Soil Characteristics and Its Behavior in the Lower Flood Plain of River Daya in Odisha, India

T.K. Lohani¹ and K.P. Dash²

¹, ² Department of Civil Engineering, Orissa Engineering College, Bhubaneswar, Odisha, India

Correspondence should be addressed to Lohani T.K., tklohani@gmail.com

Publication Date: 19 February 2013


Abstract The river bank of Daya in the S-E of the state of Odisha is presently mushrooming with constructions and infrastructural developments. Since the region is devoid of solid and hard rock basement, it has become a matter of concern for the technocrats and architects to provide suitable and stabilized foundations for those upcoming massive structures. The present study reflects the complex behavior of the soil parameters whose index and engineering properties have been determined strictly based on Indian Standard codes. The lithological variation of the land shows the entire region is spread by a thick blanket of clayey soil having high porosity with less permeability generating a swampy land throughout the year. But fortunately at a shallow to deep the stratum is defined by a compact, hard and impervious lateritic bed that gives ample support for a safe and stable foundation. Due to this, selection of foundation for construction purpose has become a challenging job. In the present research two nos. of boreholes were drilled up to 10m NGL, laboratory experiments were conducted and soil parameters were determined. From the various studies of soil it was found that clayey sand, sandy clay and thick blanket of clay pre-dominates the study area. Load bearing structures are completely unfavorable on such type of soil. Due to expansive nature of soil, deep foundation/pile foundation is suggested.

Keywords SPT, UDS, Borehole Logs, Shear Strength, Safe Bearing Capacity

1. Introduction

The coastal alluvium forms unconsolidated material of which the study area is a part of that. These formations composed of sand, gravel, silt, clay and laterite. It has extensive unconfined and confined zone down to 150m - 300m. This zone is underlain by the Mahanadi graben extending in a NW-SE direction. The physical and index parameters of soil under the study area with an aerial extension of around 120km² are completely dependent on the percolation and penetration of surface and groundwater. As the water of Daya is comparatively sweeter it may be assessed that impact of saline environment is too negligible on the soil characters. The spectacular hydrogeological set up of the study area owes to the varied geomorphic and geological set up which controls the physical and chemical behavior of the soil strata. Geotechnical parameters at various depths of soil strata along the
river Daya is alarming. The primary reason behind the variation is the impact of coastal environment, rapid growth of population, abandonment of agricultural lands and conversion of cultivable lands to infrastructural projects. Stratigraphic, lithologic and geomorphic set ups partially control the performance of soil. The annual rainfall in the area also varies considerably from year to year which affects the physico-chemical characteristic of soil and its strength parameters. Large number of central and state level organizations has been setup to investigate the soil strength in district and block level to meet the requirement for infrastructural development but still remarkable work is lacking.

The study area which extends from Sundarpada under Bhubaneswar Municipal Corporation to Harirajpur block of Khurda district a stretch of 12.3km locates between the latitude of 20°08’ to 20°29’ and longitude 85°044’ to 85°073’ constituting the part of Khurda district has its own importance due to massive infrastructural growth, mushrooming educational institutes and high rise apartments. The scope of work comprises of conducting detail soil investigation, laboratory testing, conducting and estimation of safe bearing capacity for the proposed work on drilling two nos. of boreholes.

2. Methodology

The methods of investigation consist of visual reconnaissance, drilling of boreholes, laboratory experiments and determination of soil parameters and analysis of the results. The field borehole drillings are extended up to 10m below Natural Ground Level (NGL) or refusal. This is followed by collection of UDS samples as per [4] and finally the soil samples are transported to the Civil engineering laboratory of Orissa Engineering College. The bulk density, moisture content, grain size analysis, shear strength, liquid limit, plastic limit, specific gravity, DFS, water absorption, porosity and density of the samples are determined in the laboratory [11]. For detailed laboratory investigation SPT is conducted at 1.5m intervals or at change of soil strata in different boreholes. Disturbed soil samples from both the boreholes were collected at 1.5m SPT tests were conducted as [2] and [3] respectively in different levels at the boreholes in a continuous manner using spilt-spoon samplers. The SPT sampler was lowered inside the borehole after drilling the required level and is driven by a 63.50kg hammer with a free fall of 750mm driving 450mm in three stages 150mm each and the number of blows for each 150mm penetration for 2nd and 3rd 150mm drive recorded as “N”. Refusal is considered for N>100. In the course of drilling groundwater was encountered at a depth of 1.20m to 1.50m NGL.

