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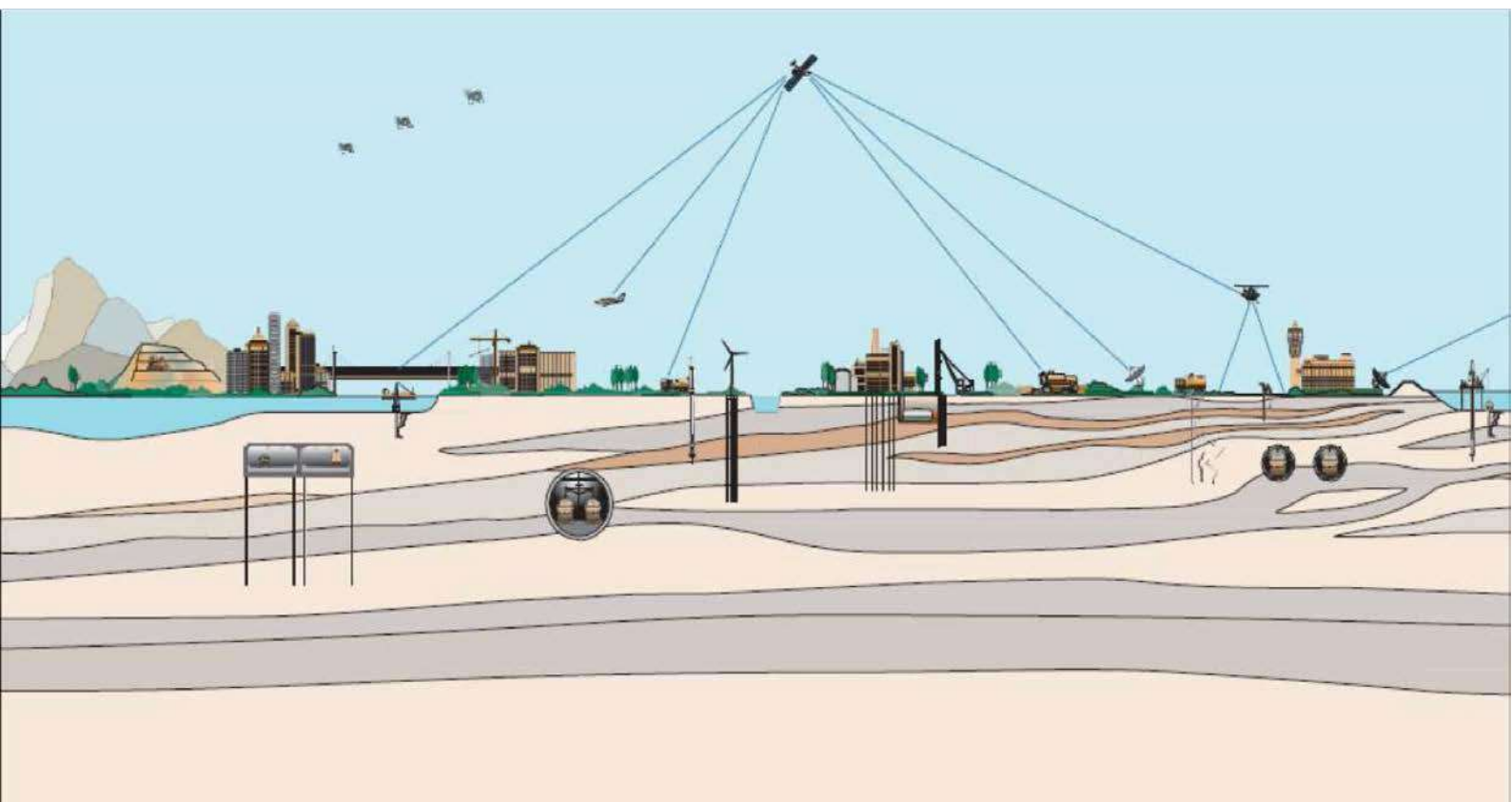


Report No. S-24-1162

GEOTECHNICAL INVESTIGATION REPORT FOR SINDH SOLAR ENERGY PROJECT, DEH HALKANI, DISTRICT WEST, KARACHI

(REV. 0.0, DATED: AUGUST 16, 2024)

CLIENT: GOVERNMENT OF SINDH





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SOIL TESTING SERVICES 	Geotechnical Investigation Report	Revision	
		#	Date
	Report No.: Vol I	00	16/08/2024

PROJECT: Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani, District West, Karachi

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ISSUE/REVISION INDEX

Issue Code	Revision					Revision Details
	No.	By	Rev'd.	App.	Date	
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Issue Codes: RC = Released for Construction, RD = Released for Design, RF = Released for Fabrication, RI = Released for Information, RP = Released for Purchase, RPA = Released for Permit Application, RQ = Released for Quotation, RR = Released for Review and Comments.

SOIL TESTING SERVICES

EXECUTIVE SUMMARY

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani, District West, Karachi was carried out in order to determine geotechnical parameters of subsurface deposits. Scope of field work included drilling of eighteen (18) boreholes up to the depth of 5.0 meters below the existing ground level. Soil and rock samples were collected during field investigation. Laboratory testing of these samples has been carried out in the Soil Testing Services laboratory, Karachi.

The deposition of the area mainly consists of '*very dense*, fine grained, silty, sand' and '*very weak to weak*, highly weathered and fractured, limestone'. Groundwater table was not encountered up to the maximum explored depth of 5.0 meters below the existing ground level in the boreholes drilled at site, at the time of this investigation.

Keeping these conditions under consideration:

- Allowable bearing pressures for pad foundations have been provided at a depth of 1.0 - 2.0 meters below the existing ground level for Solar Panels foundations.
- Allowable pile capacities are documented for various diameters and lengths of piles intended for Solar Panels foundations.
- Earth pressure parameters have been provided for earth retaining structures.
- Seismic soil profile has been taken as ' S_c ' for the foundations in accordance with PBC-21.

The exposure of underground concrete to aggressive chemicals is found to be '*negligible*' for sulphates and chlorides which have influenced the selection of cement for underground concreting and it is recommended to use *Ordinary Portland Cement (OPC)* for all underground concrete works.

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1. INTRODUCTION

Planning for Sindh Solar Energy Project, Deh Halkani, District West, Karachi is underway. In order to confirm the geotechnical parameters of the subsurface deposits, *M/s. Soil Testing Services (STS)* were entrusted by *Government of Sindh* to perform the confirmatory geotechnical investigation at the project site.

Scope of field work included drilling of eighteen (18) boreholes up to the depth of 5.0 meters below the existing ground level. Elevation of the drilling platform at each borehole location was noted with respect to the mean sea level and is mentioned in borehole logs attached in Appendix B. Standard penetration tests were carried out at regular intervals in the boreholes along with the collection of soil samples via split spoon sampler. Boreholes in rock were advanced through continuous coring. Rock core samples were extracted with the help of double tube core barrels. The samples retrieved from the field work were tested in the laboratory and this report is prepared from the information obtained from the field and laboratory tests.

The report consists of five chapters with *Chapter 2* describing the site's existing condition, *Chapter 4* discusses the subsurface deposits in detail, *Chapter 5* includes the recommendations for foundation design, and *Chapter 6* contains a summary of conclusions regarding the ground conditions, with respect to geotechnical engineering for this project.

2. THE SITE

The project site is situated on both sides of the Karachi Northern By-Pass M10, near New Jodia Bazar. The Hub Dam is located approximately 27 kilometers to the north of the site.

The topography of the terrain is not plain with significant changes in elevation observed across the site. Bushes and different types of wild plants were also found across the site.

Figure 1 shows the google image of the site.



Figure 1: Google image of the the Neighbourhood area (Courtesy: Google Earth)

3. GROUND CONDITIONS

The subsurface deposits up to the explored depth consist of the following units:

- Sand
- Limestone

Following sub-sections describe the strength characteristics of the geological unit and the groundwater conditions. Soils are classified as per Unified Soil Classification System (USCS) and rocks are classified as per BS-5930.

3.1 SAND

Deposits of *fine to coarse grained*, sand were encountered in five (05) of the boreholes drilled at site. State of compactness according to SPT 'N' counts has been determined to be 'medium dense to *very dense*'. The grain size analysis has been carried out of samples collected from these deposits. Unified Classification System (UCS) classifies these deposits as 'SM', 'SW-SM', 'SP-SM'. *Table 1* summarizes the details of these deposits.

Table 1: Deposits of Sand

Borehole No.	Depth (meters)
BH-02	0.0 – 1.3
BH-05	0.0 – 1.8
BH-16	0.0 – 1.3
BH-17	0.0 – 1.7
BH-18	0.0 – 1.2

3.2 LIMESTONE

Deposits of *distinctly weathered*, limestone were encountered in all the boreholes drilled at the site. Disturbed and undisturbed rock core samples were collected from these deposits which were tested for moisture content, density and unconfined compression test. According to BS 5930, these deposits are classified as '*weak*' rock. *Table 2* summarizes the details of these deposits.

Table 2: Deposits of Limestone

Borehole No.	Depth (meters)
BH-01	0.0 – 5.0
BH-02	1.3 – 5.0
BH-03	0.0 – 5.0
BH-04	0.0 – 5.0
BH-05	1.8 – 5.0
BH-06	0.0 – 5.0
BH-07	0.0 – 5.0
BH-08	0.0 – 5.0
BH-09	0.0 – 5.0
BH-10	0.0 – 5.0
BH-11	0.0 – 5.0
BH-12	0.0 – 5.0
BH-13	0.0 – 5.0
BH-14	0.0 – 5.0
BH-15	0.0 – 5.0
BH-16	1.3 – 5.0
BH-17	1.7 – 5.0
BH-18	1.3 – 5.0

3.3 GROUNDWATER CONDITIONS

Groundwater table was not encountered up to the maximum explored depth of 5.0 meters below the existing ground level in the boreholes drilled at site, at the time of this investigation.

4. ENGINEERING DESIGN CONSIDERATIONS

Foundation type for a structure depends on the expected loads taken by the foundation and the type of soil underlying it. The characteristics of subsurface soil deposits have been discussed in the previous section. As per the information provided by the client, following structures are proposed at the project site:

Table 3: Details of proposed structures and foundations

Structure	Soil Profile Reference	Proposed Foundation Type
Solar Panel's Foundations	Soil Profile 1	Pad Foundation Deep Foundation

Keeping in view the subsoil conditions prevailing at the site and the loads expected to be transferred to the foundations and as per the project specifications, recommendations for both shallow foundation and deep foundation (bored cast in-situ pile foundation) are provided. Following sections discusses recommendations for shallow and deep foundations, in detail.

4.1 DESIGN PARAMETERS

The design soil parameters are based on grain size, material type, SPT N-values, field and laboratory testing data. Our recommended design soil parameters used in our analysis are presented below.

Table 4: Engineering Design Parameters

Layer Depth below EGL (m)		Layer Thickness (m)	Design SPT-N	Material Type	Cohesion, C, (KPa)	Angle of Internal friction (Φ), (degree)	Unit Weight co-related with SPT N (kN/m ³)	Modulus of Elasticity, E (kN/m ²)
Top	Bottom							
0.0	2.0	2.0	12	Sand	-	30	17.0	12,000
2.0	5.0	3.0	-	Limestone	200	40	21.0	150,000

NOTE:

- The values of **internal angle of friction (Φ)** for soil and rock are taken as under:
 - Values are taken as presented in Chapter 2 of Book "Rock Slope Stability Analysis by G.P. Giani".

- The values of **cohesion (c)** are taken as under:
- Values are taken as presented in Chapter 11 of Book “Handbook of Geotechnical Investigation & Design Tables by Burt Look.
- The values of **Elastic Modulus (E)** are taken as under:
 - Values are taken as presented in Chapter 11 of Book “Handbook of Geotechnical Investigation & Design Tables by Burt Look.

4.2 DESIGN CRITERIA FOR SHALLOW FOUNDATIONS

A suitable shallow foundation for any structure must satisfy two basic independent criteria with respect to the underlying foundation soils. First, the foundation must have an adequate factor of safety against exceeding the bearing capacity of the foundation soils. Second the vertical movements of the foundation due to settlement or swelling of the foundation soils must be within tolerable limits for the structure.

Dynamically loaded foundations, such as those supporting vibrating machinery, must satisfy additional criteria as follows:

- vibrations transmitted to the foundation soils must not cause excessive settlement of the structures or its surroundings;
- vibrations of the dynamically loaded structure, and its surroundings, must not interfere with planned operations and adjacent structures.

The foundation bearing pressures should be limited so that settlements do not exceed tolerable limits for the structures.

4.3 ALLOWABLE BEARING PRESSURES FOR SHALLOW FOUNDATION

The allowable bearing pressure for shallow foundation supported on natural soils/rocks at the site will be limited either by the settlement tolerance of individual structures, or by the bearing capacity of the soil, depending on the foundation width and depth of influence. Typically, for shallow raft footings, the bearing pressure should be limited so that the total foundation settlement does not exceed 50 mm, with differential settlements of about 50 percent of the total settlement, or so that the bearing capacity is not exceeded, whichever is the lower of the two values.

The ratio of differential to total settlements for raft foundations on sand is typically half that of an isolated/pad footing (Terzaghi, Peck and Mesri, 1996). Consequently, the amount of settlement that a raft foundation can tolerate is twice that of an isolated foundation, usually

50 mm. However, the actual settlement tolerance of various structures should be defined by the structural engineer.

We estimated the allowable bearing pressures for pad foundations as the lower of the two values calculated based on settlement and shear criteria. Table 5 gives the allowable bearing pressures for pad foundations at the depth range of 1.0 to 2.0 meters.

Table 5: Allowable Bearing Pressures for Solar Panel Foundations

Minimum Embedment below EGL (meter)	Foundation Dimensions (meter × meter)	Pad Foundation (kPa / tsf)
1.0	1.0 × 1.0	200.0 / 2.0
	1.5 × 1.5	220.0 / 2.20
	2.0 × 2.0	250.0 / 2.50
1.5	1.0 × 1.0	260.0 / 2.60
	1.5 × 1.5	300.0 / 3.00
	2.0 × 2.0	350.0 / 3.50
2.0	1.0 × 1.0	400.0* / 4.00*
	1.5 × 1.5	400.0* / 4.00*
	2.0 × 2.0	400.0* / 4.00*

* Bearing capacities of pad footings for solar panels footings have been restricted to 400 kPa due to practical considerations.

Proper drainage shall be provided to avoid infiltration of water into the foundation soil. It should be ensured that the foundation is not placed on the fill material. The settlement of pad foundations due to net allowable pressure has been estimated to be within the allowable limit of 25mm (1-inches).

Cohesive material shall not be used for backfilling purposes. Check for tension must be carried out before finalising the dimensions of the footing in order to ensure adequate safety against uplift forces. Due to the horizontal seismic forces, and wind forces, uplift can occur at one end of the foundation. This uplift can be balanced by increasing the

dimensions of the foundation and the weight of the soil above the foundation. The angle of internal friction for limestone and other type of rocks can be taken as 40 - 42 degrees.

4.4 MODULUS OF SUBGRADE REACTION

The modulus of subgrade reaction, k_s , may be required to design raft foundations. The modulus principally depends on the soil stiffness, raft foundation stiffness and foundation size.

We recommend computing the modulus of subgrade reaction values for raft foundations at the site using the allowable bearing pressures that could be obtained from the bearing pressures presented in this report and the following equation:

$$k_s = \frac{1}{A} (SF) q_a$$

where:

- k_s = Modulus of subgrade reaction, kN/m²/m;
- SF = Factor of safety;
- q_a = Allowable bearing pressure, kPa; and
- A = Allowable settlement, mm.

The above equation assumes that the rafts will tend towards flexible rather than rigid behaviour. For perfectly rigid rafts the modulus values obtained from the above equation should be doubled.

Mat foundations will behave as:

Perfectly rigid if $h/B > 1/5$

Perfectly flexible if $h/B < 1/55$

where:

- h = thickness of raft foundation; and
- B = width of raft foundation

*Table 6: Modulus of subgrade reaction based on allowable bearing pressure
(Solar Panel Foundations)*

Minimum Embedment below EGL (m)	Foundation Dimensions (meter × meter)	Modulus of subgrade reaction (MN/m ³ / tcf)
1.0	1.0 × 1.0	24.0 / 72.0
	1.5 × 1.5	26.40 / 79.20
	2.0 × 2.0	30.0 / 90.0
1.5	1.0 × 1.0	31.20 / 93.60
	1.5 × 1.5	36.0 / 108.0
	2.0 × 2.0	42.0 / 126.0
2.0	1.0 × 1.0	47.24 / 141.73
	1.5 × 1.5	47.24 / 141.73
	2.0 × 2.0	47.24 / 141.73

4.5 DEEP FOUNDATIONS - ALLOWABLE PILE CAPACITIES

The ultimate compressive capacity, Q , for a given bored concrete pile penetration is taken as the sum of the skin friction on the pile wall, Q_s , and the end bearing on the pile tip, Q_p , so that:

$$Q = Q_s + Q_p = \sum f A_s + q A_p$$

Where A_s and A_p represent, respectively, the embedded surface and pile end area; f and q represent, respectively, the unit skin friction and unit end bearing. When computing ultimate tensile capacity, the end bearing term in the above equation is neglected. Therefore, the value of the ultimate tensile capacity is the same value as the ultimate compression capacity due to skin friction Q_s .

The design parameters for calculating pile capacities have been derived from shear strength determination, through in-situ field tests and laboratory tests of collected soil samples. Table 7 provides pile capacities for diameters of 150mm, 200mm, 250, 300mm.

Table 7: Allowable Pile Capacities for Solar Panels

Table 7: Allowable Pile Capacities for Solar Pile-Drilled			
Diameter (mm)	Length of Pile Below Existing Ground Level (meters)	Tension (kN)	Compression (kN)
150	2.0	2	37
	2.5	40	75
	3.0	78	114
	3.5	117	152
	4.0	155	190
200	2.0	2	65
	2.5	53	116
	3.0	104	167
	3.5	156	218
	4.0	207	269
250	2.0	3	101
	2.5	67	165
	3.0	131	229
	3.5	194	293
	4.0	258	356
300	2.0	3	145
	2.5	80	221
	3.0	157	298
	3.5	233	375
	4.0	310	451

The design approach followed is based on FOS and as per this design approach, the settlement criteria of “Net settlement not to exceed 1% of the pile diameter at working load and Total penetration of the base not to exceed 10% of the pile diameter at test load” shall be fulfilled.

4.6 RECOMMENDED DRILLING METHOD AND CONFIRMATORY TESTING

The recommended drilling method for the construction of bored cast in-situ piles is straight rotary. Tentative pile capacity values given in *Table 7* have been computed by static formulae which suffer from limitations. As such capacity values shall be verified by full scale load tests under the guidance of geotechnical engineer. Pile capacity shall be suitably adjusted if warranted by results of load tests. This report will be valid only if requirement of pile load tests is fulfilled.

The test pile should be loaded to 2.0 to 2.5 times the Specified Working Load (SWL) and the working pile should be loaded to 1.5 times the Specified Working Load (SWL). The calculations for allowable pile capacities for Solar Panel Project, bored cast in-situ piles are presented in appendix E of this report.

4.7 PILE CONSTRUCTION

Allowable pile capacities have been derived from combination of end bearing and skin friction components. It is, therefore, essential to adopt the following construction methodology to satisfy following requirements:

1. Excessive disturbance to sub-surface along shaft and pile tip shall be avoided during the course of drilling.
2. The bottom of pile shall be cleaned of all loose materials which may accumulate during the course of drilling.

Pile concreting shall be undertaken only when above conditions are fulfilled. It is understood that subsurface materials will be carefully examined during pilling and it shall be ensured that all piles are placed in proper stratum. This exercise will serve as safeguard against variations in quality and level of occurrence of dense stratum.

