

REPORT ON
GEOTECHNICAL INVESTIGATIONS
FOR THE PROPOSED
C/O
GIZ-NSP INDIA WASTE MANAGEMENT
AT
BAZAR SAMITI, PATNA (BIHAR)

[Contract No. NF/23/CC/023]

SUBMITTED TO
German Development Cooperation
GIZ-NSP INDIA WASTE MANAGEMENT PROJECT
GIZ GmbH, Office New Delhi
A2/18, Safdurjung Enclave
New Delhi – 110029, INDIA

May, 2025



INVESTIGATIONS DONE BY
SOILTECH® CONSULTANTS INDIA PVT. LTD.
[EMPANELLED IN B.C.D. & B.P.B.C.C., GOVT. OF BIHAR]
AN ISO 9001:2015 & ISO/IEC 17025:2017 CERTIFIED,
NABL ACCREDITED LAB

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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 4 - 5** 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 – 1981. 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. **[shown in figure 1.]**

The numbers of blows for each 15 cm of penetration were recorded. The blows required to penetrate the initial 15 cm of the split spoon for seating the sampler is ignored due to the possible presence of loose materials or cuttings from the drilling operation. The cumulative number of

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blows required to penetrate the balance 30 cm of the 45 cm sampling interval is termed the SPT value of the 'N' value.

The 'N' values are presented on the each borehole. Refusal to further boring penetration was considered when the 'N' values exceed 50 or when practical refusal to further penetration by shell and auger was encountered.

Where the 'N' value exceeds 50, the penetration of split spoon sampler (after initial seating) is recorded together with the number of blows given of the sampler. Where the seating blow count exceeds 50, the 'N' value is recorded as "Refusal".

SPT 'N' values are correlated with relative density of non-cohesive stratum and with consistency of cohesive stratum :

CORRELATION FOR CLAY / PLASTIC SILT		CORRELATION FOR SAND/NON-PLASTIC SILT	
Consistency	Penetration Value (blows)	Relative Density	Penetration Value (blows)
Very Soft	0 - 2	Very Loose	0 - 4
Soft	3 - 4	Loose	5 - 10
Medium Stiff	5 - 8	Medium	11 - 30
Stiff	9 - 16	Dense	31 - 50
Very Stiff	17 - 32	Very Dense	> 50
Hard	> 32		

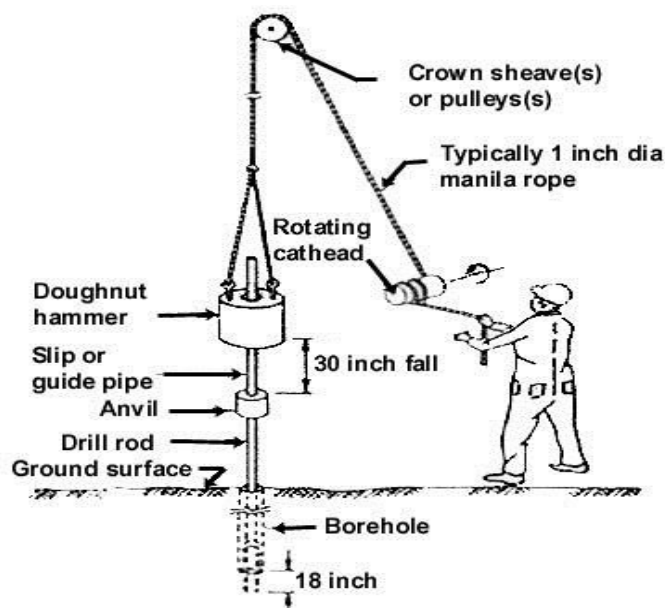


Figure 1 : Standard Penetration Test

2.3.2. Ground Water

The level of ground water in each bore hole was recorded 24 hours after the completion of boring.

2.4. Chemical Test

Chemical analyses of subsoil water and soil samples were carried out and pH, Chloride and Sulphate values were calculated. The result of chemical analysis of subsoil sample indicates that the pH values, sulphate content, chloride content are within permissible limit and the RCC work prepared with Ordinary Portland Cement shall not be deteriorated when placed over/within site subsoil.

3. LABORATORY TESTS

The laboratory testing has been carried out in our **laboratory at Patna**. The quality procedures in our laboratory conform to **ISO 9001:2015**.

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
- (h) Other tests as and when required

4. PRESENTATION OF TEST RESULTS

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

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5. SOIL STRATIFICATION

The three bore holes sunk at the site and the results of laboratory tests conducted on the collected soil samples indicate the following stratification.

The top soil formation is filledup soil up to 1.5m depth. After 1.5m depth the subsoil is clayey silt of type ML up to about 4.0 m depth followed by silty clay of type CL up to the investigated depth of 15.0 m below GL.

Ground water table was struck at about 6.0 m bgl in May, 2025. 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 proposed structure may be provided with either shallow foundations [strip, square or raft] or with plane pile foundations.

