

REPORT ON  
**GEOTECHNICAL INVESTIGATIONS**

FOR THE PROPOSED BUILDING

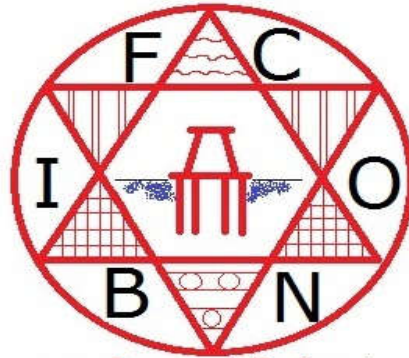
In

**U.H.S. Building at Sonhan,  
Basudevpur, Dist. Darbhanga**

Your Letter No.- BSEIDC/Tech/1933/2018-669 Patna/Dated – 29.01.2019

Submitted to  
The Chief Engineer  
BSEIDC, Patna

February, 2019



तमसो मा ज्योतिर्गमय

**BIHAR FOUNDATION CONSULTANTS**

[A unit of Baidyanath Foundation Consultants Pvt. Ltd.]  
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**Patna – 10**

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## U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga



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

**PN - 190205**

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Report on Sub Soil Investigation for the proposed  
U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga

**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** of this Report.

**2. FIELD WORK**

The fieldwork consisted of sinking a bore hole, conducting the necessary field tests in it and collecting soil samples from it for conducting laboratory tests on them.

**2.1. Boring**

Taking guidance from IS: 1892, one bore hole of 150 mm diameter was sunk at the location 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 from the bore hole 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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**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) Chemical tests on soil/ground water
- (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 silty clay / sandy silty clay [type CI / CL] in variable thicknesses and variable sequences up to the investigated depth of 10.5 m bgl. It is also gritty as some locations and depths.

*Ground water table was struck at about 2.90 m to 3.10 m depth below GL in February, 2019. 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.

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**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 silty clay / sandy silty clay [type CI / CL] in variable thicknesses and variable sequences up to the investigated depth of 10.5 m bgl. It is also gritty as some locations and depths.

*Ground water table was struck at about 2.90 m to 3.10 m depth below GL in February, 2019. It is subject to seasonal variations.*

1. The proposed structure may be provided with shallow foundation at a depth of 1.5 m or more.
2. As the formation below top soil in BH 1 and BH 3 has sand content, hence placement of bored cast in situ pile or u/r pile may not be desirable as this formation may collapse during such pile placement. Driven piles may be uneconomical.

The values of net allowable bearing pressures of foundations of certain sizes have been calculated [vide sample of Calculation in Appendix - F] and are tabulated below.

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

Depth (m) below GL	Width (m)	Net allowable bearing pressure (t/m <sup>2</sup> )			Maximum expected settlement (mm)
		Strip footing	Square footing	Raft foundation	
1.5	2.0	7.2	8.8	....	75
	3.0	5.1	8.4	....	75
	10.0	...	...	7.1	100
2.0	2.0	8.5	10.3	....	75
	3.0	5.9	9.7	....	75
	10.0	...	...	7.6	100
2.5	2.0	9.9	12.0	...	75
	3.0	6.6	11.2	...	75
	10.0	...	...	8.1	100
3.0	2.0	11.1	13.9	...	75
	3.0	7.3	12.8	...	75
	10.0	...	...	8.5	100
3.5	2.0	12.3	16.4	...	75
	3.0	8.0	14.0	...	75
	10.0	...	...	8.8	100
4.0	2.0	13.6	18.4	...	75
	3.0	8.7	15.3	...	75
	10.0	...	...	9.3	100

**Note:**

If a soil condition much different from those reported herein is met with during foundation trenching, suitable steps should be taken.

For Bihar Foundation Consultants,

(Dr. K.S.P. Singh, FIE, MIGS)

Senior Consultant.

PN: 190205

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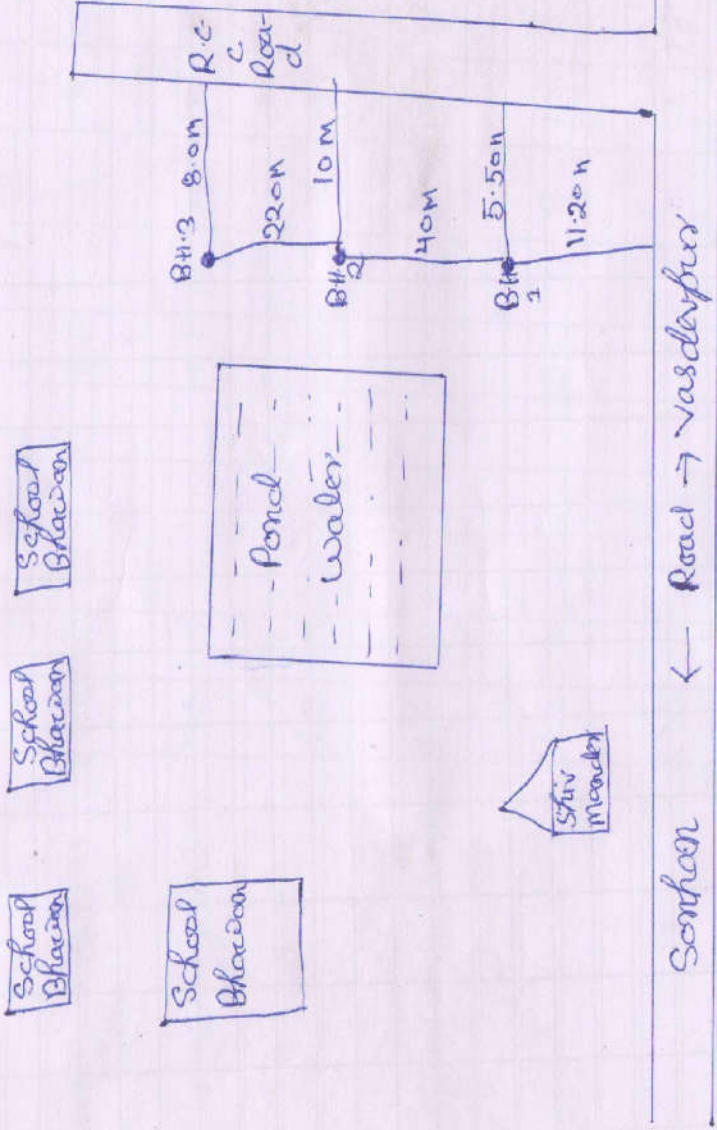
3