3. Results and Discussion

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Borehole reference</th>
<th>Sample Depth (in m.)</th>
<th>Bulk density (gm/cc)</th>
<th>Natural Moisture Content</th>
<th>Dry Density</th>
<th>Cohesion (Kg/cm²)</th>
<th>Angle of Internal Friction (in degrees)</th>
<th>Attenberg’s Limit (in %)</th>
<th>Void ratio</th>
<th>DFS (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BH-1, SPT-1</td>
<td>1.5 1.81</td>
<td>18.2 1.53</td>
<td>xxxx xxxx</td>
<td>35 21 14</td>
<td>2.69</td>
<td>0.757 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BH-1, SPT-2</td>
<td>3 1.81</td>
<td>18.5 1.53</td>
<td>xxxx xxxx</td>
<td>34 21 13</td>
<td>2.69</td>
<td>0.761 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BH-1, SPT-3</td>
<td>4.5 1.81</td>
<td>18.7 1.52</td>
<td>xxxx xxxx</td>
<td>34 21 13</td>
<td>2.69</td>
<td>0.764 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>BH-1, UDS-1</td>
<td>6 1.82</td>
<td>19.6 1.52</td>
<td>0.41 7</td>
<td>45 24 21</td>
<td>2.69</td>
<td>0.768 35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>BH-1, SPT-4</td>
<td>7.5 1.82</td>
<td>19.4 1.52</td>
<td>xxxx xxxx</td>
<td>44 24 20</td>
<td>2.69</td>
<td>0.765 35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BH-1, UDS-2</td>
<td>9 1.83</td>
<td>19.1 1.54</td>
<td>xxxx xxxx</td>
<td>45 24 21</td>
<td>2.69</td>
<td>0.751 32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>BH-1, SPT-5</td>
<td>10 1.83</td>
<td>19.2 1.54</td>
<td>xxxx xxxx</td>
<td>45 24 21</td>
<td>2.69</td>
<td>0.752 32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>BH-2, SPT-1</td>
<td>1.5 1.8</td>
<td>18.3 1.52</td>
<td>xxxx xxxx</td>
<td>36 22 14</td>
<td>2.69</td>
<td>0.768 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>BH-2, SPT-2</td>
<td>3 1.8</td>
<td>18.7 1.52</td>
<td>xxxx xxxx</td>
<td>35 21 14</td>
<td>2.69</td>
<td>0.774 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>BH-2, SPT-3</td>
<td>4.5 1.81</td>
<td>18.9 1.52</td>
<td>xxxx xxxx</td>
<td>35 21 14</td>
<td>2.69</td>
<td>0.767 20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Result of different properties from different boreholes
The result of different properties of soil samples in the study area is shown in Table 1.

### A. Calculation of Safe Bearing Capacity from Strength Parameters (SPT Values)

<table>
<thead>
<tr>
<th>Borehole No-1</th>
<th>At 1.50m</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH-2, UDS-1</td>
<td>6.00</td>
</tr>
<tr>
<td>BH-2, SPT-4</td>
<td>7.50</td>
</tr>
<tr>
<td>BH-2, UDS-1</td>
<td>9.00</td>
</tr>
<tr>
<td>BH-2, SPT-5</td>
<td>10.00</td>
</tr>
</tbody>
</table>