By way of example, the values of safe capacities of (1) shallow foundations and (2) plane piles of certain sizes and different 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) 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	7.1	8.5	--	75
	3	6.9	8.2	--	75
	10	--	--	8.5	100
2.5	2	7.9	9.4	--	75
	3	7.6	8.9	--	75
	10	--	--	9.0	100
3.0	2	8.8	10.3	--	75
	3	8.3	9.6	--	75
	10	--	--	9.5	100

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Table 2 : Safe capacities of Plane Piles

Pile length below GL (m)	Safe Pile Capacity (tonnes) For Shaft Diameter		
	0.3 m	0.4 m	0.5 m
8.0	10.9	16.5	21.9
12.0	18.0	26.0	33.9
15.0	23.8	34.1	44.3

* The cut off level 0.5 m below GL has been considered.

Notes :

1. The report presented is representative of the bore locations and does not represent entire area of construction as a whole.
2. If in the course of excavation, if sub soil strata differ from the bore log strata the same shall be reported for necessary steps.
3. The comments given in this report and the opinion expressed are based on the ground conditions encountered during the site work and based on the results of tests made in field and in the laboratory. There may however, special conditions prevailing at the site which have not been disclosed by the investigation and which have not been taken in to account in the report. Any variation in stratification in any of the foundation location shall be studied thoroughly before executing the foundation work.
4. DMC and tremie method of pile concreting should be adopted as the water table is near the ground surface.
5. When boring for a pile through sand layer, Bentonite slurry or Casing pipes may have to be used to stabilize the sides of the bore holes for the cast in situ bored plane piles.
6. 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 Soiltech Consultants India Pvt. Ltd.,

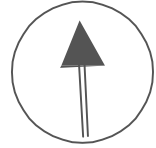
(Er. KASHIF AHMAD)
Managing Director

IS CODE REFERENCES

1. IS : 2720 (PART IV), GRAIN SIZE ANALYSIS
2. IS : 2720 (PART XIV), DETERMINATION OF DENSITY INDEX
3. IS : 2720 (PART V), DETERMINATION OF LIQUID & PLASTIC LIMITS
4. IS : 1498-1970, CLASSIFICATION & IDENTIFICATION OF SOILS
5. IS : 2720 (PART XV), DETERMINATION OF CONSOLIDATION PROPERTIES
6. IS : 2720 (PART XI) 1975, TRIAXIAL TEST (UUT)
7. IS : 2720 (PART X) 1973, UNCONFINED COMPRESSIVE STRENGTH
8. IS : 1892-1962, SITE INVESTIGATION
9. IS : 2131-1981, METHOD FOR SPT
10. IS : 2132-1981, THIN WALLED TUBE SAMPLING OF SOILS
11. IS : 1904-1978, STRUCTURAL SAFETY OF BUILDING FOUNDATIONS
12. IS : 6403-1981, DETERMINATION OF BEARING CAPACITY OF FOUNDATIONS
13. IS : 8009 (PART I) 1976, CALCULATION OF SETTLEMENT OF FOUNDATIONS
14. IS : 2950 (PART I) 1981, CODE OF PRACTICE FOR RAFT FOUNDATIONS
15. IS : 5313-1980, GUIDE FOR CORE DRILLING
16. IS : 11315-1985, METHOD FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASSES
17. IS : 4464-1985, CODE OF PRACTICE FOR PRESENTATION OF DRILLING INFORMATION AND CORE DESCRIPTION IN FOUNDATION INVESTIGATION.
18. IRC : 78-2000, STANDARD SPECIFICATION AND CODE OF PRACTICES FOR ROAD BRIDGES SECTION – VII
19. IS : 13365 (PART I) 1998, QUANTITATIVE CLASSIFICATION SYSTEM OF ROCK MASS-GUIDELINES
20. IS : 12070, BEARING CAPACITY OF FOUNDATION ON ROCKS
21. ARORA, K.R. SOIL MECHANICS & FOUNDATION ENGG.
22. MURTHY, VNS, PRINCIPLES OF SOIL MECHANICS & FOUNDATION ENGG.
23. PUNAMIA,, B.C. SOIL MECHANICS & FOUNDATION ENGG.
24. NAYAK, M.V., FOUNDATION DESIGN MANUAL
25. BRAHMA, S.P. SOIL MECHANICS
26. SINGH, ALAM MODERN GEOTECHNICAL ENGINEERING

Sub- Soil Investigations for C/O
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BORE - HOLE LOCATION MAP



ROAD

Water Logged Area

Building

BH-2

BH-1

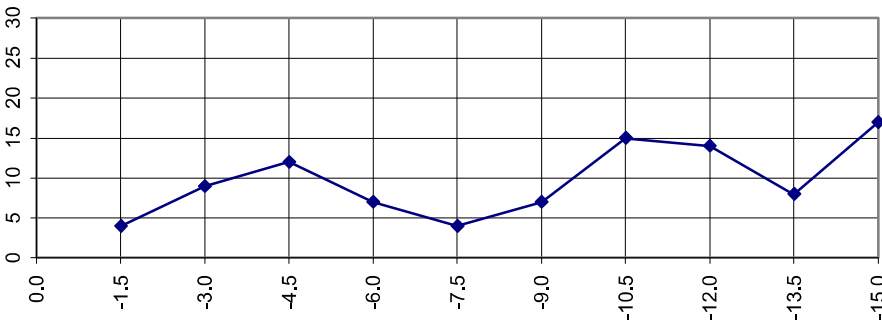
BH-3

Cold Storage

Site Incharge : Karan

Not to scale

Sub-Soil Investigation For The Proposed Construction Of
GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)

