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ENGINEERING CHALLENGES IN RETAINING WALL DESIGN: A STUDY OF EARTH PRESSURE AND STABILITY ANALYSIS

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Abstract: Structures called retaining walls are employed to sustain soil slopes that are vertical or nearly vertical. Lateral earth pressures are the horizontal strains brought on by the soils on the walls. These barriers routinely collapse, creating a serious environmental risk and worrying b uilding engineers. A geotechnical engineer must determine the magnitude of the lateral earth pressures, which depend on the unit weight, angle of friction, and cohesiveness of the soil contained behind the wall. It is expected that the soil behind the wall (known as the backfill soil) is close to failing and satisfies some failure criterion, such as the MohrCoulomb failure criterion, in order to accurately quantify the magnitude of this lateral earth pressure.The kind and quantity of wall movement, the backfill type, the backfill soil's effective unit weight, and the location of groundwater all have an impact on lateral earth pressure, drainage conditions in the backfill, ground surcharge, and the application of surcharge. At rest, active, and passive are t he three main types of Earth pressure. Retaining walls must remain stable throughout construction since they are susceptible to falling over at their feet, sliding along their bases, and failing because the soil supporting the foundation isn't strong enough to hold them. Earth pressure sensors, laserbased displacement transducers, slope inclinometers, and earth pressure sensors are widely used to monitor failure in preinstalled retaining walls. Potentiometers and strain gauges make it easy to find geo-foam deformation in small scale models.

Keywords: Earth pressure, retaining walls, and environmental risk

INTRODUCTION

Retaining walls are structures that are commonly built to reinforce and stabilize slopes, embankments, and other earthworks. They are recognized as one of the most common geo structures that have significant flexibility against outburst loads and are less sensitive to settlement (Ghanbari and Taheri 2012).“A retaining wall is also defined by (Day, 1997) as a structure whose primary purpose is to provide lateral support for soil or rock". "There are situations where retaining walls may support vertical load, such as basement walls and bridge abutments.

Excessive runoff can wash out roadways and structures causing a big environmental issue as the support material exerts force on the structures and eventually result to sliding and overturning, certain amount of strain must develop within the soil mass in order that the shear stresses that help to support the soil may be fully mobilized, a certain amount of tilt of the wall must be allowed before the lateral earth pressure reduces to the value of active lateral earth pressure. Therefore, the main objective of retaining wall is to ensure stability of hillsides and protect it from erosion, overturning, sliding or tilting (Diwalkar, 2020)".

Two major soil retentions systems were pointed out by Khan, 2004; externally and internally stabilized walls, designed to withstand the lateral Earth pressure resulting from surcharge loads and self weight. Gravity walls, reinforced concrete counterfort walls and reinforced concrete cantilever walls are typical examples of externally stabilized retaining walls (Fig: 1.7a - d.). In internally stabilized walls, the lateral earth pressures are sustained by soil reinforcement or passive resistance from the anchor block. Typical examples are; metal strip walls, anchored earth walls and geotextile reinforced walls (Khan, 2004).Importantly in engineering practice, lateral earth pressures are estimated during the design of many geotechnical engineering structures viz retaining walls. "Retaining walls attributed to cohesionless backfill soil are specially designed based on the distribution of active lateral earth pressure as a result of outward tilt about the base. Earth pressure theories (Coulomb's and Rankine's) are widely used for this purpose (Bang, 1985)".

"The Coulomb theories are only valid for the limiting condition where an active horizontally translating sliding wedge has developed in the soil mass behind the retaining wall. These solutions often do not provide valid distributions of lateral earth pressures that are needed for the design of walls for which the shearing resistance of the soil mass behind the wall is not necessarily completely mobilized (Chang, M. F. (1997)".

The earth forces acting on the wall due to backfill are a major problem in practical design, and thus it is critical to calculate the thrust on the wall precisely, allowing the assessment of the wall's safety during its operation time. Coulomb or Rankine Earth pressures theory based on limit equilibrium analysis could be used to calculate the forces exerted on the wall. Coulomb (1776) was a pioneer in the research of lateral earth pressures on retaining walls by assuming a planar failure surface under limit equilibrium conditions.

