

REPORT ON
GEOTECHNICAL INVESTIGATIONS

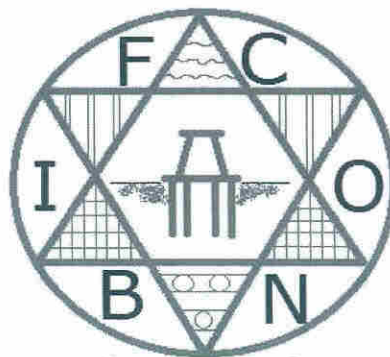
FOR THE PROPOSED
General Condition of Soil
at
Murarpur, Muzaffarpur
(Plot No. 5P, 7P and 10P)

[In response to a telephonic call on 25.01.2022 from Sri Devashish ji]

Submitted to

Mr. Devashish
Patna

February, 2022



तमसो मा ज्योतिर्गमय

BAIDYANATH FOUNDATION CONSULTANTS PVT. LTD.

[Unit : Bihar Foundation Consultants]

Having an

NABL Accredited / ISO 9001: 2015 Certified Laboratory

Ganga Darshan Apartment, Flat No. 403.

Patna - 10

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Deputy General Manager
Biada, Motipur Cluster

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General Condition of Soil at Murarpur, Muzaffarpur



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

PN -220108

Deputy General Manager
Biada, Motipur Cluster

Deputy General Manager
Biada, Motipur Cluster

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Report on Sub Soil Investigations for the Proposed
General Condition of Soil at Murarpur, Muzaffarpur

1. INTRODUCTION

The subsoil investigations reported herein were taken up [in response to a telephonic call on 25.01.2022 from Sri Devashish Ji] 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 **pages 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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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) Heavy compaction test followed by
- (h) Soaked CBR test on soil samples taken from 0.5 m depth in each bore hole.

4. PRESENTATION OF TEST RESULTS

The field and laboratory tests (a) to (f) are given in the **Appendix B** while those for tests (g) Compaction Tests and (h) soaked CBR Tests are in **Appendices G, and H** respectively and in table 3

5. SOIL STRATIFICATION

The results of field tests in two bore hole 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 sub soil in both BH's is silty clay / sandy silty clay [types CL/CI] up to the depth of about 13.5 m in BH 1 and 3.0 m in BH 2 then follows clayey sandy silt / sandy clayey silt [type ML/MI] up to the investigated depth of 25.5 m bgl. But in both BH's it is clayey silty sand [type SC-SM] from about 16.5 m to 19.5 m in BH 1 and 15.0 m to 18.0 m bgl in BH 2. It is also gritty at both locations and various depths

Ground water table was struck at about 1.10 m to 1.15 m depth below GL in January, 2022 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 sub soil in both BH's is silty clay / sandy silty clay [types CL/CI] up to the depth of about 13.5 m in BH 1 and 3.0 m in BH 2 then follows clayey sandy silt / sandy clayey silt [type ML/MI] up to the investigated depth of 25.5 m bgl. But in both BH's it is clayey silty sand [type SC-SM] from about 16.5 m to 19.5 m in BH 1 and 15.0 m to 18.0 m bgl in BH 2. It is also gritty at both locations and various depths.

Ground water table was struck at about 1.10 m to 1.15 m depth below GL in January, 2022 It is subject to seasonal variations.

Hence, any one or more of the following two alternative foundation types may be used, depending on structural and economic considerations:

1. The proposed structure may be provided with shallow foundation at a depth of 2.0 m or more.
2. Plane piles of lengths 6.0 m to 25.0 m with shaft diameters 0.30 m, 0.40 m, 0.60 m, 1.00 m, 1.20 and 1.50 m may be adopted.

By way of example, the values of safe capacities of each one of the above two types of foundations of the above mentioned sizes and depths have been calculated (vide Samples of Calculations 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)
		Strip footing	Square footing	Raft footing	
2.0	2.0	8.5	12.9	...	75
	3.0	5.8	10.2	...	75
	10.0	...	...	7.6	100
2.5	2.0	9.8	14.3	...	75
	3.0	6.6	11.5	...	75
	10.0	...	...	8.0	100
3.0	2.0	11.3	16.6	...	75
	3.0	7.4	13.0	...	75
	10.0	...	...	8.5	100
3.5	2.0	12.5	18.8	...	75
	3.0	8.1	14.3	...	75
	10.0	...	...	9.0	100
4.0	2.0	13.9	20.0	...	75
	3.0	8.9	15.7	...	75
	10.0	...	...	9.5	100

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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] For Plane Piles of diameters (m) (<i>SUBJECT TO CHECKING FOR SLENDERNESS RATIO**</i>)					
	0.3 m	0.4 m	0.6 m	1.0 m	1.2 m	1.5 m
6.0	9.7	13.4	21.4	40.1	50.8	68.7
8.0	12.5	18.0	29.3	54.5	68.8	92.5
10.0	15.5	22.8	38.8	71.8	90.3	120.8
12.0	18.7	27.8	48.7	92.3	115.8	154.3
14.0	22.2	32.2	59.1	116.3	145.4	193.0
16.0	25.9	38.9	69.8	143.0	178.3	235.6
17.0	28.8	42.5	76.2	162.1	202.7	265.5
19.0	31.0	47.5	88.2	192.3	248.1	325.8
20.0	33.2	50.9	94.5	207.4	270.1	355.8
22.0	37.8	57.8	107.4	237.0	310.5	416.1
24.0	42.6	65.0	120.5	267.0	351.4	480.6
25.0	45.0	68.6	127.3	282.3	372.3	512.1

**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.
 $k \text{ (kN/m}^3\text{)} = 240 c$, where $c \text{ (kN/m}^2\text{)}$ is the value of cohesion of the soil at the concerned depth.

Table 3 : Results of Compaction and CBR Tests

[For soil samples taken form 0.5 m depth in each one of the 2 bore hole, compacted in CBR Moulds to the predetermined (vide App. G1,2) Maximum Dry Density [MDD] under Heavy IS Compaction at O.M.C, soaked for 4 days and tested under a surcharge equivalent to 14 cm of pavement for CBR values, vide App. H1 and H2.]

BH No.	OMC %	MDD g/cm ³	Average of two Values of CBR, %
1	16.0	1.79	11.4
2	16.2	1.80	11.8

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 concreting of piles is to be done below water table, DMC and tremie method should be adopted.
3. If u/r piles are provided, care should be taken to ensure proper formation of bulbs.
4. Shallow foundations or pile caps should be isolated from the surrounding expansive soil by layers of compacted local sand.
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 Baidyanath Foundation Consultants Pvt. Ltd.,

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

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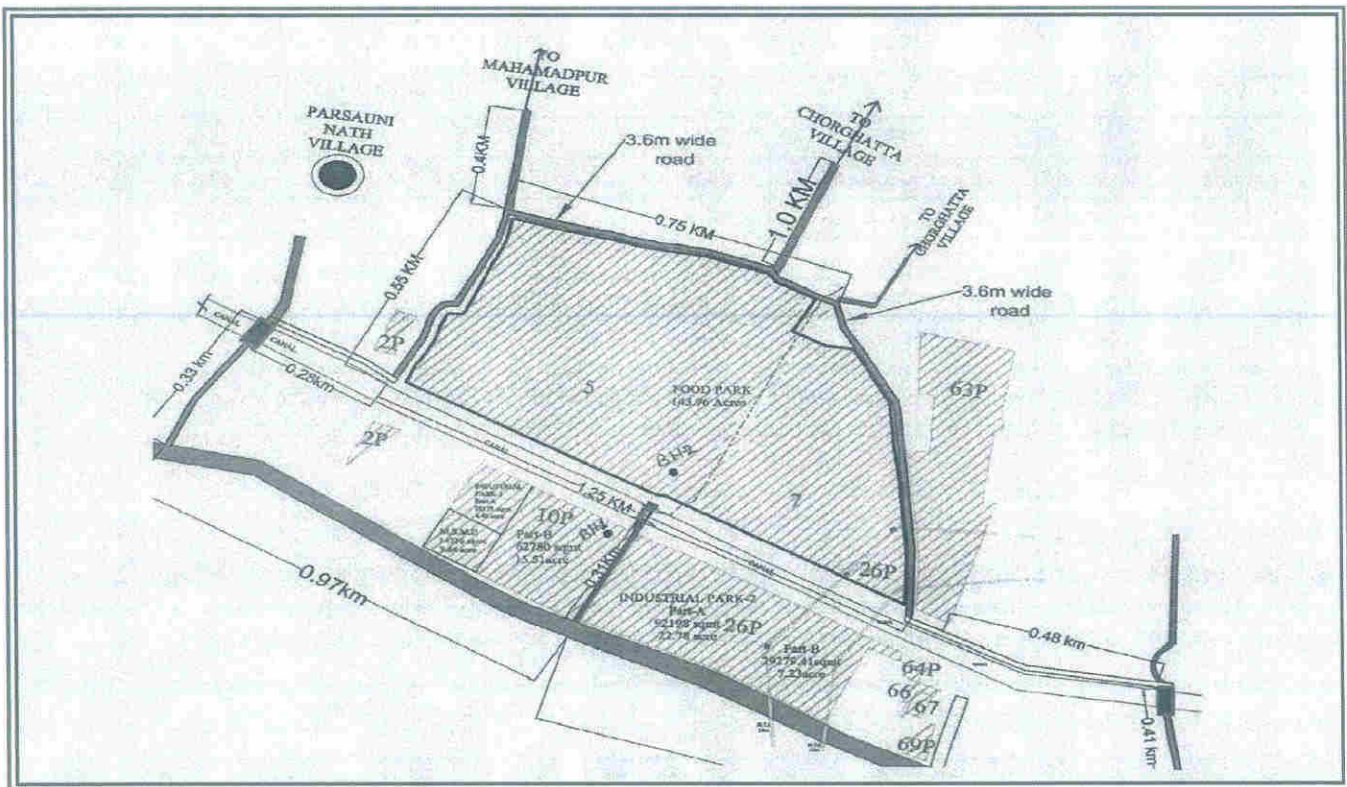
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Bhadr, Motipur Cluster

