

**Report of  
Geotechnical Investigation works  
at the prop. New 10000 MT  
Ammonia Storage at FACT –CD,  
Ambalamedu**

**Clients : FACT – Cochin Division,  
Ambalamedu, Kochi**

**Consultants : FEDO, Udyogmandal, Kochi**

**MAY 2021**



**Testing agency:**

**GEO FOUNDATIONS & STRUCTURES PVT. LTD.  
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## 1.0 INTRODUCTION

- 1.1 M/s FACT Cochin Division, Ambalamugal has awarded the work of conducting Geotechnical Investigation works at the prop. New 10000 MT Ammonia Storage at FACT –CD, Ambalmedu to us against WO No. 4800014795dt.13/04/2021.
- 1.2 The field investigation and laboratory study for subject work was carried out in April 2021. This report summarizes the investigations and furnishes the field & laboratory tests results with suggestions for suitable foundation at the location of each structure.

## 2.0 SCOPE OF WORK

The scope of work at this site comprised of the following:

- 2.1 Mobilisation of calyx boring rig with all necessary equipment and personnel.
- 2.2 Boring of nine boreholes at for prop. Ammonia tank, Compressor House, Cooling tower, Flare Stake and the proposed Road to be formed. with rotary power drilling equipments through sand, silt, clay & rock., as instructed by Engineer – In – Charge.
- 2.3 Drilling three additional boreholes to understand the variations of rock profile in the Ammonia tank area.
- 2.4 Conducting Standard Penetration tests in bore-holes and collecting the representative and disturbed samples including packing and transportation to laboratory.
- 2.5 Drilling in rocky strata / rock with rock core barrels and collection of rock samples for testing.
- 2.6 Collecting water samples from the boreholes for necessary testing in the lab
- 2.7 To conduct the following laboratory tests on soil samples:
  - (a) Particle size analysis:
    - (i) Sieve analysis
    - (ii) Hydrometer analysis
  - (b) Index properties:
    - (i) Liquid limit
    - (ii) Plastic limit

- (c) Bulk and dry density including moisture content
- (d) Specific gravity
- (e) Unconfined Compression test
- (f) Consolidation test on non granular soils
- (g) Tri axial(draind) test on cohesive soils
- (h) Shear box test on non cohesive granular soils
- (i) Uni axial compression test on rock samples
- (j) Chemical analysis on water samples
- (k) Chemical analysis on soil samples
- (l) Modified Proctor test
- (m) Soaked CBR Test

2.8 Preparation and submitting detailed report compiling the field and laboratory test results.

### **3.0 FIELD INVESTIGATIONS - Borehole studies**

- 3.1 To conduct the borehole studies at site, rotary calyx drilling rigs – engine driven - with all requisite equipment and accessories were mobilized at the work site. A team of technical personnel with skilled labours were also deputed with the rigs.
- 3.2 Five boreholes were to be bored in the Ammonia tank area, one borehole each for Compressor house, Cooling tower, Flare and Road. However, during boring works for Ammonia tankage, since there was a huge variation in the soil profile, three more boreholes were suggested by the clients in this Ammonia tankage area to get a fair idea of the soil profile and depth of availability of rock. Thus a total of 12 boreholes were taken up and these bores were terminated after drilling into rock and as per client's instructions. The boreholes were made as per IS:1892 - 1979.
- 3.3 Standard Penetration Tests were conducted in the bore holes at regular intervals of 1.00m upto 10.0 mtr and 1.5 mtr interval subsequently as per the technical specifications. In this test, the standard split spoon sampler is driven into the ground at the required

depth by means of standard hammer of 63.5 kgs weight, falling from a height of 75cm. Number of blows for the first 15cm is not taken into consideration because of possible disturbances or presence of settled, suspended matters at the bottom of the bore- holes. The total number of blows for the next 30cm depth of penetration is considered as SPT 'N' values are shown in graphical representation of N value.

- 3.4 The samples from the Split Spoon sampler of SPT setup are collected as Representative samples. These samples so collected were carefully packed, sealed and numbered with full particulars for identification and sent to the laboratory for necessary testing.
- 3.5 Undisturbed soil samples were not collected during the boring works since the soil encountered is not suitable for the same.
- 3.6 Soil boring is done by using normal cutting tools / soil cutters fitted to the drilling rods. Once the refusal is obtained i.e SPT "N" value is greater than 100, the soil cutting tools are replaced by rock core barrels fitted with either tungsten carbide bits or diamond bits. Rock Core Recovery (CR) and Rock Quality Designation (RQD) values are recorded at site based on the rock samples retrieved during drilling. The core samples were collected and sent to laboratory for further tests/ procedures.
- 3.7 In addition to the samples collected from the boreholes, bulk samples were collected from trial pits taken at three locations. These samples were sent to laboratory for conducting Modified Proctor Density and California Bearing Ration tests.

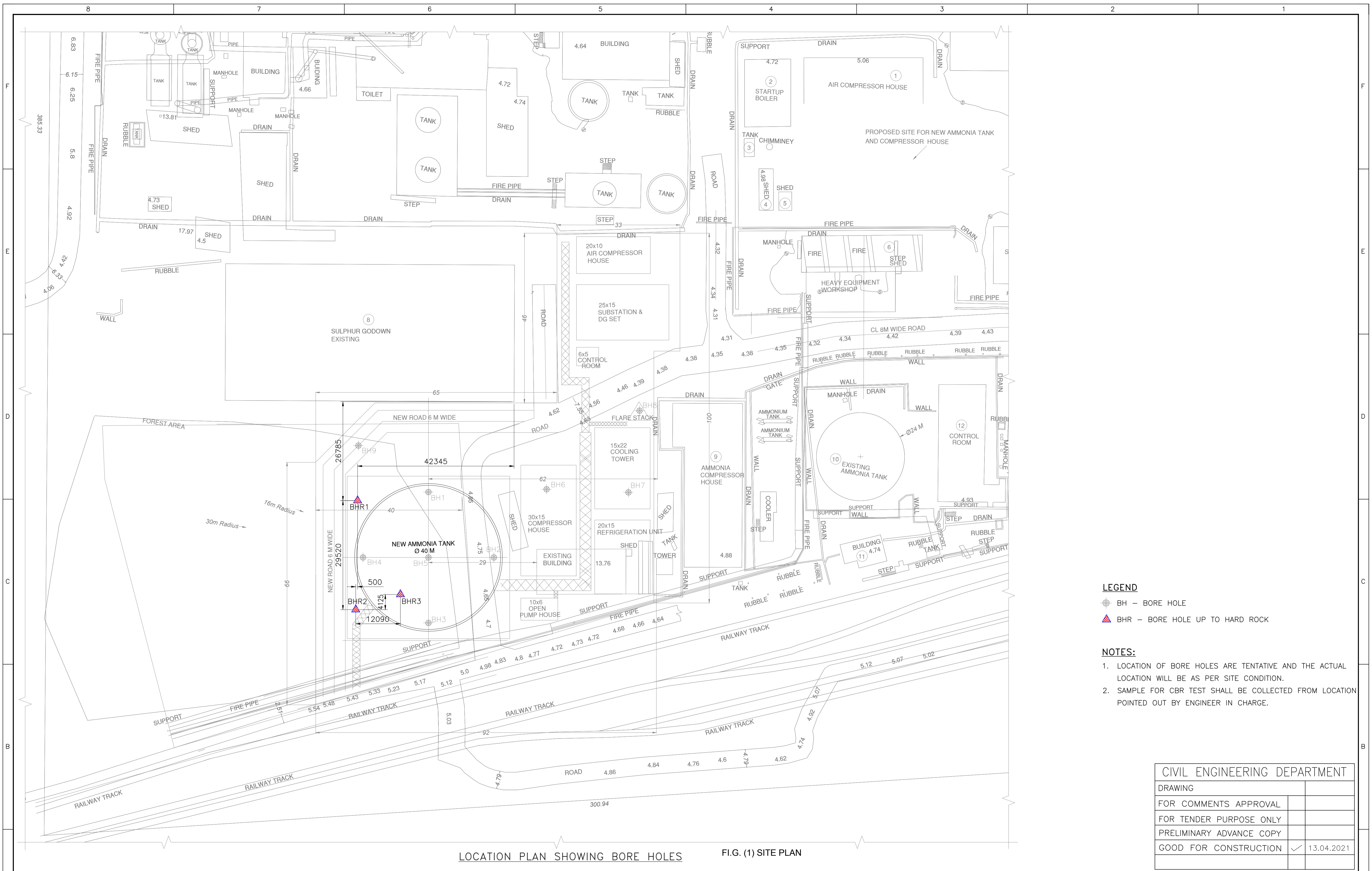
#### **4.0 LABORATORY INVESTIGATION**

The following laboratory tests were conducted on the selected samples recovered from the test bore-holes:

- a) Particle size analysis:
  - (i) Sieve analysis
  - (ii) Hydrometer analysis

- b) Index properties:
  - (i) Liquid limit
  - (ii) Plastic limit
- c) Bulk and dry density including moisture content
- d) Specific gravity
- e) Shear box test on non cohesive granular soil
- f) Unconfined compressive strength
- g) Uni axial compressive strength of rock
- h) Chemical Analysis on soil
- i) Chemical Analysis on water
- j) Modified Proctor Density
- k) California Bearing Ratio

All the above laboratory tests were carried out as per relevant Indian Standards.



LOCATION PLAN SHOWING BORE HOLES FIG. (1) SITE PLAN

A  <
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## **ANNEXURE – A**

**10000 MT Ammonia Storage Tank Area**

**(BH-01 to BH 05, BHR-1, BHR-2 and BHR-3)**

## A.1 SITE SOIL DESCRIPTION

### A.1.1 Soil Stratification

A.1.1.1 At this tankage location, the rock is available at a very shallow depth with not much of overburden soil. Even the general terrain of this area is undulating. Reduced levels in the above table indicates the same. Rock is identified to be of granitic nature, in general in all these locations.

Though five borehole locations were proposed to be done at this tankage area, due to the varying rock profile, three additional bores R1, R2 and R3 were asked to be done.

Soil particulars at each borehole location are as described below:

A1.1.2 **BH - 1** : The top layer in this borehole location consists of loose silty sandy soil in the shallow depths upto about 2.0 mtr and this soil improved to be of dense nature till 4.0 mtr depth. Hard Rock with high RCR and RQD values is available from 4.0 mtr to 6.0 mtr depth below ground level.

A.1.1.3 **BH - 2** :At this borehole location also, top 5.0 mtr is identified as predominantly silty sandy in nature with loose to dense consistency. Hard rock is met with from 5.0 mtr and drilling is progressed upto 7.0 mtr to confirm this rock. Borehole is terminated at 7.0 mtr depth below GL after drilling 2 mtr in rock with high RCR and RQD values.

A.1.1.4 **BH-3** :This borehole consists of a top layer of 1.0 mtr thick silty sandy soil followed by a 1.30 mtr thick layer of soft rock with  $N > 100$ . From 2.30 mtr to 4.30 mtr depth, hard rock is met with indicated by very high RCR and RQD values.

A.1.1.5 **BH- 4**: At this borehole location, since bore could not be progressed with soil cutter, rock core barrel was used since the ground level itself to progress the borehole. The strata was a mix of rock pieces and sandy natured soil even upto 4.6 mtr depth. As there was water loss at 4.60 mtr, borehole is abandoned since further drilling was not possible. Rig was shifted to BH 4A.

A.1.1.6 **BH – 4A** :At this location also, the strata at shallow depths is identified to be a mix of rock and soil. Borehole could be processed only by using rock core barrel. Refusal strata

was encountered at 2.80 mtr itself. Hard rock is available during further drilling for 1.80 mtr depth i.e upto a depth of 4.60 mtr below EGL.

A.1.1.7 **BH – 5** :The borehole study at this location resulted In identifying medium to very dense silty sand strata upto a depth of 1.80 mtr below EGL. Hard rock with very high RCR and RQD values is encountered from 1.80 mtr to 4.30 mtr depth where the borehole is terminated.

A.1.1.8 **BH – R1** :Soil available from ground level for 1.0 mtr depth is identified to be silty sandy in nature. Refusal strata was met with from 1.0 mtr itself and hard rock was available from 2.30 mtr to 2.80 mtr depth below EGL.

A.1.1.9 **BH – R2** :The soil at this location is loose silty sandy in nature even upto 4.0 mtr where refusal strata (  $N > 100$ ) is met with. Rock drilling is done for half a meter and borehole is terminated since RCR and RQD is 46%.

A.1.1.10 **BH – R3** :At this location, rock is available almost at the ground level after a thin layer of 20cms top soil. Half a meter drilling in rock is done to confirm the strata and the borehole is terminated at 0.7 mtr as the RCR and RQD is 88%.

## **A.2 CROSS SECTION PROFILE & DESIGN BORELOG:**

Based on the individual borelogs at the site, a cross section profile is made as given in **page No.11 & 12** which gives an idea of the rock profile variations in this tankage area. Details of Borehole 02 is considered as the Design Borelog considering the as compared to the soils in other borehole locations.

## **A.3 DISCUSSION ON TYPE OF FOUNDATION**

A.3.1 The proposed facilities at this borehole location is a 10000 MT cap. Ammonia Storage Tank of about 38mtr.diameter and 20 mtr height. Such a structure of this heights will surely induce more of lateral loads /moments at the ground level in addition to the vertical loads.

- A.3.2 From the borelogs & results tables of the boreholes taken up in this area, it can be observed that the soils are basically sandy soils of loose nature. Hard Rock with high RCR and RQD values is available at varying depths from the ground level in this tankage area.
- A.3.3 With loose soils available for shorter thickness in general and expecting loads of high magnitude, it is found necessary that the loads coming from the structure need to be transferred to a firm stratum. Based on the soil condition and the availability of rock at shallow depths, raft foundation resting on rock strata is considered to be a feasible foundation system.
- A.3.4 From the cross section profile, it can be observed that excavation of soils / breaking of rocky strata to a level of -0.5 mtr RL shall provide a firm strata to take up the raft foundation. Bearing capacity of a 38.0 mtr diameter raft foundation placed on rock is worked out as per relevant clauses of Indian Standard Code of Practice IS: 12070 – 1987 : RA 2016. Safe Bearing capacity is estimated from the strength of rock cores collected from the boreholes and given below:

**Table No: A.3.1 (Circular Raft)**

Size of footing (m)	Depth below EGL	Rock strength ( UCS ) Kg/sq.cm	Safe Bearing pressure (T/M <sup>2</sup> )
38 mtr diameter	- 0.5 RL	290	290.0

#### **A.4 METHOD OF COMPUTING BEARING CAPACITY FOR SHALLOW FOUNDATIONS**

Safe Bearing capacity for shallow foundation on Rock is worked out based on the uniaxial Compressive strength of rock cores and the relevant clause No. 6 of IS : 12070 – 1987. From the borelogs, the average rock quality designation (RQD) values are about 70% and the spacing in discontinuities are more than 30%.

As per the abovesaid clause,

$$q_s = q_c * N_1$$

where  $q_s$  is the safe bearing pressure ;

$q_c$  is the avg. uniaxial strength of rock core and

N1 is the empirical coefficient depending on the spacing of discontinuities

With the discontinuities are more than 30%, N1 is taken as 0.1 from Table no. 4 of the above said IS Code.

## **A.5 CONCLUDING REMARKS**

- A.5.1 Based on the soil profile and availability of rock at shallow depth, it is suggested to provide Shallow foundations raft foundation on rock layer. The safe bearing capacity is as given below :

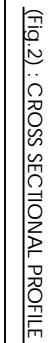
**Table No: A.5.1 (Circular Raft)**

Size of footing (m)	Depth below EGL	Rock strength ( UCS ) Kg/sq.cm	Safe Bearing pressure (T/M <sup>2</sup> )
38 mtr diameter	- 0.5 RL	290	290.0

- A.5.2 The suggestions given in this draft report are based on the results of tests on sub-soil samples collected from the bore-holes. If in actual execution any variation is found, this office may also referred to.

**For GEO FOUNDATIONS & STRUCTURES PVT LTD.,**

**A.V.S.CHAKRAVARTI**  
**M.Tech (Geotechnical Engg.)**  
**MIGS, MICI**  
**SR. GENERAL MANAGER**

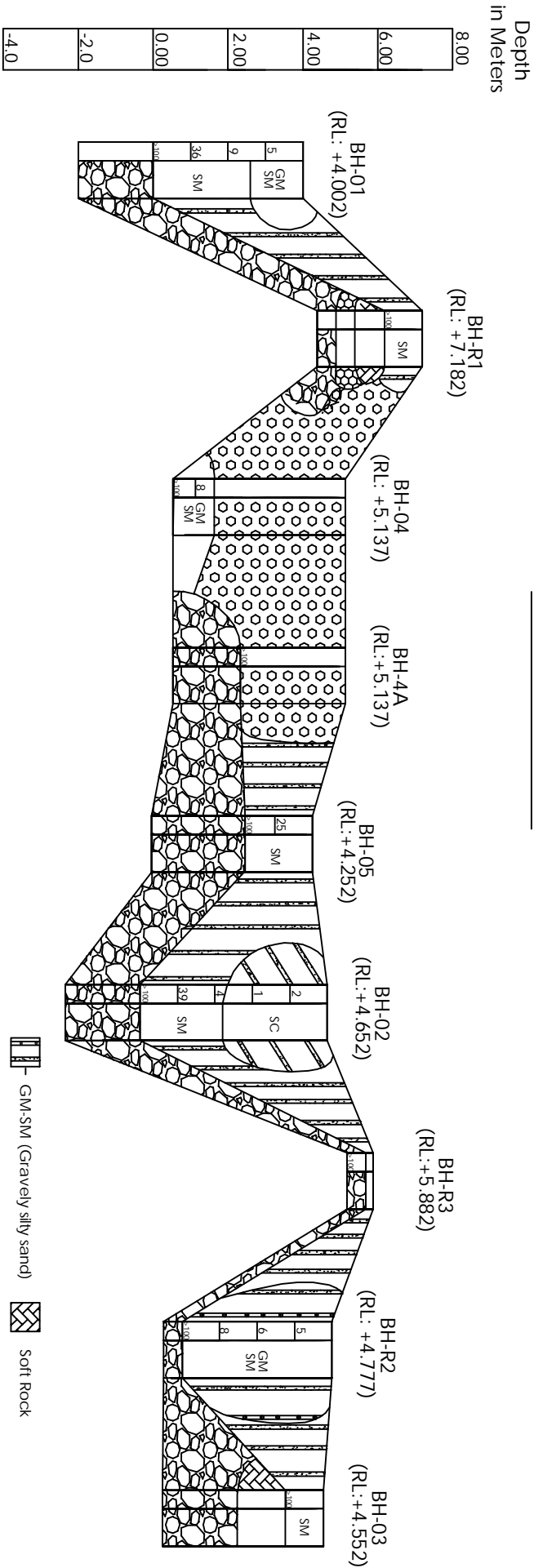


	GM-SM (Gravelly silty sand)		Soft Rock
	SC-Clayey sand		Pieces of Rock
	SM (silty sand)		Rock

PROJECT: SOIL INVESTIGATION WORK FOR THE PROPOSED NEW 1000MT AMMONIA STORAGE TANK



LOCATION : TANK AREA



(Fig.3) : CROSS SECTIONAL PROFILE

**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

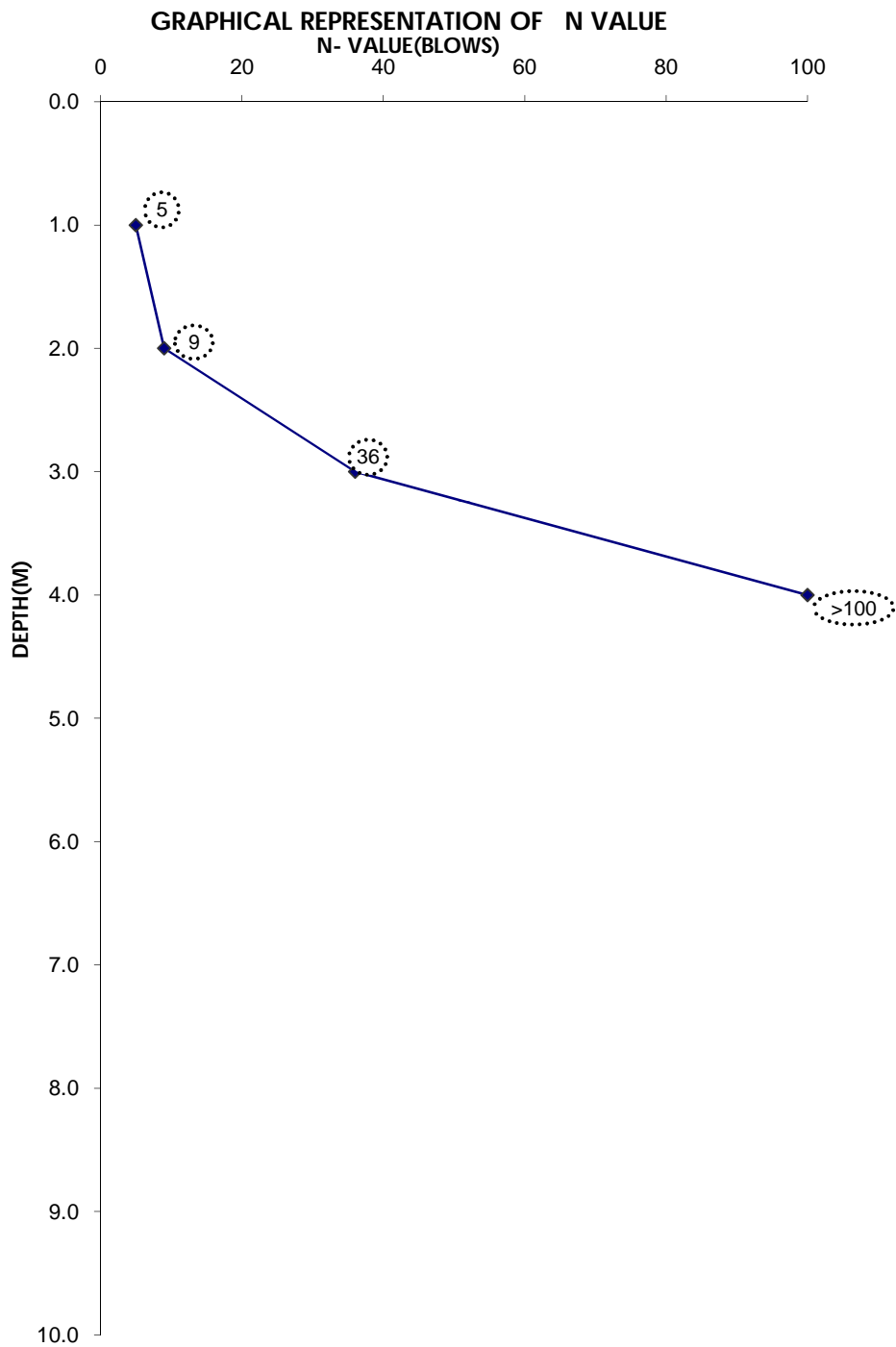
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-01**  
Type of Boring : Rotary  
Ground Water Level : 0.85m

Date of Boring Started : 27.04.2021  
Date of Boring Completed : 27.04.2021  
Termination Depth : 6.00 M



**TC-5397**



**BORE HOLE TERMINATED AT 6.00 M**

**FIG.4**







NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No	: BH-01	Boring Started	: 27.04.2021		<b>TC-5397</b>						
		Type of Boring	: Rotary	Boring Completed	: 27.04.2021								
		Termination Depth	: 6.0 M	Ground Water Level	: 0.85 M								
		Reduced Level	: +4.002	Co-ordinates :									
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	1.40	Gravely silty sand (Br./red)	GM-SM	1.00	1.00-1.45	2	3	2	5				
	2.60	Silty sand with gravel(Brown)	SM	2.00	2.00-2.45	3	4	5	9				
3.00				3.00-3.45	13	16	20	36					
4.50													
	2.00	Rock		4.00 to 5.00	DRILLING DONE USING DIAMOND BIT				85	70			
				5.00									
				5.00 to 6.00	DRILLING DONE USING DIAMOND BIT				79	79			
				6.50									
Termination Depth : 6.0m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :5

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397			
			LOCATION : Tank Area	Ground Water Level : 0.85m				Date of Boring Started : 27.04.2021 Boring completed : 27.04.2021 Termination Depth : 6.0m				Table No.:1								
ULR-TC539720000000253F																				
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC (%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø ( <sup>o</sup> )
BOREHOLE BH-01																				
5	1.00	SPT-01	Gravely silty sand(Br./red)	GM-SM	54	25	19	2	23	No Limit										
9	2.00	SPT-02	Silty sand with gravel(Brown)	SM	31	51	18	0	21	No Limit					2.62	1.69	1.40	DST	0	26
36	3.00	SPT-03	Silty sand with gravel(Brown)	SM	30	55	15	0	21	No Limit										
	4.00 to 6.00		Rock																	

:15:

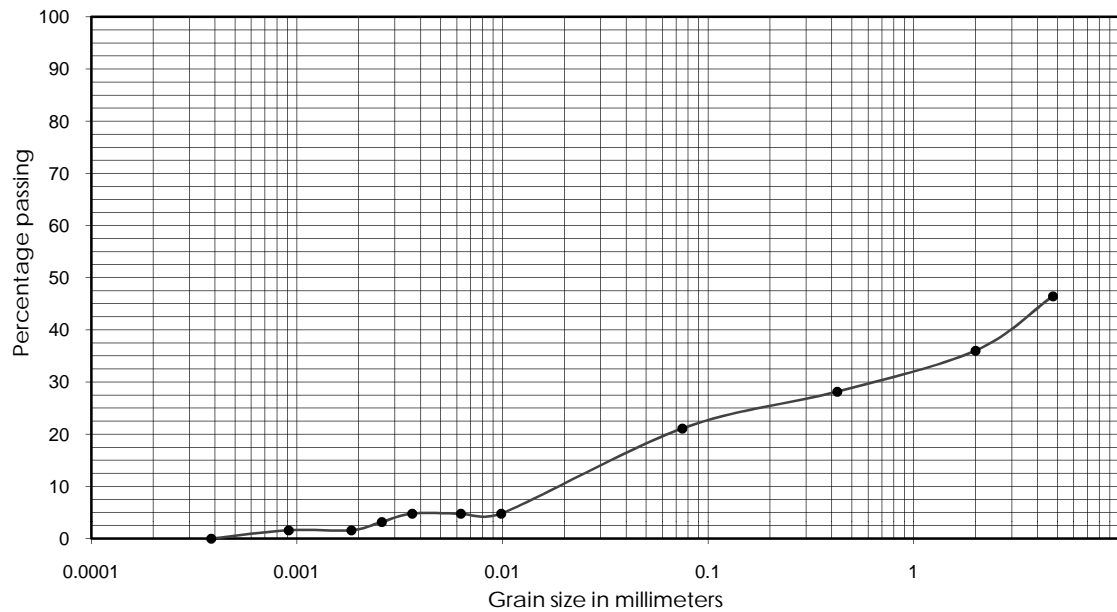


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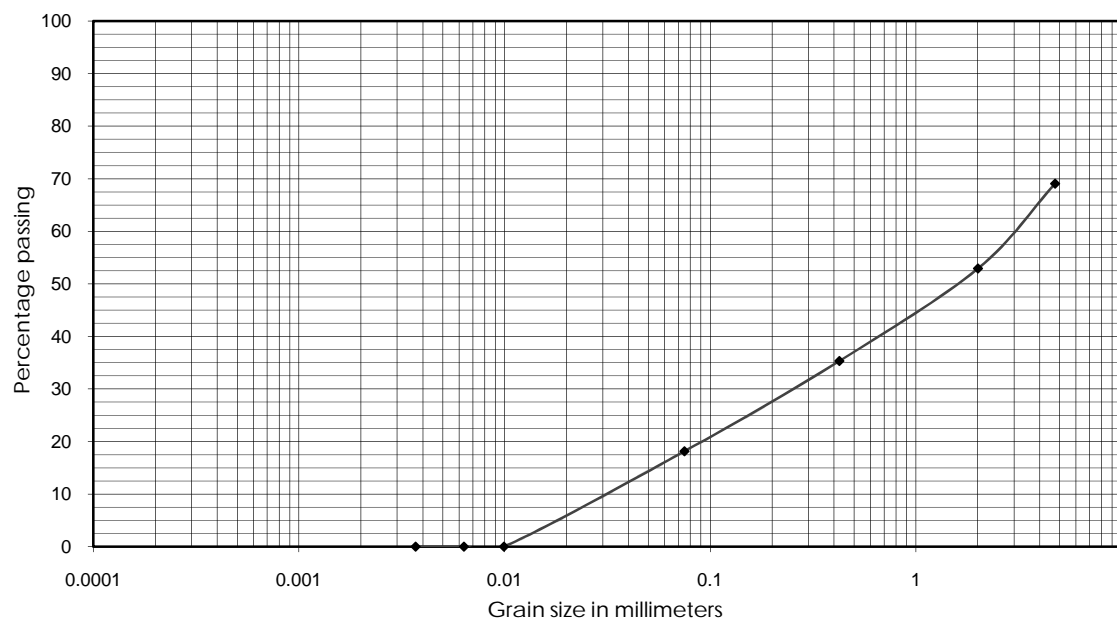


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-01	1.00	GM-SM	54	25	19	2			



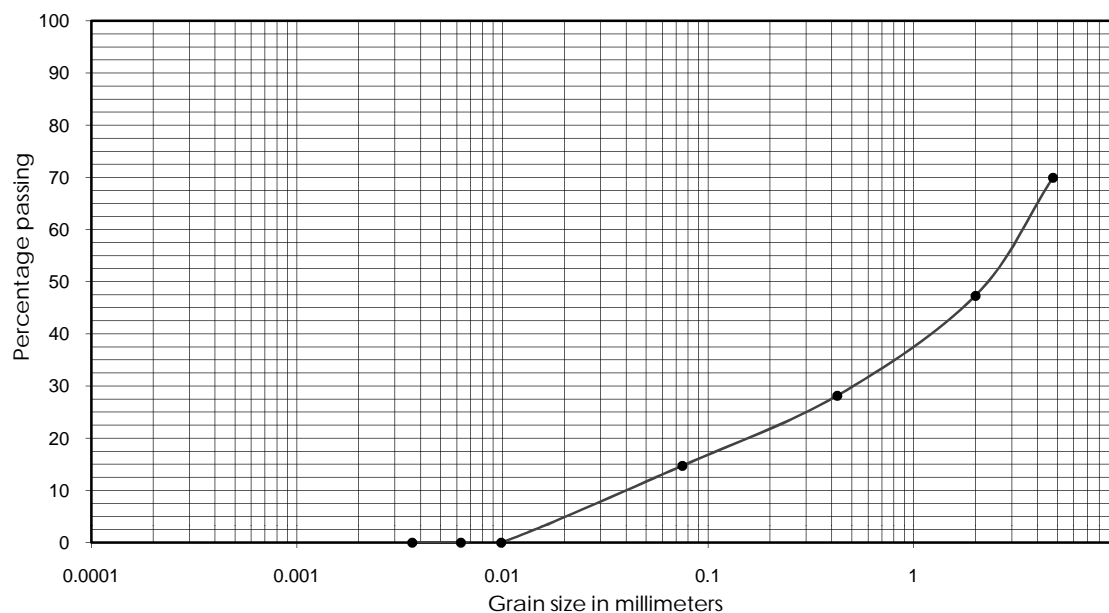
BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-01	2.00	SM	31	51	18	0			

FIG.6

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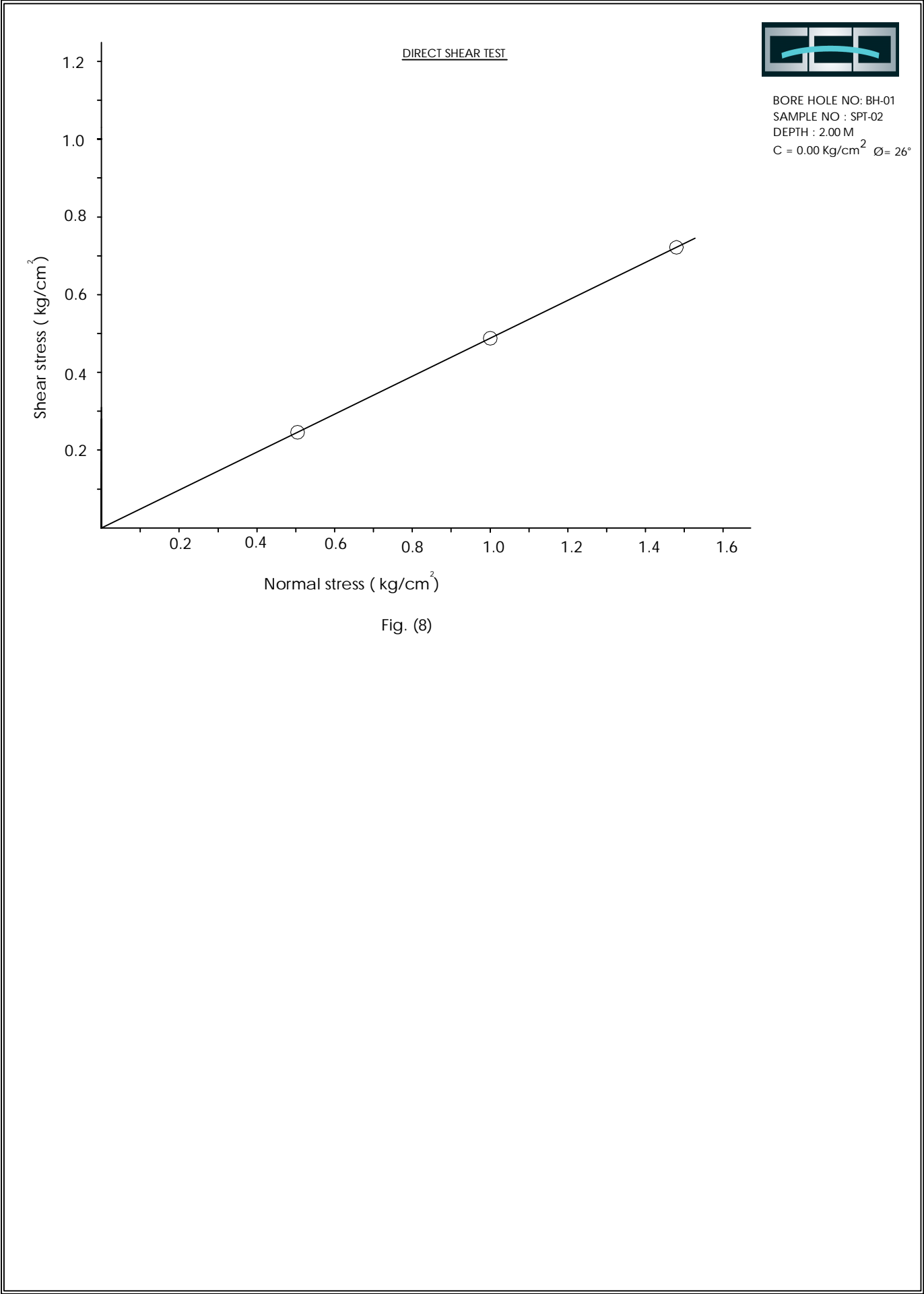
**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-01	3.00	SM	30	55	15	0			

FIG.7



**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

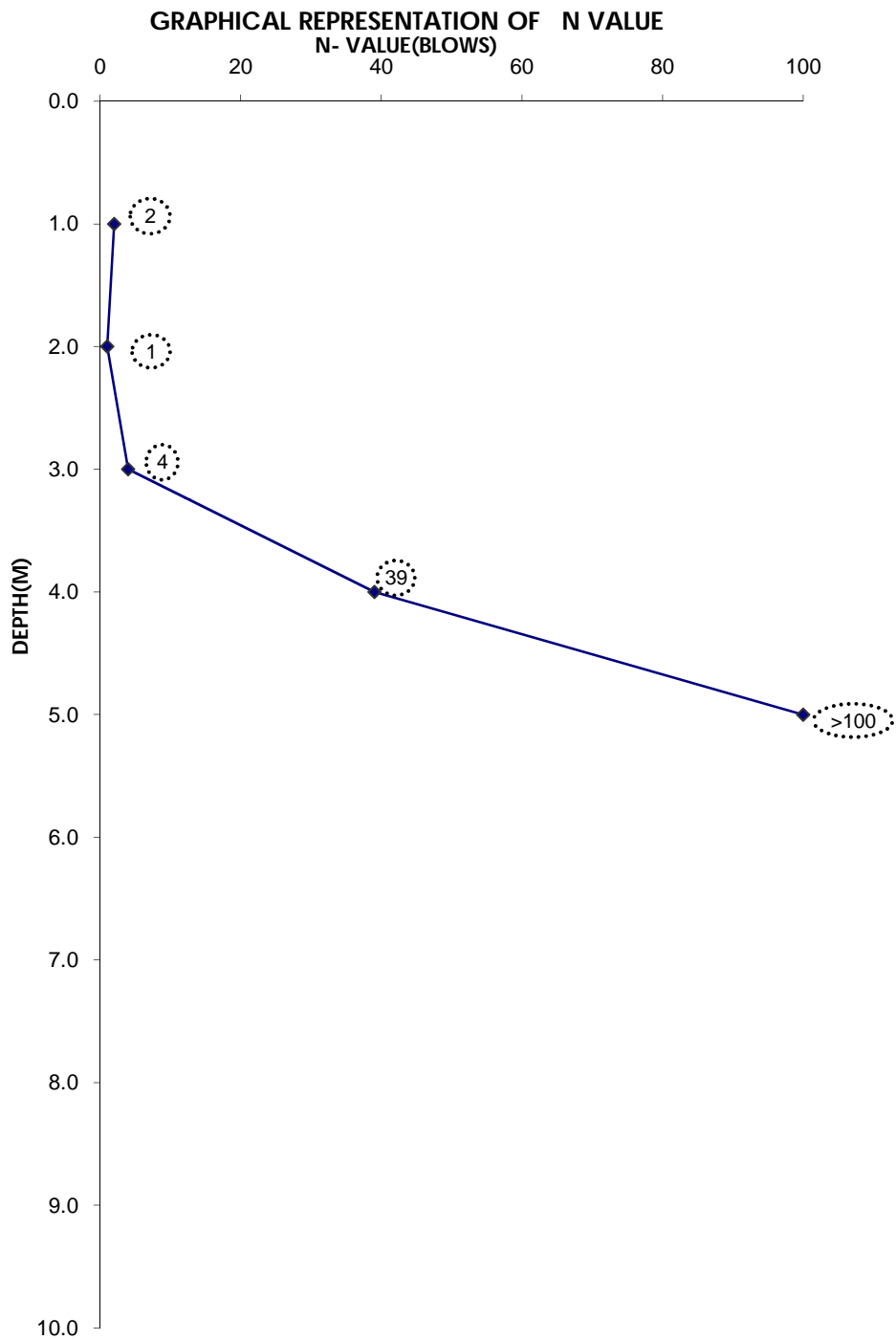
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Bore Hole No : **BH-02**  
Type of Boring : Rotary  
Ground Water Level : 1.50m