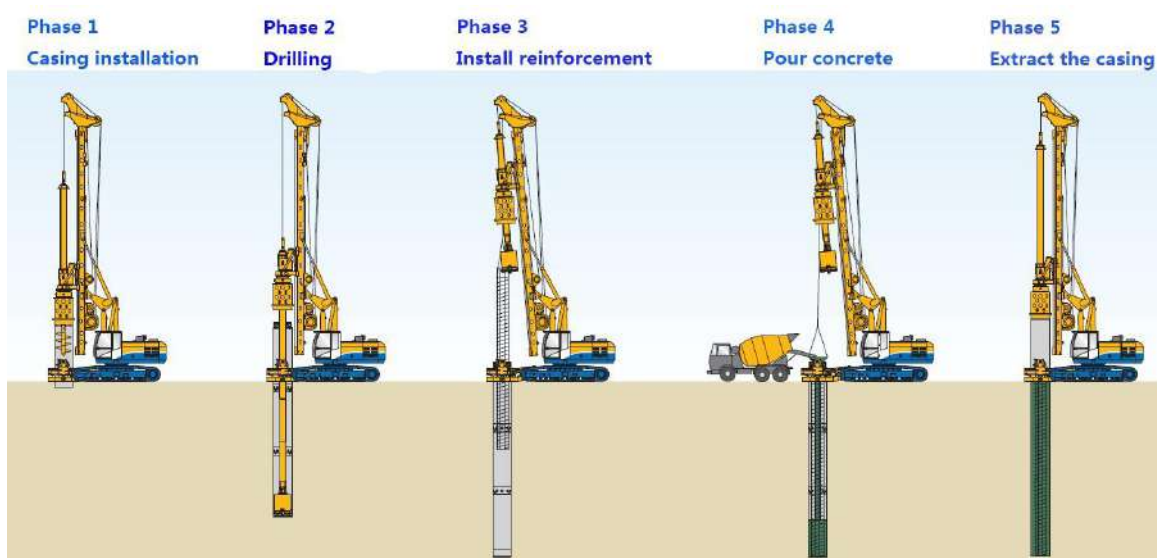


Figure 2: Construction of cast in situ piles by straight rotary

4.8 EARTH RETAINING STRUCTURE

All measures shall be taken to provide safety to adjacent structures. Properly designed earth retaining structure must be constructed prior to deep excavation.

Earth pressure parameters required for the design of structure to retain the excavation are given in *Table 8*.

Table 8: Earth pressure parameters

Strata	Φ' (Undisturbed)	k_a (Coefficient of active earth pressure)	k_p (Coefficient of passive earth pressure)
Sand	30°	0.333	3.000
Limestone	40°	0.217	4.600

4.9 SEISMIC GROUND MOTION PARAMETERS (BCP – 2021)

4.9.1 SITE CLASS

Chapter 16 of BCP – 2021 defines the site class definition in accordance with Chapter 20 ASCE-7 to be used for determining site coefficients. Based on the field data obtained from sub-soil exploration, the soil class will be taken as “**S_c**”.

4.9.2 SHORT PERIOD SPECTRAL RESPONSE ACCELERATION (S_s)

Chapter 16 of BCP – 2021, Section 1613.2.1 deals with the mapped values for 0.2-seconds spectral acceleration corresponding to Maximum Considered Earthquake (MCE) defined as the ground motion level with 2% probability of exceedance in 50 years (2475 years return period). The S_s for project site will be taken as 1.0284.

4.9.3 LONG PERIOD SPECTRAL RESPONSE ACCELERATION (S_1)

Chapter 16 of BCP – 202, Section 1613.2.1 deals with the mapped values for 1-second spectral acceleration corresponding to Maximum Considered Earthquake (MCE) defined as the ground motion level with 2% probability of exceedance in 50 years (2475 years return period). The S_1 for project site will be taken as 0.2775.

4.10 TYPE OF CEMENT

Tests on collected soil and rock samples obtained from the boreholes indicate ‘negligible’ exposure to sulphate and chloride. Under these conditions it is recommended to use *Ordinary Portland Cement (OPC)* for all underground concrete works.

5. CONCLUSIONS

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani, District West, Karachi was carried out in order to determine geotechnical parameters of subsurface deposits. Scope of field work included drilling of eighteen (18) boreholes up to the depth of 5.0 meters below the existing ground level. Soil and rock samples were collected during the field investigation. Laboratory testing on these samples has been carried out in the lab and includes determination of index properties through grain size analysis, density, moisture content and unconfined compression test etc. Chemical characteristics of soil have also been assessed through determination of sulphate content, chloride content and pH.

Keeping in view, the results from field, and laboratory tests and the expected loads being transferred to the founding stratum, recommendations for both shallow foundation and deep foundation are provided. Exposure to chloride and sulphate salts is '*negligible*' for collected soil and rock samples, therefore, *Ordinary Portland Cement (OPC)* may be used for all underground concreting works.

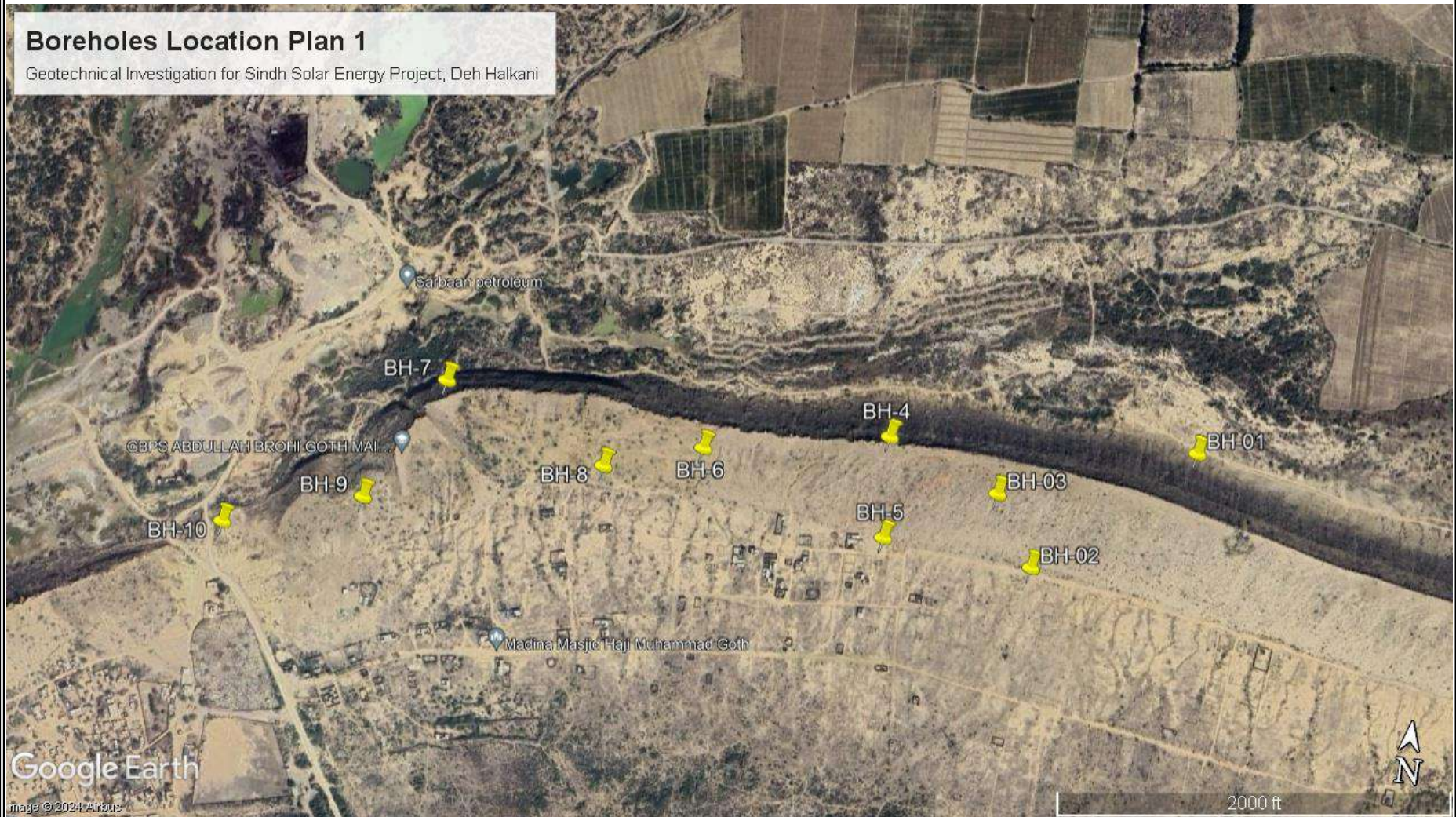
None of the executed boreholes has shown any evidence of underground cavities up to the maximum depth of 5m.

Appendix A

Boreholes Location Plan

Boreholes Location Plan 1

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani



Borehole Location Plan 1

S-24-1162

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani, District West,
Karachi



Boreholes Location Plan 2

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani



Borehole Location Plan 2

S-24-1162

Geotechnical Investigation for Sindh Solar Energy Project, Deh Halkani, District West,
Karachi



Borehole Logs

Mud Rotary Log BH-01

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.


Depth: 5 (m)
GWL:- N.E
Drill Date: 11.08.2024
Logged By: IK

Elevation: 53.34m from MSL
Easting: 295002.64
Northing: 2769936.71
Method: Mud Rotary

Company Info.

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Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits					Dry Unit-Weight (gr/cm3)	Bulk	Test Type	Direct Shear Test	qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments				
				* SPT 10 20 30 40 50								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	w (%)							Cc	Cs	Pc (kg/cm2)	PH	SO3	CL					
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>							0																								0	Run - 1	
1		■																																	1	CR - 36% / RQD - Nil
2		■																																	2	SPT(C) - 1 SPT(C) Drive - 25mm
3		■																																	3	Run - 2 CR - 53% / RQD - 13% UDC - 1 (2.15 - 2.28m)
4		■																																	4	Run - 3 CR - 45% / RQD - Nil
5		■	End of Log @ 5 (m)							5																							5	Run - 4 CR - 49% / RQD - Nil		

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌋ SPT Sample
- Water Sample
- ≡ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-02

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.

Depth: 5 (m)
GWL:- N.E
Drill Date: 11.08.2024
Logged By: IK

Elevation: 41.75m from MSL
Easting: 294766.18
Northing: 2769731.10
Method: Mud Rotary

Company Info.

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Material Testing Laboratory
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Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Dry Unit Weight Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3		
0			SAND <i>Yellowish brown, very dense, fine to coarse grained, little silt, traces of gravel, pieces of limestone at places</i>																												
1		U									SM A-2-4(0)	8.5	72.1	19.4		NLL	-	NPI	10.3	1.72	1.9										
2		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>																												
3		■																	2.4	2.16	2.2			74.27							
4		+																													
5			End of Log @ 5 (m)																												

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- U SPT Sample
- Water Sample
- Δ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI


- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)


- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-03

Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 55.77m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:294698.24			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:11.08.2024	Northing:2769838.99				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)			Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments	
				* SPT 10 20 30 40 50							Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	Dry Unit Weight (gr/cm3)		Bulk	Test Type	C (kg/cm2)	Fi (o)	Cc		Cs	Pc (kg/cm2)	PH	SO3	CL			
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>							0																					0	Run - 1	
1		□									1																					1	CR - 33% / RQD - Nil
2		■									2																					2	SPT(C) - 1 SPT(C) Drive - 50mm
3		+									3																					3	Run - 2 CR - 44% / RQD - Nil
4		■									4																					4	Run - 3 CR - 58% / RQD - 16% UDC - 1 {3.26 - 3.39m}
5			End of Log @ 5 (m)							5																				5	Run - 4 CR - 45% / RQD - Nil		

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
Abbreviations	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
	∇ Groundwater Level			C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	

Mud Rotary Log BH-04

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.

Depth: 5 (m)
GWL:- N.E
Drill Date: 11.08.2024
Logged By: IK

Elevation: 60.65m from MSL
Easting: 294522.28
Northing: 2769904.01
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL	
0		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone		* 50	0																			0	Run - 1 CR - 40% / RQD - Nil	
1		□				1																				1	SPT(C) - 1 SPT(C) Drive - 25mm
2		+				2										3.1	2.14	2.2		62.65						2	Run - 2 CR - 50% / RQD - 11% UDC - 1 (2.20 - 2.31m)
3		■				3																				3	Run - 3 CR - 56% / RQD - 14% UDC - 2 (3.00 - 3.13m)
4		■				4																				4	Run - 4 CR - 44% / RQD - Nil
5			End of Log @ 5 (m)			5																			5		

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌋ SPT Sample
- ⌋ Water Sample
- ⌋ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI


- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained


Mud Rotary Log BH-05

Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 41.14m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:294534.32			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:11.08.2024	Northing:2769749.06				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Dry Unit Weight	Bulk	Test Type	C (kg/cm2)		Fi (o)	Cc	Cs	Pc (kg/cm2)	PH		
0			SAND Yellowish brown, medium dense, fine to coarse grained, little silt and gravel, pieces of limestone at places							0																					
1		U								1	SP-SM A-2-4(0)	15.9	73.7	10.4		NLL	-	NPI	11.2	1.71	1.9									SPT - 1	
2		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone							2																				Run - 1 CR - 37% / RQD - Nil	
3		■								3									3	2.11	2.2			83.5						Run - 2 CR - 55% / RQD - 19% UDC - 1 {3.00 - 3.15m}	
4		■								4																					
5			End of Log @ 5 (m)							5																				Run - 3 CR - 45% / RQD - Nil	

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
Abbreviations	Δ Groundwater Level			C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	

Mud Rotary Log BH-06

Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 47.24m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:294241.69			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:11.08.2024	Northing:2769852.94				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments	
				* SPT 10 20 30 40 50							Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	Dry Unit Weight (gr/cm3)		Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL		
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>						* 50																					0	Run - 1	
1		□																													1	CR - 42% / RQD - Nil
2		■																													2	SPT(C) - 1 SPT(C) Drive - 25mm
3		+																													3	Run - 2 CR - 56% / RQD - 16% UDC - 1 (2.58 - 2.62m)
4		■																													4	Run - 3 CR - 49% / RQD - Nil
5		■	End of Log @ 5 (m)																	2.7	2.05	2.1		57.35					5	Run - 4 CR - 45% / RQD - Nil		

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
Abbreviations	Groundwater Level			C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	

Mud Rotary Log BH-07

Project Info.

Project :GI at Sindh Solar Energy Project
Client :M/S. Government of Sindh
Location :Deh Halkani, Sindh
Job No.:S-24-1162

Borehole Info.


Depth:5 (m)
GWL:- N.E
Drill Date:11.08.2024
Logged By:IK

Elevation: 59.74m from MSL
Easting:293838.67
Northing:2769907.41
Method:Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests		Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidati on		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50					Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3		
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>				0																	0	Run - 1			
1		+						1																	1	CR - 50% / RQD - 12%		
2		■						2																	2	UDC - 1 {0.98 - 1.11m}		
3		+						3																	3	SPT(C) - 1		
4		■						4																	4	SPT(C) Drive - 25mm		
5		■	End of Log @ 5 (m)			5								3	2.17	2.2			88.63				5	Run - 2				
																									CR - 57% / RQD - 17%			
																									UDC - 2 {2.30 - 2.43m}			
																									Run - 3			
																									CR - 44% / RQD - Nil			
																									Run - 4			
																									CR - 48% / RQD - Nil			

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌋ SPT Sample
- ⌋ Water Sample
- ⌋ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-08

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.


Depth: 5 (m)
GWL:- N.E
Drill Date: 11.08.2024
Logged By: IK

Elevation: 41.18m from MSL
Easting: 294091.84
Northing: 2769806.29
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3) Bulk	Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)			C (kg/cm2)	F _i (o)		Cc	Cs	P _c (kg/cm2)	PH	SO3		
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>			0																	0	SPT(C) Drive - 25mm		
1		□					1																	1	CR - 34% / RQD - Nil	
2		■					2																	2	SPT(C) - 1	
3		■					3																	3	Run - 4	
4		■					4																	4	Run - 1	
5		■	End of Log @ 5 (m)			5								3.2	2.15	2.2			72.24				5	CR - 42% / RQD - Nil		
																								Run - 2		
																								CR - 54% / RQD - 13%		
																								UDC - 1 (3.00 - 3.13m)		
																								Run - 3		
																								CR - 48% / RQD - Nil		

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌋ SPT Sample
- ⌋ Water Sample
- ⌋ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-09

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.


Depth: 5 (m)
GWL:- N.E
Drill Date: 11.08.2024
Logged By: IK

Elevation: 40.53m from MSL
Easting: 293729.39
Northing: 2769714.96
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments		
				* SPT 10 20 30 40 50							Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Dry Unit Weight	Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL			
0		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor to poor quality of rock, interbedded with mudstone							0																					0	Run - 1 CR - 41% / RQD - Nil	
1		U									1																					1	SPT(C) - 1 SPT(C) Drive - 25mm
2		+									2									2.9	2.2	2.3			89.23							2	Run - 2 CR - 54% / RQD - 16% UDC - 1 (2.15 - 2.29m)
3		+									3																					3	Run - 3 CR - 62% / RQD - 25% UDC - 2 (3.36 - 3.52m)
4		■									4																					4	Run - 4 CR - 49% / RQD - Nil
5			End of Log @ 5 (m)							5																				5			

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌵ SPT Sample
- ⊞ Water Sample
- ≡ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI


- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained


Mud Rotary Log BH-10


Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 32.30m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:293513.81			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:11.08.2024	Northing:2769649.50				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
				* SPT 10 20 30 40 50								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)			Dry Unit Weight	Bulk	Test Type		C (kg/cm2)	Fi (o)	Cc	Cs	Pc (kg/cm2)			PH	SO3	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
0			LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
Abbreviations	Δ Groundwater Level			C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	


Mud Rotary Log BH-11


Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 75.89m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:299330.95			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:12.08.2024	Northing:2768877.79				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3) Bulk		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50							Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	C (kg/cm2)		Fi (o)	Cc	Cs	Pc (kg/cm2)		PH	SO3	CL				
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone</i>							0																		0	Run - 1		
1		■									1																		1	CR - 39% / RQD - Nil	
2		■									2									2.4	2.18	2.2			94.95				2	SPT(C) - 1 SPT(C) Drive - 25mm	
3		■									3																		3	Run - 2 CR - 55% / RQD - 17% UDC - 1 (2.00 - 2.14m)	
4		■									4																		4	Run - 3 CR - 51% / RQD - Nil	
5		■	End of Log @ 5 (m)						5																		5	Run - 4 CR - 44% / RQD - Nil			

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
Abbreviations	Δ Groundwater Level			C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	

Mud Rotary Log BH-12

Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 81.07m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:299439.50			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:12.08.2024	Northing:2768508.07				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Dry Unit Weight (gr/cm3)	Bulk	Test Type	C (kg/cm2)	Fi (o)	qu (kg/cm2)	Cc	Cs	Pc (kg/cm2)		
0		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone							0																		0	Run - 1	
1		□									1																		1	CR - 44% / RQD - Nil
2		+									2																		2	SPT(C) - 1 SPT(C) Drive - 25mm
3		■									3																		3	Run - 2 CR - 53% / RQD - 16% UDC - 1 (2.19 - 2.32m)
4		+									4																		4	Run - 3 CR - 49% / RQD - Nil
5		+	End of Log @ 5 (m)						5																		5	Run - 4 CR - 59% / RQD - 20% UDC - 2 (4.64 - 4.77m)		

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed						
Sample Types	■ Water Sample	PL : Plastic Limit	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	F : Fast	UU : Unconsolidated, Undrained
	□ Shelby / U4						
Sample Types	■ Core Cutter	PI : Plastic Index	C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	S : Slow	CU : Consolidated, Undrained	
	■ Groundwater Level						
Abbreviations	■ None PI	NPI : None PI	Phi' : Friction Angle (CU)	K : Permeability Coeff.			

Mud Rotary Log BH-13

Project Info.

Project :GI at Sindh Solar Energy Project
Client :M/S. Government of Sindh
Location :Deh Halkani, Sindh
Job No.:S-24-1162

Borehole Info.


Depth:5 (m)
GWL:- N.E
Drill Date:12.08.2024
Logged By:IK

Elevation: 55.16m from MSL
Easting:299178.78
Northing:2768342.36
Method:Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Test Type	Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50							Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	Dry		Bulk	C (kg/cm2)		Fi (o)	Cc		Cs	Pc (kg/cm2)	PH	SO3	CL		
0		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone							0																				0	Run - 1	
1		□									1																				1	CR - 41% / RQD - Nil
2		■									2																				2	SPT(C) - 1 SPT(C) Drive - 25mm
3		+									3																				3	Run - 2
4		■									4																				4	CR - 54% / RQD - 14% UDC - 1 (2.52 - 2.64m)
5		■	End of Log @ 5 (m)							5									2.6	2.23	2.3		91.17						5	Run - 3		
																															CR - 48% / RQD - Nil	

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- ⌵ SPT Sample
- ⊞ Water Sample
- ≋ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-14

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.