**Square Footing**
- Field SPT Value N = 6
- Overburden Pressure = 0.271 kg/cm² [3]
- Dilatancy Factor, the corrected SPT Value N’ = 6 [3]
- Taken corresponding C = 0.00 kg/cm²
- Angle of shearing resistance value Φ for zone = 28 degrees
- Size of Footing = 2m X 2m.
- Cohesion C = 0.00 kg/cm² [7]
- Angle of Shearing resistance Φ = 28 degree [8]
- Φ’ = 19 degree [9]
- Specific Gravity Gs = 2.69 (IS: 2720-1980, Part III)
- Void ratio e = 0.757 [7]
- Bulk density γ = 1.810 g/cc [5]
- Depth of foundation Df = 1.50 m
- Assuming width of footing B = 2.00 m
- Q = (Df x γ)/10 = 0.271 kg/cm²
- Bγ = (B x γ)/10 = 0.3620 kg/cm²

**Bearing Capacity Factors**

<table>
<thead>
<tr>
<th>Φ &amp; Φ’</th>
<th>Nc &amp; Nc’</th>
<th>Nq &amp; Nq’</th>
<th>Ny &amp; Ny’</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>26.372</td>
<td>15.304</td>
<td>17.792</td>
</tr>
<tr>
<td>19</td>
<td>14.06</td>
<td>5.908</td>
<td>4.842</td>
</tr>
</tbody>
</table>

**Shape Factors**

| Sc = 1.3 | Sq = 1.2 | Sy = 0.8 |

**Depth Factors & Inclination Factors**

| dc = 1 + 0.2 X (Df/B) X tan (45 + Φ/2) = 1.25 |
| dp = dc - 1.125 |
| ic = iq = 1 |

**Effect of Water Tables**

| w’ = 0.5 |

**In Case of Local Shear Failure for Circular Footing**

Qd’ = q (Nq’ - 1)Scdpd + 0.5 BγNγdγ

= 1.796 + 0.394

= 2.190 kg/cm²

**Ultimate Bearing Capacity Obtained from Interpolation**

Qd = 2.190 kg/cm²

**Net Safe Bearing Capacity Considering Factor of Safety of 3**

NSBC = 7.30 T/m²
B. Calculation of Safe Bearing Capacity from Strength Parameters (SPT Values)

(At 3.00m)  Borehole No. 1

Square Footing  Depth of foundation = 3.00m
Field SPT Value N = 8
Overburden Pressure  0.542 kg/cm² [3]
Dilatancy Factor, the corrected SPT Value N’ 8 [3]
Taken corresponding C= 0.00 kg/cm²
Angle of shearing resistance value Φ for zone = 28 degrees
Size of Footing = 2m X 2m
Cohesion C =
Angle of Shearing resistance Φ = 28 degree
Φ′ = 19 degree

Specific Gravity Gs =
Void ratio e = 0.761
Bulk density γ =
Depth of foundation Df = 3.00 m
Assuming width of footing B = 2.00 m
Q = (Df X (γ))/10
Bγ = (Bxγ)/10

Bearing Capacity Factors [1]
Φ & Φ’  Nc & Nc’  Nq & Nq’  Ny & Ny’
28  6.372  15.304  17.792
19  4.06   5.908   4.842

Shape Factors [1]
Sc = 1.3  Sq = 1.2  Sv = 0.8

Depth Factors & Inclination Factors [1]
dc = 1 + 0.2 X (Df/B) X Tan (45 + Φ/2) = 1.499
dc = dc = 1.25
ic = iq = iv = 1

Effect of Water Tables [1]
w’ = 0.5

In case of Local Shear Failure for Circular Footing [1]
Qd’ = q (Nq’ - 1)Scdcq + 0.5 BγNγSγNγSγW
= 3.99 + 0.438
= 4.428 kg/cm²

Ultimate Bearing Capacity Obtained from Interpolation = Qd [1]
Qd = 4.428 kg/cm²

Net Safe Bearing Capacity Considering Factor of Safety of 3 = 1.476 kg/cm²
=> SBC = 14.76 T/m²