Date of Boring Started : 23.04.2021  
Date of Boring Completed : 24.04.2021  
Termination Depth : 7.00 M



**TC-5397**



**BORE HOLE TERMINATED AT 7.00 M**

**FIG.9**








NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No : <b>BH-02</b>	Boring Started : 23.04.2021										
		Type of Boring : Rotary	Boring Completed : 24.04.2021										
		Termination Depth : 7.0 M	Ground Water Level : 1.50 M										
		Reduced Level : +4.652	Co-ordinates :										
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	2.80	Clayey sand with presence of gravel (Brown)	SC	1.00	1.00-1.45	1	1	1	2				
				2.00	2.00-2.45	1	0	1	1				
				3.00	3.00-3.45	1	2	2	4				
	2.20	Silty sand with gravel (Brown)	SM	4.00	4.00-4.45	14	16	23	39				
				5.50									
				6.50	5.00 to 6.00	DRILLING DONE USING DIAMOND BIT			71				
	2.00	Hard Rock		7.50	6.00 to 7.00	DRILLING DONE USING DIAMOND BIT			75	68			
Termination Depth : 7.00m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :10

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													 TC-5397				
			LOCATION : Tank Area		Ground Water Level : 1.50m			Date of Boring Started : 23.04.2021 Boring completed : 24.04.2021 Termination Depth : 7.0m				Table No.:2								
														ULR-TC539720000000253F						
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SPG IS 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-02																				
2	1.00	SPT-01	Clayey sand with presence of gravel(Brown)	SC	10	47	25	18	33	No Limit					2.57	1.56	1.17	DST	0.14	23
1	2.00	SPT-02	Clayey sand with presence of gravel(Brown)	SC																
4	3.00	SPT-03	Silty sand with gravel(Brown)	SM	28	55	17	0	22	No Limit										
39	4.00	SPT-04	Silty sand with gravel(R/Brown)	SM	20	59	21	0	24	No Limit					2.62	1.72	1.39	DST	0.02	31
	5.00 to 7.00		Rock																	

:21:

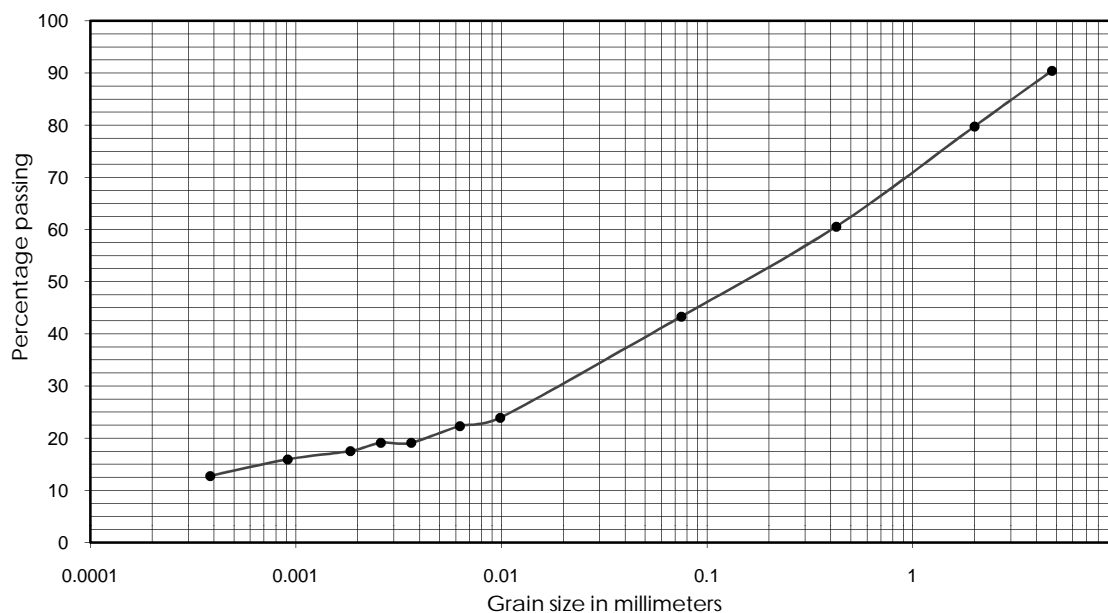


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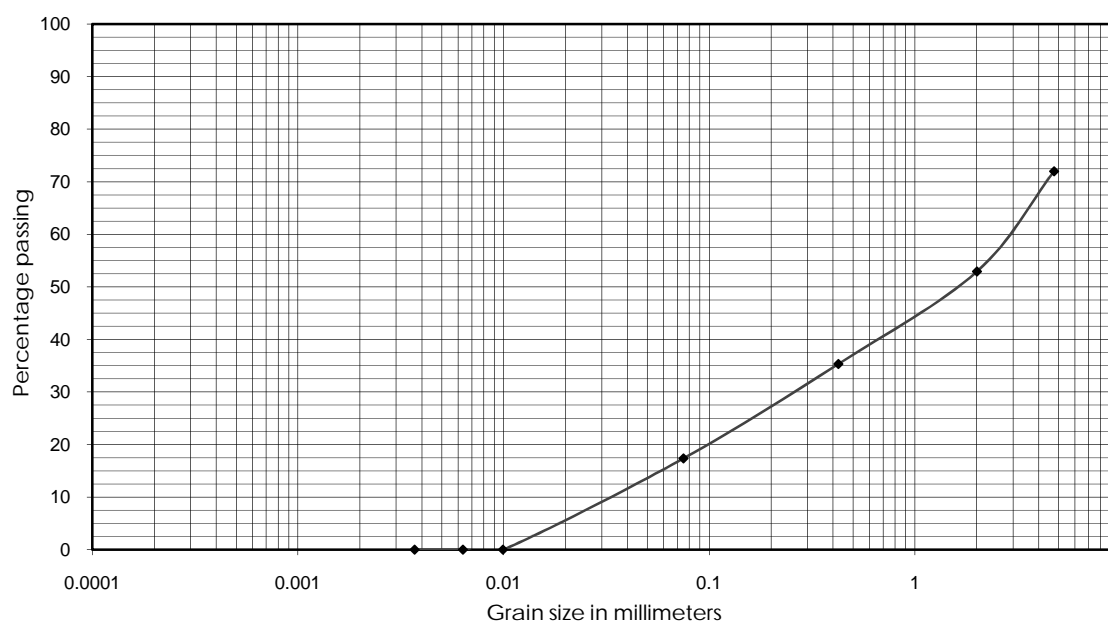


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST




BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-02	1.00	SC	10	47	25	18			



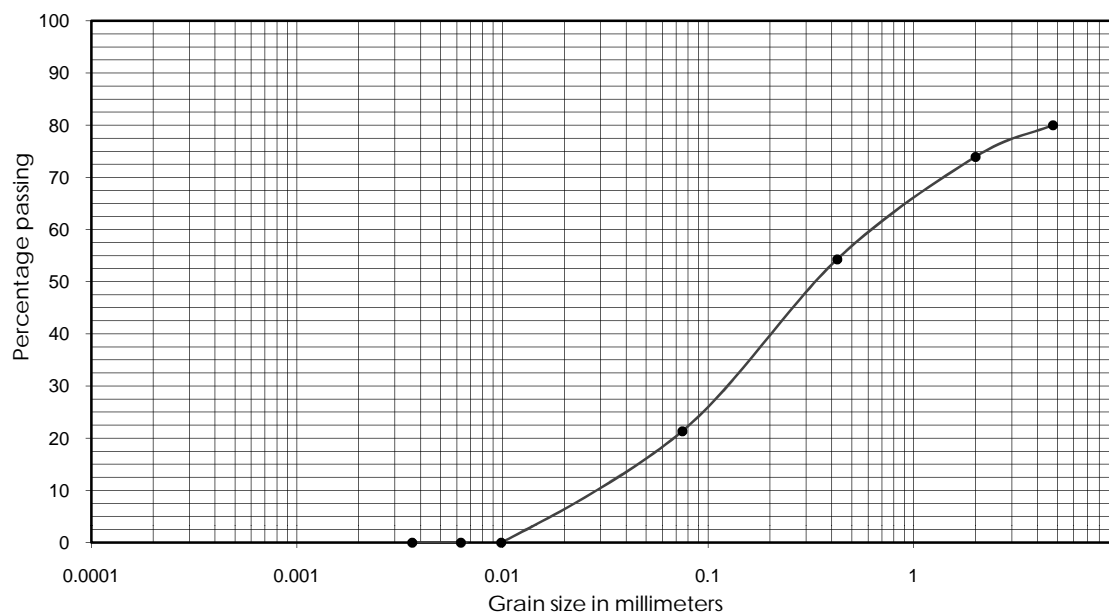
BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-02	3.00	SM	28	55	17	0			

FIG.11

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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-02	4.00	SM	20	59	21	0			

FIG.12



BORE HOLE NO: BH-02  
SAMPLE NO : SPT-01  
DEPTH : 1.00 M  
 $C = 0.14 \text{ Kg/cm}^2$   $\phi = 23^\circ$

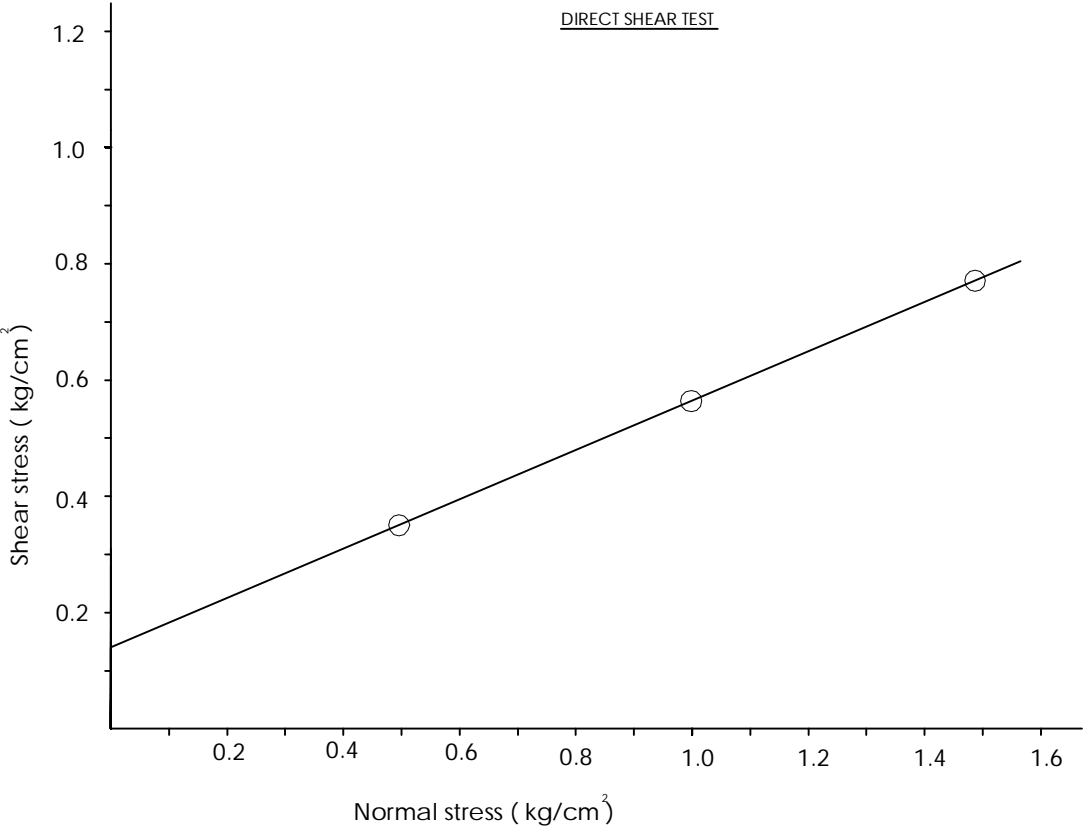
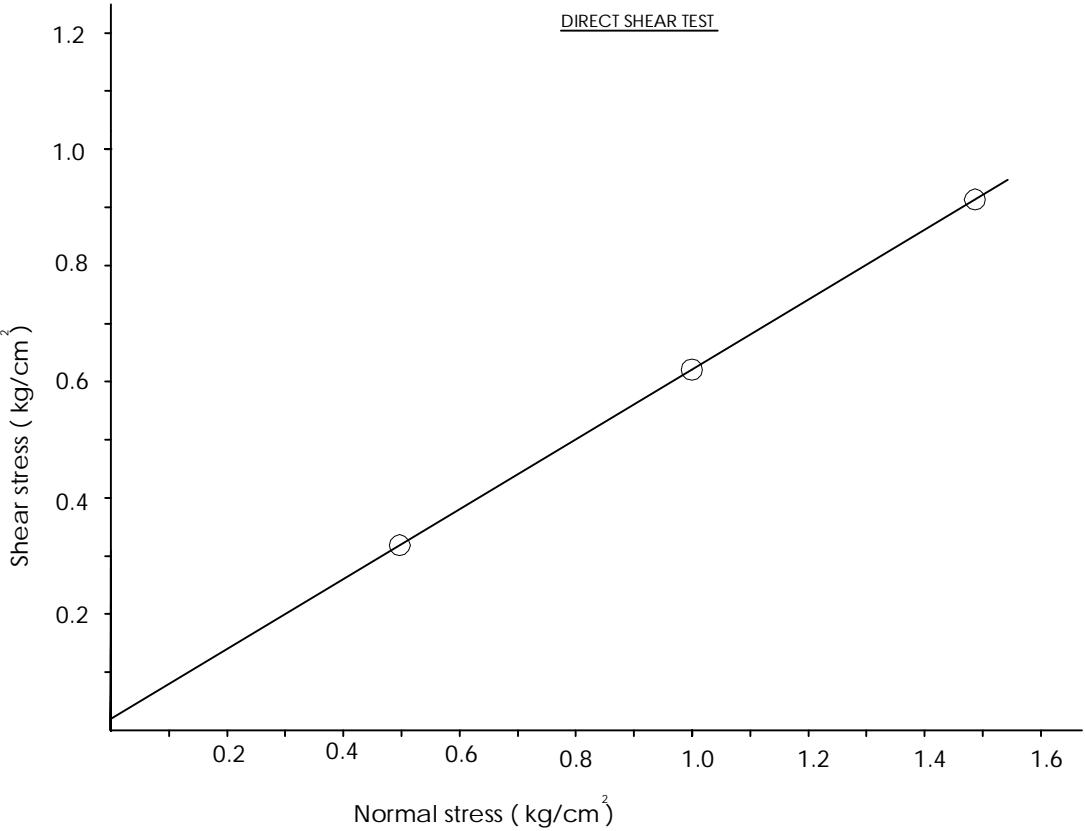


Fig. (13)



BORE HOLE NO: BH-02  
SAMPLE NO : SPT-04  
DEPTH : 4.00 M  
 $C = 0.02 \text{ Kg/cm}^2$   $\phi = 31^\circ$

Fig. (14)



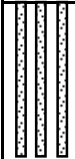




NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No	: BH-03	Boring Started	: 29.04.2021		<b>TC-5397</b>						
		Type of Boring	: Rotary	Boring Completed	: 29.04.2021								
		Termination Depth	: 4.30 M	Ground Water Level	: Not met with								
		Reduced Level	: +4.552	Co-ordinates :									
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	1.00	Silty sand with gravel(R/brown)	SM	0.50	0.50	DS-01						SPT REBOUND	
				1.00	1.00	100	-	-					>100
	1.30	Soft rock		2.50	1.00 to 2.30	DRILLING DONE USING DIAMOND BIT			NIL	NIL			
	2.00	Rock		3.50	2.30 to 3.30	DRILLING DONE USING DIAMOND BIT			79	71			
				4.50	3.30 to 4.30	DRILLING DONE USING DIAMOND BIT			100	100			
Termination Depth : 4.30m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :15

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397				
			LOCATION : Tank Area	Ground Water Level : Not met with	Date of Boring Started : 29.04.2021 Boring completed : 29.04.2021 Termination Depth : 4.30 M				Table No.:3			ULR-TC539720000000253F									
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS 2720 (Part2):1973 NMC (%)	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986			
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø ( <sup>o</sup> )	
BOREHOLE BH-03																					
	0.50	DS-01	Silty sand with gravel(R/brown)	SM	22	63	15	0	27	No Limit					2.64	1.62	1.28	DST	0	29	
>100	1.00 to 2.30		Soft Rock																		
	2.30 to 4.30		Hard Rock																		

26:

:26:



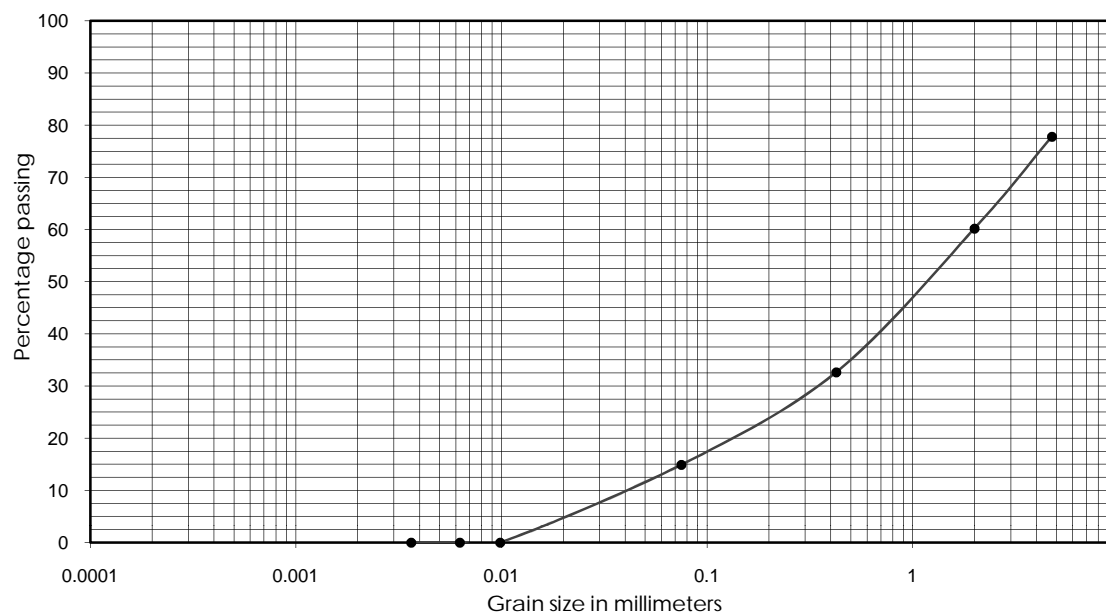
GEO FOUNDATIONS AND STRUCTURES PVT. LTD



TC-5397

NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-03	0.50	SM	22	63	15	0			

FIG.16

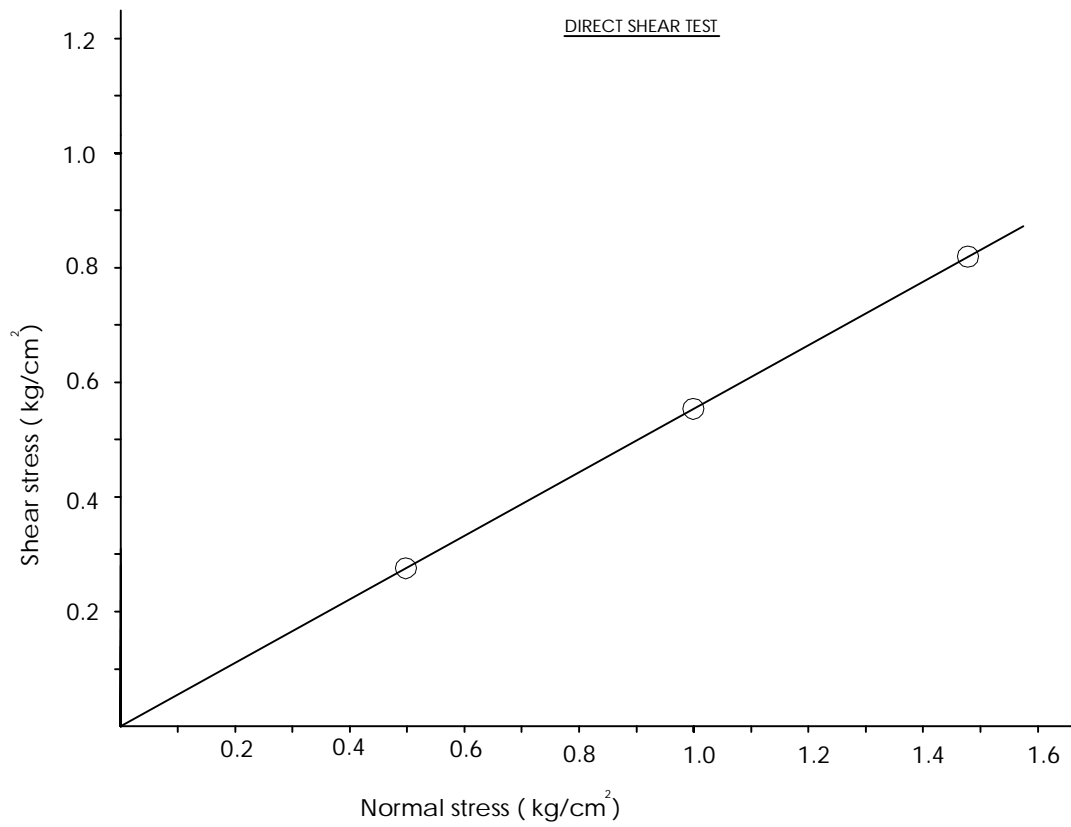


Fig. (17)

**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

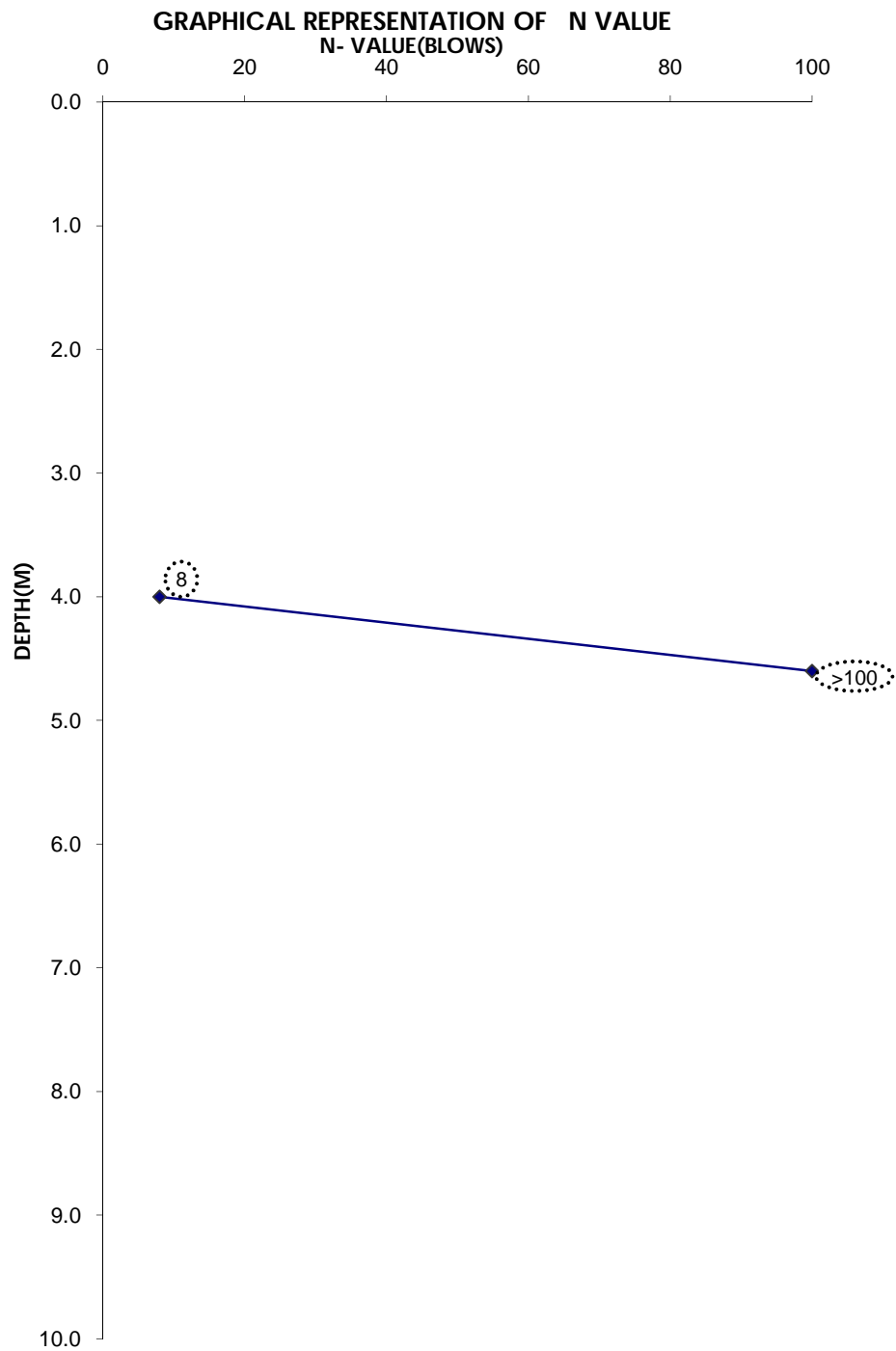
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-04**  
Type of Boring : Rotary  
G. W. L. : Not met with

Date of Boring Started : 22.04.2021  
Date of Boring Completed : 23.04.2021  
Termination Depth : 4.60 M



**TC-5397**



**BORE HOLE TERMINATED AT 4.60 M**

**FIG.18**



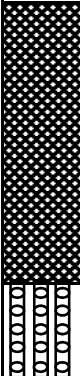



NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	GEO FOUNDATIONS & STRUCTURES PVT. LTD	Bore Hole No : BH-04	Boring Started : 22.04.2021	 TC-5397									
		Type of Boring : Rotary	Boring Completed : 23.04.2021										
		Termination Depth : 4.60 M	Ground Water Level : Not met with										
		Reduced Level : +5.137	Co-ordinates :										
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	3.50	Pieces of Rock		1.00	1.00								SPT Rebound
				2.00	2.00								
				3.00	3.00								
	1.10	Gravely silty sand(Red)	GM-SM	4.00	4.00-4.45	4	4	4	8				
				4.60	4.60	100	-	-	>100				
		HARD STRATA											
Termination Depth : 4.60m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :19

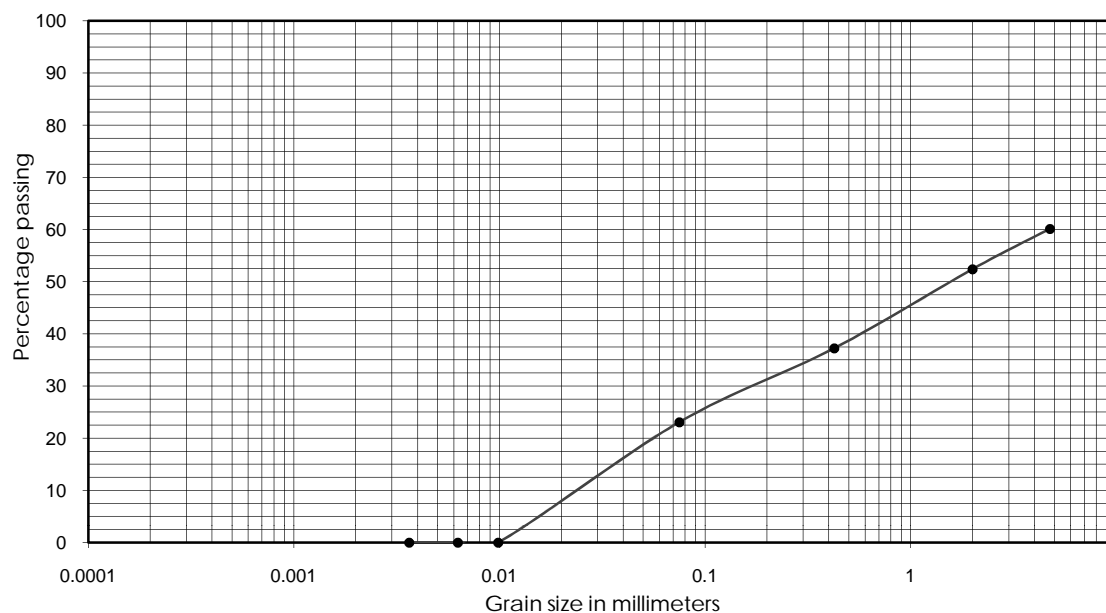
			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE															 TC-5397							
			LOCATION : Tank Area	Ground Water Level : Not met with	Date of Boring Started : 22.04.2021 Boring completed : 23.04.2021 Termination Depth : 4.60 M			Table No.:4			ULR-TC539720000000253F														
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part-3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986							
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)					
BOREHOLE BH-04																									
	0.00 to 3.50		Filled up with rock pebbles																						
8	4.00	SPT-1	Gravely silty sand (Red)	GM-SM	40	37	23	0	22	No Limit					2.63	1.70	1.39	DST	0.03	25					
	4.60		Hard Rock, SPT REBOUND																						

: 31 :

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-04	4.00	GM-SM	40	37	23	0			

FIG.20

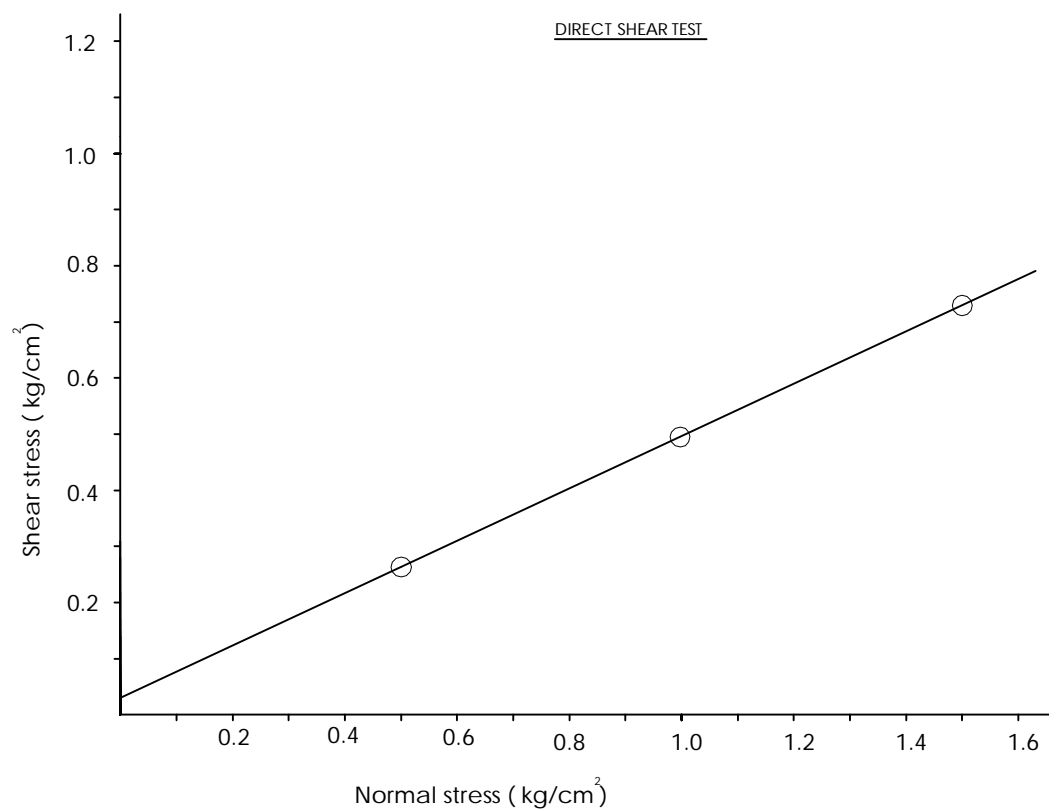


Fig. (21)



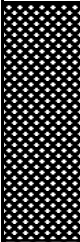



NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No : <b>BH-04A</b>	Boring Started : 01.05.2021		<b>TC-5397</b>								
		Type of Boring : Rotary	Boring Completed : 03.05.2021										
		Termination Depth : 4.30 M	Ground Water Level : Not met with										
		Reduced Level : +5.137	Co-ordinates : E- 649670.205, N- 1103249.063										
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	2.80	Pieces of Rock		1.00	1.00								SPT Rebound
				2.00	2.00								
				2.80	2.80	100	-	-	>100				
	1.8	Rock		4.00	2.80 to 3.80	DRILLING DONE USING DIAMOND BIT			98	89			
					3.80 to 4.60	DRILLING DONE USING DIAMOND BIT			87	87			
				5.00									
Termination Depth : 4.60m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :22

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397				
			LOCATION : Tank Area		Ground Water Level : Not met with			Date of Boring Started : 01.05.2021 Boring completed : 03.05.2021 Termination Depth : 4.60 M					Table No.:5								
								ULR-TC539720000000253F													
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS 2720 (Part2):1973 NMC (%)	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986			
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)	
BOREHOLE BH-04A																					
	0.00 to 2.80		Filled up laterite with rock pebbles																		
	2.80 to 4.60		Hard Rock																		

: 35 :

**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

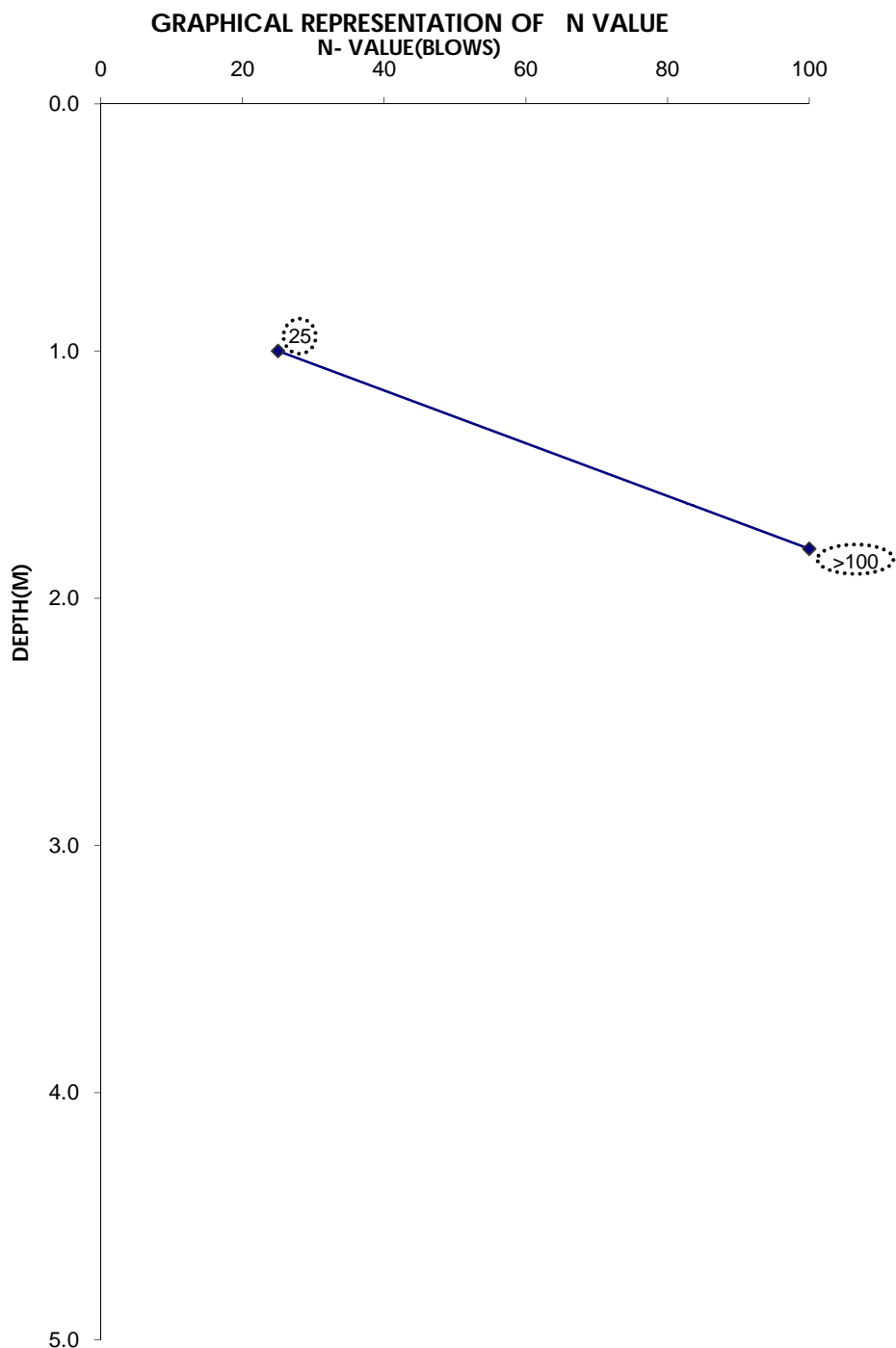
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-05**  
Type of Boring : Rotary  
Ground Water Level : 0.75m

