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Bearing Capacity of Soils I

Course Number: GE-02-301

PDH: 5

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Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the fundamental differences between ultimate, allowable, and design bearing capacities.
- **Select** appropriate Factors of Safety (FS) based on structure type and subsurface reliability.
- **Evaluate** the impact of soil type and groundwater table location on foundation stability and failure modes.

Executive Summary: Bearing capacity is the soil's ability to support engineered loads without shear failure or excessive settlement. While ensuring safety against shear failure is critical, settlement analysis often dictates the final design bearing pressure, especially for structures sensitive to movement.

Purpose and Scope

This course provides technical guidelines for calculating the **bearing capacity** of soil for shallow and deep foundations. These principles apply to buildings, towers, embankments, and water-retaining structures.

Key Technical Exclusions

- Analysis of foundations bearing on **rock**.
- Bearing capacity evaluations influenced by **seismic forces**.

Design Fundamentals

The evaluation of bearing capacity follows a rigorous multi-step procedure to ensure both structural stability and serviceability.

Table 1-1: Bearing Capacity Evaluation

Step	Procedure
1	Evaluate the ultimate bearing capacity pressure (qu) or bearing force (Qu) using the guidelines provided in this course and Equation 1-1.
2	Determine a reasonable Factor of Safety (FS) based on available subsurface information, the variability of the soil, soil layering and strengths, the type and importance of the structure, and engineering experience. The FS will typically be between 2 and 4. Typical values are provided in Table 1-2.
3	Evaluate the allowable bearing capacity (qa) by dividing the ultimate capacity by the factor of safety. Use the following relationships: $q_a = q_u$ / FS (Equation 1-2a) or $Q_a = Q_u$ / FS (Equation 1-2b).
4	Perform a settlement analysis when possible and adjust the bearing pressure until settlements are within tolerable limits. The resulting design bearing pressure (q_d) may be less than the allowable bearing capacity (q_a). Settlement analysis is particularly critical when compressible layers are present beneath the zone of potential bearing failure, and must be performed for important structures or those sensitive to movement.

Core Definitions

Bearing Capacity

This is the soil's capacity to carry structural pressure without **shear failure** and large settlements.

⚠️ **Safety Constraint:** A bearing pressure that is safe against shear failure does **not** guarantee that settlement will be within acceptable limits. Always perform a settlement analysis for sensitive structures.

Ultimate Bearing Capacity (qu)

This represents the pressure required to cause failure along a critical slip path.

Equation 1-1a:

$$q_u = c\, N_c \zeta_c + \sigma'_D N_q \zeta_q + 0.5\, \gamma'_H B\, N_\gamma \zeta_\gamma$$

Equation 1-1b:

$$Q_u = q_u B\, W$$

Where:

- **q_u** = ultimate bearing capacity pressure (k_{sf})
- **Q_u** = ultimate bearing capacity force (kips)
- **c** = soil cohesion or undrained shear strength (k_{sf})
- **B** = foundation width (ft)
- **W** = foundation lateral length (ft)
- **γ_H'** = effective unit weight beneath foundation base within failure zone (k_{cf})
- **$\sigma D'$** = effective surcharge pressure at foundation depth D (k_{sf})
- **N_c, N_γ, N_q** = dimensionless bearing capacity factors
- **ζ_c, ζ_γ, ζ_q** = dimensionless geometry/soil correction factors

Calculation Note: Ultimate shear failure is rarely the controlling design factor because most structures cannot tolerate the large deformations (0.5 ft to 10+ ft) that precede total collapse.

Allowable Bearing Capacity (q_a)

The ultimate capacity reduced by a safety factor to ensure stability.

Equation 1-2a:

$$q_a = \frac{q_u}{FS}$$

Equation 1-2b:

$$Q_a = \frac{Q_u}{FS}$$

Factors of Safety

The selection of FS depends on the reliability of subsoil data and the consequences of failure.

