3 SHALLOW FOUNDATIONS

3.1 GENERAL

3.1.1 Scope

1 The provisions of this Section apply to shallow foundations including isolated, pads, strips and rafts.

2 The purpose of QCS is to provide as a general technical guide for acceptable construction work practices in the State of Qatar, considering this; any addition for technology, material, specification, standard that are not mentioned in this section or their modification, shall be subject to approval as stated in the introduction of QCS (00-02).

3.1.2 Definition

1 Shallow foundations are taken to be those where the depth below finished ground level is less than 3 m and include isolated, pad, strip and raft foundations. The choice of 3 m is arbitrary; shallow foundations where the depth/breadth ratio is high may need to be designed as deep foundations.

3.1.3 References

BS 5930 ....Code of practice for ground investigations

BS 8004 ....Code of practice for foundations.

EN 1990 ....Eurocode 0: Basis of Structural Design

EN 1991 ....Eurocode 1: Actions on structures

EN 1992 ....Eurocode 2: Design of concrete structures

EN 1993 ....Eurocode 3: Design of steel structures

EN 1994 ....Eurocode 4: Design of composite steel and concrete structures

EN 1995 ....Eurocode 5: Design of timber structures

EN 1996 ....Eurocode 6: Design of masonry structures

EN 1997-1 ....Eurocode 7: Geotechnical design - Part 1: General rules

EN 1997-2 ....Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing

EN 1998 ....Eurocode 8: Design of structures for earthquake resistance

3.1.4 Limit States Considerations

1 The following limit states shall be considered and an appropriate list shall be compiled:

(a) Loss of overall stability;

(b) Bearing resistance failure, punching failure, squeezing;

(c) Failure by sliding;

(d) Combined failure in the ground and in the structure;

(e) Structural failure due to foundation movement;

(f) Excessive settlements;

(g) Excessive heave due to swelling, frost and other causes;

(h) Unacceptable vibrations.

3.2 DESIGN CONSIDERATIONS

3.2.1 General

1 The depth to which foundations should be carried depends on two principal factors:

(a) Reaching an adequate bearing stratum;

(b) Penetration below the zone in which trouble may be expected from seasonal weather changes.

2 Other factors such as ground movements, changes in groundwater conditions, long-term stability and heat transmitted from structures to the supporting ground may be important.

3 Shallow foundations are particularly vulnerable to certain soil conditions, e.g. loose water-bearing sands and soils that change structure when loaded. Specialist advice should be sought where such conditions are indicated by ground investigation.

3.2.2 Allowable Bearing Pressure

1 The center of area of a foundation or group of foundations should be arranged vertically under the centre of gravity of the imposed loading. If this is not possible, the effects on the structure of rotation and settlement of the foundation need to be considered.

2 Where foundation support is provided by a number of separate bases these should, as far as practicable, be proportioned so that differential settlement is minimal.

3 For soil: it is recommended to use soil mechanics theories, the bearing capacity calculation is based on angle of internal friction, cohesion and type and depth of foundation.

4 For Rock: it is recommended to use Rock mechanics theories, the bearing capacity should be based on the strength and quality of Rock (RQD, GSI, RMR...etc.).

3.2.3 Selection of Types of Shallow Foundation

1 The selection of the appropriate type of shallow foundation will normally depend on the magnitude and disposition of the structural loads, the bearing capacity and settlement characteristics of the ground and the need to found in stable soil.

2 A pad foundation is used for the purpose of distributing concentrated loads. Unless special conditions control the design, relatively heavy column loads make it advantageous to use pad foundations.

3 Strip foundations may be more appropriate where column loads are comparatively small and closely spaced or where walls are heavy or heavily loaded.

4 Adjacent pad foundations can be combined or joined together with ground beams to support eccentric loads, to resist overturning or to oppose horizontal forces. Walls between columns may be carried on ground beams spanning between the pad foundations.

5 Where the allowable bearing pressure would result in large isolated foundations occupying the majority of the available area, it may be logical to join them to form a raft and spread the loads over the entire area. The combination of isolated foundations to form a raft sometimes results in a complex design and a large increase in the reinforcement requirement.