**U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga**

P.No- 190205

U.H.S Sonhan Vasdevpur Darbhanga  
Agricultural land

N  
↑



Rajmanki Mandali

Penchayat Bhawan

Durga Mandali

*Signature*

H.M. Sonhan,  
U.H.S. Sonhan,  
Basudevpur,  
Dist. Darbhanga

*Signature*  
SUNIL KUMAR SINHA  
LE.BSEDC Lucknow

*Signature*  
7-12-11g  
Assistant Engineer  
BSEIDC Ltd.  
Darbhanga Division

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

NAME OF WORK : Sub soil Investigation for C/O								BORING FINISH DATE : 06.02.19		WATER TABLE : 2.90 m bgl									
U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga								BORING METHOD : Rotary											
BORE HOLE NO. : 1		Site Incharge - N.K. Tiwari						TERMINATION DEPTH : 10.5 m		RECORD ON : 06.02.19									
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 Indx, %	Bulk Density (gm/cm <sup>3</sup> )	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C <sub>c</sub> )			
		Obsr.		from	to								Type of Test	Cohesion, c (kg/cm <sup>2</sup> )	Friction Angle, φ°				
1.0			Greyish silty clay, CL	0.0		3.0													
1.5	S1	7						33.4	21.1	12.3	1.97	27.0	2.69		0.34	4.0			
2.5																			
3.0	S2	8			3.0					1.98	27.2	2.69		0.39	4.4				
4.0			Greyish sandy silty clay, CL with grits	3.0		1.5													
4.5	S3	11			4.5			34.0	23.5	10.5	2.01	25.6	2.70		0.51	5.1	0.139		
5.5			Greyish yellowish sandy silty clay, CI	4.5		3.0													
6.0	S4	18									2.02	24.7	2.70		0.69	5.2			
7.0																			
7.5	S5	15			7.5		41.9	13.1	28.8	2.01	25.3	2.69		0.63	5.1				
8.5			Greyish yellowish sandy silty clay, CI with grits	7.5		3.0													
9.0	S6	22									2.03	24.1	2.69		0.77	5.2			
10.0																			
10.5	S7	25					10.5												

