



# Retaining Walls for Non-Geotechnical Engineers

An Online Continuing Education Course for Engineers

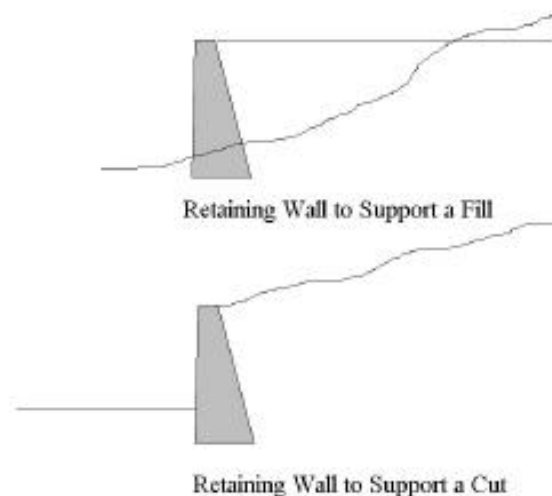
**Course Number: G-2004**

**Credit: 2 Hours / 2 PDH / 2 CPD**

# Retaining Walls For Non-Geotechnical Engineers

## Introduction

Retaining walls are structures that support backfill and allow for a change of grade. For instance a retaining wall can be used to retain fill along a slope or it can be used to support a cut into a slope.



**Figure 1 – Example of Retaining Walls**

Retaining wall structures can be gravity type structures, semi-gravity type structures, cantilever type structures, and counterfort type structures. Walls might be constructed from materials such as fieldstone, reinforced concrete, gabions, reinforced earth, steel and timber. Each of these walls must be designed to resist the external forces applied to the wall from earth pressure, surcharge load, water, earthquake etc.

The objective of this course is to familiarize primarily the non-geotechnical engineer with methods for calculating the active earth pressure force against a retaining wall and for assessing its stability with respect to sliding, overturning and bearing capacity.

This course is not meant to be exhaustive nor does it discuss the structural design of a retaining wall. There are many textbooks and publications that treat detailed loading conditions in depth including:

Foundations and Earth Structures, NAVFAC, Design Manual 7.2

Retaining and Flood Walls, Technical Engineering and Design Guides As Adapted from The US Army

Corps Of Engineers, No. 4, ASCE Standard Specifications for Highway Bridges, AASHTO  
At the end of this course you will have learned: Calculating the lateral earth pressure force.  
Calculating factors of safety for overturning, sliding and bearing capacity.

The reader should already be familiar with methods for calculating the earth pressure. If not, textbooks or the companion course Lateral Earth Pressure for Non-Geotechnical Engineers will be helpful.

### **Lateral Earth Pressure**

There are three categories of lateral earth pressure:

- At Rest Pressure
- Passive Pressure
- Active Pressure

This course only discusses the active earth pressure because it is the active pressure that produces the destabilizing earth force behind retaining walls. Although passive pressures might develop along the toe of the wall and provide resistance it is commonly ignored and therefore not discussed in this course. This course also does not discuss other kinds of lateral forces, such as those resulting from surcharge, earthquake, etc., which also produce additional destabilizing forces.

Since soil backfill is typically granular material such as sand, silty sand, sand with gravel, this course assumes that the backfill material against the wall is coarse-grained, non-cohesive material. Thus, cohesive soil such as clay is not discussed.

The lateral earth pressure is equal to vertical effective overburden pressure times the appropriate earth pressure coefficient. There are published relationships, tables and charts for calculating or selecting the appropriate earth pressure coefficient.

**When calculating the lateral earth pressure force there are two methods that are widely used:**

- Rankine Earth Pressure
- Coulomb Earth Pressure

#### **The Rankine method assumes:**

- There is no adhesion or friction between the wall and soil
- Lateral pressure is limited to vertical walls
- Failure (in the backfill) occurs as a sliding wedge along an assumed failure plane defined by the friction angle of the soil backfill ( $\phi$ ).
- Lateral pressure varies linearly with depth and the resultant pressure is located one-third of the height (H) above the base of the wall. The resultant force is parallel to the backfill surface.