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Appendix - A

[Signature]
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NAME OF WORK : Sub soil Investigation for C/O								BORING FINISH DATE : 31.01.2022				WATER TABLE : 1.15 m bgl.						
General Condition of Soil at Murarpur, Muzaffarpur								BORING METHOD : Rotary										
BORE HOLE NO. : 1		Site Incharge :- Ashok Pandey						TERMINATION DEPTH : 25.5 m				RECORD ON : 30.01.2022						
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 Index, %	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C _c)		
				from	to								Type of Test	Cohesion, c (kg/cm ²)	Friction Angle, φ ^o			
1.0			Greyish silty clay, CL	0.0		3.0	28.8	21.4	7.4	1.99	26.6	2.70		0.44	5.0	0.143		
1.5	SPT	9																
2.5																		
3.0	SPT	13			3.0							2.01	25.4	2.70		0.59	5.1	0.137
4.0			Greyish silty clay, CL	3.0		6.0												
4.5	SPT	15						37.3	24.4	12.9	2.03	25.4	2.70		0.63	5.1	0.135	
5.5																		
6.0	SPT	16										2.02	24.7	2.70		0.65	5.1	
7.0			Yellowish silty clay, CL			7.5												
7.5	SPT	17			7.5			40.1	25.2	14.9	2.02	24.7	2.70		0.67	5.1		
8.5																		
9.0	SPT	20			9.0							2.02	24.6	2.69		0.73	5.2	
10.0			Greyish sandy silty clay, CL with grits	9.0		4.5												
10.5	SPT	23						33.2	22.6	10.6	2.03	24.3	2.70		0.79	5.3		
11.5																		
12.0	SPT	27										2.04	23.5	2.70		0.87	5.3	
13.0			Greyish clayey sandy silt, ML with grits			3.0												
13.5	SPT	28			13.5			31.6	20.8	10.8	2.04	23.5	2.70		0.89	5.3		
14.5																		
15.0	SPT	31										1.97	28.0	2.69		0.26	17.6	
16.0			Greyish clayey silty sand, SC-SM with grits			3.0												
16.5	SPT	33			16.5							1.97	28.1	2.69		0.28	17.8	
17.5																		
18.0	SPT	35										1.84	35.3	2.61		0.00	30.6	
19.0			Greyish clayey sandy silt, ML with grits			5.0												
19.5	SPT	38			19.5							1.84	35.6	2.61		0.00	31.4	
20.5																		
21.0	SPT	41										1.97	28.2	2.69		0.36	18.6	
22.0																		
22.5	SPT	47						29.0	23.3	5.7	1.97	28.3	2.69		0.39	18.7		
23.5																		
24.0	SPT	52										1.98	28.8	2.69		0.41	18.9	
25.0																		
25.5	SPT	58			25.5			27.1	22.0	5.1	1.98	29.3	2.69		0.42	19.2		

Appendix- B1

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NAME OF WORK : Sub soil Investigation for C/O						BORING FINISH DATE : 01.02.2022					WATER TABLE : 1.10 m bgl.							
General Condition of Soil at Murarpur, Muzaffarpur						BORING METHOD : Rotary												
BORE HOLE NO. : 2		Site Incharge :- Ashok Pandey					TERMINATION DEPTH : 25.5 m					RECORD ON : 31.01.2022						
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 Index, %	Bulk Density (gm/cm3)	Natural Moisture Content (%)	Specific Gravity	Shear Test			Compression Index (C _c)		
				from	to								Type of Test	Cohesion, c (kg/cm ²)	Friction Angle, ϕ °			
1.0			Greyish silty clay, CL	0.0		3.0				1.98	27.4	2.70		0.40	4.6			
1.5	SPT	8																
2.5																		
3.0	SPT	11	Greyish gravelly sandy clayey silt, ML with grits		3.0	4.5	28.3	21.4	6.9	2.01	25.4	2.70		0.51	5.1			
4.0					3.0							1.99	28.2	2.64		0.14	16.0	
4.5	SPT	15																
5.5																		
6.0	SPT	18						31.5	26.2	5.3	1.94	28.1	2.64		0.16	16.3		
7.0																		
7.5	SPT	20			7.5						1.95	28.5	2.67		0.17	16.5		
8.5					7.5													
9.0	SPT	22	Greyish gravelly sandy clayey silt, MI with grits			6.0	38.5	28.9	9.6	1.95	28.5	2.67		0.19	16.7			
10.0																		
10.5	SPT	25									1.95	28.3	2.65		0.22	17.0		
11.5																		
12.0	SPT	26						35.2	24.8	10.4	1.95	28.2	2.65		0.22	17.1		
13.0																		
13.5	SPT	29			13.5				1.96	28.1	2.68		0.26	17.4				
14.5			Greyish gravelly sandy clayey silt, ML with grits	13.5		1.5												
15.0	SPT	32			15.0		32.2	23.6	8.6	1.97	28.0	2.69		0.27	17.7			
16.0																		
16.5	SPT	34	Greyish clayey silty sand, SC-SM with grits			3.0				1.80	35.2	2.61		0.00	30.5			
17.5																		
18.0	SPT	37			18.0						1.84	35.6	2.63		0.00	31.3		
19.0			Greyish gravelly sandy clayey silt, ML with grits	18.0		7.5												
19.5	SPT	39									1.97	28.2	2.69		0.34	18.4		
20.5																		
21.0	SPT	42						27.0	22.8	4.2	1.97	28.4	2.69		0.37	18.6		
22.0																		
22.5	SPT	46									1.97	28.5	2.69		0.39	18.8		
23.5																		
24.0	SPT	52						27.2	22.1	5.1	1.98	29.3	2.69		0.39	18.9		
25.0			Greyish gravelly sandy clayey silt, ML with grits			7.5												
25.5	SPT	56			25.5						1.98	29.4	2.69		0.42	19.0		

