5. FOUNDATIONS

5.1 GENERAL PRINCIPLES

! All foundations should be taken down to an adequate bearing stratum, which ensures the settlement under load will be acceptable to the structure.

! Settlement under loads should always be considered. This may be done by calculation and/or by reference to successful use of similar foundations in similar materials, preferably in the local neighbourhood of the site. Advice from Building Control Engineers is helpful in this respect.

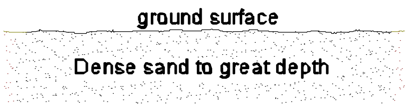
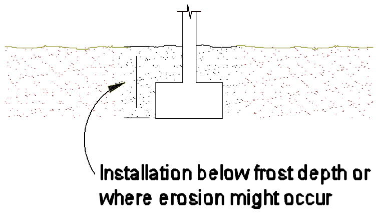
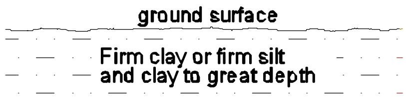
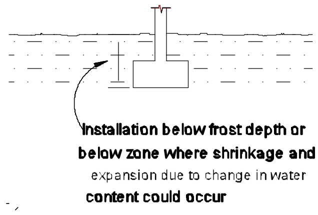
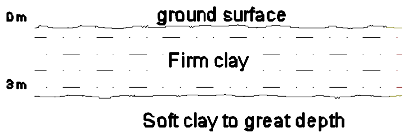
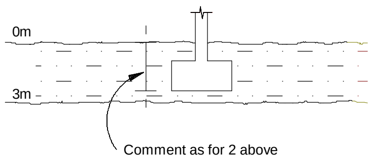
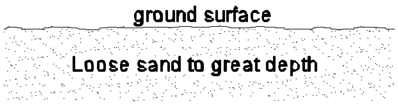
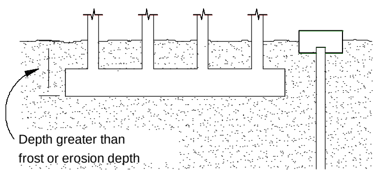
! In assessing settlement the interaction between foundations needs to be considered plus the overall load of the complete structure as well as the loading of an individual foundation.

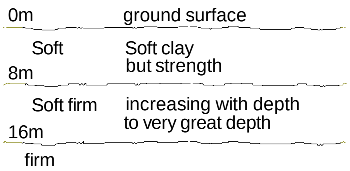
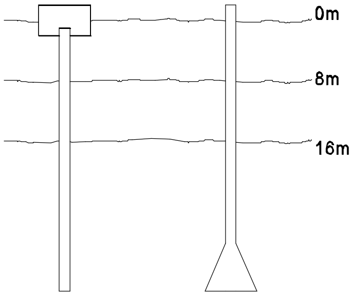
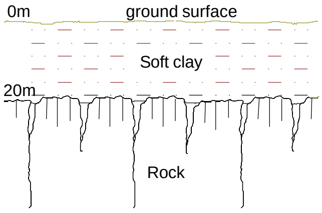
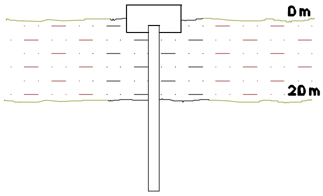
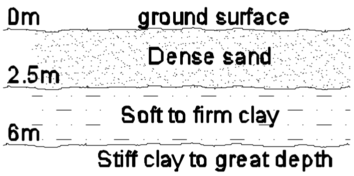
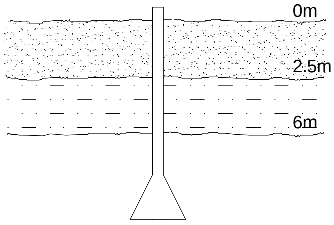
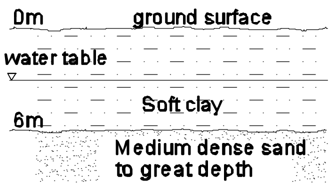
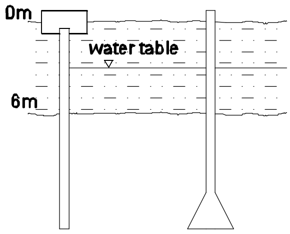
! Settlement arises from the following:
  - Undrained elastic settlement which occurs on loading and hence during construction
  - Consolidation settlement of clays as porewater pressures dissipate (time dependant)
  - secondary consolidation of soft clays and peat (time dependant)
  - creep of fill (time dependant)
  - settlement induced by construction vibration, seismic loading or inondation
  - creep of natural granular deposits (time dependant but usually small)

