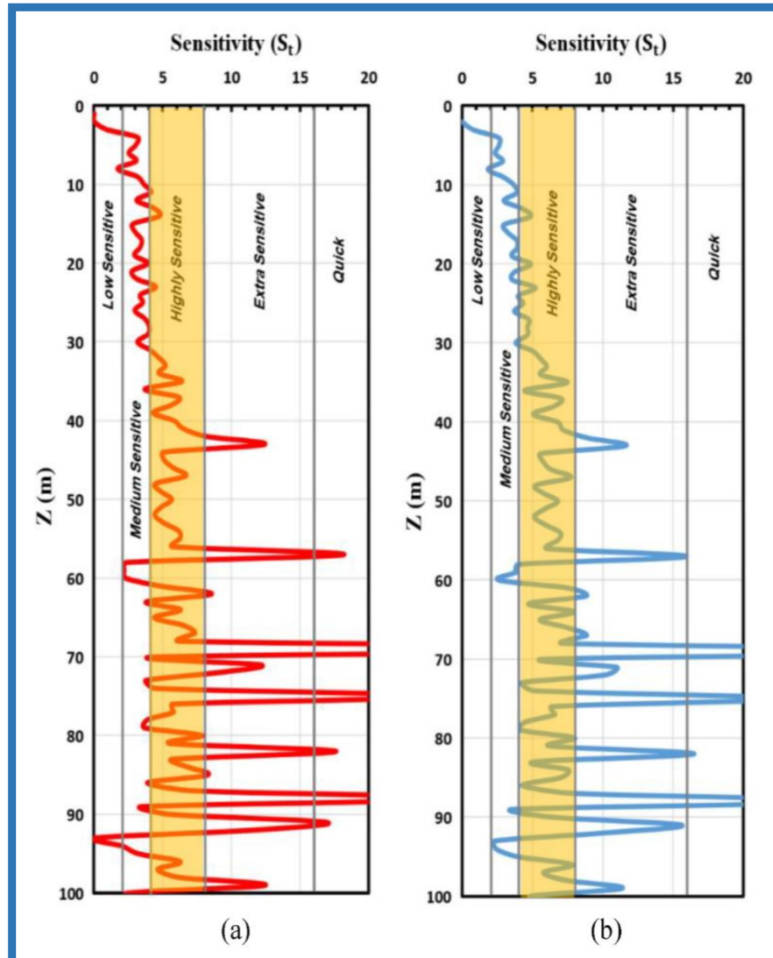
Based on a new categorization, significancy and feasibility of vector-acting foundations for offshore challenging substructures are emphasized. A marine challenging status is typically related to loading, investigations, sub-surface, environment, construction and sustainability requirements. The issue of the interaction of piles and complex subsoil is discussed in this paper. Three scenarios are studied comprising sensitive deposits at the full depth, the most impressive one, compressible deposits at the top layer and soft soil underlain by strong deposits. The role of CPTu records is addressed in recognition of problematic layers, geotechnical design and embedment depth designation. The effect of soil sensitivity on shaft and toe resistance is quantified through static analysis and reduction factors are suggested. Since bearing capacity, settlement and axial load are interactive, the neutral plane concept is applied, unifying the mentioned aspects. Through the neutral plane approach and considering the downdrag force due to the collapse of sensitive soil, primary design criteria incorporating sensitivity are discussed and quantified. Applying ground modification as a supplement for deep foundations is realized through two case studies, leading to enhancement in geotechnical performance. Overall, the mentioned phenomena must be discovered comprehensively in extraordinary conditions, aiming for a safe, reliable, knowledge-based and optimum design.

Study No.10

Piling in Marine Challenging Conditions
(Ebrahimipour & Eslami, 2024)



Soil behavior classification (SBC) of Urmia Lake deposits via a) Robertson et al. (1986), b) Robertson (1990), c) Eslami & Fellenius (1997), d) triangular chart (Eslami et al., 2023)



Sensitivity profiles of Urmia Lake deposit via two approaches (Ebrahimipour & Eslami, 2024)

Study No.10

Piling in Marine Challenging Conditions
(Ebrahimipour & Eslami, 2024)

$$\Psi = \frac{S_u}{\sigma'_v} \qquad S_t = \frac{S_{u-undisturbed}}{S_{u-remolded}}$$

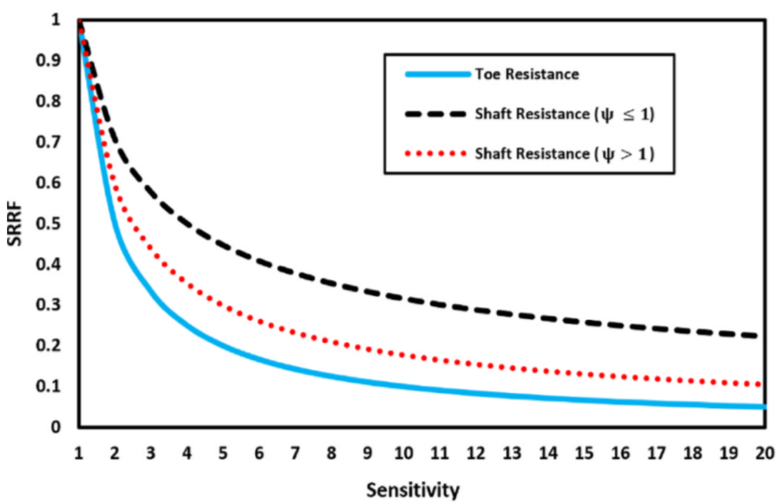
Shaft Resistance:

$$\text{For } \Psi \le 1 \rightarrow \frac{r_{s-undisturbed}}{r_{s-disturbed}} = S_t^{0.5}$$

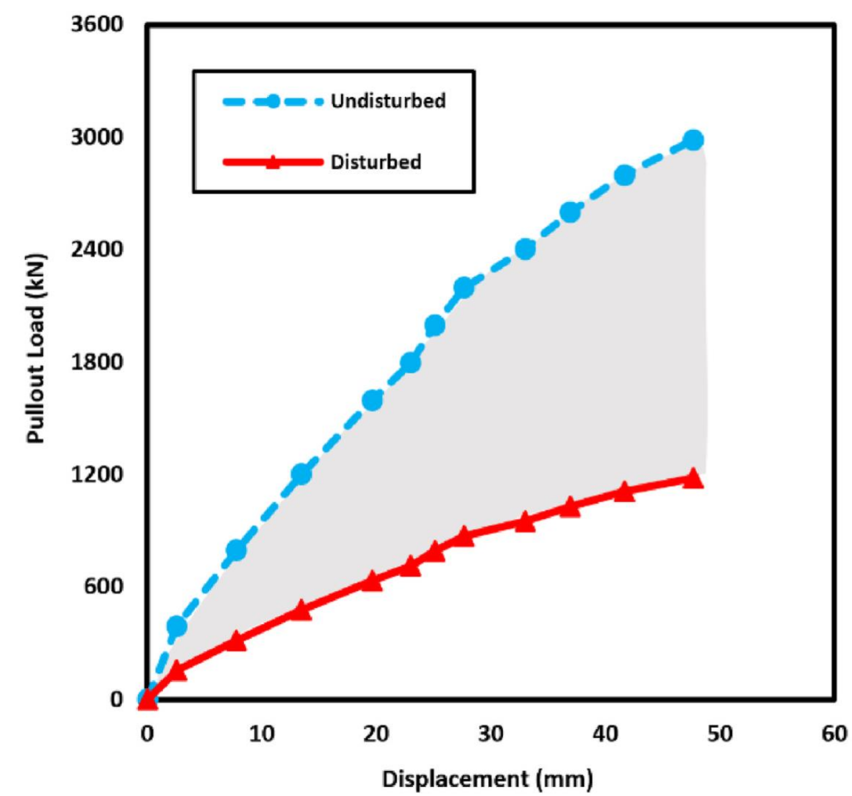
$$\text{For } \Psi > 1 \rightarrow \frac{r_{s-undisturbed}}{r_{s-disturbed}} = S_t^{0.75}$$

