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ORIGINAL RESEARCH

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

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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 As_1 and As_2 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 parametres also shows a valid correlations similar to other authors.

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

Introduction

The standard penetration test (SPT) is still the most commonly used in-situ tests for obtaining the required geotechnical parameters for foundation analysis and design in Bangladesh [11]. Geotechnical engineers in Bangladesh are likely to request CPT tests only for moderate to high-risk projects [8]. Recently some mega projects are commenced in Bangladesh especially in Dhaka city and therefore more accurate soil parameters are highly demanded. In contrast, the Cone Penetration Test (CPT) is becoming more popular for site investigations and geotechnical design because of its continuous data measurement. CPT test is relatively costly and not available always for ordinary practice and local contractors do not offer them also.

The correlation of CPT data with the SPT N-value is very beneficial since in most situations, only SPT data is available and numerous soil parameters are related to the SPT *N*-value. However, unfortunately, there are no available SPT-CPT correlations for Dhaka alluvial soil is established. This paper aims at presenting correlations between the SPT-N60 value, cone tip resistance (qc) and sleeve friction resistance (fs) for an alluvial soil 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 qc/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]

$$q_c = (2.5\, to\, 5.5)\, N_{60} * 0.098(\mathrm{MPa}) \tag{1}$$

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

$$(q_c/p_a)/N_{60} = 8.5(1 - Ic/4.6) \tag{2}$$

and

$$(q_c/p_a)/N_{60} = 10^{(1.1268 - 0.2817Ic)} \tag{3}$$

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

$$(q_c/p_a)/N_{60} = 4.25 - (FC/41.3) \tag{4}$$

$$q_c/p_a)/N_{60} = 5.44\,(D_{50})^{0.26} \tag{5}$$

$$(q_c/p_a)/N_{60} = 4.75 - (FC/20) \tag{6}$$

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 N60 is then calculated from the field SPT N-value by using the following formula Das [2].

$$SPT\, N_{60} = \frac{SPT\, N \times \eta_H \times \eta_S \times \eta_R}{60} \tag{7}$$

where SPT N_{60} = Corrected standard penetration number for field condition; SPT N_{60} = Measured standard penetration number for 300 mm penetration; η_H = Hammer efficiency (%); η_S = Sampler correction; η_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 CPTest 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)
		Easting	Northing		
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, *Ic*	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 (Ac_1) 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 (As_1) and dense to very

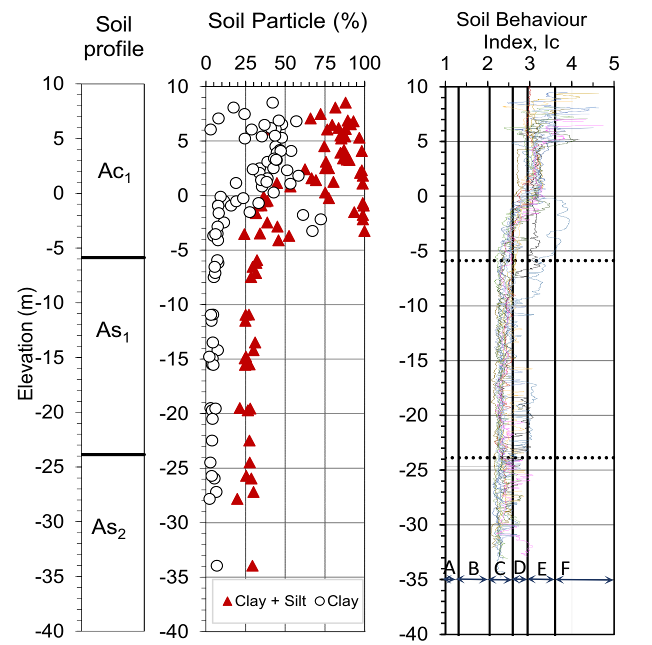

Fig. 1 Soil profile of Dhaka soil with particle percentage and soil behaviour index (*Ic*) with depth

