ASSAM ELECTRICITY GRID CORPORATION LIMITED
OFFICE OF THE MANAGING DIRECTOR
Regd. Office:(FIRST FLOOR), BIJULEE BHAWAN, PALTANBAZAR; GUWAHATI - 781001
CIN: U40101AS2003SGC007238 GSTIN: 18AAFCA4973J9Z3
PHONE: 0361-2739520 Web: www.aegcl.co.in Email: cgm.ppd@aegcl.co.in

CORRIGENDUM-I

Bid Identification No.: AEGCL/MD/Tech-750/IOCL-BGR/220kV Power/2018/Part File-I/10 Dated 08.02.2023
Short Tender Notice No.: AEGCL/MD/Tech-750/IOCL-BGR/220kV Power/2018/Part File-I/11 Dated 08.02.2023
NIT No.: AEGCL/MD/Tech-750/IOCL-BGR/220kV Power/2018/Part File-I/12 Dated 08.02.2023

Name of Work: "Preparation of Master Plan for 220/132/33kV GIS for AEGCL at IOCL-BGR (Dhaligaon) complex and 220/33kV GIS for IOCL-BGR at |OCL-BGR (Dhaligaon) complex including 132kV underground cable Route Survey for associated Transmission Line Link including remote end bay at existing 132kV Dhaligaon GSS under AEGCL and 220kV underground cable Route Survey for associated Transmission Line Link for connecting both above mention GIS".

A. **The response to the query for bids identified against the above referred Bid identification; IFB & NIT nos. is noted to the following extent –**

Query	Response from AEGCL
1. Ref. sl. no. (a) of the "Scope of Work" (220/132/33kV GIS): Please inform the source of power supply to the 220kV bus. Is it by stepping up from 132kV supply received from Dhaligaon GSS?	220kV D/c LILO of both circuits of Salakati-Rangia 220kV D/c line. The route survey has already been done considering D/c towers however, all the four circuits shall be terminated via multi-circuit towers. However, Dead end towers shall be D/c towers. The survey reports will be attached as **Annexure-I**.
2. Ref. sl. No. (e) of the "Scope of Work" (Route survey of 132kV Cable): Please inform the approx. route distance between existing Dhaligaon GSS and new 220/132/33kV GIS. It is required for pricing of the survey work. Moreover, the method of Underground survey (like GIS etc.) for these cables should be clarified. Simple contour survey is insufficient for UG cables.	The approximate distance from 132kV Dhaligaon GSS to proposed 220/132/33kV GSS is 5km (Approx.) by road. However, for exact distance, the firm shall carry out a site visit. It is to mention that price escalation will not be entertained by AEGCL if the distance exceeds beyond 5 kms. UG line survey using GIS method is not required at present. The survey shall be carried by properly collecting data as mentioned, as mentioned in the tender, from all the concerned authorities. However, check survey by EPC shall be carried out by using GIS method and the same shall be included in the project BoQ
3. Ref. sl. No. (f) of the "Scope of Work" (Route survey of 220kV Cable): Please inform the approx. route distance between new 220/132/33kV GIS and new 220/33kV GIS. It is required for pricing of the survey work. Moreover, the method of Underground survey (like GIS etc.) for these cables should be clarified. Simple contour survey is insufficient for UG cables.	The sub-stations 220/132/33kV GISand 220kV/33kV GIS shall be back-to-back. For familiarizing with site conditions vendor may carry site visit before submission of offer. UG line survey using GIS method is not required at present. The survey shall be carried by properly collecting data from all the required authorities. However, check survey by EPC shall be carried out by using GIS method and the same shall be included in

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	the project BoQ
4. Ref. sl. No. (g) of the "Scope of Work" (33kV Interconnection with 11kV Main Dist. Switchboard at existing CPP): Please inform the following: a. No of circuits. b. Route distance between 220/132/33kV GIS and 11kV Main Dist. Switchboard at existing CPP. c. CPP rating in MW. d. Method of interconnection between the new 220/132/33kV GIS and 11kV Main Dist. Switchboard at existing CPP. Whether the interconnecting cables will be laid in overhead cable trestle or laid underground? e. If the cables are laid underground, specify the method of Underground survey (like GIS etc.). Simple contour survey is insufficient for UG cables.	a. The number of circuits shall be 4. (CPP-1, CPP-2 and New DG Set) The proposed interconnection includes shifting of existing 11kV generators connection to 33kV new switchboard with suitable transformer. b. Cable route distance will be within 3kM. However, for exact distance, the firm shall carry out a site visit. It is to mention that price escalation will not be entertained by AEGCL if the distance exceeds beyond 3 kms c. CPP rating is total 69MW (3*16MW STG + 1*21MW GTG) d. Preferred cable laying is through overhead trays. e. UG line survey using GIS method is not required at present. However, check survey by EPC shall be carried out by using GIS method and the same shall be included in the project BoQ
5. Refer to sl. no. 13 of the "Instruction for Bidders and General Terms and Conditions (Chapter-III)". It is not understood what it means by "Registration with the concerned department of Government of Assam/Govt. of India". Please clarify which Department's registration is required to participate in this Tender.	Firm/Company registration document may be submitted.
6. For the proposed 132kV cable route survey works (both inside and outside IOCL-BGR premises), please confirm that all the required access/ permissions/ clearances from respective authorities shall be arranged by AEGCL.	Not accepted. Shall be in the scope of the successful bidder
7. Please confirm that all the required permissions / access / clearances from IOCL-BGR (Dhaligaon) shall be arranged by AEGCL for all survey, data collection, site visit, meetings by the Consultant within IOCL-BGR premises.	Required access for site visit and data collection shall be provided by IOCL –BGR however, request should be routed through Dhaligaon Division, AEGCL.
8. Since the scope of work includes preparation of civil estimates and civil BOQs of the entire work, please confirm that conducting Soil investigation test at one point in Substation plots (10m depth) and one point at every 2 km (10m depth) along the UG Transmission	Soil investigation test for the substation plot has already been carried out by IOCL-BGR and the same will be shared as **Annexure-II**. However, soil investigation for the UG transmission line route shall be included in the BoQ for the project work which

line routes are included in the scope. If it is included in scope, please confirm that price of Geotech investigations shall be included in sl. No. 1.1 & 1.2 of the Price schedule (Master Plan).	will be carried out by the EPC at detailed engineering stage.
9. No geotechnical investigation for the 220kV, 132kV and 33kV UG cable routes shall be included in the scope of work. Please confirm.	Confirmed
10. Refer to clause no. 3.1 of the Technical Specification. Under the heading "Collection of details of other utilities" it is mentioned that, information about the existing underground facilities of other utilities shall be arranged by the Bidder. Please confirm that all the permissions required to collect those inputs shall be arranged by AEGCL.	Not accepted. Shall be carried out by the successful bidder
11. Refer to clause no. 3.1 of the Technical Specification – Please confirm that collection of approval of drawings, documents and reports from IOCL-BGR is excluded from the scope of work.	Endorsement of IOCL BGR shall be required for finalization of the report.
12. Refer to clause no. 3.1 of the Technical Specification – Please confirm that collection of approval of drawings, documents and reports from any other third party (Forest, Railway etc.) is excluded from the scope of work.	Not accepted. Shall be carried out by the successful bidder
13. The Payment Terms are not mentioned in the Tender document. The document "General Conditions of Supply and Erection 2009" does not mention the Payment Terms for this type of works. Hence please confirm that we can mention our Payment Terms in our Offer.	Complete payment shall be made after completion of the whole scope of the work.
14. Please inform whether the signed copy of the Tender document needs to be submitted along with the Offer.	Yes
15. Please confirm that we can deviate from some clauses / requirements of the Tender, such as the specified Delivery time which we felt to be unachievable.	As per tender

All other terms and conditions shall remain same.

18/4/23

Chief General Manager (PP&D)
Assam Electricity Grid Corporation Ltd
Bijulee Bhawan, Paltanbazar, Guwahati –01

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Azadi Ka Amrit Mahotsav

Memo No. AEGCL/MD/Tech-750/IOCL-BGR/220kV Power/2018/Part File-I/17(a) **Dated: .02.2023**

Copy to:

1. The AGM -IT, O/o the MD, AEGCL, for publication of the notice in AEGCL's Website.

18/2/23

Chief General Manager (PP&D)
Assam Electricity Grid Corporation Ltd

Annexure-I

TOWER SCHEDULE

PROPOSED 220 KV D/C LILO FROM TOWER NO. 45/1 OF 220 KV SALAKATHI - RANGIA LINE TO PROPOSED 220 KV DHALIGAON S/S (IN BONGAIGAON REFINERY CAMPUS)

SL.NO	ANGLE POINT	TOWER NO	SPAN (M)	TYPE OF TOWER	ANGLE OF DEVIATION	WEIGHT SPAN (M)			WIND SPAN (M)	TYPE OF FOUNDATION	CROSSING	GPS CO-ORDINATE	REMARKS
						LEFT	RIGHT	TOTAL					
1	EX. TOWER			B+6				0				N26° 33.830' E90°32.055'	
			20										
2	AP1	NT 01/00		D+6	06°21'59"RT		156	156	145	FS		N26° 33.810' E90°32.064'	PADDY FIELD
			270								EMBANKMENT		
3		NT 01/01		A+3	00°00'00"	114	148	262	270	WET			PADDY FIELD
			270										
4	AP2	NT 02/00		C+3	16°14'33" RT	123	141	264	279.5	PS			PADDY FIELD
			289								GRAVEL ROAD. WALL		
5	AP3	NT 03/00		B+3	06°16'14" LT	148	168	316	324.5	WET		N26° 33.411' E90°32.244'	PADDY FIELD
			360										
6		NT 03/01		A+6	00°00'00"	192	183	375	360	PS			PADDY FIELD
			360						0		GRAVEL ROAD.		
7		NT 03/02		A+6	00°00'00"	177	181	358	360	FS			PADDY FIELD
			360								CATCHA ROAD.		

Checked by
Deputy Manager
O/o the G.M. (P&E)
AEGCL, Narengi, Guwahati-26

Checked
AGM, O/o the G.M. (P&E)

Checked
DGM, O/o the G.M. (P&E)

HI-TECH DESIGN ENGINEERS GHY-3 Phone:- 9435400185

Approved
General Manager (P&E)

TOWER SCHEDULE

PROPOSED 220 KV D/C LILO FROM TOWER NO. 45/1 OF 220 KV SALAKATHI - RANGIA LINE TO PROPOSED 220 KV DHALIGAON S/S (IN BONGAIGAON REFINERY CAMPUS)

SL.NO	ANGLE POINT	TOWER NO	SPAN (M)	TYPE OF TOWER	ANGLE OF DEVIATION	WEIGHT SPAN (M)			WIND SPAN (M)	TYPE OF FOUNDATION	CROSSING	GPS CO-ORDINATE	REMARKS
						LEFT	RIGHT	TOTAL					
8		NT 03/03		A+6	00°00'00"	179	174	353	355	WET			PADDY FIELD, AND TREE CUTTING
			350								WATER STREAM		
9	AP4	NT 04/00		D+6	39°41'21" RT	176	154	330	310	PS		N26° 32.673' E90°32.511'	PADDY FIELD
			270								GRAVEL ROAD. LT, HT LINE		
10	AP5	NT 05/00		C+3	16°17'21" LT	116	155	271	281.5	WET		N26° 32.538' E90°32.450'	PADDY FIELD
			293										
11		NT 05/01		A+3	00°00'00"	137	146	283	293	PS			PADDY FIELD
			293										
12	AP6	NT 06/00		D+3	50°36'58"LT	147	138	285	281	FS		N26° 32.222' E90°32.412'	PADDY FIELD
			269								GRAVEL ROAD.AND CATCHA ROAD		
13	AP7	NT 07/00		D+3	30°32'18" RT	131	144	275	274.5	WET		N26° 32.119' E90°32.526'	PADDY FIELD
			280								CATCHA ROAD, 11 KV LINE		

Checked by

Deputy Manager
O/o the G.M. (P&E)
AEGCL, Narengi, Guwahati-26

Checked

AGM, O/o the G.M. (P&E)

Checked

DGM, O/o the G.M. (P&E)

Approved

General Manager (P&E)
AEGCL

HI-TECH DESIGN ENG... GHY-3 Phone:- 9435400185

TOWER SCHEDULE

PROPOSED 220 KV D/C LILO FROM TOWER NO. 45/1 OF 220 KV SALAKATHI - RANGIA LINE TO PROPOSED 220 KV DHALIGAON S/S (IN BONGAIGAON REFINERY CAMPUS)

SL.NO	ANGLE POINT	TOWER NO	SPAN (M)	TYPE OF TOWER	ANGLE OF DEVIATION	WEIGHT SPAN (M)			WIND SPAN (M)	TYPE OF FOUNDATION	CROSSING	GPS CO-ORDINATE	REMARKS
						LEFT	RIGHT	TOTAL					
14		NT 07/01		A+3	00°00'00"	136	142	278	280	FS			PADDY FIELD
			280										
15		NT 07/02		A+3	00°00'00"	138	148	286	280	WET			PADDY FIELD
			280										
16		NT 07/03		A+3	00°00'00"	132	166	298	281.5	WET			PADDY FIELD
			283										
17	AP8	NT 08/00		D+0	29°27'32"RT	117		117	181	FS		N26° 31.529' E90°32.694'	LOW LAND
			79										
18	GANTRY			10 M	00°00'00"			0	66.5	WET			PADDY FIELD,AND GANTRY AREA COVERED BY FENCING
			54										
19	AP9	NT 09/00		D+0	02°57'20"RT		115	115	156	PS		N26° 31.459' E90°32.673'	PADDY FIELD
			258										
20	AP10	NT 10/00		D+3	37°38'11"LT	143	153	296	292	FS		N26° 31.331' E90°32.612'	PADDY FIELD
			326								CANAL		
21	AP11	NT 11/00		D+3	30°32'38"RT	173	55	228	163	WET		N26° 31.161' E90°32.664'	TREE CUTTING

Checked by
Deputy Manager
O/o the G.M. (P&E)
AEGCL, Narengi, Guwahati-26

Checked
AGM, O/o the G.M. (P&E)

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DGM, O/o the G.M. (P&E)

Approved
General Manager (P&E)
AEGCL

HI-TECH DESIGN ENGG. GHY-3 Phone:- 9435400185

TOWER SCHEDULE

PROPOSED 220 KV D/C LILO FROM TOWER NO. 45/1 OF 220 KV SALAKATHI - RANGIA LINE TO PROPOSED 220 KV DHALIGAON S/S (IN BONGAIGAON REFINERY CAMPUS)

SL.NO	ANGLE POINT	TOWER NO	SPAN (M)	TYPE OF TOWER	ANGLE OF DEVIATION	WEIGHT SPAN (M) LEFT	RIGHT	TOTAL	WIND SPAN (M)	TYPE OF FOUNDATION	CROSSING	GPS CO-ORDINATE	REMARKS
			176								CATCHA ROAD, B WALL TREE		
22	AP12	NT 12/00		C+6	23°11'18"RT	121				WET		N26° 31.068' E90°32.635'	TREE CUTTING
			71								PITCH ROAD,33 KV LINE B WALL		
23	AP13	NT 13/00		D+3	58°13'03"RT					PS			IOCL CAMPUS
	TOTAL		**5491**										

SUMMARY OF TOWERS:

TYPE OF TOWERS (AS PER NEW CONCEPT) :
A TYPE 0° - 2°
B TYPE 2°-15°
C TYPE 15°-30°
D TYPE 30° TO 60°

1. QTY. OF TOWERS (AS PER NEW CONCEPT) :

A+3	5	
A+6	3	(ALL DOUBLE CKT. TOWERS)
B+3	1	
C+3	2	
C+6	1	
D+0	2	
D+3	5	
D+6	2	
TOTAL	**21**	

GANTRY = 1 (3 Nos. Column + 2 Nos. Beam)

NOTE : GANTRY AREA COVERED BY FENCING

Approved

General Manager (P&E)
AEGCL

DATE : 19-02-2019

Checked by

Deputy Manager
O/o the G.M. (P&E)
AEGCL, Narengi, Guwahati-26

Deputy General Manager
Bongaigaon T&T Circle
AEGCL, Dhaligaon

Assistant General Manager
EHV Grid Sub Station Division
AEGCL, DHALIGAON

HI-TECH DESIGN ENGG. & CONS. GHY-3 Phone:- 9435400185

PREPARED BY : HI-TECH DESIGN ENGINEERING & CONSTRUCTION

Checked

AGM, O/o the G.M. (P&E)

Checked

DGM, O/o the G.M. (P&E)

Annexure-II

Report on Soil Testing at Bongaigaon Refinery

-Client-
Indian Oil Corporation Limited, Bongaigaon Refinery
Dhaligaon, Chirang, Assam

-Turnkey Investigating & Consulting Agency-
Project Engineering & Controls Pvt. Ltd.
160D, Bakul Bagan Road,
Kolkata – 700025

-Geotechnical Consultant -
Dr. S.P. Mukherjee & Dr. Gupinath Bhandari
Department of Civil Engineering
Jadavpur University
Kolkata 700032

-Geotechnical Consulting Authority-
Industry Institute Partnership Cell
Jadavpur University
Kolkata 700032

May, 2016

C O N T E N T

1. INTRODUCTION:

M/s Indian Oil Corporation Limited, Bongaigaon Refinery, Assam (IOCL), A Govt. of India Undertaking has proposed to develop ground mounded LPG bullet plant. Accordingly for the purpose of the foundation design and construction of the proposed infrastructure of the project, a subsoil exploration work was entrusted to M/s Project Engineering and Controls Private Limited, 160D, Bakul Bagan Road, Kolkata – 700025 (PECPL) vide their LOA No. 24690094 dated 04.03.2016. Pursuant to the said LOA, the field investigation was commenced by PECPL on 8th April, 2016 and completed on 16th April, 2016. PECPL approached Department of Civil Engineering, Jadavpur University for testing of disturbed and undisturbed soil samples and preparation of soil testing report with recommendation for foundation design.

The undisturbed and SPT samples were sent to Soil Mechanics Laboratory, Dept. of Civil Engineering, Jadavpur University. This report deals with soil profile as obtained from borehole and engineering properties of each soil stratum alongwith recommendation for foundation design for different structures to be built at the site.

1.1. Brief Description of the Proposed Construction:

The proposed structure is LPG Mounded Bullets. These are horizontal bullets installed for bulk storage of liquefied petroleum gas (LPG). Offering a safer method for storing highly inflammable LPG; mounded LPG bullets are large, buried, horizontal cylindrical steel tanks.

1.2. Purpose and Scope of Investigation:

Soil Testing is very important in understanding the physical properties of soil and the rocks beneath. This is required to ascertain the type of foundation required for the proposed construction. Various tests have been done to explore the sub surface and surface characteristics of soil.

The Scope of work broadly consists of the followings:

I. Mobilization of various tools, tackle and manpower at site for boring, collection of soil/water samples, carrying out field tests as per specification and demobilization.
II. Carrying out laboratory tests on soil and water samples for determination of design parameters as per specification.
III. Submission of Report as per specification.

