PN - 170236

REPORT ON

GEOTECHNICAL INVESTIGATIONS

FOR THE PROPOSED

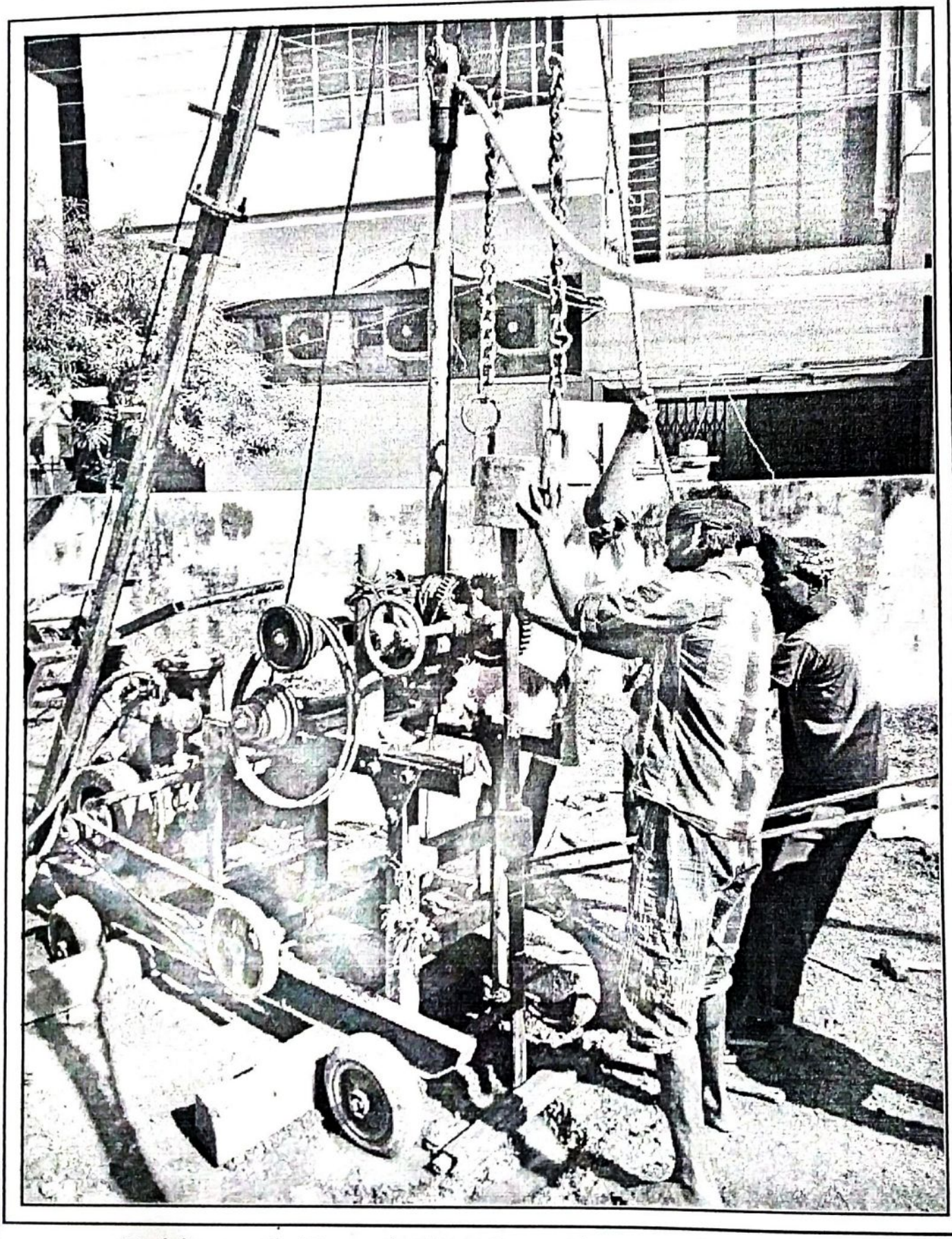
Commercial Complex
On
Ashiana Digha Road,
Patna

Submitted to
Kamini Engicons Pvt. Ltd.
Boring Road,
Patna

March, 2017

BAIDYANATH FOUNDATION CONSULTANTS PVT. LTD.
[Unit : Bihar Foundation Consultants]
Ganga Darshan Apartment, Flat No. 403.
Patna – 10
[e-mail : bifcon.pat@gmail.com, Phone No: + 91612 – 2272826]

Commercial Complex on Ashiana Digha Road, Panta



Baidyanath Foundation Consultants Pvt. Ltd.,
403, Ganga Darshan Apartment, Patna-10
[Unit : Bihar Foundation Consultants]

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[Containing Figures and Tables]

Report on Sub Soil Investigations for the Proposed
Commercial Complex on Ashiana Digha Road, Panta

1. INTRODUCTION

The subsoil investigations reported herein were taken up to find out the nature of subsoil at the site of the proposed construction and to recommend the capacity and type of its foundation. After certain tests on the soil, as detailed below, the desired recommendations have been made on **page 3 - 4** of this Report.

2. FIELD WORK

The fieldwork consisted of sinking bore holes, collecting soil samples and conducting the necessary field tests.

2.1. Boring

Taking guidance from IS: 1892, 150 mm diameter bore holes were sunk at locations shown in the bore hole location map.

2.2 Sampling

2.2.1 Undisturbed Soil Samples

Open drive samplers of 100-mm diameter and about 450-mm length were used for obtaining undisturbed samples of cohesive soils. The collection, sealing, labeling and transportation of the samples to the laboratory were done as per the IS guide-lines.

2.2.2 Disturbed Soil Samples

Disturbed soil samples were collected at suitable intervals of depth (not more than 2.5 m) and at all depths of change in the nature of the subsoil. These samples were sealed in polythene bags with proper identification labels.

2.3 Field Tests

2.3.1 Standard Penetration Tests (SPT)

These tests were conducted as per IS: 2131 – 1963. The depth interval between two consecutive tests was 1 to 1.5 m. The tests were located in between the levels at which undisturbed soil samples were collected.

3. LABORATORY TESTS

Some or all of the following laboratory tests, as necessary, were done on the collected soil samples. Representative soil samples were selected for this from the different soil strata encountered during boring. The tests were performed as per the relevant Indian Standard Codes of Practice.

(a) Natural moisture content

(b) Bulk density

(c) Grain size analysis (using sieves and / or hydrometer)

(d) Specific gravity of soil solids

(e) Atterberg's limit tests (liquid, plastic and shrinkage limits)

(f) Shear Tests :

- [I] Triaxial compression test (unconsolidated – undrained), generally for fine- grained soils
- [II] Unconfined compression tests, only on cohesive soils
- [III] Direct shear tests, generally for coarse-grained soils

(g) Other tests as and when required.

4. PRESENTATION OF TEST RESULTS

The field and laboratory test are given in the **Appendix B.**

5. SOIL STRATIFICATION

The three bore holes sunk at the site [vide Location Sketch in App. A] and the results of laboratory tests conducted on the collected soil samples indicate the following stratification.

The subsoil consists of silty clay (type CI) up to about 4.5 m in BH 1, 12 m in BH 2, and 9 m in BH 3. This is followed by silty clay (type CL) up to the investigated depth of 20 m in the three bore holes.

Ground water table was struck at about 1.00 m to 1.40 m depth below GL in February, 2017. It is subject to seasonal changes.

6. FOUNDATION ANALYSIS

The safe capacity of foundation of any type and size may be determined on the basis of the soil data given in this Report by using the standard methods of foundation design and following the relevant Indian Standard Codes.

7. RECOMMENDATIONS

The design of the foundation for the proposed structure depends on the nature of both (i) the subsoil and (ii) the structure.

The subsoil consists of silty clay (type Cl) up to about 4.5 m in BH 1, 12 m in BH 2, and 9 m in BH 3. This is followed by silty clay (type CL) up to the investigated depth of 20 m in the three bore holes.

Ground water table was struck at about 1.00 m to 1.40 m depth below GL in February, 2017. It is subject to seasonal changes.

Hence, depending on structural and financial constraints, the proposed commercial complex may be supported on

[a] either a shallow foundation, with or without a basement, or

[b] under-reamed piles.

By way of example, the calculated values (vide Samples of Calculations in Appendix F) have been tabulated below of safe capacities of

(1) shallow foundations of certain sizes and depths and

(2) single or double bulbed u/r piles of certain depths and diameters.