6 In connection with the provision of foundations to an extension of an existing building, allowance should be made for differential movement of the foundations between the new and existing structure; such movement affects the structure above foundations. Where a degree of cracking and subsequent remedial work is not acceptable, provision for a joint between the extension and existing building should be considered. Where the foundations of an extension about the foundations of the existing building, the stability of the existing foundations should be ensured.

3.2.4 Pad foundations

1 For buildings such as low rise dwellings and lightly framed structures, pad foundations may be of unreinforced concrete provided that the angle of spread of load from the pier or base plate to the outer edge of the ground bearing does not exceed one (vertical) in one (horizontal) and that the stresses in the concrete due to bending and shear do not exceed tolerable limits. For buildings other than low rise and lightly framed structures, it is customary to use reinforced concrete foundations.

2 The thickness of the foundation should under no circumstances be less than 150 mm and will generally be greater than this to maintain cover to reinforcement where provided.

3 Where concrete foundations are used they should be designed in accordance with the design method appropriate to the loading assumptions.

3.2.5 Strip foundations

1 Similar considerations to those for pad foundations apply to strip foundations. On sloping sites strip foundations should be on a horizontal bearing, stepped where necessary to maintain adequate depth.

2 In continuous wall foundations it is recommended that reinforcement be provided wherever an abrupt change in magnitude of load or variation in ground support occurs. Continuous wall foundations will normally be constructed in mass concrete provided that the angle of spread of load from the edge of the wall base to the outer edge of the ground bearing does not exceed one (vertical) in one (horizontal). Foundations on sloping ground, and where regarding is likely to take place, may require to be designed as retaining walls to accommodate steps between adjacent ground floor slabs or finished ground levels. At all changes of level unreinforced foundations should be lapped at the steps for a distance at least equal to the thickness of the foundation or a minimum of 300mm. Where the height of the step exceeds the thickness of the foundation, special precautions should be taken. The thickness of reinforced strip foundations should be not less than 150mm, and care should be taken with the excavation levels to ensure that this minimum thickness is maintained. For the longitudinal spread of loads, sufficient reinforcement should be provided to withstand the tensions induced. It will sometimes be desirable to make strip foundations of inverted tee beam sections, in order to provide adequate stiffness in the longitudinal direction. At corners and junctions the longitudinal reinforcement of each wall foundation should be lapped.

3 Where the use of ordinary strip foundations would overstress the bearing strata, wide strip foundations designed to transmit the foundation loads across the full width of the strip may be used. The depth below the finished ground level should be the same as for ordinary strip foundations.

4 Where the nature of the ground is such that narrow trenches can be neatly cut down to the bearing stratum, an economical foundation may be achieved by filling the trenches with concrete. When deciding the trench width, account should be taken of normal building tolerances in relation to setting out dimensions. Where the thickness of such a foundation is 500mm or more, any step should be not greater than the concrete thickness and the lap at such a step should be at least 1 m or twice the step height, whichever is the greater?

5 Where fill or other loose materials occur above the bearing stratum adequate support is required to any excavation. Consideration may be given to the use of lean mix mass concrete replacement under ordinary strip footings placed at shallow depth. This mass concrete can be poured against either permanent or recoverable shuttering. This form of foundation provides a method of dealing with local areas where deeper foundations are required.

3.2.6 Raft foundations

1 *General.* Suitably designed raft foundations may be used in the following circumstances.

(a) For lightly loaded structures on soft natural ground where it is necessary to spread the load, or where there is variable support due to natural variations, made ground or weaker zones. In this case the function of the raft is to act as a bridge across the weaker zones. Rafts may form part of compensated foundations.

(b) Where differential settlements are likely to be significant. The raft will require special design, involving an assessment of the disposition and distribution of loads, contact pressures and stiffness of the soil and raft.