! Foundations should be taken to a depth at which they will not be affected by seasonal changes, including both frost and action and swelling and shrinkage due to changes of water content. Frost action is particularly important in silty soils, including chalk, and shrinkage is important in many clays, especially if there are trees nearby. BRE Digests and NHBC guidelines provide advice on foundations in clay deposits which have become desiccated due to vegetation.

! It is important that all foundation designs are reviewed by a geotechnical engineer - preferably in advance of any design decisions. In addition advice may be required to determine the geological character of the founding strata and whether any unusual features may be present.

5.2 APPROPRIATE FOUNDATION SOLUTIONS

SOIL CONDITIONS	APPROPRIATE FOUNDATION TYPE AND LOCATION	DESIGN COMMENTS
1. 		Spread footings most appropriate for conventional foundation needs. A deep foundation such as piles could be required if uplift forces were to act.
2. 		Spread footings most appropriate solution in many cases, depending on settlement considerations
3. 		Spread footings would be appropriate for low to medium range of loads if not installed too close to soft clay. Take care to not overstress the soft clay. If settlements become excessive deep foundation might be required. Cyclic loading may cause larger settlements.
4. 		Spread footings may settle excessively or require use of very low bearing pressures. Any later disturbance to the sand by vibration, groundwater changes or seismic loading for example, may cause large settlements. Consider mat (raft) foundations or consider compacting sand by vibroflotation or other method then use spread footings. Driven piles could be used and would densify the sand. Also consider continuous flight auger piles.

<table>
<tr><th>SOIL CONDITIONS</th><th>APPROPRIATE FOUNDATION TYPE AND LOCATION</th><th>DESIGN COMMENTS</th></tr>
<tr><td>5.
</td><td></td><td>Spread footings probably not appropriate. Friction piles or piers would be satisfactory if some settlement could be tolerated. Long piles would reduce settlement problems. Also consider mat or floating foundation.</td></tr>
<tr><td>6.
</td><td></td><td>Deep foundations - piles, piers, caissons - bearing directly on or in the rock. Downdrag (negative skin friction) may add to the loads on the piles. The weathering, infill etc. of the rock may be critical in the design of the socket</td></tr>
<tr><td>7.
</td><td></td><td>For heavy loads, spread footings in upper sand layer would probably experience large settlement because of underlying soft clay layer. Consider straight shafted piles or piles with bells in the stiff clay layer. Bells may be difficult to form in some clay strata. If time is available preloading might make it possible to use shallow foundations.</td></tr>
<tr><td>8.
</td><td></td><td>Deep foundations best, continuous flight auger piles suitable. Expanded base piles into sand layer not common. Bored piles require water (if cased) or bentonite (if not) to balance water pressures.</td></tr>
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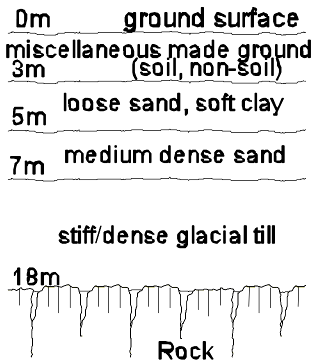
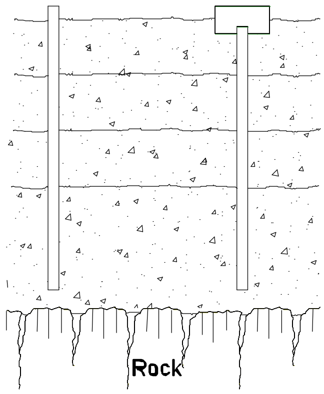
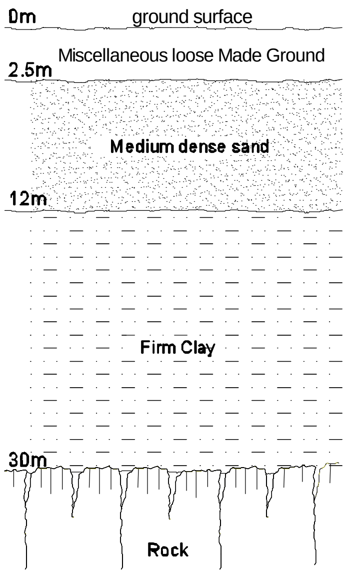
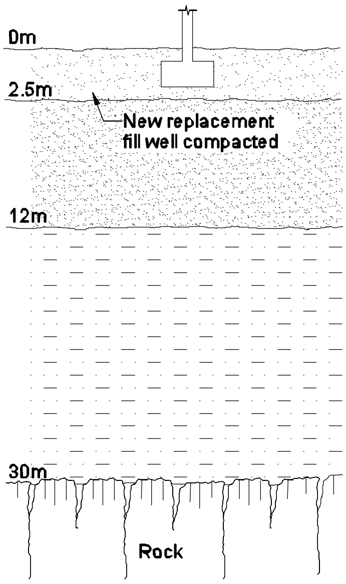

