Geotechnical Characteristics of Subsoil for Different Sectors of Islamabad

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Abstract

Geotechnical site investigations are essential in determining subsoil stratigraphy and soil strength and is considered mandatory for the design of foundations. This study presents the generalized profiles for subsurface stratigraphy and insitu soil strength (average SPT N values) for different sectors of Islamabad on the basis of wide-ranging experimental work carried out by several agencies in field and laboratory testing carried out at the number of locations in the study area. Data from 208 geotechnical site investigations of Islamabad have been collected and subsurface profiling for those sectors is carried out that had more than four data points. The experimental data of the study area has shown potential for development of profile map for 11 different sectors of Islamabad using data of 144 geotechnical site investigations. Generalized soil profile and average SPT N values for each sector have been generated to a depth of 7m which is considered sufficient for lightly loaded structures with shallow foundations. Average SPT N value profile coupled with soil stratigraphy for each zone is established that can use to determine shear strength parameters and bearing capacity of soil using SPT-based empirical correlations. The generalized soil profiles will be helpful during feasibility study and planning geotechnical site investigations for mega projects and can also be used to determine engineering properties of subsoil for small scale projects.

Keywords: Soil Stratigraphy, SPT Statistics, Foundation design, Geotechnical Site Investigations.

Introduction

Geotechnical site investigations are an important part of the planning and designing for underground construction/other structures. The subsoil profiling and determination of hydrological and engineering properties of soil can be facilitated by developing generalized soil profiles and establishing Geotechnical Zonation Maps (GZMs). The GZMs and sub-soil profiling will help in the preliminary design of foundations, feasibility study and planning of detailed geotechnical site investigation (Ahmad et. al. 2013). In past few years, the number of construction projects has increased, therefore, these generalized soil profiles can be used for the design of small residential buildings whereas detailed geotechnical site investigations may be required for large-scale projects. Suwanwiwattana et. al. (2001) used Geographic Information System (GIS) to develop a geotechnical database for Bangkok soil. Ahmad et. al. (2013) and Kamal et. al. (2015) used geotechnical data to develop GZMs for Peshawar and Faisalabad soil respectively. This study aims to develop GZMs for Islamabad soil (Capital of Pakistan). With an increasing number of major projects on the horizon, there is a need for the development of subsoil stratigraphy and average shear strength that can be used for preliminary designing of structures. Hence this study is more relevant and has wide range practical applications.

Description of the Study Area

The study area lies between 72°45′ and 73°30′ Easting and 33°30′ and 33°50′ Northing in the foothill of Margalla. The region has historically been a part of the crossroads of Punjab and Khyber Pakhtunkhwa with the Margalla Pass acting as the gateway between the two regions. The rapid growth of population in the study area has made ever-increasing demands on natural resources and Potential problems for administration authorities. The number of construction projects is increasing rapidly, therefore, the use of GMZs will help in reducing cost and time for geotechnical site investigations. In this study, subsoil profiling is carried out for developed and developing sectors of Islamabad (e.g F-6, D-17, G-13 etc.). The boundaries of sectors are marked by Capital Development Authority (CDA) and named alphabetically. A master plan with boundaries of each sector is shown in Figure-1. The study is divided into 55 sectors (residential, educational, recreational and industrial). The research study is designed to prepare sub-soil profile, GZMs and to furnish sufficient necessary reliable data regarding percentage of soil class distribution, classification characteristics and insitu soils strength (SPT N values) in the selected under study area of the Islamabad. This research work will assist the geotechnical and civil engineers beforehand to plan the detail geotechnical investigation based on the provided sub-soil profile and GZMs.

Geology of the Area

The study area has significant variation in its terrain such that the elevations differences may reach up to 1175m. The site The Margalla hills, Kala Chitta, outer and lower Himalaya's ranges are main geological features of the study area. Some ridges may reach a height of 1600m with complex thrust and folded shales and limestones (Arshid et. al. 2013).