Depth: 5 (m)
GWL:- N.E
Drill Date: 12.08.2024
Logged By: IK

Elevation: 56.09m from MSL
Easting: 299035.02
Northing: 2768606.46
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests					Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3) Bulk		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
				* SPT 10 20 30 40 50								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		C (kg/cm2)	Fi (o)	Cc	Cs		Pc (kg/cm2)	PH	SO3	CL			
0		■	LIMESTONE <i>Yellowish brown, weak, distinctly weathered, very poor to poor quality of rock, interbedded with mudstone</i>							0																			0	Run - 1	
1		□									1																			1	CR - 39% / RQD - Nil
2		■									2																			2	SPT(C) - 1 SPT(C) Drive - 25mm
3		■									3							3.3	2.08	2.1			71.51							3	Run - 2 CR - 48% / RQD - Nil
4		■								4																			4	Run - 3 CR - 57% / RQD - 21% UDC - 1 (3.00 - 3.15m)	
5		+ ■	End of Log @ 5 (m)							5																		5	Run - 4 CR - 61% / RQD - 26% UDC - 2 (4.74 - 4.87m)		

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- SPT Sample
- Water Sample
- ∇ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI


- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-15

Project Info.	Project :GI at Sindh Solar Energy Project	Borehole Info.	Depth:5 (m)	Elevation: 82.29m from MSL		Company Info.	Soil Testing Services	
	Client :M/S. Government of Sindh		GWL:- N.E	Easting:299259.94			Geotechnical Engineers & Material Testing Laboratory www.sts.com.pk	
	Location :Deh Halkani, Sindh		Drill Date:12.08.2024	Northing:2768620.12				
	Job No.:S-24-1162		Logged By:IK	Method:Mud Rotary				

Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments		
				* SPT 10 20 30 40 50				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		Dry Unit Weight	Bulk	Test Type	C (kg/cm2)	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL		
0		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone			0																					0	Run - 1	
1		□				1																					1	CR - 42% / RQD - Nil	
2		■				2																					2	SPT(C) - 1 SPT(C) Drive - 25mm	
3		■				3										3.2	2.13	2.2				88.63					3	Run - 2 CR - 58% / RQD - 19% UDC - 1 (2.30 - 2.42m)	
4		■				4																					4	Run - 3 CR - 48% / RQD - Nil	
5		■				5																					5	Run - 4 CR - 51% / RQD - Nil	
			End of Log @ 5 (m)																										

Sample Types	● Disturbed	SPT Sample	LL : Liquid Limit	C : Cohesion	Cc : Cc	w : Moisture Content	CD : Consolidated, Drained
	+ Undisturbed		PL : Plastic Limit				
Abbreviations	□ Shelby / U4	Water Sample	PI : Plastic Index	Phi : Friction Angle	Cs : Cs	qu : Unconfined Comp. Qu	UU : Unconsolidated, Undrained
	■ Core Cutter		NPI : None PI				
				C' : Cohesion (CU)	Pc : Pre-Consolidation Pressure	F : Fast	CU : Consolidated, Undrained
				Phi' : Friction Angle (CU)	K : Permeability Coeff.	S : Slow	

Mud Rotary Log BH-16

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.

Depth: 5 (m)
GWL:- N.E
Drill Date: 12.08.2024
Logged By: IK

Elevation: 58.52m from MSL
Easting: 299232.45
Northing: 2769317.61
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)				C	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL	
0			SAND Yellowish brown, dense, fine to coarse grained, little silt, and gravel, pieces of limestone at places	* SPT 10 20 30 40 50		0																				0	
1		U				1	SM A-2-4(0)	16.5	66.3	17.2		NLL	-	NPI	9.8	1.7	1.9									1	SPT - 1
2		+	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone			2																				2	Run - 1 CR - 52% / RQD - 19% UDC - 1 {1.96 - 2.09m}
3		■				3									2.5	2.15	2.2			101.2 7						3	Run - 2 CR - 63% / RQD - 27% UDC - 2 {3.10 - 3.25m}
4		■				4																				4	Run - 3
5		■				5																				5	CR - 47% / RQD - Nil
			End of Log @ 5 (m)																								

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- U SPT Sample
- Water Sample
- Δ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-17

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.

Depth: 5 (m)
GWL:- N.E
Drill Date: 12.08.2024
Logged By: IK

Elevation: 55.77m from MSL
Easting: 298923.71
Northing: 2769394.11
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm ³)		Direct Shear Test		qu (kg/cm ²)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)				C	Fi (o)		Cc	Cs	Pc (kg/cm ²)	PH	SO ₃	CL	
0			SAND Yellowish brown, medium dense, fine grained, traces of silt and gravel, pieces of limestone at places	* SPT 10 20 30 40 50		0																				0	
1		U		* 12		1	SW-SM A-2-4(0)	6.3	84.8	8.9		NLL	-	NPI	8.6	1.73	1.9									1	SPT - 1
2		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone			2																				2	Run - 1 CR - 42% / RQD - Nil
3		+				3									3.1	2.17	2.2			77.03						3	Run - 2 CR - 57% / RQD - 19% UDC - 1 (3.24 - 3.37m)
4		■				4																				4	
5			End of Log @ 5 (m)			5																				5	Run - 3 CR - 49% / RQD - Nil

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- U SPT Sample
- Water Sample
- Δ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Mud Rotary Log BH-18

Project Info.

Project : GI at Sindh Solar Energy Project
Client : M/S. Government of Sindh
Location : Deh Halkani, Sindh
Job No.: S-24-1162

Borehole Info.

Depth: 5 (m)
GWL:- N.E
Drill Date: 12.08.2024
Logged By: IK

Elevation: 59.13m from MSL
Easting: 299226.41
Northing: 2769187.30
Method: Mud Rotary

Company Info.

Soil Testing Services
Geotechnical Engineers &
Material Testing Laboratory
www.sts.com.pk



Depth (m)	GWL (m)	Sample Type	Lithology Description	Field Tests	Symbol	Depth (m)	USCS / AASHTO	Sieve Analysis Test				Atterberg Limits			w (%)	Dry Unit Weight (gr/cm3)		Direct Shear Test		qu (kg/cm2)	Consolidation		Chemical Tests			Depth (m)	Remarks & Comments
								Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)				C	Fi (o)		Cc	Cs	Pc (kg/cm2)	PH	SO3	CL	
0			SAND Yellowish brown, dense, fine to coarse grained, little gravel, traces of silt	* SPT 10 20 30 40 50		0																				0	
1		U				1	SP-SM A-2-4(0)	12.8	77.5	9.7		NLL	-	NPI	10.1	1.71	1.9									1	SPT - 1
2		■	LIMESTONE Yellowish brown, weak, distinctly weathered, very poor quality of rock, interbedded with mudstone			2																				2	Run - 1 CR - 40% / RQD - Nil
3		■				3									2.5	2.09	2.1			83.54						3	Run - 2 CR - 55% / RQD - 16% UDC - 1 (3.00 - 3.17m)
4		■				4																				4	
5			End of Log @ 5 (m)			5																				5	Run - 3 CR - 49% / RQD - Nil

Sample Types

- Disturbed
- + Undisturbed
- Shelby / U4
- Core Cutter
- U SPT Sample
- Water Sample
- Δ Groundwater Level

Abbreviations

- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI

- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)

- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.

- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow

- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

Laboratory Test Results

Summary of Lab. Tests

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Soil Testing Services



Sieve Analysis Test

Borehole	Sample Depth (m)	Soil Class	D10 mm	D30 mm	D60 mm	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Cobble (%)	LL	PL
BH-02	1	SM A-2-4(0)	-1	0.221	1.651		19.4	72.1	8.5		-1	-1
BH-05	1	SP-SM A-2-4(0)	-1	0.221	1.651		10.4	73.7	15.9		-1	-1
BH-16	1	SM A-2-4(0)	-1	0.221	1.651		17.2	66.3	16.5		-1	-1
BH-17	1	SW-SM A-2-4(0)	-1	0.221	1.651		8.9	84.8	6.3		-1	-1
BH-18	1	SP-SM A-2-4(0)	-1	0.221	1.651		9.7	77.5	12.8		-1	-1

Density & Moisture Test

Borehole	Sample Depth (m)	Soil Class	Moisture Content (%)	Dry Density (gr/cm3)
BH-01	2.15		3.7	2.13
BH-02	1	SM A-2-4(0)	10.3	1.721
BH-02	3.1		2.4	2.16
BH-03	3.26		3.1	2.08
BH-04	2.2		3.1	2.14
BH-05	1	SP-SM A-2-4(0)	11.2	1.714
BH-05	3		3	2.11
BH-06	2.58		2.7	2.05
BH-07	2.3		3	2.17
BH-08	3		3.2	2.15
BH-09	2.15		2.9	2.2
BH-10	1.14		4	2.05
BH-10	3.2		4	2.05
BH-11	2		2.4	2.18
BH-12	2.19		3.5	2.06
BH-13	2.52		2.6	2.23
BH-14	3		3.3	2.08
BH-15	2.3		3.2	2.13
BH-16	1	SM A-2-4(0)	9.8	1.703
BH-16	3.1		2.5	2.15
BH-17	1	SW-SM A-2-4(0)	8.6	1.731
BH-17	3.24		3.1	2.17
BH-18	1	SP-SM A-2-4(0)	10.1	1.709
BH-18	3		2.5	2.09

Unconfined Compression Test

Borehole	Sample Depth (m)	Soil Class	Diameter (cm)	Height (cm)	qu (kg/cm2)
BH-01	2.15		5.417	8.238	68.4
BH-02	3.1		5.521	9.041	74.27
BH-03	3.26		5.619	10.141	82.38
BH-04	2.2		5.315	8.74	62.65
BH-05	3		5.422	9.534	83.5
BH-06	2.58		5.617	10.334	57.35
BH-07	2.3		5.626	8.738	88.63

Summary of Lab. Tests

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Soil Testing Services



Borehole	Sample Depth (m)	Soil Class	Diameter (cm)	Height (cm)	qu (kg/cm2)
BH-08	3		5.417	8.238	72.24
BH-09	2.15		5.322	9.044	89.23
BH-10	1.14		5.42	7.935	65.51
BH-10	3.2		5.414	8.238	85.7
BH-11	2		5.622	9.942	94.95
BH-12	2.19		5.424	8.938	76.35
BH-13	2.52		5.421	9.833	91.17
BH-14	3		5.522	9.142	71.51
BH-15	2.3		5.417	8.238	88.63
BH-16	3.1		5.527	10.743	101.27
BH-17	3.24		5.417	8.338	77.03
BH-18	3		5.622	9.342	83.54

Sieve Analysis Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-02

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1 (m)

Job No.: S-24-1162

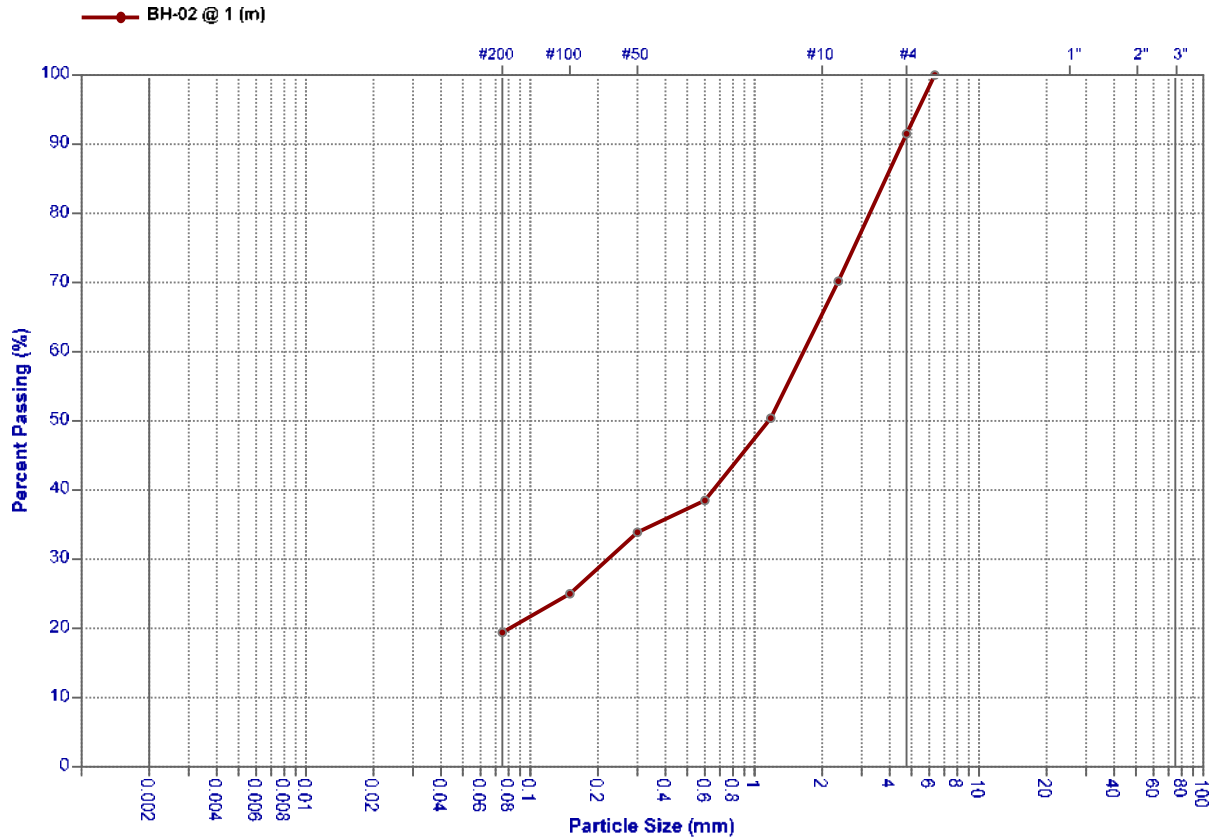
Classification : SM | A-2-4(0)

Location : Deh Halkani, Sindh

Sample Type : SPT Split Spoon



ASTM C136



Particle Distribution (%)

Clay	Silt	Sand	Gravel	Cobble
-	19.4	72.1	8.5	-

Classification

Borehole	Sample Depth (m)	D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Cc	Cu	LL (%)	PI (%)	Disp. (%)	USCS	AASHTO
BH-02	1	-	0.221	1.153	1.651	0.394	-	-	-	N/A	SM	A-2-4(0)

USCS Soil Description : Silty Sand With Gravel
AASHTO Soil Description : Silty or clayey gravel and sand (0)

Tested By :

Sieve Analysis Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-05

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1 (m)

Job No.: S-24-1162

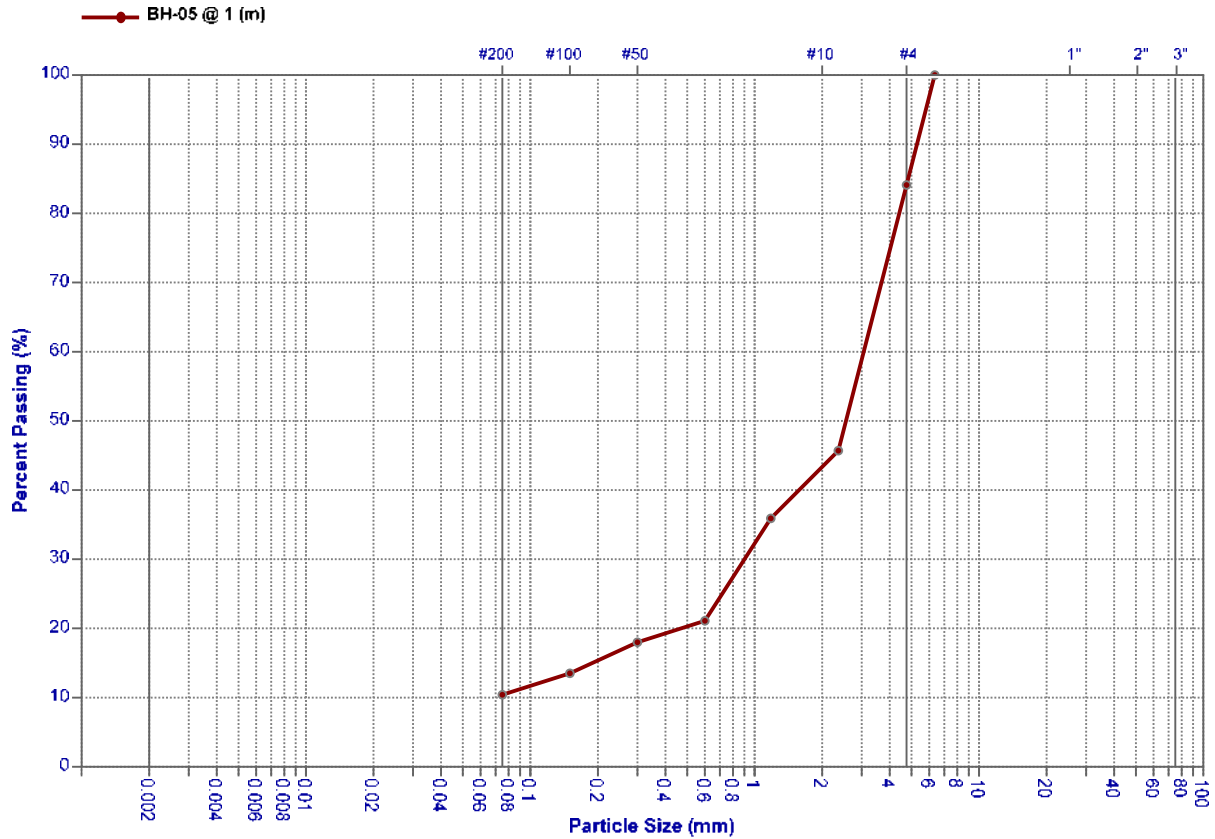
Classification : SP-SM | A-2-4(0)

Location : Deh Halkani, Sindh

Sample Type : SPT Split Spoon



ASTM C136



Particle Distribution (%)

Clay	Silt	Sand	Gravel	Cobble
-	10.4	73.7	15.9	-

Classification

Borehole	Sample Depth (m)	D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Cc	Cu	LL (%)	PI (%)	Disp. (%)	USCS	AASHTO
BH-05	1	-	0.901	2.552	3.062	3.488	-	-	-	N/A	SP-SM	A-2-4(0)

USCS Soil Description : Poorly Graded Silty Sand With Gravel & Clay
AASHTO Soil Description : Silty or clayey gravel and sand (0)

Tested By :

Sieve Analysis Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-16

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1 (m)

Job No.: S-24-1162

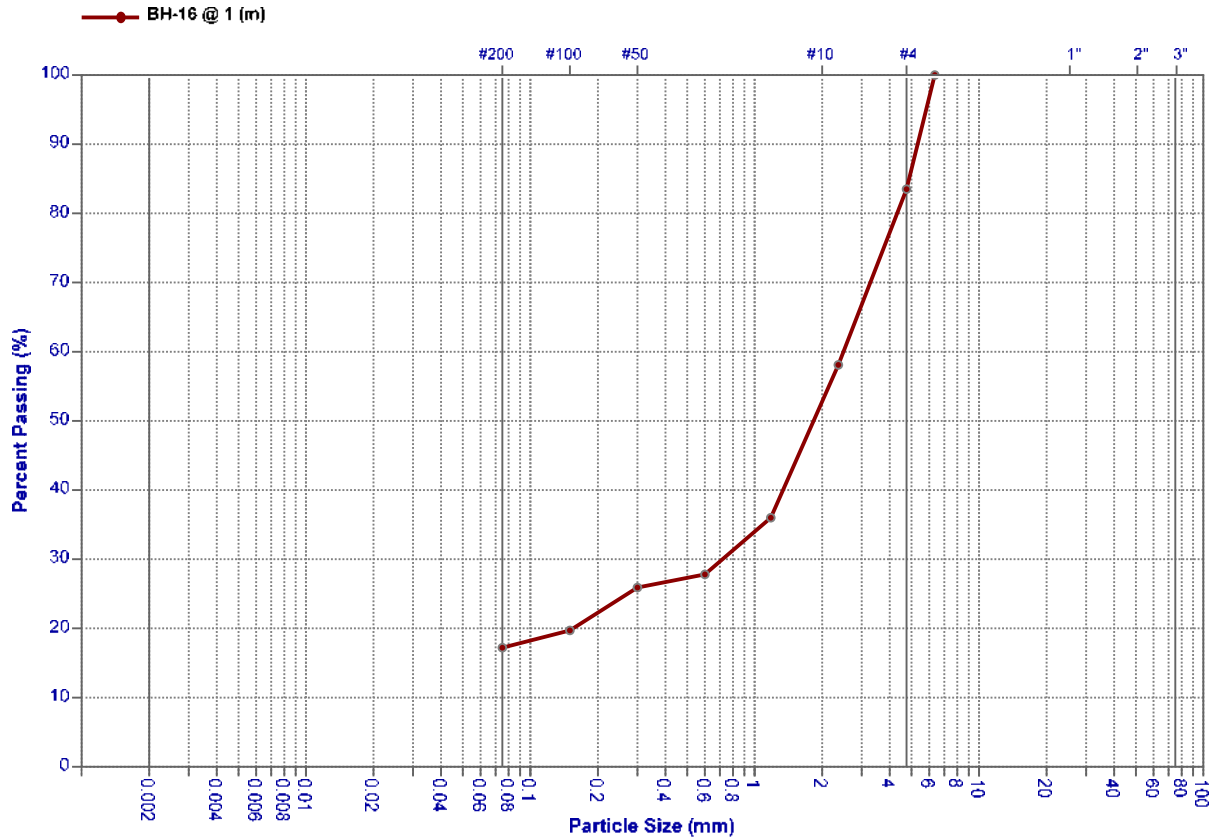
Classification : SM | A-2-4(0)