3.3 BASIS OF GEOTECHNICAL DESIGN

3.3.1 Design Requirements

1 For each geotechnical design situation it shall be verified that no relevant limit state is exceeded.

2 When defining the design situations and the limit states, the following factors should be considered:

(a) Site conditions with respect to overall stability and ground movements;

(b) Nature and size of the structure and its elements, including any special requirements such as the design life;

(c) Conditions with regard to its surroundings (e.g.: neighboring structures, traffic, utilities, vegetation, hazardous chemicals);

(d) Ground conditions;

(e) Ground-water conditions;

(f) Regional seismicity;

(g) Influence of the environment (hydrology, surface water, subsidence, seasonal changes of temperature and moisture).

3 Limit states can occur either in the ground or in the structure or by combined failure in the structure and the ground.

4 Limit states should be verified by any appropriate method such as calculation method as described in 3.4;

5 In practice, experience will often show which type of limit state will govern the design and the avoidance of other limit states may be verified by a control check.

6 Buildings should normally be protected against the penetration of ground-water or the transmission of vapor or gases to their interiors.

7 If practicable, the design results should be checked against comparable experience.

8 In order to establish minimum requirements for the extent and content of geotechnical investigations, calculations and construction control checks, the complexity of each geotechnical design shall be identified together with the associated risks. In particular, a distinction shall be made between:

(a) Light and simple structures and small earthworks for which it is possible to ensure that the minimum requirements will be satisfied by experience and qualitative geotechnical investigations, with negligible risk;

(b) Other geotechnical structures.

9 For structures and earthworks of low geotechnical complexity and risk, such as defined above, simplified design procedures may be applied.

10 To establish geotechnical design requirements, three Geotechnical Categories, 1, 2 and 3, may be introduced.

11 A preliminary classification of a structure according to Geotechnical Category should normally be performed prior to the geotechnical investigations. The category should be checked and changed, if necessary, at each stage of the design and construction process.

12 The procedures of higher categories may be used to justify more economic designs, or if the designer considers them to be appropriate.

13 The various design aspects of a project can require treatment in different Geotechnical Categories. It is not required to treat the whole of the project according to the highest of these categories.

14 **Geotechnical Category 1** should only include small and relatively simple structures:

(a) For which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations;

(b) With negligible risk.

15 Geotechnical Category 1 procedures should be used only where there is negligible risk in terms of overall stability or ground movements and in ground conditions, which are known from comparable local experience to be sufficiently straightforward. In these cases the procedures may consist of routine methods for foundation design and construction.

16 Geotechnical Category 1 procedures should be used only if there is no excavation below the water table or if comparable local experience indicates that a proposed excavation below the water table will be straightforward.

17 **Geotechnical Category 2** should include conventional types of structure and foundation with no exceptional risk or difficult soil or loading conditions

18 Designs for structures in Geotechnical Category 2 should normally include quantitative geotechnical data and analysis to ensure that the fundamental requirements are satisfied.

19 Routine procedures for field and laboratory testing and for design and execution may be used for Geotechnical Category 2 designs.

(a) the following are examples of conventional structures or parts of structures complying with Geotechnical Category 2:

(i) Shallow foundations;

(ii) Pile foundations;

(iii) Walls and other structures retaining or supporting soil or water;

(iv) Excavations;

(v) Bridge piers and abutments;

(vi) Embankments and earthworks;

(vii) Ground anchors and other tie-back systems;

(viii) Tunnels in hard, non-fractured rock and not subjected to special water tightness or other requirements.

20 **Geotechnical Category 3** should include structures or parts of structures, which fall outside the limits of Geotechnical Categories 1 and 2.

21 Geotechnical Category 3 should normally include alternative provisions and rules to those in this standard.

(a) Geotechnical Category 3 includes the following examples:

(i) Very large or unusual structures;

(ii) Structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions;

(iii) Structures in highly seismic areas;

(iv) Structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.