Since the water table may be high during the construction of foundation, proper steps may have to be taken for dewatering the foundation trenches and for stabilizing their walls. If a basement is to be provided, it will have to be a waterproof construction. In case of pile foundations, the concreting under water surface has to be done by DMC and tremie method.

Table 1: Allowable Net Bearing Pressures [q_{na}] and Settlements Expected [s]

Depth (m)	Width (m)	Net allowable bearing pressure (t/m²) for			Maximum expected settlement (mm)
		Strip footing	Square footing	Raft footing	
2.0	2.0	9.0	15.1	...	75
	3.0	6.1	10.8	...	75
	10.0	...	...	7.9	100
2.5	2.0	10.3	16.3	...	75
	3.0	6.9	12.0	...	75
	10.0	...	...	8.3	100
3.0	2.0	11.5	17.9	...	75
	3.0	7.5	13.2	...	75
	10.0	...	...	8.7	100
3.5	2.0	12.8	19.5	...	75
	3.0	8.3	14.5	...	75
	10.0	...	...	9.1	100
4.0	2.0	15.0	19.8		75
	3.0	9.5	16.7		75
	10.0			10.0	100
4.5	2.0	16.3	20.0	...	75
	3.0	10.3	18.0	...	75
	10.0	...	...	10.4	100

Table 2. Safe Capacities of U/R Piles [Factor of safety = 2.5]

[Bulb diameter = 2.0 times the shaft diameter]

Pile length below pile Cap (m)	Stem diameter (m)	Bulb diameter (m)	[b] Safe Pile Capacity [tonnes]	
			One bulb	Two bulbs
6.0	0.30	0.60	11.4	14.0
	0.40	0.80	18.2	22.8
	0.50	1.00	26.4	33.7
8.0	0.30	0.60	14.1	17.3
	0.40	0.80	21.9	27.5
	0.50	1.00	31.3	40.1
10.0	0.30	0.60	17.7	21.3
	0.40	0.80	27.0	33.4
	0.50	1.00	38.1	48.1
12.0	0.30	0.60	20.9	25.0
	0.40	0.80	31.5	38.7
	0.50	1.00	43.9	55.2
14.0	0.30	0.60	24.2	28.5
	0.40	0.80	36.0	43.8
	0.50	1.00	49.8	61.9
16.0	0.30	0.60	27.6	32.1
	0.40	0.80	40.7	48.9
	0.50	1.00	55.9	68.6

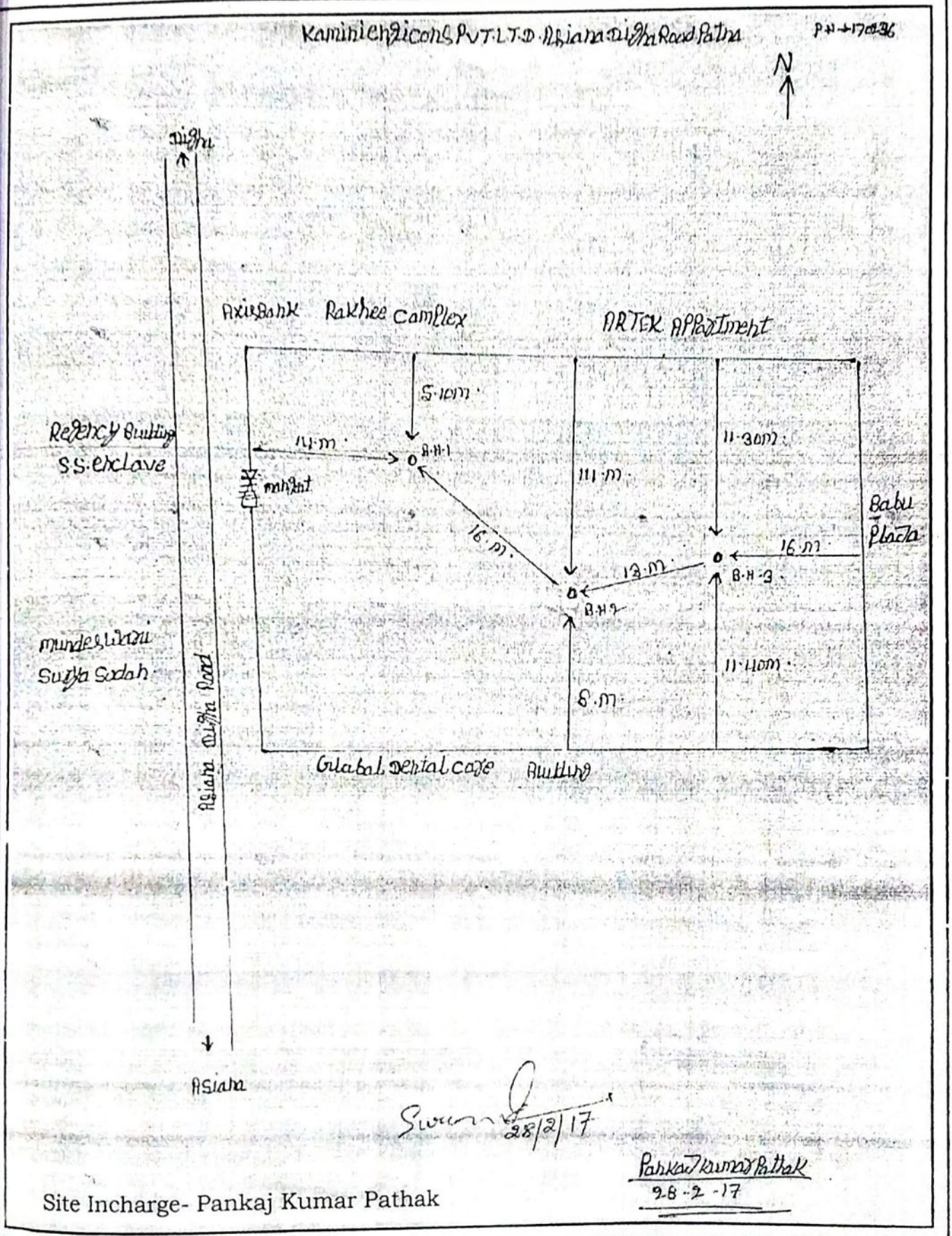
Notes:

1. If a subsoil condition much different from those reported herein is met with during foundation trenching or piling, suitable steps should be taken.
2. If the depth of a shallow foundation is below the water table, dewatering of the foundation trench has to be done, and its side walls of may have to be suitably supported at the time of the construction of the foundation.
3. If the bottom of a basement, in case it is being provided, its base and walls have to be safeguarded against the likely ingress of ground-water.
4. If concreting for a pile has to be done under water, DMC and tremie method of concreting should be adopted.
5. As per the provisions of the IS Code, **an appropriate number of piles must be subjected to routine load tests to check the veracity of the above recommended values of the safe capacities of piles.**
6. Shallow foundations or pile caps should be isolated from the surrounding expansive soil of type CI by layers of compacted local sand.

For Baidyanath Foundation Consultants Pvt. Ltd.,

(Dr. C.N. Sinha, FIE)
Chief Consultant.

Commercial Complex on Ashiana Digha Road, Panta



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Appendix - A

NAME OF WORK : Sub soil Investigation for C/O

Commercial Complex on Ashiana Digha Road, Panta

BORE HOLE NO. : 1

Site Enginerr - Panjak Kumar Pathak

BORING FINISH DATE : 27.02.17

BORING METHOD : Rotary

TERMINATION DEPTH : 20.0 m

WATER TABLE : 1.20 m bgl

RECORD ON : 26.02.17

Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m) from	Depth(m) to	Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test: Type of Test	Shear Test: Cohesion, c (kg/cm^2)	Shear Test: Friction Angle, ϕ°	Compression Index (C_c)
1.0			Greyish silty clay, CI	0.0												
1.5	S1	16			1.5	1.5				2.02	24.9	2.71		0.65	5.1	
2.5			Greyish gritty silty clay, CI	1.5												
3.0	S2	10			3.0	1.5	41.9	26.9	15.0	2.00	26.2	2.71		0.49	5.1	
4.0			Greyish silty clay, CI	3.0												
4.5	S3	12			4.5	1.5				2.01	25.4	2.70		0.57	5.1	0.136
5.5			Greyish yellowish silty clay, CL	4.5												
6.0	S4	16			6.0	1.5				2.02	24.7	2.70				
7.0			Yellowish greyish silty clay, CL	6.0												
7.5	S5	17			7.5	1.5	33.1	22.0	11.1	2.02	24.7	2.70		0.68	5.1	
8.5			Yellowish greyish gritty silty clay, CL	7.5												
9.0	S6	18								2.02	24.6	2.70				
10.0																
10.5	S7	24								2.03	24.2	2.70		0.82	5.3	
11.5																
12.0	S8	23					33.4	22.1	11.3	2.03	24.2	2.70		0.80	5.3	
13.0																
13.5	S9	26								2.04	23.5	2.70				
14.5						12.5										
15.0	S10	25								2.04	23.6	2.70		0.84	5.3	
16.0																
16.5	S11	29								2.04	23.4	2.70				
17.5																
18.0	S12	33								2.05	22.9	2.70		1.00	5.3	
19.0																
19.5																
20.0	S13	30			20.0		41.0	26.1	14.9	2.05	23.0	2.70				