Location : Deh Halkani, Sindh

Sample Type : SPT Split Spoon



ASTM C136



Particle Distribution (%)

Clay	Silt	Sand	Gravel	Cobble
-	17.2	66.3	16.5	-

Classification

Borehole	Sample Depth (m)	D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Cc	Cu	LL (%)	PI (%)	Disp. (%)	USCS	AASHTO
BH-16	1	-	0.719	1.831	2.487	2.772	-	-	-	N/A	SM	A-2-4(0)

USCS Soil Description : Silty Sand With Gravel
AASHTO Soil Description : Silty or clayey gravel and sand (0)

Tested By :

Sieve Analysis Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-17

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1 (m)

Job No.: S-24-1162

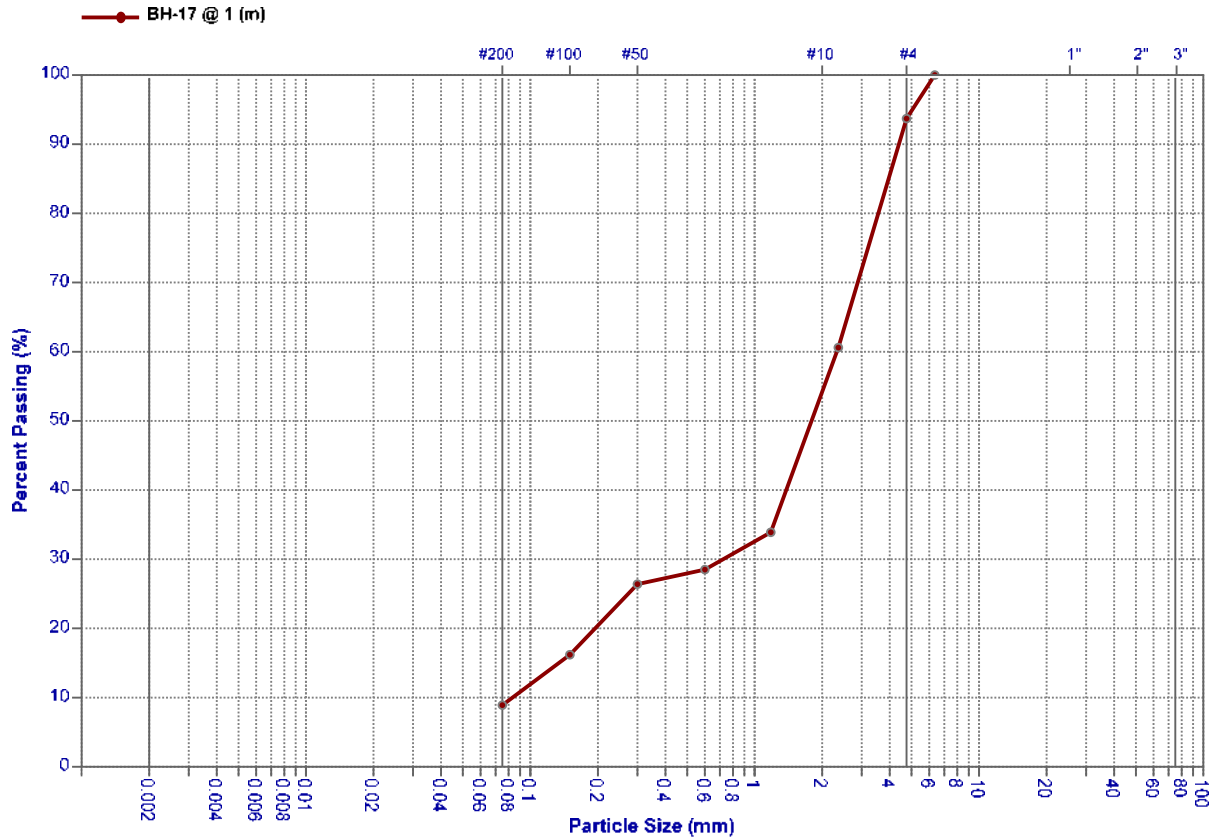
Classification : SW-SM | A-2-4(0)

Location : Deh Halkani, Sindh

Sample Type : SPT Split Spoon



ASTM C136



Particle Distribution (%)

Clay	Silt	Sand	Gravel	Cobble
-	8.9	84.8	6.3	-

Classification

Borehole	Sample Depth (m)	D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Cc	Cu	LL (%)	PI (%)	Disp. (%)	USCS	AASHTO
BH-17	1	0.083	0.724	1.792	2.324	2.717	28	-	-	N/A	SW-SM	A-2-4(0)

USCS Soil Description : Well Graded Silty Sand With Gravel & Clay
AASHTO Soil Description : Silty or clayey gravel and sand (0)

Tested By :

Sieve Analysis Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-18

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1 (m)

Job No.: S-24-1162

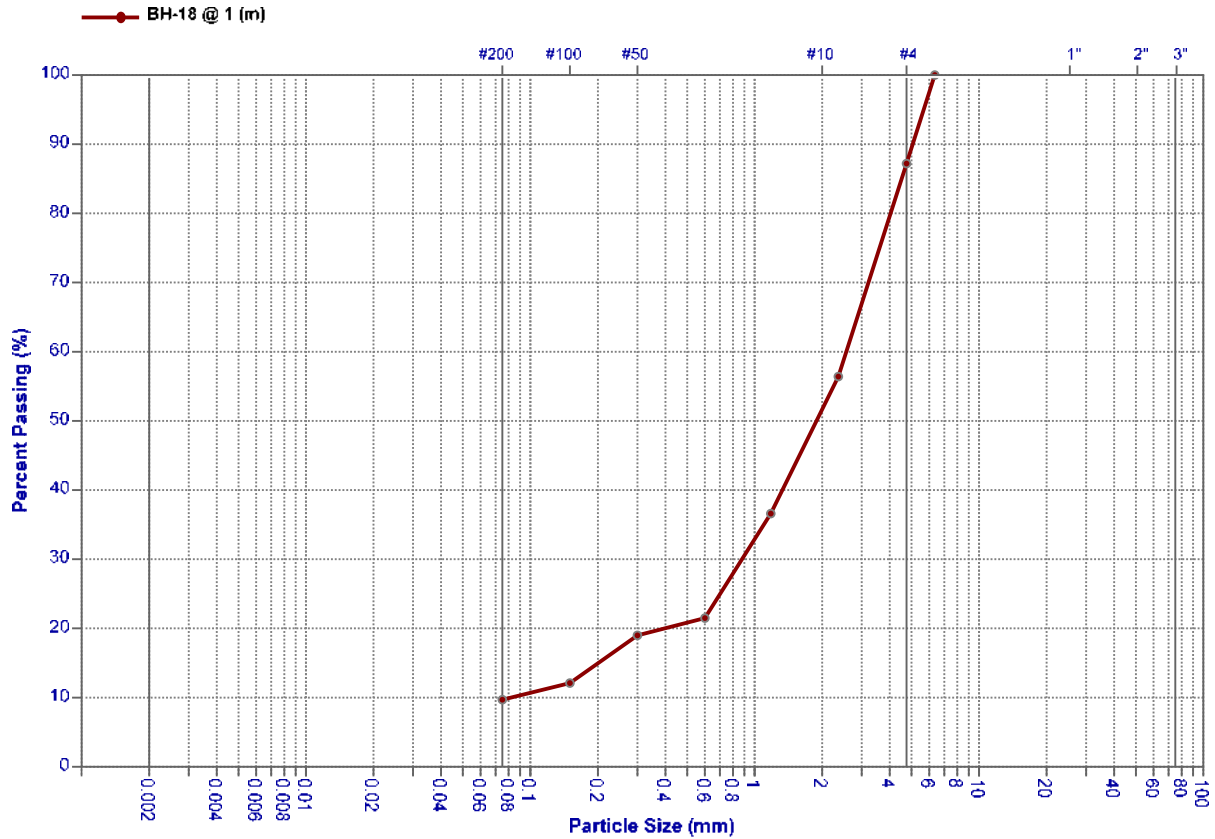
Classification : SP-SM | A-2-4(0)

Location : Deh Halkani, Sindh

Sample Type : SPT Split Spoon



ASTM C136



Particle Distribution (%)

Clay	Silt	Sand	Gravel	Cobble
-	9.7	77.5	12.8	-

Classification

Borehole	Sample Depth (m)	D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Cc	Cu	LL (%)	PI (%)	Disp. (%)	USCS	AASHTO
BH-18	1	0.082	0.878	1.886	2.561	3.671	31.232	-	-	N/A	SP-SM	A-2-4(0)

USCS Soil Description : Poorly Graded Silty Sand With Gravel & Clay
AASHTO Soil Description : Silty or clayey gravel and sand (0)

Tested By :

Density & Moisture Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Soil Testing Services



ASTM D4643, D2216

Borehole	Sample Depth (m)	Moisture Content (%)	Dry Density (gr/cm3)	Wet Density (gr/cm3)
BH-01	2.15	3.7	2.13	2.21
BH-02	1	10.3	1.72	1.9
BH-02	3.1	2.4	2.16	2.21
BH-03	3.26	3.1	2.08	2.14
BH-04	2.2	3.1	2.14	2.21
BH-05	1	11.2	1.71	1.91
BH-05	3	3	2.11	2.17
BH-06	2.58	2.7	2.05	2.11
BH-07	2.3	3	2.17	2.24
BH-08	3	3.2	2.15	2.22
BH-09	2.15	2.9	2.2	2.26
BH-10	1.14	4	2.05	2.13
BH-10	3.2	4	2.05	2.13
BH-11	2	2.4	2.18	2.23
BH-12	2.19	3.5	2.06	2.13
BH-13	2.52	2.6	2.23	2.29
BH-14	3	3.3	2.08	2.15
BH-15	2.3	3.2	2.13	2.2
BH-16	1	9.8	1.7	1.87
BH-16	3.1	2.5	2.15	2.2
BH-17	1	8.6	1.73	1.88
BH-17	3.24	3.1	2.17	2.24
BH-18	1	10.1	1.71	1.88
BH-18	3	2.5	2.09	2.14

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-01

Sample Depth : 2.15 (m)

Rock Name : Limestone

Sample Type : Undisturbed

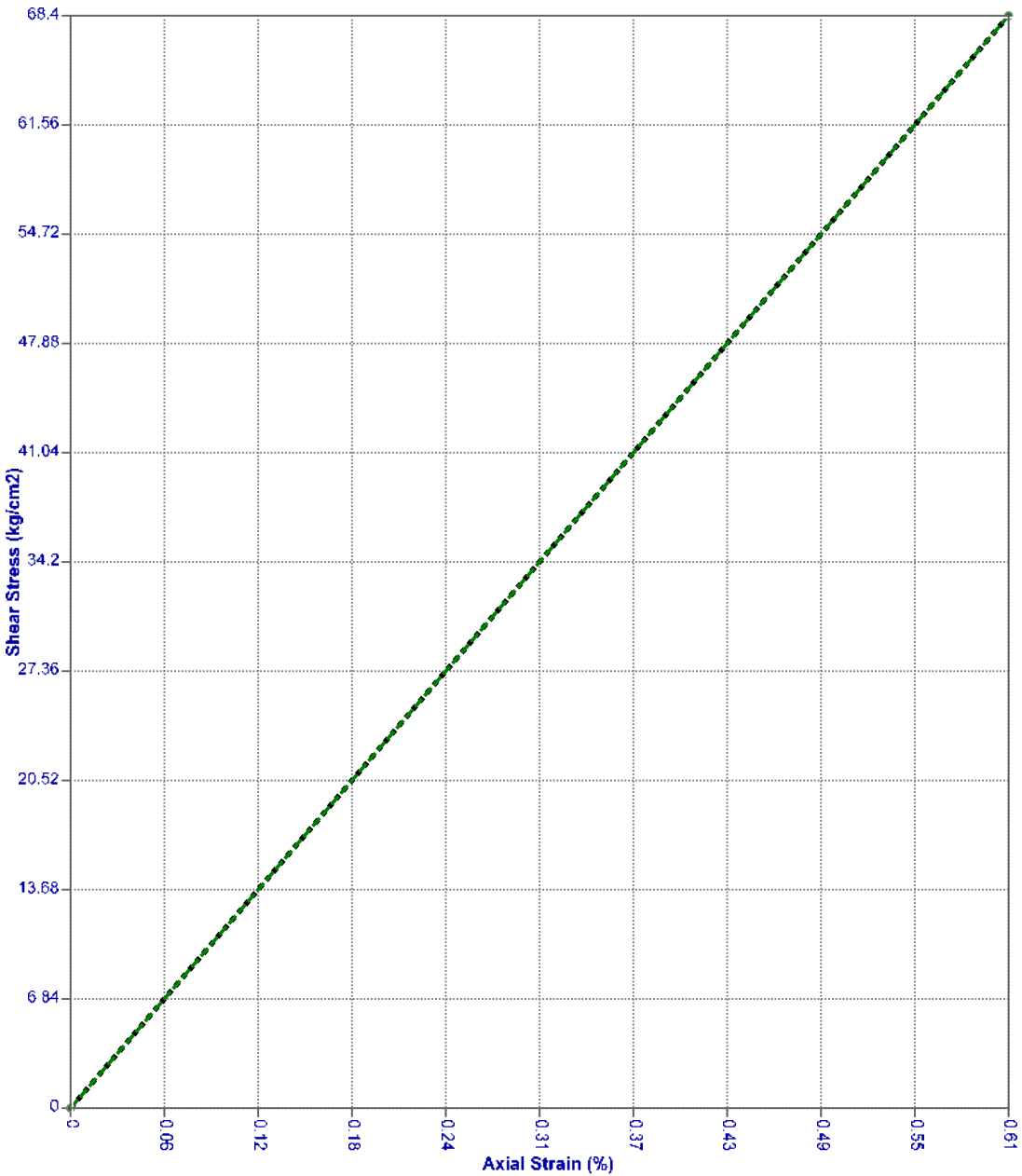
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.417	8.238	1	Moist	3.7	2.13	68.4	34.2



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-02

Sample Depth : 3.1 (m)

Rock Name : Limestone

Sample Type : Undisturbed

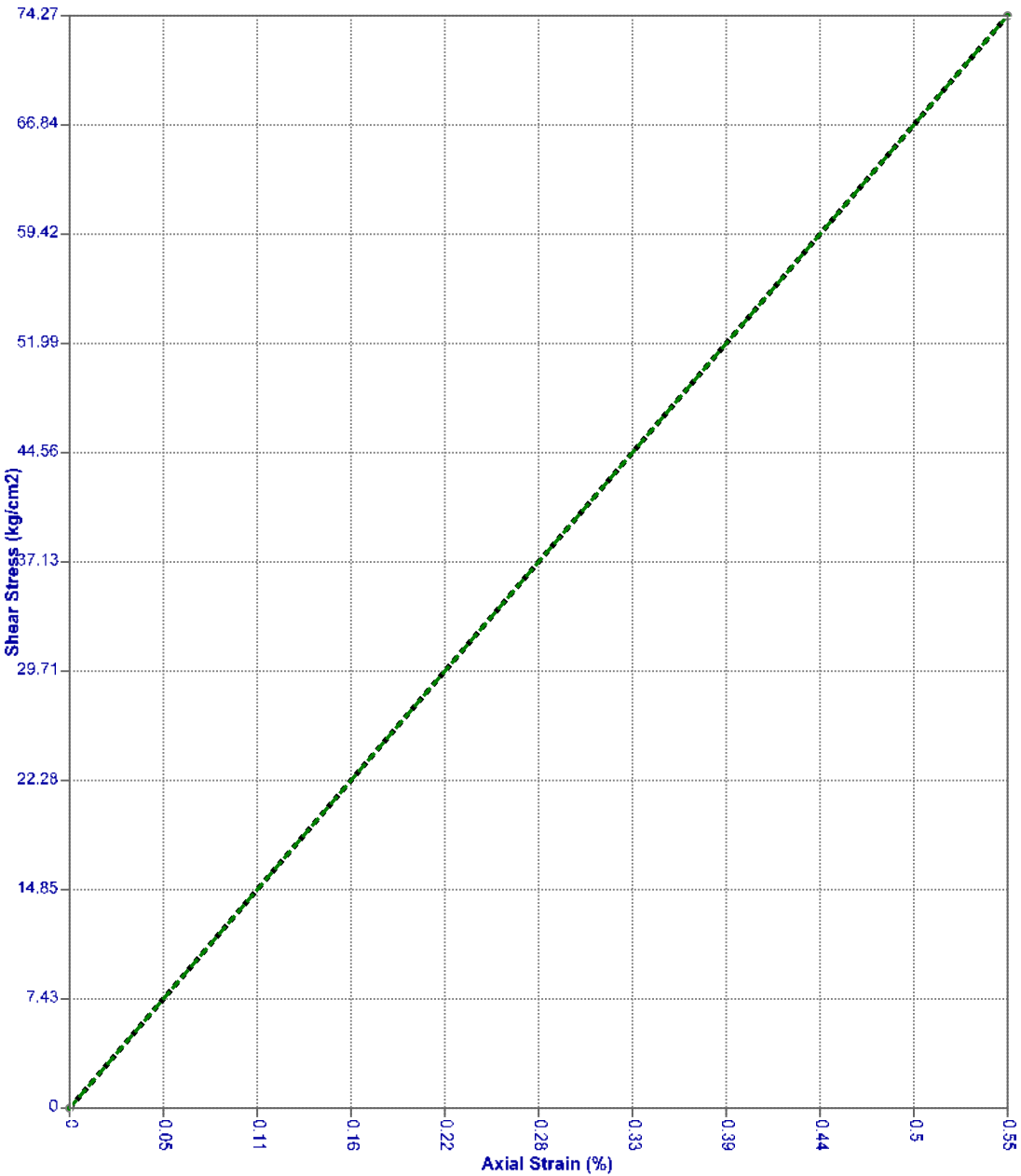
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.521	9.041	1	Moist	2.4	2.16	74.27	37.13



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-03

Sample Depth : 3.26 (m)

Rock Name : Limestone

Sample Type : Undisturbed

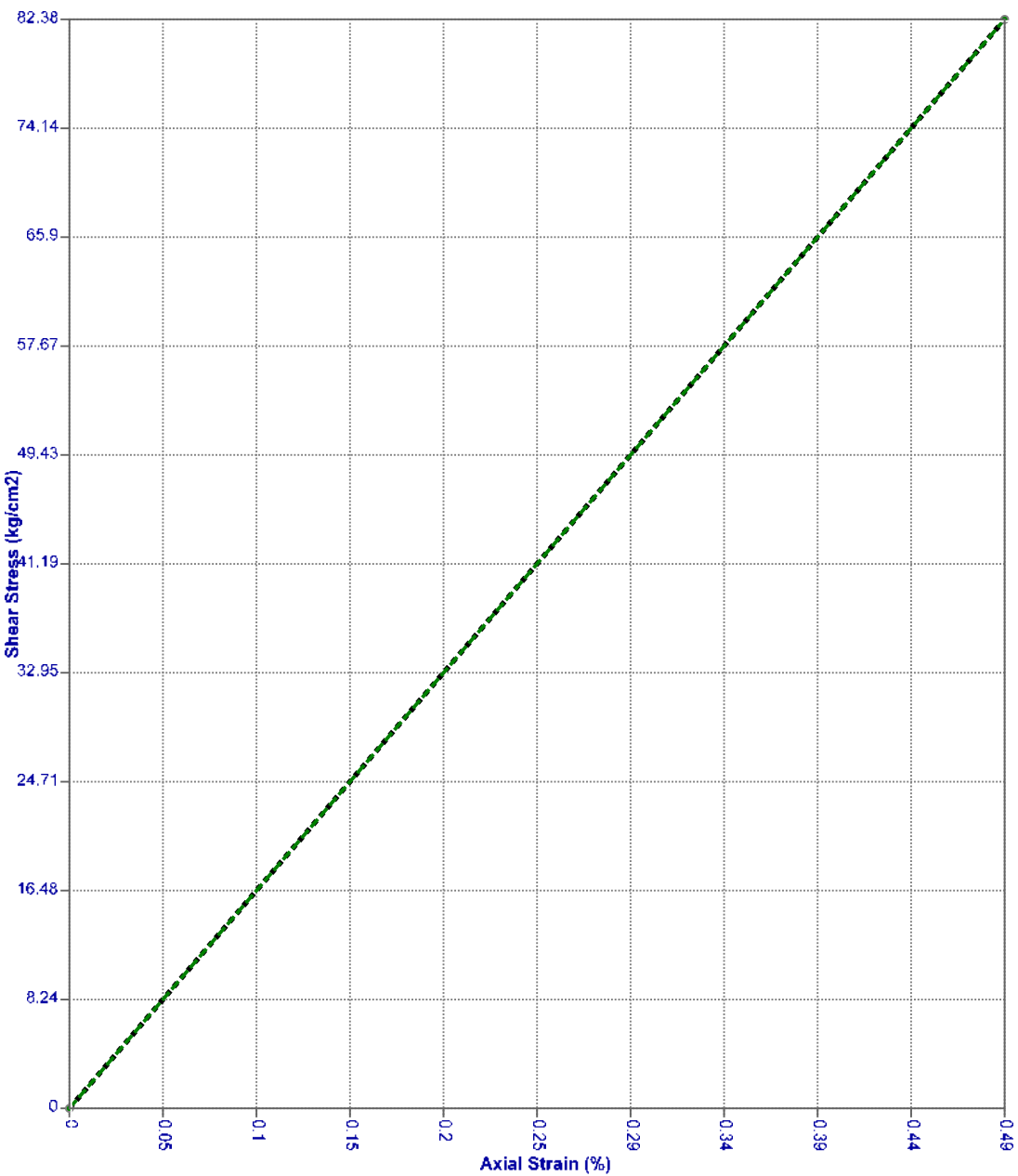
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm ³)	Unconfined Comp. Qu (kg/cm ²)	Su (kg/cm ²)
5.619	10.141	1	Moist	3.1	2.08	82.38	41.19



