PN – 141116

REPORT ON

GEOTECHNICAL INVESTIGATIONS

FOR THE PROPOSED

CONSTRUCTION OF

U.S.S.

AT

M.S. ARAIYA

MANSHI, KHAGARIA

Letter No. BSEIDC/FIN/639/201-5812 PATNA, Dated 21.10.14

Submitted to

Mr. Brajesh Prasad

Chief Engineer

BSEIDC, Patna

January, 2015

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Appendix

[Containing Figures and Tables]

Report on Sub Soil Investigations for the Proposed Construction of
U.S.S. AT M.S. ARAIYA, MANSHI (KHAGARIA)

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 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 **[Appendix-A].**

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 field and laboratory tests conducted on the collected soil samples indicate that the soil stratification at the site is as describe below.

The subsoil is clayey silt of type MI/ML up to the investigated depth of 10.5 m below GL.

Water table was struck at about 4.5 m to 7.0 m bgl in November, 2014.

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. In the present case, shallow foundations may be provided.

7. RECOMMENDATIONS

Construction of bored cast in situ plane or u/r pile may not be practicable since the subsoil is silt. Hence they are not recommended in the present case.

Therefore, the proposed structure may be provided with shallow foundations [rectangular or square].

The net allowable bearing pressure of a footing of any size and depth may be calculated by standard methods using the relevant BIS Code and soil properties reported herein.

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)	Width (m)	Net allowable bearing pressure (t/m^2) for		Maximum expected settlement (mm)
		Rectangular footing *	Square footing	
1.5	1.0	8.1	8.7	50
	1.5	7.6	8.1	50
	2.0	7.5	7.9	50
2.0	1.0	9.4	10.1	50
	1.5	8.7	9.3	50
	2.0	8.4	8.9	50

