SOIL INVESTIGATION REPORT

PROJECT
GEOTECHNICAL INVESTIGATION FOR PROPOSED WINDMILL FOUNDATION AT LOCATION JDA-13 AT BALNABA VILLAGE, BHUJ-KUTCH

CLIENT
M/S SUZLON INFRASTRUCTURES SERVICES LTD

PROJECT NO.
GTH/SRBH-2010 /SUZLON/JDA-13, DT: 08/04/2010
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</table>
1.0 INTRODUCTION

Sub surface investigation and laboratory tests for proposed Wind Foundation project was referred to us by Suzlon Infrastructures Services Ltd.

The objective of the exploration work was to determine the probable sub surface conditions such as stratification, denseness or hardness of the strata, position of ground water table etc. and to evaluate probable range of safe bearing capacity for the structure. To fulfill the objective, the work carried out is comprises of:

- Drilling one borehole up to the depth of 10.0m below existing ground level in order to know the sub surface stratification, conducting necessary field tests and to collect disturbs and undisturbed soil samples for laboratory testing.
- Testing soil samples in the laboratory to determine its physical and engineering properties of the soil samples, and
- Analyzing all field and laboratory data to evaluate safe bearing capacity of the soil for given foundation sizes and necessary recommendations for foundation design and construction.

The structure is located at JDA-13 Location near Balnaba Village, Bhuj

2.0 SUB SURFACE EXPLORATION

The actual investigation work was started on 18/02/2010 and was completed on 19/02/2010.

2.1 Drilling

One borehole of 150mm diameter is drill up to the depth of 10.0m. Where caving of the borehole occurred, casing was used to keep the borehole stable. The work was in general accordance with IS: 1892 – 1979. The borehole is located at the center of the wind mill foundation.

2.1.1 Disturbed Samples: Disturbed representative samples were collected, logged, labelled and placed in polythene bags.
2.1.2 **Undisturbed Samples:** Undisturbed soil samples are collected in 100 mm diameter thin walled sampler (Shelby tube) from the borehole. The sampler used for the sampling had smooth surface and appropriate area ratio and cutting edge angle thereby minimizing disturbance of soil during sampling. Samples are logged and labelled properly and transfer to the laboratory for further testing.

2.1.3 **Water Table:** Water table was encountered during the sub soil exploration work carried out in the month of February 2011.

2.1.4 **Method of Sampling:** Sampler is coupled together with a sampler head to form a sampling assembly. The sampler head provide a non-flexible connection between the sampling tube and the drill rods. Vent holes are provided in the sampler head to allow escape of water from the top of sampler tube during penetration. The sampling tubes are made free from dust and rust. Coating of oil is applied on both sides to obtain the undisturbed samples in best possible manner.

The sampler is then lowered inside the bore hole on a string of rods and driven to a pre-determined level. On completion of driving the sampler is first rotated within the borehole to shear the soil sample at bottom and then pulled out. Upon removal of the sampling tubes, the length of sample in the tube is recorded. The disturbed material in the upper end of the tube, if any, is completely removed before sealing.

The soil at the lower end of the tube is trimmed to a distance of about 10 to 20 mm. After cleaning and inserting an impervious disc at each end, both ends are sealed. The empty space in the sampler, if any, is filled with the moist soil, and the ends covered with tight wrapper. The identification mark is then made on each sample.

2.2 **Standard Penetration Test**

The standard penetration tests are conducted in each bore as per IS: 2131: 1981 (Reaffirmed 2002). The split spoon sampler resting on the bottom of bore hole is allowed to sink under its own weight, then the split spoon sampler is seated 15 cm with the blows of hammer falling through 750mm. The driving assembly consists of a driving head and a 63.5 kg weight. It is ensured that the energy of the falling weight is not reduced by friction between the drive weight and the guides or between ropes. The rods to which the sampler is attached
for driving are straight, tightly coupled and straight in alignment. Thereafter the split spoon sampler is further driven by 30cm. The number of blows required to drive each 15cm penetration is recorded. The first 15cm of drive considered as seating drive. The total blows required for the second and third 15cm penetration is termed as a penetration resistance - N value. The N-values for each bore hole are given in bore logs attached as Plate 1.

3.0 LABORATORY TEST

The laboratory tests on soil samples were started immediately after the receipt of the same in the laboratory. Following laboratory tests are carried out to determine the physical and engineering properties of undisturbed and disturbed soil samples.