Various developments rooted in Coulomb earth pressures theory have been reported in recent years, for example, surcharge loading (Motta 1994; Greco 2005), seismic effects (Wang et al., 2008a; Ahmad 2013; Brandenberg et al. 2015), cohesive-frictional backfill (Ahmadabadi and Ghanbari 2009; Chen 2014; Xu 2015), and different slip surfaces (Ouyang et al., 2013). The purpose of this paper is to provide environmentalist and geotechnical engineers an overview of recent developments on Earth pressure and its stability.

2.0 EARTH PRESSURES

The earth loads and pressure distributions are altered as a result of wall movement, which may be brought on by shifts or local deformations. Setting system movements in the context of extreme circumstances is a traditional method for evaluating their impact. According to Clough and Duncan (1991), these are referred to as the active and passive ground pressure loadings.

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Lateral earth pressure is a function of various elements, including (a) the kind and quantity of wall movement, (b) soil shear strength parameters, (c) soil unit weight, and (d) drainage conditions in the backfill. The figures below depict a retaining wall of height AB (Robert, 2013).

To determine the magnitude of the forces operating on retaining walls, two approaches are used: the Coulomb wedge (a force technique) and the Rankine theory (which describes pressure distributions). From the figures above, there are three types of Lateral Earth Pressure (LEP):

a)At Rest Lateral Earth Pressure: The wall might be prevented from moving, for instance, the basement wall might be prevented from moving because of the basement slab; in this case, the lateral earth force is denoted by the letter "Po".

b) Active Lateral Earth Pressure:" If the wall is free from its upper edge (retaining wall), the wall may move away from the retained soil with distance "+ H" (i.e. the soil pushes the wall away), indicating that the soil is active, and the force of this pushing is called active force and is denoted by "Pa."" (Robert, 2013).

c)Passive Lateral Earth Pressure:

For the wall shown above (retaining wall), the soil on the left side is lower in height than the soil on the right, and as previously stated, the right soil will push the wall away, so the wall will be pushed into the left soil (i.e. soil compresses the left soil), indicating that the soil has a passive effect, and the force in this case is called passive force and denoted by " Pp".

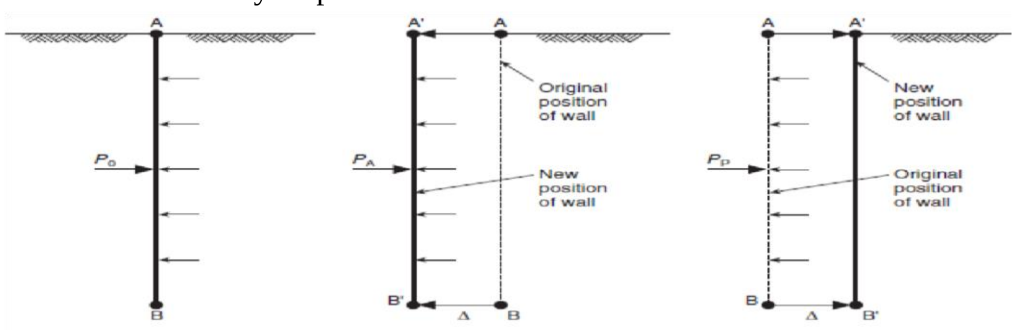

Fig 1.0: The effect of wall movement on earth pressures (Robert, 2013).

The first person to establish guidelines for the design of retaining structures with the intention of withstanding soil lateral pressure was a French military engineer named Marshal Vauban in 1687. Numerous experts have put forth a number of theories regarding ground pressure, along with field experiments. "Classical earth pressure theories" refer only to the theories of Coulomb (1773) and Rankine (1860) that were created and applicable to cohensionless soil backfill, the ideal circumstance for loose backfill against a wall taking into account the angle of internal friction in soils.

