International Journal of Natural and Engineering Sciences 7 (1): 77-86, 2013
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Evaluation of Geotechnical Properties of Clayey Soils in Different Areas of Karachi (Pakistan) City

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Received: August 19, 2012
Accepted: September 24, 2012

Abstract

As a result of an increase in urbanization of Karachi, construction of small, medium and huge civil structures are also increasing and need due considerations of the geotechnical properties of rocks and soils to be used as foundation materials. The samples of clayey soils, which are being used as foundation materials for the construction of civil structures, have been collected from different towns of Karachi and investigated for the evaluation of their geotechnical characteristics. The main geotechnical properties of clayey soils like Natural Moisture Content, Bulk Density, Bearing Capacity Consistency Limits, Unconfined Compressive Strength, Shear Strength, Activity and Swelling Potential were determined and evaluated according to ASTM standards. In general the clayey soils of low to medium plasticity, low Unconfined Compressive and Shear Strengths, Inactive and low Swelling Potential were reported from the selected towns of Karachi city. In the light of present findings it is concluded that the clayey soils in different towns under study are suitable for the construction of small and medium civil structures.

Keywords:

INTRODUCTION

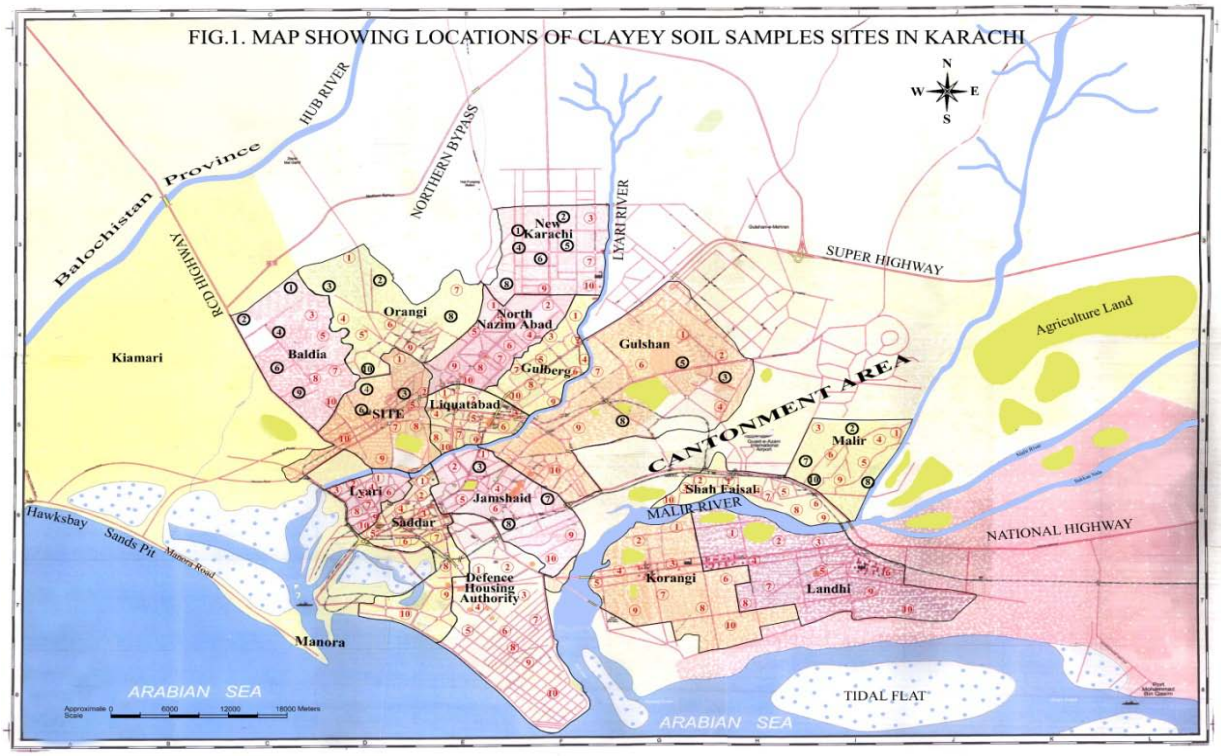
Karachi urban area is the southernmost end of the landmass along the coast of North Arabian Sea.The present area under study lies between longitude 66°39′ and 67°35′ and latitudes 24°45′ and 25°0′. Most of the surface of Karachi urban area is dominated by alluvial deposits of variable thicknesses. The foundation materials as soil are generally developed on Gaj Formation of Miocene age, which is mainly composed of argillaceous limestone alternating with shale and clays of variable thicknesses.

The clayey soils developed on these rock types exhibit variable geotechnical properties and need to be investigated for the assessment of load and design of civil structures to be constructed. The area limited under present study comprises of the land mass of rivers Malir and Lyari and also the area between River Lyari and River Hub, which is the western limit of the study area. The distribution of population at present and also the future planning of development appears to be more concentrated in the landmass of Malir and River Lyari valleys. The industries developing and already developed are also concentrated in this part of the city, known as central urban area.

