Correlation Between Undrained Shear Strength and Standard Penetration Test in Surface Clayey Soils of Basrah Province

Taha Yaseen Abdulnabi[1,2] and Mahdi Karkush[1,3b*]

[1]Iraqi Scientific Geotechnical Society, Baghdad, Iraq.

[2]Al-Yasir Bureau for Piles Testing, Baghdad, Iraq.

[3]Department of Reconstruction and Projects, University of Baghdad, Baghdad, Iraq.

[a]tahayaseen58@yahoo.com, [b]mahdi_karkush@yahoo.com

*Corresponding author

Received: 1 April 2025
Revised : 1 August 2025
Accepted: 5 September 2025

Abstract. The Standard Penetration Test (SPT) is one of the most widely applied in-situ techniques for evaluating soil strength parameters in both coarse- and fine-grained soils. In this study, an attempt is made to establish a reliable correlation for estimating the undrained shear strength (Su) of very soft clayey soils in Basrah Province, southern Iraq, using the corrected blow count (N_{60}) from SPT results. A regression-based approach was adopted to develop a local correlation between Su and N-values, and the obtained results were validated against widely used empirical correlations proposed by Terzaghi and Peck (1967), Stroud (1974), Decourt (1990), and Nassaji and Kalantari (2011). The analysis produced a coefficient of determination (R^2) of 0.704, suggesting that the proposed equation provides a reliable predictive tool for local soil conditions. The findings indicate that the developed correlation reduces estimation errors associated with generic formulas and offers a practical approach tailored to the geotechnical behavior of soft clayey soils in Basrah.

Keywords: Shear strength, SPT, soft soil, vane shear, Basrah.

1. INTRODUCTION

Due to the unavailability of specialized equipment, as well as financial and time limitations in many projects, it is often necessary to estimate geotechnical parameters indirectly through empirical correlations with values obtained from in-situ tests. One of the most important parameters in this regard is the undrained shear strength, commonly denoted as Su or c_u. This parameter can be estimated from in-situ tests such as the cone penetration test (CPT) and the standard penetration test (SPT), among others. The earliest documented reference to the SPT procedure appears in a paper by Terzaghi in 1943 [1]. The test was later standardized in the United States in 1958, and is currently covered by ASTM D1586-99, as well as many other international standards [2]. The SPT remains one of the simplest, most economical, and most widely adopted field tests in geotechnical engineering, and is routinely applied in soil investigations worldwide.

Traditionally, the SPT has been used to evaluate the static and dynamic properties of coarse-grained soils, including internal friction angle (ϕ′), relative density (Dr), bearing capacity, settlement, and shear wave velocity (Vs), as well as for liquefaction potential assessment. Despite its original development for coarse-grained soils, the SPT has also been applied to fine-grained soils to estimate engineering parameters such as undrained compressive strength (q_u), undrained shear strength (Su), and the coefficient of volume compressibility (m_v). However, its applicability to fine-grained soils remains a subject of debate [3]. The SPT procedure is performed in a borehole by driving a standard split-spoon sampler into the soil using repeated blows of a 63.5 kg (140 lb.) hammer dropped from a height of 762 mm (30 in.). The hammer, operated at the top of the borehole, is connected to the sampler through drill rods. The sampler is driven to a penetration depth of 450 mm (18 in.), and the number of blows required for each 76 mm (3 in.) increment is recorded. The penetration resistance, commonly referred to as the SPT N-value, is defined as the number of blows required to achieve the final 300 mm (1 ft) of penetration [4].

In the laboratory, Su can be directly determined from the unconfined compressive strength test (UCS) or the unconsolidated undrained triaxial test (UU). The UCS test provides the unconfined compressive strength (q_u), and under conditions of full saturation, the undrained shear strength is estimated from the relationship [5]:

$$\mathbf{Su = 0.5 \times q_u} \quad (1)$$

One of the earliest attempts to establish a relationship between unconfined compressive strength (q_u) and the Standard Penetration Test N-value was conducted by Terzaghi and Peck [6], as summarized in Table 1.

Their work was based on a variety of fine-grained soils with different consistencies and Atterberg limits. Following their pioneering contribution, numerous researchers have investigated and refined correlations between SPT results and soil strength parameters. Sanglerat [7] was among the first to present a (q_u–N) correlation that explicitly accounted for the type of fine-grained soil. By considering the plasticity index (PI) of clay soils, he proposed dividing soils into two categories: clay and silty clay, thereby improving the applicability of the correlation across different soil types. Building on this, Stroud [8] analyzed correlations using undrained shear strength (Su) values obtained from unconsolidated undrained (UU) triaxial tests. His findings indicated that for soils with plasticity index values less than 30%, the undrained shear strength decreases as PI increases at a constant NNN-value. In contrast, Sowers [9] reported an opposite trend, showing that (Su) tends to increase with increasing plasticity index. These contradictory results underscore the complexity of soil behavior and highlight the need for cautious application of empirical correlations, with consideration of soil type, plasticity, and local geotechnical conditions.