C. Calculation of Safe Bearing Capacity from Strength Parameters (SPT Values)

(At 1.50m)  Borehole No-2

Square Footing  Depth of Foundation = 1.50m
Field SPT Value N = 2
Overburden Pressure \(0.270\) kg/cm\(^2\) [3]
Dilatancy Factor, the corrected SPT Value \(N'\) \(2\) [3]
Taken corresponding \(C=\) \(0.00\) kg/cm\(^2\)
Angle of shearing resistance value \(\Phi\) for zone = \(28\) degrees
Size of Footing = 2m. X 2m.
Cohesion \(C=\) \(0.00\) kg/cm\(^2\)
Angle of Shearing resistance \(\Phi=\) \(28\) degree
\(\Phi'=\) \(19\) degree
Specific Gravity \(G_s=\) \(2.69\)
Void ratio \(e=\) \(0.768\)
Bulk density \(\gamma=\) \(1.80\) g/cc
Depth of foundation \(D_f=\) \(1.50\) m
Assuming width of footing \(B=\) \(2.00\) m
\(Q = \frac{D_f X \gamma}{10}\) \(0.270\) kg/cm\(^2\)
\(B\gamma = \frac{(B\times\gamma)}{10}\) \(0.360\) kg/cm\(^2\)

<table>
<thead>
<tr>
<th>Bearing Capacity Factors [1]</th>
<th>(\Phi &amp; \Phi')</th>
<th>(Nc &amp; Nc')</th>
<th>(Nq &amp; Nc')</th>
<th>(Ny &amp; Ny')</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>26.372</td>
<td>15.304</td>
<td>17.792</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>14.06</td>
<td>5.908</td>
<td>4.842</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shape Factors [1]</th>
<th>(S_c = 1.3)</th>
<th>(S_q = 1.2)</th>
<th>(S_y = 0.8)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Depth Factors &amp; Inclination Factors [1]</th>
<th>(d_c = 1 + 0.2 X (D_f/B) X \tan (45 + \Phi/2) = 1.25)</th>
<th>(d_p = d_q = 1.125)</th>
<th>(i_c = i_q = i_y = 1)</th>
</tr>
</thead>
</table>

Effect of Water Tables [1]
\(w' = 0.5\)

In Case of Local Shear Failure for Circular Footing [1]
\(Qd' = q(Nq' - 1)S_dq,i_q + 0.5 \times B\gamma N_y N_{Sy} S_{Sy} W\)
\(= 1.789 + 0.392\)
\(= 2.181 \) kg/cm\(^2\)

Ultimate Bearing Capacity Obtained from Interpolation = \(Qd\) [1]
\(Qd = 2.181 \) kg/cm\(^2\)

Net Safe Bearing Capacity Considering Factor of Safety of \(3 = 0.727 \) kg/cm\(^2\)
\(\Rightarrow\) NSBC = 7.27 T/m\(^2\)

D. Calculation of Safe Bearing Capacity from Strength Parameters (SPT Values)

<table>
<thead>
<tr>
<th>(At 3.00m)</th>
<th>Borehole No-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Footing</td>
<td>Depth of Foundation = 3.0m</td>
</tr>
<tr>
<td>Field SPT Value (N=)</td>
<td>4</td>
</tr>
<tr>
<td>Overburden Pressure</td>
<td>(0.540 ) kg/cm(^2)  IS: 2131-1981, Clause 3.6.1</td>
</tr>
<tr>
<td>Dilatancy Factor, the corrected SPT Value (N'=)</td>
<td>(2)  IS: 2131-1981, Clause 3.6.1</td>
</tr>
<tr>
<td>Taken corresponding (C=)</td>
<td>(0.00 ) kg/cm(^2)</td>
</tr>
<tr>
<td>Angle of shearing resistance value (\Phi) for zone =</td>
<td>(28) degrees</td>
</tr>
</tbody>
</table>
Size of Footing = 2m X 2m
Cohesion C = 0.00 kg/cm²
Angle of Shearing resistance Φ = 28 degree
Φ’ = 19 degree
Specific Gravity Gs = 2.70
Void ratio e = 0.774
Bulk density γ = 1.80 g/cc
Depth of foundation Df = 3.00 m
Assuming width of footing B = 2.00 m
Q = (Df X γ)/10
Bγ = (Bxγ)/10

