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Pile Foundation in High Water Table

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ABSTRACT:
A pile foundation is used where the bearing capacity of soil is low and the water table is high then the normal water table. The piles act as a resistance to improve the bearing capacity of soil and nowadays it is highly recommended for the construction of flyovers, bridges, buildings where the resistance of soil to the super imposed structure cannot withstand the loads acting on the soil so piles are used to make this capacity high and are either casted in-situ or already casted.

Deep foundations such as pile foundations can be chosen for a number of different reasons. In some cases, the sheer size of a building may dictate the use of a deep foundation because a shallow foundation could not support the building. The underlying ground can also be a factor, as some types of ground cannot support a building safely, and a deep foundation may be used to anchor a building to bedrock. Seismic activity is another thing which can influence foundation decisions, as earthquakes can be a safety concern.

There are two ways to install a concrete pile. One method involves drilling and casting on site. This is sometimes known as a “cast in situ” pile, because it is created on the construction site. The other method is pile driving, using a preformed pile which is driven into the earth sort of like a nail is driven into wood, except that a concrete pile is much, much larger than the average nail. Reinforced, prestressed, and precast concrete can all be used for piles which are driven.

Keywords: Pile Foundation, Field Investigation, Laboratory Investigation, Computation of Safe Bearing capacity

Introduction:
Pile foundations have been used as load carrying and load transferring systems for many years. Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Pipe piles can be either open-ended or close-ended. It has been documented that the behavior of open-ended piles is different from that of closed-ended piles. At the earlier time, the capacity of pile groups was taken as equal to the sum of the capacities of the individual piles. However, in practice, when piles are placed close to each other, the stresses transmitted to the soil through neighboring piles will overlaps, resulting in a considerable change of the group capacity .According to the field test results of Szechy (1959), the blow count necessary for driving a pile to a certain depth in sands is lower for an open-ended pile than for a closed-ended pile. Thus, it is generally acknowledged that an open-ended pile requires less installation effort than a closed-ended pile under the same soil conditions

FOUNDATION DESIGN PARAMETERS

The results of field investigations/SPT and laboratory investigations have been employed for determination of Safe Bearing Capacity at various depth intervals at the proposed construction site. The SBC of the stratum has been evaluated on the basis of:

1. Shear Strength Criterion (IS-code procedure): considering Local Shear Failure criterion and un-drained conditions (for c- soil system).
2. Settlement Criterion (IS-code procedure): restricting maximum probable static settlement at a given depth to Permissible/Limiting Settlement.
3. N-values, using (IS-code, International procedures and empirical methods, wherever applicable).
4. Based on UCS using empirical methods (wherever applicable).

4.1.1 COMPUTATION OF SAFE BEARING CAPACITY FOR WELL/PILE

Following preliminary parameters have been considered for SBC calculation.

a) Length to Breadth ratio of well foundation "L_w/B_f" = 1.0
b) Minimum width of foundation "$B_f=d_w$" = 6.0m to 8.0m.
c) Depth of Well foundation D_{wf}= variable
(Final Depth depends on bottom plugging depth chosen and in no case <2.5 d_w =20.0)
d) Limiting/Maximum Permissible Settlement δ_{max}=100 to 125mm
e) Min embedment of Well De≥25m
f) Based on Bierbaumer's & Terzaghi's Analysis for Soil arching effect,
No Arching Zone **D'_{NA}'>25.0m**
g) Considering No Soil arching effect, Minimum (conservative) effective overburden depth available **D_o''=25.0m.**
h) Minimum Pile Diameter D_p=1.0m to 1.2m (Bored cast in-situ pile)
i) Minimum Length of Pile L_p= 25m to 30m (Based on initial theoretical estimate of working loads).
j) Critical Depth of Pile L_c= 15D (for **φ≤30**□) = 18m <D_o' (OK).
k) For Bored cast in-situ piles, it has been strictly assumed that the bottom of the hole iscleaned thoroughly by continuous mud circulation.
l) At rest coefficient of EP: K_o=(1-Sin φ), K/K_o = 0.7 to 1.5 for Bored cast in-situ pilebased on method of installation.
m) Addition factor " α" has been chosen based on soil denseness/consisten cy/N-Values.
n) Angle of Wall friction "δ"= 0.67(φ).
o) Ultimate base resistance for bored cast in-situ piles has been restricted to 1000t/m^2.
p) Limiting side friction in sands has been restricted to 6.0t/m^2.
q) Limiting value of adhesion in silt-clays has been restricted to 7.0t/m^2
r) Factor of Safety = 1.5 for pile side-friction.
s) Factor of Safety = 3.0 for SBC/Base Resistance (Based on Structure ImportanceFactor).

