



Settlement Analysis in Geotechnical Engineering: Principles, Methods, and Practical Pitfalls

Part - 1

Important Notes



1. Introduction

Settlement analysis is one of the most critical aspects of geotechnical engineering because most foundation failures are serviceability failures, not collapse failures. Excessive or differential settlement can render a structure unusable even when bearing capacity is adequate. This document explains settlement concepts in a clear, practice-oriented way, supported by essential formulas, without excessive laboratory or theoretical depth.

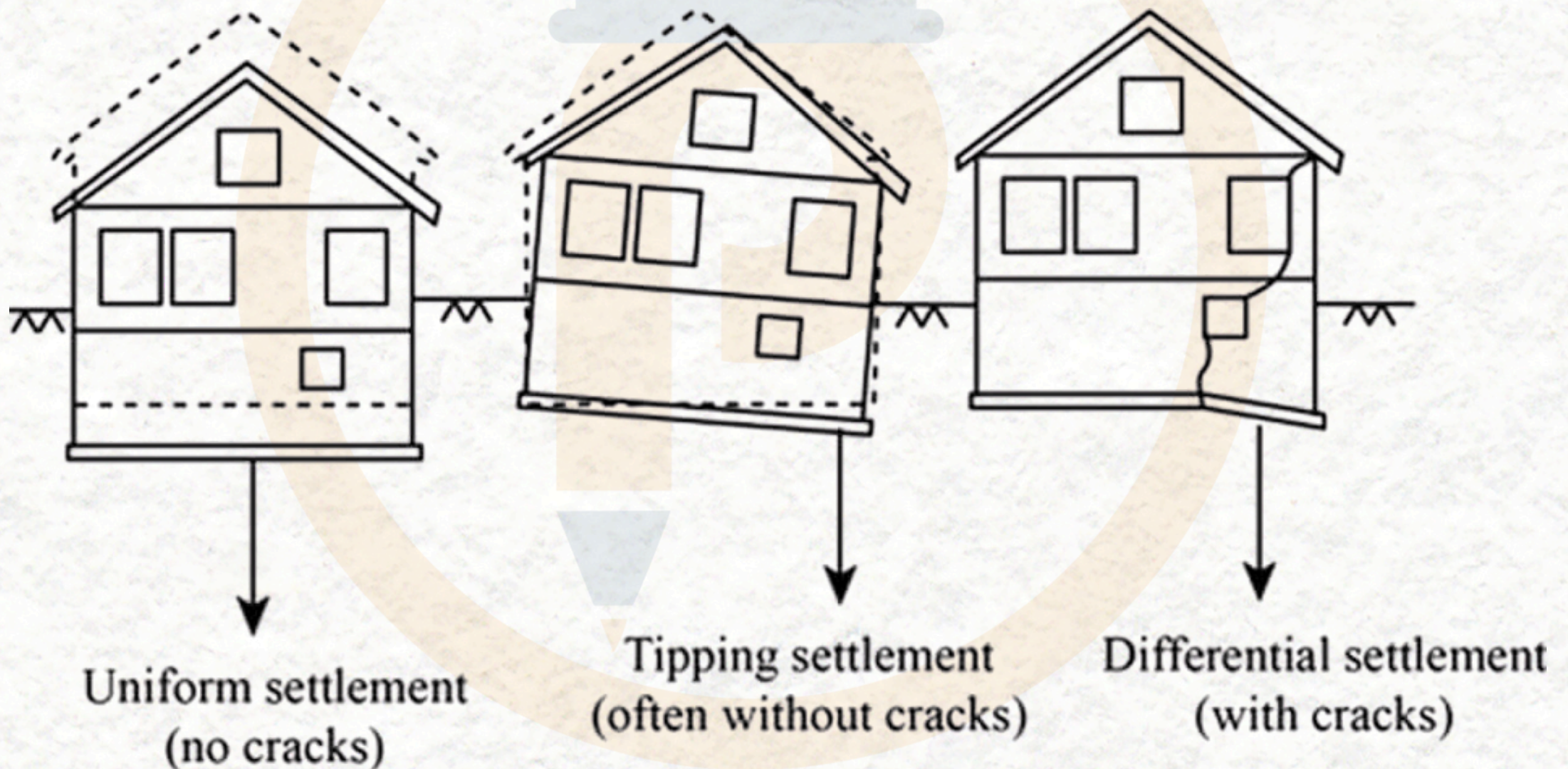


FIGURE - GEOTECHNICAL SETTLEMENT TENSARCORP

2. What is Settlement?

Settlement is the vertical downward movement of the ground caused by the application of load from structures such as buildings, embankments, pavements, or tanks.