*** Length of rectangular footing = 2 x width.**

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

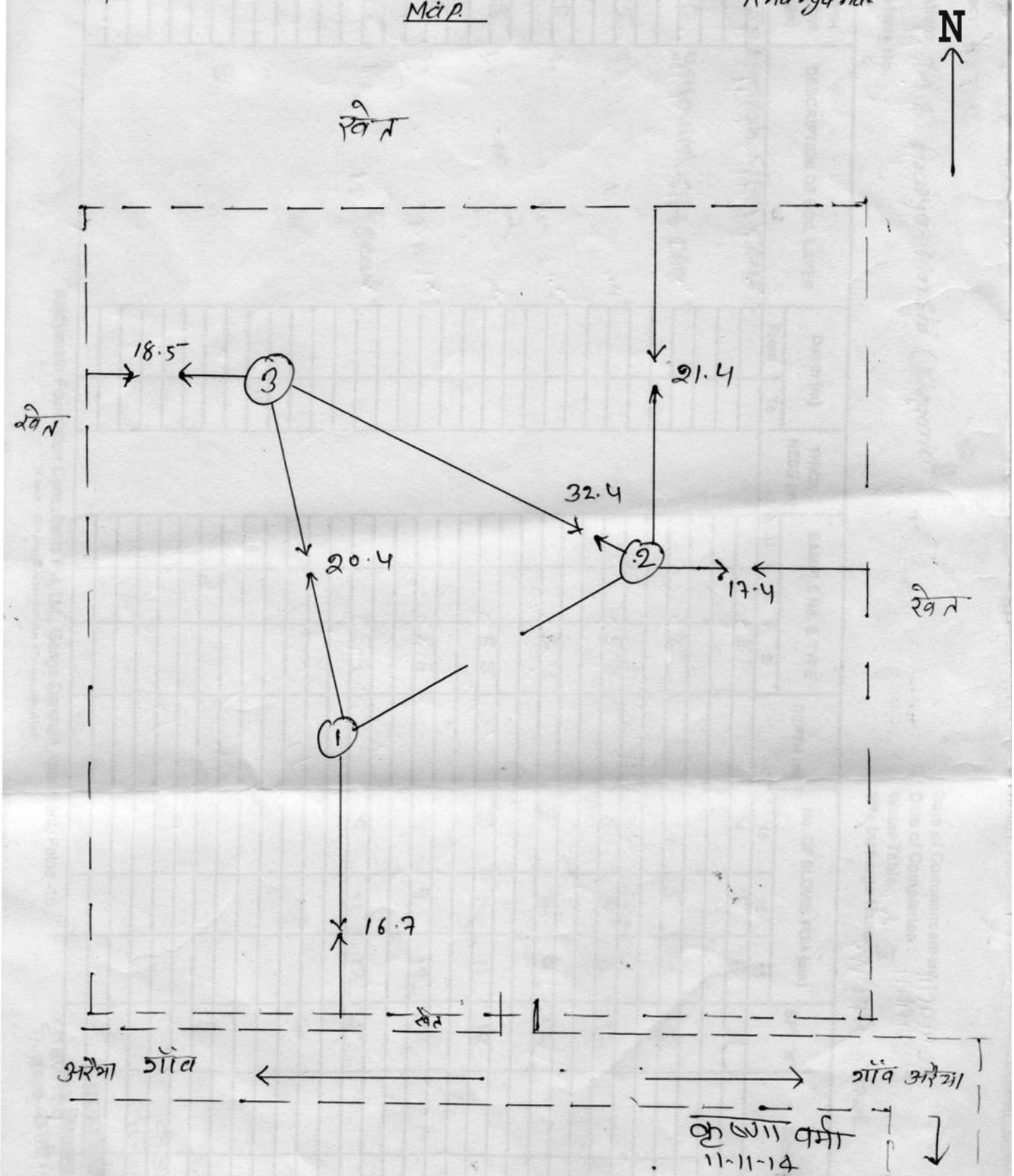
For Bihar Foundation Consultants,

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

Pathe
11.11.14

Bore location Map

M.S Araiya- Manshi
Khargaria.



कृष्णा वर्मा
11-11-14

Site Incharge : Vikash Kumar

P.No.- 141116 Bihar Foundation Consultants Appendix- A
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प्रधानाध्यापक
मध्य विद्यालय अरैया
मंझौल-मानसी (खगड़िया)

NAME OF WORK : Sub soil Investigation for C/O
U.S.S. at M.S. Araiya, Manshi (Khagaria)
BORE HOLE NO. : 1

BORING FINISH DATE : 10.11.14
BORING METHOD : Rotary
TERMINATION DEPTH 10.5 m

WATER TABLE : 4.5 m bgl
RECORD ON : 11.11.14

Depth Below GL (m)	Sample No.	SPT 'N' Value observation (Obsr.)	Visual Description of Soil with IS Classification	Depth(m) from	Depth(m) to	Thickness (m)	Liquid Limit	Plastic Limit	Bulk Density (gm/cc)	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				0.0											
1.5	S1	11	Greyish clayey silt. MI			2.5	39.4	26.3	1.95	28.5	2.68	DS	0.12	15.7	
2.5					2.5										
3.0	S2	13		2.5					1.96	28.1	2.68				
4.0															
4.5	S3	14					36.9	25.8				DS	0.16	14.8	
5.5															
6.0	S4	16							1.97	27.7	2.69				
7.0			Yellowish grey clayey silt. MI			8.0									
7.5	S5	18										DS	0.22	13.4	
8.5															
9.0	S6	21					37.4	25.7							
10.0															
10.5	S7	23			10.5				1.98	26.5	2.68	DS	0.26	12.5	

NAME OF WORK : Sub soil Investigation for C/O
U.S.S. at M.S. Araiya, Manshi (Khagaria)
BORE HOLE NO. : 2

BORING FINISH DATE : 11.11.14
BORING METHOD : Rotary
TERMINATION DEPTH 10.5 m

WATER TABLE : 6.7 m bgl
RECORD ON : 12.11.14

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	Bulk Density (gm/cc)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C_c)
		Obsr.		from	to							Type of Test	Cohesion, c (kg/cm^2)	Friction Angle, ϕ°	
1.0				0.0											
1.5	S1	10					31.6	24.5	1.94	28.5	2.65	DS	0.10	15.3	
2.5															
3.0	S2	11					34.9	24.1				DS	0.13	14.9	
4.0															
4.5	S3	13							1.96	28.0	2.68				
5.5															
			Greyish clayey silt. ML			10.5									
6.0	S4	14										DS	0.16	13.3	
7.0															
7.5	S5	19					34.6	24.3	1.97	27.3	2.68				
8.5															
9.0	S6	21							1.98	26.8	2.69	DS	0.24	12.8	
10.0															
10.5	S7	26			10.5				1.99	26.4	2.69				

