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Appraisal of Geotechnical Characteristics of Soil for Different Zones of Faisalabad (Pakistan)

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Abstract

Appraisal of Geotechnical Characteristics through ground investigation is essential to obtain subsurface information and parameters for foundation design. Technologically advanced countries had already developed geotechnical zoning maps to facilitate geotechnical engineers and geologists for preliminary scheduling, feasibility studies and to design a variety of engineering projects. As rich speckled data is available for sub soils of Faisalabad, the study aimed to develop geotechnical zones of Faisalabad based on SPT statistics and appraisal of bearing capacity for all the proposed zones. The subsurface soils up to 1 meter depth comprised of slightly cohesive fill material/ Clayey Silt overlaying medium dense non-cohesive Silty Sand/Fine Sand that is underlain by dense poorly graded fine Sand to very dense Sand. Faisalabad has been divided into three zones I, II & III based on geotechnical characteristics. Zone-I comprised of areas having SPT values ≤ 4, Zone-II from 5-8 and the bearing capacity was evaluated based on shear failure and settlement criteria for Zone-III the N-value ranged from 9-15. For each zone bearing capacity can be assessed by assigning type of footing and its width. This would facilitate the engineers to assess the bearing capacity with confidence, for feasibility studies, preliminary scheduling and designing of variety of engineering projects.

Key Words: Bearing capacity; Foundation design; Geotechnical zones; Shear failure; SPT Statistics

1. Background

Faisalabad plays an important strategic industrial and administrative role as the second largest city of Punjab, Province. It has been a hub of agriculture, trade, and business since its setting up as district back in 1904. It's rapidly increasing industry and resulting population demands more infrastructure and housing facilities.

Realizing the importance of geotechnical zoning and to assist the designers, a study was focused to describe characteristics of subsoil, development of geotechnical zones, assessment of allowable bearing capacity for each zone and guidelines for foundation design.

Land use pattern

A diverse nature of land use exists in the town from which it could be assessed to have a balanced physical growth of the area. The trunk roads are surrounded by foremost trade and production and the total area comprised of 12115 hectares. [1]

The land development can be divided into three types;

- **Slums:** Private land development without any approval from the concerned authorities.
- **Squatter:** Katchi Abadis: These are settlements built on an adhoc basis illegitimately engaged by squatter.
- **Planned developments:** The schemes developed following building by laws.

The land use in Faisalabad as revealed by survey carried out during 1996 is tabulated in Table 1.

Table 1: Land-Use Distribution

Land Use	Area (in Hectares)	Percentage
Residential Area*	5706	47.31
Commercial Area*	376	4.23
Industrial Area*	713	6.35
Educational Area	435	3.56
Open Space	189	1.59
Public Buildings	512	4.02
Agricultural Area	3985	31.12
Major Roads	221	1.83
Total Area	**12115**	**100.00**
*contain trivial roads and streets		

Geology

Faisalabad is situated in gentle sloping plains of Upper Indus Basin as shown in Figure-1. These plains are covered by Quaternary Unconsolidated deposits of enormous thickness and bedrock belonging to Indian Basement exists at a greater depth. The Quaternary deposits comprised of silty clay and sand in varying proportions which are accumulated by braided tributaries of Indus river system, originating from the north-west Himalayas [2].

The geologic study is based on general site reconnaissance and detailed geologic and geotechnical investigations. The project sites are located on nearly horizontal flood plains covered by fine grained loamy soils. Bedrock is not exposed

within the project sites and its vicinity not encountered within the investigated depth of boreholes.

The substrata comprised of alluvial deposits of the Indus river system. The sediments are unconsolidated as deep as 900 feet. The unlined irrigation canals and distributaries including water courses are the main source of groundwater recharge. Rain fall contribution to groundwater recharge is not considerable. Ponds also slightly contribute towards the recharge.

2. Seismicity

The Punjab Plain, in which the city is located, shows low to moderate level of seismicity which is associated with the faulting in the basement rocks covered by the deep alluvial deposits. The basement high**,** depicted by outcrops of basement rocks near Sargodha, Chiniot, Shahkot and extending from Sargodha to Faisalabad and further southeast towards Indian border, shows a concentration of earthquakes with magnitude up to 5.5 on the Richter scale. A moderate earthquake originating from the basement high in Punjab plain could produce appreciable ground shaking at sites due to the thick alluvial deposits.

According to the Seismic Zoning Map of Pakistan, the project sites falls in Zone 2A, consequently the structures should be designed in accordance with the requirement of seismic design after due consideration to other structural design parameters.