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-04

Sample Depth : 2.2 (m)

Rock Name : Limestone

Sample Type : Undisturbed

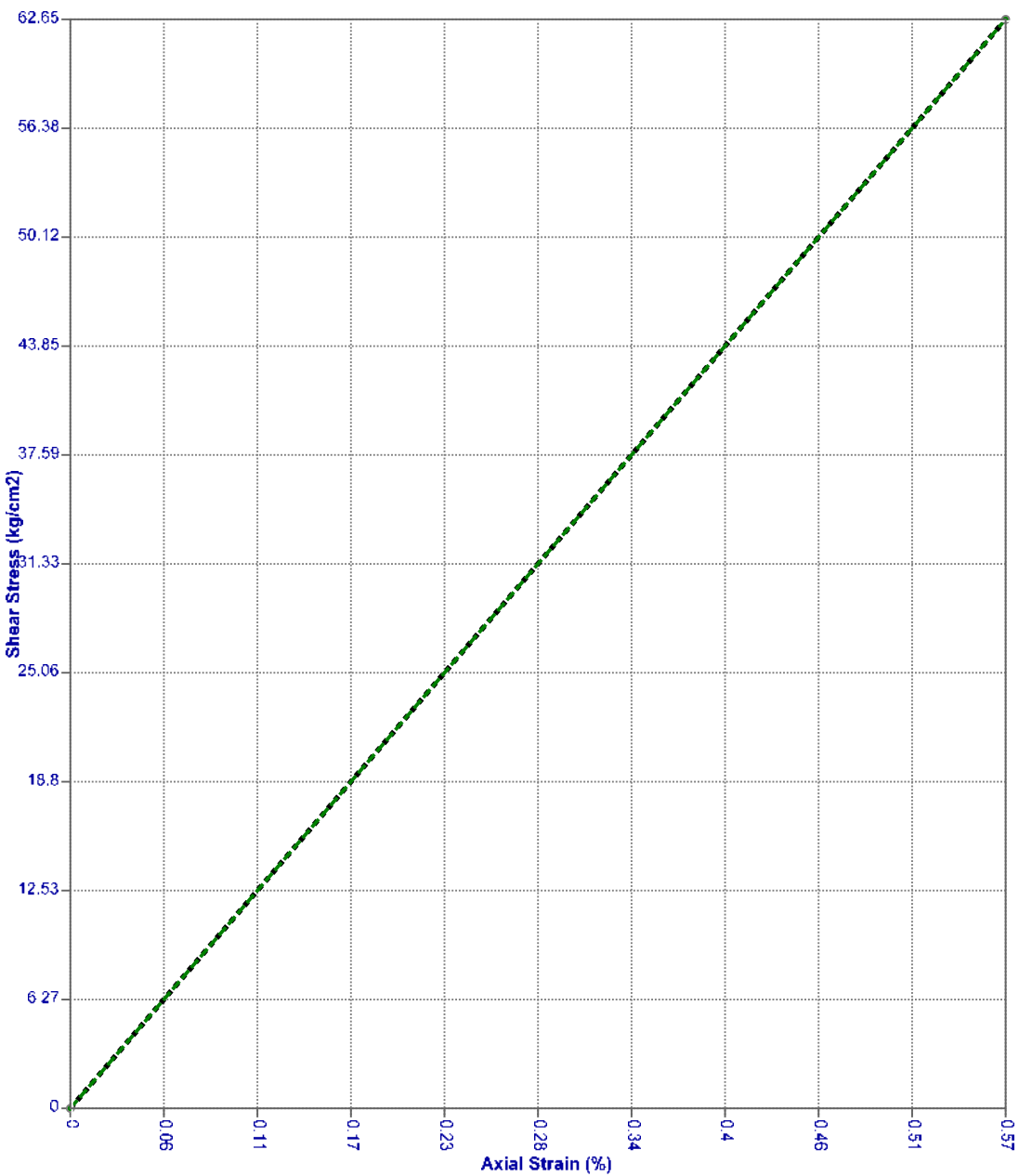
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.315	8.74	1	Moist	3.1	2.14	62.65	31.33



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-05

Sample Depth : 3 (m)

Rock Name : Limestone

Sample Type : Undisturbed

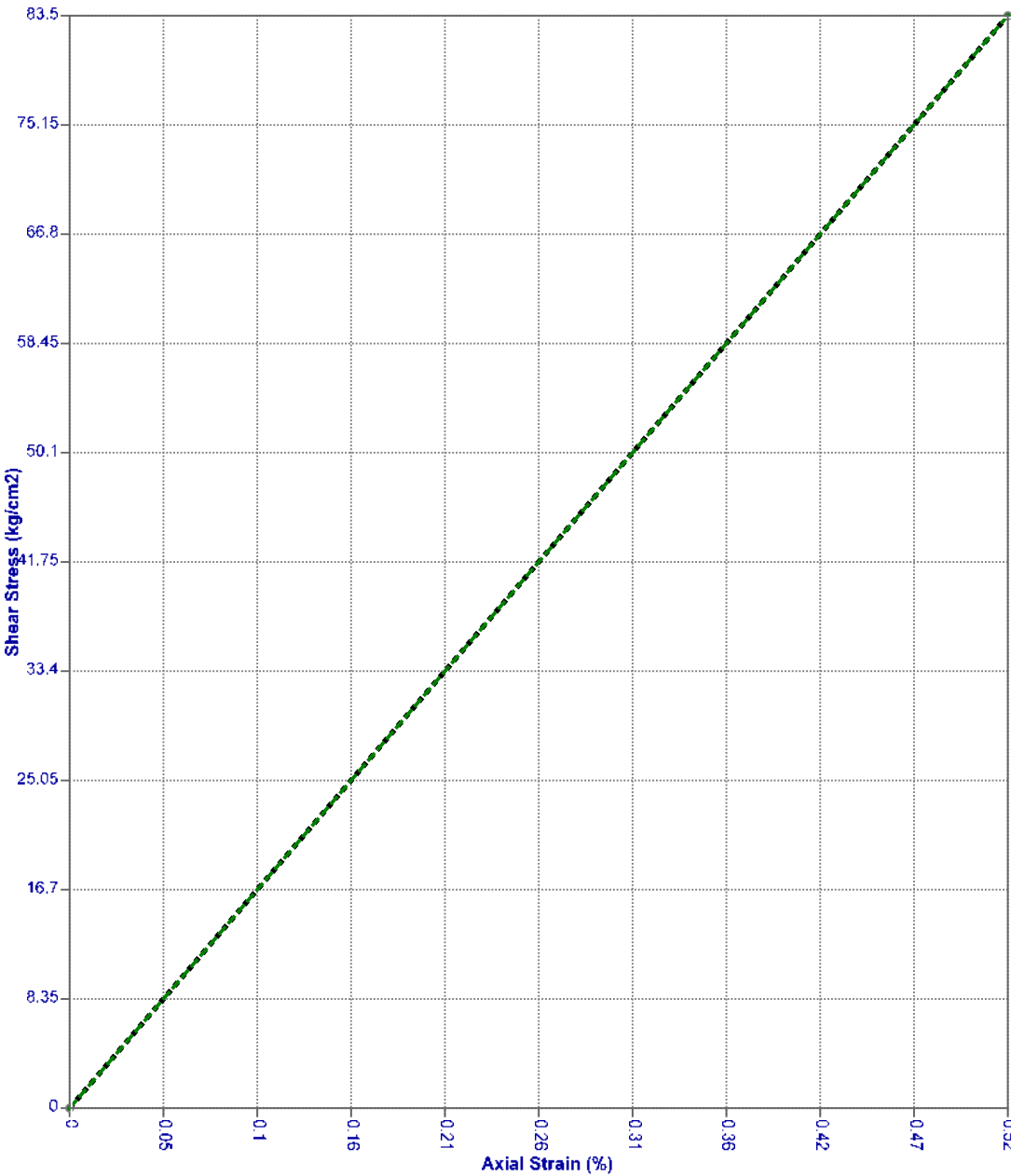
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.422	9.534	1	Moist	3	2.11	83.5	41.75



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-06

Sample Depth : 2.58 (m)

Rock Name : Limestone

Sample Type : Undisturbed

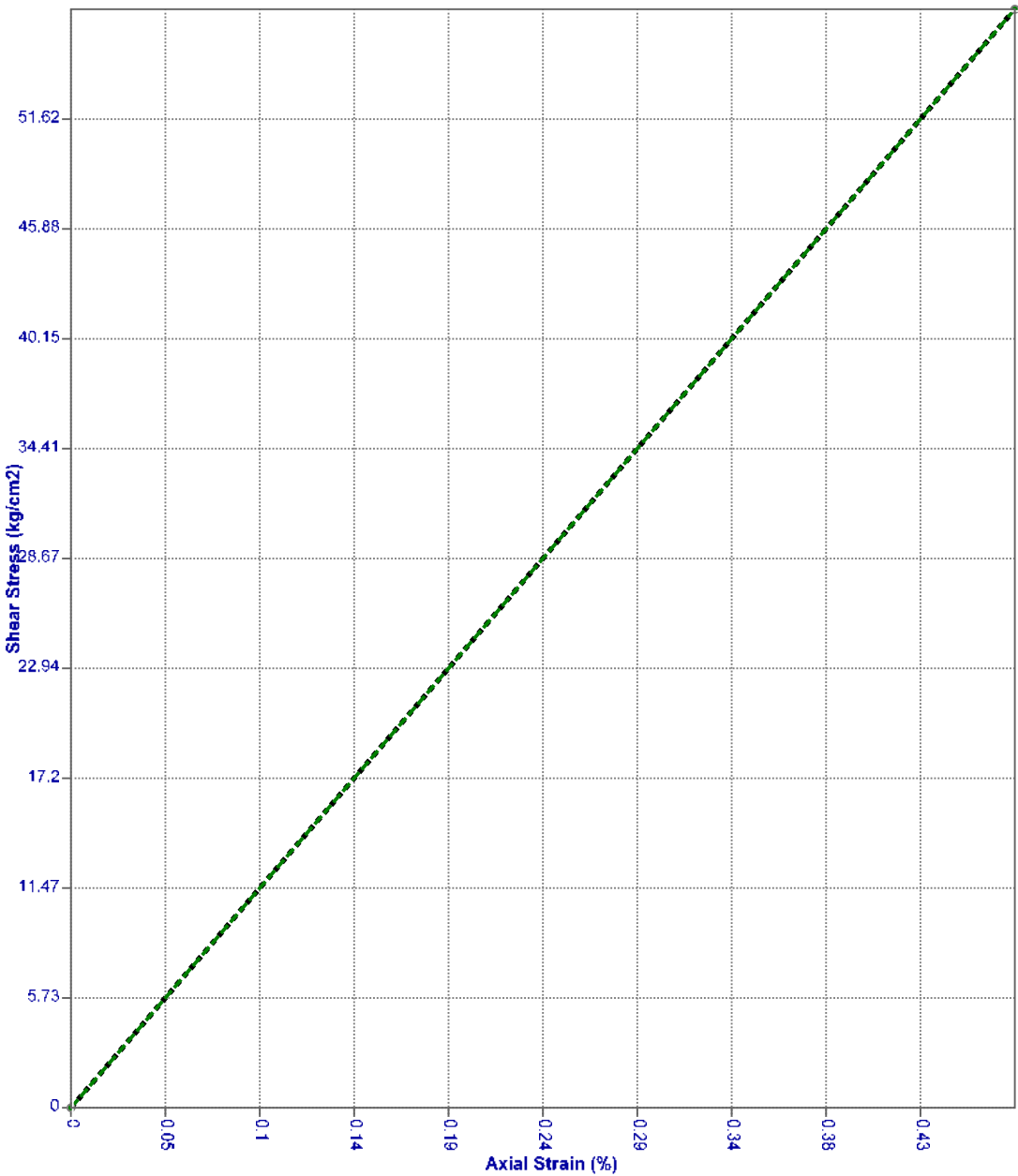
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.617	10.334	1	Moist	2.7	2.05	57.35	28.67



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-07

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 2.3 (m)

Job No.: S-24-1162

Rock Name : Limestone

Location : Deh Halkani, Sindh

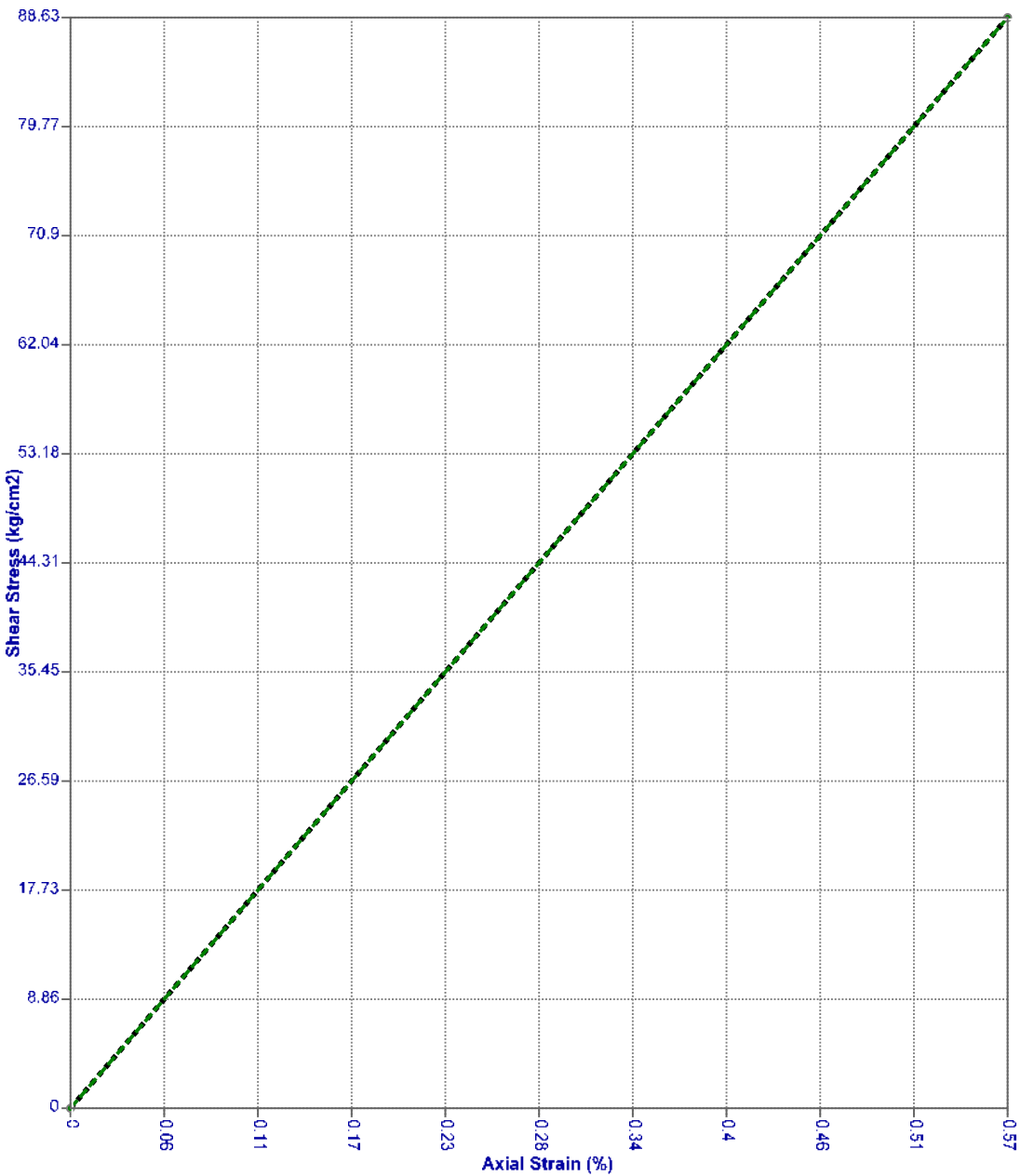
Sample Type : Undisturbed



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm ³)	Unconfined Comp. Qu (kg/cm ²)	Su (kg/cm ²)
5.626	8.738	1	Moist	3	2.17	88.63	44.31



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-08

Sample Depth : 3 (m)

Rock Name : Limestone

Sample Type : Undisturbed

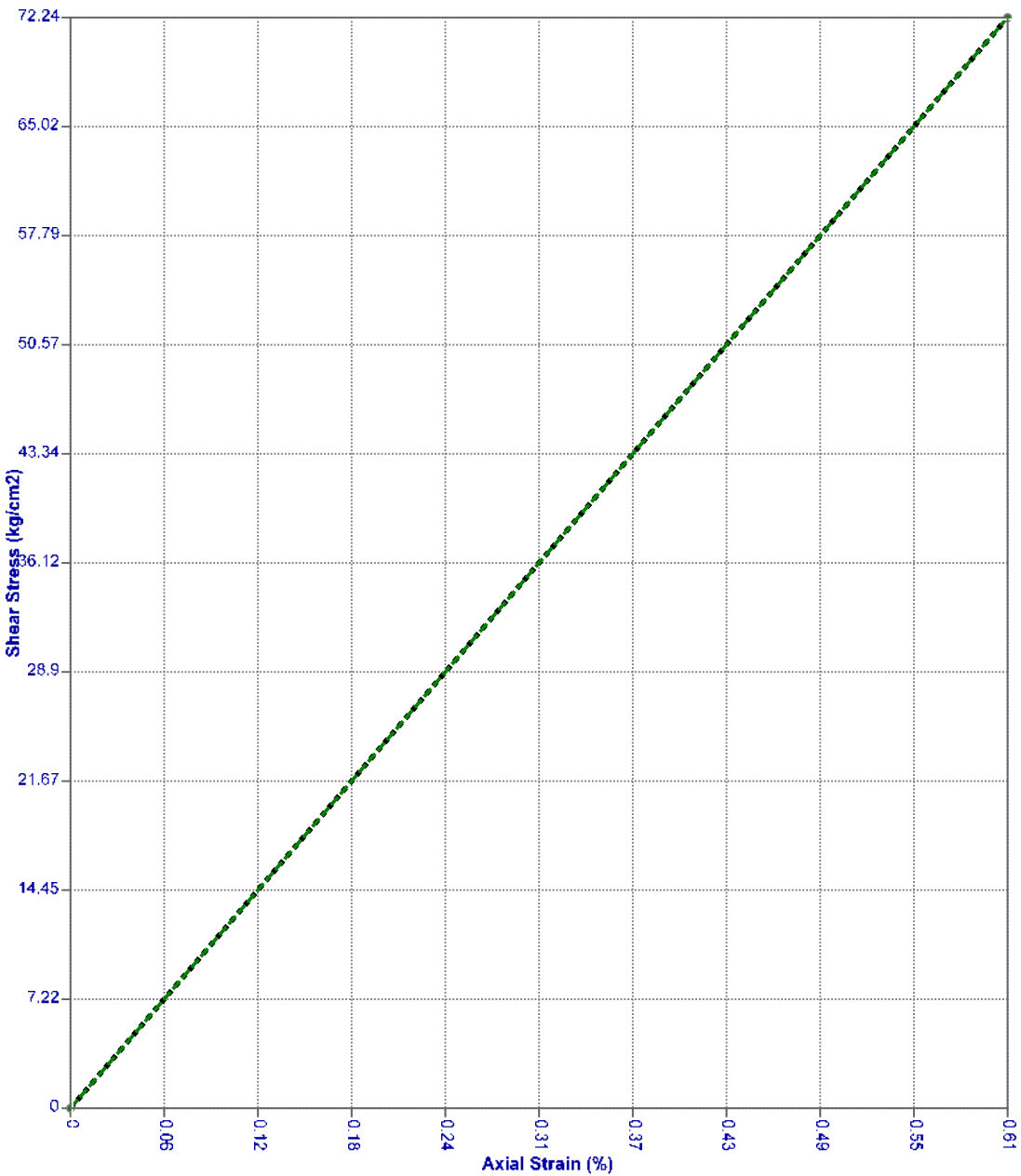
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.417	8.238	1	Moist	3.2	2.15	72.24	36.12