Table 3 Physical properties of soil layers

Physical properties	Alluvial silty clay or clayey silt (Ac_1)		Medium dense alluvial silty fine sand (As_1)		Dense to very dense silty fine to medium sand (As_2)	
	No. of data	Range	No. of data	Range	No. of data	Range
Specific gravity, G_s	34	2.66 to 2.72	52	2.65 to 2.71	52	2.65 to 2.71
Natural water content, w (%)	34	21.0 to 26.8	–		–	
Mean particle size, D_{50} (mm)	34	0.0014 to 0.029	52	0.115 to 0.210	52	0.157 to 0.270
Fine content, FC (%)	34	73.1 to 94.3	52	21.0 to 36.0	52	19.7 to 27.3
Clay (%)	34	31.97 to 49.4	23	3.6 to 11.8	13	3.0 to 5.8
Silt (%)	34	33.4 to 52.6	23	20.7 to 30.1	13	19.8 to 22.0
Liquid limit, LL (%)	34	37 to 53	–		–	
Plastic limit, PL (%)	34	16 to 20	–		–	
SPT N_{60}	60	6 to 20	208	14 to 38	210	34 to 66

dense silty fine to medium sand (As_2) layers are present having clay and silt particles between 19.8 to 30.1% and soil behaviour index (I_c) mostly lie between 2.0 to 3.0. The physical and index properties of different soil layers (Ac_1, As_1 and As_2) are presented in Table 3.

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

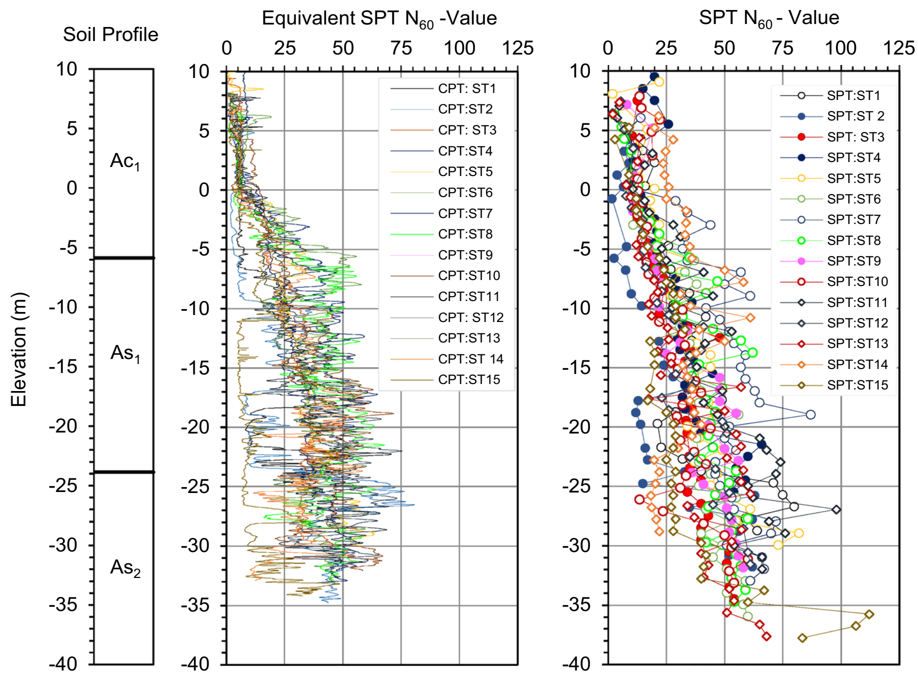

Fig. 2 Soil profile of Dhaka soil with equivalent *SPT N*-value and corrected *SPT N*-value with depth

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:

$$Equivalent\ SPT\ N_{60} = 0.60\,SPT\ N_{60} \tag{8}$$

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:

$$Equivalent\ SPT\ N_{60} = 1.15\,SPT\ N_{60} \tag{9}$$

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,

$$Equivalent\ SPT\ N_{60} = 0.9273\,SPT\ N_{60} \tag{10}$$

For, clayey silt or silty clay layer, Ac_1

$$Equivalent\ SPT\ N_{60} = 0.5356\,SPT\ N_{60} \tag{11}$$

For, medium dense silty fine sand, As_1

$$Equivalent\ SPT\ N_{60} = 0.940\,SPT\ N_{60} \tag{12}$$

For, very dense silty fine to medium sand As_2 layer,

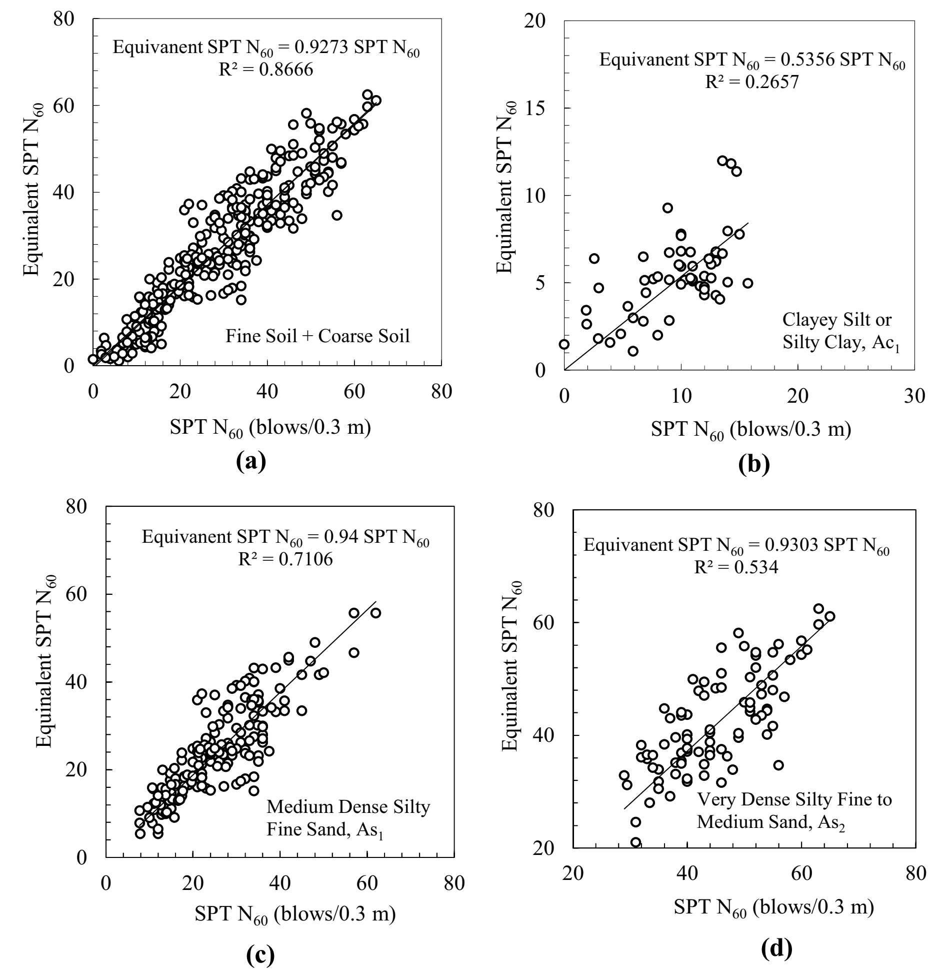

Fig. 3 Correlation between equivalent *SPT* N_{60}-value and corrected *SPT* N_{60}-value

$$Equivalent\ SPT\ N_{60} = 0.9303\,SPT\ N_{60} \tag{13}$$

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 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:

$$q_c = 4.0N_{60} * 0.098 \tag{14}$$

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

$$q_c = (2.5\ to\ 5.5)\ N_{60} * 0.098(\text{MPa}) \tag{15}$$

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.

