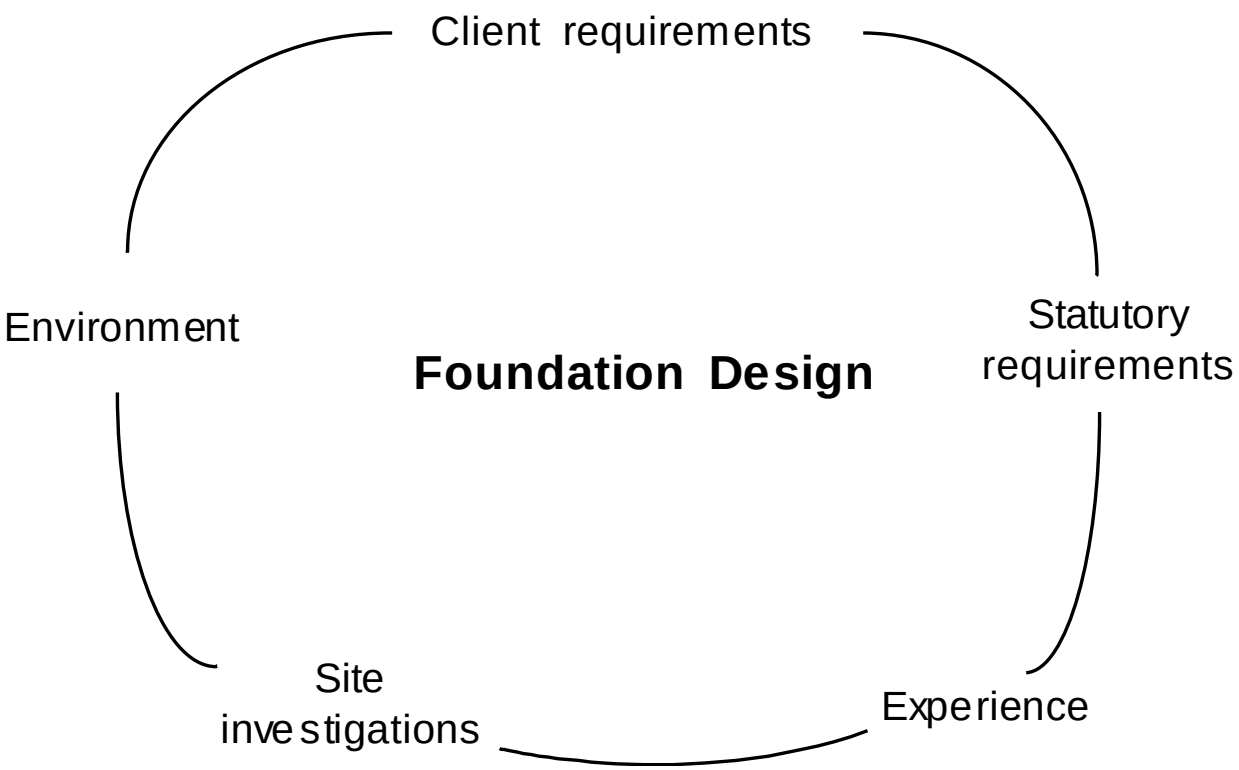
FOUNDATION DESIGN REQUIREMENTS



General Design Requirements

- **Owners needs and statutory requirements**
- **Information regarding the structure type, its function, anticipated structure life span including any special requirements**
- **Subsoil profile and GWT conditions**
- **Available construction procedure and construction materials**