Toe Resistance:

$$\frac{r_{t-undisturbed}}{r_{t-disturbed}} = S_t$$



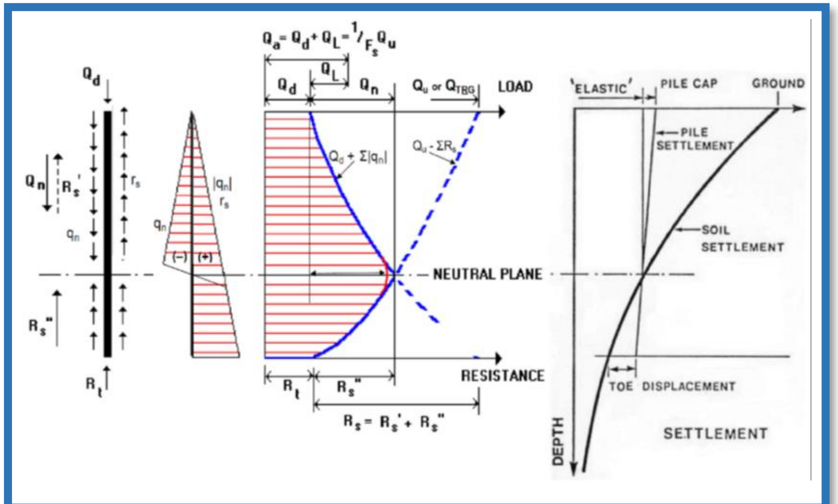
Sensitivity-based reduction factors (Ebrahimipour & Eslami, 2024)



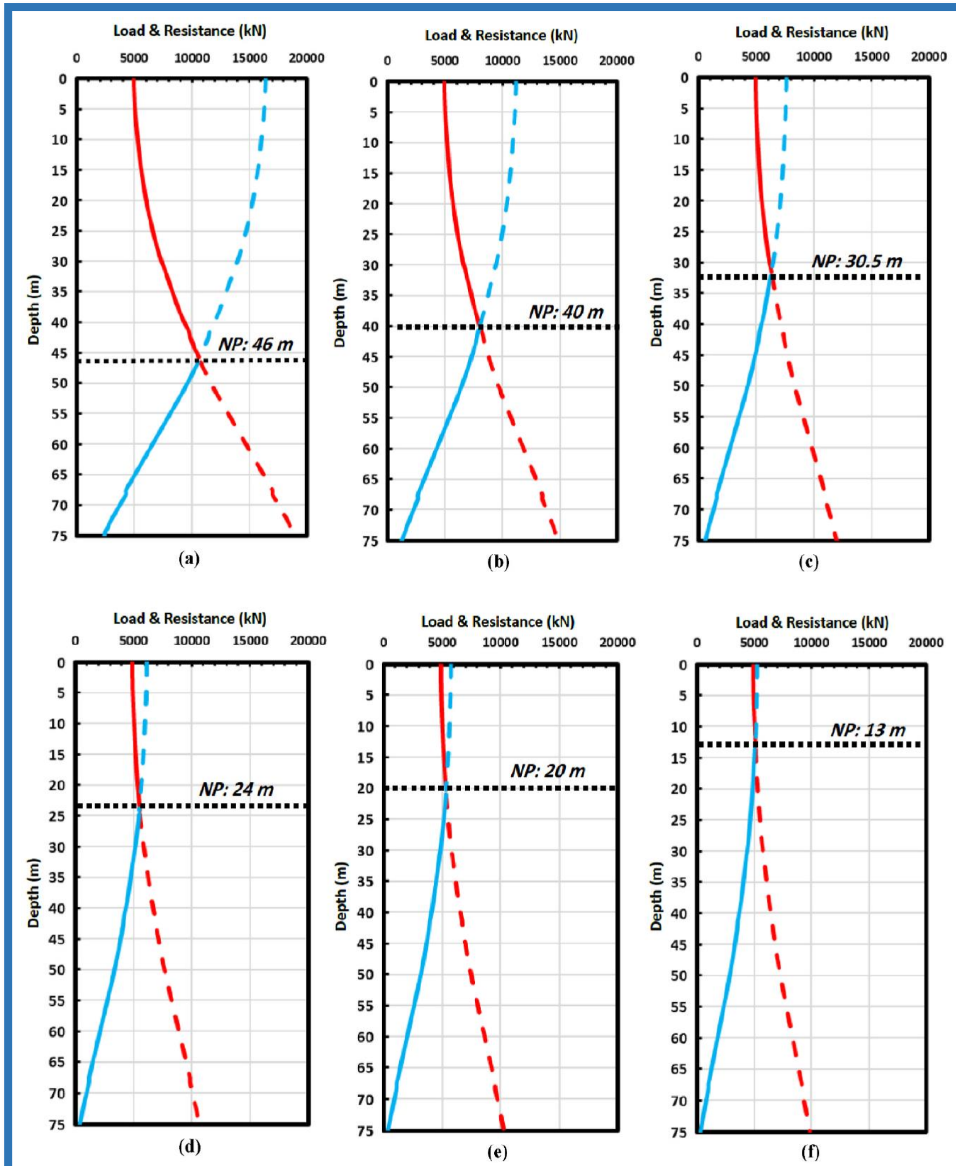
Pullout load-displacement of 70 m pile in disturbed and undisturbed condition (Ebrahimipour & Eslami, 2024)

Study No.10

Piling in Marine Challenging Conditions *(Ebrahimipour & Eslami, 2024)*



Neutral plane concept (Fellenius, 2023)



Variation of load, resistance & neutral plane depth through altering the sensitivity for a typical pipe pile in the Urmia lake: a) reference condition, b) St = 2, c) St = 4, d) St = 6, e) St = 6.75, f) St = 8 (Ebrahimipour & Eslami, 2024)

Study No.11

Piles Capacity Loss Under Dynamic Conditions
(Eslami, Shadlou & Ebrahimipour, 2025)

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Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

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

Pore water pressure generation and sensitivity aspects for pile dynamics and capacity loss: CPTu records and case studies

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A R T I C L E I N F O

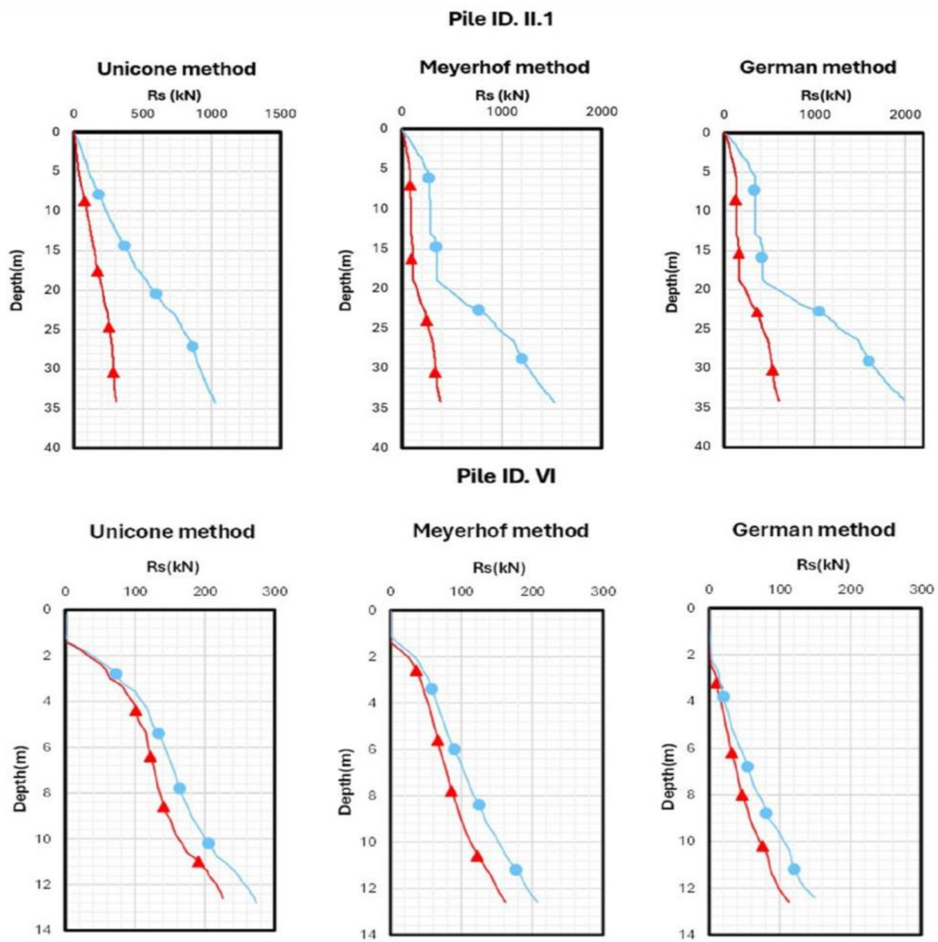
Keywords:
Pore water pressure
Sensitivity
Pile dynamics
Capacity loss
CPTu
Case studies

A B S T R A C T

Soil disturbance and excess pore water pressure generation, induced by dynamics and transient excitations such as pile driving, seismic loading, and impact effects, can significantly degrade the geotechnical strength and stiffness. Given the critical importance of axial capacity in sustaining superstructures, it is essential to recognize and mitigate potential damages. This research investigates the piles reduction of axial capacity through CPTu records, which offer rapid and reliable data. Aiming to quantify the consequences of soil sensitivity and excess pore water pressure, a comprehensive dataset has been compiled comprising CPTu and pile performance records from 11 diverse sites worldwide, focusing on soft and loose deposits. The research identifies problematic sub-layers and, by incorporating an analytical approach, evaluates the intact and reduced shaft and toe resistance through three distinct methods. Results indicate a substantial reduction in bearing capacity due to dynamic loading on piles. Four levels of capacity loss concern are recognized quantitively. Through case studies, the response of the problematic deposit under dynamic loading is more apprehended, conforming with the findings. The current research addresses and emphasizes the necessity of realizing pile dynamics and problematic deposit interaction. It can lead to safe, reliable, and optimal design practices based on a comprehensive understanding of soil-pile interaction.