FIELD TESTS RESULTS AND OBSERVATIONS					LABORATORY TESTS RESULTS											
BH No. 1					Visual description & IS classification of soil	($\bar{\epsilon}$) T ₃₀ -10	Atterberg's limits				Bulk dens. γ g/c.c.	Moist. Cont. m %	Sp.gr. Gs	Trx. Comp./ Direct Shear Test		Comp. Index Cc
Depth (m)	Sample No.	SPT 'N' values Observed	Plot of observed N Vs. Depth (m)				LL %	PL %	PI %	Type of test				Cohe- sion c kg/cm ²	Ang. of int.fric. (deg.)	
0.0					Filledup with soil, brick bats, garbages etc.	0.0										
1.0																
1.5	S1	4														
2.5																
3.0	S2	9	Blackish clayey silt - ML			1.5		28.5	22.9	5.6	1.94	12.4	2.66	DS	0.09	13.5
4.0																
4.5	S3	12														
5.5																
6.0	S4	7	Yellowish/Reddish/Grayish silty clay - CL		4.0		30.2	24.1	6.1	1.95	13.9	2.67	DS	0.12	14.9	
7.0																
7.5	S5	4														
8.5																
9.0	S6	7														
10.0																
10.5	S7	15														
11.0																
12.0	S8	14														
13.0																
13.5	S9	8														
14.0																
15.0	S10	17														
					15.0	32.3	21.6	10.7	1.99	17.8	2.69	UU	0.34	6.9		

Water table : 6.0 m bgl

NP = Non Plastic, DS = Direct Shear Test, UU = Unconsolidated Undrained Test

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Appendix - B1

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FIELD TESTS RESULTS AND OBSERVATIONS					LABORATORY TESTS RESULTS													
BH No. 2					Visual description & IS classification of soil	From-To (m)	Atterberg's limits			Bulk dens. γ g/c.c.	Moist. Cont. m %	Sp.gr. Gs	Trx. Comp./ Direct Shear Test		Comp. In dex Cc			
Depth (m)	Sample No.	SPT 'N' values Observed	Plot of observed N Vs. Depth (m)	LL %			PL %	PI %	Type of test				Cohe- sion c kg/cm ²	Ang. of int.frict. (deg.)				
0.0				Filledup with soil, brick bats, garbages etc.	0.0													
1.0																		
1.5	S1	4				1.5	34.2	25.4	8.8	1.94	29.5	2.65	DS	0.11	12.6			
2.5				Blackish clayey silt - ML	4.0													
3.0	S2	10				32.5	24.9	7.6	1.95	28.6	2.66	DS	0.16	14.3				
4.0																		
4.5	S3	6																
5.5				Yellowish/Reddish/Grayish silty clay - CL	15.0													
6.0	S4	8				30.5	20.8	9.7	1.98	27.2	2.70	UU	0.23	5.3				
7.0																		
7.5	S5	5																
8.5																		
9.0	S6	11																
10.0																		
10.5	S7	16	34.5			21.9	12.6	1.96	23.2	2.70	UU	0.34	6.2					
11.0																		
12.0	S8	17	35.5			22.6	12.9	1.95	25.3	2.70	UU	0.37	6.6					
13.0																		
13.5	S9	11	32.8	20.9	11.9	1.99	24.7	2.68	UU	0.33	5.9							
14.0																		
15.0	S10	16																

Water table : 6.0 m bgl

NP = Non Plastic, DS = Direct Shear Test, UU = Unconsolidated Undrained Test

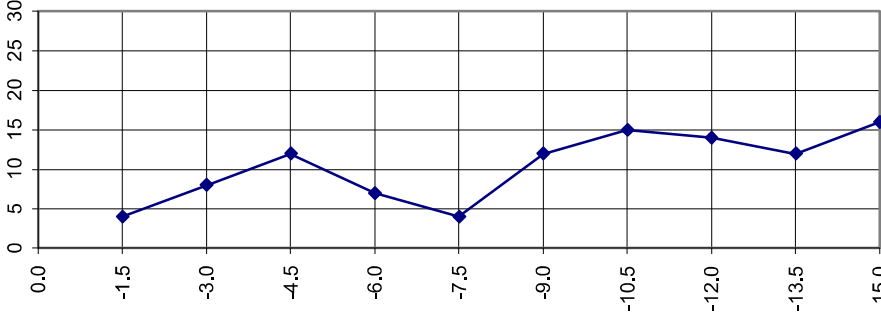
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Appendix - B2

Job No.- 25110

Sub-Soil Investigation For The Proposed Construction Of
GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)