Date of Boring Started : 28.04.2021  
Date of Boring Completed : 28.04.2021  
Termination Depth : 4.30 M



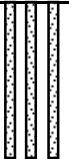



**TC-5397**



**BORE HOLE TERMINATED AT 4.30 M**

**FIG.23**



NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No	: BH-05	Boring Started	: 28.04.2021		<b>TC-5397</b>						
		Type of Boring	: Rotary	Boring Completed	: 28.04.2021								
		Termination Depth	: 4.30 M	Ground Water Level	: 0.75 m								
		Reduced Level	: +4.252	Co-ordinates :									
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	1.80	Silty sand with gravel(Y/brown)	SM	1.00	1.00-1.45	7	11	14	25				SPT Rebound
				1.80	1.80	100	-	-	>100				
	2.50	Hard Rock		3.00	1.80 to 2.80	DRILLING DONE USING DIAMOND BIT			99	96			
				4.00	2.80 to 3.80	DRILLING DONE USING DIAMOND BIT			84	71			
				5.00	3.80 to 4.30	DRILLING DONE USING DIAMOND BIT			60	60			
				5.00									



Termination Depth : 4.30m

Note : UDS- Undisturbed Sample

SPT "N"-Standard Penetration Test "N"

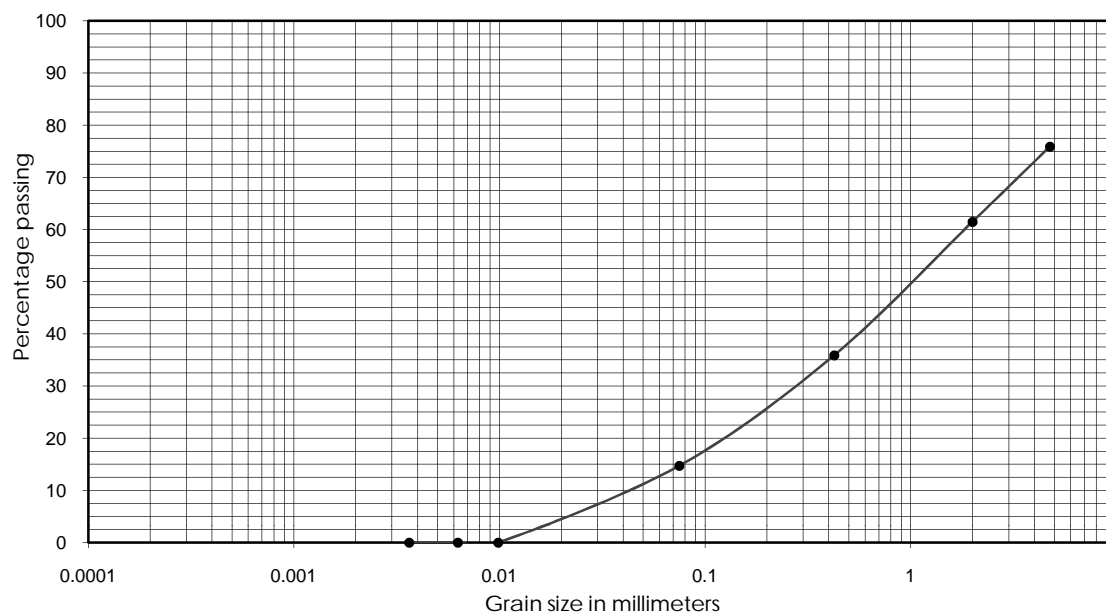
Fig :24

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397			
			LOCATION : Tank Area	Ground Water Level : 0.75m				Date of Boring Started : 28.04.2021 Boring completed : 28.04.2021 Termination Depth : 4.30m				Table No.:6								
ULR-TC539720000000253F																				
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-05																				
25	1.00	SPT-01	Silty sand with gravel(Y/brown)	SM	24	61	15	0	23	No Limit					2.63	1.76	1.43	DST	0.03	28
	1.80 to 4.30		Rock																	

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-05	1.00	SM	24	61	15	0			

FIG.25



BORE HOLE NO: BH-05  
SAMPLE NO : SPT-01  
DEPTH : 1.00 M  
 $C = 0.03 \text{ Kg/cm}^2$   $\phi = 28^\circ$

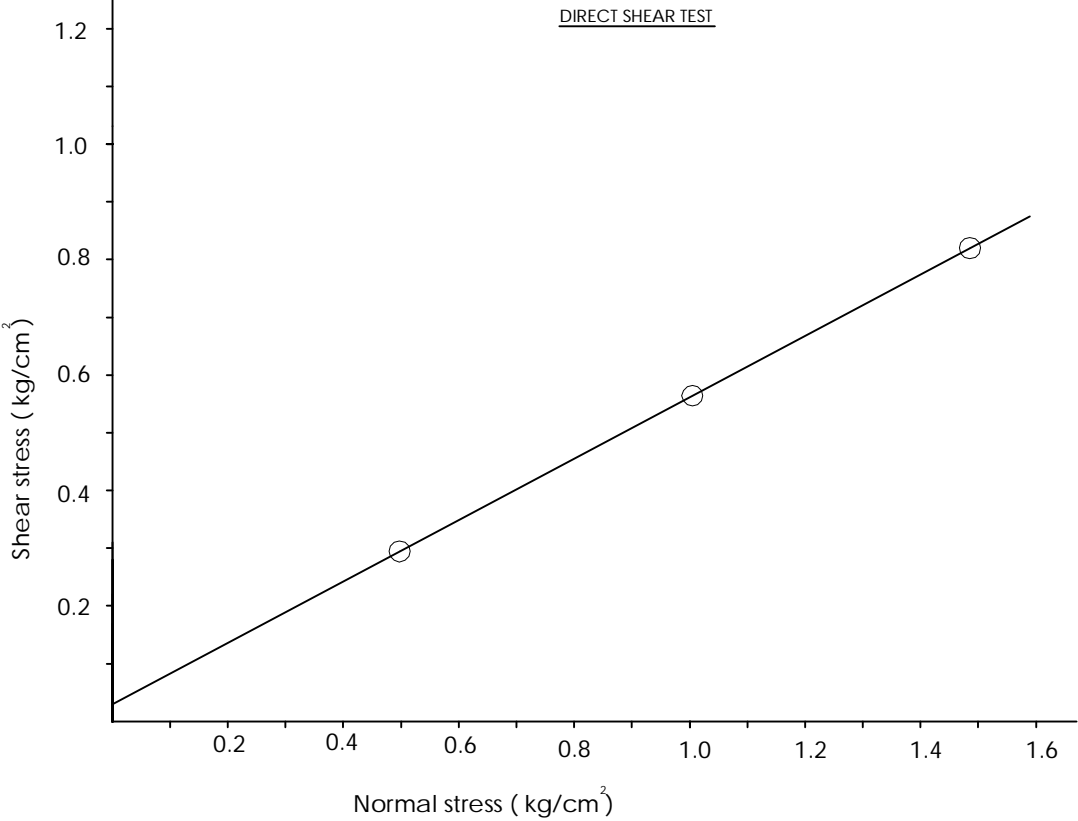


Fig. (26)



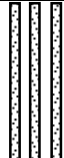






NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No : <b>BH-R1</b>	Boring Started : 03.05.2021		<b>TC-5397</b>								
		Type of Boring : Rotary	Boring Completed : 04.05.2021										
		Termination Depth : 3.50 M	Ground Water Level : Not met with										
		Reduced Level : +7.182	Co-ordinates :										
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	1.00	Silty sand with gravel(Br./red)	SM	0.50	0.50	DS-01						SPT Rebound	
				1.00	1.00	100	-	-					>100
	0.80	Soft Rock		2.00	1.00 to 1.80	DRILLING DONE USING DIAMOND BIT			NIL	NIL			
	0.50	Disintegrated Rock			1.80 to 2.30	DRILLING DONE USING DIAMOND BIT			28	NIL			
	0.50	Rock			2.30 to 2.80	DRILLING DONE USING DIAMOND BIT			52	50			
				3.00									
Termination Depth : 2.80m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :27

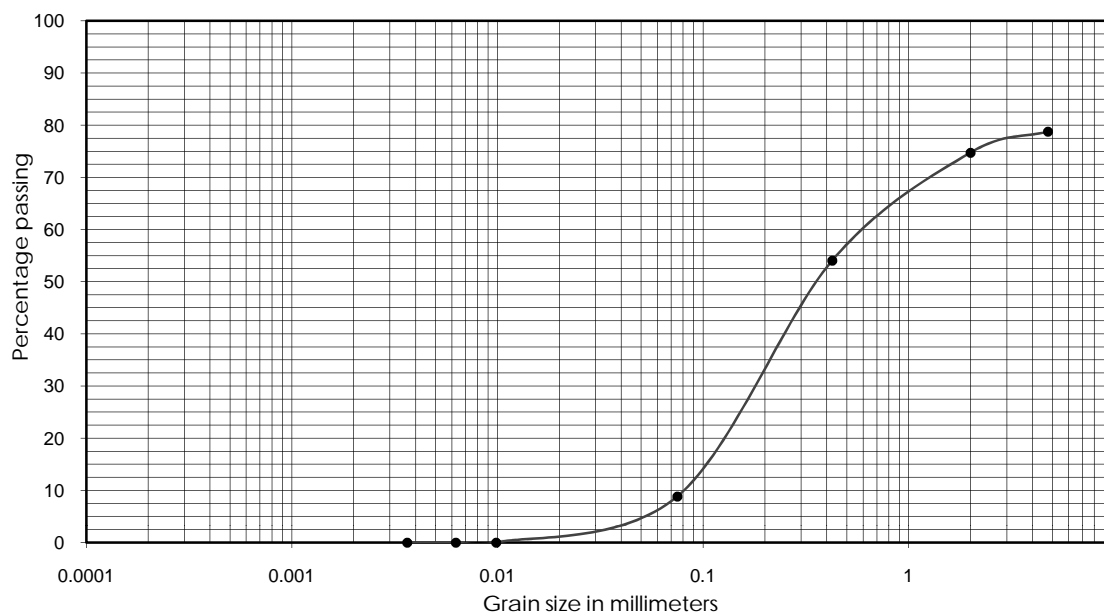
			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397			
			LOCATION : Tank Area		Ground Water Level : 1.60m				Date of Boring Started : 03.05.2021 Boring completed : 04.05.2021 Termination Depth : 2.80 M				Table No.:7							
ULR-TC539720000000253F																				
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SpG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-R1																				
	0.50	DS-01	Silty sand with gravel(Br./red)	SM	21	70	9	0	5	No Limit					2.65	1.75	1.67	DST	0	30
>100	1.00 to 1.80		Soft Rock																	
	1.80 to 2.30		Disintegrated Rock																	
	2.30 to 2.80		Hard Rock																	

:42:

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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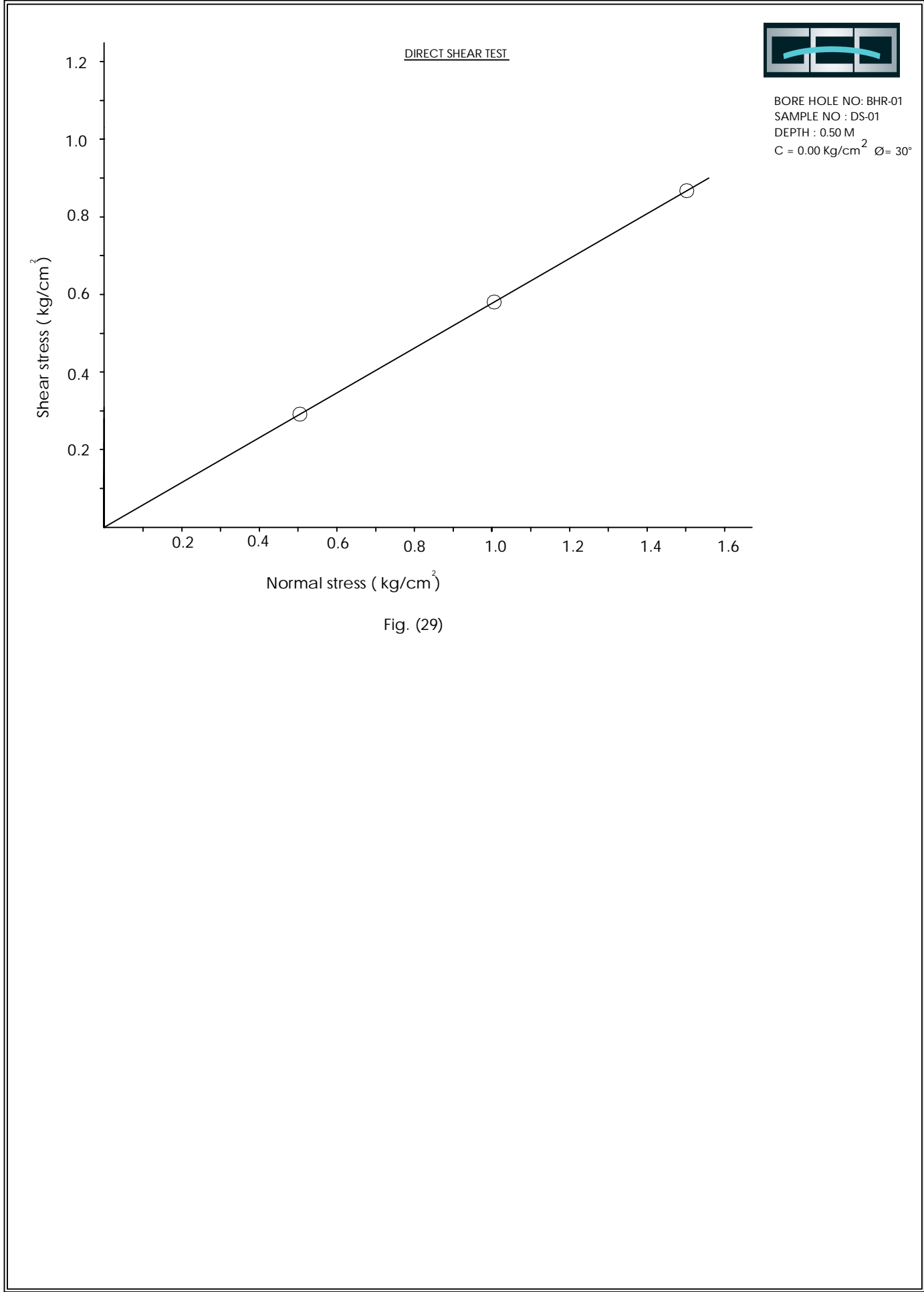
**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BHR-01	0.50	SM	21	70	9	0			

FIG.28



**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

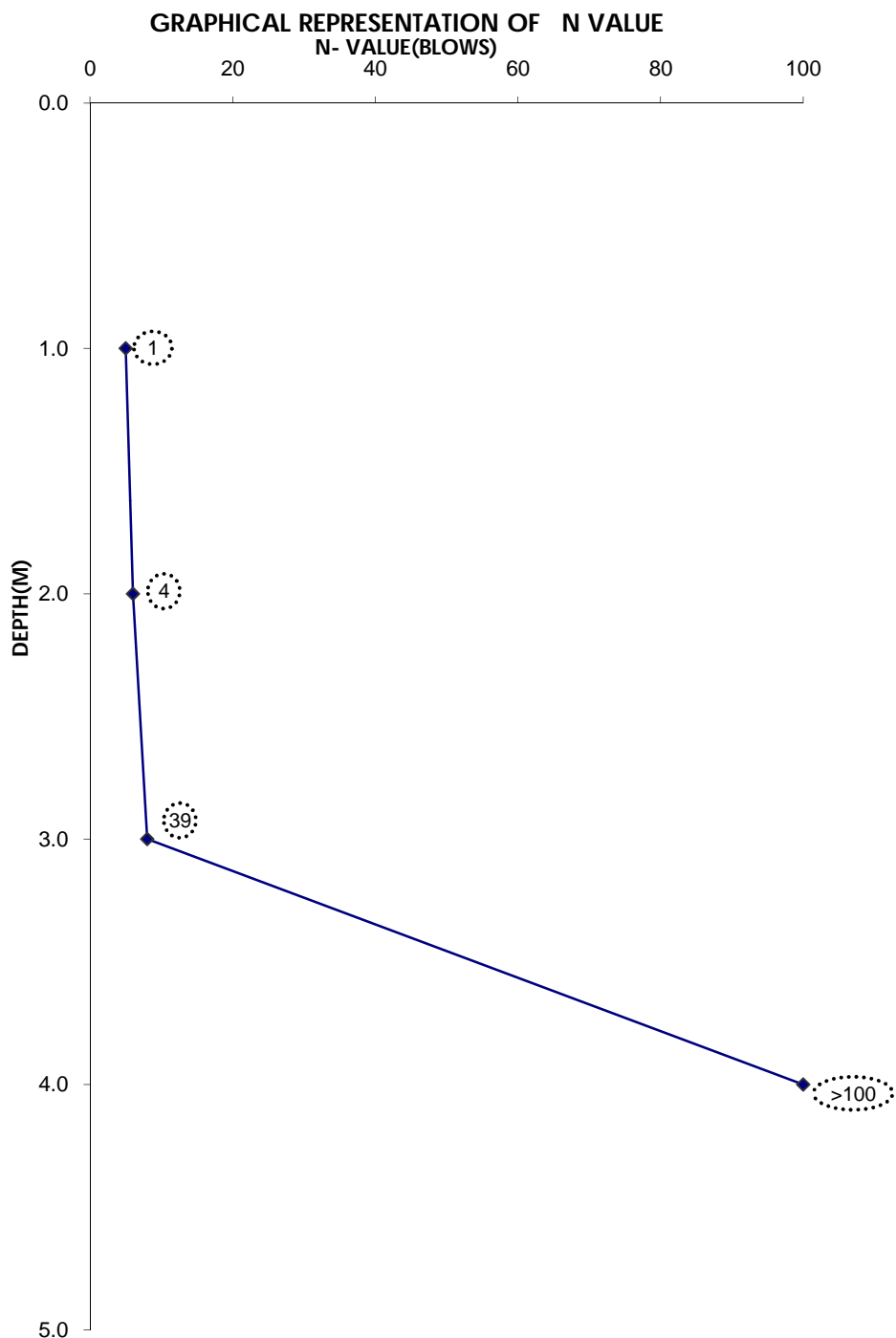
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BHR-02**  
Type of Boring : Rotary  
Ground Water Level : 1.60m

Date of Boring Started : 30.04.2021  
Date of Boring Completed : 01.05.2021  
Termination Depth : 4.50 M



**TC-5397**



**BORE HOLE TERMINATED AT 4.50 M**

**FIG.30**







NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No : <b>BH-R2</b>	Boring Started : 30.04.2021										
		Type of Boring : Rotary	Boring Completed : 01.05.2021										
		Termination Depth : 4.50 M	Ground Water Level : 1.60 M										
		Reduced Level : +4.777	Co-ordinates :										
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			0
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	4.00	Gravely silty sand (Red)	GM-SM	1.00	1.00-1.45	2	2	3	5				SPT Rebound
		Gravely silty sand (Y/brown)		2.00	2.00-2.45	2	3	3	6				
		Gravely silty sand (Red)		3.00	3.00-3.45	3	4	4	8				
				4.00	4.00	100	-	>100					
	0.50	Rock		4.50	4.00 to 4.50	DRILLING DONE USING DIAMOND BIT				46	46		
Termination Depth : 4.50m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :31

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE														 TC-5397			
			LOCATION : Tank Area	Ground Water Level : 1.60m				Date of Boring Started : 30.04.2021 Boring completed : 01.05.2021 Termination Depth : 4.50 M				Table No.:8								
															ULR-TC539720000000253F					
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC (%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SpG 2720(Part-3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-R2																				
5	1.00	SPT-01	Gravely silty sand (Red)	GM-SM	41	38	21	0	30	No Limit					2.61	1.65	1.27	DST	0.02	25
6	2.00	SPT-02	Gravely silty sand(Y/brown)	GM-SM					23											
8	3.00	SPT-03	Gravely silty sand (Red)	GM-SM	44	39	17	0	20	No Limit					2.60	1.67	1.39	DST	0	26
	4.00 to 4.50		Rock																	

:47:

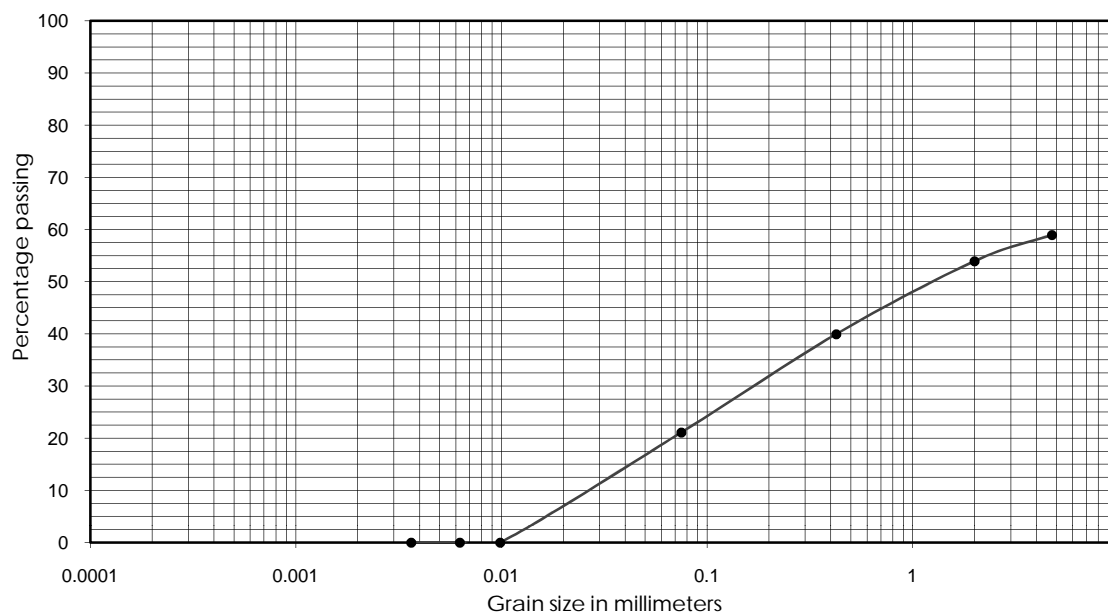


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

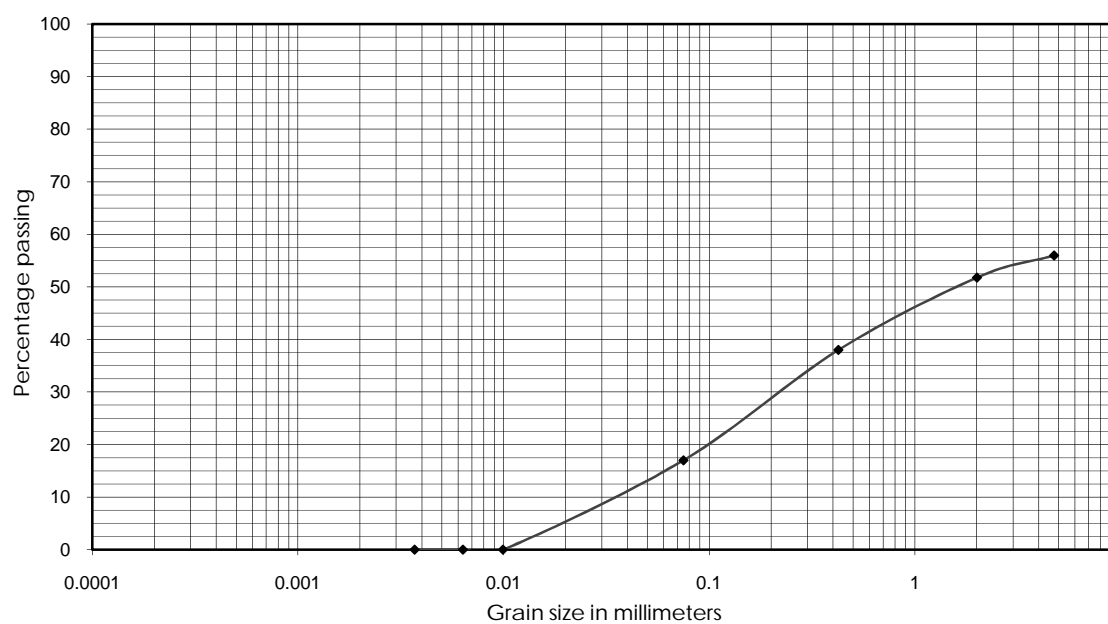


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 1000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BHR-02	1.00	GM-SM	41	38	21	0			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BHR-02	3.00	GM-SM	44	39	17	0			

FIG.32

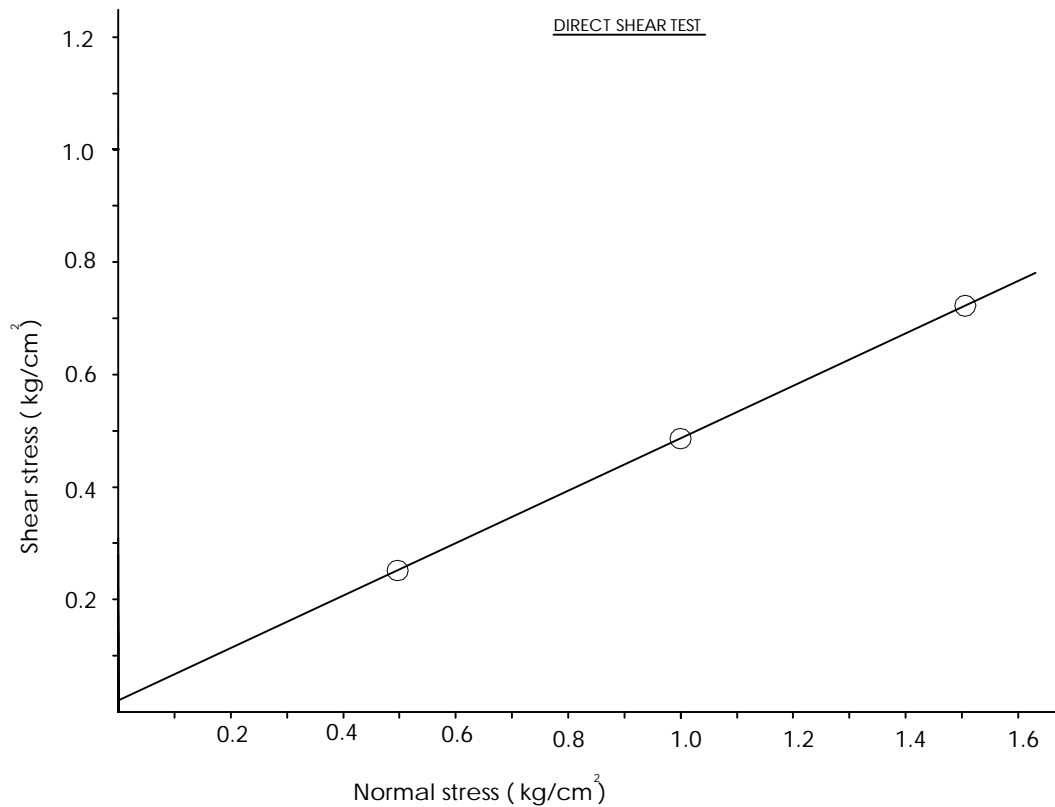


Fig. (33)

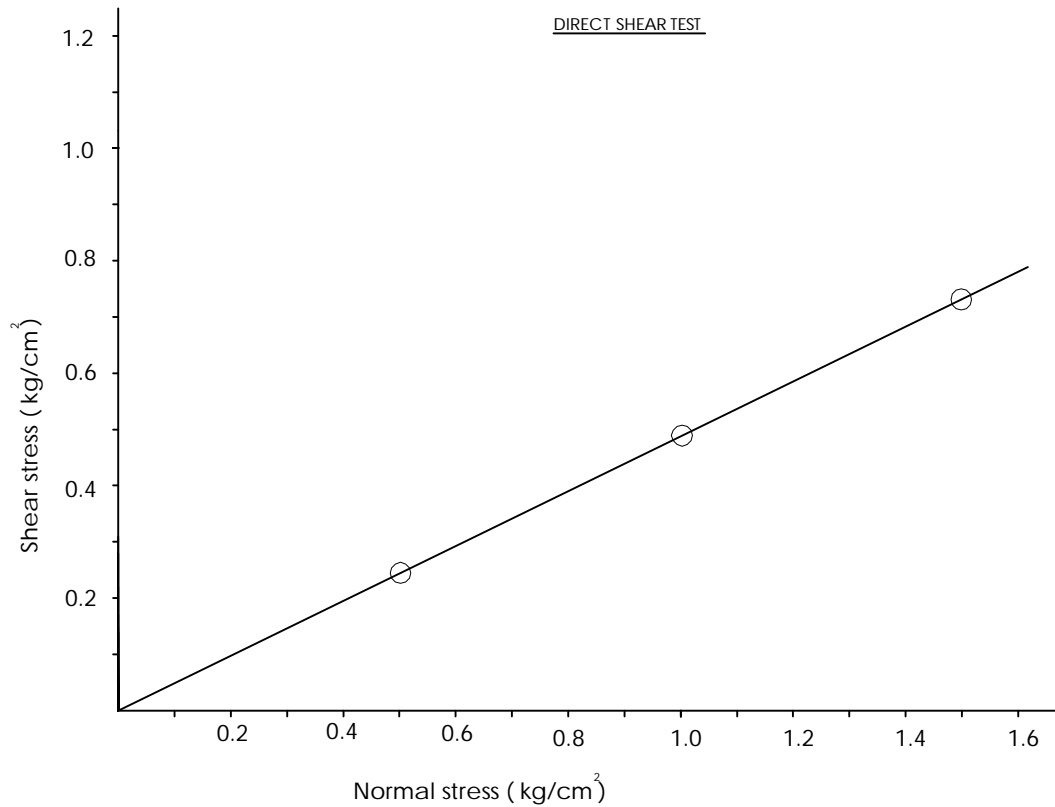


Fig. (34)







NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No	: BH-R3	Boring Started	: 30.04.2021		<b>TC-5397</b>						
		Type of Boring	: Rotary	Boring Completed	: 30.04.2021								
		Termination Depth	: 0.70 M	Ground Water Level	: Not met with								
		Reduced Level	: +5.882	Co-ordinates :									
LOCATION : Tankage Area													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	0.20	Ordinary soil		0.20	1.00	100	-	-	>100				SPT REBOUND
	0.50	Rock		0.70	0.20 to 0.70	DRILLING DONE USING DIAMOND BIT			88	88			
Termination Depth : 0.70m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :35

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE																 TC-5397		
			LOCATION : Tank Area	Ground Water Level : Not met with	Date of Boring Started : 30.04.2021 Boring completed : 30.04.2021 Termination Depth : 0.70 M				Table No.:9			ULR-TC539720000000253F									
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS 2720 (Part2):1973 NMMC (%)	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986			
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)	
BOREHOLE BH-R3																					
	0.00 to 0.20		Ordinary soil																		
	0.20 to 0.70		Hard Rock																		

5:1

:51:

## **ANNEXURE – B**

### **Compressor House**

**(BH-06)**

**B.1 SITE SOIL DESCRIPTION**

**B.1.1 BH - 06 :** The strata at this borehole location is predominantly medium silty sandy natured soils even upto about 13.0 mtr from existing ground level. Generally the soil is lateritic in nature and classification / stratification after lab analysis is as given in the borelog sheet. Hard rock is encountered from 13.0 mtr to 15.0 mtr wherein rock core recovery is greater than 50% and RQD is close to 40%.

**B.2 DISCUSSION ON TYPE OF FOUNDATION**

B.2.1 The proposed structure at this location is a Compressor house with auxillary units like Refrigeration unit, control room etc. in an area of about 30 m x 15 m to a height of 12 to 15 mtrs. It is given to understand that there are heavily loaded structures as well as some lightly loaded structures in this area.

B.2.2 From the borelog& results table of the borehole study ( BH 06), it can be observed that the soils are basically silty sandy soils with loose nature in the shallow depths improving to medium nature with increase in depth. Rock is available at about 13.0 mtr depth below the ground level.

B.2.3 The project area is in Seismic Zone III of the Map of India. In case the soils are induced to seismic loadings there can be liquefaction in the sandy natured soils available in between. This may cause undue settlements to the structure in case if shallow foundations are provided.

B.2.4 Hence it is found necessary that the loads coming from the heavily loaded structure need to be transferred to a firm stratum. Based on the soil condition and the availability of rocky strata, pile foundation shall be a better foundation system for the proposed structure with these piles resting in the rocky strata available below.

B.2.5 Thus RCC bored cast in situ piles by DMC method installed as per the relevant clauses of IS 2911 : Part 1 / Sec 2 - 2010 shall be provided as the foundation. It is suggested that piles shall be socketed into rocky strata by half times the diameter of piles (1/2 D).

- B.2.6 The safe carrying capacities for different diameters of piles calculated as per relevant clauses of above said IS Code are tabulated and given below in Table **No.B.5.1**. A factor of safety of 2.5 is considered for calculating the safe capacities.
- B.2.7 However in case of lightly loaded structures, wherein pile foundation shall be costly, it is considered that shallow square footings at a depth of about 1.0 mtr below ground level may be suitable as foundation.
- B.2.8 Bearing capacity of different types of footings are worked out as per relevant clauses of Indian Standard Code of Practice IS: 6403 - 1981 for shear criterion and IS: 8009 (Part – I) – 1976 for settlement criterion. Values calculated for different sizes of footing to be placed at different depths from the existing ground level are as given in the table No B.2.1. The bearing capacities were calculated from shear criterion and with corrected N value for 50mm settlement after considering the water table correction factor.

**Table No: B.2.1 (Square footing)**

Size of footing (m)	Depth below EGL	Bearing capacity from shear criterion (T/M <sup>2</sup> )	Bearing capacity from settlement criterion (T/M <sup>2</sup> )
2.0 x 2.0	1.0 m	3.50	1.25
	1.5 m	4.20	1.50
3.0 x 3.0	1.0 m	3.60	1.25
	1.5 m	4.10	1.80

- B.2.9 It is the general practice that the least value calculated from the shear criterion and the settlement criterion is considered as the safe bearing capacity(SBC) for the proposed size of footing placed at the suggested depth.
- B.2.10 In case the SBC values calculated above are less than the required values, instead of providing pile foundation for these small structures, ground improvement by sand piling method can be considered to increase the general condition of soil upto a depth of about 7.0 mtr below ground level. This method will improve the N values within the sand piles and thus achieve an increased bearing capacity for the structure.

The specifications and technical details of Sand Piles is given on Page No. 39

B.2.11 There is no established procedure to calculate the increase in the bearing capacity of soils due to this ground improvement method. However, from past experience of experts in this field, it is given to understand that the N values shall double at respective depths after the sand piling is installed. This increases the safe bearing capacity of soils to the values as given in table below in Table No. B.2.2. The bearing capacities have to be, however, confirmed by conducting a plate load test as per the relevant clauses of IS: 1888-1982 before finalizing the foundation design.

**Table No: B.2.2 (Square footing)**

Size of footing (m)	Depth below EGL	Bearing capacity from shear criterion (T/M <sup>2</sup> )	Bearing capacity from settlement criterion (T/M <sup>2</sup> )
2.0 x 2.0	1.0 m	4.00	4.00
	1.5 m	4.80	4.10
3.0 x 3.0	1.0 m	4.20	6.00
	1.5 m	4.80	6.00

As already mentioned earlier, the least of these two values are taken as SBC.