Soil Exploration and Sampling

The aim of the subsurface investigation was to obtain a detailed understanding of the engineering and geological properties of the soil/rock strata and groundwater conditions. Soil exploration techniques include in-situ and laboratory testing, appraisal of sub-soil characteristics and evaluation of bearing capacity.

In-situ tests carried out during geotechnical investigations were Standard penetration tests (SPT), cone penetration tests (CPT), flat plate dilatometer tests (DMT), pressure meter tests (PMT), and vane shear tests. SPT and CPT are the most frequently in-situ tests being used in Pakistan.

Geotechnical Maps

Geotechnical maps are prevalent nowadays due to the existence of Geographical Information Systems (GIS) and Global Position Systems (GPS). These maps provide a powerful database and strong visual presentation of data. The use of such maps saves effort, time, and provide quick source of information for engineering projects, especially in civil engineering field, such as the construction of buildings, dams, roads and tunnels, etc. [4] The standardized methodology and procedures of regional geotechnical mapping proposed by the Council for Geosciences in South Africa follows a systematical approach and can be divided into the following phases:

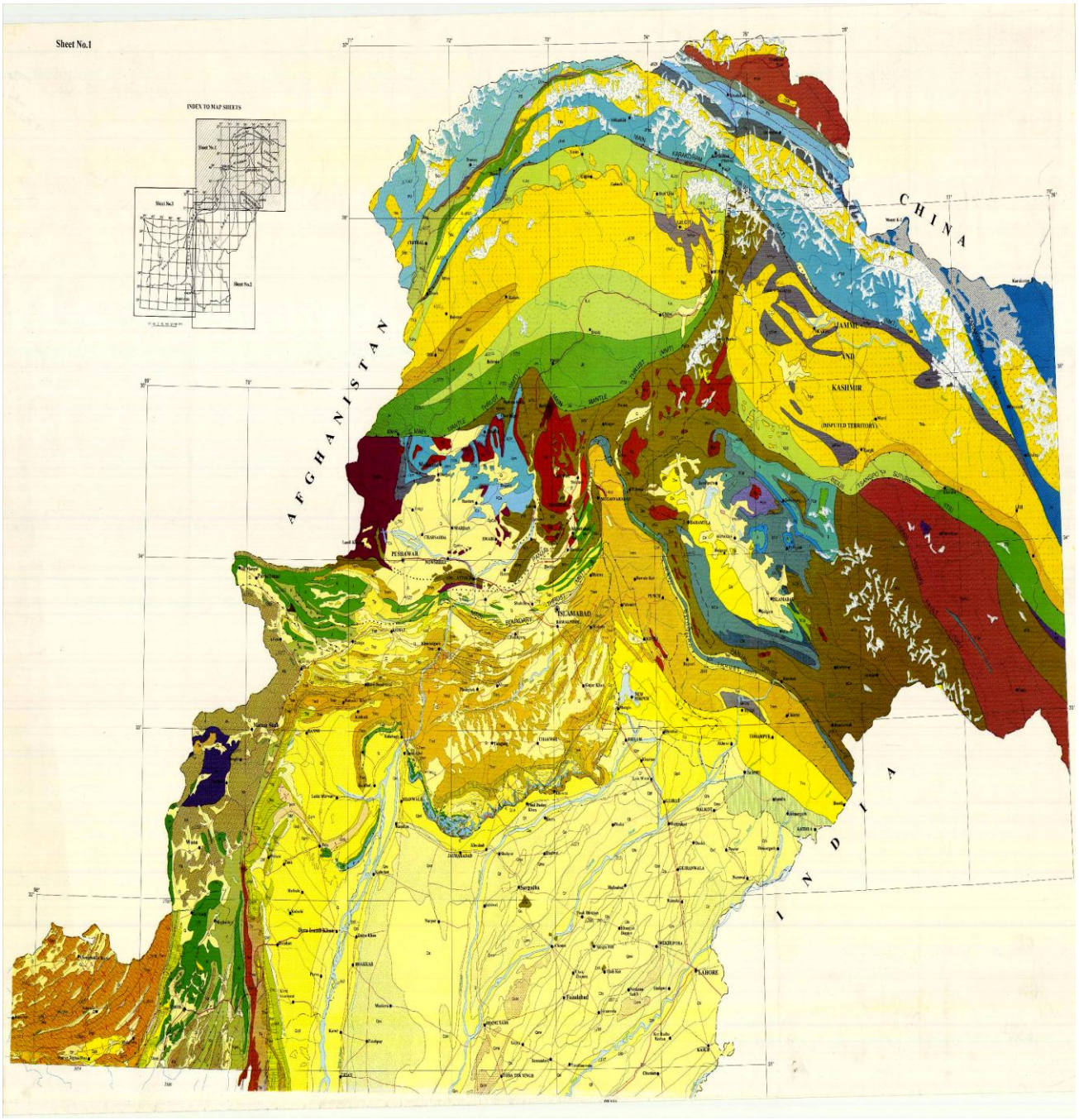


Fig. 1: Geological map of Faisalabad region, Pakistan 2008 [3]

Legends:

Qfx	=	stream bed and meander plain
QC	=	Loess and flood plain deposits, middle terrace deposits
Qtx	=	Deltaic Flood Plain
CK	=	Older Alluvial Complex deposits

1. Data gathering or desk study.
2. Reconnaissance survey.
3. Field mapping.
4. Laboratory analysis.
5. Compilation of the engineering geotechnical map and
6. Report writing.

Geotechnical maps had already been developed by some countries across the globe which includes; Australia [5], South Africa [6]and Nablus – Palestine [4].

The importance of developing geotechnical map for Faisalabad region is the fast and simple access to the information regarding foundation and allowable bearing capacity. In addition, this map will help in preliminary studies, feasibility studies, and land use policies.

3. Methodology

Geotechnical data for 115 sites at scattered locations throughout the Faisalabad city was collected. The collected data from these locations contained, standard penetration test N values, soil classification, soil stratigraphy, sub-soil characteristics of top 3- meter soil.

Geotechnical Zoning

Zoning of Faisalabad city has been proposed on the basis of SPT–N values for 3- meter overburden soils. The area was divided into three zones, zone I, II & III and has shown in Figure 2, 3 & 4 based on N-values suggested by Terzaghi for soft, medium and hard consistency soils [7] as shown in Table 2.

Table 2 Selected Zoning Criteria (Terzaghi and Peck, 1948)

Sr. No.	Zone	Range of N values
1.	Zone – I	1-4
2.	Zone – II	5-8
3.	Zone – III	9-15

Figures: 2, 3 and 4 show SPT profiles for Zone-I, Zone-II and Zone-III respectively.