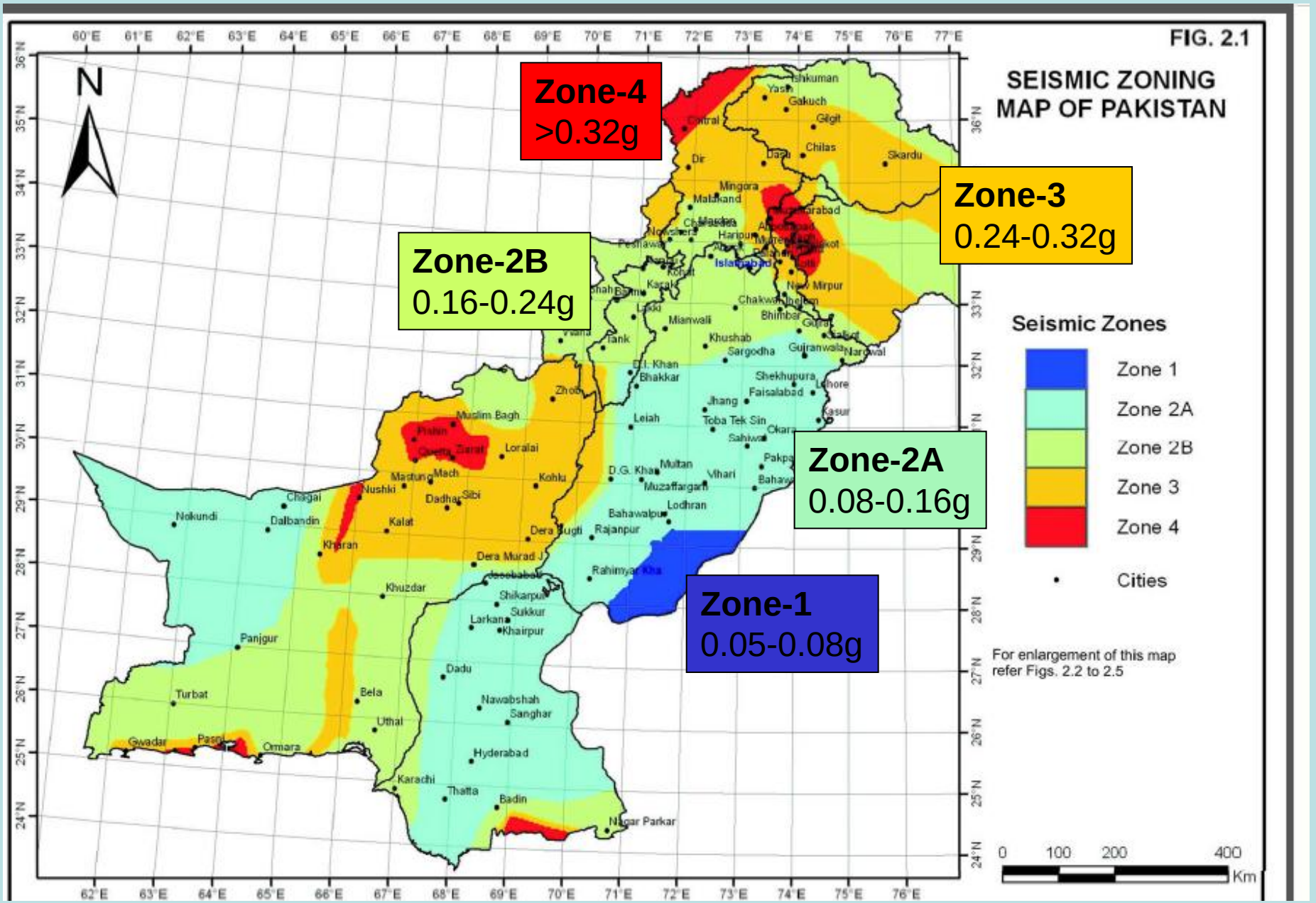
Impact on environment, noise, gas emission/health hazards etc.

- **Rigidity & durability i.e., safety against overturning, sliding, uplift etc.**

General Design Requirements

- Protection against concrete/steel deterioration
- Ease of construction and compatibility
- Influence of the environment (hydrology, surface water, subsidence, seasonal changes of moisture)
- Conditions with regard to its surroundings (neighboring structures, traffic, utilities, vegetation, hazardous chemicals etc.)
- Regional seismic considerations

SEISMIC ZONING MAP OF PAKISTAN, BCP-2007



Seismic Soil Profile Characterization

Soil Profile Type	Soil Profile Name/ Generic Description	Average Properties for Top 30 M (100 ft) of Soil Profile		
		Shear Wave Velocity, v_s m/sec (ft/sec)	Standard Penetration Tests, N [or N_{CH} for cohesionless soil layers] (blows/foot)	Undrained Shear Strength, s_u kPa (psf)
S_A	Hard Rock	>1,500 (>4,920)	–	–
S_B	Rock	750 to 1,500 (2,460 to 4,920)		
S_C	Very Dense Soil and Soft Rock	350 to 750 (1,150 to 2,460)	>50	>100 (>2,088)
S_D	Stiff Soil Profile	175 to 350 (575 to 1,150)	15 to 50	50 to 100 (1,044 to 2,088)
S_E	Soft Soil Profile	<175 (<575)	<15	<50 (<1,044)
S_F	Soil requiring Site-specific Evaluation. See 4.4.2 (BCP-2007)			