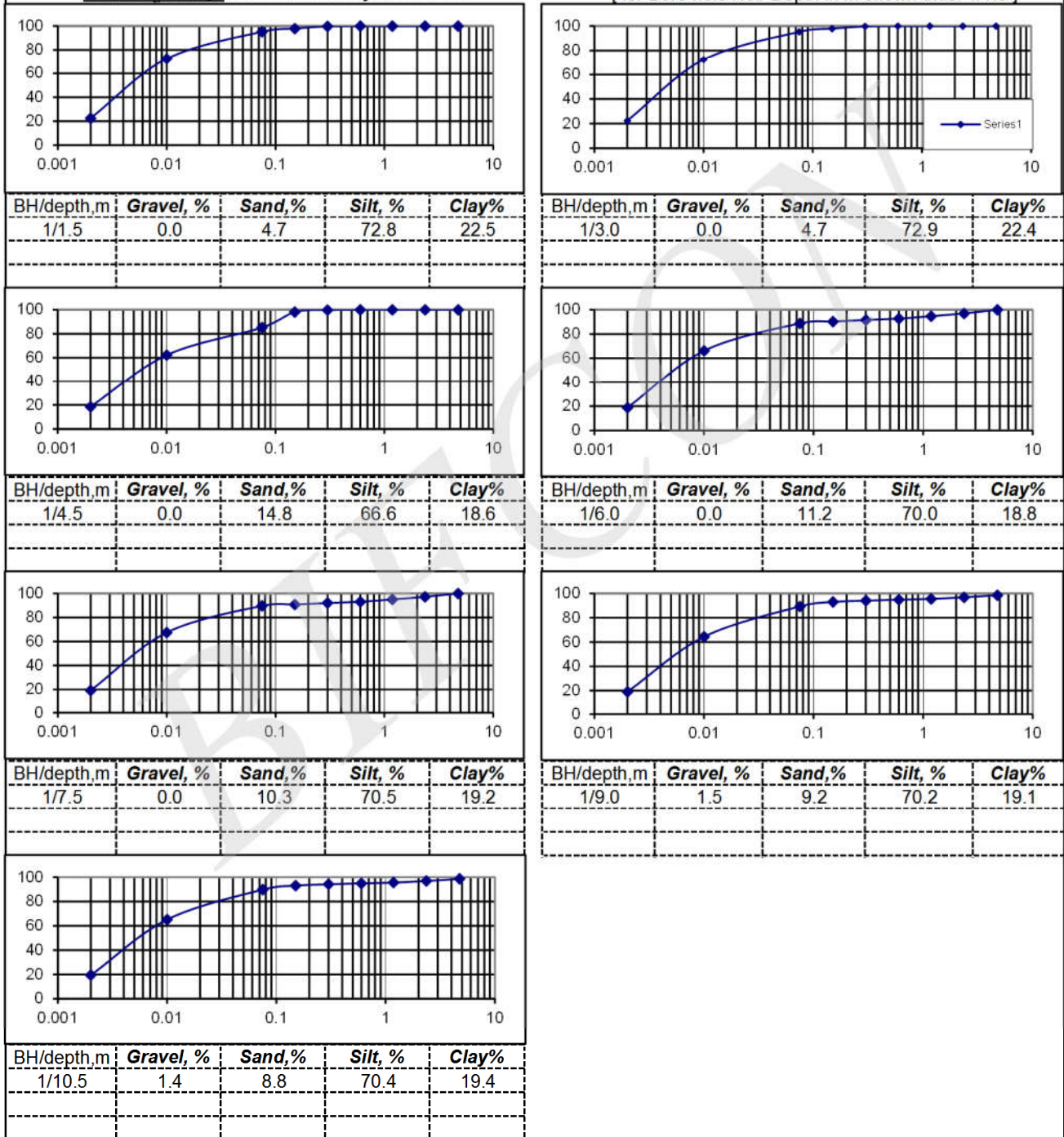


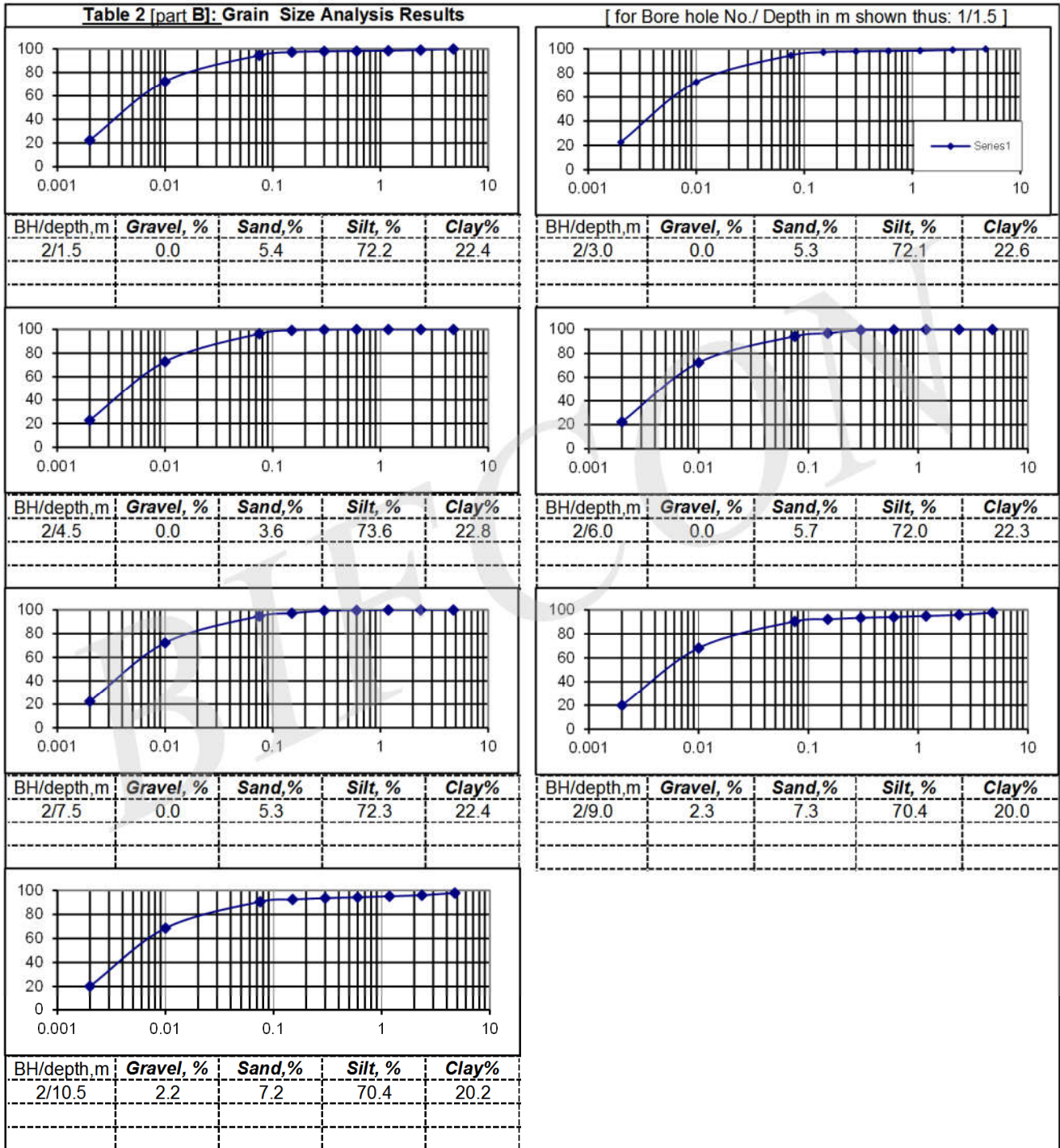
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U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga								BORING METHOD : Rotary									
BORE HOLE NO. : 2		Site Incharge - N.K. Tiwari						TERMINATION DEPTH : 10.5 m		RECORD ON : 06.02.19							
Depth Below GL (m)	Sample No.	SPT 'N' Value observation	Visual Description of Soil with IS Classification	Depth(m)		Thickness (m)	Liquid Limit	Plastic Limit	Plasticity Indix, %	Bulk Density (gm/cm <sup>3</sup> )	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C <sub>c</sub> )	
		Obsr.		from	to								Type of Test	Cohesion, c (kg/cm <sup>2</sup> )	Friction Angle, φ°		
1.0			Greyish silty clay, CI	0.0		3.0				1.98	27.2	2.69		0.39	4.4		
1.5	S1	8															
2.5																	
3.0	S2	10			3.0			37.0	23.1	13.9	2.00	25.8	2.69		0.48	5.0	
4.0			Greyish silty clay, CI with grits	3.0		1.5											
4.5	S3	13			4.5						2.01	25.4	2.70		0.59	5.1	0.136
5.5			Greyish yellowish silty clay, CI	4.5		3.0											
6.0	S4	16						37.5	22.3	15.2	2.02	24.7	2.70		0.65	5.1	
7.0																	
7.5	S5	14			7.5						2.02	25.4	2.70		0.61	5.1	
8.5			Greyish yellowish silty clay, CI with grits	7.5		3.0											
9.0	S6	24						43.4	26.8	16.6							
10.0																	
10.5	S7	28			10.5												