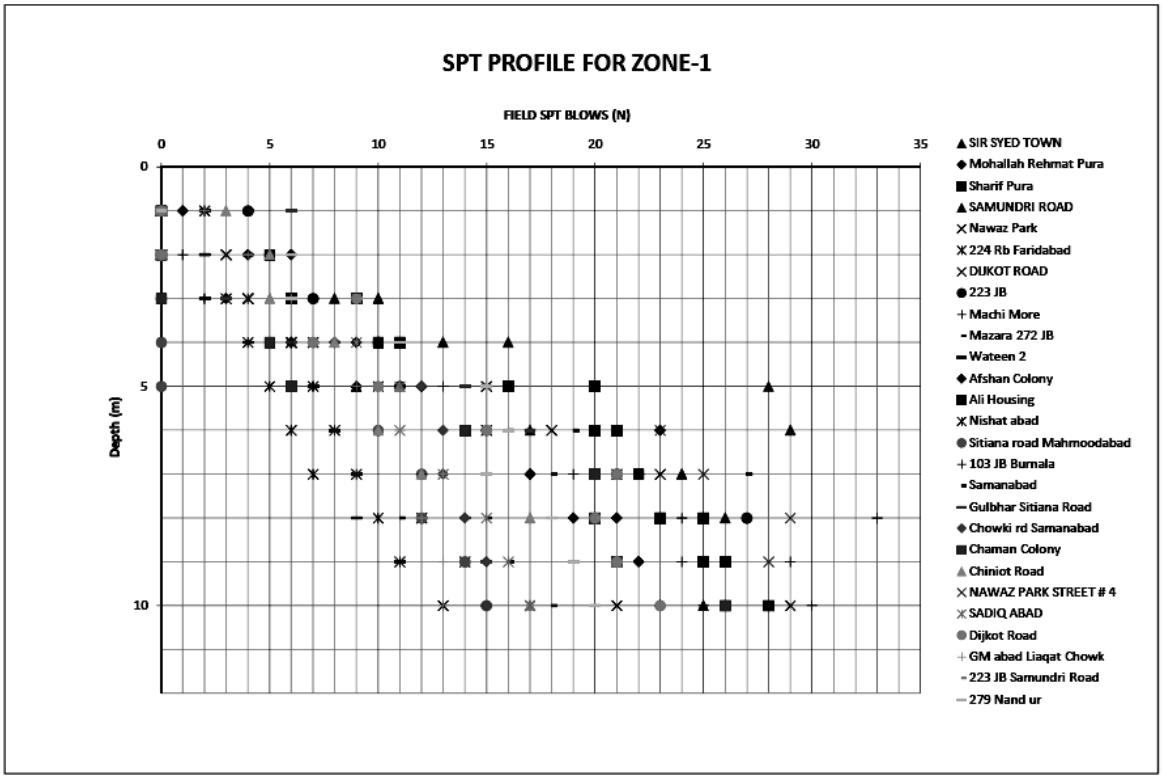


Fig. 2: SPT Profile for Zone-I