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2.1 COULOMB WEDGE ANALYSIS

Coulomb considers a rigid mass of soil sliding on a shear surface that was a straight line set at an angle above the horizontal (Figure 1.2). He was well aware that the critical shear surface might not be flat, but he observed that a straight failure surface was a decent approximation to the true behavior (Coulomb 1776). If the soil behind the wall is in an Active condition, the forces acting on the soil wedge can be placed in a force polygon (of W, T, N, and P), as seen in Figure 1.2.

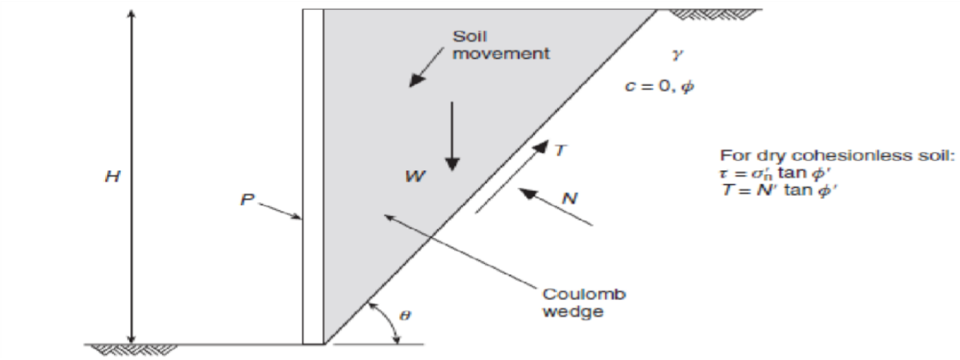

Figure 1.2: The Coulomb wedge (Adopted from Robert, 2013).

Thus, designing a retaining wall based on its smoothness is a conservative technique, but it is not overly conservative for Active situations, and it is frequently the most realistic model. This is because the physical roughness of the wall is not the determining element in establishing whether or not a shear force is occurring on the rear of a wall. There must be considerable sliding motion between the soil and the back of the wall for a shear force to be generated (rather than just a potential force) (Robert, 2013).

Since the soil is cohesion less, the effective Active thrust is then given as;

$$P_A^{!} = \frac{1}{2}\gamma H^2 tan^2\left(45^{\circ} - \frac{\emptyset^{!}}{2}\right) - 2c^{!}\mathrm{H}\tan\left(45^{\circ} - \emptyset^{!}\right) \qquad 1$$

While the effective Passive thrust is given by Robert, 2013

$$P_p^{!} = \frac{1}{2}\gamma H^2 tan^2\left(45^{\circ} + \frac{\emptyset^{!}}{2}\right) + 2c^{!}\tan\left(45^{\circ} + \emptyset^{!}\right) \qquad 2$$

The main drawback with the Coulomb wedge analysis is that the point of application of the thrust on the wall is not known, and if moments are to be calculated, this point of action is needed. The point of application of the water force is known because the water pressure behind the wall increases linearly with depth.

2.2 RANKLINE ANALYSIS (EFFECTIVE EARTH PRESSURES)

In contrast to Coulomb's solution, which considered a soil mass restricted by a single failure surface, Rankine (1857) extended earth pressures theory by finding a solution for a full soil mass in a condition of failure. Bell's (1915) following investigation included the influence of cohesiveness on earth pressures. The Mohr-Coulomb diagram can be used to derive expressions for the earth pressures exerted on a smooth vertical wall by a cohesive-frictional fill (with a horizontal ground surface) by considering the behavior of an element of soil immediately adjacent to a smooth wall (Figure 1.3 and 1.4) that has been installed without disturbing the ground.

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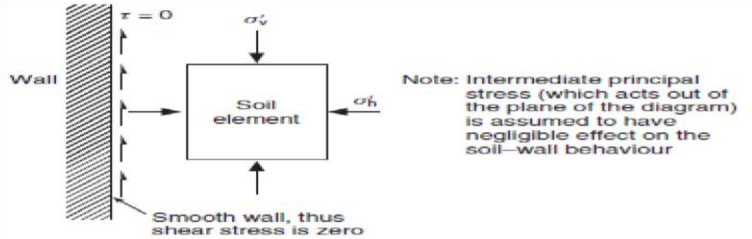

Figure 1.3: An element of soil adjacent to a 'smooth' wall (Robert, 2013).