FIELD TESTS RESULTS AND OBSERVATIONS					LABORATORY TESTS RESULTS										
BH No. 3					Visual description & IS classification of soil	From-To (m)	Atterberg's limits			Bulk dens. γ g/c.c.	Moist. Cont. m %	Sp.gr. Gs	Trx. Comp./ Direct Shear Test		Comp. In dex Cc
Depth (m)	Sample No.	SPT 'N' values Observed	Plot of observed N Vs. Depth (m)	LL %			PL %	PI %	Type of test				Cohe- sion c kg/cm ²	Ang. of int.fric. (deg.)	
0.0				Filledup with soil, brick bats, garbages etc.	0.0										
1.0															
1.5	S1	4			1.5	34.2	22.5	11.7	1.93	28.5	2.66	DS	0.09	13.2	
2.5				Blackish Clayey silt - ML											
3.0	S2	8			4.0										
4.0															
4.5	S3	12													
5.5				Yellowish/Reddish/Grayish silty clay - CL											
6.0	S4	7													
7.0															
7.5	S5	4			30.2	20.9	9.35	1.95	26.5	2.69	UU	0.24	4.2		
8.5															
9.0	S6	12													
10.0															
10.5	S7	15			32.5	19.5	13	1.97	24.1	2.70	UU	0.33	5.1		
11.0															
12.0	S8	14													
13.0															
13.5	S9	12													
14.0															
15.0	S10	16	15.0	31.8	20.4	11.4	1.99	24.7	2.70	UU	0.39	6.9			

Water table : 6.0 m bgl

NP = Non Plastic, DS = Direct Shear Test, UU = Unconsolidated Undrained Test

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Job No.- 25110

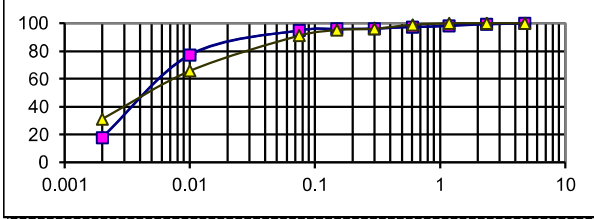
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S. NO.	TEST PARAMETER	TEST METHOD	RESULT	REQUIREMENT AS PER IS :	CONFORMITY
1.	ARSENIC, mg/L	IS: 3025 (PT-37)	0.003	0.01	Yes
2.	ZINC, mg/L	IS: 3025 (PT-49)	0.9	5	Yes
3.	CADMIUM, mg/L	IS: 3025 (PT-41)	0.0011	0.003	Yes
4.	COPPER, mg/L	IS: 3025 (PT-42)	0.01	0.05	Yes
5.	NICKEL, mg/L	IS: 3025 (PT-53)	0.0019	0.02	Yes
6.	IRON, mg/L	IS: 3025 (PT-53)	0.1	0.3	Yes
7.	CHROMIUM, mg/L	IS: 3025 (PT-52)	0.009	0.05	Yes

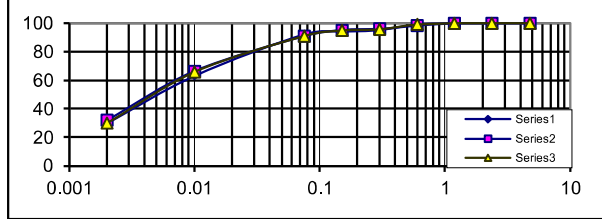
**Report on Sub Soil Investigation for the proposed C/O
GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)**

Table : Grain Size Analysis Results

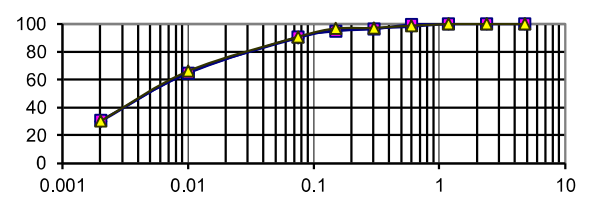
[for Bore hole No./ Depth in m shown thus: 1/1.5]



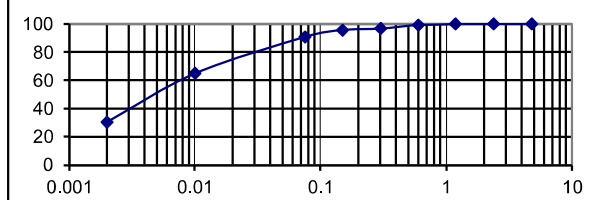
BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/1.5	0.0	4.9	76.6	18.5
1/3.0	0.0	4.9	77.0	18.1
1/4.5	0.0	8.8	60.0	31.3



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/6.0	0.0	7.8	62.4	29.9
1/7.5	0.0	8.8	59.0	32.3
1/9.0	0.0	8.8	61.0	30.3



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/10.5	0.0	9.7	60.2	30.1
1/12.0	0.0	9.2	59.9	30.9
1/13.5	0.0	9.1	60.3	30.5



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
1/15.0	0.0	8.9	60.7	30.4

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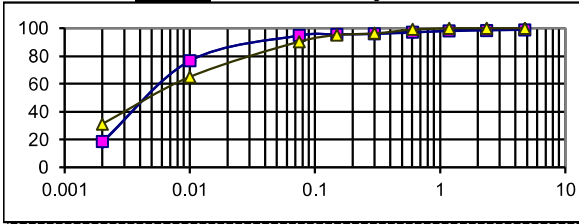
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Job No. - 25110

Appendix - C1

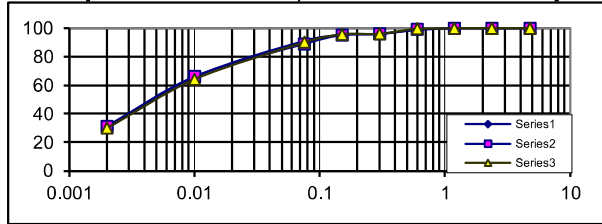
**Report on Sub Soil Investigation for the proposed C/O
GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)**