2. SITE CONDITIONS

2.1. Site Geology – general description:

The area forms a part of the vast alluvial plains of Brahmaputra River system and sub-basin of River Manas. Physiographically, it is characterised by the alluvial plains. The formation is comprised of sand, clay with mixtures of pebble, cobble and boulders. The Newer alluvium includes sand, gravel, pebble with silt and clay.

2.2. Potential Geological Hazards:

This is well known as a flood prone or Erosion prone district but equally it is also declared as one of the multi hazard area of Assam from the viewpoint of earth quake disasters. The region also falls within the highest seismic belt and experienced two major earthquakes, one in 1897 and another in 1950. In recent times the upcoming mushrooming man-made structures, mostly the non engineered buildings, really severe the situation and strengthen the intensity of damages from the probable hazard like earthquake.

2.3. Site Surface Description:

The surface of the site falls in a jungle with results presence of sandy-silty clay at the top of the surface.

2.4. Site Topography – general description:

The site falls in a slightly undulated area with ample of branching trees and bushes.

2.5. Description of above ground obstructions:

At the site, no above ground obstruction was found.

3. SUBSURFACE CONDITION

3.1. Stratigraphy and General Description of Subsurface Material Properties

Stratigraphy as revealed by borings is shown in Annexure. The depth wise variation of N values along the boreholes is shown alongside the soil profile. The worst subsoil stratification has been encountered in BH-1 and this has been considered for the design. The soil stratification therefore has been summarized as shown in Table – 1.

Table – 1: Subsoil Profile

Stratum	Description	Thickness (m)	N-Value
I	Medium Stiff brownish grey sandy clayey silt	7.50	9-13
II	Medium dense brownish grey silty fine sand with mica	4.50	14-28
III	Dense brownish grey silty medium to fine sand with mica	3.00	30-49
IV	Very dense brownish grey silty fine sand with mica and gravel	10.00	50-89

3.2. Groundwater elevations and expected variations:

Groundwater was encountered at a depth between 2.8m to 3.2m below ground level. Water levels reflect a dynamic balance between ground-water recharge, storage, and discharge. If recharge exceeds discharge, the volume of water in storage will increase and water levels will rise; if discharge exceeds recharge, the volume of water in storage will decrease and water levels will fall. Because recharge and discharge are not distributed uniformly in space and time, ground-water levels are continuously rising or falling to adjust to the resulting imbalances. Therefore with seasonal variation water table is likely to fluctuate and the water table has been considered to be at ground surface for design purpose.

3.3. Description of underground obstructions encountered or otherwise identified:

No underground obstructions were encountered or during the field work. However, if required, underground utility survey may be carried out before construction.

3.4. Corrosion Potential for Underground Utilities and Storage Tanks:

Table 2A and 2B of the geotechnical report suggest that average pH value of groundwater and subsurface soil is about 6.5. Further the soil resistivity is in general greater than 20Ω-m for any depth as per ERT carried out by PECPL.

The standard given in Table 2 of the document "Soil Corrosivity Analysis" available in internet (*www.corrosionsurvey.co.kr/viewer/pdf/n_02.pdf*) may be referred for studying corrosivity of soil and water.

Considering both pH and resistivity criteria it is observed that corrosivity comes to 0 point in the scale hence it is expected buried steel or concrete foundations would not come under corrosive attack.

4. FIELD INVESTIGATION

4.1. Summary of Operations:

Derrick mounted winch rig was deployed to execute the boring works. Boreholes of 150 mm diameter were made and the borehole progressed with the combination of Auger boring technique followed by Rotary Mud Circulation method. Wherever hard strata were met with, sinker bar and chisel were used to proceed with the boring. Casing pipes and bentonite slurry were used to prevent collapse of the loose materials inside the borehole.

The borings progressed down to the specified depth. Where caving of the borehole occurred, casing was used to keep the borehole stable.

4.2. Description of Sampling Procedures:

Three types of samples were collected from the field namely SPT samples and Undisturbed soil samples and Groundwater samples.

i. **SPT Samples:** Disturbed samples were collected from the split spoon after conducting SPT. The samples were preserved in transparent polythene bags.

ii. Undisturbed Soil Samples: Undisturbed samples were collected by attaching 75mm diameter thin walled 'Shelby' tubes and driving the sampler. The tubes were sealed with wax at both ends.

iii. Groundwater Samples: The water level in borehole allowed to stabilize after completion of boring. When water level inside the borehole was found stable, the depth of water level below ground level was measured and the water collected in plastic jerry can.

4.3. Description of field tests:

i. Standard Penetration Test:

Standard Penetration Tests(SPT) were conducted in the boreholes at 1.5 m depth intervals by connecting a split spoon sampler to 'A' rods and driving it by 45cm using a 65kg hammer falling freely from a height of 75 cm. The number of blows for each 15 cm of penetration of the split spoon sampler was recorded. The blows required to penetrate the initial 15 cm of the split spoon for seating the sampler was ignored due to the possible presence of loose materials or cuttings from the drilling operation. The cumulative number of blows required to penetrate the balance 30 cm of the 45 cm sampling interval is termed the SPT value or the 'N' value. The 'N' values were presented on the soil profile for each borehole.

ii. Electrical Resistivity Test:

The electrical resistivity test was used for shallow subsurface exploration by means of electrical measures made at the ground surface. Resistivity measurements were made by driving four electrodes in to the soil at pre-selected electrode spacing. The Wenner electrode configuration was used for this study. The four electrodes were spaced at equal distance along a line.

Measurements were made by causing a current, 'I', to pass through the earth and distribute within a relatively large hemispherical earth mass. The portion of the current that flows along the surface produces a voltage drop, 'V'. The resistance 'R', ratio of voltage drop 'V' to current 'I' is directly measured by Digital Earth Resistance Tester. The resistivity was determined from the following equation:

$$\rho = 2\pi aR$$

Where,

ρ = Apparent Resistivity in ohm-m

a = Spacing between the electrodes in m

R = Resistance in ohm

The apparent resistivity of the subsurface stratum comes more than 40Ω-m.

iii. California Bearing Ratio Test:

For each test, the CBR plunger of 5 cm diameter was penetrated into the soil under a standard surcharge load at a rate of approximately 1.25 mm per minute. A proving ring is to be used to measure the load. A dial gauge of 0.01 mm sensitivity was used to measure the penetration with reference to a stable datum. The CBR value was calculated as percent ratio of pressure applied for specified penetrations into the soil to that required to penetrate into the standard material.

4.4. Logs of borings:

A boring log is a written record of information about the soil removed from a hole drilled in the earth which contains the soubsoil stratification, N-values and details of samples. Logs of Boring, which represent the field data, are attached in the Annexure.

4.5. Location Plan:

Borehole Locations were marked with the help of IOCL personnel and the Borehole Location plan is attached in the Annexure

5. LABORATORY TESTS

The following tests were done on representative samples.

a) Grain Size Analysis
b) Natural Moisture Content
c) Dry Density and Bulk Density
d) Liquid Limit and Plastic Limit
e) Unconsolidated Undrained Triaxial Test
f) Consolidation Test
g) Specific Gravity
h) Direct Shear Test
i) Chemical Test of Soil and Water to determine pH, Cl^- and SO_4^{2-}

The laboratory tests were run to ascertain the average engineering properties of the sub-soil strata and to obtain the necessary data required for determination of particulars of the foundation. These are detailed below. A summary of all test results has been given in the enclosed laboratory sheet.

5.1. Description of Tests:

I. Grain Size Analysis:

a. SIEVE ANALYSIS

The complete sieve analysis can be divided into two parts, i.e, the coarse analysis and fine analysis. An oven dried samples of soil is separated into two fractions by sieving it through a 4.75 mm IS sieve. The portion retained of it (+4.75mm size) is termed as the gravel fraction and is kept for the coarse analysis, while the portion passing through it (-4.75mm size) is subjected to fine sieve analysis.

b. HYDROMETER ANALYSIS

In the wet method of mechanical analysis or sedimentation analysis, the soil fraction, finer than 75 micron size is kept in suspension in a liquid (usually water) medium. The analysis is based on stoke's law, according to which the velocity at which grains settle out of suspension, all other factor being equal, is depended upon the shape, weight and size of the particles/grains.

II. Natural Moisture Content:

It is the ratio of the weight of water to the dry weight of soil determined by oven drying.

III. Dry Density and Bulk Density:

These were determined by measuring the weights and dimensions of tri-axial shear and unconfined compressive strength test samples before testing and after oven drying. The bulk density & dry density values of the samples have been given in the enclosed laboratory sheet.

IV. Liquid Limit and Plastic Limit:

These are arbitrary moisture contents to determine the instant at which the soil is on the verge of being viscous liquid (Liquid limit) or non–plastic /Plastic limit. Liquid limits determined with the help of a liquid limit apparatus. Plastic limit is the water content at which the soil begins to crumble when rolled out into a thin thread of 3mm.

V. Unconsolidated Undrained Triaxial Test:

For triaxial shear and unconfined compressive strength tests, three no. 38mm diameter 76mm long specimens were obtained by jacking out the soil core, each into a thin-walled brass tube, having the wall thickness of 1/32". The inside of the tubes was coated with a thin layer of silicon oil.

These were run on the clayey silt samples to determine their shear strengths. The cell pressures employed were 0.5, 1.0 and 1.5 kg/sq.cm. The samples were tested under quick condition at a rate of 1.25 mm/min and were loaded up to maximum 20% axial strain.

VI. Consolidation Test:

To obtain specimens for consolidation test, the odometer ring was placed on the trimmed horizontal faces of the soil within the 10 cm diameter sampling tube and the soil around the cutting edge was gradually removed with a spatula as the ring was gently pushed into the soil. The ring with the soil was then removed by cutting across the soil core with the help of a piano wire saw.

Consolidation tests were run in floating ring type odometers, in single & four unit consolidation frames under standard load increment ratio starting from 0.25 kg/sq.cm and going up to 16 kg/sq.cm in general. The pressure vs void ratio curves are given in this report.

VII. Specific Gravity:

The Specific Gravity of the soil samples was determined by adopting standard procedure. The soil sample was dried in oven dried for 24 hours and pulverized. The sample was then poured into a specific gravity bottle and topped up with distilled water. The specific gravity bottle was stirred and heated to eliminate air bubbles. The weight of the specific gravity bottle was recorded along with the temperature of the sample.

VIII. Direct Shear Test:

Direct Shear Test is a strength test which is performed on the soil sample to determine the value of angle of internal friction.

The direct shear test is generally conducted on cohesion less soil as consolidated drained (CD) test. In the present case, the soil samples were prepared for various depths and were tested in the Direct Shear Apparatus under CD-condition.

The result of all the laboratory tests have been reflected in a borehole log and test result data sheet enclosed at the annexure. Graphical and pictorial presentations of test observations wherever relevant are to be also reflected and enclosed at the annex for their better appreciation.

5.2. Test Results:

Soil Test Result:

A summary of all laboratory test results is given in Annexure. From a study of these test results, the engineering properties of different strata can be summarized as follows:

Stratum I: Medium Stiff brownish grey sandy clayey silt (0.00 – 7.50m below G.L)

Bulk density: 1.86t/m^3
Natural moisture content: 30 %
LL: 38%
PL: 23%
C_u: 3.0t/m^2
ϕ: 8^0
m_v: 0.0040m^2/t, At Pressure range (0.50-1.00 kg/cm^2)

Stratum II: Medium dense brownish grey silty fine sand with mica (7.50m – 12.00m below GL)

Bulk density: 1.88t/m^3
ϕ: 30^0

Stratum III: Dense brownish grey silty medium to fine sand with mica. (12.00m – 15.00m below GL)

Bulk density: 1.92t/m^3
ϕ: 32^0

Stratum IV: Very dense brownish grey silty fine sand with mica and gravel. (15.00m – 25.00m below GL)

Bulk density: 1.94t/m^3
ϕ: 33^0

Chemical Test Result:

The test results on chemical analysis of water and subsoil samples have been appended in Table 2(A and B), which was carried out by M/s Aglow Quality Control Laboratory Pvt. Ltd., Kolkata - 700107. Chemical Tests were conducted in six (6) soil samples and six (6) groundwater samples to determine pH, Cloride (Cl) and Sulphate (SO_4) ions. The results of the tests are given below:

Table – 2A: Chemical Test Result of Soil Samples

Sl. No.	Sample No.	pH	Chloride (as Cl) in mg/Kg	Sulphate (as SO_4) in mg/Kg
01	IOCL/BH01/SPT/1.50	5.95	1638.5	BDL
02	IOCL/BH02/SPT/6.00	5.5	983.1	BDL
03	IOCL/BH03/SPT/10.50	6.29	1968	BDL
04	IOCL/BH04/SPT/15.00	6.55	1521.7	BDL
05	IOCL/BH05/SPT/19.50	6.30	657	BDL
06	IOCL/BH06/SPT/24.00	6.54	952.15	BDL

NB: BDL = Below Detection Level < 10.00 mg/Kg

Table – 2B: Chemical Test Result of Water Samples

Sl. No.	Sample No.	pH	Chloride (as Cl) in mg/L	Sulphate (as SO_4) in mg/L
01	IOCL/BH01/GW/2.90	7.05	50.17	77.17
02	IOCL/BH02/GW/3.10	6.25	33.45	105.40
02	IOCL/BH03/GW/3.20	6.50	66.90	95.2
04	IOCL/BH04/GW/2.80	6.57	66.90	70.58
05	IOCL/BH05/GW/3.10	6.47	66.90	99.29
06	IOCL/BH06/GW/3.20	6.45	50.17	60.70

6. Foundation Recommendation:

General Consideration:

- Foundation of a structure is to be designed from considerations of superstructure loading as well as subsoil condition at the site. Suitable foundations for a structure should satisfy the following basic design criteria.
- For ultimate bearing capacity, groundwater table calculation is not needed for clayey soil as per IS:6403. However, parameters have been considered for saturated condition with water table at ground surface.
- There must be adequate factor of safety of the foundations against any possible bearing capacity failure and the settlement of the foundations must be within permissible limits.
- On the basis of requirement, both shallow and deep foundation may be adopted at the site for different types of structures. Hence both shallow and deep foundation has been studied as follows:

a. Shallow Foundation:

i. Shallow Footing:

Net allowable bearing capacity of shallow foundation of different width in the form of strip and isolated footings has been obtained as per IS: 6403. The value of net allowable bearing capacity has been furnished in Table – 3A, 3B and 3C. The sample calculation has been furnished in annexure.

Table – 3A: Bearing Capacity of Square Footing

Size of Footing	Depth of Footing	Net Safe Bearing Capacity (t/m^2)	Estimated Settlement (mm)	Suggested Net Allowable Bearing Capacity (t/m^2)		
				25mm	40mm	50mm
1mx1m	1.0m	9.62	18	Not Possible	Not Possible	Not Possible
2mx2m		8.82	32	6.89	Not Possible	Not Possible
3mx3m		8.55	47	4.55	7.28	Not Possible
4mx4m		8.42	62	3.40	5.43	6.79
5mx5m		8.34	75	2.78	4.45	5.56
1mx1m	2.0m	9.62	17	Not Possible	Not Possible	Not Possible
2mx2m		9.62	35	6.87	Not Possible	Not Possible
3mx3m		9.09	50	4.55	7.27	9.09
4mx4m		8.82	64	3.45	5.51	6.89
5mx5m		8.66	75	2.89	4.62	5.77
1mx1m	3.0m	9.62	18	Not Possible	Not Possible	Not Possible
2mx2m		9.62	35	6.87	Not Possible	Not Possible
3mx3m		9.62	53	4.54	7.26	9.08
4mx4m		9.22	65	3.55	5.67	7.09
5mx5m		8.98	75	2.99	4.79	5.99

Table – 3B: Bearing Capacity of Circular Footing

Size of Footing	Depth of Footing	Net Safe Bearing Capacity (t/m^2)	Estimated Settlement (mm)	Suggested Net Allowable Bearing Capacity (t/m^2)		
				25mm	40mm	50mm
1m	1.0m	9.62	18	Not Possible	Not Possible	Not Possible
2m		8.82	32	6.89	Not Possible	Not Possible
3m		8.55	47	4.55	7.28	Not Possible
4m		8.42	62	3.40	5.43	6.79
5m		8.34	75	2.78	4.45	5.56
1m	2.0m	9.62	17	Not Possible	Not Possible	Not Possible
2m		9.62	35	6.87	Not Possible	Not Possible
3m		9.09	50	4.55	7.27	9.09
4m		8.82	64	3.45	5.51	6.89
5m		8.66	75	2.89	4.62	5.77
1m	3.0m	9.62	18	Not Possible	Not Possible	Not Possible
2m		9.62	35	6.87	Not Possible	Not Possible
3m		9.62	53	4.54	7.26	9.08
4m		9.22	65	3.55	5.67	7.09
5m		8.98	75	2.99	4.79	5.99

Table – 3C: Bearing Capacity of Strip Footing

Size of Footing	Depth of Footing	Net Safe Bearing Capacity (t/m^2)	Estimated Settlement (mm)	Suggested Net Allowable Bearing Capacity (t/m^2)		
				25mm	40mm	50mm
1m	1.0m	7.40	27	6.85	Not Possible	Not Possible
2m		6.78	49	3.46	5.53	Not Possible
3m		6.58	72	2.28	3.66	4.57
4m		5.61	75	1.87	2.99	3.74
5m		4.93	75	1.64	2.63	3.29
1m	2.0m	7.40	27	6.85	Not Possible	Not Possible
2m		7.40	54	3.43	5.48	6.85
3m		6.88	75	2.29	3.67	4.59
4m		6.01	75	2.00	3.21	4.01
5m		5.32	75	1.77	2.84	3.55
1m	3.0m	7.40	27	6.85	Not Possible	Not Possible
2m		7.40	54	3.43	5.48	6.85
3m		6.88	75	2.29	3.67	4.59
4m		6.58	75	2.19	3.51	4.39
5m		5.83	75	1.94	3.11	3.89

ii. Raft Foundation:

Raft foundation of size 25mx95m founded at depth of 1m, 2m and 3m below GL may be adopted for the foundation of mounded bullets and the values of net allowable bearing capacities have been furnished in Table – 3D. The sample calculation has been furnished in annexure.

Table – 3D: Bearing Capacity of Raft Foundation

Size of Footing	Depth of Footing	Net Safe Bearing Capacity (t/m^2)	Estimated Settlement (mm)	Suggested Net Allowable Bearing Capacity (t/m^2)		
				25mm	40mm	50mm
25mx95m	1.0m	3.89	100	0.97	1.56	1.94
	2.0m	4.16	100	1.04	1.66	2.08
	3.0m	4.49	100	1.12	1.79	2.24

b. Deep Foundation:

Deep foundation in the form of RCC bored cast-in-situ piles has been investigated. Pile toe may be kept at 15.0 below the Existing Ground Level. Cut-off level may be considered at 1.5m below the EGL. The ultimate load carrying capacity (Qu) of a pile foundation has been estimated as given below and shown in the Annexure of the report.