From the figure above the coefficient is given as $k_\circ = \sigma_3^! / \sigma_1^!$ (ratio horizontal and vertical pressures) because for over consolidated soils with unknown stress history K_0 can be determined only experimentally. As vertical stress decreases in an overconsolidated clay, some horizontal stress remains 'locked-in,' and K_0 approaches or exceeds unity. The horizontal to vertical stress ratio of an undisturbed soil at rest is determined is the function of the following factors:

• The kind of soil.
• Its geological past
• Any transitory loads that may have operated on the soil's surface.
• The terrain.
• Variations in ground strain or groundwater regime.

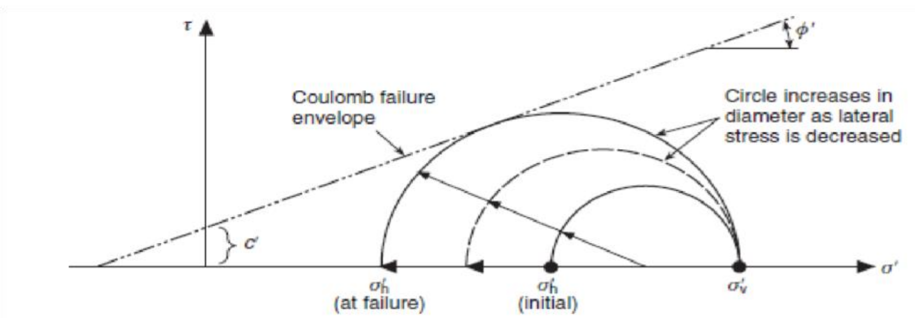

Fig 1.4: The Mohr–Coulomb diagram for Active failure(Robert, 2013).

The Mohr's circle can only get so big before the lateral tension can no longer be alleviated. The minimal lateral stress that the wall must exert at this point in order to offer a factor of safety of unity against soil failure is hence known as the minor primary stress. In this instance, we have:

$\sigma_1^! = \sigma_3^! k^! + 2c^! \sqrt{k^!}$ and $k = \frac{1+\sin \emptyset^!}{1-sin\emptyset^!}$ 3

For a smooth wall, we have:

$\sigma_1^! \equiv \sigma_v^!$ 4

$\sigma_3{}^! \equiv \sigma_h{}^! \equiv p_A{}^!$ 5

Therefore, the effective Active pressure on the wall is obtained from

$P_A^! = \sigma_3^! = \frac{\sigma_1^!}{K^!} - \frac{2c^!}{\sqrt{K^!}} = k_A^! \sigma_V^! - 2c^! \sqrt{k_A^!}$ 6

$K_A^! = \frac{1}{K^!} = \frac{1-\sin \emptyset^!}{1+\sin \emptyset^!} = tan^2(45^\circ - \frac{\emptyset^!}{2})$ 7

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The resultant Active earth pressure diagram (the variation in the lateral effective stress, with depth, on the back of the wall) is illustrated in Figure 1.5. The effective Active thrust P'_A is the algebraic sum of the areas in the foregoing diagram, and, if there are no pore pressures, it is given by

$$P'_A = \frac{1}{2}\gamma H^2 K'_A - 2c' H\sqrt{K'_A} \qquad 8$$

This value obtained is exactly the same as that given by the Coulomb wedge analysis.

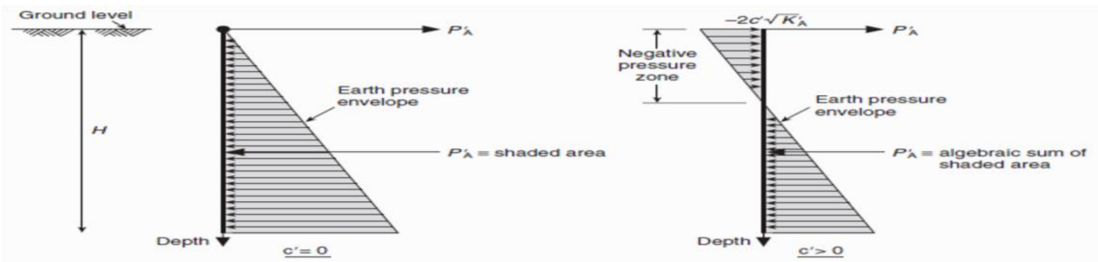

Figure 1.5: Earth pressure distributions (Robert, 2013).