Table 1. Correlation between q_u-N-value (SPT) [6].

N-value	Description of consistency	Consistency index =(LL-WC)/PI	Undrained strength q_u=2c_u, kPa
0 -2	Very soft	< 0.5	<25
2 -4	Soft	0.5 -0.75	25 - 50
4 -8	Medium stiff	0.5 -0.75	50 -100
8 -16	Stiff	0.75 – 1.0	100 -200
16 -32	Very stiff	1.0 -1.5	200 -400
>32	Hard	>1.5	> 400
Undrained shear strength (q_u) for clay equal to (12.5×SPT-value) And (q_u) equal to (10×SPT-value) for clay with PI >30			

Several research studies have extensively utilized Standard Penetration Test (SPT) data obtained from different locations and depths to evaluate the bearing capacity of soils for both shallow and deep foundations. Since raw SPT values can be influenced by testing conditions, they are typically subjected to multiple corrections to improve reliability. These adjustments include considerations for hammer energy efficiency, rod length, borehole diameter, overburden pressure, and groundwater table effects. Such corrections are essential to ensure that the derived parameters more accurately represent the actual in-situ soil conditions [10–12]. Beyond direct application in empirical bearing capacity correlations, corrected SPT data have also been integrated with advanced computational tools such as MATLAB and ArcGIS. These platforms were used to generate three-dimensional (3D) surface models, illustrating how soil bearing capacity varies with depth and spatial coordinates. The resulting 3D visualizations provide valuable insights into subsoil variability, highlight weak and strong soil zones, and enable engineers to develop a more comprehensive understanding of the site conditions [13–15].

The outcomes of these approaches are particularly beneficial in engineering practice. They not only facilitate rapid and reasonably accurate estimation of soil bearing capacity but also support informed decision-making during the planning and design stages of foundation works. Furthermore, the incorporation of geostatistical modeling and visualization enhances the reliability of site characterization, helping to optimize foundation design and reduce risks associated with soil heterogeneity [11–15]. In this context, several researchers have contributed important correlations between SPT and soil strength parameters. Sivrikaya and Toğrol [16] conducted a broad investigation on fine-grained soils using unconfined compressive strength (UCS) test results and proposed a new empirical relationship. Hettiarachchi and Brown [17] introduced an energy balance approach by considering the SPT sampler as an open-ended pile, presenting correlations based on N_{60} values (the blow count corrected to 60% hammer energy efficiency). Similarly, Decourt [18], Nixon [19], and Ajayi and Balogun [20] explored correlations between undrained shear strength (Su) and SPT N-values. A summary of these existing correlations is presented in Table 2. Given the variety of correlations reported in the literature and the differences in their applicability, the present study focuses on evaluating the capability of SPT to estimate the undrained shear strength of fine-grained soils in southern Iraq. To achieve this, regression trend-line analysis was carried out using Microsoft Excel, aiming to establish reliable correlations tailored to local soil conditions.

2. DATA COLLECTION

To establish correlations between corrected Standard Penetration Test values ($N_{corrected}$) and laboratory-derived undrained shear strength (Su), data were collected from geotechnical investigations conducted in southern Iraq. The objective was to evaluate the feasibility of using SPT blow counts to estimate the Su of fine-grained soils in the region. Soils in southern Iraq are predominantly fine-grained, very soft deposits with varying degrees of plasticity ranging from low to high. Determining the unconfined compressive strength (q_u) in the laboratory through the Unconfined Compressive Strength (UCS) test proved challenging due to the very soft and sensitive nature of the soil samples, which often exhibited difficulties in sample preparation and handling.

As an alternative, undrained shear strength values (c_u) were obtained from both vane shear tests and correlations with SPT results. A total of 31 boreholes were drilled across the study area, reaching depths ranging from 10 m to 40 m below the natural ground surface. The results of these investigations, including corrected SPT blow counts and measured undrained shear strengths, are summarized in Table 3.

Table 2. Previous correlations between Su-N-value (SPT-value).

Researchers	Explanation	Su (kPa)
Sanglerat [7]	Clay Silty clay	12.5 N and 10 N
Terzaghi and Peck [6]	Fine-grained soil	6.25 N
Hara et al. [5]	Fine-grained soil	$29\ N^{0.72}$
Sowers [9]	Highly plastic soil Medium plastic clay Low plastic soil	12.5 N 7.5 N 3.75 N
Nixon [19]	Clay	12 N
Sivrikaya and Toğrol [16]	Highly plastic soil	$4.85\ N_{field}$ and $6.82\ N_{60}$
	Low plastic soil	$3.35\ N_{field}$ and $4.93\ N_{60}$
	Fine-grained soil	$4.32\ N_{field}$ and $6.18\ N_{60}$
Stroud [8]	PI<20	(6-7) N
	20<PI<30	(4-5) N
	PI>30	4.2 N
Decourt [18]	Clay	12.5 N and 15 N_{60}
Ajayi and Balogun [20]	Fine-grained soil	1.39N+74.2
Hettiarachchi and Brown [17]	Fine-grained soil	4.1 N_{60}
Sivrikaya [3]	UU Test	3.33N – 0.75wn+ 0.20LL + 1.67PI
	UU Test	4.43N_{60} – 1.29wn + 1.06LL + 1.02PI
	UCS Test	2.41N – 0.82wn + 0.14LL + 1.44PI
	UCS Test	3.24N60 – 0.53wn – 0.43LL + 2.14PI
Nassaji and Kalantari [21]	Fine-grained soil	2.1N_{60} + 17.6

Table 3. locations of boreholes in the Basrah province.