$Qu = Ap\ (0.5xDx\gamma xN\gamma + PdxNq) + \sum \alpha\ C\ As + K\ Pdi\ tan\delta\ Asi$

where, Ap = Cross-sectional area of pile toe, D = Pile stem diameter,

γ = Effective unit weight of soil at pile toe,

Pd = Effective overburden pressure at pile toe,

Nγ & Nq = Bearing capacity factors depending upon the angle of internal friction (Φ) of soil at pile toe,

∑ = Summation for n layers in which pile is installed,

α = Reduction factor, C = Average cohesion of soil,

As = Surface area of pile stem, K = Coefficient of earth pressure = 1.5,

Pdi = Effective overburden pressure for the ith layer;

δ = Angle of wall friction between pile and soil in degrees (may be taken equal to Φ) and

Asi = Surface area of pile stem in the i^{th} layer.

Values of safe load carrying capacity of RCC Bored Cast in situ pile with tip resting at 15.0m from EGL (with 1.5m cut-off from EGL) for different diameters have been estimated as shown in the Annexure of the report and given as shown in the Table – 4 below :

Table – 4: Bearing Capacity of Pile Foundation

Pile Diameter (mm)	Cut off Depth below GL (m)	Pile Tip Depth below GL (m)	Pile Length below cut of Depth (m)	Safe Vertical Pile Capacity (MT)	Safe Uplift Load Capacity (MT)	Safe Lateral Load Capacity (MT)	Depth of Fixity (m)
450	1.5	15	13.5	40	28	2.79	4.77
600	1.5	15	13.5	60	37	4.46	6.36
750	1.5	15	13.5	85	46	6.97	7.95
1000	1.5	15	13.5	145	62	12.38	10.59

The above tabulated pile capacities should be checked at the site by conducting initial land routine load tests on piles according to IS: 2911 (Part-IV). Minimum pile spacing should be kept equal to 3 times the diameter of pile. It is also suggested to supplement the pile capacity by conducting dynamic load test by pile driving analyzer (PDA) and to carry out pile integrity test to check the soundness of the piles to be cast in situ.

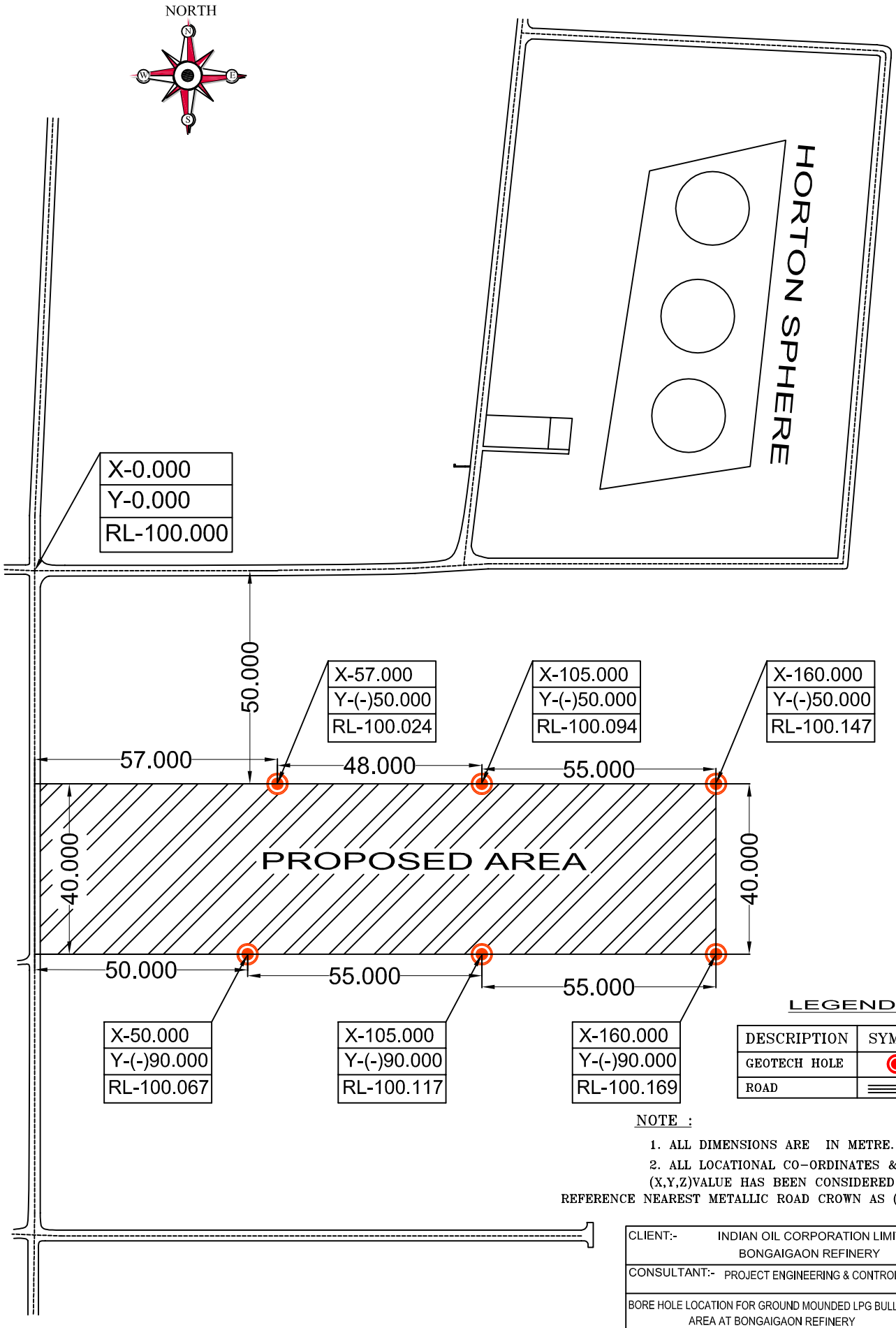
RECOMMENDATIONS:

It has been proposed to construct three mounded bullets alongwith some ancillary structures at the site. A detailed soil investigation programme was undertaken to assess the quality of the existing subsoil and to suggest suitable foundation systems for the proposed structures. Based on field and laboratory tests and analysis of the results the following recommendations may be made.

1. At this site, shallow foundations may be adopted and the values of net allowable bearing capacity for strip, square and circular footings of different sizes founded at 1m, 2m and 3m below G.L. are recommended as shown in Table – 3A, 3B and 3C.
   1.1. Tie beams, properly designed against probable differential settlement, if any, should be provided between columns.
   1.2. Safety of adjacent structures must be ensured during excavation work and also during construction of foundations.
   1.3. For mounded bullets, raft foundation of 25mx95m, founded at a depth of 1m, 2m and 3m below GL, may be adopted and the values of net allowable bearing capacities have been furnished in Table – 3D. However, in case raft foundation is not capable of bearing the load intensity, deep foundation in the form of pile foundation may be adopted.
2. R.C.C. Cast- in- situ bored piles of shaft length 13.5 m below cut off length of 1.5m below GL is suggested.
   2.1. The capacity of such piles of different diameter with 1.5m cut off length has been given in the preceding chapter in Table – 4. There should be adequate provision for Load test of piles according to IS 2911 – Part IV (latest edition). The minimum spacing of piles should be kept equal to 3 times the pile diameter.
   2.2. For use of pile, higher diameter may be chosen for increased capacity and reduction of number of piles. For further increase in pile length, at least three borings of minimum 50m depth should be done as per clause no. 4.1(a) of IS:2911-1-4 (2010)
3. Liquefaction is not likely to occur under present site condition since there is a cohesive deposit covering the sandy soil and it has a sufficient depth of 7.5m. It is therefore expected that it will prevent dissipation of pore water pressure since its permeability is comparatively low.
4. Downdrag forces do not arise since there is no recently placed fill.
5. Active earth pressure, at-rest earth pressure etc. are to be obtained from the given shear strength parameters.
6. For Slabs, Pavements and Roadways, CBR value has been given. Improvement, if required, is to be addressed by the constructor.
7. If required, scheme for deep excavation including dewatering can be made by conducting field permeability test and on the basis of the soil data presented in this report.
8. If required, ground improvement techniques, appropriate to the site condition may be adopted and proper scheme has to be designed for that purpose based on the soil data presented in this report.

ANNEXURES

Borehole Location Plan



LEGEND

DESCRIPTION	SYMBOL
GEOTECH HOLE	
ROAD	

NOTE :

1. ALL DIMENSIONS ARE IN METRE.
2. ALL LOCATIONAL CO-ORDINATES & RL (X,Y,Z)VALUE HAS BEEN CONSIDERED WITH REFERENCE NEAREST METALLIC ROAD CROWN AS (0,0,100)

CLIENT:-	INDIAN OIL CORPORATION LIMITED BONGAIGAON REFINERY
CONSULTANT:-	PROJECT ENGINEERING & CONTROLS PVT.LTD.
BORE HOLE LOCATION FOR GROUND MOUNDED LPG BULLET PLANT AREA AT BONGAIGAON REFINERY	

SCALE	DWG. NO.	REV.
1:1100	PEC/P-045/001	0

Borelogs

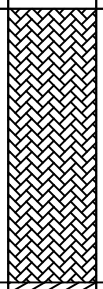
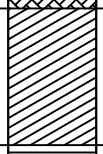
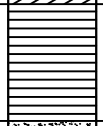
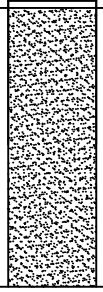
BORELOG DATA SHEET

BORE HOLE NO. : 1(ONE)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

FIELD TEST

(a) COMMENCED ON : 10.04.2016
(b) COMPLETED ON : 10.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 2.40m

DESCRIPTION		Depth (m)		Thickness (M)	N-Value	Type & marked	Samples Depth (M)
		From	To				
Medium Stiff brownish grey sandy clayey silt		0'0	7.50	7.50	-	DS	0.50
					-	DS	1.00
					-	UDS	2.00
					11	SPT	3.00
					-	UDS	4.00
					12	SPT	6.00
					20	SPT	7.50
Medium dense brownish grey silty fine sand with mica		7.50	12.00	4.50	23	SPT	9.00
					27	SPT	10.50
					32	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	15.00	3.00	49	SPT	13.50
					53	SPT	15.00
Very dense brownish grey silty fine sand with mica		15.00	25.00	10.00	60	SPT	16.50
					64	SPT	18.00
					69	SPT	19.50
					72	SPT	21.00
					80	SPT	22.50
					87	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

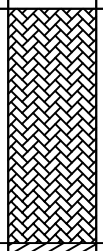
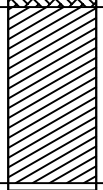
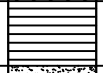
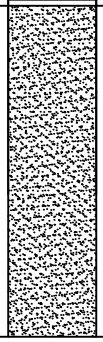
BORELOG DATA SHEET

BORE HOLE NO. : 2(TWO)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

FIELD TEST

(a) COMMENCED ON : 08.04.2016
(b) COMPLETED ON : 08.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 3.10m

DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Medium Stiff brownish grey sandy clayey silt		0'0	6.00	6.00	-	DS	0.50
					-	DS	1.00
					-	UDS	2.00
					12	SPT	3.00
					10	SPT	4.50
					-	UDS	6.00
Medium dense brownish grey silty fine sand with mica		6.00	12.00	6.00	21	SPT	7.50
					23	SPT	9.00
					26	SPT	10.50
					33	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	13.50	1.50	50	SPT	13.50
Very dense brownish grey silty fine sand with mica		13.50	25.00	11.50	62	SPT	15.00
					74	SPT	16.50
					75	SPT	18.00
					73	SPT	19.50
					82	SPT	21.00
					84	SPT	22.50
					80	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

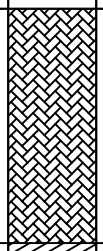
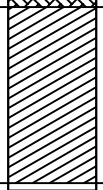
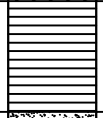
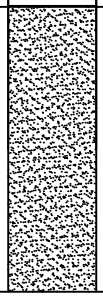
BORELOG DATA SHEET

BORE HOLE NO. : 3(THREE)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

FIELD TEST

(a) COMMENCED ON : 09.04.2016
(b) COMPLETED ON : 09.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 3.20m

DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Medium Stiff brownish grey sandy clayey silt		0'0	6.00	6.00	-	DS	0.50
					-	DS	1.00
					11	SPT	1.50
					13	SPT	3.00
					12	SPT	4.50
					15	SPT	6.00
Medium dense brownish grey silty fine sand with mica		6.00	12.00	6.00	22	SPT	7.50
					25	SPT	9.00
					28	SPT	10.50
					32	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	15.00	3.00	47	SPT	13.50
					62	SPT	15.00
Very dense brownish grey silty fine sand with mica		15.00	25.00	10.00	69	SPT	16.50
					71	SPT	18.00
					82	SPT	19.50
					85	SPT	21.00
					84	SPT	22.50
					88	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

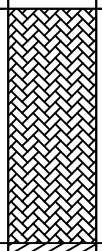
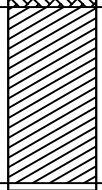
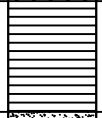
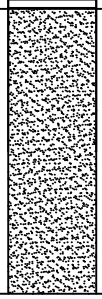
BORELOG DATA SHEET

BORE HOLE NO. : 4(FOUR)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

FIELD TEST

(a) COMMENCED ON : 13.04.2016
(b) COMPLETED ON : 13.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 2.80m

DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Medium Stiff brownish grey sandy clayey silt		0'0	6.00	6.00	-	DS	0.50
					-	DS	1.00
					-	UDS	2.00
					12	SPT	3.00
					-	UDS	4.00
					-	UDS	6.00
Medium dense brownish grey silty fine sand with mica		6.00	12.00	6.00	19	SPT	7.50
					22	SPT	9.00
					27	SPT	10.50
					30	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	15.00	3.00	44	SPT	13.50
					57	SPT	15.00
Very dense brownish grey silty fine sand with mica		15.00	25.00	10.00	69	SPT	16.50
					73	SPT	18.00
					80	SPT	19.50
					82	SPT	21.00
					85	SPT	22.50
					89	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

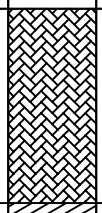
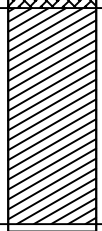
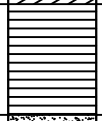
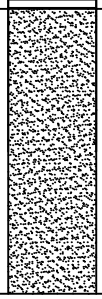
BORELOG DATA SHEET

BORE HOLE NO. : 5(FIVE)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

FIELD TEST

(a) COMMENCED ON : 12.04.2016
(b) COMPLETED ON : 12.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 3.10m

DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Medium Stiff brownish grey sandy clayey silt		0'0	4.50	4.50	-	DS	0.50
					-	DS	1.00
					-	UDS	2.00
					13	SPT	3.00
					-	UDS	4.00
					-	UDS	6.00
Medium dense brownish grey silty fine sand with mica		4.50	12.00	7.50	20	SPT	7.50
					25	SPT	9.00
					28	SPT	10.50
					31	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	15.00	3.00	48	SPT	13.50
					54	SPT	15.00
Very dense brownish grey silty fine sand with mica		15.00	25.00	10.00	68	SPT	16.50
					76	SPT	18.00
					85	SPT	19.50
					86	SPT	21.00
					88	SPT	22.50
					88	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

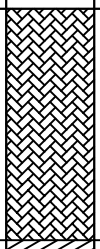
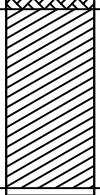
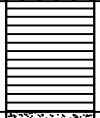
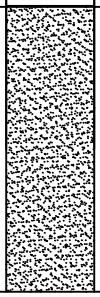
BORELOG DATA SHEET

BORE HOLE NO. : 6(SIX)
LOCOTION : Bongaigaon Refinery, Indian Oil Corporation Limited

DIA. OF BORE HOLE : 150 MM.
DEPTH OF BORE HOLE : 25.00 M.

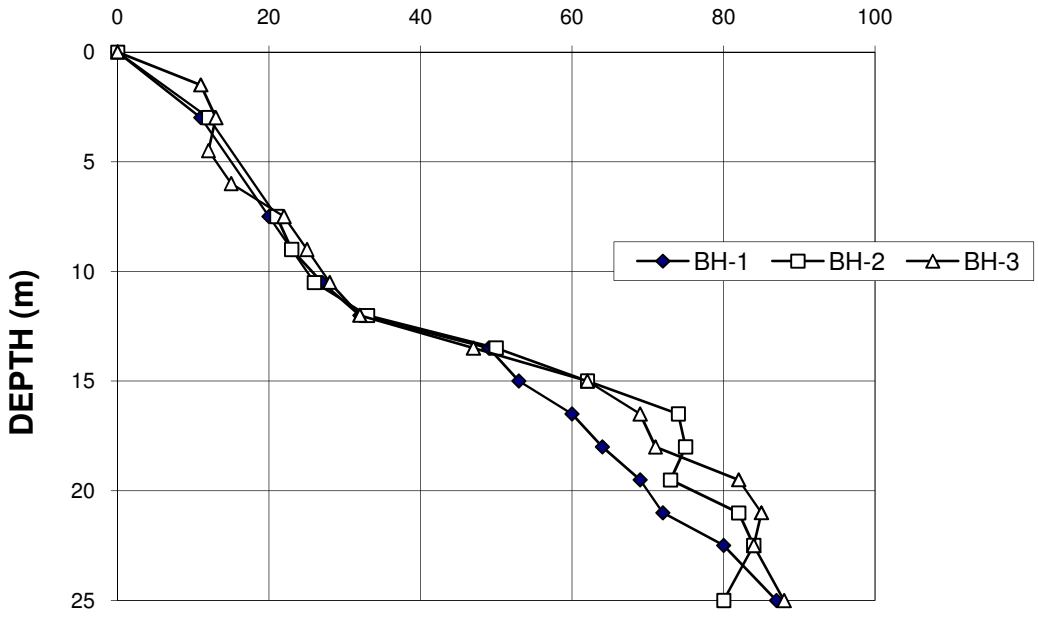
FIELD TEST

(a) COMMENCED ON : 11.04.2016
(b) COMPLETED ON : 11.04.2016
TYPE OF BORING : SHELL CUM ROTARY
LOCATION OF G.W.L. : 3.20m

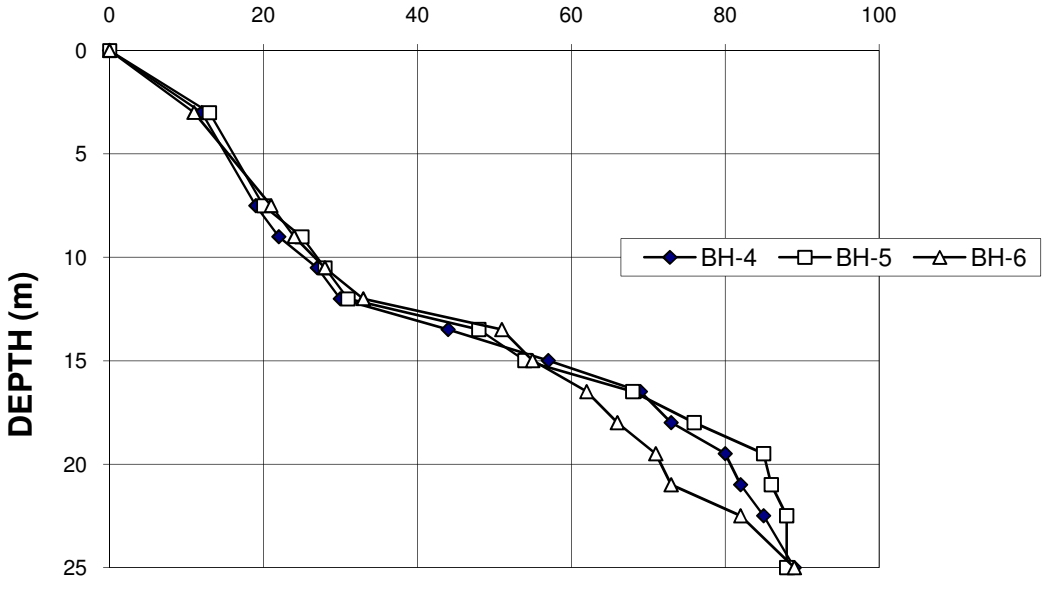
DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Medium Stiff brownish grey sandy clayey silt		0'0	6.00	6.00	-	DS	0.50
					-	DS	1.00
					-	UDS	2.00
					11	SPT	3.00
					-	UDS	4.00
					-	UDS	6.00
Medium dense brownish grey silty fine sand with mica		6.00	12.00	6.00	21	SPT	7.50
					24	SPT	9.00
					28	SPT	10.50
					33	SPT	12.00
Dense brownish grey silty medium to fine sand with mica		12.00	15.00	3.00	51	SPT	13.50
					55	SPT	15.00
Very dense brownish grey silty fine sand with mica		15.00	25.00	10.00	62	SPT	16.50
					66	SPT	18.00
					71	SPT	19.50
					73	SPT	21.00
					82	SPT	22.50
					89	SPT	25.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

