An initiative to correlate the SPT and CPT data for an alluvial deposit of Dhaka city

Arifuzzaman1* and Md. Anisuzzaman2

Introduction
The standard penetration test (SPT) is still the most commonly used in-situ tests for soil investigations. On the other hand, the Cone Penetration Test (CPT) is considered one of the best investigation tools. Many CPT-SPT correlation relationships have been proposed worldwide to estimate soil parameter from the other’s available data. However, unfortunately, no available SPT-CPT correlations are established for the alluvial soil of Dhaka city. This paper aims at presenting correlations among the SPT-N value, cone tip resistance ($q_c$), sleeve friction resistance ($f_s$), soil behavior index ($I_c$) and mean particle size ($D_{50}$) for an alluvial soil deposit of Dhaka city. It is found that for the relationship between equivalent SPT N$_{60}$-value and SPT N$_{60}$-value the coarser soil layers As1 and As2 show the coefficient of correlation ($R^2$) is 0.7106 and 0.534 respectively, which indicate a reliable relationship. In addition, the correlation between cone tip resistance ($q_c$) and SPT N$_{60}$-value shows very strong relationship which is very similar to proposed Meyerhof correlation. Furthermore, the relations between other mentioned parameters also shows a valid correlations similar to other authors.

Keywords: SPT, CPT, Tip resistance, Sleeve friction, Correlation

Abstract
The Standard Penetration Test (SPT) is the most common in-situ tests for soil investigations. On the other hand, the Cone Penetration Test (CPT) is considered one of the best investigation tools. Many CPT-SPT correlation relationships have been proposed worldwide to estimate soil parameter from the other’s available data. However, unfortunately, no available SPT-CPT correlations are established for the alluvial soil of Dhaka city. This paper aims at presenting correlations among the SPT-N value, cone tip resistance ($q_c$), sleeve friction resistance ($f_s$), soil behavior index ($I_c$) and mean particle size ($D_{50}$) for an alluvial soil deposit of Dhaka city. It is found that for the relationship between equivalent SPT N$_{60}$-value and SPT N$_{60}$-value the coarser soil layers As1 and As2 show the coefficient of correlation ($R^2$) is 0.7106 and 0.534 respectively, which indicate a reliable relationship. In addition, the correlation between cone tip resistance ($q_c$) and SPT N$_{60}$-value shows very strong relationship which is very similar to proposed Meyerhof correlation. Furthermore, the relations between other mentioned parameters also shows a valid correlations similar to other authors.

Keywords: SPT, CPT, Tip resistance, Sleeve friction, Correlation
deposit of Dhaka city. The correlations were devised from the results of 15 bore log data of SPT and CPT test.

**Available SPT-CPT correlations**

Many Geotechnical researchers have explicit the importance of SPT-CPT correlations. The researchers have focused on some parameters like the SPT-N$_{60}$ value, cone tip resistance ($q_c$), the $q_c/N$ ratio, the mean grain size ($D_{50}$), fine contents (FC) of the soil, atmospheric pressure (Pa) and soil behaviour index ($I_c$). Some of the commonly accepted CPT–SPT correlations are presented by the following equations.

According to Meyerhof [6]

$$q_c = (2.5 \text{ to } 5.5) \, N_{60} \times 0.098 \, (\text{MPa})$$

(1)

According to Lunne et al. [5] and Robertson [9]:

$$\frac{(q_c/p_a) \times N_{60}}{N_{60}} = 8.5(1 - I_c/4.6)$$

(2)

and

$$\frac{(q_c/p_a) \times N_{60}}{N_{60}} = 10^{(1.1268 - 0.2817I_c)}$$

(3)

According to Kulhawy and Mayne [4] and Chin et al. [1]

$$\frac{(q_c/p_a) \times N_{60}}{N_{60}} = 4.25 - (FC/41.3)$$

(4)

$$\frac{(q_c/p_a) \times N_{60}}{N_{60}} = 5.44 \, (D_{50})^{0.26}$$

(5)

$$\frac{(q_c/p_a) \times N_{60}}{N_{60}} = 4.75 - (FC/20)$$

(6)