Study No.11

Piles Capacity Loss Under Dynamic Conditions
(Eslami, Shadlou & Ebrahimipour, 2025)



$$\Psi = \frac{S_u}{\sigma'_v} \qquad r_u = \frac{\Delta u}{\sigma'_v}$$

Shaft Resistance:

$$\text{For} \quad \psi \leq 1 \Rightarrow \text{SRRF} = \frac{1}{St^{0.5}}$$

$$\text{For} \ \psi > 1 \Rightarrow \text{SRRF} = \frac{1}{St^{0.75}}$$

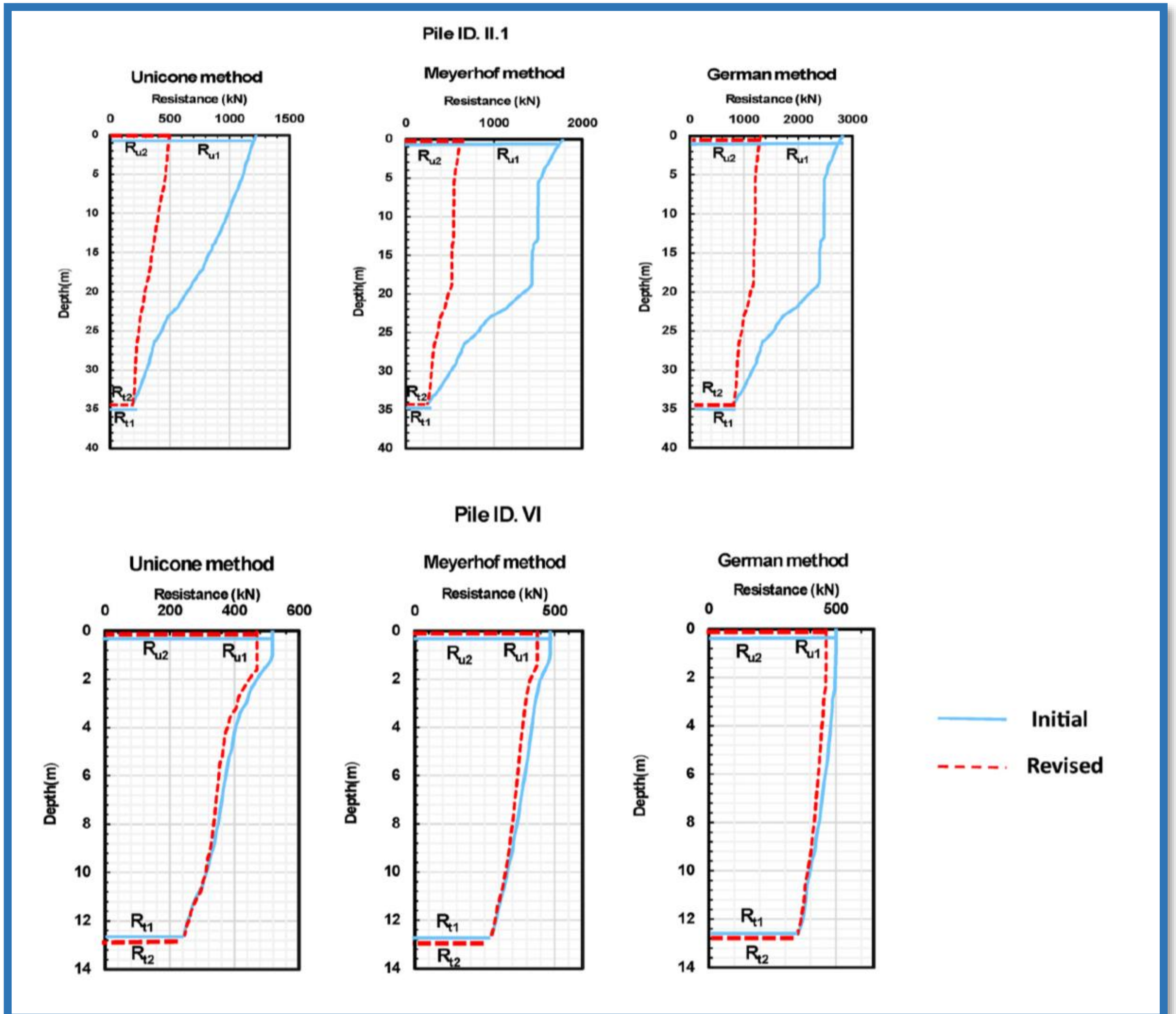
Toe Resistance:

$$\frac{q_E}{q_t} = \frac{q_t - u_2}{q_t} = 1 - \frac{u_2}{q_t}$$

Shaft distribution before and after revision based on SRRF

Study No.11

Piles Capacity Loss Under Dynamic Conditions
(Eslami, Shadlou & Ebrahimipour, 2025)

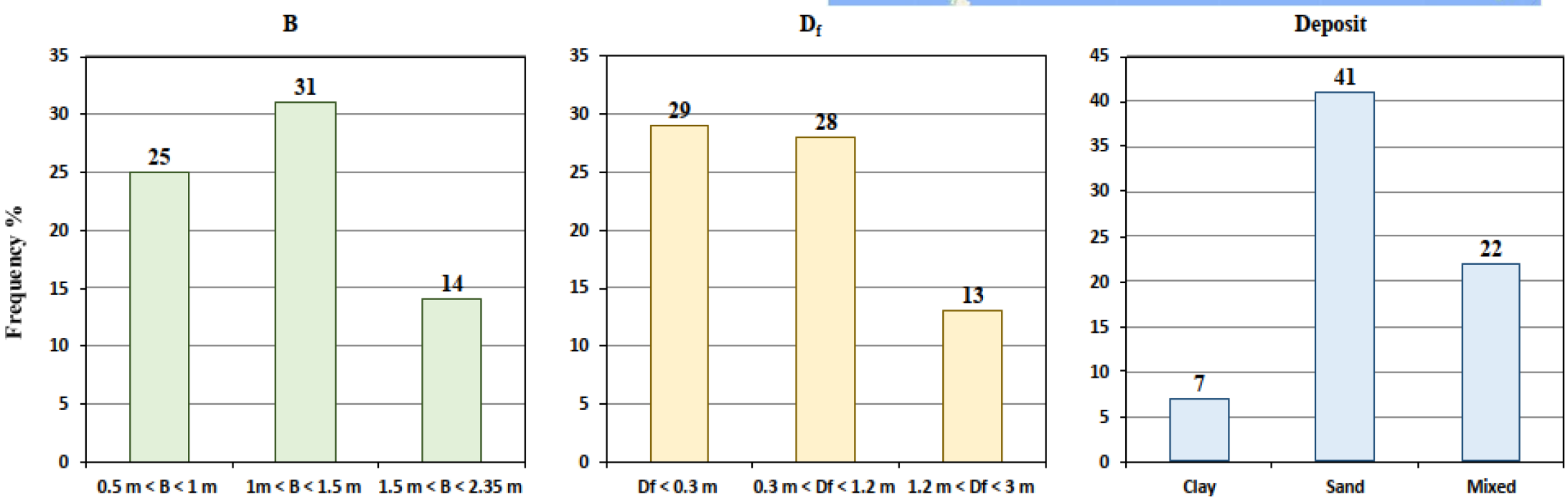


Total resistance before and after revision in pile cases II.1, VI

I. Safety Factor Assessment

Load-Displacement Appraisal of Spread Footings
(Heidari, Rahimnejad, Eslami, & Ebrahimipour, 2025)