NAME OF WORK : Sub soil Investigation for C/O
U.S.S. at M.S. Araiya, Manshi (Khagaria)
BORE HOLE NO. : 3

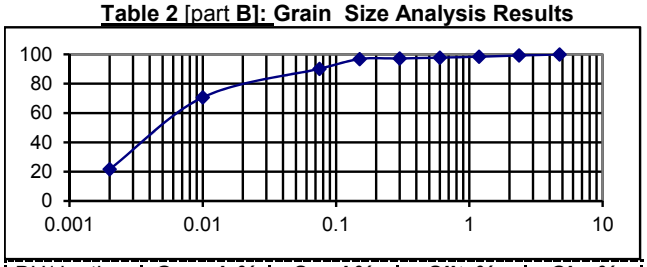
BORING FINISH DATE : 11.11.14
BORING METHOD : Rotary
TERMINATION DEPTH 10.5 m

WATER TABLE : 7.0 m bgl
RECORD ON : 12.11.14

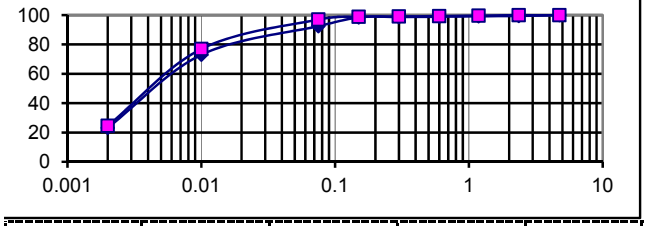
Depth Below GL (m)	Sample No.	SPT 'N' Value observation (Obsr.)	Visual Description of Soil with IS Classification	Depth(m) from	Depth(m) to	Thickness (m)	Liquid Limit	Plastic Limit	Bulk Density (gm/cc)	Natural Moisture Content (%)	Specific Gravity	Shear Test: Type of Test	Shear Test: Cohesion, c (kg/cm^2)	Shear Test: Friction Angle, ϕ°	Compression Index (C_c)
1.0				0.0											
1.5	S1	13	Greyish clayey silt. ML			2.5	32.9	27.6	1.96	28.0	2.68	DS	0.15	14.2	
2.5					2.5										
3.0	S2	14		2.5			35.6	24.6	1.96	27.8	2.67				
4.0															
4.5	S3	18							1.97	27.4	2.68	DS	0.21	13.6	
5.5															
6.0	S4	19					37.4	25.5							
7.0			Greyish clayey silt. MI			8.0									
7.5	S5	21							1.98	26.7	2.68	DS	0.24	12.8	
8.5															
9.0	S6	25													
10.0															
10.5	S7	28			10.5				1.99	26.4	2.69	DS	0.33	11.6	

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

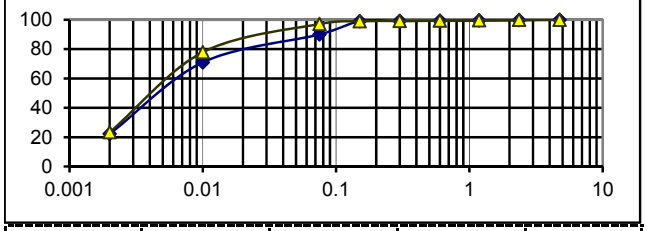
[for Bore hole No./ Depth in m shown thus: 1/1.5]



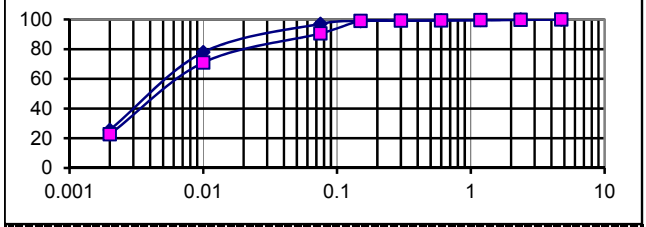
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/1.5	0.0	9.8	68.5	21.7
1/3.0	Almost same as 1/1.5			
1/4.5	Almost same as 1/1.5			