**Field test and data selection**

**SPT test**

The Standard Penetration Test as per ASTM D 1586 was executed using an automatic trip hammer at 1 m intervals of depth. The drilling was facilitated using heavy-duty rotary drill rigs, equipped with a minimum 120 mm cutting tool. An SPT sampler, connected with the required length of BW size rod to a 63.5 kg hammer, is inserted into the boring. SPT sampler is split- spoon sampler with a ball valve to permit exit of air or water from the top during driving and to assist in retaining sample during withdrawal; in addition, the sampler has a tapered shoe for allowing penetration into the hard ground. The number of blows required to progress the sampler 450 mm is recorded in every 150 mm intervals. The field SPT N-value is calculated by summing the hammer blows required to advance the sampler during the last two intervals of the test. The corrected SPT N$_{60}$ is then calculated from the field SPT N-value by using the following formula Das [2].

$$SPT \, N_{60} = \frac{SPT \, N \times \eta_H \times \eta_S \times \eta_R}{60}$$

(7)
where \( SPT\ N_{60} \) = Corrected standard penetration number for field condition; \( SPT\ N_{60} \) = Measured standard penetration number for 300 mm penetration; \( \eta_H \) = Hammer efficiency (%); \( \eta_S \) = Sampler correction; \( \eta_R \) = Rod length correction.

CPT test
Electronic Cone Penetration Testing was carried out using a 15 cm\(^2\) projected area electronic cones with 60° apex angle and 225 cm\(^2\) friction sleeve area advance using a 20 Ton hydraulic penetrometer. CPT tests were conducted in accordance with ASTM D 5778. Throughout the test, the cone was advanced by applying thrust on a 1 m long 36 mm diameter rod at a rate of 2.0 cm per second. After the advancement of each 1 m segments, the subsequent rod was attached and the operation was repeated. The cone used is a subtraction type cone equipped with instruments to measure Cone Pressure, Sleeve Friction and Dynamic Pore Pressure. The depth of the cone was recorded using an opto-electric encoder. All data was recorded for every centimetre automatically in a computer running proprietary software. Prior to the commencement of each test, the pressure transducer of the cone was saturated using silicon oil. The cone was calibrated prior to commencement and at the end of each test conforming to the specification using CPTtest software, this software also automatically recorded all data from the cone.

Data selection
The bore log depth reached a maximum depth of 40.24 m from the existing Ground Level. Sample data for this study was obtained from 15 bore log data of CPT and SPT soil investigations for Dhaka Metro Rail Projects. The closest available testing locations, which are not more than 10 cm apart from each other were chosen to establish the SPT–CPT correlations for each site. Each SPT boring log contained a soil profile with different soil layers classified based on the laboratory tests (i.e., sieve analysis, hydrometer analysis, and Atterberg limits test).

Methodology
Site location
Dhaka is situated between latitudes 23° 42’ and 23° 54’ N and longitudes 90° 20’ and 90° 28’ E. The field data used in this research were collected from SPT and CPT tests conducted to investigate the subsoil for the project of Dhaka Metro Rail. The details of CPT and SPT borings are presented in Table 1.

Data matching and correlations
The SPT values were collected every 1.0 m interval on the other hand CPT values are recorded at every 0.1 m interval. The average \( q_c \) and \( f_s \) values were compared with the SPT \( N_{60} \) values located at the same elevation. As the SPT \( N_{60} \) values intervals are larger than those provided by CPT; the SPT \( N_{60} \) values were selected as the reference for the corresponding CPT values.