Seismo-Tectonic settings of the Area

The bedrocks in Islamabad are highly faulted, folded and overthrust due to the uplifting of Himalaya in Pliocene epoch. Main Boundary thrust is the main fault (Figure 2) that is widely fractured and some epicenters of the earthquake are also situated on this

http://dx.doi.org/10.24949njes.v11i1.179

fault. The area is a part of active Himalayan foreland – fold and thrust belt region in the collision zone between Indo-Pakistan and Eurasian plates (Ahmad et. al. 2005). The area has a good history of earthquakes in the past. In A.D. 25, an earthquake estimated of intensity IX destroyed the ancient city of Taxila that is located some 25km from the study area (Arshid et al., 2013). The October 8, 2005, earthquake with recorded magnitude of 7.9 on Richter scale caused vast destruction in Northern parts of the country and also caused the collapse of a residential plaza in the study area (Ali et. al. 2015). According to Building Code of Pakistan (BCP, 2007), the project sites lies in seismic zone 2B with a maximum PGA value of 0.24g.

Geotechnical Database

For this research, data from 208 geotechnical site investigations from different sites at scattered locations throughout the study area were collected and are considered enough to develop a generalized soil profile. The data collected from these locations contained a detailed record of Standard Penetration Test (SPT) blow counts (N) values, soil classification, soil stratigraphy, sub-soil characteristics for top 7m subsoil. Each data point was marked with the help of earth point on Google map using coordinates of particular borehole. A base map indicating the location of data points is shown in Figure 3.

For a selection of a zone fit for profiling a benchmark of minimum four data points was established. Sectors containing less than four data points were discarded and they can be included in the future study based on the availability of data. Based on available data subsoil generalized profiles for 11 sectors of Islamabad have been generated. The available data points for each sector are shown in Table 1.

Insitu Soil Strength

Standard penetration test (SPT) is most widely used insitu test performed all over the world to determine insitu shear strength of soil. The same is also used to determine bearing capacity of sandy soils. Therefore, the average SPT profiles for each sector is established and s shown in Figure 4. The chart shown in Figure 4 presents a variation of SPT blow count with depth for each sector and can be used to determine engineering properties (e.g. bearing capacity, shear strength parameters, unit weight etc.). The SPT blow counts are averaged to a depth of 7m below ground surface and is considered sufficient for the design of lightly loaded structures with shallow foundations.

The average SPT blow counts increase with depth for all sectors indicating an increase in shear strength and bearing capacity of soil with depth. An important aspect of geotechnical site investigation is the determination of fill material in the study area. The same is determined with the help of available SPT data. The low-lying sectors of Islamabad with respect to M.S.L have high values of SPT blow counts and gives an indication that these sectors were developed on cut areas of Islamabad and for sectors that were developed by placing fill material have shown low SPT blow counts (Figure 4). However, it is also important to mention here that the fill material cannot be regarded as uncompact fill material because the buildings (low to high rise) have not shown any sort of settlement cracks. The presence of nullah's in the study area is also a major factor in the reduction of soil strength of subsurface strata. Areas, where these nullahs were flowing in the past, have lower values of SPT blow count due to the presence of high moisture content and loose deposits of silt and clay.

Soil Stratigraphy

The subsoil profiling/stratigraphy is established using data from numerous geotechnical site investigations. The classification of soil was based on Unified Soil Classification System (USCS). The soil stratigraphy is established for 11 sectors of Islamabad and other sectors were ignored due to the availability of limited data. The stratigraphy was developed for these sectors to a depth of 7m below NSL and is shown in Table-2. The soil stratigraphy is represented in percentage of total area. Table 2 suggests that subsurface strata of Islamabad are mainly covered with layers of lean clay (CL) in medium stiff to stiff insitu state. The presence of silt, gravel and sand are also observed in quiet good percentage.