NAME OF WORK : Sub soil Investigation for C/O

Commercial Complex on Ashiana Digha Road, Panta

BORE HOLE NO. : 2 | Site Engineer - Panjak Kumar Pathak

BORING FINISH DATE : 28.02.17 | BORING METHOD : Rotary | TERMINATION DEPTH : 20.0 m | WATER TABLE : 1.40 m bgl | RECORD ON : 28.02.17

Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m) from	Depth(m) to	Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test: Type of Test	Shear Test: Cohesion, c (kg/cm^2)	Shear Test: Friction Angle, ϕ °	Compression Index (C_c)
1.0																
1.5	S1	9	Greyish silty with grits clay, CI	0.0												
2.5					1.5	1.5	43.2	27.8	15.4	1.99	26.9	2.71		0.45	5.0	
3.0	S2	22		1.5												
4.0			Greyish silty with grits clay, CI							2.03	24.4	2.71		0.77	5.2	
4.5	S3	17				4.5										
5.5							45.0	27.7	17.3	2.02	24.9	2.71		0.68	5.1	0.131
6.0	S4	19			6.0											
7.0				6.0						2.02	24.7	2.70				
7.5	S5	22														
8.5										2.03	24.2	2.70		0.78	5.2	
9.0	S6	26	Yellowish greyish with grits silty clay, CI													
10.0						6.0				2.04	23.6	2.70				
10.5	S7	27														
11.5							38.2	23.4	14.8	2.04	23.5	2.70		0.68	5.3	
12.0	S8	26			12.0											
13.0				12.0						2.04	23.6	2.70				
13.5	S9	27														
14.5							32.8	22.0	10.8	2.04	23.5	2.70		0.88	5.3	
15.0	S10	28														
16.0										2.04	23.4	2.70				
16.5	S11	32	Reddish yellowish greyish silty clay, CL			8.0										
17.5							35.6	22.6	13.0	2.05	22.9	2.70				
18.0	S12	38														
19.0										2.06	22.4	2.70		1.10	5.3	
19.5																
20.0	S13	32			20.0					2.05	22.9	2.70		0.98	5.3	

NAME OF WORK : Sub soil Investigation for C/O

Commercial Complex on Ashiana Digha Road, Panta

BORE HOLE NO. : 3

Site Enginerr - Panjak Kumar Pathak

BORING FINISH DATE : 01.03.17

BORING METHOD : Rotary

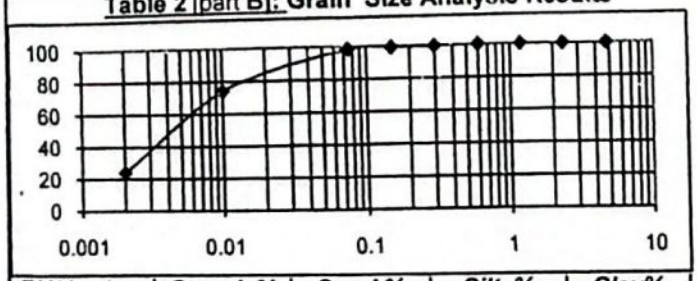
TERMINATION DEPTH : 20.0 m

WATER TABLE : 1.0 m bgl

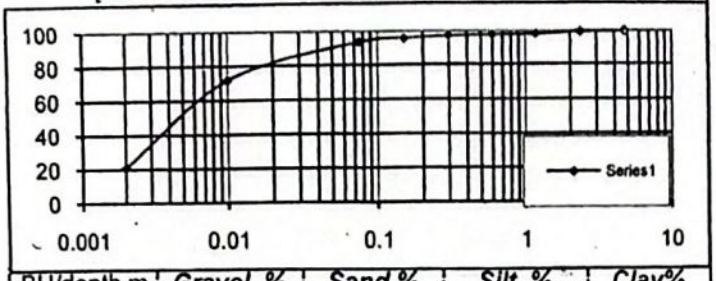
RECORD ON : 01.03.17

Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m) from	Depth(m) to	Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test: Type of Test	Shear Test: Cohesion, c (kg/cm^2)	Shear Test: Friction Angle, ϕ °	Compression Index (C_c)
1.0			Greyish silty clay, CI	0.0		1.5										
1.5	S1	11			1.5					2.01	25.6	2.71		0.53	5.1	
2.5			Greyish gritty silty clay, CI	1.5		3.0										
3.0	S2	14					47.3	29.2	18.1	2.01	25.5	2.71		0.66	5.1	
4.0																
4.5	S3	14			4.5					2.01	25.5	2.71		0.66	5.1	0.135
5.5			Greyish silty clay, CI	4.5		4.5										
6.0	S4	18					45.0	27.6	17.4	2.02	24.6	2.70				
7.0																
7.5	S5	22								2.03	24.3	2.70				
8.5																
9.0	S6	24			9.0		36.9	26.4	10.5	2.03	24.2	2.70		0.82	5.3	
10.0			Yellowish greyish silty clay, CL	9.0		3.0										
10.5	S7	26								2.04	23.6	2.70				
11.5																
12.0	S8	27			12.0					2.04	23.5	2.70		0.88	5.3	
13.0			Reddish yellowish greyish with grits silty clay, CL	12.0		8.0										
13.5	S9	26								2.04	23.6	2.70				
14.5																
15.0	S10	28					33.2	22.8	10.4	2.04	23.4	2.70		0.90	5.3	
16.0																
16.5	S11	30								2.05	23.0	2.70				
17.5																
18.0	S12	31					31.4	20.3	11.1	2.05	23.0	2.70		0.96	5.3	
19.0																
19.5																
20.0	S13	32			20.0					2.05	22.9	2.70		0.98	5.3	

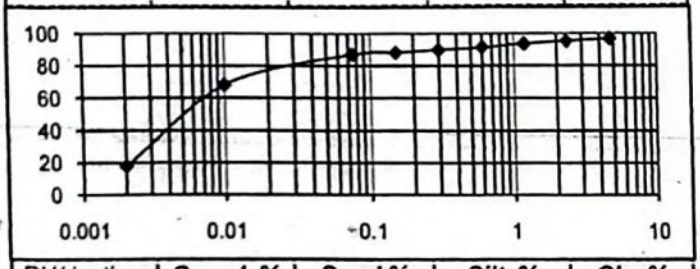
Table 2 [part B]: Grain Size Analysis Results [for Bore hole No./ Depth in m shown thus: 1/1.5]



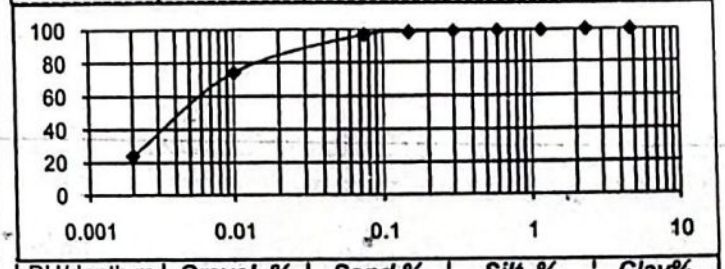
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/1.5	0.0	1.7	74.3	24.0



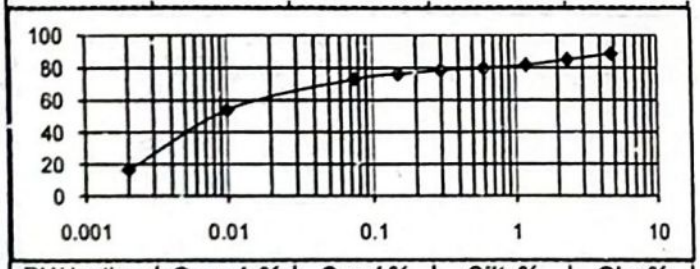
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/3.0	0.0	6.5	72.5	21.0