Environment (Check List)

The nature of the environment within which the design is set includes the following:

- Changes to ground surface (scour, erosion, excavation)
- Chemical corrosion
- Weathering
- Freezing
- Ground water fluctuation (flooding, failure of drainage, vegetation etc.)
- Gases emission
- Changes to materials (creep, mammals, vegetations)
- Earthquake
- Subsidence (mining, solution cavities)
- The tolerance of structures to deformation
- The effect of the new structure on existing structures or services.

Footing Depth (D_f) & Location

Physical Requirements:

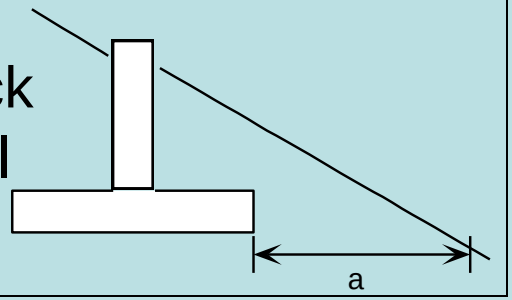
- Below top organic soil containing roots
- Below peats, muck or humus (organic soil) or soft soil
- Below shallow caverns (voids) or any other form of anomalies
- Below frost line

  (a) place footing below frost line or

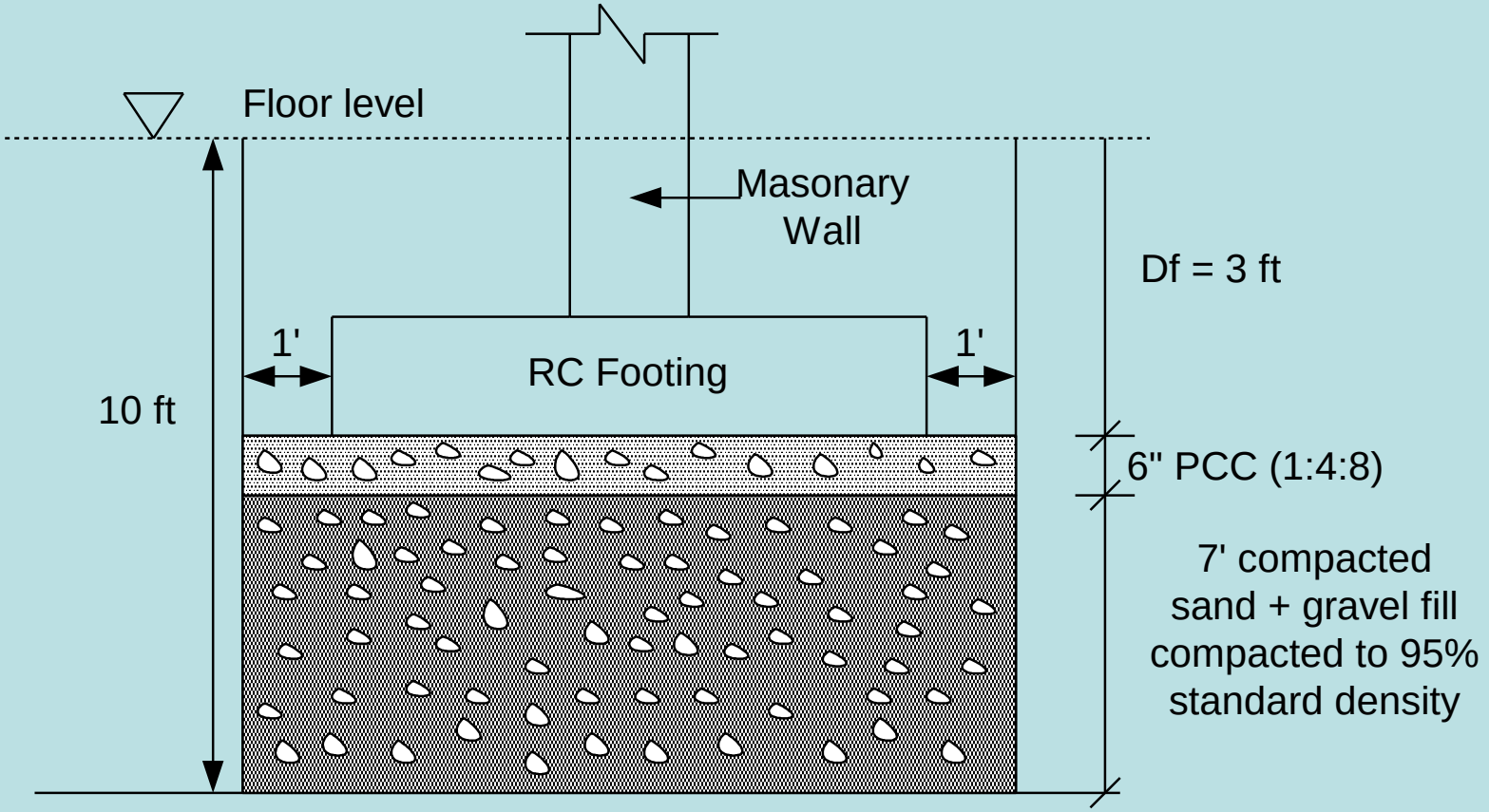
  (b) replace frost susceptible soil – frost susceptible soils are very fine sand and silts
- Below surface erosion zone (generally min. depth 1-1.5m)
- Below volume sensitive zone or weather susceptible zone
- Below difficult soils, expansive, fill, collapsible soil etc.
- Proper slope edge protection