Settlement matters because:

- It affects serviceability (cracks, tilting, malfunction)
- It controls the long-term performance of structures
- It often governs foundation design more than bearing capacity

3. Types of Settlement

3.1 Immediate (Elastic) Settlement

Occurs immediately after loading, without drainage of pore water.

- Dominant in sands and gravels
- Controlled by soil stiffness

Basic expression (conceptual):

$$S_i = q \times B \times (1 - \nu^2) / E$$

Where:

- q = net applied pressure
- B = foundation width
- ν = Poisson's ratio
- E = Young's modulus of soil

3.2 Primary Consolidation Settlement

Occurs due to the dissipation of excess pore water pressure in saturated cohesive soils.

- Time-dependent
- Most significant in clays

Terzaghi's 1D consolidation equation:

$$S_C = (C_C / (1 + e_0)) \times H \times \log(\sigma'_f / \sigma'_o)$$

Where:

- C_C = compression index
- e_0 = initial void ratio
- H = thickness of compressible layer
- σ'_o = initial effective stress
- σ'_f = final effective stress

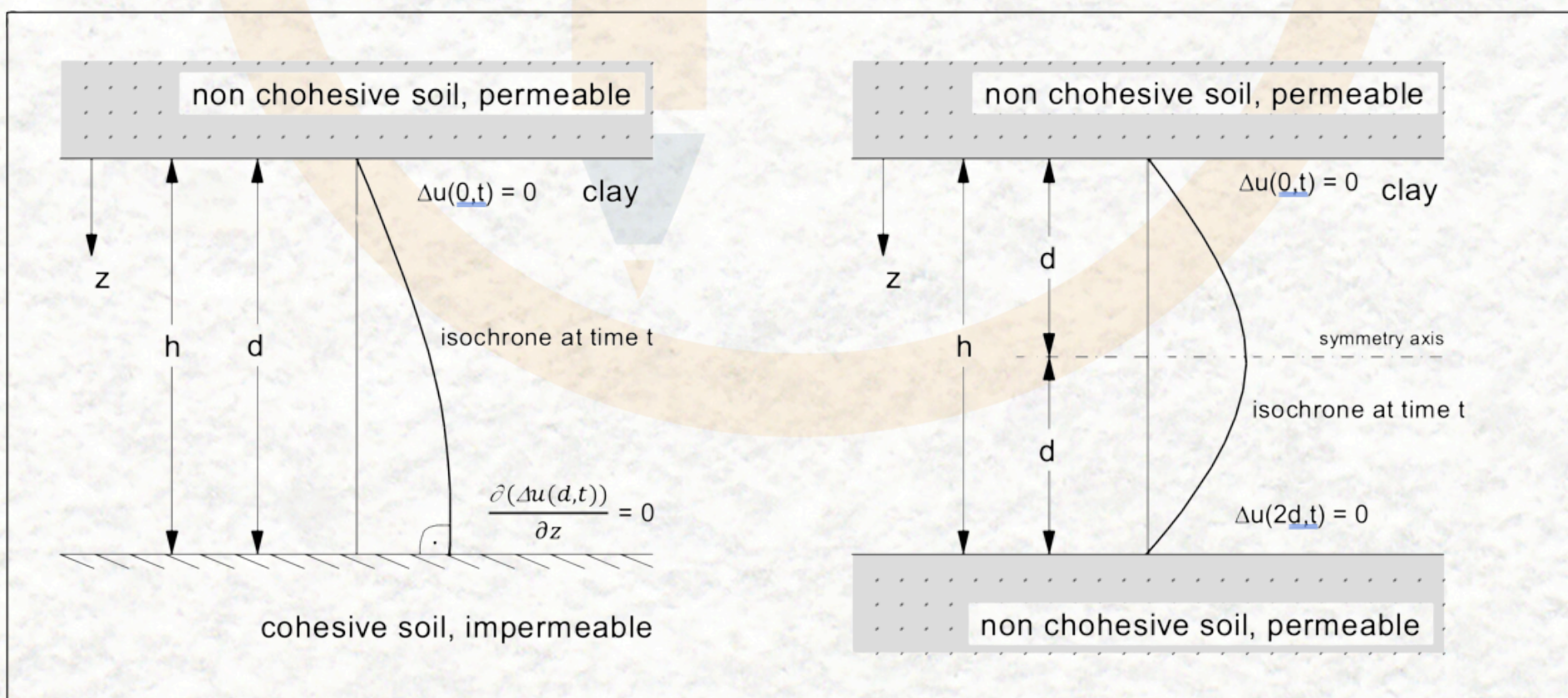
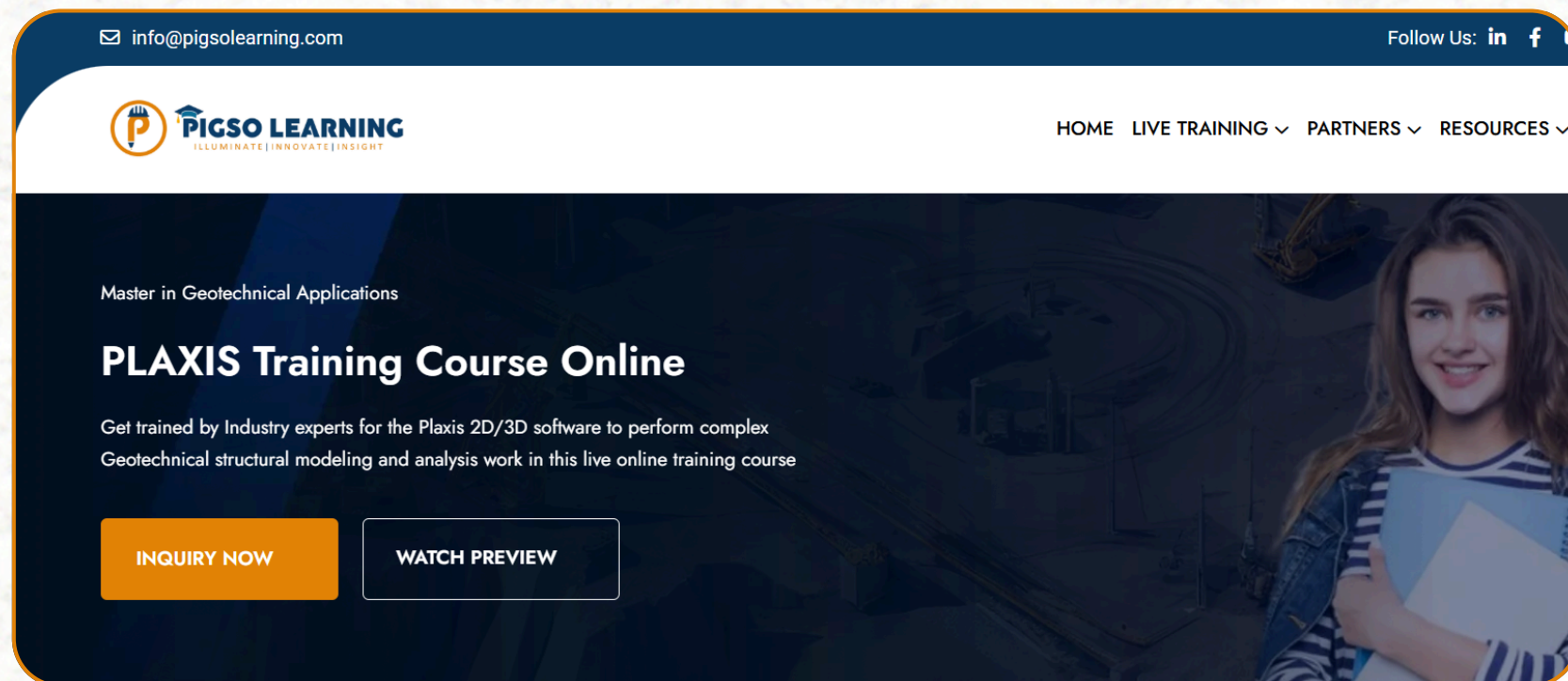