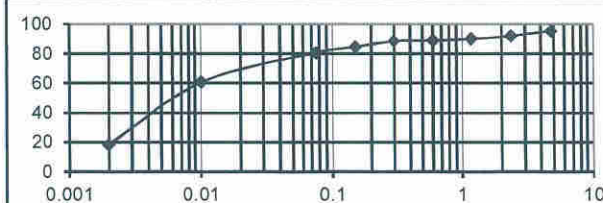
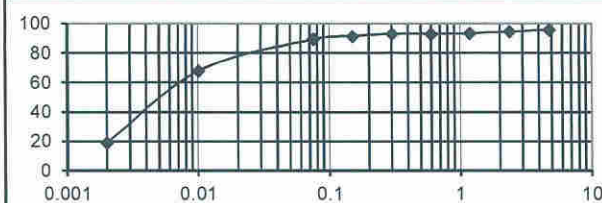
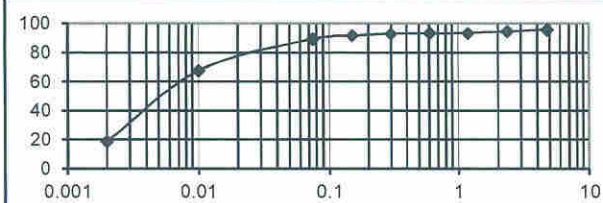
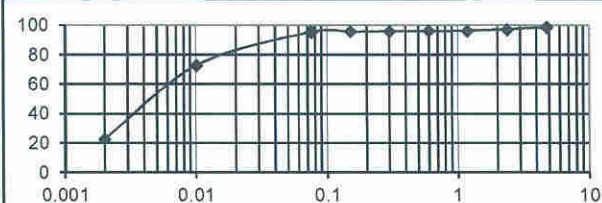
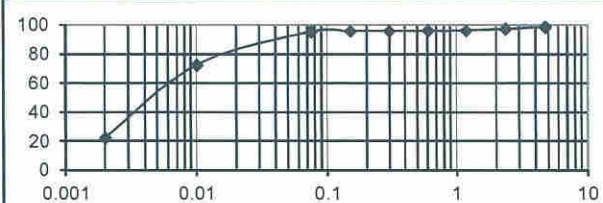
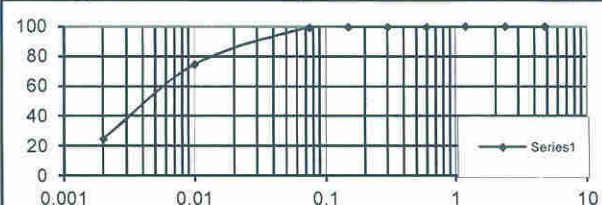
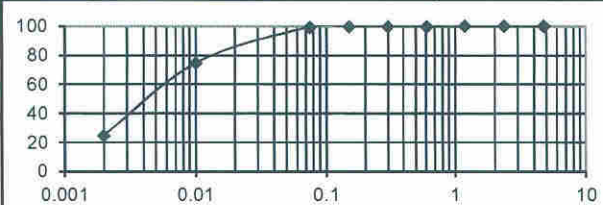
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Biada, Motipur Cluster

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Table 2 [part B]: Grain Size Analysis Results

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



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Appendix - C1

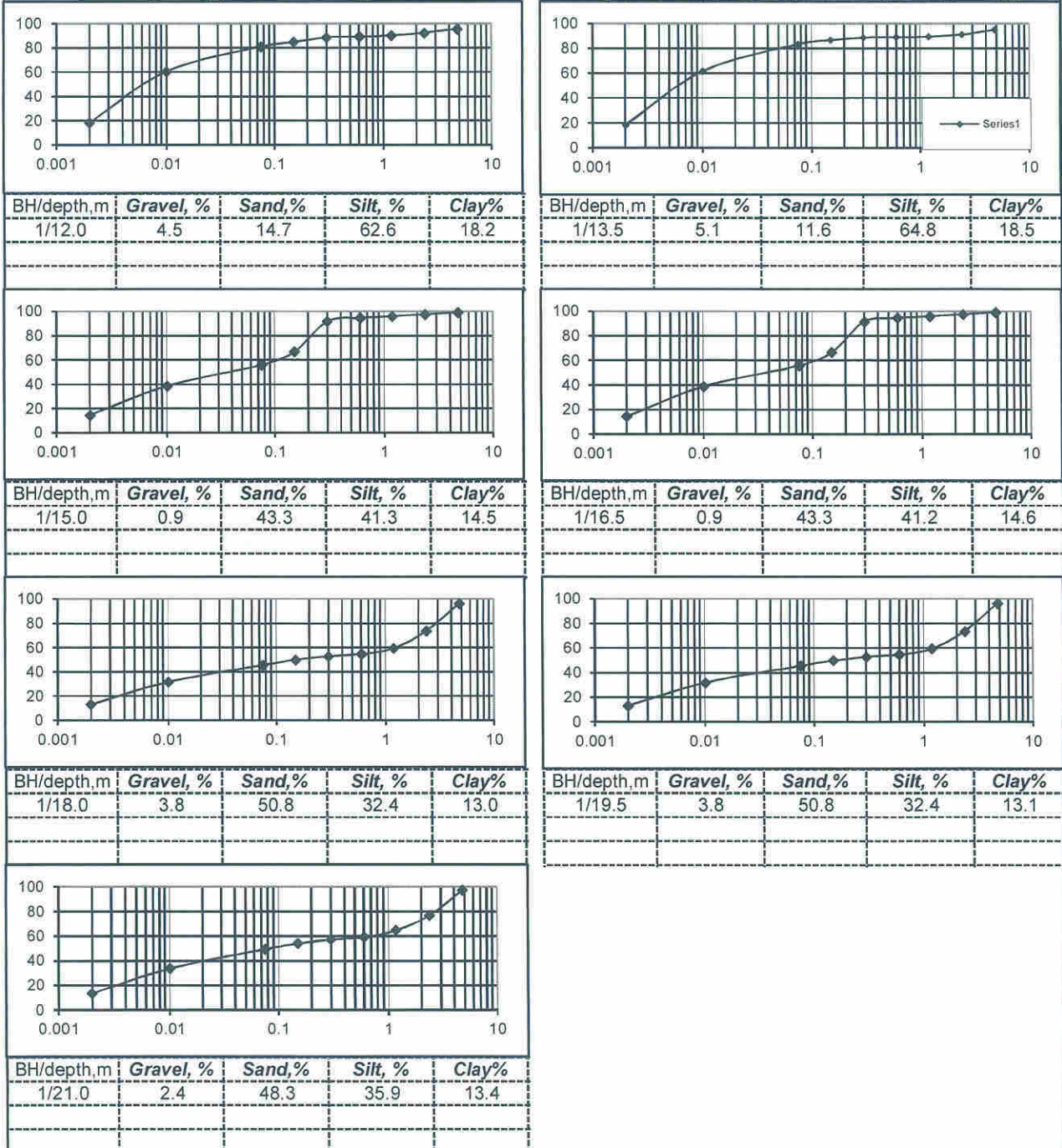
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Table 2 [part B]: Grain Size Analysis Results

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



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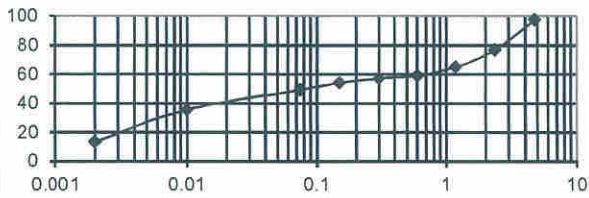
Appendix - C2

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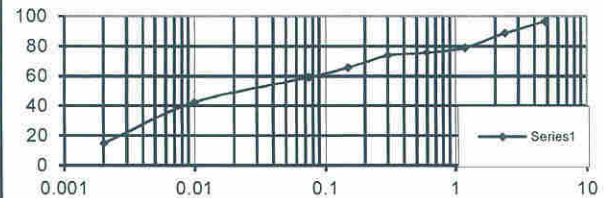
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Table 2 [part B]: Grain Size Analysis Results