NAME OF WORK : Sub soil Investigation for C/O								BORING FINISH DATE : 07.02.19		WATER TABLE : 2.90 m bgl									
U.H.S. Building at Sonhan, Basudevapur, Dist. Darbhanga								BORING METHOD : Rotary											
BORE HOLE NO. : 3		Site Incharge - N.K. Tiwari						TERMINATION DEPTH : 10.5 m		RECORD ON : 07.02.19									
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 Indx, %	Bulk Density (gm/cm <sup>3</sup> )	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C <sub>c</sub> )			
		Obsr.		from	to								Type of Test	Cohesion, c (kg/cm <sup>2</sup> )	Friction Angle, φ°				
1.0			Greyish silty clay, CI	0.0		3.0													
1.5	S1	6						36.5	22.4	14.1	1.96	28.4	2.69		0.30	3.6			
2.5																			
3.0	S2	8			3.0						1.98	27.2	2.69		0.39	4.4			
4.0			Greyish yellowish sandy silty clay, CI	3.0		1.5													
4.5	S3	11			4.5			35.8	22.1	13.7	2.01	25.6	2.70		0.51	5.1			
5.5			Greyish yellowish silty clay, CI	4.5		3.0													
6.0	S4	14									2.01	25.4	2.70		0.61	5.1			
7.0																			
7.5	S5	18			7.5						2.02	24.7	2.70		0.69	5.2			
8.5			Greyish yellowish silty clay, CI with grits	7.5		3.0													
9.0	S6	23																	
10.0																			
10.5	S7	30			10.5			38.9	23.3	15.6									