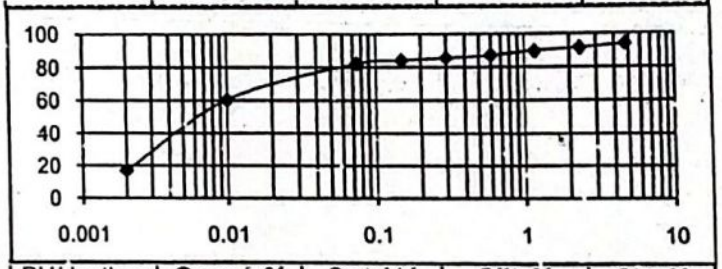
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/4.5	3.2	9.8	69.0	18.0



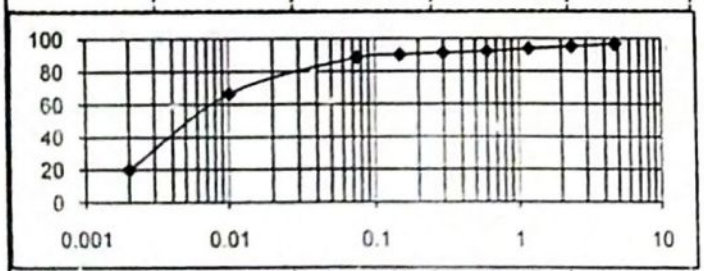
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/6.0	0.0	2.9	73.0	24.1



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/7.5	11.2	15.7	56.6	16.5
1/10.5	Almost same as above			

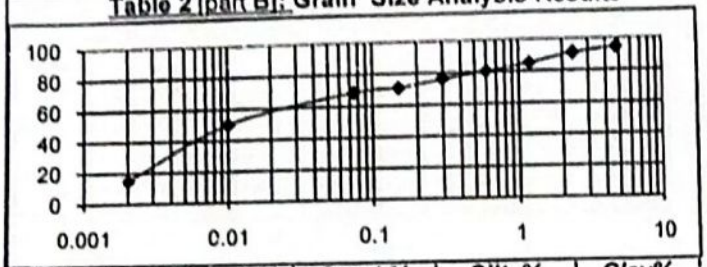


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/12.0	6.0	11.8	65.4	16.8
1/15.0	Almost same as above			

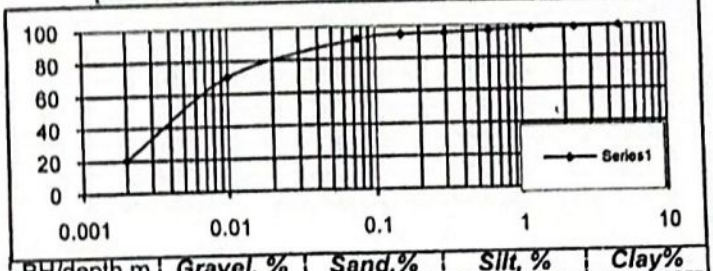


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/16.5	3.4	8.3	68.3	20.0
1/20.0	Almost same as above			

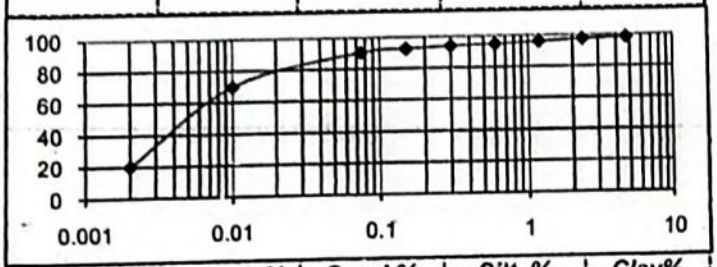
Table 2 [part B]: Grain Size Analysis Results [for Bore hole No./ Depth in m shown thus: 1/1.5]



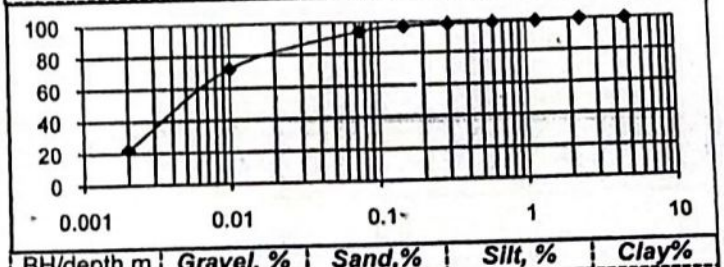
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/1.5	5.5	25.7	54.0	14.8
2/3.0	Almost same as above			



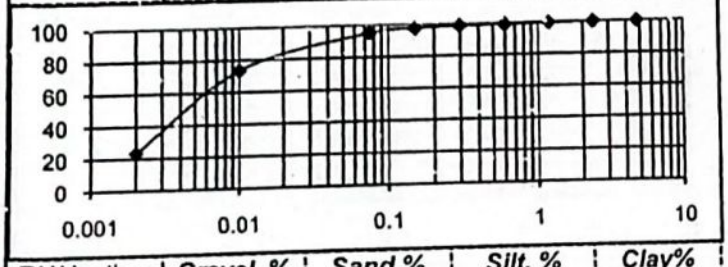
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/4.5	0.6	7.0	71.8	20.6
2/6.0	Almost same as above			



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/7.5	1.5	7.8	70.5	20.2
2/10.5	Almost same as above			

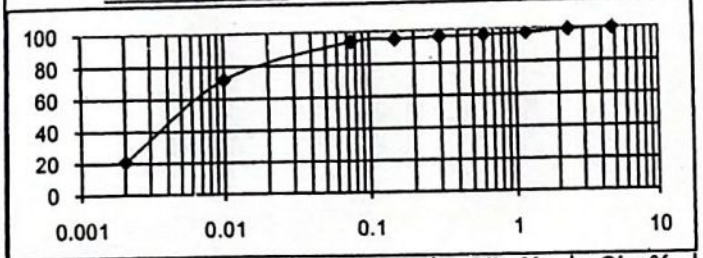


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/12.0	0.0	5.7	72.2	22.1
2/15.0	Almost same as above			

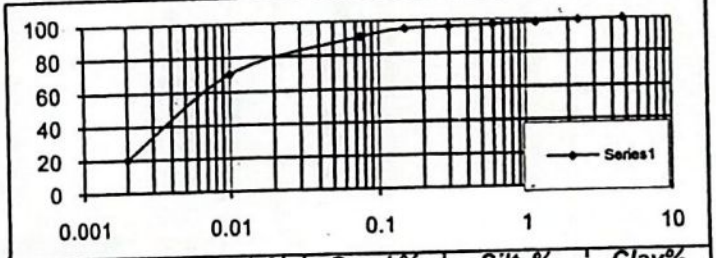


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/16.5	0.0	4.9	71.6	23.5
2/20.0	Almost same as above			

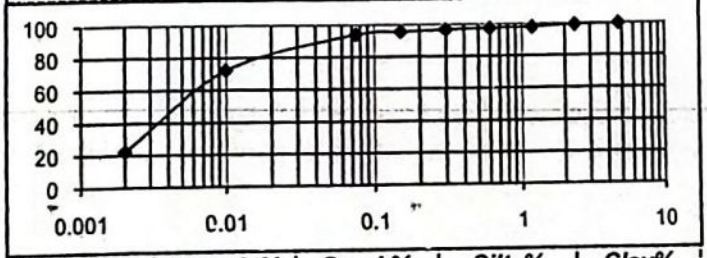
Table 2 [part B]: Grain Size Analysis Results [for Bore hole No./ Depth in m shown thus: 1/1.5]



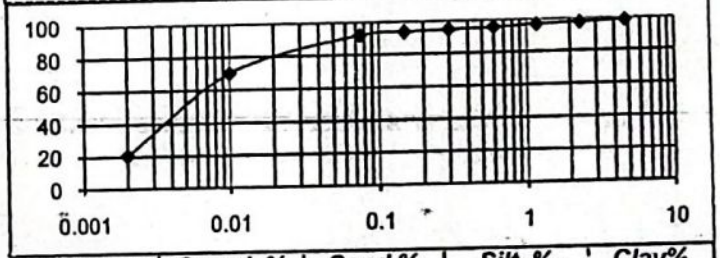
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/1.5	0.0	5.9	73.1	21.0
3/3.0	Almost same as above			