BH No.	Borehole location	Drilling depth (m)
1	Storage water tank	22
2	Storage water tank	22
3	Nano Filter Building	15
4	Lamella clarifier filter	15
5	Coarse grid screen	15
6	Storage water tank	15
7	Chlorine tank	10
8	Intake	10
9	Lamella clarifier Filter	22
10	Deoxygenation tower	22
11	First stage storage tank	15
12	Al-Mufakia	20
13		20
14	Al-Andalus city	30
15		30
16	Al-Gazara district	35
17		35
18	Al-Jamiyat	6.0
19	Al –Fersi	40
20		40
21	Shatt – AL Arab	30
22		30
23		30
24	Alsyab City	15
25		15
26		15
27		15
28		15
29		15
30		15
31		15

3. CORRECTING SPT BLOW COUNTS TO N_{60} VALUES

The Standard Penetration Test (SPT) is not fully standardized with respect to all factors influencing its results. The raw blow count (N) obtained from the test is typically adjusted to account for variations in equipment, procedures, and site conditions. One of the most widely applied corrections involves normalizing the measured blow count to an equivalent value corresponding to 60% hammer energy efficiency, denoted as N_{60}. The parameter N_{60} represents the number of blows required to achieve penetration when the effective energy delivered to the sampler is 60% of the theoretical free-fall hammer energy. This normalization ensures greater consistency and comparability of SPT results across different projects and testing conditions. The correction is performed using Equation (2) [22]:

$$\mathbf{N_{60}} = \mathbf{N} \times \boldsymbol{\eta}_\mathbf{H} \times \boldsymbol{\eta}_\mathbf{B} \times \boldsymbol{\eta}_\mathbf{S} \times \boldsymbol{\eta}_\mathbf{R}/60 \qquad (2)$$

Where
N = measured SPT blow count,
η_H = hammer efficiency (%), see Table 4.
η_B = correction for borehole diameter, see Table 4.
η_S = sampler correction, see Table 5.
η_R = correction for rod length, see Table 5.

The Standard Penetration Test (SPT) offers several advantages that contribute to its widespread use in geotechnical investigations. First, it allows for the retrieval of representative soil samples, which can subsequently be subjected to detailed laboratory testing to determine index and engineering properties. Second, the boreholes created during the SPT procedure can serve as access points for conducting additional in-situ tests, such as the vane shear test or permeability measurements. Moreover, the SPT is capable of penetrating dense granular soils, where other sampling methods may encounter difficulties. Finally, the simplicity of the equipment, the relatively low cost, and the wide availability of both the apparatus and trained personnel make the SPT one of the most practical and versatile field tests in geotechnical engineering.

Table 4. Correction factors η_H and η_B in the United States.

Hammer type	Hammer release	η_H (%)	Borehole diameter	η_B
Safety hammer	Rope and pulley	60	60 − 120 mm	1.0
Donut hammer	Rope and pulley	45	150 mm	1.05
Automatic	Trip	73	200 mm	1.15

Table 5. Correction factors η_S and η_R in the United States.

Samplers	η_S	Rod length	η_R
Standard sampler without liner (not recommended)	1.2	> 10 m	1.0
Standard sampler	1.0	6 − 10 m	0.95
With liner for dense sand and clay	0.8	4 −6 m	0.85
With liner for loose sand	0.9	0 −4 m	0.75

4. VANE SHEAR TESTS

Field vane shear tests were conducted to determine both the peak and remolded undrained shear strengths of clay soils. The testing apparatus consists of a lower vane borer and shoe, the vane itself, extension rods, and a hand-operated torque readout device. The instrument can accommodate two different vane sizes 19 mm and 33 mm in width each having four rectangular blades. The peak undrained shear strength, Su_{vane}, was calculated following the standard interpretation method for a rectangular-bladed vane with a height-to-diameter ratio of 2:1.

$$\mathbf{Su_{vane}} = \mathbf{6T}/\mathbf{7\pi}\boldsymbol{D}^3 \qquad (3)$$

In the equation, T represents the maximum recorded torque, and D is the diameter of the blade. This interpretation assumes that the soil shears as a cylinder, with shear stress distributed uniformly across the horizontal planes at the top and bottom of the vane, as well as along the vertical plane defined by the vane's perimeter. The same formula was applied to determine the remolded undrained shear strength, Su_{vane} using the torque measured after remolding the soil.