The correlation process involved separating each type of soil from all boreholes and combining them into a single analysis. The type of the soil is also confirmed from both laboratory investigation results and from soil behaviour index \( (I_c) \) values obtained from the CPT test.
Table 1  Bore log location of SPT and CPT

| Serial no. | Borehole name | Surveyed coordinates | Ground elevation (m) | Penetration depth (m) |
|------------|---------------|-----------------------|----------------------|-----------------------|
| 1          | ST1           | 231,909.000 2,642,226.000 | 5.97                | 30.74                 |
| 2          | ST2           | 231,655.000 2,641,202.000 | 5.16                | 40.01                 |
| 3          | ST3           | 231,488.517 2,637,578.649 | 9.41                | 40.05                 |
| 4          | ST4           | 231,575.000 2,636,726.000 | 12.46               | 40.02                 |
| 5          | ST5           | 231,855.355 2,634,597.502 | 9.94                | 40.04                 |
| 6          | ST6           | 232,227.499 2,634,466.291 | 6.90                | 40.04                 |
| 7          | ST7           | 232,550.607 2,633,584.036 | 6.85                | 40.06                 |
| 8          | ST8           | 232,994.650 2,632,208.537 | 7.11                | 40.06                 |
| 9          | ST9           | 233,290.654 2,630,836.830 | 7.98                | 40.18                 |
| 10         | ST10          | 233,687.125 2,629,992.400 | 8.71                | 40.10                 |
| 11         | ST11          | 234,249.975 2,629,123.045 | 7.88                | 40.04                 |
| 12         | ST12          | 234,549.245 2,627,800.611 | 8.13                | 40.06                 |
| 13         | ST13          | 234,625.519 2,626,931.132 | 8.18                | 33.93                 |
| 14         | ST14          | 235,811.027 2,626,747.089 | 7.08                | 40.06                 |
| 15         | ST15          | 236,889.439 2,626,499.568 | 5.87                | 40.24                 |

Table 2  CPT soil behaviour type

| No | Soil behavior type index, $I_c$ | Soil behavior type (SBT) |
|----|---------------------------------|--------------------------|
| A  | < 1.31                          | Gravelly sand and dense sand |
| B  | 1.31 ~ 2.05                     | Clean sand to silty sand |
| C  | 2.05 ~ 2.60                     | Silty sand to sandy silt |
| D  | 2.60 ~ 2.95                     | Clayey silt to silty clay |
| E  | 2.95 ~ 3.60                     | Silty clay to clay |
| F  | 3.60 <                          | Peat materials |

The relationship between $I_c$ and soil behavior type developed by Robertson and Wride [10] is presented in Table 2.

Results and discussions

Subsoil characteristics

Figure 1 shows a generalized soil profile of Dhaka soil, as well as the results of soil behaviour index ($I_c$) and percentage of soil particle type with depth. The soil particle percentages are calculated from laboratory investigations and the samples were collected during SPT tests. The types of the soil layers are confirmed based on both laboratory investigations results as well as soil behaviour index ($I_c$) values of different layers obtained from the CPT test. From Fig. 1 it is revealed that the subsoil is composed of a surficial layer of alluvial silty clay or clayey silt (Ac1) of the thickness of about 15 m to 17 m. Moreover, soil behaviour index ($I_c$) values mostly lie between 2.60 to 3.60. It means that soil is clayey silt to silty clay. Again, from Fig. 1 it is observed that in this layer the percentage of clay and silt particles varies between 53.2 to 99.8%. It indicates that this layer is a fine layer and can be classified as silty clay or clay silt (CH or CL). Underneath the alluvial clayey silt or silty clay layer, medium dense alluvial silty fine sand (As1) and dense to very...
dense silty fine to medium sand (As2) layers are present having clay and silt particles between 19.8 to 30.1% and soil behaviour index (Ic) mostly lie between 2.0 to 3.0. The physical and index properties of different soil layers (Ac1, As1 and As2) are presented in Table 3.