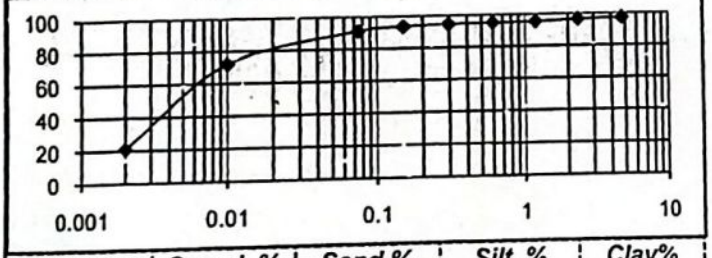
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/4.5	0.0	9.2	70.4	20.5
3/7.5	Almost same as above			



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/9.0	0.0	5.8	71.8	22.4
3/10.5	Almost same as above			

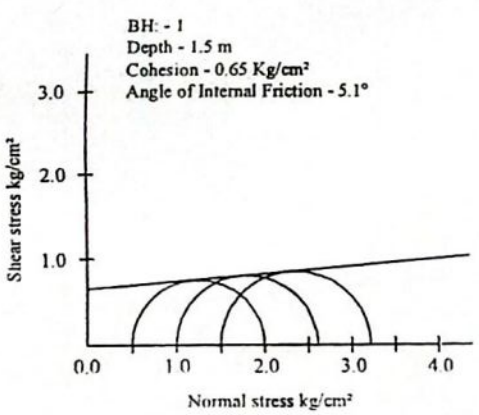


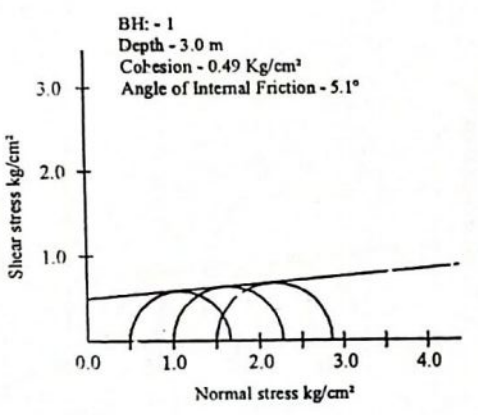
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/12.0	1.2	6.6	71.7	20.5
3/15.0	Almost same as above			

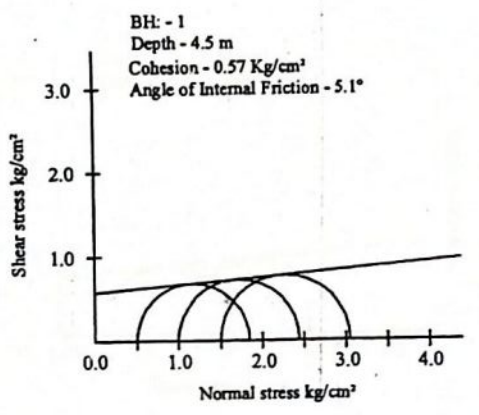


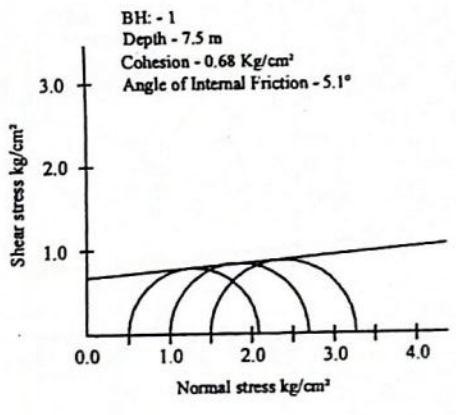
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/16.5	2.8	6.1	70.0	21.1
3/20.0	Almost same as above			

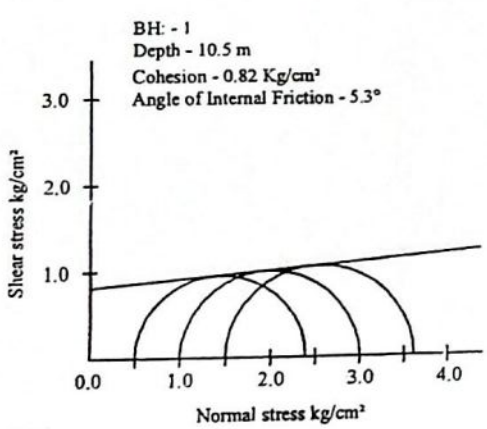
TRIAXIAL / DIRECT SHEAR TEST PLOTS

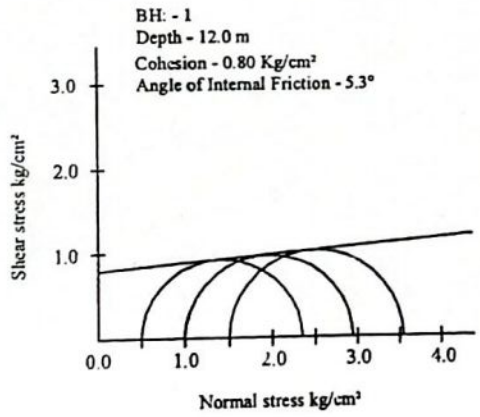


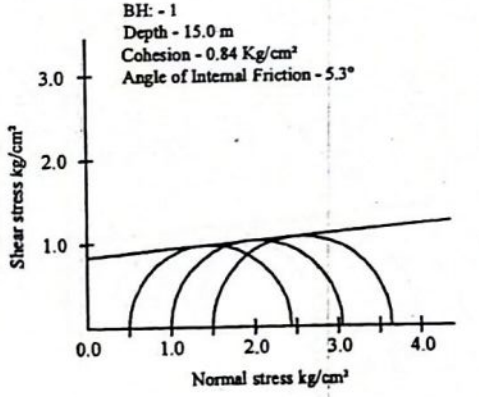


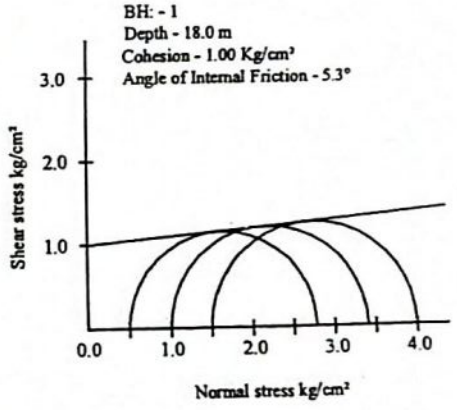












Appendix - D1

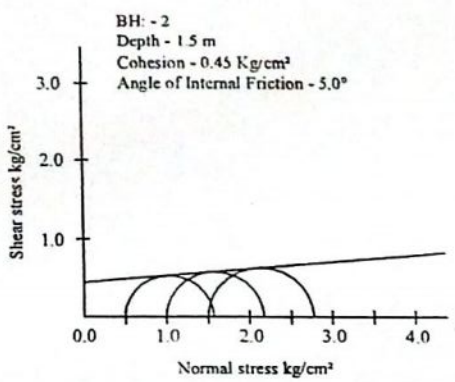
Baidyanath Foundation Consultants Pvt. Ltd.,
[Unit : Bihar Foundation Consultants]

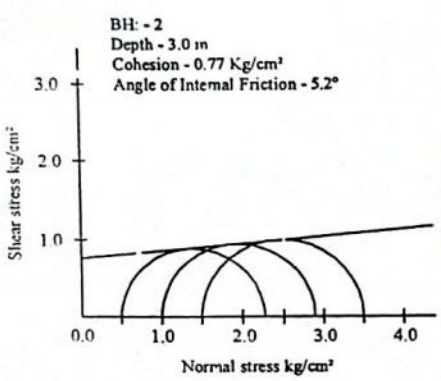
Project No. 170236

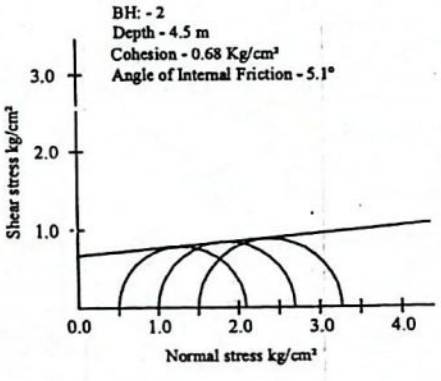
For the Proposed

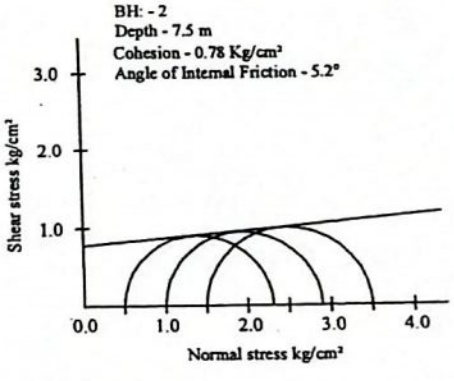
Commercial Complex on Ashiana
Digha Road, Panta