Table : Grain Size Analysis Results

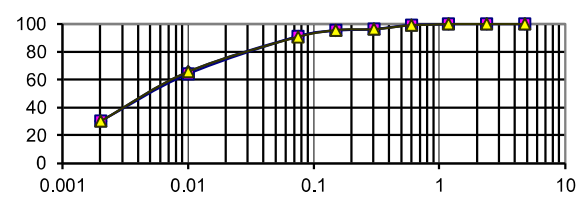


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/1.5	0.1	5.1	76.8	18.0
2/3.0	1.0	4.2	76.2	18.6
2/4.5	0.0	9.5	59.2	31.3

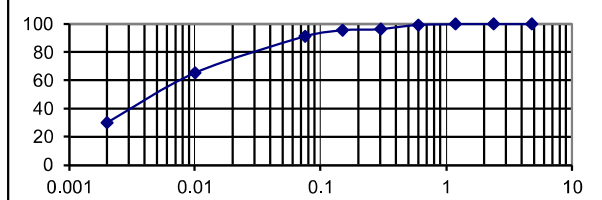
[for Bore hole No./ Depth in m shown thus: 2/1.5]



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/6.0	0.0	8.8	61.1	30.1
2/7.5	0.0	10.8	58.0	31.3
2/9.0	0.0	9.8	60.0	30.3



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/10.5	0.0	8.8	61.0	30.3
2/12.0	0.0	8.8	60.8	30.4
2/13.5	0.0	9.1	60.3	30.6



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
2/15.0	0.0	8.8	61.1	30.2

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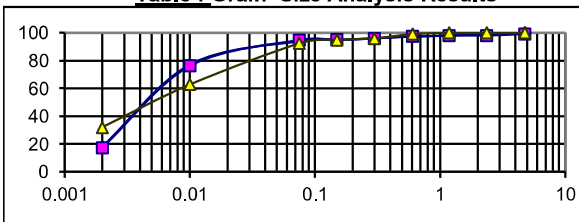
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Appendix - C2

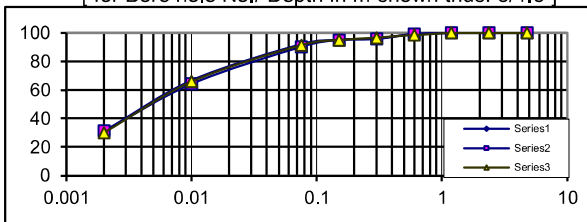
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Table : Grain Size Analysis Results

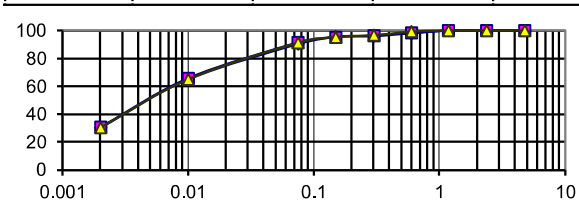


BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/1.5	0.0	5.8	75.9	18.3
3/3.0	0.7	4.3	77.4	17.6
3/4.5	0.0	7.4	60.4	32.3

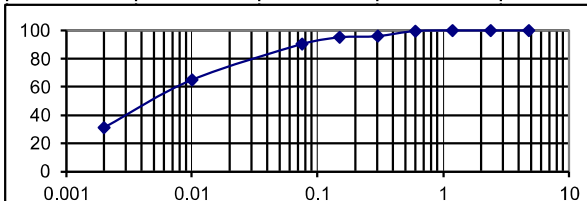
[for Bore hole No./ Depth in m shown thus: 3/1.5]



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/6.0	0.0	7.8	61.2	31.0
3/7.5	0.0	9.8	59.0	31.3
3/9.0	0.0	8.5	61.3	30.2



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/10.5	0.0	9.7	60.1	30.3
3/12.0	0.0	8.5	60.6	30.9
3/13.5	0.0	8.5	60.9	30.6



BH/depth,m	Gravel, %	Sand,%	Silt, %	Clay%
3/15.0	0.0	9.4	59.3	31.3

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Appendix - C3

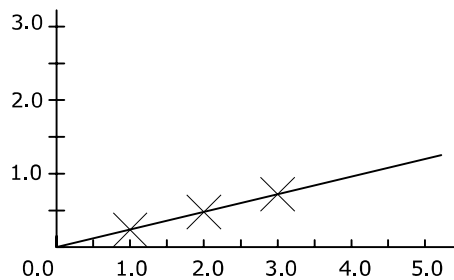
Sub- Soil Investigations For The Proposed C/O
GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)

Fig. Triaxial/Direct Shear Test Plots

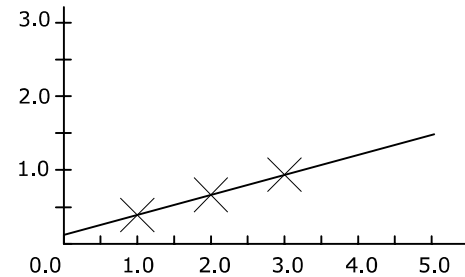
X- Axis Normal Stress (kg/cm^2)

