Geotechnical Engineering Series - Earth Retaining Structures

An Online Continuing Education Course for Engineers

Course Number: G-4004

Credit: 4 Hours / 4 PDH / 4 CPD

Geotechnical Engineering Series: Earth Retaining Structures

EARTH RETAINING STRUCTURES

Earth retaining structures or systems are used to hold back earth and maintain a difference in the elevation of the ground surface, as shown in Figure 1. The retaining wall is designed to withstand the forces exerted by the retained ground or "backfill" and other externally applied loads, and to transmit these forces safely to a foundation and/or to a portion of the restraining elements, if any, located beyond the failure surface.

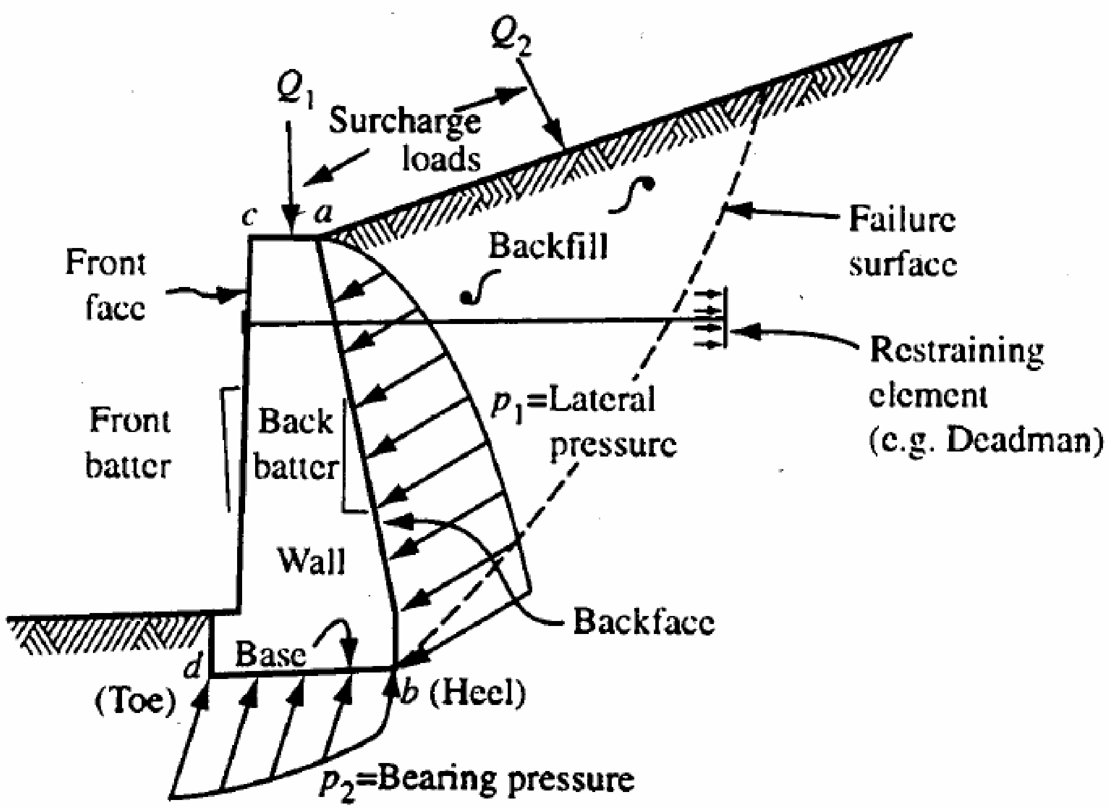

Figure 1. Schematic of a retaining wall and common terminology.

In general, the cost of constructing a retaining wall is usually high compared with the cost of forming a new slope. Therefore, the need for a retaining wall should be assessed carefully during preliminary design and an effort should be made to keep the retained height as low as possible.

In highway construction, retaining walls are used along cuts or fills where space is inadequate for construction of cut slopes or embankment slopes. Bridge abutments and foundation walls, which must support earth fills, are also designed as retaining walls.
Typical applications for earth retaining structures in highway construction include:

- new or widened highways in developed areas;
- new or widened highways at mountain or steep slopes;
- grade separation;
- bridge abutments, wing walls and approach embankments;
- culvert walls;
- tunnel portals and approaches;
- flood walls, bulkheads and waterfront structures;
- cofferdams for construction of bridge foundations;
- stabilization of new or existing slopes and protection against rockfalls; and
- groundwater cut-off barriers for excavations or depressed roadways.