Discussion on Results

The summary of results for each sector is discussed below;

- The average SPT N values for the D-17 sector are very high ranging between 18-35 and increasing with depth. More than 60% of the area is covered with lean clay (CL) deposits. Silt is present in approximate 18% of the area to a depth of 5m below NSL. Deposits of gravels are found at deeper depths i.e. beyond 5m.
- The SPT N values for E-11 sector increase linearly with depth and ranges between 12-24. The area is mainly covered with two distinct soil types i.e. lean clay and gravel deposits with varying percentages of fine-grained soil. A greater percentage of granular material is present at deeper depths.
- The average SPT N values for the F-6 sector are generally low in top 2m depth i.e. ≤ 8. However, these increase significantly to a depth of 6m and thereafter SPT refusal was recorded. The area in general consist of fine-grained soil (silt and clay) underlain by granular soil deposits (sands and gravel). Granular soil deposits dominate the general area at depths > 2m mixed with varying percentages of fine-grained soil. Low SPT blow counts in top 2m subsoil can be attributed to the presence of fine-grained soil while SPT refusal

at a depth ≥ 6m is due to the presence of granular soil deposits.

- The average SPT N values for the F-7 sector are generally low in top 2m depth i.e. ≤ 7. However, below this depth high values of SPT blow counts, i.e. 40 are recorded in several based on results of 4 geotechnical site investigations. The subsoil of this area generally consists of two soil types i.e. lean clay (CL) and poorly graded gravel (GP). Lean clay is present in top 2m of subsoil while gravel covers 25% of the area below 2m depth.
- The average SPT N values for the F-8 sector are very low ranging between 7-15 and slightly increase with depth. The subsoil for the whole sector consists of lean clay to a depth of 7m.
- The average SPT N values for F-11 sector range between 12-21 and increase with depth. The subsoil generally consists of lean clay and clayey sand. 74% of the area is covered with lean clay in medium stiff to stiff insitu state. While 26% of the area is covered with clayey sand in medium dense to dense insitu state.
- The average SPT N values for G-8 sector range between 14-20 and almost remain consistent with depth with a slight increase at 7m depth. The area in general consists of lean clay, clay with silt and poorly graded gravel.
- The average SPT N values for the G-11 sector are high and range between 24-31. The SPT N values increase to a depth of 5m and thereafter show a slight reduction. The subsoil consists of lean clay and poorly graded gravel. Lean clay cover 70% of the area with thin films of silt at some locations while resting 30% area consists of gravel.
- The average SPT N values for the G-13 sector are high and increase linearly between 15-29. The subsoil consist of lean clay (up to 67% of area) and gravelly soil deposits (clayey gravel and poorly graded gravel with silt).
- The average SPT N values for the G-15 sector are high and vary between 14-33 and increase with depth. The area in general mainly consists of fine-grained soil (i.e. clay and silt). Clayey sand covers 10% of the area to a depth of 5m below NSL underlain by clayey gravel.
- The average SPT N values for I-8 sector vary between 6-17. The SPT N values are generally low in this sector compared to other sectors. The subsoil consists of lean clay and silt to a depth of 7m below NSL. The reason that can be attributed to low SPT blow counts is the presence of fine-grained soil strata till a depth of investigation.
    - The top 4m subsoil consists of lean clay and clay with silt while poorly graded soil is present at a depth of 4-7m in 22% of the area.
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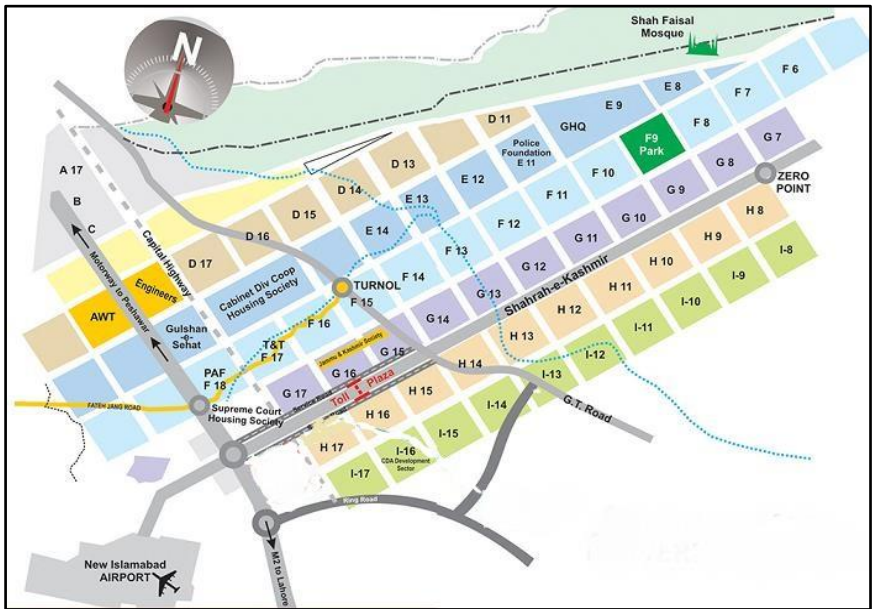


