BEARING CAPACITY AND FOUNDATION DESIGN FOR FUSION MALL, BAHRIA ENCLAVE, ISLAMABAD

By

MUHAMMAD ABDULLAH AWAN

HASSAN RAZA

Department of Earth and Environmental Sciences

Bahria University, Islamabad, Pakistan

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MUHAMMAD ABDULLAH AWAN
HASSAN RAZA

Department of Earth and Environmental Sciences
Bahria University, Islamabad, Pakistan

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ABSTRACT

This piece of work gathers the study which explains soil bearing capacity and provides the safe and economical foundation design at Fusion Mall Project, Plot No. 2B, Avenue-01, Sector F, Bahria Enclave, Islamabad. Total 5 boreholes have been drilled at different locations comprising an average depth of 30 m. Straight rotary was adopted for borehole drilling, and samples were then acquired. Standard Penetration Test (SPT) and Cone Penetration Test (CPT) were conducted on the field using ASTM parameters. The tests, including Atterberg limits, Moisture Content, Sieve Analysis, Density and Specific gravity were carried out in the laboratory. Meyerhof bearing capacity equation was applied and by using SPT values, soil bearing capacity was determined.

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

A famous Leonardo da Vinci worked in geology and architecture at the late 15th century. He observed the soil behavior and came up with the process of estimating the bearing capacity of soil, to measure angle of repose of sand and also worked on the processes related to the ground water hydrology but unfortunately his work was limited only to books and it was not applied practically during his time (Shah, S.M., 2009).

Terzaghi (1925) did a great job by working on this subject and published a book which is named as “Mechanics of earth construction based on soil physics”. He provided the stress and consolidation theory and contributed on the need of different observations done in the field.

Meyerhof (1951) updated the work of Terzaghi and added the equation of deep and shallow foundations. Terzaghi included s-q which is a shape factor along with depth term Nq (supercharge) and apart from that he added the factors of depth and factors of inclination.

Italy is known for being tilted for one of the towers called Pisa, and the reason it was tilted was the lack of soil investigation. Now it is tilted because of the loose and compressible soil below the tower according to the latest investigations. In any building to be built, it is incidents like these that provide a spark for the need for soil investigation.

1.2 Bearing Capacity and its types

Soil bearing capacity is defined as the ability of the soil to bear load that come from the base. The slightly resistant pressure from the ground to the load is called allowable bearing pressure.

Here are some of the types of soil bearing capacity:

1.2.1 Ultimate bearing capacity (qu)

The ultimate load-bearing capacity is the theoretical maximum pressure, which can be carried perfectly; permissible load capacity is the maximum load-bearing capacity divided by a protective factor. The gross pressure is considered the maximum load-bearing power at the base of the foundation, where the ground fails.

1.2.2 Net ultimate bearing capacity (q_{nu})

We can obtain the final net bearing capacity by ignoring the excess pressure of the ultimate bearing.

$$q_{nu} = q_u - \Upsilon D_f$$

Where Υ= unit weight of soil; Df = depth of foundation.

1.2.3 Net safe bearing capacity (q_{ns})

Taking shear failure into account only, net total bearing capacity is divided by a certain safety factor in order to obtain net safe bearing capacity.

qns = qnu/ F

Where F = factor of safety = 3 (usual value).

1.2.4 Gross safe bearing capacity (q_s)

When the final bearing capacity is divided by the safety factor, then gross safe bearing capacity will be provided.

qs = qu/F

1.2.5 Net safe settlement pressure (q_{np})

Net safe settlement pressure is the pressure that the soil can bear no more than the allowable settlement.

1.2.6 Net allowable bearing pressure (qna)

Energy use to lay down the foundations known as qna. If qnp>qns, that is equal to net safe bearing strain. In the reverse case, the net safe pressure for settlement is equivalent.

A strong foundation has the capability to spread the load all over the ground while reducing the stress on soil. If stress upon soil is too high, it can cause depression in the region and damage the engineering structures. Therefore, the firms that are researching the region need to find out the soil's bearing ability.

1.3 Types of foundation

The type of foundation to be used is dependent on the structure and therefore the soil that has been found. The basic forms are mainly categorized into two classes; shallow and deep foundations. Such definitions are used to describe the depth of soil with which to lay the base. The shallow foundations are laid at depths of about 9 meters while the deep foundations are laid at about 20-60 meters. Shallow foundations are built for the small and light structures. And the deep foundations are favored for large and high weight structures.

1.3.1 Shallow Foundation

A shallow foundation is a construction foundation that, rather than an underground layer or at a variety of depths, such as a deep base, carries a building load very close to the surface.

The depth of the foundation must meet the safety requirements of the failure, and once the load is applied, the entire structure will sink to acceptable limits.

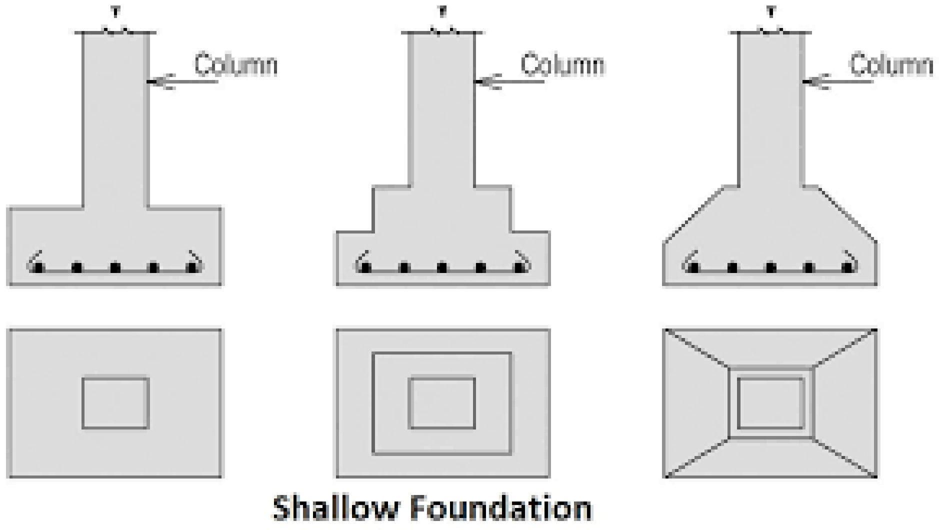


Figure 1.1 Shallow Foundation (Bowels, 1996)

The types of shallow foundation are:

i. Raft Foundation
ii. Isolated foundation
iii. Strip Foundation

1.3.1.1 Raft Foundation

It consists of thick cemented slice of block on a large area of soil strengthened by steel which then supports the columns/walls and moves the load throughout the soil. It is also known as Mat Foundation. It is applicable where:

i. Bearing capacity of soil is low.
ii. When the load of the structure is to be divided equally on a large area.
iii. Basement needs to be built.

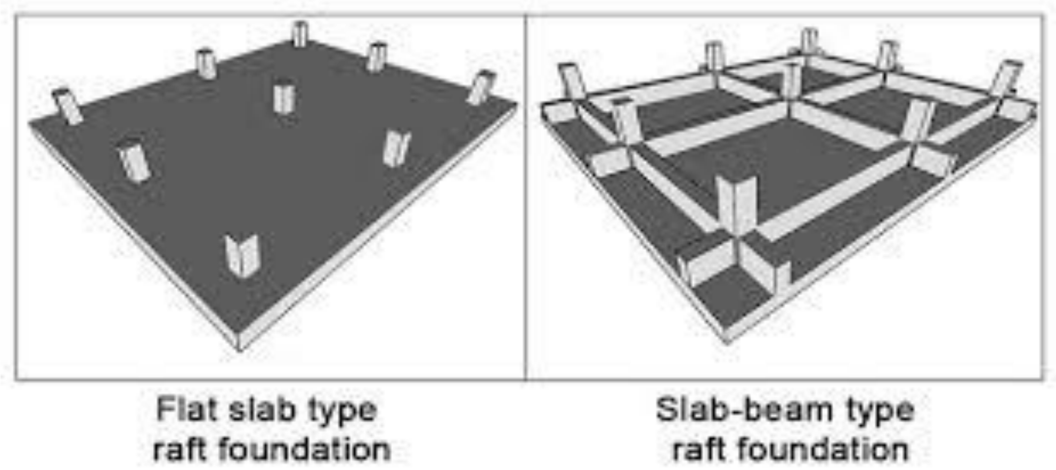


Figure 1.2 Raft Foundation (Bowels, 1996)

1.3.1.2 Isolated Footing

They are called as pad or spread footing foundation. They are also called as Pillars because they can carry and divide the load of the structure and are used for the shallow foundation. This type of footing may be enforcement or non-enforcement. The non-strengthened footing should be large or heightened to give the required load division.

It is applicable where:

i. A single column needs to be supported.
ii. When columns are arranged at relatively longer distance.

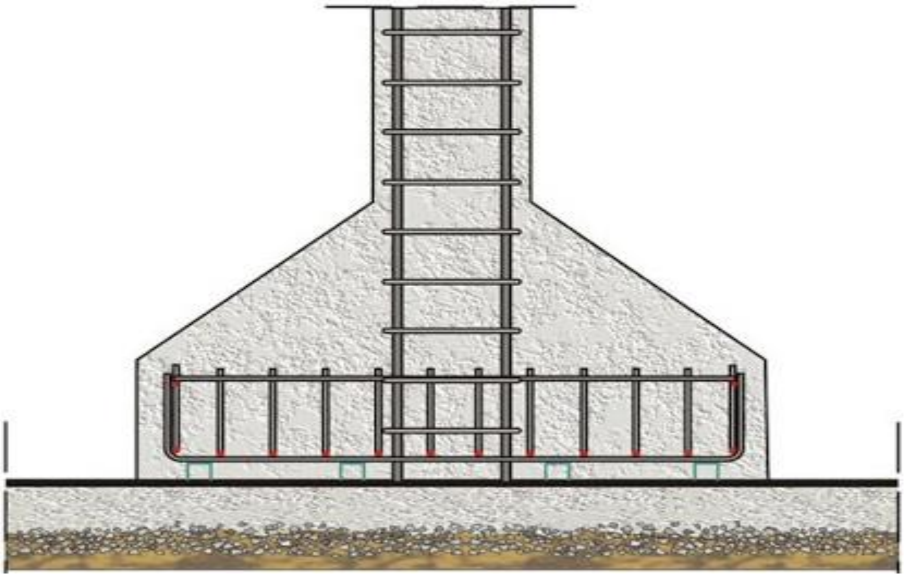


Figure 1.3 Isolated Footing

1.3.1.3 Strip Footing

The foundation of a wall or a strip is a continuous concrete strip, which helps to distribute the weight of a bearing wall over a surface of the ground. It is a shallow base component. They are mostly used as the foundation of walls which are carrying the load. Its width is mostly two times to that of the wall, or it can be wider as well. The width and the material used for strengthening totally depends upon bearing capacity of the soil of foundation.

Used soil has reasonable bearing ability and the strip foundations are used. The main strip base sizes are identical for the construction of a concrete cavity wall and a wood frame wall cavity. The band size and location are directly correlated with the wall width.

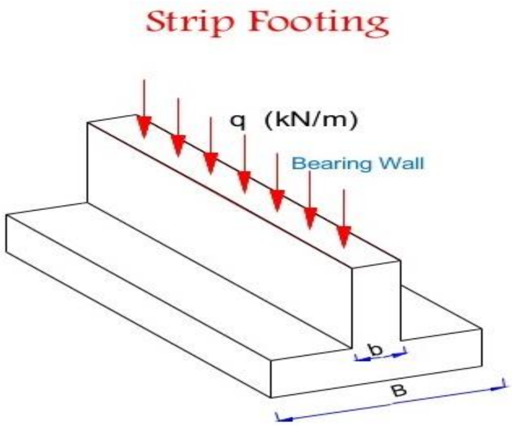


Figure 1.4 Strip Footing (Bowels, 1996)

When the surface soil is solid and firm to support the structure, a shallow base form is applied. Nevertheless, they are fragile and can be compressed by the building when there is poorly compacted land or when there are alluvial deposits.

1.3.2 Deep Foundation

A deep foundation is that type of foundation that takes building loads from the surface and transfers deeper down to the earth than transfers to a subsurface layer or depth range from a shallow foundation.

The base is laid deep into the ground in deep foundations, making it more stable and resistant to some form of disruption due to earthquakes or other natural occurrences.

Usually, the depth would have to go beyond 10 feet deep, so that the base is really a deep base.

Types of Deep Foundation

- i. Basements.
- ii. Buoyancy rafts (hollow box foundations)
- iii. Caissons.
- iv. Cylinders.
- v. Shaft foundations.
- vi. Pile foundations.

1.3.2.1 Basement Foundation

They are hollow and designed to provide less space or storage. The structure is fed by its actual requirements, not taking into account the most effective methods of external soil resistance and hydrostatic pressure. In open excavations, they are built on construction sites.

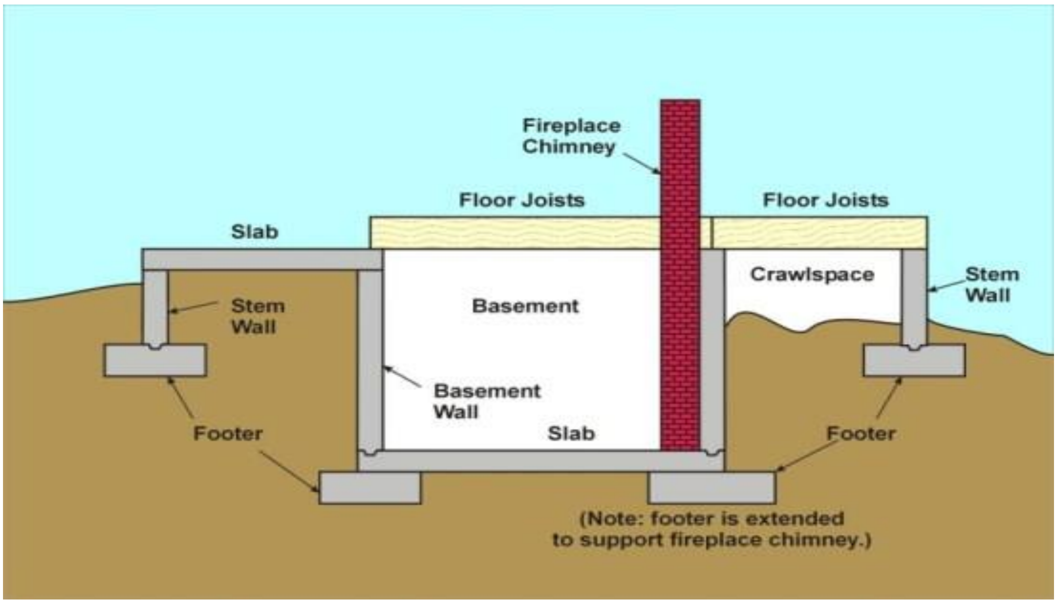


Figure 1.5 Basement Foundation (Bowels, 1996)

1.3.2.2 Buoyancy Raft Foundation

These are hollow sub-structures that built for providing a buoyant and semi-buoyant sub-structure under which, net soil loading is reduced to the required low intensity. Buoyancy rafts can be constructed to be sunk as caissons and can also be placed in open excavations.

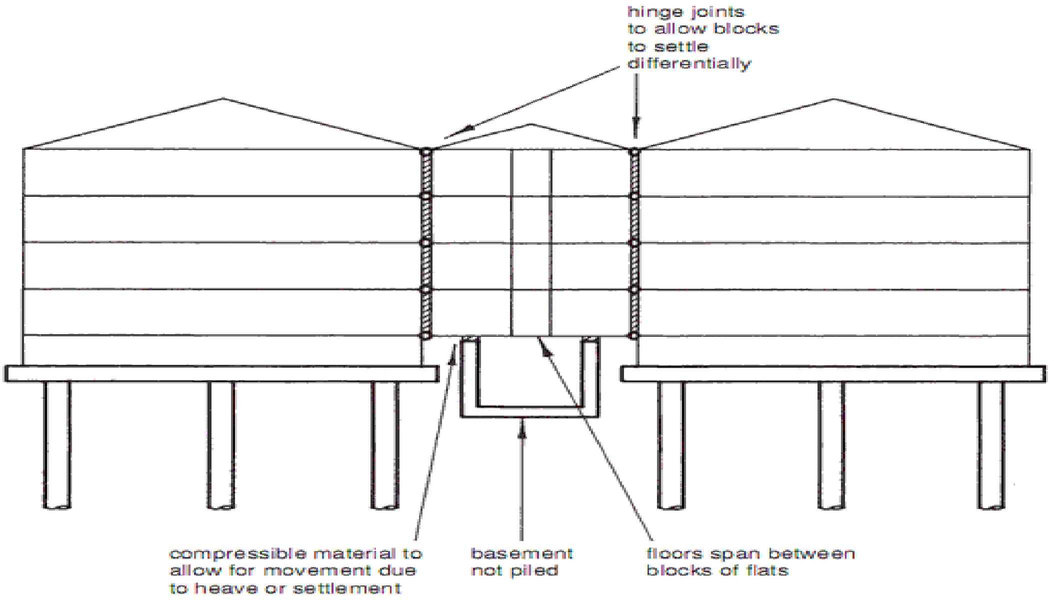


Figure 1.6 Buoyancy Raft Foundation (Bowels, 1996)

1.3.2.3 Caissons Foundation

A caisson foundation is also called a pier foundation. Caissons are hollow sub-structures built to be constructed on or near the surface and then submerged as a single unit at the appropriate level.

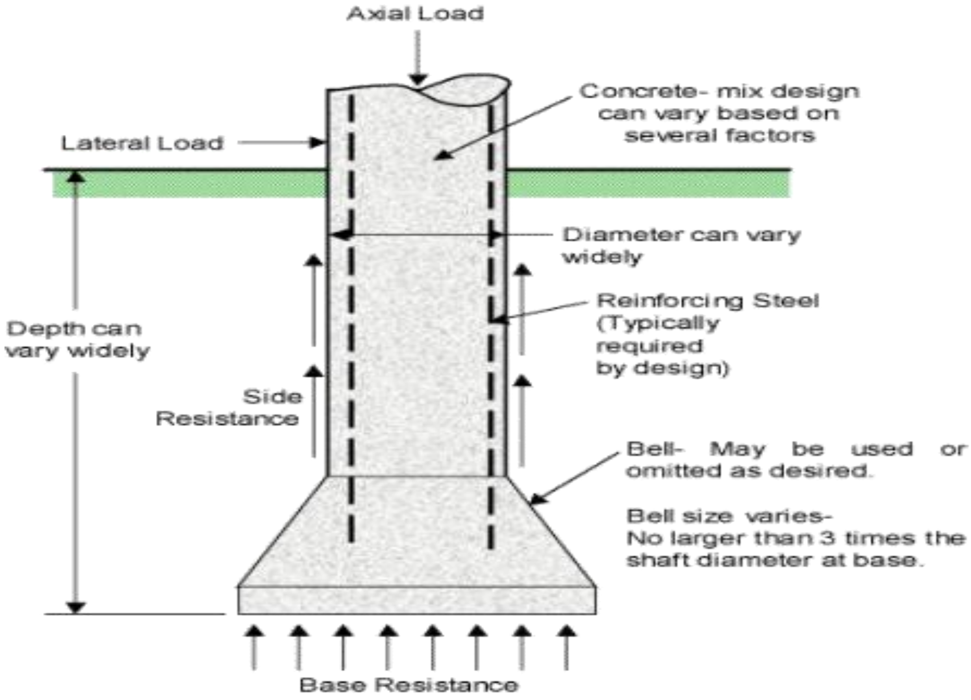


Figure 1.7 Caissons Foundation (Bowels, 1996)

1.3.2.4 Cylinders Foundation

They are small single-cell caissons. Concrete base cylinders are hydraulically pressed into the soil under the floor, using the mass of the structure as resistance.

