Correlation between CPT and SPT in Adapazari, Turkey

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ABSTRACT: In literature, it is known that there are different correlations between Cone Penetration Test (CPT) and Standard Penetration Test (SPT). Generally, these investigations have been done in homogeneous soils or similar homogeneous soils. The soils which are in Adapazarı City, Turkey have a heterogeneous structure in the vertical and horizontal directions. In this study, it has shown that the correlations between SPT and CPT gave lower ratios than literature values.

1 INTRODUCTION

The Standard Penetration Test (SPT) is the most common in situ test for site investigations in Turkey and most of foundation designs have been based on SPT-N values and physical properties of soils recovered in the SPT sampler. The SPT has some disadvantages such as potential variability of measured resistances depending on operator variability and possibility of missing delicate changes of soil properties owing to the inevitable discrete record.

Around the world the Cone Penetration Test (CPT) is becoming increasingly popular as an in situ test for site investigation and geotechnical design especially in deltaic areas since it provides a continuous record which is free from operator variability (Suzuki et al. 1998). In Turkey geotechnical engineers have gained considerable experience in design based on local SPT correlations. Thus there is a need for reliable CPT-SPT correlations so that CPT data can be used.

1.1 *Previous Works*

It is very valuable to correlate the static cone tip resistance q_c, to SPT N-value so that the available database of the field performances and property correlations with N-value could be effectively utilized. Hence many empirical relations have been established between the SPT N-values and CPT cone bearing resistances, q_c (Robertson et all. 1983). Table 1 summarizes most of the works.

Table 1. Previous works for CPT and SPT correlations.

Author(s)	Soil Types	Relationship
(De Alencar Velloso 1959)	Clay and silty clay	n = q_c / N = 0.35
	Sandy clay and silty sand	n = q_c / N = 0.2
	Sandy silt	n = q_c / N = 0.35
	Fine sand	n = q_c / N = 0.6
	Sand	n = q_c / N = 1.00
(Meigh & Nixon 1961)	Coarse sand	n = q_c / N = 0.2
	Gravelly sand	n = q_c / N = 0.3-0.4
(Franki Piles 1960) from (Akca 2003)	Sand	n = q_c / N = 1.00
	Clayey sand	n = q_c / N = 0.6
	Silty sand	n = q_c / N = 0.5
	Sandy clay	n = q_c / N = 0.4
	Silty clay	n = q_c / N = 0.3
	Clays	n = q_c / N = 0.2
(Schmertmann 1970)	Silt, sandy silt and silt-sand mix.	n = (q_c+fs)/N= 0.2
	Fine to medium sand, silty sand	n = (q_c+fs)/N= 0.3-0.4
	Coarse sand, sand with gravel	n = (q_c+fs)/N= 0.5-0.6
	Sandy gravel and gravel	n = (q_c+fs)/N= 0.8-1.0
(Barata et al. 1978)	Sandy silty clay	n = q_c / N *= 1.5-2.5
	Clayey silty sand	n = q_c / N * = 2.0-3.5
(Ajayi & Balogun 1988)	Lateritic sandy clay	n = q_c / N * = 3.2
	Residual sandy clay	n = q_c / N * = 4.2
(Chang 1988)	Sandy clayey silt	n = q_c / N *= 2.1
	Clayey silt, sandy clayey silt	n = q_c / N *= 1.8
(Danziger & de Valleso 1995)	Silt, sandy silt and silt-sand	n = (q_c+fs)/N= 0.2
	Fine to medium sand, silty sand	n = (q_c+fs)/N= 0.3-0.4
	Coarse sand, sand with gravel	n = (q_c+fs)/N= 0.5-0.6
	Sandy gravel and gravel	n = (q_c+fs)/N= 0.8-1.0
	Silt, sandy silt and silt-sand	n = (q_c+fs)/N= 0.2
	Silty sand	n = q_c / N * = 7.0
(Danziger et al. 1998)	Sand	n = q_c / N * = 5.7
	Silty sand, Silty clay	n = q_c / N * = 5.0-6.4
	Clayey silt	n = q_c / N * = 3.1
	Clay, silt and sand mixtures	n = q_c / N * = 1.0-3.5
	Clayey sand and silty clay	n = q_c / N * = 4.6-5.3
	Sandy clay	n = q_c / N * =1.8-3.5
	Clay	n = q_c / N * =4.5
(Emrem et al. 2000)	Turkey soils	n = q_c/N= func(D_{50})
(Akca 2003)	Sand	n = q_c / N = 0.77
	Silty sand	n = q_c / N = 0.70
	Sandy silt	n = q_c / N = 0.58