Y- Axis Shear Stress (kg/cm^2)

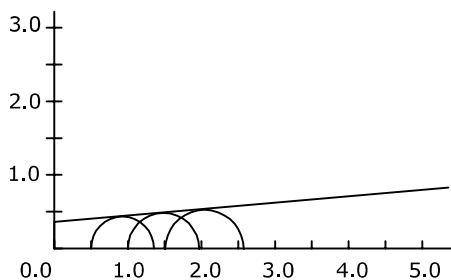
BH-1
Depth-1.5m
Cohesion- 0.09Kg/cm^2
Angle of Friction- 13.5°



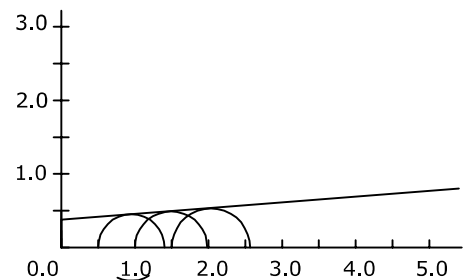
BH-1
Depth-3.0m
Cohesion- 0.12Kg/cm^2
Angle of Friction- 14.9°



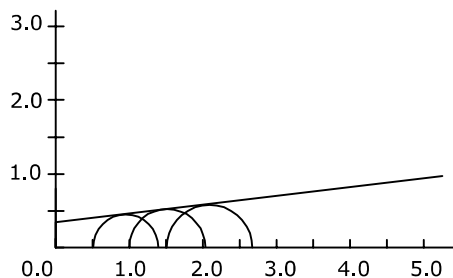
BH-1
Depth-4.5m
Cohesion- 0.36Kg/cm^2
Angle of Friction- 5.0°



BH-1
Depth-9.0m
Cohesion- 0.29Kg/cm^2
Angle of Friction- 6.1°



BH-1
Depth-15.0m
Cohesion- 0.34Kg/cm^2
Angle of Friction- 6.9°



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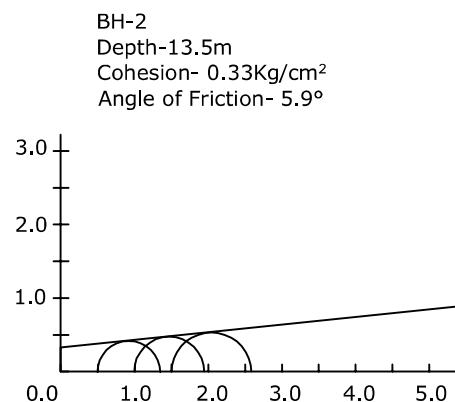
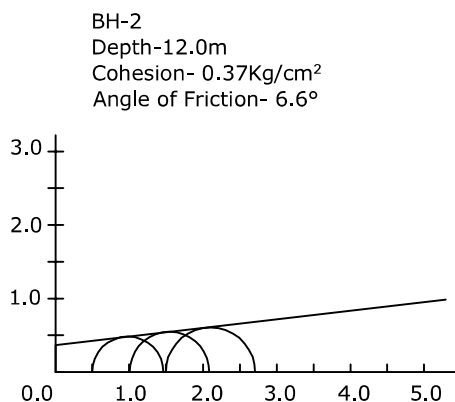
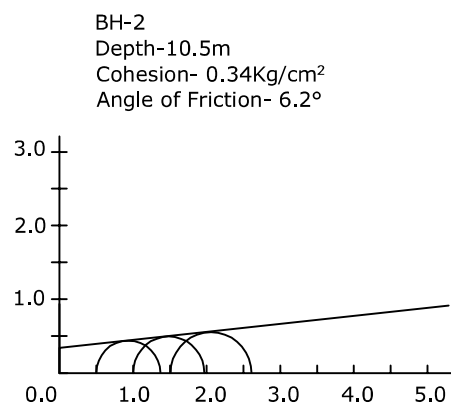
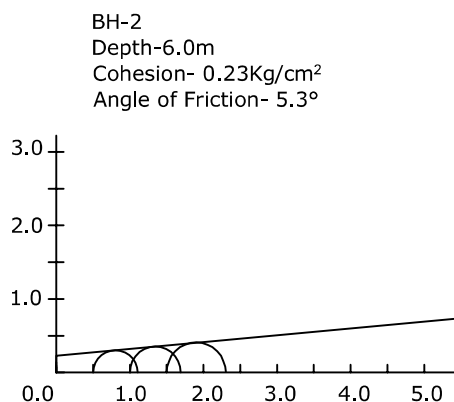
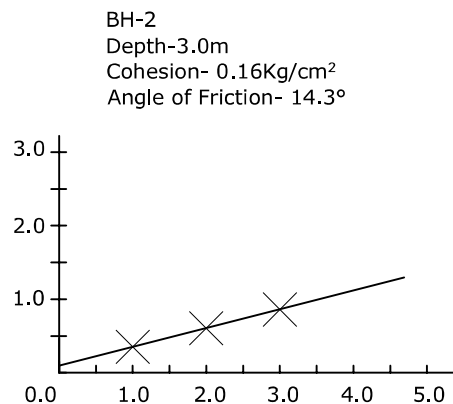
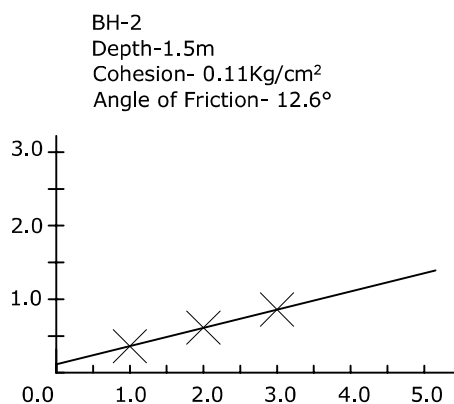
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Fig. Triaxial/Direct Shear Test Plots