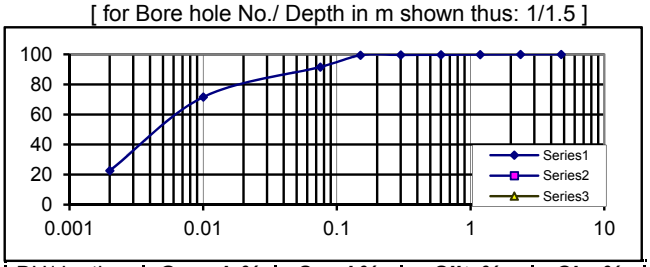
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/10.5	0.0	7.5	69.3	23.2
2/1.5	0.0	3.0	72.4	24.6
2/3.0	Almost same as 2/1.5			



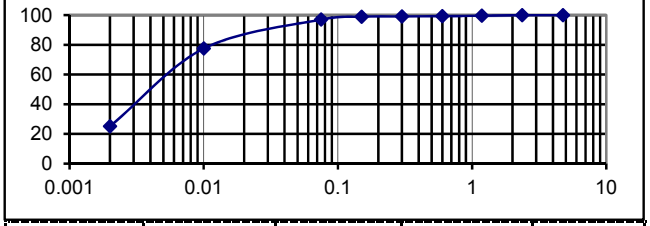
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/9.0	0.0	10.0	67.7	22.3
2/10.5	Almost same as 2/9.0			
3/1.5	0.0	2.9	73.8	23.4



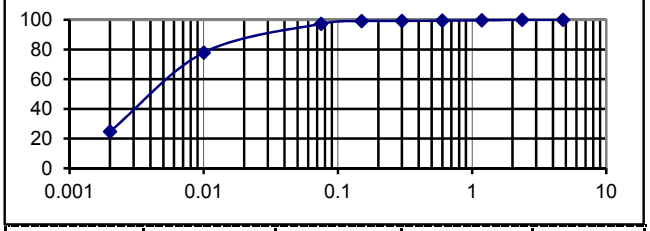
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/7.5	0.0	3.0	71.4	25.6
3/9.0	0.0	9.4	67.9	22.6
3/10.5	Almost same as 3/9.0			



BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
1/6.0	0.0	8.4	69.0	22.6
1/7.5	Almost same as 1/6.0			
1/9.0	Almost same as 1/6.0			

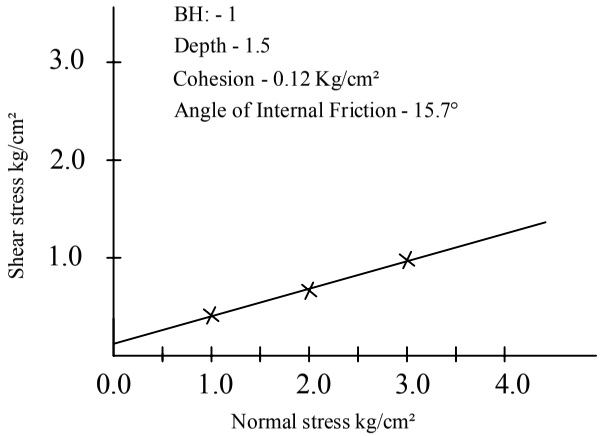


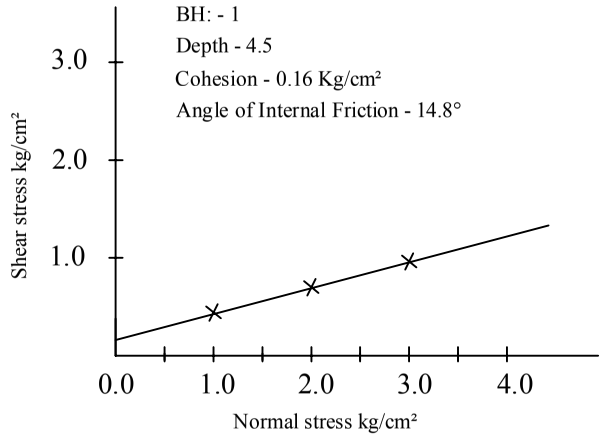
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
2/4.5	0.0	3.0	71.9	25.1
2/6.0	Almost same as 2/4.5			
2/7.5	Almost same as 2/4.5			