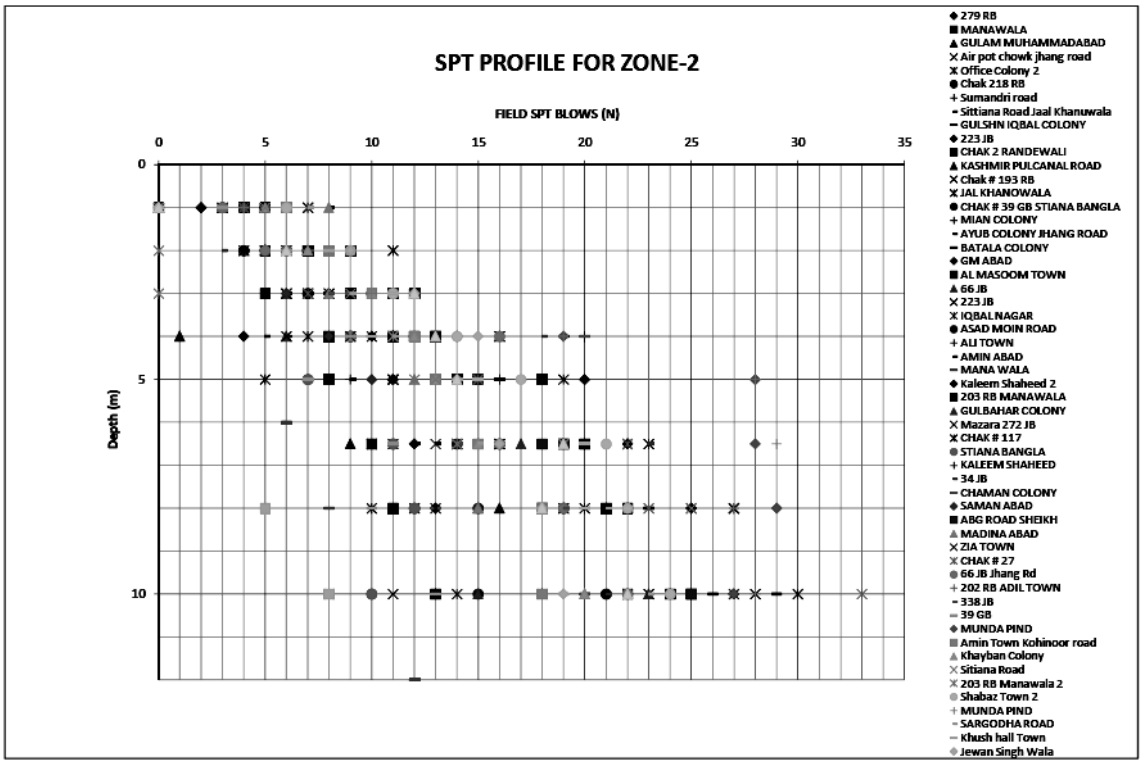


Fig. 3: SPT Profile for Zone-II