q_c/N in MPa
*q_c/N in bar per blow 0.3m

1.2 *The city of Adapazari*

Adapazari, the capital of the Sakarya Province, is home to approximately 180,000 people. The heart of the city lies in a fertile plain formed by recent fluvial activity of the Sakarya and Çark rivers, giving the city its name, i.e. 'island market'. The city is densely developed in most areas, primarily with 3–5 storey reinforced concrete frame buildings and older 1–2 storey timber/brick buildings. Reinforced concrete construction is primarily non-ductile, with shallow, reinforced concrete stiff mat foundations located at depths of typically 1.5 m due to shallow ground water.

Most of the city is located over deep alluvial sediments. A deep boring recently performed in Yenigün District by the Federal Dam Agency (D.S.I.) did not reach bedrock at a depth of 200 m. The shallow soils (<10 m) are recent deposits laid down by the Sakarya and Çark rivers, which frequently flooded the area until flood control dams were built recently. Sands accumulated along bends of the meandering rivers, and the rivers flooded periodically leaving behind predominantly non-plastic silts, silty sands, and clays throughout the city. Clay-rich sediments were deposited in lowland areas where floodwaters ponded (Bray et al. 2000).

1.3 *Soil characterization in Adapazari*

Four general subsurface site categories were developed. These soil profile types are described as follows (Bray et al. 2000).

Soil Type 1. This site category is characterized by the presence of brown to reddish brown, loose non-plastic silt and sandy silt in the upper 4 m of the soil column. The thickness of this stratum across the area explored ranges from 0.5 to 2.5 m. Liquid limit (LL) indices for the silt range from 25 to 35% and its natural water content is generally greater than 0.9LL. The fines content (FC) of the soil samples recovered in this stratum ranges from 52 to 97%, and is generally greater than 75%. The percentage of particles smaller than 5 μm ranges from 10 to 35%, and is normally between 20 and 30%. The corrected penetration resistance of this stratum, $(N_1)_{60}$ ranges from 3 to 15 (blows / 30 cm), and is generally between 7 and 10. Organic matter within this material at a depth of 4 m was dated to be approximately 1000 years old, indicating that the upper brown silty materials are recent flood plain deposits that have a high susceptibility to liquefaction.

Interspersed strata of low plasticity clays and medium dense to dense silt to sandy silt underlie the upper brown silt. The color of these lower strata transitions from brown to gray at approximately 5 m. At depths greater than about 9 m the soils consist of interbedded clays, silts and sands.

Soil Type 2. This site category is similar to Soil Type 1, however, this category differs from Type 1 in that the soil directly beneath the brown loose silt is replaced by dense (q_{c1N} > 160 and $(N_1)_{60}$ > 30), gray sand to a depth of approximately 9 m. Samples from this sand layer generally contained less than 5% fines and also contained less than 5% gravel. However, at a few locations retrieved samples had fine gravel contents as high as 27%. The mean grain size (D_{50}) of this stratum ranges from 0.4 to 1.7 mm.

Soil Type 3. The soil between approximately 1.5 and 4 m depth in this type profile is brown highly plastic silty clay underlain by interspersed lenses and layers of low to highly plastic silty clay and clayey silt. These plastic sediments continue to depths of approximately 7 m. The soil's color transitions from brown to gray at approximately 5 m. The values of LL range from 29 to 65%, but most are greater than 35%. Some of these soils have natural water contents that are close to or in excess of the LL. The thickness of each silt layer is generally less than 25 cm, but some were as thick as 50 cm. The combined thickness of these strata range is from 1 to 3 m. The penetration resistances of the silts and clay-silt mixtures are low qc < 2 MPa, $q_{c1N} < 15$ and $(N_1)_{60} < 10$. From approximately 7 m to a depth of 8–9 m the soil is generally gray medium dense $40 < q_{c1N} < 90$, $12 < (N_1)_{60} < 22$ sandy silt to silty sand interbedded with seams of silty clay. These lower non-plastic silts overlie dense $q_{c1N} > 160$ and $(N_1)_{60} > 30$ gray sand to sand with silt to a depth of approximately 14 m. Soil samples from this layer contained between 5 and %25 fines. D_{50} from these samples ranged between 0.1 and 0.6 mm, but was predominantly between 0.2 and 0.3 mm. At greater depths the soils consist of interbedded clays, silts and sands.