- **70 Cases of Spread Footings**
- **Constructed in Sand, Clay and Mixed Soils**
- **Embedment Depths between 0 to 3 m**
- **Breadth between 0.5 to 2.2 m**



Records characteristics distribution

I. Safety Factor Assessment

Load-Displacement Appraisal of Spread Footings

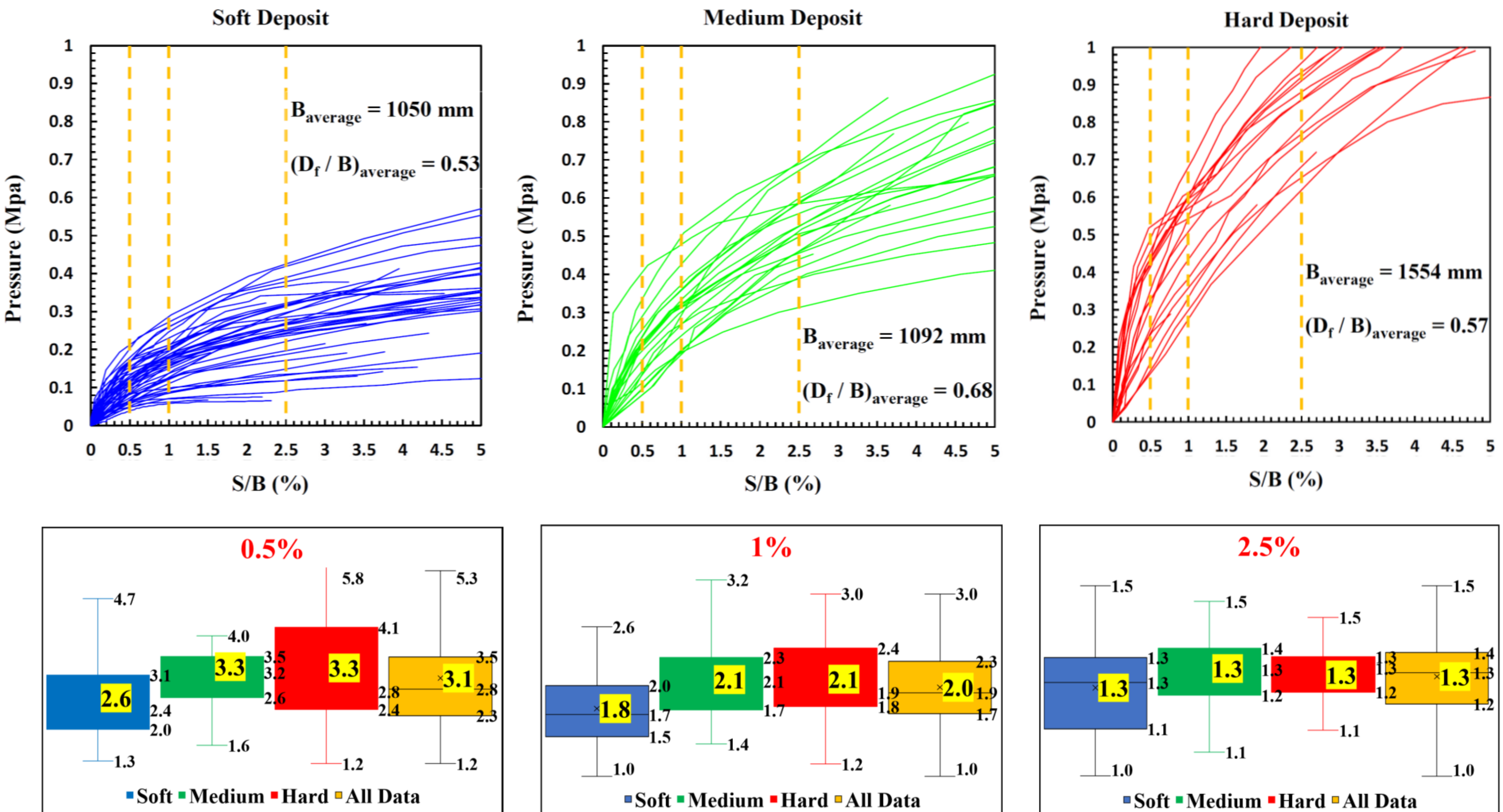
(Heidari, Rahimnejad, Eslami, & Ebrahimipour, 2025)

Case ID	Reference	Location	Foundation Data					Deposit	Maximum Measurement	
			Section	B (mm)	L (mm)	D_f (m)	D_f / B		Load (kN)	Disp. (mm)
1	Amar (1998)	Labenne, France	Square	700	700	0	0	Soft	445.85	140.97
2			Square	700	700	0	0	Soft	432.69	110.62
3	Andersen and Stenhamar (1982)	Haga, Norway	Square	1000	1000	0	0	Soft	377.76	33.07
4		Haga, Norway	Square	2000	2000	0	0	Soft	350.28	31.49
5	Bauer, (1976) & Shields (1975)	Ottawa, Canada	Circular	3100	-	1.3	0.42	Hard	2767.68	23.74
6	Bazaraa (1967)	Illinois, United States	Square	1200	1200	0	0	Hard	1491.15	39.18
7		Illinois, United States	Square	1200	1200	0	0	Hard	1481.25	75.14
8	Bergdahl (1985)	Kolbyttemon, Sweden	Rectangular	2300	2500	1.56	0.68	Hard	2716.99	22.6
9		Kolbyttemon, Sweden	Rectangular	1100	1300	0.72	0.65	Hard	1885.44	50.74
10		Kolbyttemon, Sweden	Rectangular	1600	1800	1.04	0.65	Hard	1694.24	20.96
11		Kolbyttemon, Sweden	Rectangular	550	650	0.36	0.65	Medium	493.35	40.32
12		Fittja, Sweden	Rectangular	2300	2500	1.5	0.68	Soft	1856.93	51.63
13		Fittja, Sweden	Rectangular	1100	1300	0.72	0.65	Soft	202.75	41.16
14		Fittja, Sweden	Rectangular	1600	1800	1.04	0.65	Soft	1189.17	63.21
15		Fittja, Sweden	Rectangular	550	650	0.36	0.65	Soft	212.53	55.89
16	Brand (1972)	Rangsit, Thailand	Square	1050	1050	1.6	1.52	Soft	143.27	35.85
17		Rangsit, Thailand	Square	900	900	1.6	1.78	Soft	124.76	37.65
18	Canepa (1990)	Brie Plateau, France	Square	1000	1000	0.35	0.35	Soft	449.32	134.51
19		Brie Plateau, France	Square	1000	1000	0	0	Soft	450.77	99.74
20		Brie Plateau, France	Square	1000	1000	0	0	Soft	452.17	98.73
21		Brie Plateau, France	Square	710	710	0	0	Soft	241.8	54.92
22		Brie Plateau, France	Square	710	1400	0	0	Soft	318.38	30.53
23		Brie Plateau, France	Square	1000	1000	0.43	0.43	Soft	451.14	121.47
24		Brie Plateau, France	Square	1000	1000	0.63	0.63	Soft	499.51	151.9
25		Brie Plateau, France	Square	1000	1000	0	0	Soft	450.68	56.21
26	Consoli (1998)	Brazil	Square	700	700	1.2	1.71	Soft	211.23	100.12
27		Brazil	Circular	600	-	1.2	2	Soft	145.15	100
28		Brazil	Square	1000	1000	1.2	1.2	Soft	268.25	35.29
29		Brazil	Circular	600	-	1.2	2	Soft	150.35	100
30	Deshmukh (1994)	Bombay, India	Square	600	600	0	0	Soft	68.89	19.69
31		Bombay, India	Square	600	600	0	0	Soft	69.7	22.61
32	DiMillio (1994)	Virginia, United States	Square	610	610	0	0	Soft	99.84	11.04
33		Virginia, United States	Square	610	610	0	0	Soft	114.18	25.1
34		Virginia, United States	Square	910	910	0	0	Soft	311.22	80.64
35		Virginia, United States	Square	610	610	0	0	Soft	119.87	37.44
36	Frost (1970)	Perth, Australia	Square	610	610	0	0	Soft	80.27	18.33
37		Perth, Australia	Square	610	610	0	0	Soft	90.59	26.42
38	Gaone (2018)	N.S.W Australia	Square	1800	1800	1.5	0.83	Soft	212.21	41.65
39		N.S.W Australia	Square	1800	1800	1.5	0.83	Soft	224.09	29.94
40		N.S.W Australia	Square	1800	1800	1.5	0.83	Soft	243.26	39.55
41	Greenwood (1975)	East Glasgow, Russia	Square	910	910	0.6	0.67	Soft	151.82	21.34
42	Ismael (1985)	Kuwait	Square	750	750	1	1.33	Medium	405.1	20.23
43		Kuwait	Square	1000	1000	1	1	Medium	580.28	19.13
44	Lehane (2008)	Perth, Australia	Square	1500	1500	1	0.67	Soft	358.49	15.56
45		Perth, Australia	Square	1000	1000	0.5	0.5	Soft	191.82	15.36
46		Perth, Australia	Square	1000	1000	1	1	Soft	185.53	13.96
47		Perth, Australia	Square	670	670	1	1.49	Soft	184.92	50.57
48	Levy & Morton (1974)	Depford, UK	Square	610	610	0	0	Hard	384.61	15.58
49		Bermondsey, UK	Square	610	610	0	0	Hard	389.65	13.8
50	Long (1998)	Garbo, Sweden	Square	800	800	0	0	Soft	226.92	39.86