  a = minimum 0.6 m (2 ft) for footings on rock

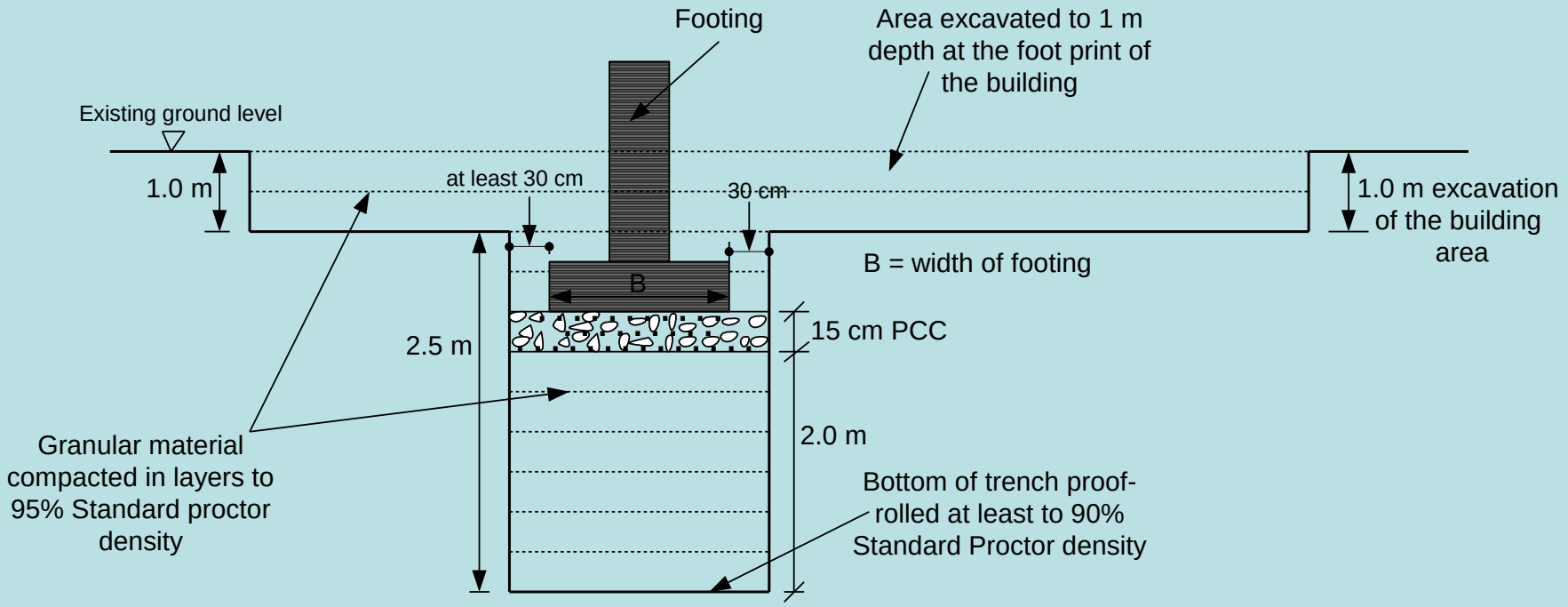
  = minimum 0.9 m (3 ft) for footings on soil