Ten soil samples were collected from each town of the city, out of which clayey samples are selected for the present study and most of the remaining soil samples were classified as non-cohesive silty sand (Fig. 1). The study of the geotechnical properties of clayey soils like Natural Moisture Content, Bulk Density, Bearing Capacity, Atterberg Limits, Unconfined Compressive Strength, Shear Strength, Activity and Swelling Potential are expected to facilitate better understanding of the surface and subsurface foundation materials for programming development work of the city. Most of the towns of the city are dominated by silty sand except in SITE, Baldia, Orangi, New Karachi, Jamshed Town, Gulshan-e-Iqbal and Malir Towns, where clayey soils are exposed sporadically.

Geotechnical properties of clayey soils in different towns of Karachi

The geotechnical properties of the clayey soils have been investigated by estimating natural moisture content, bulk density, bearing capacity, liquid limit, plasticity index, unconfined compressive strength, shear strength, activity and swelling potential, wherever possible in different towns of Karachi.



Natural Moisture Content

The natural moisture content in the soil samples collected from different towns were estimated according to ASTM D-216 method.

The moisture content percentages observed in clayey soil samples from sites-3,4 and 6 of SITE Town were 11-05%,7.51% and12.25% respectively. The SITE Town is situated at the downhill slope side of Orangi ridge which is composed of shale, argillaceous limestone and the sandstones. It appears that the downhill slope of the soil of SITE Town receives moisture contents from the adjacent towns because of its geographical location on down-slope of the hill. The samples from other sites contain less percentages of natural moisture as compared to samples from sites-3, 4 and 6 (Table 1).

The natural moisture in the soil samples of Baldia Town appeared erratic and range between 5.59% to 13.57% at sites-1 and 6 respectively. This demographic setup most probably is the source of variable percentages of moisture in the soils. The soil samples from the sites-1, 2 and 9 of Baldia showed very little percentages of moisture contents. The variation in porosity due to variable texture and compaction of soils is also an important factor which should be taken in account to explain the radical differences in percentages of moisture in soils.

The natural moisture content in the soils samples of Orangi town range between 7.95% and 10.25% at sites-3 and 8 respectively. The people of Orangi Town get limited water supply from the city management and have tube wells or dug wells of variable depths to fulfill their daily life requirements. The sewage system is either in the form of septic tanks or open drainage which is considered the source of water in soils and the cause of erratic variations in moisture content of the soils at different sites.

The demographic setup and the establishment of the Industries of New Karachi Town are considered as the causes of relatively higher percentages of moisture with few exceptions at sites- 4 and 6 where the moisture content is less than 10 %. The variable percentages of moisture content also appear to reflect the textural variations of the soils and can be taken as an indicator of soil porosity and permeability differences.

Table 1

Sr #	Name Of Towns	Sites	Natural Moisture Content (%)
1	SITE	3,4,6	11.05, 7.51, 12.25
2	Baldia	1,2,4,6,9	5.59, 5.85, 7.05, 13.57, 6.21
3	Orangi	2,3,8,10	8.93, 7.95, 10.25, 8.52
4	New Karachi	1,4,5,6,8	10.93, 9.50, 15.50, 8.95, 17.05
5	Jamshed Town	3,7,8	11.52, 18.44, 7.43
6	Gulshan-e-Iqbal	3,5,8	8.50, 12.50, 10.81
7	Malir	2,7,8,10	14.52, 11.71, 16.25, 9.52

The soil of Jamshed Town is alluvial in character with fairly higher porosity. The lowest moisture of 7.43% was noted at site8 and the highest value of 18.44% at site 7. This appears to reflect differential porosity in clayey soils which was also noticeable in dug wells, from where the samples were collected. The second highest moisture content of 11.52%was determined at site-3.

In Gulshan-e-Iqbal town the lowest moisture 8.50% in the clayey soil was noted at site-3 which is far away from Lyari River. The highest moisture content of 12.50% was found at site-5. It appears logical and reflects to the impact of Lyari fluid effluents on the soil of site-5.

The town of Malir is not far from Malir River and is situated along the tributaries of the river. Site- 8 of the town showed the highest percentage of moisture, 16.25% and the lowest moisture content of 9.52% was noted at site-10, which is at a fairly larger distance from the tributaries. The erratic variations in percentage of moisture contents most probably reflect to lateral variation in soil type with respect to texture and relative percentages of fine fractions of sediments in addition to the impact of industrial effluents of Malir Industrial Trading Estate (MITE). The sewage outflows through the tributaries of Malir River also appear to be important contributors of moisture and pollution. The higher percentage of moisture at sites-8 appears logical.

Bulk Density

The bulk density of the samples of soil collected from different sites of the towns of Karachi was determined according ASTM-1556-90.

The bulk density of the top soil up to a depth of 5 feet varies in values between 1.83 and 1.91 gm/cm^3 at sites- 3 and 4 respectively in the central and southern part of SITE Town (Table 2).

Baldia Town is on the southward slope of the piedmont and the bulk density values of soils of this town ranges between 1.95gm/cm^3 at site-6 to a maximum of 2.26gm/cm^3 at site-9 which is in southern part of the town. The soil from the site-6 represents to the middle of the town. The tendency of decrease in bulk density value is well exhibited in the sample of site -6. In the southern part of the town the values of bulk density gradually increase and reach to a maximum of 2.26gm/cm^3 at site-9.