Figure 2 provides schematic illustrations of several retaining wall systems traditionally used in highway applications. A great number of wall systems have been developed in the past two decades by specialty contractors who have been promoting either a special product or a specialized method of construction, or both. Due to the rapid development of these diversified systems and their many benefits, the design engineer is now faced with the difficult task of having to select the best possible system; design the structure; and ensure its proper construction.

An important breakthrough in the design of earth retaining structures (ERS) that occurred in this era was the recognition that the earth pressure acting on a wall is a function of the type of wall and the amount and distribution of wall movement. Classical earth pressure theories, which were developed by Coulomb (1776) and Rankine (1857), were formalized for use by Caquot and Kerisel (1948) and others. Sophisticated analyses of soil-structure interaction and wall/soil movements began in the 1960s with the development of finite difference and finite element analytical procedures. The simultaneous advancement of geotechnical instrumentation equipment and monitoring procedures made the "observational method" of design (Peck, 1969) popular and cost-effective.

Since 1970 there has been a dramatic growth in the number of methods and products for retaining soil. O'Rourke and Jones (1990) describe two trends in particular that have emerged since 1970. First, there has been an increasing use of reinforcing elements, either by incremental burial to create reinforced soils (MSE walls), or by systematic in situ installation to reinforce natural soils or even existing fills (soil nailing); see Figure 2b. Mechanically stabilized earth and soil nailing have changed the ways we construct fill or cut walls, respectively, by providing economically attractive alternatives to traditional designs and construction methods. Second, there has been an increasing use of polymeric products to reinforce the soil and control drainage. Rapid developments in polymer manufacturing have supplied a wide array of geosynthetic materials. The use of these products in construction has encouraged a multitude of different earth retention schemes.

The rapid development of these new trends and the increased awareness of the impact of construction on the environment have led to the emergence of the concept of “earth walls.”

In this concept, the soil supports itself or is incorporated into the structure and assumes a major structural or load carrying function. With this concept, structural member requirements of the system are reduced or eliminated altogether. Examples of recently developed earth walls include the soil-reinforcement systems discussed above, as well as systems involving chemical treatment of the in-situ soil such as jet grouting or deep soil mixing.

