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Correlating predictions for problematic soils with field measurements

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Abstract

Laboratory testing of problematic soils has been treated intensively in the literature. However, few contributions have been made on in situ testing of these soils. This indicates the necessity for additional research work to be done to correlate predictions based on laboratory results with in situ measurements. This paper presents a research work done at 10 different sites located in desert areas at the boundaries of Cairo. 5 of these sites are known for expansive soil formations and the other 5 sites are known for collapsible soil formations. For each site standard penetration testing was done for a depth of two meters, firstly at natural dry state; and secondly after flooding by water for 48 hours. In the same time undisturbed samples were taken from open pits adjacent to borehole locations for the determination of their physical properties as well as the determination of swelling or collapse potentials using the oedometer apparatus. Relationships were then made to correlate the number of blows (N, N') for the standard penetration testing at dry and wet state respectively with the parameters determined from laboratory testing. These relationships were made to test the validity of predictions based on laboratory results and to provide parameters required for the most appropriate and economical design of foundations on problematic soils.

Keywords: *swelling potential; collapse potential; standard penetration test; dry state; wet state.*

1 Introduction

The traditional approach to the determination of engineering properties during geotechnical investigation consists of a chain of events of which the in- situ and laboratory testing techniques represent the principal approaches. Since both approaches involve considerable compromise with regard to ideal testing circumstances, a careful combination of the two would provide the most relevant information.

Problematic soils, particularly expansive and collapsible soils, have been treated intensively in the literatures. However, very few contributions have been made on in- situ testing of these soils (e.g. Kruizinga, 1982; Nixon, 1982; Marcuson, 1979; Parry, 1977 and Bazaraa, 1967. This necessitate additional research to be done to correlate predictions based on laboratory results with in- situ test measurements.

The present work is, therefore, done to correlate laboratory testing with standard penetration testing which is used very widely in borehole investigations in Egypt as well as many countries of the world.

2 The Standard Penetration Test

The standard penetration test originated with Raymond Pile Company in U.S.A. in the late 192o's, with the aim of obtaining both a quantitative indication of soil strength and a sample to allow reliable and rapid identification.
The essential feature of standard penetration test is that it can be carried out at or very close to the surface of undisturbed soil in the borehole. Furthermore, the test has application in all soils, having the advantage that it is relatively simple to carry out and the test results and a soil sample are immediately available.

The test utilizes a 50 mm O.D. split sample tube of heavy wall construction which is driven into undisturbed soil in a borehole and subsequently extracted and dismantled to recover the sample. The tube, connected by drill rods to the surface, is driven under the impact of a 63 kg hammer with a free fall of 750 mm. It is normal for the tube to be driven in three successive increments of 150 mm, the first 150 mm drive being regarded as "seating" and the S.P.T. or "N" value being taken as the blows required to drive the last 300 mm. The test procedure and the equipment required are fully detailed in ASTM designation: D 1586-84.

3 Summary of Site Profiles

Ten different sites located in desert areas at the boundaries of Cairo were chosen (Figure 1). Five of the sites are located at relatively high lands of ancient geological sediments (from Eocene to Pliocene ages) and known for the expansive behavior of their formations. The other five sites are located in relatively low lands of Recent geological sediments and known for the collapsing behavior of their formations.

The geological features of these sites may be summarized from literature (Hume, 1925; Attia, 1954; Abu Al-Izz, 1971; Said, 1962 and EGSMA, 1981) as follows:

- The Eocene sediments are of deep marine origin and are represented by thick beds of limestone with intercalations of clayey shale and marl of swelling natural.

- The Oligocene sediments are of fluviatile origin and are represented by sands and gravels containing some lenses of clayey shale of swelling natural.

- The Miocene and Pliocene sediments are of shallow marine origin and are represented by thin beds of sandy limestone or calcareous sandstone with considerable interbeddings of clayey sandy limy shale of swelling and/or collapsing natural.