3.3.2 Design Situations

1 Both short-term and long-term design situations shall be considered.

2 In geotechnical design, the detailed specifications of design situations should include, as appropriate:

(a) The actions, their combinations and load cases;

(b) The general suitability of the ground on which the structure is located with respect to overall stability and ground movements;

(c) The disposition and classification of the various zones of soil, rock and elements of construction, which are involved in any calculation model;

(d) Dipping bedding planes;

(e) Mine workings, caves or other underground structures;

(f) In the case of structures resting on or near rock:

(i) inter bedded hard and soft strata;

(ii) faults, joints and fissures;

(iii) possible instability of rock blocks;

(iv) solution cavities, such as swallow holes or fissures filled with soft material, and continuing solution processes;

(g) The environment within which the design is set, including the following:

(i) effects of scour, erosion and excavation, leading to changes in the geometry of the ground surface;

(ii) effects of chemical corrosion;

(iii) effects of weathering;

(iv) effects of long duration droughts;

(v) variations in ground-water levels, including, e.g. the effects of dewatering, possible flooding, failure of drainage systems, water exploitation;

(vi) the presence of gases emerging from the ground;

(h) Earthquakes;

(i) Ground movements caused by subsidence due to mining or other activities;

(j) The sensitivity of the structure to deformations;

(k) The effect of the new structure on existing structures, services and the local environment.

3.3.3 Durability

1 At the geotechnical design stage, the significance of environmental conditions shall be assessed in relation to durability and to enable provisions to be made for the protection or adequate resistance of the materials.

2 In designing for durability of materials used in the ground, the following should be considered:

(a) For concrete:

(i) Aggressive agents in the ground-water or in the ground or fill material, such as acids or sulfate salts;

(b) For steel:

(i) Chemical attack where foundation elements are buried in ground that is sufficiently permeable to allow the percolation of ground-water and oxygen;

(ii) Corrosion on the faces of sheet pile walls exposed to free water, particularly in the mean water level zone;

(iii) The pitting type of corrosive attack on steel embedded in fissured or porous concrete, particularly for rolled steel where the mill scale, acting as a cathode, promotes electrolytic action with the scale-free surface acting as an anode;

(c) For timber:

(i) Fungi and aerobic bacteria in the presence of oxygen;

(d) For synthetic fabrics:

(i) The ageing effects of UV exposure or ozone degradation or the combined effects of temperature and stress, and secondary effects due to chemical degradation.

3 Reference should be made to durability provisions in construction materials standards.

3.4 GEOTECHNICAL DESIGN BY CALCULATION

3.4.1 General

1 Design by calculation shall be in accordance with the fundamental requirements of EN 1990 and with the particular rules of this specification. Design by calculation involves:

(a) Actions, which may be either imposed loads or imposed displacements, e.g. from ground movements;

(b) Properties of soils, rocks and other materials;

(c) Geometrical data;

(d) Limiting values of deformations, crack widths, vibrations etc;

(e) Calculation models.

2 It should be considered that knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are usually more significant to fulfilling the fundamental requirements than is precision in the calculation models and partial factors.

3 The calculation model shall describe the assumed behavior of the ground for the limit state under consideration.

4 If no reliable calculation model is available for a specific limit state, analysis of another limit state shall be carried out using factors to ensure that exceeding the specific limit state considered is sufficiently improbable. Alternatively, design by prescriptive measures, experimental models and load tests, or the observational method, shall be performed.

5 The calculation model may consist of any of the following:

(a) An analytical model;

(b) A semi-empirical model;

(c) A numerical model.

6 Any calculation model shall be either accurate or err on the side of safety.

7 A calculation model may include simplifications.

8 If needed, a modification of the results from the model may be used to ensure that the design calculation is either accurate or errs on the side of safety.

9 If the modification of the results makes use of a model factor, it should take account of the following:

(a) The range of uncertainty in the results of the method of analysis;

(b) Any systematic errors known to be associated with the method of analysis.

10 If an empirical relationship is used in the analysis, it shall be clearly established that it is relevant for the prevailing ground conditions.

11 Limit states involving the formation of a mechanism in the ground should be readily checked using a calculation model. For limit states defined by deformation considerations, the deformations should be evaluated by calculation or otherwise assessed.

