PN – 211223

REPORT ON

GEOTECHNICAL INVESTIGATIONS

FOR THE PROPOSED

Degree College
In
Ballia (Begusarai) Block Campus, Begusarai

Your Letter No.- BSEIDC/Tech/1960(PART)/2018-8505, Dated – 08.12.2021

Submitted to
The Chief Engineer
BSEIDC, Patna

December, 2021

BIHAR FOUNDATION CONSULTANTS
[A unit of Baidyanath Foundation Consultants Pvt. Ltd.]
Having an
NABL Accredited / ISO 9001: 2015 Certified Laboratory
Ganga Darshan Apartment, Flat No. 403.
Patna – 10
[e-mail : bifcon.pat@gmail.com, Phone No: + 91612 – 2272826]

Degree College in Ballia (Begusarai)
Block Campus, Begusarai

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

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Appendix

[Containing Figures and Tables]

INTRODUCTION

The subsoil investigations reported herein were taken up (vide W.O. No. BSEIDC/Tech/1960(PART)/2018-8505 Dated – 08.12.2021 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.

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*It was learnt from Sri Subodh Ji, [Mob. No. 7004172431], J.E. Begusarai that there being no land available in the Ballia Block Campus, the soil test had to be done in the campus of G.D.R. H.S. School, Ballia.

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

(h) Other tests as and when required.

4. PRESENTATION OF TEST RESULTS

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

5. SOIL STRATIFICATION

The results of field tests in 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 that the soil stratification at the site is as describe below.

The subsoil in all BH's is sandy silty clay / silty clay [type CI/CL] up to up to the investigated depth of 10.5 m bgl. But in BH 2 and 3 it is sandy clayey silt [type ML] from about 4.5 m to 7.5 m in BH 2 and 7.5 m to 10.5 m depth in BH 3.

Ground water table was struck at about 3.40 m to 3.50 m depth below GL in December, 2021 It is subject to seasonal variations.

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 [a] the subsoil and [b] the structure.

The subsoil in all BH's is sandy silty clay / silty clay [type CI/CL] up to up to the investigated depth of 10.5 m bgl. But in BH 2 and 3 it is sandy clayey silt [type ML] from about 4.5 m to 7.5 m in BH 2 and 7.5 m to 10.5 m depth in BH 3.

Ground water table was struck at about 3.40 m to 3.50 m depth below GL in December, 2021 It is subject to seasonal variations.

Considering the above facts,

1. The subsoil up to about 8 m depth is soft or loose. Hence placement of shallow foundation may not be economical in the present case. However the capacities of footing placed at depths of 2 m to 4.5 m have been calculated.
2. Alternatively, plane piles of lengths 4.0 m to 10.0 m with shaft diameters 0.25 m, 0.30 m, 0.40 m and 0.50 m may be provided, using casing pipes where ever a need arises.

By way of example, the values of safe capacities of

[1] Shallow foundations and [2] Plane piles of the above mentioned sizes and depths have been calculated (vide Samples of Calculations in Appendix F) and the safe capacities are given below in Tables 1 and 2 respectively.

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

Depth (m) below Ground Level	Width (m)	Net allowable bearing pressure (t/m^2)			Maximum expected settlement (mm)
		Strip footing	Square footing	Raft footing	
2.0	2	5.1	6.1	…	75
	3	4.9	5.8	…	75
	10	…	…	5.4	100
2.5	2	6.0	7.1	…	75
	3	5.6	6.7	…	75
	10	…	…	6.2	100
3.0	2	6.9	8.2	…	75
	3	6.4	7.6	…	75
	10	…	…	6.9	100
3.5	2	7.2	8.5	…	75
	3	6.6	7.8	…	75
	10	…	…	7.0	100
4.0	2	7.5	8.9	…	75
	3	6.8	8.1	…	75
	10	…	…	7.1	100
4.5	2	7.8	9.3	…	75
	3	7.0	8.4	…	75
	10	…	…	7.2	100

Table 2. Safe Capacities of Plane Piles
[Factor of safety = 2.5 in skin friction and 3 in bearing]

Pile length [m]	Safe Capacities [tonnes] (SUBJECT TO CHECKING FOR SLENDERNESS RATIO*) for Piles of diameters (m):			
	0.25 m	**0.30 m**	**0.40 m**	**0.50 m**
4.0	3.0	3.6	5.1	6.8
5.0	3.7	4.5	6.3	8.1
7.0	4.9	6.2	9.1	11.8
9.0	6.2	8.0	12.1	16.7
10.0	7.0	9.1	13.8	19.2

*For a preliminary checking of the slenderness ratio, the modulus of subgrade reaction (k) may be estimated from the following empirical relation given in IS: 2950-1981 (Second Revision) Table 1. k (kN/m^3) = 240 c, where c (kN/m^2) is the value of cohesion of the soil at the concerned depth.