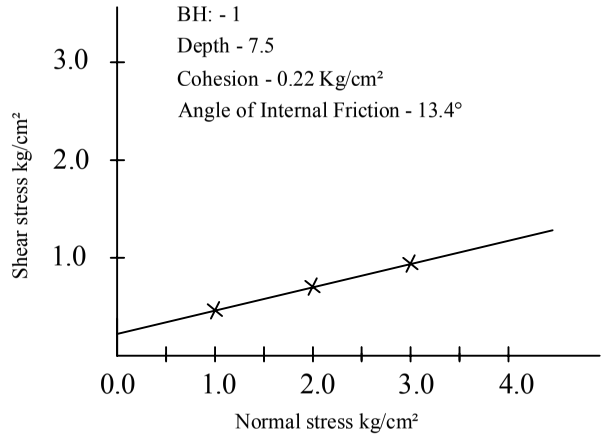


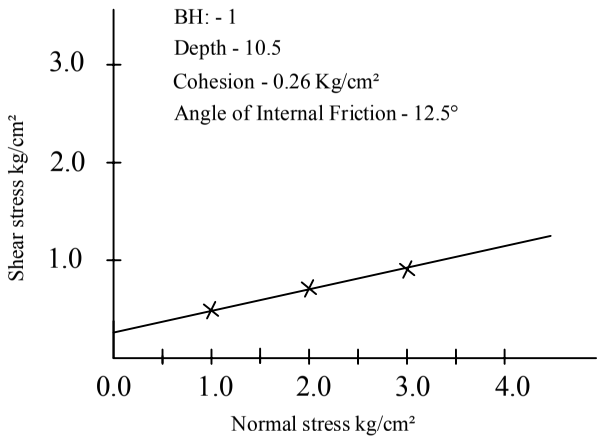
BH/depth,m	*Gravel, %*	*Sand,%*	*Silt, %*	*Clay%*
3/3.0	0.0	2.7	72.6	24.7
3/4.5	Almost same as 3/3.0			
3/6.0	Almost same as 3/3.0			