The soil samples collected from the sites of Orangi town showed variable bulk density values and range from 1.92 gm/cm^3 at site-8 to 2.10 gm/cm^3 at site-10 in the north west of this town. It is significant to note that the samples from middle of the town showed lower values of density than the marginal sides. This variation pattern appears to be related to the imperceptible creep of soil materials from the north to the south.

The bulk density values at different sites of New Karachi town varied between 1.91 to 2.10 gm/cm. The soils characteristics in different parts of the town are mostly clayey, silty sand and gravel. The highest value of bulk density 2.10gm/cm^3 noted at sites-1.It appears that the density values are related to the degree of heterogeneity in respect of grades which is considered as common factor for the increase in density.

In Jamshed town the bulk density values of soils range between 1.65gm/cm^3 at site-7 to 2.10gm/cm^3 at site- 8. It is significant to note that at most of sites in this town the bulk density ranges from 1.65 to 2.10gm/cm^3 which appear to be so because of the soil characters noted to be as mostly sandy gravel, silty sand and clay of low plasticity.

The town of Gulshan-e-Iqbal, situated on the left bank of Lyari River has the largest area among all the towns of the city. The lowest bulk density of soil, 1.94gm/cm^3 was noted at site-8 and the highest value of density, 2.12gm/cm^3 was at site-3. This is so most probably due to the dominance of silty clay of low plasticity.

In case of Malir the bulk density values at different sites range between1.70gm/cm^2 at site-8 and1.95gm/cm^2 at site-7. The values of bulk density appear logical however some degree of variation in the soil samples within the town can be expected from the local factors like the soil moisture relationship and the degree of compaction.

Table 2

Sr. No	Name Of Towns	Sites	Bulk Density (gm/cm^3)
1	SITE	3,4,6	1.83, 1.91, 1.85
2	Baldia	1,2,4,6,9	2.20, 2.18, 2.43, 2.41, 2.41
3	Orangi	2,3,8,10	2.02, 2.10, 1.92, 2.10
4	New Karachi	1,2,4,5,6,8	2.10, 1.92, 2.00, 1.95, 2.10, 1.91
5	Jamshed Town	3,7,8	1.98, 1.65, 2.10
6	Gulshan-e-Iqbal	3,5,8	2.12, 1.98, 1.94
7	Malir	2,7,8,10	1.85, 1.95, 1.70, 1.90

Bearing Capacity

The data of SPT resistance (N-Values) as an index value, indicates directly to the soil strength, has been borrowed from the geoservices companies like Soil Testing Services, Soil Mat and Geo-technical Services and are thankfully acknowledged. They have adopted ASTM designated D-1586 for determination of SPT test values of the building materials.

The values of bearing capacity have been described in Kilo-Pascal (Kpa) for the present work but foundation engineering companies in Pakistan prefer to describe bearing capacity values in Ton per square feet (TSF).

The bearing capacity values have been calculated with the help of bearing capacity factors like N-Values, depth and breadth of the foundation. For the present work depth of 1.523 m (5ft) and breadth of 10m (32.829 ft) were taken for all of the selected sites. The calculations of bearing capacity were made by using the following formula suggested by Bowell F.J (1996).

$$q_u = N/0.08\left(\frac{B+0.3}{3}\right)^2 (1+0.33\, D/B)$$

Where

q_u=Bearing capacity of foundation material
N=Numbers of Blows
B=Breadth of the foundation
D=Depth of the foundation
0.08, 0.3, and 0.33 are the constants

The bearing capacity determined for the foundation materials of SITE Town showed appreciable degree of variations in their values and range between 111.40 Kpa to 153.18 Kpa (Table 3). These variations in the values of bearing capacity fairly indicate to the variable degree of compaction of the soil being subjected to variable moisture contents and this variation in the density of the soil is also prominently indicated by the N-values which showed positive correspondence with the values of the bearing capacity.

Baldia Town indicated the highest bearing capacity value of 236.73 Kpa at site-9 and the lowest value of 181.03 Kpa at site-6. The N-values in the sites of this town were corresponding appreciably to the bearing capacity values.

In Orangi Town the foundation materials showed significant variation in the values of bearing capacity at sites-2, 3,8 and 10 due to human activities and industrial urbanization.These values range between 181.03Kpa and194.95Kpa. In New Karachi Town the highest value of bearing capacity was found to be 194.95 Kpa at sites-1 and 6,and the lowest value of 167.10 Kpa at sites- 4 and 5 nearly in the middle of the town. Jamshed Town showed fairly high values especially at site-8(208.87Kpa). The lowest value of bearing capacity (83.55 Kpa) was noted at at site-7 not far from the border of Gulshan-e-Iqbal Town. The lowest value of bearing capacity appeared to be because of the higher clay fractions in the soil samples which are further supported by the shearing strength value of the sample (36 Kpa).

The values of bearing capacity noted at sites-3,5and 8 of Gulshan-e-Iqbal Town were 208.87Kpa, 181.03Kpa and 208.87Kpa.