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-09

Sample Depth : 2.15 (m)

Rock Name : Limestone

Sample Type : Undisturbed

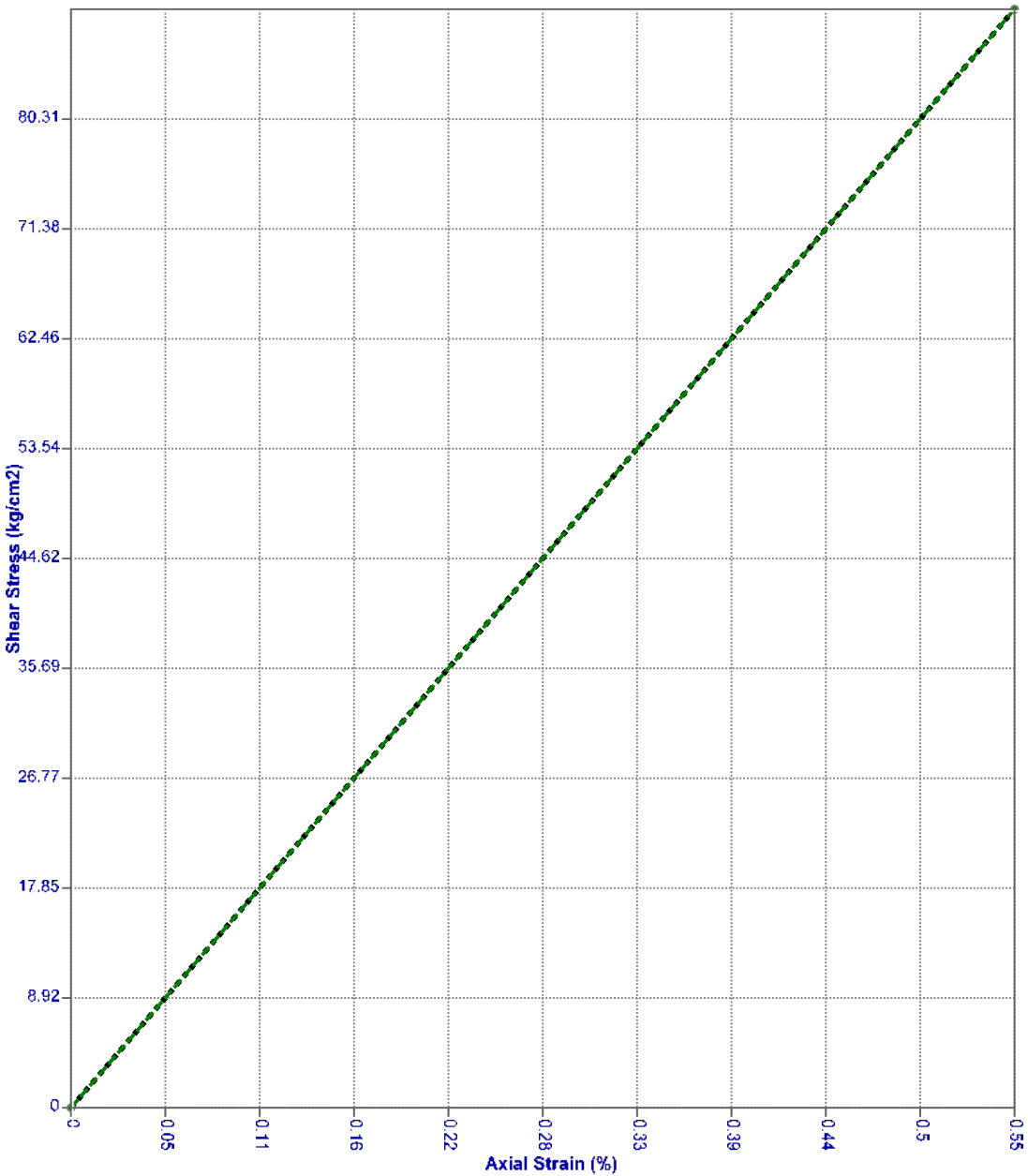
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.322	9.044	1	Moist	2.9	2.2	89.23	44.62



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-10

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 1.14 (m)

Job No.: S-24-1162

Rock Name : Limestone

Location : Deh Halkani, Sindh

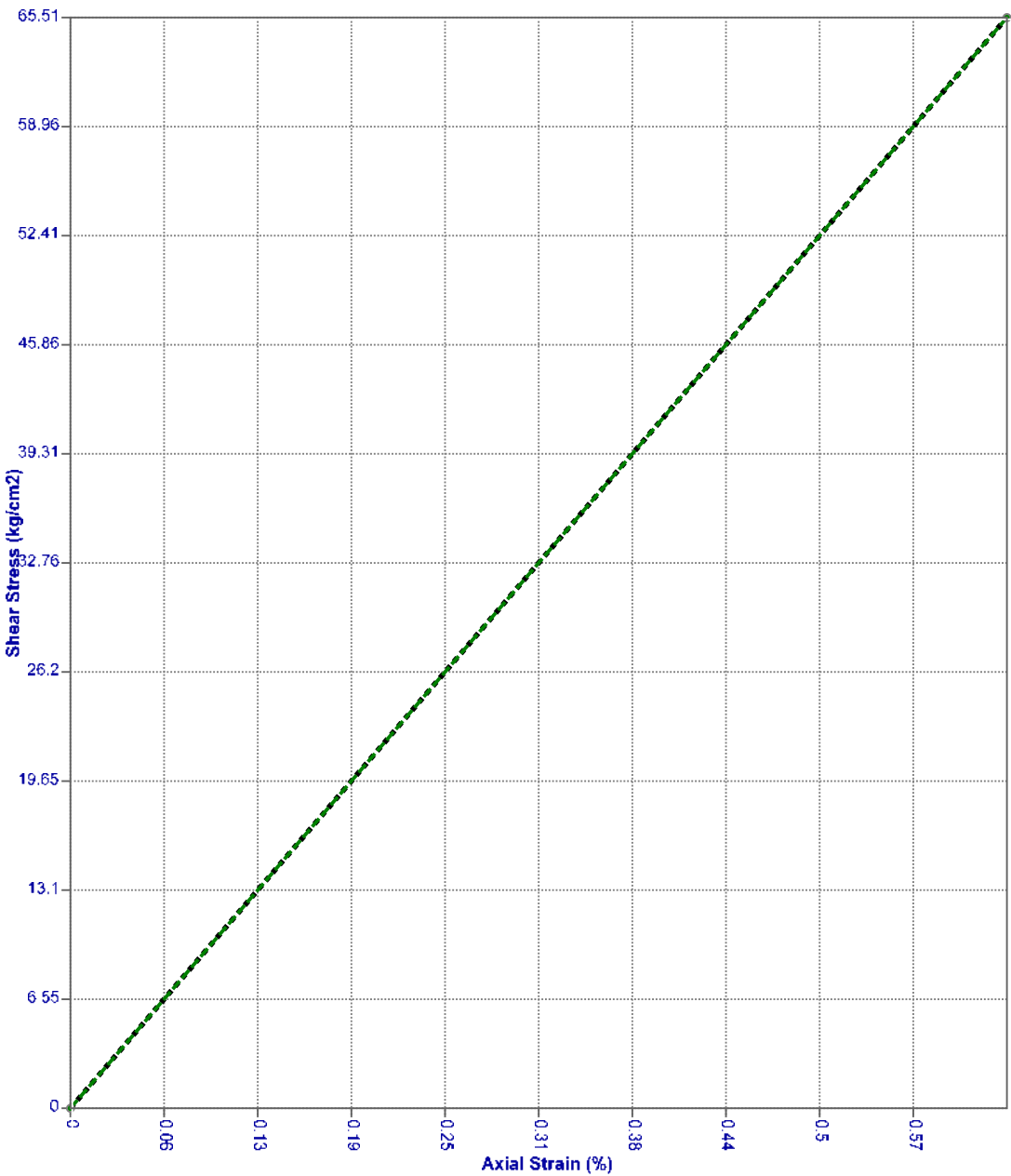
Sample Type : Undisturbed



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.42	7.935	1	Moist	4	2.05	65.51	32.76



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-10

Sample Depth : 3.2 (m)

Rock Name : Limestone

Sample Type : Undisturbed

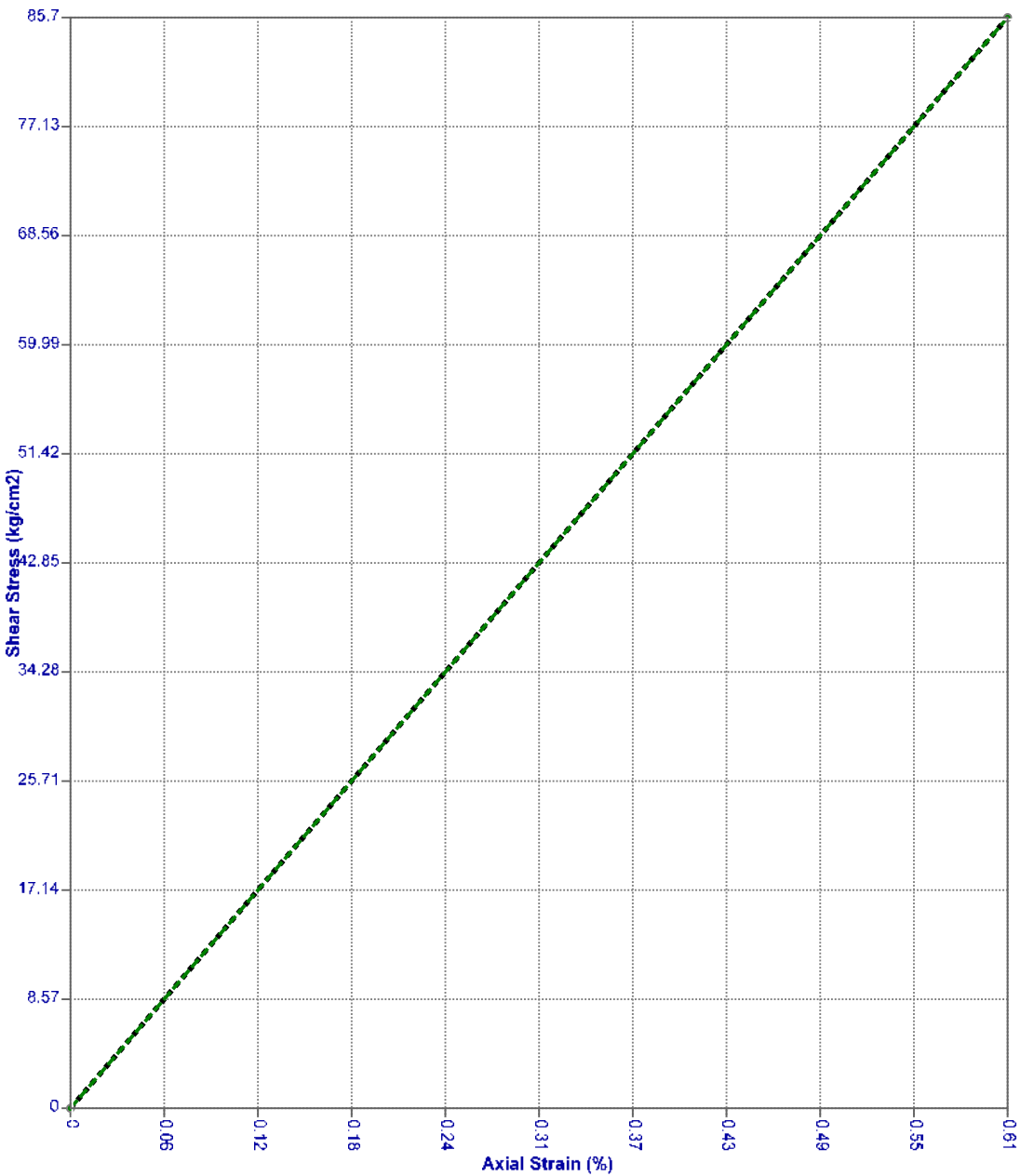
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.414	8.238	1	Moist	3.2	2.14	85.7	42.85



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-11

Sample Depth : 2 (m)

Rock Name : Limestone

Sample Type : Undisturbed

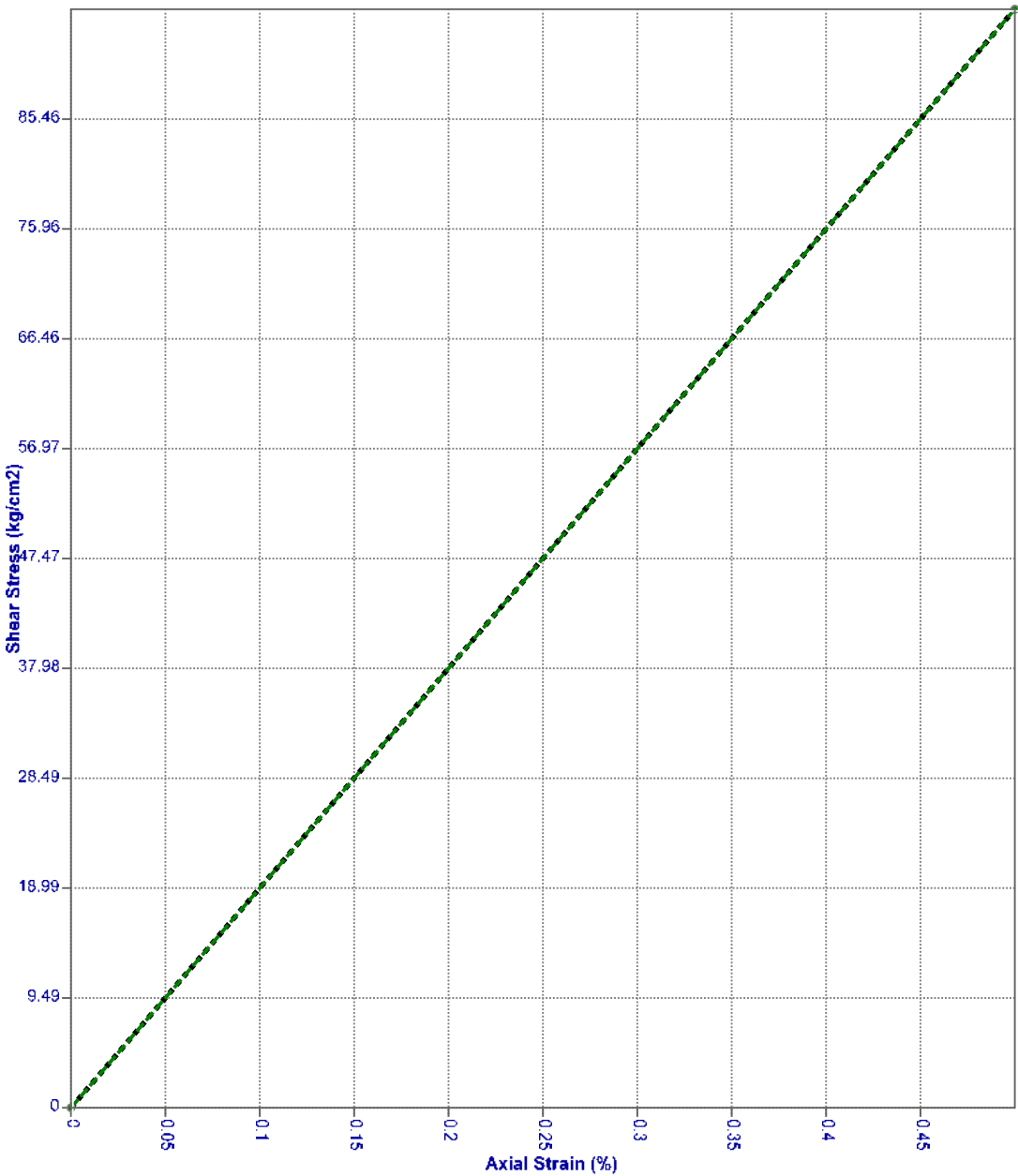
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.622	9.942	1	Moist	2.4	2.18	94.95	47.47



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-12

Sample Depth : 2.19 (m)

Rock Name : Limestone

Sample Type : Undisturbed

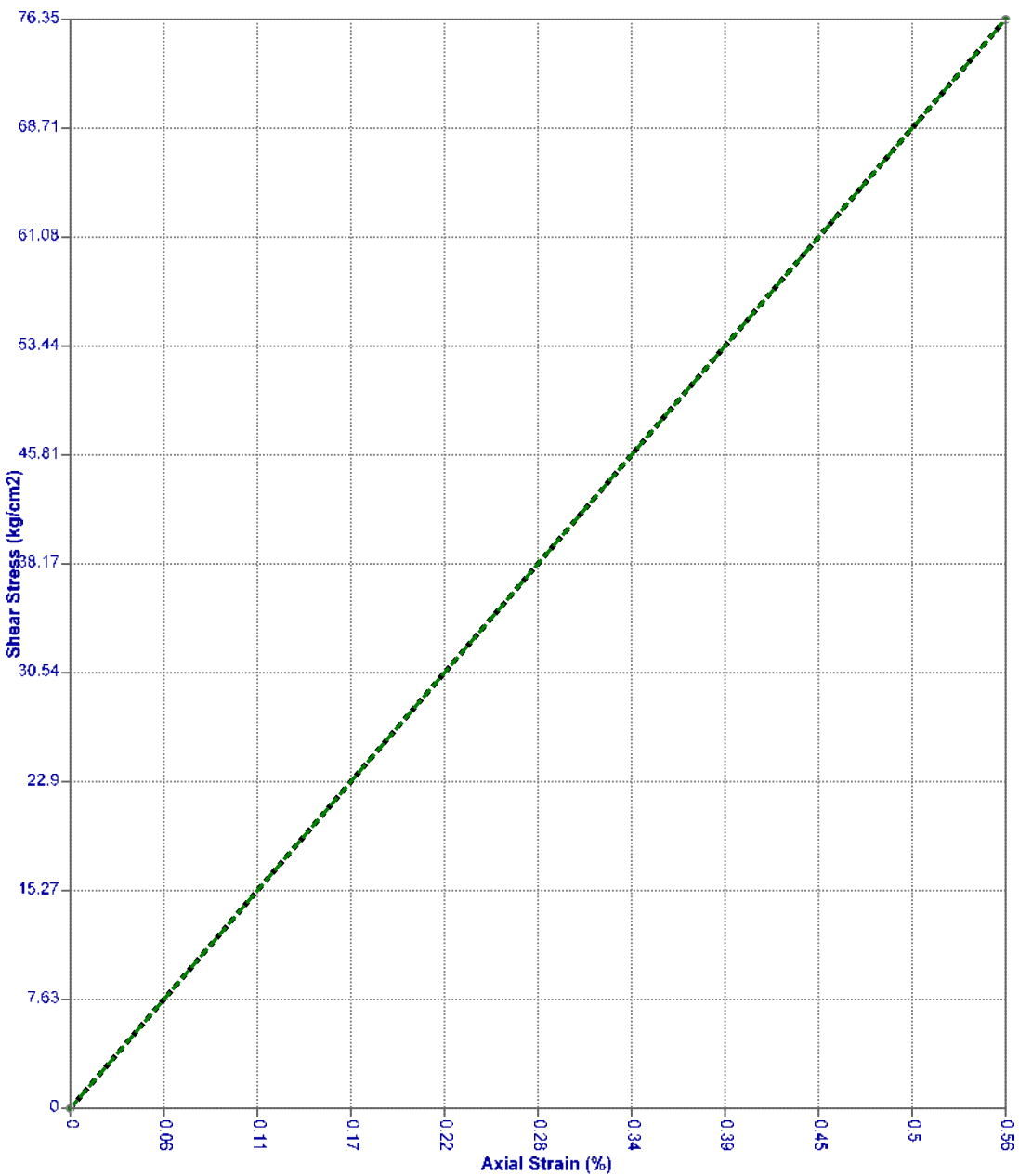
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm ³)	Unconfined Comp. Qu (kg/cm ²)	Su (kg/cm ²)
5.424	8.938	1	Moist	3.5	2.06	76.35	38.17



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-13

Sample Depth : 2.52 (m)