**Table 2 [part B]: Grain Size Analysis Results**

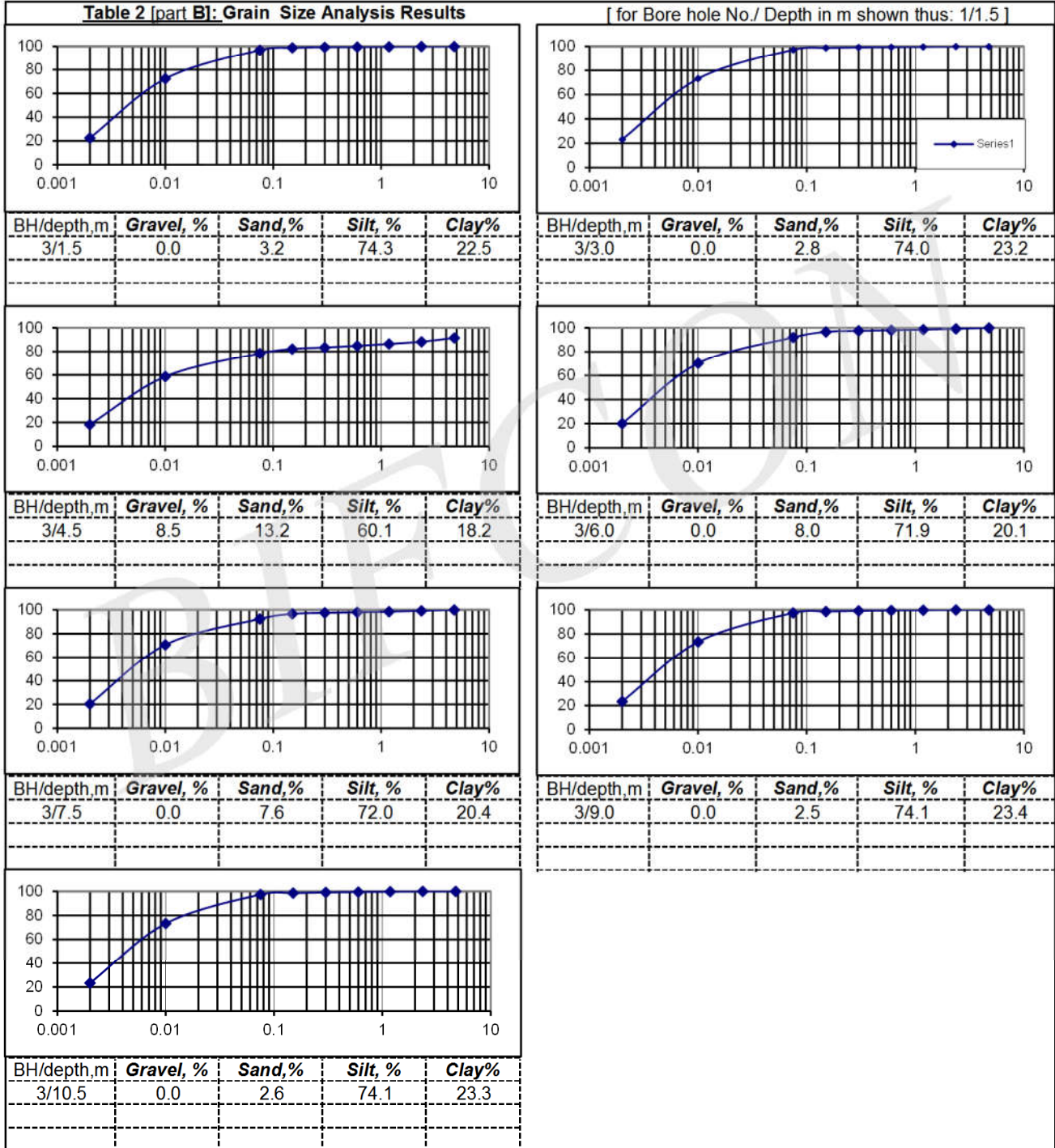
[ for Bore hole No./ Depth in m shown thus: 1/1.5 ]



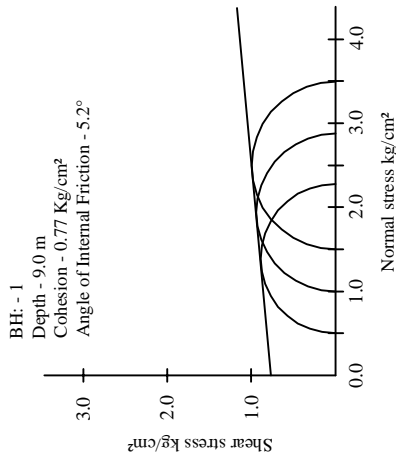
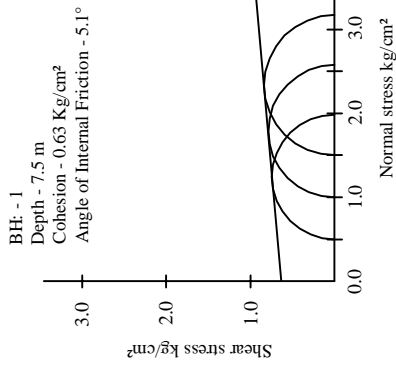
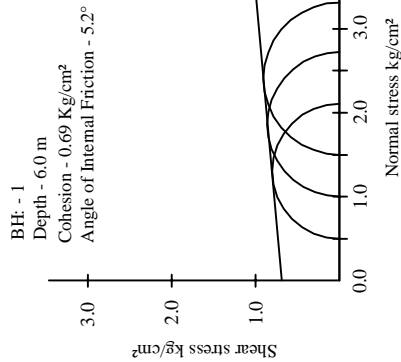
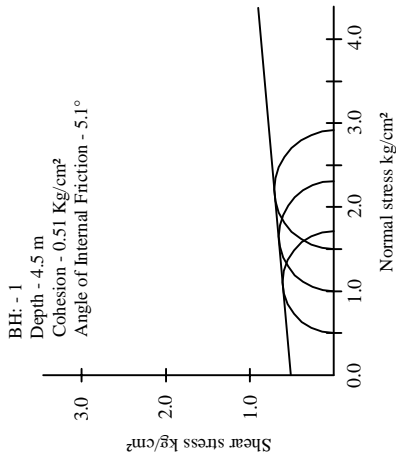
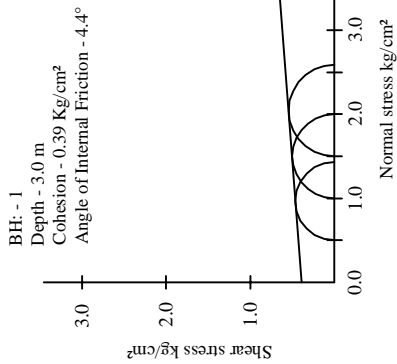
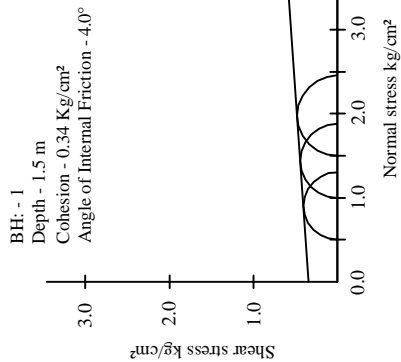