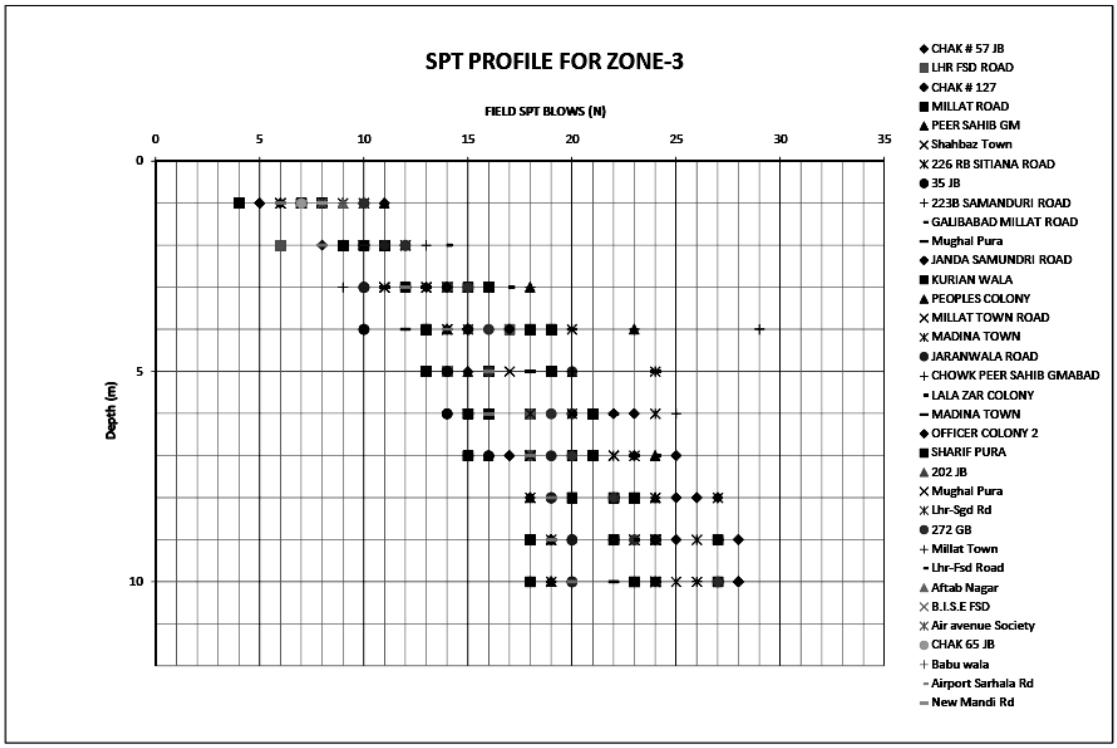
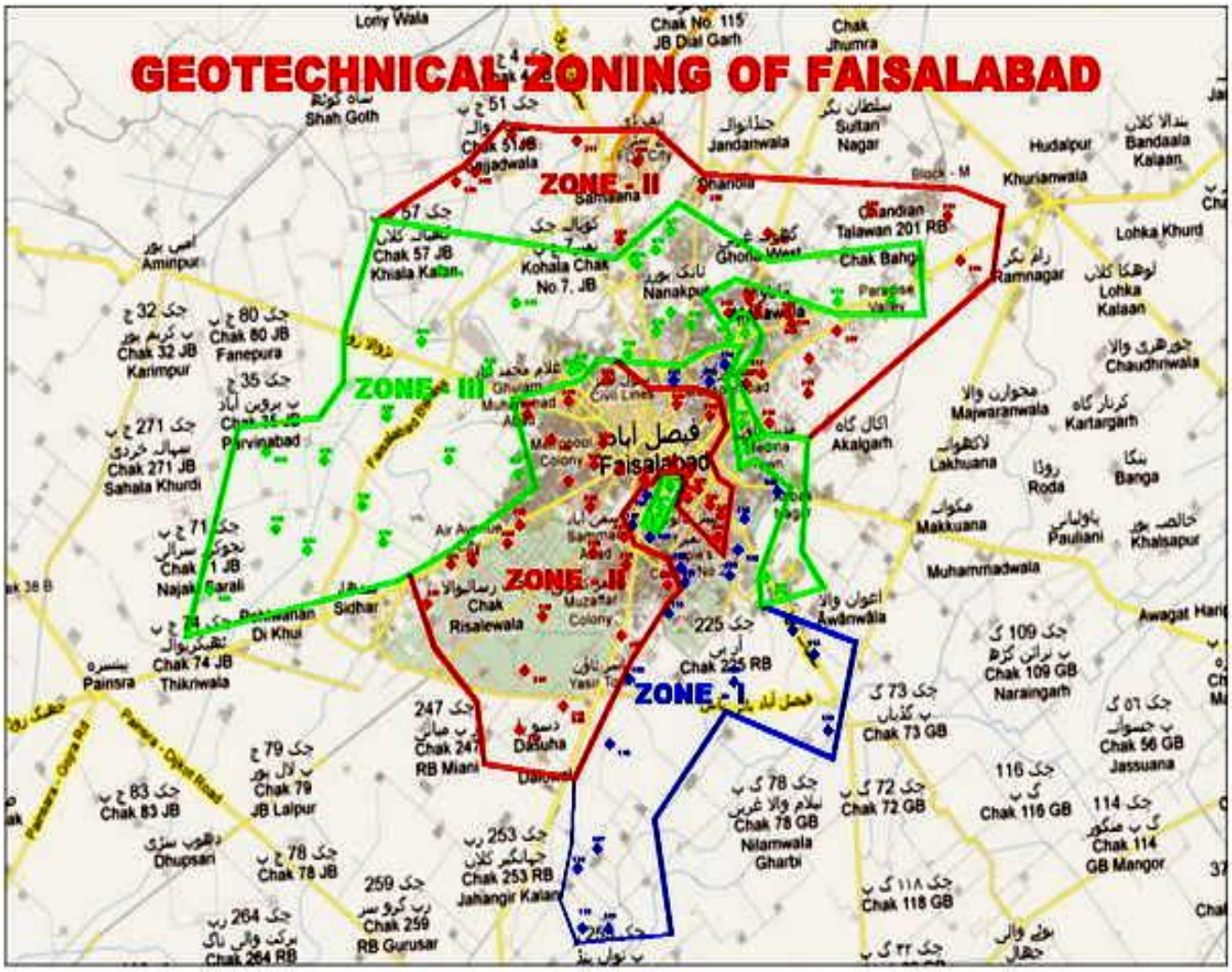