Table 1-2: Typical Factors of Safety

Structure Type	**Recommended FS**
Earth Retaining Structures	
Retaining Walls	3.0
Temporary Braced Excavations	> 2.0
Bridges	
Railway Bridges	4.0
Highway Bridges	3.5
Buildings	
Silos	2.5
Warehouses	2.5*
Apartments and Office Buildings	3.0
Light Industrial and Public Buildings	3.5
Shallow Foundations	
Individual Footings	3.0
Mat Foundations	> 3.0
Deep Foundations	
Piles/Shafts with Static Load Tests	2.0
Driven Piles with Wave Equation Analysis (Calibrated)	2.5
Piles/Shafts without Load Tests	3.0
Foundations in Multilayer Soils	4.0
Pile Groups	3.0

***Note:** Modern warehouses requiring "super-flat" floors for specialized transport equipment require extreme limitations on total and differential movement, necessitating a Factor of Safety greater than 3.0.

Foundation Classification

Shallow Foundations

Typically placed at a depth (**D**) less than the minimum width (**B**).

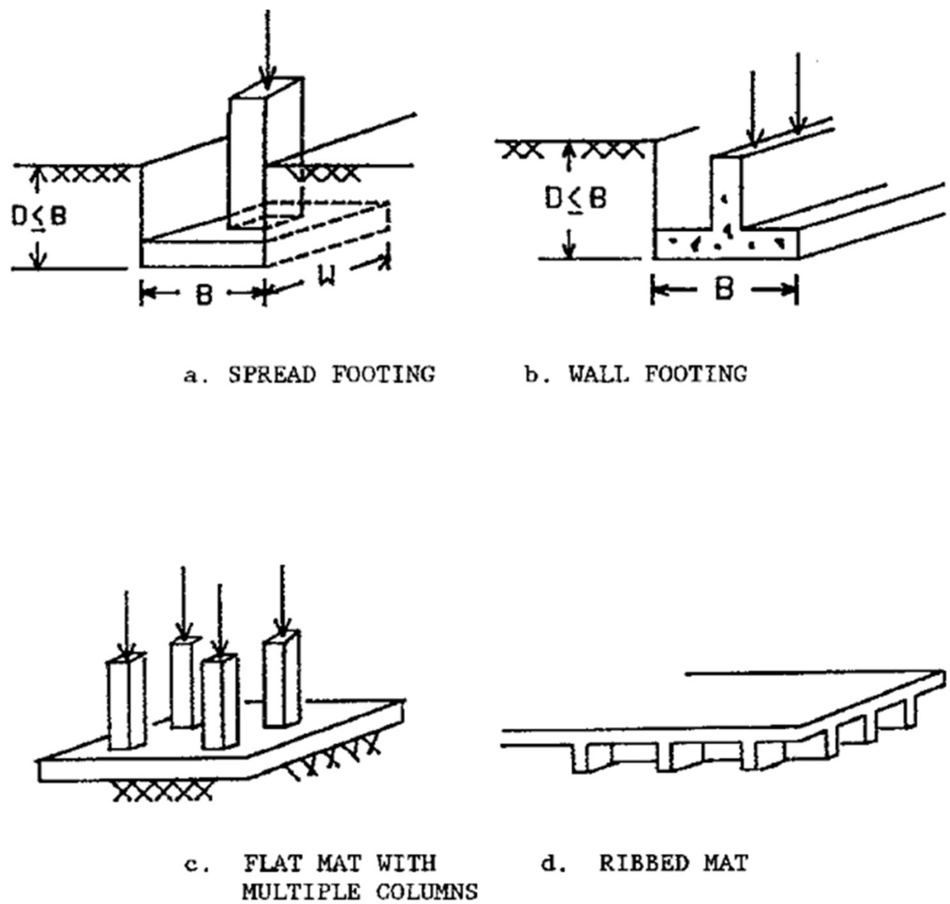

Figure 1-1. Shallow Foundations

- **Spread Footing:** Distributes column loads where B ≤ W ≤ 10B.
- **Continuous (Wall) Footing:** A long footing where W > 10B.
- **Mat Foundation:** A large slab supporting multiple columns. **Ribbed mats** are preferred in unstable soils (expansive/collapsible) to limit differential movement.

Deep Foundations

Used to bypass poor soil (loose sands, soft clays) to reach competent strata.