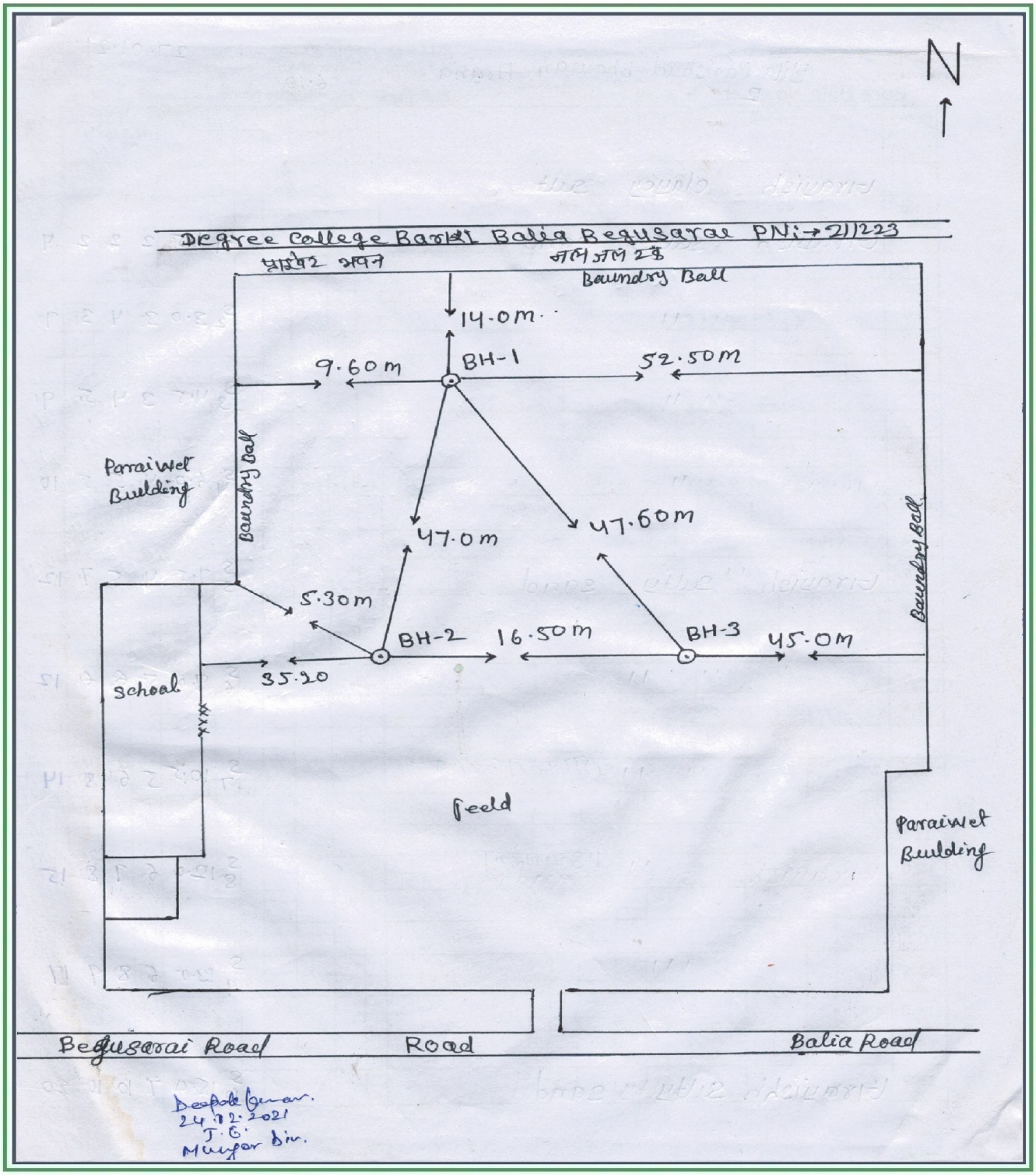
Notes:

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. In case a basement is being provided, its base and side 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.**

For Bihar Foundation Consultants

(Prof. C.N. Sinha, Dr.-Ing., FIE)
Chief Consultant.

Degree College in Ballia (Begusarai)
Block Campus, Begusarai



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403, Ganga Darshan Apartment, Patna-10
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PN - 211223 **Appendix - A**

NAME OF WORK : Sub soil Investigation for C/O							BORING FINISH DATE : 24.12.2021					WATER TABLE : 3.50 m bgl				
Degree College in Ballia (Begusarai) Block Campus, Begusarai							BORING METHOD : Rotary									
BORE HOLE NO. : 1			Site Incharge - Mukesh Singh				TERMINATION DEPTH : 10.5 m					RECORD ON : 24.12.2021				

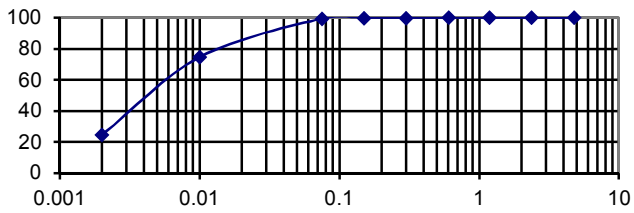
Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m)		Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C_c)
													Type of Test	Cohesion, c (kg/cm2)	Friction Angle, ϕ °	
		Obsr.		from	to											
1.0				0.0												
1.5	S1	5	Greyish silty clay, CL			3.0	32.4	23.3	9.1	1.95	29.3	2.70		0.25	3.0	
2.5																
3.0	S2	6			3.0					1.96	28.6	2.70		0.30	3.6	0.154
4.0				3.0												
4.5	S3	5					34.3	22.3	12.0	1.95	29.3	2.70		0.25	3.0	0.157
5.5																
6.0	S4	3	Greyish sandy silty clay, CL			4.5				1.94	29.8	2.69		0.15	2.0	
7.0																
7.5	S5	4			7.5		29.2	15.1	14.1	1.94	29.7	2.70		0.20	2.5	
8.5				7.5												
9.0	S6	5	Greyish silty clay, CL			3.0				1.95	29.3	2.70		0.25	3.0	
10.0																
10.5	S7	8			10.5					1.98	27.4	2.70		0.40	4.6	

NAME OF WORK : Sub soil Investigation for C/O							BORING FINISH DATE : 24.12.2021					WATER TABLE : 3.40 m bgl				
Degree College in Ballia (Begusarai) Block Campus, Begusarai							BORING METHOD : Rotary									
BORE HOLE NO. : 2			Site Incharge - Mukesh Singh				TERMINATION DEPTH : 10.5 m					RECORD ON : 24.12.2021				

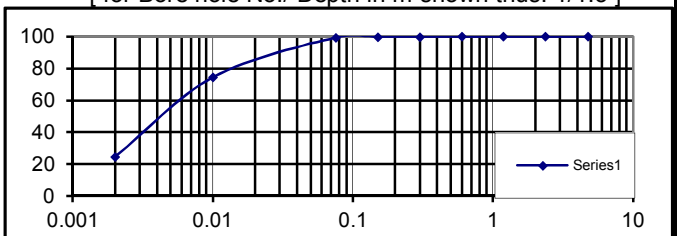
Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m)		Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C_c)
													Type of Test	Cohesion, c (kg/cm2)	Friction Angle, ϕ °	
		Obsr.		from	to											
1.0			Greyish sandy silty clay, CI	0.0		3.0										
1.5	S1	6								1.96	28.6	2.70		0.30	3.6	
2.5																
3.0	S2	7			3.0		36.0	24.3	11.7	1.97	28.0	2.70		0.35	4.1	0.151
4.0			Greyish silty clay, CI	3.0		1.5										
4.5	S3	6			4.5					1.96	28.6	2.70		0.30	3.6	0.154
5.5			Greyish sandy clayey silt, ML	4.5		3.0										
6.0	S4	4					30.7	26.0	4.7	1.94	28.9	2.66		0.05	13.5	
7.0																
7.5	S5	5			7.5					1.94	28.9	2.66		0.06	14.6	
8.5			Greyish sandy silty clay, CL	7.5		3.0										
9.0	S6	7					29.2	16.9	12.3	1.97	27.9	2.70		0.35	4.1	
10.0																
10.5	S7	9			10.5					1.99	26.6	2.70		0.44	5.0	