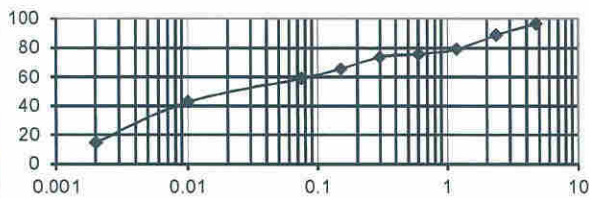


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/22.5	2.4	48.3	35.7	13.6

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



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/24.0	3.3	37.6	44.3	14.8



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/25.5	3.3	37.6	44.2	14.9

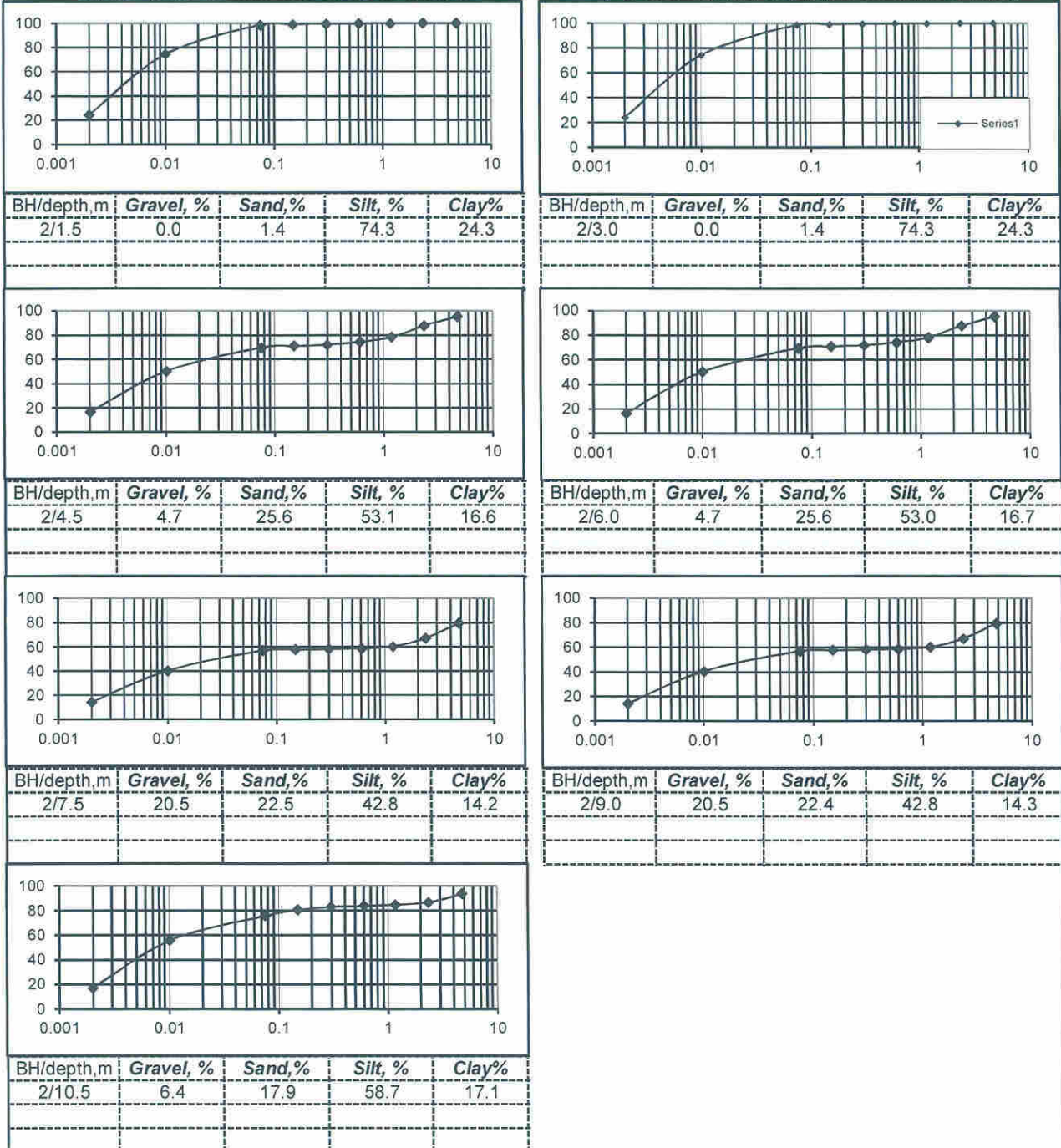
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Table 2 [part B]: Grain Size Analysis Results

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



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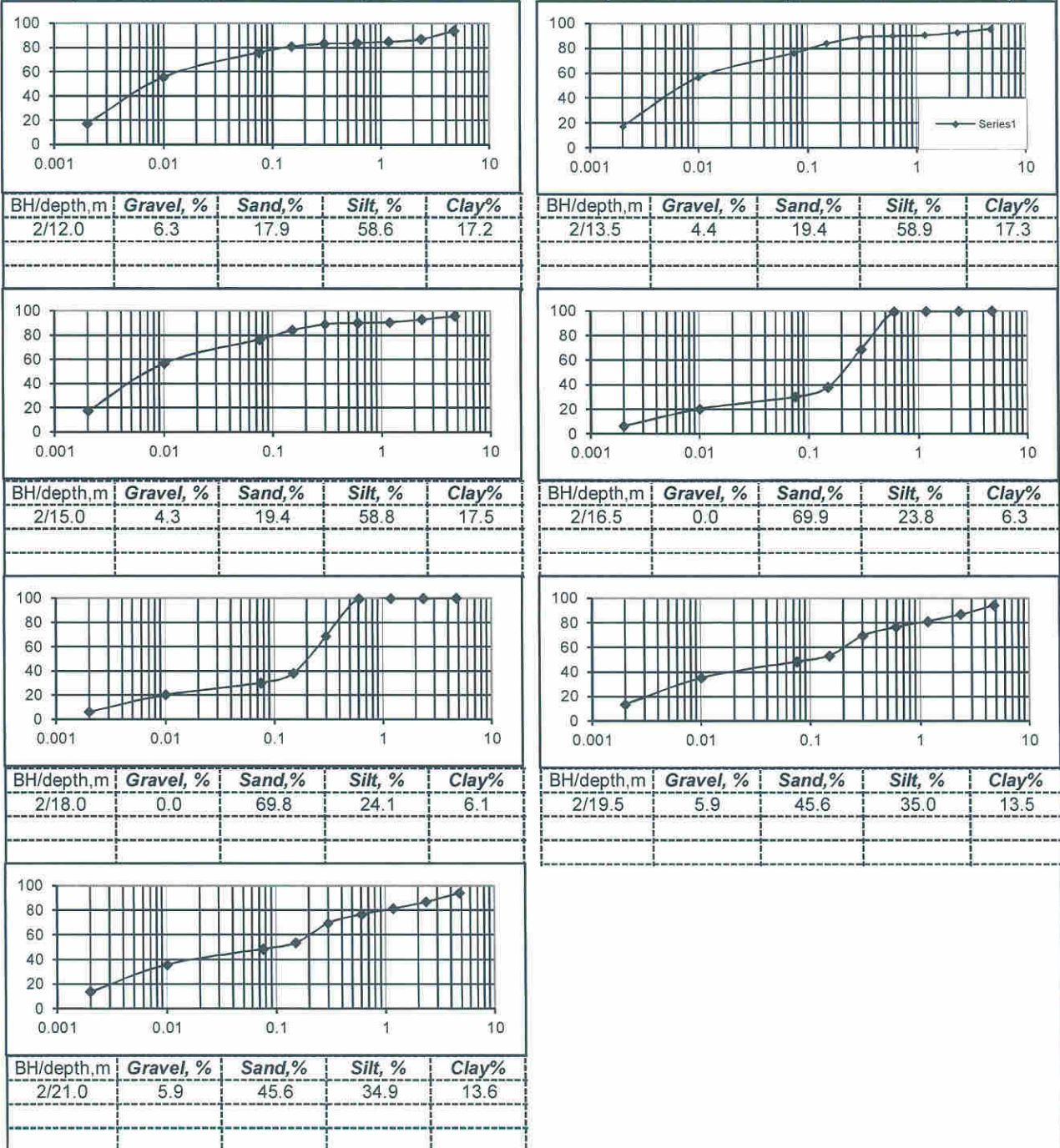
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Biada, Motipur Cluster

[Signature]
Deputy General Manager
Biada, Motipur Cluster

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Table 2 [part B]: Grain Size Analysis Results

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



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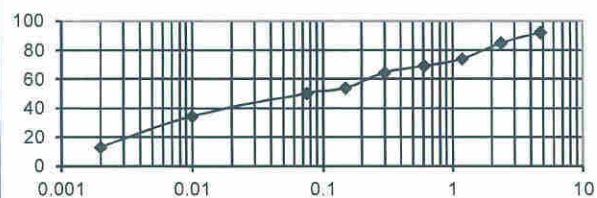
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Biada, Motipur Cluster

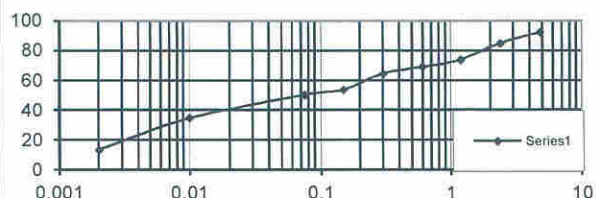
Report on sub-soil investigation for the proposed
General Condition of Soil at Murarpur, Muzaffarpur