Fig 1: Master plan of Islamabad indicating different sectors (CDA,2014)

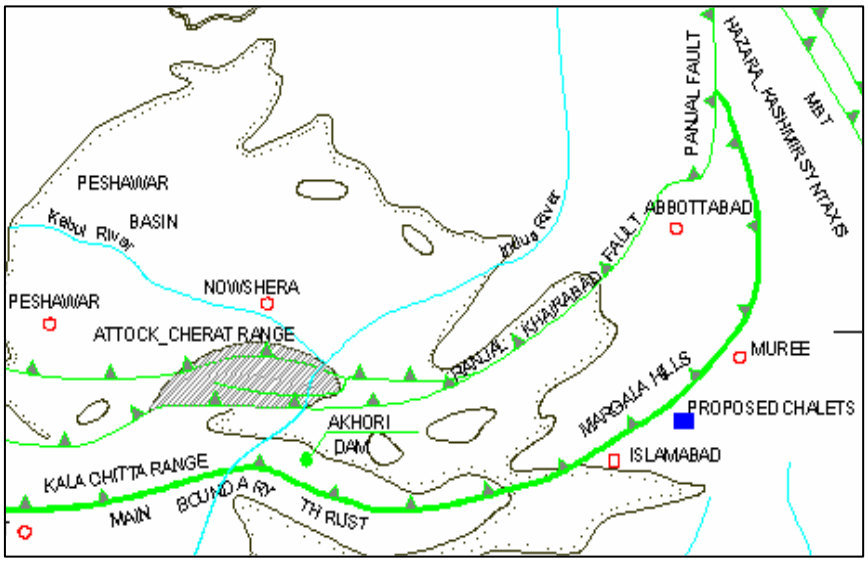


Fig 2: Tectonic setting of the area