- The Recent sediments are alluvial deposits of flood plain and river terraces and are represented by thick beds of sands and gravels with pockets of slightly to moderately cemented silty or limy or clayey sand and gravel of collapsing natural.

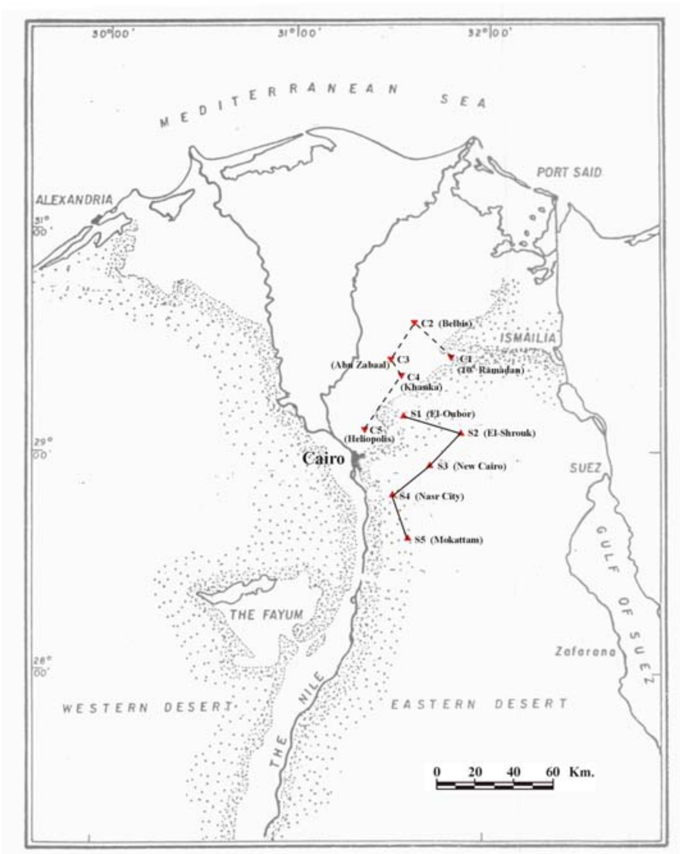

Figure 1. Location map

However, the sediments in relatively ancient geological ages (mainly clay and silt) proved to have high values of dry density and indicating swelling behavior. Whereas the sediments in relatively recent times (mainly sand and silt) proved to have low values of dry density and indicating collapsing behavior This would be attributed to lateral shift of the Nile tributaries along the past geological ages control the distribution of these sediments.

4 Field Measurements

For each of the ten sites, drilling was performed and samples were collected at the top of the hole and standard penetration testing was made for a depth of two meters. Penetration states were recorded firstly at natural dry state and secondly after flooding by water for 48 hours. This to obtain N' and N' values for dry and wet conditions.

Simultaneously, undisturbed soil samples were taken from open pits adjacent to the borehole location, where standard penetration testing was performed. The undisturbed samples were collected, rapped in aluminum foil, coated paraffin wax and reserved in plastic bags taking sufficient care to prevent moisture changes from occurring prior and during dispatching to laboratory.

5 Laboratory Measurements

The collected samples were used for the determination of their physical and index properties as well as the swelling or collapse potentials. Swelling potential is considered, here, as the swelling percentage of a laterally confined undisturbed sample when soaked (in the oedometer) under a light surcharge stress of 10 KPa. Collapse potential is considered as the collapsing percentage of a laterally confined undisturbed sample which had been incrementally loaded at its moisture content to a stress of 100 Kpa before being soaked in the oedometer.

6 Correlations between Field and Laboratory Measurements

Summary of geological age, standard penetration test values, physical and index properties and swelling or collapse potential are summarized in Tables 1& 2. Field and laboratory test results are correlated and drawn as given in Figures 2 – 9.
Figure 2 shows the relationships between swelling and collapse potential and the dry density. It indicates that the swelling potential increases with the increase of dry density; whereas the collapse potential increases with decreasing values of dry density.