NOTE: many calculation models are based on the assumption of a sufficiently ductile performance of the ground/structure system. A lack of ductility, however, will lead to an ultimate limit state characterized by sudden collapse.

12 Numerical methods can be appropriate if compatibility of strains or the interaction between the structure and the soil at a limit state are considered.

13 Compatibility of strains at a limit state should be considered. Detailed analysis, allowing for the relative stiffness of structure and ground, may be needed in cases where a combined failure of structural members and the ground could occur. Examples include raft foundations, laterally loaded piles and flexible retaining walls. Particular attention should be paid to strain compatibility for materials that are brittle or that have strain-softening properties.

14 In some problems, such as excavations supported by anchored or strutted flexible walls, the magnitude and distribution of earth pressures, internal structural forces and bending moments depend to a great extent on the stiffness of the structure, the stiffness and strength of the ground and the state of stress in the ground.

15 In these problems of ground-structure interaction, analyses should use stress-strain relationships for ground and structural materials and stress states in the ground that are sufficiently representative, for the limit state considered, to give a safe result.

3.4.2 Actions

1 The definition of actions shall be taken as:

(a) Set of forces (loads) applied to the structure (direct action);

(b) Set of imposed deformations or accelerations caused for example, by temperature changes, moisture variation, uneven settlement or earthquakes (indirect action).

The values of actions shall be taken from EN 1991 or equivalent international standard, where relevant.

2 The values of geotechnical actions to be used shall be selected, since they are known before a calculation is performed; they may change during that calculation.

NOTE: Values of geotechnical actions may change during the course of calculation. In such cases they will be introduced as a first estimate to start the calculation with a preliminary, known value.

3 Any interaction between the structure and the ground shall be taken into account when determining the actions to be adopted in the design.

4 In geotechnical design, the following should be considered for inclusion as actions:

(a) the weight of soil, rock and water;

(b) stresses in the ground;

(c) earth pressures and ground-water pressure;

(d) free water pressures, including wave pressures;

(e) ground-water pressures;

(f) seepage forces;

(g) dead and imposed loads from structures;

(h) surcharges;

(i) mooring forces;

(j) removal of load or excavation of ground;

(k) traffic loads;

(l) movements caused by mining or other caving or tunneling activities;

(m) swelling and shrinkage caused by vegetation, climate or moisture changes;

(n) movements due to creeping or sliding or settling ground masses;

(o) movements due to degradation, dispersion, decomposition, self-compaction and solution;

(p) movements and accelerations caused by earthquakes, explosions, vibrations and dynamic loads;

(q) temperature effects, including frost action;

(r) imposed pre-stress in ground anchors or struts;

(s) down drag.

5 Consideration shall be given to the possibility of variable actions occurring both jointly and separately.

6 The duration of actions shall be considered with reference to time effects in the material properties of the soil, especially the drainage properties and compressibility of fine-grained soils.

7 Actions, which are applied repeatedly, and actions with variable intensity shall be identified for special consideration with regard to, e.g. continuing movements, liquefaction of soils, change of ground stiffness and strength.

8 Actions that produce a dynamic response in the structure and the ground shall be identified for special consideration.

9 Actions in which ground- and free-water forces predominate shall be identified for special consideration with regard to deformations, fissuring, variable permeability and erosion.

NOTE Unfavorable (or destabilizing) and favorable (or stabilizing) permanent actions may in some situations be considered as coming from a single source. If they are considered so, a single partial factor may be applied to the sum of these actions or to the sum of their effects.

3.4.3 Ground Properties

1 Properties of soil and rock masses, as quantified for design calculations by geotechnical parameters, shall be obtained from test results, either directly or through correlation, theory or empiricism, and from other relevant data.

2 Values obtained from test results and other data shall be interpreted appropriately for the limit state considered.

3 Account shall be taken of the possible differences between the ground properties and geotechnical parameters obtained from test results and those governing the behavior of the geotechnical structure.