**Table 2 [part B]: Grain Size Analysis Results**

[ for Bore hole No./ Depth in m shown thus: 1/1.5 ]



# TRIAXIAL / DIRECT SHEAR TEST PLOTS



For the Proposed

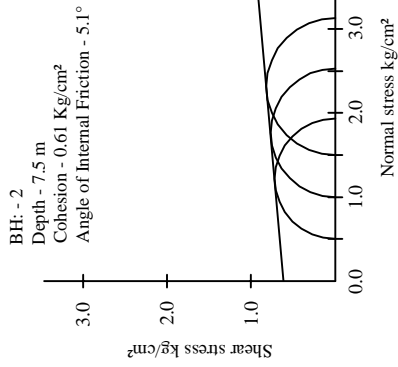
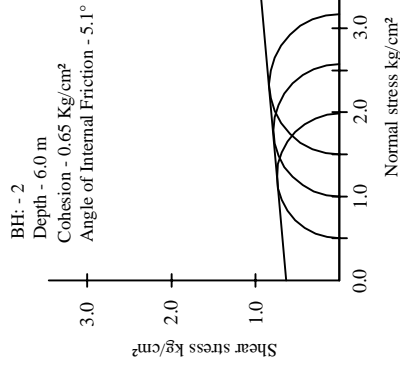
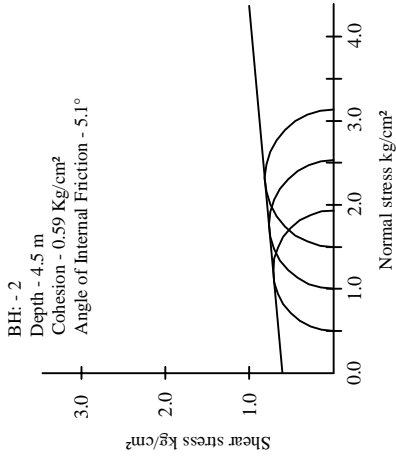
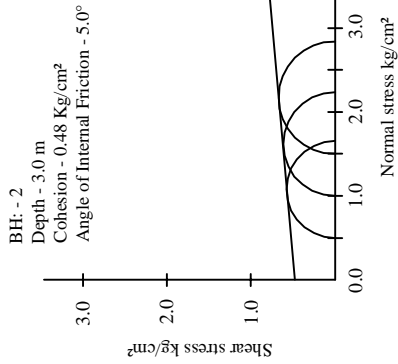
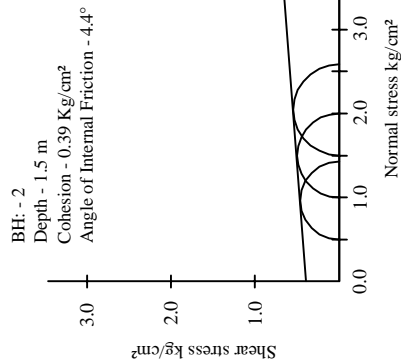
Appendix - D1

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**U.H.S. Building at Sonhan,  
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**Project No. 190205**

# TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D2

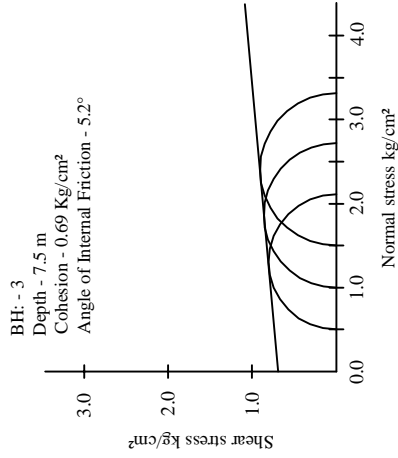
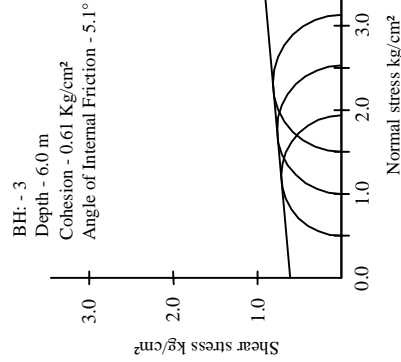
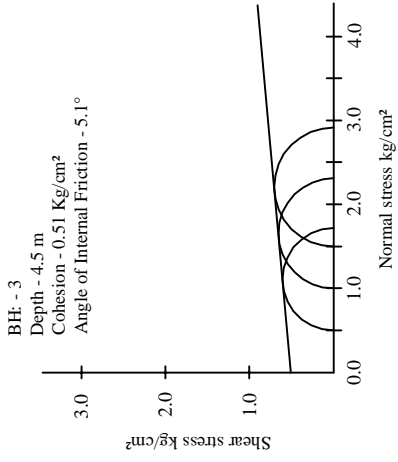
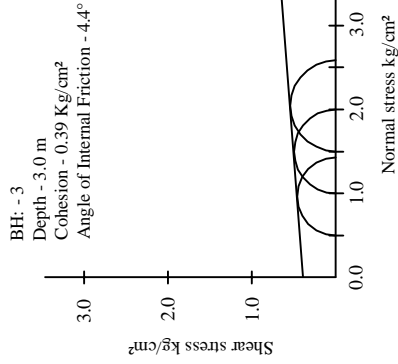
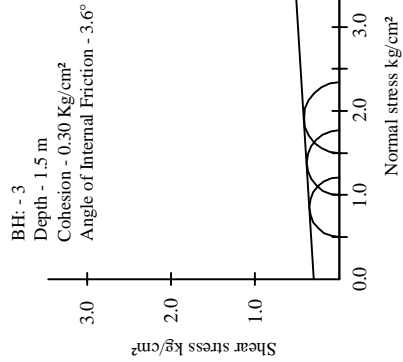
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**Project No. 190205**