Table 2 [part B]: Grain Size Analysis Results

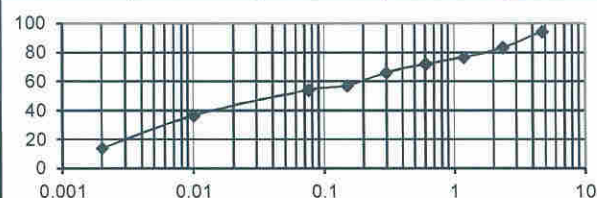


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/22.5	7.9	41.9	37.0	13.2

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



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/24.0	7.9	41.8	36.9	13.4



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/25.5	5.7	40.2	40.2	13.9

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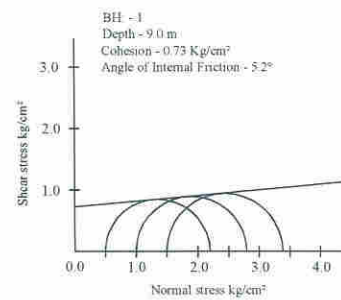
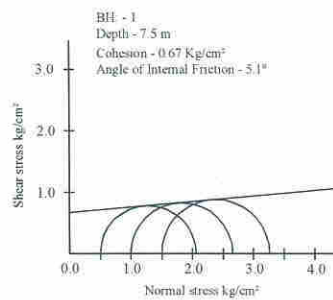
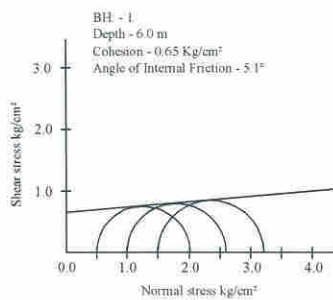
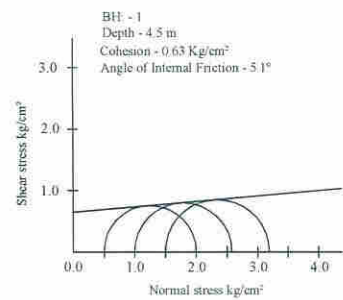
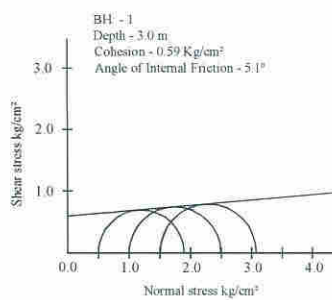
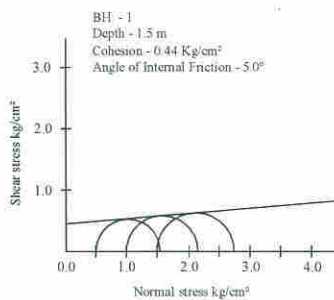
PN - 220108

Appendix - C6

Deputy General Manager
Biada, Motipur Cluster

Deputy General Manager
Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D1

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[Unit : Bihar Foundation Consultants]

Project No. 220108

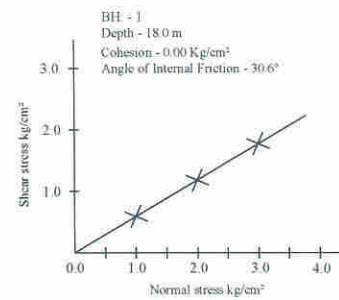
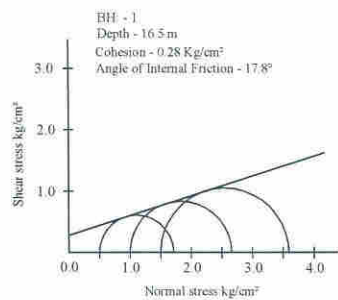
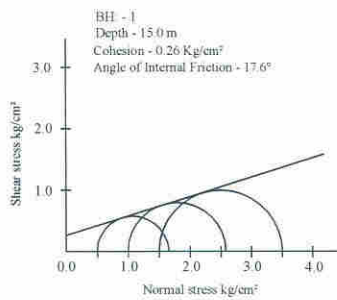
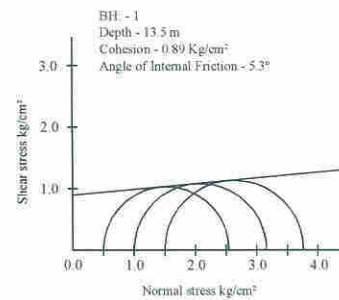
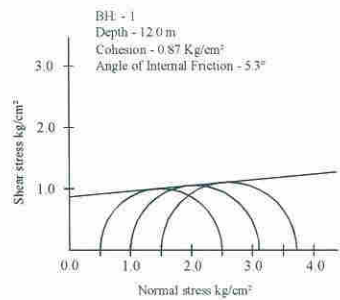
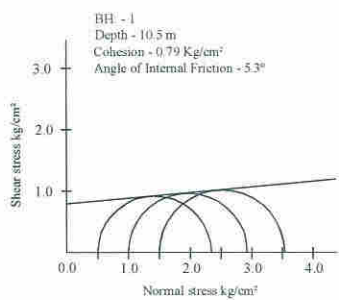
For the Proposed

General Condition of Soil at Murarpur, Muzaffarpur

Deputy General Manager
Biada, Motipur Cluster


Deputy General Manager
Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



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

Project No. 220108

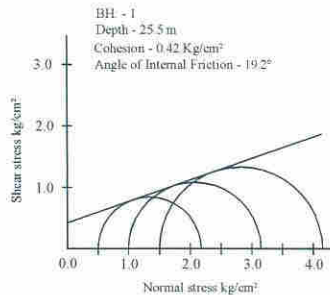
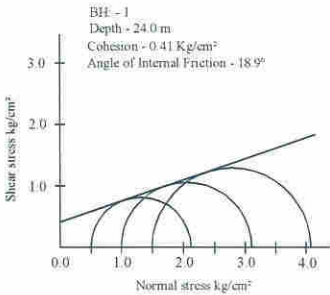
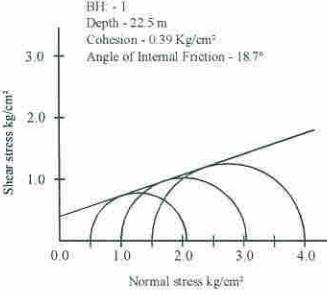
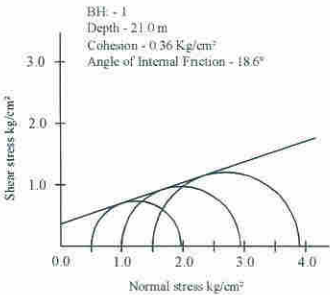
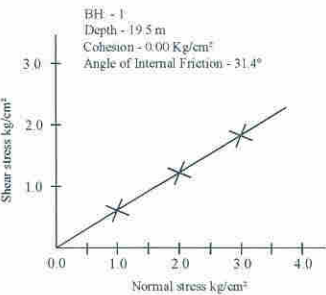
For the Proposed

General Condition of Soil at Murarpur, Muzaffarpur

Deputy General Manager
 Biada, Motipur Cluster

Deputy General Manager
 Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



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

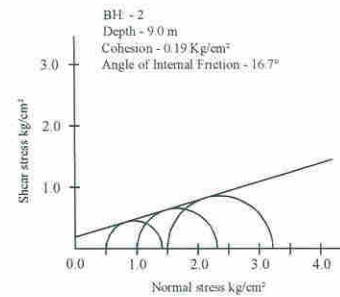
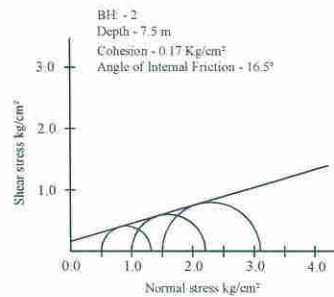
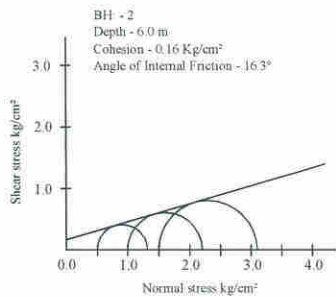
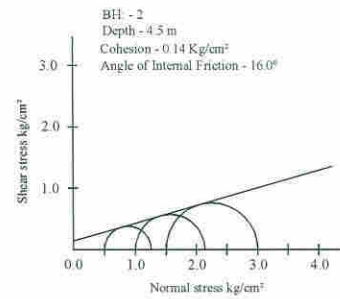
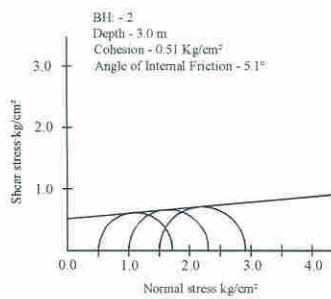
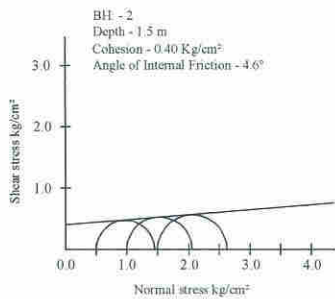
Project No. 220108