Figure - Terzaghi's consolidation theory GGU Software

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3.3 Secondary Settlement (Creep)

Occurs after primary consolidation, at constant effective stress.

- Important for organic soils and soft clays

Secondary settlement:

$$S_s = C_\alpha \times H \times \log(t_2 / t_1)$$

Where:

- C_α = secondary compression index
- t_1, t_2 = time interval

4. Stress Increase in Soil Due to Foundations

Settlement depends on how stress spreads in soil.

Common approaches:

- 2:1 stress distribution method
- Elastic theory (Boussinesq)

method (simplified):

$$\Delta\sigma = Q / [(B + z)(L + z)]$$

Where:

- Q = applied load
- z = depth below foundation
- B, L = footing dimensions

5. Settlement Analysis Methods

5.1 Layered Soil Approach

- Soil profile divided into layers
- Settlement calculated for each layer
- Total settlement = sum of individual layers

$$S_{total} = \sum S_{layer}$$

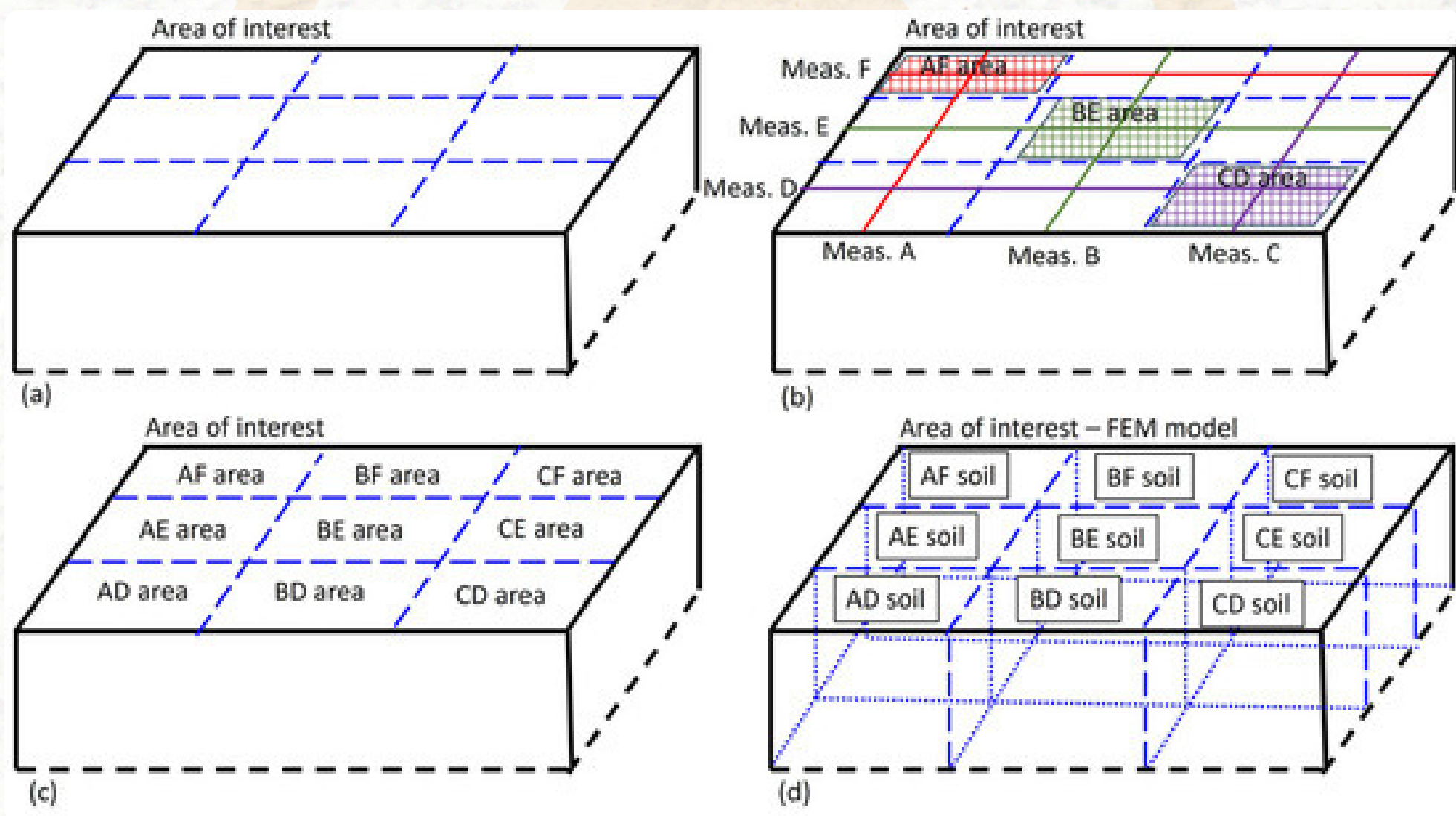


Figure - Layered Soil Model MDPI

5.2 Elastic Theory-Based Methods

Used mainly for:

- Sands
- Raft foundations

Relies on modulus values from:

- SPT
- CPT
- Pressuremeter tests

5.3 Consolidation Theory-Based Methods

Used for:

- Soft clays
- Long-term settlement prediction

Requires:

- Consolidation parameters
- Drainage conditions
- Time factor

Time factor equation:

$$T_v = (C_v \times t) / H^d^2$$

Where:

- C_v = coefficient of consolidation
- H^d = drainage path length

6. Differential Settlement - The Real Danger

Uniform settlement is usually tolerable. Differential settlement causes:

- Cracking
- Structural distortion
- Serviceability failure

Common causes:

- Non-uniform soil layers
- Uneven loading
- Adjacent excavations
- Variable groundwater conditions

7. Allowable Settlement Limits (Typical Values)

| Structure Type | Allowable Settlement |
|-------------------------|----------------------|
| Isolated footing | 25-50 mm |
| Raft foundation | 50-75 mm |
| Machine foundation | 10-20 mm |
| Differential settlement | L/300 to L/500 |

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