Foundation on Soft Soil (FPSC Building)



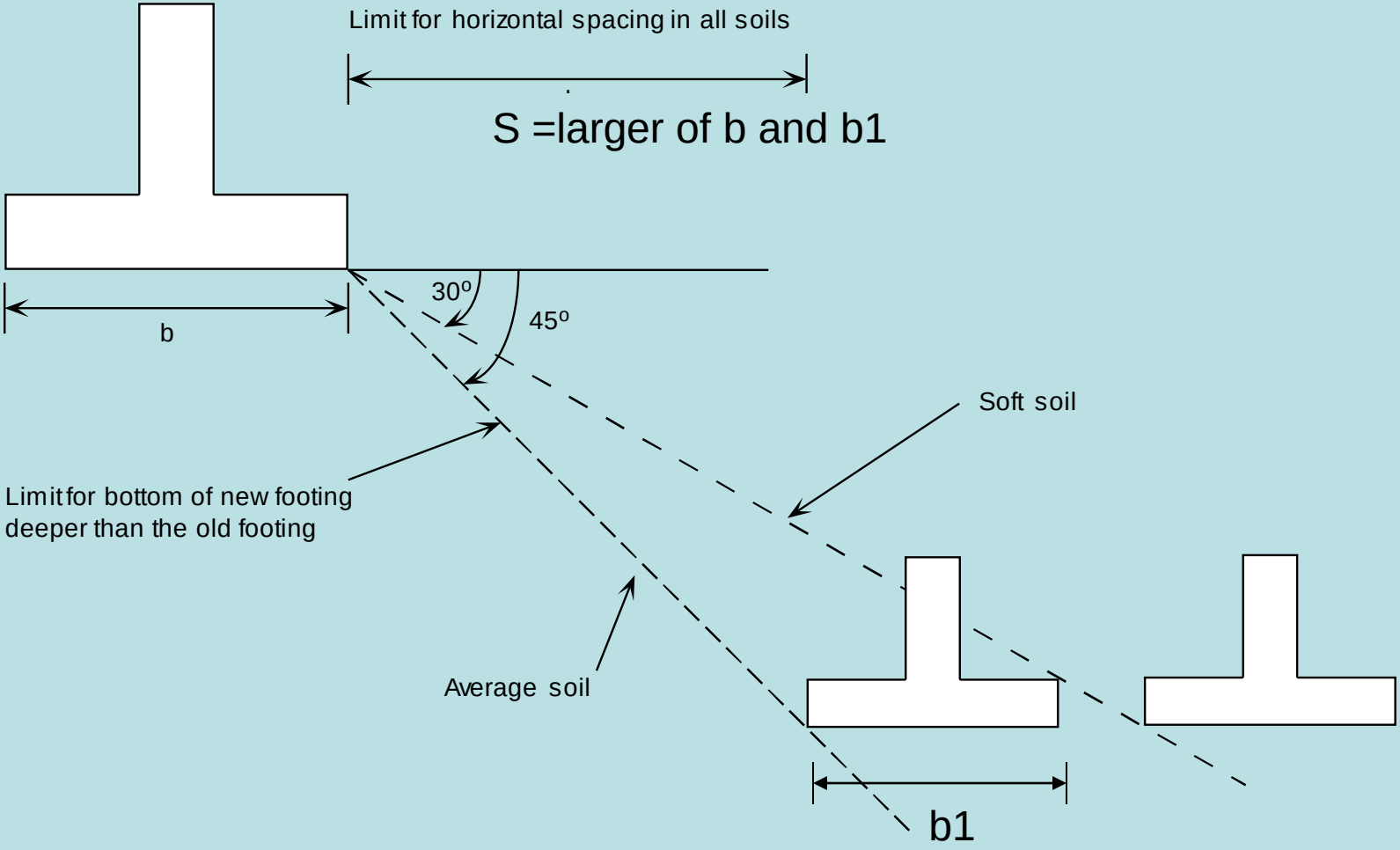
Foundation on Loose filling (Filling station at DHA Phase-II)



Loose Filling up to 8 m of silty clay with stone/pebble

Physical Requirements

- Footings with different elevations



Mechanical Requirements

- Scour depth (footings should be placed well below the scour depth)