Malir Towns showed erratic values of bearing capacity at different sites of the towns and the degree of heterogeneity in respect to geotechnical characteristics is prominent. The bearing capacity values range 167.10Kpa to 83.00Kpa in the soils of this town.

Atterberg limits

In this case ASTM-D4318 has been adopted for the determinations of the Atterberg limits. The plasticity index, which shows the difference between liquid limit and plastic limit, has been determined and assessed the degree of sensitivity of the clayey soil in different towns of Karach . In some of the towns the clay fraction is totally absent. In others few sites of the towns showed the presence of clays in large percentages. This is most probably due to changes in geomorphic expressions and the impact of the rivers Lyari and Malir.

Table 3

Sr.No	Name Of Towns	Sites	Bearing Capacity (Kpa)
1	SITE	3,4,6	111.40, 167.10, 153.18
2	Baldia	1,2,4,6,9	208.87, 194.95, 193.95, 181.03, 236.73
3	Orangi	2,3,8,10	181.03, 194.95, 167.10, 194.95 00,
4	New Karachi	1,4,5,6,8	194.95, 167.10, 167.10, 194.95, 167.10
5	Jamshed Town	3,7,8	181.03, 83.55, 208.87
6	Gulshan-e-Iqbal	3,5,8	208.87, 181.03, 208.87
7	Malir	2,7,8,10	125.33, 167.10, 83.0, 167.10

Table 4a

Sr.No	Name Of Towns	Sites	Liquid Limit (%)
1	SITE	3,4,6	34.6, 30.8, 35.4
2	Baldia	1,2,4,6,9	49.0, 42.0, 35.0, 38.0, 35.0
3	Orangi	2,3,8,10	48.0, 36.0, 33.0, 50.0 00,
4	New Karachi	1,2,4,5,6,8	32.5, 26.7, 33.5, 32.6, 36.5, 32.5
5	Jamshed Town	3,7,8	31.0, 22.0, 30.0
6	Gulshan-e-Iqbal	3,5,8	32.0, 27.0, 25.6
7	Malir	2,7,8,10	24.0, 28.0, 32.5, 36.4

Table 4b

Sr.No	Name Of Towns	Sites	Plasticity Index (%)
1	SITE	3,4,6	11.7, 9.9, 14.2
2	Baldia	1,2,4,6,9	21.0, 17.0, 12.0, 14.5, 11.2
3	Orangi	2,3,8,10	22.0, 12.0, 10.0, 23.0 00,
4	New Karachi	1,2,4,5,6,8	10.3, 5.4, 10.5, 9.6, 12.6, 10.0
5	Jamshed Town	3,7,8	9.5, 13.0, 12.0
6	Gulshan-e-Iqbal	3,5,8	9.3, 9.0, 4.9
7	Malir	2,7,8,10	8.0, 9.0, 10.0, 11.6

The SITE Town situated on lower part of pediment showed clayey soil fractions at sites-3, 4 and 6 .The liquid limits (Table 4a) estimated for these three sites are 34.6%, 30.8% and 35.4%, respectively, which are less than 50% and are considered as lower values of liquid limits. Similar is the case of plasticity indices (Table 4b) of these samples which showed the values of11.7%, 9.9% and 14.2% respectively and indicated to low sensitivity or plasticity.

In Baldia Town the fine fraction ranges between 97% and 58%. The higher percentages of fine fractions (>58%) were noted in most of the samples collected from different sites of this town due to the development of soils from Gaj Shales of Miocene age which formed the pediment. The liquid limit percentages in the samples were noted to be between 35% at sites-4 and 9 to a maximum of 49% at site-1.The plasticity indices varied between 21% at site-1 and 11.2% at site-9. The percentages of plasticity index reflect variations in plasticity or sensitivity from nearly high to low.

The sites of Orangi Town also showed great variations in the percentages of fine fractions. The variations in percentages of fines range between 97% at site-10 and 58 % at site-8 and represent to the upper northern part of the town. .The possible causes of higher percentages of fine fractions can be attributed to local factors as in adjacent Baldia Town. The liquid limit percentages vary between 33.00% at sites- 8 and 50.00% at site-10. Plasticity Indices are also fairly high at sites-2, 9 and 10. The town of New Karachi in the northern most part of the Karachi city is situated on the right bank of River Lyari. In this town fine fractions showed a fairly higher percentages of fines and range from 84.60% at sites- 6 and 56.1% at site-8.The sites showing higher percentages of fine fractions (<50%) exhibited liquid limits in the range of 36.5% to 32.5% at sites-6 and 4 respectively. The geographical location of this town on down slope of pediment may be the cause of higher percentages of fine fractions in the soil samples. Plasticity Index values range between 12.6% at site-6 and 5.4% at site-2. It is inferred from the plasticity index values that the soils are not of plastic or sensitive nature. The soil samples of most of the sites of this town were classified on the basis of classification chart of plasticity (Casagrande, 1948), as clayey soil of low plasticity (CL).