Table 1. Summary of field and laboratory test results of expansive clayey beds of the investigated sites

Site No.	**Location of investigate site**	**Geological Age**	**Physical& index properties of clayey bed at 2.00 m depth**					**SPT (Dry) N**	**SPT (Wet) N '**	**ΔN= N '–N**
			Grain size content			**Dry density Υ_d (kN/m^3)**	**Swelling Potential % ***			
			Clay %	**Silt %**	**Sand %**					
1	El-Oubor	Pliocene	26	63	11	17.65	+ 4.65	35	25	- 10
2	El-Shrouk	Miocene	32	57	11	18.06	+ 5.45	41	26	- 15
3	New Cairo	Oligocene	30	55	15	18.80	+ 7.52	60	29	- 31
4	Nasr City	Oligocene	25	65	10	18.56	+ 6.85	48	28	- 20
5	Mokattam	Eocene	36	58	6	19.02	+ 8.66	75	30	- 45

* Swelling potential = Swelling percentage of undisturbed sample soaked under 1.00 kPa in the oedometer

Table 2. Summary of field and laboratory test results of collapsible sandy beds of the investigated sites

Site No.	**Location of investigate site**	**Geological Age**	**Physical& index properties of sandy bed at 2.00 m depth**					**SPT (Dry) N**	**SPT (Wet) N '**	**ΔN= N '–N**
			Grain size content			**Dry density Υ_d (kN/m^3)**	**Collapse potential* %**			
			Sand %	**Silt %**	**Lime &Clay %**					
1	10thRamadan	Recent	65	30	5	17.56	- 3.50	57	60	+ 03
2	Belbis desert	Recent	72	20	8	16.45	- 4.56	36	46	+ 10
3	Abu Zabaal Desert	Recent	60	34	6	16.12	- 5.22	32	44	+ 12
4	Khanka desert	Recent	70	20	10	17.05	- 4.15	48	54	+ 06
5	Heliopolis desert	Recent	40	45	15	15.57	- 5.70	22	40	+ 18

*Collapse potential=Collapse percentage of undisturbed sample soaked after incrementally loaded to 10 kPa in the oedometer