1. Dry density and moisture content (IS 2720 part – 2 & 29)
2. Particle size analysis – (IS 2720 part – 4 1985)
3. Atterberg's limit - (IS 2720 part – 5 1985)
5. Shear test - (IS 2720 part – 11 1986)
7 Free swell and Swell pressure test - (IS 2720 part – 40 1977, part – 41 1977))

All laboratory tests are carried out as per the respective Indian Standards.

3.1 Field Dry Density & Natural Moisture Content

The weight of undisturbed soil sample with sampler (Shelby tube) is determined after removing paraffin wax and loose soil. The total length of soil sample recovery is determined after deducting empty length from the total length of sampler. The volume of soil mass retained in sampler is thus determined from the known inside diameter of sampler and total length of soil mass. The soil mass is then removed and the average moisture content is determined by keeping the soil sample along with crucible in oven at 100-105 degree centigrade for 24 hours. The empty weight of the sampler is then found out. From the total weight of sampler with soil mass, the weight of empty sampler is deducted. The field density is then found out as

Field density (bulk) = \[ \frac{\text{weight of soil mass}}{\text{volume of soil mass}} \]
And, Field dry density $= \frac{\text{Field bulk density}}{1 + w}$

Where $w$ is water content.

3.2 Particle Size Analysis

The sieve analysis is carried out in accordance with IS: 2720 (Pt.IV). The results are presented in the form of Grain size distribution curve.

Representative soil sample is obtained from the bulk soil sample collected or received from site by method of coning and quartering. Quantity of soil taken will be dependent on the maximum size of particle size present in the soil. Sieve analysis is conducted in two parts:

1) Soil fraction retained on 4.75mm ISS

Soil portion retained on 4.75 ISS is weighed. The sample is then separated into various fractions by sieving through the following sieves:

100, 75, 19 and 4.75 mm ISS

While sieving through each sieve, sieve is agitated so that sample rolls in irregular motion over the sieve, at no time the particles are pushed through; Care is also taken to see that no individual soil particles are broken, though particles adhering one another are rubbed by rubber pestle when required. Care is also taken not to over load the sieve beyond the permitted maximum load for respective sieve.

The mass of the material retained on each sieve is recorded. The percentage of soil retained on each sieve is then calculated on the basis of the total mass of soil taken and from these results, the percentage passing through each sieve is calculated.

2) Soil fraction passing 4.75 ISS

The portion of the soil passing 4.75 mm ISS is oven dried at 105 to 110 c. The portion is coned & quartered to obtain required representative quantity of the material. The material is weighed and placed in tray/bucket filled with water for soaking and loosening the adhered cohesive materials. The soaked soil specimen is then washed on 75 micron IS Sieve until
the water passing the sieve is almost clear. The material retained on 75 micron IS Sieve is then transferred in a tray, dried in oven.

Sieve analysis is then conducted on a nest of sieves (viz. 2 mm, 425 and 75 micron ISS) either by hand or by using mechanical sieve shaker. The fraction retained on each of the sieves is weighed separately and masses recorded. Cumulative mass of soil fraction retained on each sieve is then calculated. The weights are then converted into cumulative percentage retained and passing on the basis of the mass of the sample passing 4.75 ISS taken. The combined gradation on the basis of the total sample taken for analysis is finally calculated.

3.3 Atterberg's Limit

Liquid and plastic limits are determined by using procedure given in IS: 2720 (Pt-V). The results are given in result sheet. The weight of cone plus rod and plate is 148 gm. A soil sample weighing about 150gm from the thoroughly mixed portion of soil passing 425 micron was used for testing. The thoroughly wet soil paste is transferred to the cylindrical trough 150mm diameter and 50mm high of the cone penetrometer apparatus and leveled up to the top of trough. The penetrometer is adjusted such that the cone point just touches the surface of the soil paste in trough. The scale of the penetrometer is adjusted to zero and the vertical rod is released so that the cone is allowed to penetrate into the soil paste under its own weight. The penetration is noted after 30 sec. from the release of the cone. The reading is considered if the penetration reading is between 20mm and 30 mm. The moisture content of the soil paste corresponding to this is determined. The liquid limit of the soil which corresponds to the moisture content of a paste which would give 25 mm penetration of the cone is determined using formula:

$$W_{LL} = Wx + 0.01 (25 - W) (Wx + 15)$$

For determination of plastic limit, a soil sample weighing at least 20 gm from the soil sample passing 425micron IS sieve is thoroughly mixed with water such that it can be easily moulded with fingers. A ball is formed with about 8 to 10 gm of this soil & is rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter of 3mm throughout its length. The soil is then kneaded together to a uniform mass and rolled again. The process is continued until the thread crumbles. The
pieces of crumbled soil thread are collected and moisture content is determined and reported as plastic limit.