Jamshed Town situated in the land between rivers Lyari and Malir, showed a wide variation in the percentages of fines, it ranges between 84.00% at sites-7 and 60.00% at site-3. The distributions of the fine fractions in the soil samples of the sites generally reflect lower percentages at the sites adjacent to rivers Lyari and Malir. The higher percentages of fines were found in the middle of the town which may be attributed to river action at the border region of the town. .The samples from sites-3,7 and 8 showed

liquid limits 31.00%,22,00%,and 30.00% respectively.. The plasticity indices were noted to be 9.5%, 13% and 12.00% at sites-3,7and 8 respectively and reflect to low plastic

The samples of Gulshan-e-Iqbal Town showed erratic variations of fine fractions between77.20%, 89.00% and 49.20% at sites-3,5 and 8 respectively . The variations in liquid limit range between 32% at site -3 to 25.60% at site-8. Likewise the plasticity indices also showed a very low values ranging between 9.30% in sample -3 to 4.9% in sample-8. These values are the indicators of low sensitivity of the soils.

The soil samples from Malir Town also showed erratic values in percentages of fines .It ranges between 88.30% at site -10 to 57.00% at site -7. The sites-2,7,8 and 10 showed liquid limit values in the range of 36.40% to24.00 % and were grouped as the soils of low liquid limits percentages. Similarly the plasticity index which has the values in the range of 11.60% to 8.00% represent to low sensitivity of the soil of the localities.

Unconfined Compressive Strength

The Unconfined Compressive Strength of the fine grained cohesive soil understudy have been determined and described according to ASTM D-2166-85. In this connection the guidelines for Unconfined Compressive Strength of cohesive soil (Table 5) recommended by Terzagi and Peck, 1948, have been followed. The present data of unconfined compressive strength in Kilo pascal (Kpa) obtained from the samples of the towns are expected to give an overall assessment so far as the response of clays to civil structure load imposition is concerned.

Table 5. Guidelines for Unconfined Compressive Strength of Cohesive Soils

Unconfined compressive strength (Kpa)	Consistency
<23.9	Very soft
23.9-47.88	Soft
47.88-95.76	Medium
95.76-191.52	Stiff
191.52-383.04	Very stiff
>383.04	Hard

In SITE Town, the clayey samples were noted only at sites-3, 4 and 6 .The values of unconfined compressive strength (qu) were noted to be 96.00, 164.00, and 150.00 Kpa respectively (Table 6) and with reference to consistency, the soils were grouped as stiff clays.

In Baldia Town the soils of sites-1, 2, 4, 6 and 9 showed the presence of clayey soils as the foundation material. The values of unconfined compressive strength in samples ranged between 196.00 to 166.00 Kpa. According to the values of unconfined compressive strength, the soil samples of above sites were classified as stiff. The unconfined compressive strength value of soil sample of site 9 also indicates very stiff consistency (196.00 Kpa) .Most probably the stiff conditions of the clayey soil of the sites-1, 2, 4, 6 and 9 is due to the movement of the soil on the piedmont slope. This action most probably affected the density of the soil and hence the values noted at different sites appear to be good indicators of the soil conditions with respect to the density of the foundation material.

The soil samples of Orangi Town mostly developed on Gaj Shales alternating with Limestone showed the development of clayey soils at sites-2, 3, 8 and 10. These soils, showed unconfined compressive strength values of 178.00 Kpa at site- 3 to 152.00 Kpa at site- 8.According to these values the soils are classified as stiff.

In New Karachi town the sites-1, 4, 5, 6 and 8 represent to the western side of the town show the presence of clayey soils as a result of soil creep from the north to south. The values of unconfined compressive strength noted in the sample of the sites mentioned above range between 196 Kpa and 150 Kpa. According to the values obtained, the consistency of the soil samples of site-1 was very stiff whereas samples from sites- 4, 5, 6 and 8 showed their consistency as stiff.

The Jamshed Town is in between left bank of River Lyari in the northwest and at right bank of River Malir in the south west. The soils at sites-3, 7 and 8 are clayey in nature. The unconfined compressive strength of the samples of sites- 3, 7 and 8 were noted to be 166.00, 72.00 and 192.00 Kpa respectively .The impact of the rivers which brought the load of fluvial deposits is quite evident. The soils were found to be stiff at site- 3, medium at site-7 and very stiff at site- 8.

Table 6

Sr.No	Name Of Towns	Sites	Unconfined Compressive Strength (Kpa)
1	SITE	3,4,6	96.0, 164.0, 150.0
2	Baldia	1,2,4,6,9	188.0, 176.0, 180.0, 166.0, 196.0 00
3	Orangi	2,3,8,10	164.0, 178.0, 152.0, 174.0 00,
4	New Karachi	1,2,4,5,6,8	196.0,--, 154.0, 150.0, 184.0, 154.0
5	Jamshed Town	3,7,8	166.0, 72.0, 192.0
6	Gulshan-e-Iqbal	3,5,8	194.0, 170.0, --
7	Malir	2,7,8,10	110.0, 152.0, 74.0, 150.0

The Gulshan-e-Iqbal Town represents to the largest town of the city which was developed and populated in the years seventies and eighties along the right bank of River Lyari. In this town the soils of sites- 3 and 5 classified as clayey soil of low plasticity (CL) showed their unconfined compressive strength (qu) in the range of 194.00 Kpa and 170.00Kpa respectively. The consistency of the soils of the sites-3 and 5 was noted to be very stiff and stiff respectively.