Soil Type 4. This site category is similar to Soil Type 2, but differs in that the shallow loose brown silt characteristic of Type 2 is replaced by 1.5–4 m of medium to high plasticity silty clay. Thin layers and lenses (thickness < 0.5 m) of low plasticity clayey silt may lie within the upper 4–5 m of the soil column (Bray et al. 2000)

2 DATA SELECTION

All data used in this study are from the area of Adapazari town center. All the available data are from site investigation reports made from Sakarya University. The data are separated from archive of Sakarya Public Works and Settlement Directorate. The data without location map were not used in this study. The used data set that SPT and CPT test location has no distance or the distance is less than 30meter. The data has more than 30meter distance were not used in this study. However for the data set, some statistical methods need to be applied before starting the correlation. For the data set comparison of the test result may be started directly, because the distance named small.

2.1 *Number of Boreholes and CPT points*

In this study, data were used from 65 boreholes with SPT tests and 47 CPT points in small distance. From 65 SPT boreholes and 47 CPT points there are 611 data pairs (N and q_c) available for correlation.

2.2 *Results of SPT and CPT*

The cone resistance q_c are the average values over a length of 30cm where the corresponding N-Values were measured.

In this study the same rig and equipments are used on all the SPT tests. The N-Values used here were corrected to an energy efficiency of 75% (CC=1, CB= 1, CA=0.85, CS=1.2, CE=0.75) (Sivrikaya, 2003).

3 ANALYSIS OF THE DATABASE

3.1 *Arithmetic average method*

All data were combined to calculate n-value (q_c/N) for each soil type. Arithmetic average method is used for calculate the n-values. The results of n-value are given in Table 2.

Table 2. Number of data sets and the results of n-values.

Soil Type	Number of n	n value
Clay	326	0.19
Silt	186	0.35
Sand	98	0.42

In this study, for clay and silt similar literature n-values have calculate. Calculated n-value for sand is lover than literature values.

3.2 *Statistical analysis*

Two statistical analyses were performed. First, an analysis of all data was performed (Figure 1).

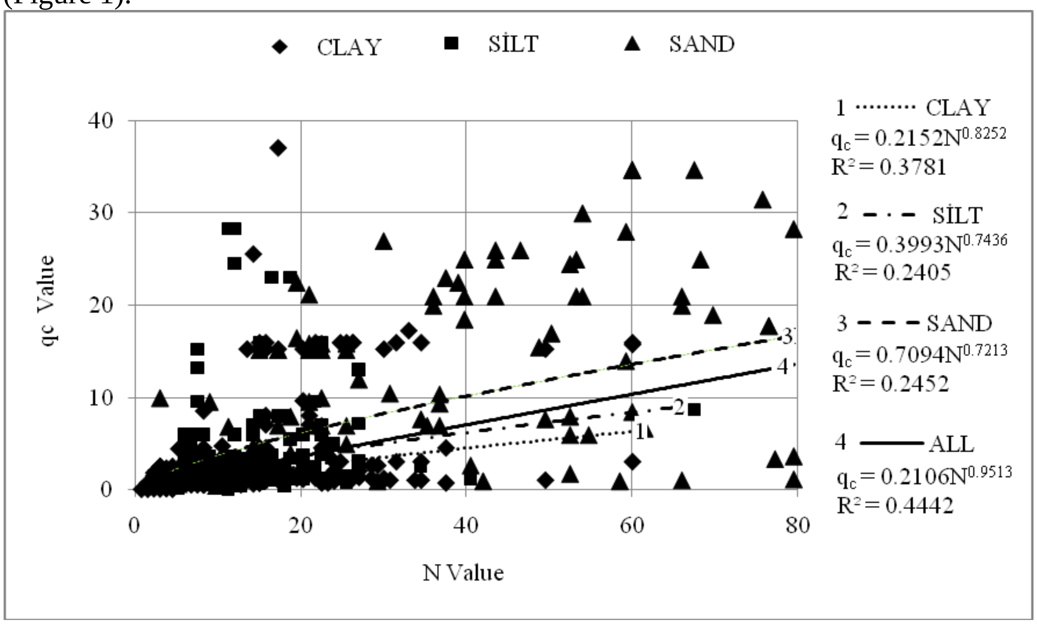

Fig 1. Relation between cone penetration resisitance and SPT N-value of all data

After this first analysis some data were eliminated. This elimination aimed at filtering data situated far from the general trend. The procedure for filtering selected data is that: ± of the two standard deviation (2σ) of the mean value of n were disregarded (by using 2σ, 95% of the data is still allowed in the investigation range. After this elimination, the same trend was confirmed to be maintained in the N versus q_c plot (Figure 2).