4 The above differences can be due to the following factors:

(a) many geotechnical parameters are not true constants but depend on stress level and mode of deformation;
(b) soil and rock structure (e.g. fissures, laminations, or large particles) that may play a different role in the test and in the geotechnical structure;
(c) time effects;
(d) the softening effect of percolating water on soil or rock strength;
(e) the softening effect of dynamic actions;
(f) the brittleness or ductility of the soil and rock tested;
(g) the method of installation of the geotechnical structure;
(h) the influence of workmanship on artificially placed or improved ground;
(i) the effect of construction activities on the properties of the ground.

5 When establishing values of geotechnical parameters, the following should be considered:

(a) published and well recognized information relevant to the use of each type of test in the appropriate ground conditions;
(b) the value of each geotechnical parameter compared with relevant published data and local and general experience;
(c) the variation of the geotechnical parameters that are relevant to the design;
(d) the results of any large scale field trials and measurements from neighboring constructions;
(e) any correlations between the results from more than one type of test;
(f) any significant deterioration in ground material properties that may occur during the lifetime of the structure.

6 Calibration factors shall be applied where necessary to convert laboratory or field test results according to EN 1997-2 into values that represent the behavior of the soil and rock in the ground, for the actual limit state, or to take account of correlations used to obtain derived values from the test results.

3.4.4 Geometrical Data

1 The level and slope of the ground surface, water levels, levels of interfaces between strata, excavation levels and the dimensions of the geotechnical structure shall be treated as geometrical data.

3.4.5 Characteristic and Representative Values of Actions

1 Characteristic and representative values of actions shall be derived in accordance with EN 1990 and the various parts of EN 1991.

3.4.6 Characteristic Values of Geotechnical Parameters

1 The selection of characteristic values for geotechnical parameters shall be based on results and derived values from laboratory and field tests, complemented by well-established experience.

2 The characteristic value of a geotechnical parameter shall be selected as a cautious estimate of the value affecting the occurrence of the limit state.

3 The selection of characteristic values for geotechnical parameters shall take account of the following:

(a) geological and other background information, such as data from previous projects;

(b) the variability of the measured property values and other relevant information, e.g. from existing knowledge;

(c) the extent of the field and laboratory investigation;

(d) the type and number of samples;

(e) the extent of the zone of ground governing the behavior of the geotechnical structure at the limit state being considered;

(f) the ability of the geotechnical structure to transfer loads from weak to strong zones in the ground.

4 Characteristic values can be lower values, which are less than the most probable values, or upper values, which are greater.

5 For each calculation, the most unfavorable combination of lower and upper values of independent parameters shall be used.

6 The zone of ground governing the behavior of a geotechnical structure at a limit state is usually much larger than a test sample or the zone of ground affected in an in situ test. Consequently the value of the governing parameter is often the mean of a range of values covering a large surface or volume of the ground. The characteristic value should be a cautious estimate of this mean value.

7 If the behavior of the geotechnical structure at the limit state considered is governed by the lowest or highest value of the ground property, the characteristic value should be a cautious estimate of the lowest or highest value occurring in the zone governing the behavior.

8 When selecting the zone of ground governing the behavior of a geotechnical structure at a limit state, it should be considered that this limit state may depend on the behavior of the supported structure. For instance, when considering a bearing resistance ultimate limit state for a building resting on several footings, the governing parameter should be the mean strength over each individual zone of ground under a footing, if the building is unable to resist a local failure. If, however, the building is stiff and strong enough, the governing parameter should be the mean of these mean values over the entire zone or part of the zone of ground under the building.

9 If statistical methods are employed in the selection of characteristic values for ground properties, such methods should differentiate between local and regional sampling and should allow the use of a prior knowledge of comparable ground properties.

10 If statistical methods are used, the characteristic value should be derived such that the calculated probability of a worse value governing the occurrence of the limit state under consideration is not greater than 5%.

11 NOTE : In this respect, a cautious estimate of the mean value is a selection of the mean value of the limited set of geotechnical parameter values, with a confidence level of 95%; where local failure is concerned, a cautious estimate of the low value is a 5% fractal.