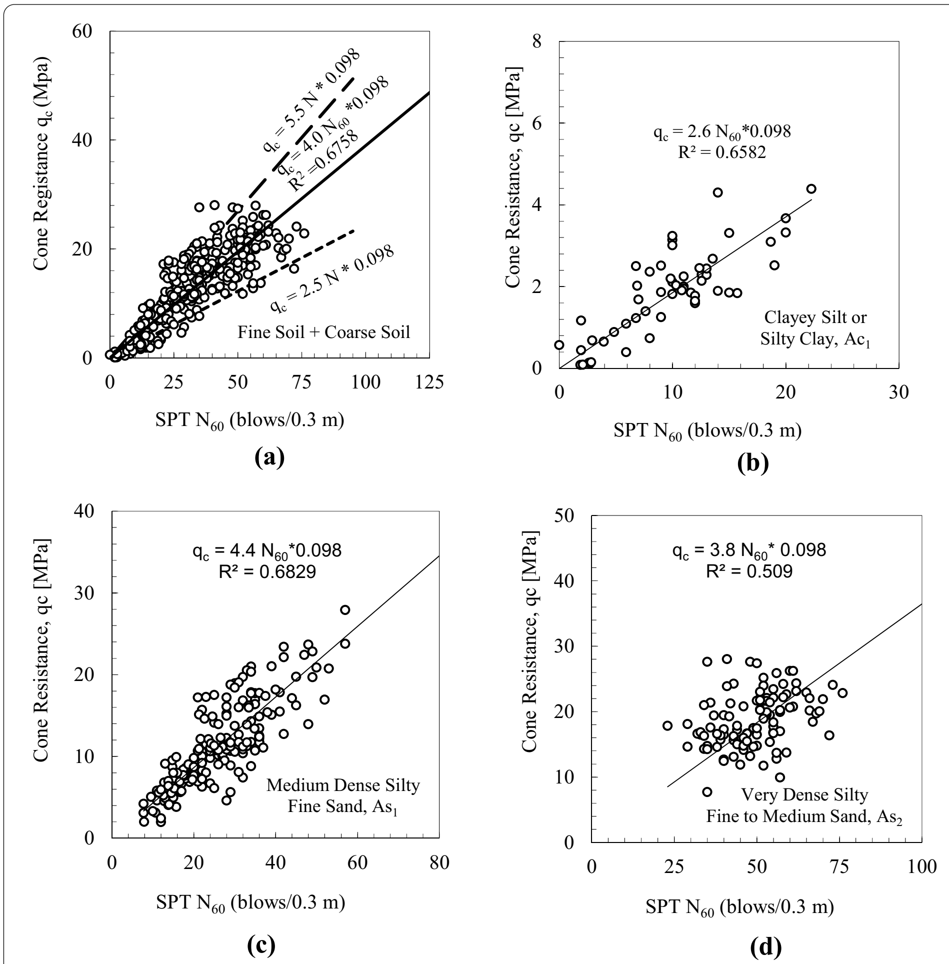

Fig. 4 Correlation between q_c and *SPT* N_{60}-value for different soil layers

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 (As_1 and As_2) 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 (Ac_1) 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 sleev 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:

$$\textit{Sleeve friction resistance}, f_s = 4.66N_{60} + 70.2 \quad (16)$$

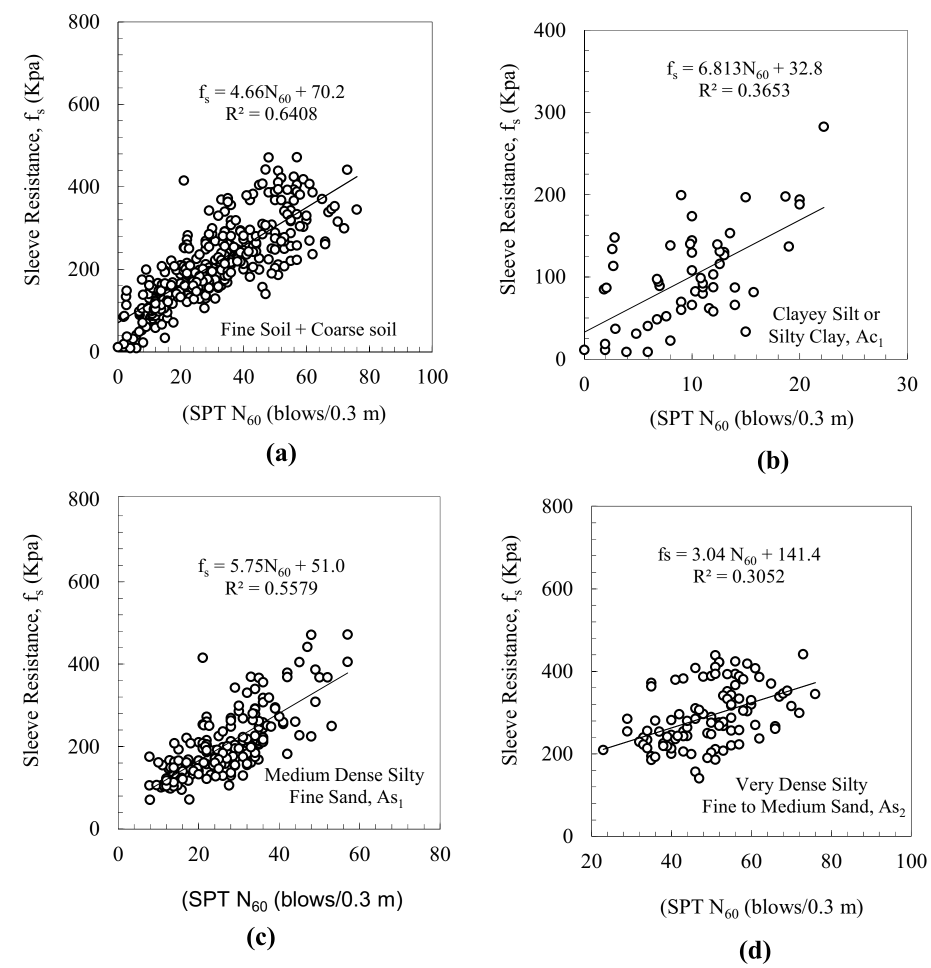

Fig. 5 Correlation between f_s and *SPT* N_{60}-value for different soil layers

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, Ac_1

$$\textit{Sleeve friction resistance}\, f_s = 6.81N_{60} + 32.8 \tag{17}$$

For, medium dense silty fine sand, As_1

$$\textit{Sleeve friction resistance}\, f_s = 5.75N_{60} + 51.0 \tag{18}$$

For, very dense silty fine to medium sand As_2 layer,

$$\textit{Sleeve friction resistance}\, f_s = 3.04N_{60} + 141.4 \tag{19}$$

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)