**Table 3** Physical properties of soil layers

| Physical properties                            | Alluvial silty clay or clayey silt (Ac1) | Medium dense alluvial silty fine sand (As1) | Dense to very dense silty fine to medium sand (As2) |
|------------------------------------------------|------------------------------------------|--------------------------------------------|--------------------------------------------------|
| No. of data                                    | 34                                       | 52                                         | 52                                               |
| Range                                         | 2.66 to 2.72                             | 2.65 to 2.71                               | 2.65 to 2.71                                    |
| Specific gravity, Gs                          |                                          |                                            |                                                 |
| Natural water content, w (%)                   |                                          |                                            |                                                 |
| Mean particle size, D_{50} (mm)                |                                          |                                            |                                                 |
| Fine content, FC (%)                          | 34                                       | 52                                         | 52                                               |
| Clay (%)                                       |                                          |                                            |                                                 |
| Silt (%)                                       |                                          |                                            |                                                 |
| Liquid limit, LL (%)                          |                                          |                                            |                                                 |
| Plastic limit, PL (%)                         |                                          |                                            |                                                 |
| SPT N_{60}                                     |                                          |                                            |                                                 |
| No. of data                                    | 60                                       | 208                                        | 210                                              |
| Range                                         | 6 to 20                                  | 14 to 38                                  | 34 to 66                                        |

Correlation between SPT N-Value and equivalent SPT N-value from CPT

Figure 2 shows the equivalent SPT N_{60} value obtained from CPT and SPT N_{60} value with depth. SPT N_{60} value was taken at every 1.0 m interval whereas CPT N_{60} value was recorded from CPT test at 0.1 m interval for the same test location. An attempt is taken to correlate the equivalent SPT N_{60} value obtained from CPT test and SPT N_{60} value for

![Graph showing correlation between SPT N-value and equivalent SPT N-value from CPT.](image-url)
individual soil layers. Tissoni [12] compares the SPT $N_{60}$ from Standard Penetration Test and equivalent SPT $N_{60}$ from a dynamic cone penetration test. The tests were carried out in sandy-silty gravel.

According to the author:

$$
\text{Equivalent SPT } N_{60} = 0.60 \times \text{SPT } N_{60}
$$

(8)

Again, Muromachi and Kobayashi [7] also studied the correlation between SPT $N_{60}$ and equivalent SPT $N_{60}$ for both fine and coarse soil. According to the author:

$$
\text{Equivalent SPT } N_{60} = 1.15 \times \text{SPT } N_{60}
$$

(9)

Figure 3 shows the correlation between equivalent SPT $N_{60}$-value and SPT $N_{60}$-value for different alluvial soil layers for the current study. The linear correlation observed for these layers are:

For, fine and coarse soil,

$$
\text{Equivalent SPT } N_{60} = 0.9273 \times \text{SPT } N_{60}
$$

(10)

For, clayey silt or silty clay layer, $Ac_1$

$$
\text{Equivalent SPT } N_{60} = 0.5356 \times \text{SPT } N_{60}
$$

(11)

For, medium dense silty fine sand, $As_1$

$$
\text{Equivalent SPT } N_{60} = 0.940 \times \text{SPT } N_{60}
$$

(12)

For, very dense silty fine to medium sand $As_2$ layer,
It is observed that the obtained correlations between the equivalent SPT $N_{60}$-value and corrected SPT $N_{60}$-value is very similar to the correlation obtained by previous authors. Therefore, this correlation should be used to correlate the equivalent SPT $N_{60}$-value and corrected SPT $N_{60}$-value for Dhaka soil.

The coefficient of correlation ($R^2$) measures the strength of the correlation between two variables. For the alluvial clayey silt or silty clay (Ac$_1$) layer, the $R^2$ value is 0.2657, which indicates that there is a poor correlation between equivalent SPT $N_{60}$-value and corrected SPT $N_{60}$-value. However, the coarser soil layer As$_1$ and As$_2$ the coefficient of correlation ($R^2$) are 0.7106 and 0.534 respectively, which indicate reliable relationships between equivalent SPT $N_{60}$-value and SPT $N_{60}$-value. The reason behind this dissimilarity because of the wide range of particle size, fine content, density of soil layers and index properties etc. In addition, the number of data of each soil layer is also a very important factor. It is clearly shown that the correlation is very sound for combined fine and coarse layers, compared to individual soil layers because of having