NAME OF WORK : Sub soil Investigation for C/O							BORING FINISH DATE : 25.12.2021						WATER TABLE : 3.50 m bgl				
Degree College in Ballia (Begusarai) Block Campus, Begusarai							BORING METHOD : Rotary										
BORE HOLE NO. : 3		Site Incharge - Mukesh Singh					TERMINATION DEPTH : 10.5 m						RECORD ON : 25.12.2021				
Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m)		Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix,%	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C_c)
													Type of Test	Cohesion, c (kg/cm2)	Friction Angle, ϕ °	
		Obsr.		from	to											
1.0			Greyish silty clay, CI	0.0		3.0										
1.5	S1	4					36.1	24.3	11.8	1.94	29.7	2.70		0.20	2.5	
2.5																
3.0	S2	6			3.0					1.96	28.6	2.70		0.30	3.6	
4.0			Greyish silty clay, CL	3.0		1.5										
4.5	S3	5			4.5		32.0	22.3	9.7	1.95	29.3	2.70		0.25	3.0	
5.5			Greyish sandy silty clay, CL	4.5		3.0										
6.0	S4	4								1.94	29.7	2.70		0.20	2.5	
7.0																
7.5	S5	6			7.5					1.96	28.6	2.70		0.30	3.6	
8.5			Greyish sandy clayey silt, ML	7.5		3.0										
9.0	S6	9								1.94	28.6	2.65		0.08	15.4	
10.0																
10.5	S7	11			10.5		29.3	26.6	2.7	1.94	28.4	2.65		0.10	15.6	

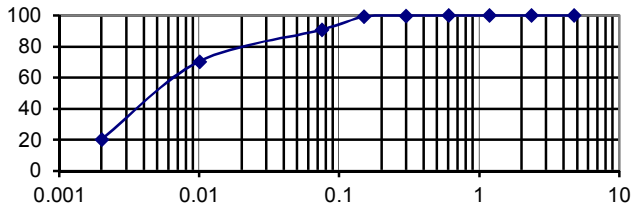
Table 2 [part **B]: Grain Size Analysis Results** [for Bore hole No./ Depth in m shown thus: 1/1.5]



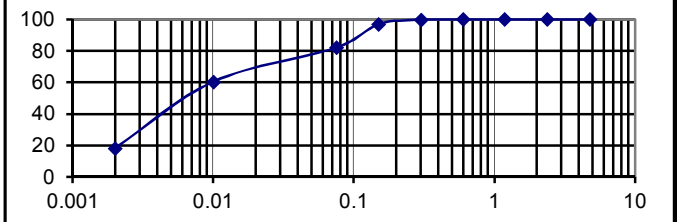
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/1.5	0.0	0.6	74.8	24.6



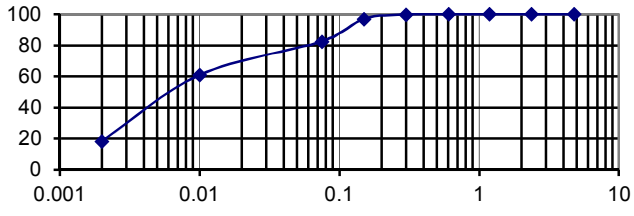
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/3.0	0.0	0.6	74.9	24.5



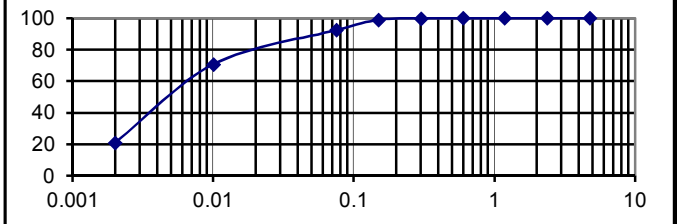
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/4.5	0.0	9.2	70.3	20.5



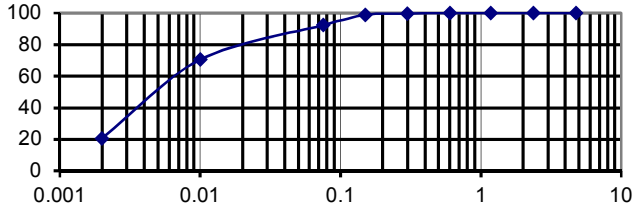
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/6.0	0.0	17.9	63.8	18.3



BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/7.5	0.0	17.4	64.1	18.5

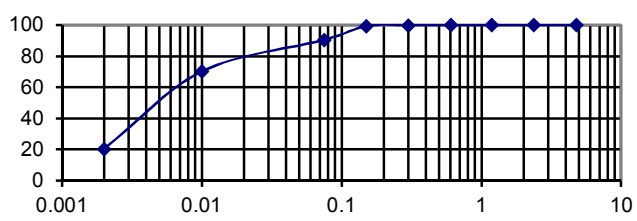


BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/9.0	0.0	7.5	71.7	20.8

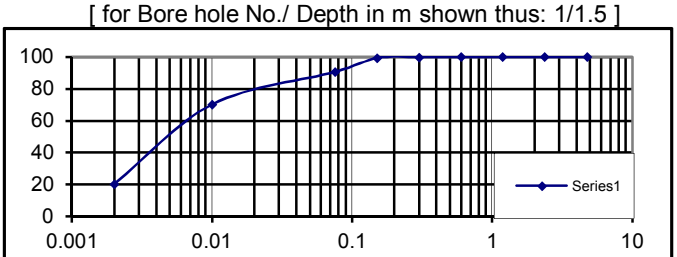


BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/10.5	0.0	7.5	71.9	20.6

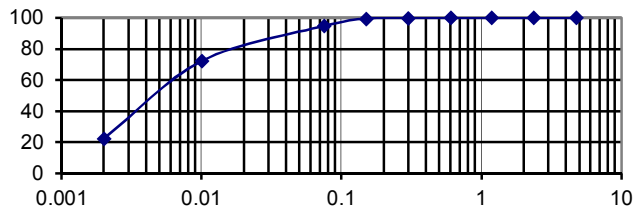
Table 2 [part **B]: Grain Size Analysis Results** [for Bore hole No./ Depth in m shown thus: 1/1.5]



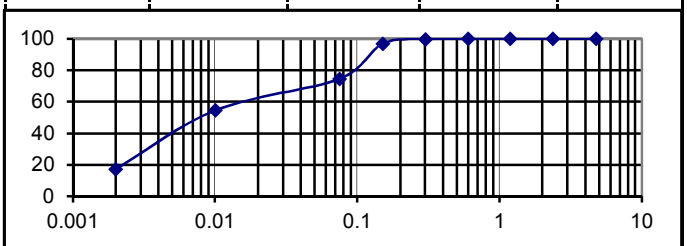
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/1.5	0.0	9.6	70.2	20.2