Das [23] indicated that fairly reliable estimates of the undrained shear strength (Ø=0 concept) for very soft to medium cohesive soils can be obtained directly from vane shear tests. In this study, the in-situ shear vane apparatus used had diameters of 19 mm and 33 mm. Since the project primarily involved medium-consistency soil samples, the tests were performed within the sampling tubes to minimize disturbance and preserve the natural soil structure. However, Bjerrum [24] demonstrated that as the plasticity of soils increases, the undrained shear strength (c_u) obtained from vane shear tests may overestimate the actual soil strength, potentially leading to unsafe design values for foundations. Consequently, the measured cuc_ucu values must be adjusted using correction factors. Following this, Morris and Williams [25] proposed the following correction formula:

$$\mathbf{c_{u,design}} = \mathbf{C_F} \times \mathbf{c_{u,vane}} \quad (4)$$

Where
C_F = Correction factor = $1.18\ e^{-0.08}\ (PI) + 0.57$ for $PI > 5$
PI = Plasticity index

Based on the results of Standard Penetration Tests (SPT) conducted in the study area, and after applying necessary corrections for factors such as hammer energy efficiency, overburden pressure, and groundwater conditions, an empirical correlation was developed to estimate the undrained shear strength of the soil. This proposed equation provides a practical means of relating the corrected SPT values to the undrained shear strength ($c_{u,design}$) obtained from vane shear tests. The correlation is designed to enhance the reliability of soil strength characterization, particularly in regions where direct measurements of shear strength are limited or unavailable. By establishing this relationship, the equation serves as a useful tool for preliminary geotechnical design and assessment, allowing engineers to quickly estimate shear strength values from routine SPT data. The proposed expression is presented as follows:

$$c_{u,design} = 10.98 \times N_{60} + 10.99 \quad (5)$$

The variation of the corrected undrained shear strength ($c_{u,design}$) with depth and with SPT blow count is presented in Figures 1 and 2, respectively. As expected, the results show a general trend of increasing shear strength with depth, which reflects the influence of overburden pressure, effective stress, and progressive consolidation on soil behavior. Deeper soil strata typically experience greater confining stresses, leading to reduced void ratios and higher resistance to shear deformation. Similarly, the positive correlation observed between $c_{u,design}$ and the corrected SPT values (N_{60}) indicates that soils exhibiting higher penetration resistance tend to develop greater undrained shear strength. This relationship is practically significant because it demonstrates the potential of using SPT data, which is widely available from routine site investigations, to provide preliminary estimates of soil strength without the need for more complex or costly testing.

However, the coefficients of determination R^2=0.5782 for depth and R^2=0.5893 for N_{60} suggest only moderate levels of correlation. This indicates that while depth and SPT blow counts are important contributing factors, they alone cannot fully explain the variability in undrained shear strength. Other influences, such as soil plasticity, natural variability in mineralogical composition, depositional environment, and the presence or fluctuation of the groundwater table, introduce additional scatter in the data. For instance, soils with a higher plasticity index may exhibit lower shear strength values for the same penetration resistance due to their reduced stiffness and higher compressibility. Similarly, local heterogeneity such as thin soft layers or lenses of silty material within otherwise stronger clay can weaken the overall soil response. Therefore, while the correlations obtained provide valuable first-order estimations, they should be applied with caution and ideally supplemented with in-situ tests such as field vane shear or cone penetration tests, as well as laboratory measurements (e.g., UU or triaxial tests). Incorporating multiple sources of data not only improves the reliability of site characterization but also reduces the risk of under- or overestimating soil strength parameters in geotechnical design.

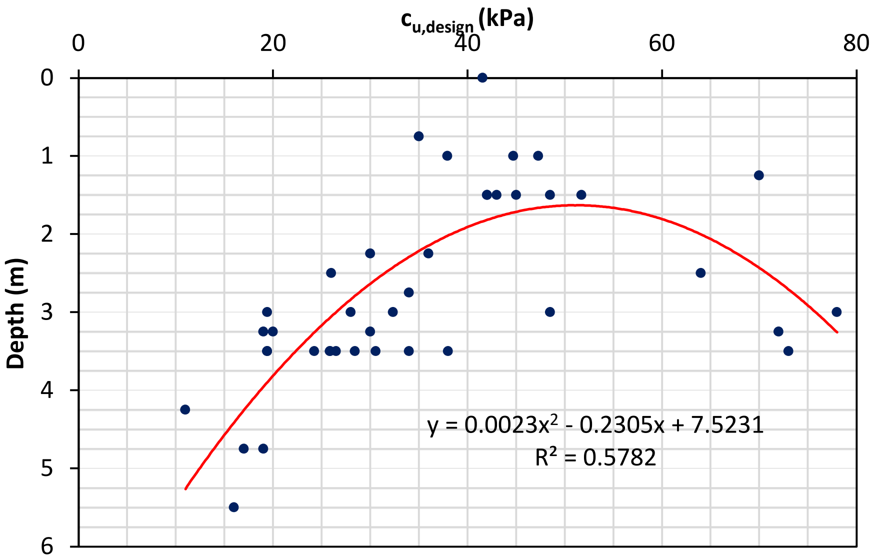

Figure 1. Variation of undrained vane shear strength with depth.