X- Axis Normal Stress (kg/cm^2)

Y- Axis Shear Stress (kg/cm^2)



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Appendix - D2

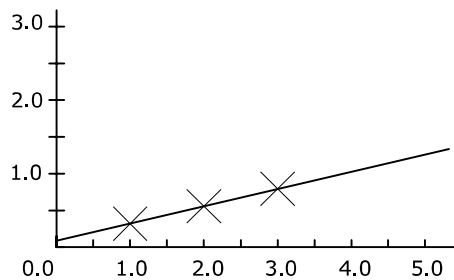
Sub- Soil Investigations For The Proposed C/O
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Fig. Triaxial/Direct Shear Test Plots

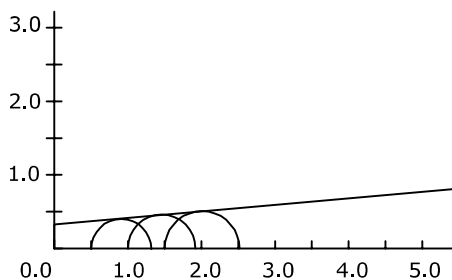
X- Axis Normal Stress (kg/cm^2)

Y- Axis Shear Stress (kg/cm^2)

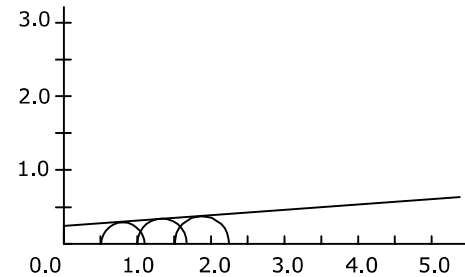
BH-3
Depth-1.5m
Cohesion- 0.11Kg/cm^2
Angle of Friction- 13.2°



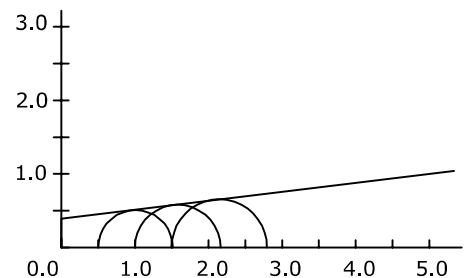
BH-3
Depth-9.0m
Cohesion- 0.33Kg/cm^2
Angle of Friction- 5.1°



BH-3
Depth-6.0m
Cohesion- 0.24Kg/cm^2
Angle of Friction- 4.2°



BH-3
Depth-9.0m
Cohesion- 0.39Kg/cm^2
Angle of Friction- 6.9°



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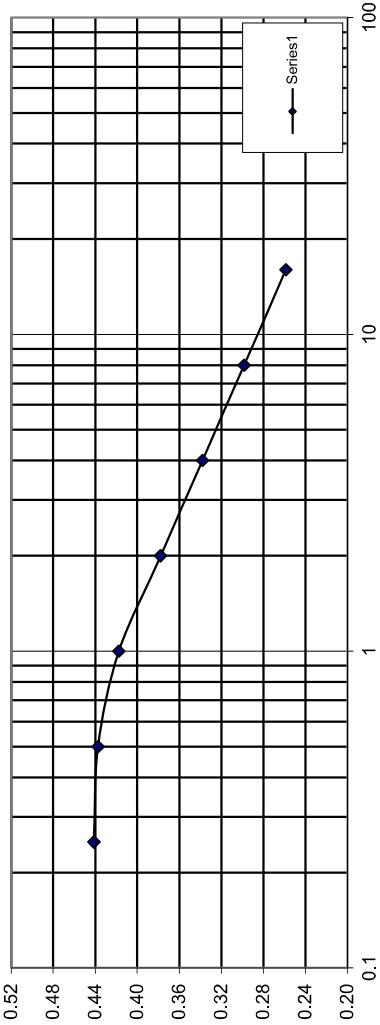
Appendix - D3

Fig. e - log p Plots from Consolidation Tests

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

Y-axis : Void ratio, e

BH No./	Cc	Initial V.R. e ₀	CURVE
Depth (m)			
1/4.5	0.132	0.4439	Series1



Report on Sub Soil Investigations for the Proposed Construction of **GIZ-NSP INDIA WASTE MANAGEMENT AT BAZAR SAMITI, PATNA (BIHAR)**

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].

} related to cohesion, surcharge and density of subsoil respectively

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	$d_c =$	$1 + 0.2 (N_f)^{0.5} D/B$	D_w at	G.L.	Fou'dn.Level
$s_q =$	1.2	1+0.2B/L	1	$d_q = d_\gamma =$	1	for	$f < 10^\circ$	$w =$ 0.5
$s_\gamma =$	0.8/0.6	1-0.4B/L	1	$d_q = d_\gamma =$	$1 + 0.1(N_f)^{0.5} D/B$		$f > 10^\circ$	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 = 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).