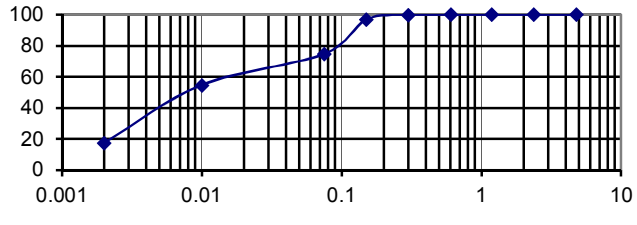
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/3.0	0.0	9.4	70.3	20.3



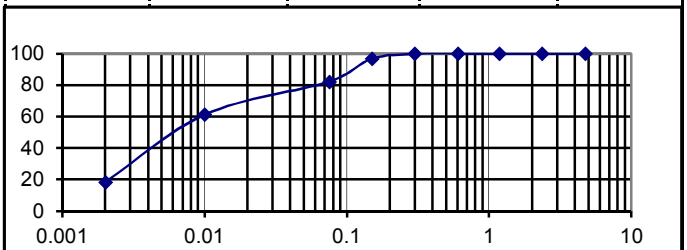
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/4.5	0.0	5.3	72.4	22.3



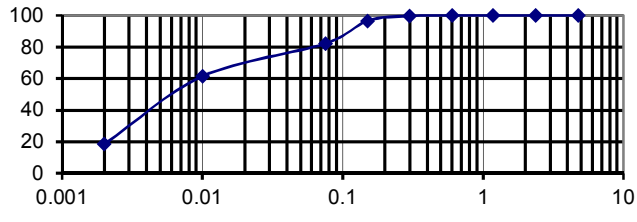
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/6.0	0.0	25.4	57.4	17.2



BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/7.5	0.0	25.4	57.1	17.5

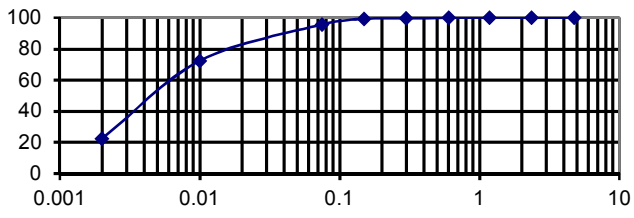


BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/9.0	0.0	17.8	63.8	18.4

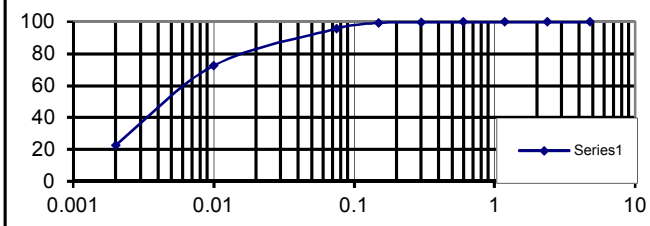


BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/10.5	0.0	17.7	63.8	18.5

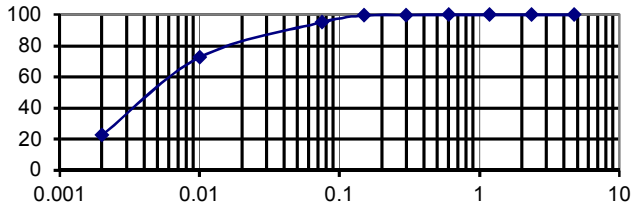
Table 2 [part **B]: Grain Size Analysis Results** [for Bore hole No./ Depth in m shown thus: 1/1.5]



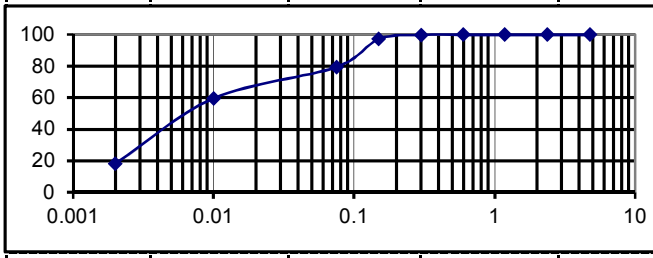
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/1.5	0.0	4.2	73.3	22.5



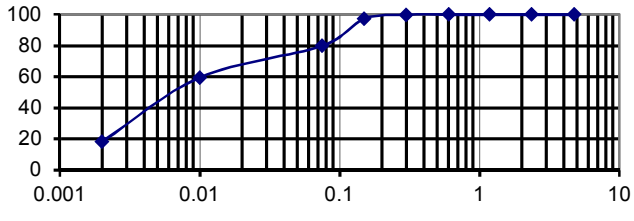
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/3.0	0.0	4.2	73.2	22.6



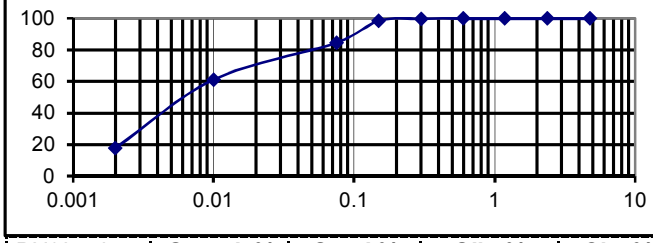
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/4.5	0.0	4.8	72.5	22.7



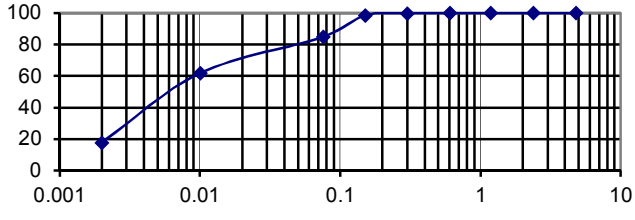
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/6.0	0.0	20.5	61.3	18.2



BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/7.5	0.0	20.1	61.6	18.3



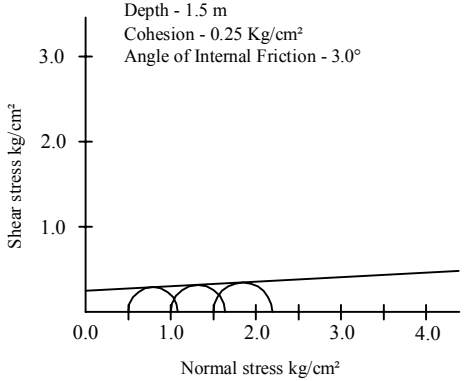
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/9.0	0.0	15.2	67.0	17.8