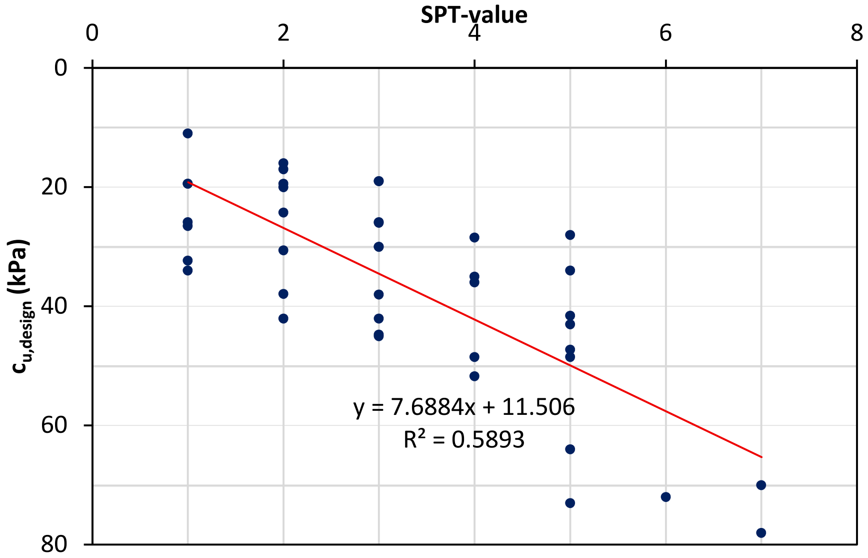

Figure 2. Variation of undrained vane shear strength with SPT value.

5. TEST RESULTS AND CALCULATIONS

In this study, the calculations and correlations were developed using simple regression analysis in Microsoft Excel to process the collected field and laboratory data. Linear regression was employed to quantify the relationships between the dependent variable, the undrained shear strength (c_u), and independent variables, primarily the corrected Standard Penetration Test (SPT) blow counts (N_{60}) and other relevant soil parameters. The coefficient of determination (R^2) was used as the main criterion to evaluate the quality of the fit, indicating how well the regression model explains the variability of the observed data. A higher R^2 value suggests a stronger correlation and provides confidence in using the resulting equation for predictive purposes. The corrected undrained shear strength values ($c_{u,design}$) were also compared with estimates obtained from existing empirical equations in the literature, as summarized in Table 6. This comparison allows for a critical evaluation of the applicability of previous correlations to the local soil conditions in southern Iraq, where the soils are generally fine-grained, soft to medium in consistency, and exhibit a wide range of plasticity. By assessing these variations, the study highlights potential discrepancies and limitations of generalized correlations, particularly for soils with high plasticity or low density, which may not be adequately represented in standard equations.

While regression-based correlations provide a practical tool for estimating soil strength, several factors may influence their accuracy. For instance, SPT results can be affected by hammer energy variations, borehole diameter, rod length, operator technique, and the presence of groundwater. Even after corrections, these factors introduce uncertainties that can propagate through the regression model. Similarly, vane shear tests, while useful for fine-grained soils, may underestimate or overestimate undrained shear strength depending on soil disturbance, plasticity, and scale effects. These uncertainties underscore the importance of interpreting regression-derived correlations with caution and considering them as part of a broader geotechnical assessment rather than as absolute values. Developing site-specific correlations provides practical advantages. Engineers can estimate undrained shear strength quickly from routine SPT results without extensive laboratory testing, reducing costs and time requirements. These correlations also support preliminary foundation design, load assessment, and risk evaluation, particularly in areas where direct measurements such as unconfined compressive strength (UCS) or laboratory UU tests are limited. By combining corrected in-situ test data with regression analysis, the approach enhances the reliability of soil strength characterization and helps mitigate risks associated with soil heterogeneity.

For future research, integrating additional soil properties such as plasticity index, moisture content, and bulk density into regression models could improve predictive accuracy. Moreover, advanced machine learning techniques, such as artificial neural networks or ensemble methods, could be employed to capture non-linear relationships between SPT values and undrained shear strength. Validation of correlations through field load tests or additional laboratory testing would further enhance their credibility. Finally, expanding the study to include a wider range of soil types and stratigraphy could provide more generalizable models applicable to other regions with similar geotechnical conditions. Overall, the study demonstrates that combining corrected SPT data with regression analysis provides a valuable, efficient, and practical framework for estimating undrained shear strength of fine-grained soils in southern Iraq, while also acknowledging the inherent uncertainties and opportunities for methodological improvements in future work.

Table 6. Variation of c_u and SPT test results with depth.