Cylinders are placed on top of each other and pushed down until the column has adequate resistance to raise the structure.

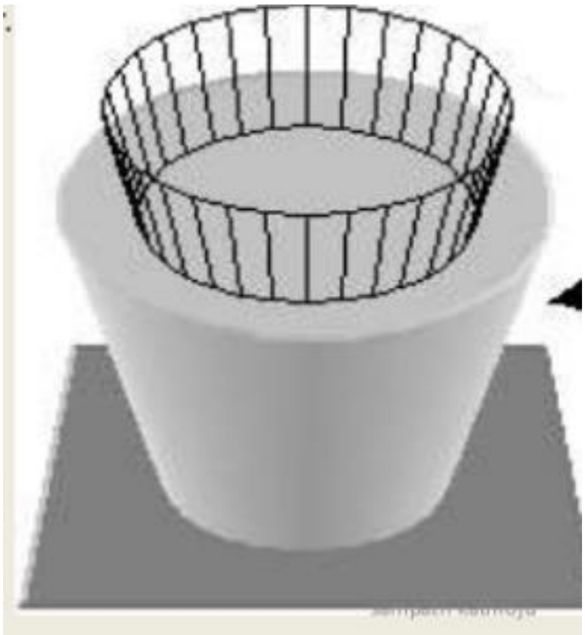


Figure 1.8 Cylinders Foundation (Bowels, 1996)

1.3.2.5 Drilled Shaft Foundation

A caisson, drilled pipe, Cast-in-drilled-hole piles (CIDH piles) or Cast-in - Situ piles are also named. They are piles that are mounted deep into the field and have a diameter of around 0.6 meters. This has many benefits, some of which include:

1. Only one drilled shaft can be adequate rather than a collection of piles.
2. No noise pollution caused by hammering as opposed to pile pushing.
3. They can withstand strong forces coming from lateral loads.

Like other devices, drilled shafts have their own drawbacks, such as delaying the process due to bad weather, and they also need continuous monitoring.

1.3.2.6 Pile Foundations

Tubes that are filled with concrete before or during withdrawal, or by drilling unlined or partially lined boreholes that are then filled with concrete, are comparatively long, lean components constructed by driving preformed units to the appropriate foundation point, or by driving or drilling tubes to the necessary depth.

They are used in scenarios like:

i. It will support the systems in the same way if they are below the water table to prevent forces from moving upwards.
ii. In the case of horizontal forces acting in that area, the same can be done to prevent bending and support the structure’s load at the same time.

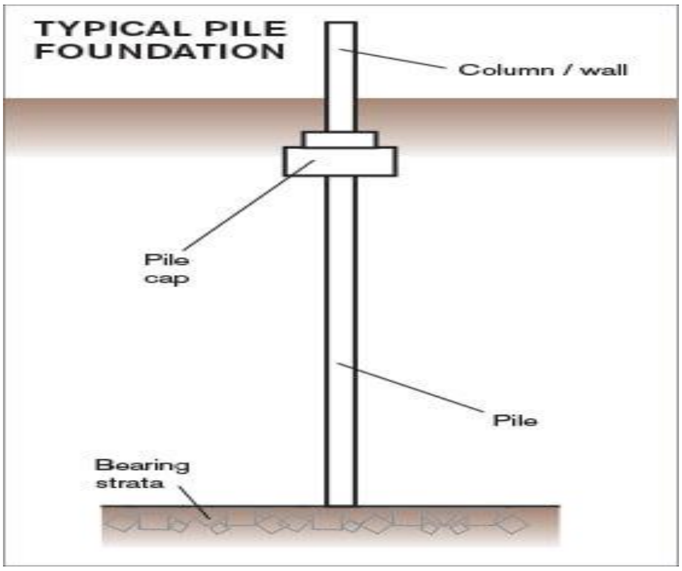


Figure 1.9 Typical Pile Foundation (Bowels, 1996)

1.4 Location of Study Area

The location of our study area is at Sector F, Bahria Enclave, Islamabad Capital Territory, Pakistan. This area is around 15.4km ahead of Bahria University Islamabad. The site is located between coordinates 33°40'53.96"N, 73°13'126.69"E. Total 5 boreholes were planned in the study area, which had no strict rules for borehole spacing. Disturbed and undisturbed were retrieved from the boreholes, which were then tested in the lab for the foundation analysis. Figure 1.1 represents the position of the area of investigation.

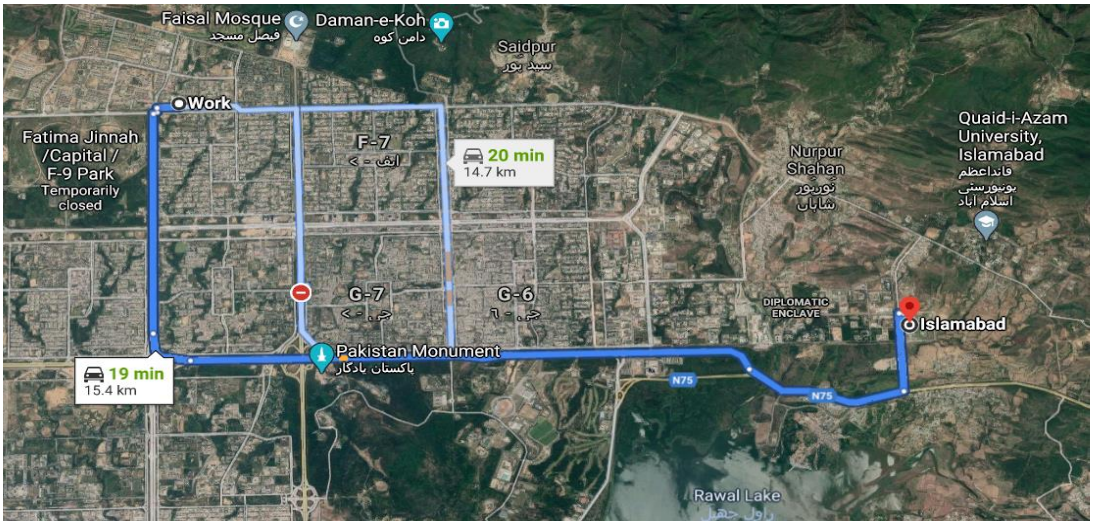


Figure 1.10 Study area accessibility map (Google Earth)

Figure 1.11 Map showing the proposed location of the study area (Google Earth)

1.5 Objective

a) To define the geological conditions of the project area.

b) To find the bearing capacity of the soil.

c) To suggest the safe and economical foundation design.

1.6 Methodology

The methodology of research work involves field activities including borehole drilling and excavation of representative samples. Field testing was done by using Standard Penetration Test (SPT) for soil and Rock Quality Designation (RQD) was performed for rock strata. Tests that were performed in the laboratory include Atterberg limit and Sieve analysis. Eventually, test results were interpreted and the bearing capacity of the foundation is calculated by using Meyerhof equation. The flow chart of the methodology is shown in figure.1.2.

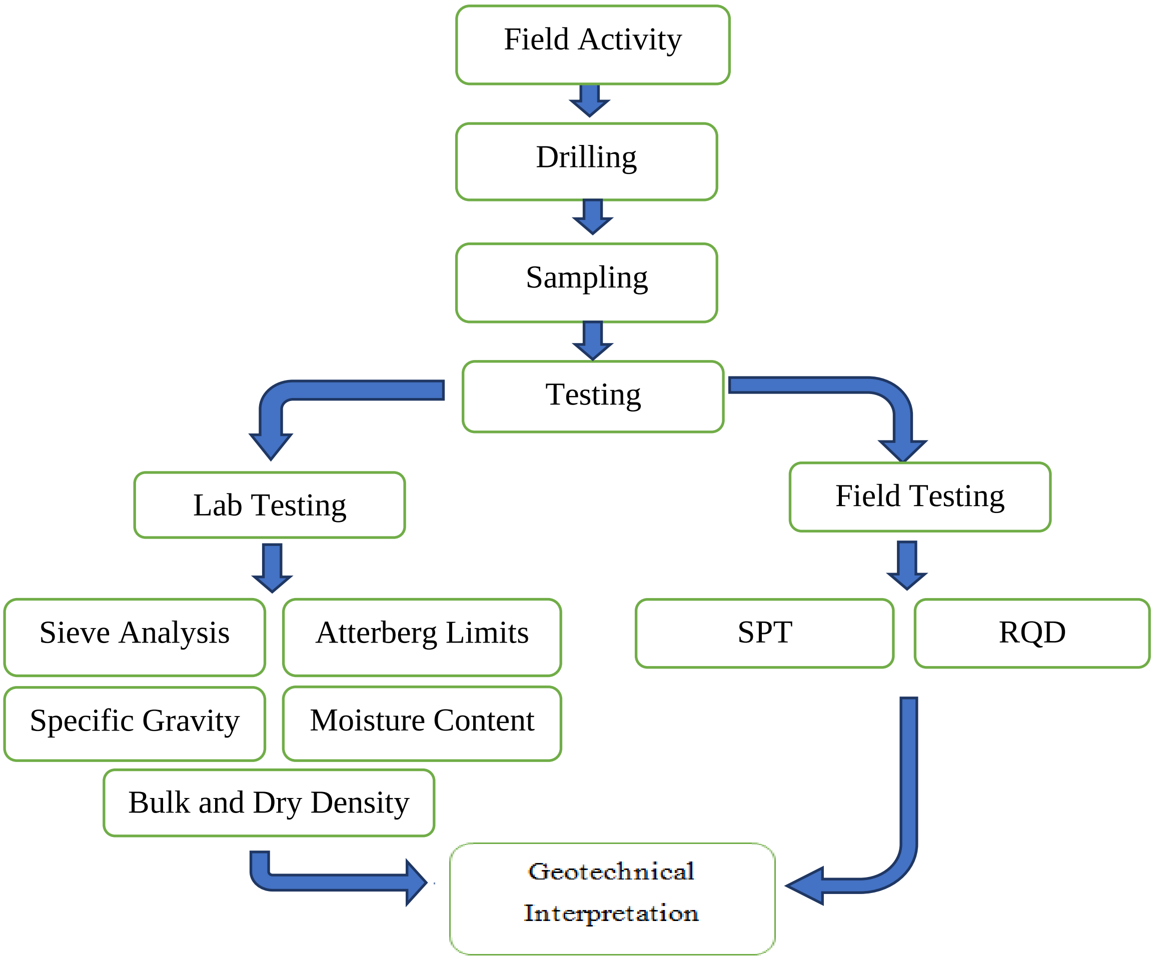


Figure 1.12 Flow Chart of Methodology

CHAPTER 2

GENERAL GEOLOGY AND TECTONICS OF AREA

2.1 History

The geological history of the area reveals that the Galiat hills were formed during the mountain building process (Orogeny) of Himalayas (Mehdiratta, 1989). The modern concept of Himalayan Orogeny is based on "plate tectonic theory". Under this process, the crustal material is supposed to be generated from a deep mantle depth in the mid-oceanic ridges and "spread side-ways". Geological investigations have proved that the crust together with a thickness of the upper mantle down to the "Low Seismic Velocity Layer" (100-150km from the earth surface) — the two together being called the lithosphere. The lithosphere is broken into smaller plates. These plates move and push against each other, converge, diverge or plunge. As a result, trenches are formed; sediments are laid down and folded to form mountains. It is envisaged that India, Africa, Australia, and South Africa were once one big continent lying in the southern hemisphere of the earth (Mehdiratta, 1989). This landmass was separated by Tethys Ocean from another supercontinent in the northern hemisphere consisting of North America, Greenland, and Eurasia. Tethys was a big ocean and existed from Tibet to the Mediterranean Sea. About 130 to 180 million years ago, the supercontinent in the southern hemisphere got disintegrated into drifting plates which ultimately developed into mid-oceanic ridges (Gohar, 1987). The distance between these ridges increased with time and resulted in the development of Indian Ocean. Further northward advance of African and Indian plates towards Eurasian plates closed the intervening Tethys and resulted in Himalayan Orogeny. The upheaval of Himalayas was not a continuous process; it took place in four successive stages (Mehdiratta, 1989). The first rise or push up of sediments of Tethys took place in the upper Eocene period resulting in the breaking up of the continuity of the ocean basin into smaller areas of sedimentation. During the interval that followed were laid the sediments of Murree, Nari, and Ghaj formations.

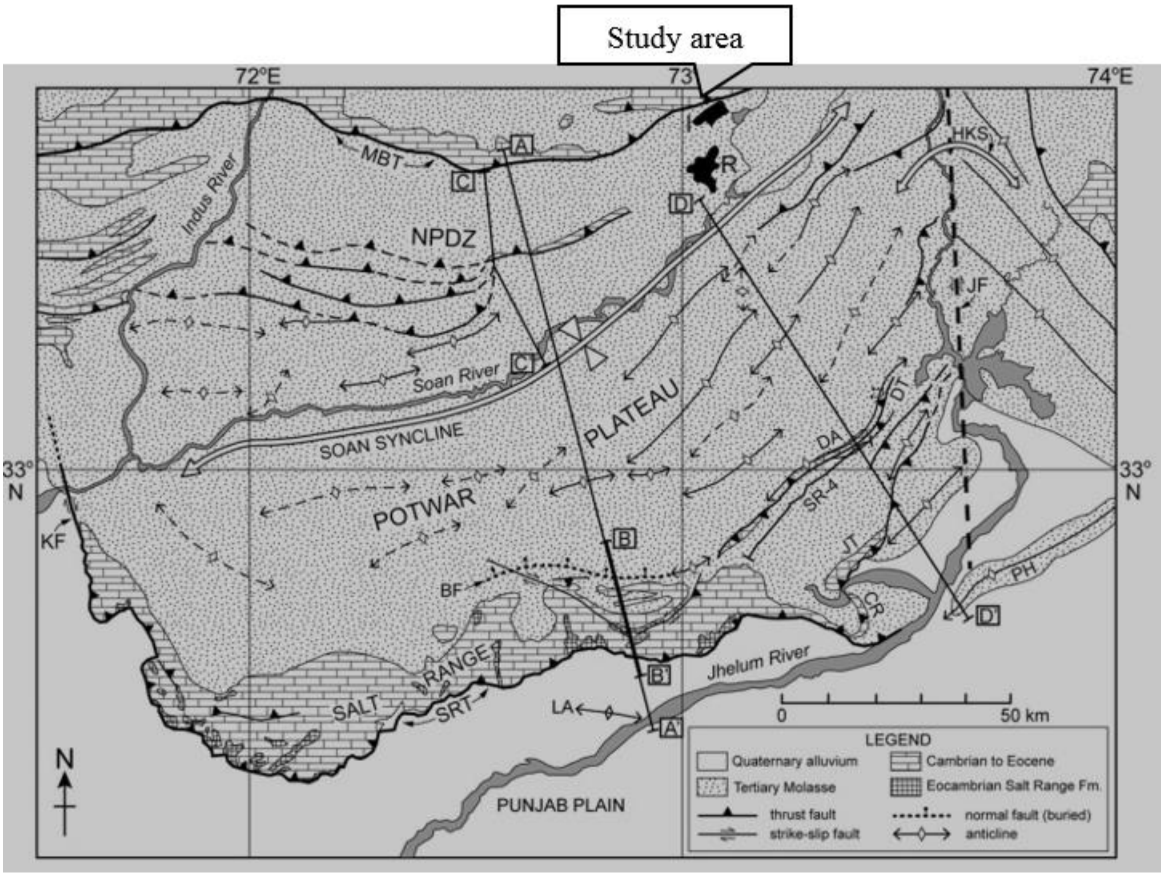


Figure 2.1 Geology and tectonics map of study area (Jaswal et al. 1997)

2.2 Tectonics of the Area

Himalayan system is classified into three longitudinal portions differing from one another, in well-marked orographic boundaries (Gohar, 1987):

i. Outer or Sub Himalayas
ii. Central or Middle or Lesser Himalayas
iii. Northern or Tibetan Zone

The study area is tectonically placed on the southward extension of the Garhi Habib Ullah syncline located in the outer Himalaya (Gohar, 1987). Indian sub-continent is drifting at a rate of approximately 4 cm / year to the north. The collision leads to the highest mountain range in the world like the Himalayas, the Karakoram, the Pamir and the Hindu Kush. As the Indian Plate pushes northward, much of the compressive movement between these two collision plates has been and continues to be adapted to a series of large thrust defects that dip northwards under these mountain ranges, subdued or forced under the Eurasian Plate. The Main Frontal Thrust (MFT), the Main Central Thrust (MCT), the Main Boundary (MBT) and the Main Thrust (MMT) have all been included in these groups.

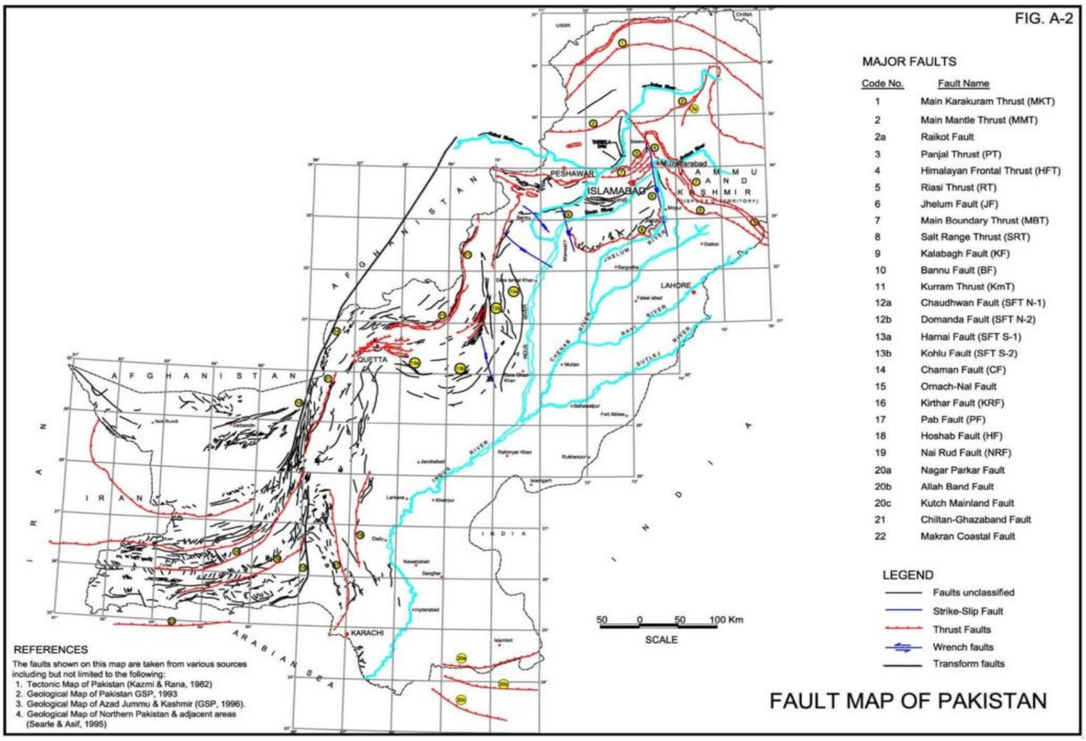


Figure 2.2 Fault map of Pakistan(Adhami and others, 1980)

There are three main thrust zones recognized in the study area, the southernmost part of these thrust zones is generally designated as Main Boundary Thrust (MBT) (Gohar, 1987). MBT is the result of the folding and thrusting of the Murree formation rocks against the Paleozoic rocks in the foreland of the Himalayan zone. The other faults are Panjal and Zankasar Thrust faults. Tectonic map of the Northern Pakistan is shown fig. (GSP, 1999).