The samples of the four sites of Malir Town namely sites-2, 7, 8 and 10 appeared clayey soil of low plasticity (CL). The unconfined compressive strength values of these samples were noted to be 110.00, 152.00, 74.00 and 150.00 Kpa respectively. The consistency values indicate medium at site 8 and stiff at sites-2, 7 and 10 situated on the western side of the town.

Shear Strength

Soils like any other material fail at some point when they are subjected to increasing shear stresses. They cannot resist shear stress larger than their shear strengths. Deformation in soils takes place when the applied shear stress exceeds their shear strength. Shear strength is very important property, because the bearing capacity of foundation, earth pressure on retaining walls and the stability of slopes are directly dependent on the shear strength of the soil. Shear strength is not constant for a particular soil type. Deep in the ground the soil is stronger than it is near the surface, because the strength is dependent on the confining pressure coming from the layers above. Shear strength were determined with the help of Direct Shear Box Test (ASTM-D3080-90). The shear strength formula mentioned below was followed for the determination of the shear strength values in the soil samples under study.

$$S = C + \sigma \tan \phi$$

Where:

S = shear strength.

C = cohesion intercept.

б = normal stress on shear plain.

Φ = angle of shearing resistance or friction angle.

The un-drained shear strength (Su) of a cohesive soil or clayey soil is equal to one-half of the unconfined compressive strength (qu) provided the angle of friction is zero. The most critical condition for the soil usually occurs immediately after the construction which represents un-drained conditions when the un-drained shear strength is basically equal to the cohesion.

$$Su = C = qu/2$$

Su=un-drained shear strength

C=cohesion intercept

qu=unconfined compressive strength.

For the shear strength of cohesive soil, the values recommended by McCarthy (1998) have been adopted for the present work (Table 7).

Table 7. Undrained Shear Strength of Clayey Soil when the Angle of Shearing Resistance is Zero

Relative Condition of Soil	Approximate Cohesion, C, KN/m^3 (Kpa)
Soft	12-24
Medium	24-48
Stiff	48-96
Very Stiff	96-190
Hard	>190

The soil samples collected from SITE Town of the city showed some erratic shear strength values of the foundation materials especially at sites-3, 4 and 6. Most probably it is so because of untrained clayey soil where the angles of friction were taken as 0o .The values in Kilo pascal (Kpa) of these three sites are 48, 82 and 75 (Table 8) respectively which represent to stiff soils showing higher degree of cohesion. Cohesive or clayey soils were mostly reported from the northern side of the town.

In adjacent Baldia Town, the sites-1, 2, 4, 6 and 9 showed undrained clayey soils and exhibited higher degrees of shear strength. The shear strength of cohesive soils was found to be relatively higher as compared to the adjacent town of SITE. The possible reason which could be attributed in this connection is due to the exposure of the rocks of Gaj Formation exhibiting alternate beds of argillaceous limestone and shale. The shear strengths of the clayey soil samples range between 93KPa to 83KPa.

The samples of Orangi Town developed on Gaj Limestone and shale, showed clayey soils of low to medium plasticity at sites- 2, 3, 8 and 10 where the angles of friction were taken as 0o. In this town smaller exposures of argillaceous limestone and shale of Gaj Formation are still exposed and subjected to active weathering due to human activities related to cutting and leveling of the ground for the construction of houses. The shear strength values of soil samples of sites- 2, 3, 8 and 10 ranges between 89KPa to 76KPa.

Table 8

Sr.No	Name Of Towns	Sites	Shear Strength (Kpa)
1	SITE	3,4,6	48.0, 82.0, 75.0
2	Baldia	1,2,4,6,9	94.0, 88.0, 90.0, 83.0, 98.0 00
3	Orangi	2,3,8,10	82.0, 89.0, 76.0, 87.0 00,
4	New Karachi	1,2,4,5,6,8	93.0, 30.25, 77.0, 75.0, 92.0, 77.0
5	Jamshed Town	3,7,8	83.0, 36.0, 96.0
6	Gulshan-e-Iqbal	3,5,8	97.0, 85.0, 30.41
7	Malir	2,7,8,10	55.0, 76.0, 37.0, 75.0

The soil samples from the sites of 1, 4, 5, 6 and 8 of New Karachi Town showed clayey soils of low to medium plasticity. Their shear strength values range between 93.0Kpa to 75.0Kpa. The sites of clayey soils are mostly on the upper western part of the town, fairly away from River Lyari. The clay fractions of the soils seem to have the source similar to the soils of Orangi and Baldia Towns which developed on piedmont sloping southward.

In Jamshed Town the sites-3, 7 and 8 showed clayey soils of low to medium plasticity and hence the angles of friction were taken as 00. The shear strength values of these sites were noted to be 83, 36 and 96Kpa respectively.

