7.4. Geotechnical Concerns

The main geotechnical concern of a buried tank below high water table (about a meter from the existing ground) will be the uplift or buoyant force. The uplift force will be exacerbated should liquefaction occur (arising from the excess high pore water pressure) during a strong ground motion (Major earthquake).

A second concern would be the stability of the envisioned vertical cut. Retaining structure is necessary to contain the envisioned 6m vertical cut, and will have to be designed for a) active earth pressure, b) the full hydrostatic forces assuming water level at the ground surface, c) earthquake forces, d) effects of surcharge loads arising from nearby structures or roadways.

Another concern would be the ground subsidence in the surrounding area during excavation works, especially when dewatering (water table is lowered by pumping). Ground subsidence is reasonably expected as the retaining wall moves (or rotates) towards the excavation for the active earth pressure (minimum lateral resistance) to act. Dewatering works in the area will exacerbate ground subsidence unless soil improvement is first provided.

7.5. Foundation Schemes

Based on the above findings, the proposed structure(s) may be supported on deep or piled foundations. In addition to the required compressional load, the piles will have to provide tensile resistance to resist the buoyant forces of the buried tank (i.e., when empty).

Driven piles or bored piles may be considered for this purpose.

Shallow foundation scheme may only be considered for non-essential and low-rise structures, or when soil improvement has been undertaken to arrest possible effects of liquefaction phenomenon and ground subsidence.

Both schemes are discussed in the following sections.

7.5.1. Piled Foundations

Based on the above discussion, the use of single-stick, prestressed, reinforced, precast concrete piles are recommended for the project. The single-stick is underlined for emphasis in anticipation of the required pullout resistance, as jointed piles may have questionable pullout resistance.

Considering the built-up surroundings (1-2 storey residential / commercial buildings), the use of static pile driver is recommended to eliminate noise and air pollutions and unwanted vibrations that may affect the operations of the surrounding residences / businesses / buildings.

Piles will have to bear directly on the medium dense layer (Layer C), with minimum depth of embedment at 24m reckoned from the existing ground surface.

In the event that the use of driven piles might not be plausible, bored piles maybe considered.

The advantage of using bored piles is that it can be drilled and socketed into the more dense material, thus offering higher shaft resistance.

Pile capacity estimates are graphically presented in the next page.

A suitable safety factors, typically 2.5 for compression and 2.75 for tension, may be applied to the calculated ultimate pile capacity to arrive at the allowable pile capacity.