2.3 Geologic Hazards

The Islamabad-Rawalpindi area present in tectonically active zone, where faulting; folding; and earthquakes have been frequent in the recent geologic past. Quaternary deposits are tectonically deformed throughout the map area. Studies by National Engineering Services of Pakistan (NESPAK) indicated that a realistic seismic factor for building design should probably be higher than that indicated on the seismic zoning map of Pakistan. (Adhami and others, 1980, p.133). They recommended design for 0.125-g (gravitational acceleration) horizontal acceleration for ordinary structures, and for 0.2 g without collapse for important structures. For sensitive structures, site-specific designs are required that consider the strength of the underlying soil and bedrocks and the distance from the probable earthquake sources (Adhami and others, 1980, p. 137).

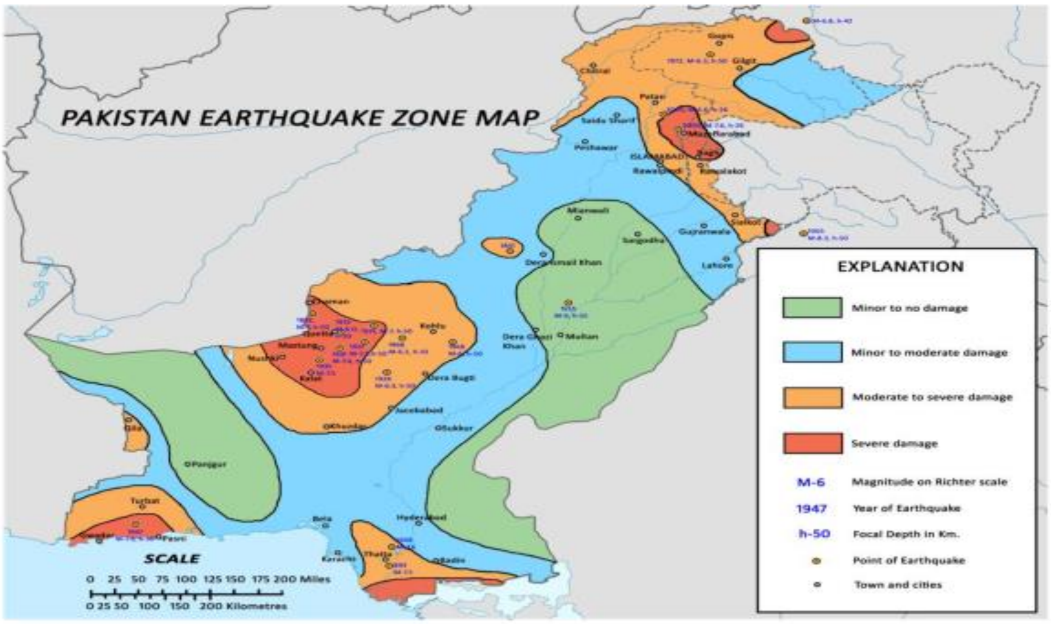


Figure 2.3PakistanEarthquake Zone Map(Adhami and others, 1980)

2.4 Stratigraphy

Stratigraphy is the branch of geology concerned with the study of rock layers and layering. It is primarily used in the study of sedimentary and layered volcanic rocks

2.4.1 Makarwal Group

Ranikot of kirthar range has sometimes been extended to denote Paleocene units of Upper Indus Basin in Kohat Potwar Province. Although the paleocene of Kohat Potwar province has chronostratigraphic equivilance with that of Lower Indus Basin. Yet both of them has considerable difference interms of rock characters. The name makarwal group was propsed by Shah 1980 is adopted here to assamble here mix deposits of continental and marine ficies represented by Hangu, Lockhart and Patala formation.

2.4.1.1 Hangu Formation

The lithology of Hangu formation varies from quartzose sandstone, intercalated shales and claystones. The properties of sandstone include brownish color, brittleness, apart from that it has more than 90% quartz which makes it quartzose. On the other hand, Shale and Claystone are greenish in color. The sequence in Hangu Formation is observed to be finning upward having a thickness of around 6-10m and makes a conformable contact with Lockhart Formation (Williams et al., 1999).

2.4.1.2 Lockhart limestone

As the name implies it mostly comprises of limestone but other than that it also contains shale as well as marl. The limestone here is light grey to dark grey and contains fossils. The marl also contains fossils and the color is grey to black. The thickness of Lockhart limestone can go up to 280m and apart from that it is conformable with Patala Formation (Williams et al., 1999).

2.4.2 Surghur Group (Jurassic-Lower Cretaceous Age)

The name Surghur Group was proposed by Shah 1980 for the Jurassic and Cretaceous Formations exposed in The Surghur Range and Salt Rnage. They represent mixed environmental conditions starting from continental deposits at the base, passing through marine environment and ending at the continental deposits at the top.

2.4.2.1 Samana Suk Formation

The lithology of this formation comprises of gray to brown limestone as well as marl at some places which is greenish gray in color having thin beds. The thickness can be at least 190 meters which can go up to 360 meters. This formation makes an unconformable contact with Chichali Formation above having an unknown base that is not exposed (Fatmi, 1990).

2.4.2.2 Chichali Formation

This formation’s lithology consists of glauconitic sandstone, shale, claystone. The color of these lithologies varies, like in case of siltstone and limestone they have a greenish-grey color whereas the shale has a more greenish or dark grey color. On the other hand, the grain size of glauconitic sandstone varies from fine to coarse grain. Its thickness can be up to 50 meters and then makes a gradational contact with Lumshiwal Formation above (Williams et al., 1999).

2.4.2.3 Lumshiwal Formation

This formation mostly contains shale, limestone and sandstone. Properties of these lithologies like limestone includes thin beds having yellowish color with lots of sand. The sandstone here has a moderate thickness which consists of glauconites, along with that, some fossils like ammonoids and brachiopods are also present in some areas. This formation makes an unconformable contact with Hangu present above (Williams et al., 1999).

2.4.3 Chharat Group (Lower Eocene Age)

After the chharat villege in the Attock district of Punjab Province, Chharat series of Pinfolf 1918 was formalised by stratigraphic committed of Pakistan as Chharat group. The group comprises the following groups in various parts of the province of Kohat Potwar and the region of Hazara. Kohat Formation, Kuldana Formation, Jatta Gypsum, Shekhan Formation, Penoba Shale and Bahadur Khel salt represent the group in the Kohat region.

2.4.3.1 Margalla Hill Limestone

As the name suggests, this formation also mostly contains limestone with shale and also marl. The limestone here is dark grey, with thick beds and are also nodular. The marl here has a grey color which is comparatively harder. The Margalla Hill Limestone consists of splintery shale having greenish grey color. Overall thickness of this formation is between 60-90m which makes a conformable contact with Chorgali Formation (Williams et al., 1999).

2.4.3.2 Chorgali Formation

The Chorgali Formation is divided into two parts, upper and lower. In the upper area this formation contains yellowish limestone which may contain some amount of chert and it also contains fossils. The Marl has a light grey color and overall thickness of this area is up to 120m.

On the other hand, the lower portion contains mostly shale having greenish-grey color; apart from that the limestone can also be found in between. Some foraminifera fossils can also be found in coquina beds. The whole unit makes a conformable contact with Kuldana Formation (Williams et al., 1999).

2.4.3.3 Kuldana Formation

The main lithology in this area contains marine and non-marine claystone, marl, limestone and small number of sandstones. Now, the color of marl is pale greyish with small amount of gypsum. As far as limestone is concerned, its color white-light brown. Overall thickness of this formation can go up to 120m which has an unconformable boundary with Murree Formation of Rawalpindi Group (Williams et al., 1999).

2.4.4 Rawalpindi Group (Miocene Age)

After the rawalpindi district, the stratigraphic commettee of Pakistan accepted the term rawalpindi group as propounded by Pinfold for the rocks consisting of murree formation and kamlial formation in kohat and potwar province consisting of fresh water sanstone and shale.

2.4.4.1 Murree Formation

They were called “Mari Group” by Wynne (1874) and then its name was officially changed to the Murree Formation by the Stratigraphic Committee of Pakistan (Fatmi, 1972).

In this formation, sandstone and siltstone are present with conglomerates in minority. The color of sandstone is reddish grey and thickness is not the same, it is different in different areas of this formation but it can go up to around 2900m (Williams et al., 1999).

This formation is conformably overlain by Kamlial Formation but unconformably overlies Kohat Formation (Amjad Ali, 1997).

2.4.4.2 Kamlial Formation

The Stratigraphic Committee of Pakistan was the one who came up with the name Kamlial Formation (Fatmi, 1973).

The lithology contains shale, siltstone, conglomerate and sandstone. The difference between Murree Formation and Kamlial Formation can be observed by the fact that spheroidal weathering occurs in Kamlial Formation and also, tourmaline is abundantly present there as well. The thickness is around 1500 to 1600m and is conformably overlain by Chinji Formation 115 km away from Islamabad (Johnson et al., 1985).

2.4.5 Siwalik Group (Neogene to Pleistocene Age)

The Siwalik community nomanclature suggests that the word Siwalik was first used by Meddlicot for the upper part of the Siwalik and Simla Hills of India's Sub Himalayan system. Three fault divisions were suggested by Pilgrim of the Siwalik system, each of which was divided into different faunal zones. Six Pilgrim faunal zones were used (Lewis, 1937) as formal lithographic units.

2.4.5.1 Chinji Formation

The name was termed to “Chinji Stage” which was then agreed by the Stratigraphic Committee of Pakistan (Shah, 1977).

This Formation mostly contains siltstone which is breakable and contains sandstone in between. The sandstone’s color is smoky and also with a tone of brown. It is famous because of its brick-red color. The thickness of Chinji is between 850-1170 meters and it is conformably overlain by Nagri formation (Johnson et al., 1985).

2.4.5.2 Nagri Formation

Nagri Formation was named as Nagri stage of Pilgrims before, but it was renamed by Lewis which was then agreed by the Stratigraphic Committee of Pakistan (Shah, 1977).

Sandstone dominates here which has a greenish grey color with clay in between. In different areas conglomerates are also present within the formation. It has a characteristic pattern of salt and pepper which forms because of ilmenite and magnetite. The thickness of this formation is between 500-900m and is conformably overlain by Dhok Pathan (Johnson et al., 1985).

2.4.5.3 Dhok Pathan Formation

The pilgrim came up with the name “Dhok Pathan” which was changed to “Dhok Pathan Formation” by cotter in 1933, and now, this name has been formalized (Fatmi, 1973).Orange colored siltstone dominates in this area including sandstone of greyish color and hard claystone. Its thickness is founded to be between 500-820m. It is conformably overlain by Soan Formation (Johnson et al., 1985).

2.4.5.4 Soan Formation

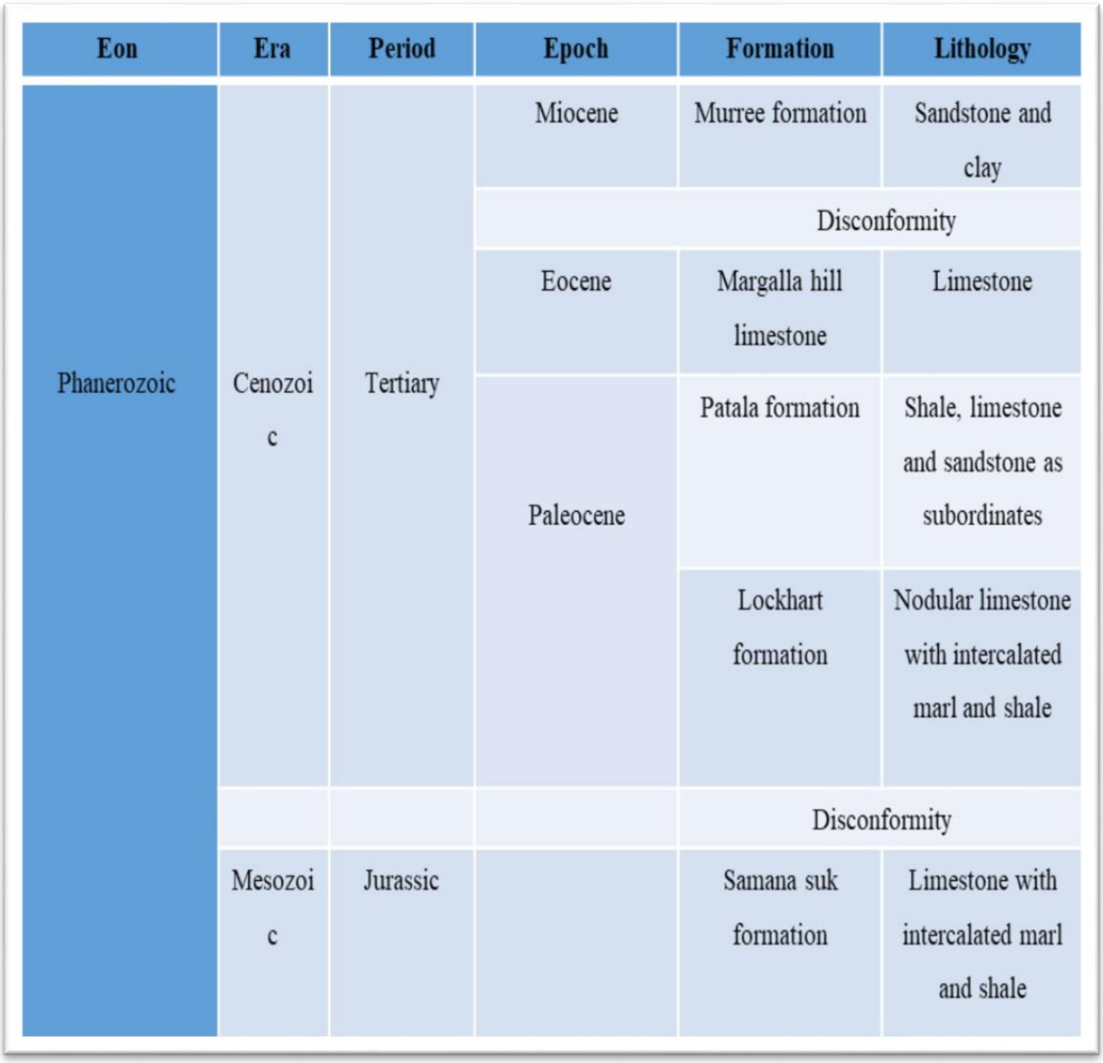
It was accepted by the Stratigraphic Committee of Pakistan after it was given by Kravtchenko in 1964 (Rahman, 1968).

The lithology of this formation contains siltstone, clay stone, sandstone including clays and conglomerates. The grains in sandstone are clearly visible and it has a greenish grey color whereas the color of clay stone is light pink and brownish. The thickness varies from 200-300m which is conformably overlain by Lei conglomerates (Johnson et al., 1982).

2.4.6 Units on Surface (Pleistocene-Holocene)

2.4.6.1 Lei Conglomerate

Pilgrim came up with the name “Boulder Conglomerate” in 1910 but then “Lei Conglomerates” was introduced by Gill in 1952. This area is mostly flat and nearer to sea-level. However, folds and faults are present in the local areas. Lei Conglomerates overlay Rawalpindi and Siwalik group. Since the volcanic ash is younger than Soan Formation and older than the Lei Conglomerates, the age of Lei Conglomerates can be roughly estimated by the fission track method which shows that the max age of Lei Conglomerates is around 1.6-18 million years (Johnson et al., 1982).



Eon	Era	Period	Epoch	Formation	Lithology
Phanerozoic	Cenozoic	Tertiary	Miocene	Murree formation	Sandstone and clay
			Disconformity		
			Eocene	Margalla hill limestone	Limestone
			Paleocene	Patala formation	Shale, limestone and sandstone as subordinates
				Lockhart formation	Nodular limestone with intercalated marl and shale
				Disconformity	
	Mesozoic	Jurassic		Samana suk formation	Limestone with intercalated marl and shale

Figure 2.4 Generalized Stratigraphic column of study area. (Litsey, 1958)

CHAPTER 3

METHODOLOGY

3.1 Field Investigation

The study area was gone through geotechnical investigation by drilling 5 boreholes in which the depth was 30 meters (100 feet) to observe the soil properties within the ground. The method chosen for drilling was straight rotary. Standard Penetration tests (SPT) and also Cone Penetration tests (CPT) were performed at depth interval of 5 feet. Undisturbed soil samples were also collected by using pitcher tube from boreholes.

3.1.1 Borehole Coordinates

The coordinates and depth of boreholes are given in table 3.1 and aerial view of boreholes on site is shown in figure 3.1.

Table 3.1 Borehole coordinates

Borehole Number	**Coordinates**	**Maximum Depth (m)**
BH 01	33°40'53.96"N, 73°13'126.69"E	30 Meters
BH 02	33°40'54.17"N, 73°13'127.95"E	
BH 03	33°40'53.35"N, 73°13'128.14"E	
BH 04	33°40'53.67"N, 73°13'127.46"E	
BH 05	33°40'53.27"N, 73°013'127.00"E	

Figure 3.1 Borehole location on ground (Google Map)

3.1.2 Standard Penetration Test (ASTM D1586)

This type of test is applied in drilled boreholes. In this test it is observed how much the soil resists into the strata while penetrating it into the borehole. It is one of the most helpful techniques to find out the comparative density and the angle of shear resistance of cohesion less soil. Moreover, this technique applied for finding the unconfined compressive strength of cohesive soil.

If the number of blows are more than 50 the result is taken as refusal and the test is stopped.

3.1.2.1 Safety measures

i. The sampler must be in a proper working condition.
ii. The cutting shoe must not be broken.
iii. The height of hammer from where it needs to be dropped must be 30 inch or else the values of N will not be accurate.
iv. The drill rods must be in normal shape, if for some reason they are bent, the results will not be accurate.
v. The bottom potion of borehole must be clean before performing the test.

Figure 3.2 Split Spoon Sampler

Figure 3.3 Drop hammer of 63.5kg used for SPT.

3.1.3 Rock Quality Designation (RQD)

A rough measure of the degree of joining and fracturing in the rock mass, measured in lengths of 10 cm or more as a percentage of the drill core. High-quality rock has more than 75 percent RQD, less than 50 percent low-quality. The percentage of intact rock obtained from a borehole is denoted by the RQD. The total length of the core run is summed and divided by all fragments of the intact rock core equal to or greater than 100 mm (4 in.) length.

Figure 3.4 Rotary Machine

3.2 Laboratory Testing

Soil samples from the drilled boreholes were properly marked and then transported to the laboratory to perform the following tests.

1. Sieve Analysis.
2. Atterberg limits.
3. Moisture Content
4. Bulk and Dry Density
5. Specific Gravity

3.2.1 Sieve Analysis Test (ASTM D 422)

Sieve analysis was conducted to determine soil grain size distribution. The soil samples are put in the drying binder to carry out the examination. After this they move through the sieves which are stacked from top to bottom in the order of decreasing size.

The smallest number of sieves used was 200, while the wider sieve was No.4. The retained weight of the samples on each sieve was measured and the results were plotted on logarithmic chart.

3.2.1.1 Apparatus

i. Stacked sieves with pan and cover
ii. An electronic weighing machine having an accuracy of 0.01 grams
iii. Ceramic mortar and pestle to crush the lumped soil
iv. Sieve shaker
v. Binder

3.2.2 Atterberg Limit (ASTM D 4318)

Depending on the water content of the soil, Atterberg 's boundary values are a simple indicator of the quality of fine-grained soil. In four states, it can occur: solid , semi-solid, plastic and liquid. The quality and actions of the soil are different in all nations, and so these are also technical characteristics. Therefore, it is possible to establish the boundary between the various states according to a shift in soil behaviour. It is possible to use Atterberg 's limits to tell the difference between Silt and Clay, and it may make the difference between different silts and clays. Albert Atterberg, a Swedish chemist, established these boundaries. They were then refined by Casagrande Arthur.