$$\text{Equivalent SPT } N_{60} = 0.9303 \times \text{SPT } N_{60}$$

$$R^2 = 0.8666$$

**Fine Soil + Coarse Soil**

$$\text{Equivalent SPT } N_{60} = 0.9273 \times \text{SPT } N_{60}$$

$$R^2 = 0.8666$$

**Clayey Silt or Silty Clay, Ac$_1$**

$$\text{Equivalent SPT } N_{60} = 0.5356 \times \text{SPT } N_{60}$$

$$R^2 = 0.2657$$

**Medium Dense Silty Fine Sand, As$_1$**

$$\text{Equivalent SPT } N_{60} = 0.94 \times \text{SPT } N_{60}$$

$$R^2 = 0.7106$$

**Very Dense Silty Fine to Medium Sand, As$_2$**

$$\text{Equivalent SPT } N_{60} = 0.9303 \times \text{SPT } N_{60}$$

$$R^2 = 0.534$$
large data. However, more case study with experimental data is required to clarify this variation.

**Correlation between q_c and SPT N_60-value and comparison with Meyerhof**

Figure 4a shows the correlation of q_c and SPTN_60 (simply N_60) obtained from all the data points of fifteen locations of this study. It is found in Fig. 4a that:

\[ q_c = 4.0N_{60} \times 0.098 \]  \hspace{1cm} (14)

and the coefficient of correlation \((R^2)\) is 0.6758 indicating a good relationship. According to Meyerhof [6]:

\[ q_c = (2.5 \text{ to } 5.5) N_{60} \times 0.098 \text{(MPa)} \]  \hspace{1cm} (15)

The found correlation is in the middle of the range of Meyerhof analysis. It represents very strong relationship between q_c and SPTN_60 for the alluvial soil deposit of Dhaka city.

![Fig. 4](image-url)  
Fig. 4 Correlation between q_c and SPT N_60-value for different soil layers
An attempt is also taken to investigate this relationship for individual soil layers. Figure 4b–d show the correlation of $q_c$ and SPT $N_{60}$ for different alluvial soil layers. It is observed that both the alluvial silty fine sand and silty fine to medium sand layers ($A_{s1}$ and $A_{s2}$) provide good correlations and remain in the middle of the range of Meyerhof analysis.

However, the correlation between $q_c$ and SPT $N_{60}$ for cohesive soil layer ($A_{c1}$) is remained in the lower of the range of Meyerhof [6] analysis. It indicates that alluvial coarse soil shows better correlations than the alluvial fine soil.

**Correlation between $f_s$ and SPT $N_{60}$-value**

Figure 5a shows the correlation between sleeve friction resistance ($f_s$) and SPT $N_{60}$ obtained from all the data points of different soil layers (fine and coarse) of fifteen locations. It is found from the Fig. 5a that:

\[
Sleeve \ friction \ resistance, \ f_s = 4.66N_{60} + 70.2
\]  

(16)
and the coefficient of correlation ($R^2$) is 0.6408 it indicates a good relationship exists between $f_s$ and SPT $N_{60}$. In addition, Fig. 5b–d represent the correlation between $f_s$ and SPT $N_{60}$ for individual soil layers. The linear correlation observed for these layers are:

For, clayey silt or silty clay layer, $A_{C1}$

\[
Sleeve\ friction\ resistance\ f_s = 6.81N_{60} + 32.8
\]  

(17)

For, medium dense silty fine sand, $A_{S1}$

\[
Sleeve\ friction\ resistance\ f_s = 5.75N_{60} + 51.0
\]  

(18)

For, very dense silty fine to medium sand $A_{S2}$ layer,

\[
Sleeve\ friction\ resistance\ f_s = 3.04N_{60} + 141.4
\]  

(19)

Jarushi et al. [3] studied the correlation between SPT and CPT for various soil in Florida. The observed correlation by the author are:

For, silty fine sand soil (SM)

\[
Sleeve\ resistance\ f_s = 0.5N_{60} + 92
\]  

(20)

For, clayey fine sand soil (SC)

\[
Sleeve\ resistance\ f_s = 1.8N_{60} + 65
\]  

(21)

For, fine sand with silt soil (SM/SC)

\[
Sleeve\ resistance\ f_s = 6.2N_{60} - 16
\]  

(22)

It is observed that the obtained correlation from this study has a similar trend as obtained by Jarushi et al. [3]. However, some dissimilarity is observed in the correlation and it is justifiable because of a wide range of dissimilarities of soil properties all over the world.