3.4 Specific Gravity

The specific gravity of soil solids is determined by a 50ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccator, is put in the bottle, and weight (W2) of the bottle and the soil is taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying vacuum or by shaking the bottle. The weight (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

\[
\text{Specific Gravity (G)} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}
\]

3.5 Shear Test

**Tri-axial (undrained) tests** are carried out to determine the shear parameters. The shear tests are carried out in accordance with IS: 2720 (pt. X, XI, XII and XIII) on saturated samples. For unconsolidated undrained tri-axial compression test, the undisturbed soil specimen having diameter 38 mm and height to diameter ration 2 is prepared and placed on the pedestal of the tri-axial cell. The cell is then assembled with the loading ram and then placed in the loading machine. The cell fluid is admitted to the cell and the pressure is raised to the desired value. An initial reading of the gauge measuring axial compression of the specimen is recorded. The test is then commenced and sufficient number of simultaneous readings of load and compression measuring gauge being taken. The test is continued until the maximum value of the stress has been passed or until an axial strain of 20 per cent has been reached. Additional tests are carried out on identical specimen at confining pressure of 1 kg/cm², 2 kg/cm² and 3 kg/cm². The shear parameters are obtained from the plot of Mohr circles.

**Direct shear test** is carried out using shear box with the specimens (60mmx60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly
placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement/shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

3.6 Consolidation Test

The consolidation tests were carried out on undisturbed soil specimen in order to determine the settlement characteristics of soil at different depths. The tests were conducted in accordance to IS: 2720 (Pt-XV).

An undisturbed soil specimen is extruded to the consolidation ring of 60mm diameter. The edge is trimmed carefully such that the sample flushes with the top and bottom edges of the ring. The thickness of the specimen is measured and the weight is recorded. The bottom porous stone is then centered on the base of the consolidation cell.

The specimen is placed centrally between the bottom porous stone and the upper porous stone. A filter paper is provided in-between specimen and porous stones. Then the loading cap is placed on the top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the cell and the loading cap. A seating pressure of 0.05 kg/cm² is applied to the specimen. The cell is kept filled with water. After 24 hours the test is continued using a loading sequence on the soil specimen of 0.25, 0.5, 1.0, 2.0, 4.0, and 8.0 kg/cm². For each loading increment after application of load, readings of the dial gauge is taken using time sequence 0, 0.25, 1, 2.25, 6.25, 9, 16, 25, 36, 49 ... up to 24 hrs. From the observations of all incremental pressure, void ratio versus log (pressure) curve is obtained. The slope of the straight line portion is designated as compression index cc.

3.7 Differential Free Swell Test

In order to determine the swelling characteristics of the soil, differential free swell test is carried out. An oven dried soil sample, 10 gm passing through 425 micron is poured in two
100 ml graduated cylinders. One cylinder was filled with distilled water and another with kerosene up to 100 ml mark. After removal of entrapped air, sample was allowed sufficient time to attain equilibrium state of volume. The final volume of soil in each cylinder was recorded.

\[
Sp = \frac{\text{Soil volume in water} - \text{soil volume in kerosene}}{\text{soil volume in kerosene}} \times 100
\]

Where \( Sp \) = Differential Free swell (%)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of the loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring is noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated from the difference between the final & initial dial readings of the proving ring.
4.0 DISCUSSION ON FIELD AND LABORATORY TESTS:

Sub soil Stratification: The field data and laboratory classification reveals in general, the proposed site is having single major layer up to depth of investigation i.e. 10.0m.
Layer I is Brownish Black Silty Clay of High Plasticity with Little Gravel
Layer II is Brownish Yellow Very Stiff Silty Clay of Medium Plasticity with Little Gravel
Layer III is Yellow Hard Silty Clay of Low Plasticity with Little Gravel

Standard Penetration Test: This test was conducted during the course of investigation work. From the bore logs it is inferred that the SPT ` N ' value increases with depth as shown below. Depth Vs N value graph is shown in Bore log.