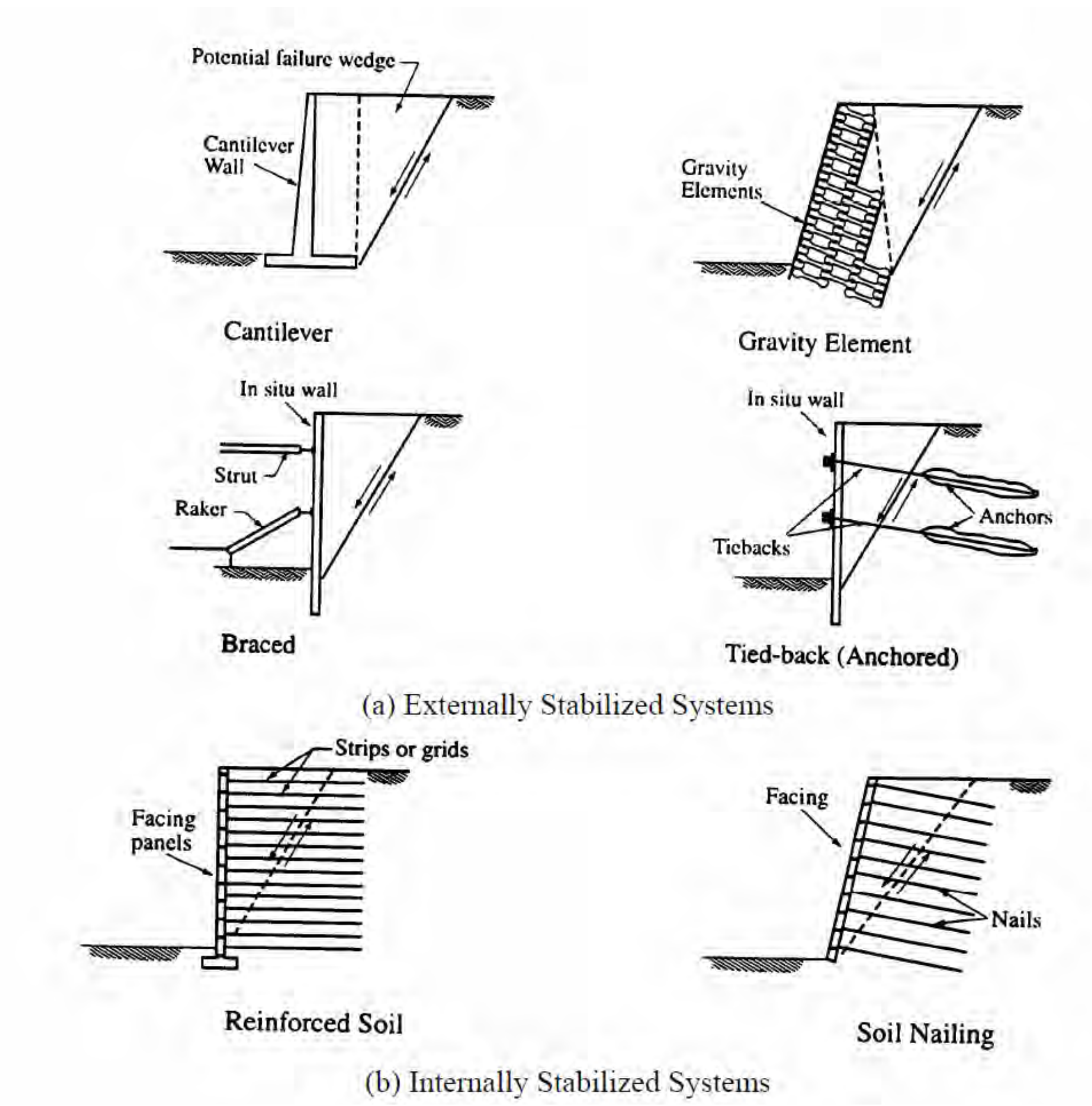

Figure 2. Variety of retaining walls (after O’Rourke and Jones, 1990)

CLASSIFICATION OF EARTH RETAINING STRUCTURES

Earth retaining systems may be classified according to:

- load support mechanism, i.e., externally or internally stabilized walls;
- construction method, i.e., fill or cut walls; and
- system rigidity, i.e., rigid or flexible walls.

Every retaining wall can now be classified by using these three factors. For example, a sheet-pile wall would be classified as an **externally-stabilized cut** wall that is relatively **flexible**. A mechanically stabilized earth (MSE) wall is an **internally stabilized fill** wall that is relatively **flexible**. Further description of these classifications is provided subsequently.

Classification by Load Support Mechanism

The stability component of walls can be organized according to two principal categories: externally and internally stabilized systems (O'Rourke and Jones, 1990) as shown in Figure 3. An externally stabilized system uses an external structural wall against which stabilizing forces are mobilized. An internally stabilized system involves reinforcements installed within the retained soil mass and extending beyond the potential failure plane. Hybrid systems combine elements of both internally and externally supported walls.