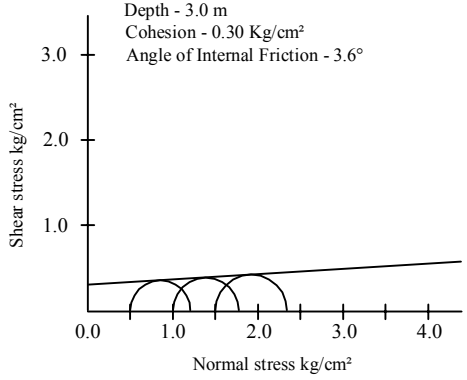
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/10.5	0.0	15.1	67.0	17.9

TRIAXIAL / DIRECT SHEAR TEST PLOTS

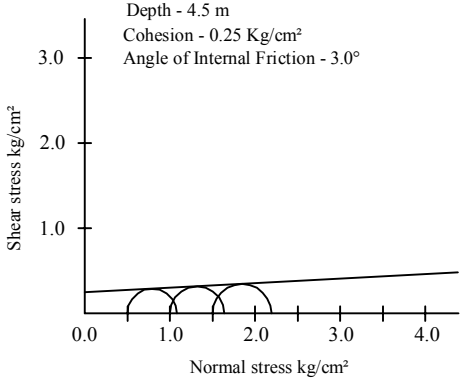
BH: - 1
Depth - 1.5 m
Cohesion - 0.25 Kg/cm²
Angle of Internal Friction - 3.0°



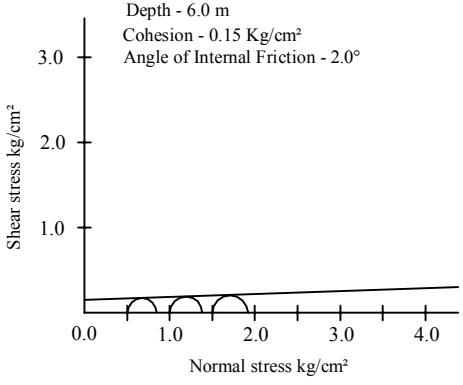
BH: - 1
Depth - 3.0 m
Cohesion - 0.30 Kg/cm²
Angle of Internal Friction - 3.6°



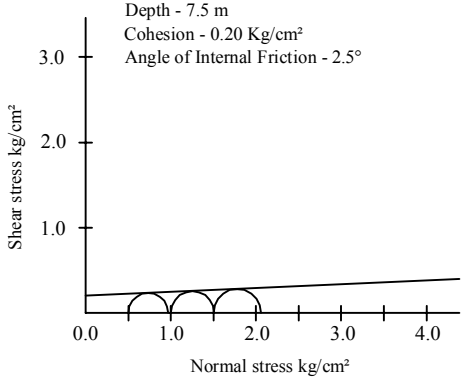
BH: - 1
Depth - 4.5 m
Cohesion - 0.25 Kg/cm²
Angle of Internal Friction - 3.0°



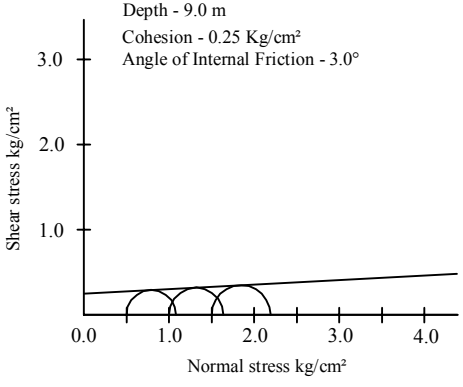
BH: - 1
Depth - 6.0 m
Cohesion - 0.15 Kg/cm²
Angle of Internal Friction - 2.0°



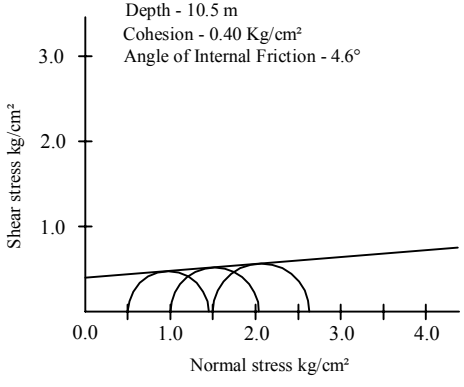
BH: - 1
Depth - 7.5 m
Cohesion - 0.20 Kg/cm²
Angle of Internal Friction - 2.5°



BH: - 1
Depth - 9.0 m
Cohesion - 0.25 Kg/cm²
Angle of Internal Friction - 3.0°



BH: - 1
Depth - 10.5 m
Cohesion - 0.40 Kg/cm²
Angle of Internal Friction - 4.6°



Appendix - D1

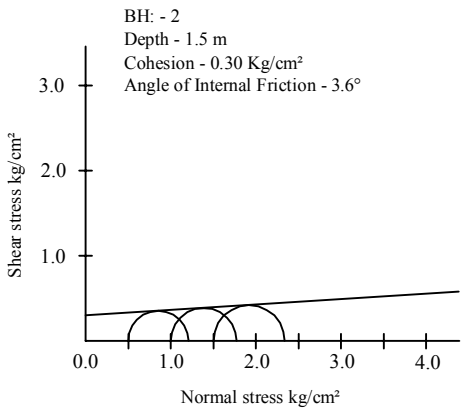
Bihar Foundation Consultants,
[A unit of Baidyanath Foundation Consultants Pvt. Ltd.]

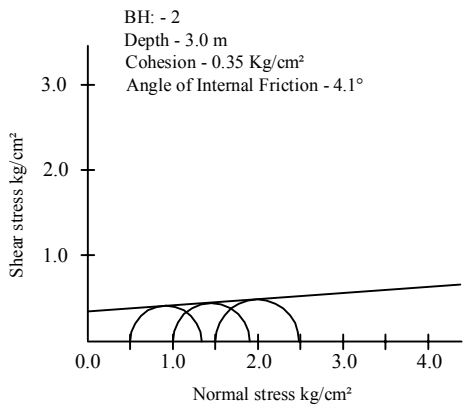
Project No. 211223

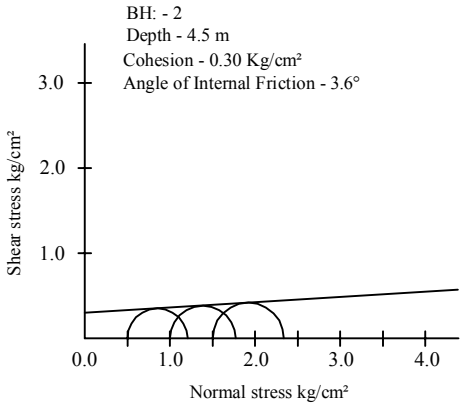
For the Proposed

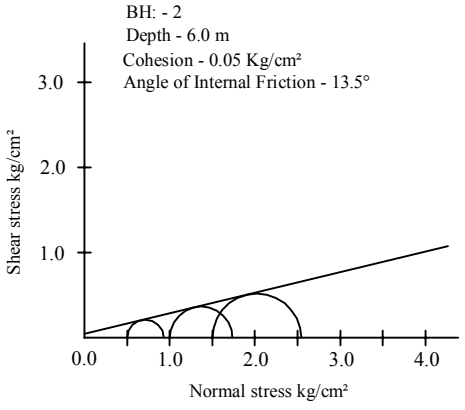
Degree College in Ballia (Begusarai) Block Campus,
Begusarai