When soils are selected to establish structures on top, these distinctions in the soil are used. In the event of moisture, water accumulation and volume stretching, the amount of expansion depends on the water absorption potential of the soil and its structural composition. These tests are primarily used on clay and muddy soils, since they are soils that, due to moisture levels, stretch and shrink. Such soils react with water and thus adjust the size and have various shear thicknesses. Thus, in the early stages of the construction of any building, these tests are commonly used to ensure that the soil has the proper shear resistance and not too much volume variation, since it stretches and shrinks with various levels of moisture. The measure of soil plasticity is the plasticity index. The scale of the water content in which the soil has plastic properties is the plasticity index (PI)..

Figure 3.5 Casagrande Apparatus

3.2.3 Natural Moisture Content (ASTM D 2216)

The ratio between the weight of the water and the weight of the solids in each mass of the soil is the natural moisture content. Normally, this ratio is expressed as a percentage. The soil's natural moisture content has to be determined in almost all soil studies.

Knowledge of the natural moisture content is essential in all studies of soil mechanics. To see some of them, the natural moisture content is used to determine the mileage and the regulation. The natural moisture content will give an impression of the condition of the soil in the field.

3.2.4 Bulk and Dry Density (ASTM D 7263)

Density is a fundamental property of a substance that refers to the mass of objects separated by the volume of that substance. It can be difficult, however, to establish a certain density for certain rock materials. This challenge stems from a variety of sources, such as irregular volume, porosity, material moisture content, and material permeability. In evaluating the bulk density of the rock core, the key challenge is obtaining a reliable estimation of the total rock core thickness.

Understanding the density and porosity of the reservoir is a key factor in assessing its hydrocarbon potential.

3.2.5 Specific Gravity (ASTM D891 – 09)

It refers to the quality of the solid material in a given soil sample in relation to the equivalent amount of water. This number indicates how much light the material weighs as water. We use the this to calculate other technical properties, such as the volume of solids in the sample.

CHAPTER 4

RESULTS AND CONCLUSION

4.1 Laboratory Test Results

4.1.1 Sieve analysis

It was performed for soil samples collected from BH-1 with the interval of 1.5 m from the depth of 1.5m, 3m and 4.5m. Results obtained from sieve analysis are shown in figure 4.1, 4.2 and 4.3. Results indicate the silty clay at a depth of 1.5m and 3m, whereas; silty clay with gravel at a depth of 4.5m.

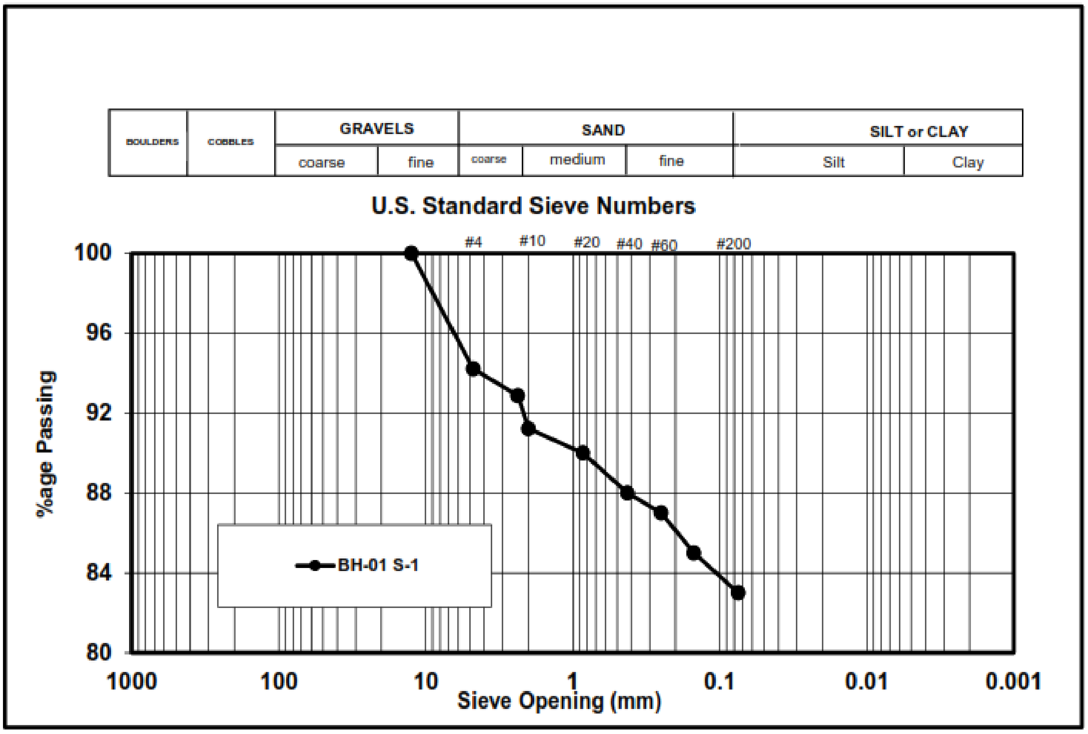


Figure 4.1 Sieve Analysis of borehole 1 (sample 1) at 1.5m depth

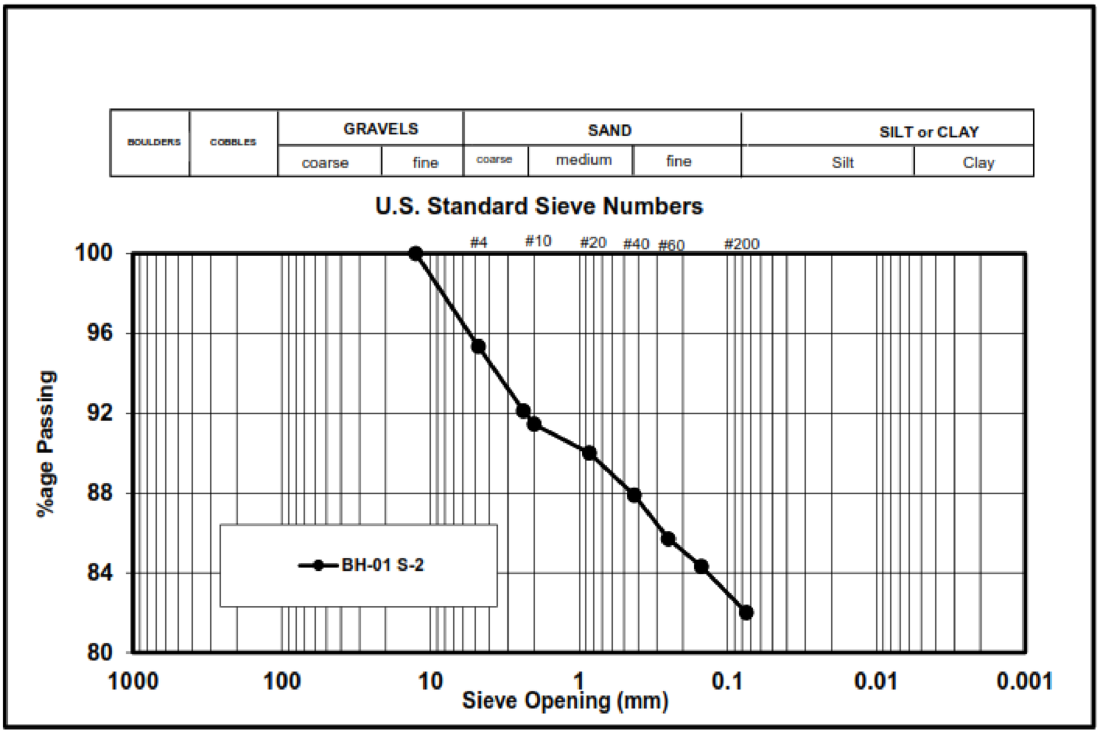


Figure 4.2 Sieve Analysis of borehole 1 (sample 2) at 3m depth

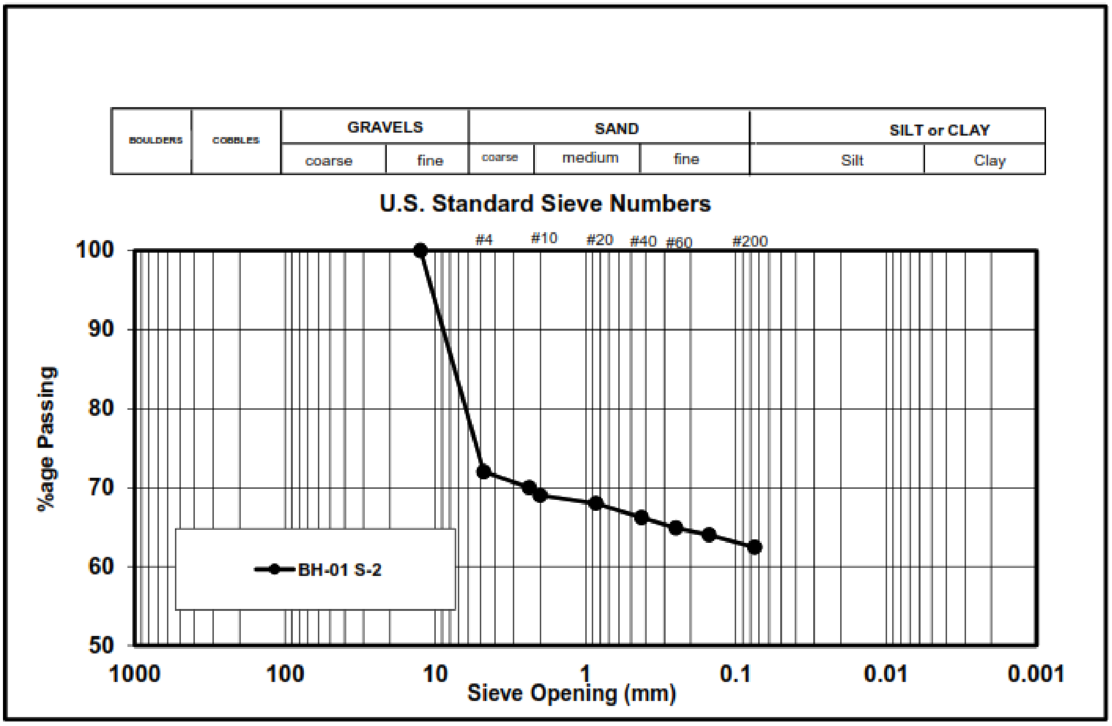


Figure 4.3 Sieve Analysis BH 1 (sample 3) at depth 4.5m

4.1.2 Atterberg limits

These limits were calculated for obtained soil samples. For liquid limit casagrande cup method and for plastic limit thread method was used. Atterberg limits were calculated for the soil samples collected from BH-1 at a depth of 1.5m, 3m and 4.5m. The results of Atterberg limits are shown in the following table (4.1, 4.2, 4.3, 4.4, 4.5, 4.6) and figure (4.4, 4.5, 4.6).

Table 4.1 Liquid Limit Test of BH 1 (sample 1) at depth 1.5m

Test Number	**Weight of can (g)**	**Weight of Can + wet soil (g)**	**Weight of Can + dry soil (g)**	**Blow Count**	**Weight Content (%)**	**Water Content fitted (%)**
	W_c	**W_w**	**W_d**	**N**	**W**	
1	13.00	25.00	24.91	49	0.76	10.81
2	12.00	24.78	22.14	34	26.04	19.41
3	11.21	26.78	22.61	26	36.58	25.72
4	11.70	25.00	21.71	14	32.87	40.29

Liquid Limit (%) = 27

Slope of flow line = 2.602

Table 4.2 Plastic Limit and Plasticity Index of BH 1 (sample 1) at depth 1.5m

Test Number	**1**	**2**	**3**
Weight of Container	11.22	11.10	10.32
Weight of Container + Wet soil (gm)	15.01	14.87	13.93
Weight of Container + Dry soil (gm)	14.51	14.22	13.19
Weight of Water (gm)	0.50	0.65	0.74
Weight of Soil (gm)	3.29	3.12	2.87
Water Content (%)	15.20	20.83	25.78
Plastic Limit (%)	21		
Plasticity Index (LL – PL)	6		

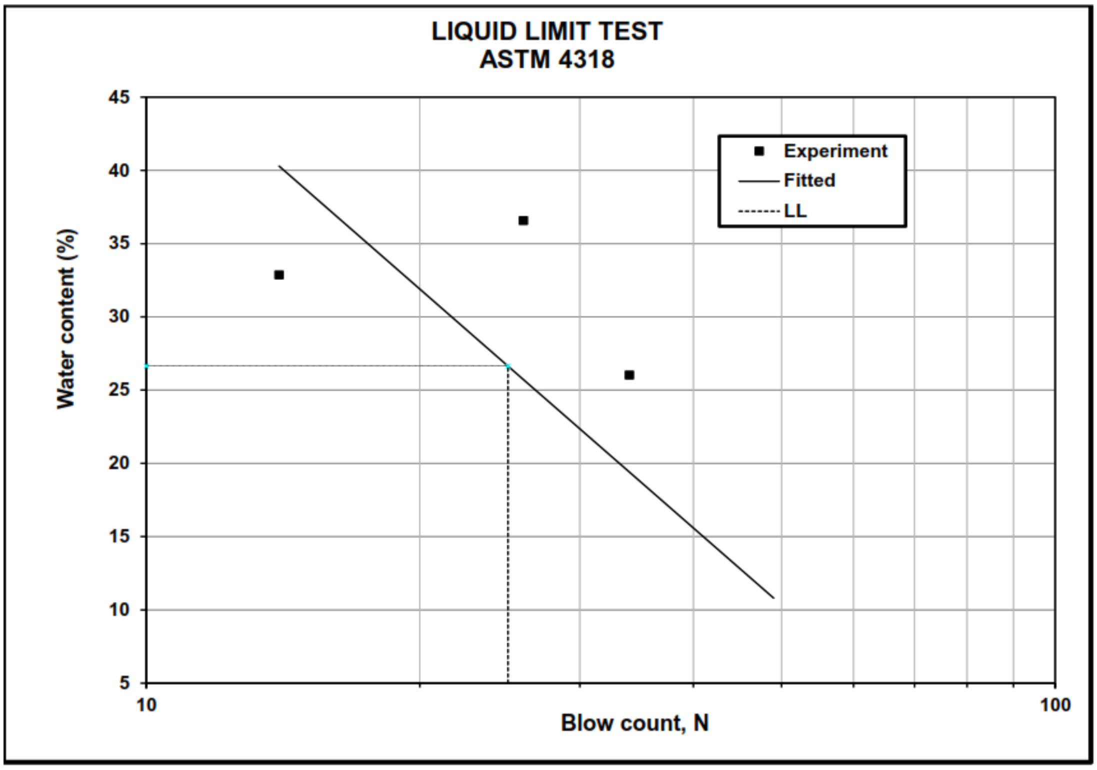


Figure 4.4 Liquid Limit test BH 1(sample 1) at depth 1.5m

Table 4.3 Liquid Limit Test of BH 1 (sample 2) at depth 3m

Test Number	**Weight of can (g)**	**Weight of Can + wet soil (g)**	**Weight of Can + dry soil (g)**	**Blow Count**	**Weight Content (%)**	**Water Content fitted (%)**
	W_c	**W_w**	**W_d**	**N**	**W**	
1	11.78	24.28	24.18	46	0.81	4.89
2	12.00	24.92	22.71	33	20.63	15.91
3	12.21	24.32	21.65	24	28.28	26.47
4	10.90	25.00	21.71	15	39.60	42.06

Liquid Limit (%) = 25

Slope of flow line = 3.120

Table 4.4 Plastic Limit and Plasticity Index of BH 1 (sample 2) at depth 3m

Test Number	**1**	**2**	**3**
Weight of Container	11.00	10.80	10.70
Weight of Container + Wet soil (gm)	15.18	15.98	14.21
Weight of Container + Dry soil (gm)	14.78	15.21	13.47
Weight of Water (gm)	0.40	0.77	0.74
Weight of Soil (gm)	3.78	4.41	2.77
Water Content (%)	10.58	17.46	26.71
Plastic Limit (%)	18		
Plasticity Index (LL – PL)	7		

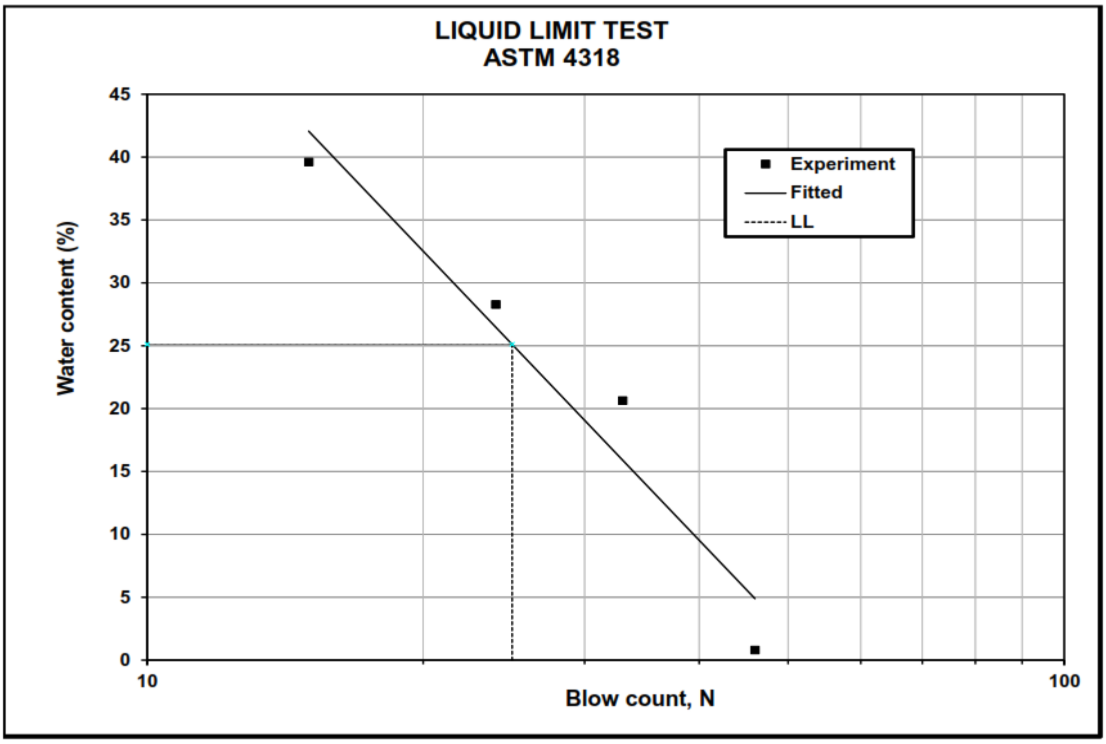


Figure 4.5 Liquid Limit Test BH 1 (sample 2) at depth 3m

Table 4.5 Liquid Limit Test of BH 1 (sample 3) at depth 4.5m

Test Number	**Weight of can (g)**	**Weight of Can + wet soil (g)**	**Weight of Can + dry soil (g)**	**Blow Count**	**Weight Content (%)**	**Water Content fitted (%)**
	W_c	**W_w**	**W_d**	**N**	**W**	
1	12.00	24.56	24.48	55	0.64	6.68
2	12.00	24.81	23.00	46	16.45	11.87
3	11.30	23.32	21.00	32	26.67	22.41
4	12.50	24.00	20.67	18	36.31	39.11