Fig. 4: SPT Profile for Zone-III



Geotechnical zoning map based on SPT has been developed and has been shown in Figure 5, with colored lines showing the boundaries of each zone.

Zone-I generally consists of a top 1-meter fill material comprised of lean clay with pieces of pottery and brick bats underlain by non-cohesive sandy silt/silty sand as shown in Figure 6. Zone-II generally consists of top 3-meters layer of silty sand followed by 4-meters layer of sand with silt that is underlain by fine sand as shown in the Figure 6. Zone-III generally consists of top 1-meter fill material consisting of clay with brick bats underlain by silty sand that is underlain by poorly graded sand and then dense sand, shown in Figure 6. Water table was encountered at 2 sites only out of 115.

4. Bearing Capacity Appraisal

Geotechnical Zones have been proposed based on SPT database for 3- meter overburden soil. The position of station points have also been marked on the administrative map. Typical stratigraphic and SPT profile for each zone, analysis of laboratory and field data and foundation design parameters have been made, based on which allowable bearing capacity have been calculated for each zone. These parameters are tabulated in the Table 3, 4 & 5 for zone-I, II and III respectively.

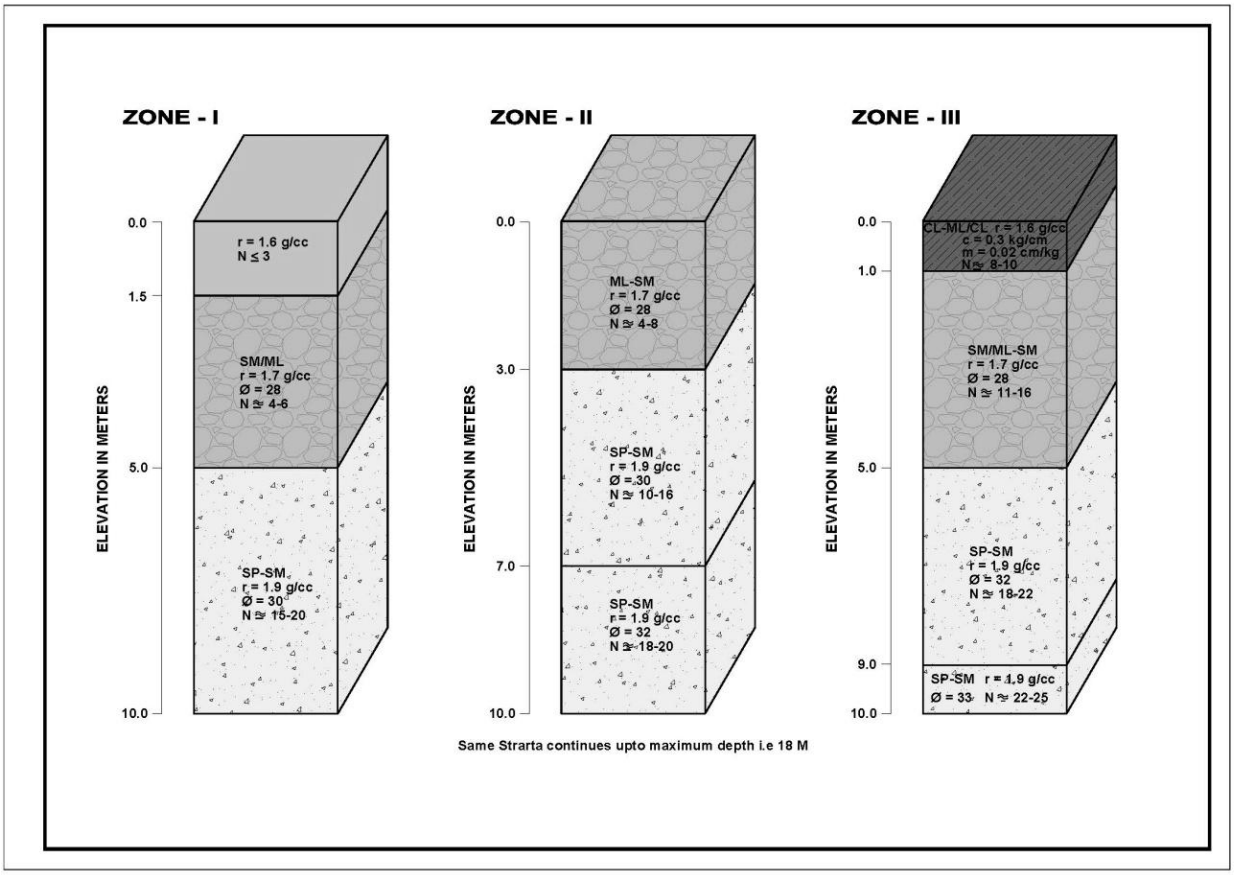


Fig. 6: General Stratification for Zone-I, II and III

Table 3: Zone-I, Parameters for Foundation Design

Soil Identification	Depth (m)		Bulk Density (kg/cm^3)	Undrained Cohesion (kg/cm^2)	Coefficient of compressibility (cm^2/kg)	Angle of Internal Friction (Degree)
	From	To				
Lean Clay/Fill	0	1.5	0.0016	0.2	0.02	-
Silty fine sand	1.5	5.0	0.0017	-	-	28
Fine Sand with silt	5.0	10.0	0.0019	-	-	32
Fine Sand with Silt	10.0	18.0	0.0019	-	-	32

Table 4: Zone-II, Parameters for Foundations Design