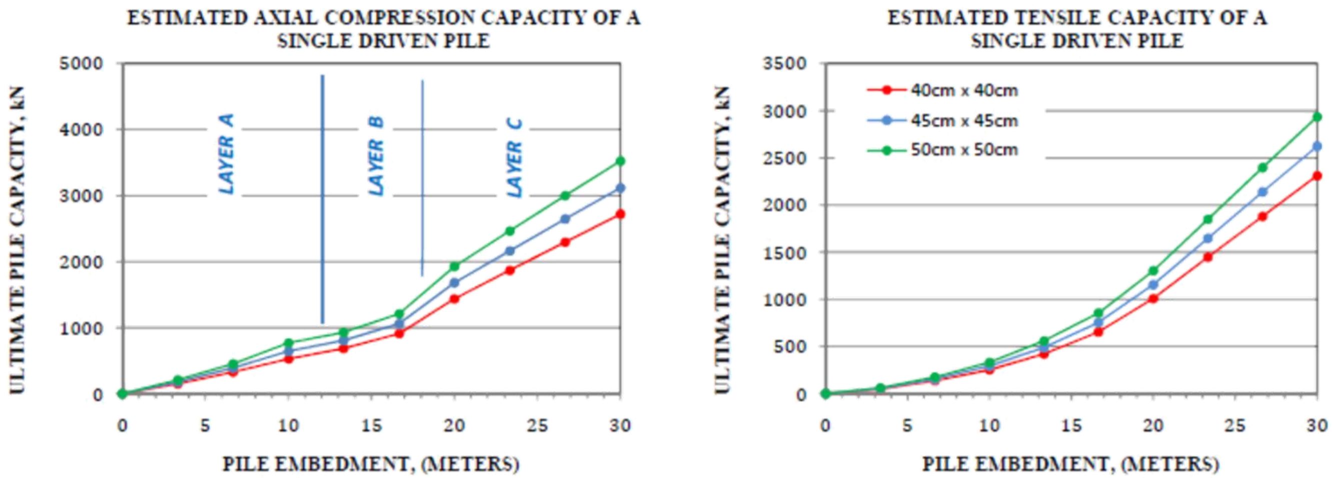

Figure 7-2. Estimated ultimate capacity of single-stick driven piles

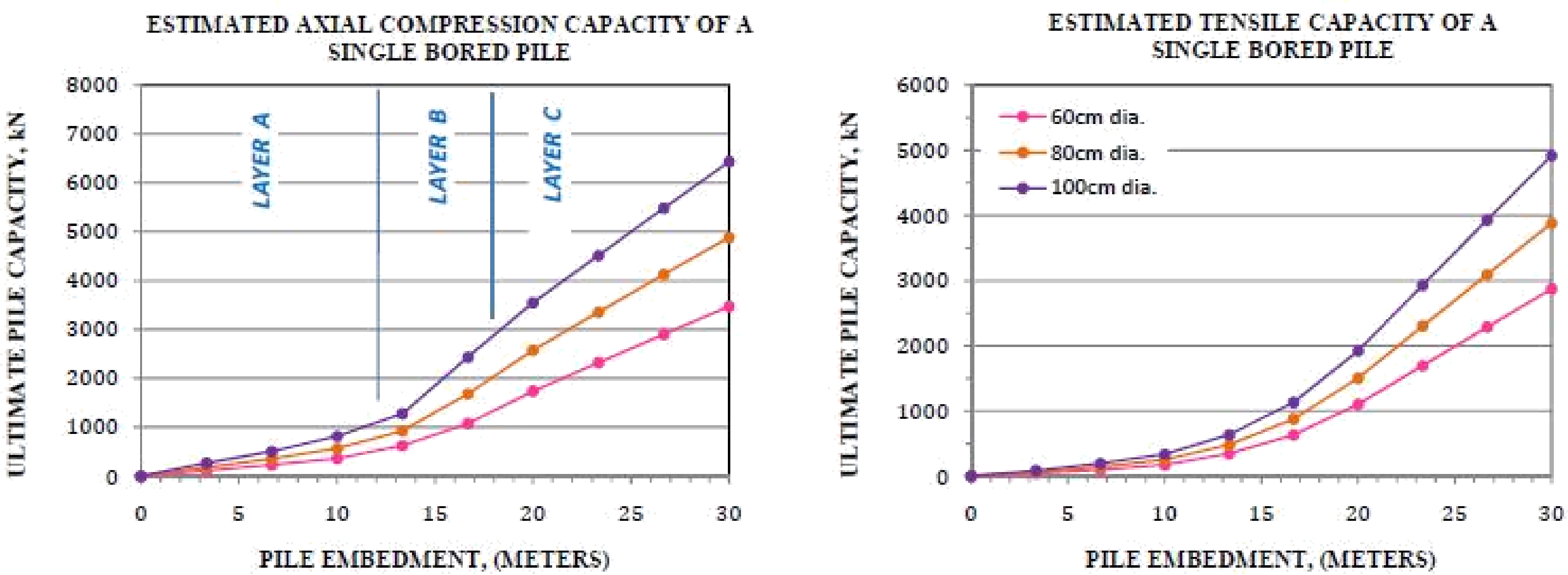

Figure 7-2. Estimated ultimate capacity of a single bored pile

7.5.1.1. Other Pile Design Considerations

Verification of Actual Pile Capacity& Integrity

The tabulated pile capacities are based purely on theoretical computations. The actual capacity of the piles will have to be confirmed / determined by actual pile load tests - either by the Static Test (ASTM D1143) or the Dynamic (ASTM D4945) Testing Procedures. The latter will be the more practical choice as more piles can be tested at a much lesser time and cost.

Foundation Quality Control during Construction

Quality control of piles may be best checked using appropriate testing methods such as Pile Integrity Testing (ASTM D 5882) &Cross-hole Logging Tests (ASTM D 6760) for integrity testing, and High-strain dynamic testing (ASTM D 4945) for capacity verification.

Pile Driving

Pile driving should be done continuously since relatively long stoppages would make re-driving difficult. A wave equation analysis (GRLWEAP) may have to be conducted to verify size of hammers suitable for driving to the prescribed or desired depth, and check driving stresses as well.

Pile Spacing

To minimize stress overlapping, piles should be spaced as far as practicable. A minimum spacing of 2.5 to 3.0D from center to center of piles may be adopted, where D is the diameter of the pile.

Efficiency of Pile Group

Since friction is the major component of the pile capacity, it is recommended that the efficiency of pile groups be calculated using the Converse-Labarre equation calculated as follows:

$$E_g = 1 - \theta \frac{(n-1)m + (m-1)n}{90mn}$$

Where:

n = number of rows

m = number of columns

$\theta = \tan^{-1} \frac{D}{s}$

D = diameter

s = spacing

7.5.2. Shallow Foundations

The use of shallow foundation should be limited to non-essential and light structures, as there is a serious risk associated with liquefaction (described in Section 7.2) and/or ground subsidence.

For the above purpose, footings may be founded on 1.0 – 1.2m below the existing ground level, bypassing any unconsolidated deposits. A conservative net allowable bearing capacity of 50 kPa (1,000 psf) may be assumed in proportioning the footings.

Isolated footings or foundations should be connected with tie-beams to provide structural rigidity and help resist differential settlement especially during strong earthquake.

7.5.3. Coefficient of Lateral Subgrade Modulus, k_h

As a guide, the ranges of k_h that may be used indesigning the piled foundation to resist lateral loads are as follows:

Table 7-2. Coefficient of Lateral Subgrade Modulus, k_h

Layer	General Description	Estimated Lateral Subgrade Modulus (MN/m^3)
A	Very loose to loose Sand (Ave=8)	4 – 6
B	Soft to stiff Clay (Ave=12)	15 - 20
C	Medium dense gravel/sand-sized Limestone fragments with clay (Ave=24)	30 – 40