Liquid Limit (%) = 30

Slope of flow line = 2.813

Table 4.6 Plastic Limit and Plasticity Index of BH 1 (sample 3) at depth 4.5m

Test Number	**1**	**2**	**3**
Weight of Container	12.00	10.70	12.10
Weight of Container + Wet soil (gm)	15.28	15.28	14.32
Weight of Container + Dry soil (gm)	14.93	14.45	13.75
Weight of Water (gm)	0.35	0.83	0.57
Weight of Soil (gm)	2.93	3.75	1.65
Water Content (%)	11.95	22.13	34.55
Plastic Limit (%)	23		
Plasticity Index (LL – PL)	7		

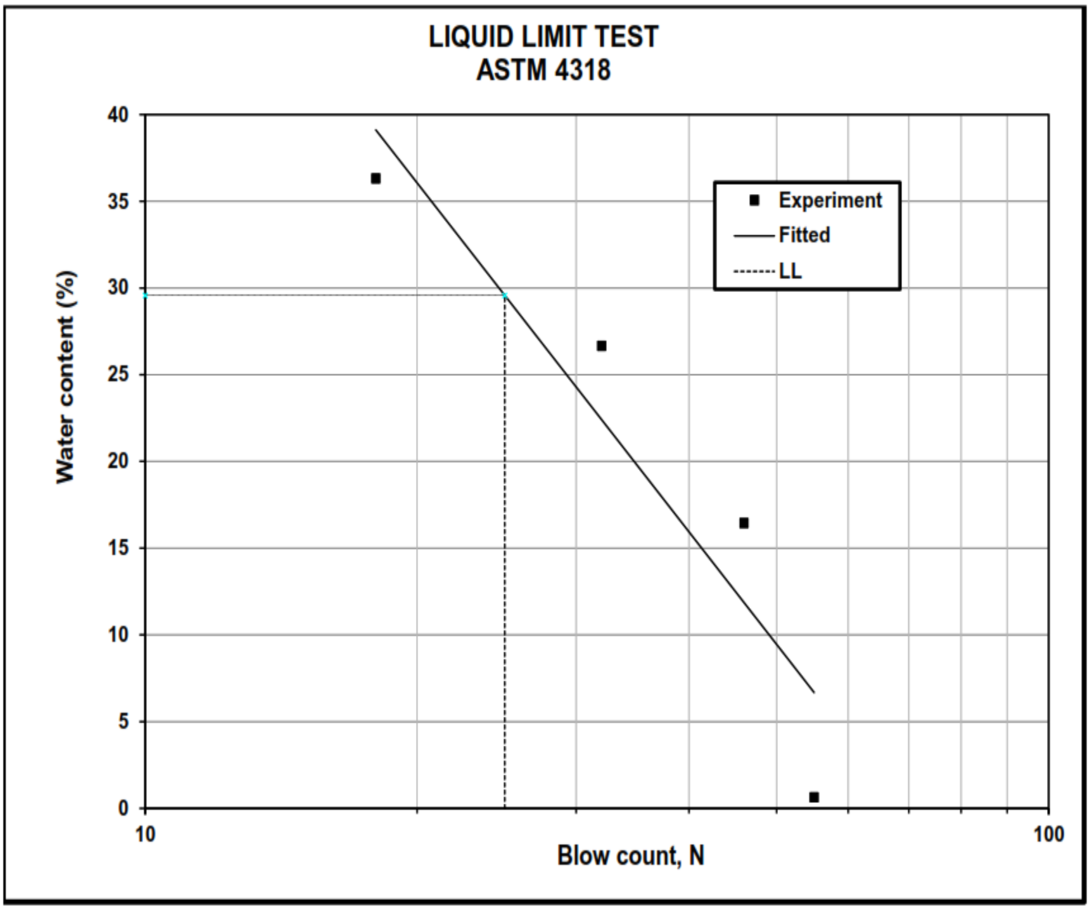


Figure 4.6 Liquid Limit Test BH 1 (sample 3) at depth 4.5m

4.1.3 Physical properties

Physical properties including moisture content, bulk density, dry density and specific gravity were also calculated for the samples collected from BH-1, 2, 3, 4 and 5. Obtained result values are shown in table 4.7.

Table 4.7 Showing value of bulk and dry density, specific gravity and moisture content

BH No.	**Run no.**	**Depth (m)**	**Bulk Density (gm/cc)**	**Moisture Content (%)**	**Dry Density (gm/cc)**	**Specific Gravity (Gs)**
BH-01	R-04	9.0-10.5	2.443	4.21	2.344	2.64
BH-01	R-10	18-19.5	2.553	3.68	2.462	2.49
BH-02	R-08	12-13.5	2.667	0.47	2.655	2.42
BH-02	R-16	24-25.5	2.424	0.13	2.421	2.51
BH-03	R-03	4.5-6.5	2.003	0.34	1.996	2.54
BH-03	R-14	21-22.5	2.561	0.29	2.554	2.46
BH-04	R-05	7.5-9.0	2.304	6.26	2.168	2.59
BH-04	R-12	18-19.5	2.667	0.47	2.655	2.39
BH-05	R-06	9.0-10.5	2.556	0.21	2.551	2.44
BH-05	R-18	27-28.5	3.012	0.13	3.008	2.50

4.2 Bearing Capacity of Soil

It can be calculated with Standard penetration test (SPT). Bearing capacity from SPT can be calculated with the Meyerhof's (1956; 1974) equation:

$Qa = (N/4) (Kd)$ * (width (B) ≤ 4)

$Qa = (N/6) (B+1/B)^2 (Kd)$ * (B >4)

Where

$Kd = 1+0.33(D/B) \leq 1.33$

4.3 Summary of Bearing Capacity

Bearing capacity for raft footing and strip footing calculated at different depths. While calculating bearing capacity for raft footing, width is 417ft and depth are 1.5m, 3m, 4.5m. The results are given below

Table 4.8 Results of Bearing Capacity of Raft Foundation

Bearing Capacity for Raft Footing	
Depth(m)	**Bearing capacity(tsf)**
1.5	2.65
3	4.38
4.5	9.53

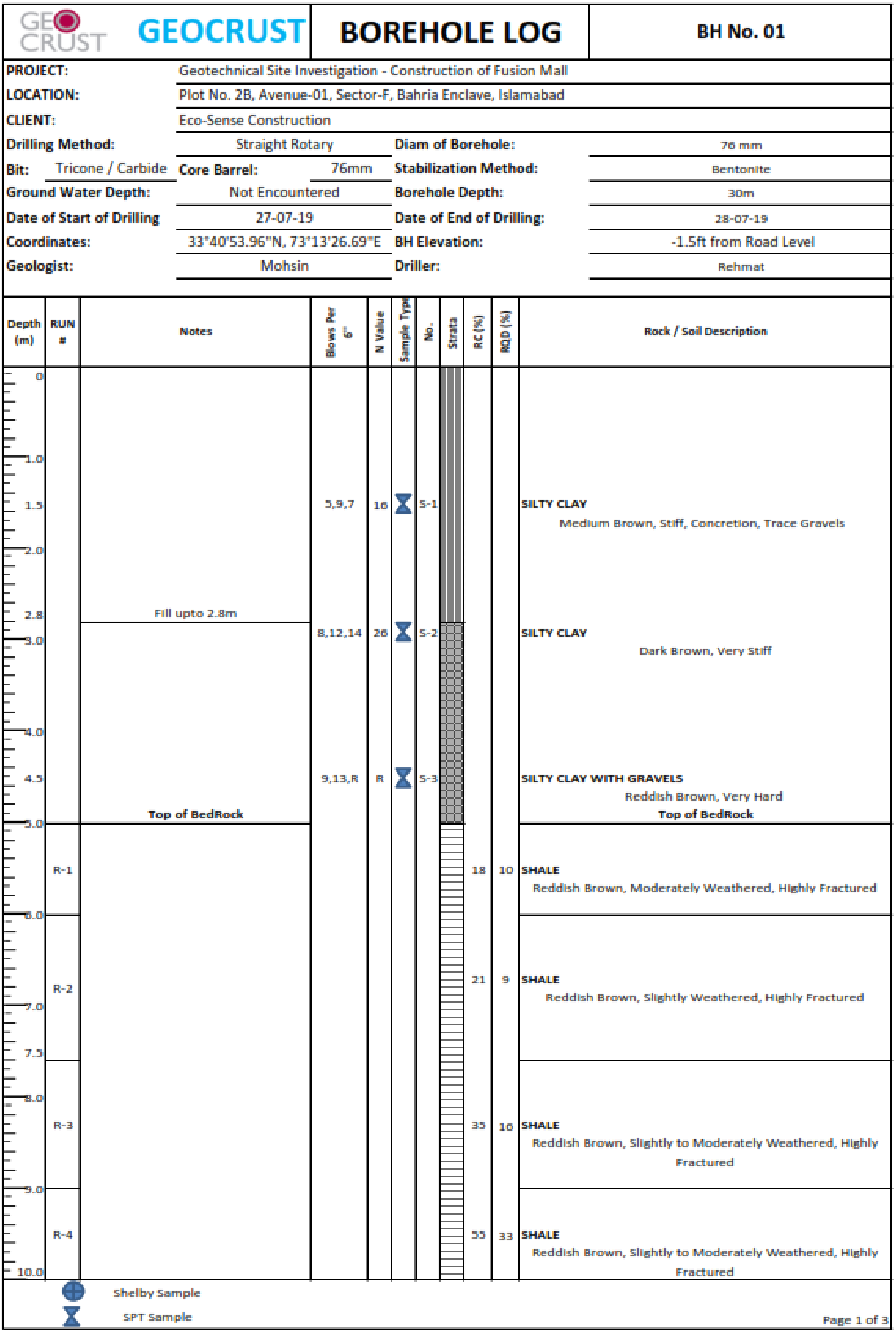
While calculating bearing capacity for strip foundation, width is 10ft and the depth are 1.5m, 3m, 4.5m.

Table 4.9 Results of Bearing Capacity of Strip Footing

Bearing Capacity for Strip Footing	
Depth(m)	**Bearing capacity(tsf)**
1.5	2.3
3	4.36
4.5	8.29

4.4 Encountered Strata

Five boreholes were drilled at the proposed site. The site is mainly underlain by sandstone / shale type deposits. Detail of strata encountered in each borehole is given in borehole logs.



GEOCRUST **BOREHOLE LOG** **BH No. 01**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	27-07-19	**Date of End of Drilling:**	28-07-19
Coordinates:	33°40'53.96"N, 73°13'26.69"E	**BH Elevation:**	-1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
0										
1.0										
1.5			5,9,7	16	⧗	S-1				**SILTY CLAY** Medium Brown, Stiff, Concretion, Trace Gravels
2.0										
2.8		Fill upto 2.8m								
3.0			8,12,14	26	⧗	S-2				**SILTY CLAY** Dark Brown, Very Stiff
4.0										
4.5			9,13,R	R	⧗	S-3				**SILTY CLAY WITH GRAVELS** Reddish Brown, Very Hard
5.0		**Top of BedRock**								**Top of BedRock**
	R-1							18	10	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
6.0										
	R-2							21	9	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
7.0										
7.5										
8.0										
	R-3							35	16	**SHALE** Reddish Brown, Slightly to Moderately Weathered, Highly Fractured
9.0										
	R-4							55	33	**SHALE** Reddish Brown, Slightly to Moderately Weathered, Highly Fractured
10.0										

⊕ Shelby Sample

⧗ SPT Sample

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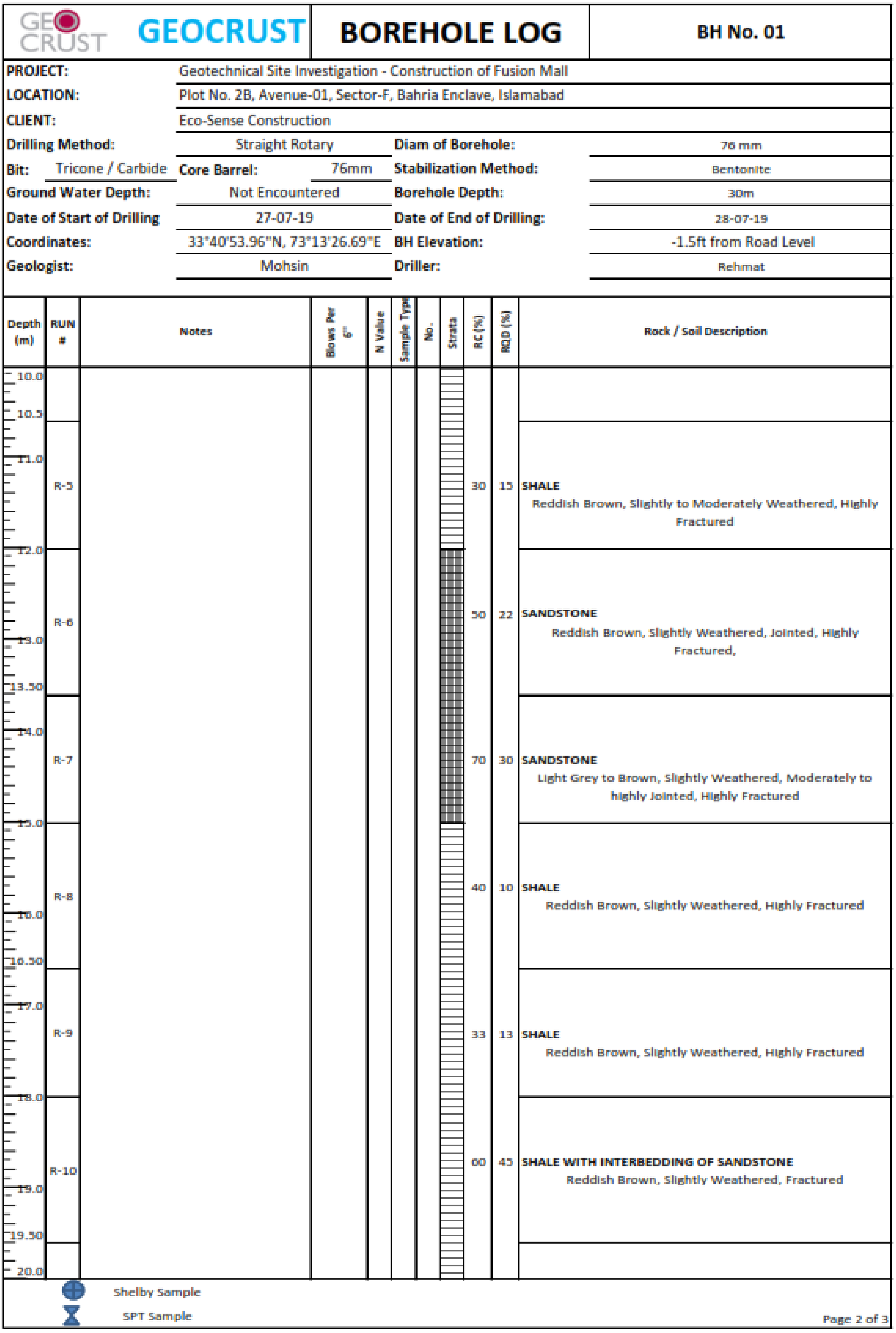
Figure 4.7 Borehole log BH 01 from 0m to 10m depth



GEOCRUST **BOREHOLE LOG** **BH No. 01**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	27-07-19	**Date of End of Drilling:**	28-07-19
Coordinates:	33°40'53.96"N, 73°13'26.69"E	**BH Elevation:**	-1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
10.0 10.5										
11.0	R-5							30	15	**SHALE** Reddish Brown, Slightly to Moderately Weathered, Highly Fractured
12.0 13.0	R-6							50	22	**SANDSTONE** Reddish Brown, Slightly Weathered, Jointed, Highly Fractured,
13.50 14.0	R-7							70	30	**SANDSTONE** Light Grey to Brown, Slightly Weathered, Moderately to highly Jointed, Highly Fractured
15.0 16.0	R-8							40	10	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
16.50 17.0	R-9							33	13	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
18.0 19.0	R-10							60	45	**SHALE WITH INTERBEDDING OF SANDSTONE** Reddish Brown, Slightly Weathered, Fractured
19.50 20.0										

⊕ Shelby Sample

⧗ SPT Sample

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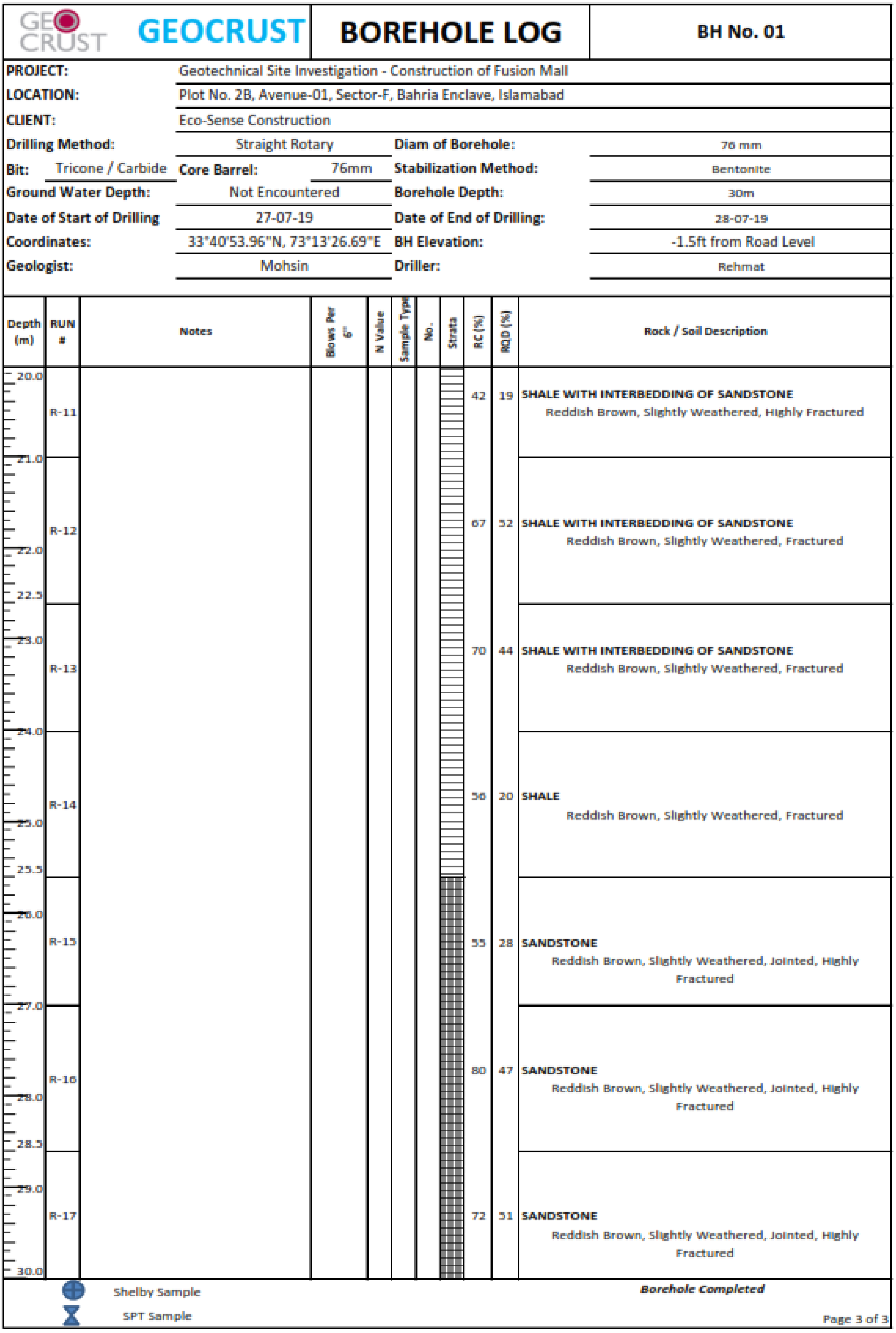
Figure 4.8 Borehole log BH 01 from 10m to 20m depth