N-Value vs Depth Curve



N-BLOWS/30CM,LOCATION - Bongaigaon Refinery, IOCL



N-BLOWS/30CM, LOCATION - Bongaigaon Refinery, IOCL

Laboratory Test Results

LABORATORY TEST RESULTS

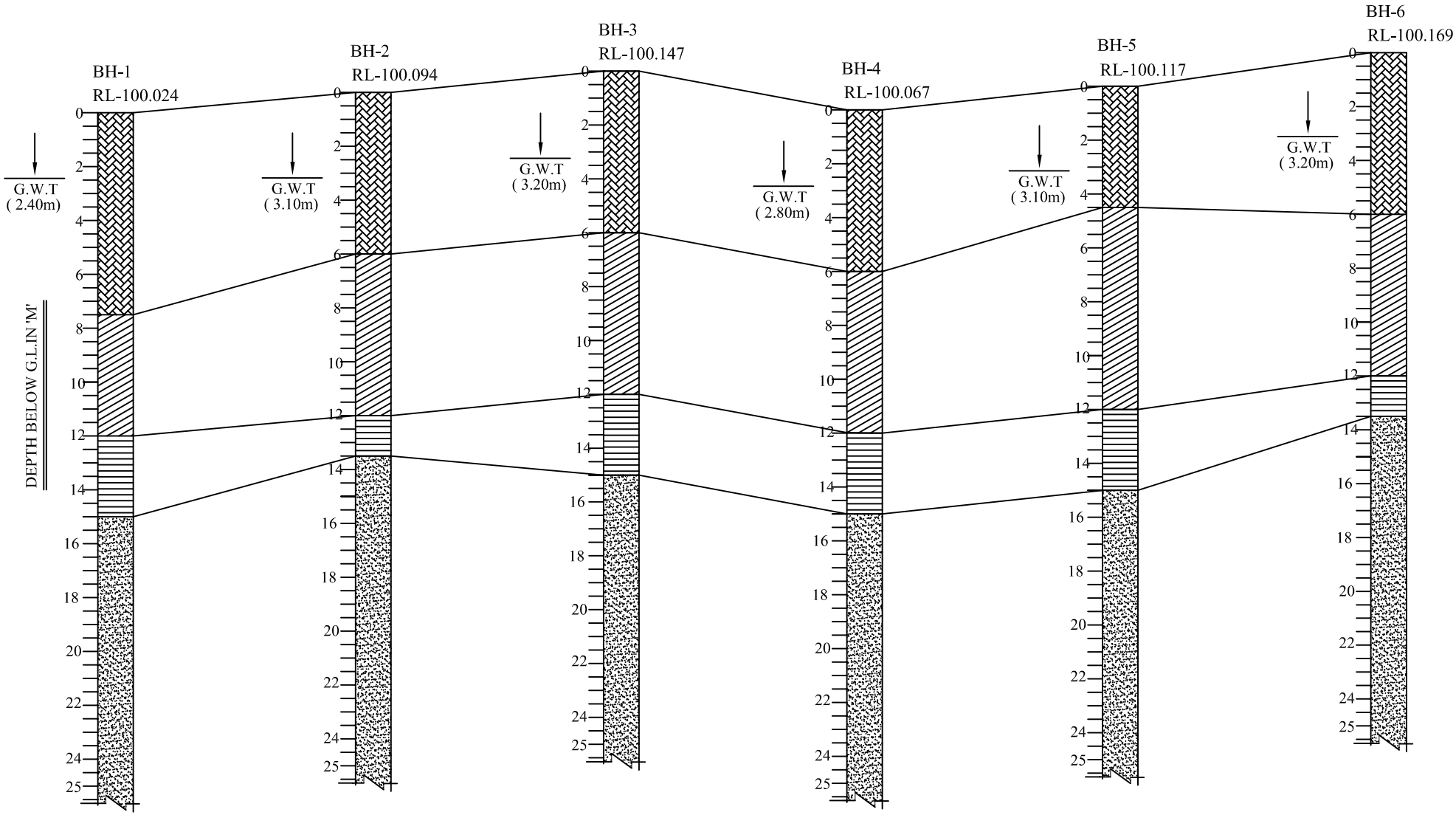
Project: Soil Testing at Bongaigaon Refinery, Indian Oil Corporation Limited

BH No	Depth (m)	Sample Type	Bulk density (t/m^3)	NMC (%)	Sp. Gr.	Atterberg Limit		Shear Strength			Consolidation	Grain Size			
						LL (%)	PL (%)	Type of Test	C (kg/cm^2)	ϕ°	m_v (cm^2/kg)	Gravel (%)	Coarse and Medium Sand (%)	Fine Sand (%)	Silt and Clay (%)
1	1.50	SPT	-	-	-	42	23	-	-	-	-	0	0	10	90
	2.00	UDS	1.85	31.80	2.66	40	23	UU	0.28	7	0.043	0	3	12	85
	4.00	UDS	1.88	28.05	2.68	38	24	UU	0.21	10	0.035	0	6	17	77
	9.00	SPT	1.90	20.00	-	NP	NP	DS	0	30	-	8	14	50	28
	18.00	SPT	-	-	-	NP	NP	-	-	-	-	12	8	45	35
2	2.00	UDS	1.86	30.62	2.65	42	22	UU	0.26	8	0.044	0	0	14	86
	3.00	SPT	-	-	-	38	24	-	-	-	-	0	0	17	83
	6.00	UDS	1.88	21.90	2.65	NP	NP	DS	0	30	-	0	10	60	30
	10.50	SPT	-	-	-	NP	NP	-	-	-	-	6	12	44	38
	21.00	SPT	1.94	20.00	2.64	NP	NP	DS	0	33	-	18	10	46	26
3	1.50	SPT	-	-	-	40	22	-	-	-	-	0	0	15	85
	13.50	SPT	1.92	20.00	2.64	NP	NP	DS	0	32	-	12	8	56	24
	15.00	SPT	-	-	-	NP	NP	-	-	-	-	10	7	45	38
4	2.00	UDS	1.85	31.96	2.67	39	24	UU	0.27	8	0.041	0	0	13	87
	4.00	UDS	1.87	30.23	2.66	35	25	UU	0.22	11	0.036	0	0	25	75
	6.00	UDS	1.87	23.15	-	32	NP	DS	0	29	-	0	5	55	40
	12.00	SPT	-	-	-	NP	NP	-	-	-	-	8	10	63	19
	22.50	SPT	-	-	-	NP	NP	-	-	-	-	15	9	55	21
	24.00	SPT	1.94	20.00	-	NP	NP	DS	0	33	-	19	14	43	24
5	2.00	UDS	1.85	30.95	2.68	40	21	UU	0.30	6	0.047	0	0	12	88
	4.00	UDS	1.87	30.12	2.65	36	23	UU	0.25	7	0.038	0	4	16	80
	6.00	UDS	1.89	21.50	2.64	NP	NP	DS	0	31	-	0	12	63	25
	7.50	SPT	-	-	-	32	NP	-	-	-	-	6	13	33	47
	21.00	SPT	-	-	-	NP	NP	-	-	-	-	13	9	51	27
6	1.50	SPT	-	-	-	38	24	-	-	-	-	0	0	18	82
	2.00	UDS	1.86	30.64	2.66	41	22	UU	0.25	8	0.043	0	2	13	85
	4.00	UDS	1.88	29.46	2.66	35	24	UU	0.21	9	0.035	0	8	12	80
	6.00	UDS	1.88	21.97	2.65	30	NP	DS	0	30	-	0	7	63	30
	12.00	SPT	1.92	20.00	-	NP	NP	DS	0	32	-	7	13	60	20
	24.00	SPT	-	-	-	NP	NP	-	-	-	-	17	12	45	26

Subsoil Profile

SOIL PROFILE THROUGH SELECTED BORE HOLES

Project : Bongaigaon Refinery, Indian Oil Corporation Limited



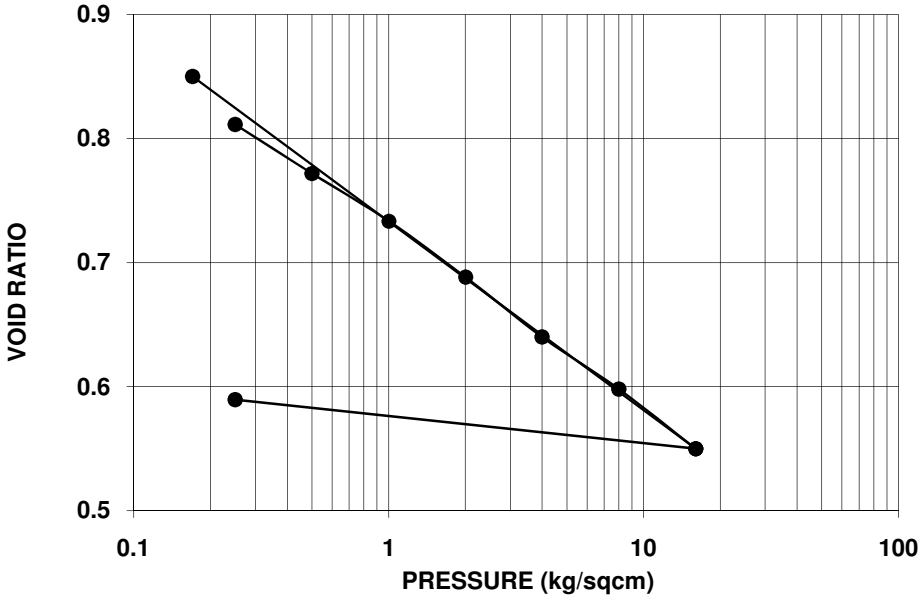
*(RL CONSIDERING THE ROAD TOP OF 100M.)

Tables, Graphs and Charts

Grain Size Analysis

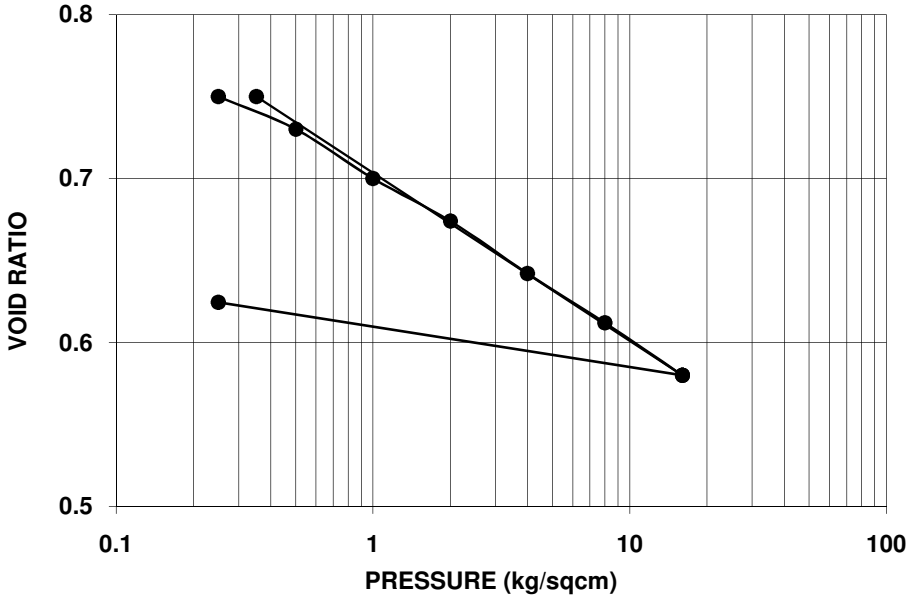
BH No	Depth (m)	Sample Type	% of Passing			Mechanical Analysis			
			4.75mm Sieve	0.425 mm sieve	0.075 mm sieve	Gravel (%)	Coarse and Medium Sand (%)	Fine Sand (%)	Silt and Clay (%)
1	1.50	SPT	100	100	90	0	0	10	90
	2.00	UDS	100	97	85	0	3	12	85
	4.00	UDS	100	94	77	0	6	17	77
	9.00	SPT	92	78	28	8	14	50	28
	18.00	SPT	88	80	35	12	8	45	35
2	2.00	UDS	100	100	86	0	0	14	86
	3.00	SPT	100	100	83	0	0	17	83
	6.00	UDS	100	90	30	0	10	60	30
	10.50	SPT	94	82	38	6	12	44	38
	21.00	SPT	82	72	26	18	10	46	26
3	1.50	SPT	100	100	85	0	0	15	85
	13.50	SPT	88	80	18	12	8	56	24
	15.00	SPT	90	83	38	10	7	45	38
4	2.00	UDS	100	100	87	0	0	13	87
	4.00	UDS	100	100	75	0	0	25	75
	6.00	UDS	100	95	40	0	5	55	40
	12.00	SPT	92	82	19	8	10	63	19
	22.50	SPT	85	76	21	15	9	55	21
	24.00	SPT	81	67	24	19	14	43	24
5	2.00	UDS	100	100	88	0	0	12	88
	4.00	UDS	100	96	80	0	4	16	80
	6.00	UDS	100	88	25	0	12	63	25
	7.50	SPT	94	81	47	6	13	33	47
	21.00	SPT	87	78	27	13	9	51	27
6	1.50	SPT	100	100	82	0	0	18	82
	2.00	UDS	100	98	85	0	2	13	85
	4.00	UDS	100	92	80	0	8	12	80
	6.00	UDS	100	93	30	0	7	63	30
	12.00	SPT	93	80	20	7	13	60	20
	24.00	SPT	83	71	26	17	12	45	26

Consolidation Curves



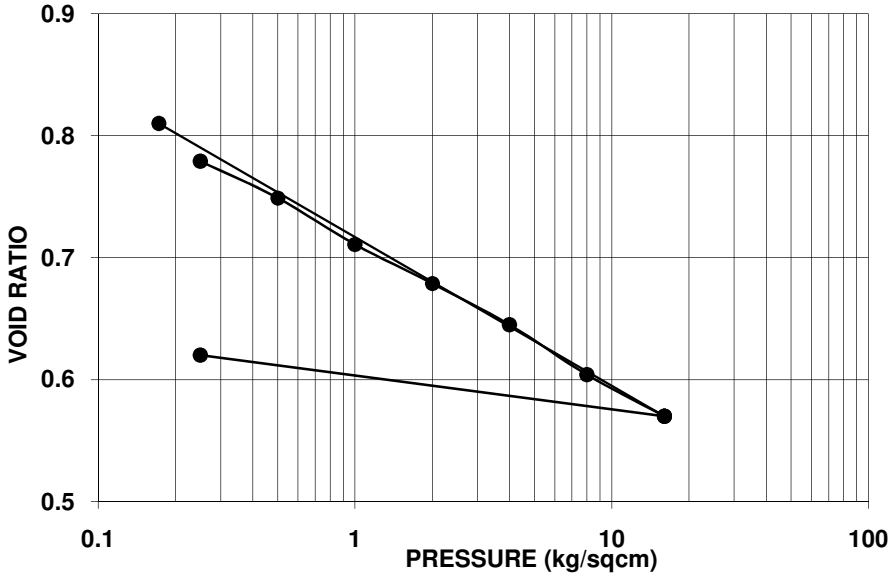
BH No. -1
Depth - 2.00m
e0 = 0.85
mv=0.043sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



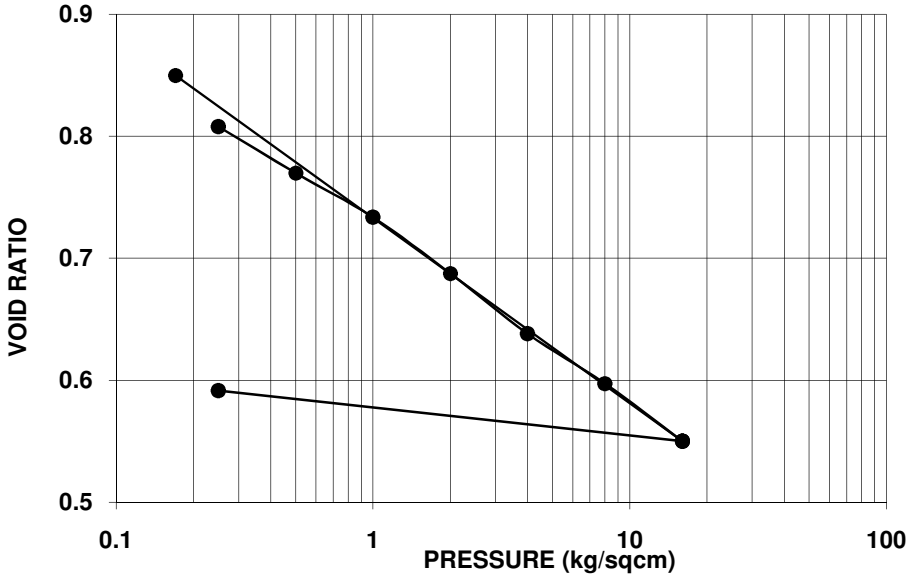
BH No. -1
Depth - 4.00m
e0 = 0.75
mv=0.035sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