(BIS recommends a value of 2.5 as factor of safety to obtain the net safe bearing capacity q_{ns}byusing the physical characteristics of the foundation and relevant shear strength parameters of the soil. However, for very loose or soft soils higher factor of safety may be used as per rational discretion).

Methodology:
Bore log, Bearing Capacity, Shear Failure and other tests on piles.

Bore Log Test

TABLE-1(a) BORE LOG

FIELD BORE LOG FOR SUBSURFACE EXPLORATION							Dated: 18-07-13 Job No: 1 Sheet 1 of 8
PROJECT: Construction of Flyover/Elevated Bridge Structure/ Express-Way Corridor.							CLIENT: ERA, through SIMPLEX Infrastructure Limited.
Site / Location: Jahangir Chowk to Rambagh, Srinagar, Kashmir (J&K)							Borehole No: BH-1, RD:1200 Boring Diameter: 150mm
GPS Marking: N 34° 03' 37.3" E 74° 48' 08.9"							Target/Intended Boring Depth: 40m
Boring Type: Auger/ Wash (DS)							Sampling Type: Standard Split Spoon (With SPT)/ UDS
Soil/Rock Classification System: IS							Elevation Reference: NSL (+0.00)
Seepage water encountered at: NIL (m)							Ground water encountered at: 2.50 (m) below EGL
Depth interval below NSL (m)	Blow Count (45cm Penetration) 0-15cm	15-30cm	30-45cm	SPT values (N)	(VISUAL IDENTIFICATION) For TYPE- DS/UDS samples Approximate description of disturbed bored material (Soil colour, Consistency, Grain size, Compressibility etc.)	Remarks	PENETRATION RESISTANCE CHART (Not to scale) 5 10 15 20 40 60
1.5m 3.0m	1	1	2	3	Brown Silt/silt-clay soil of soft consistency and compressible nature.	90% silt-clay, <5% sand, 5% OM	
3.0m 4.5m	1	2	2	4	Brownish Grey silt/silt-clay soil of soft consistency, with little sand intrusions.	90% silt-clay, 10% sand	
4.5m 6.0m	1	3	5	8	Grey silt-clay soil of medium consistency.	95% silt-clay, <5% sand	
6.0m 7.5m	3	9	12	21	Grey silty fine to medium sand of overall medium to dense nature.	20% silt-clay, >80% sand	
7.5m 9.0m	3	10	13	23	Grey fine to medium sand of overall medium to dense nature.	15% silt-clay, >85% sand	
9.0m 10.5m	5	7	9	16	Grey silty fine to medium sand of overall medium dense nature.	40% silt-clay, >60% sand	
10.5m 12.0m	4	8	10	18	Grey silty soil with OM and fine sand intrusions of overall medium to stiff consistency.	75% silt-clay, <5% sand, 20% OM	
12.0m 13.5m	1	0	3	3	Dark-Blackish Grey silt-clay soil of overall soft consistency, with decomposed organic matter.	65% silt-clay, 5% sand, 30% OM	
13.5m 15.0m	1	2	1	3	Dark Grey silt-clay/clayey-silt soil of overall soft consistency, with decomposed organic matter.	45% silt-clay, 5% sand, 50% OM	
15.0m 16.5m	1	3	6	9	Grey silt-clay/clayey-silt soil of overall medium soft consistency, with decomposed organic matter.	80% silt-clay, 5% sand, 15% OM	
18.0m 21.0m	3	4	5	9	Dark-Blackish Grey silt-clay soil with compressible/decomposed peat of overall soft consistency.	55% silt-clay, 5% sand, 40% OM/Peat	