<table>
<thead>
<tr>
<th>Layer / Thk. Of Strata in mt.</th>
<th>Identification</th>
<th>Range of N</th>
<th>Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>II / From 0.3m to 5.1 m</td>
<td>Brownish Yellow Silty Clay</td>
<td>11-30</td>
<td>Very Stiff</td>
</tr>
<tr>
<td>III / From 5.1m to 10.0m</td>
<td>Yellow Silty Clay</td>
<td>&gt;100</td>
<td>Hard</td>
</tr>
</tbody>
</table>
5.0 SAFE BEARING CAPACITY:

Looking to the site conditions and sub soil stratification encountered and type of proposed project RCC Circular Raft Foundation is recommended along with safe bearing capacity at different depth. Intensity of bearable load determined as soil bearing capacity (SBC) and soil bearing pressure (SBP) on soil.

**SBC BASED ON SHEAR:** The ultimate net bearing capacity is evaluated after taking into consideration of shape factor and depth factor of the foundation in accordance with I.S. 6403-1981. The net bearing capacity worked out using the following equation. The sample calculation of Soil Bearing Capacity is attached in the report as Plate No.3

\[ Q = C N_c S_c d_c + q (N_q - 1) S_q d_q + 0.5 B \gamma N_r S_r d_r \]

Where,  
- \( C \) = Cohesion 
- \( q \) = Overburden Pressure 
- \( \gamma \) = Density 
- \( B \) = Width of the Footing 
- \( N_c, N_q, N_r \) = Bearing capacity Factor 
- \( S_c, S_q, S_r \) = Shape Factor 
- \( d_c, d_q, d_r \) = Depth Factor

5.1 Design Parameters for Shear and Settlement Criteria

Following parameters are adopted for the evaluation of bearing capacity for shallow foundation.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesion (kg/cm²)</td>
<td>0.48</td>
</tr>
<tr>
<td>Angle of Internal Friction (Degree)</td>
<td>8</td>
</tr>
<tr>
<td>Dry Density (in gm/cc)</td>
<td>1.541</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.551</td>
</tr>
<tr>
<td>Coefficient of volume change (m_v)</td>
<td>0.0128</td>
</tr>
<tr>
<td>Factor of Safety</td>
<td>2.5</td>
</tr>
<tr>
<td>Void ratio, ( e ) (Computed)</td>
<td>0.655</td>
</tr>
<tr>
<td>Type of Shear Failure Considered</td>
<td>Intermediate</td>
</tr>
</tbody>
</table>
Thus, intermediate shear failure was considered for safe bearing capacity computation. The net safe bearing capacity for various sizes of individual rigid footings having vertical static load intensity is evaluated as in Table -I. Settlement computed from Coefficient of volume change ‘mv’ for over consolidated clay as per I.S.8009, Part I for 100mm permissible settlement as shown in Plate-4.

**TABLE- I, SAFE BEARING CAPACITY AND SAFE BEARING PRESSURE**

<table>
<thead>
<tr>
<th>FOUNDATION DETAILS</th>
<th>Type</th>
<th>Size (mtr.)</th>
<th>Depth (mtr.)</th>
<th>Safe Bearing Capacity (SBC) in t/m²</th>
<th>Safe Bearing Pressure for 100 mm permissible (SBP) settlement in t/m²</th>
<th>Recommended value of SBC for design of foundation in t/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCC Circular Raft Footing</td>
<td>Dia=16.0</td>
<td>2.25</td>
<td>16.30</td>
<td>+19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCC Circular Raft Footing</td>
<td></td>
<td>2.50</td>
<td>16.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCC Circular Raft Footing</td>
<td></td>
<td>3.00</td>
<td>16.85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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6.0 CONCLUSIONS & RECOMMENDATIONS

1. Sub soil stratification of proposed site up to depth of investigation is as below.
   From 0.0 to 0.3m: Brownish Black Silty Clay of High Plasticity with Little Gravel
   From 0.3 to 5.1m: Brownish Yellow Very Stiff Silty Clay of Medium Plasticity with Little Gravel
   From 5.1 to 10.0m: Yellow Hard Silty Clay of Low Plasticity with Little Gravel

2. Looking to the proposed type of project RCC Circular Raft footing is recommended along with their Safe Bearing Capacities considering factor of safety of 2.5 as shown in Table - I.