$$\textit{Sleeve resistance} f_s = 0.5N_{60} + 92 \tag{20}$$

For, clayey fine sand soil (*SC*)

$$\textit{Sleeve resistance}\, f_s = 1.8N_{60} + 65 \tag{21}$$

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

$$\textit{Sleeve resistance}\, f_s = 6.2N_{60} - 16 \tag{22}$$

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 Ac_1 layer is between 0.0017 to 0.027 mm, for As_1 layer is between 0.07 to 0.30 mm and for As_2 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

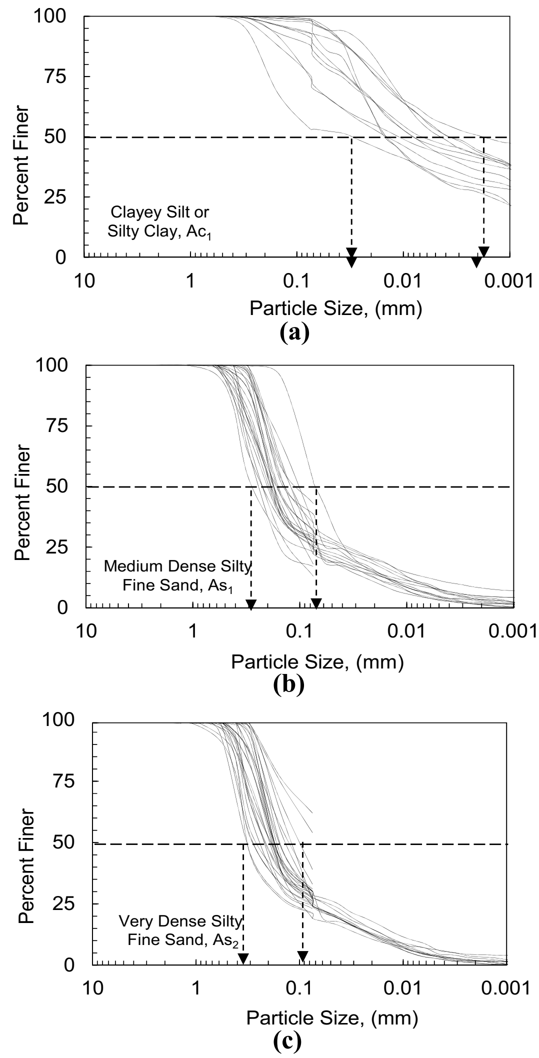

Fig. 6 Grain size distribution of the studied soil samples of the fifteen stations

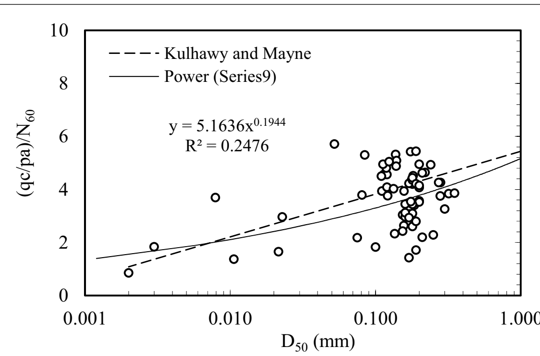

Fig. 7 Correlation between $(q_c/p_a)/N_{60}$ and D_{50}

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:

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

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

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

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 (Ic)

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

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

And the correlation obtained from this study is:

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

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 (*Ic*).

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.

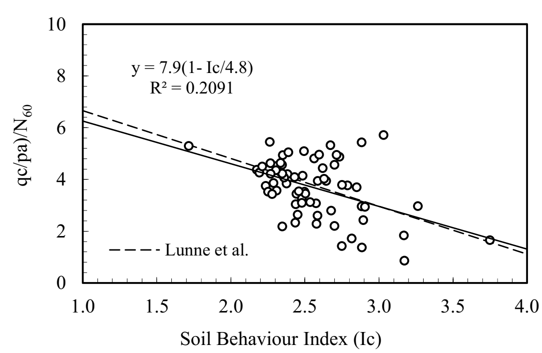

Fig. 8 Correlation between $(q_c/p_a)/N_{60}$ and *Ic*

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.

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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.

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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 JJM (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 821:1–19
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 corlelations 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 353:442–459
11. Sarker D, Abedin Z (2015) MATLAB modeling of SPT and grain size data in producing soil-profile. Int J Sci Eng Investig 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.

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