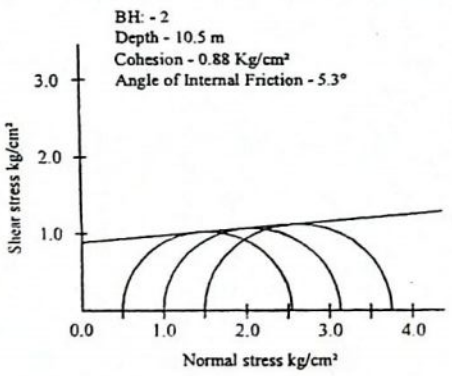
TRIAXIAL / DIRECT SHEAR TEST PLOTS

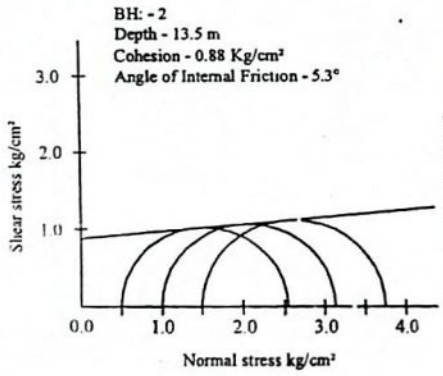


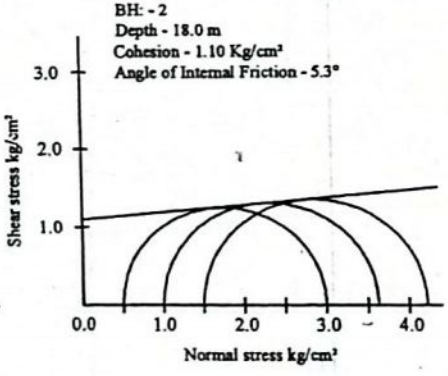


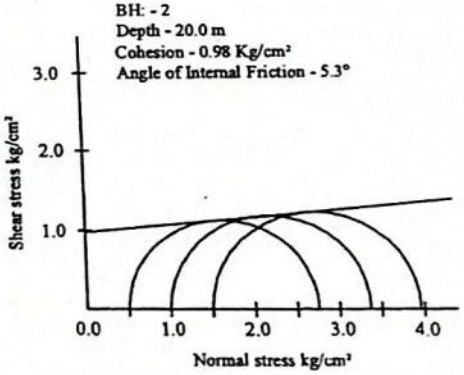












Appendix - D2

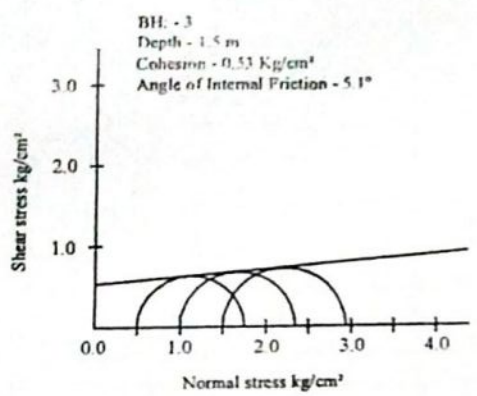
Baidyanath Foundation Consultants Pvt. Ltd.,
[Unit : Bihar Foundation Consultants]

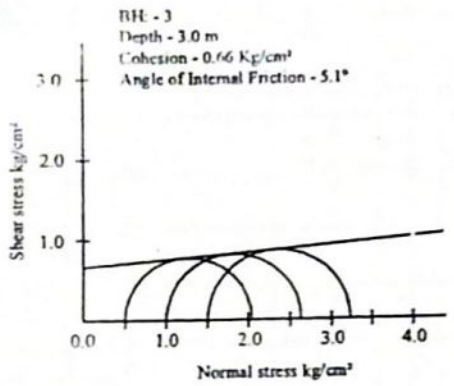
Project No. 170236

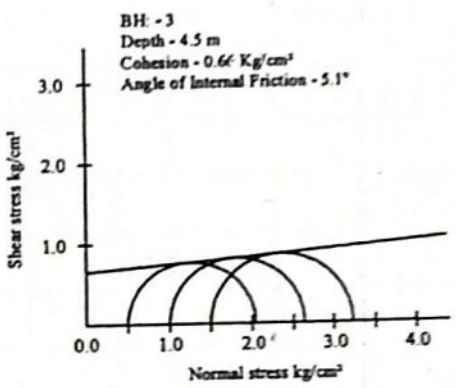
For the Proposed

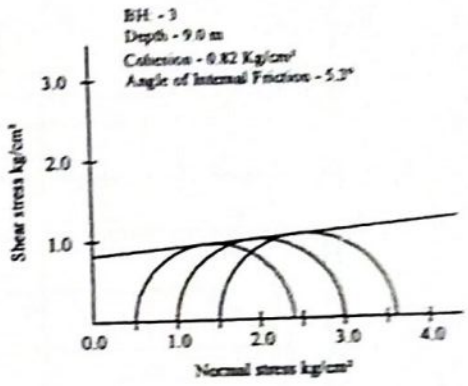
Commercial Complex on Ashiana
Digha Road, Panta

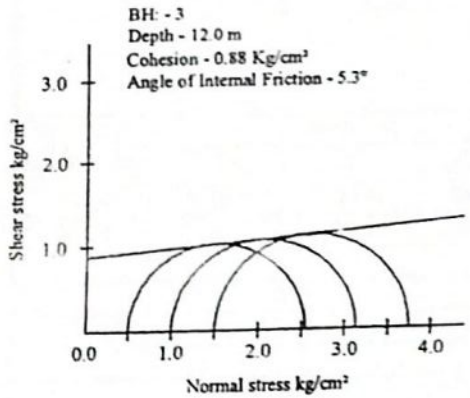
TRIAXIAL / DIRECT SHEAR TEST PLOTS

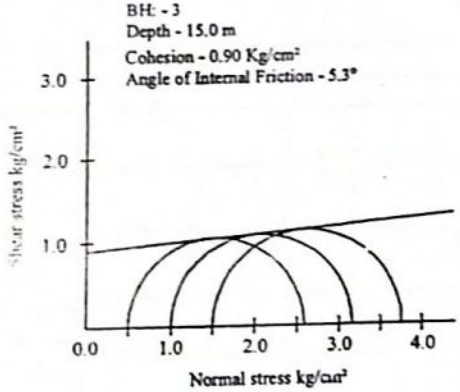


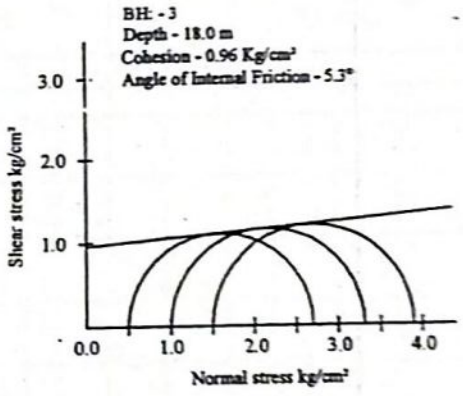


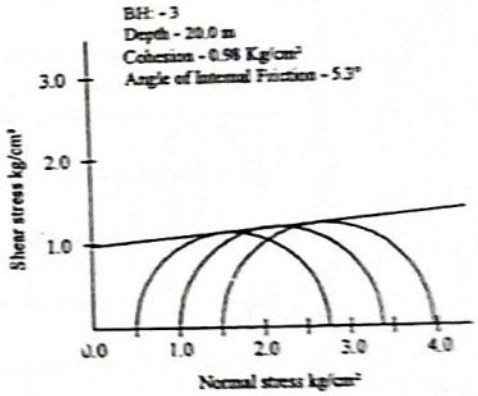












Appendix - D3

Baidyanath Foundation Consultants Pvt. Ltd.,
[Unit : Bihar Foundation Consultants]