For the Proposed
 General Condition of Soil at Murarapur, Muzaffarpur


 Deputy General Manager
 Biada, Motipur Cluster

Deputy General Manager
 Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D4

Baidyanath Foundation Consultants Pvt. Ltd.,
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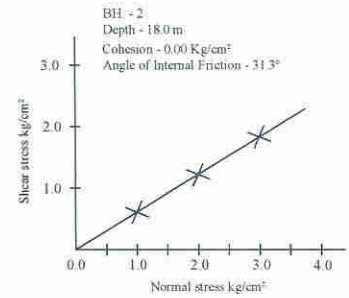
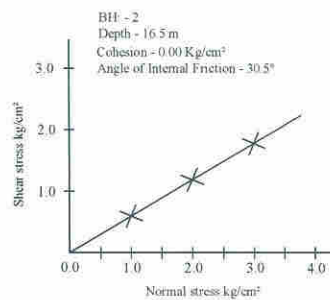
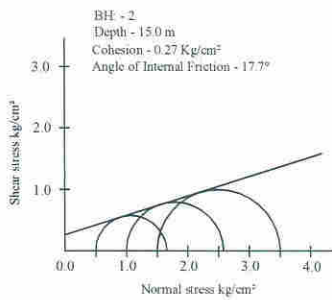
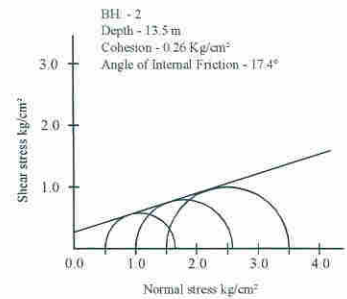
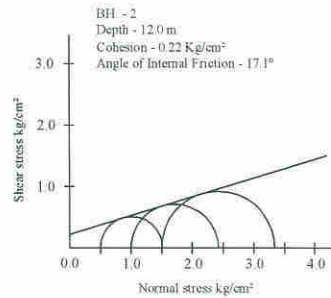
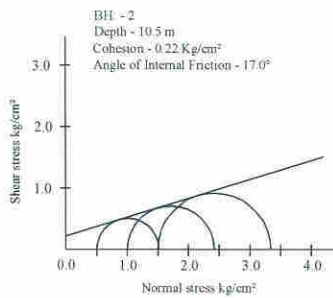
For the Proposed

General Condition of Soil at Murarpur, Muzaffarpur

Deputy General Manager
Biada, Motipur Cluster


Deputy General Manager
Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D5

Baidyanath Foundation Consultants Pvt. Ltd.,
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Project No. 220108

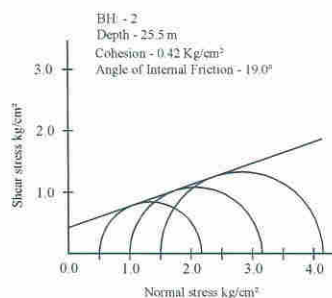
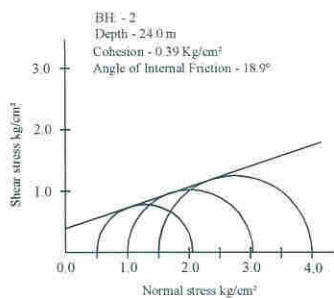
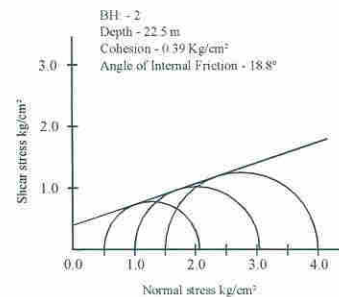
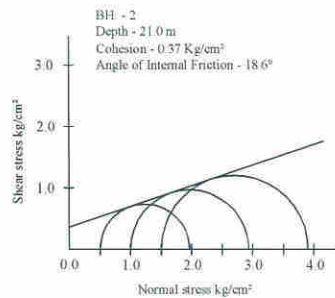
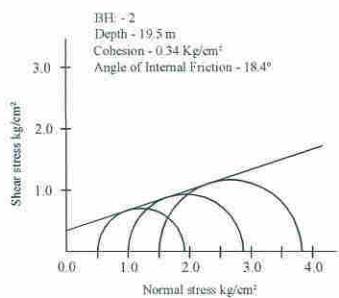
For the Proposed

General Condition of Soil at Murarpur, Muzaffarpur

Deputy General Manager
Biada, Motipur Cluster

Deputy General Manager
Biada, Motipur Cluster

TRIAXIAL / DIRECT SHEAR TEST PLOTS



Appendix - D6

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

Project No. 220108

For the Proposed

General Condition of Soil at Murarpur, Muzaffarpur

Deputy General Manager
 Biada, Motipur Cluster


 Deputy General Manager
 Biada, Motipur Cluster

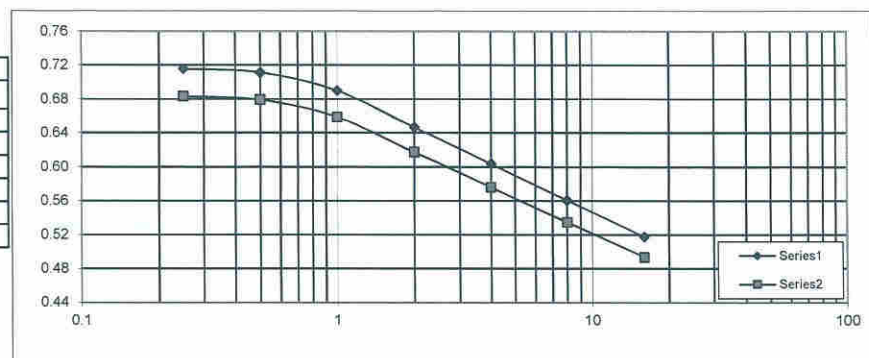
Report on SubSoil Investigations for the proposed
General Condition of Soil at Murarpur, Muzaffarpur

Fig. e - log p Plots from Consolidation Tests

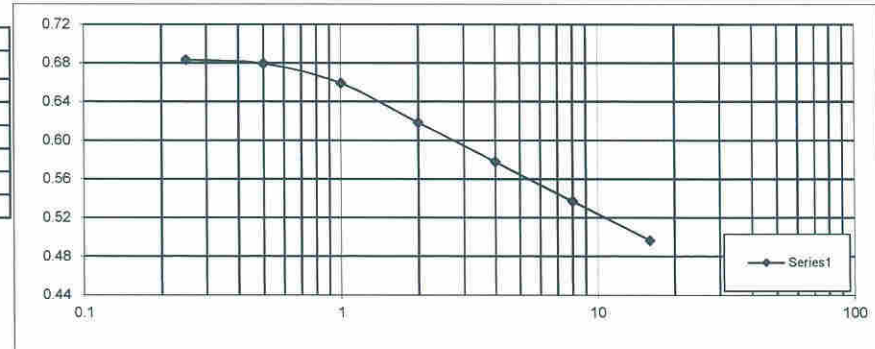
X-axis : Pressure, p (kg/cm²) on log scale.

Y-axis : Void ratio, e

BH No./		Initial V.R.	
Depth (m)	C _c	e ₀	CURVE
1/1.5	0.143	0.7182	Series1
1/3.0	0.137	0.6858	Series2



BH No./		Initial V.R.	
Depth (m)	C _c	e ₀	CURVE
1/4.5	0.135	0.6858	Series1



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Appendix-E

PN - 220108

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Deputy General Manager
Biada, Motipur Cluster

Report on Sub Soil Investigations for the proposed General Condition of Soil at Murarpur, Muzaffarpur

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
 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 ϕ) ^{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	$\phi < 10^\circ$	0.5	1
$s_\gamma =$	0.8/0.6	1-0.4B/L	1	$d_q = d_\gamma =$	1+ 0.1 (N ϕ) ^{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 (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

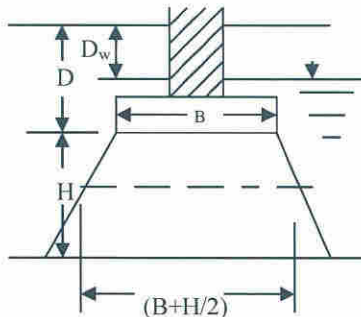
Report on Sub Soil Investigations for the proposed General Condition of Soil at Murarpur, Muzaffarpur

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.