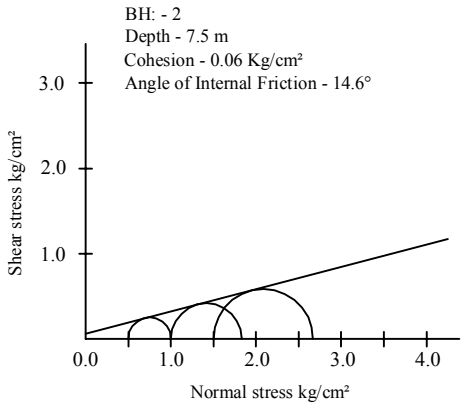
TRIAXIAL / DIRECT SHEAR TEST PLOTS

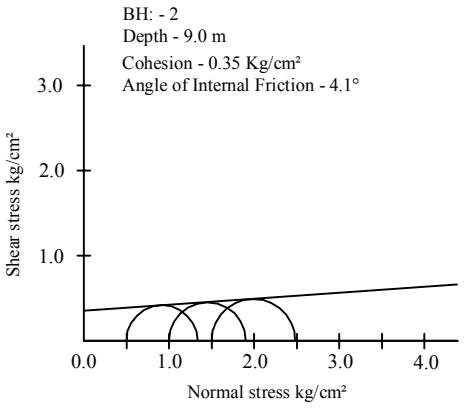


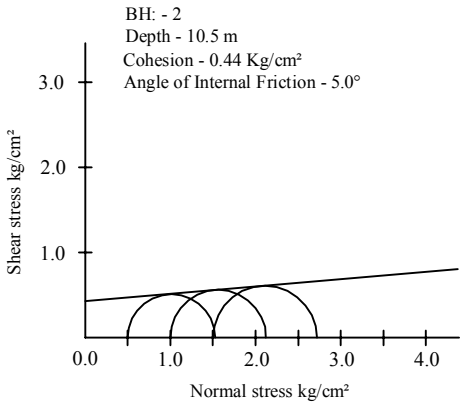












Appendix - D2

Bihar Foundation Consultants,
[A unit of Baidyanath Foundation Consultants Pvt. Ltd.]

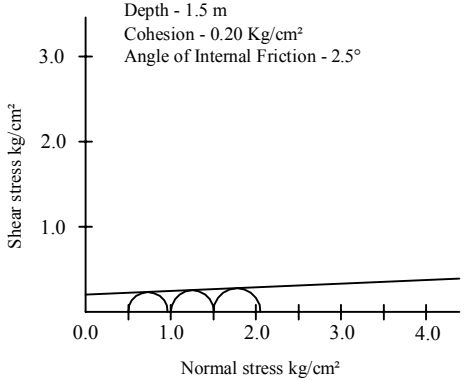
Project No. 211223

For the Proposed

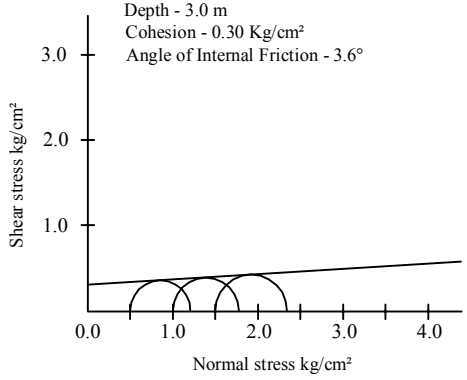
Degree College in Ballia (Begusarai) Block Campus,
Begusarai

TRIAXIAL / DIRECT SHEAR TEST PLOTS

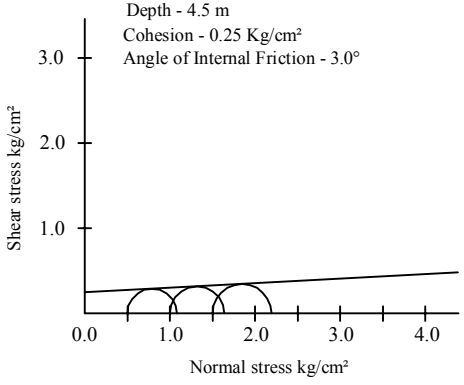
BH: - 3
Depth - 1.5 m
Cohesion - 0.20 Kg/cm²
Angle of Internal Friction - 2.5°



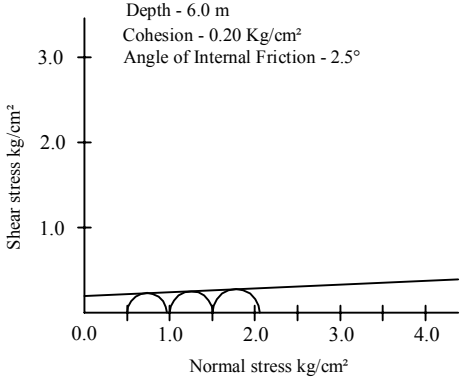
BH: - 3
Depth - 3.0 m
Cohesion - 0.30 Kg/cm²
Angle of Internal Friction - 3.6°



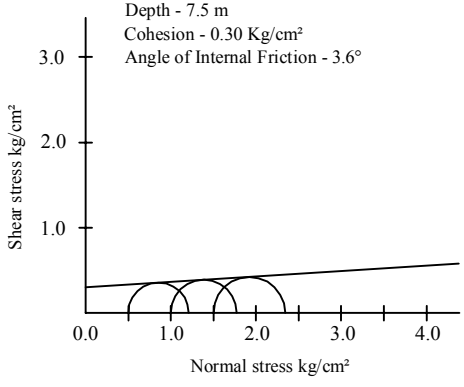
BH: - 3
Depth - 4.5 m
Cohesion - 0.25 Kg/cm²
Angle of Internal Friction - 3.0°