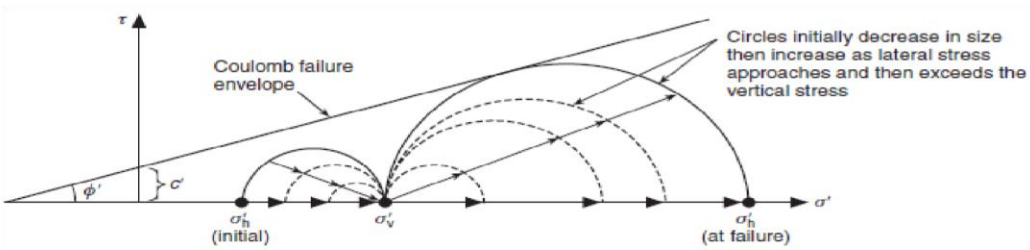

Figure 1.6 The Mohr–Coulomb diagrams for Passive failure (Robert, 2013).

Pressure distribution the$\boldsymbol{K'_A\sigma'_V}$and a rectangular distribution the$-\mathbf{2}\boldsymbol{c}'\sqrt{\boldsymbol{K'_A}}$preceding approach can also be applied to the determination of a relationship for the Passive case, only in this derivation the wall is pushed into the soil (i.e. the horizontal effective stress $\boldsymbol{\sigma}'\mathbf{h}$is increased to bring the soil to failure).Since the vertical stress remains constant, the Mohr's circle is likely to decrease in size initially until $\boldsymbol{\sigma}'\mathbf{h}$ exceeds$\boldsymbol{\sigma}\mathbf{v}'$, after which the Mohr's circle will grow in size until it touches the failure envelope (Figure 1.6). At this stage, Passive failure of the soil occurs (both the self-weight and shear strength have resisted deformation), and the following stress conditions apply, for a smooth wall with a vertical back and horizontal ground surface:

$$\boldsymbol{\sigma'_1 \equiv \sigma'\mathrm{h} \equiv \mathrm{P'_P}} \textbf{ and } \boldsymbol{\sigma'_3 \equiv \sigma'_V} \qquad 9$$

Thus, the effective Passive pressure on a smooth wall is obtained from

$$\mathbf{P'p = \sigma' = \sigma'_3K' + \ 2c'\sqrt{K'} \equiv K'p}\boldsymbol{\sigma'_V} + \mathbf{2c'\sqrt{K'}p} \qquad 10$$

$$\mathbf{k'\,p = k'} \ = \frac{\mathbf{1+\sin\emptyset'}}{\mathbf{1-\sin\emptyset'}} = \mathbf{\tan^2(45^2} + \frac{\emptyset'}{\mathbf{2}}) \qquad 11$$

Equation 11 is then used to produce the resulting passive earth pressure diagram, which shows how the lateral effective stress varies with depth on the back of the wall. This diagram's area, which corresponds to the effective Passive push P'p, can be calculated as follows:

$$\overline{\mathbf{P'p}} = \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{\gamma}\mathbf{H^2}\boldsymbol{K}'\mathrm{p} + 2\ \mathbf{c'H}\sqrt{\mathrm{K'p}} \qquad 12$$

2.3 ACCURACY OF K_A AND K_P

The failure surfaces are curved, contrary to the assumptions made by Rankine and Coulomb analyses, which both assume linear surfaces. The assumption of linear surfaces does not account for the fact that curved surfaces are more crucial, which results in an underestimation of active pressures and an overestimation of passive pressures. According to Handy and Spangler (2007), "the error, which is of the order of 10%, must therefore be included in a safety factor.