BH No.	Depth, m	Corrected SPT value N-value	$c_{u,design}$ (kPa)					
			Vane shear test Eq. 4	Stroud [8] $c_u = 5N$	Terzaghi and Peck [6] $c_u = 6.25N$	Decourt [18] $c_u=15N_{60}$	Nassaji and Kalantari [21] $c_u = 2.1N_{60} + 17.6$	Proposed Eq. 5 $c_u = 7.6884N_{60} +11.506$
1	1	5	41.56	25	31.25	75	28.1	47.15
	3.5	2	30.58	10	12.5	30	21.8	28.20
2	3	1	19.4	5	6.25	15	19.7	21.88
3	1.5	3	42.03	15	18.75	45	23.9	34.51
	3.5	2	19.4	10	12.5	30	21.8	28.20
4	3	1	32.33	5	6.25	15	19.7	21.88
5	1	3	44.72	15	18.75	45	23.9	34.51
	3.5	1	26.5	5	6.25	15	19.7	21.88
6	1.5	4	51.73	20	25	60	26	40.83
	3	5	48.49	25	31.25	75	28.1	47.15
7	1.5	4	48.49	20	25	60	26	40.83
	3.5	2	24.25	10	12.5	30	21.8	28.20
8	1	5	47.29	25	31.25	75	28.1	47.15
	3.5	1	25.86	5	6.25	15	19.7	21.88
9	3.5	1	19.4	5	6.25	15	19.7	21.88
10	1.5	2	42.03	10	12.5	30	21.8	28.20
	3.5	3	25.86	15	18.75	45	23.9	34.51
11	1	2	37.92	10	12.5	30	21.8	28.20
	3.5	4	28.44	20	25	60	26	40.83
12	1.5	5	43	25	31.25	75	28.1	47.15
	3.5	1	34	5	6.25	15	19.7	21.88
13	2.5	3	26	15	18.75	45	23.9	34.51
14	2.25	3	30	15	18.75	45	23.9	34.51
15	2.25	4	36	20	25	60	26	40.83
16	4.75	3	19	15	18.75	45	23.9	34.51
17	4.75	2	17	10	12.5	30	21.8	28.20
18	0.75	4	35	20	25	60	26	40.83
19	3.25	3	19	15	18.75	45	23.9	34.51
20	1.25	7	70	35	43.75	105	32.3	59.78
	4.25	1	11	5	6.25	15	19.7	21.88
21	3.25	3	30	15	18.75	45	23.9	34.51
22	2.50	5	64	25	31.25	75	28.1	47.15
23	3.25	2	20	10	12.5	30	21.8	28.20
24	1.50	3	45	15	18.75	45	23.9	34.51
25	2.75	5	34	25	31.25	75	28.1	47.15
26	3.25	6	72	30	37.5	90	30.2	53.47
27	3.50	5	73	25	31.25	75	28.1	47.15
28	3.00	7	78	35	43.75	105	32.3	59.78
29	5.50	2	16	10	12.5	30	21.8	28.20
30	3.50	3	38	15	18.75	45	23.9	34.51
31	3.00	5	28	25	31.25	75	28.1	47.15

The variation of undrained shear strength estimated using different empirical correlations those proposed by Decourt [18], Stroud [8], Terzaghi and Peck [6], Nassaji and Kalantari [21], along with the proposed Equation (5) is shown in Figures 3 and 4. The comparison highlights that these correlations do not yield identical results, as each was developed under different soil conditions and geotechnical environments. Among the examined formulas, the proposed Equation (5) demonstrates the closest agreement with the field vane shear test results, suggesting that it better reflects the specific soil characteristics of the study area. In contrast, some of the existing correlations either overestimate or underestimate c_u, emphasizing the need for localized calibration when applying empirical methods. Overall, these findings highlight the value of developing site-specific correlations for geotechnical design. While SPT-based methods provide a practical and widely accessible approach to estimating undrained shear strength, the variability among existing correlations reinforces the importance of validating these predictions with in-situ testing (e.g., vane shear) or laboratory measurements. By integrating both empirical and site-specific approaches, engineers can achieve more reliable soil strength characterization, ultimately improving the safety and efficiency of foundation design.