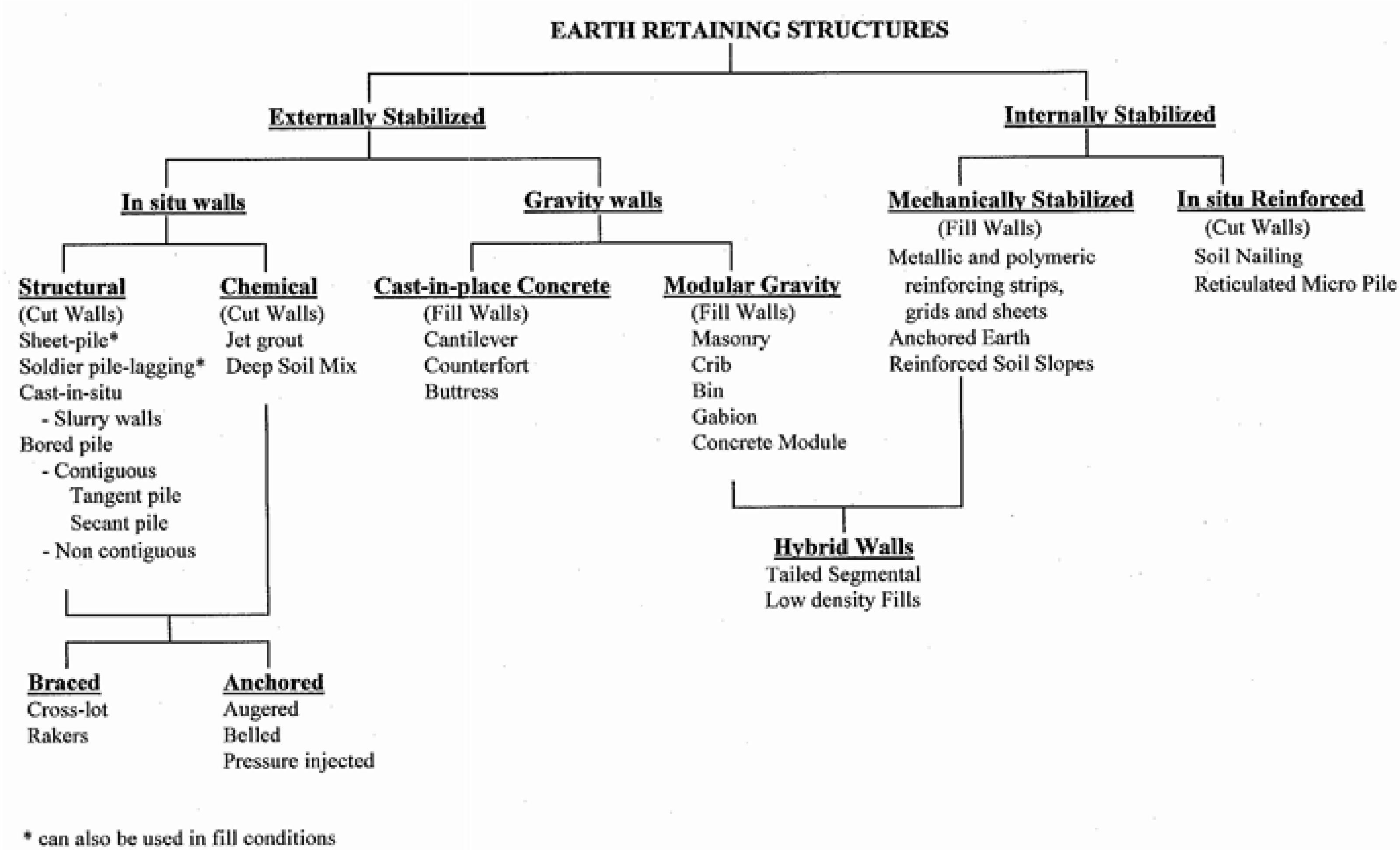

Figure 3. Classification of earth retaining systems (after O' Rourke and Jones, 1990).

Virtually all traditional types of walls may be regarded as externally stabilized systems (Refer to Figure 2a). Gravity walls, in the form of cantilever structures or gravity elements (e.g., bins, cribs, and gabions), support the soil and, through their weight and stiffness, resist sliding, overturning, and shear. Bracing systems, such as cross-lot struts and rakers, provide temporary support for in situ structural and chemically stabilized walls. Ground anchors provide support through their pullout capacity in stable soils outside of the zone of potential failure.

It is in the area of internally stabilized systems that relatively new concepts have been introduced (Refer to Figure 2b). Shear transfer to mobilize the tensile capacity of closely spaced reinforcing elements embedded in the retained soil mass has enabled retaining structures to be constructed without an external structural wall element. The shear transfer mechanism allows a composite system of reinforcing elements and soil to serve as the primary structural entity. A facing is required on an internally stabilized system; however, its purpose is to prevent raveling and deterioration rather than to provide primary structural support.

Classification by Construction Method

Earth retaining structures (ERS) can also be classified according to the method required for their construction, i.e., fill construction or cut construction. Fill wall construction refers to a wall system in which the wall is constructed from the base of the wall up to the top, i.e., "bottom-up" construction. Cut wall construction refers to a wall system in which the wall is constructed from the top of the wall down to the base concurrent with excavation operations, i.e., "top-down" construction. The classification of each wall system accordin... construction method is also presented in Figure 3.

It is important to rec... to how the wall is constructed, not nec... th the project. For example, a prefabrica... etain earth for a major highway cut, is con... ot complete until the backfill has been plac... he cut has reached its final grade.

Classification by Syst...

The rigidity or flexibili... ding of the development of earth pr... rigid if it moves as a unit in rigid body rotati... ing deformations. Most gravity walls can ... that undergo bending deformations in addition... redistribution of lateral pressures from th... Virtually all wall systems, except gravity w...