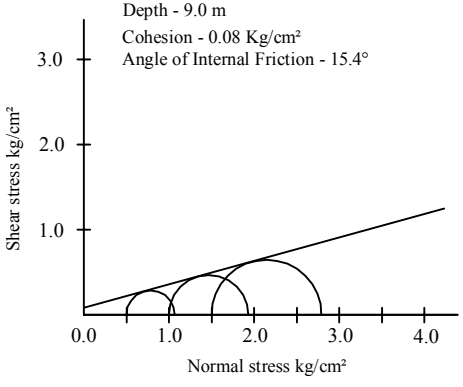
BH: - 3
Depth - 6.0 m
Cohesion - 0.20 Kg/cm²
Angle of Internal Friction - 2.5°



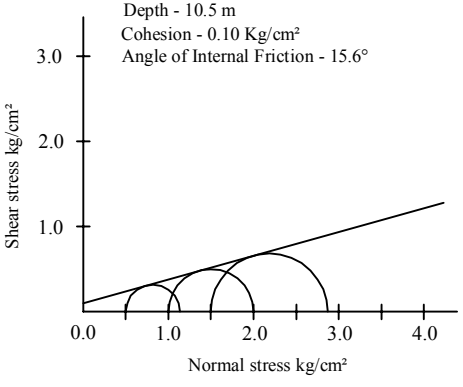
BH: - 3
Depth - 7.5 m
Cohesion - 0.30 Kg/cm²
Angle of Internal Friction - 3.6°



BH: - 3
Depth - 9.0 m
Cohesion - 0.08 Kg/cm²
Angle of Internal Friction - 15.4°



BH: - 3
Depth - 10.5 m
Cohesion - 0.10 Kg/cm²
Angle of Internal Friction - 15.6°



Appendix - D3

Bihar Foundation Consultants,
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Project No. 211223

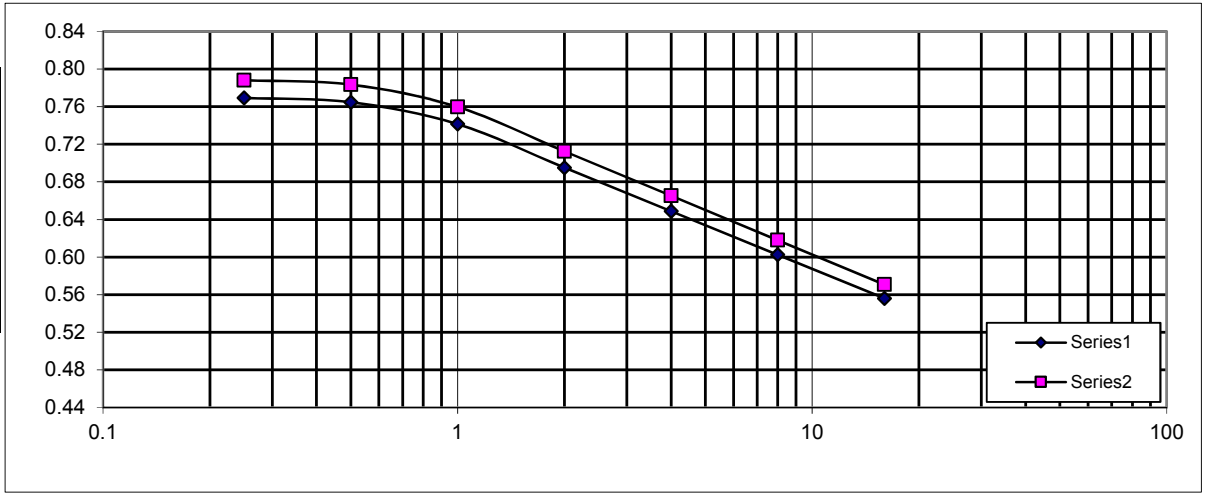
For the Proposed

Degree College in Ballia (Begusarai) Block Campus,
Begusarai

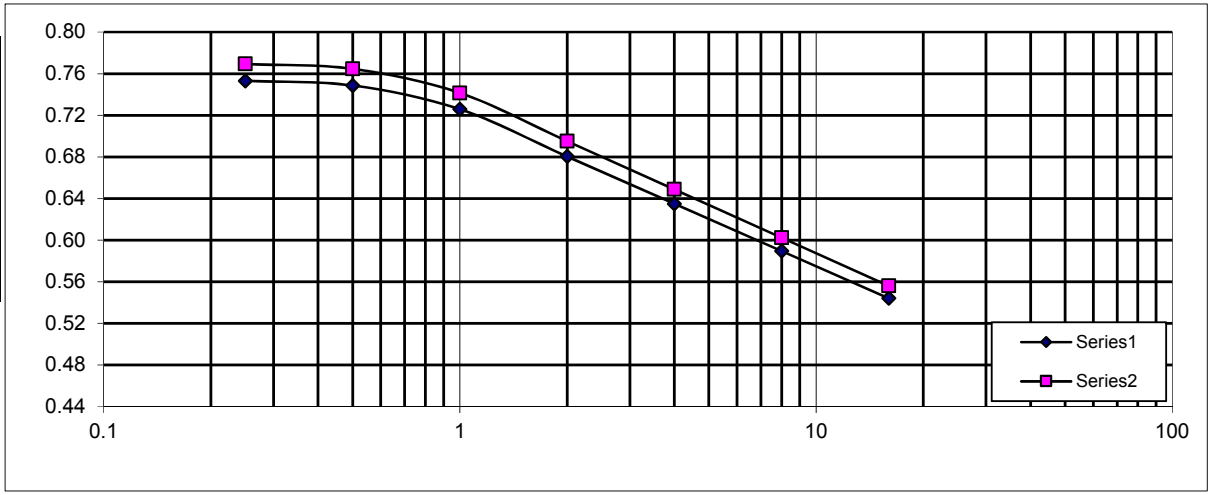
Fig. e - log p Plots from Consolidation Tests

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

BH No./		Initial V.R.	
Depth (m)	**Cc**	e_0	CURVE
1/3.0	0.154	0.7722	Series1
1/4.5	0.157	0.7911	Series2



BH No./		Initial V.R.	
Depth (m)	**C_c**	e_0	CURVE
2/3.0	0.151	0.7560	Series1
2/4.5	0.154	0.7722	Series2



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 = 1 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).