SPT Tests

STANDARD CORRECTIONS FOR SPT *N-values*

Depth below Reference Level (m)	Observed N-Values BH-1	STANDARD CORRECTIONS				Observed N-Values BH-2	STANDARD CORRECTIONS				Observed N-Values BH-3	STANDARD CORRECTIONS				Observed N-Values BH-4	STANDARD CORRECTIONS			
		N'	N''	N_{70}	N-Value avg		N'	N''	N_{70}	N-Value avg		N'	N''	N_{70}	N-Value avg		N'	N''	N_{70}	N-Value avg
1.5m	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	6	6	6	6	6
3.0m	4	4	4	4	4	3	3	3	3	3	4	4	4	4	3	3	3	3	3	5
4.5m	8	8	8	8	5	12	12	12	13	6	0	0	0	0	2	7	7	7	7	6
6.0m	21	21	18	19	9	11	11	11	12	8	5	5	5	5	3	12	12	12	13	7
7.5m	23	23	19	20	11	< 10	10	10	11	8	5	5	5	5	3	4	4	4	4	7
9.0m	16	16	16	16	12	8	8	8	8	8	6	6	6	6	4	9	9	9	9	7
10.5m	18	18	17	17	13	11	11	11	12	9	5	5	5	5	4	8	8	8	8	7
12.0m	3	3	3	3	11	10	10	10	11	9	7	7	7	7	4	9	9	9	9	8
13.5m	3	3	3	3	11	11	11	11	12	9	<5	5	5	5	4	6	6	6	6	7
15.0m	9	9	9	9	10	11	10	10	11	9	9	9	9	9	5	7	7	7	7	7
18.0m	9	8	9	9	10	36	32	24	25	11	22	20	17	18	6	11	10	10	11	8
21.0m	20	17	16	17	11	23	19	17	18	11	11	9	9	9	6	9	8	8	8	8
24.0m	40	32	23	25	12	36	29	22	23	12	12	10	10	11	7	18	14	14	15	8
27.0m	14	11	14	15	12	40	30	23	24	13	30	23	19	20	8	16	12	12	13	9
30.0m	16	12	13	14	12	40	29	22	23	14	20	14	14	15	8	13	9	9	9	9
33.0m	60	41	28	30	13	67	46	31	32	15	41	28	22	23	9	17	12	12	13	9
36.0m	39	26	20	21	14	61	40	28	29	16	48	32	23	25	10	44	29	22	23	10
39.0m	R	R	R	R	R	23	15	15	16	16	31	20	17	18	10	46	29	22	23	11
Representative Cum Average N-value		BH-1		14		BH-2			16		BH-3			10		BH-4			11	

Hydrometer/ Sedimentation Analysis

TYPICAL HYDROMETER/ SEDIMENTATION ANALYSIS									
Borehole No: BH-I			Depth: 4.5m			Sample No:S3			
Soil Type : Silt-clay			Sample weight : 50gr			Specific Gravity: 2.64			
S.No	Elapsed time (t)	Hydrometer Reading Rh'	Temperature (°C)	Corrected Hydrometer reading (Rh)	Effective Height (He) cm	(He/t)%	Particle Size D (mm)	Particle Size D (μ)	Percentage finer (N)
1	0.5min	1.0275	28.7	1.0280	9.30	4.31	0.0529	52.9	86.77
2	1 min	1.0250	28.7	1.0255	10.18	3.19	0.0391	39.1	79.02
3	2 min	1.0215	28.7	1.0220	11.40	2.39	0.0293	29.3	68.18
4	4 min	1.0170	28.5	1.0175	12.98	1.80	0.0221	22.1	54.23
5	8 min	1.0105	28.5	1.0110	15.25	1.38	0.0170	17.0	34.09
6	15 min	1.0040	28.0	1.0045	17.53	1.08	0.0134	13.4	13.95
7	30 min	1.0015	28.2	1.0020	18.40	0.78	0.0097	9.70	6.20
8	1 hr	1.0005	29.5	1.0010	18.75	0.56	0.0068	6.80	3.10
9	2 hrs	1.0000	30.4	1.0005	18.93	0.40	0.0048	4.80	1.55
10	4 hrs	1.0000	29.0	1.0005	18.93	0.28	0.0034	3.40	1.55
11	8hrs	1.0000	29.0	1.0005	18.93	0.20	0.0024	2.40	1.55

TYPICAL WET ANALYSIS (Particle size >75μ)					
Borehole No: BH-I	Depth: 4.5m		Sample No:S3		
Soil Type : Silt-clay	Sample weight : 900gr		Specific Gravity: 2.64		
S.No	Sieve Size	Wt. Ret (gr)	%age Retained	Cum. %age Ret.	%age finer N
1	80.0mm	0	0.00	0.00	100
2	20.0mm	0	0.00	0.00	100
3	10.0mm	0	0.00	0.00	100
4	4.75mm	0	0.00	0.00	100
5	2.36mm	1.23	0.14	0.14	100
6	1.0mm	3.06	0.34	0.48	100
7	600μ	1.53	0.17	0.65	99
8	425μ	1.62	0.18	0.83	99
9	212μ	4.86	0.54	1.37	99
10	150μ	3.27	0.36	1.73	98
11	75μ	12.18	1.35	3.08	97