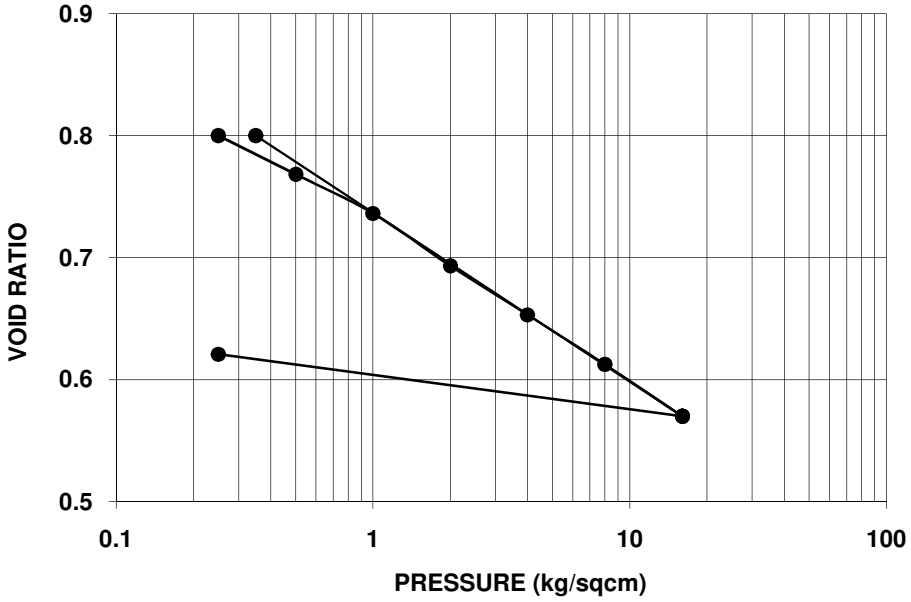
BH No. -2
Depth - 2.00m
e0 = 0.81
mv=0.044sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



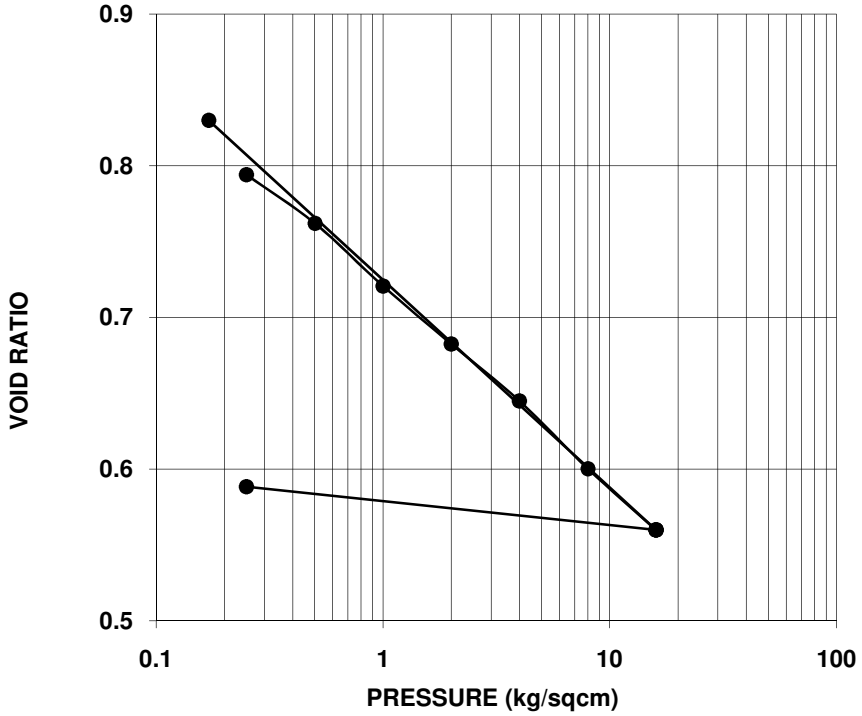
BH No. -4
Depth - 2.00m
e0 = 0.85
mv=0.041sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



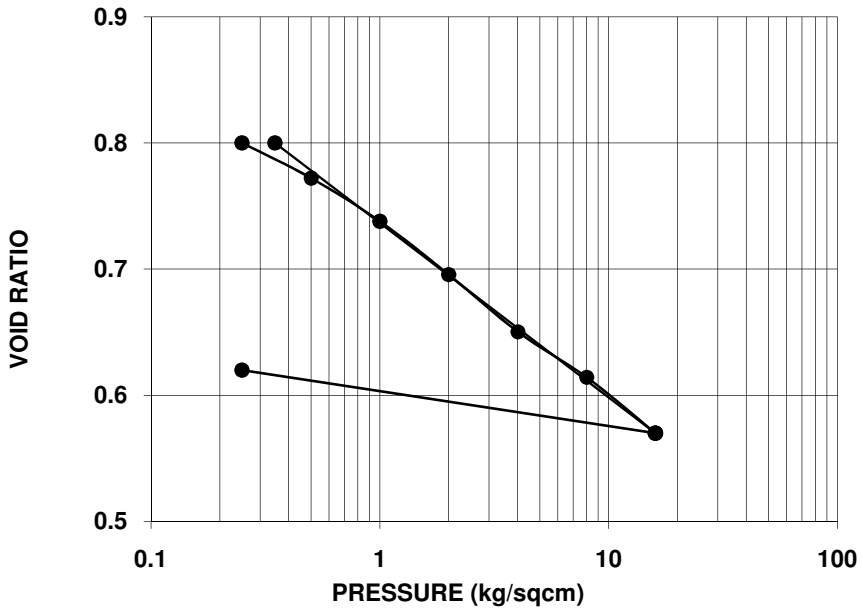
BH No. -4
Depth - 4.00m
e0 = 0.80
mv=0.036sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



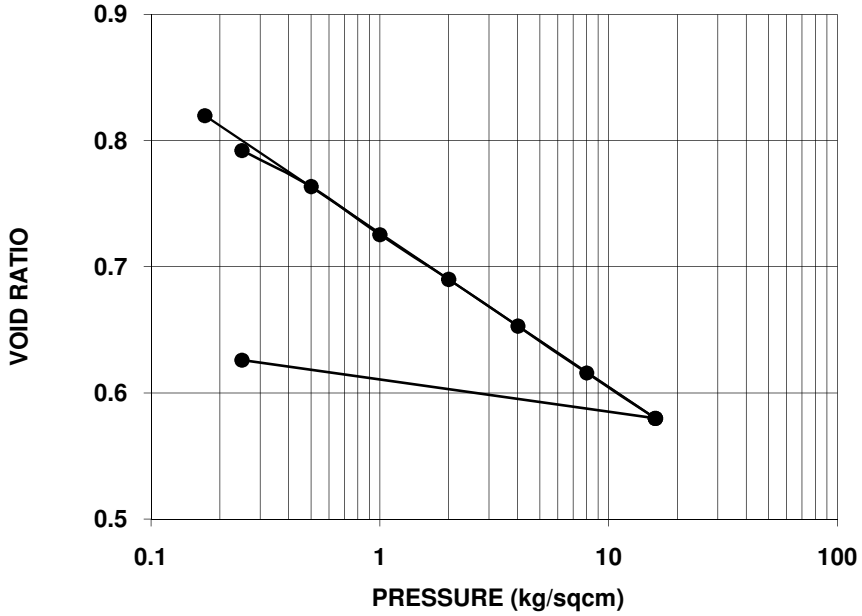
BH No. -5
Depth - 2.00m
e0 = 0.83
mv=0.047sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



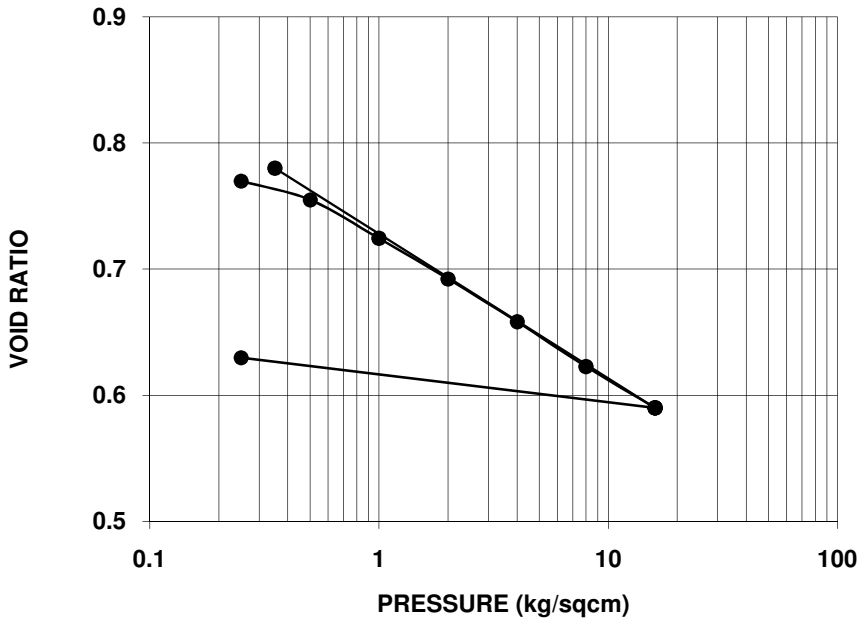
BH No. -5
Depth - 4.00m
e0 = 0.80
mv=0.038sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



BH No. -6
Depth - 2.00m
e0 = 0.82
mv=0.043sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE



BH No. -6
Depth - 4.00m
e0 = 0.78
mv=0.035sqcm/kg

VOID RATIO VS LOGARITHIM OF PRESSURE CURVE

Triaxial Test Curves

TRIAXIAL COMPRESSION TEST

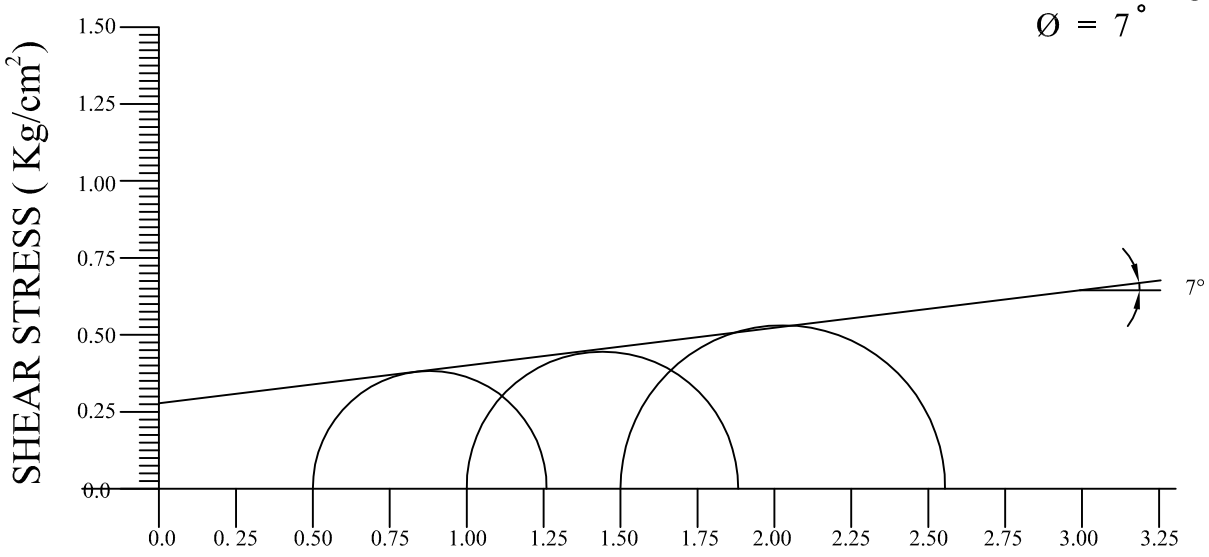
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

BH-1,DEPTH-2.00M

UU TEST

C = 0.28 Kg/cm^2

Ø = 7°



NORMAL STRESS (Kg/cm^2)

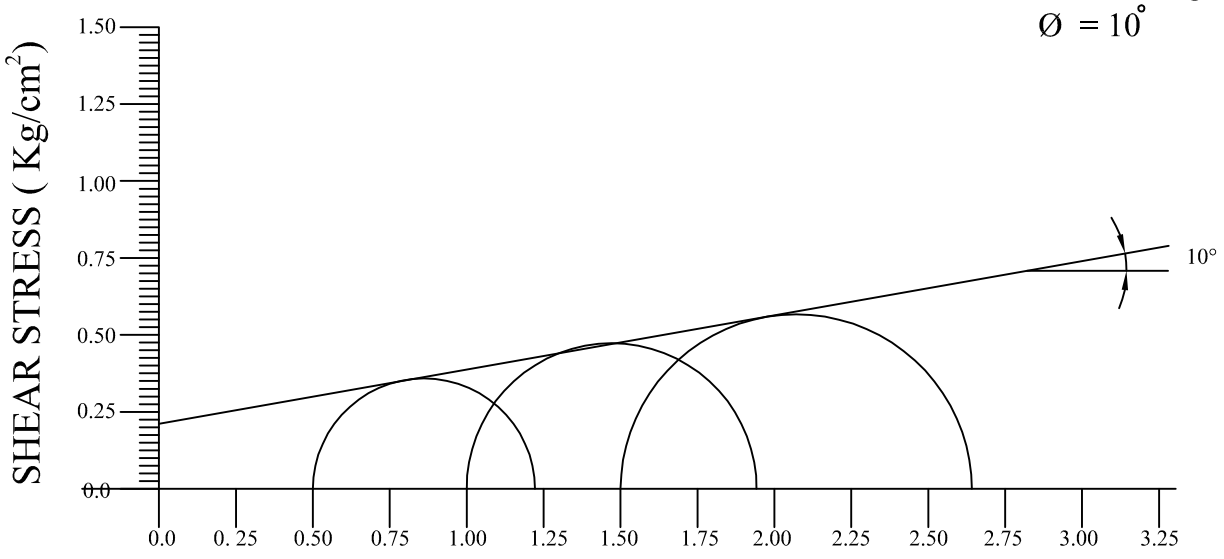
MOHR'S ENVELOP

BH-1,DEPTH- 4.00M

UU TEST

C = 0.21 Kg/cm^2

Ø = 10°



NORMAL STRESS (Kg/cm^2)

MOHR'S ENVELOP

TRIAXIAL COMPRESSION TEST

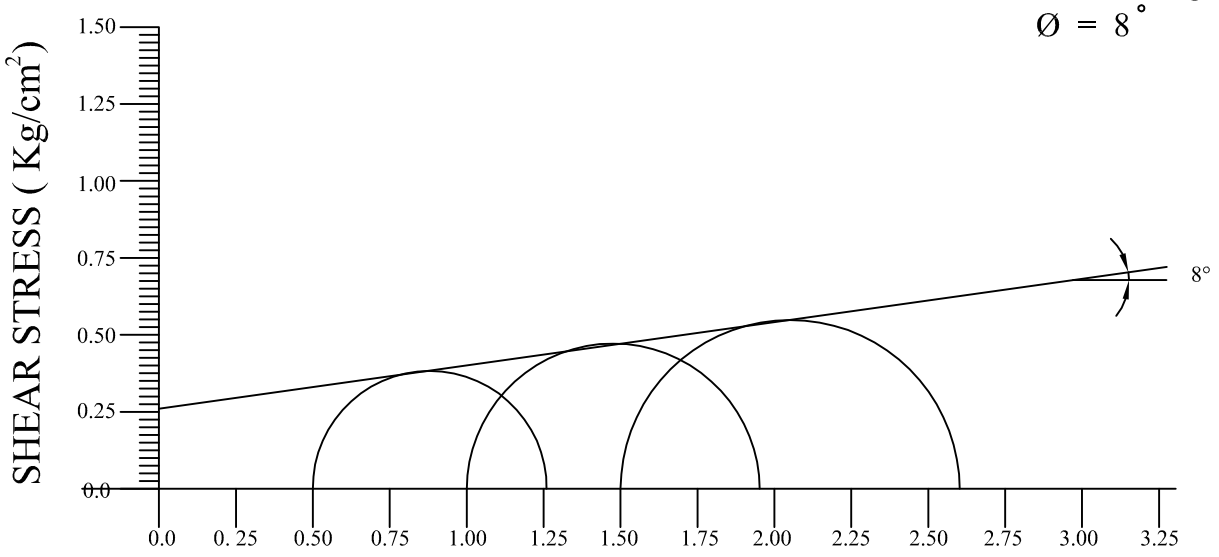
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

BH-2,DEPTH-2.00M

UU TEST

C = 0.26 Kg/cm^2

Ø = 8°



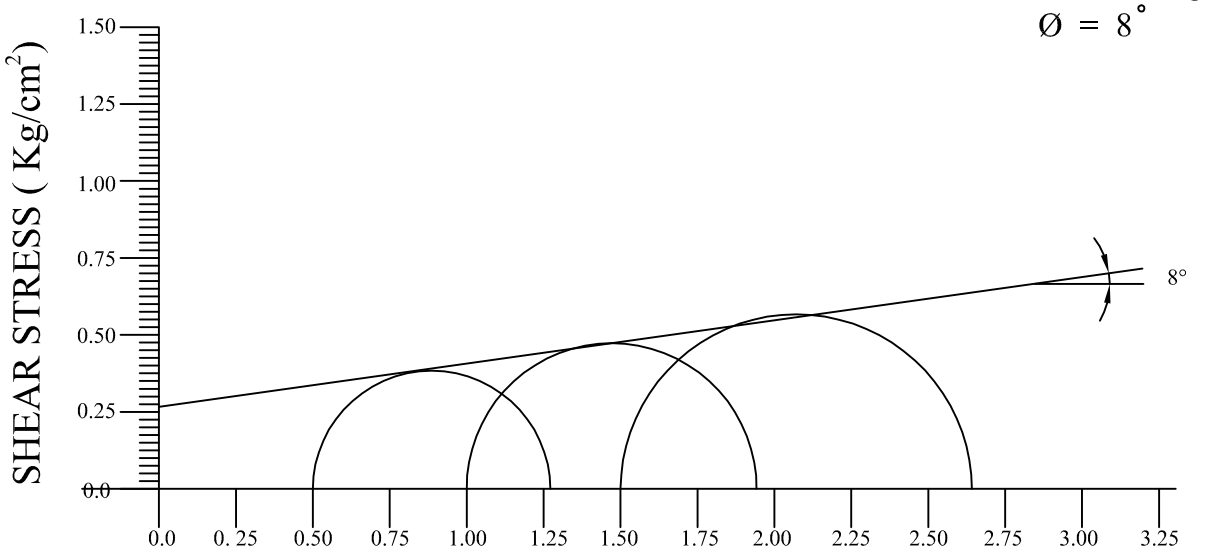
MOHR'S ENVELOP

BH-4,DEPTH- 2.00M

UU TEST

C = 0.27 Kg/cm^2

Ø = 8°



MOHR'S ENVELOP

TRIAXIAL COMPRESSION TEST

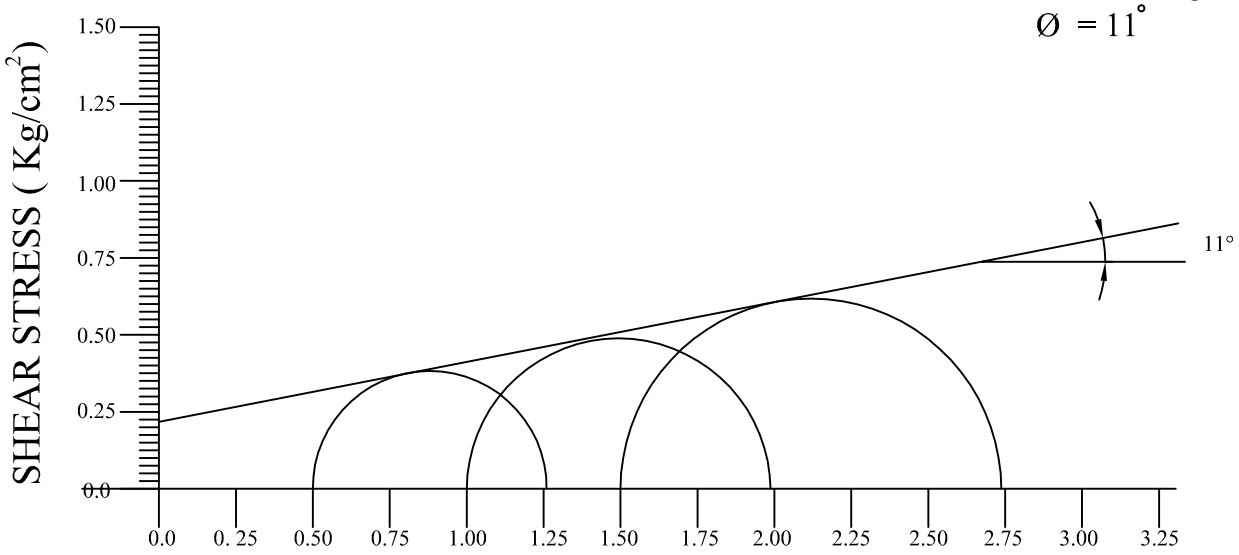
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

