University of Anbar
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Civil Engineering Department

CHAPTER ONE

INTRODUCTION

LECTURE
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1.1 Geotechnical Engineering

In the general sense of engineering, ***soil*** is defined as the uncemented aggregate of mineral grains and decayed organic matter (solid particles) along with the liquid and gas that occupy the empty spaces between the solid particles. Soil is used as a construction material in various civil engineering projects, and it supports structural foundations. Thus, civil engineers must study the properties of soil, such as its origin, grain-size distribution, ability to drain water, compressibility, shear strength, load bearing capacity, and so on.

Soil mechanics is the branch of science that deals with the study of the physical properties of soil and the behavior of soil masses subjected to various types of forces.

Rock mechanics is a branch of science that deals with the study of the properties of rocks. It includes the effect of the network of fissures and pores on the nonlinear stress strain behavior of rocks as strength anisotropy. Rock mechanics (as we know now) slowly grew out of soil mechanics. So, collectively, soil mechanics and rock mechanics are generally referred to as ***geotechnical engineering***.

1.2 FOUNDATIONS: THEIR IMPORTANCE AND PURPOSE

All engineered construction resting on the earth must be carried by some kind of interfacing element called *a* ***foundation (substructure)*** as in Fig.1 .1 . The foundation is the part of an engineered system that transmits to, and into, the underlying soil or rock the loads supported by the foundation and its self-weight. The resulting soil stresses—except at the ground surface—are in addition to those presently existing in the earth mass from its self-weight and geological history.

The term ***superstructure*** is commonly used to describe the engineered part of the system bringing load to the foundation, or substructure as in Fig. 1.1. The term ***superstructure*** has particular significance for buildings and bridges; however, foundations also may carry only machinery, support industrial equipment (pipes, towers, tanks), act as sign bases, and the like. For these reasons it is better to describe a foundation as that part of the engineered system that interfaces the load-carrying components to the ground.

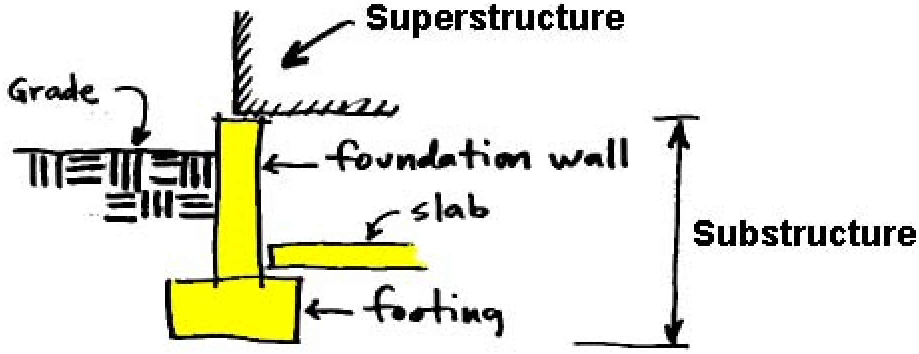

Fig. 1.1 The foundation (substructure) and superstructure

1.3 Foundation Engineering

Foundation engineering is the application and practice of the fundamental principles of soil mechanics and rock mechanics (i.e., geotechnical engineering) in the design of foundations of various structures. These foundations include those of columns and walls of buildings, bridge abutments, embankments, and others. It also involves the analysis and design of earth-retaining structures such as retaining walls, sheet-pile walls, and braced cuts. This notes is prepared, in general, to elaborate upon the foundation engineering aspects of these structures.

1.4 General Format of the Notes

This Notes is divided into four major parts.

- **Part I—Exploration of Soil (Chapters 2)**
- **Part II—Foundation Analysis (Chapters 3 through 6).**

Foundation analysis, in general, can be divided into two categories: shallow foundations and deep foundations.