Gulshan-e-Iqbal Town which is relatively younger in its development and population setting showed clayey soils of low to medium plasticity. At sites-3, 5 and 8 the shear strength values to be noted were 97, 85 and 30.41Kpa respectively.

In case of Malir Town the sites-2, 7, 8 and 10 showed clayey soils of low to medium plasticity. The shear strength values of these sites range between 76.0Kpa to 37.0Kpa.

Activity of Clays

Activity is a measure of the property of clay to swell in the presence of water and is used to identify expansive clays. According to Skempton, 1953, the activity is the ratio of the plasticity index to the percentage of the material finer than 0.002mm .It gives an indication of the plasticity of the clay sized portion of the soil. High activity values are associated with those clay minerals that can absorb large amount of water within their mineral lattices.

According to Mitchell et al (2005) the activity of kaolinite is low (0.5). illite has medium (1- 0.5) and montmorillonite has high activity (7-1). Skempton is of the opinion that the presence of cation like Ca and Na do affect the activity of the clays, for example montmorillonite becomes more active if Na dominates (activity=7.2) as compared to Ca(activity =1.5) but in illite and kaolinite no such differences were noted in the activity.

This property could be determined only in those soil samples of study area which showed more than 50% clay fractions. The activities of clays were evaluated with the help of activity (Table 9) recommended by Skempton, (1953) and Mitchell, (1993).

Table 9: Activity of clays

Description	Activity
Inactive	< 0.75
Normal	0.75-1.25
Active	1.25-2
Highly active	>2
(e.g., bentonite)	6 or more

This study was carried to investigate the capability of swell and shrinkage of clays due to leaking or loosing of water, depending upon the environmental conditions at sample sites.

In SITE Town the values of activity could only be determined in the soil samples of sites-3, 4 and 6. Clayey soil of sites-3 and 4 showed activity values of 0.68 and 0.61 respectively which are less than 0.75 and therefore noted as inactive clayey soils. The activity value of site-6 is more than 0.75 and taken as soil of normal activity. The clayey soils of sites-3 and 4 indicate to the presence of illitic component of the soils (Table 10).

The samples from different sites-1, 2, 4, 6 and 9 of Baldia Town showed the activity values between 0.57 and 0.50 and are considered as inactive clays.

In Orangi Town the values of activity were observed in the samples of sites-2, 3, 8 and 10. The values of activity range between 1.7 in sample from site-10 and 0.48 in sample of site-3, which indicated to the presence of inactive soil mostly of illitic nature except at site-10 which showed significantly higher value of activity (1.27). Most probably the clay fraction indicates to montmorillonitic composition. It appears that the demographic effects due to varying density of population, the outflow of water through poor civic drainage and water lines in addition to the surface flow of used water are the sources which caused chemical action on argillo-calcareous soil. The concentration of illitic soil in general and montmorillonitic only at site-10 most probably indicates to the lower pH values with some exceptions. It can also be anticipated that the montmorillonite was derived from the weathering of argillaceous limestones deposited in calm alkaline marine environment.

Table 10. The Sites of the Towns where Clayey Soils were found and Activities were determined.

Sr.No	Name Of Towns	Sites	ActivityValues (%)
1	SITE	3,4,6	0.68, 0.61, 0.78.
2	Baldia	1,2,4,6,9	0.57, 0.51, 0.50, 0.55, 0.50.
3	Orangi	2,3,8,10	0.59, 0.50, 0.48, 1.27
4	New Karachi	1,2,4,5,6,8	0.66,0.40,0.57,0.53,0.36,0.47
5	Jamshed Town	3,7,8	0.71,0.54,0.52
6	Gulshan-e-Iqbal	3,5,8	0.47,0.40,0.40
7	Malir	2,7,8,10	0.50,0.45,0.45,0.48

The soils of New Karachi Town were mostly of clayey nature. The values of activity range between 0.66 at site -1 to 0.36 at site-6 of the town. All these values reflect to inactive clayey character and are mostly illitic or kaolinitic in composition.

In Jamshed Town the soils showed fine fractions to a maximum of 84.00% at site-7 whereas 60% and 81% at sites-3 and 8 respectively. In these samples the activity values calculated were 0.71, 0.54 and 0.52 and represent to inactive types of clay of illitic or kaolinitic composition. In Gulshan-e-Iqbal Town site- 3, 5 and 8 show 71.2%, 80.0% and 46.9% of fines fraction in soil samples respectively. In these samples the activities values were 0.47, 0.40 and 0.40 were reported respectively and which indicate the presence of inactive clayey soil mostly of illitic nature.

The sites- 2, 7 and 8 of Malir Town showed fine fractions as 61.0 %, 57 % and 62.1 % respectively and were considered for activity determination. The values of activity obtained in samples of sites-2, 7 and 8 lies between 0.50 and 0.45 and the clayey soils were considered as inactive.