I. Safety Factor Assessment

Load-Displacement Appraisal of Spread Footings
(Heidari, Rahimnejad, Eslami, & Ebrahimipour, 2025)

Assuming ultimate load at S/B = 5%



Evaluating factor of safety for spread footings based on displacement ratios

II. Normalized Load-Displacement

Load-Displacement Appraisal of Driven Piles *(Eslami & Ebrahimipour, 2024)*

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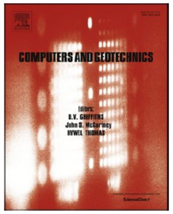

Research Paper

Load-displacement appraisal and analysis for driven piles; a data-centric approach

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Linear stiffness

ABSTRACT

Data-centric geotechnics is an ever-evolving field for facilitating digital transformation. The major issues for foundation design, bearing capacity, settlement and interactions of super and substructure are inherently emanated in load–displacement records. Considering the pivotal role of load–displacement behavior, it is believed to be a data center in foundation engineering. In this study, from the compiled FELADD database, including twelve foundation types load–displacement records, 71 driven piles have been gained. Aiming toward the data-centric approach, records have been processed, organized and filtered. For computing ultimate and limit load, three criteria of 10%B, Brinch-Hansen 80% and hyperbolic function are engaged. Through adopting promising criteria for normalizing load–displacement, dominant factors including embedment depth, breadth and surrounding soil type were appraised. The results indicated that higher stiffness and ultimate load are achieved for piles with higher embedment depth and larger breadth, in competent layers. Load-displacement normalization has revealed significant points. The relative displacement of 1% is recognized as the appropriate point in elastic stiffness calculation, somehow compatible with safety factor of 2. Moreover, the yielding trend is mobilized for relative displacement in the range of 5 to 10%. Overall, the load–displacement records and processing, as a data center proceeds value engineering in foundation design.

II. Normalized Load-Displacement

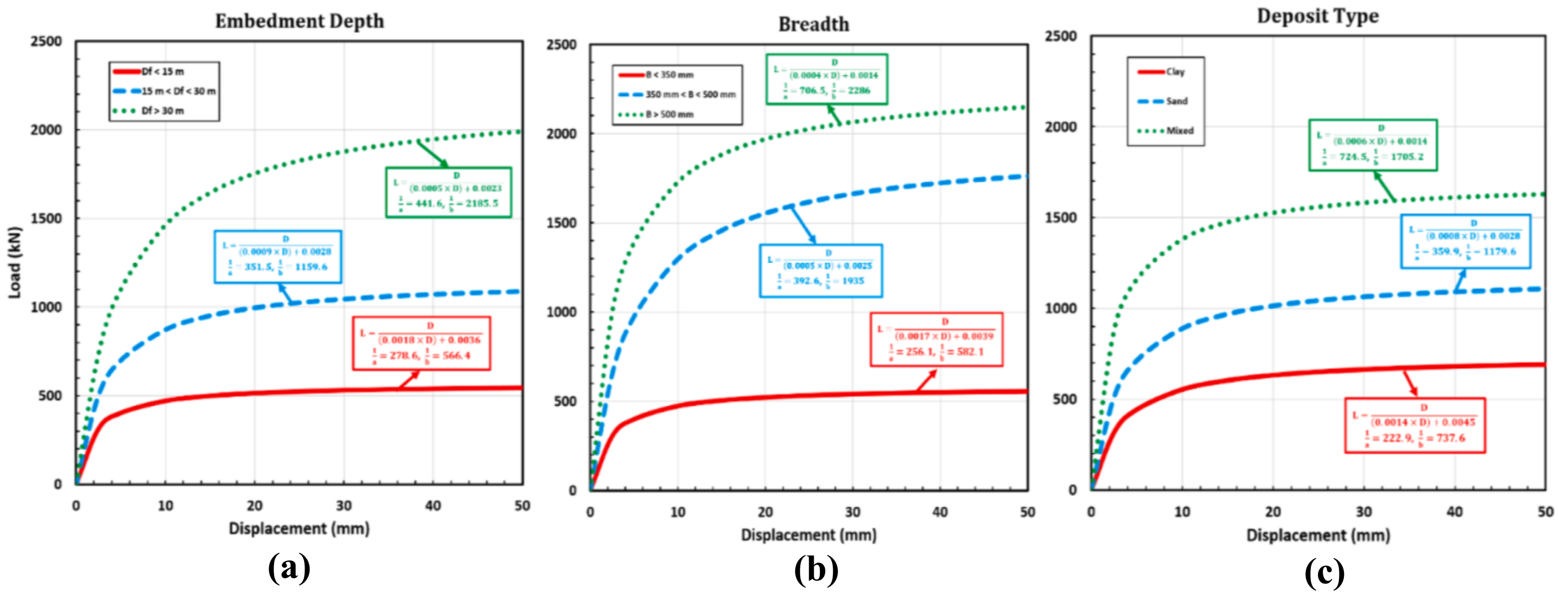
Load-Displacement Appraisal of Driven Piles *(Eslami & Ebrahimipour, 2024)*

- 71 Cases of Driven Piles
- Driven in Sand, Clay and Mixed Deposits
- Embedment Depths between 6 to 56 m
- Diameter between 235 to 914 mm

Case ID	Reference	Location	Pile Data				Deposit	Maximum Measurement	
			Section	Material	D_f(m)	B (mm)		Load (kN)	Disp. (mm)
01/NOR.R/DP1	Gregersen et al.(1973)	Norway	Round	Concrete	16	280	Sand	506	36.6
02/NOR.R/DP2		Norway	Round	Concrete	11.5	280	Sand	332.6	36.8
03/NOR.R/DP3		Norway	Round	Concrete	15.5	280	Sand	471	37.6
04/NOR.R/DP4		Norway	Round	Concrete	19.5	280	Sand	650	34.4
05/NOR.R/DP5		Norway	Round	Concrete	23.5	280	Sand	928.6	35.2
06/LSU/DP1	Tumay &Fahkroo(1981)	USA	Round	Concrete	37.8	900	Mixed	3960	12
07/LSU/DP2		USA	Square	Concrete	36.5	450	Clay	3000	18.5
08/LSU/DP3		USA	CE Pipe	Steel	41.8	400	Mixed	1890	9.5
09/YOG/DP1	Milovoc &Stevanovic (1982)	Yogoslavia	Round	Concrete	12	520	Clay	430	40
10/YOG/DP2		Yogoslavia	Round	Concrete	14.5	520	Clay	700	35
11/ITA/DP	Gambini (1985)	Italy	CE Pipe	Steel	10	330	Mixed	630	19
12/UBC.D/DP1	Davies (1987)	Canada	CE Pipe	Steel	11.83	324	Mixed	213.5	18.3
13/UBC.D/DP2		Canada	CE Pipe	Steel	13.9	324	Mixed	296.7	23.9
14/UBC.D/DP3		Canada	CE Pipe	Steel	16.8	324	Mixed	651.9	24.4
15/UBC.D/DP4		Canada	OE Pipe	Steel	23.2	324	Mixed	1098	29.6
16/UBC.D/DP5		Canada	CE Pipe	Steel	31.1	324	Mixed	1086.1	38.8
17/AUS/DP1	Haustorfer & Plesiotis (1988)	Australia	Square	Concrete	13.75	450	Sand	4200	37
18/AUS/DP2		Australia	Square	Concrete	10.2	355	Sand	1300	60
19/USA.VA/DP1	Patton & Barnhill (1988)	USA	Square	Concrete	21.33	305	Mixed	1506.5	11.3
20/USA.VA/DP2		USA	Square	Concrete	15.24	305	Mixed	867.4	17
21/TWN/DP1	Yen et al. (1989)	Taiwan	CE Pipe	Steel	34.25	609	Mixed	4250	78
22/TWN/DP2		Taiwan	CE Pipe	Steel	34.25	609	Mixed	4500	22
23/USA.L&D/DP1	Briaud et al. (1989)	USA	H-Pile	Steel	16.5	346 × 371	Sand	2925	66.8
24/USA.L&D/DP2		USA	H-Pile	Steel	16.2	346 × 371	Sand	3600	36.3
25/USA.L&D/DP3		USA	CE Pipe	Steel	14.6	400	Sand	1800	72.5
26/UBC.C/DP1	Campanella et al.(1989)	Canada	CE Pipe	Steel	13.7	324	Clay	302.7	18.8
27/UBC.C/DP2		Canada	CE Pipe	Steel	16.8	324	Mixed	636	22.6
28/UBC.C/DP3		Canada	CE Pipe	Steel	31.1	324	Mixed	1100	37
29/NWU/DP1	Finno(1989)	USA	CE Pipe	Steel	15.2	450	Mixed	1021.5	78.3
30/NWU/DP2		USA	H-Pile	Steel	15.2	371 × [illegible]	Mixed	810	17.5