Rock Name : Limestone

Sample Type : Undisturbed

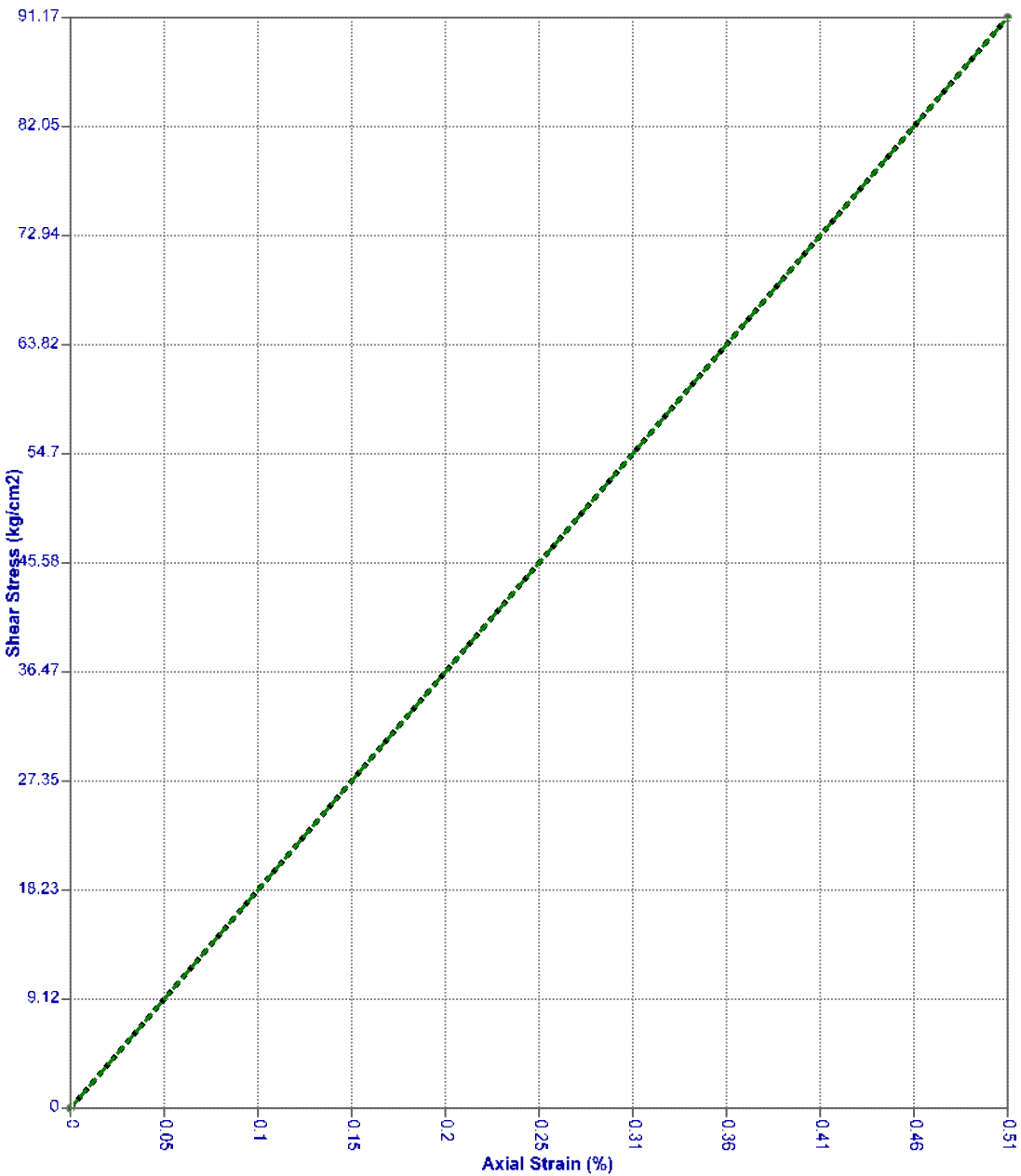
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.421	9.833	1	Moist	2.6	2.23	91.17	45.58



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Borehole : BH-14

Soil Testing Services

Client : M/S. Government of Sindh

Sample Depth : 3 (m)

Job No.: S-24-1162

Rock Name : Limestone

Location : Deh Halkani, Sindh

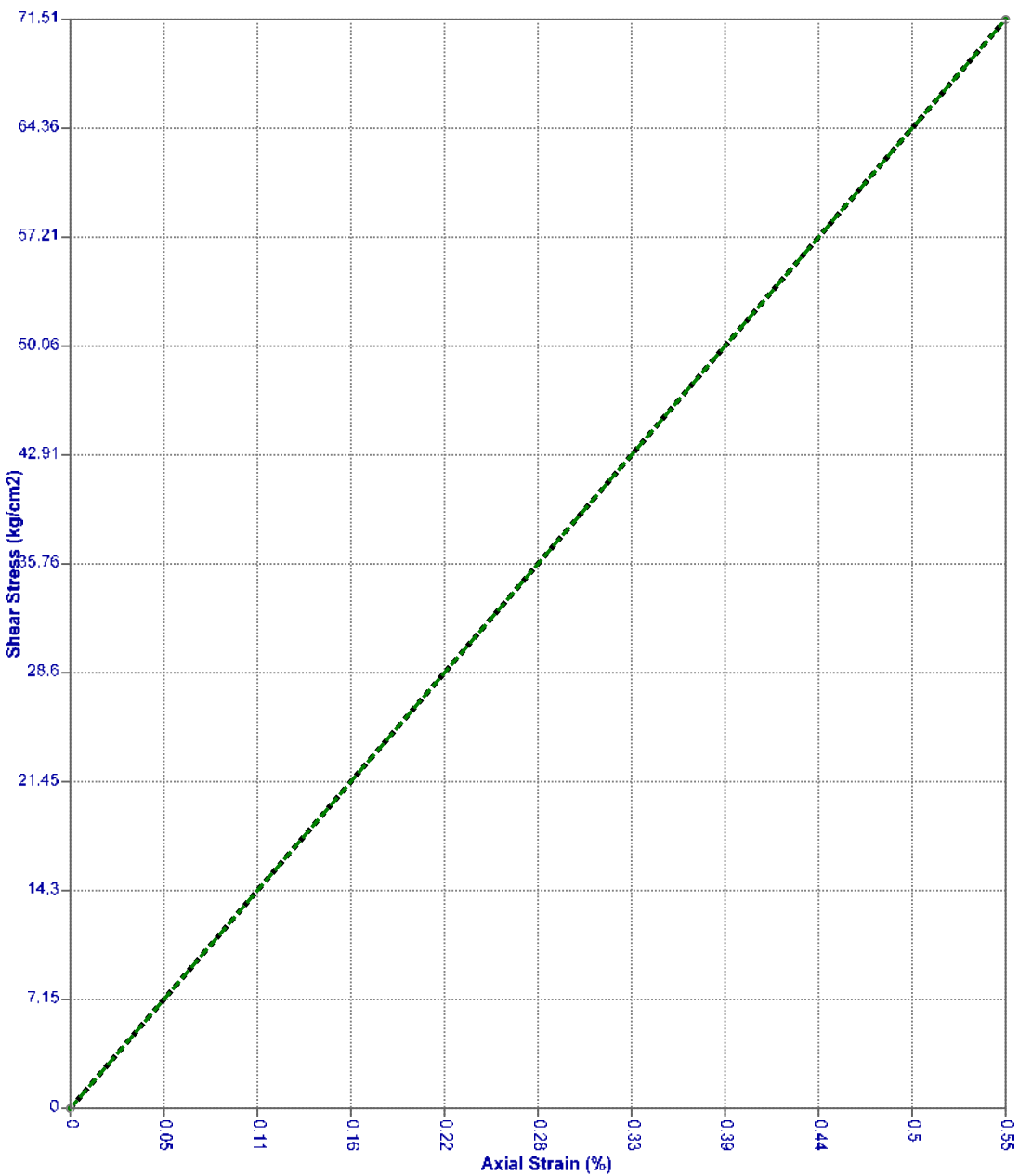
Sample Type : Undisturbed



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.522	9.142	1	Moist	3.3	2.08	71.51	35.76



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-15

Sample Depth : 2.3 (m)

Rock Name : Limestone

Sample Type : Undisturbed

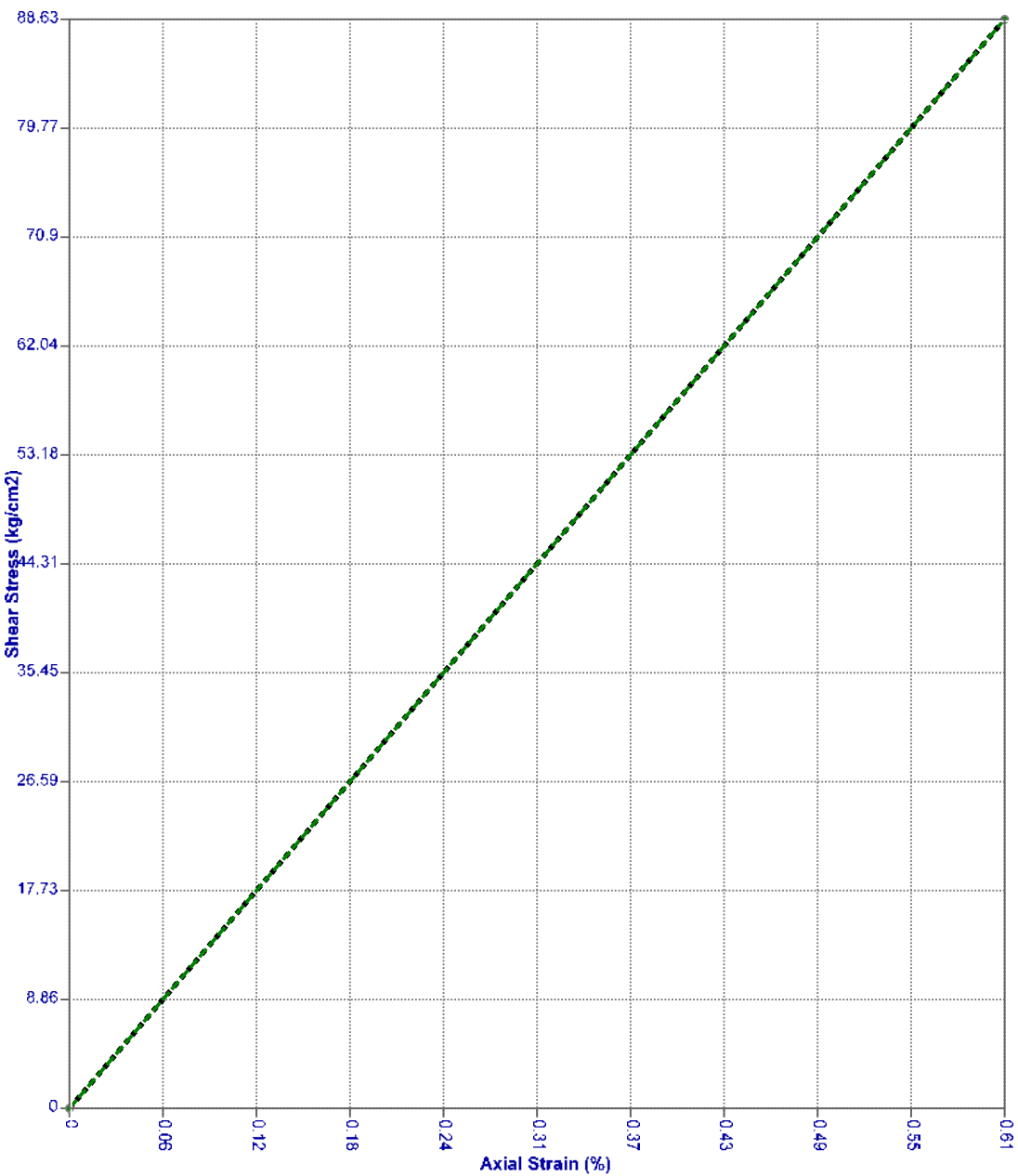
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm ³)	Unconfined Comp. Qu (kg/cm ²)	Su (kg/cm ²)
5.417	8.238	1	Moist	3.2	2.13	88.63	44.31



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-16

Sample Depth : 3.1 (m)

Rock Name : Limestone

Sample Type : Undisturbed

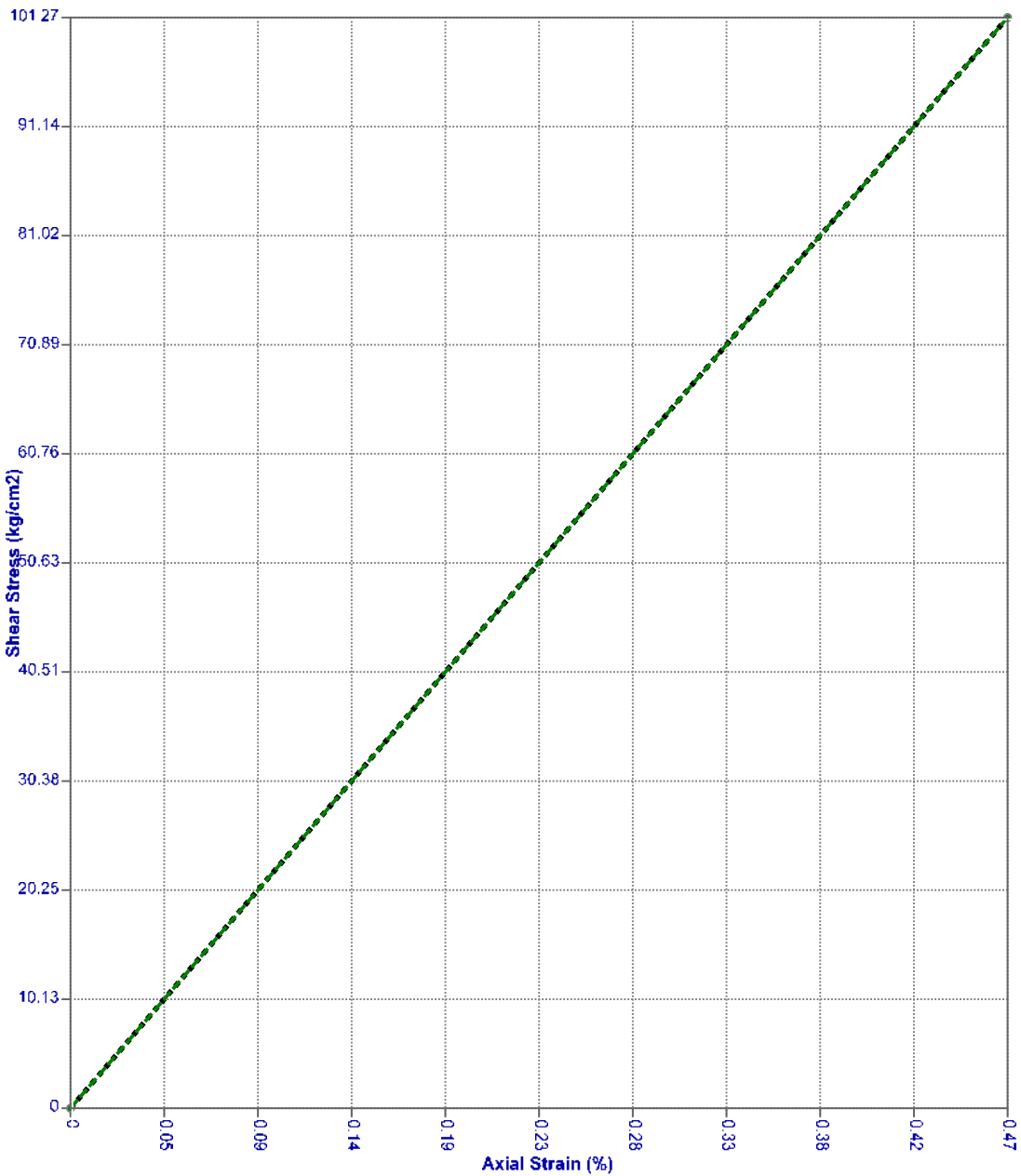
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.527	10.743	1	Moist	2.5	2.15	101.27	50.63



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-17

Sample Depth : 3.24 (m)

Rock Name : Limestone

Sample Type : Undisturbed

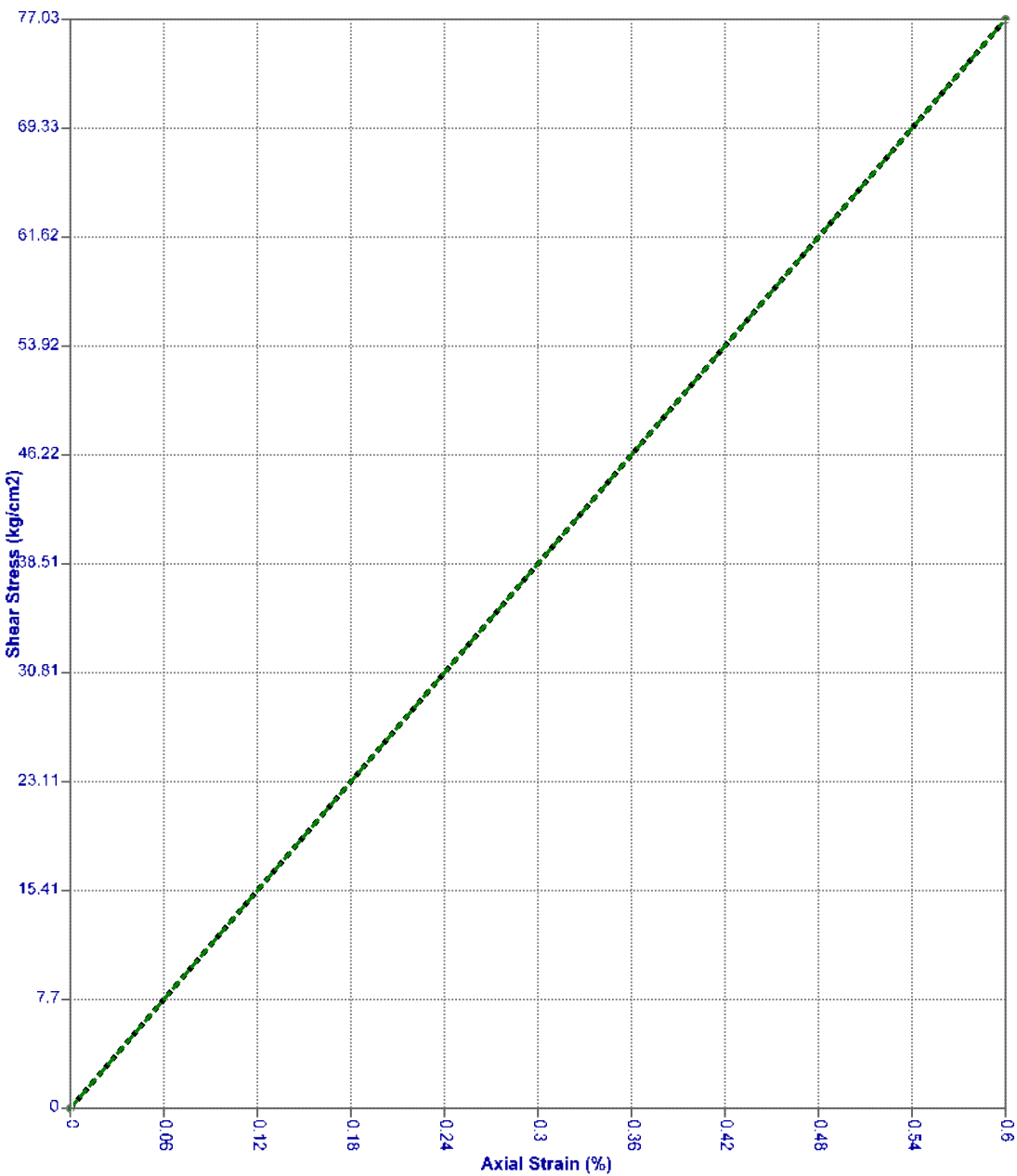
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.417	8.338	1	Moist	3.1	2.17	77.03	38.51



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Unconfined Compression Test

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Borehole : BH-18

Sample Depth : 3 (m)