Project No. 170236

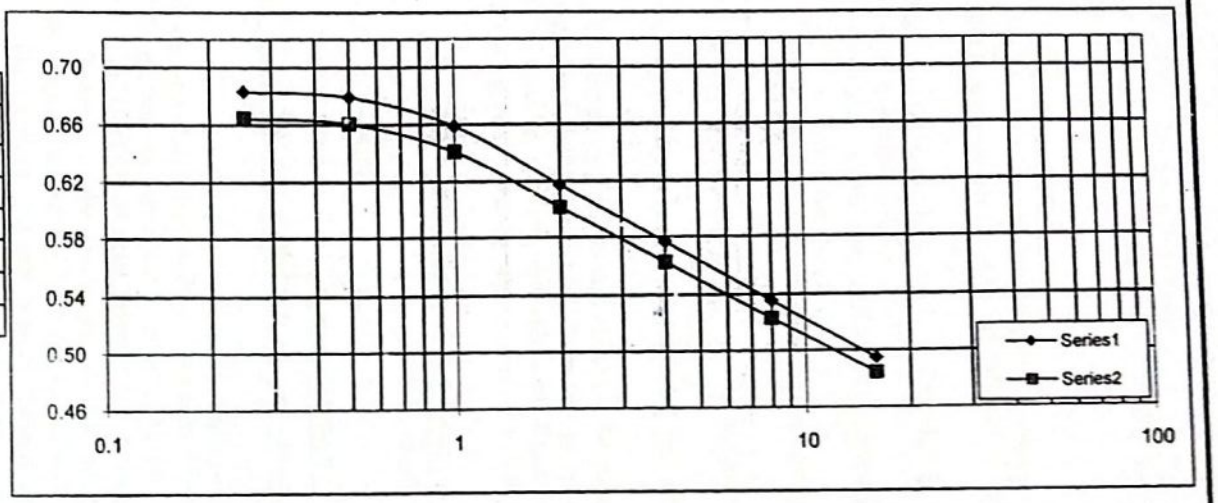
For the Proposed

Commercial Complex on Ashiana
Digha Road, Panta

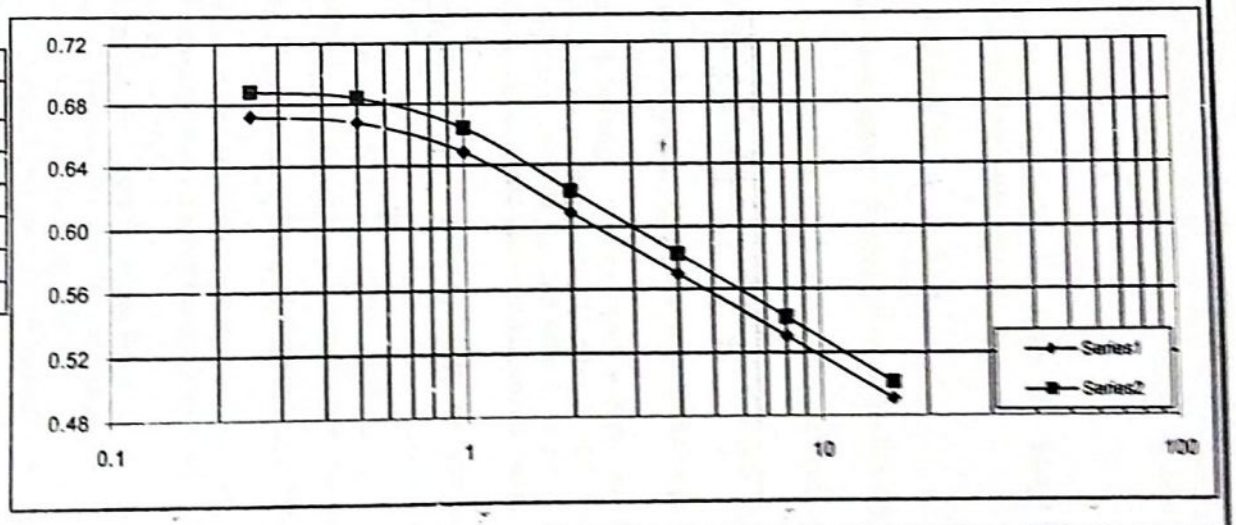
Fig. e - log p Plots from Consolidation Tests

X-axis : Pressure, p (kg/cm^2) on log scale. **Y-axis :** Void ratio, e

BH No./ Depth (m)	Cc	Initial V.R. e_0	CURVE
1/4.5	0.136	0.6858	Series1
1/6.0	0.130	0.6669	Series2



BH No./ Depth (m)	C_c	Initial V.R. e_0	CURVE
2/4.5	0.131	0.6748	Series1
3/4.5	0.135	0.6911	Series2



Report on Sub Soil Investigations for the Proposed Commercial Complex on Ashiana Digha Road, Panta

SAMPLE CALCULATION OF BEARING CAPACITY OF SHALLOW FOUNDATION

The determination of the **net safe bearing capacity,** q_{ns}, is done on the basis of the shear failure criterion after dividing the value of the **net ultimate bearing capacity** q_{nf}, calculated as described below, by a suitable factor of safety. The **net soil pressure,** q_s, for a given permissible settlement is then calculated as explained in the next section. The lower of the two values, q_{ns} and q_s, thus determined is taken as the **allowable bearing capacity** of the soil.

1. Shear Failure Criterion :

The **net ultimate bearing capacity** q_{nf} (t/m^2) of a shallow foundation of breadth B (m) and depth D (m) is given as per IS:6403-1981 (Sec.5.1.2) by the following equation :

$$q_{nf} = c\,N_c\,s_c\,d_c\,I_c + q\,(N_q - 1)\,s_q\,d_q\,I_q + 0.5\,\gamma\,B\,N_\gamma\,s_\gamma\,d_\gamma\,I_\gamma\,w$$

where c = cohesion (t/m^2)

γ = unit weight of subsoil (t/m^3) [submerged unit weight, γ', is taken where so applicable]

q = effective surcharge (t/m^2) = γD

N_c, N_γ, N_q = bearing capacity factors, which are functions of ϕ, the angle of internal friction of the soil.

s_c, s_q, s_γ = shape factors
d_c, d_q, d_γ = depth factors
I_c, I_q, I_γ = inclination factors
} related to cohesion, surcharge and density of subsoil respectively

w' = water table factor (= 0.5 to 1.0) depending on the depth, D_w of water table [vide Table below].

The bearing capacity factors (N's) are functions of ϕ, the angle of internal friction of the soil. The values of these factors are found for general shear failure by referring to standard tables. If subsoil conditions are such as to lead to local shear failure, the values of these factors are found for a reduced value of angle of internal friction (ϕ') given by the equation : $\tan \phi' = 0.67 \tan \phi$. The value of cohesion is also reduced to $c' = 0.67\,c$.

The values of the other factors in the above equation for usual conditions are as tabulated below :

s_c =	1.3	1+0.2B/L	1	d_c = 1+ 0.2 $(N\varphi)^{0.5}$ D/ B		D_w at	G.L.	Fou'dn.Level
s_q =	1.2	1+0.2B/L	1	$d_q = d_\gamma$ = 1	for $\varphi < 10^o$	w =	0.5	1
s_γ =	0.8//0.6	1-0.4B/L	1	$d_q = d_\gamma$ = 1+ 0.1$(N\varphi)^{0.5}$ D/ B	$\varphi > 10^o$		Interpolation	between
FOR	sq.// O	Rect.	STRIP	I_c, I_q, I_γ = ! for vertical load			these values	is linear.

In the present case, the representative values of cohesion © and angle of internal friction (ϕ) may be obtained from the soil data given earlier. Full submergence of the soil has been assumed. The **safe bearing capacity,** q_{ns} has been obtained by dividing q_{nf} by a **safety factor, 3.**

One example of calculation of safe bearing capacity for a certain shape, depth and width of a footing is given in **Table A** on the next page. The net safe bearing capacity for the footing is entered in the last column of Table A. Calculations for other depths and widths of footings are done similarly.

The value of net safe bearing capacity (q_{ns}) calculated for each set of values of B and D is used for calculating the consolidation settlement s as explained in Sec. 2 below.