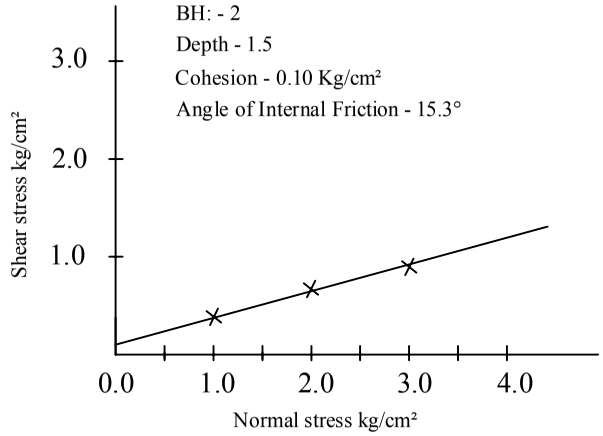
TRIAXIAL / DIRECT SHEAR TEST PLOTS

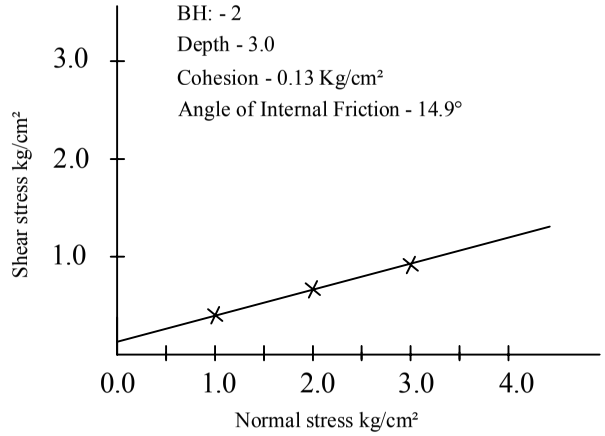












Appendix - D1

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Proposed Construction of

U.S.S.
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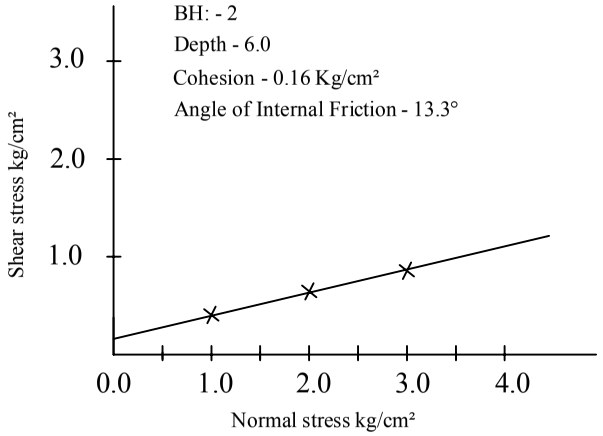
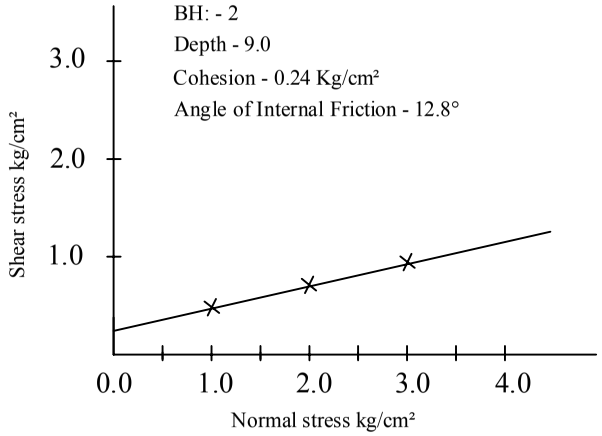
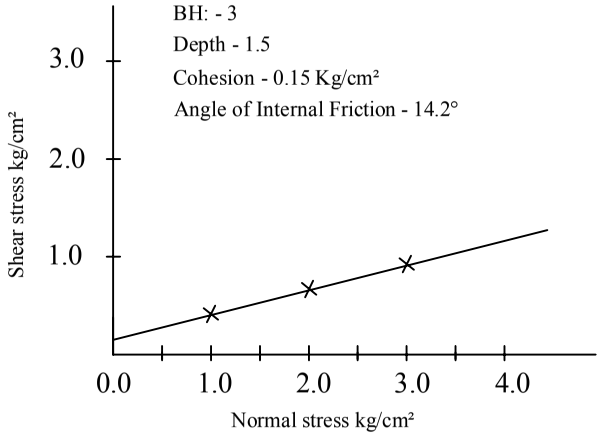
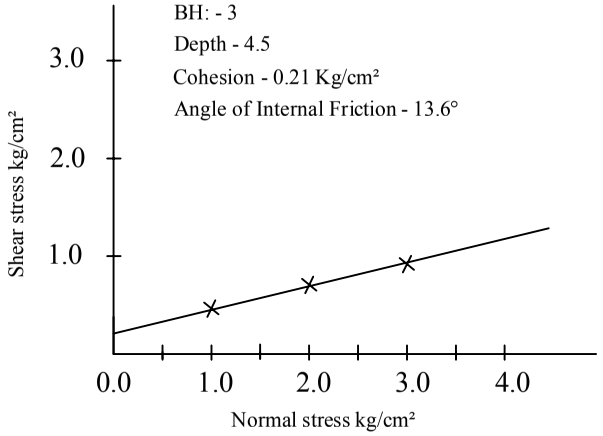
M.S. ARAIYA
MANSHI, KHAGARIA