Rock Name : Limestone

Sample Type : Undisturbed

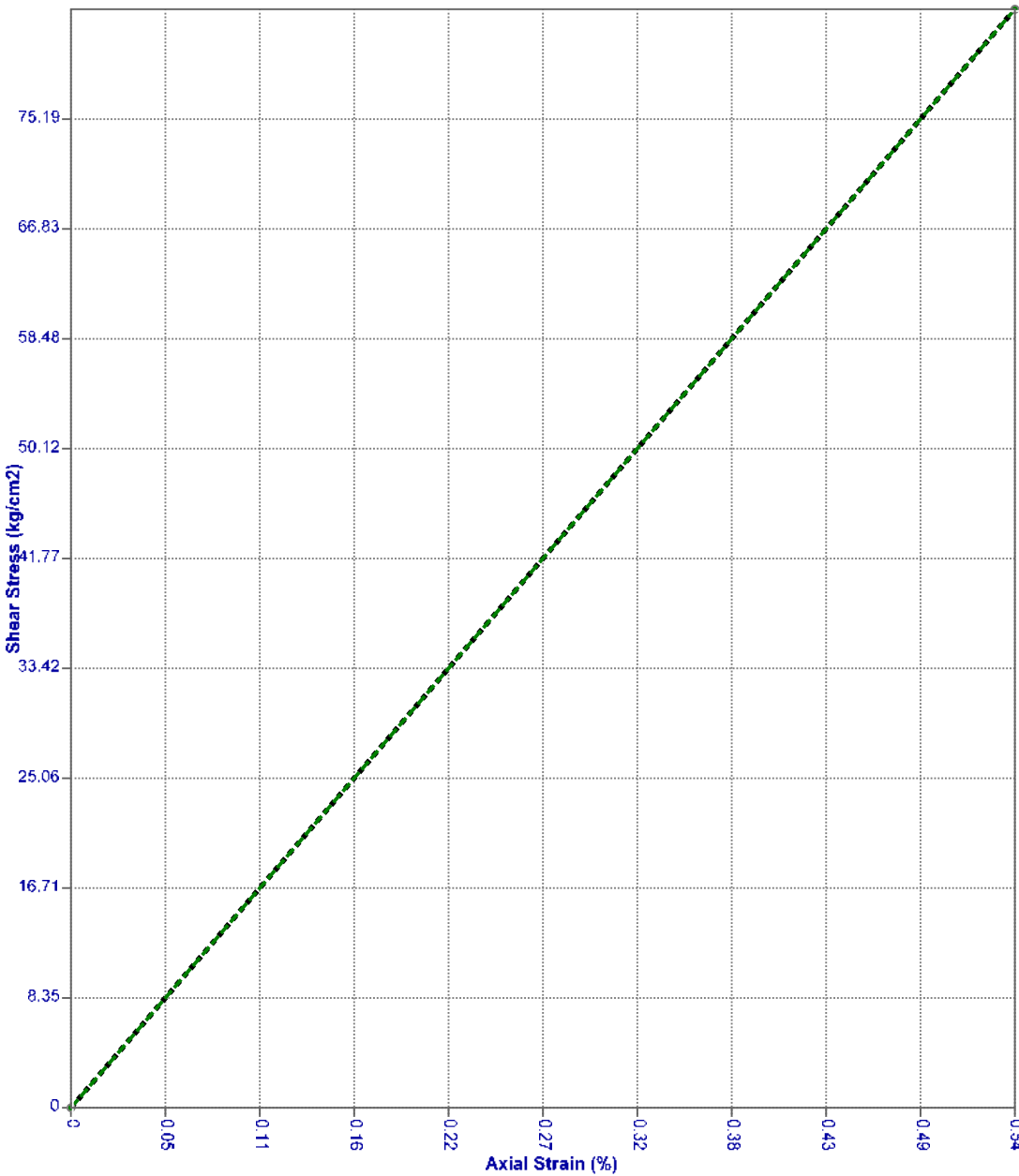
Soil Testing Services



ASTM D2938

Test Results

Diameter (cm)	Height (cm)	Loading rate (mm/min)	Moisture Status	Moisture Content (%)	Dry Density (gr/cm3)	Unconfined Comp. Qu (kg/cm2)	Su (kg/cm2)
5.622	9.342	1	Moist	2.5	2.09	83.54	41.77



USCS Soil Description :
AASHTO Soil Description :

Tested By :

Chemical Test Results

Project : GI at Sindh Solar Energy Project

Client : M/S. Government of Sindh

Job No.: S-24-1162

Location : Deh Halkani, Sindh

Soil Testing Services



ASTM D4972, D512, D516

Borehole	Sample Depth (m)	Description	Value
BH-01	2.15	pH value	7.36
BH-02	1		7.65
BH-05	1		7.52
BH-01	2.15	Sulphate Content (%)	0.018
BH-02	1		0.02
BH-05	1		0.017
BH-01	2.15	Chloride Content (%)	0.201
BH-02	1		0.235
BH-05	1		0.194

General Information on Testing Procedures

A. DRILLING, FIELD TESTING & SAMPLING

The field testing program consisted of drilling works, and in-situ testing including Standard Penetration Tests (SPT), collection of soil samples and collection of rock samples. The following sections describe these activities in further detail.

A.1. DRILLING METHOD

All the boreholes were drilled by using rotary/wash boring method; in this method soil or rock is cut by the constant rotation of various types of bits. Drilling fluid, which is either water or bentonite slurry, is circulated through drilling rods. The returning fluid lifts loosened material.

The drilling in rock was carried out by double tube core barrels in conjunction with carbide or diamond bit. In a double tube core barrel the outer barrel is rotated by the drill rods, while, the inner barrel, which is mounted on a swivel, does not rotate during the drilling process. The core cut by the coring bit passes into the inner barrel. Core was prevented from dropping out by a steel core catcher. It was then extruded and wrapped with waxed bandage tape, to preserve the natural moisture of the recovered core.

Details of the boreholes are given in Table 9.

Table 9: Details of Boreholes

Borehole No.	Co-ordinates		Borehole Depth (meters)	Water table Depth (meters)
	Easting	Northing		
BH-01	295002.64	2769936.71	5.0	Not Encountered
BH-02	294766.18	2769731.10	5.0	Not Encountered
BH-03	294698.24	2769838.99	5.0	Not Encountered
BH-04	294522.28	2769904.01	5.0	Not Encountered
BH-05	294534.32	2769749.06	5.0	Not Encountered
BH-06	294241.69	2769852.94	5.0	Not Encountered
BH-07	293838.67	2769907.41	5.0	Not Encountered

Borehole No.	Co-ordinates		Borehole Depth (meters)	Water table Depth (meters)
	Easting	Northing		
BH-08	294091.84	2769806.29	5.0	Not Encountered
BH-09	293728.39	2769714.96	5.0	Not Encountered
BH-10	293513.81	2769649.50	5.0	Not Encountered
BH-11	299330.95	2768877.79	5.0	Not Encountered
BH-12	299439.50	2768508.07	5.0	Not Encountered
BH-13	299178.78	2768342.36	5.0	Not Encountered
BH-14	299035.02	2768606.46	5.0	Not Encountered
BH-15	299259.94	2768620.12	5.0	Not Encountered
BH-16	299232.45	2769317.61	5.0	Not Encountered
BH-17	298923.71	2769394.11	5.0	Not Encountered
BH-18	299226.41	2769187.30	5.0	Not Encountered

A.2. FIELD TESTING

Field testing carried out at the site includes Standard Penetration Test (SPT). Soil samples were extracted from the boreholes with the help of “SPT sampler for all types of soils”.

Following sections indicate the processes carried out in each of the field tests.

A.2.1. STANDARD PENETRATION TESTS

The standard penetration tests (SPT) were carried out at regular interval of 1.0 - 1.5 meter in the overburden above the bedrock. The standard penetration test was carried out by “Safety” type sliding hammer. Split-spoon sampler was used in cohesive and fine granular soils to conduct SPT.

The standard penetration test was carried out by an assembly of the following parts:

- Drive-weight assembly, consisting of a drive head and a 63.5kg impact hammer, a hammer fall guide and the drop system. The drop mechanism will ensure a constant free fall of 760mm.
- Drive rods connect the drive-weight assembly to the sampler.
- The split spoon sampler was used to carry out the test, along with retrieving disturbed samples.

The base of the borehole was made clean and reasonably undisturbed at the test elevation. Following precautions were taken during the testing sequence:

- The level of water or bentonite slurry was maintained at a sufficient level above the groundwater level, to ensure any entry of water through the bottom of the borehole.
- The casing was not driven below the level at which the test will start.

The test was executed in the following steps:

- The sampler and the drive rods were lowered in the borehole and the hammer assembly added to it.
- The sampler is penetrated over seating drive of 150mm and the numbers of blows are recorded.
- In the same way the sampler is driven over a test drive of 300mm in two increments of 150mm.
- The numbers of blows are recorded during each of the last two increments.

- The test was deemed finished when total number of blows equal to 50 was reached. The standard penetration test was carried out in accordance with the procedure given in BS 1377-9:1990.



Figure 3: Standard Penetration Test in progress

A.3. SAMPLING

Sampling forms an essential part of the geotechnical investigation process and good sampling is essential for proper laboratory testing of samples for determining strength and compressibility characteristics of soil.

A.3.1. SPT SAMPLES

Samples were recovered from standard penetration testing. The samples were recovered in split-spoon sampler and then stored in plastic bags. The storage of split-spoon samples in bags ensured retention of natural moisture of the samples which were later tested for gradation, consistency and chemical characteristics.

A.3.2. ROCK CORE SAMPLES

Rock core samples were collected from the deposits through coring. Double tube core barrel (HQ size) was used to collect these samples. The samples were recovered in core barrel, packed in aluminium foil, and then stored in rock core boxes. The storage of rock core samples in aluminium foil ensured retention of natural moisture. Unconfined compressive strength, natural moisture content, density, etc. of these samples was determined in the laboratory.

B. LABORATORY TESTING

Laboratory testing was carried out on retrieved samples. The following section enlists and gives details of relevant tests carried out on selected samples as required for determining the subsurface conditions and correlating with the information obtained from field testing and sampling.

B.1. GRAIN SIZE ANALYSIS

The purpose of grain size analysis is to determine the sizes of the assemblage of particles that make up the soil. The grain size analysis is conducted in two parts: for particles above the “# 200 US sieve”, sieve analysis is carried out by passing the selected soil sample from various sieves. For particles finer than the “# 200 US sieve”, hydrometer analysis is carried out. The combined process of determination of the size of particles is termed as the grain size analysis.

The results are appended with the report in Appendix C. Grain size analysis soil samples was carried out as per *ASTM C-136* & *ASTM D-6918*.

B.2. NATURAL MOISTURE CONTENT

Natural moisture content is the quantity of water contained in a soil or rock sample. It is the ratio of the weight of water to the weight of solids in a given volume of soil or rock sample. Natural moisture content of samples was determined in accordance with *ASTM 2216-05*.

B.3. DENSITY

The weight per unit volume of the solid portion of soil is called particle (dry) density. Whereas, the oven dry weight of a unit volume of soil inclusive of pore spaces is called bulk (wet) density. The bulk density of a soil is always smaller than its particle density. Density of samples was determined in accordance with the procedure described in *ASTM D 7263-09*.

B.4. UNCONFINED COMPRESSION TEST

Unconfined compressive strength test involves axially loading a cylindrical rock core or undisturbed clay sample to failure. The term unconfined is used because the lateral force on the sample is zero. The unconfined compressive strength test was carried out in accordance with *ASTM D 7012*. The strength of the retrieved samples tested came out

ranging between 57.35 Kg/cm² – 101.27 Kg/cm². The results of the unconfined compression test are summarized in Appendices.

B.5. CHEMICAL TESTS

Sulphate in groundwater or soil can attack concrete placed in the ground or on surface. A reaction takes place between the sulphate and the aluminate compounds present in the cement, causing crystallisation of complex compounds. The expansion, which accompanies crystallisation, induces stresses in the concrete, which results in mechanical disintegration. In moist conditions, such as exposure to seawater, the presence of chloride ion, Cl⁻, presents a serious possibility of the corrosion of the reinforcement. The presence of Ca(OH)₂ provides a strong alkaline environment in which a thin film of iron oxide is formed on the metal surface which protects it against corrosion. However, if the concrete is permeable to the extent that the soluble chlorides can reach up to the reinforcing steel, then in the presence of water and oxygen, the corrosion of the reinforcement will take place. Rust occupies more volume than the original steel, and hence the ensuing expansion of concrete, results in cracking and spalling.

Due to adverse effect of sulphates and chlorides on the quality of concrete it is essential to conduct chemical tests on soil and groundwater. This helps in quantifying the expected exposure of concrete to these chemicals and in devising precautionary measures to ensure integrity of concrete. The following chemical tests were carried out on soil and water samples:

- Total dissolved solids
- Chloride content
- Sulphate content
- pH

Chemical tests were carried out in accordance with *ASTM C 1580-09, and D 4972-01*. The selection of cement for underground concreting and is discussed in *Chapter 4*.

Table 10: ACI standards for concrete for sulphate exposure

Sulphate Exposure	Water Soluble Sulphates in Soil (%)	Sulphate in Water (mg/L)	Cement Type
Negligible	0.00-0.10	0- 150	OPC
Moderate	0.10-0.20	150- 1500	Type II
Severe	0.20-2.00	1500-10000	Type V
Very Severe	Over 2.00	Over 10000	Type V plus pozzolan

Pile Capacity Calculations

(A) - CALCULATION OF ALLOWABLE SKIN FRICTION :

Depth	Rock	Diameter	Length	Effective σ for this layer	Effective overburden (kN/m ²)	phi	c	q_{uc}	α	α	β	δ	$\tan \delta$	k_s	FOS	Q_{skin}	Q_{skin} (Cum)
	Encountered	of Pile (m)	of Layer (m)				(kN/m ²)	(kN/m ²)	adhesion	reduction- rock	correction					(kN)	(kN)
0.0 - 0.5	Cohesionless	0.15	0.5	7.5	3.8	28	-	-	-	-	-	21	0.38	0.641	2.0	0	0
0.5 - 1.0	Cohesionless	0.15	0.5	7.5	11.3	28	-	-	-	-	-	21	0.38	0.641	2.0	0	0
1.0 - 1.5	Cohesionless	0.15	0.5	7.5	18.8	28	-	-	-	-	-	21	0.38	0.641	2.0	1	1
1.5 - 2.0	Cohesionless	0.15	0.5	7.5	26.3	28	-	-	-	-	-	21	0.38	0.641	2.0	1	2
2.0 - 2.5	Rock	0.15	0.5	10.5	35.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	38.3	40.0
2.5 - 3.0	Rock	0.15	0.5	10.5	45.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	38.3	78.3
3.0 - 3.5	Rock	0.15	0.5	10.5	56.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	38.3	116.7
3.5 - 4.0	Rock	0.15	0.5	10.5	66.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	38.3	155.0

(A) - CALCULATION OF ALLOWABLE SKIN FRICTION :

Depth	Rock	Diameter	Length	Effective σ for this layer	Effective overburden (kN/m ²)	phi	c	q_{uc}	α	α	β	δ	$\tan \delta$	k_s	FOS	Q_{skin}	Q_{skin} (Cum)
	Encountered	of Pile (m)	of Layer (m)				(kN/m ²)	(kN/m ²)	adhesion	reduction- rock	correction					(kN)	(kN)
0.0 - 0.5	Cohesionless	0.20	0.5	7.5	3.8	28	-	-	-	-	-	21	0.38	0.641	2.0	0	0
0.5 - 1.0	Cohesionless	0.20	0.5	7.5	11.3	28	-	-	-	-	-	21	0.38	0.641	2.0	0	1
1.0 - 1.5	Cohesionless	0.20	0.5	7.5	18.8	28	-	-	-	-	-	21	0.38	0.641	2.0	1	1
1.5 - 2.0	Cohesionless	0.20	0.5	7.5	26.3	28	-	-	-	-	-	21	0.38	0.641	2.0	1	2
2.0 - 2.5	Rock	0.20	0.5	10.5	35.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	51.1	53.4
2.5 - 3.0	Rock	0.20	0.5	10.5	45.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	51.1	104.5
3.0 - 3.5	Rock	0.20	0.5	10.5	56.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	51.1	155.5
3.5 - 4.0	Rock	0.20	0.5	10.5	66.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	51.1	206.6

(A) - CALCULATION OF ALLOWABLE SKIN FRICTION :

Depth	Rock	Diameter	Length	Effective σ for this layer	Effective overburden (kN/m ²)	phi	c	q_{uc}	α	α	β	δ	$\tan \delta$	k_s	FOS	Q_{skin}	Q_{skin} (Cum)
	Encountered	of Pile (m)	of Layer (m)				(kN/m ²)	(kN/m ²)	adhesion	reduction- rock	correction					(kN)	(kN)
0.0 - 0.5	Cohesionless	0.25	0.5	7.5	3.8	28	-	-	-	-	-	21	0.38	0.641	2.0	0	0
0.5 - 1.0	Cohesionless	0.25	0.5	7.5	11.3	28	-	-	-	-	-	21	0.38	0.641	2.0	1	1
1.0 - 1.5	Cohesionless	0.25	0.5	7.5	18.8	28	-	-	-	-	-	21	0.38	0.641	2.0	1	2
1.5 - 2.0	Cohesionless	0.25	0.5	7.5	26.3	28	-	-	-	-	-	21	0.38	0.641	2.0	1	3
2.0 - 2.5	Rock	0.25	0.5	10.5	35.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	63.8	66.7
2.5 - 3.0	Rock	0.25	0.5	10.5	45.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	63.8	130.6
3.0 - 3.5	Rock	0.25	0.5	10.5	56.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	63.8	194.4
3.5 - 4.0	Rock	0.25	0.5	10.5	66.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	63.8	258.3

(A) - CALCULATION OF ALLOWABLE SKIN FRICTION :

Depth	Rock	Diameter	Length	Effective σ for this layer	Effective overburden (kN/m ²)	phi	c	q _{uc}	α	α	β	δ	tan δ	k _s	FOS	Q _{skin}	Q _{skin} (Cum)
	Encountered	of Pile (m)	of Layer (m)				(kN/m ²)	(kN/m ²)	adhesion	reduction- rock	correction					(kN)	(kN)
0.0 - 0.5	Cohesionless	0.30	0.5	7.5	3.8	28	-	-	-	-	-	21	0.38	0.641	2.0	0	0
0.5 - 1.0	Cohesionless	0.30	0.5	7.5	11.3	28	-	-	-	-	-	21	0.38	0.641	2.0	1	1
1.0 - 1.5	Cohesionless	0.30	0.5	7.5	18.8	28	-	-	-	-	-	21	0.38	0.641	2.0	1	2
1.5 - 2.0	Cohesionless	0.30	0.5	7.5	26.3	28	-	-	-	-	-	21	0.38	0.641	2.0	2	3
2.0 - 2.5	Rock	0.30	0.5	10.5	35.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	76.6	80.1
2.5 - 3.0	Rock	0.30	0.5	10.5	45.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	76.6	156.7
3.0 - 3.5	Rock	0.30	0.5	10.5	56.3	40	-	1000	-	0.50	0.65	-	-	-	2.0	76.6	233.3
3.5 - 4.0	Rock	0.30	0.5	10.5	66.8	40	-	1000	-	0.50	0.65	-	-	-	2.0	76.6	309.9

ALLOWABLE END BEARING RESISTANCE :



Socket	Diameter of Pile		Length of Pile below Existing Ground Level		N ϕ	Q _{UC}	FOS	Q _{END}	Q _{END}
	mm	Inches	Meter	Feet		(kN/m ²)		(tons)	(kN)
Rock	150	6	2.0	7	3.0	1000.0	3.0	3.6	35.3
Rock	150	6	2.5	8	3.0	1000.0	3.0	3.6	35.3
Rock	150	6	3.0	10	3.0	1000.0	3.0	3.6	35.3
Rock	150	6	3.5	11	3.0	1000.0	3.0	3.6	35.3
Rock	150	6	4.0	13	3.0	1000.0	3.0	3.6	35.3
Rock	200	8	2.0	7	3.0	1000.0	3.0	6.4	62.8
Rock	200	8	2.5	8	3.0	1000.0	3.0	6.4	62.8
Rock	200	8	3.0	10	3.0	1000.0	3.0	6.4	62.8
Rock	200	8	3.5	11	3.0	1000.0	3.0	6.4	62.8
Rock	200	8	4.0	13	3.0	1000.0	3.0	6.4	62.8
Rock	250	10	2.0	7	3.0	1000.0	3.0	10.0	98.2
Rock	250	10	2.5	8	3.0	1000.0	3.0	10.0	98.2

ALLOWABLE END BEARING RESISTANCE :

Socket	Diameter of Pile		Length of Pile below Existing Ground Level		N ϕ	Q _{uc}	FOS	Q _{END}	Q _{END}
	mm	Inches	Meter	Feet		(kN/m ²)		(tons)	(kN)
Rock	250	10	3.0	10	3.0	1000.0	3.0	10.0	98.2
Rock	250	10	3.5	11	3.0	1000.0	3.0	10.0	98.2
Rock	250	10	4.0	13	3.0	1000.0	3.0	10.0	98.2
Rock	300	12	2.0	7	3.0	1000.0	3.0	14.4	141.4
Rock	300	12	2.5	8	3.0	1000.0	3.0	14.4	141.4
Rock	300	12	3.0	10	3.0	1000.0	3.0	14.4	141.4
Rock	300	12	3.5	11	3.0	1000.0	3.0	14.4	141.4
Rock	300	12	4.0	13	3.0	1000.0	3.0	14.4	141.4



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