**U.H.S. Building at Sonhan,  
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# TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D3

For the Proposed

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**U.H.S. Building at Sonhan,  
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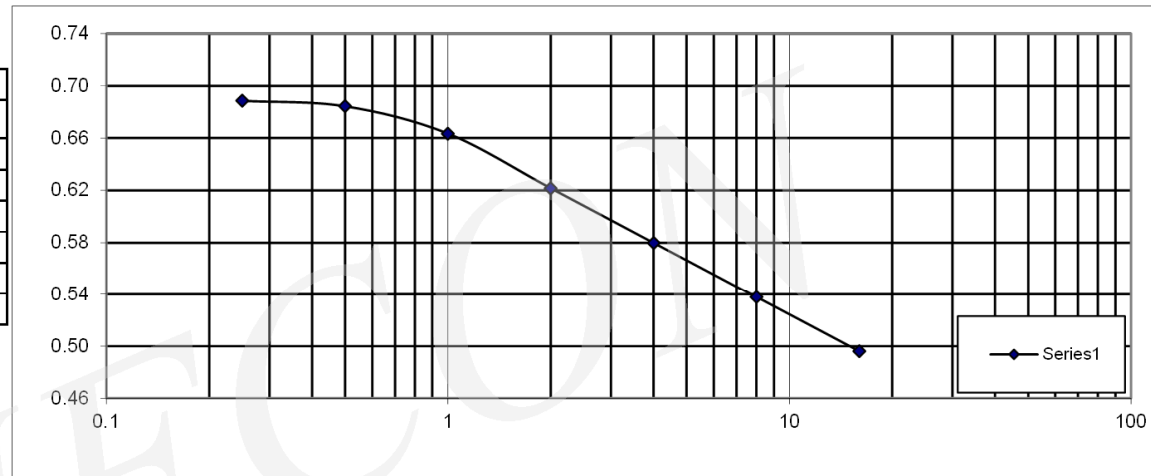


**Fig. e - log p Plots from Consolidation Tests**

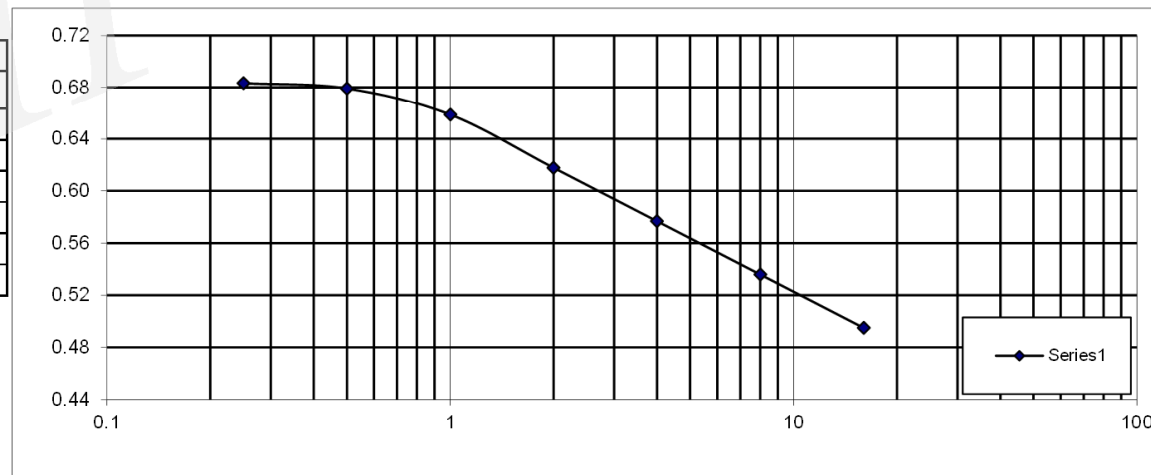
**X-axis :** Pressure,  $p$  ( $\text{kg/cm}^2$ ) on log scale.

**Y-axis :** Void ratio,  $e$

BH No./	Initial V.R.		
Depth (m)	$C_c$	$e_0$	CURVE
1/4.5	0.139	0.6912	Series1



BH No./	Initial V.R.		
Depth (m)	$C_c$	$e_0$	CURVE
2/4.5	0.136	0.6858	Series1



Report on Sub Soil Investigations for the Proposed  
U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga  
**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 ( $t/m^2$ )

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

$q$  = effective surcharge ( $t/m^2$ ) =  $\gamma D$

$N_c, N_\gamma, N_q$  = bearing capacity factors, which are functions of  $\phi$ , the angle of internal friction of the soil.