Spread footings and mat (or raft) foundations are referred to as shallow foundations. A *spread footing* is simply an enlargement of a load-bearing wall or column that makes it possible to spread the load of the structure over a larger area of the soil. In soil with low load-bearing capacity, the size of the spread footings is impracticably large. In that case, it is more economical to construct the entire structure over a concrete pad. This is called a *mat foundation*. Piles and drilled shafts are deep foundations. They are structural members used for heavier structures when the depth requirement for supporting the load is large. They transmit the load of the superstructure to the lower layers of the soil.

- **Part III—Lateral Earth Pressure and Earth-Retaining Structures (Foundation Engineering II ch1 through ch6).**

This part includes discussion of the general principles of lateral earth pressure on vertical or near-vertical walls based on wall movement and analyses of retaining walls, sheet pile walls, braced cuts and slope stability.

The types foundations shown in Fig.1.2, 1.3 and Table 1.1.

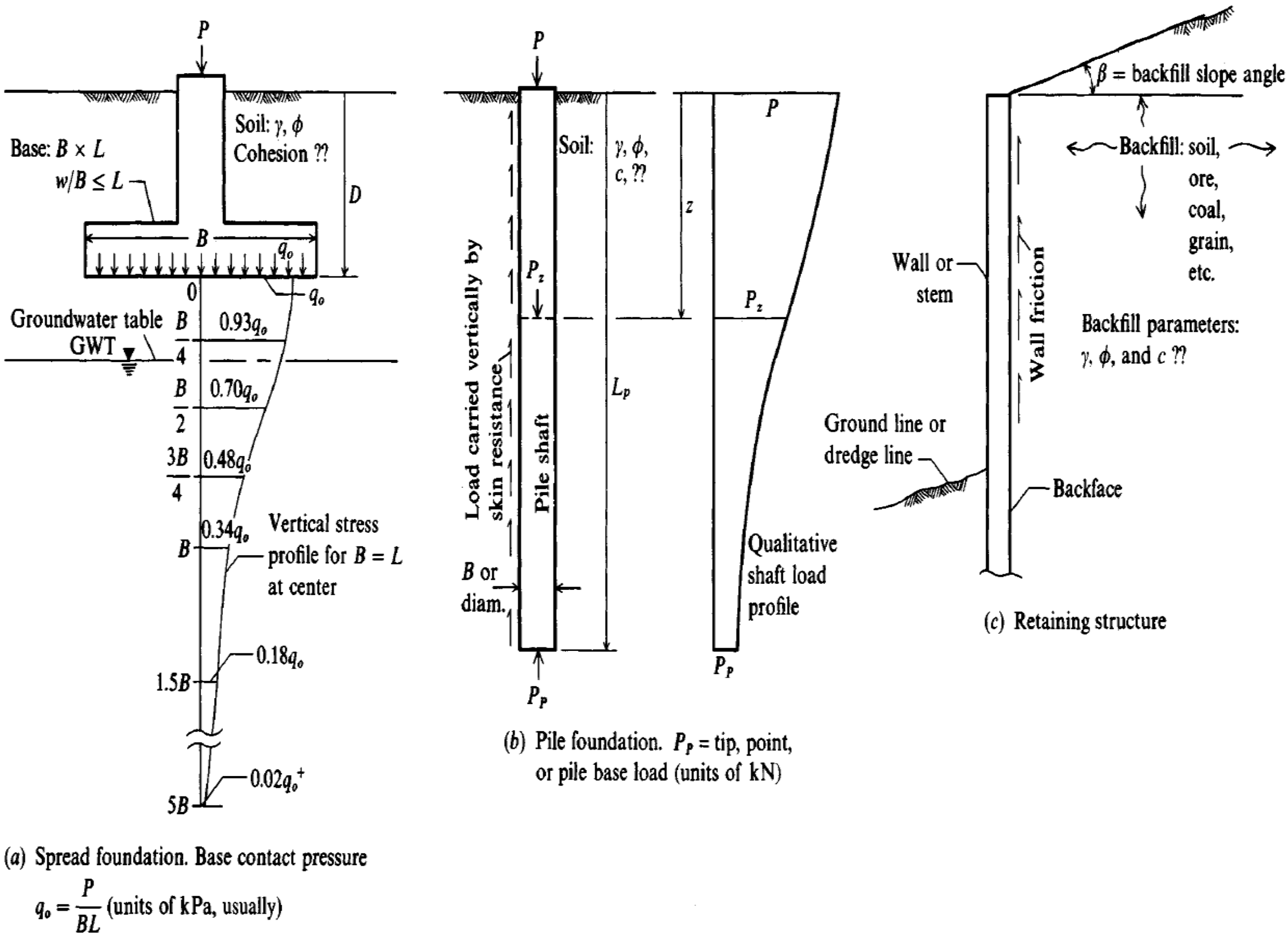

Fig. 1.2 Types of foundation engineering.

TABLE 1-1
Foundation types and typical usage

Foundation type	Use	Applicable soil conditions
	Shallow foundations (generally $D/B \le 1$)	
Spread footings, wall footings	Individual columns, walls	Any conditions where bearing capacity is adequate for applied load. May use on a single stratum; firm layer over soft layer or soft layer over firm layer. Check settlements from any source.