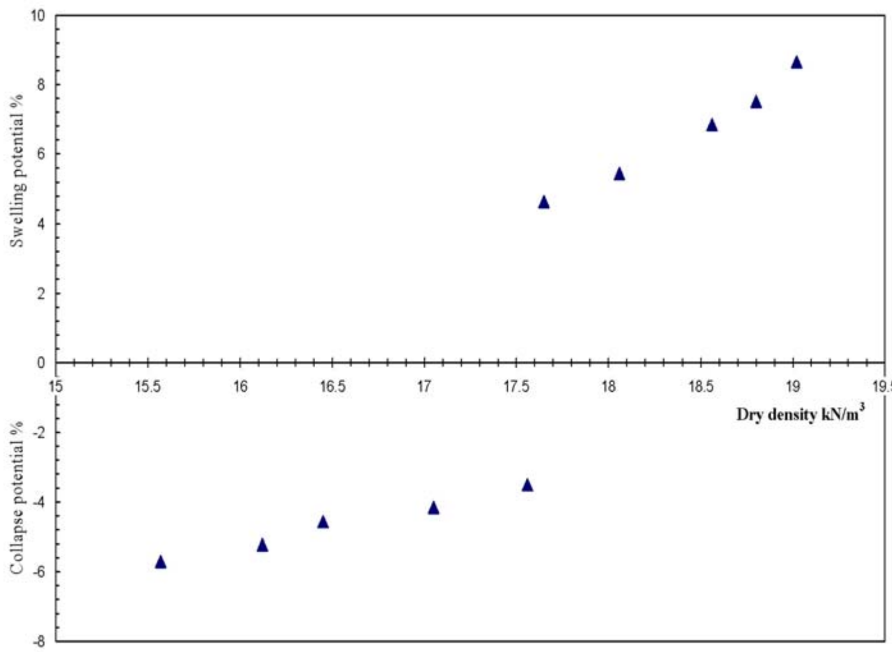

Figure 2. Swelling and collapse potential in function of dry density

Figure 3 shows the relationship between dry densities and penetration values N and N' before and after wetting of expansive clayey soils at depth of 2.00 meter from the ground surface. It indicates that penetration values at the dry state (N) increases with the increase of dry unit weight of the soil; whereas penetration values for wet condition (N') increases very slightly with the increase of the dry unite weight. However, penetration values N' is significantly low as regard to the corresponding penetration values N and the difference (N' – N) is of negative sign. The same trend has observed for the relationships between penetration values (N& N') and swelling potential (Figure 4).

Figure 5 shows the relationship between dry densities and penetration values N and N' before and after wetting of collapsible soils at depth of 2.00 meter from the ground surface. It indicates that penetration values increases with the increase of dry unit weight. However, penetration values in case of wet condition (N') is higher than the corresponding penetration value at dry density state (N) and the difference (N' – N) is of positive sign. The same trend has observed for the relationships between penetration values (N& N') and collapse potential (Figure 6).

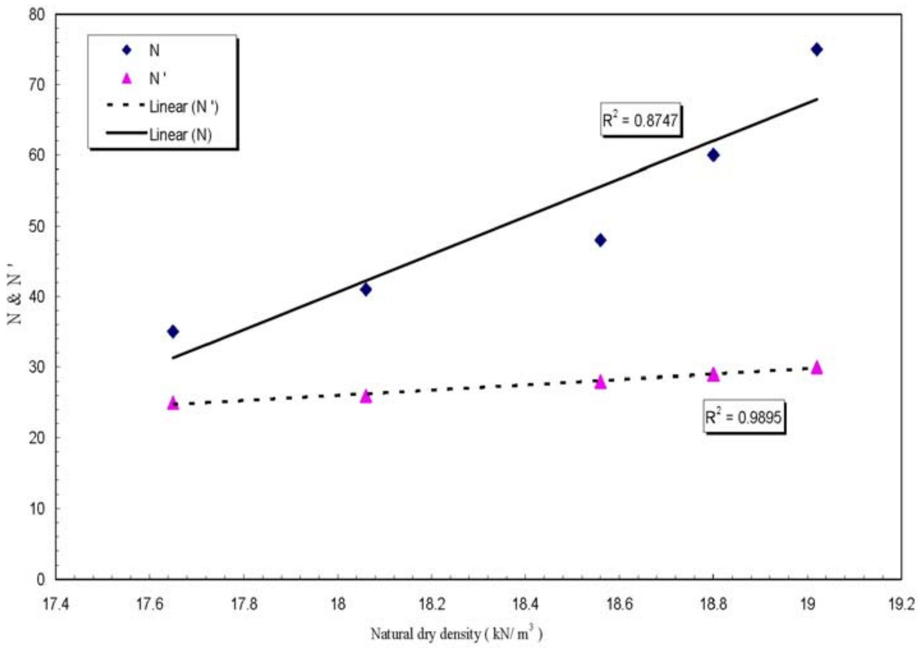

Figure 3. SPT befor & after wetting (N & N ') on the top of expansive soils
in function of natural dry density