BH-4,DEPTH-4.00M

UU TEST

C = 0.22 Kg/cm^2

Ø = 11°



NORMAL STRESS (Kg/cm^2)

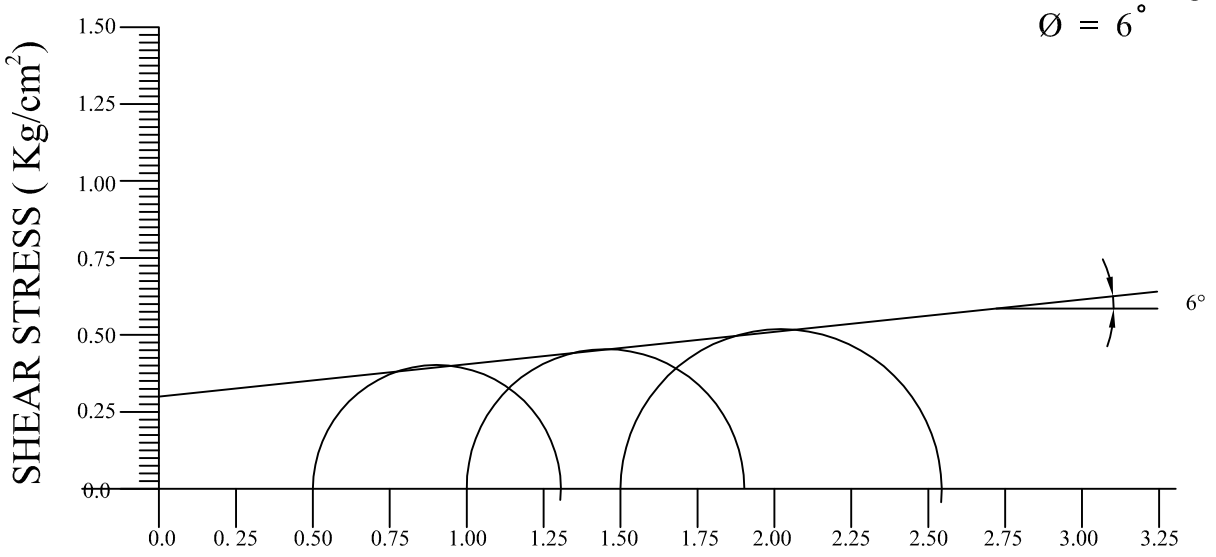
MOHR'S ENVELOP

BH-5,DEPTH- 2.00M

UU TEST

C = 0.30 Kg/cm^2

Ø = 6°



NORMAL STRESS (Kg/cm^2)

MOHR'S ENVELOP

TRIAXIAL COMPRESSION TEST

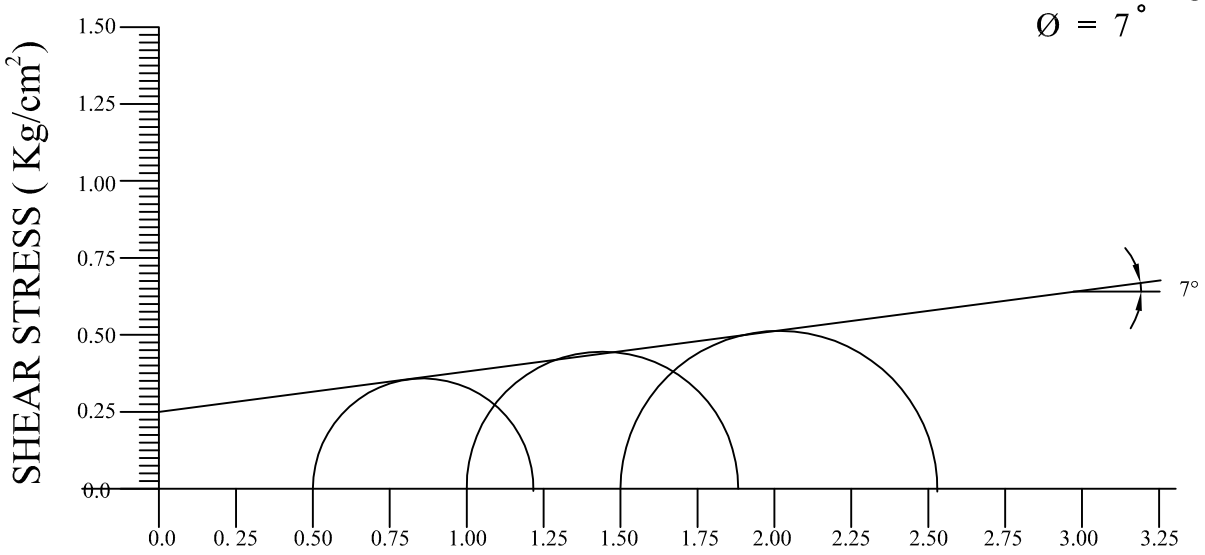
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

BH-5,DEPTH-4.00M

UU TEST

C = 0.25 Kg/cm^2

Ø = 7°



NORMAL STRESS (Kg/cm^2)

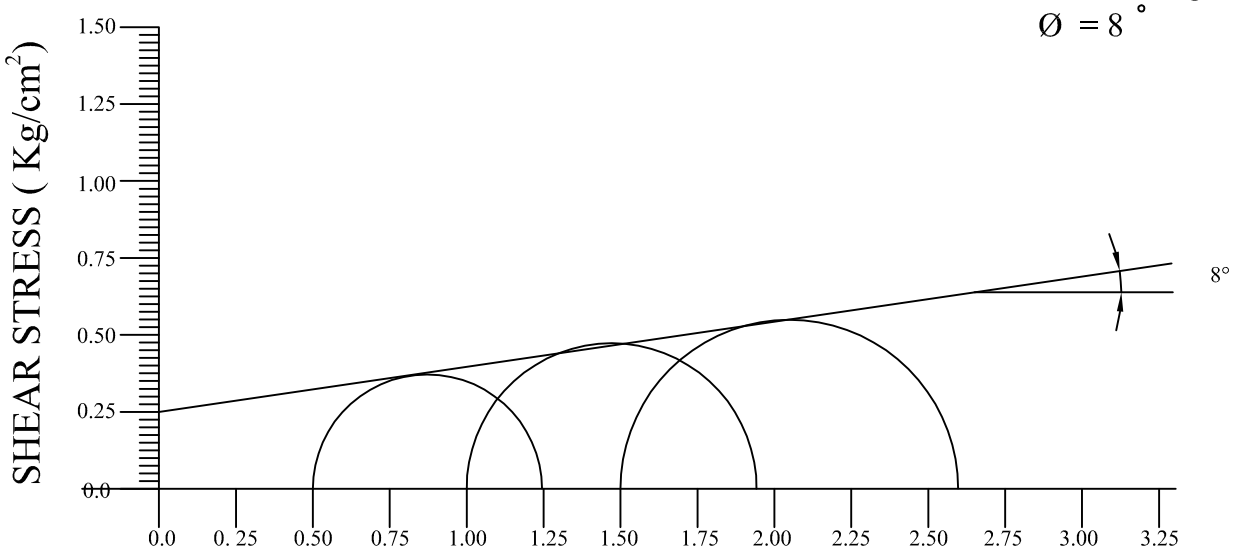
MOHR'S ENVELOP

BH-6,DEPTH- 2.00M

UU TEST

C = 0.25 Kg/cm^2

Ø = 8°



NORMAL STRESS (Kg/cm^2)

MOHR'S ENVELOP

TRIAXIAL COMPRESSION TEST

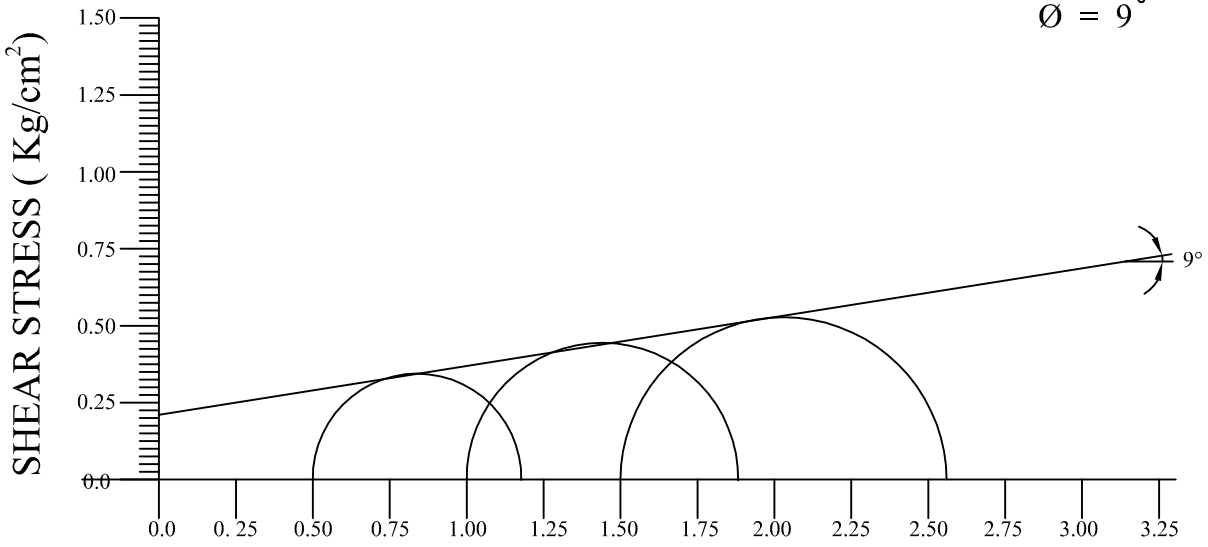
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

BH-6,DEPTH- 4.00M

UU TEST

C = 0.21 Kg/cm^2

Ø = 9°



MOHR'S ENVELOP

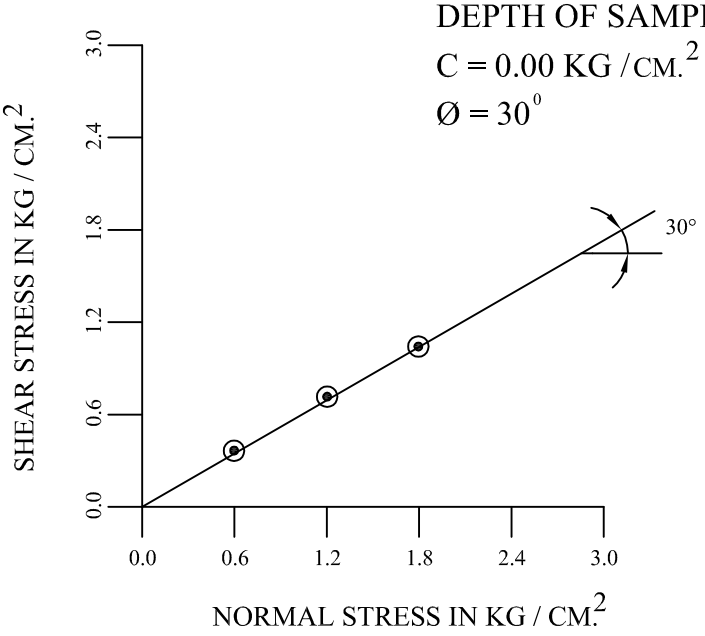
Direct Shear Test Curves

GRAPH FOR DIRECT SHEAR TEST

LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

TEST FROM REMOULDED SPT SAMPLE AT DENSITY 1.90gm/cc W.C.-20.00%

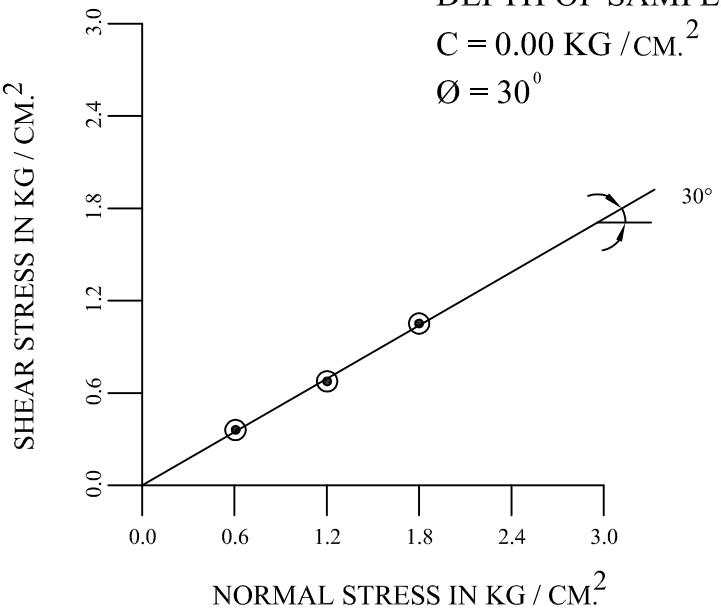
B. H. NO. - 1
DEPTH OF SAMPLE : 9.00m (SPT)
C = 0.00 KG / CM.^{2}
Ø = 30^0



DIRECT SHEAR TEST

TEST FROM UDS DENSITY 1.88gm/cc W.C.-21.90%

B. H. NO. -2
DEPTH OF SAMPLE : 6.00m (UDS)
C = 0.00 KG / CM.^{2}
Ø = 30^0



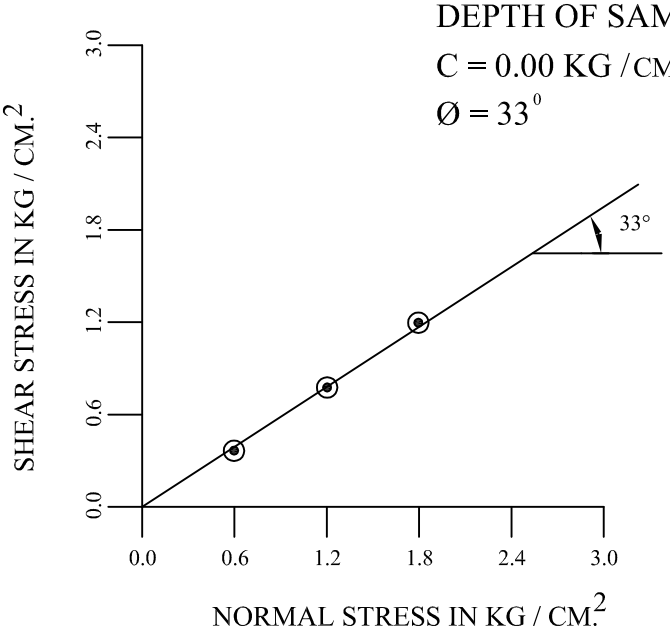
DIRECT SHEAR TEST

GRAPH FOR DIRECT SHEAR TEST

LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

TEST FROM REMOULDED SPT SAMPLE AT DENSITY 1.94gm/cc W.C.-20.00%

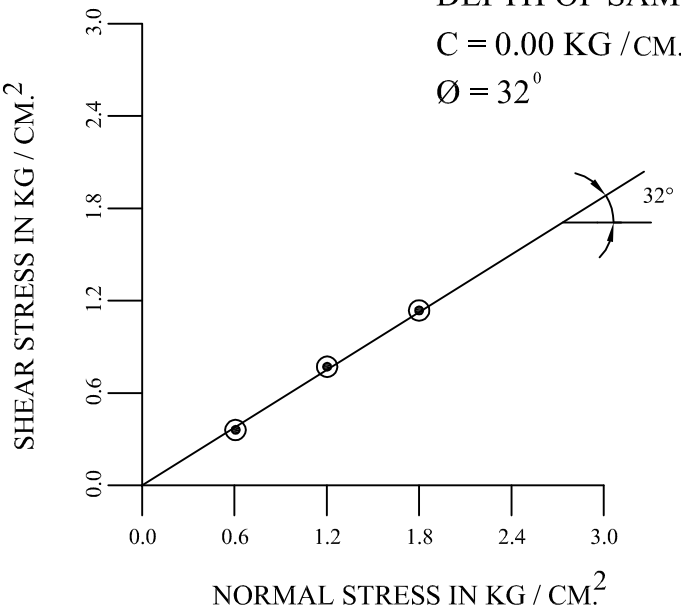
B. H. NO. - 2
DEPTH OF SAMPLE : 21.00m (SPT)
C = 0.00 KG /CM.^{2}
Ø = 33^0