</td><td>
</td><td>Deep foundation types extending into medium dense sand, or preferably into compact glacial till. Strong possibility for drilled pile bored under bentonite. Also consider cast-in-place and driven concrete pile, steel piles,CFA piles. (Cannot underream in till.) Negative skin frcition should be considered</td></tr>
<tr><td>10.

</td><td>
</td><td>Deep foundations penetrating through fill are appropriate. With piles or piers consider stopping in upper zone of sand layer to limit consolidation of clay layer. Also consider replacing poor fill with new imported, compacted, fill, then use spread footings in the new fill. Calculate settlements due to consolidation of clay under complete load of new structure.</td></tr>
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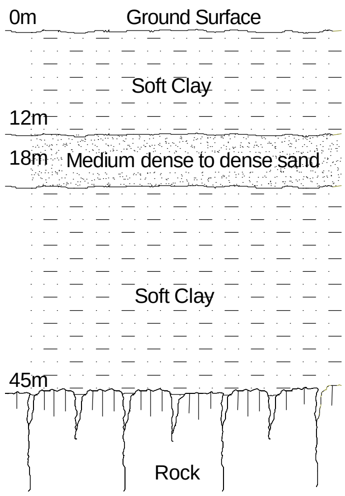
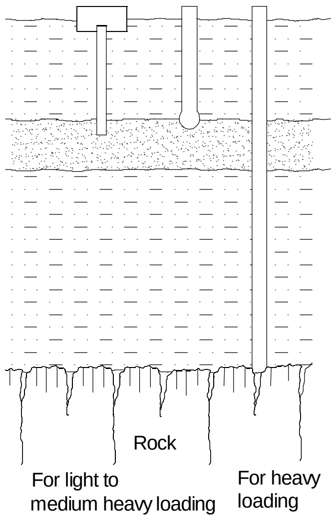
SOIL CONDITIONS	APPROPRIATE FOUNDATION TYPE AND LOCATION	DESIGN COMMENTS

11.





If foundation loads are not too heavy, consider using piles or piers bearing in the upper zone of sand layer and check for settlement. If foundation loads are heavy, consider driven piles (steel) or caissons to rock. Also consider floating foundation. Nature of rock is very important. Driving can induce positive pore presures and negative skin friction.

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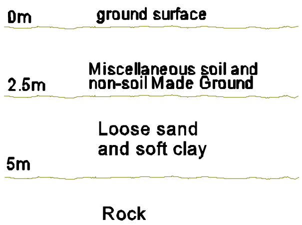
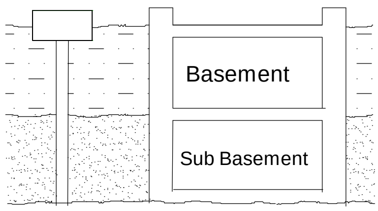
12.





Foundations should bear directly on the rock which is relatively close to the ground surface. If no basement areas are needed for the building consider piers. If basement areas are useful, consider full excavation to rock and construction of two basement levels.

5.3 PRESUMED ALLOWABLE BEARING VALUES UNDER STATIC, NON-ECCENTRIC STATIC LOADING

Bearing values relate to characteristic loads.
Further values are given in BS8004.
This information is given for preliminary assessment purposes only.