GEOCRUST **BOREHOLE LOG** **BH No. 01**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	27-07-19	**Date of End of Drilling:**	28-07-19
Coordinates:	33°40'53.96"N, 73°13'26.69"E	**BH Elevation:**	-1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
20.0	R-11							42	19	**SHALE WITH INTERBEDDING OF SANDSTONE** Reddish Brown, Slightly Weathered, Highly Fractured
21.0 22.0	R-12							67	52	**SHALE WITH INTERBEDDING OF SANDSTONE** Reddish Brown, Slightly Weathered, Fractured
22.5 23.0	R-13							70	44	**SHALE WITH INTERBEDDING OF SANDSTONE** Reddish Brown, Slightly Weathered, Fractured
24.0 25.0	R-14							56	20	**SHALE** Reddish Brown, Slightly Weathered, Fractured
25.5 26.0	R-15							55	28	**SANDSTONE** Reddish Brown, Slightly Weathered, Jointed, Highly Fractured
27.0 28.0	R-16							80	47	**SANDSTONE** Reddish Brown, Slightly Weathered, Jointed, Highly Fractured
28.5 29.0 30.0	R-17							72	51	**SANDSTONE** Reddish Brown, Slightly Weathered, Jointed, Highly Fractured

⊕ Shelby Sample

⧗ SPT Sample

Borehole Completed

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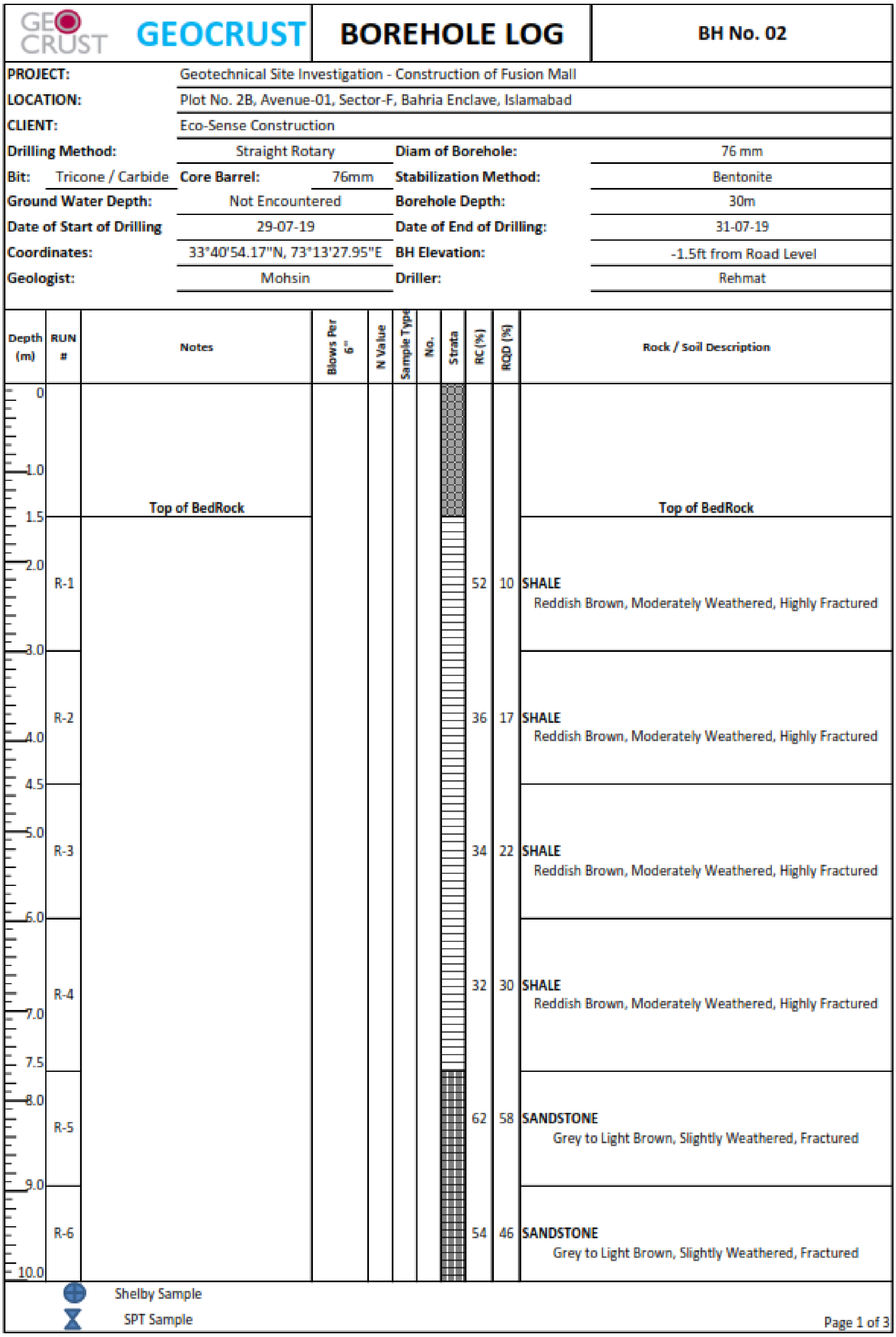
Figure 4.9 Borehole log BH 01 from 20m to 30m depth



GEOCRUST **BOREHOLE LOG** **BH No. 02**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall
LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad
CLIENT: Eco-Sense Construction
Drilling Method: Straight Rotary **Diam of Borehole:** 76 mm
Bit: Tricone / Carbide **Core Barrel:** 76mm **Stabilization Method:** Bentonite
Ground Water Depth: Not Encountered **Borehole Depth:** 30m
Date of Start of Drilling 29-07-19 **Date of End of Drilling:** 31-07-19
Coordinates: 33°40'54.17"N, 73°13'27.95"E **BH Elevation:** -1.5ft from Road Level
Geologist: Mohsin **Driller:** Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
0 1.0 1.5		Top of BedRock								Top of BedRock
2.0 3.0	R-1							52	10	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
4.0 4.5	R-2							36	17	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
5.0 6.0	R-3							34	22	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
7.0 7.5	R-4							32	30	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
8.0 9.0	R-5							62	58	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
10.0	R-6							54	46	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured

⊕ Shelby Sample
⧗ SPT Sample

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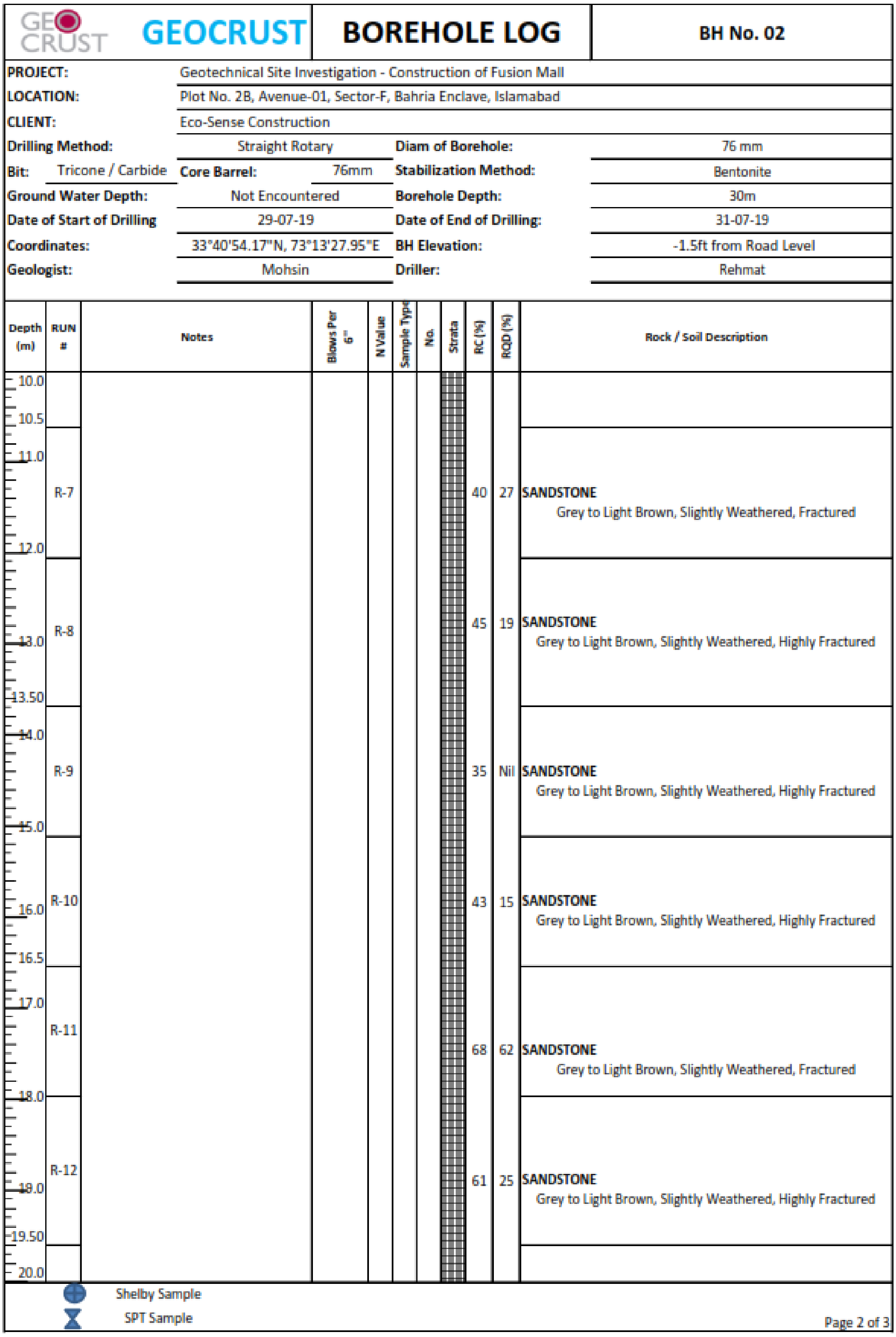
Figure 4.10 Borehole log BH 02 from 0m to 10m depth



GEOCRUST **BOREHOLE LOG** **BH No. 02**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad
CLIENT:	Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	29-07-19	**Date of End of Drilling:**	31-07-19
Coordinates:	33°40'54.17"N, 73°13'27.95"E	**BH Elevation:**	-1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
10.0 10.5							▦			
11.0 12.0	R-7						▦	40	27	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
13.0 13.50	R-8						▦	45	19	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
14.0 15.0	R-9						▦	35	Nil	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
16.0 16.5	R-10						▦	43	15	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
17.0 18.0	R-11						▦	68	62	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
19.0 19.50	R-12						▦	61	25	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
20.0							▦			

⊕ Shelby Sample

⧗ SPT Sample

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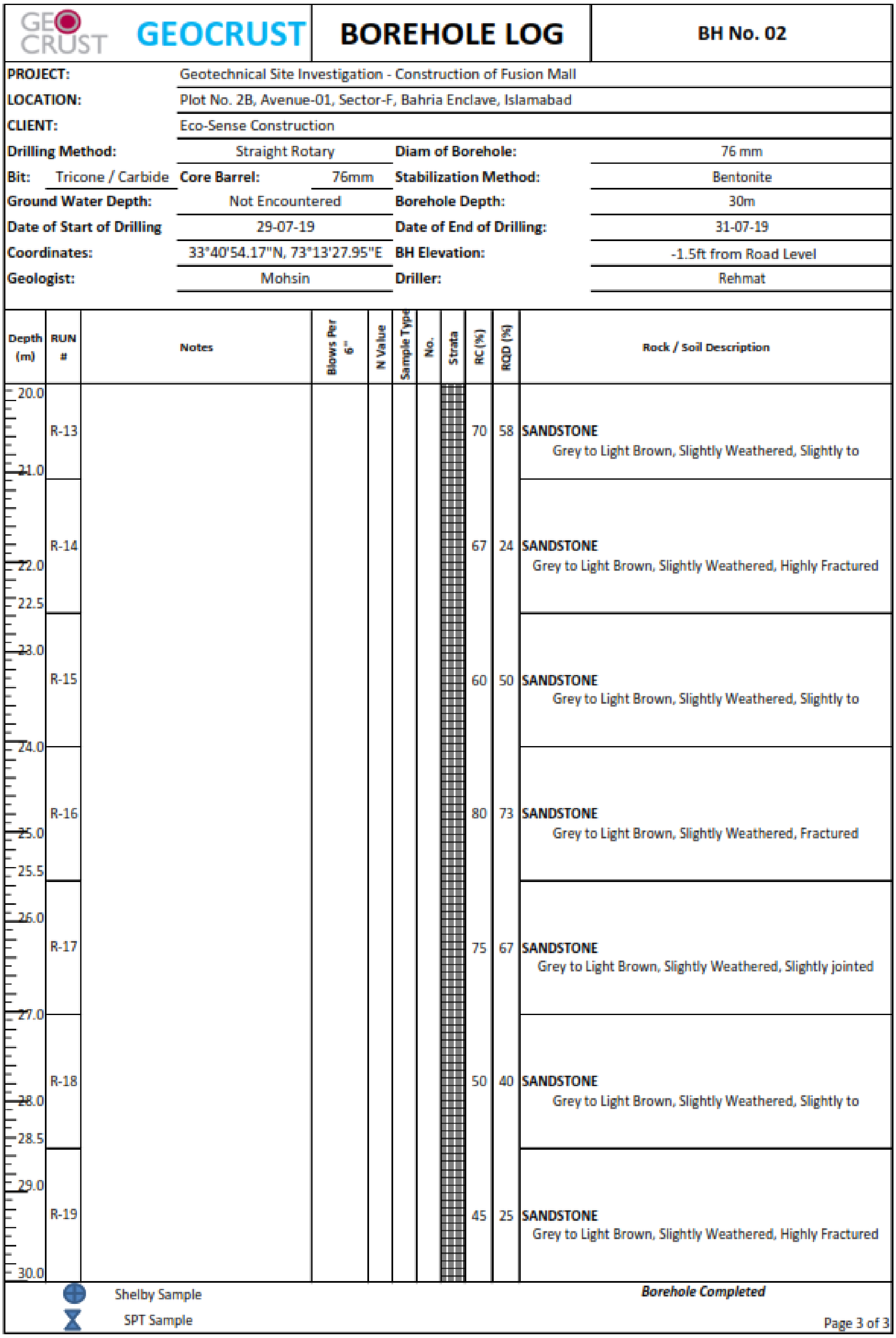
Figure 4.11 Borehole log BH 02 from 10m to 20m depth



GEOCRUST **BOREHOLE LOG** **BH No. 02**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	29-07-19	**Date of End of Drilling:**	31-07-19
Coordinates:	33°40'54.17"N, 73°13'27.95"E	**BH Elevation:**	-1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
20.0 21.0	R-13						▦	70	58	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Slightly to
22.0 22.5	R-14						▦	67	24	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
23.0 24.0	R-15						▦	60	50	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Slightly to
25.0 25.5	R-16						▦	80	73	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
26.0 27.0	R-17						▦	75	67	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Slightly jointed
28.0 28.5	R-18						▦	50	40	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Slightly to
29.0 30.0	R-19						▦	45	25	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured

⊕ Shelby Sample

⧗ SPT Sample

Borehole Completed

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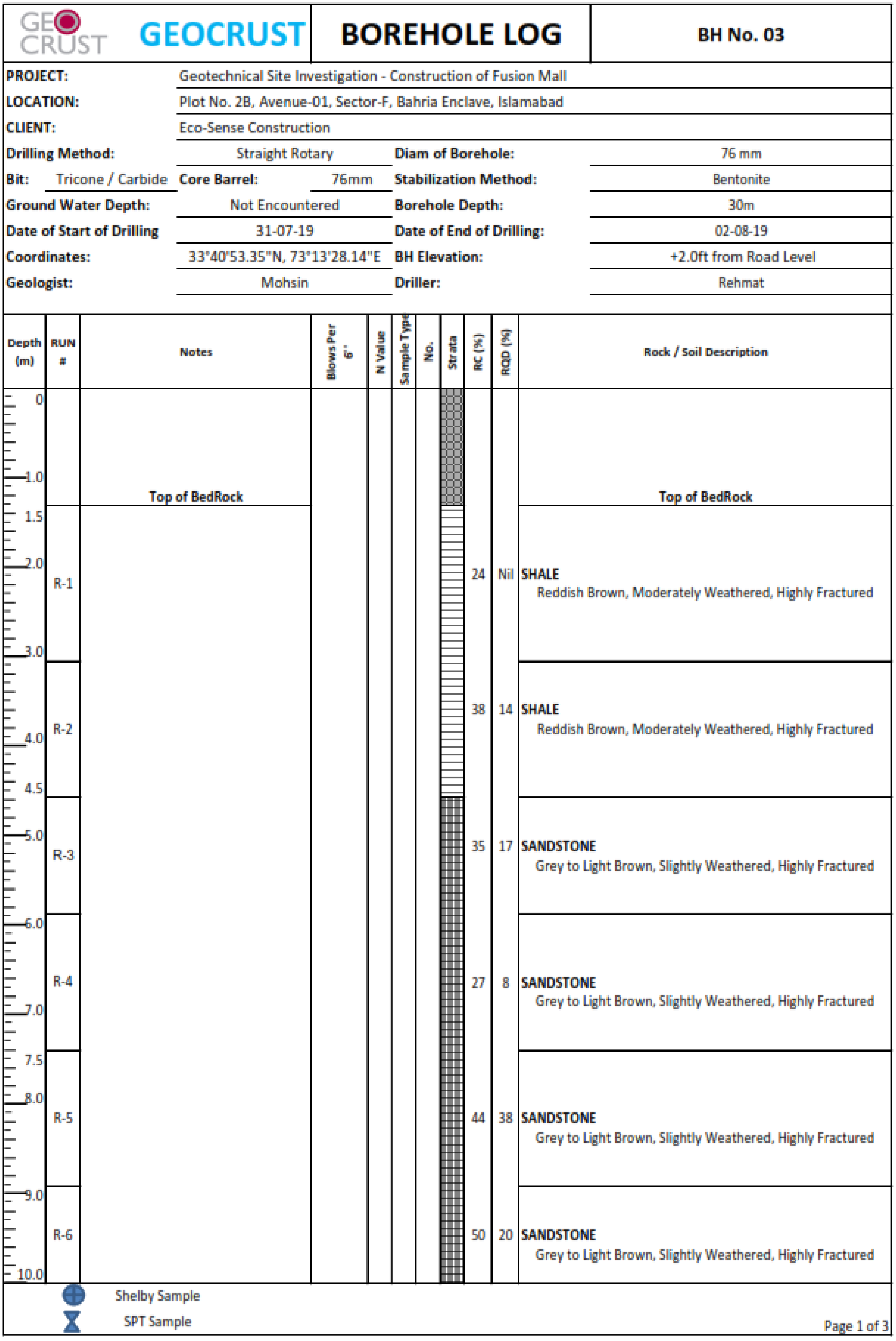
Figure 4.12 Borehole log BH 02 from 20m to 30m depth



GEOCRUST **BOREHOLE LOG** **BH No. 03**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall

LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad

CLIENT: Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	31-07-19	**Date of End of Drilling:**	02-08-19
Coordinates:	33°40'53.35"N, 73°13'28.14"E	**BH Elevation:**	+2.0ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
0 1.0		Top of BedRock								Top of BedRock
1.5 2.0	R-1							24	Nil	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
3.0 4.0	R-2							38	14	**SHALE** Reddish Brown, Moderately Weathered, Highly Fractured
4.5 5.0	R-3							35	17	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
6.0 7.0	R-4							27	8	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
7.5 8.0	R-5							44	38	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
9.0 10.0	R-6							50	20	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured

⊕ Shelby Sample

⧗ SPT Sample

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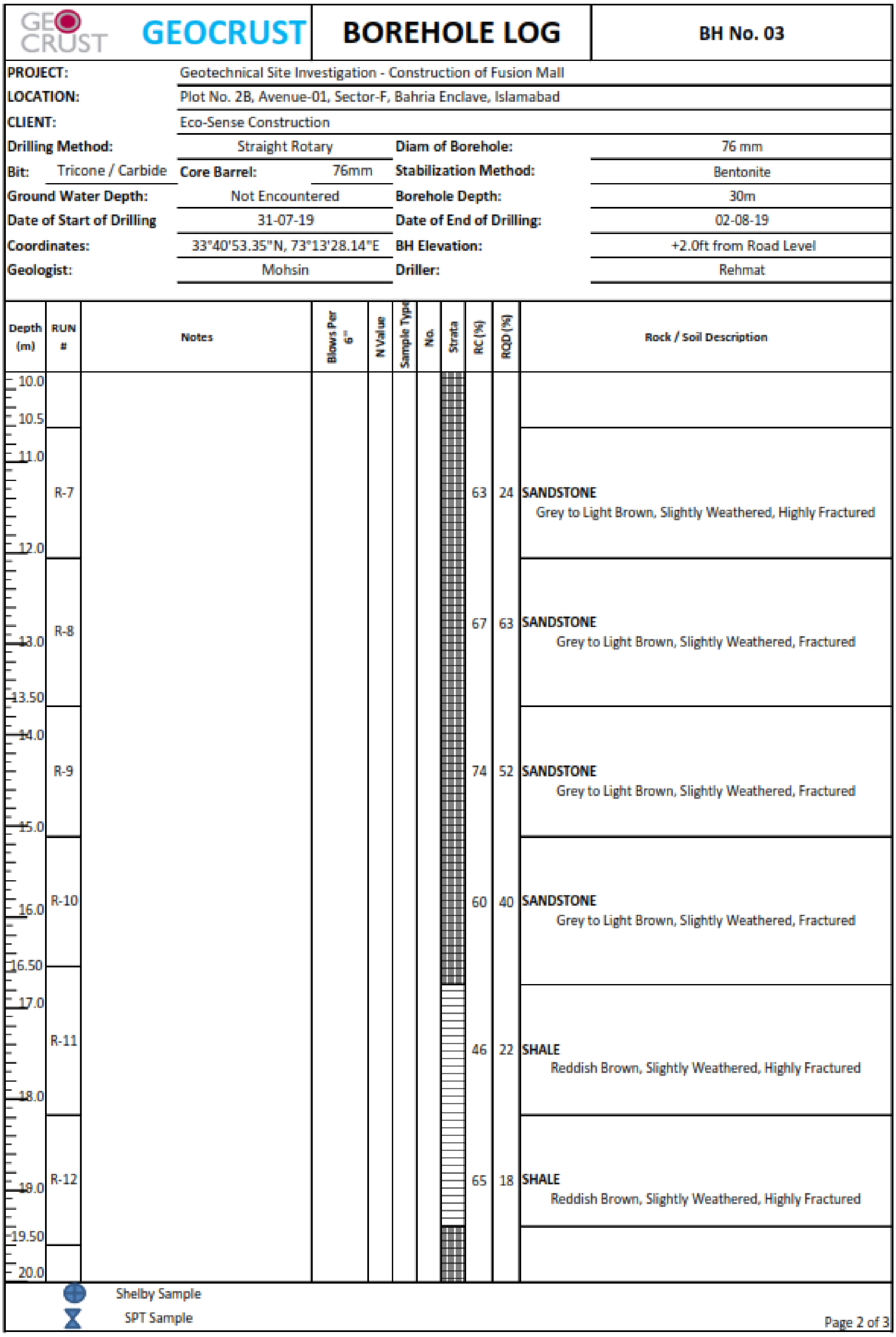
Figure 4.13 Borehole log BH 03 from 0m to 10m depth



GEOCRUST **BOREHOLE LOG** **BH No. 03**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall

LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad

CLIENT: Eco-Sense Construction

Drilling Method: Straight Rotary **Diam of Borehole:** 76 mm

Bit: Tricone / Carbide **Core Barrel:** 76mm **Stabilization Method:** Bentonite

Ground Water Depth: Not Encountered **Borehole Depth:** 30m

Date of Start of Drilling 31-07-19 **Date of End of Drilling:** 02-08-19

Coordinates: 33°40'53.35"N, 73°13'28.14"E **BH Elevation:** +2.0ft from Road Level

Geologist: Mohsin **Driller:** Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
10.0										
10.5										
11.0										
	R-7							63	24	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Fractured
12.0										
13.0	R-8							67	63	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
13.50										
14.0										
	R-9							74	52	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
15.0										
16.0	R-10							60	40	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
16.50										
17.0										
	R-11							46	22	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
18.0										
19.0	R-12							65	18	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
19.50										
20.0										

⊕ Shelby Sample

⧗ SPT Sample

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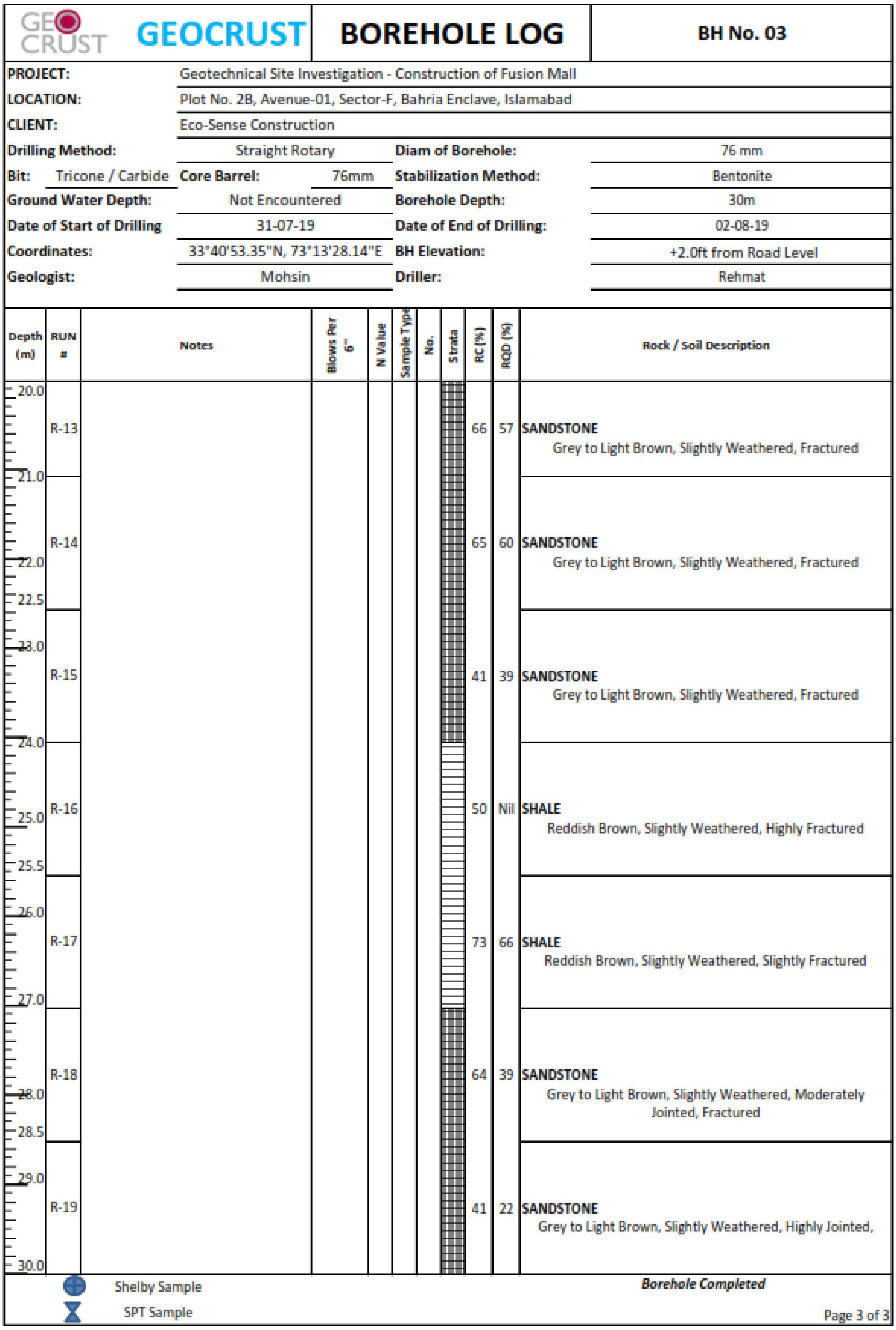
Figure 4.14 Borehole log BH 03 from 10m to 20m depth



GEOCRUST **BOREHOLE LOG** **BH No. 03**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall

LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad

CLIENT: Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	31-07-19	**Date of End of Drilling:**	02-08-19
Coordinates:	33°40'53.35"N, 73°13'28.14"E	**BH Elevation:**	+2.0ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
20.0	R-13						▦	66	57	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
21.0 22.0	R-14						▦	65	60	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
22.5 23.0	R-15						▦	41	39	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Fractured
24.0 25.0	R-16						▤	50	Nil	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
25.5 26.0	R-17						▤	73	66	**SHALE** Reddish Brown, Slightly Weathered, Slightly Fractured
27.0 28.0	R-18						▦	64	39	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed, Fractured
28.5 29.0 30.0	R-19						▦	41	22	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Jointed,

⊕ Shelby Sample

⧗ SPT Sample

Borehole Completed

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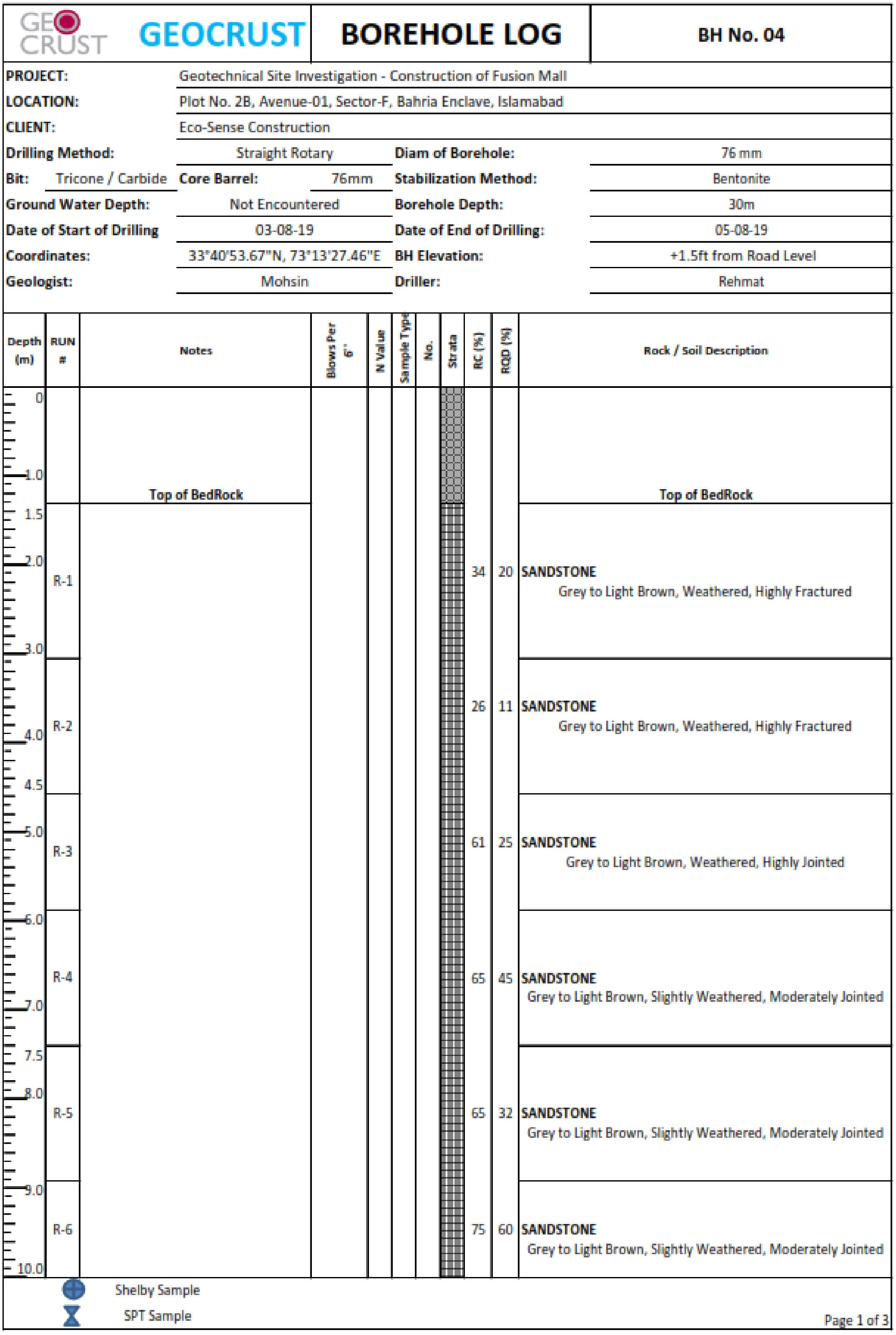
Figure 4.15 Borehole log BH 03 from 20m to 30m depth



GEOCRUST | BOREHOLE LOG | BH No. 04

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall
LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad
CLIENT: Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	03-08-19	**Date of End of Drilling:**	05-08-19
Coordinates:	33°40'53.67"N, 73°13'27.46"E	**BH Elevation:**	+1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
0 1.0		Top of BedRock								Top of BedRock
1.5 2.0	R-1							34	20	**SANDSTONE** Grey to Light Brown, Weathered, Highly Fractured
3.0 4.0	R-2							26	11	**SANDSTONE** Grey to Light Brown, Weathered, Highly Fractured
4.5 5.0	R-3							61	25	**SANDSTONE** Grey to Light Brown, Weathered, Highly Jointed
6.0 7.0	R-4							65	45	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
7.5 8.0	R-5							65	32	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
9.0 10.0	R-6							75	60	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed

⊕ Shelby Sample
⧗ SPT Sample

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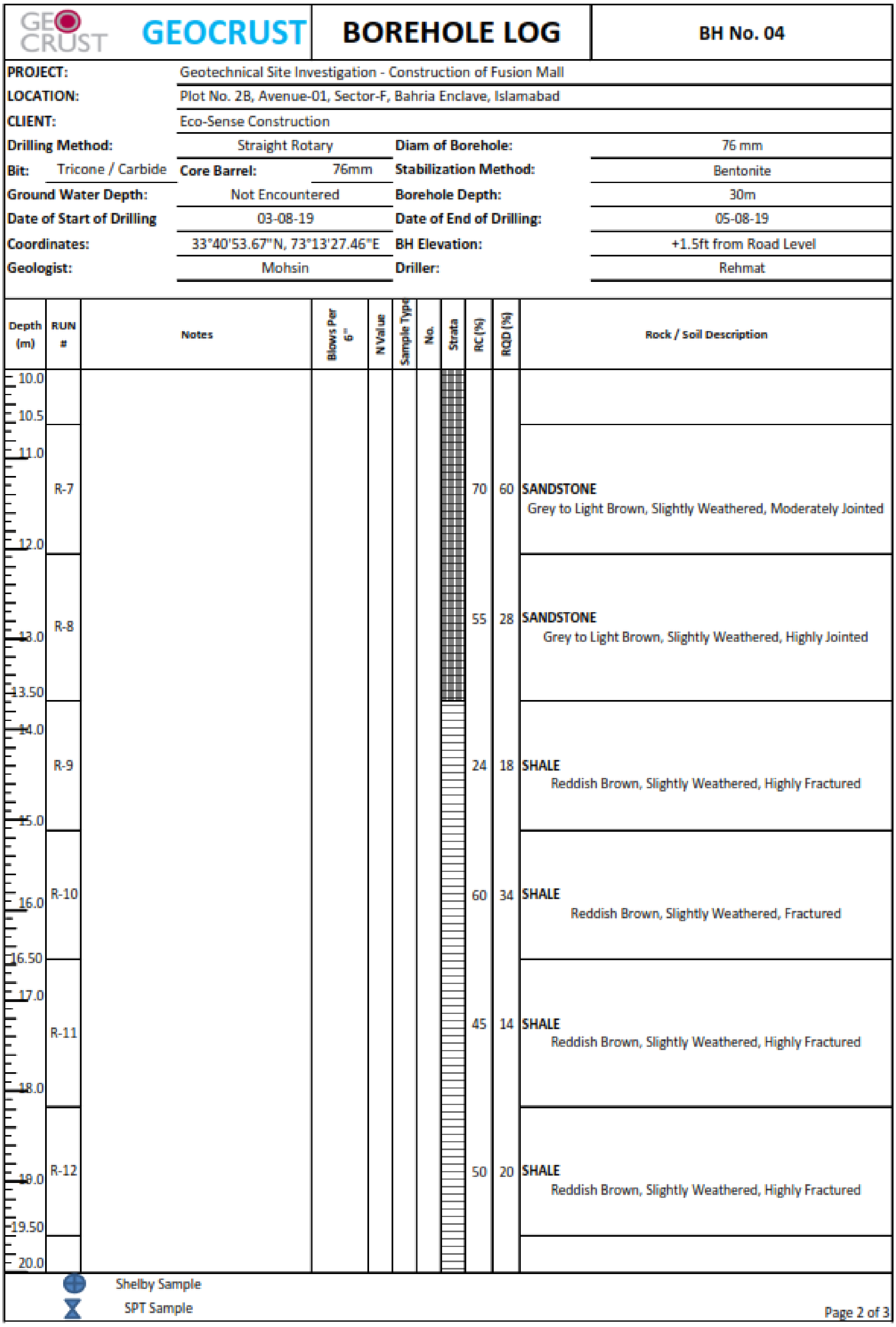
Figure 4.16 Borehole log BH 04 from 0m to 10m depth



GEOCRUST **BOREHOLE LOG** **BH No. 04**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall

LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad

CLIENT: Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	03-08-19	**Date of End of Drilling:**	05-08-19
Coordinates:	33°40'53.67"N, 73°13'27.46"E	**BH Elevation:**	+1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
10.0 10.5							▦			
11.0 12.0	R-7						▦	70	60	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
13.0 13.50	R-8						▦	55	28	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Jointed
14.0 15.0	R-9						▤	24	18	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
16.0 16.50	R-10						▤	60	34	**SHALE** Reddish Brown, Slightly Weathered, Fractured
17.0 18.0	R-11						▤	45	14	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
19.0 19.50	R-12						▤	50	20	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
20.0							▤			