II. Normalized Load-Displacement

Load-Displacement Appraisal of Driven Piles
(Eslami & Ebrahimipour, 2024)



Hyperbolic trending of load–displacement for dominant factors: a) embedment depth, b) breadth, c) surrounding soil type (Eslami & Ebrahimipour, 2024)

II. Normalized Load-Displacement

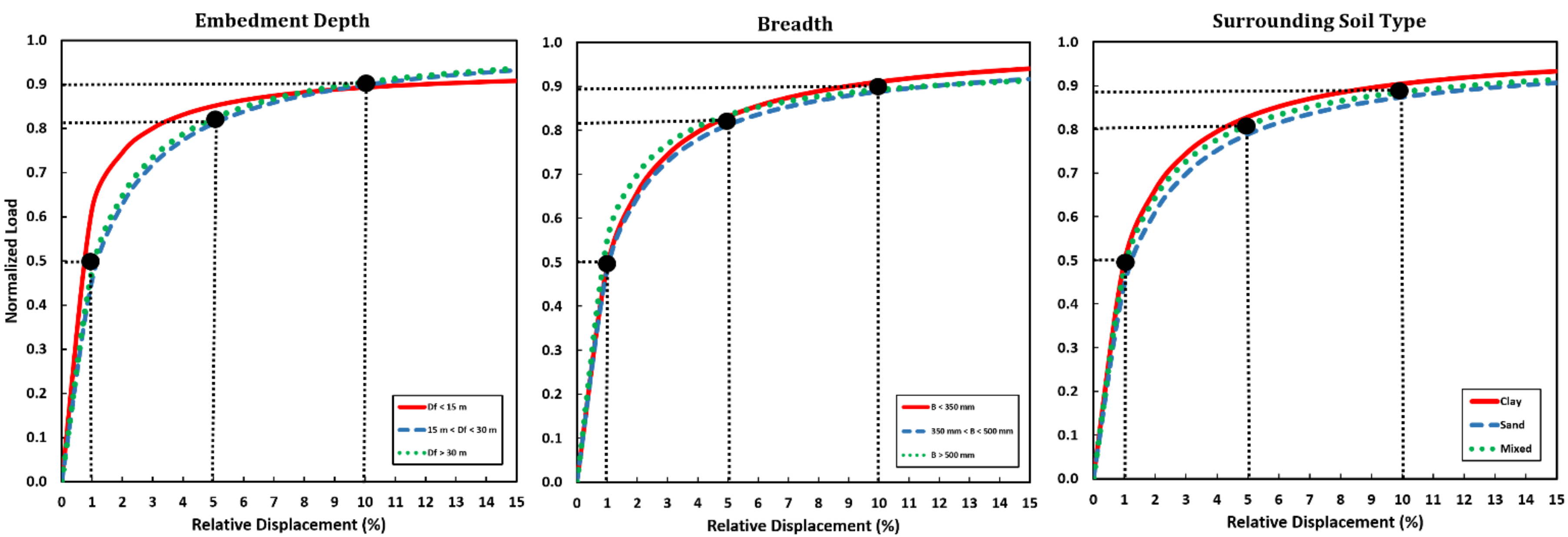
Load-Displacement Appraisal of Driven Piles
(Eslami & Ebrahimipour, 2024)

Normalization Approach:

- Load: Brinch-Hansen 80% (1963)
- Displacement: Breadth

Relative Displacement & Normalized Load:

- 1 % → 0.5 Pu **(FS=2)**
- 5 % → 0.8 Pu
- 10 % → 0.9 Pu

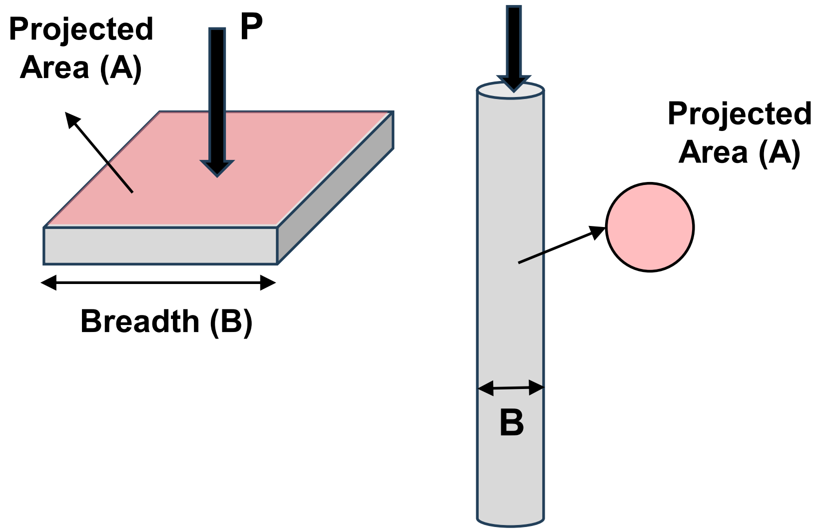


(a) (b) (c)

Normalized hyperbolic trending of load-displacement for dominant factors: a) embedment depth, b) breadth, c) surrounding soil type (Eslami & Ebrahimipour, 2024)

III. Stress-Strain Approach

General Concept



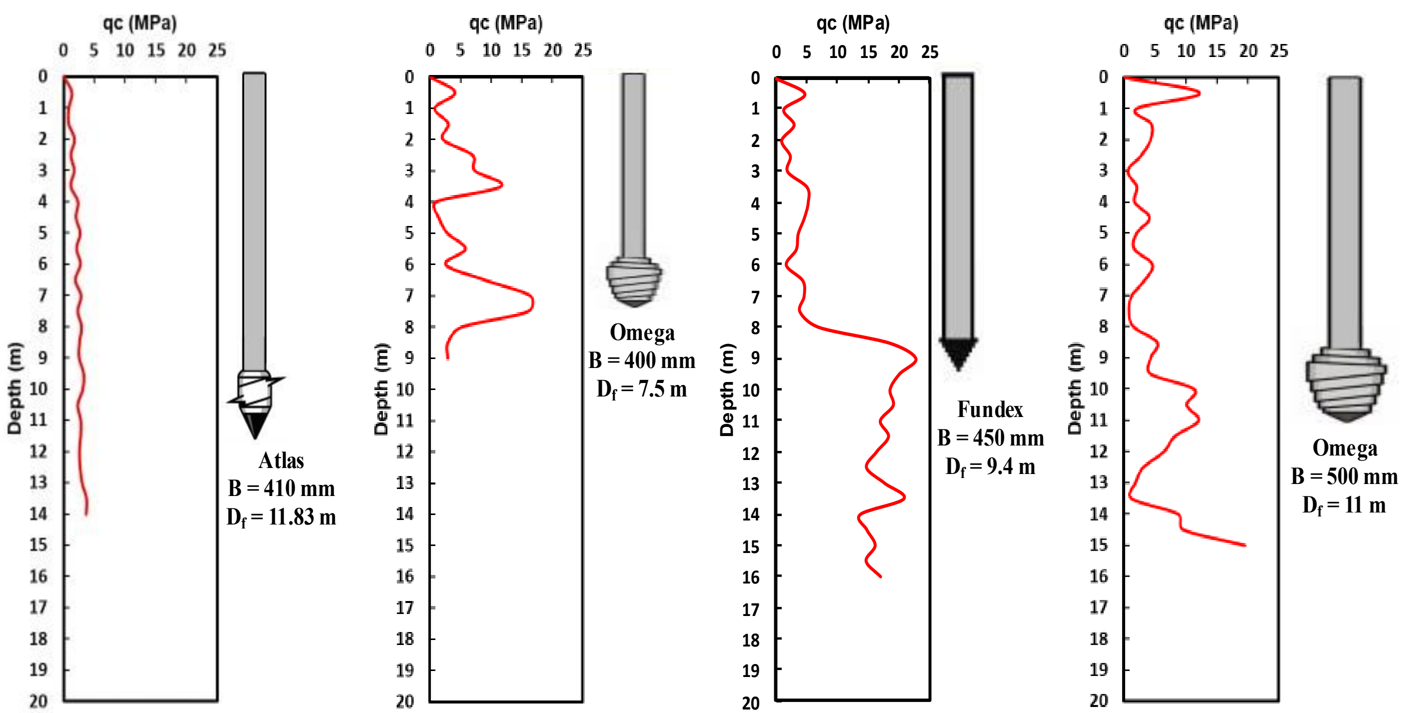
$$\text{Stress } (\sigma) = \frac{\text{Axial Load (P)}}{\text{Projected Area (A)}}$$