$s_c, s_q, s_\gamma$  = shape factors

$d_c, d_q, d_\gamma$  = depth factors

$I_c, I_q, I_\gamma$  = inclination factors

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

} related to cohesion, surcharge and density of subsoil respectively

The bearing capacity factors ( $N$ 's) are functions of  $\phi$ , 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 ( $\phi'$ ) 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	$d_c =$	$1 + 0.2 (N_\phi)^{0.5} D/B$	$D_w$ at	G.L.	Fou'dn.Level
$s_q =$	1.2	1+0.2B/L	1	$d_q = d_\gamma =$	1	for	0.5	1
$s_\gamma =$	0.8/0.6	1-0.4B/L	1	$d_q = d_\gamma =$	$1 + 0.1 (N_\phi)^{0.5} D/B$	$\phi > 10^\circ$	Interpolation between	
FOR	sq// O	Rect.	STRIP	$I_c, I_q, I_\gamma = 1$ for vertical load			these values is linear.	

In the present case, the representative values of cohesion  $c$  and angle of internal friction ( $\phi$ ) 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 =  $its\ m/c (m) \times sp.$  Gravity

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

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

$\lambda$  = correction factor

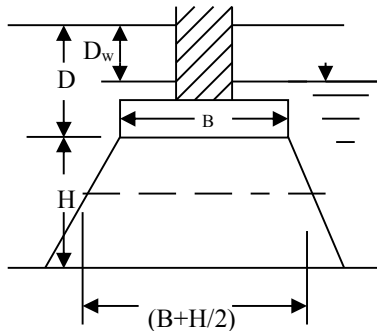
## Report on Sub Soil Investigations for the Proposed U.H.S. Building at Sonhan, Basudevpur, Dist. Darbhanga

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 desired value of  $q_{na}$ . One example of this settlement analysis is given below the **Table B** in Sec. 3.

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



$D_w$  = depth of water table below ground level.  
 $D$  = depth of foundation  
 $B$  = breadth of foundation  
 $H = 1.5 \times B$  = 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:			F.S. = $\gamma, \text{ t/m}^3 =$		$c =$	$\phi =$	$N_c =$	$N_q =$	$N_\gamma =$	
STRIP			3		3	3.6	6.07	1.38	0.30	
$D$ [m]	$B$ [m]	$d_c$	$d_q = d_g$	$c$	$q$	I Term	II Term	III Term	$q_{nf}$	$q_{nf}/F$
1.5	2	1.16	1.08	3	1.47	21.12	0.61	0.32	22.04	7.35

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**

$m = 0.284$		$G_s = 2.69$		$e_o = 0.764$		$C_c = 0.142$		$D_w = 0$	
Depth	Width	$q_{nf}/F$	$p_o$	$H$	$\Delta p$	$\log(1 + \Delta p/p_o)$	$s$ [mm]	$\lambda s$ mm	Remarks
$D$ [m]	$B$ [m]	$\text{t/m}^2$	$\text{t/m}^2$	m	$\text{t/m}^2$		mm	mm	
1.5	2.0	7.3	2.9	3.0	4.2	0.4	94.3	75.4	Not OK
1.5	2.0	7.2	2.9	3.0	4.1	0.4	93.1	74.5	OK

Hence the net allowable bearing pressure for a strip footing of width 2.0 m and depth = 1.5 m below ground level will be = 7.2  $\text{t/m}^2$ .

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



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प्रेषक : मुख्य अभियंता

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सेवा में,

बिहार फाउंडेशन कंसलटेंट

फ्लैट नं. - 403, सदाकत आश्रम के पश्चिम

पटना - 800 010

बिषय : निर्माण स्थल के मिट्टी जाँच कर प्रतिवेदन समर्पित करने के सम्बन्ध में ।

प्रसंग : भवन निर्माण विभाग का पत्रांक - 2030, दिनांक - 21.04.2006

महाशय,

बिहार राज्य शैक्षणिक आधारभूत संरचना विकास निगम लिमिटेड के अधीन दरभंगा जिला के प्रखंड - दरभंगा सदर, पंचायत - वासुदेवपुर स्थित उत्कर्मित उच्च विद्यालय, सोनहान में भवन निर्माण कार्य प्रस्तावित है । उक्त वर्णित विद्यालय में भवन निर्माण स्थल पर मिट्टी का जाँच कराया जाना है ।

अतः अनुरोध है कि संलग्न सूची में दर्शाये गये स्थल पर प्रति स्थल तीन विन्दुओं पर 10.5 मीटर गहराई तक प्रत्येक 1.5 मीटर गहराई में मिट्टी का नमूना संग्रह कर प्रासंगिक पत्रांक - 2030, दिनांक - 21.04.2006 के आलोक में प्रतिवेदन समर्पित करें । साथ ही संलग्न विहित प्रपत्र में मिट्टी के भार वहन क्षमता की गणना (Isolated, Strip एवं Pile Foundation के लिये अलग - अलग) भी समर्पित करें ।

इस जाँच कार्य को इस तरह सम्पादित करें कि Transportation एवं Mobilization खर्च कम से कम हो । इस स्थल पर संपर्क हेतु सम्बंधित विद्यालय के प्रधानाध्यापक / कार्यपालक अभियंता (मोबाइल नं. - 98014 94702) उपस्थित रहेंगे ।

विश्वासभाजन

प्र.स. 28/01/19  
मुख्य अभियंता

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