Combined footings	Two to four columns on footing and/or space is limited	Same as for spread footings above.
Mat foundations	Several rows of parallel columns; heavy column loads; use to reduce differential settlements	Soil bearing capacity is generally less than for spread footings, and over half the plan area would be covered by spread footings. Check settlements from any source.
	Deep foundations (generally $L_p/B \ge 4^+$)	
Floating pile	In groups of 2^+ supporting a cap that interfaces with column(s)	Surface and near-surface soils have low bearing capacity and competent soil is at great depth. Sufficient skin resistance can be developed by soil-to-pile perimeter to carry anticipated loads.
Bearing pile	Same as for floating pile	Surface and near-surface soils not relied on for skin resistance; competent soil for point load is at a practical depth (8–20 m).
Drilled piers or caissons	Same as for piles; use fewer; For large column loads	Same as for piles. May be floating or point-bearing (or combination). Depends on depth to competent bearing stratum.
	Retaining structures	
Retaining walls, bridge abutments	Permanent material retention	Any type of soil but a specified zone (Chaps. 11, 12) in backfill is usually of controlled fill.
Sheeting structures (sheet pile, wood sheeting, etc.)	Temporary or permanent for excavations, marine cofferdams for river work	Retain any soil or water. Backfill for waterfront and cofferdam systems is usually granular for greater drainage.