$$\text{Strain } (\varepsilon) = \frac{\text{Displacement}}{\text{Breadth (B)}}$$

III. Stress-Strain Approach

Strain-Based Performance of Drilled Displacement Piles
(Eslami, Ebrahimipour & Mehrazma, 2026)

- 60 Cases of DD Piles: Fundex, De Waal, Olivier, Berkel D, APGD, Omega, and Atlas
- Installed in Sand, Clay and Mixed Deposits
- Embedment Depths between 6 to 21 m
- Diameter between 356 to 720 mm

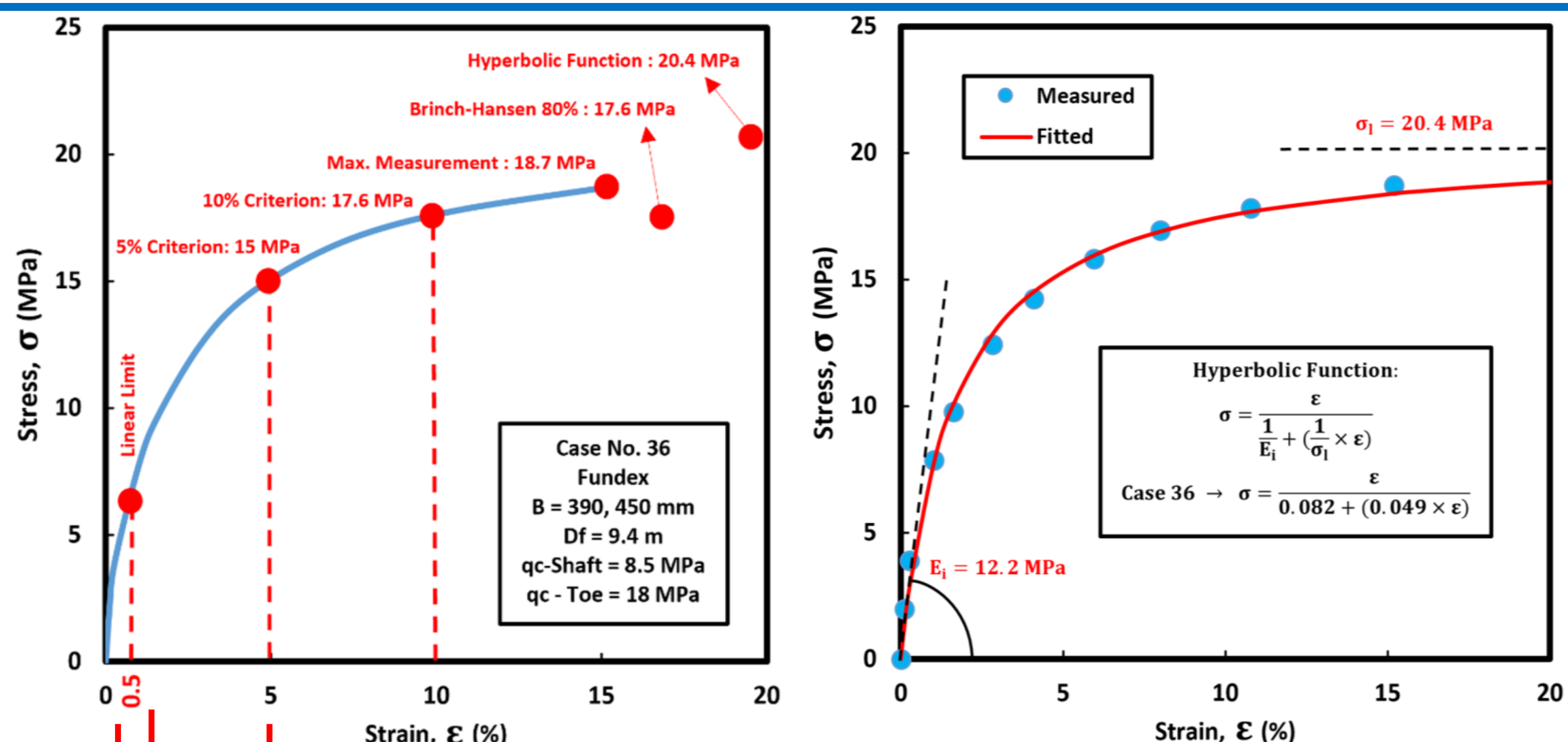


Cone penetration test (CPT) q_c and schematic pile profile for selected cases

III. Stress-Strain Approach

Strain-Based Performance of Drilled Displacement Piles
(Eslami, Ebrahimipour & Mehrazma, 2026)

Various Criteria



$$\sigma = \frac{\varepsilon}{\frac{1}{E_i} + (\frac{1}{\sigma_l} \times \varepsilon)}$$

$$\text{Case 36} \rightarrow \sigma = \frac{\varepsilon}{0.082 + (0.049 \times \varepsilon)}$$

Ultimate Limit State (ULS), Plastic: 1 → 5 to 10 %

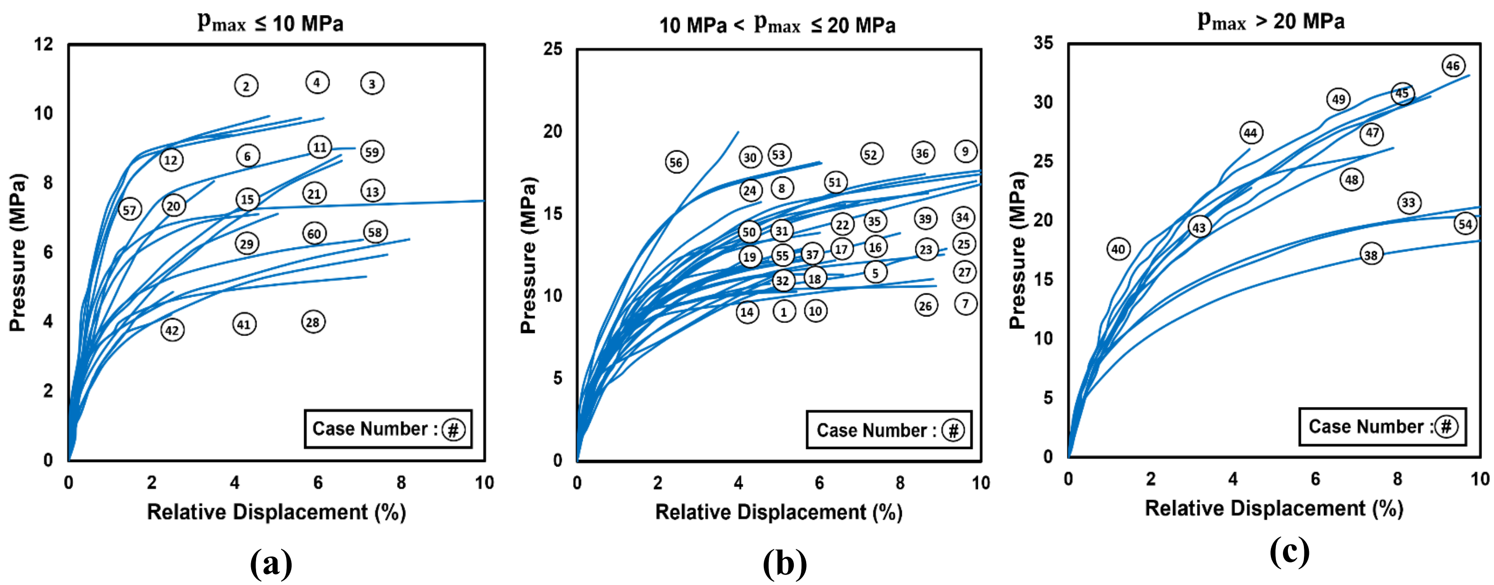
Serviceability Limit State (SLS), Non-Linear Elastic: 0.1 → 0.5 to 1 %