**The Coulomb method is similar to Rankine except that:**

- There is friction between the wall and soil and takes this into account by using a soil-wall friction angle of  $\delta$  that ranges from  $\phi/2$  to  $2\phi/3$  and  $\delta = 2\phi/3$  is commonly used.
- Lateral pressure is not limited to vertical walls
- The resultant force is not necessarily parallel to the backfill surface because of the soil-wall friction value( $\delta$ ).

It is important to note that the full active earth pressure condition will only develop if the wall is allowed to move a sufficient distance. The lateral outward movement required to develop the full active pressure condition ranges from:

**Granular soil:** 0.001H to 0.004H

**Cohesive soil:** 0.01H to 0.04H Where H is the height of the wall.

The Rankine active earth pressure coefficient for the specific condition of a horizontal backfill surface is calculated as follows:

$$K_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) \quad (1.0)$$

The expression is modified if the backfill surface were sloped.

The Coulomb active earth pressure coefficient is a more complicated expression that depends on the angle of the back of the wall, the soil-wall friction and the angle of backfill slope. Although the expression is not shown, these values are readily obtained in textbook tables or by programmed computers and calculators. The Table below shows some examples of the Coulomb active earth pressure coefficient for the specific case of a wall with a back of wall angle ( $\beta$ ) of 80 degrees and a horizontal backfill surface. In this Table, the soil-wall friction value ( $\delta$ ) has been taken as  $(2/3)\phi$ .

**Table 1 - Coulomb Active Pressure Coefficient**

[ Note:  $\delta = (2/3)\phi$  ]

$\phi$ (deg)	$\beta = 80$ deg
28	.4007
30	.3769
32	.3545

If water pressure were allowed to build up behind a retaining wall, then the total pressure and the resulting total force along the back of the wall is increased considerably. Therefore, it is common for walls to be designed with adequate drainage to prevent water from accumulating behind the wall and producing large additional forces. Thus, weepholes, lateral drains or blanket drains along with granular soil (freely draining backfill) are commonly used behind retaining walls.

### Calculating the Total Active Earth Pressure Force

The total lateral force is the area of the pressure diagram acting on the wall surface. The examples in this course assume drained conditions and a homogeneous granular soil backfill behind the wall, which results in a simple triangular distribution. Although this is a common case, the pressure diagram can become more complicated depending upon actual soil conditions that might have different values.

With the Coulomb method, the active force acts directly on the wall and friction develops between the soil and wall. With the Rankine method however, wall friction is ignored and the active force acts directly on a vertical face extending through the heel of the wall. If the back of the wall were vertical, then the force acts on the wall. On the other hand, if the back of the wall were sloping, then the force acts on the vertical soil plane as illustrated in Figure 2.

In the example shown later in this course, the area of the earth pressure diagram is the earth pressure at the bottom of the wall ( $K_a\gamma H$ ) times the height of the wall ( $H$ ) times one-half ( $1/2$ ) since the pressure distribution increases linearly with depth creating a triangular shape. Thus the total active earth pressure force ( $P_a$ ) acting along the back of the wall is the area of the pressure diagram expressed as:

$$P_a = \frac{1}{2} K_a \gamma H^2 \quad (2.0)$$

The total force acts along the back of the wall at a height of  $H/3$  from the base of the wall. So far we have not stated whether this is the Rankine or Coulomb Case. The calculation for the active earth pressure force ( $P_a$ ) is the same provided that the appropriate earth pressure coefficient ( $K_a$ ) is used. Selecting whether the Rankine method or Coulomb method will be used is usually a matter of choice or convention.

The example shown in Figure 2 relates specifically to a wall supporting a horizontal backfill. Thus the active earth pressure coefficient ( $K_a$ ) can be derived directly from Expression (1.0) or Table 1. For the case of a sloping backfill and other wall geometries, the reader should refer to the published references.

This example assumes that a 9-foot high gravity type retaining structure supports soil backfill having a total unit weight of 125 pcf. Groundwater is well below the structure and the backfill material is freely draining. The backfill soil has an angle of internal friction ( $\phi$ ) of 32 degrees and the backfill surface behind the wall is horizontal. Both the Rankine and Coulomb earth

pressure force is shown.