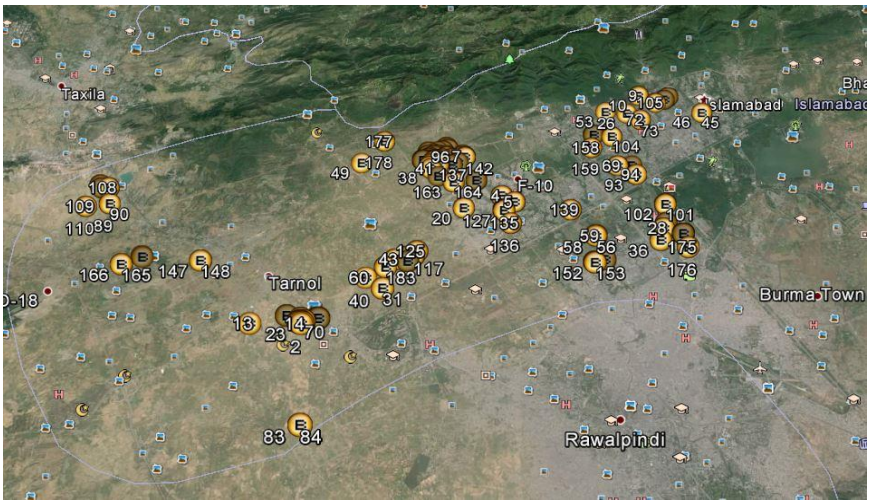


Fig 3: A Base Map for location of Boreholes

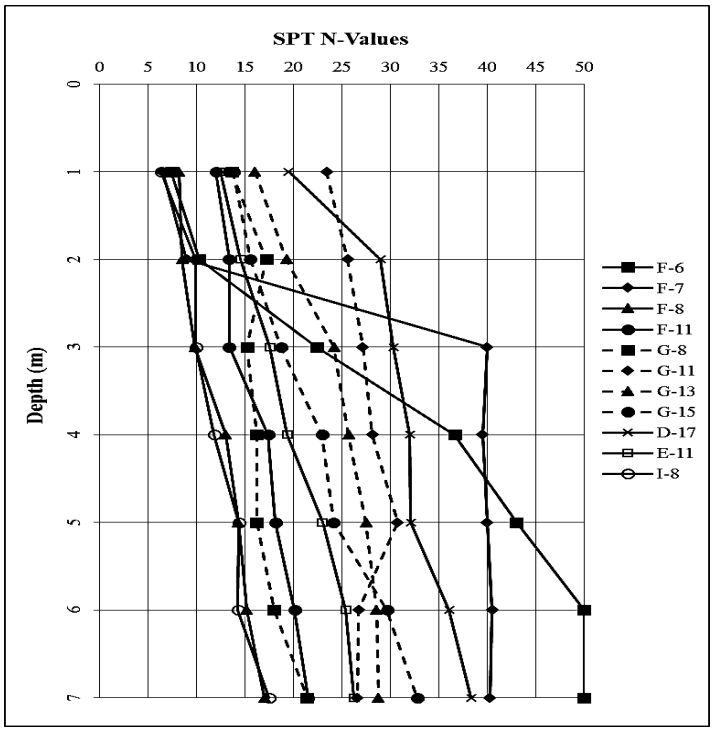
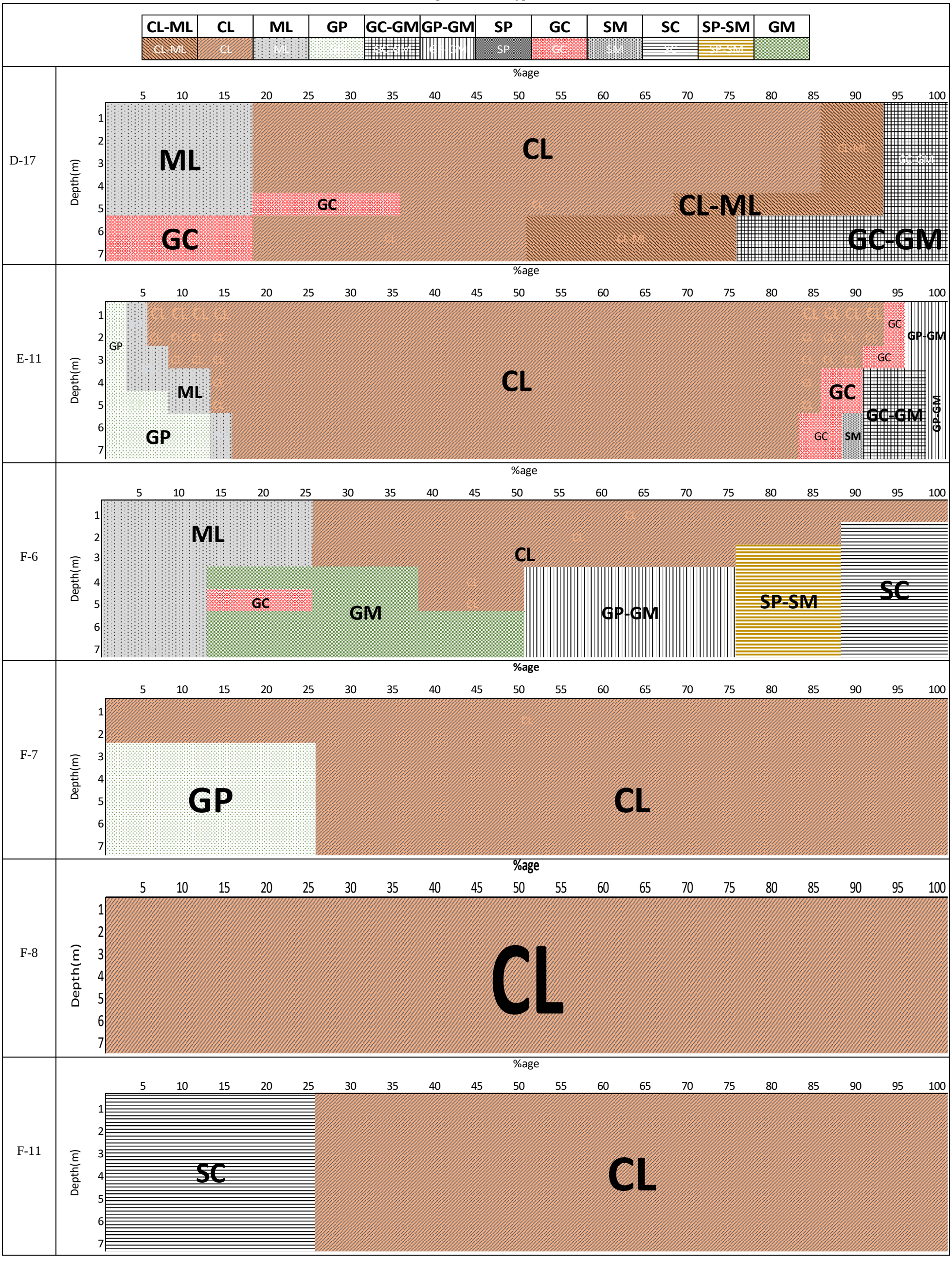