If $D_w > (D + 1.5 B/2)$, $p_o = \gamma (D + 1.5 B/2) \text{ t/m}^2$, 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	1.98	4	4.6	6.36	1.51	0.40
D [m]	B [m]	dc	dq = dg	c	q	I Term	II Term	III Term	qnf / F
2	2	1.22	1	4	1.98	30.99	1.01	0.40	32.40
									10.80

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

$m = 0.274$		$G_s = 2.7$		$eo = 0.7398$		$Cc = 0.141$		$D_w = 0$	
Depth	Width	qnf / F	p_o	H	Δp	$\log (1 + \Delta p / p_o)$	s [mm]	λs mm	Remarks
D [m]	B [m]	t/m^2	t/m^2	m	t/m^2		mm	mm	
2.0	2.0	10.8	3.4	3.0	6.2	0.4	108.7	86.9	Not OK
2.0	2.0	8.5	3.4	3.0	4.9	0.4	93.1	74.5	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 8.5 t/m^2 .

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

Calculations of Capacity of Plane Pile for the proposed General Condition of Soil at Murarpur, Muzaffarpur

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°).

WHEN Pile diameter, D (m) =

0.30

Area of pile base, $A_p \text{ (m}^2\text{)} = 0.071$

& circ'mfr'nce (in m) of pile base, $j = 3.14 \times D = 0.942$

Surface area of pile's contact with soil, $A \text{ (m}^2\text{)} = j \times t$

where t = thickness of soil layer in contact with pile.

In **CLAY**: Skin friction in clay, Q_s

$$= cA,$$

End bearing, $Q_b = A_p C_p N_c$

where $N_c=9$

In SAND: Skin friction, $Q_s = K P_{\text{mid}} A \tan \delta$, where

 $K = 1.5$

and $\delta =$. End bearing, $Q_b = A_p(0.5 D_f N_f + P_{tip} N_d)$.

where P = overburden press. at mid-layer or pile tip, as the case be,

and the values of N_q and N_y are to be taken from the IS Code.

*Max'm permissible $P[t/m^2] = 15 \text{ to } 20 \times \text{pile diameter (D)} \times \gamma_{\text{sub}}$

$$= 4.5 \text{ to } 6 \times \gamma_{\text{sub}} \text{ t/m}^2$$

4.545 to 6.06 μm .

Total Ultimate capacity of pile, $Q_u = Q_s + Q_b$.

Safe capacity of pile, $Q_{st} = (Q_s / t_s + Q_b / t_b)$

Let factor of safety in

friction, $f_s = 2.5$
bearing, $f_b = 3.0$

[illegible]

Deputy General Manager
Bisda, Motion Cluster

Deputy General Manager
Biada, Motipur Cluster

Soil Exploration Along Proposed
General Condition of Soil at Murarpur, Muzaffarpur

**SUBSOIL INVESTIGATIONS FOR Proposed New Bridge at Murarpur, Muzaffarpur
BH -1, Depth- 0.5**

HEAVY IS Compaction Test

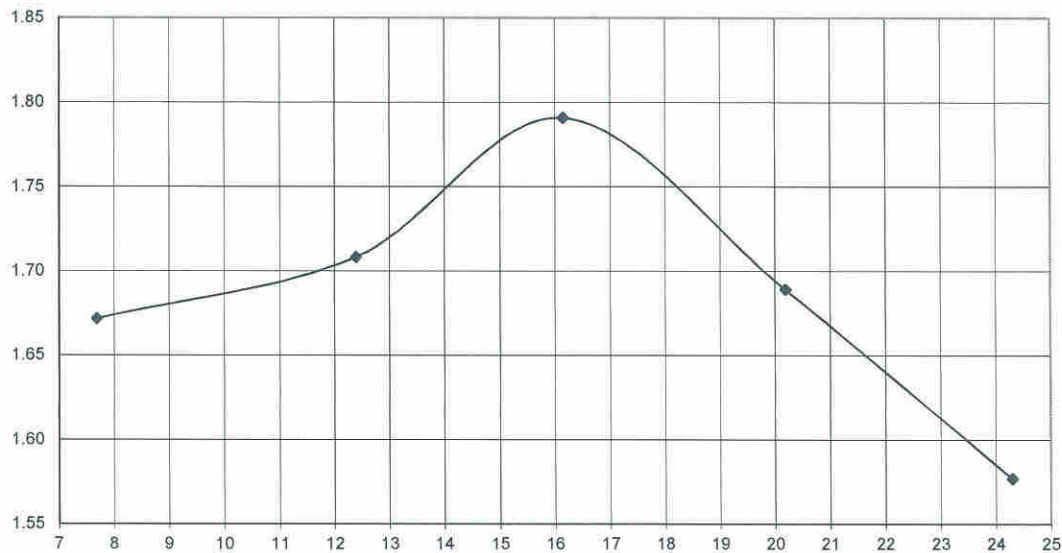
PN 220108

Moisture Content (%) vs. Density(g/cc) Curves

(BASED ON THE tabulated observations and calculations below) give OMC (%) & MDD (g/cc) as hereunder:

Sample:	AS READ FROM THE CURVE BELOW :	
	OMC =	MDD =
	16.0 %	1.79 g/c.c.

BH -1, Depth- 0.5



BH -1, Depth- 0.5

	Tested on 08.02.2022					g/c.c.		c.c.
	Wts. In g	can empty	can + wet	can+ dry	mold+soil	m, %	dry density	mould wt.
			soil	soil			g/c.c.	c.c.
BH -1, Depth- 0.5	35.29	95.97	91.64	3920	7.68	1.67	2120	1000
	35.55	90.50	84.44	4040	12.40	1.71	2120	1000
	34.81	95.64	87.18	4200	16.15	1.79	2120	1000
	34.83	109.23	96.73	4150	20.19	1.69	2120	1000
	35.27	128.00	109.87	4080	24.30	1.58	2120	1000
					16.70			

Date
08.02.2022

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[Unit : Bihar Foundation Consultants]

Appendix- G1

Deputy General Manager
Biada, Motipur Cluster

Soil Exploration Along Proposed
General Condition of Soil at Murarpur, Muzaffarpur

**SUBSOIL INVESTIGATIONS FOR Proposed New Bridge at Murarpur, Muzaffarpur
BH-2, Depth- 0.5**

HEAVY IS Compaction Test

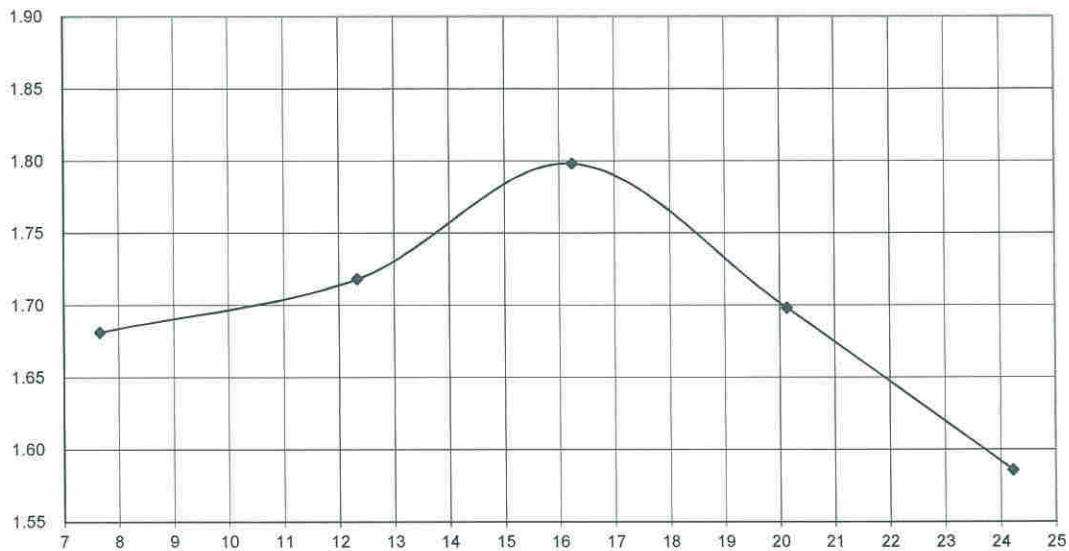
PN 220108

Moisture Content (%) vs. Density(g/cc) Curves

(BASED ON THE tabulated observations and calculations below) give OMC (%) & MDD (g/cc) as hereunder:

Sample:	AS READ FROM THE CURVE BELOW :	
	OMC =	MDD =
	16.2 %	1.80 g/c.c.