3 Safe Bearing pressure calculated for 100mm permissible as per I.S 8009 Part I for over consolidated clay as shown in Plate-4

4 Water table was considered in the analysis of SBC.

5 Suitability of Soil for back filling: The top layer of soil is of High swelling characteristic, which is not suitable for back filling purpose.

For GEO TEST HOUSE

(Technical Manager)
# BORE LOG
(As per I.S. 1892 : 1979)

**Type of Boring:** Mechanical/ Auger Drilling

**Date of Start:** 18/02/2010

**Diameter of Boring:** 150mm, Depth 10.0mt

**Date of Comp.:** 19/02/2010

**Location:** Proposed Project for Windmill Foundation (Location: JDA 13), Balnaba Village.

**Water Table:** 1.20 mtr

### Depth Description

<table>
<thead>
<tr>
<th>Depth in Mtr. from EGL</th>
<th>Description of Strata</th>
<th>Soil Type</th>
<th>Lab. Depth</th>
<th>Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Brownish Black Silty Clay of High Plasticity with Little Gravel</td>
<td>UDS</td>
<td>0.3</td>
<td>N</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td>SPT</td>
<td>1.0</td>
<td>11</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>UDS</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>SPT</td>
<td>3.0</td>
<td>16</td>
</tr>
<tr>
<td>2.5</td>
<td>Brownish Yellow Very Stiff Silty Clay of Medium Plasticity with Little Gravel</td>
<td>UDS</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td>SPT</td>
<td>4.0</td>
<td>30</td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td>UDS</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td>SPT</td>
<td>5.0</td>
<td>100</td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td>UDS</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td>SPT</td>
<td>5.0</td>
<td>100</td>
</tr>
<tr>
<td>5.5</td>
<td></td>
<td>UDS</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>SPT</td>
<td>6.0</td>
<td>100</td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td>UDS</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>7.0</td>
<td></td>
<td>SPT</td>
<td>7.0</td>
<td>100</td>
</tr>
<tr>
<td>7.5</td>
<td>Yellow Hard Silty Clay of Low Plasticity with Little Gravel</td>
<td>UDS</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td>SPT</td>
<td>8.5</td>
<td>100</td>
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<tr>
<td>8.5</td>
<td></td>
<td>UDS</td>
<td>9.0</td>
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<td>9.0</td>
<td></td>
<td>SPT</td>
<td>9.0</td>
<td>100</td>
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<tr>
<td>9.5</td>
<td></td>
<td>UDS</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td>UDS</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

**Plate No. 1**

**BH - 01**

**N:** SPT Value

**Checked By:**

---

**UDS:** Undisturb Sample

**DS:** Disturbed sample
### SUMMARY OF LABORATORY TEST RESULTS

#### LOCATION NO. JDA-13

<table>
<thead>
<tr>
<th>BH NO</th>
<th>Lab No.</th>
<th>Depth (IN M.)</th>
<th>FDD (gms/cc)</th>
<th>FMC %</th>
<th>Grain Size Distribution</th>
<th>Atterbergs Limit</th>
<th>I.S. Classification</th>
<th>Shear Parameter</th>
<th>Consolidation</th>
<th>Specific Gravity</th>
<th>Free Swell %</th>
<th>Swell Pressure Kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.0</td>
<td>1.535</td>
<td>18.65</td>
<td>5 27 68</td>
<td>41.7 21.3 20.4</td>
<td>CI</td>
<td></td>
<td></td>
<td></td>
<td>2.538</td>
<td>48 0.13</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>1.541</td>
<td>17.20</td>
<td>8 21  71</td>
<td>44.3 22.7 21.6</td>
<td>CI 0.48 8</td>
<td></td>
<td></td>
<td></td>
<td>2.551</td>
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<td>45.7 22.8 22.9</td>
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<td>10 29  61</td>
<td>31.3 19.3 12.0</td>
<td>CL</td>
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<td>11 24  65</td>
<td>30.3 18.3 12.0</td>
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<td>8.5</td>
<td>1.625</td>
<td>13.10</td>
<td>8 34  58</td>
<td>29.2 18.5 10.7</td>
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<td>18 27  55</td>
<td>31.2 19.2 12.0</td>
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<td></td>
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</tbody>
</table>

**Abbreviations:**

- **G** - Gravel
- **S** - Sand
- **M** - Silt
- **C** - Clay
- **L.L.** - Liquid Limit
- **PL.** - Plastic Limit
- **PI.** - Plasticity Index
- **FDD** - Field Dry Density
- **FMC** - Field Moisture Content
- **C** - Cohesion (Shear test-UU)
- **Φ** - Angle of Internal Friction
- **B.D.** - Bulk Density
- **Cc** - Compression Index
- **Pc** - Pre consolidation pressure