Bearing Capacity Factors [1]

Φ & Φ’
Nc & Nc’
Nq & Nq’
Ny & Ny’
28
26.372
15.304
17.792
19
14.06
5.908
4.842

Shape Factors [1]
Sc =1.3
Sq =1.2
Sy = 0.8

Depth Factors & Inclination Factors [1]
dc = 1 + 0.2 X (Df/B) X tan (45 + Φ/2) = 1.499
dp = dc = 1.25
ic = iq = ic = 1

Effect of Water Tables [1]
w’ = 0.5

In Case of Local Shear Failure for Circular Footing [1]
qd’ = q (Nq’ - 1)Sqdq + 0.5 BγNySdγdγ
= 3.975 + 0.436
= 4.411 kg/cm²

Ultimate Bearing Capacity Obtained from Interpolation = Qd [1]
Qd = 4.411kg/cm²

Net Safe Bearing Capacity Considering Factor of Safety of 3 = 1.47 kg/cm²
=> NSBC = 14.70 T/m²

Design of Pile Foundation
D = Diameter of Pile = 30.00 cm
L = Length of Pile = 10 m
DU = Diameter of Under ream = 75.00 m
Grade of Concrete = M-20

For Sandy Zone
Thickness Layer = 500 cm
Qu = Ap (1/2 D λ N1 + λ dN2) + A2 (1/2 D λ N2 + λ dN3) + 1/2π D λ K Tan σ Df²
Aa = (π/4) X (D2u – D2) is the under reamed bulb diameter
Aa = 3709.13 cm²
Aq = Cross section area of pile stem at toe level = 706.50 cm²
N = Number of the under reamed bulbs = 1.00
Λ = Average submerged unit weight of soil = 0.871 X 10⁻³gm/cc
N_λ = Bearing Capacity factors depending upon the angle of internal friction = 17.79
N_q = Bearing Capacity factors depending upon the angle of internal friction = 15.30
d_f = Total Depth of pile in sandy strata = 500.00 cm
K = Earth pressure co-efficient = 1.00
σ = Angle of wall friction = 28
Qu = Ultimate Bearing Capacity of Pile
Qu = Ap(1/2 D λ N_1 + λ d_f N_q) + A_2(1/2 D_u n λ N_2 + λ d_f N_q) + 1/2π D λ K Tanσ D_f^2
Qu = 36744.064 KG
   = 36.7441 MT

For Clay Zone (Screen Friction)
Thickness Layer =500 cm
Qu = AaN_cC'a + C'aA'a + αCsAs
N_c = Bearing Capacity Factor Usually taken As 9 = 9.00
A_a = π/4 (Du^2-D^2), Where Du & D are the diameters of under ream & pile stem in cm
   = 3709.125 cm^2
C'a = Average Cohesion of Soil along the pile stem in (kgf/cm^2) = 0.39 kgf/cm^2
A'a = Surface area of the Cylinder Circumscribing the under reamed bulb in cm^2
   = 2943.75 cm^2
α = Reduction Factor Usually 0.5
Average Cohesion of Soil around under reamer =0.33 kgf/cm^2
C_s = Bulb in (kgf/cm^2)
A_s = Surface area of stem in cm^2
   = 47115.00 cm^2
Qu = Ultimate Bearing Capacity of pile
Qu = For Clay Zone = 21.941 MT
Qu = For Sandy Zone = 36.74 MT
Total Load Carrying = 58.685 MT
Safe Load Carrying Capacity of Pile (Assuming F O S: 3.0)
Say = 19.56 MT
   = 20.00 MT

N.B: The load carrying capacity of the pile may be confirmed by conducting pile load test [10]

Design of Pile Foundation
D = Diameter of Pile = 37.80 cm
L = Length of Pile = 10.00 m
D_u = Diameter of Under ream = 23.75 m
Grade of Concrete = M-20