Soil Identification	Depth (m)		Bulk Density (kg/cm^3)	Undrained Cohesion (kg/cm^2)	Coefficient of compressibility (cm^2/kg)	Angle of Internal Friction (Degree)
	From	To				
Silty sand	0	3.0	0.0017	-	-	28
Sand with Silt	3.0	7.0	0.0017	-	-	30
Fine Sand	7.0	18.0	0.0019	-	-	32

Table 5: Zone-III, Parameters for Foundations Design

Soil Identification	Depth (m)		Bulk Density (kg/cm^3)	Undrained Cohesion (kg/cm^2)	Coefficient of compressibility (cm^2/kg)	Angle of Internal Friction (Degree)
	From	To				
Silty Clay/Fill material	0	1.0	0.0016	0.3	0.02	-
Silty sand	1.0	5.0	0.0017	-	-	28
Fine Sand	5.0	9.0	0.0019	-	-	32
Dence Sand	9.0	18.0	0.0019	-	-	33

Geotechnical design criteria adopted for evaluating the allowable bearing capacities for foundations of lightly loaded structures was based on no shear failure of the supporting soil using a factor of safety 3.0 for an allowable settlement of 25 mm for strip and square footings.

For lightly loaded structures, spread foundations like square or strip, are appropriate. Allowable bearing capacities in overburden soils have been evaluated for 1.0 to 4.0 m wide spread footings. The depth of foundation is taken as 1.5 m from NSL for zones I and II and 1.0 m for zone III.

Foundation proportioning curves for three Zones have been plotted and shown in Fig. 7. The allowable

Foundation proportioning curves for three Zones have been plotted and shown in Figure 7. The allowable soil pressures are quite low for Zone-I and the soil is weak at shallow depth. Therefore to have increased bearing capacity proper compaction of top layerup to the influence Zone has been suggested.

The allowable capacities for Zone-II are fairly good at shallow depth, even better for Zone-III as compared to Zone-II with very good soil characteristics at shallow depth.