### **B.3 METHOD OF COMPUTING CAPACITIES FOR PILE FOUNDATIONS:**

Safe capacity of RCC Bored cast-in-situ pile can be computed by using the formula given in IS: 2911 (Part-1/Sec-2)-2010:

Ultimate bearing capacity  $Q_u$  of piles in Cohesion less soil:

$$Q_u = A_p(0.5 \cdot D \cdot \gamma \cdot N_\gamma + PD \cdot N_q) + \sum_{i=1}^n k_i \cdot P D_i \cdot \tan \delta_i \cdot A_{s_i}$$

Where,

$A_p$  = Cross sectional area of pile toe in cm<sup>2</sup>

$D$  = Stem dia. in cm

$\gamma$  = effective unit weight of soil at pile toe in kg /cm<sup>3</sup>

$P_D$  = effective overburden pressure in  $\text{Kg} / \text{cm}^2$

$N_\gamma$  and  $N_q$  = bearing capacity factors depending upon the angle of internal friction  $\phi$  at toe

$I=n$   
 $\sum_{I=1}^n$  = Summation of  $N$  layers in which pile is installed  
 $I=1$

$K$  = Coefficient of earth pressure

$P_{Di}$  = effective overburden pressure in  $\text{Kg} / \text{cm}^2$  for the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

$\delta$  = angle of wall friction between pile and soil in degree (may be taken equal to  $\phi$ )

$A_{si}$  = Surface area of pile stem in  $\text{cm}^2$  in the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

#### **For cohesive soil:-**

Safe capacity of pile =  $1/F \{A_P.N_c.C_p + \alpha.C.A_s\}$

Where

$A_P$  - c/s area of pile toe in  $\text{cm}^2$

$N_c$  - bearing capacity factor

$C_p$  - average cohesion at pile tip in  $\text{Kg}/\text{cm}^2$

$\alpha$  - Reduction factor

$C$  – average cohesion throughout the length of pile in  $\text{Kg}/\text{cm}^2$

$S$  - Surface area of pile shaft in  $\text{cm}^2$

$F$  - Factor of safety.

#### **B.4 METHOD OF COMPUTING BEARING CAPACITY FOR SHALLOW FOUNDATIONS**

Bearing capacity for shallow foundation is worked out based on the Shear criteria as given in relevant clauses of IS: 6403 – 1981 RA-2016 and settlement criteria as given in IS: 8009(part-1)–1976 RA-2013. The least of these two values is considered as the Safe / Allowable Bearing Capacity value for the given foundation.

**B.4.1 Calculation as per Shear Criteria:**

$$q_{ds} = 1/F \{ C.N_c.Sc.dc.ic + q(N_q-1).Sq.dq.iq + 1/2.B.\gamma.N_\gamma.S_\gamma.d_\gamma.i_\gamma.W' \}$$

where,

$q_{ds}$  – Safe allowable bearing capacity in Kg/cm<sup>2</sup>

C - Cohesion of the soil in Kg/cm<sup>2</sup>

q - Overburden pressure in Kg/cm<sup>2</sup>

B – Width of footing in cm

$\gamma$  - Unit wt. Of soil in Kg/cc

$Sc, Sq \& S_\gamma$  - Shape factors

$dc, dq, d_\gamma$  - Depth factors

$ic, iq \& i_\gamma$  - inclination factors

$N_c, N_q \& N_\gamma$  - Bearing capacity factors depending upon the angle of internal friction of the soil.

F – Factor of safety

W' – Correction factor for water table

**B.4.2 Calculation as per Settlement Criteria:****Calculation as per Settlement Criteria for Sandy Layer:-**

Settlement is calculated from the graph given in Fig.No.9 of IS 8009 Part-1

From the said graph, Settlement for unit pressure of 1Kg/cm<sup>2</sup> for the width of foundation B is correlated.

**Calculation as per Settlement Criteria for clayey Layer:-**

Consolidation settlement,  $S_t$  is given by,

$$S_t = \frac{C_c}{1+e_0} H \log \frac{p_0 + \Delta p}{p_0}$$

**C<sub>c</sub> - Compression index****e<sub>0</sub> - Initial void ratio****H - Thickness of clay stratum****P<sub>0</sub> - Consolidation pressure****Δp - Net change in pressure****B.5 CONCLUDING REMARKS**

- B.5.1 RCC Bored cast in situ piles to be considered for the heavily loaded components of the proposed structure. The Safe capacities for different diameter of piles at different depth socketed by 0.5 times the diameter of piles in to the rock strata is given below in Table No.B.5.1.

**Table No.B.5.1**

<b>Dia. Of Pile</b>	<b>Safe Capacity</b>		
	<b>Compression</b>	<b>Tension</b>	<b>Shear</b>
<b>50 cms</b>	<b>110</b>	<b>23</b>	<b>1.30</b>
<b>60 cms</b>	<b>180</b>	<b>29</b>	<b>1.70</b>
<b>70 cms</b>	<b>280</b>	<b>35</b>	<b>2.10</b>
<b>80 cms</b>	<b>375</b>	<b>40</b>	<b>2.70</b>

- B.5.2 It is also suggested that the carrying capacities of the piles given above shall be verified by Conducting Initial pile load test as per relevant clauses of IS 2911(Part-4)-2013.
- B.5.3 In case of lightly loaded structures, it is recommended to use Shallow foundations for light weight and non-sensitive structures using the following allowable bearing capacities.

**Table No: B.5.2 (Square footing)**

Size of footing (m)	Depth below EGL	Safe Bearing capacity (T/M <sup>2</sup> )
2.0 x 2.0	1.0 m	1.25
	1.5 m	1.50
3.0 x 3.0	1.0 m	1.25
	1.5 m	1.80

- B.5.4 It is suggested to improve the soils in the shallow depths by Sand Piling Method to increase these bearing capacities to certain extent. The increased SBC values are as given in table below :

**Table No: B.5.3 (Square footing)**

Size of footing (m)	Depth below EGL	Safe Bearing capacity (T/M <sup>2</sup> )
2.0 x 2.0	1.0 m	4.00
	1.5 m	4.10
3.0 x 3.0	1.0 m	4.20
	1.5 m	4.80

- B.5.5 The suggestions given in this report are based on the results of tests on sub-soil samples collected from the bore-holes. If in actual execution any variation is found, this office may also referred to.

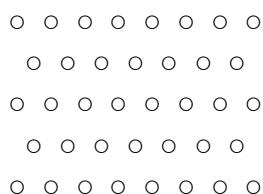
**For GEO FOUNDATIONS & STRUCTURES PVT LTD.,**

**A.V.S.CHAKRAVARTI**  
**M.Tech (Geotechnical Engg.)**  
**MIGS, MICI**  
**SR. GENERAL MANAGER**

### SPECIFICATIONS FOR SAND PILES

- The diameter of the sand piles for this site shall be 4" (100 mm) diameter and 7.0 mtr length below EGL. The centre to centre spacing of the sand piles shall be 30 cms in a triangular pattern / zigzag manner. M Sand of Zone II / Zone III classification used for concreting works shall be used for these sand piles.
- The suggested method of installation will be similar to driven cast in situ concrete piles, using a casing pipe with its bottom closed with a detachable shoe, except that the material for the pile consists of sand. Ramming of the sand poured in to the casing pipe shall be done in layers of 300 mm thickness, inside the casing pipe. A casing pipe with a hinged closed bottom which can only open downwards (while pouring the sand into the casing pipe) or a dispensable / detachable shoe at the bottom of the casing pipe may be used. The dispensable shoe can be of a conical shaped mild steel plate or concrete.
- Each layer of sand poured shall be rammed with a rammer having a bottom plate diameter of 150 mm. The weight of the rammer shall be at least 75 to 100 kg and it shall be dropped with a free fall of about 1.5 m.
- The effective actual diameter of the sand piles will be much larger than the casing pipe inner diameter of 100 mm, due to ramming / compaction of sand. This solidifies the neighboring loose sandy soil thus improving the N values resulting the increase in bearing capacity.
- These sand piles shall be driven in a triangular pattern for footings / along the radius in case of circular rafts. Sand piles shall be driven with an extra offset of about 1000 mm all around the periphery of the size of footings. On completion of all the sand piles, a layer of sand is spread out below the PCC area. There shall not be any clay intrusion between the top of the sand piles and the sand layer.

The arrangement for sand piles shall be with a 30cms c/c spacing in both directions



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**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

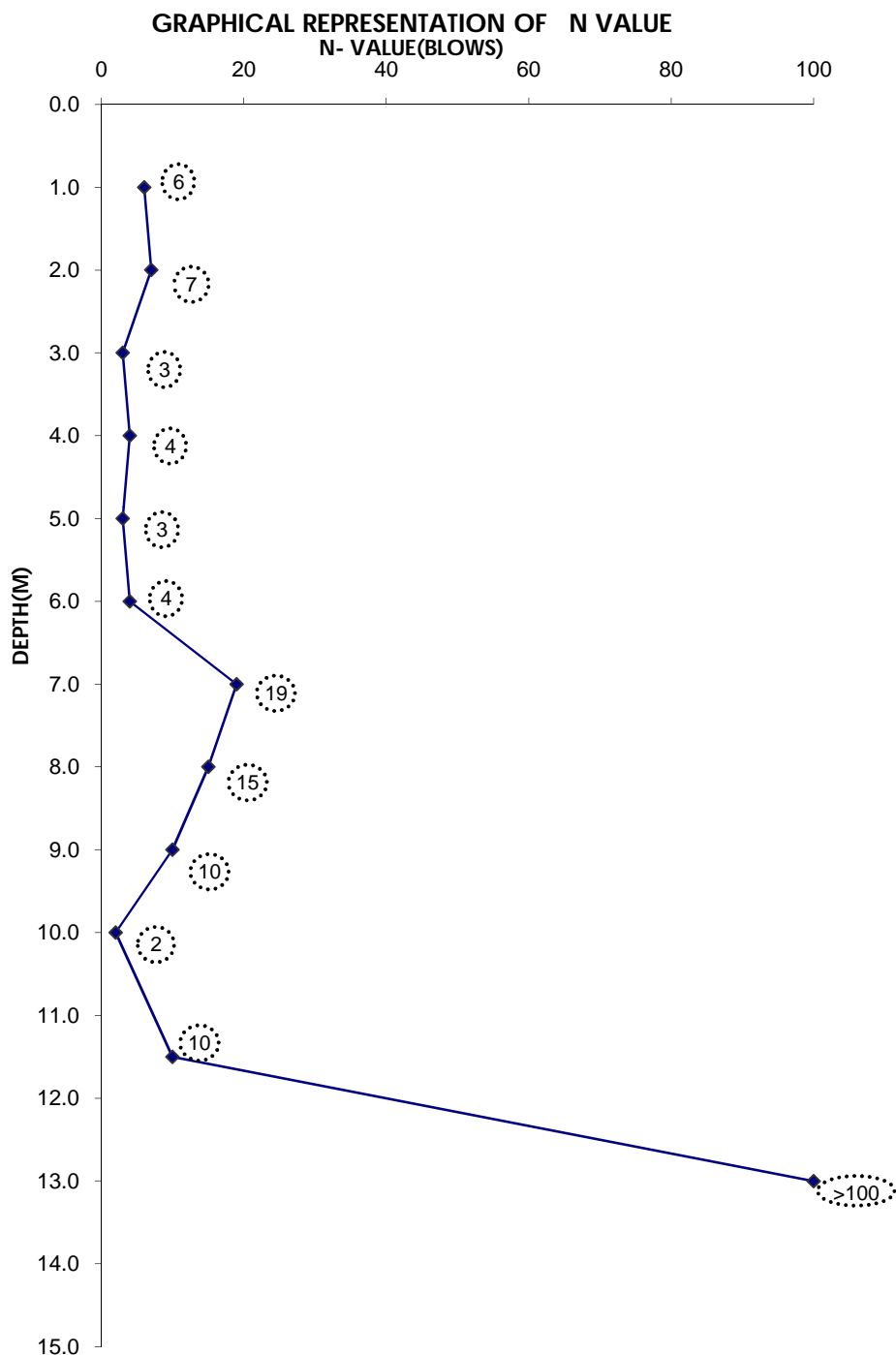
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-06**  
Type of Boring : Rotary  
Ground Water Level : 0.85m

Date of Boring Started : 07.05.2021  
Date of Boring Completed : 07.05.2021  
Termination Depth : 15.00 M



**TC-5397**



**BORE HOLE TERMINATED AT 15.00 M**

**FIG.36**





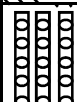
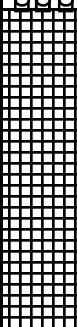

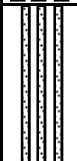



NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 1000 MT AMMONIA STORAGE														
		<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>		Bore Hole No : <b>BH-06</b> Type of Boring : Rotary Termination Depth : 15.0 M Reduced Level :		Boring Started : 07.05.2021 Boring Completed : 07.05.2021 Ground Water Level : 0.85 M Co-ordinates :				 <b>TC-5397</b>				
LOCATION : Compressor House														
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSI FICATI ON	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS	
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>		
	0.20	Concrete with rock pebbles												
	1.00	Sandy clayey silt with gravel(W/brown)	CI	1.00	1.00-1.45	2	3	3	6					
	1.60	Gravelly silty sand (R/brown)	GM-SM	2.00	2.00-2.45	3	3	4	7					
	4.00	Silty sand with gravel and clay(Br./grey)	SM-SC	3.00	3.00-3.45	2	1	2	3					
				4.00	4.00-4.45	1	2	2	4					
				5.00	5.00-5.45	1	1	2	3					
				6.00	6.00-6.45	1	2	2	4					
				7.00	7.00-7.45	8	9	10	19					
	2.90	Gravelly silty sand (R/brown)	GM-SM	8.00	8.00-8.45	11	9	6	15					
				9.00	9.00-9.45	4	5	5	10					
				10.0	10.0-10.45	1	1	1	2					
	3.30	Silty sadn with presence of clay (White)  Silty sand (Br./white)	SM	11.5	11.5-11.95	4	4	6	10					
				13.5										
				14.5	13.0 to 14.0	DRILLING DONE USING DIAMOND BIT			60	15				
	2.00	Rock		15.5	14.0 to 15.0	DRILLING DONE USING DIAMOND BIT			72	39				
Termination Depth : 15.0m														
Note : UDS- Undisturbed Sample														
SPT "N"-Standard Penetration Test "N"														

Fig :37

<div></div>			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE TANK																<div> TC-5397</div>			
			LOCATION : Compressor house	Ground Water Level : 0.85m	Date of Boring Started : 07.05.2021 Boring completed : 07.05.2021 Termination Depth : 15.0m						Table No.:10			ULR-TC539720000000253F								
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	CLASSIFICATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part-3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986				
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)		
BOREHOLE BH-06																						
6	1.00	SPT-01	Sandy clayey silt with gravel (W/brown)	CI	6	28	40	26	24	47	23	24										
7	2.00	SPT-02	Gravely silty sand(R/brown)	GM-SM	49	26	23	2	18	No Limit					2.59	1.57	1.33	DST	0.05	22		
3	3.00	SPT-03	Silty sand with gravel and clay (Br./grey)	SM-SC	28	38	22	12	23	38	NP	-										
4	4.00	SPT-04	Silty sand with gravel and clay (Br./grey)	SM-SC	31	36	22	11	32													
3	5.00	SPT-05	Silty sand with gravel and clay (Br./grey)	SM-SC																		
4	6.00	SPT-06	Silty sand with gravel and clay (Br./grey)	SM-SC	28	31	29	12	31	39	NP	-			2.57	1.59	1.21	DST	0.18	24		
19	7.00	SPT-07	Gravely silty sand(R/brown)	GM-SM	50	30	18	2	19	No Limit												
15	8.00	SPT-08	Gravely silty sand(R/brown)	GM-SM					27													
10	9.00	SPT-09	Gravely silty sand(R/brown)	GM-SM	47	36	15	2	23	No Limit												
2	10.0	SPT-10	Silty sand with presence of clay (White)	SM	1	74	20	5	22	No Limit												
10	11.5	SPT-11	Silty sand(Br./white)	SM	1	70	29	0	21	No Limit					2.63	1.64	1.36	DST	0	28		
	13.0 to 15.0		Rock																			

:99:

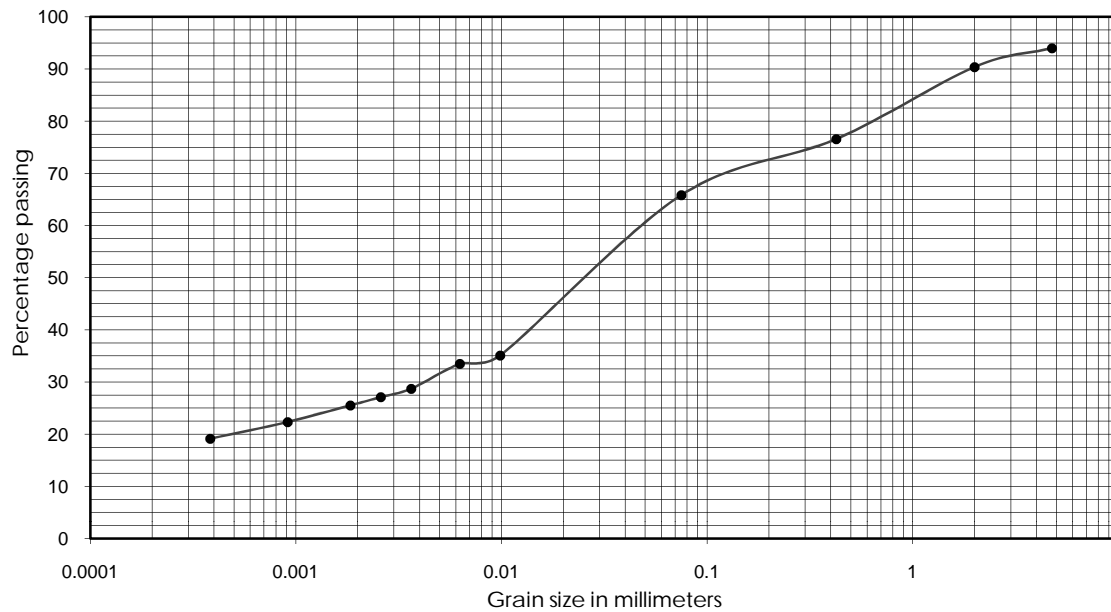


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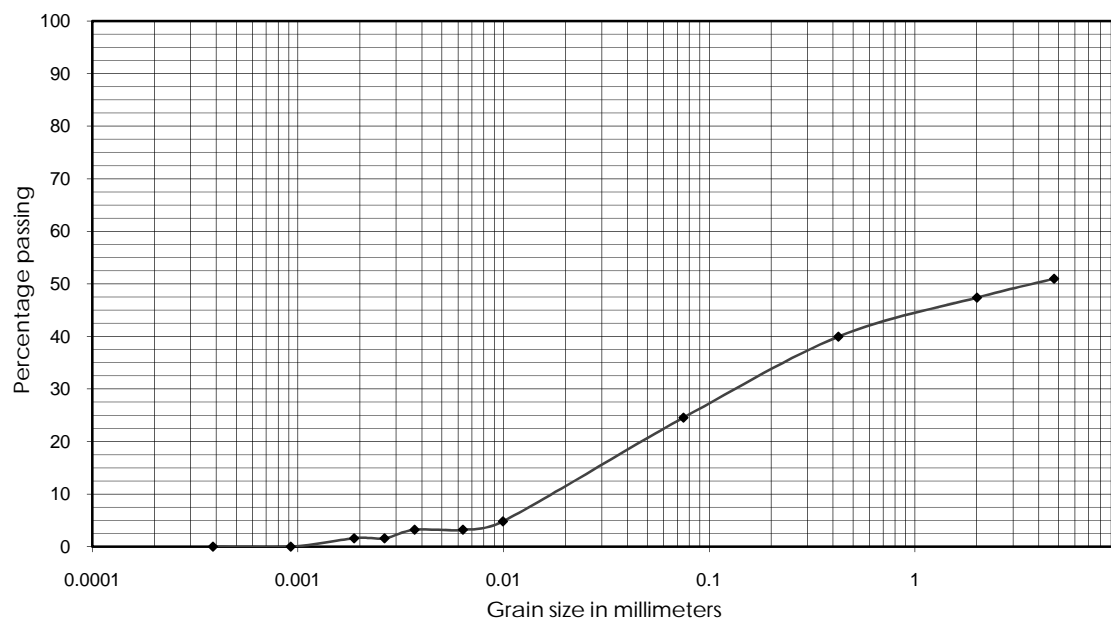


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-06	1.00	CI	6	28	40	26			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-06	2.00	GM-SM	49	26	23	2			

FIG.38

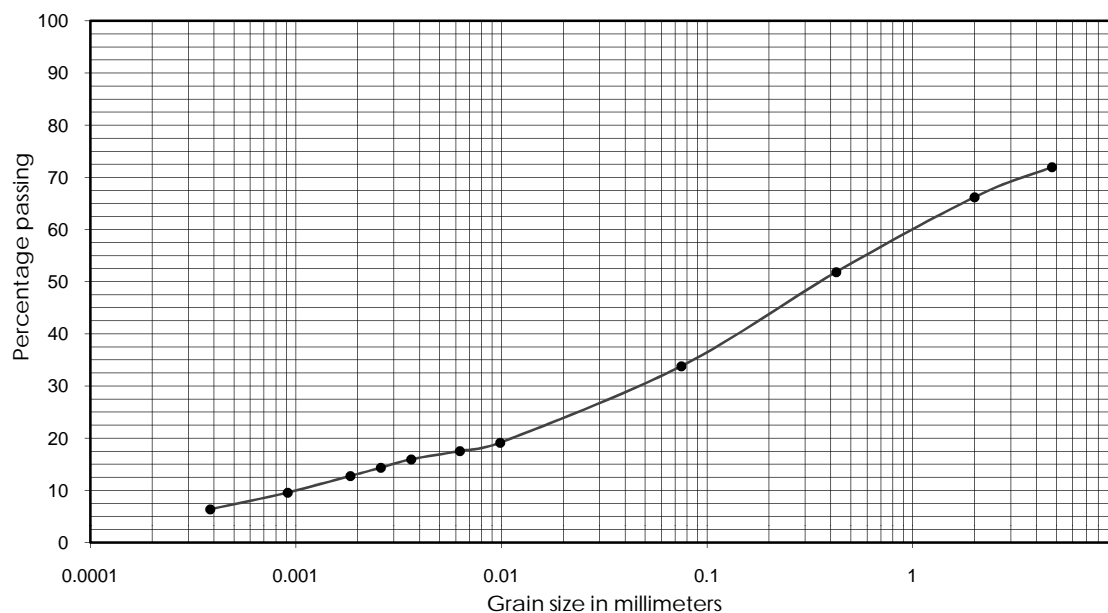


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

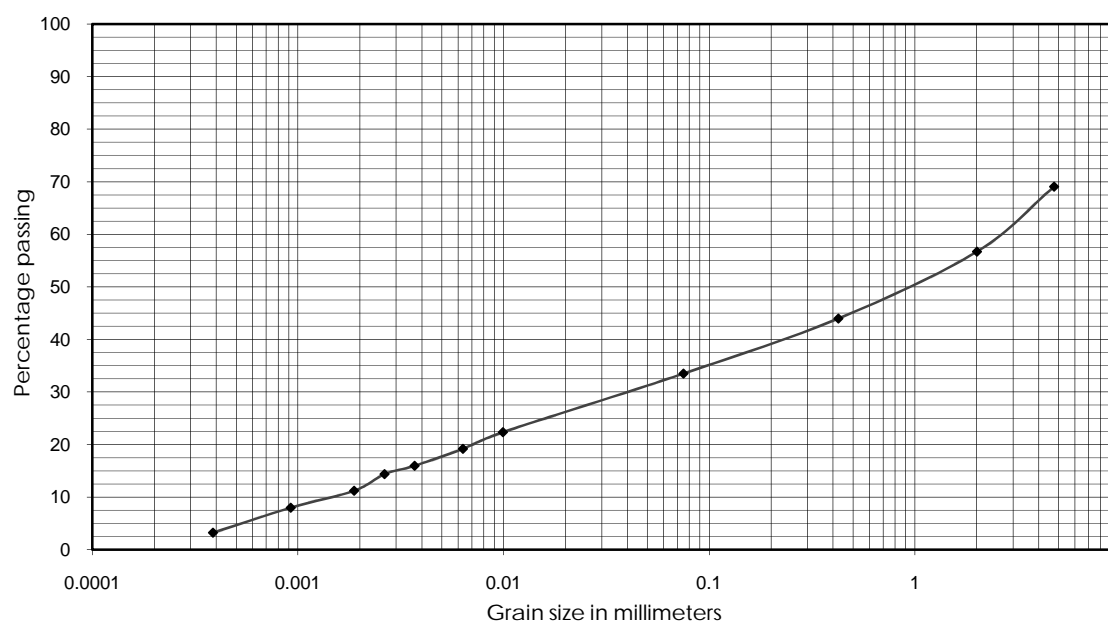


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-06	3.00	SM-SC	28	38	22	12			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-06	4.00	SM-SC	31	36	22	11			

FIG.39

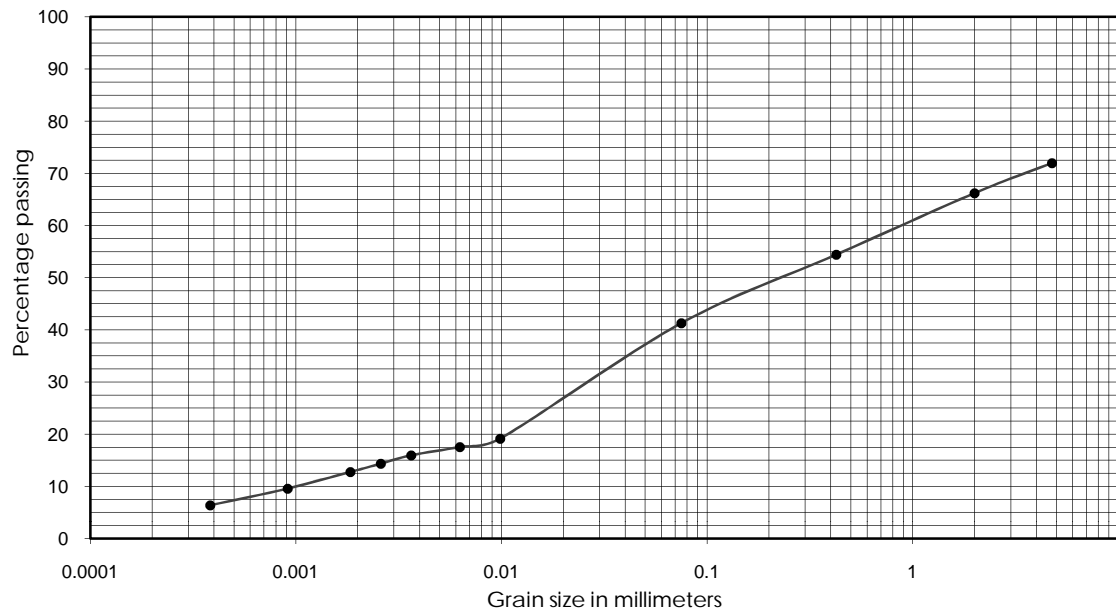


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

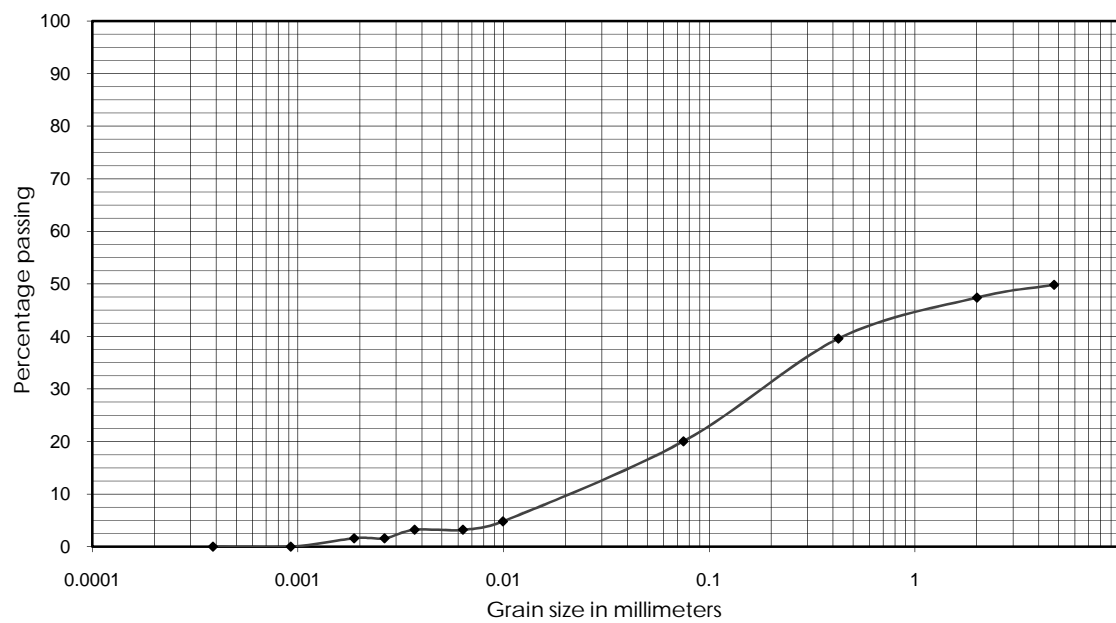


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-06	6.00	SM-SC	28	31	29	12			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-06	7.00	GM-SM	50	30	18	2			

FIG.40

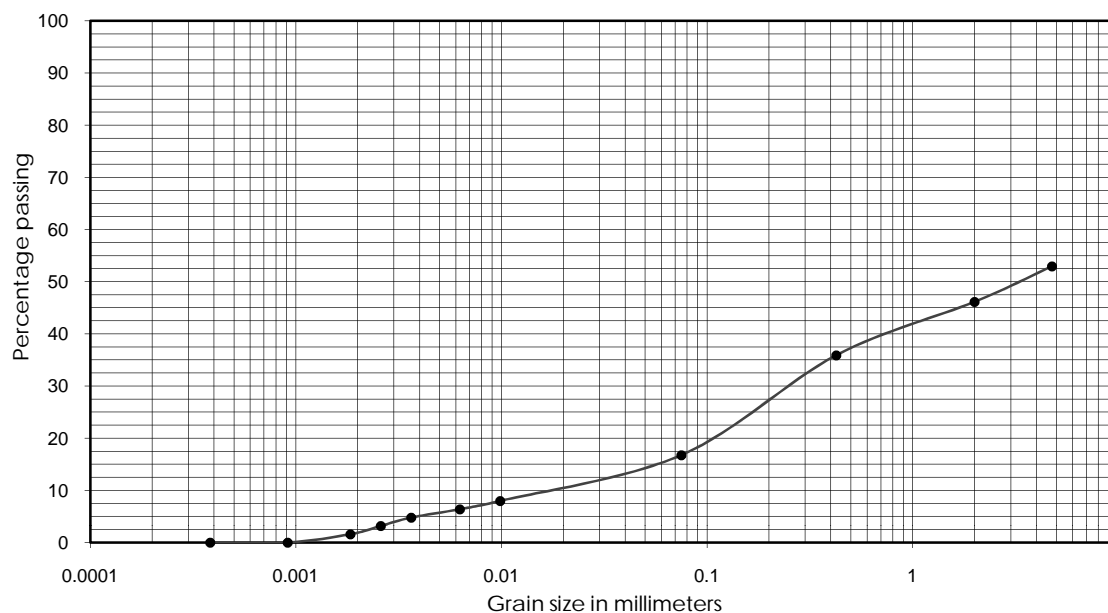


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

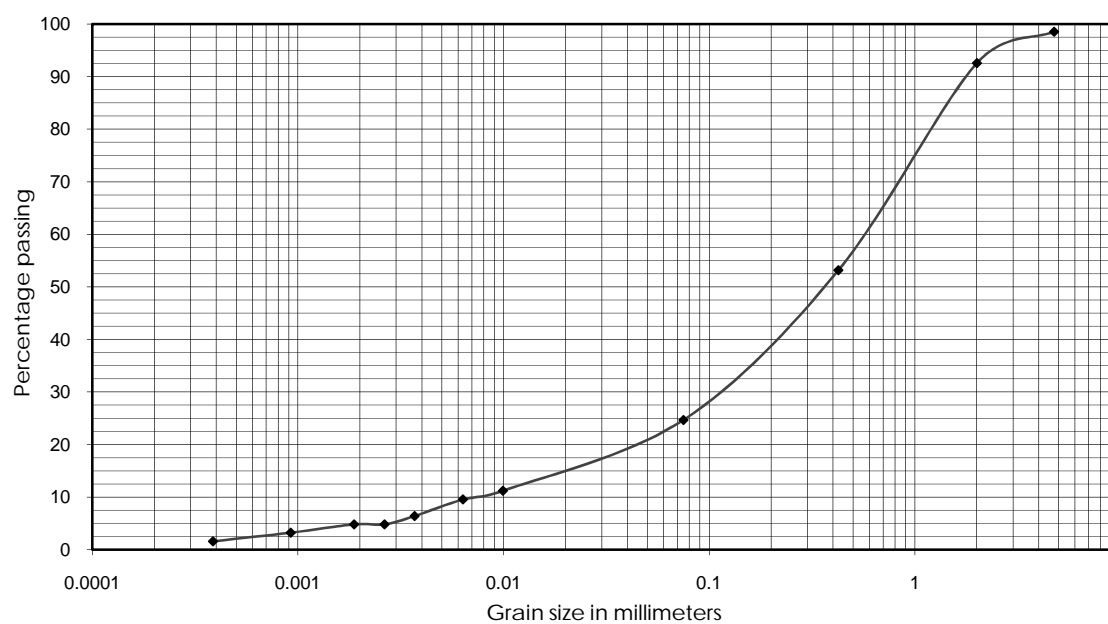


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST





BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-06	9.00	GM-SM	47	36	15	2			



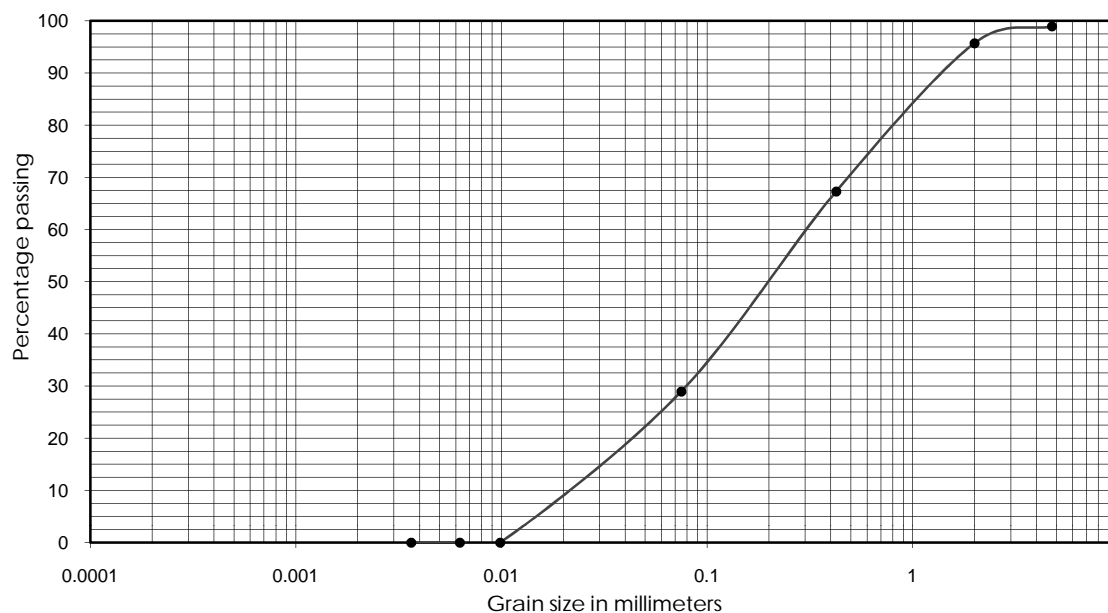
BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-06	10.00	SM	1	74	20	5			