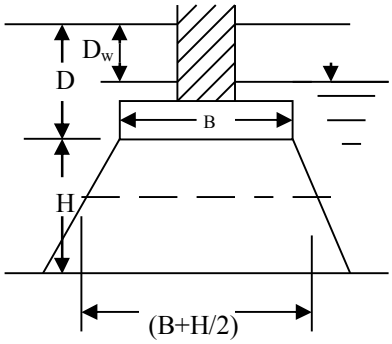
λ = correction factor

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= 1.94		c = 2.1	ϕ = 2.5	Nc = 5.76	Nq = 1.25	Nγ = 0.20
D [m]	B [m]	dc	dq = dg	c	q	I Term	II Term	III Term	qnf	qnf /F
2	2	1.21	1	2.1	1.94	14.64	0.49	0.19	15.32	5.11

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 = 0.297		Gs = 2.7		eo = 0.8019		Cc = 0.154		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	5.1	3.3	3.0	2.9	0.3	70.7	56.5	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 5.1 t/m².

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

Calculations of Capacity of Plane Pile for the proposed Degree College in Ballia (Begusarai) Block Campus, Begusarai

Based on IS:2911 (Part I, Sec. 2) 2010, Annex B, (Clauses 6.3.1.1 and 6.3.2)

using both cohesion (c), in t/m^2 and angle of internal friction (ϕ^o).

WHEN **Pile diameter, D (m)=** **0.25** Area of pile base, **Ap** (m^2) = 0.049 & circ'mf'r'nce (in m) of pile base, **j =** 3.14 x D = 0.785

Surface area of pile's contact with soil, **A (m^2)** = j x t where t = thickness of soil layer in contact with pile.

In **CLAY:** **Skin friction** in clay, **Qs** = c A ,
where Reduction factor, **α depends on c, as given in Fig. 2** of Annex. B of the above IS Code:2911

End bearing, Q_b= $A_p\ c_p\ N_c$, where N_c=9

In **SAND:** **Skin friction**, **Qs** = $KP_{mid}A \tan \delta$, where K = 1.5
and δ = . **End bearing, Qb** = $Ap(0.5\ D\gamma\ N_\gamma + P_{tip}N_q)$,
where P = overburden press.at mid-layer or pile tip , *as the case be,*
and the values of Nq and **$N\gamma$** are to be taken from the IS Code.
*Max'm permissible P[t/m^2] = 15 to 20 X pile diameter (D) X γ_{sub}
= 3.75 to 5 X γ_{sub} t/m^2.
3.525 to 4.7 t/m .

Total Ultimate capacity of pile, Qu = Qs + Qb.
Safe capacity of pile, Qsf = (Qs /f_s + Qb/f_b)

Let factor of safety in
friction, f_s = 2.5
bearing, f_b = 3.0

Depth of soil layer (m)	Soil type	γ_{sub} t/m^3	c t/m^2	α	φ	t [m]	p = γ x t t/m^2	P_{tip} =Σp t/m^2	Permissible P_{tip} t/m^2	Permissible P_{mid} t/m^2	A = j x t m^2	Qs' (for 1 layer) t	Qs = ΣQs' t	Qb t	Qu t	**Qsf** [runded off] **tonnes**	**Pile Length m**
0.0-0.5	silty clay					0.5	0.00	0.00	0.0	0.0	Not considered due to cut-off and very soft layers.						**0.5**
0.5-2.0	silty clay	0.94	2.00	1.00	2.50	1.5	1.41	1.41	1.4	0.7	1.18	2.41	2.41	1.11	3.51		**2.0**
2.0-4.0	silty clay	0.94	2.30	1.00	2.75	2.0	1.88	3.29	3.3	2.4	1.57	3.88	6.29	1.32	7.60	**3.0**	**4.0**
4.0-5.0	sandy silty clay	0.95	2.50	1.00	3.00	1.0	0.95	4.24	3.5	3.5	0.79	2.18	8.47	0.86	9.32	**3.7**	**5.0**
5.0-7.0	sandy clayey silt	0.94	0.53	1.00	13.85	2.0	1.88	6.12	3.5	3.5	1.57	2.88	11.34	0.98	12.33	**4.9**	**7.0**
7.0-9.0	sandy clayey silt	0.94	0.68	1.00	14.80	2.0	1.88	8.00	3.5	3.5	1.57	3.26	14.60	1.12	15.72	**6.2**	**9.0**
9.0-10.0	sandy clayey silt	0.94	0.88	1.00	15.50	1.0	0.94	8.94	3.5	3.5	0.79	1.84	16.44	1.18	17.62	**7.0**	**10.0**

				Qb for ϕ			**Qb** for c	
Depth,d	γ_{sub}	ϕ^o	* N_γ	* N_q	# Qb	c	# Qb
4.0	0.95	3.00	0.24	1.31	0.21	2.50	1.10
5.0	0.94	13.85	2.24	3.54	0.62	0.53	0.23
7.0	0.94	14.80	2.57	3.87	0.68	0.68	0.30
9.0	0.94	15.50	2.85	4.13	0.73	0.88	0.39
10.0	0.94	15.60	2.89	4.17	0.74	1.00	0.44

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

Degree College in Ballia (Begusarai)
Block Campus, Begusarai

बिहार राज्य शैक्षणिक आधारभूत संरचना विकास निगम लिमिटेड
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Tel. No. : 0612 - 2660850 • Fax No. : 0612 - 2660256
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प्रेषक,

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सेवा में,

बिहार फाउंडेशन कंसल्टेन्ट
गंगा दर्शन अपार्टमेंट, फ्लैट न०–403,
सदाकत आश्रम के पश्चिम,
पटना– 800010

विषयः— निर्माण स्थल के मिट्टी जाँच हेतु।

प्रसंगः— भवन निर्माण विभाग का पत्र संख्या–2030, दिनांक–21.04.2006

महाशय,

बिहार राज्य शैक्षणिक आधारभूत संरचना विकास निगम लि० के अधीन "**बलिया (बेगूसराय) अनुमंडल**" के परिसर में डिग्री महाविद्यालय के भवन निर्माण कार्य प्रस्तावित है। इस भवन के निर्माण स्थल पर मिट्टी की जाँच कराना है।

अतः अनुरोध है कि उपरोक्त स्थल का तीन बिन्दुओं पर 10.5 मीटर गहराई तक प्रत्येक 1.5 मीटर गहराई में मिट्टी का नमूना संग्रह कर प्रतिवेदन समर्पित करें। साथ ही विहित प्रपत्र में मिट्टी के भार वहन क्षमता की गणना (Isolated एवं Pile Foundation के लिए अलग–अलग) भी Hard Copy एवं Soft Copy में समर्पित करें।

इस जाँच कार्य को इस तरह संपादित करें कि ट्रान्सपोर्टेशन एवं मोबलाईजेशन खर्च कम से कम हो। कार्य स्थल पर सम्पर्क व्यक्ति, कार्य से संबंधित प्राचार्य / संबंधित कार्यपालक अभियंता रहेंगे।

विश्वासभाजन

मुख्य अभियंता

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

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