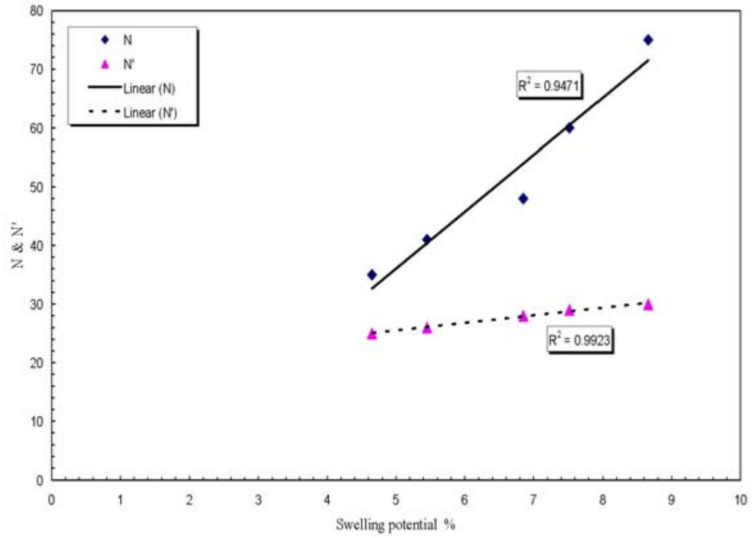

Figure 4. SPT before & after wetting (N & N') on the top of expansive soils
in function of swelling potential

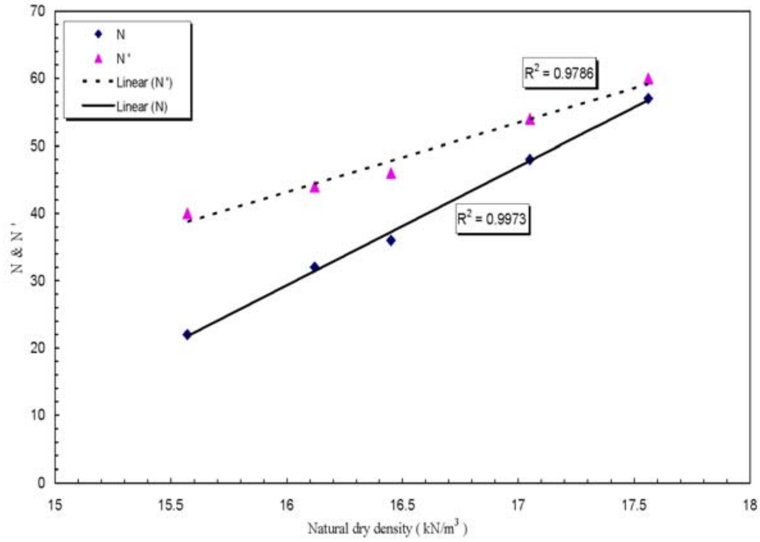

Figure 5. SPT before & after wetting (N & N ') on the top of collapsible soils ils
in function of natural density

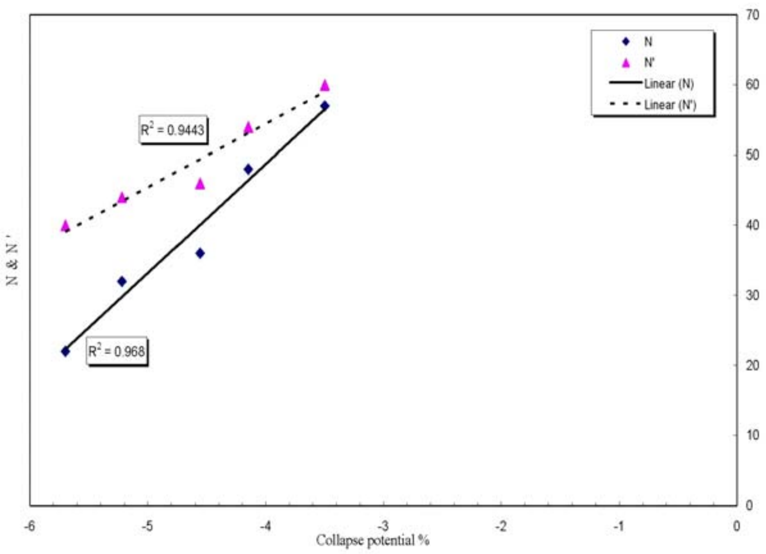

Figure 6. SPT before & after wetting (N & N ') on the top of collapsible soils
in function of collapse potential

The difference between N value and N' value related to swelling potential and collapse potential are shown on Figures 7 and 8 respectively. They indicate an increase of negative values of (N' – N) for expansive soils with the increase of swelling percent signifying an increase of swelling potential. On other hand, there is an increase of positive values of (N' – N) with the increase of collapse percent signifying an increase of collapse potential.