FIG.41

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-06	11.50	SM	1	70	29	0			

FIG.42

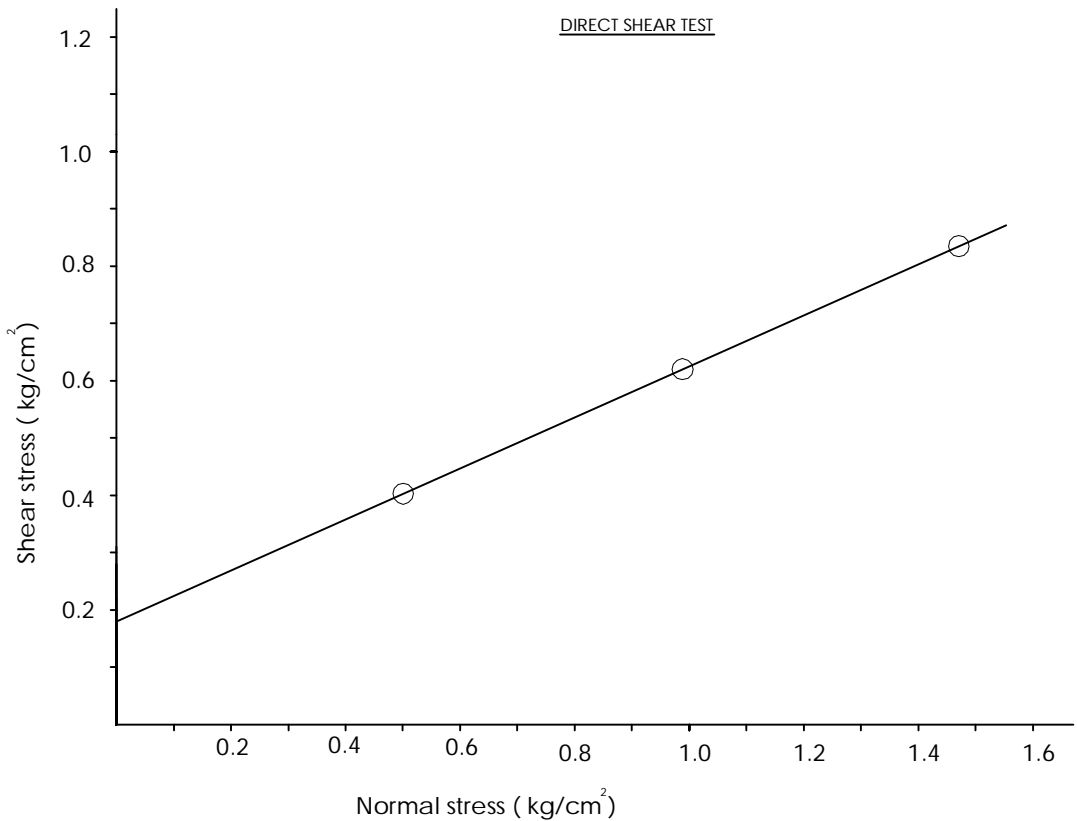


Fig. (43)

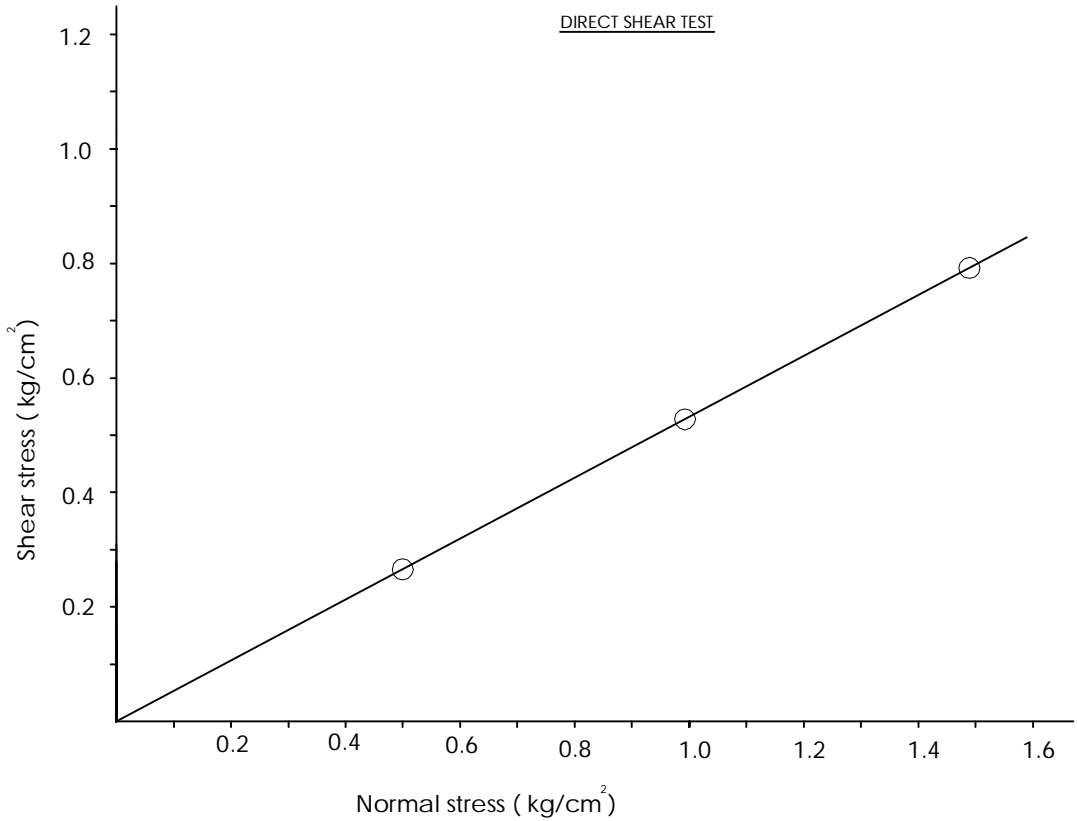


Fig. (44)

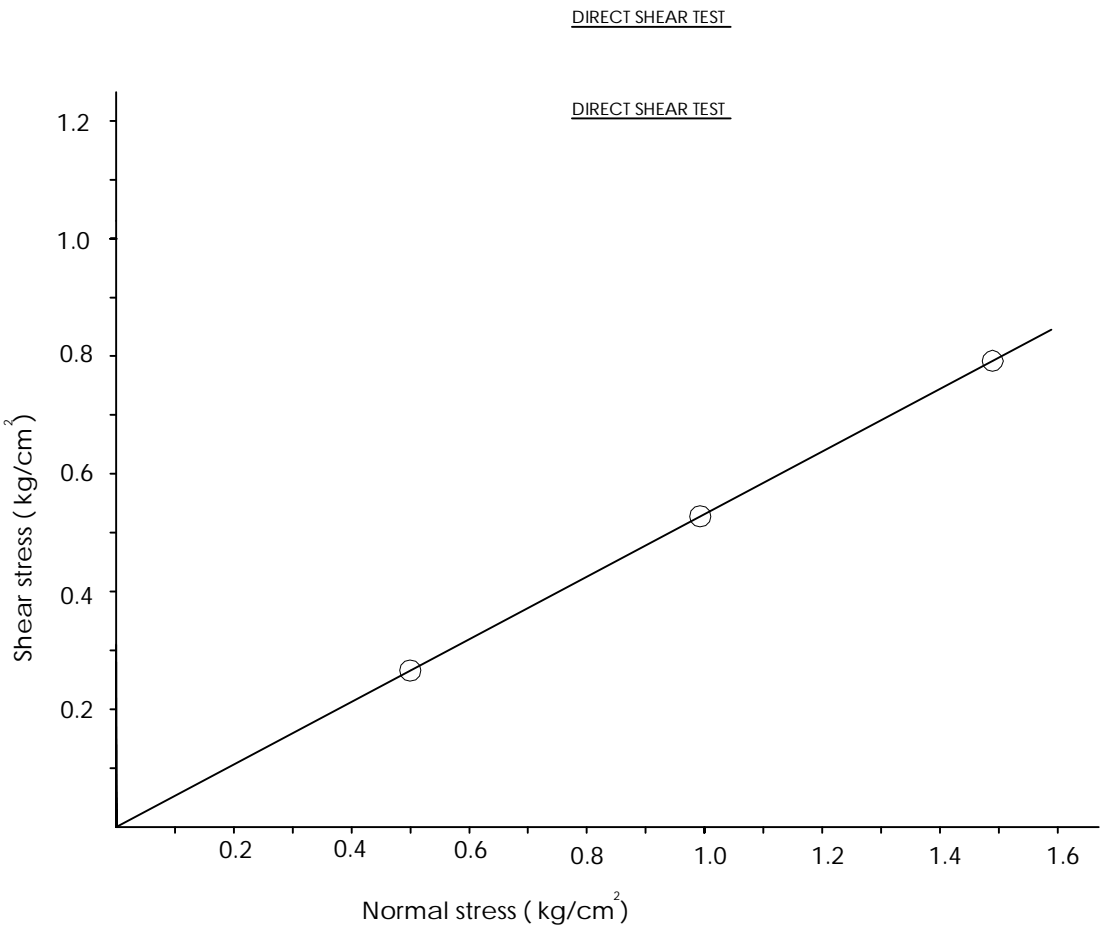


Fig. (44 A)

## **ANNEXURE – C**

### **Cooling Tower**

**(BH-07)**

## **C.1 SITESOIL DESCRIPTION**

- C.1.1 **BH - 07** :The strata at this borehole location is predominantly medium silty sandy natured soils even upto about 14.50mtr from existing ground level. The soil is lateritic in nature by visual identification and classification / stratification after lab analysis is as given in the borelog sheet. Soft rocky strata is available from 14.5 m to 15.5 m. Strata improved to medium rock with RCR of 20% and 30% in two metre of drilling. Though the rock samples are observed to be of granitic nature of black and white streaks, RQD is NIL may be due to the presence of closely spaced discontinuities.

## **C. 2 DISCUSSION ON TYPE OF FOUNDATION**

- C.2.1 The proposed structure at this location is a Cooling Tower in an area of 15 x 22 mtr and height of about 10 m. Based on these dimensions, it can be understood that the structure will also induce more of lateral loads /moments at the ground level in addition to the vertical loads.
- C.2.2 From the Borelog & results table of the borehole study, though the soils are silty sandy in nature, with the SPT "N" values being less than 15. Rock is available at varying depths from the ground level.
- C.2.3 With the project site located in Kerala, which is categorized in Zone III of Seismic Map of India, the presence of loose sandy soils with N values less than 15 in the shallow depths, even upto 14.5 m, indicate the possibility of liquefaction.
- C.2.4 Referring to the Pt. No.4 of Notes given along with Table No.1 (cl.6.3.5.2) of IS : 1893 (Part 1) – 2016, wherein it mentions that the minimum 'N' value required is 15 and above to avoid liquefaction in sandy soils. It is because, in case the soils are induced to seismic loadings there may be undue settlements to the structure because of liquefaction, in case if shallow foundations are provided. Otherwise it suggests adopting of suitable ground improvement technique to improve the natural soil conditions or alternatively, provided deep foundation thus transferring the loads to firm strata below.

C.2.5 Hence it is found necessary that the loads coming from the structure need to be transferred to a firm stratum. Based on the soil condition and the availability of rocky strata, pile foundation shall be a better foundation system for the proposed structure with these piles resting in the rocky strata available below 14.0 mtr depth.

C.2.6 RCC bored cast in situ piles by DMC method installed as per the relevant clauses of IS 2911 : Part 1 / Sec 2 - 2010 shall be provided as the foundation. It is suggested that piles shall be socketed into rocky strata by one time the diameter of piles (1 D).

C.2.6 The length of piles is expected to be about 14.5mtr plus socket length below the existing ground level. Socketing by one times the diameter of piles (1D) into rocky strata is to ensure the end bearing component of the carrying capacity. The safe carrying capacities for different diameters of piles calculated as per relevant clauses of above said IS Code are tabulated and given below in Table **No.C.2.1**. A factor of safety of 2.5 is considered for calculating the safe capacities.

**Table No: C.2.1**

Dia. Of Pile	Safe Capacity (T)		
	Compression	Tension	Shear
60 cms	165	25	3.30
70 cms	270	34	4.20
80 cms	400	42	5.30
90 cms	500	52	6.40

C.2.7. It is also suggested that the carrying capacities of the piles given above shall be verified by conducting pile load test as per relevant clauses of IS 2911(Part-4)-2013.

### **C.3 METHOD OF COMPUTING CAPACITIES FOR PILE FOUNDATIONS:**

Safe capacity of RCC Bored cast-in-situ pile can be computed by using the formula given in IS: 2911 (Part-1/Sec-2)-2010:

Ultimate bearing capacity  $Q_u$  of piles in Cohesion less soil:

$$Q_u = A_p(0.5.D.\gamma.N_\gamma + PD.N_q) + \sum_{i=1}^n k_i . PD_i . \tan \delta . A_{s_i}$$

Where,

$A_p$  = Cross sectional area of pile toe in  $\text{cm}^2$

$D$  = Stem dia. in cm

$\gamma$  = effective unit weight of soil at pile toe in  $\text{kg / cm}^3$

$PD$  = effective overburden pressure in  $\text{Kg / cm}^2$

$N_\gamma$  and  $N_q$  = bearing capacity factors depending upon the angle of internal friction  $\phi$  at toe

$\sum_{i=1}^n$  = Summation of  $N$  layers in which pile is installed

$K$  = Coefficient of earth pressure

$PD_i$  = effective overburden pressure in  $\text{Kg / cm}^2$  for the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

$\delta$  = angle of wall friction between pile and soil in degree (may be taken equal to  $\phi$ )

$A_{s_i}$  = Surface area of pile stem in  $\text{cm}^2$  in the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

#### **For cohesive soil:-**

Safe capacity of pile =  $1/F \{A_p.N_c.C_p + \alpha . C.A_s\}$

Where

$A_p$  - c/s area of pile toe in  $\text{cm}^2$

$N_c$  - bearing capacity factor

$C_p$  - average cohesion at pile tip in  $\text{Kg/cm}^2$

$\alpha$  - Reduction factor

$C$  – average cohesion throughout the length of pile in  $\text{Kg/cm}^2$

$S$  - Surface area of pile shaft in  $\text{cm}^2$

$F$  - Factor of safety.

**C.4 CONCLUDING REMARKS**

- C.4.1 RCC Bored cast in situ piles to be considered for the proposed structure. The Safe capacities for different diameter of piles at different depth socketed by one times the diameter of piles in to the rocky strata is given below in Table No.C.4.1.

**Table No.C.4.1**

<b>Dia. Of Pile</b>	<b>Safe Capacity</b>		
	<b>Compression</b>	<b>Tension</b>	<b>Shear</b>
<b>60 cms</b>	<b>165</b>	<b>25</b>	<b>3.30</b>
<b>70 cms</b>	<b>270</b>	<b>34</b>	<b>4.20</b>
<b>80 cms</b>	<b>400</b>	<b>42</b>	<b>5.30</b>
<b>90 cms</b>	<b>500</b>	<b>52</b>	<b>6.40</b>

- C.4.2 It is also suggested that the carrying capacities of the piles given above shall be verified by Conducting Initial pile load test as per relevant clauses of IS 2911(Part-4)-2013.
- C.4.3 The suggestions given in this report are based on the results of tests on sub-soil samples collected from the bore-holes. If in actual execution any variation is found, this office may also referred to.

**For GEO FOUNDATIONS & STRUCTURES PVT LTD.,**

**A.V.S.CHAKRAVARTI**  
**M.Tech (Geotechnical Engg.)**  
**MIGS, MICI**  
**SR. GENERAL MANAGER**

**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

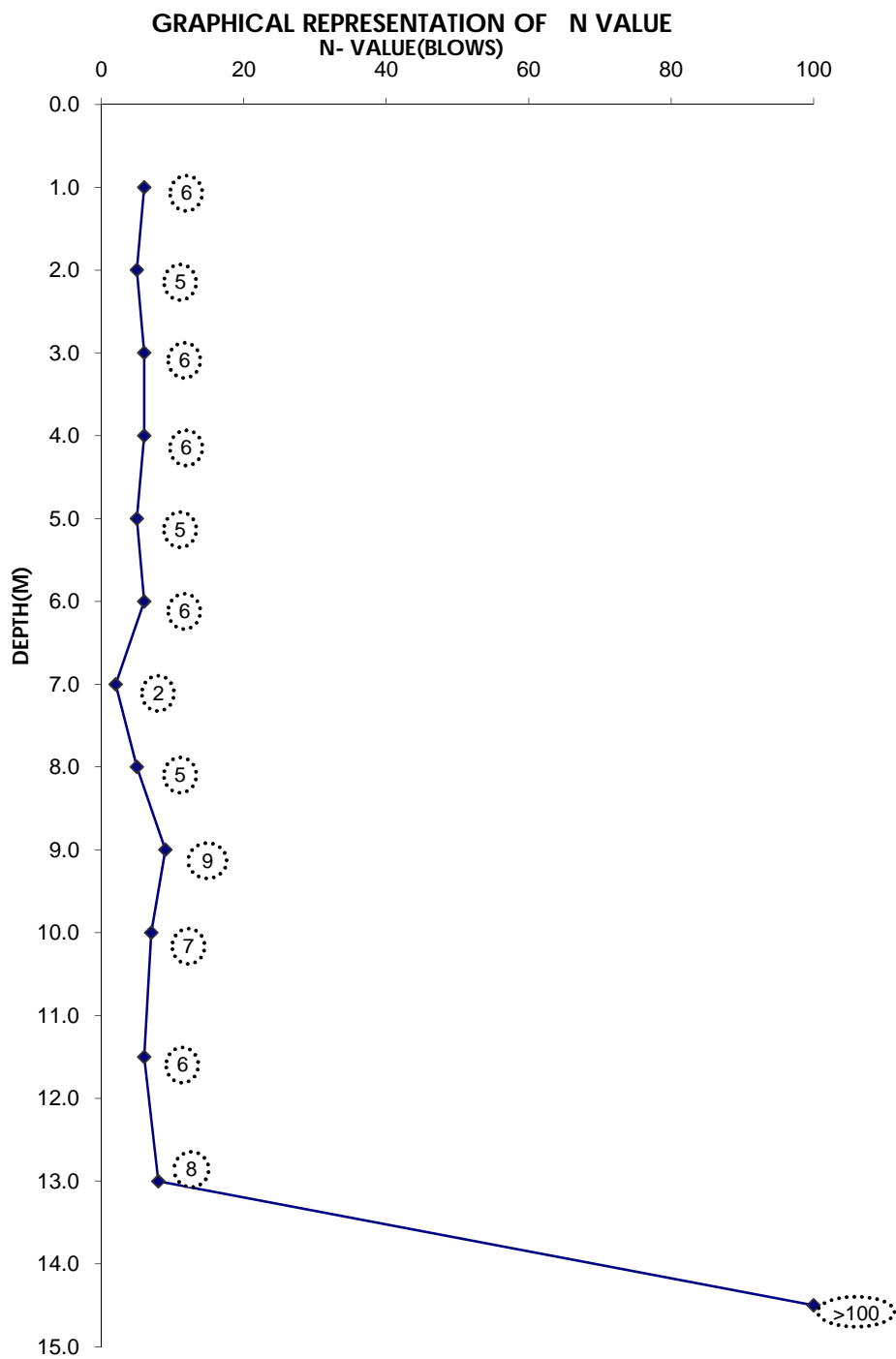
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-07**  
Type of Boring : Rotary  
Ground Water Level : 0.40m

Date of Boring Started : 06.05.2021  
Date of Boring Completed : 06.05.2021  
Termination Depth : 17.50 M



**TC-5397**



**BORE HOLE TERMINATED AT 17.50 M**

**FIG.45**










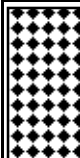


NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE													
	GEO FOUNDATIONS & STRUCTURES PVT. LTD	Bore Hole No : BH-07		Boring Started : 06.05.2021		 TC-5397							
		Type of Boring : Rotary		Boring Completed : 06.05.2021									
		Termination Depth : 17.5 M		Ground Water Level : 0.40 M									
		Reduced Level :		Co-ordinates :									
LOCATION : Cooling Tower													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	0.20	Concrete with Rock Pebbles											
	2.60	Gravely silty sand (Red)	GM-SM	1.00	1.00-1.45	2	3	3	6				By Point load index
				2.00	2.00-2.45	3	3	2	5				
	1.00	Clayey sand with presence of gravel (Gr./brown)	SC	3.00	3.00-3.45	2	3	3	6				
				4.00	4.00-4.45	2	4	2	6				
	1.10	Gravely silty sand (R/Brown)	GM-SM	5.00	5.00-5.45	3	2	3	5				
				6.00	6.00-6.45	4	3	3	6				
	2.80	Clayey sand with presence of gravel (Grey)	SC	7.00	7.00-7.45	1	1	1	2				
				8.00	8.00-8.45	2	2	3	5				
				9.00	9.00-9.45	3	4	5	9				
				10.0	10.0-10.45	3	3	4	7				
	2.50	Sandy clayey silt with gravel(Gr./red)	CH	11.5	11.5-11.95	2	2	4	6				
				13.0	13.0-13.45	3	3	5	8				
	1.00	Soft Rock		15.0	14.5 to 15.5	DRILLING DONE USING DIAMOND BIT			NIL	NIL	-		
				16.0	15.5 to 16.5	DRILLING DONE USING DIAMOND BIT			20	NIL	85		
	2.00	Rock		17.0	16.5 to 17.5	DRILLING DONE USING DIAMOND BIT			30	NIL	-		
				18.0									
Termination Depth : 17.5m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :46

<div></div>			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK														<div> TC-5397</div>			
			LOCATION : Cooling Tower	Ground Water Level : 0.40m	Date of Boring Started : 06.05.2021 Boring completed : 06.05.2021 Termination Depth : 17.5m			Table No.:11												
										ULR-TC539720000000234F										
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	CLASSIFICATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS 2720 (Part2):1973 NMC(%)	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	SpG IS 2720(Part-3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-07																				
6	1.00	SPT-01	Gravely silty sand(Red)	GM-SM	49	40	9	2	22	No Limit										
5	2.00	SPT-02	Gravely silty sand(Red)	GM-SM					28						2.63	1.61	1.26	DST	0.03	23
6	3.00	SPT-03	Clayey sand with presence of gravel(Gr./Brown)	SC	10	42	28	20	32	43	21	22								
6	4.00	SPT-04	Gravely silty sand (R/brown)	GM-SM	45	41	12	2	23	No Limit										
5	5.00	SPT-05	Silty sand with clay and gravel (Gr./brown)	SM-SC	30	39	17	14	30	36	NP	-								
6	6.00	SPT-06	Clayey sand with presence of gravel(Grey)	SC	8	47	28	17	23						2.57	1.57	1.28	DST	0.16	24
2	7.00	SPT-07	Clayey sand with presence of gravel(Grey)	SC					25	40	21	19								
5	8.00	SPT-08	Clayey sand with presence of gravel(Grey)	SC	10	48	24	18	24											
9	9.00	SPT-09	Sandy clayey silt with gravel (Gr./red)	CH	28	20	31	21	25	72	29	43								
7	10.0	SPT-10	Sandy clayey silt with gravel (Gr./red)	CH					27						2.44	1.52	1.20	UCS	0.24	-
6	11.5	SPT-11	Silty sand with presence of clay (White)	SM	1	72	23	4	20	No Limit										
8	13.0	SPT-12	Silty sand(Br./white)	SM	1	73	26	0	17	No Limit					2.59	1.50	1.28	DST	0	25
	14.5 to 15.5		Soft Rock																	
	15.5 to 17.5		Hard Rock																	

:08

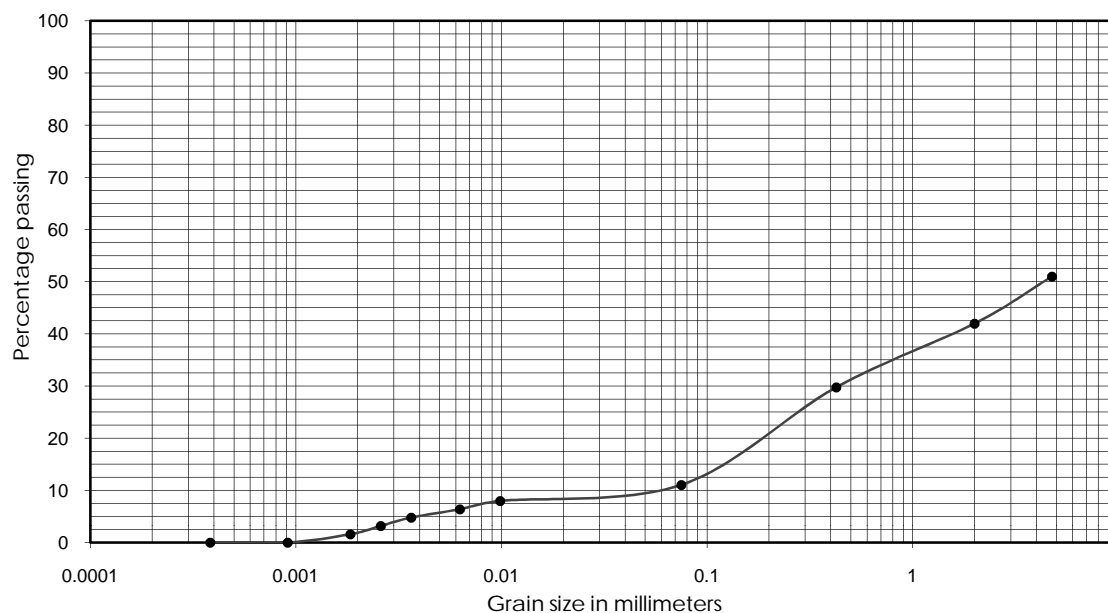


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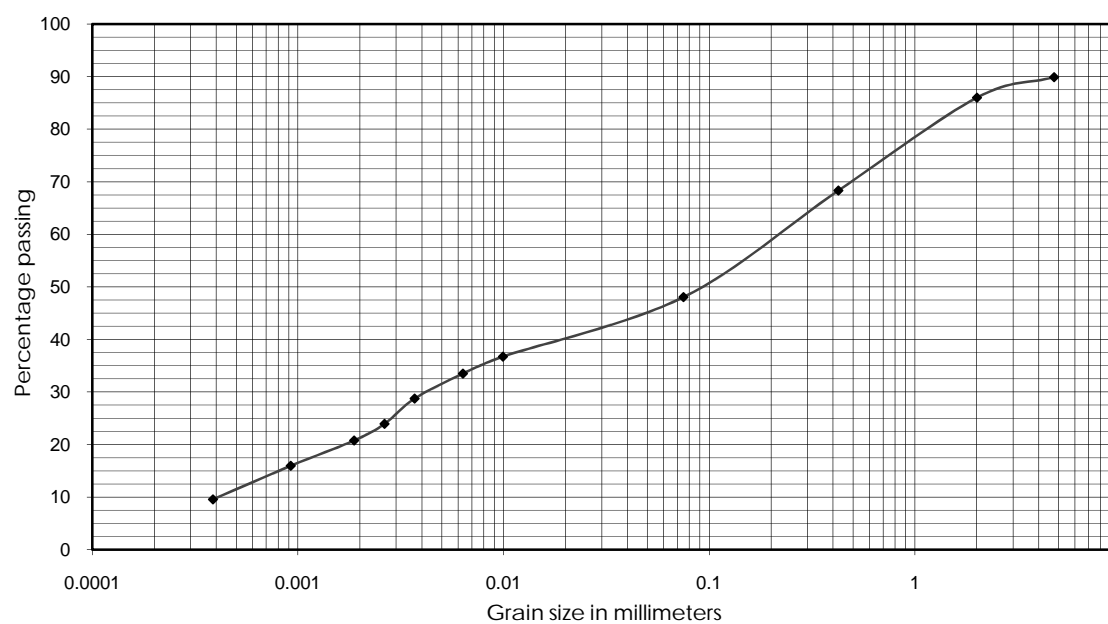


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-07	1.00	GM-SM	49	40	9	2			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-07	3.00	SC	10	42	28	20			

FIG.47

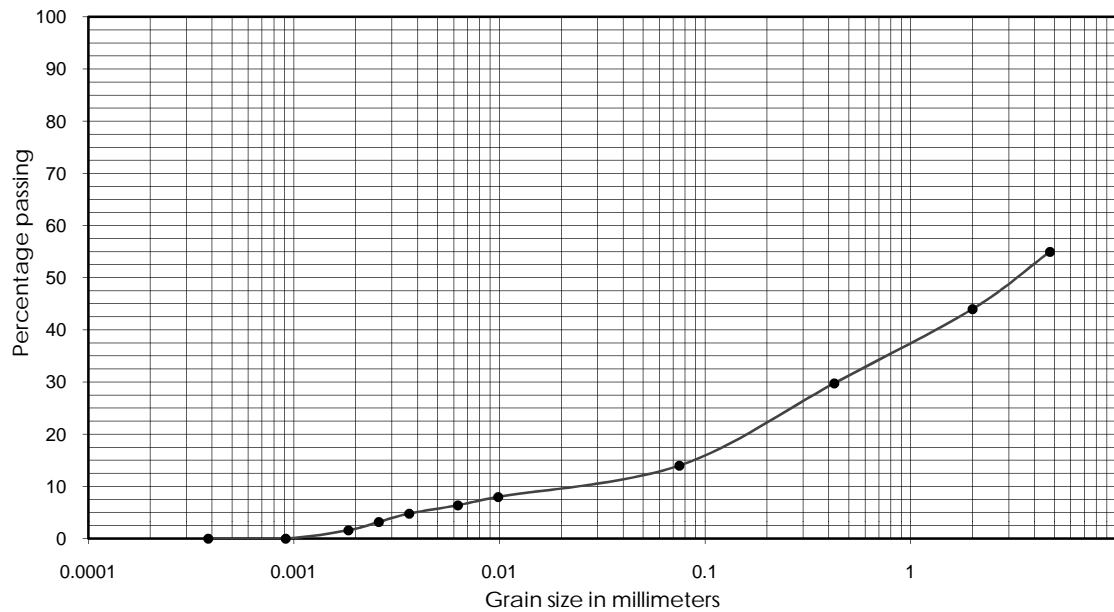


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

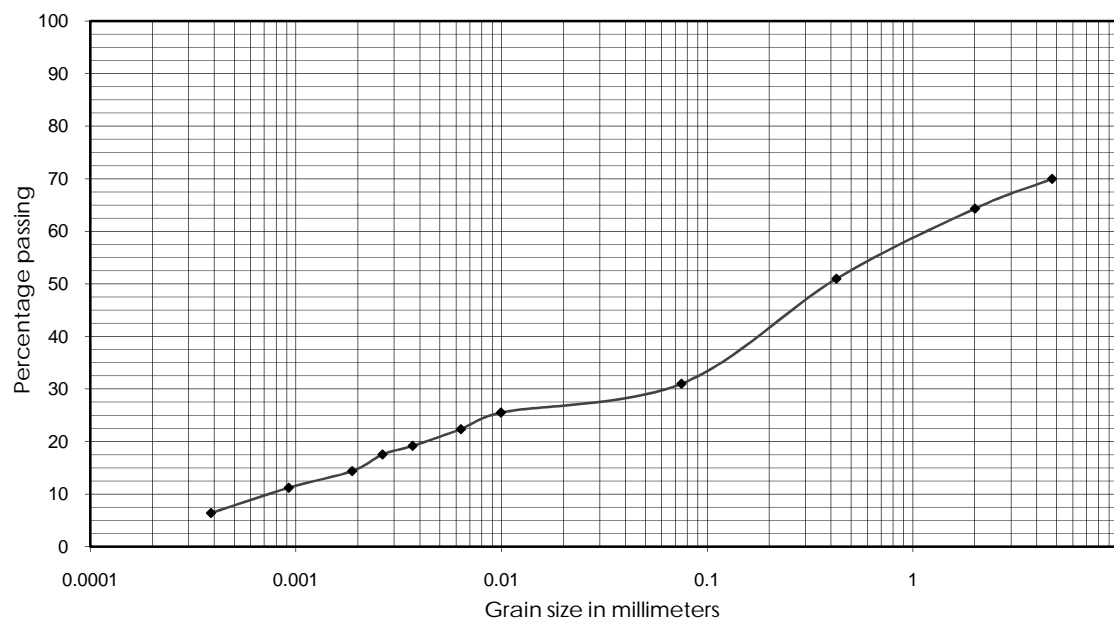


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-07	4.00	GM-SM	45	41	12	2			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-07	5.00	SM-SC	30	39	17	14			

FIG.48

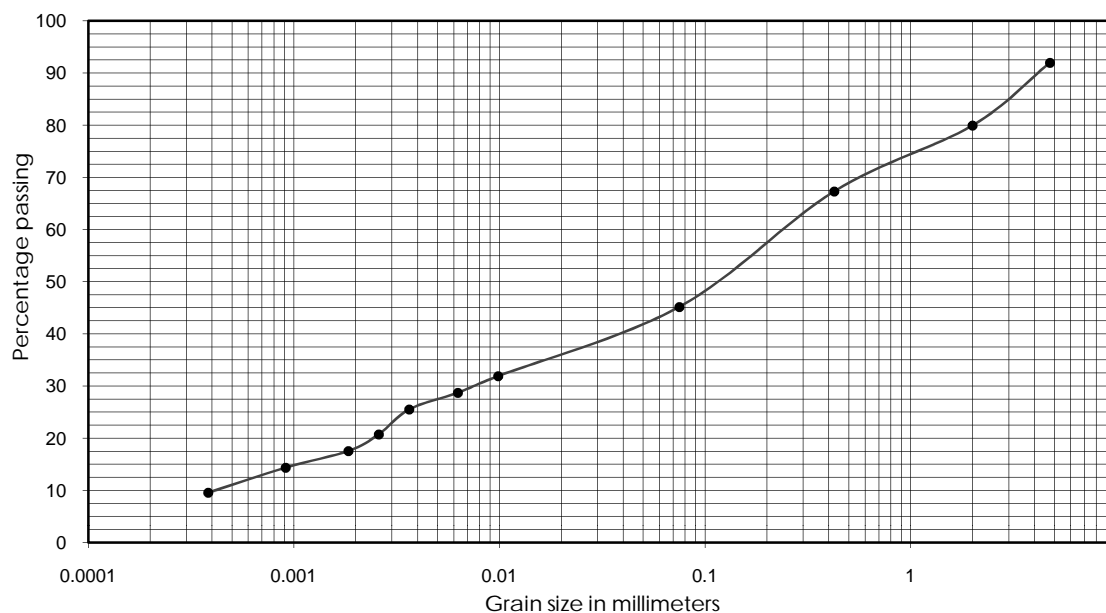


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

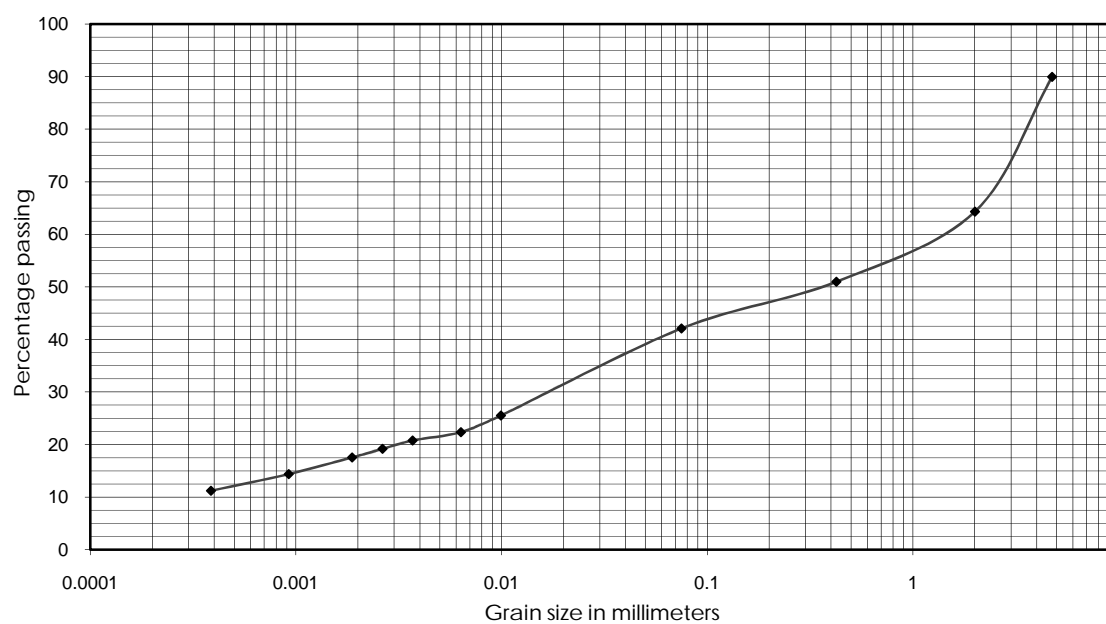


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-07	6.00	SC	8	47	28	17			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-07	8.00	SC	10	48	24	18			

