Lateral Earth Pressure for Non-Geotechnical Engineers

An Online Continuing Education Course for Engineers

Course Number: G-1003

Credit: 1 Hour / 1 PDH / 1 CPD

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Introduction

Lateral earth pressure represents pressures that are "to the side" (horizontal) rather than vertical. The objective of this course is to familiarize primarily the non-geotechnical engineer such as civil engineers, structural engineers, architects and landscape architects with simple background theory and considerations.

Calculating lateral earth pressure is necessary in order to design structures such as:

- Retaining Walls
- Bridge Abutments
- Bulkheads
- Temporary Earth Support Systems
- Basement Walls

At the end of this course you will have learned:

- Basic method of calculating lateral earth pressure
- Other considerations when developing the total lateral force against a structure

Categories of Lateral Earth Pressure

There are three categories of lateral earth pressure and each depends upon the movement experienced by the vertical wall on which the pressure is acting. In this course, we will use the word wall to mean the vertical plane on which the earth pressure is acting. The wall could be a basement wall, retaining wall, earth support system such as sheet piling or soldier pile and lagging etc.

The three categories are:

- At rest earth pressure
- Active earth pressure
- Passive earth pressure

The at rest pressure develops when the wall experiences no lateral movement. This typically occurs when the wall is restrained from movement such as a basement wall that is supported at the bottom by a slab and at the top by a floor framing system prior to placing soil backfill against the wall.

The active pressure develops when the wall is free to move outward such as a typical retaining wall and the soil mass stretches sufficiently to mobilize its shear strength. On the other hand, if the wall moves into the soil, then the soil mass is compressed sufficiently to mobilize its shear strength and the passive pressure develops. This situation might occur along the section of wall that is below grade and on the opposite side of the wall from the higher section. Some engineers use the passive pressure that develops along this buried face as additional restraint to lateral movement.

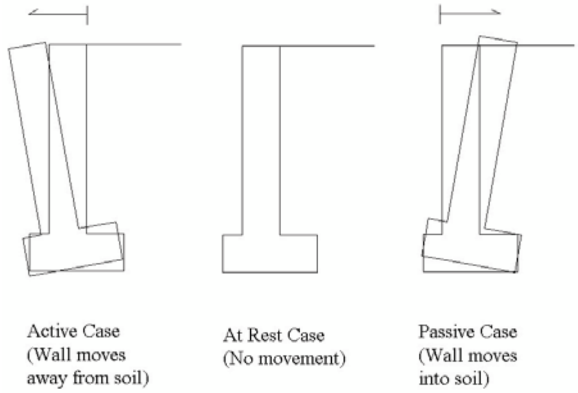

Figure 1 Wall Movement

In order to develop the full active pressure or the full passive pressure, the wall has to move. If the wall does not move a sufficient amount, then the full pressure will not develop. If the full active pressure does not develop behind a wall, then the pressure will be higher than the expected active pressure. Likewise, significant movement is necessary to mobilize the full passive pressure. This is illustrated in Figure 2. Note that the at rest condition is shown where the wall rotation is equal to 0, which is the condition for zero lateral strain.

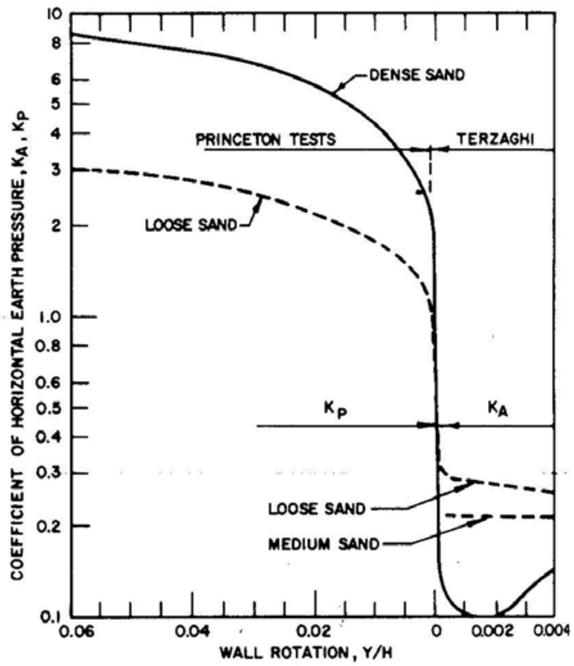

Figure 2 Effect of Wall Movement on Wall Pressure
[Ref: NAVFAC DM-7]

From this figure, it is shown that:

- As the wall moves away from the soil backfill (left side of Figure 1), the active condition develops and the lateral pressure against the wall decreases with wall movement until the minimum active earth pressure force (Pa) is reached.
- As the wall moves toward (into) the soil backfill (right side of Figure 1), the passive condition develops and the lateral pressure against the wall increases with wall movement until the maximum passive earth pressure (Pp) is reached.