Operation State, Linear Elastic: 0.01 → 0.1 %

III. Stress-Strain Approach

Strain-Based Performance of Drilled Displacement Piles
(Eslami, Ebrahimipour & Mehrazma, 2026)

Stress-Strain Trending



Pressure (stress)-relative displacement (strain) diagrams for all compiled cases: a) pmax ≤ 10 MPa, b) 10 < pmax ≤ 20 MPa, c) pmax > 20 MPa (Eslami et al., 2026)

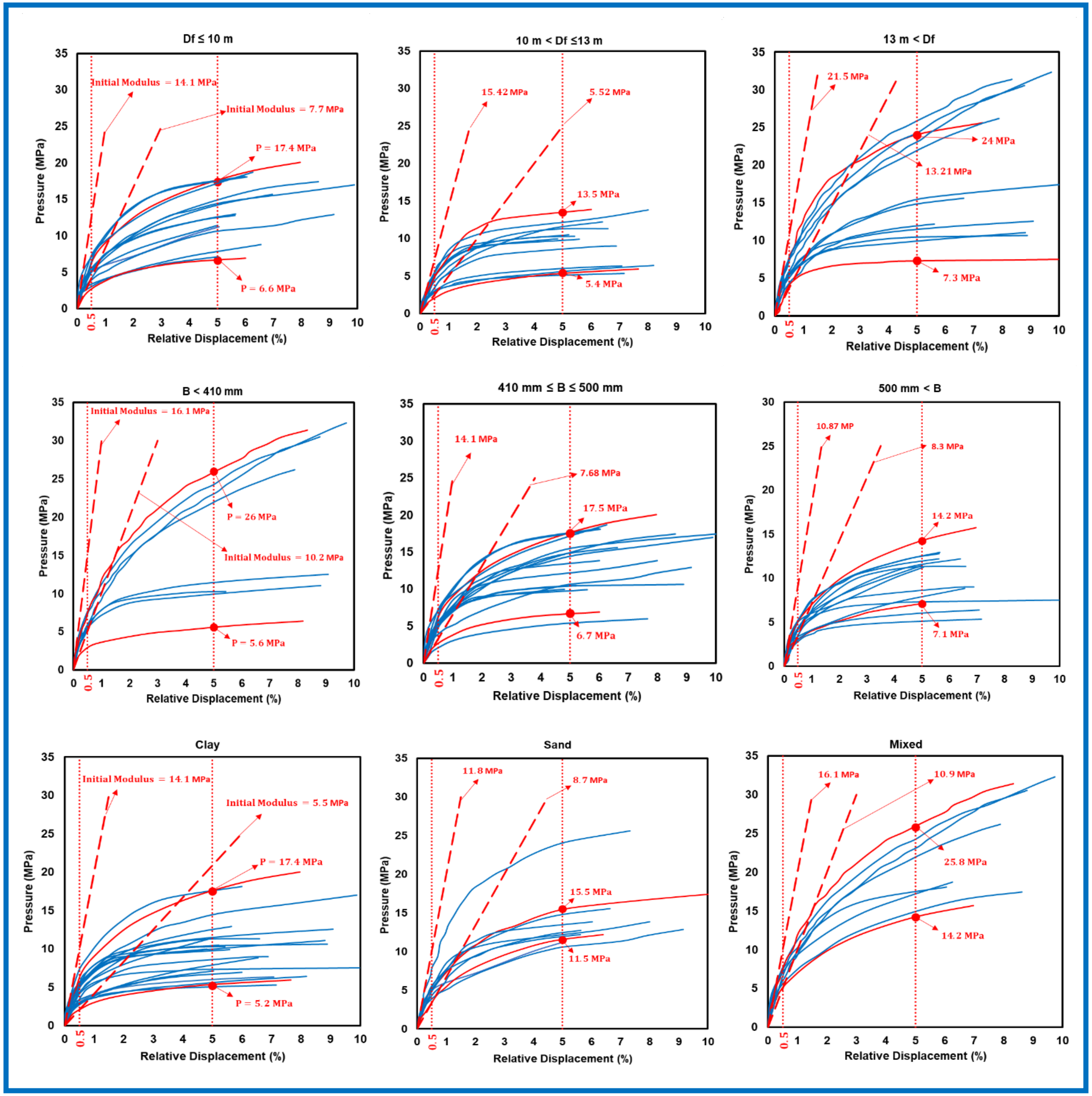
III. Stress-Strain Approach

Strain-Based Performance of Drilled Displacement Piles

(Eslami, Ebrahimipour & Mehrazma, 2026)

Dominant Factors Appraisal

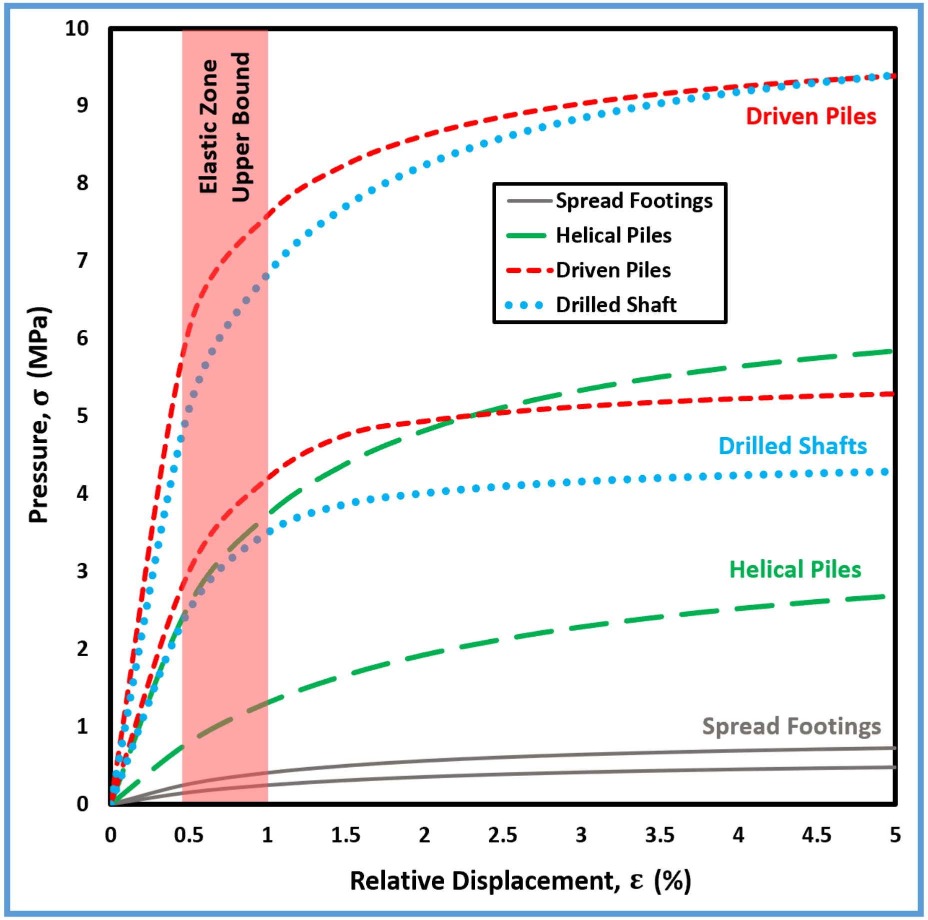
- **Embedment Depth**
- **Pile Breadth**
- **Surrounding Deposit: (Shaft and Toe)**



III. Stress-Strain Approach

Strain-Based Performance of Drilled Displacement Piles
(Eslami, Ebrahimipour & Mehrazma, 2026)

Stress – Strain Comparison for Various Foundations



Pressure (Stress, σ) – relative displacement (Strain, ε) diagrams for various foundations

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