⊕ Shelby Sample

⧗ SPT Sample

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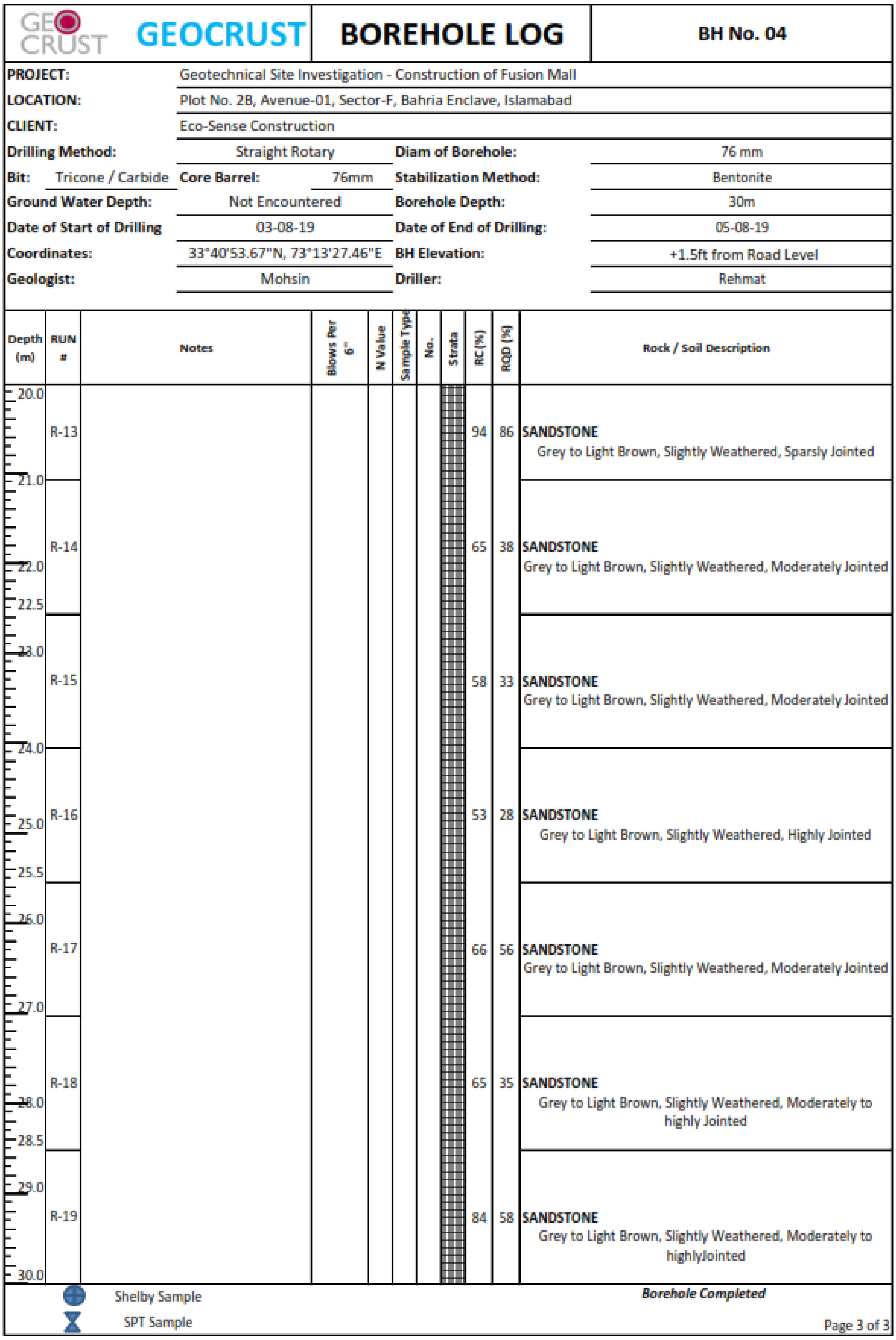
Figure 4.17 Borehole log BH 04 from 10m to 20m depth



GEOCRUST **BOREHOLE LOG** **BH No. 04**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 76mm	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	03-08-19	**Date of End of Drilling:**	05-08-19
Coordinates:	33°40'53.67"N, 73°13'27.46"E	**BH Elevation:**	+1.5ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
20.0	R-13						▦	94	86	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
21.0 22.0	R-14						▦	65	38	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
22.5 23.0	R-15						▦	58	33	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
24.0 25.0	R-16						▦	53	28	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Jointed
25.5 26.0	R-17						▦	66	56	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
27.0 28.0	R-18						▦	65	35	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highly Jointed
28.5 29.0 30.0	R-19						▦	84	58	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highlyJointed

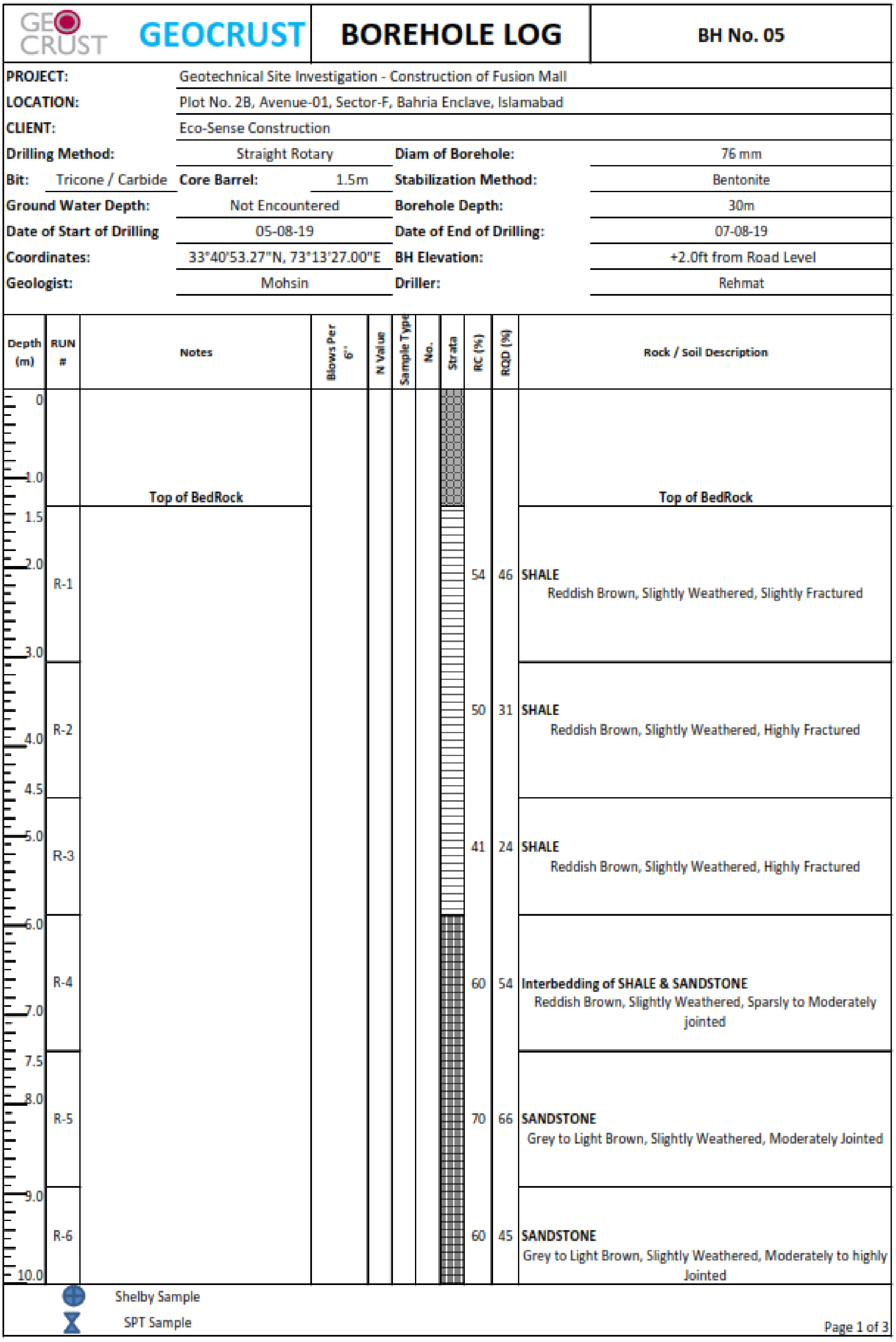
⊕ Shelby Sample

⧗ SPT Sample

Borehole Completed

Page 3 of 3

Figure 4.18 Borehole log BH 04 from 20m to 30m depth



GEOCRUST **BOREHOLE LOG** **BH No. 05**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall		
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad		
CLIENT:	Eco-Sense Construction		
Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 1.5m	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	05-08-19	**Date of End of Drilling:**	07-08-19
Coordinates:	33°40'53.27"N, 73°13'27.00"E	**BH Elevation:**	+2.0ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
0 1.0		Top of BedRock								Top of BedRock
1.5 2.0	R-1							54	46	**SHALE** Reddish Brown, Slightly Weathered, Slightly Fractured
3.0 4.0	R-2							50	31	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
4.5 5.0	R-3							41	24	**SHALE** Reddish Brown, Slightly Weathered, Highly Fractured
6.0 7.0	R-4							60	54	**Interbedding of SHALE & SANDSTONE** Reddish Brown, Slightly Weathered, Sparsly to Moderately jointed
7.5 8.0	R-5							70	66	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
9.0 10.0	R-6							60	45	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highly Jointed

⊕ Shelby Sample

⧗ SPT Sample

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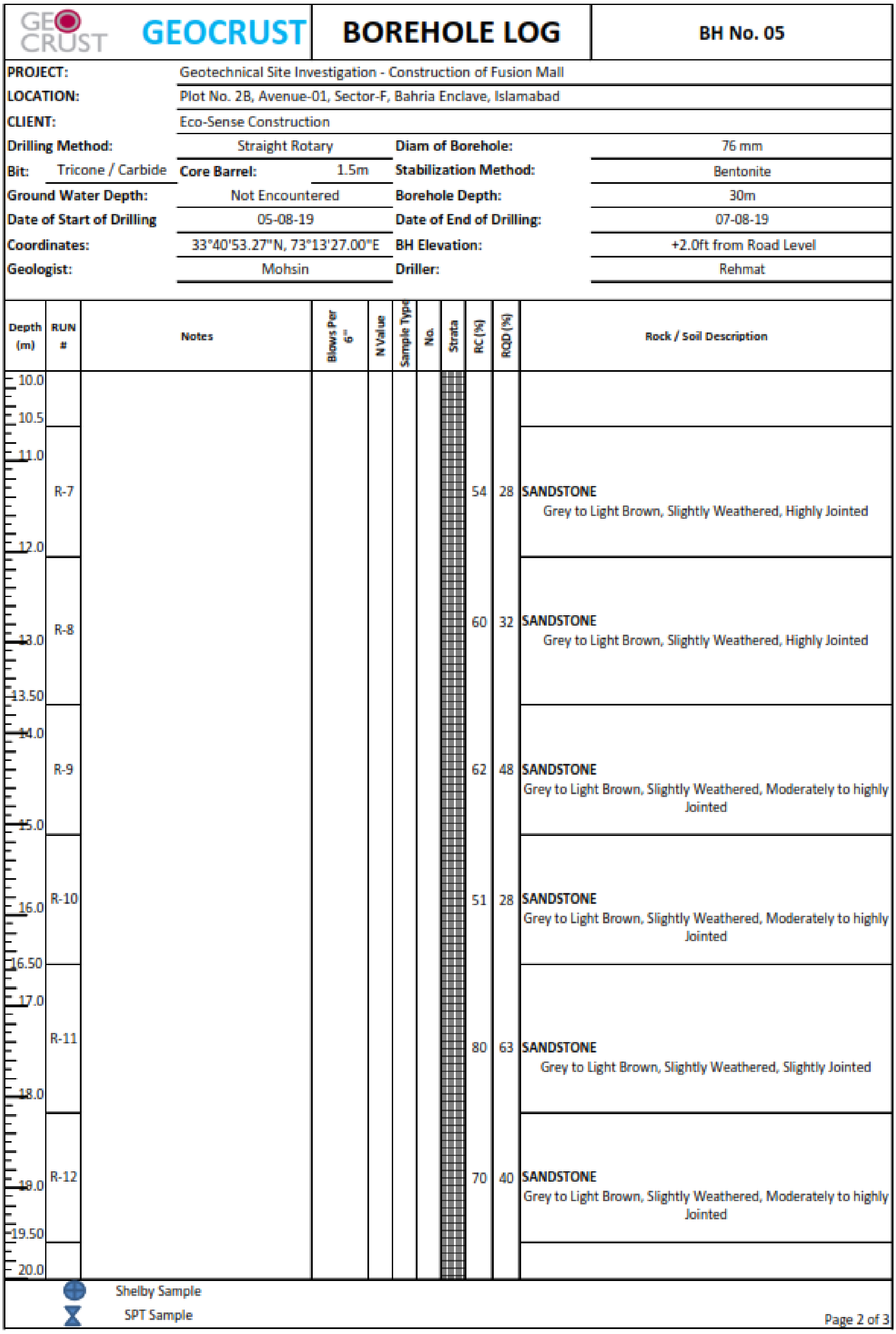
Figure 4.19 Borehole log BH 5 from 0m to 10m depth



GEOCRUST **BOREHOLE LOG** **BH No. 05**

PROJECT: Geotechnical Site Investigation - Construction of Fusion Mall

LOCATION: Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad

CLIENT: Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 1.5m	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	05-08-19	**Date of End of Drilling:**	07-08-19
Coordinates:	33°40'53.27"N, 73°13'27.00"E	**BH Elevation:**	+2.0ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC (%)	RQD (%)	Rock / Soil Description
10.0 10.5							▦			
11.0 12.0	R-7						▦	54	28	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Jointed
13.0 13.50	R-8						▦	60	32	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Highly Jointed
14.0 15.0	R-9						▦	62	48	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highly Jointed
16.0 16.50	R-10						▦	51	28	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highly Jointed
17.0 18.0	R-11						▦	80	63	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Slightly Jointed
19.0 19.50	R-12						▦	70	40	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately to highly Jointed
20.0							▦			

⊕ Shelby Sample

⧗ SPT Sample

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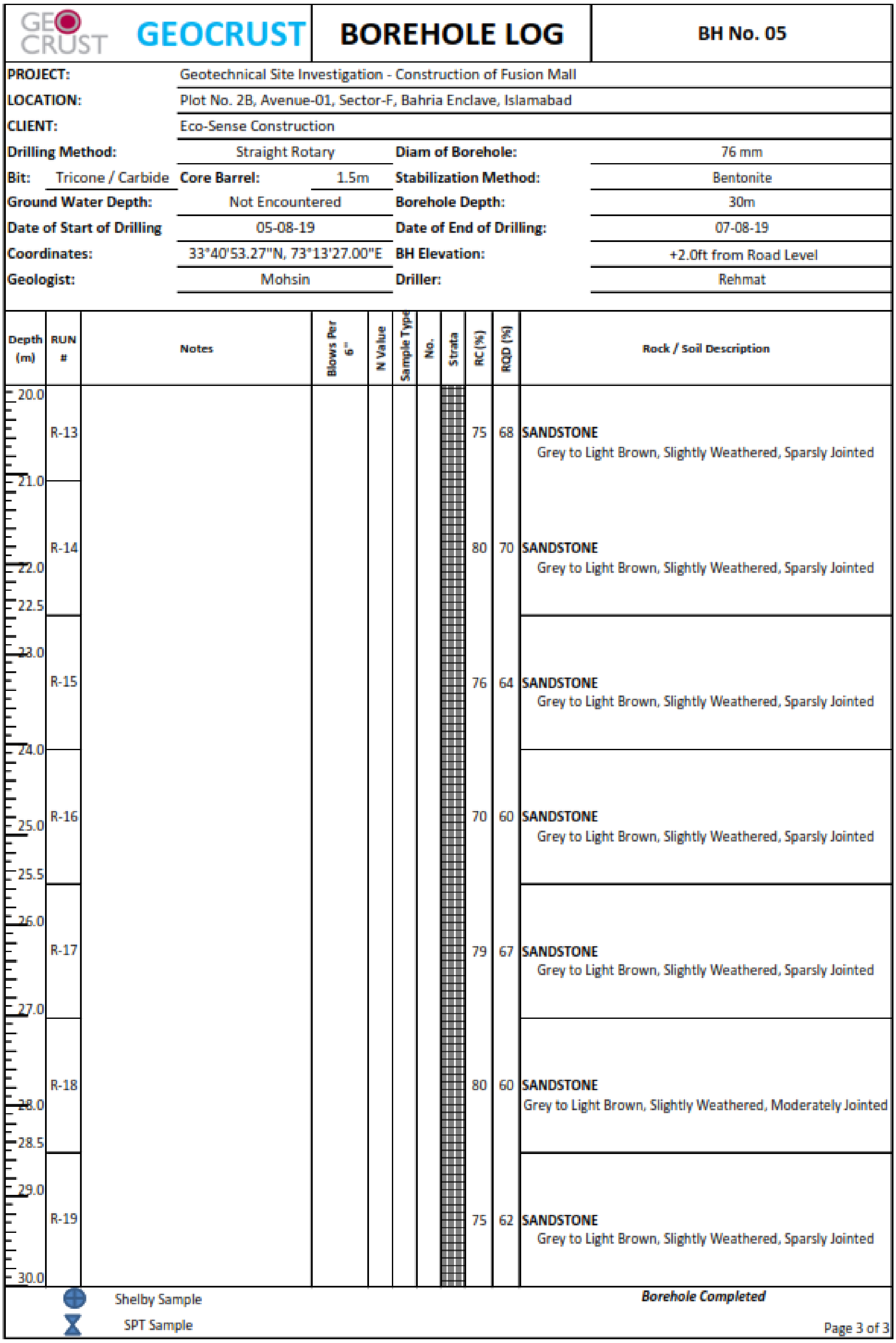
Figure 4.20 Borehole log BH 05 from 10m to 20m depth



GEOCRUST **BOREHOLE LOG** **BH No. 05**

PROJECT:	Geotechnical Site Investigation - Construction of Fusion Mall
LOCATION:	Plot No. 2B, Avenue-01, Sector-F, Bahria Enclave, Islamabad
CLIENT:	Eco-Sense Construction

Drilling Method:	Straight Rotary	**Diam of Borehole:**	76 mm
Bit: Tricone / Carbide	**Core Barrel:** 1.5m	**Stabilization Method:**	Bentonite
Ground Water Depth:	Not Encountered	**Borehole Depth:**	30m
Date of Start of Drilling	05-08-19	**Date of End of Drilling:**	07-08-19
Coordinates:	33°40'53.27"N, 73°13'27.00"E	**BH Elevation:**	+2.0ft from Road Level
Geologist:	Mohsin	**Driller:**	Rehmat

Depth (m)	RUN #	Notes	Blows Per 6"	N Value	Sample Type	No.	Strata	RC(%)	RQD (%)	Rock / Soil Description
20.0	R-13							75	68	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
21.0 22.0	R-14							80	70	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
22.5 23.0	R-15							76	64	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
24.0 25.0	R-16							70	60	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
25.5 26.0	R-17							79	67	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed
27.0 28.0	R-18							80	60	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Moderately Jointed
28.5 29.0 30.0	R-19							75	62	**SANDSTONE** Grey to Light Brown, Slightly Weathered, Sparsly Jointed

Shelby Sample

SPT Sample

Borehole Completed

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Figure 4.21 Borehole log BH 05 from 20m to 30m depth

CONCLUSIONS

i. During the investigation, the subsurface was explored at maximum depth which is 30m below the existing surface. Soil varieties, including Silty clay and silty clay with gravel, was found only in BH-1 up to the depth of 5m. Two types of rocks, including shale and sandstone, were observed in all five boreholes. The ground water table was not encountered in any borehole up to maximum explored depth.

ii. The allowable bearing capacity for the strip footing at a depth of 1.5m is 2.3tsf. Strip footing will be suitable for light weight structures such as boundary walls and guard room structure. For basement raft footing at a depth of 3m, having an allowable bearing capacity of 4.3tsf is suitable.

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