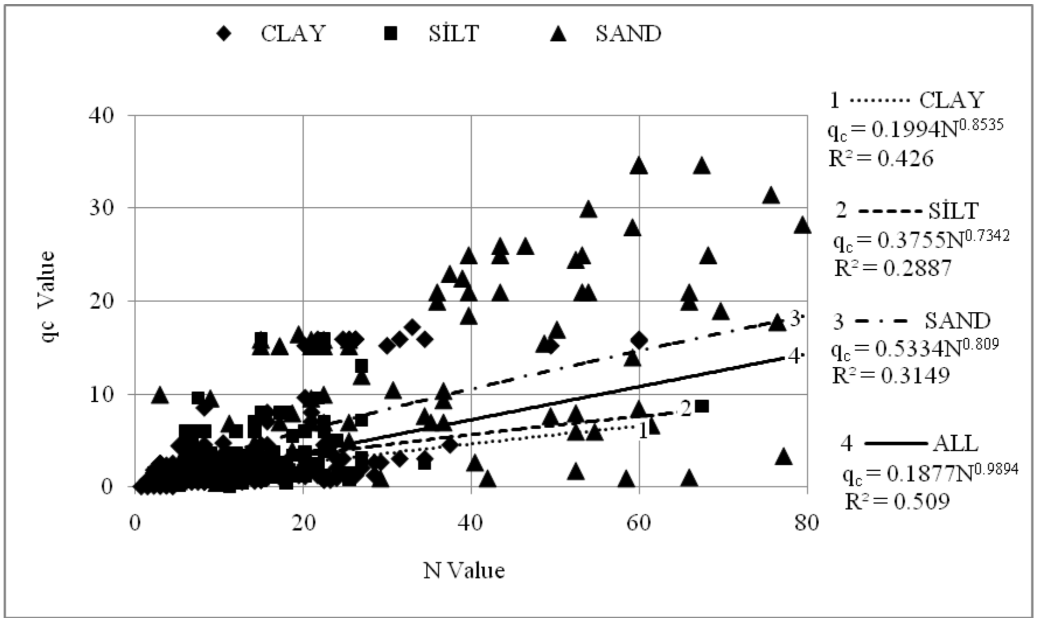

Figure 2. Relation between cone penetration resisitance and SPT N-value of filtered data

In the analysis it has been chosen a correlation function which is most suited to the data for each soil type. Correlation functions were determined for all data group and filtered data. Power correlation gives the highest correlation coefficient values. Although the correlation coefficients are lower than literature values (Table 3). The correlation coefficients found from filtered data for all soil types were greater than the data analyses including all data.

Table 3: Correlation equations and coefficients of Adapazari Soils

	Correlation equations		Correlation coefficients (R^2)	
	All Data	Filtred Data	All Data	Filtred Data
Clay	$q_c = 0.2152N^{0.8252}$	$q_c = 0.1994N^{0.8535}$	0.38	0.43
Silt	$q_c = 0.3993N^{0.7436}$	$q_c = 0.3755N^{0.7342}$	0.24	0.29
Sand	$q_c = 0.7094N^{0.7213}$	$q_c = 0.5334N^{0.809}$	0.25	0.31
All	$q_c = 0.2106N^{0.9513}$	$q_c = 0.1877N^{0.9894}$	0.44	0.51

4 CONCLUSIONS

Some correlative work made on Turkey soils. There is almost no correlative work on Adapazari soils as well. In this study investigated correlations among cone penetration resistance qc and SPT N-value.

For n=q_c/N ratio in Adapazarı can be made the following conclusions; In this study similar literature n-values have been calculated for clay and silt. Calculated n-value for sand is lover than literature values. The reason of lower n ratio for sands may be fine contents high ratios.

Power correlation gives the highest correlation coefficient values. The correlation coefficients found from filtered data for all soil types were greater than the data analyses including all data. Although the correlation coefficients are lower than literature values. The reason of lower correlation coefficients are heterogonous structure of Adapazari soils.

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