Particle Size and Hydrometer Calibration Plot

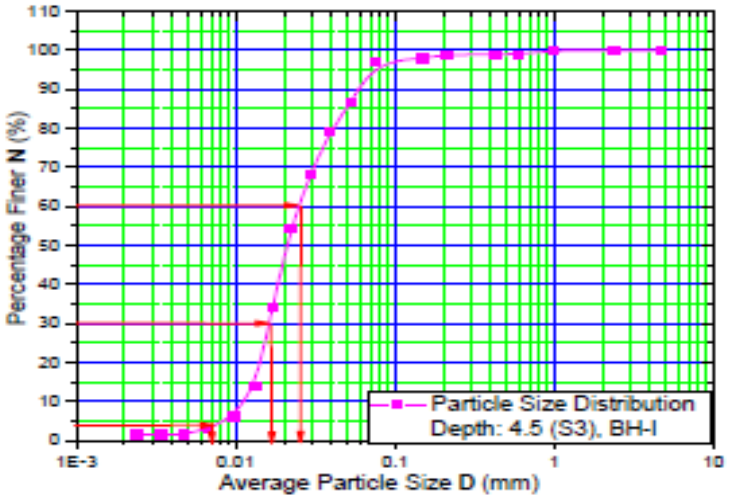


Fig-1: Typical combined PSD curve (S3-BH-1).

(Uniform Graded within the range indicated above)

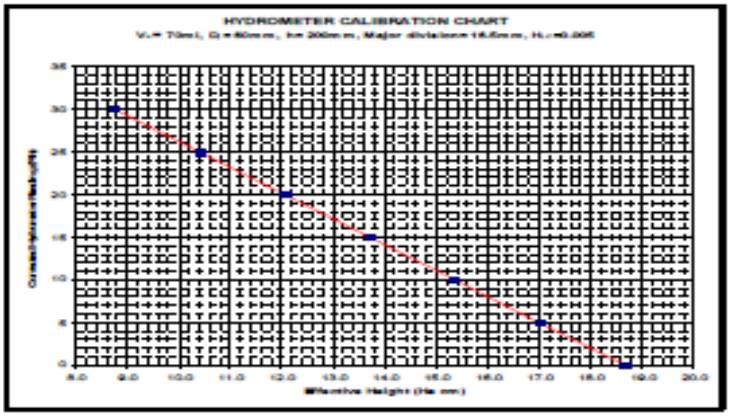
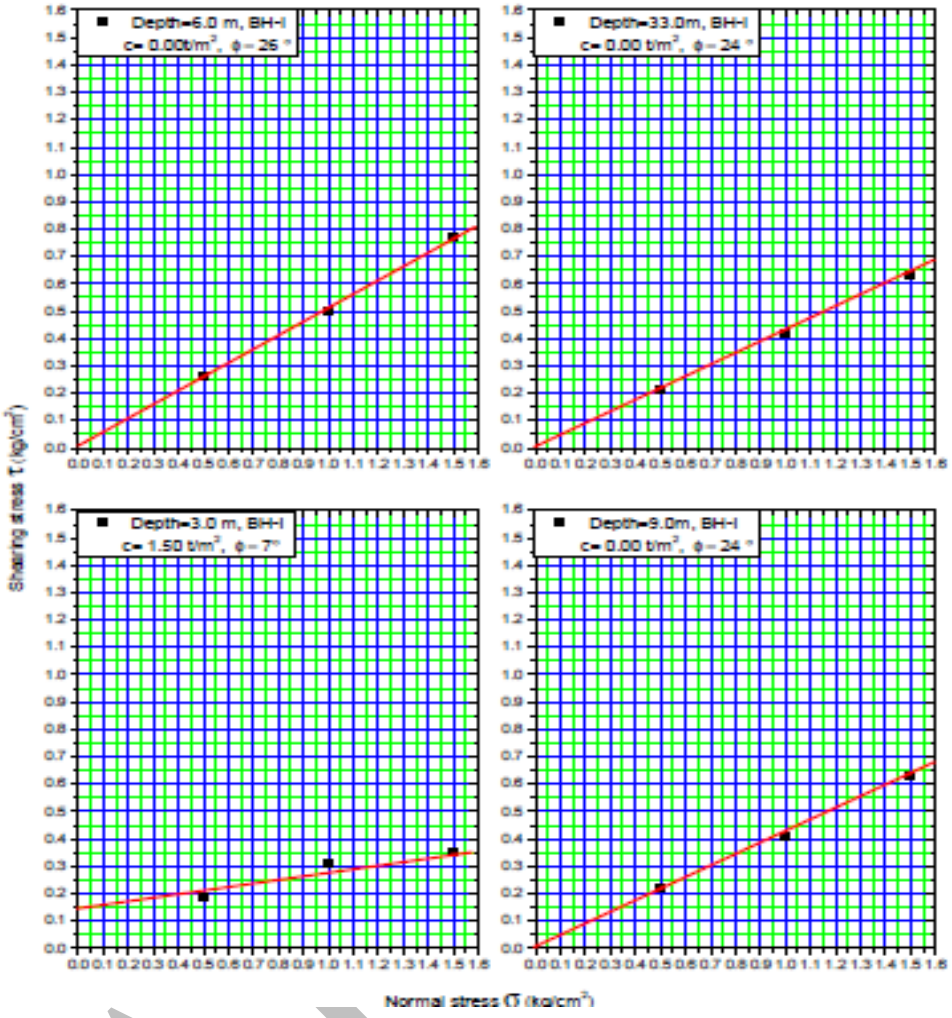