2. Settlement Criterion for Foundation on cohesive soil.

As per IS:8009(Part I)-1976, Sec. 9.2.2.2, the settlement s (in mm) is given by the equation :

$$s = [1000\ H\ C_c \log (1 + \Delta p / p_o)] / (1 + e_o)\,\lambda$$

where H = thickness (in m) of the compressible layer

C_c = compression index of the soil

e_o = initial void ratio at mid-height of compressible soil layer = its m/c (m) x sp. Gravity

p_o = initial effective pressure at mid-height of the layer (t/m^2)

Δp = pressure increment at the mid-height of the layer due to the foundation (t/m^2).

λ = correction factor

Appendix F 1

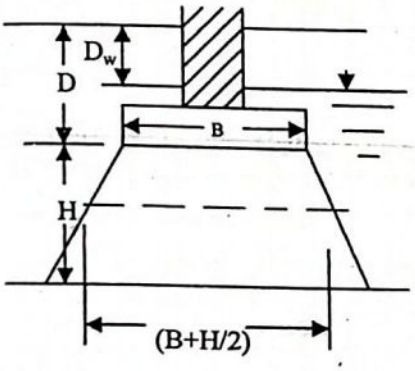
Baidyanath Foundation Consultants Pvt. Ltd.,
403, Ganga Darshan Apartment, Patna-10
[Unit : Bihar Foundation Consultants]

If there are different layers with different compression indices and void ratios, s is calculated for each one of these and then added together to get the settlement.

The pressure increment at any plane due to the footing load may be calculated by assuming the dispersion of load at a slope of 1 horizontal to 2 vertical. Hence the load applied over a width B of a foundation (vide the Fig. below) is spread at a depth H/2 below it over a width (B + H/2).

A correction factor $\lambda = 0.80$ is used as per IS Code to find the corrected settlement. If this value of corrected s is within the permissible limit specified in the Code, the corresponding value of q_{ns} is also the net allowable bearing capacity q_{na}. If not, trials give the desirued value of q_{na} . One example of this settlement analysis is given below the **Table B** in Sec. 3.

If $D_w > (D+ 1.5\ B/2)$, $p_o = \gamma\ (D+1.5\ B/2)$ t/m^2, otherwise, $p_o = \gamma\ D_w + (\gamma - 1)(D- D_w + H/2)$ t/m^2



D_w = depth of water table below ground level .
D = depth of foundation
B = breadth of foundation
H = 1.5 x B = thickness of compressible soil layer in the zone of influence of the loaded foundation.
Breadth of the influence zone at the mid-plane of the compressible layer, of thickness H = (B + H/2).
In case of a rectangular or square footing a similar dispersion of load takes place along the other side of footing.

3. SAMPLE CALCULATION

Table A **Calculation of Net Safe Bearing Capacity**

Shape of Foundation:		STRIP	F.S.= 3	γ, t/m³=	1.99	c =	ϕ =	Nc =	Nq =	Nγ =
						4.6	5.0	6.49	1.57	0.45
D [m]	B [m]	dc	dq = dg	c	q	I Term	II Term	III Term	qnf	qnf /F
2	2	1.22	1.109	4.6	1.99	36.37	1.25	0.50	38.12	12.71

The net safe bearing capacity for the footing is to be seen in the last column of the above Table A. This value is checked for settlement as shown below.

Table B **Calculation of Settlement**

m = 0.269		Gs = 2.71		eo = 0.729		Cc = 0.136		Dw = 0	
Depth D [m]	Width B [m]	qnf /F t/m²	po t/m²	H m	Δp t/m²	log (1+ Δp/po)	S [mm] mm	λs mm mm	Remarks
2.0	2.0	12.7	3.5	3.0	7.3	0.5	115.8	92.6	Not OK
2.0	2.0	9.0	3.5	3.0	5.1	0.4	93.3	74.6	OK

Hence the net allowable bearing pressure for a strip footing of width 2.0 m and depth = 2.0 m below ground level will be = 9.0 t/m^2.

The calculations for footings of other sizes and depths are done similarly.

Appendix F 2

U/R **Pile Capacity Calculation**

Qu = Ap Nc cp+ AaNc c'a+ [0.5]As ca+ A's.ca'

where Ap = area of base of pile = pi $D^2/4$

Aa = area of annular ring = pi $Du^2/4$ - Ap

As = area of stem = pi D(L- 1.5 (n-1) Du-0.55-0.5)

As' = area of cyl. bet.bulbs= pi Du 1.5(n-1) Du

aver.coh.

at base, cp over depth (L-0.55) to (L+ 0.45)

at bulbs, c'a over depth (L-0.55- 1.5 Du) to (L-0.55)

on stem, ca over depth 0 -(L- 1.5 Du) & (L-0.55) to L

cyl. Bet. Bulbs, ca' Bulb dia = 2 x shaft dia

Factor of safety = *2.50*

L	D	Du	No.of bulbs, n=	Ap	Aa	As	As'	cp	c'a	ca	ca'
m	m	m		m^2	m^2	m^2	m^2	t/m^2	t/m^2	t/m^2	t/m^2
6.0	0.30	0.60	1	0.07	0.21	4.67	0.00	6.60	6.60	5.00	5.10
6.0	0.30	0.60	2	0.07	0.21	3.82	1.70	6.60	6.60	5.00	5.10
8.0	0.30	0.60	1	0.07	0.21	6.55	0.00	6.90	6.90	5.40	6.00
8.0	0.30	0.60	2	0.07	0.21	5.70	1.70	6.90	6.90	5.40	6.00
10.0	0.30	0.60	1	0.07	0.21	8.44	0.00	7.60	7.60	5.90	6.80
10.0	0.30	0.60	2	0.07	0.21	7.59	1.70	7.60	7.60	5.90	6.80
12.0	0.30	0.60	1	0.07	0.21	10.32	0.00	8.00	8.00	6.20	7.50
12.0	0.30	0.60	2	0.07	0.21	9.47	1.70	8.00	8.00	6.20	7.50
14.0	0.30	0.60	1	0.07	0.21	12.21	0.00	8.40	8.40	6.40	8.00
14.0	0.30	0.60	2	0.07	0.21	11.36	1.70	8.40	8.40	6.40	8.00
16.0	0.30	0.60	1	0.07	0.21	14.09	0.00	8.80	8.80	6.60	8.40
16.0	0.30	0.60	2	0.07	0.21	13.24	1.70	8.80	8.80	6.60	8.40

L	D	Du	No.of bulbs, n=	ApNc cp	AaNc ca'	[0.5]As ca	As' ca'	Qu	Qs
m	m	m		t	t	t	t	t	t
6.0	0.30	0.60	1	4.20	12.60	11.66	0.00	28.46	11.4
6.0	0.30	0.60	2	4.20	12.60	9.54	8.65	34.99	14.0
8.0	0.30	0.60	1	4.39	13.17	17.69	0.00	35.24	14.1
8.0	0.30	0.60	2	4.39	13.17	15.40	10.18	43.13	17.3
10.0	0.30	0.60	1	4.83	14.50	24.88	0.00	44.22	17.7
10.0	0.30	0.60	2	4.83	14.50	22.38	11.54	53.26	21.3
12.0	0.30	0.60	1	5.09	15.27	31.99	0.00	52.35	20.9
12.0	0.30	0.60	2	5.09	15.27	29.36	12.72	62.44	25.0
14.0	0.30	0.60	1	5.34	16.03	39.06	0.00	60.43	24.2
14.0	0.30	0.60	2	5.34	16.03	36.34	13.57	71.29	28.5
16.0	0.30	0.60	1	5.60	16.79	46.50	0.00	68.89	27.6
16.0	0.30	0.60	2	5.60	16.79	43.70	14.25	80.34	32.1

L	D,stem	Du	No.of bulbs,n=	Qs
6.0	0.30	0.60	1	11.4
6.0	0.30	0.60	2	14.0
8.0	0.30	0.60	1	14.1
8.0	0.30	0.60	2	17.3
10.0	0.30	0.60	1	17.7
10.0	0.30	0.60	2	21.3
12.0	0.30	0.60	1	20.9
12.0	0.30	0.60	2	25.0
14.0	0.30	0.60	1	24.2
14.0	0.30	0.60	2	28.5
16.0	0.30	0.60	1	27.6
16.0	0.30	0.60	2	32.1