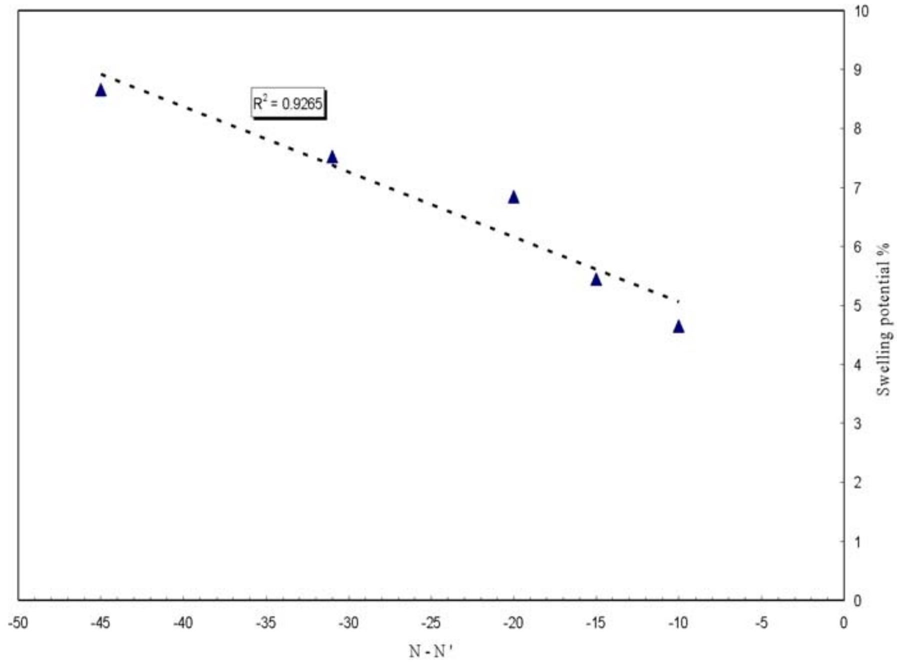

Figure 7. Swelling potential in function of difference of SPT Number (N - N')

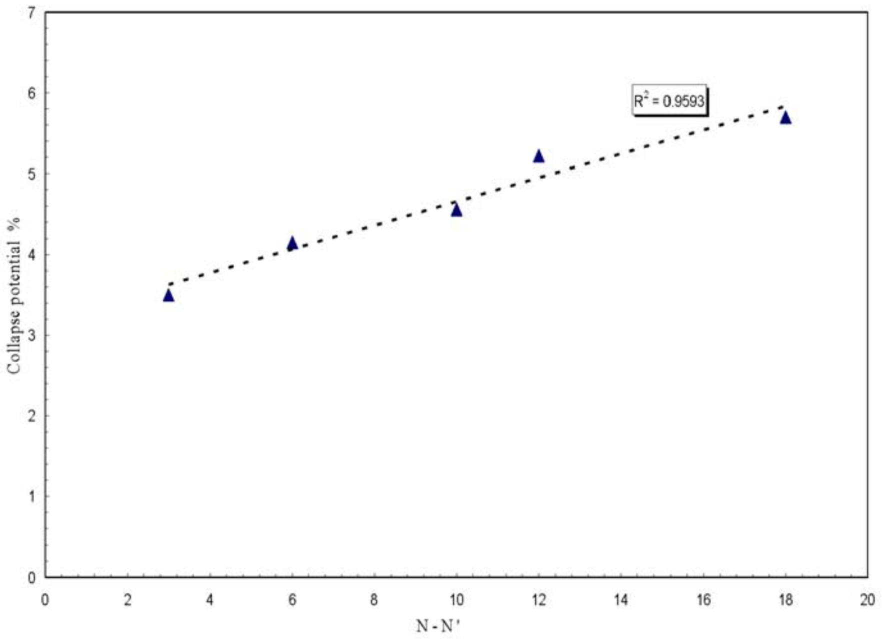

Figure 8. Collapse potential in function of the difference of SPT Number (N - N ')

The previously results are summarized in Figure 9. It correlates the values of the difference between N' and N for both cases of expansive and collapsible soils. From this figure an estimated value of swelling or collapse potential could be obtained after determination of number of blows of standard penetration test for the soil at dry state and after wetting.