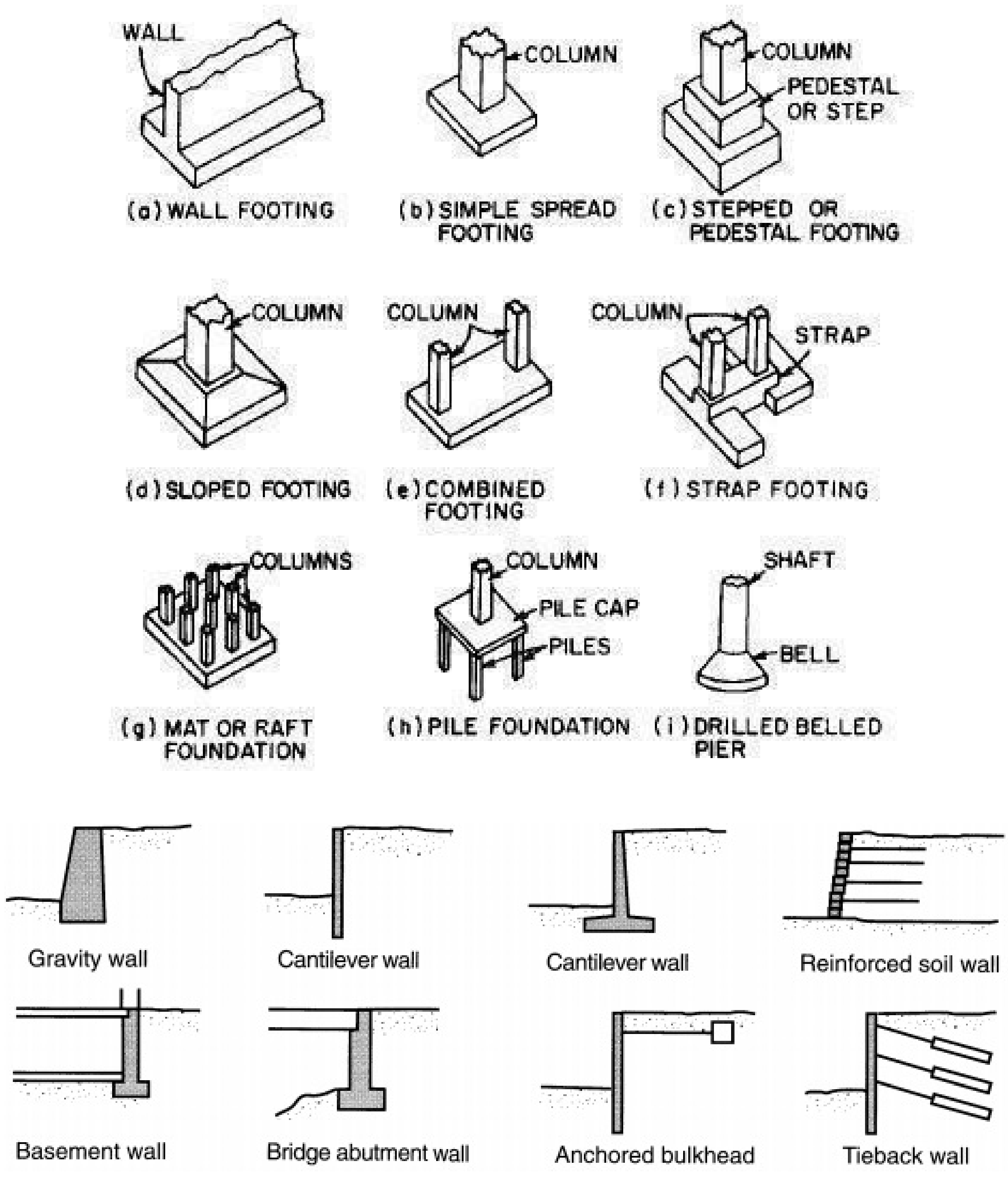

Fig. 1.3 Various types of foundations

1.5 Design Methods

The *allowable stress design* (ASD) has been used for over a century in foundation design and is also used in this edition of the notes. The ASD is a deterministic design method which is based on the concept of applying a factor of safety (FS) to an ultimate load Q_u (which is an ultimate limit state). Thus, the allowable load Q_{all} can be expressed as

$$Q_{all} = Q_u / FS \tag{1.1}$$

According to ASD,

$$Q_{design} \leq Q_{all} \tag{1.2}$$

where Q_{design} is the design (working) load.

Over the last several years, *reliability based design methods* are slowly being incorporated into civil engineering design. This is also called the *load and resistance factor* design method (LRFD). It is also known as the ultimate strength design (USD). The LRFD was initially brought into practice by the American Concrete Institute (ACI) in the 1960s.

Several codes in North America now provide parameters for LRFD.

- American Association of State Highway and Transportation Officials (AASHTO) (1994, 1998)
- American Petroleum Institute (API) (1993)
- American Concrete Institute (ACI) (2002)

According to LRFD, the factored nominal load Qu is calculated as

$$Q_u = (LF)_1 Q_{u(1)} + (LFd)_2 Q_{u(2)} + \ . \ . \ . \tag{1.3}$$

where

Q_u = factored nominal load

$(LF)_i$ (i = 1, 2, . . .) is the load factor for nominal load $Q_{u(i)}$ (i= 1, 2, . . .)

Most of the load factors are greater than one. As an example, according to AASHTO (1998), the load factors are

Load	LF
Dead load	1.25 t0 1.95
Live Load	1.35 to 1.75
Wind Load	1.4
Seismic	1.0

The basic design inequality then can be given as

$$Q_u \leq \phi Q_n \quad (1.4)$$

where

Q_n = nominal load capacity

ϕ = resistance factor (<1)