Foundations in non-cohesive soils at a minimum depth of 0.75m below ground level

Description of soil	N-value in standard penetration test	Presumed bearing value (kN/m^2 or kgf/cm^2 x 100) for foundation of width		
		1m	2m	4m
Very dense sands and gravels	>50	600	500	400
Dense sands and gravals	30-50	350-600	300-500	250-400
Medium-dense sands and gravels	10-30	150-350	100-300	100-250
Loose sands and gravals	5-10	50-150	50-100	50-100

The allowable bearing pressure is defined as that causing 25mm settlement under the foundation width.

If the water table is within a depth equal to the width of the foundation and the depth of the foundation is small in relation to its width, the settlements will be doubled.
If settlements must not exceed 25mm, the allowable bearing values should be halved.

Foundations in conhesive soils at a minimum depth of 1m below ground level

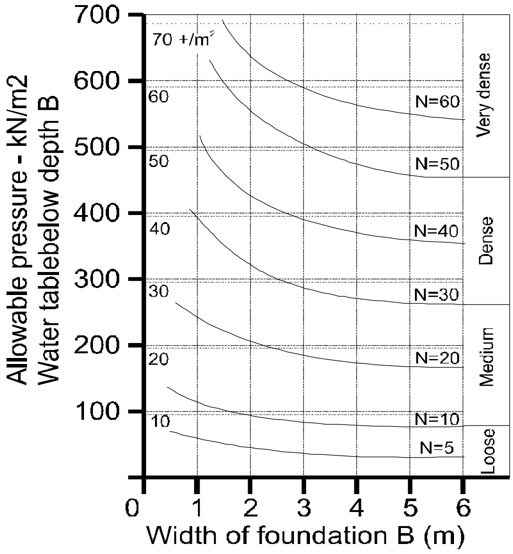
Description	Cohesive strength (kN/m^2 or kgf/cm^2 x 100)	Presumed bearing value (kN/m2 or kgf/cm2 x 100) for foundation of width		
		1m	2m	4m
Hard boulder clays, hard fissured clays (e.g. deeper London and Gault clays)	>300	800	600	400
Very stiff boulder clay, very stiff 'blue' London Clay	150-300	400-800	300-500	150-250
Stiff fissured clays (e.g. stiff 'blue' and brown London clay), stiff weathered boulder clay	75-150	200-400	150-250	75-125
Firm normally consolidated clays (at depth), fluvio-glacial and lake clays, upper weathered 'brown' London clay	40-75	100-200	75-100	50-75
Soft normally consolidated alluvial clays (e.g. marine, river and estuarine clays)	20-40	50-100	25-50	Negligible

Chart for estimating allowable bearing pressure for foundations in sands

SPT 'N' values are shown as belows per 300mm

If the water table is within a depth equal to the width of the foundation and the depth of the foundation is small in relation to its width, the settlements will be doubled.

If settlements must not exceed 25mm, the allowable bearing values should be halved.



5.4 SHALLOW FOUNDATIONS

$$\text{Area of foundation} = \frac{\text{Characteristic load}}{\text{Allowable bearing pressure}}$$

5.5 PILED FOUNDATIONS

Working load on pile < 0.25fcu (0.1fcu for continuous flight auger)

Warning: The following relationships apply only to bored cast in place concrete piles in London clay. For all other piles check with Geotechnics (which should always be done anyway).

$$\text{Working bearing capacity of straight shafted piles} = \left(\frac{0.5\overline{c_u}\ x\ \text{perimeter}}{3}\right) + \left(\frac{9c_{u,base}\ x\ \text{base area}}{3}\right)$$

$$\text{Working bearing capacity of large under-reamed piles} = \left(\frac{0.35\overline{c_u}\ x\ \text{perimeter}}{f_1}\right) + \left(\frac{9c_{u,base}\ x\ \text{base area}}{f_2}\right)$$

For straight sided piles higher capacities may be available by following the guidelines for Site Investigations and pile tests in the London District Surveyors Association Publication, Guide Notes for the Design of Straight Shafted Piles in London Clay (1996)

C_u = undrained shear strength of London Clay
Typically diameter of under-ream = 3 x diameter of shaft

Factor of safety : $f_1 = f_2 = 2.5$
or $f_1 = 1$ $f_2 = 3$ whichever gives the lower capacity

Minimum spacing of pile shafts = 3 x diameter (ensure under-reams do not encroach)