DIRECT SHEAR TEST

TEST FROM REMOULDED SPT SAMPLE AT DENSITY 1.92gm/cc W.C.-20.00%

B. H. NO. -3
DEPTH OF SAMPLE : 13.50m (SPT)
C = 0.00 KG /CM.^{2}
Ø = 32^0



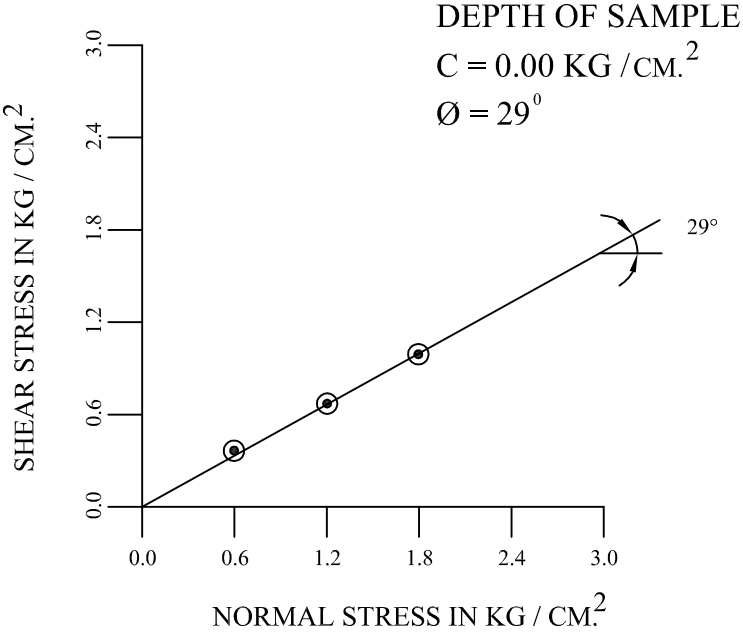
DIRECT SHEAR TEST

GRAPH FOR DIRECT SHEAR TEST

LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

TEST FROM UDS AT DENSITY 1.87gm/cc W.C.-23.15%

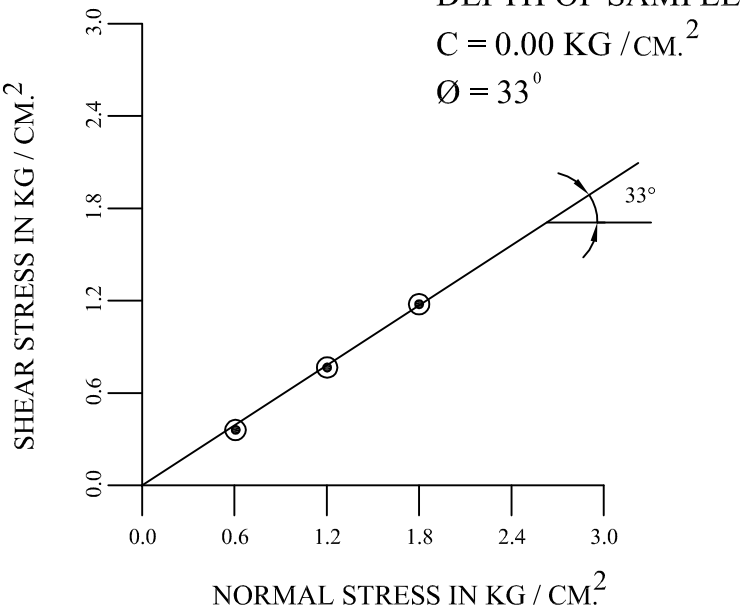
B. H. NO. - 4
DEPTH OF SAMPLE : 6.00m (UDS)
C = 0.00 KG /CM.^{2}
Ø = 29^0



DIRECT SHEAR TEST

TEST FROM SPT REMOULDED SAMPLE AT DENSITY 1.94gm/cc W.C.-20.00%

B. H. NO. -4
DEPTH OF SAMPLE : 25.00m (SPT)
C = 0.00 KG /CM.^{2}
Ø = 33^0



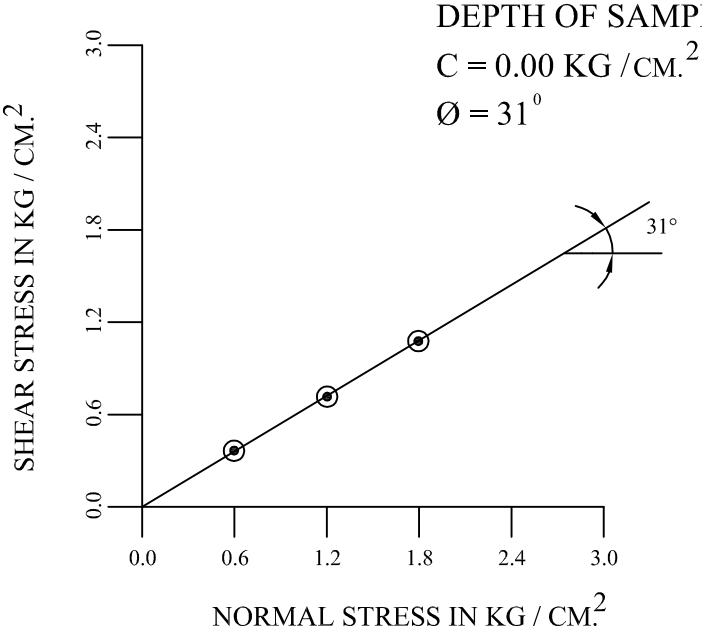
DIRECT SHEAR TEST

GRAPH FOR DIRECT SHEAR TEST

LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

TEST FROM UDS AT DENSITY 1.89gm/cc W.C.-21.50%

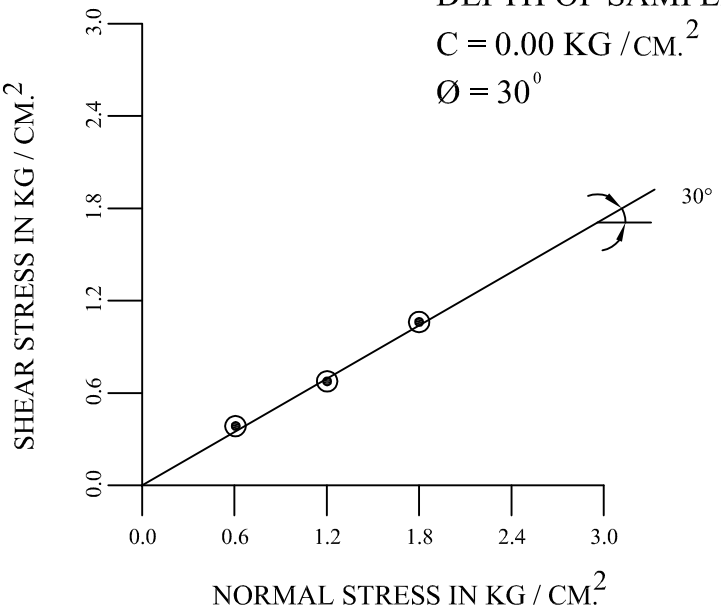
B. H. NO. - 5
DEPTH OF SAMPLE : 6.00m (UDS)
C = 0.00 KG /CM.^{2}
Ø = 31^0



DIRECT SHEAR TEST

TEST FROM UDS DENSITY 1.88gm/cc W.C.-21.97%

B. H. NO. -6
DEPTH OF SAMPLE : 6.00m (UDS)
C = 0.00 KG /CM.^{2}
Ø = 30^0



DIRECT SHEAR TEST

GRAPH FOR DIRECT SHEAR TEST

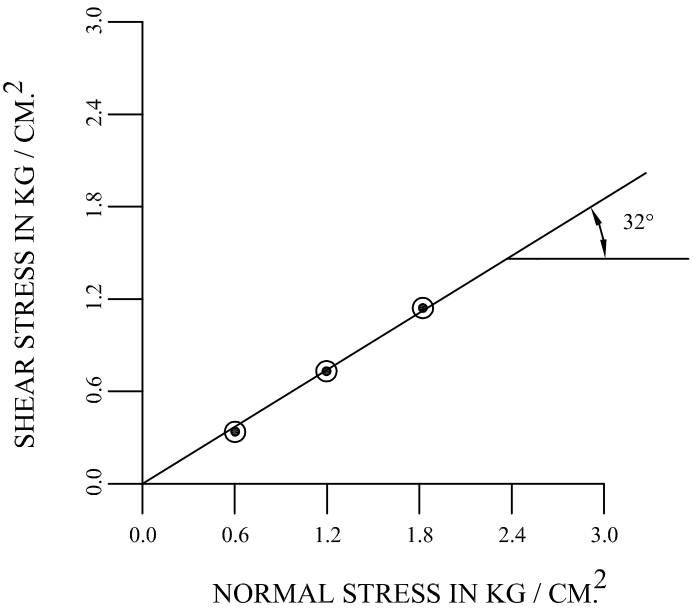
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited

TEST FROM REMOULDED SPT SAMPLE AT DENSITY 1.92gm/cc W.C.-20.00%

BH-6/DEPTH -12.00m

$C = 0.00 \text{ kg / cm}^2$

$\text{Ø} = 32^0$



DIRECT SHEAR TEST

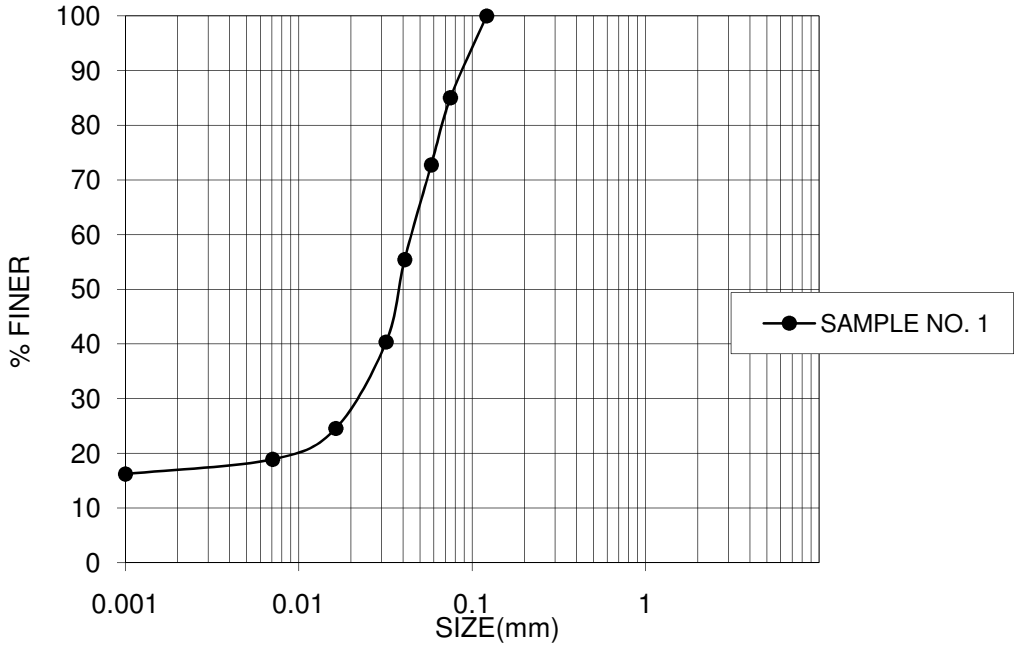
CBR Test

Laboratory Test Results of CBR Test

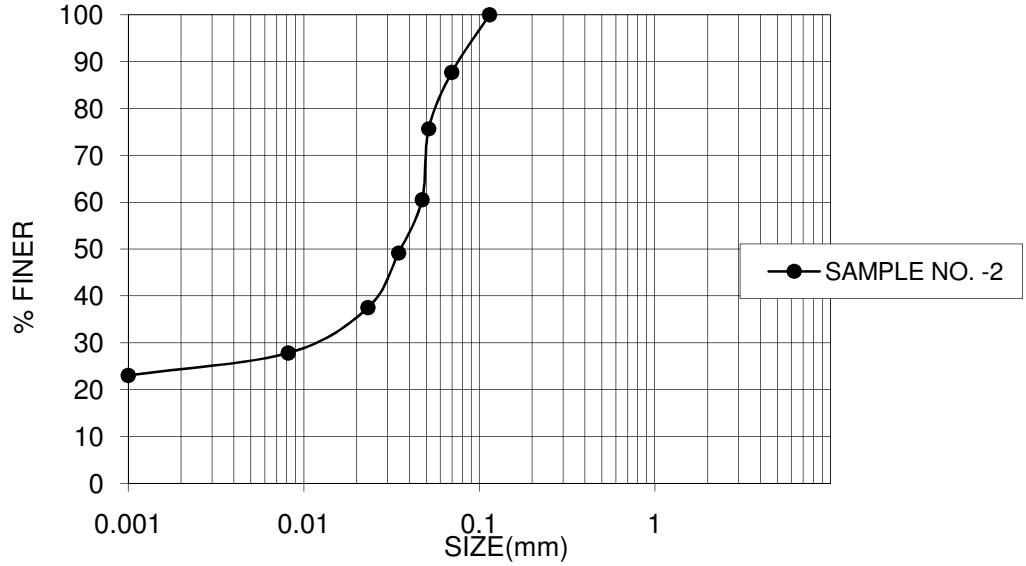
Project: Soil Testing at Bongaigaon Refinery

Sl. No.	Sample No.	Grain Size			Atterberg Limit			OMC (%)	MDD (gm/cc)	Unsoaked CBR		Soaked CBR	
		Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)			2.5 (%)	5.0 (%)	2.5 (%)	5.0 (%)
1	1	15	67	18	38	22	16	14.60	1.75	5.8	5.5	4.30	4.10
2	2	10	66	24	42	21	21	15.64	1.72	5.5	5.0	4.10	3.80

Particle Size Distribution:

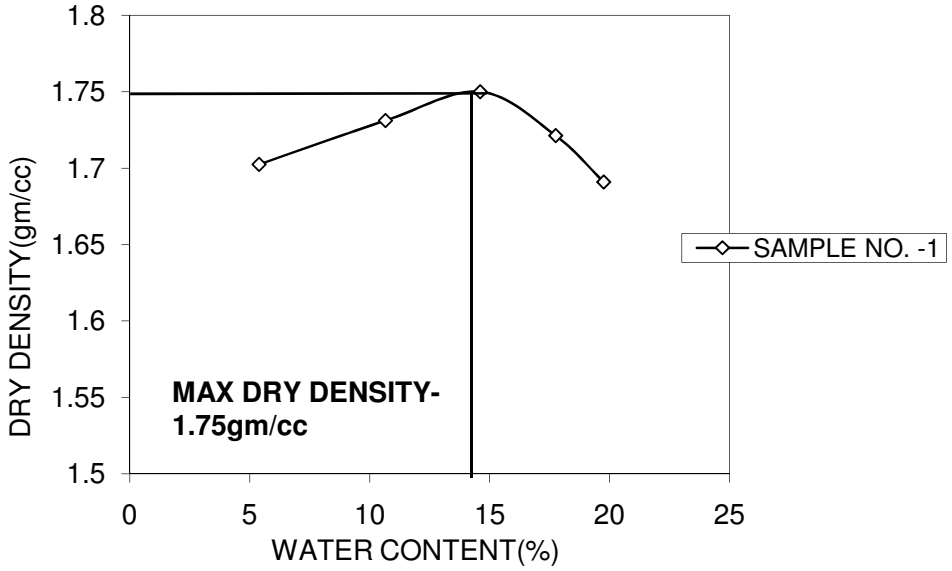


PARTICLE SIZE DISTRIBUTION CURVE
LOCATION -**Bongaigaon Refinery, Indian Oil Corporation Limited**

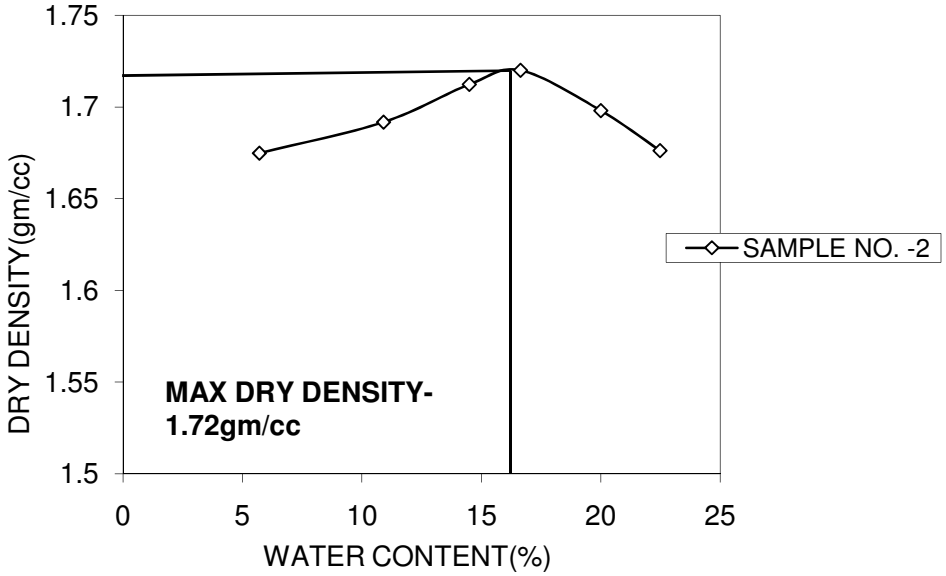


PARTICLE SIZE DISTRIBUTION CURVE
LOCATION -**Bongaigaon Refinery, Indian Oil Corporation Limited**

Proctor Test:

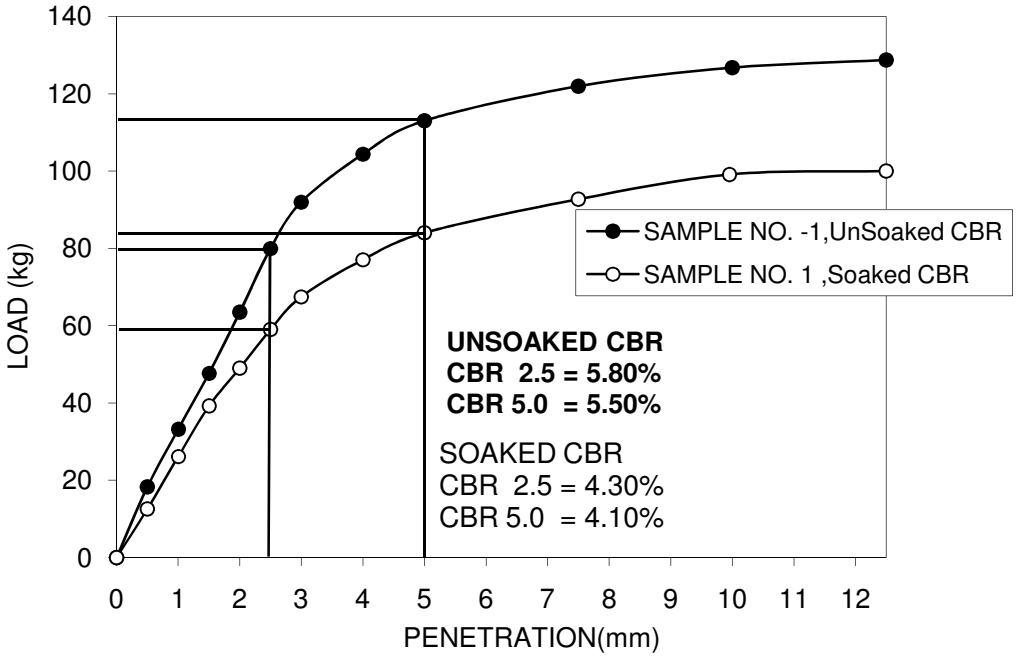


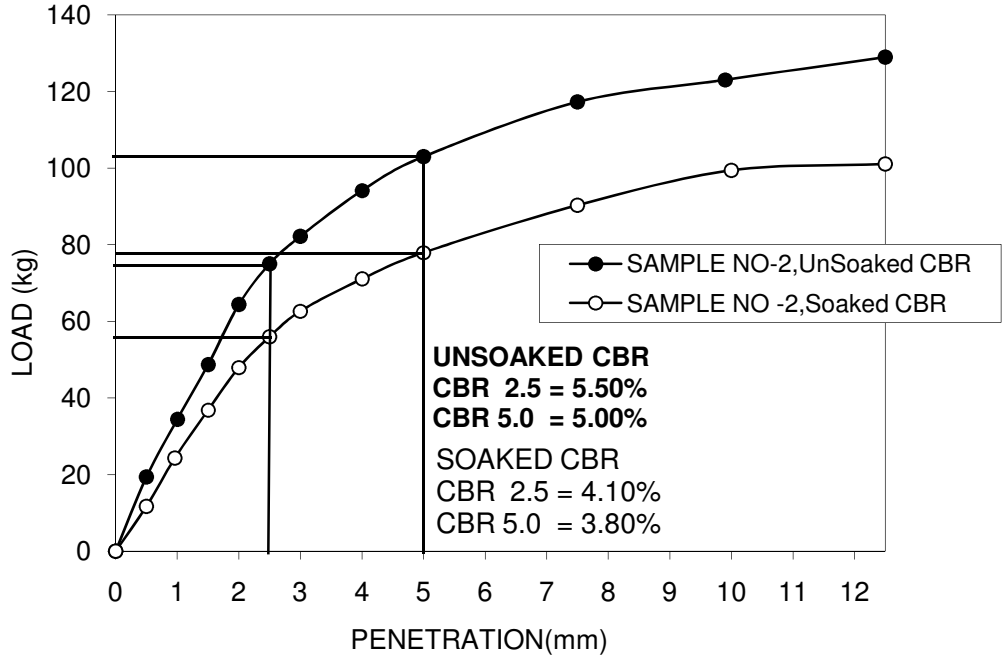
STANDARD PROCTOR COMPACTION TEST
LOCATION - Bongaigaon Refinery, Indian Oil Corporation Limited