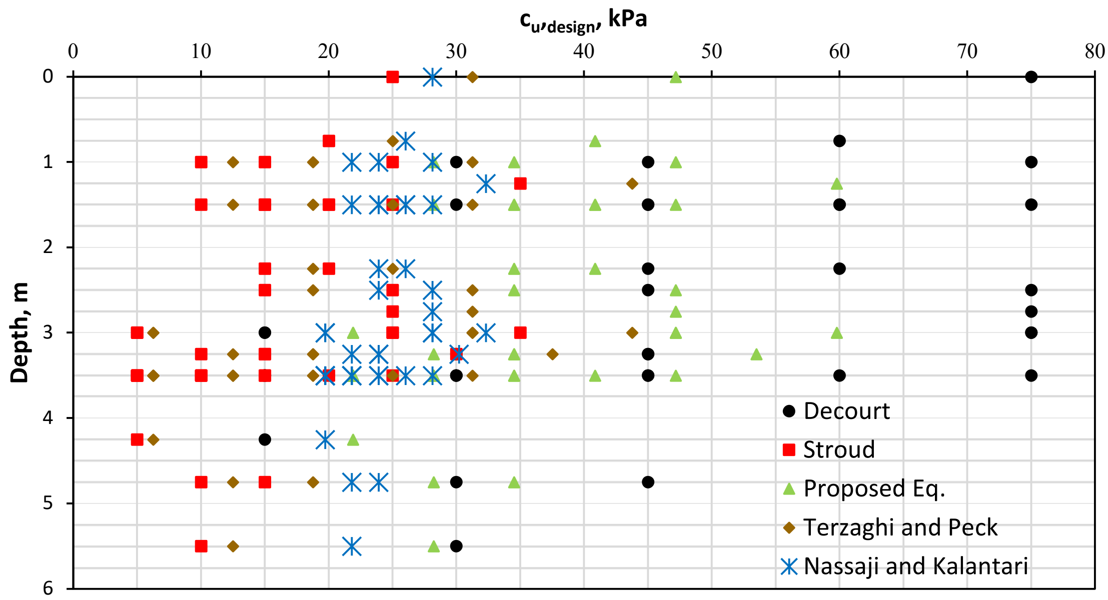

Figure 3. Comparison of undrained shear strength calculated using Eq. 5 with those calculated by previous proposed correlations.

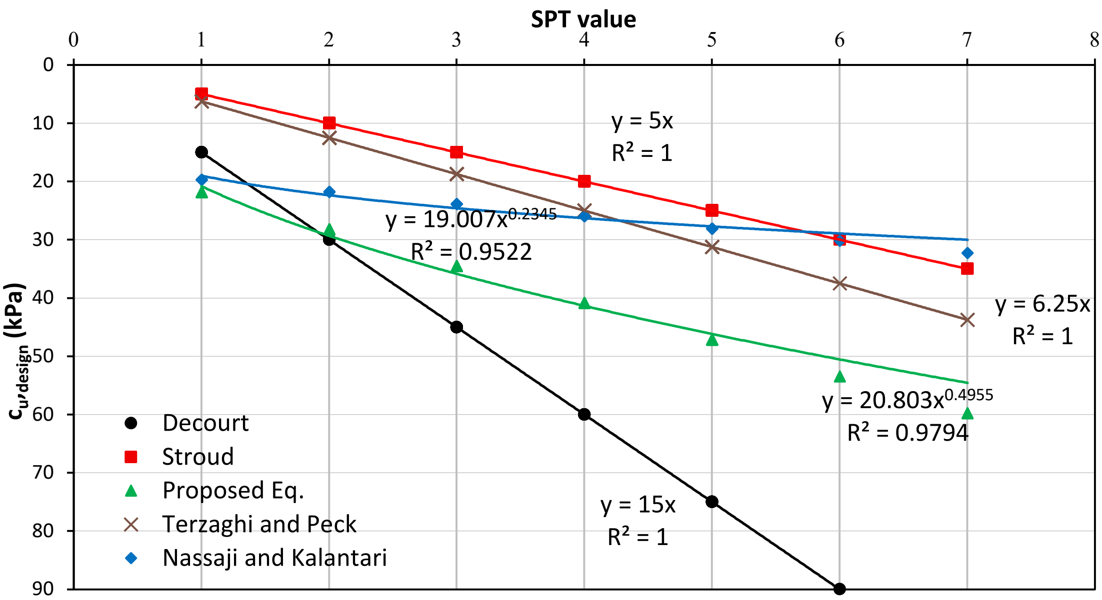

Figure 4. Correlation between the undrained shear strength of soil calculated using several proposed models.

6. CONCLUSIONS

- Due to the unavailability of equipment and also financial and time limitations in a project, in many cases, a relationship may be needed to estimate the geotechnical parameters from the values that are extracted from the in-situ tests. One of these important parameters is undrained shear strength that could be estimated from the in-situ tests such as standard penetration test (SPT).
- The result of vane tests in all fields of top layer strata showed that the undrained shear strength is arranged between (11.0 - 112.0) kPa in the site for depths ranged between (1.00 – 3.50) meters, it is practically distinguished soft to very soft in consistency.
- The correlations were developed using simple regression analysis from Excel software for obtaining data from the sites which was adopted in this study, and comparing the results of current proposed correlations with previous proposed correlations from other approaches of Terzaghi and Peck [6], Stroud [8], Decourt [18], and Nassaji and Kalantari [21].
- The proposed correlation in this research Eq. 5 is suitable to use for the formation of soft to very soft crust layer, which is distributed in Basrah province in Iraq. The R- square value for the above proposed linear correlation equal to 0.5893.