Although the $f_s$ has customarily been realized as less reliable than the cone tip resistance plays an important role in the quality of soil type. Nevertheless, the relationship between $f_s$ and $N_{60}$ were investigated to quantify the effect of soil type.

The above correlations were obtained by using the same process as in the $q_c$ and SPT $N_{60}$ analysis. The alluvial clayey silt or silty clay soil layer shows a linear relationship between $f_s$ and SPT $N_{60}$ with a coefficient of correlation ($R^2$) that is 0.3653. However, medium dense alluvial silty fine sand and dense to very dense alluvial silty fine sand have a coefficient of correlation ($R^2$) of 0.5579 and 0.3052 respectively. It is exposed that the medium dense alluvial silty fine sand layer shows a better relationship among the other soil types.

**Correlation between $(q_c/p_a)/N_{60}$ with mean particle size ($D_{50}$)**

The grain size distribution of the studied soil samples of the fifteen stations are present in Fig. 6. It is revealed that the mean particle size for $A_{C1}$ layer is between 0.0017 to 0.027 mm, for $A_{S1}$ layer is between 0.07 to 0.30 mm and for $A_{S2}$ layer is between 0.095 to 0.35 mm. The correlation between $(q_c/p_a)/N_{60}$ and mean particle size ($D_{50}$) is presented...
Fig. 6 Grain size distribution of the studied soil samples of the fifteen stations

Fig. 7 Correlation between \( (q_c/p_y)/N_{60} \) and \( D_{50} \)
in Fig. 7. It is found that the correlation between \((q_c/p_a)/N_{60}\) and \(D_{50}\) is quite representative as it is very close to the correlation of Kulhawy and Mayne [4].

According to Kulhawy and Mayne [4] the correlation between \((q_c/p_a)/N_{60}\) and \(D_{50}\) is:

\[
(q_c/p_a)/N_{60} = 5.44(D_{50})^{0.26}
\] (23)

On the other hand, the relation obtained from this study is presented by:

\[
(q_c/p_a)/N_{60} = 5.1636(D_{50})^{0.1944}
\] (24)

This minor variation may occur because of the wide range of mean particle size \((D_{50})\) from 0.0017 mm to 0.35 mm.

**Correlation between \((q_c/p_a)/N_{60}\) with soil behaviour index \((I_c)\)**

The correlation between \((q_c/p_a)/N_{60}\) and soil behaviour index \((I_c)\) is presented in Fig. 8. It is revealed from Fig. 8 that the obtained correlation between \((q_c/p_a)/N_{60}\) with \(I_c\) is almost similar to the proposed correlation of Lunne et al. [5]. According to Lunne et al. [5]:

\[
(q_c/p_a)/N_{60} = 8.5(1 - I_c/4.6)
\] (25)

And the correlation obtained from this study is:

\[
(q_c/p_a)/N_{60} = 7.9(1 - I_c/4.8)
\] (26)

However, the coefficient of correlation \((R^2)\) of the obtained correlation is 0.2091, which indicates a satisfactory linear relationship between \((q_c/p_a)/N_{60}\) and soil behaviour index \((I_c)\).

**Conclusion**

This study was conducted to develop a \(CPT-SPT\) correlation among various alluvial soil deposits of Dhaka city. There is no theoretically sound as well empirical method that can be used to describe accurately the \(CPT-SPT\) relationship. Many \(SPT-CPT\) correlation methods have been developed in various countries but their worldwide application is limited due to the inherent variability of the test techniques and the nature and condition of the soils tested.