**Tested By:**

**Checked by:**
SAFE BEARING CAPACITY OF SOIL

Shape of footing = Raft

Depth of footing $D = 2.25$ m

Width of footing $B = 16.00$ m

Length of footing $L = -$ m

Cohesion $C = 0.48$ kg/sq cm

Angle of Int.Fric $\phi = 8$ degrees

Specific Gravity $G = 2.551$

Inclination Angle $\alpha = 0$ degrees

Water Table Occurrence $0.5$ Water table Considered

Dry Density $Y_d = 1.541$

Sat. density $Y_{sat} = 1.937$

Submerged density $= 0.937$

Factor of Safety $= 2.5$

Void Ratio $e_o = \frac{G \times Y_w}{\gamma}$

$Y_d = 0.6554$ it is $> 0.55 & < 0.75$

hence it is an intermediate shear failure

$\phi' = \tan^{-1}(0.67 \tan \phi)$

$= 5.38$

$N_{c''} = 7.092$ $N_c' = 0.00$ $N_c = 0.000$

$N_{q''} = 1.861$ $N_q' = 0.00$ $N_q = 0.000$

$N_{\gamma''} = 0.699$ $N_{\gamma'} = 0.00$ $N_{\gamma} = 0.000$

$qu = cN_cScdcic + q(N_q-1) Sqdqiq + 0.5 B \gamma N \gamma S \gamma d \gamma i \gamma W''$

for general shear failure

$= 0.00$ $qs = 0.00$ t/m²

$qu = 0.67cN_cScdcic + q(N_q-1) Sqdqiq + 0.5 B \gamma N' \gamma S \gamma d \gamma i \gamma W''$

for local shear failure

$= 0.00$ $qs = 0.00$ t/m²

$qu = cN_cScdcic + q(N_q-1) Sqdqiq + 0.5 B \gamma N'' \gamma S \gamma d \gamma i \gamma W''$

for intermediate shear failure

$= 40.75$ t/m² $qs = 16.30$ t/m²
### Sample Calculation

<table>
<thead>
<tr>
<th>D in m = 2.25</th>
<th>Width of Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B = 16.00 mtr</td>
<td>Total Thickness of compressible strata</td>
</tr>
<tr>
<td>H = 7.75 mtr</td>
<td>Length of foundation</td>
</tr>
</tbody>
</table>

Assume pressure 19.84 t/m²

\[ \frac{L}{B} = 1 \]

\[ \frac{D}{\sqrt{LB}} = 0.141 \]

<table>
<thead>
<tr>
<th>Zi in m</th>
<th>Z = 2 x Zi in m</th>
<th>B / Z</th>
<th>L/Z</th>
<th>C</th>
<th>Influence factor I = 4 x C</th>
<th>( \Delta P ) = ( p \times I ) Kg/cm²</th>
<th>H cm</th>
<th>mV, cm²/kg</th>
<th>Settlement, cm</th>
<th>Depth factor</th>
<th>Rigidity factor</th>
<th>Soil factor</th>
<th>Final settlement, in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.88</td>
<td>7.75</td>
<td>2.06</td>
<td>2.06</td>
<td>0.235</td>
<td>0.94</td>
<td>1.865</td>
<td>775</td>
<td>0.013</td>
<td>18.50</td>
<td>0.965</td>
<td>0.800</td>
<td>0.700</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Total Settlement, mm 100.00

At 19.84 t/m² pressure, settlement arrived is 100.00mm, which is equal to 100mm permissible settlement. Hence SBP recommended 19.84 t/m².

### Coefficients for Soil Factor as per IS : 8009 ( Part I ) - 1976

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Sensitive Clays (Soft Alluvial, Estuarine and Marine Clays)</td>
<td>1.00 to 1.20</td>
</tr>
<tr>
<td>Normally Consolidated Clays</td>
<td>0.70 to 1.00</td>
</tr>
<tr>
<td>Over Consolidated Clays</td>
<td>0.50 to 0.70</td>
</tr>
<tr>
<td>Heavily Overconsolidated Clays</td>
<td>0.20 to 0.50</td>
</tr>
</tbody>
</table>

Depth factor considered from Fig. 12 of IS : 8009 Part-1