REFERENCES

[1] Terzaghi K. Theoretical soil mechanics. 1943.
[2] Robertson PK. Guide to In-Situ Testing, Gregg Drilling and Testing. Inc., Signal Hill, CA. 2006.
[3] Sivrikaya OS. Comparison of artificial neural networks models with correlative works on undrained shear strength. Eurasian Soil Science. 2009 Dec;42(13):1487-96.
[4] Clayton CR. The Standard Penetration Test (SPT): Methods and Use. Construction Industry Research and Information Association Report 143. CIRIA, London; 1995, 143 pp.
[5] Hara A, Ohta T, Niwa M, Tanaka S, Banno T. Shear modulus and shear strength of cohesive soils. Soils and foundations. 1974 Sep 15;14(3):1-2.
[6] Terzaghi K, Peck RB, Mesri G. Soil mechanics in engineering practice. John wiley & sons; 1996 Feb 7.
[7] Sanglerat G. Interpretation of penetration diagrams-theory and practice. Developments in geotechnical engineering. Elsevier publishing company. Amsterdam, The Netherlands. 1972.
[8] Stroud MA. The standard penetration test in insensitive clays and soft rocks. In Proceedings of the 1st European Symposium on Penetration Testing 1974 Jun 5 (Vol. 2, No. 2, pp. 367-375).
[9] Sowers GF. Introductory soil mechanics & foundations. Geotechnical engineering. 1979; 92:114-7.
[10] Abdulnabi TY, Karkush MO, Safa Y, Mahdi AH. Effect of Embedment Depth on the Load-Settlement Behavior of Precast Pile in Al-Gharraf Oil Field. In International Conference on Geotechnical Engineering-IRAQ 2022 May 17 (pp. 211-221). Singapore: Springer Nature Singapore.
[11] Karkush MO, Ahmed MD, Sheikha AA, Al-Rumaithi A. Thematic maps for the variation of bearing capacity of soil using SPTs and MATLAB. Geosciences. 2020 Aug 20;10(9):329.
[12] Karkush MO, Sabaa MR, Salman AD, Al-Rumaithi A. Prediction of bearing capacity of driven piles for Basrah governatore using SPT and MATLAB. Journal of the Mechanical Behavior of Materials. 2022 Jan 1;31(1):39-51.
[13] Salman AD, Khadim SS, Karkush M, Al-Rumaithi A. Production of maps for bearing capacity of the shallow foundation in Baghdad city using SPTs and MATLAB software. In IOP Conference Series: Earth and Environmental Science 2024 Aug 1 (Vol. 1374, No. 1, p. 012023). IOP Publishing.
[14] Sabaa MR, Salman AD, Dakhil AJ, Jawad SI, Karkush MO, Athab A. Production thematic maps of bearing capacity of shallow foundation for Al-Basrah soil using standard penetration data and GIS. Journal of Rehabilitation in Civil Engineering. 2023 Nov 1;11(4):77-90.
[15] Al-Mirza HA, Falih MR, Wattan S, Salman AD, Karkush M. Utilization of GIS to Generate a Digital Geotechnical Map of Baghdad City. In IOP Conference Series: Earth and Environmental Science 2024 Aug 1 (Vol. 1374, No. 1, p. 012052). IOP Publishing.
[16] Sivrikaya O, Toğrol E. Relations between SPT-N and qu. In5th international congress on advances in civil engineering 2002 Sep 25 (pp. 943-952).
[17] Hettiarachchi H, Brown T. Use of SPT blow counts to estimate shear strength properties of soils: energy balance approach. Journal of Geotechnical and Geoenvironmental engineering. 2009 Jun;135(6):830-4.
[18] Decourt L. The standard penetration test, state-of-the-art report. Proc. 12th ICSMFE, Rio De Janeiro. 1989; 4:2405-16.
[19] Nixon IK. Standard penetration test State-of-the-art report. In Penetration Testing, volume 1 2021 Feb 25 (pp. 3-22). Routledge.
[20] Ajayi LA, Balogun LA. Penetration testing in tropical lateritic and residual soils-Nigerian experience. In International Symposium on penetration testing; ISOPT-1. 1 1988 (pp. 315-328).
[21] Nassaji F, Kalantari B. SPT capability to estimate undrained shear strength of fine-grained soils of Tehran, Iran. Electronic Journal of Geotechnical Engineering. 2011;16(2011):1229-38.
[22] McGregor JA, Duncan JM. Performance and use of the standard penetration test in geotechnical engineering practice. Virginia Polytechnic Institute and State University, the Charles E. Via, Jr. Department of Civil Engineering, Center for Geotechnical Practice and Research; 1998.
[23] Das BM. Advanced soil mechanics. CRC press; 2019 Apr 15.
[24] Bjerrum L. Problems of soil mechanics and construction of soft clays and structurally unstable soils. Proc. 8th ICSMFE, Moscow, 3. 1973:109-59.
[25] Morris PH, Williams DJ. Effective stress vane shear strength correction factor correlations. Canadian Geotechnical Journal. 1994 Jun 1;31(3):335-42.