STANDARD PROCTOR COMPACTION TEST
LOCATION -Bongaigaon Refinery, Indian Oil Corporation Limited

CBR Test Curve:





Sample Calculation for Bearing Capacity

Sample Calculation for net allowable bearing capacity of square footing :

The net allowable bearing capacity of 1 m x 1 m square footing founded at 3 m below G.L. has been obtained as follows :

Depth of foundation (Df) = 3.00 m
Length of the foundation (L) = 1.00 m Breadth of the foundation (B) = 1.00 m

Safe bearing capacity of soil (qn) = 1/F x C x Nc x sc x dc x ic

Where,

C (Cohesion) = 3.0 t/m²
Nc = 5.14
sc (Shape factor) = 1.30
dc (Depth factor) = 1 + 0.2 Df/B = 1.20
ic (Inclination factor) = 1.0
F (factor of safety) = 2.5

qs = 9.62 t/m² Say = 9.62 t/m²

Estimation of settelment :

a) Immediate settlement (Si) = $(qn \times B) \times (1-v^2) I_{e/E}$

Where,

qn (Net foundation pressure) = 9.62 t/m²
B (Bredth of the foundation) = 1000 mm
E (Young's modulus of soil) = 1800 t/m²
v (Poisson,s ratio) = 0.5
Iρ (Influence coefficient) = 1.12

Si = 4.49 mm

b) Consolidation Settlement (Sc) = $mv \times H \times \delta\tau$

Where,

i)1st stratum m_v (Coefficient of volume compressibility) = 0.004
H (Thickness of the statum considered) = 1.50 m
(Increase of effective pressure at the center of the stratum considered) = 3.141903673 t/m²
Sc = 18.85 mm

Therefore total settlement = 17.69 mm mm
Say = 17.69 mm < 75 Hence ok

The suggested net safe bearing capacity to be adopted for the 1m x 1m isolated footing at 3 m depth is 9.62208 t/m² with an estimated settlement of 17.6859954285714 mm.

Sample Calculation for net allowable bearing capacity of strip footing :

The net allowable bearing capacity of 2 m wide strip footing founded at 3 m below G.L. has been obtained as follows :

Depth of foundation (Df) = 3.00 m
Breadth of the foundation (B) = 2.00 m

Safe bearing capacity of soil (qn) = 1/F x C x Nc x sc x dc x ic

Where,

C (Cohesion) = 3.0 t/m²
Nc = 5.14
sc (Shape factor) = 1.00
dc (Depth factor) = 1 + 0.2 Df/B = 1.20
ic (Inclination factor) = 1.0
F (factor of safety) = 2.5

qs = 7.40 t/m² Say = 7.40 t/m²

Estimation of settelment :

a) Immediate settlement (Si) = $(qn \times B) / E \times (1-v^2) I_e$

Where,

qn (Net foundation pressure) = 7.40 t/m²
B (Bredth of the foundation) = 2000 mm
E (Young's modulus of soil) = 1800 t/m²
v (Poisson,s ratio) = 0.5
Iρ (Influence coefficient) = 2

Si = 12.34 mm

b) Consolidation Settlement (Sc) = mv x H x δτ

Where,

i)1st stratum m_v (Coefficient of volume compressibility) = 0.004
H (Thickness of the statum considered) = 4.00 m
(Increase of effective pressure at the center of the stratum considered) = 3.7008 t/m²
Sc = 59.21 mm

Therefore total settlement = 53.79 mm mm
Say = 53.79 mm < 75 Hence ok

The suggested net safe bearing capacity to be adopted for the 2m wide strip footing at 3 m depth is 7.4016 t/m² with an estimated settlement of 53.78896 mm.

Sample Calculation for net allowable bearing capacity of circular footing :

The net allowable bearing capacity of 1 m circular footing founded at 3 m below G.L. has been obtained as follows :

Depth of foundation (Df) = 3.00 m

Breadth of the foundation (B) = 1.00 m

Safe bearing capacity of soil (qn) = 1/F x C x Nc x sc x dc x ic

Where,

C (Cohesion) = 3.0 t/m²
Nc = 5.14
sc (Shape factor) = 1.30
dc (Depth factor) = 1 + 0.2 Df/B = 1.20
ic (Inclination factor) = 1.0
F (factor of safety) = 2.5

qs = 9.62 t/m² Say = 9.62 t/m²

Estimation of settelment :

a) Immediate settlement (Si) = $(qn \times B) \times (1-v^2) I_{e/E}$

Where,

qn (Net foundation pressure) = 9.62 t/m²
B (Bredth of the foundation) = 1000 mm
E (Young's modulus of soil) = 1800 t/m²
v (Poisson,s ratio) = 0.5
Iρ (Influence coefficient) = 1.12

Si = 4.49 mm

b) Consolidation Settlement (Sc) = mv x H x δτ

Where,

i)1st stratum m_v (Coefficient of volume compressibility) = 0.004
H (Thickness of the statum considered) = 1.50 m
(Increase of effective pressure at the center of the stratum considered) = 0 t/m²
Sc = 0.00 mm

Therefore total settlement = 4.49 mm mm

Say = 4.49 mm < 75 Hence ok

The suggested net safe bearing capacity to be adopted for the 1m isolated footing at 3 m depth is 9.62208 t/m² with an estimated settlement of 4.49 mm.

Sample Calculation for net allowable bearing capacity of raft foundation :

The net allowable bearing capacity of 25 m x 95 m raft founded at 1 m below G.L. has been obtained as follows :

Depth of foundation (Df) = 1.00 m
Length of the foundation (L) = 95.00 m Breadth of the foundation (B) = 25.00 m

Safe bearing capacity of soil (qn) = 1/F x C x Nc x sc x dc x ic

Where,

C (Cohesion) = 3.0 t/m²
Nc = 5.14
sc (Shape factor) = 1 + 0.2 B/L = 1.05
dc (Depth factor) = 1 + 0.2 Df/B = 1.01
ic (Inclination factor) = 1.0
F (factor of safety) = 2.5

qs = 6.54 t/m²

Estimation of settelment :

a) Immediate settlement (Si) = (qn x B) x (1-v²) $I_{e/E}$

Where,

qn (Net foundation pressure) = 6.54 t/m²
B (Bredth of the foundation) = 25000 mm
E (Young's modulus of soil) = 1800 t/m²
v (Poisson,s ratio) = 0.5

Iρ (Influence coefficient) = 1.59

Si = 108.39 mm

b) Consolidation Settlement (Sc) = mv x H x δτ

Where,

i)1st stratu m_v (Coefficient of volume compressibility) = 0.004
H (Thickness of the statum considered) = 6.50 m
(Increase of effective pressure at the center of the stratum considered) = 5.600076
Sc = 145.60 mm

Therefore total settlement = 210.31 mm
(Taking rigidity correction factor =0.8) Total 168.25 mm > 100 mm

The suggested net safe bearing capacity to be adopted for the 25m x 95m raft foundation at 1 m is 3.89t/m² with an estimated settlement of 100 mm.

SAMPLE CALCULATION OF PILE CAPACITY

CUT OFF LEVEL AT 5.00 (m)	AVG. THICK.	A_P	D in (m)	γ	N_γ	P_D	N_q	K	P_{Di}	Φ	tan δ	A_{Si}	A_P	C_p	N_c	α	C	A_S
CUT OFF	1.50			1.86							-0.05	D						D
STRATUM I	6.00			1.86	0.00	0.00	0.00	0.00	3.87	0	-0.05	D				1.00	3.00	18.85 D
STRATUM II	4.50			1.88	15.49	15.00	13.00	1.00	8.43	30	0.51	D				1.00	0.00	14.13 D
STRATUM III	3.00			1.92	20.10	15.00	18.00	1.10	11.79	32	0.55	D				1.00	0.00	9.42 D
END PROP	3.00	0.785		1.92	20.10	15.00	18.00	1.10	13.17	32	0.55	D	0.785	0.00	9.00	1.00	0.00	32.98 D
					SAND									CLAY				

Here, $A_P = \frac{\pi D^2}{4}$, $N\gamma = (N_q\text{-}1) \times \tan(1.5 \times \text{deg})$, K = 1 OR 2 , $\tan\delta = \tan(\Phi\text{-}3^0)$, $A_{Si} = \pi Dh$

Ultimate Skin Resistance

$$Q_{ult} = (\alpha \times C \times A_s) + \Sigma K \times P_{Di} \times \tan\delta \times \pi \times D \times h$$

For Cohesive Soil

$$(\alpha \times C \times A_s) = (\alpha \times C \times \pi \times D \times h)$$

Depth 1.50 m to 7.50 m - Q_{Ui} = 1.00 x 3.00 x 3.141 x D x 6.00 = 56.538

For Non - Cohesive Soil

$$\Sigma K \times P_{Di} \times \tan\delta \times \pi \times D \times h$$

Depth 7.50to 12.00m - Q_{Uii} = 1.00 x 8.43 x 0.510 x 3.141 x D x 4.50 = 60.712 D

Depth 12.00 m to 15.00 m - Q_{Uiii} = 1.10 x 11.79 x 0.554 x 3.141 x D x 3.00 = 67.740 D

Total Ultimate Skin Resistance = 184.99 D

P_{Di} Calculation

$P_{di\ (ii)}$ = (0.860 x 1.500) + (0.860 x 6.00) + (0.880 x 2.250) = 8.43

$P_{di\ (iii)}$ = (0.860 x 1.500) + (0.860 x 6.00) + (0.880 x 4.500) + (0.920 x 1.500) = 11.79

END BEARING

For Non Cohesive Soil

$$Q_{uit} = A_p (0.5 D \gamma N_\gamma + P_D N_q)$$

$$= \frac{\pi D^2}{4} \{ (0.500 \times D \times 0.92 \times 20.100) + (15.000 \times D \times 0.800 \times 18.000) \}$$

$$= (7.2581 D^3 + 169.560 D^3)$$

Ultimate load carrying capcity in Compression = 176.818 D^3 + 0.000 D^2 + 184.99 D

Ultimate load carrying capcity in Tension = 184.990 D

For uniform diameter straight shaft RCC bored Pile when toe at 15.00m below EGL and cut off at 1.50 m below EGL

	450	500	550	600
Safe load carrying capacity in Compression (MT) (Using Factor of Safety = 2.50)	40	46	52	60
Safe load carrying capacity in Tension (MT) (Using Factor of Safety = 3)	28	31	34	37

SAMPLE CALCULATION OF LATERAL CAPACITY OF PILE
(As per IS 2911 - Part 1 - Section 2 : 2010)

SITE:

Pile Dia (D) = 0.60 meter

Grade of Concrete = M 25

UCS Value = 60 KN/m^2

Depth of Fixity Calculation

Terzaghi's mod^{n} of horizontal of subgrade reaction (k_1) = 10.8 MN/m^2
(From Table of IS 2911-Part 1-Sec-2 : 2010)

Modulus of horizontal of subgrade reaction (K) = $k_1/5$ = 2.16 MN/m^2

Here, E = $5000\sqrt{f_{ck}}$ = 25000.00 MN/m^2

$$I = \frac{\pi D^4}{64} = 0.006361725 \ m^4$$

Hence, relative stiffness factor R = $\sqrt[4]{\frac{EI}{KB}}$ = 3.33 meter

Unsupported length of pile(L_1) = 0 meter

Therefore, L_1/R = 0.00

From graph (L_f/R -Vs- L_1/R) for normally loaded clays and fixed head pile, L_f/R = 2.17
(From IS 2911-Part 1-Section 2 : 2010)

Therefore, depth of fixity (L_f) = 7.22 m

Considering pile as a cantilever to its point of fixity, then $L_{eff} = L_1 + L_f$ = 7.22 m

Calculation of Lateral Load Capacity

Deflection δ = 0.005 upto 500 dia pile and above 500 dia 1% of pile dia.

Here, δ = 0.006 m

Lateral Load Capcity of Pile = $[Q]_D = \frac{12EI \times \delta}{(L_f + L_1)^3}$ = 0.0303939 MN = 3.04 ton

SAMPLE CALCULATION OF PILE CAPACITY

CUT OFF LEVEL AT 5.00 (m)	AVG. THICK.	A_P	D in (m)	γ	N_γ	P_D	N_q	K	P_{Di}	Φ	tan δ	A_{Si}	A_P	C_p	N_c	α	C	A_S
CUT OFF	1.50			1.86							-0.05	D						D
STRATUM I	6.00			1.86	0.00	0.00	0.00	0.00	3.87	0	-0.05	D				1.00	3.00	18.85 D
STRATUM II	4.50			1.88	15.49	15.00	13.00	1.00	8.43	30	0.51	D				1.00	0.00	14.13 D
STRATUM III	3.00			1.92	20.10	15.00	18.00	1.10	11.79	32	0.55	D				1.00	0.00	9.42 D
END PROP	3.00	0.785		1.92	20.10	15.00	18.00	1.10	13.17	32	0.55	D	0.785	0.00	9.00	1.00	0.00	32.98 D
					SAND									CLAY				

Here, $A_P = \frac{\pi D^2}{4}$, $N\gamma = (N_q\text{-}1) \times \tan(1.5 \times \text{deg})$, K = 1 OR 2 , $\tan\delta = \tan(\Phi\text{-}3^0)$, $A_{Si} = \pi Dh$

Ultimate Skin Resistance

$$Q_{ult} = (\alpha \times C \times A_s) + \Sigma K \times P_{Di} \times \tan\delta \times \pi \times D \times h$$

For Cohesive Soil

$$(\alpha \times C \times A_s) = (\alpha \times C \times \pi \times D \times h)$$

Depth 1.50 m to 7.50 m - Q_{ui} = 1.00 x 3.00 x 3.141 x D x 6.00 = 56.538

For Non - Cohesive Soil

$$\Sigma K \times P_{Di} \times \tan\delta \times \pi \times D \times h$$

Depth 7.50to 12.00m - Q_{uii} = 1.00 x 8.43 x 0.510 x 3.141 x D x 4.50 = 60.712 D
Depth 12.00 m to 15.00 m - Q_{uiii} = 1.10 x 11.79 x 0.554 x 3.141 x D x 3.00 = 67.740 D

Total Ultimate Skin Resistance = 184.99 D

P_{Di} Calculation

$P_{di\ (ii)}$ = (0.860 x 1.500) + (0.860 x 6.00) + (0.880 x 2.250) = 8.43
$P_{di\ (iii)}$ = (0.860 x 1.500) + (0.860 x 6.00) + (0.880 x 4.500) + (0.920 x 1.500) = 11.79

END BEARING

For Non Cohesive Soil

$Q_{uit} = A_p (0.5\ D\ \gamma\ N_\gamma + P_D\ N_q)$

$= \frac{\pi D^2}{4} \{ (0.500 \times D \times 0.92 \times 20.100) + (15.000 \times D \times 0.800 \times 18.000) \}$

$= (7.2581\ D^3 + 169.560\ D^3)$

Ultimate load carrying capcity in Compression = 176.818 D^3 + 0.000 D^2 + 184.99 D
Ultimate load carrying capcity in Tension = 184.990 D

For uniform diameter straight shaft RCC bored Pile when toe at 15.00m below EGL and cut off at 1.50 m below EGL

	450	600	750	1000
Safe load carrying capacity in Compression (MT) (Using Factor of Safety = 2.50)	40	60	85	145
Safe load carrying capacity in Tension (MT) (Using Factor of Safety = 3)	28	37	46	62

Sample Calculation of Lateral Capacity of Pile
(As per IS:2911 – Part 1 – Section2 – 2010)

Pile Dia (D) = 0.60 meter

Grade of Concrete = M 25

UCS Value = 60 KN/m^2

Depth of Fixity Calculation

Terzaghi's mod^{n} of horizontal of subgrade reaction (k_1) = 10.8 MN/m^2
(From Table of IS 2911-Part 1-Sec-2 : 2010)

Modulus of horizontal of subgrade reaction (K) = (k_1/5)x(1/B) 3.6 MN/m^2

Here, E = $5000\sqrt{f_{ck}}$ = 25000.00 MN/m^2

$$I = \frac{\pi D^4}{64}$$ = 0.006361725 m^4

Hence, relative stiffness factor R = $\sqrt[4]{\frac{EI}{KB}}$ = 2.93 meter

Unsupported length of pile(L_1) = 0 meter

Therefore, L_1/R = 0.00

From graph (L_f/R -Vs- L_1/R) for normally loaded clays and fixed head pile, L_f/R = 2.17
(From IS 2911-Part 1-Section 2 : 2010)

Therefore, depth of fixity (L_f) = 6.36 m

Considering pile as a cantilever to its point of fixity, then $L_{eff} = L_1 + L_f$ = 6.36 m

Calculation of Lateral Load Capacity

Deflection δ = 0.005 upto 500 dia pile and above 500 dia 1% of pile dia.

Here, δ = 0.006 m

Lateral Load Capcity of Pile = $[Q]_D = \frac{12EI \times \delta}{(L_f + L_1)^3}$ = 0.0445833 MN = 4.46 ton