FIG.49

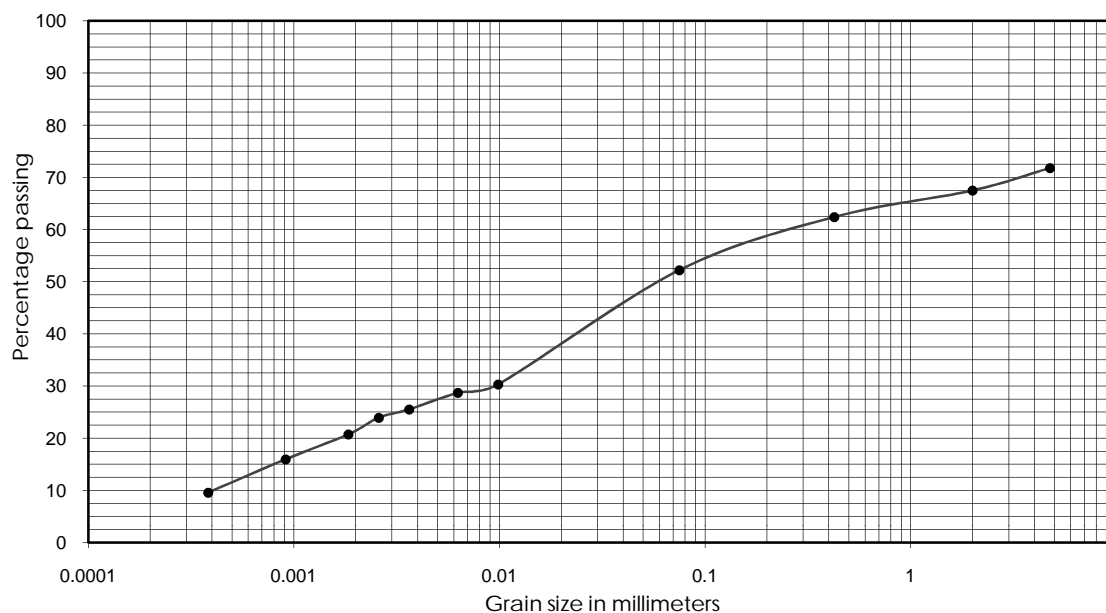


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

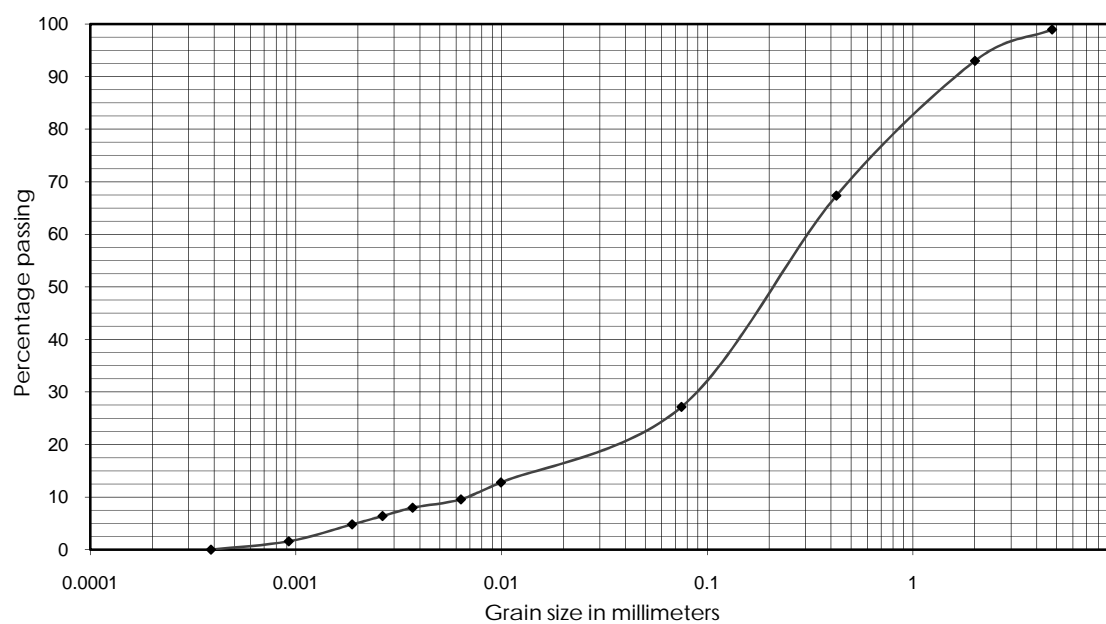


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST




BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-07	9.00	CH	28	20	31	21			



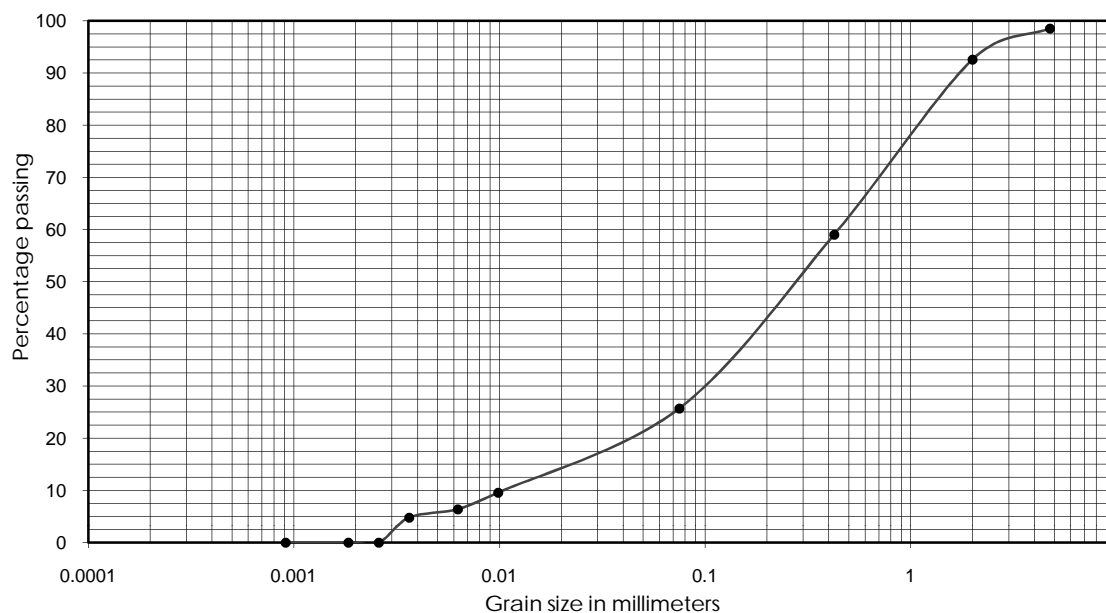
BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-07	11.50	SM	1	72	23	4			

FIG.50

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-07	13.00	SM	1	73	26	0			

FIG.51



BORE HOLE NO: BH-07  
SAMPLE NO : SPT-02  
DEPTH : 2.00 M  
 $C = 0.03 \text{ Kg/cm}^2$   $\phi = 23^\circ$

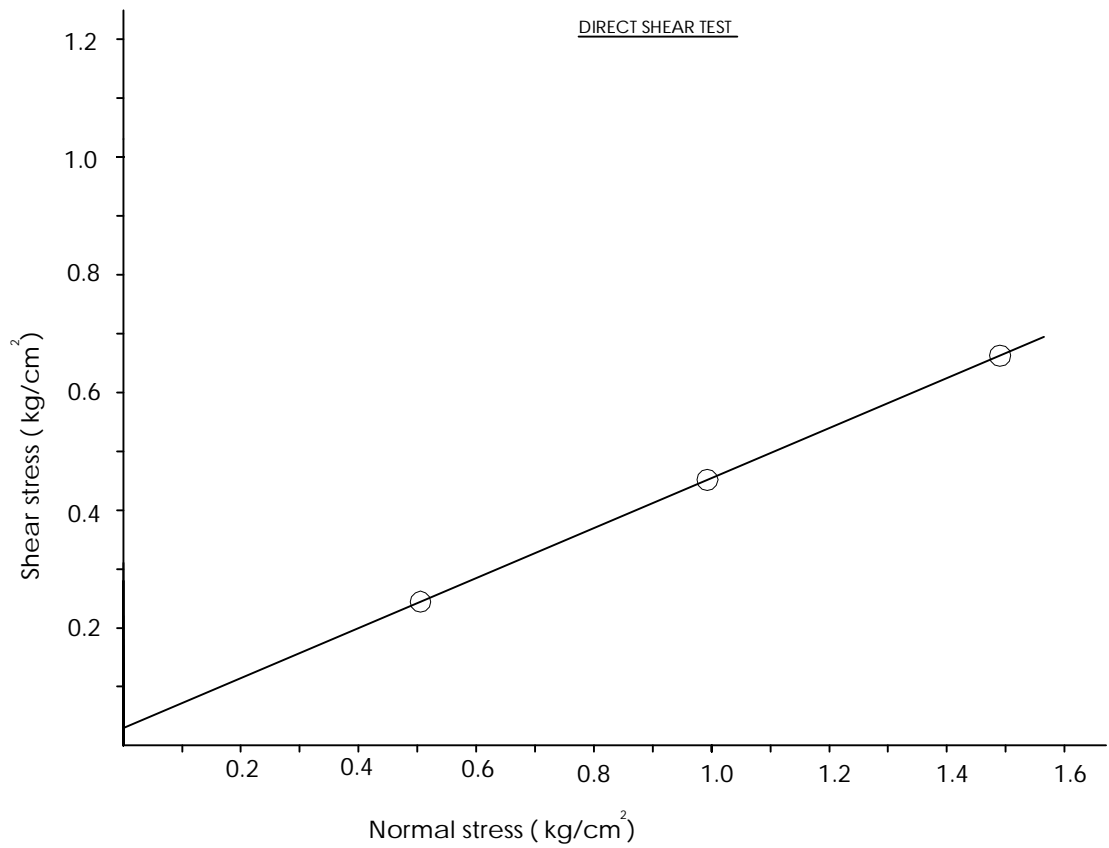


Fig. (52)

BORE HOLE NO: BH-07  
SAMPLE NO : SPT-06  
DEPTH : 6.00 M  
 $C = 0.16 \text{ Kg/cm}^2$   $\phi = 24^\circ$

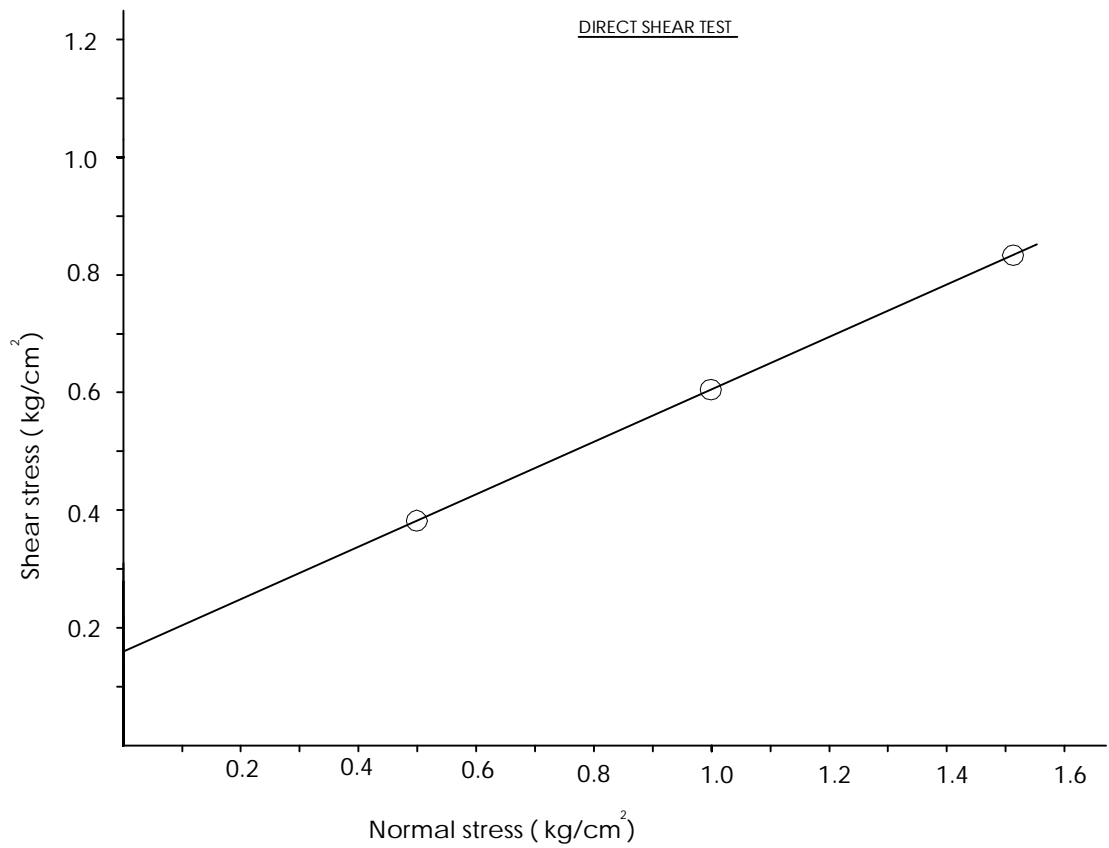


Fig. (53)

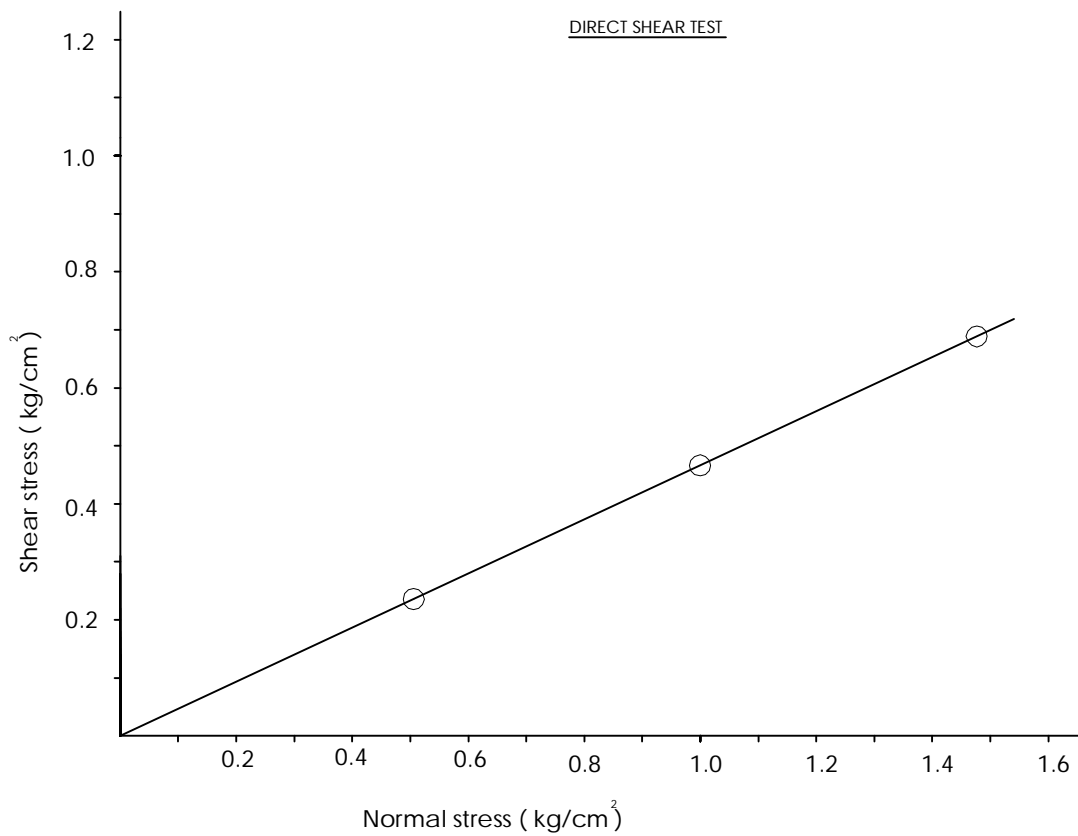


Fig. (54)

## **ANNEXURE – D**

### **FLARE STACK (BH-08)**

## **D.1 SITE SOIL DESCRIPTION**

D.1.1 **BH - 08** : The strata at this borehole location is medium silty sandy natured soils even upto about 3.80mtr from existing ground level. The soil is lateritic in nature by visual identification and classification / stratification after lab analysis is as given in the borelog sheet. Decayed wood is present from 3.80 mtr depth upto 5.80 mtr depth. The subsequent layer is identified as soft to medium stiff clay layer of high compressibility for a thickness of 6.50 mtr. A 2.20 m thick silty sandy soil layer is present before start of Soft rocky strata from 14.5 m to 16.20 m. Strata improved to medium hard rock with RCR and RQD values as given in the borelog. Rock samples are observed to be of granitic nature of black and white streaks.

## **D.2 DISCUSSION ON TYPE OF FOUNDATION**

D.2.1 The proposed structure at this location is a FLARE STACK of height of 30 mtr. Based on these dimensions, it can be understood that the structure will also induce more of lateral loads /moments at the ground level in addition to the vertical loads.

D.2.2 From the Borelog & results table of the borehole study (BH 08), the soils are silty sandy in nature in the shallow depths with the SPT "N" values being less than 15 followed by a decayed wood layer and medium clayey soil. Based on the dimensions of the structure, shallow foundations cannot be suggested as foundation.

D.2.3 Moreover, with the project site located in Kerala, which is categorized in Zone III of Seismic Map of India, the presence of loose sandy soils with N values less than 15 in the shallow depths upto 3.80 m, indicate the possibility of liquefaction.

D.2.4 Referring to the Pt. No.4 of Notes given along with Table No.1 (cl.6.3.5.2) of IS : 1893 (Part 1) – 2016, wherein it mentions that the minimum 'N' value required is 15 and above to avoid liquefaction in sandy soils. It is because, in case the soils are induced to seismic loadings there may be undue settlements to the structure because of liquefaction, in case if shallow foundations are provided. Otherwise it suggests adopting of suitable ground improvement technique to improve the natural soil conditions or alternatively, provided deep foundation thus transferring the loads to firm strata below.

D.2.5 Hence it is found necessary that the loads coming from the structure need to be transferred to a firm stratum. Based on the soil condition and the availability of rocky strata, pile foundation shall be a better foundation system for the proposed structure with these piles resting in the rocky strata available below 14.0 mtr depth.

D.2.6 RCC bored cast in situ piles by DMC method installed as per the relevant clauses of IS 2911 : Part 1 / Sec 2 - 2010 shall be provided as the foundation. It is suggested that piles shall be socketed into rocky strata by one time the diameter of piles (1 D).

D.2.7 The length of piles is expected to be about 14.5mtr plus socket length below the existing ground level. Socketing by one times the diameter of piles (1D) into rocky strata is to ensure the end bearing component of the carrying capacity. The safe carrying capacities for different diameters of piles calculated as per relevant clauses of above said IS Code are tabulated and given below in Table **No.D.2.1**. A factor of safety of 2.5 is considered for calculating the safe capacities.

**Table No: D.2.1**

Dia. Of Pile	Safe Capacity (T)		
	Compression	Tension	Shear
60 cms	150	19	2.60
70 cms	230	25	3.30
80 cms	340	33	4.20

D.2.7. It is also suggested that the carrying capacities of the piles given above shall be verified by conducting pile load test as per relevant clauses of IS 2911(Part-4)-2013.

### **D.3 METHOD OF COMPUTING CAPACITIES FOR PILE FOUNDATIONS:**

Safe capacity of RCC Bored cast-in-situ pile can be computed by using the formula given in IS: 2911 (Part-1/Sec-2)-2010:

Ultimate bearing capacity  $Q_u$  of piles in Cohesion less soil:

$$Q_u = A_p(0.5 \cdot D \cdot \gamma \cdot N_\gamma + P \cdot D \cdot N_q) + \sum_{i=1}^n k_i \cdot P \cdot D_i \cdot \tan \delta_i \cdot A_{si}$$

Where,

$A_p$  = Cross sectional area of pile toe in  $\text{cm}^2$

$D$  = Stem dia. in cm

$\gamma$  = effective unit weight of soil at pile toe in  $\text{kg / cm}^3$

$P_D$  = effective overburden pressure in  $\text{Kg / cm}^2$

$N_\gamma$  and  $N_q$  = bearing capacity factors depending upon the angle of internal friction  $\phi$  at toe

$i = n$

$\sum_{i=1}^n$  = Summation of  $N$  layers in which pile is installed

$K$  = Coefficient of earth pressure

$P_{Di}$  = effective overburden pressure in  $\text{Kg / cm}^2$  for the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

$\delta$  = angle of wall friction between pile and soil in degree (may be taken equal to  $\phi$ )

$A_{si}$  = Surface area of pile stem in  $\text{cm}^2$  in the  $i^{\text{th}}$  layer where  $i$  varies from 1 to  $n$ .

#### **For cohesive soil:-**

Safe capacity of pile =  $1/F \{A_p \cdot N_c \cdot C_p + \alpha \cdot C \cdot A_s\}$

Where

$A_p$  - c/s area of pile toe in  $\text{cm}^2$

$N_c$  - bearing capacity factor

$C_p$  - average cohesion at pile tip in  $\text{Kg/cm}^2$

$\alpha$  - Reduction factor

$C$  – average cohesion throughout the length of pile in  $\text{Kg/cm}^2$

$S$  - Surface area of pile shaft in  $\text{cm}^2$

$F$  - Factor of safety.

**D.4 CONCLUDING REMARKS**

- D.4.1 RCC Bored cast in situ piles to be considered for the proposed structure. The Safecapacities for different diameter of piles at different depth socketed by one times the diameter of piles in to the rocky strata is given below in Table No.D.4.1.

**Table No.D.4.1**

Dia. Of Pile	Safe Capacity		
	Compression	Tension	Shear
60 cms	150	19	2.60
70 cms	230	25	3.30
80 cms	340	33	4.20

- D.4.2 It is also suggested that the carrying capacities of the piles given above shall be verified by Conducting Initial pile load test as per relevant clauses of IS 2911(Part-4)-2013.
- D.4.3 The suggestions given in this report are based on the results of tests on sub-soil samples collected from the bore-holes. If in actual execution any variation is found, this office may also referred to.

**For GEO FOUNDATIONS & STRUCTURES PVT LTD.,**

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**MIGS, MICI**  
**SR. GENERAL MANAGER**

**NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

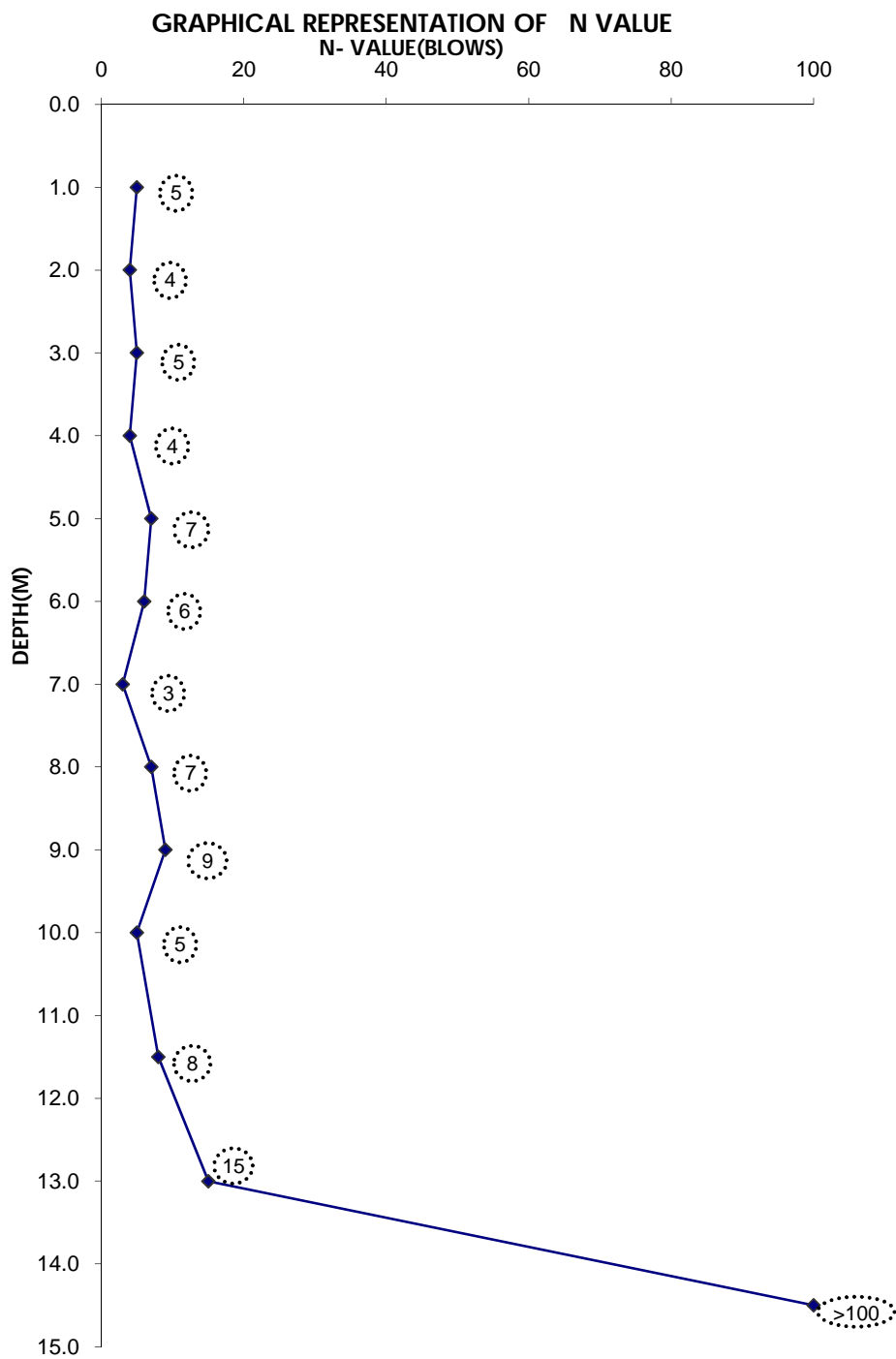
**GEO FOUNDATIONS  
& STRUCTURES  
PVT. LTD**

Bore Hole No : **BH-08**  
Type of Boring : Rotary  
Ground Water Level : 0.40m

Date of Boring Started : 04.05.2021  
Date of Boring Completed : 04.05.2021  
Termination Depth : 18.20 M



**TC-5397**



**BORE HOLE TERMINATED AT 18.20 M**

**FIG.55**





NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 10000 MT AMMONIA STORAGE																
		GEO FOUNDATIONS & STRUCTURES PVT. LTD		Bore Hole No : BH-08 Type of Boring : Rotary Termination Depth :18.20m Reduced Level :			Boring Started : 04.05.2021 Boring Completed : 05.05.2021 Ground Water Level : 0.40 M Co-ordinates :			 TC-5397						
LOCATION : Flair Store																
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS			
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>				
	1.90	Gravely silty sand (R/brown)\	GM-SM	1.00	1.00-1.45	2	2	3	5							
				2.00	2.00-2.45	1	2	2	4							
	1.90	Silty sand with presence of gravel (Grey)	SM	3.00	3.00-3.45	2	3	2	5							
				4.00	4.00-4.45	2	2	2	4							
	2.00	Decayed wood(Black)	OL	5.00	5.00-5.45	2	3	4	7							
				6.00	6.00-6.45	2	2	4	6							
	6.50	Sandy clayey silt with organic mayyer(Dark grey)	CH	7.00	7.00-7.45	1	2	1	3							
				8.00	8.00-8.45	3	4	3	7							
				9.00	9.00-9.45	4	4	5	9							
		Sandy clayey silt (Gr./red)		10.0	10.0-10.45	2	2	3	5							
				11.5	11.5-11.95	2	3	5	8							
				13.0	13.0-13.45	6	6	9	15							
	2.20	Silty sand with presence of gravel (Pale yellow)	SM	15.0												
				16.0	14.5 to 16.2	DRILLING DONE USING DIAMOND BIT			20					NIL		
	1.70	Soft Rock		17.0	16.2 to 17.2	DRILLING DONE USING DIAMOND BIT			40					23		
				18.0	17.2 to 18.2	DRILLING DONE USING DIAMOND BIT			68					31		
	2.00	Rock		19.0												
				19.0												
Termination Depth : 18.2m																
Note : UDS- Undisturbed Sample																
SPT "N"-Standard Penetration Test "N"																

Fig :56

<div></div>			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK														<div> TC-5397</div>			
			LOCATION : Flair Store	Ground Water Level : 0.40m	Date of Boring Started : 04.05.2021 Boring completed : 05.05.2021 Termination Depth : 18.2m			Table No.:12			ULR-TC539720000000234F									
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	CLASSIFICATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS NMC(%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part-3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986		
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø (°)
BOREHOLE BH-08																				
5	1.00	SPT-01	Gravely silty sand(R/brown)	GM-SM	42	39	15	4	30	No Limit										
4	2.00	SPT-02	Silty sand with presence of gravel(Grey)	SM	8	62	30	0	32	No Limit					2.64	1.55	1.17	DST	0	24
5	3.00	SPT-03	Silty sand with presence of gravel(Grey)	SM	11	65	24	0	30	No Limit										
4	4.00	SPT-04	Decayed wood(Black)	OL																
7	5.00	SPT-05	Decayed wood(Black)	OL																
6	6.00	SPT-06	Sandy clayey silt with presence of organic matter(Dark grey)	CH	0	18	47	35	78	85	30	55								
3	7.00	SPT-07	Sandy clayey silt with organic matter (Dark grey)	CH	2	24	37	37	251											
7	8.00	SPT-08	Sandy clayey silt(Gr./red)	CH	6	22	38	34	29						2.42	1.50	1.16	UCS	0.26	
9	9.00	SPT-09	Sandy clayey silt(Gr./red)	CH	5	20	44	31	23	70	28	42								
5	10.0	SPT-10	Sandy clayey silt(Gr./red)						29											
8	11.5	SPT-11	Sandy clayey silt(Gr./red)	CH	7	18	42	33	32											
15	13.0	SPT-12	Silty sand with presence of gravel(Pale yellow)	SM	10	83	7	0	22	No Limit					2.63	1.57	1.29	DST	0	29
	14.5 to 16.2		Soft Rock																	
	16.2 to 18.2		Hard Rock																	

:95:

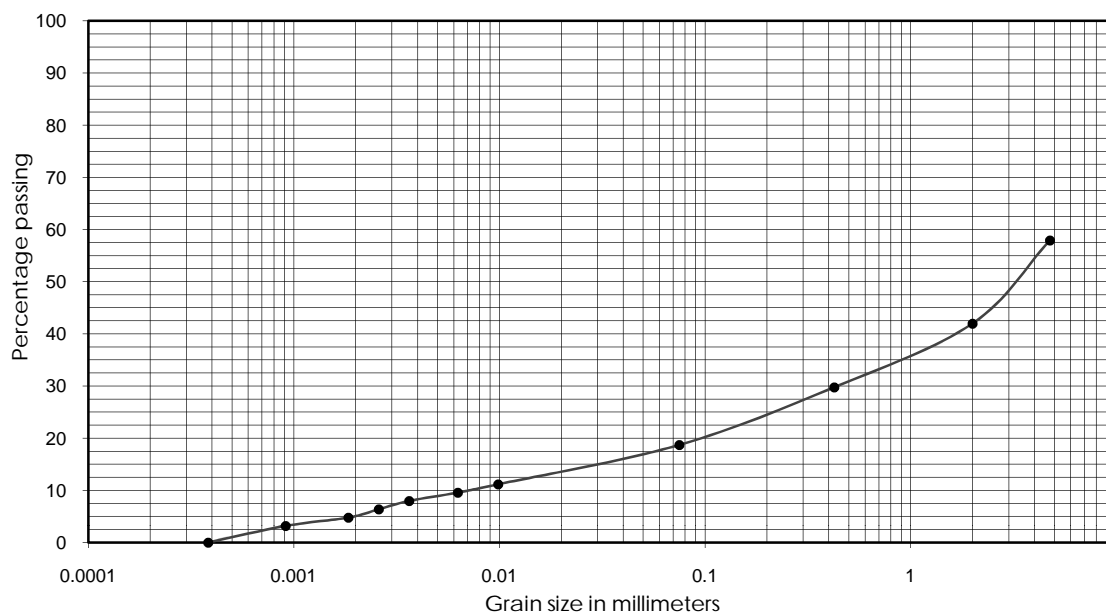


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

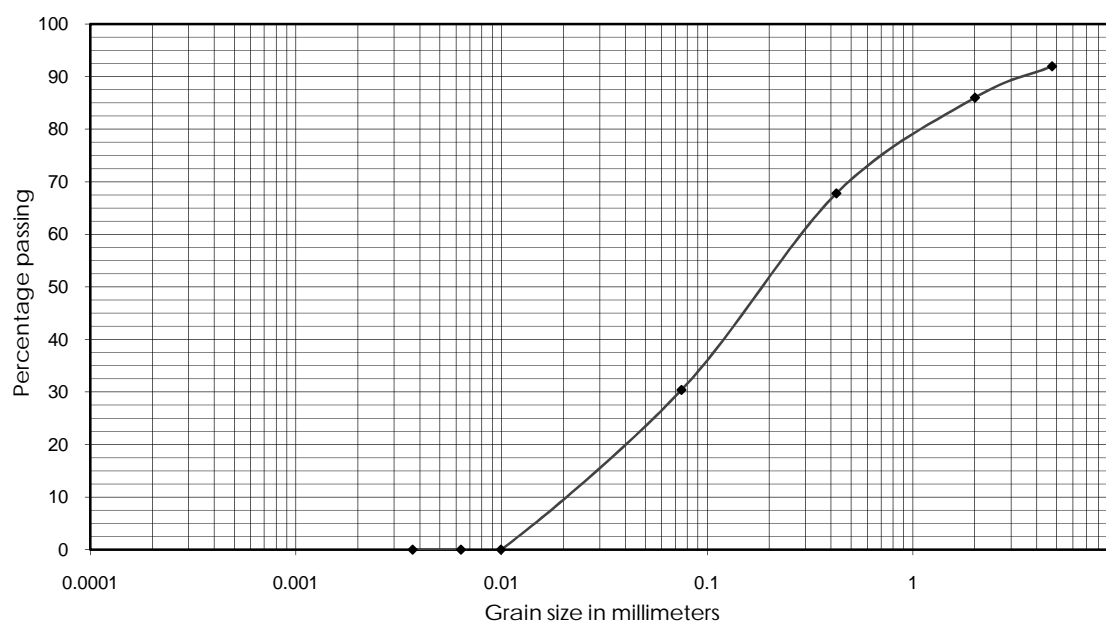


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-08	1.00	GM-SM	42	39	15	4			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-08	2.00	SM	8	62	30	0			

FIG.57

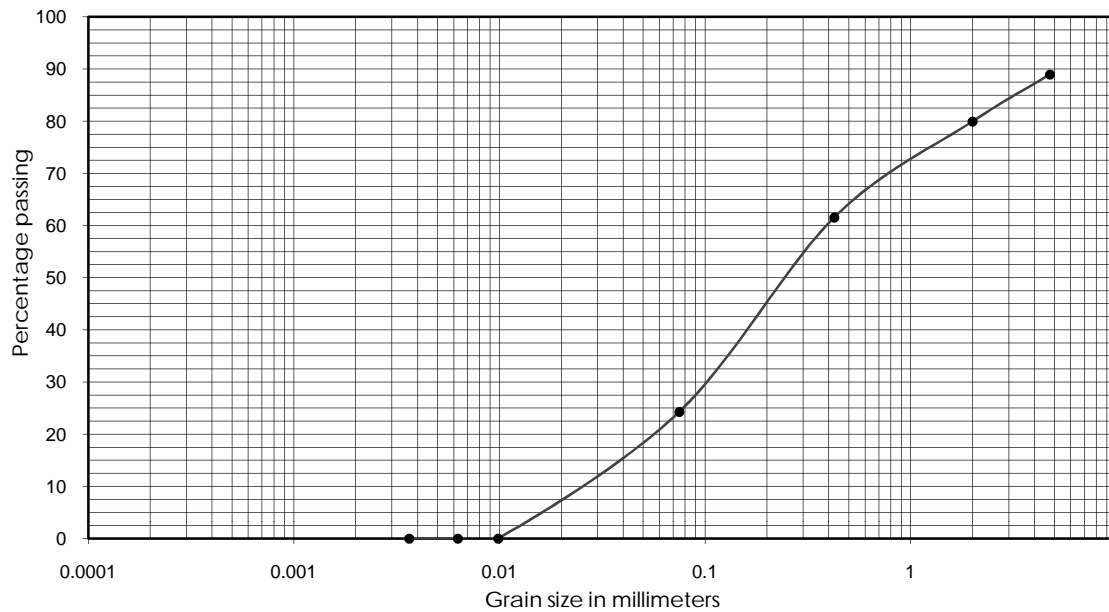


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

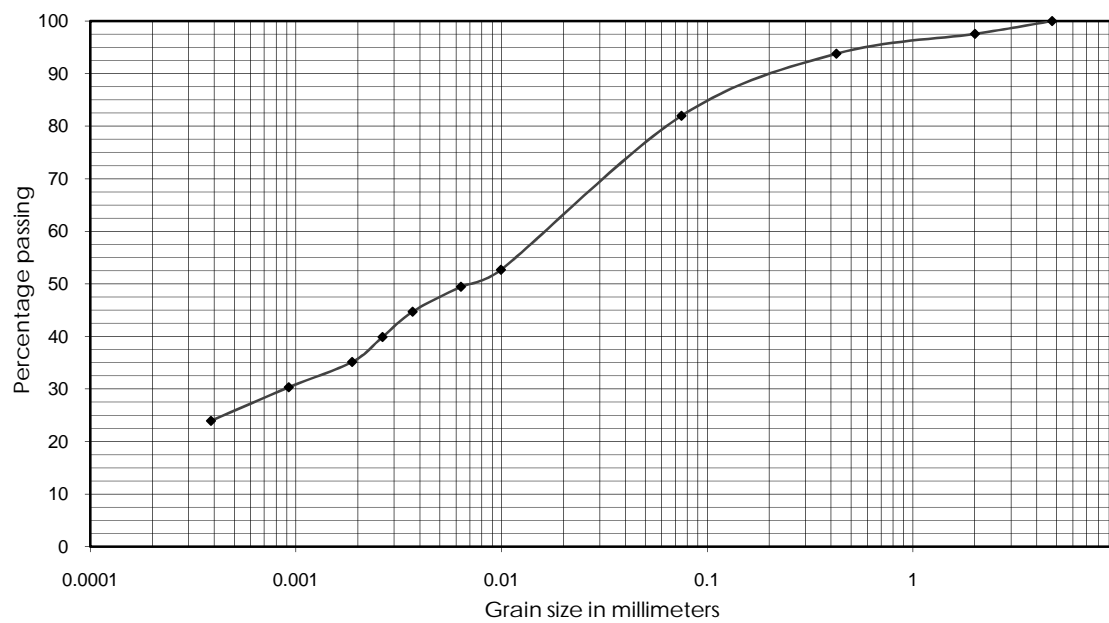


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-08	3.00	SM	11	65	24	0			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-08	6.00	CH	0	18	47	35			