12 When using standard tables of characteristic values related to soil investigation parameters, the characteristic value shall be selected as a very cautious value.

13 Angle of Internal Friction For soil shall be calculated from In-situ SPT test or from Laboratory test.

14 Angle of Internal Friction For Rock: it is recommended to be estimated using Rock mechanics theory, the estimated angle of internal friction and cohesion is based on the strength and quality of rock (Rock Quality Designation- RQD-, Geological Strength Index- GSI-, and Rock Mass Rating- RMR-). The following Ranges can be taken as a guideline:-

Unconfined Design Compressive Strength of Rock	**Cohesion of Rock**	**Angle of Internal Friction of Rock**
σ_{ci} [*MPa*]	*c* [*kPa*]	φ [°]
150	**7000 - 13000**	**46 - 68**
80	**3000 - 4000**	**30 - 65**
50	**2000 - 4000**	**40 - 60**
30	**1000 - 2000**	**40 - 60**
20	**400 - 600**	**20 - 44**
15	**300 - 500**	**24 - 38**
5	**90 - 100**	**23 -28**

15 Modulus of Subgrade Reaction: The following general formula for calculating the Modulus of Subgrade Reaction can be used: $Ks = Es/B(1-v^2)$

Es: Modulus of Elasticity of Soil (KN/m^2)

B: Foundation width (m)

V: Poisson’s Ratio of Soil

16 Friction Coefficient: The table blow presents the maximum value of friction coefficient:

Interface Materials	Maximum Coefficient, f
Mass concrete on the following foundation materials:	
Clean Sound Rock	**0.70**
Compacted Clean Gravel, Gravel-Sand Mixtures, Coarse Sand	**0.55 to 0.60**
Compacted Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	**0.45 to 0.55**
Compacted Clean fine sand, silty or clayey fine to medium sand	**0.35 to 0.45**
Medium dense Fine sandy silt, non-plastic silt	**0.30 to 0.35**
Very stiff and hard residual or pre-consolidated clay	**0.40 to 0.50**
Medium stiff and stiff clay and silty clay	**0.30 to 0.35**

17 Allowable Settlements (Distortion, Total & Differential)

Description	Isolated Footings (mm)		Raft Foundations (mm)	
	Sand	Clay	Sand	Clay
Angular Distortion				
Reinforce Concrete Building Frame	**1/666**	**1/666**	**1/500**	**1/500**
Steel Frame	**1/300**	**1/300**	**1/300**	**1/300**
Differential Settlement (L: Distance between Adjacent Columns)				
Reinforce Concrete Building Frame	**0.0015L**	**0.0015L**	**0.002L**	**0.002L**
Steel Frame	**0.003L**	**0.003L**	**0.0033L**	**0.0033L**
Maximum Settlement				
Reinforce Concrete Building Frame	**25**	**38**	**50**	**75**
Steel Frame	**25**	**38**	**50**	**75**

3.4.7 Characteristic Values of Geometrical Data

1 Characteristic values of the levels of ground and ground-water or free water shall be measured, nominal or estimated upper or lower levels.

2 Characteristic values of levels of ground and dimensions of geotechnical structures or elements should usually be nominal values.

3.4.8 Geotechnical Design Report

1 The assumptions, data, methods of calculation and results of the verification of safety and serviceability shall be recorded in the Geotechnical Design Report.

2 The level of detail of the Geotechnical Design Reports will vary greatly, depending on the type of design. For simple designs, a single sheet may be sufficient.

3 The Geotechnical Design Report should normally include the following items, with cross-reference to the Ground Investigation Report :

(a) a description of the site and surroundings;

(b) a description of the ground conditions;

(c) a description of the proposed construction, including actions;

(d) design values of soil and rock properties, including justification, as appropriate;

(e) statements on the codes and standards applied;

(f) statements on the suitability of the site with respect to the proposed construction and the level of acceptable risks;

(g) geotechnical design calculations and drawings;

(h) foundation design recommendations;

(i) a note of items to be checked during construction or requiring maintenance or monitoring.