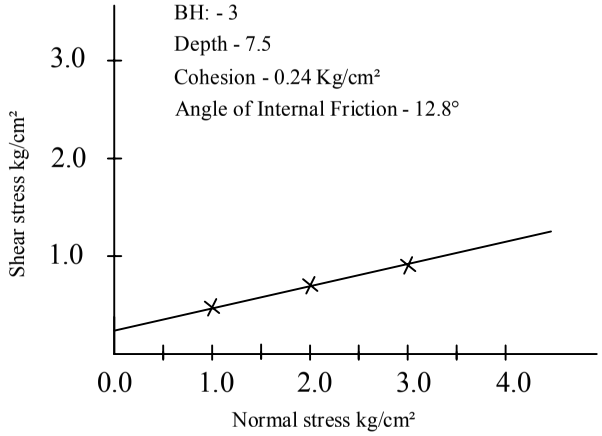
TRIAXIAL / DIRECT SHEAR TEST PLOTS

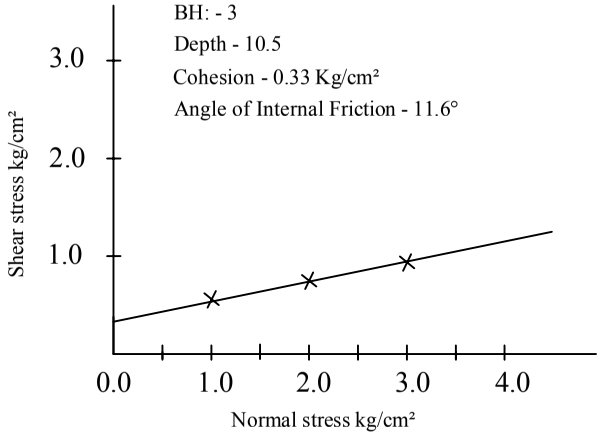












Appendix - D2

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Project No. 141116

Proposed Construction of

U.S.S.
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M.S. ARAIYA
MANSHI, KHAGARIA

Report on Sub Soil Investigations for the Proposed Construction of

U.S.S. AT M.S. ARAIYA, MANSHI (KHAGARIA)

SAMPLE CALCULATION OF BEARING CAPACITY OF SHALLOW FOUNDATION

The determination of the **net safe bearing capacity**, q_{ns}, is done first 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. <u>Shear Failure Criterion</u>.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)

q = effective surcharge (t/m^2)

γ = unit weight of subsoil (t/m^3)

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. Their values 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 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)of the soil are in general difficult to ascertain. **But if foundation depth is taken as 2 m to 3 m, the minimum values that may safely be adopted are : c = 2 t/m^2 and ϕ = 12.5 degrees.**

One example of calculation for a certain depth and width of a rectangular or square footing is given in the **Table A** on the next page. 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**. The net safe bearing capacity for a footing of the selected size and depth of footing is to be seen in its last column. Calculations of safe bearing capacities for other depths and widths of footings are done similarly.

2 Calculation of allowable bearing capacity based on settlement criterion

The **net soil pressure,** q_s (t/m^2) for a permissible settlement of 25 mm is give by Teng's formula:

$$q_s = 3.5\,[N'' - 3]\left[\,(B + 0.3)/\,2\,B\,\right]^2 \quad w'\ F_d \quad t/m^2$$

where N'' = corrected value of N from SPT

F_d = $[1 + D/B] <$ or = 2 and

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D, B and w' are as defined before.

For a permissible settlement of **S** mm, the allowable bearing capacity

$$q'_s = S\, q_s /25$$

The corrected SPT N" values used in the calculations based on the above formula for different depths below G.L. may be found from the recorded data.

The N" value used in any case is to be for the influence zone below the footing, which depends on its width. A sample of calculation of the allowable soil pressure for the chosen size and depth of footing and for the permissible settlement is given in **Table B** in the next section. Here N" = 15 has been adopted.

The net allowable bearing pressure will be the lower of the values of bearing pressures found in the two Tables A and B.

Table A

Calculation of Net Safe Bearing Pressure [based on **shear failure** criterion]

Shape of Foundation: Square			F.S.= 3	γ, t/m³= 1.94		c =	ϕ =	Nc =	Nq =	Nγ =
						1	15.3	11.17	4.06	2.77
D [m]	B [m]	dc	dq = dg	c	q	I Term	II Term	III Term	qnf	qnf /F
1.5	1	1.39	1.196	1	1.455	18.66	6.38	0.96	26.01	8.67

Table B

Calculation of Net Allowable Bearing Pressure [based on **settlement** criterion]

D	B	Fd =	N"	w'	$q_{s=25}$	S	$q_{s=s}$
m	m				t/m²	mm	t/m²
1.5	1.0	2	10	0.5	10.351	50	20.703

The adjoining Table and the comments below it are for a footing of depth, **D =** **1.5** m, and width, **B [m] =** **1.0**

The value of allowable bearing pressure from the above Table for s = 50 mm is = 20.7 t/m²

The value of safe bearing capacity from shear criterion as found from Table A = 8.7 t/m²

Hence the allowable bearing pressure for settlement, s= or < 50 mm will be = **8.7** **t/m²**

The calculations for other depths and widths of footing are similar.

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