![Fig. 8 Correlation between \((q_c/p_a)/N_{60}\) and \(I_c\)](image-url)
The analysis results of this study revealed that there is a satisfactory correlation between equivalent SPT $N_{60^*}$-value and corrected SPT $N_{60}$-value for the cohesive layer. However, for the coarse-grained soil layers, it shows reliable relationships between CPT based equivalent SPT $N_{60^*}$-value and SPT $N_{60}$-value.

It is observed that both the alluvial silty clay or clayey silt and silty fine sand layers exposed good correlations between $q_c$ and $N_{60}$. However, the correlation between $q_c$ and $N_{60}$ for cohesive soil layer is in the lower range of Meyerhof [6] analysis. In addition, it is revealed that medium dense alluvial silty the fine sand layer shows a better relationship between $f_s$ and $N_{60}$ among the other type of soil.

As an overall conclusion, the correlations between the SPT and CPT manifests a reliable correlation in the Dhaka city area for alluvial coarser soils with fines.

Acknowledgements
Authors are grateful to the Nippon Koei-NK India-DMRC-MOTT UK-MOTT India-DDC (NKDM association), and Department of Civil Engineering of Bangladesh University of Engineering and Technology for giving support for conducting this research. Authors are also grateful to Development Construction Limited (DCL) for supporting to conduct SPT and CPT Tests.

Authors’ contributions
Arifuzzaman, the corresponding author conceived the project performed all the laboratory investigations. Arifuzzaman and MA analyzed the data and wrote the manuscript. Both authors read and approved the final manuscript.

Declarations
Competing interests
The authors declare that they have no competing interests.

Author details
1 Department of Civil and Environmental Engineering, National University of Science and Technology, Muscat, Sultanate of Oman. 2 Department of Civil Engineering and Architecture, Instituto Superior Tecnico (IST), Lisbon, Portugal.

Received: 12 January 2021 Accepted: 22 September 2021
Published online: 03 February 2022

References
1. Chin C, Duann S, and Kao T (1988) SPT–CPT correlations for granular soils. International Proceedings of the 1st international symposium on penetration testing, ISOPT-1. pp. 335–339
2. Das BM (2011) Principle of Foundation Engineering, 7th edition, USA. pp. 83–84
3. Jarushi F, AlKaabim A, Cosentino P (2015) “A new correlation between SPT and CPT for various soils”. World Academy of Science, Engineering and Technology. Int J Geol Environ Eng 92:101–107
4. Kulhawy F, Mayne P (1990) Manual on estimating soil properties for foundation design. Report no. EPRI-EL-6800, Electric Power Research Institute, EPRI.
5. Lunne T, Robertson PK, Powell JIM (1997) Cone penetration testing in geotechnical practice. Blackie Academic, EF Spon/Routledge Publishers, New York.
6. Meyerhof GG (1956) Penetration tests and bearing capacity of cohesionless soil. J Soil Mech Found Div ASCE 82:1–19
7. Muromachi T, Kobayashi S (1982) Comparative study of static and dynamic penetration tests currently in use in Japan. Proceedings of the 2nd European Symp. on Penetration Testing, Amsterdam, 1. pp. 297–302
8. Ripon H, Shahriyar AM, Ansary MA (2018) SPT-CPT correlations for reclaimed areas of Dhaka. J Eng Sci 09(1):35–46
9. Robertson PK (2012) Interpretation of in-situ tests—some insights. Mitchell Lecture-ISC’4 Brazil.
10. Robertson PK, Wride C (1998) Evaluating cyclic liquefaction potential using the cone penetration test. Can Geotech J 35:442–459
11. Sarker D, Abedin Z (2015) MATLAB modeling of SPT and grain size data in producing soil-profile. Int J Sci Eng Invest 4(38):26–30
12. Tissoni A (1987) La prova SPT e SPTC a confronto nei terreni fluvioglaciali della pianura torinese. Geologia Tecnica, N°4.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.