FIG.58

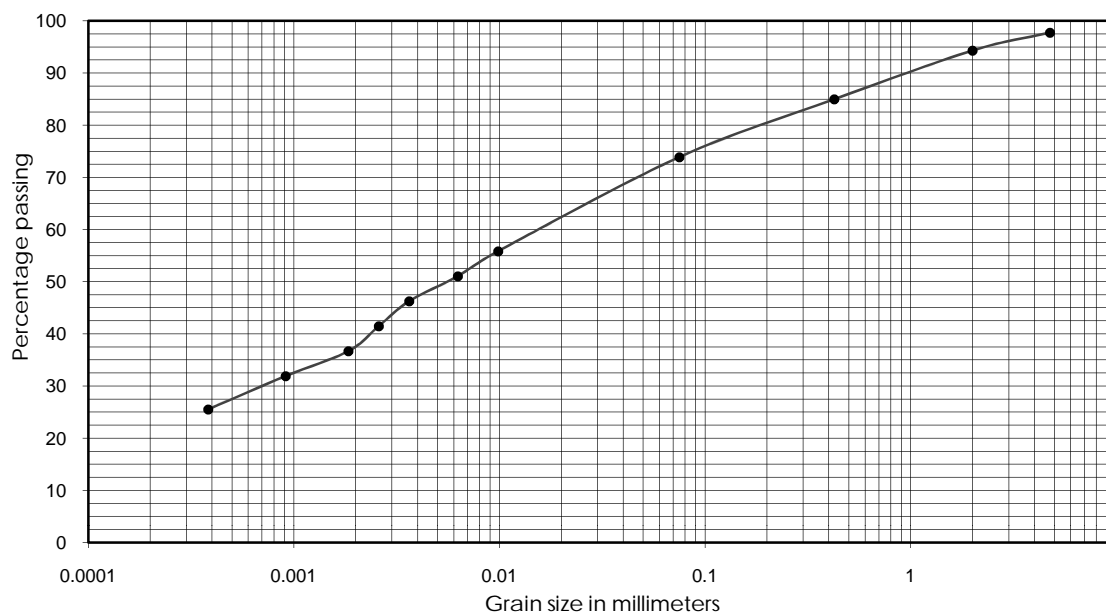


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

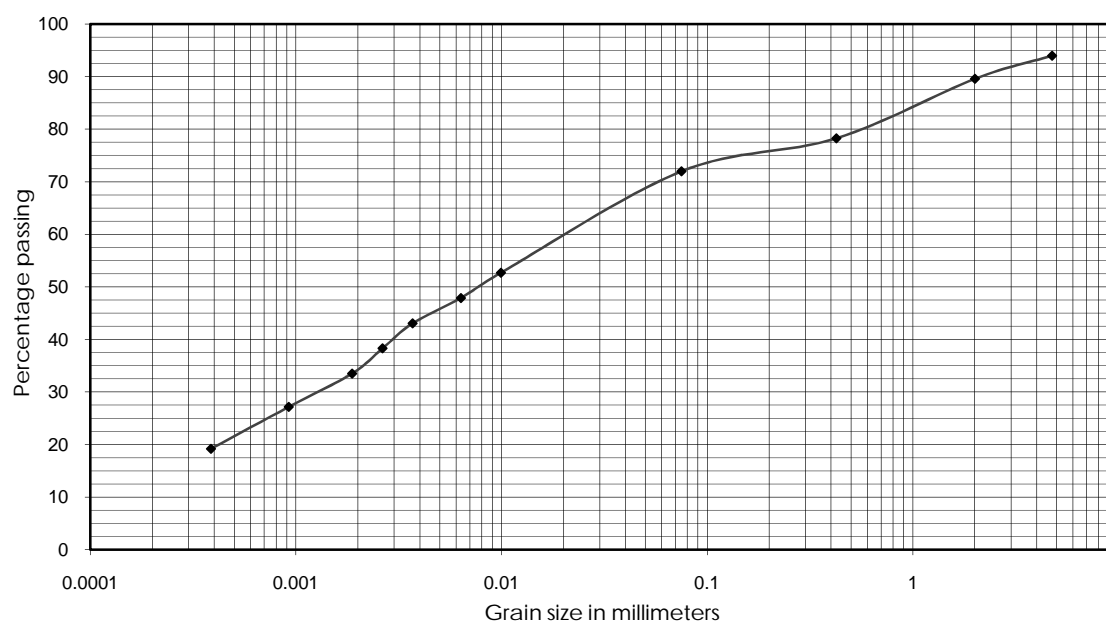


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-08	7.00	CH	2	24	37	37			



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-08	8.00	CH	6	22	38	34			

FIG.59

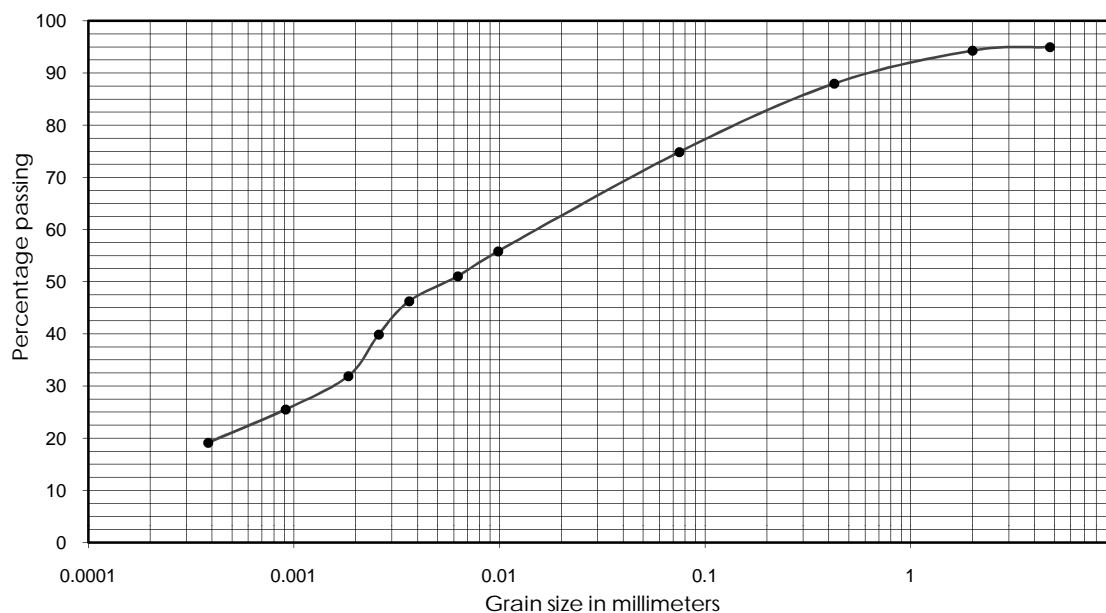


GEO FOUNDATIONS AND STRUCTURES PVT. LTD

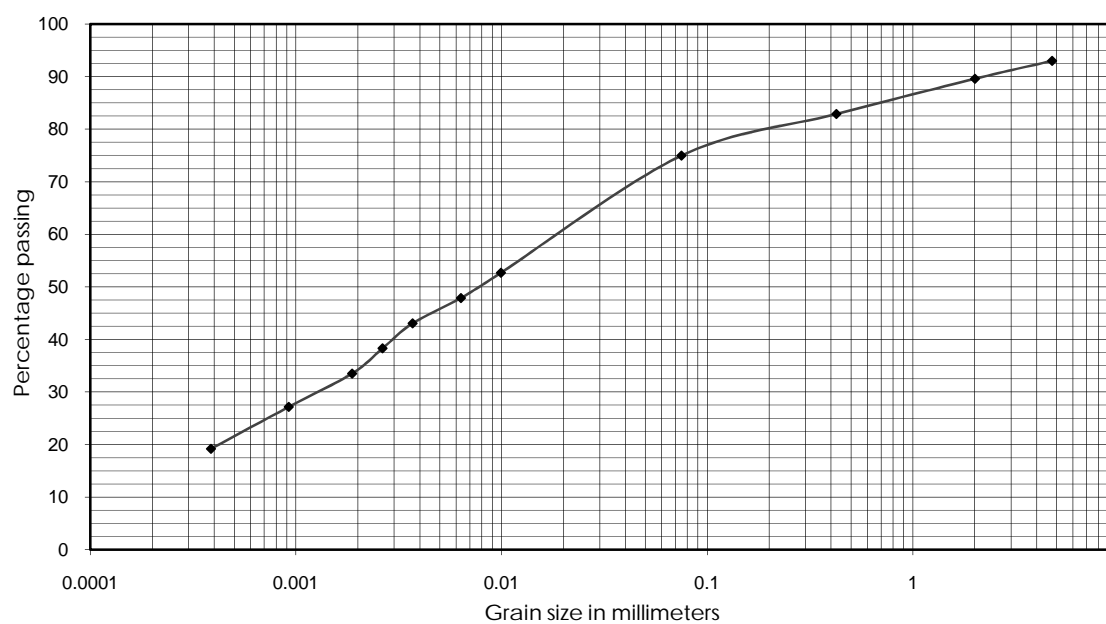


NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE

## GRAINSIZE ANALYSIS TEST




BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-08	9.00	CH	5	20	44	31			



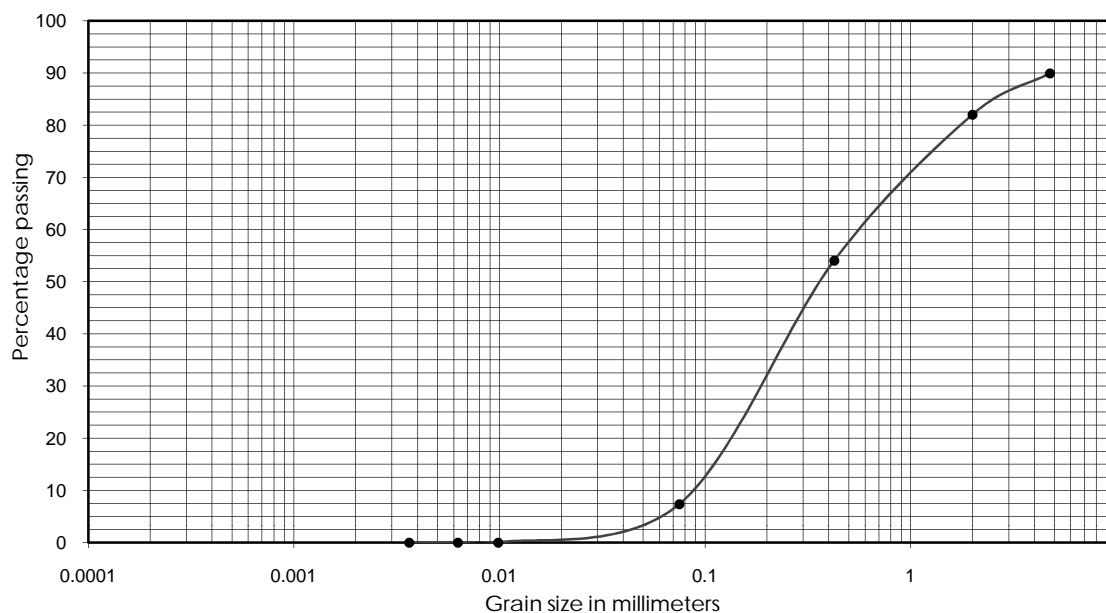
BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	D0
BH-08	11.50	CH	7	18	42	33			

FIG.60

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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-08	13.00	SM	10	83	7	0			

FIG.61

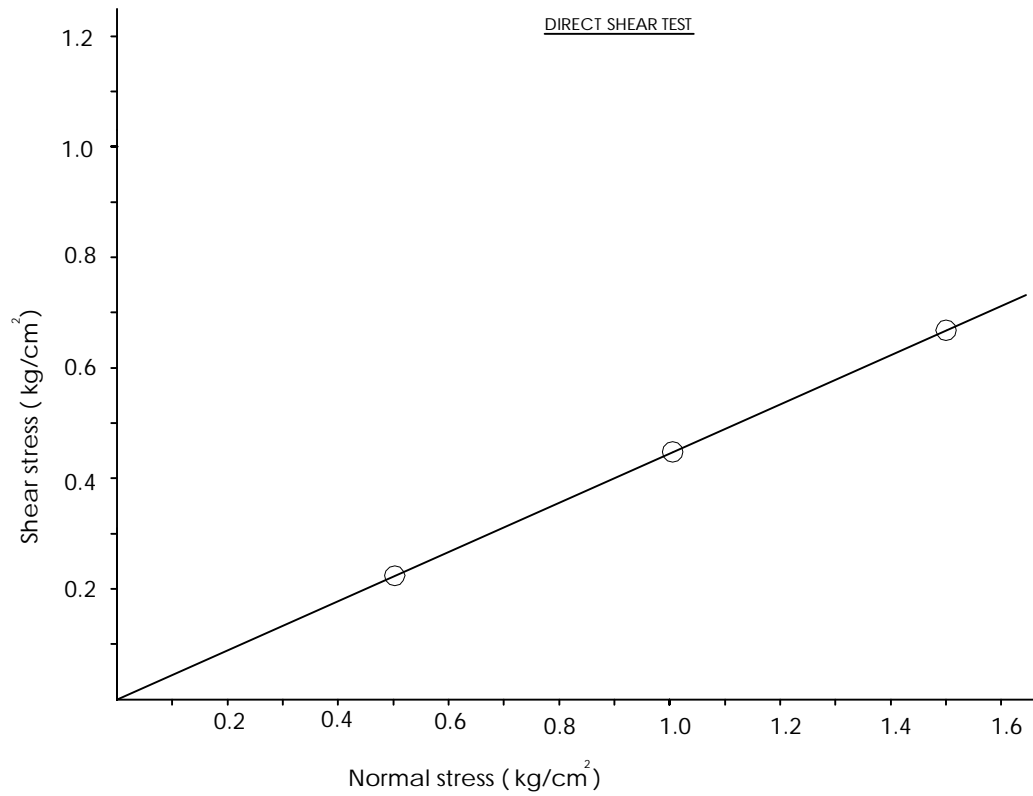


Fig. (62)

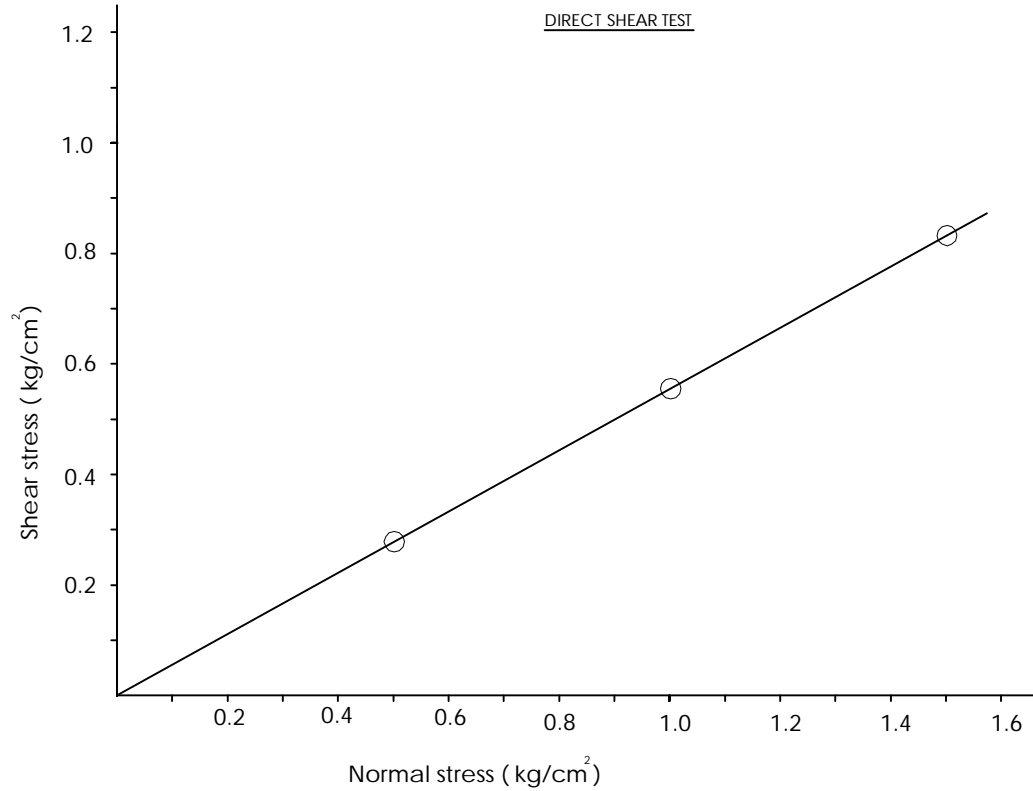


Fig. (63)

## **ANNEXURE – R**

**ROAD**

**(BH-09)**

**E.1     SITE SOIL DESCRIPTION**

E.1.1    **BH –09** : The strata in the shallow depth of 1.0 mtr at this borehole location is identified to be very dense silty sandy natured soil from existing ground level. Soft rocky strata is encountered from 1.0 m to 2.0 m. Strata improved to hard rock of granitic nature with high RCR and RQD values as given in the borelog. Borehole is terminated at 3.5 mtr below EGL

E.1.2    It is given to understand that this borehole is marked in the location where the internal roads are proposed. Borehole data shall be used as for understanding the profile of soil. Hence no foundation suggestions are provided for this location.

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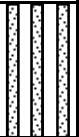





NAME OF WORK : GEOTECHNICAL INVESTIGATION WORK FOR THE PROPOSED NEW 1000 MT AMMONIA STORAGE													
	<b>GEO FOUNDATIONS &amp; STRUCTURES PVT. LTD</b>	Bore Hole No	: BH-09	Boring Started	: 26.04.2021		<b>TC-5397</b>						
		Type of Boring	: Rotary	Boring Completed	: 26.04.2021								
		Termination Depth	: 3.50 M	Ground Water Level	: 1.10m								
		Reduced Level	:	Co-ordinates :									
LOCATION : AMBALAMEDU													
SOIL PROFILE	THICKNESS OF STRATA (m)	DESCRIPTION OF STRATA	IS CLASSIFICATION	DEPTH (m)	SAMPLES	BLOWS/15cm			SPT "N"	Rock Core characteristics			REMARKS
					TEST DEPTH IN m	15cm	15cm	15cm		C.R (%)	R.Q.D (%)	UCS KG/CM <sup>2</sup>	
	1.00	Silty sand with gravel(Br./red)	SM	0.50	0.50	DS-01						SPT Rebound	
				1.00	1.00	100	-	-					>100
	1.00	Soft Rock		2.50	1.00 to 2.00	DRILLING DONE USING DIAMOND BIT			NIL	NIL			
	1.50	Rock			2.00 to 3.00	DRILLING DONE USING DIAMOND BIT			75	70			
				3.50	3.00 to 3.50	DRILLING DONE USING DIAMOND BIT			100	100			
Termination Depth : 3.50m													
Note : UDS- Undisturbed Sample													
SPT "N"-Standard Penetration Test "N"													

Fig :64

			NAME OF WORK : GEOTECHNICAL INVESTIGATION WORKS FOR THE PROPOSED NEW 1000 MT AMMONIA STORAGE															 TC-5397							
			LOCATION : Ambalamedu		Ground Water Level : 1.10m				Date of Boring Started : 26.04.2021 Boring completed : 26.04.2021 Termination Depth : 3.5m				Table No.:13			ULR-TC539720000000253F									
SPT 'N'	DEPTH (M)	SAMPLE	SOIL DESCRIPTION	I.S. CLASSIFI CATION	GRAIN SIZE ANALYSIS(%) IS 2720(Part5):1985				IS MMC (%) 2720 (Part2):1973	ATTERBERG'S LIMIT(%) IS 2720(Part-5): 1985			SL (%) IS 2720(Part6): 1972	FSI (%) IS 2720 (Part40):1977	IS SPG 2720(Part- 3/sec1):1980	UNIT WEIGHT (gm/cc)		SHEAR PARAMETER- IS 2720(Part-13):1986							
					GRA - VEL (%)	SAND (%)	SILT (%)	CLAY (%)		LL	PL	PI				WET	DRY	METHOD	C kg/cm <sup>2</sup>	Ø ( <sup>o</sup> )					
BOREHOLE BH-09																									
	0.50	DS-1	Silty sand with gravel(Br./red)	SM	20	70	10	0	8	No Limit					2.65	1.73	1.60	DST	0.02	29					
>100	1.00 to 2.00		Soft Rock																						
	2.00 to 3.50		Hard Rock																						

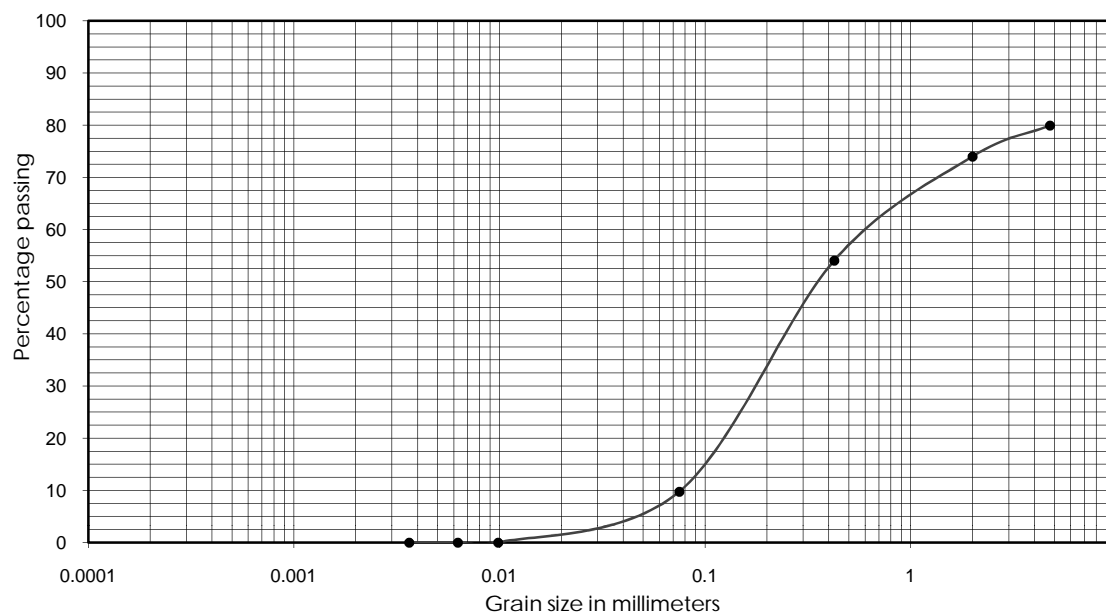
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	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORKS FOR THE PROPOSED NEW 10000MT AMMONIA STORAGE**

**GRAINSIZE ANALYSIS TEST**



BH No.	Depth	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
BH-09	0.50	SM	20	70	10	0			

FIG.66

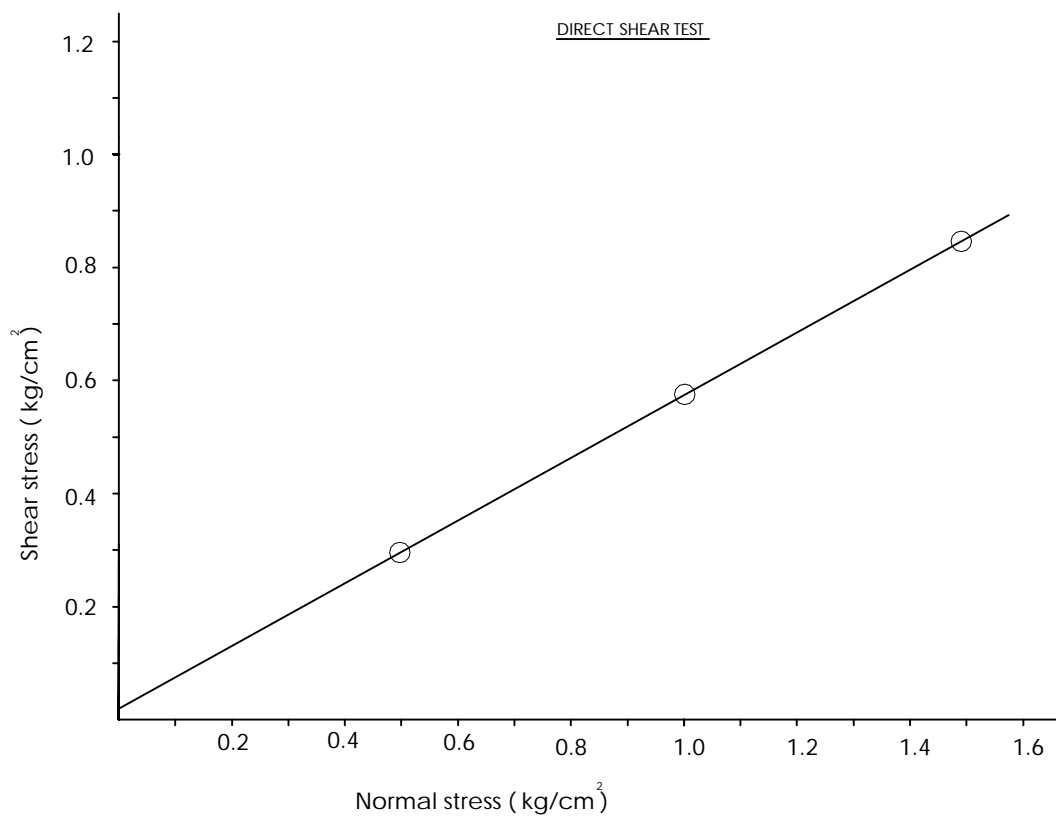


Fig. (67)

## **ANNEXURE - F**

### **TEST RESULTS OF CHEMICAL ANALYSIS** **WATER & SOIL**

- F.1** Ground water table is recorded and mentioned in the borelogs of respective boreholes. It is observed that the water table varies between 0.40m to 1.60mbelow existing ground Level and design depth of water level is taken as 0.40m. However, the soils are considered to be saturated for the purpose of calculating bearing capacities / pile capacities, which is the general practice.
- F.2** From the chemical analysis results of water and soil given in Table 8 to Table No 12( Pg.No. 80 to Pg. No.95) of this report, it can be understood that the test values of all the parameters are within the permissible limit as per IS 456:2014. Hence no additional precautions are suggested with regard to the usage of cement and / or steel reinforcement for the concrete works in this project.
- F.3** Hence Ordinary Portland Cement of 53 Grade can be used for all concrete works. The grade of concrete shall be as per specifications laid down in IS: 456 – 2000. TMT Rebars of Fe 500 Grade shall be used for the concreting works of various foundations proposed at this subject site.

**TABLE NO: 14****SOIL INVESTIGATION FOR THE NEW 10000 Mt AMMONIA STORAGE  
TANK****CHEMICAL ANALYSIS ON WATER**

BH No.	Test Results			
	Chlorides (PPM)	Salinity (PPM)	Sulphates (PPM)	PH Value
BH-01	24.0	43.36	Nil	7.0
BH-02	19.0	34.32	Nil	7.0
BH-05	22.0	39.74	Nil	7.0

**Permissible Limit as per IS 456:2000**

	For PCC	For RCC
<b>Chlorides (PPM)</b>	<b>2000</b>	<b>500</b>
<b>Sulphates (PPM)</b>	<b>400</b>	<b>400</b>
<b>Ph Value</b>	<b>6 to 9</b>	<b>6 to 9</b>

**TABLE NO: 15****SOIL INVESTIGATION FOR THE NEW 10000 MT AMMONIA STORAGE  
TANK****CHEMICAL ANALYSIS ON SOIL**

BH No.	Depth below EGL (m)	Chlorides (%)	Sulphate (%)	Calcium Carbonate (%)	pH Value
BH-01	1.00	0.095	Nil	1.85	7.0
BH-02	2.00	0.113	Nil	2.02	7.0
	4.00	0.083	Nil	2.55	7.0
BH-04	4.00	0.112	Nil	2.11	7.0
BH-05	1.00	0.142	Nil	2.38	7.0

**TABLE NO: 16****SOIL INVESTIGATION FOR THE PROPOSED COMPRESSOR HOUSE****CHEMICAL ANALYSIS ON WATER**

BH No.	Test Results			
	Chlorides (PPM)	Salinity (PPM)	Sulphates (PPM)	PH Value
BH-06	25.0	45.16	Nil	7.0

**Permissible Limit as per IS 456:2000**

	For PCC	For RCC
<b>Chlorides (PPM)</b>	<b>2000</b>	<b>500</b>
<b>Sulphates (PPM)</b>	<b>400</b>	<b>400</b>
<b>Ph Value</b>	<b>6 to 9</b>	<b>6 to 9</b>

**TABLE NO: 17****SOIL INVESTIGATION FOR THE PROPOSED COMPRESSOR HOUSE****CHEMICAL ANALYSIS ON SOIL**

BH No.	Depth below EGL (m)	Chlorides (%)	Sulphate (%)	Calcium Carbonate (%)	pH Value
BH-06	5.00	0.007	Nil	1.84	7.0
	8.00	0.005	Nil	2.06	7.0
	11.50	0.009	Nil	1.99	7.0

**TABLE NO: 18****SOIL INVESTIGATION FOR THE PROPOSED COOLING TOWER****CHEMICAL ANALYSIS ON WATER**

BH No.	Test Results			
	Chlorides (PPM)	Salinity (PPM)	Sulphates (PPM)	PH Value
BH-07	24.0	43.35	Nil	7.0

**Permissible Limit as per IS 456:2000**

	For PCC	For RCC
Chlorides (PPM)	2000	500
Sulphates (PPM)	400	400
Ph Value	6 to 9	6 to 9

**TABLE NO: 19****SOIL INVESTIGATION FOR THE NEW PROPOSED COOLING TOWER****CHEMICAL ANALYSIS ON SOIL**

BH No.	Depth below EGL (m)	Chlorides (%)	Sulphate (%)	Calcium Carbonate (%)	pH Value
BH-07	3.00	0.113	Nil	1.33	7.0
	9.00	0.008	Nil	1.09	7.0
	13.0	0.005	Nil	1.41	7.0

**TABLE NO: 20****SOIL INVESTIGATION FOR THE PROPOSED FLAIR STORE****CHEMICAL ANALYSIS ON WATER**

BH No.	Test Results			
	Chlorides (PPM)	Salinity (PPM)	Sulphates (PPM)	PH Value
BH-08	39.0	70.45	Nil	7.0

**Permissible Limit as per IS 456:2000**

	For PCC	For RCC
<b>Chlorides (PPM)</b>	<b>2000</b>	<b>500</b>
<b>Sulphates (PPM)</b>	<b>400</b>	<b>400</b>
<b>Ph Value</b>	<b>6 to 9</b>	<b>6 to 9</b>

**TABLE NO: 21****SOIL INVESTIGATION FOR THE PROPOSED FLAIR AREA****CHEMICAL ANALYSIS ON SOIL**

BH No.	Depth below EGL (m)	Chlorides (%)	Sulphate (%)	Calcium Carbonate (%)	pH Value
BH-08	3.00	0.123	Nil	2.55	7.0
	7.00	0.007	Nil	2.13	7.0
	10.0	0.008	Nil	1.95	7.0

**TABLE NO: 22****ROAD****CHEMICAL ANALYSIS ON WATER**

BH No.	Test Results			
	Chlorides (PPM)	Salinity (PPM)	Sulphates (PPM)	PH Value
BH-09	23.0	41.57	Nil	7.0

**Permissible Limit as per IS 456:2000**

	For PCC	For RCC
<b>Chlorides (PPM)</b>	<b>2000</b>	<b>500</b>
<b>Sulphates (PPM)</b>	<b>400</b>	<b>400</b>
<b>Ph Value</b>	<b>6 to 9</b>	<b>6 to 9</b>

## **ANNEXURE - G**

### **TEST RESULTS OF ROCK CORES**

**TABLE NO: 23****ROCK TEST RESULT****LOCATION : TANKAGE AREA**

BH NO.	Depth	Core Recovery (%)	RQD (%)	UCS (kg/cm <sup>2</sup> )
BH-01	4.00 – 5.00	85.0	70.0	325
	5.00 – 6.00	79.0	79.0	310
BH-02	5.00 – 6.00	71.0	71.0	290
	6.00 – 7.00	75.0	68.0	270
BH-03	2.30 – 3.30	79.0	71.0	285
	3.30 – 4.30	100.0	100.0	390
BH-4A	2.80 – 3.80	98.0	89.0	355
	3.80 – 4.60	87.0	87.0	320
BH-5	1.80 – 2.80	99.0	96.0	375
	2.80 – 3.80	84.0	71.0	295
	3.80 – 4.30	60.0	60.0	260
BHR-1	1.00 – 1.80	NIL	NIL	-
	1.80 – 2.30	28.0	NIL	-
	2.30 – 2.80	52.0	40.0	60.0
BHR-2	4.00 -4.50	46.0	46.0	145.0
BHR-3	0.20 -0.70	88.0	88.0	275.0

**TABLE NO :24****ROCK TEST RESULT****LOCATION : COMPRESSOR HOUSE**

BH NO.	Depth	Core Recovery (%)	RQD (%)	UCS (kg/cm <sup>2</sup> )
BH-06	13.0 – 14.0	60.0	15.0	-
	14.0 – 15.0	72.0	39.0	105

**TABLE NO : 25****ROCK TEST RESULT****LOCATION : COOLING TOWER**

BH NO.	Depth	Core Recovery (%)	RQD (%)	UCS (kg/cm <sup>2</sup> )-By Point load
BH-07	14.5 – 15.5	NIL	NIL	-
	15.5 – 16.5	20	NIL	85.0
	16.5 – 17.5	30	NIL	-

**TABLE NO : 26****ROCK TEST RESULT****LOCATION : FLAIR AREA**

BH NO.	Depth	Core Recovery (%)	RQD (%)	UCS (kg/cm <sup>2</sup> )
BH-08	14.5 – 16.2	NIL	NIL	-
	16.2 – 17.2	40.0	23.0	120
	17.2 – 18.2	68.0	31.0	145

**TABLE NO : 27****ROCK TEST RESULT****LOCATION : ROAD**

BH NO.	Depth	Core Recovery (%)	RQD (%)	UCS (kg/cm <sup>2</sup> )
BH-09	1.0 – 2.00	NIL	NIL	-
	2.00 – 3.00	75.0	70.0	240
	3.00 – 3.50	100.0	100.0	275

## **ANNEXURE - H**

### **TYPICAL CALCULATIONS**

TYPICAL CALCULATION FOR SHALLOW FOUNDATION ON ROCK  
(AS PER IS: 12070-1987)

**CALCULATION FOR CIRCULAR RAFT**

**LOCATION: TANKAGE AREA**

**Design Borehole considered : BH-02**

Safe Bearing capacity for shallow foundation on Rock is worked out based on the uniaxial Compressive strength of rock cores and the relevant clause No. 6 of IS : 12070 – 1987.

From the borelogs, the average rock quality designation (RQD) values are about 70% and the spacing in discontinuities are more than 30%.