  Scour depth, D = $1.338\left(\frac{q^2}{f}\right)^{1/3}$ in meters

  q = discharge per unit width in cumecs

  f = Lacey silt factor = $1.59\sqrt{d_{50}}$
  = 0.5 for fine silt
  = 9 for gravel
  d_{50} = diameter at which 50% material is finer

- Allowable Bearing Capacity Requirement
  Adjust D_f to suit required ABC
- Settlement
  settlement, in general, decreases with increasing depth. Adjust D_f to suit settlement

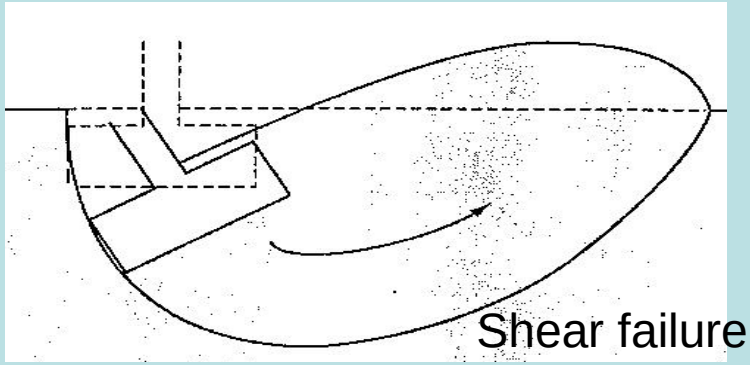
Foundation Design Criteria

There are two design criteria

1. **Shear Failure Criterion:**

   The load imposed on the underlying soil tends to shear the soil along a rupture surface in a similar manner as shear failure in a slope.

   The criterion for design is that the ratio of the shear strength of the soil to the maximum value of the mobilized shear stress must not exceed an appropriate factor of safety. Generally, in most cases not less than 3.0.



Shear failure mode

Foundation Design Criteria

2. Settlement Criterion:

The footing design should be such that the applied pressure must not exceed permissible total settlement, generally as given below:

TABLE 2.1 TYPICAL ALLOWABLE TOTAL SETTLEMENTS FOR FOUNDATION DESIGN

Type of Structure	Typical Allowable Total Settlement, δ_a (in)	Typical Allowable Total Settlement, δ_a (mm)
Office buildings	0.5–2.0 (1.0 is the most common value)	12–50 (25 is the most common value)
Heavy industrial buildings	1.0–3.0	25–75
Bridges	2.0	50

Mats	**2 in**	**50 mm**

Angular Distortion/Differential Settlement

- **The uniform settlement is not harmful but differential settlement causes distortion in structure leading to cracking, jamming doors/windows etc.**

- **The angular distortion between two points in a structure is given by:**

$$\text{Angular distortion, } \delta = \Delta/L$$

Where

Δ = differential settlement

L = distance between the two footings/points.