5. Conclusions

1. The study area primarily consist of top 1 to 1.5 meters thick lean clay (CL) or fill material that

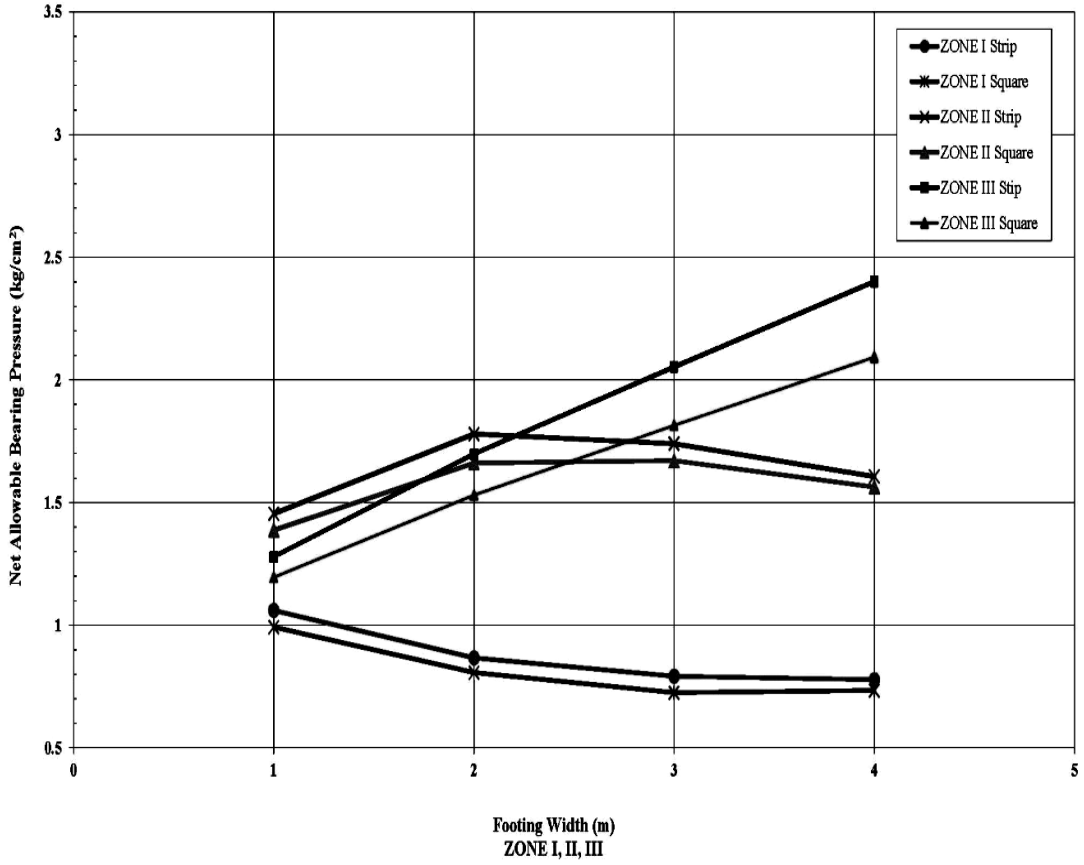


Fig.7: Foundation Proportioning Curves for Zone-I, II and III

is overlying medium dense silty Sand which in turn is overlying dense Sand.

2. Poorly graded non-plastic sands are encountered at shallow depth with varying amount of Silt. These soils fall in SP-SM and SP/SM group according to Unified Soil Classification System.
3. For Zone-I, settlement criterion controls the allowable bearing capacity.
4. For Zone-II, for small foundation widths, shear failure criterion controls the allowable bearing capacity while for large foundation widths settlement criterion controls the allowable bearing capacity.
5. For Zone-III, shear failure controls the allowable bearing capacity.
6. Zones I and II can be used for the construction of single/double storey dwellings without soil improvement. Zone III can be used for construction of multistoried structures and industrial units.
7. The data base developed in this study can be used for feasibility studies and preliminary design with a reasonable level of confidence.
8. Generally the allowable bearing pressures for strip footings are less than the bearing pressure for the square footings of the same width. But for sandy soils as encountered in this research, allowable bearing pressures for strip footings are higher than the bearing pressure for the square footings of same width. This is due to the elimination of Cohesion factor.

6. Recommendations

1. The GIS technology has taken a considerable role in engineering field; the technology may be used to improve the accuracy of geotechnical data base.

2. Similar studies for other major cities of Pakistan and compilation of such individual results may be carried out to produce provincial or national level geotechnical data base.

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