Fig 4: Average SPT N values with depth for different sectors

Tabel 1: Selected data points for Zonation of individual sectors

Sector	Data points
F-6	9, 10, 133, 134, 187, 188, 105, 106
F-7	72, 73, 53, 26
F-8	145, 146, 103, 104, 158, 159
G-8	68, 69, 67, 94, 93
I-8	91, 92, 27, 28, 36, 37, 121, 123, 122, 175, 176
G-11	126, 127, 128, 129, 130, 135, 136
F-11	115, 116, 163, 164, 19, 20, 3, 4
E-11	25, 171, 51, 52, 82, 119, 120, 131, 132, 141, 142, 7, 8, 98, 99, 171, 172, 163, 164, 138, 173, 174, 41, 42, 137, 38, 39, 50, 113, 114, 149, 150, 151, 29, 30, 95, 96, 97, 65, 66, 167, 168, 87, 88, 185, 186, 32, 33, 38, 39
G-13	124, 125, 117, 118, 179, 180, 143, 144, 43, 44, 183, 184
G-15	76, 77, 78, 79, 1, 2, 12, 23, 14, 13, 70, 71, 15, 16, 21, 22, 11, 17, 18, 61, 62
D-17	156, 157, 165, 166, 169, 170, 89, 90, 109, 110, 189, 190