As per clause No. 6 of IS: 12070 – 1987 ,

$$q_s = q_c * N_1$$

where

$q_s$  = safe bearing pressure ;

$q_c$  = avg. uniaxial strength of rock core, taken as 290 kg/cm<sup>2</sup>

$N_1$  = the empirical coefficient depending on the spacing of discontinuities

from Table no. 4 of IS: 12070 – 1987, with the discontinuities are more than 30%,  $N_1$  is taken as 0.1

$$q_s = q_c * N_1$$

$$= 290 * 0.10$$

$$= 29.0 \text{ kg/cm}^2$$

**SAY 290 T /m<sup>2</sup>**

TYPICAL CALCULATION FOR BORED CAST IN SITU PILES  
(AS PER IS: 2911 (PART-1/SEC2)-2010)

**CALCULATION FOR PILE CAPACITY IN COMPRESSION**

**LOCATION: COOLING TOWER**

**Diameter of pile** : 80 cm

**Depth of Pile** : 14.5m from EGL and socketing ID in to rocky Strata

**Borehole No.** : BH-07

**CALCULATION FOR END BEARING:-**

End Bearing :  $A_p (0.5 D \gamma N_y + P_D N_q)$

Where,

$A_p$  : Cross sectional area of pile toe in  $\text{cm}^2$

$D$  : stem diameter in cm

$\gamma$  : Effective unit weight of soil at pile toe in  $\text{Kgf/cm}^3$

$P_D$  : effective overburden pressure at pile toe in  $\text{Kgf/cm}^2$

$N_y, N_q$  : Bearing capacity factors depending upon the angle of Internal friction

Effective over Burden Pressure at pile tip,  $P_D$  (15 to 20 times the diameter of pile)

$$: 18 * 80\text{cm} = 14.4\text{m}$$

$$: (5.90 * 0.61) + (2.80 * 0.57) + (2.5 * 0.52) + (3.3 * 0.50)$$

$$= 8.145 * 10^{-1} \text{ Kg/cm}^2$$

$N_y$  : 182.34 (For  $\Phi = 43^\circ$ ) from Table No.1 of IS 6403:1981

$N_q$  : 220 (From fig 1. of IS 2911(part1/sec2)-1979

End Bearing :  $\pi/4(80^2) [(0.5 * 80 * 1.20 * 10^{-3} * 182.34) + (8.145 * 10^{-1} * 220)]$

$$: \mathbf{944.73 \text{ T}}$$

**CALCULATION FOR FRICTIONAL RESISTENCE****For Cohesion less soil :  $K * P_{Di} * \tan \Phi * A_{si}$** 

K : Coefficient of Earth Pressure

 $P_{Di}$  : Effective overburden pressure in Kg/cm<sup>2</sup> for the ith layer  
where i varies from 1 to n $A_{si}$  : Surface area of pile stem in cm<sup>2</sup> $\Phi$  : Angle of wall friction between pile and soil, in degrees.**For Cohesive soil :  $\alpha * C * A_s$**  $\alpha$  : Reduction FactorC : Average cohesion through out the length of pile in Kg/cm<sup>2</sup> $A_s$  : Surface area of pile shaft in cm<sup>2</sup>

From 0.00m to 8.70m (Cohesion less Soil)

$$: 1.50 * 2.56 * 10^{-1} * \pi * 80 * 870 * \tan 23$$

$$= \mathbf{35.64 \text{ T}}$$

From 8.70m to 11.20m (Cohesive Soil)

$$: 0.40 * 0.24 * \pi * 80 * 250$$

$$= \mathbf{6.03 \text{ T}}$$

From 11.20m to 14.5m (Cohesion less Soil)

$$: 1.50 * 7.32 * 10^{-1} * \pi * 80 * 330 * \tan 25$$

$$= \mathbf{42.46 \text{ T}}$$

From 14.5 m to 15.1m (1D in rocky strata)

$$: 1.50 * 8.145 * 10^{-1} * \pi * 80 * 80 * \tan 43$$

$$= \mathbf{22.91 \text{ T}}$$

Total Capacity : End Bearing + Total Friction

$$: (944.73 + 35.64 + 6.03 + 42.47 + 22.91)$$

$$= \mathbf{1051.79 \text{ T}}$$

Factor of Safety : 2.5

Safe Capacity = Total Capacity /Factor of Safety  
= 1051.79 / 2.5  
= **420.71 T**

**Self weight of the pile** :  $\pi/4 * D^2 * 2.5 * H$   
:  $\pi/4 * (1)^2 * 2.5 * 15.3$   
: **19.22 T**

**Net Safe Capacity** : **Safe Capacity – Self weight of the pile**  
= 420.71 - 19.22  
= **401.48 T**

**SAY 400 Tones**

TYPICAL CALCULATION FOR BORED CAST IN SITU PILES  
(AS PER IS: 2911 (PART-1/SEC2)-2010)

**CALCULATION FOR PILE CAPACITY IN TENSION**

**LOCATION: COOLING TOWER**

**Diameter of pile** : 80 cm

**Depth of Pile** : 14.5m from EGL and socketing ID in to rocky Strata

**Borehole No.** : BH-07

**CALCULATION FOR FRICTIONAL RESISTENCE**

**For Cohesion less soil** :  $K * P_{Di} * \tan \Phi * A_{si}$

K : Coefficient of Earth Pressure

$P_{Di}$  : Effective overburden pressure in Kg/cm<sup>2</sup> for the ith layer  
where I varies from 1 to n

$A_{si}$  : Surface area of pile stem in cm<sup>2</sup>

$\Phi$  : Angle of wall friction between pile and soil, in degrees.

**For Cohesive soil** :  $\alpha * C * A_s$

$\alpha$  : Reduction Factor

C : Average cohesion through out the length of pile in Kg/cm<sup>2</sup>

$A_s$  : Surface area of pile shaft in cm<sup>2</sup>

From 0.00m to 8.70m (Cohesion less Soil)

$$: 1.50 * 2.56 * 10^{-1} * \pi * 80 * 870 * \tan 23$$

$$= 35.64 \text{ T}$$

From 8.70m to 11.20(Cohesive Soil)

$$: 0.40 * 0.24 * \pi * 80 * 250$$

$$= 6.03 \text{ T}$$

---

From 11.20m to 14.5m (Cohesion less Soil)

$$: 1.50 * 7.32 * 10^{-1} * \pi * 80 * 330 * \tan 25$$

$$= \mathbf{42.46 \text{ T}}$$

From 14.5 m to 15.1(1D in rocky strata)

$$: 1.50 * 8.145 * 10^{-1} * \pi * 80 * 80 * \tan 43$$

$$= \mathbf{22.91 \text{ T}}$$

Total Frictional Resistance

$$: (35.64 + 6.03 + 42.46 + 22.91)$$

$$= \mathbf{107.04 \text{ T}}$$

Self Weight of the Pile

$$: \pi / 4 * D^2 * H * 2.5$$

$$: \pi / 4 * (0.8)^2 * 15.3 * 2.5$$

$$= \mathbf{19.22 \text{ T}}$$

Total Tension Capacity

$$= \text{Total frictional Resistance} + \text{Self weight of the pile}$$

$$= 107.04 + 19.22$$

$$= \mathbf{126.26 \text{ T}}$$

Factor of Safety

$$: 3.0$$

Safe Capacity

$$= \text{Total Tension Capacity} / \text{factor of safety}$$

$$= 126.26 / 3$$

$$= \mathbf{42.08 \text{ T}}$$

**SAY 42 Tones**

**Typical Calculation for Lateral Load Capacity as per  
IS : 2911(Part1/ Sec2) - 2010**

**LOCATION: Soil investigation work for the proposed 10000MT Ammonia  
Storage Tank**

**Location : Cooling Tower**

- |  |  |
|--|--|
| 1. Grade of Concrete                                   | : M-35(assumed)                          |
| 2. Grade of Steel                                      | : Fe 500 D                               |
| 3. Pile Diameter                                       | : 80 cms                                 |
| <b>4. Bore Hole No. considered for<br/>Calculation</b> | <b>: BH-07</b>                           |
| 5. Cut off level                                       | : 1.50m                                  |
| 6. Depth of Pile from EGL to rock level                | : 14.5m and 1 D socketed in rocky strata |
| 7. Free standing length L1 is taken as                 | : O.O                                    |

**Calculation based on Annex– C (Cl.6.5.2) of IS 2911(Part1/Sec2):2010**

**Assuming the Pile as fixed head conditions and considering an average N  
value of 6, and as sandy soil,**

From C-2.3.1 of Annex-C, Stiffness Factor, T in meters is calculated as

**$R = 5\sqrt{E \cdot I / \eta_h}$  for sandy soils**

where, E : Youngs modulus of M35 concrete  
 $= 5000\sqrt{f_{ck}} = 29580.9 \times 10^3 \text{ KN/m}^2$

I : Moment of Inertia  
 $= \pi \times D^4 / 64 = 0.02 \text{ m}^4$

**$\eta_h = 0.6 \times 10^3$  for the N value**

So,

$$T = 5\sqrt{(29580.39 \times 10^3 \times 0.02 / 0.6 \times 10^3)} = 3.96 \text{ m}$$

$$L1 / T = 0$$

From fig.4 of Annex-C of IS: 2911(part-1/sec-2):2010

For 'L1/T' of 0, Zf/T is taken from the graph **as 2.20** (For fixed head piles in sandy soils)

Thus Zf or L<sub>f</sub> (Length of Fixity) = 2.20 x 3.96 = 8.712 m

Lateral capacity H is calculated as per formula given in C-4.2 of said IS Code,

$$Y = [H * (e + Zf)^3 / 12 E I] \times 10^3$$

$$H = 5 \times 12 \times 29580.39 \times 10^3 \times 0.02 / 8.712^3$$

$$= 53.68 \text{ KN}$$

$$= \mathbf{5.36 \text{ T}}$$

**Say 5.3 Tons**

## **ANNEXURE -I**

### **TEST RESULTS OF LAB CBR TEST**

In addition to the borehole studies done at site, the scope of works includes conducting a Lab CBR test. For this purpose, bulk sample is collected from a trial pit at the given location.

**Modified Proctor Density test** as per IS:2720 (Part 8) – RA 2015 and **soaked California Bearing Ratio** as per IS:2720 (Part 16) - 2016 in the laboratory on the bulk sample. The test results are compiled and given herewith in this annexure for further procedures.

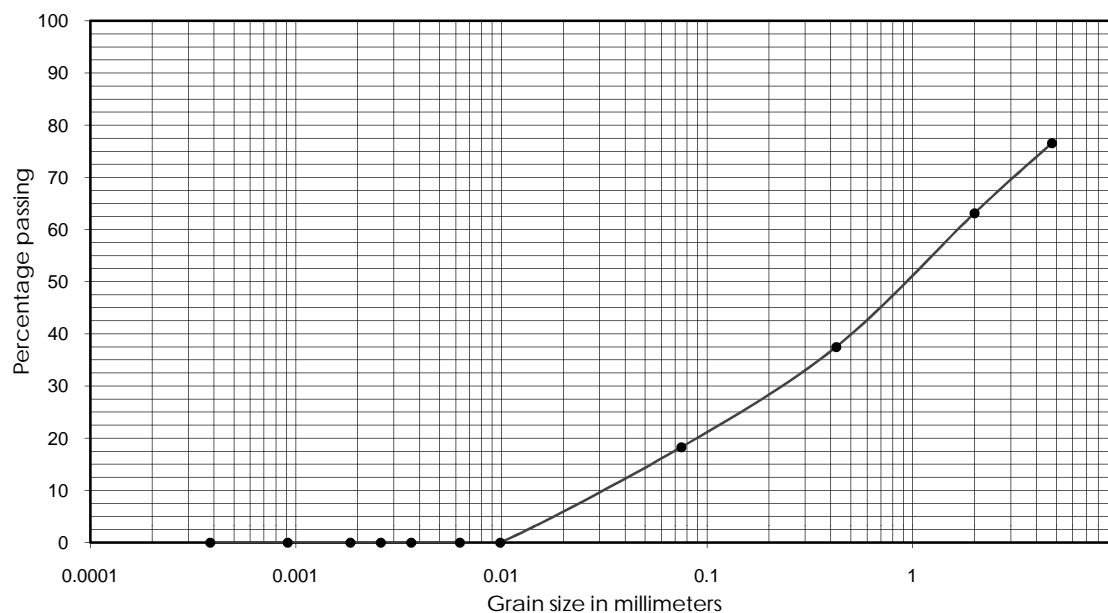
Test Number	Grain size analysis(As per IS 2720 Part-4-1985)-RA-2015				Modified Proctor Test(As per IS 2720 Part-8-1985)-RA 2015		Soaked CBR (%) -As per IS 2720 (Part-16)-1987)-RA-2011
	Grave I (%)	Sand (%)	Silt (%)	Clay (%)	Optimum Moisture Content (%)	Maximum Dry density (gm/cc)	
CBR-01	23	58	19	0	15.8	1.95	5.10
CBR-02	20	59	21	0	16.9	1.93	5.04
CBR-03	22	55	23	0	18.0	1.89	4.92

Test data is also provided herewith in subsequent pages.

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000MT AMMONIA STORAGE TANK**

**GRAINSIZE ANALYSIS TEST**



Sample	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
CBR-01	SM	23	58	19	0			

FIG.68

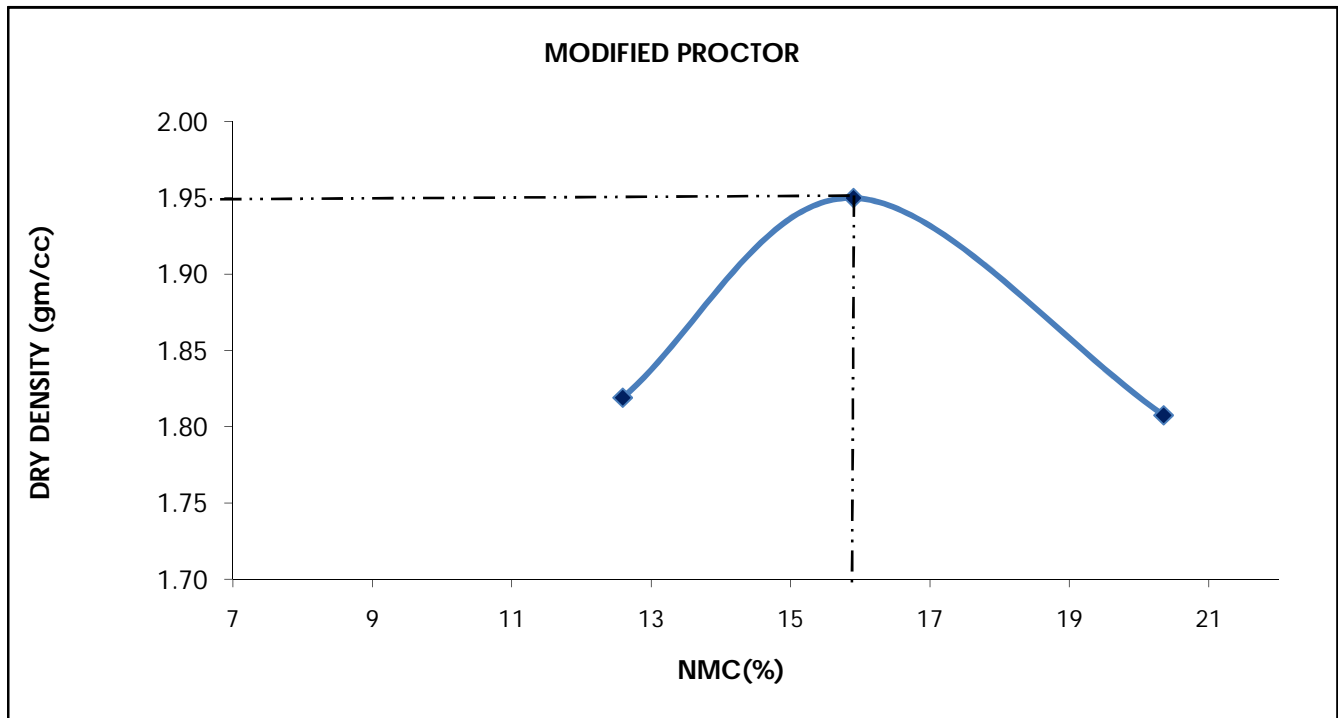
**GEO FOUNDATIONS AND STRUCTURES PVT. LTD****T/C-5397****NAME OF WORK : GEOTECHNICAL INVESTIGATION IN FACT-CD FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK****Sample No : CBR-01****Test Results**Bulk density : **2.26 gm/cc**MDD : **1.95 gm/cc**OMC : **15.8 %**

FIG.69

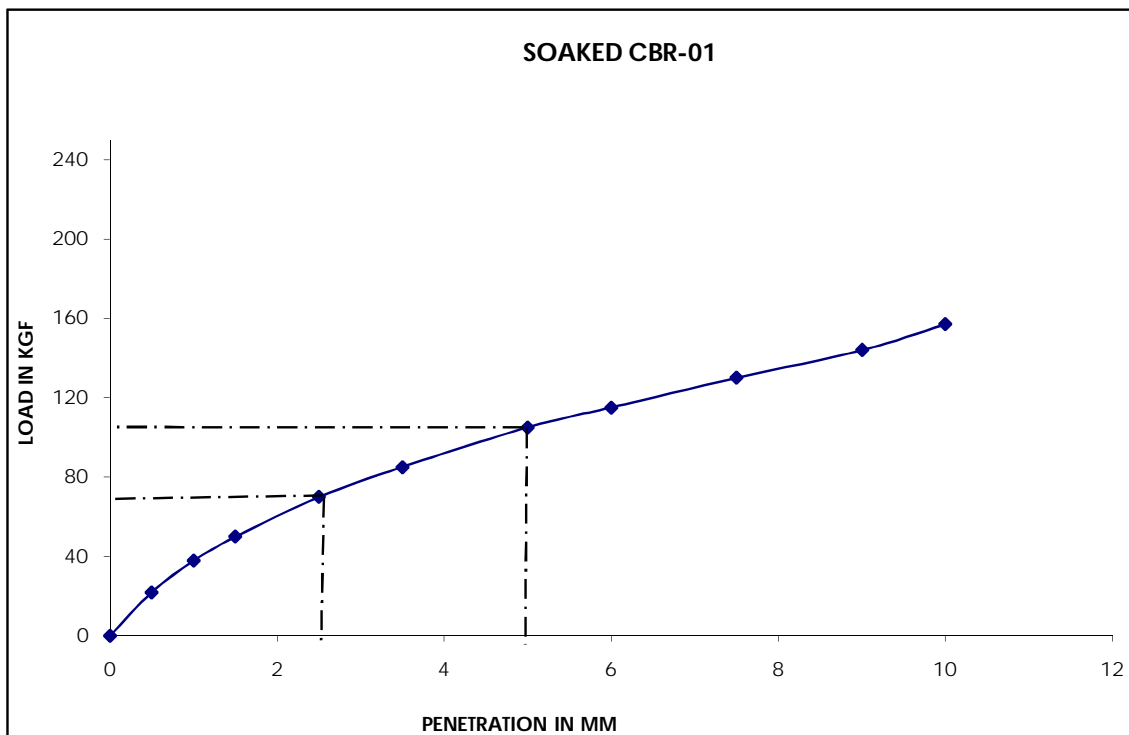


GEO FOUNDATIONS AND STRUCTURES PVT. LTD




TC-5397

PROJECT : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK



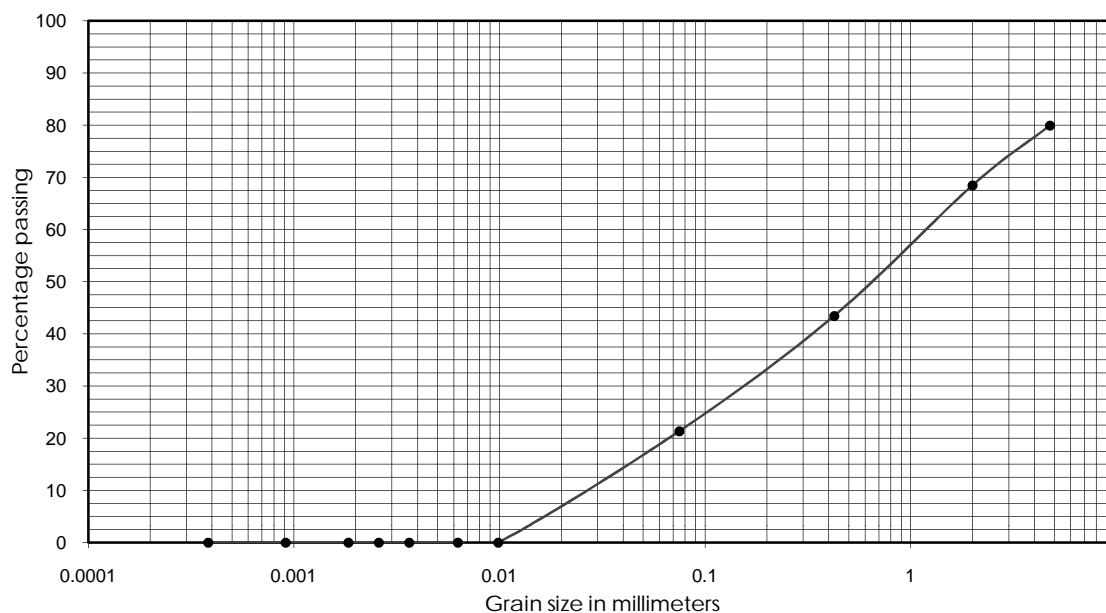
Location	: Trial Pit-01
Type of Soil	: Silty sand with gravel
Maximum Dry Density	: 1.95gm/cc
Optimum Moisture Content	: 15.80%
CBR Value	: 5.10%

FIG.70

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000MT AMMONIA STORAGE TANK**

**GRAINSIZE ANALYSIS TEST**



Sample	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
CBR-01	SM	20	59	21	0			

FIG.71

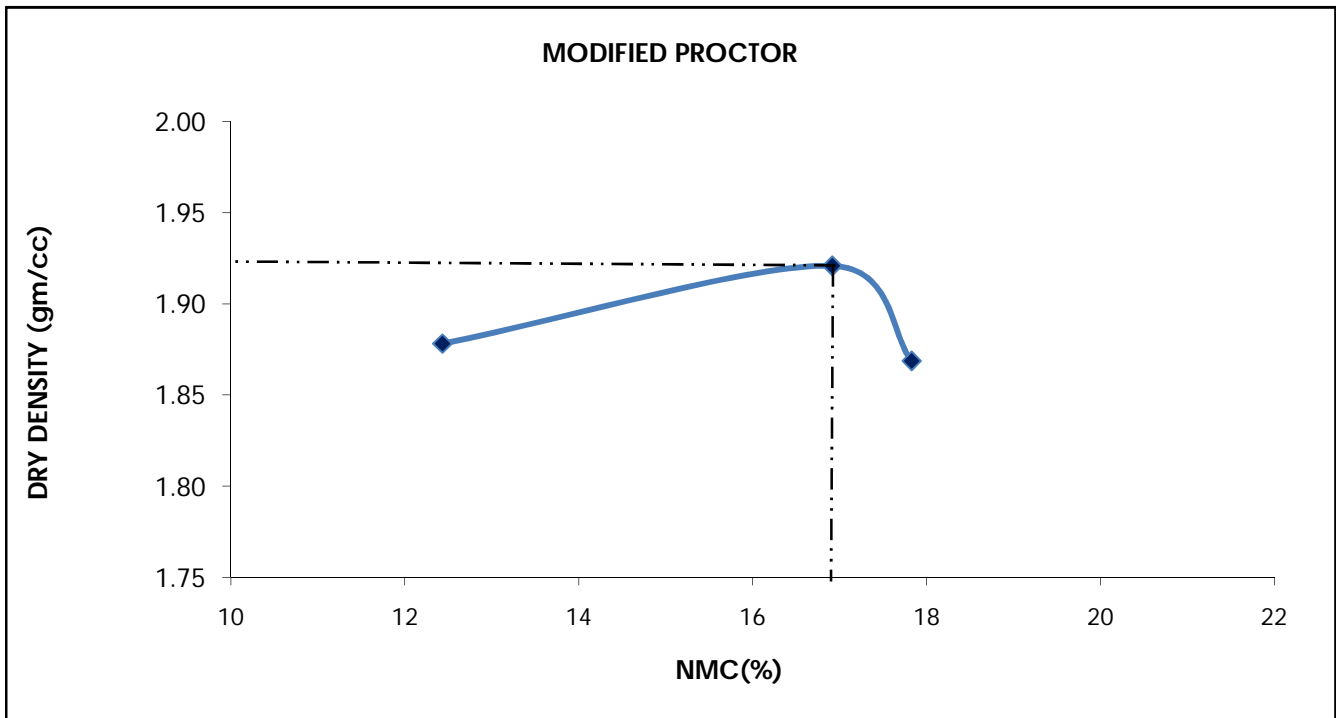
**GEO FOUNDATIONS AND STRUCTURES PVT. LTD****T/C-5397****NAME OF WORK : GEOTECHNICAL INVESTIGATION IN FACT-CD AT THE PROPOSED 10000 MT Ammonia Storage Tank****Sample No. CBR-02****Test Results**Bulk density : **2.26 gm/cc**MDD : **1.93 gm/cc**OMC : **16.9 %**

FIG.72

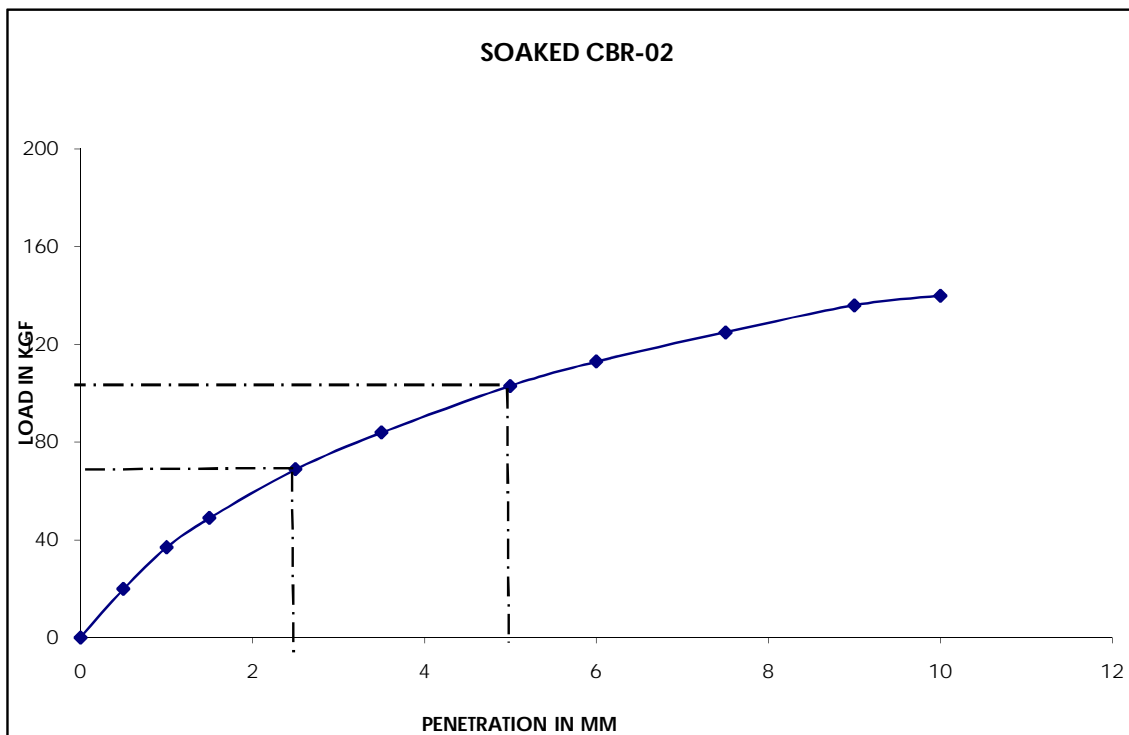


GEO FOUNDATIONS AND STRUCTURES PVT. LTD



TC-5397

PROJECT : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK



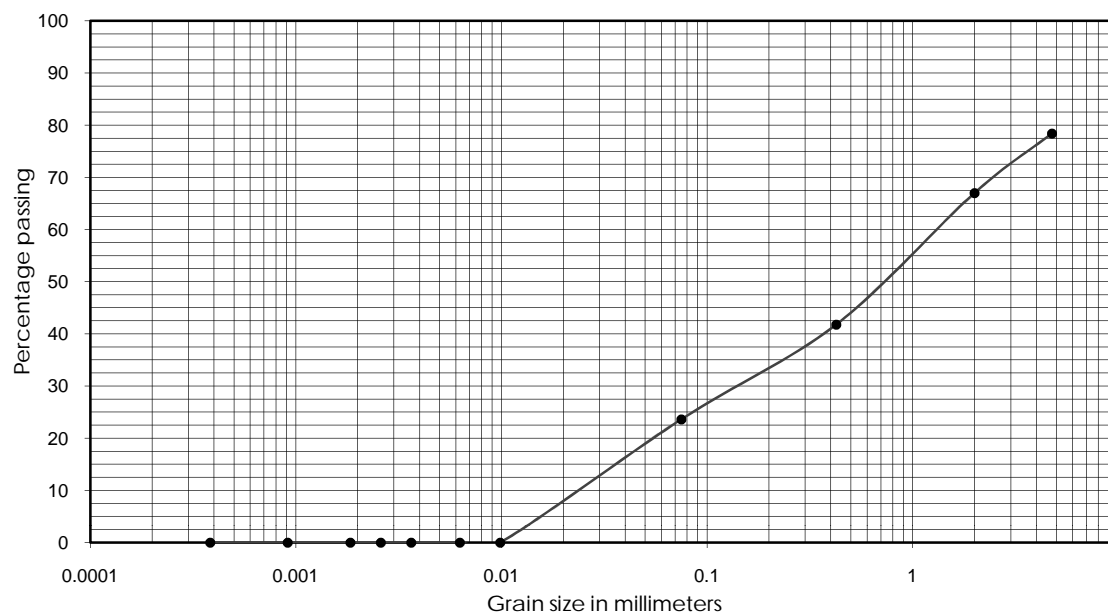
Location	: Trial Pit-02
Type of Soil	: Silty sand with gravel
Maximum Dry Density	: 1.93gm/cc
Optimum Moisture Content	: 16.90%
CBR Value	: 5.04%

FIG.73

	<b>GEO FOUNDATIONS AND STRUCTURES PVT. LTD</b>	 <b>TC-5397</b>
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**NAME OF WORK : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000MT AMMONIA STORAGE TANK**

**GRAINSIZE ANALYSIS TEST**



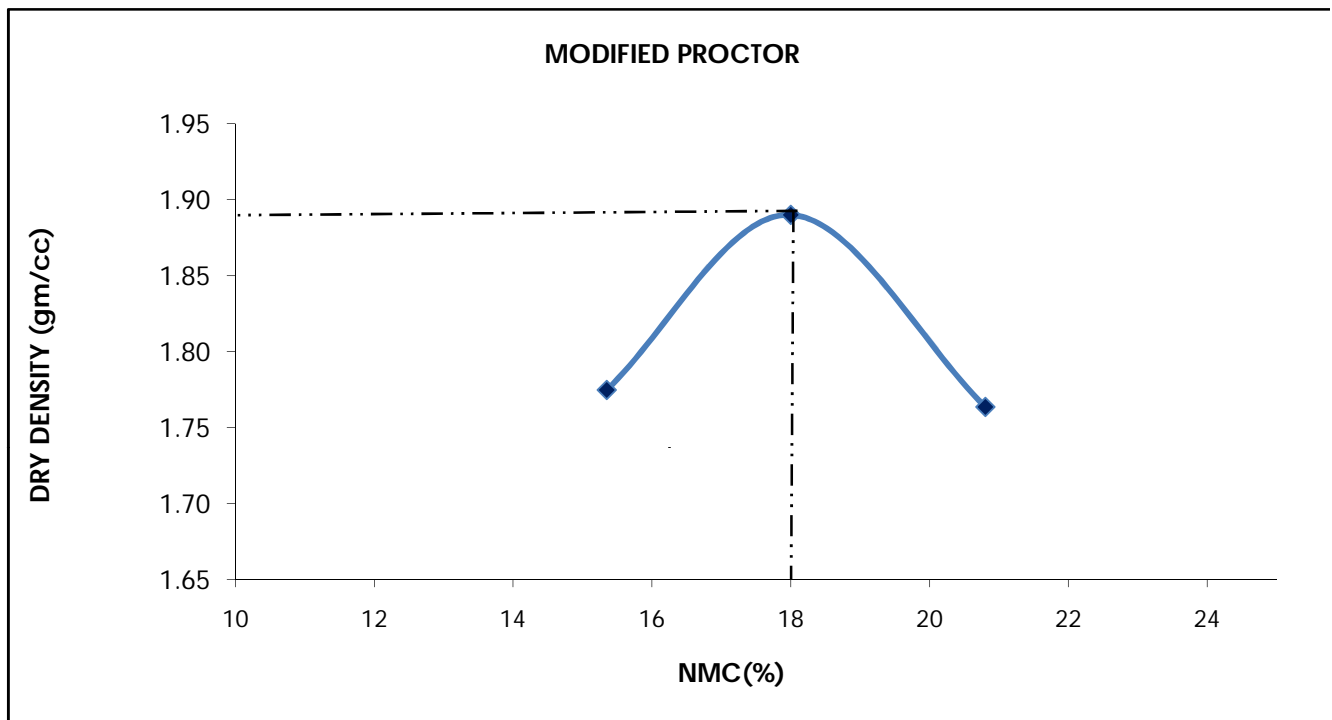
Sample	IS Class	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	D60	D10	Cu
CBR-01	SM	22	55	23	0			

FIG.74

**GEO FOUNDATIONS AND STRUCTURES PVT. LTD****T/C-5397**

**NAME OF WORK : GEOTECHNICAL INVESTIGATION IN FACT-CD AT THE PROPOSED 10000 MT AMMONIA STORAGE TANK**

**Sample No : CBR-03**



**Test Results**

Bulk density : **2.23 gm/cc**

MDD : **1.89 gm/cc**

OMC : **18.0 %**

FIG.75

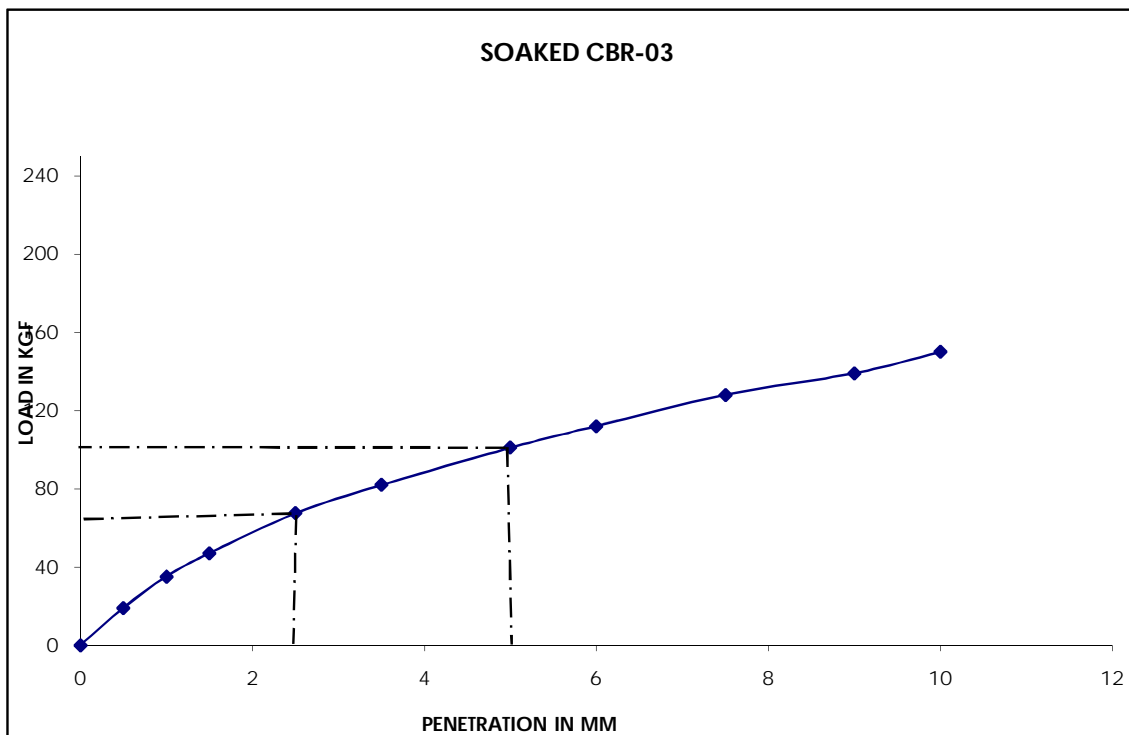


GEO FOUNDATIONS AND STRUCTURES PVT. LTD



TC-5397

PROJECT : SOIL INVESTIGATION WORK FOR THE PROPOSED 10000 MT AMMONIA STORAGE TANK



Location	: Trial Pit-03
Type of Soil	: Silty sand with gravel
Maximum Dry Density	: 1.89gm/cc
Optimum Moisture Content	: 18.00%
CBR Value	: 4.92%

FIG.76

## **ANNEXURE - J**

### **PHOTOS OF ROCK CORES**



BoreHole No.- BH-01  
 1<sup>st</sup> Lift – 4.00m to 5.00m  
 2<sup>nd</sup> Lift – 5.00m to 6.00m



BoreHole No.- BH-02  
 1<sup>st</sup> Lift - 5.00m to 6.00m  
 2<sup>nd</sup> Lift - 6.00m to 7.00m



BoreHole No.- BH-03  
 1<sup>st</sup> Lift – 2.30m to 3.30m



BoreHole No.- BH-03  
2<sup>nd</sup> Lift – 3.30m to 4.30m



BoreHole No.- BH-04 A  
1<sup>st</sup> Lift – 2.80m to 3.80m  
2<sup>nd</sup> Lift – 3.80m to 4.60m



BoreHole No.- BH-05  
1<sup>st</sup> Lift – 1.80m to 2.80m  
2<sup>nd</sup> Lift – 2.80m to 3.80m  
3<sup>rd</sup> Lift – 3.80m to 4.30m



BoreHole No.- BH-06  
 1<sup>st</sup> Lift – 13.00m to 14.00m  
 2<sup>nd</sup> Lift – 14.00m to 15.00m



BoreHole No.- BH-07  
 1<sup>st</sup> Lift – 15.50m to 16.50m  
 2<sup>nd</sup> Lift – 16.50m to 17.50m



BoreHole No.- BH-08  
 1<sup>st</sup> Lift – 16.20m to 17.20m  
 2<sup>nd</sup> Lift – 17.20m to 18.20m



BoreHole No.- BH-09  
 1<sup>st</sup> Lift – 2.00m to 3.00m  
 2<sup>nd</sup> Lift – 3.00m to 3.50m



BoreHole No.- BHR-01  
 1<sup>st</sup> Lift – 1.80m to 2.30m  
 2<sup>nd</sup> Lift – 2.30m to 2.80m



BoreHole No.- BHR-03  
 1<sup>st</sup> Lift – 0.20m to 0.70m