Fig-2: Hydrometer Calibration Plot (H2)

Typical Shear Failure Envelope At Various Depths



Bearing Capacity

TABLE-5(b) DEPTH WISE BEARING CAPACITY EVALUATION- *BH-2 (RD-1825)*

Based on Shear Parameters (IS-Method)
For Well foundation (D=6.0 to 8.0m minimum)

Depth (m)	N-Values (N_{70})CORRECTED	Bearing Capacity factors *c-ϕ soils* Limiting Values N_c	N_q	N_γ	Shape Factors Conservative Criterion S_c	S_q	S_γ	Depth Factors d_c	$d_q = d_\gamma$	NUBC t/m²	SBC t/m^2 (FOS=3)	Based on N_{70} cumava FOR WELLS (IS-Method) SBC t/m²	Based on Probable Static Settlement Criterion (I.S-Method-δ_{max} =100mm) SBC t/m²	RECOMMENDED/ AVERAGE SBC(t/m²)	Theoretical Pile Capacity (Subjected to Initial Pile Load Test Confirmation)
1.5	3	6.81	1.72	0.57	1.00	1.00	0.60	1.00	1.00	7.39	5.18	Applicable only for Wells sunk within predominantly Granular Soils/Sands/Non-Plastic Silts	3.30	4.24	For Pile of minimum D_o=1.2m, L_o= 30m, Theoretical Maximum Safe Load Capacity of 130.0 MT to 156.0 MT has been estimated.
3.0	3	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	10.28	8.83		4.02	6.42	
4.5	13	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	13.13	12.51		4.97	8.74	
6.0	12	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	13.93	15.41		5.23	10.32	
7.5	11	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	15.03	18.51		6.12	12.32	
9.0	8	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	16.89	21.92		6.80	14.36	
10.5	12	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	20.04	25.49		8.03	16.76	
12.0	11	7.53	2.06	0.86	1.00	1.00	0.60	1.00	1.00	19.97	28.07		9.09	18.58	
13.5	12	7.53	2.06	0.86	1.00	1.00	0.60	1.00	1.00	18.66	30.21		9.26	19.74	
15.0	11	7.16	1.88	0.71	1.00	1.00	0.60	1.00	1.00	21.68	33.93		9.93	21.93	
18.0	25	7.53	2.06	0.86	1.00	1.00	0.60	1.00	1.00	22.81	39.76		13.03	26.40	
21.0	18	7.92	2.25	1.03	1.00	1.00	0.60	1.00	1.00	25.69	46.03		9.93	27.98	
24.0	23	8.35	2.47	1.22	1.00	1.00	0.60	1.00	1.00	33.26	53.90		12.34	33.12	
27.0	24	8.35	2.47	1.22	1.00	1.00	0.60	1.00	1.00	28.63	57.17		12.20	34.69	
30.0	23	8.35	2.47	1.22	1.00	1.00	0.60	1.00	1.00	30.56	62.81		14.45	38.63	

NOTE-1: NUBC: Net Ultimate Bearing Capacity
SBC: Safe Bearing Capacity

NOTE-2: a) Water table corrections applied in evaluation of bearing capacity.
b) Conservative values of bearing capacity factors used for calculation.

All the test are done according to borehole-1 (BH-1)