BH-2, Depth- 0.5



BH-2, Depth- 0.5

Wts. In g	Tested on	08.02.2022				g/c.c.		c.c.
	can empty	can + wet soil	can+ dry soil	mold+soil	m, %	dry density g/c.c.	mould wt.	mould vol. c.c.
BH-2, Depth- 0.5	25.40	86.28	81.95	3930	7.66	1.68	2120	1000
	23.03	78.23	72.17	4050	12.33	1.72	2120	1000
	21.55	82.61	74.08	4210	16.24	1.80	2120	1000
	25.66	100.26	87.76	4160	20.13	1.70	2120	1000
	24.64	117.61	99.48	4090	24.23	1.59	2120	1000

Date
08.02.2022

PN - 220108

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

Appendix- G2

Deputy General Manager
Biada, Motipur Cluster

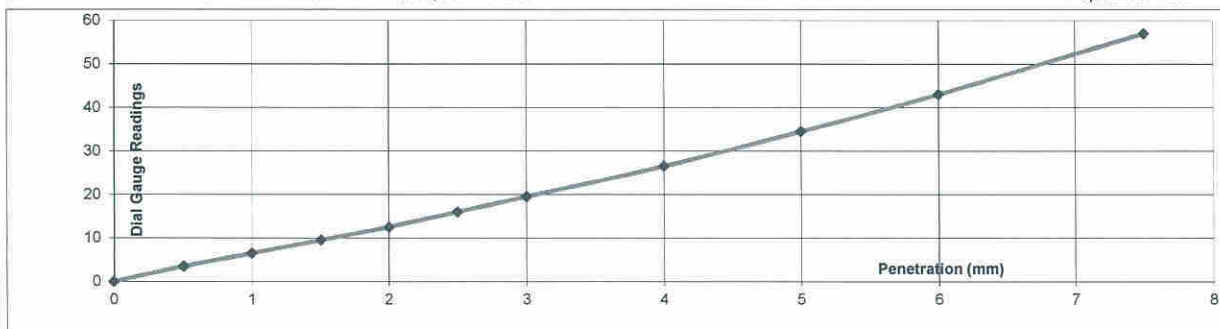
Deputy General Manager
Biada, Motipur Cluster

Soil Exploration Along Proposed
General Condition of Soil at Murarpur, Muzaffarpur

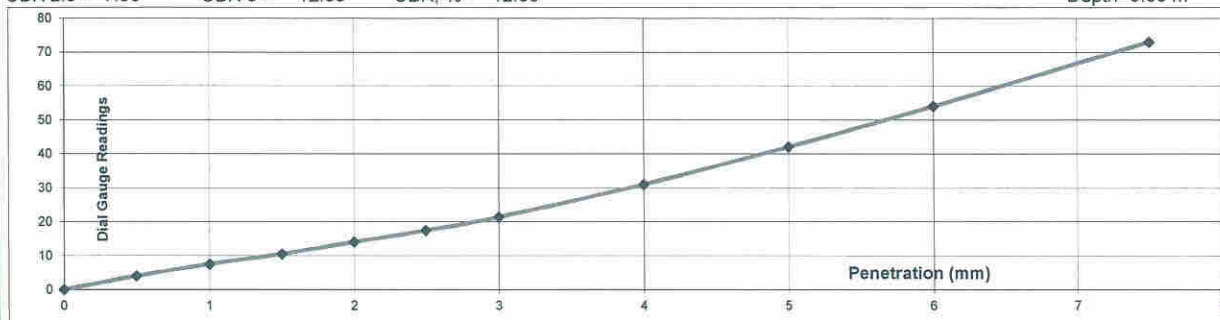
SUBSOIL INVESTIGATIONS FOR Proposed

BH-1 CBR Test Readings for Soil Samples from											
[compacted to MDD 1.79 g/c.c. at OMC 16.0 % heavy compaction]											Date 13.02.2022
Penetration											
in mm →	0	0.5	1	1.5	2	2.5	3	4	5	6	7.5
Top	0	4	7	10	13	16	20	27	35	43	57
in mm →	0	0.5	1	1.5	2	2.5	3	4	5	6	7.5
Bottom	0	4	8	11	14	17	21	31	42	54	73

CBR 2.5 = 7.17 CBR 5 = 10.31 CBR, % = 10.31 Depth- 0.50 m



CBR 2.5 = 7.80 CBR 5 = 12.55 CBR, % = 12.55 Average CBR = 11.4 Depth- 0.50 m



Deputy General Manager
Biada, Motipur Cluster

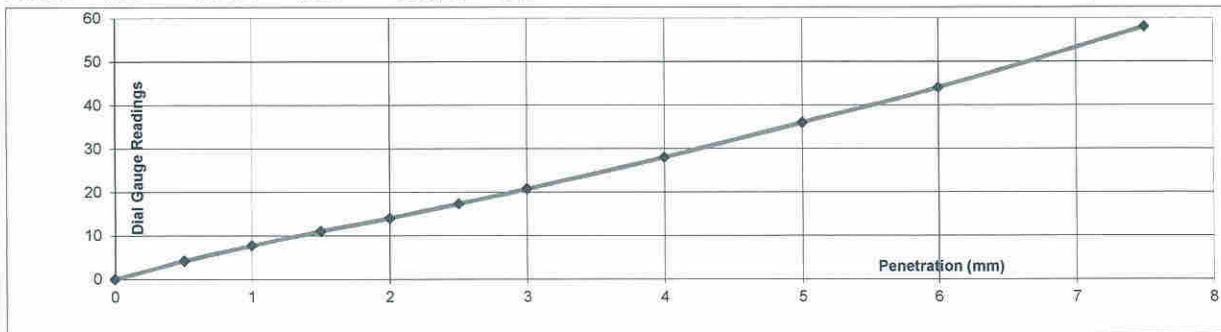
Deputy General Manager
Biada, Motipur Cluster

Soil Exploration Along Proposed
General Condition of Soil at Murarpur, Muzaffarpur

SUBSOIL INVESTIGATIONS FOR Proposed

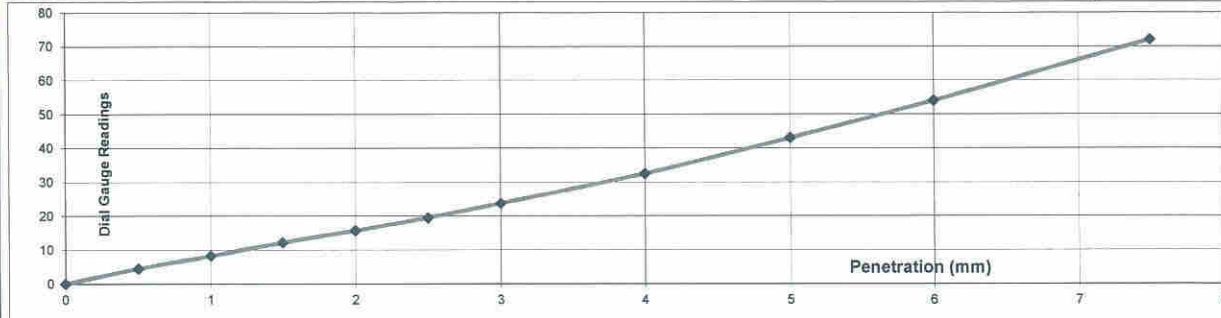
BH-2 CBR Test Readings for Soil Samples from											
[compacted to MDD 1.80 g/c.c. at OMC 16.2 % heavy compaction]											Date 13.02.2022
Penetration											
in mm	0	0.5	1	1.5	2	2.5	3	4	5	6	7.5
Top	0	4	8	11	14	17	21	28	36	44	58
in mm	0	0.5	1	1.5	2	2.5	3	4	5	6	7.5
Bottom	0	5	8	12	16	20	24	33	43	54	72

CBR 2.5 = 7.75 CBR 5 = 10.76 CBR, % = 10.76 Depth- 0.50 m



Average CBR = 11.8

CBR 2.5 = 8.74 CBR 5 = 12.85 CBR, % = 12.85 Depth- 0.50 m



Deputy General Manager
Biada, Motipur Cluster


Deputy General Manager
Biada, Motipur Cluster