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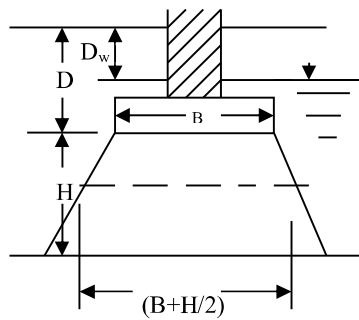
λ = correction factor

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

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



D_w = depth of water table below ground level.

D = depth of foundation

B = breadth of foundation

$H = 1.5 \times B$ = 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.

**Report on Sub Soil Investigations for the Proposed Construction of
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3. SAMPLE CALCULATION

Table A Calculation of Net Safe Bearing Capacity

NET SAFE BEARING CAPACITY IN SOIL, (IS-6403:1981)					
Length of Footing	L	=	2.0	m	
Width of Footing	B	=	2.0	m	
Depth of Footing	D	=	3.0	m	
Angle of shearing resistance, (ϕ) =		=	14.20		
Cohesion Value (C) =		=	1.10		
Bulk Density		=	1.91	t/m ³	
Type of shear failure		=	General shear failure		
Type of footing		=	Strip (Raft)		
Over burden pressure	q	=	(Y) x D	Y = 1.91	gm/cc
		=	5.73	t/m ²	
Bearing capacity factors, (From IS : 6403-1981, Table-1)					
	ϕ	Nc	Nq	N _γ	Radians
	14.2	10.49	3.65	2.36	0.25

Shape Factors (From IS : 6403-1981, Table-2)

Sc	Sq	Sg
1.30	1.20	0.80

Depth Factors & inclination Factors (From IS : 6403-1981, Clause-5.1.2.2 & Clause-5.1.2.3)

S_c =	1.3	1+0.2B/L	1	d_c =	1+0.2(Nf)^{0.5}D/B	dc =	1.386
S_q =	1.2	1+0.2B/L	1	d_q = d_γ =	1	for < 10°	dq = 1.193
S_g =	0.8	1-0.4B/L	1	d_q = d_γ =	1+0.1(Nf)^{0.5}D/B	f > 10°	dY = 1.193
for square/ O Rect. STRIP I_c, I_q, I_γ = 1 for vertical load							

Effect of water tables (From IS : 6403-1981 Clause -5.1.2.4)

D _w at	G.L.	Fou'dn.Level
w ₁ =	0.5	1
D _w at	Fou'dn.Level	> D+B
w ₂ =	0.5	1

In case of General shear failure ((Clause-5.1.2)

Net ultimate bearing Capacity (Considering Fully submerged condition)

$$q_{nf} = c N_c s_c d_c i_c + q (N_q - 1) s_q d_q i_q w_1 + 0.5 \gamma B N_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} w_2 \quad (t/m^2)$$

Term 1- c N_c s_c d_c i_c Term 2- q (N_q-1) s_q d_q i_q Term 3- 0.5 γ B N_γ s_γ d_γ i_γ w₂

20.78 9.069 1.07

$$q_{nf} = 30.92 \quad t/m^2$$

Net Ultimate bearing capacity = q_{nf} (From IS : 6403-1981, Table-3)

$$q_{nf} = 30.92 \quad t/m^2$$

$$\text{Net Safe bearing capacity (considering FOS = 3.0)} = 10.31 \quad t/m^2$$

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.

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Table B Calculation of Settlement

In the case of clay layers, the total settlement should be computed from									
$S_f = S_i + S_c$									
(where, S_i = Immediate Settlement, S_c = Consolidation settlement)									
a) Immediate Settlement									
$S_i = [q \times B \times I_f \times (1 - \mu^2) / E]$,									
Where, B = width of the loaded area or least lateral dimension									
E = elastic modulus or elasticity of soil									
μ = poisson's ratio									
I_f = influence factor depending on rigidity and shape of the loaded area.									
Immediate Settlement, $S_i =$ $q \times B \times I_f \times (1 - \mu^2) / E]$									
= 0.017 m									
b) Consolidation settlement									
The settlement is checked as per IS: 8009, Part 1.									
The settlement is calculated for bearing pressure = 10.3 T/m ²									
The consolidation settlement is given by,									
$S_c = [H_o \times C_c \times \log (1 + \Delta p / p_o)] / (1 + e_o)$									
The thickness of consolidable layer is considered to be 1.5 times the width of footing.									
For layer 1,	$C_c =$	0.132	$H_1 =$	3.0 m	(From the depth of footing)		$e_o =$	0.398	
Hence, Total consolidation settlement = 0.104 m									
Total Settlement = Immediate Settlement + Consolidation settlement									
= 0.121 m									
Now, considering depth factor = 0.85 (Ref, IS: 8009, Part 1)									
Rigidity factor = 0.8									
Pore water correction factor = 0.85 (As per table 1, for normally consolidated clays).									
Hence, Total consolidation = 60.197 mm (which is under permissible limit).									
So, allowable bearing pressure of soil considering both shear and settlement criteria, = 10.3 T/m ²									