For Sandy Zone
Thickness Layer = 500 cm
Qu = Ap(1/2 D λ N_1 + λ d_f N_q) + A_2(1/2 D_u n λ N_2 + λ d_f N_q) + 1/2π D λ K Tanσ D_f^2
A_a = (π/4) X (Du^2–D^2) is the under reamed bulb diameter
   = 5795.51 cm^2
A_p = Cross section area of pile stem at toe level
   = 1103.91 cm^2
N = Number of the under reamed bulbs
   = 1.00
Λ = Average submerged unit weight of soil
   = 0.871 X 10^{-3} gm/cc
N_λ = Bearing Capacity factors depending upon the angle of internal friction
   = 17.79
N_q = Bearing Capacity factors depending upon the angle of internal friction
   = 15.30
d_f = Total Depth of pile in sandy strata = 500.00 cm
K = Earth pressure co-efficient = 1.00
\[ \sigma = \text{Angle of wall friction} = 28 \]

\[ Q_u = \text{Ultimate Bearing Capacity of Pile} \]

\[ Q_u = A_p \left( \frac{1}{2} D \lambda N_1 + \lambda d N_2 \right) + A_c \left( \frac{1}{2} D_u n \lambda N_2 + \lambda d N_3 \right) + \frac{1}{2} \pi D \lambda K \tan \sigma D_f^2 \]

\[ Q_u = 56757.90 \text{ KG} = 56.7579 \text{ MT} \]

**For Clay Zone (Screen Friction)**

- Thickness Layer \( = 500 \text{ cm} \)
- \[ Q_u = A_a N_c C'_a + C'_a A'_a + \alpha C_s A_s \]
- \( N_c = \text{Bearing Capacity Factor Usually taken as 9} = 9.00 \)
- \( A_a = \pi/4 (D_{u2} - D^2), \text{Where} \ D_u \text{ and} \ D \text{ are the diameters of under ream} \)
- \( \text{& pile stem in cm} = 5795.508 \text{ cm}^2 \)
- \( C'_a = \text{Average Cohesion of Soil along the pile stem in (kgf/cm}^2) = 0.39 \text{ kgf/cm}^2 \)
- \( A'_a = \text{Surface area of the Cylinder Circumscribing the under} \)
- \( \text{reamed bulb in cm}^2 = 2943.75 \text{ cm}^2 \)
- \( \alpha = \text{Reduction Factor Usually 0.5} = 0.50 \)
- \( C_s = \text{Bulb in (kgf/cm}^2) \)
- \( A_s = \text{Surface area of stem in cm}^2 = 58893.75 \text{ cm}^2 \)
- \( Q_u = \text{Ultimate Bearing Capacity of pile} \)
- \( Q_u = 31207.764 \text{ Kg} = 31.206 \text{ MT} \)

Total Load Carrying Capacity is deduced as

\[ Q_u = \text{For Clay Zone} = 31.208 \text{ MT} \]

\[ Q_u = \text{For Sandy Zone} = 56.76 \text{ MT} \]

Total Load Carrying = 87.968 MT

Safe Load Carrying Capacity of Pile (Assuming F O S: 3.0) = 29.32 MT

Say = 29.00 MT

**4. Conclusion**

The study area is that zone where the importance of residential apartments and buildings are increasing day by day. Considering the importance of utility based on the present scenario the investigated results has been reviewed to ascertain the suitable type of foundation depending on stability and economy. The foundation may be shallow or deep but the most suitable type will be deep foundation for the following setbacks.

1. Soil bearing capacity is suitable to some extent for shallow foundation at a depth of 3m.
2. If shallow foundation of any suitable geometrical shape is suggested then the size of foundation will become too large as the SBC is very less and simultaneously gives un-economical foundation.
3. The soil characteristics below 3m depth show a drastic increase in differential free swell (DFS) and Plasticity Index Value (PIV).
4. This character indicates the soil is highly expansive in nature.
5. The pressure bulb lies in the soil which exhibits high compressibility, shrinkage and extremely high swelling characteristics under very little load. The permeability is extremely low.
6. Considering the above constraints in providing shallow foundation the alternative i.e. deep foundation/pile foundation is suggested.
References