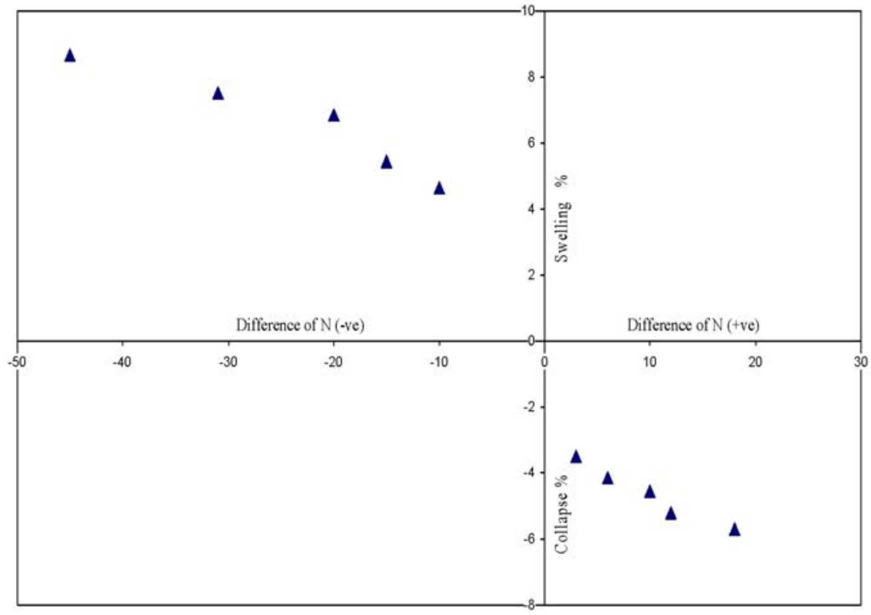

Figure 9. Difference of SPTvalues between dry and wet states correlated to swelling& collapse potential

7 Conclusions

1- The present paper presents a research work done at 10 different sites located in desert areas around Cairo. Five of these sites are known for expansive soil formations and the other 5 sites are known for collapsible soil formations.
2- The number of blows N and N' of the standard penetration testing at dry and wet state respectively were correlated with dry density as well as with swelling and collapse potential.
3- Swelling potential was found to increase with the increase of dry density, whereas the collapse potential increases with the decrease of dry density.
4- In case of expansive soils, penetration values at the dry state (N) increases with the increase of dry unit weight of the soil, whereas penetration values for wet condition (N') increases very slightly with the increase of the dry unite weight. However, penetration values N' is significantly low as regard to the corresponding penetration values N and the difference (N' – N) is of negative sign. The same trend has observed for the relationships between penetration values (N& N') and swelling potential.
5- In case of collapsible soils, penetration values increases with the increase of dry unit weight. However, penetration values in case of wet condition (N') is higher than the corresponding penetration value at dry density state (N) and the difference (N' – N) is of positive sign. The same trend has observed for the relationships between penetration values (N& N') and collapse potential.
6- An increase of negative values of (N' – N) was found occur with the increase of swelling potential. On the other hand, there is an increase of positive values of (N' – N) with the increase of collapse potential.
7- From the previous results, a summarized chart could be drawn to correlate the values of the difference between N' and N for both cases of expansive and collapsible soils. From this chart an estimated value of swelling or collapse potential could be obtained based on the N and N' values for dry and wet states respectively.

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