Thus the intensity of the active / passive horizontal pressure, which is a function of the applicable earth pressure coefficient, depends on wall movement as the movement controls the degree of shear strength mobilized in the surrounding soil.

Calculating Lateral Earth Pressure Coefficients

Lateral earth pressure is related to the vertical earth pressure by a coefficient termed the:

- At Rest Earth Pressure Coefficient (Ko)
- Active Earth Pressure Coefficient (Ka)
- Passive Earth Pressure Coefficient (Kp)

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

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. However, there are many textbooks and other publications where this topic is fully discussed.

At Rest Coefficient

Depending upon whether the soil is loose sand, dense sand, normally consolidated clay or over consolidated clay, there are published relationships that depend upon the soil's engineering values for calculating the at rest earth pressure coefficient. One common earth pressure coefficient for the "at rest" condition used with granular soil is:

$$Ko = 1 - \sin(\varphi) \qquad (1.0)$$

Where: Ko is the "at rest" earth pressure coefficient and φ is the soil friction value.

Active and Passive Earth Pressure Coefficients

When discussing active and passive lateral earth pressure, there are two relatively simple classical theories (among others) that are widely used:

- Rankine Earth Pressure
- Coulomb Earth Pressure

The Rankine Theory 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 φ.
- 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 Theory 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 δ. Note that δ ranges from φ/2 to 2φ/3 and δ = 2φ/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 δ.

The general cases for calculating the earth pressure coefficients can also be found in published expressions, tables and charts for the various conditions such as wall friction and sloping backfill. The reader should obtain these coefficients for conditions other than those discussed herein.

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

- (Active) $Ka = (1 - \sin(\varphi)) / (1 + \sin(\varphi))$ (2.0)
- (Passive) $Kp = (1 + \sin(\varphi)) / (1 - \sin(\varphi))$

(3.0) Some tabulated values base on Expression (2.0) and (3.0) are:

φ (deg)	Rankine Ka	Rankine Kp
28	.361	2.77
30	.333	3.00
32	.307	3.26

The Coulomb active and passive earth pressure coefficient is a more complicated expression that depends on the angle of the back of the wall, the soil-wall friction value and the angle of backfill. 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 and passive earth pressure coefficient for the specific case of a vertical back of wall angle and horizontal backfill surface.

Coulomb Active Pressure Coefficient

	δ (deg)				
φ (deg)	0	5	10	15	20
28	.3610	.3448	.3330	.3251	.3203
30	.3333	.3189	.3085	.3014	.2973
32	.3073	.2945	.2853	.2791	.2755

Coulomb Passive Pressure Coefficient

	δ (deg)				
φ (deg)	0	5	10	15	20
30	3.000	3.506	4.143	4.977	6.105
35	3.690	4.390	5.310	6.854	8.324

Some points to consider are:

- For the Coulomb case shown above with no soil-wall friction (i.e. $\delta = 0$) and a horizontal backfill surface, both the Coulomb and Rankine methods yield equal results.

- As the soil becomes stronger the friction value (φ) increases. The active pressure coefficient decreases, resulting in a decrease in the active force and the passive pressure coefficient increases, resulting in an increase in the passive force.

- As the soil increases in strength (i.e. friction value increases) there is less horizontal pressure on the wall in the active case.

Calculating the Vertical Effective Overburden Pressure

The vertical effective overburden pressure is the effective weight of soil above the point under consideration. The term "effective" means that the submerged unit weight of soil is used when calculating the pressure below the groundwater level. For instance, assume that a soil has a total unit weight (γ) of 120 pcf and the groundwater level is 5 feet below
the ground surface. The vertical effective overburden pressure ($\sigma v'$) at a depth of 10 feet below the ground surface (i.e. 5 feet below the groundwater depth) is:

$$\sigma v' = 5(\gamma) + 5(\gamma')$$

Where γ is the total un... submerged) unit weight of the soil ... e unit weight of water (i.e. 62.4 pcf ...

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Where ($\sigma v'$) is the vert...

If water pressure is allo... ...ning wall, then the total pressure and the resulting total fo... ...g the back of the wall is increased considerably. Therefore, it is common for walls to be designed with adequate drainage to prevent water