4 The Geotechnical Design Report shall include a plan of supervision and monitoring, as appropriate. Items, which require checking during construction or, which require maintenance after construction shall be clearly identified. When the required checks have been carried out during construction, they shall be recorded in an addendum to the Report.

5 In relation to supervision and monitoring the Geotechnical Design Report should state:

(a) the purpose of each set of observations or measurements;

(b) the parts of the structure, which are to be monitored and the locations at which observations are to be made;

(c) the frequency with which readings is to be taken;

(d) the ways in which the results are to be evaluated;

(e) the range of values within which the results are to be expected;

(f) the period of time for which monitoring is to continue after construction is complete;

(g) the parties responsible for making measurements and observations, for interpreting the results obtained and for maintaining the instruments.

6 An extract from the Geotechnical Design Report, containing the supervision, monitoring and maintenance requirements for the completed structure, shall be provided to the owner/client.

3.4.9 Actions and Design Situations

1 Design situations shall be selected in accordance with 3.3.2.

2 The actions listed in 3.4.2(4) should be considered when selecting the limit states for calculation.

3 If structural stiffness is significant, an analysis of the interaction between the structure and the ground should be performed in order to determine the distribution of actions.

3.4.10 Design and Construction Considerations

1 When choosing the depth of a shallow foundation the following shall be considered:

(a) reaching an adequate bearing stratum;

(b) the depth above which shrinkage and swelling of clay soils, due to seasonal weather changes, or to trees and shrubs, may cause appreciable movements;

(c) the level of the water table in the ground and the problems, which may occur if excavation for the foundation is required below this level;

(d) possible ground movements and reductions in the strength of the bearing stratum by seepage or climatic effects or by construction procedures;

(e) the effects of excavations on nearby foundations and structures;

(f) anticipated excavations for services close to the foundation;

(g) high or low temperatures transmitted from the building;

(h) the possibility of scour;

(i) the effects of variation of water content due to long periods of drought, and subsequent periods of rain, on the properties of volume-unstable soils in arid climatic areas;

(j) the presence of soluble materials, e.g. limestone, clay stone, gypsum, salt rocks;

(k) Minimum Foundation Depth:

Since the seasonal environmental changes in Qatar are insignificant the minimum depth of foundation can be taken at 0.3m for strong rock and up to 1.2m for loose SAND. However, in all cases the foundation shall covered with any kind of materials.

2 In addition to fulfilling the performance requirements, the design foundation width shall take account of practical considerations such as economic excavation, setting out tolerances, working space requirements and the dimensions of the wall or column supported by the foundation.

3 One of the following design methods shall be used for shallow foundations:

(a) a direct method, in which separate analyses are carried out for each limit state. When checking against an ultimate limit state, the calculation shall model as closely as possible the failure mechanism, which is envisaged. When checking against a serviceability limit state, a settlement calculation shall be used;

(b) an indirect method using comparable experience and the results of field or laboratory measurements or observations, and chosen in relation to serviceability limit state loads so as to satisfy the requirements of all relevant limit states;

(c) a prescriptive method in which a presumed bearing resistance is used.

3.4.11 Foundations on Rock; Additional Design Considerations

1 The design of shallow foundations on rock shall take account of the following features:

(a) the deformability and strength of the rock mass and the permissible settlement of the supported structure;

(b) the presence of any weak layers, for example solution features or fault zones, beneath the foundation;

(c) the presence of bedding joints and other discontinuities and their characteristics (for example filling, continuity, width, spacing);

(d) the state of weathering, decomposition and fracturing of the rock;

(e) disturbance of the natural state of the rock caused by construction activities, such as, for example, underground works or slope excavation, being near to the foundation.

2 Shallow foundations on rock may normally be designed using the method of presumed bearing pressures. For strong intact igneous rocks, gneissic rocks, limestone and sandstones, the presumed bearing pressure are limited by the compressive strength of the concrete foundation.

3 The settlement of a foundation may be assessed on the basis of comparable experience related to rock mass classification.

END OF PART