Tabel 2: Percentage of different types of soils in each Sector



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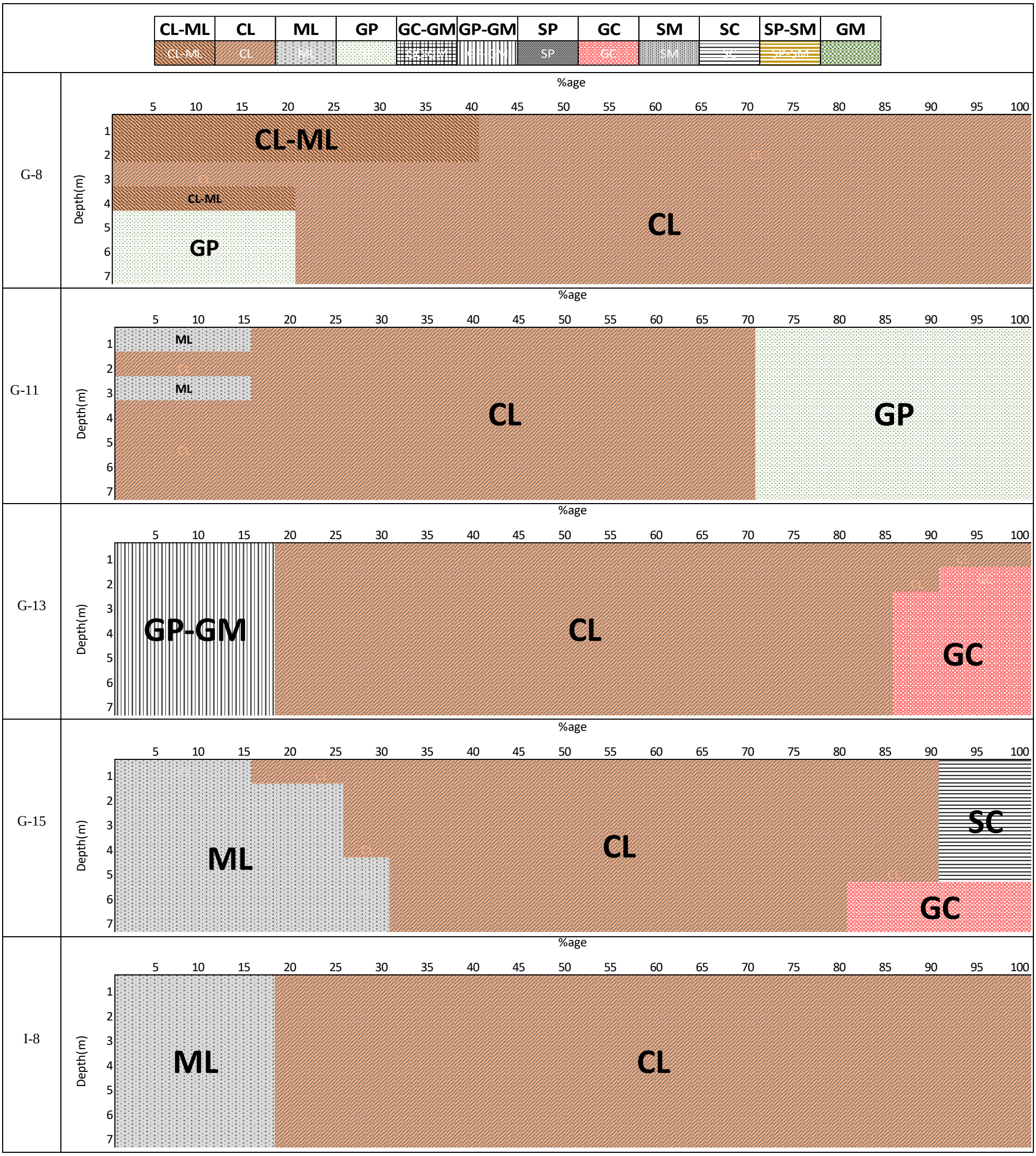

Conclusions

The present study presents the findings of geotechnical site investigation results for 11 sectors of Islamabad. Arshid et. al. (2013) used the data for 34 geotechnical site investigations to divide the area into three subclasses based on SPT N values. However, the present study aims to establish subsoil profiles of average SPT N values and soil stratigraphy for individual sectors based on data of 144 geotechnical site investigations. The main finding of this study are as under;

- The soil stratigraphy can also be used for planning geotechnical site investigations for high rise structures and underground construction.
- Each sector has a unique subsoil profile and insitu soil strength that provide a valuable guideline for geotechnical engineers to design foundations for lightly loaded structures with shallow foundations.
- The SPT N values increase with depth for all sectors indicating an increase in bearing capacity and insitu soil strength.
- The subsoil of Islamabad mainly consists of lean clay (CL) in medium stiff to stiff insitu state with a significant percentage of silt, sand and gravel as well at different locations and depths.
- The average SPT N values suggested for each sector can be used to determine shear strength parameters and bearing capacity of subsoil using SPT-based empirical correlations.
- The sectors F-8, F-11, I-8 and G-8 are well suited for construction of lightly loaded structures but will require extensive ground improvement for multistory buildings at all depths.
- The sectors G-15 and E-11 are well suited for construction of lightly loaded structures but will require ground improvement for multistory buildings at shallow depths only as the SPT blow counts at greater depths are sufficiently high.

- The sectors F-7, F-6, D-17, G-11 and G-13 are well suited for construction of multistory buildings without ground improvement provided that the is placed at depths ≥ 3m.

Acknowledgements
The authors greatly acknowledge AJK Enterprises and GeoEngineers for assistance and providing data for geotechnical site investigations.

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