Note that the location and direction of the active forces follows the assumptions stated above for the Rankine and Coulomb Theory. Although the back of the wall has an angle of 80 degrees, The Rankine force acts along a vertical plane beginning at the heel of the wall while the Coulomb force acts directly along the back of the wall. Since the Rankine Theory assumes that there is no soil – wall friction, the force (Pa) is parallel to the backfill surface. On the other hand, since the Coulomb Theory takes the soil – wall friction into consideration, the force (Pa) acts at an angle of from the perpendicular to the wall. This results in both a vertical and horizontal component of the force (Pa). The Rankine method will also produce a vertical and horizontal component of the force (Pa) if the backfill surface has a slope.

In each case, the resultant force Pa acts at a distance of H/3 from the base of the wall where H is the height of the wall. This is more complicated than Rankine theory where the force (Pa) acts at the centre of the wall.

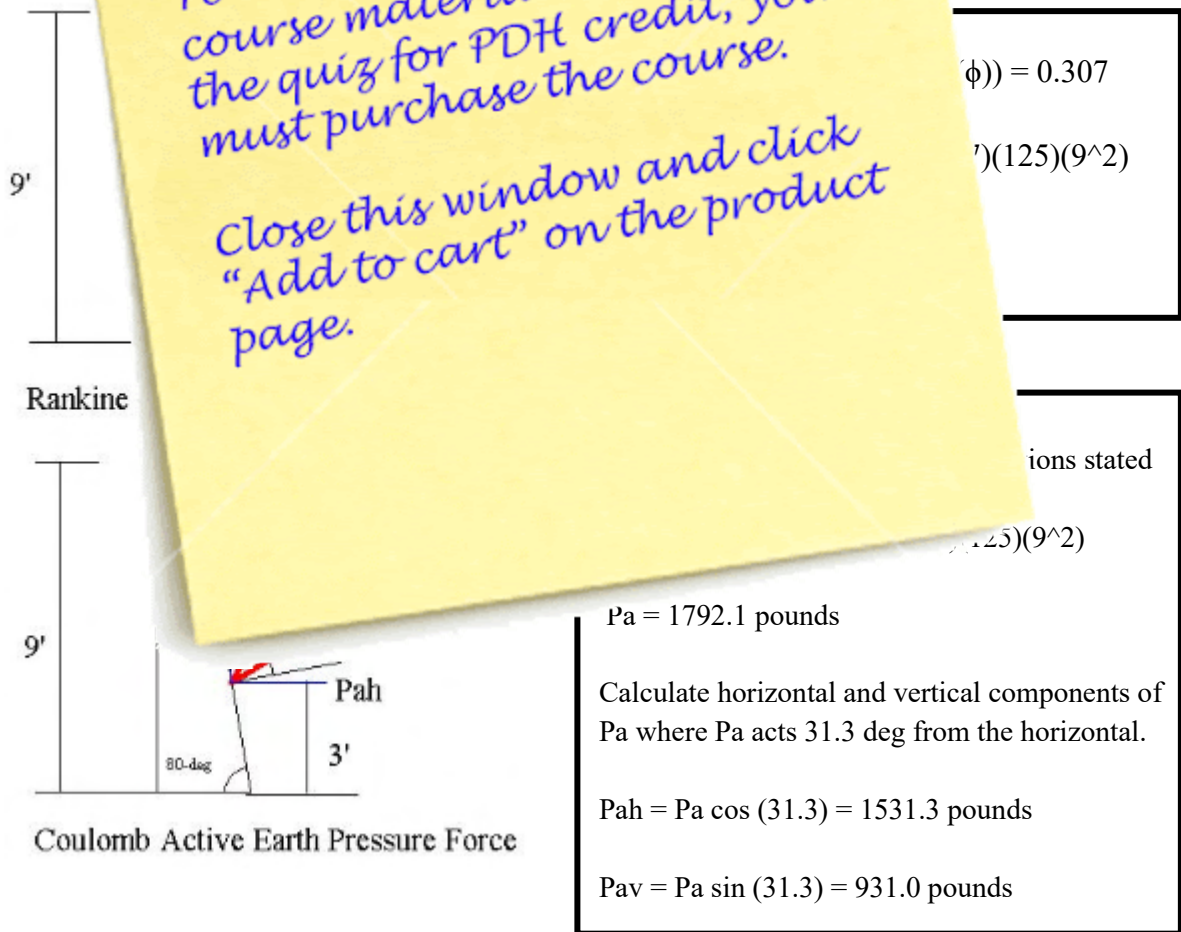


Figure 2 – Calculation of Earth Pressure Fore for a Homogeneous Cohesionless Backfill