Effect of Settlement and Distortion on Buildings

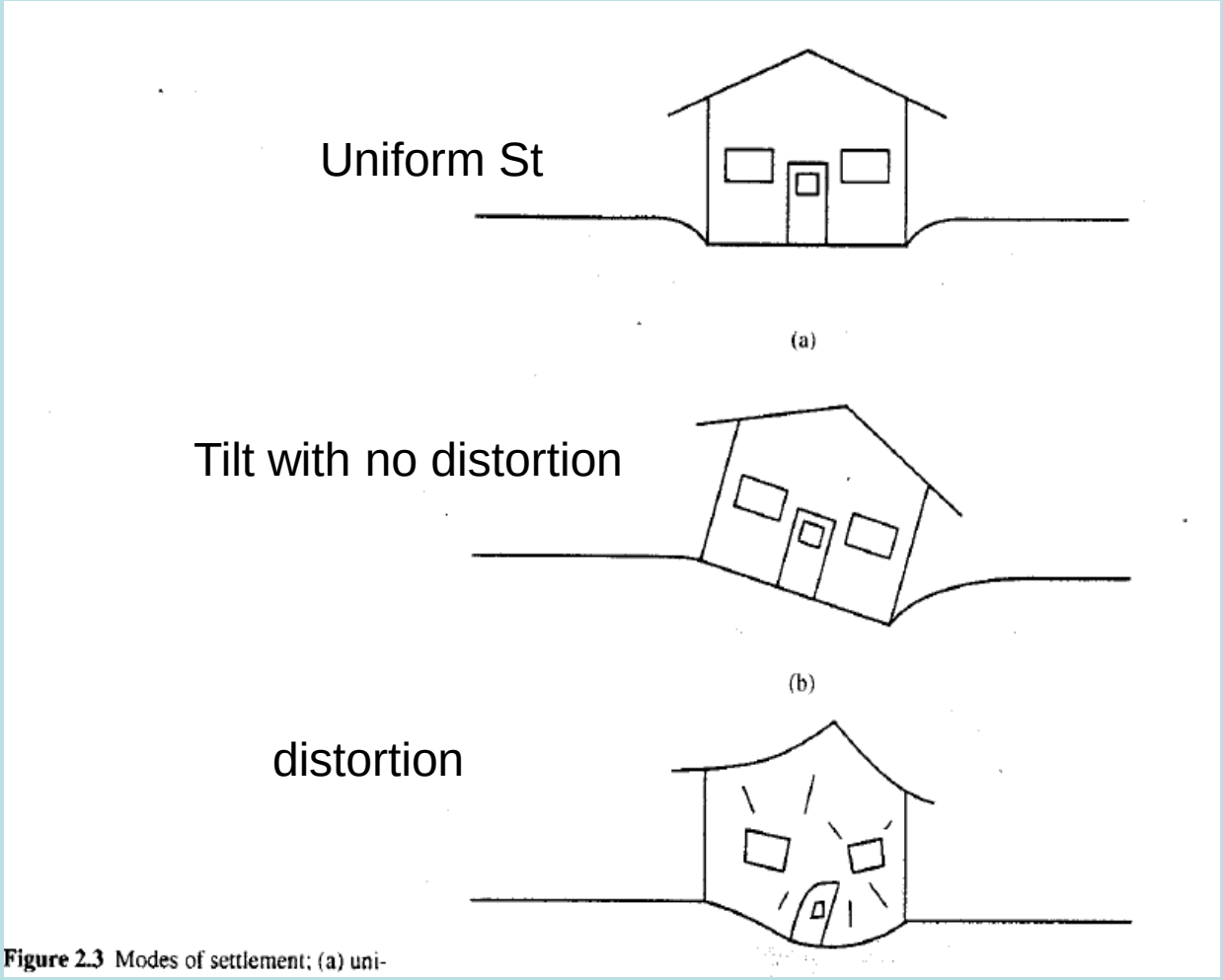


Figure 2.3 Modes of settlement; (a) uni-

Angular distortion must be controlled by controlling differential settlement in Buildings. The allowable limits of distortion are given in the next table.

TABLE 2.2 ALLOWABLE ANGULAR DISTORTION, θ_a (COMPILED FROM WAHLS, 1994; AASHTO, 1996; AND OTHER SOURCES)

Type of Structure	θ_a
Steel tanks	1/25
Bridges with simply-supported spans	1/125
Bridges with continuous spans	1/250
Buildings that are very tolerant of differential settlements, such as industrial buildings with corrugated steel siding and no sensitive interior finishes.	1/250
Typical commercial and residential buildings.	1/500
Overhead traveling crane rails.	1/500
Buildings that are especially intolerant of differential settlement, such as those with sensitive wall or floor finishes.	1/1000
Machinery[a]	1/1500
Buildings with unreinforced masonry load-bearing walls	
Length/height ≤ 3	1/2500
Length/height ≥ 5	1/1250

Example 2.4

A steel-frame office building has a column spacing of 20 ft. It is to be supported on spread footings founded on a clayey soil. What are the allowable total and differential settlements?

Solution

Per Table 2.1, use $\delta_a = 1.0$ in
Per Table 2.2, $\theta_a = 1/500$ ⇐ ***Answer***

$$\delta_{Da} = \theta_a S$$

$$= (1/500)(20)$$

$$= 0.04 \text{ ft} = \mathbf{0.5 \text{ in}} \quad \Leftarrow \textit{Answer}$$

Allowable Soil Pressures in Footing Design

The allowable soil pressure for footing design is obtained as the worst case of soil pressure w.r.t. safe bearing capacity failure and permissible settlement.

The allowable soil pressure is generally reported as the net increase in soil pressure that can be allowed in addition to currently existing overburden at foundation level.