Swelling Potential

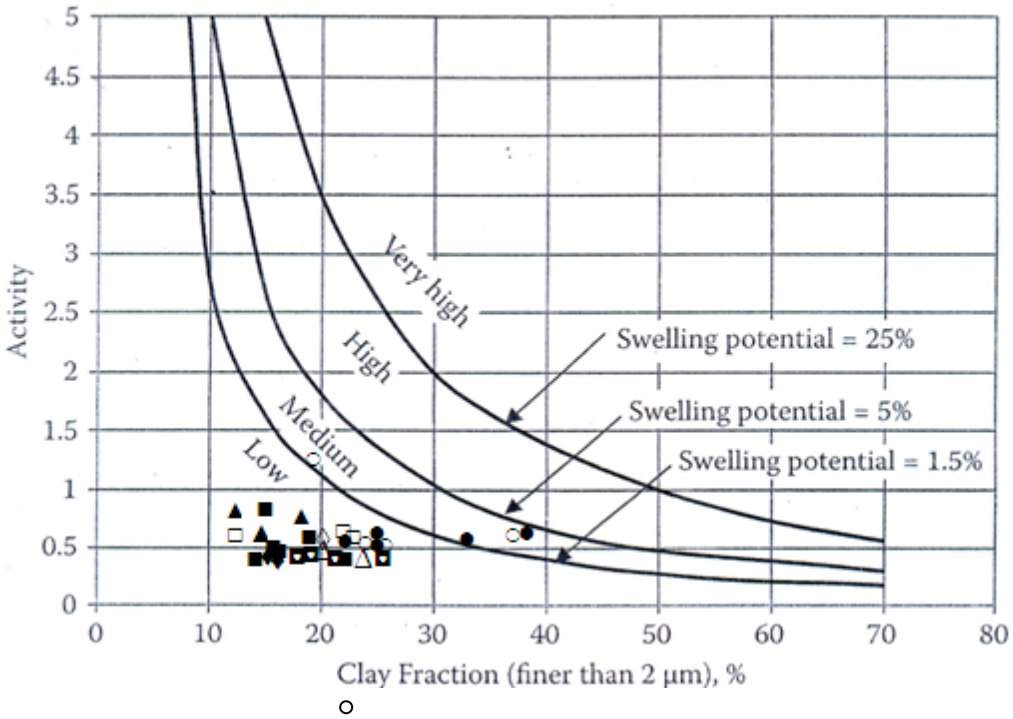
Swelling potential in expansive soils shows a marked volume change with increase and decrease of moisture content. The swelling and ground heave are caused in areas where prevailing climatic conditions show seasonal wetting and drying. The greatest seasonal heave occur in region of semi arid climate like Karachi where short wet and long dry period leads to significant changes in soil moisture contents. The activity of man such as removal of vegetation for construction work, leaking and seepages from poorly constructed water and sewage lines affect the moisture percentages in the expansive soil and need to be investigated thoroughly because they affect the foundation materials significantly with respect to consolidation and settlement types. The heterogeneity in soils with respect to clay minerals also needs to be investigated so that the shrinkage and swelling characteristics could be determined thoroughly. The higher the activity and clay fraction, the higher will be the swelling potential of the clayey soil.

For the present work the swelling potential percentages and the terminologies used are after Carter and Bentley, 1991(Table 11).

Table 11. Descriptive Terms for Swelling Potential

Swelling Potential (%)	Description
0-1.5	Low
1.5-5	Medium
5-25	High
25+	Very high

The plots of activity of clayey soil samples against finer fractions of the soils understudy revealed low potential in case of most of the samples. However, some of the samples from the towns of Baldia, Orangi and New Karachi showed medium values of swelling potential and range from 5 to1.5% (Fig 2).



SITE▲ BALDIA● ORANGI NEW KARACHI ■ JAMSHED □ GULSHAN-E-IQBAL Δ MALIR ◘

Figure 2. Classification chart for swelling potential. (After Seed, H.B., Woodward, R.J., Lundgern, R. 1962).

CONCLUSION

The variations in geotechnical characteristics of clayey soils appear to be affected by the types, density and the industrial activities of the populations, which produce chemically active fluid effluents of both civic and industrial origins. The penetration and percolation of the fluids through the soil column decomposes the calcareous soil fractions due to poor management of discharge of fluids though natural or manmade unlined channels. Consequent to this effect, fine fractions are increased in soil column in proportion to the chemical activities between the effluents and the soils. Such chemical actions and their effects can be observed in the soils of the towns like SITE, Baldia, Orangi, New Karachi, Jamshed, Gulshan-e-Iqbal and Malir.

Variable percentages of soil moisture between the localities and also among the towns are related mostly to the fine fraction of the soils, which retain water due to higher degree of porosity and lower degree of permeability and also to the amount of fluid effluents discharged improperly.

The penetration and percolation of the effluents through the soil columns appear to have ultimately affected the texture of the soils due to poor fluid outlet management system.

The shear strength and bearing capacity revealed variable degrees of strength and load taking capacity of the soils in the towns.

The present observations are similar to that of Hamid et al (1997) who studied the natural moisture content, specific gravity and bulk density of the soils of Taiser Town of Karachi and concluded that the soils were suitable for medium size civil structures. However the modern foundation designs may provide opportunities for the construction of huge civil structures as per building code of the city management.

Immediate attention to be paid to pollutants treatment devices should be adopted to avoid the negative impacts on geotechnical properties of soils

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