3.0 STABILITY OF RETAINING WALLS/ STRUCTURES

According to Basheer et al. (1996), retaining walls are often constructed to support unstable structures, create roadways, and stabilize ditches and soil slopes. A retaining wall is a solid construction that preserves the soil mass at multiple levels as well as soils with different sloped profiles, according to ChKeerthi et al., 2019. Reinforcing steel is used in reinforced retaining walls to handle stresses and tension pressures that develop within the bulk of concrete.

Various definitions of retaining walls are provided.

"According to Dhamdhere et al. (2018) and Patil et al. (2015), "a retaining wall is a structure designed to resist lateral pressure of soil when there is a change in ground elevation that exceeds the soil's angle of repose."

It is extensively used in a variety of applications, such as irrigation engineering, bridge engineering, railway engineering, and highway engineering. The tendency of the retained material to slide down slope due to gravity must be recognized and combated when designing and installing an adequate retaining wall. The angle of internal friction (∅) and cohesive strength (c) of the held material, as well as the direction and magnitude of movement experienced by the retaining structure, all contribute to the generation of lateral earth pressure behind the wall. When there is a desired change in ground elevation that exceeds the angle of repose of the soil, a retaining wall is also a structure created to resist lateral soil pressure.

The walls must be strong enough to withstand lateral forces brought on by shifting soils or, occasionally, water pressure. Every retaining wall is constructed to hold up a soil "wedge". The wedge is defined as the soil that extends past the failure plane of the soil type currently present at the wall site, and it may be calculated once the soil friction angle has been established. The wall's setback increases as the sliding wedge gets smaller.

Loads acting on retaining walls can be classified according to load categories such as selfweight of the wall, lateral loads from the soil, water table effect, superimposed load with vehicle transportation, and earthquake loads originating from ground vibrations as a result of dead load, soil pressure, surcharge load, and seismic loads. When a retaining wall holds a soil mass at a higher elevation, the retained mass tends to slide and assume a flat slope for equilibrium, which is opposed by the retaining wall (ChKeerthi et al., 2019).

This lessens the pressure on the retaining wall. TRecognizing and counteracting the tendency of the retained material to slide down slope due to gravity is the most important consideration in appropriate retaining wall design and installation. This causes lateral earth pressure to be generated behind the wall, which is dictated by the angle of internal friction (phi) and cohesive strength (c) of the retained material, as well as the direction and amplitude of movement experienced by the holding structure.

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Retaining walls must be designed to maintain stability against overturning, sliding, excessive foundation pressure, and water uplift, and they must have a safety factor of 1.5 against lateral sliding and overturning (Thornburg et al, 2013).

3.1 Types of Retaining Walls

In general, retaining walls are classified into two types: (a) Conventional retaining walls and (b) Mechanically stabilized earth walls.

In this section, I will focus on conventional retaining walls, which are broadly divided into four types (ChKeerthi et al., 2019).

(a) Gravity retaining walls

Gravity retaining walls are made of basic concrete or stone masonry (Figure 1.7a). They are reliant on the stability of their own weight as well as any soil resting on the masonry. This method of construction is not cost effective for tall walls.

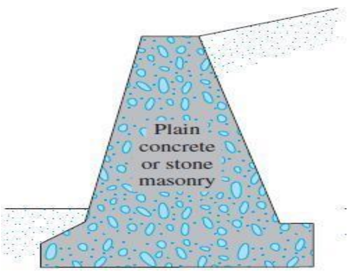

Fig: 1.7a: Gravity wall

(b) Semi-gravity retaining walls

In many circumstances, a modest amount of steel can be utilized to build gravity walls, reducing the size of wall sections. Such walls are commonly known as semi-gravity walls (Figure 1.7b).

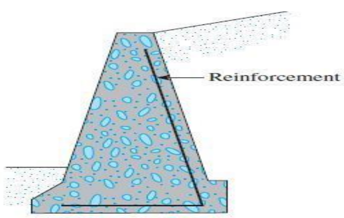

Fig: 1.7b: Semi-gravity wall

(c) Cantilever retaining walls

Cantilever retaining walls (Figure 1.7c) are made of reinforced concrete that consists of a thin stem and a base slab. This type of wall is economical to a height of about 8 m (25 ft.).

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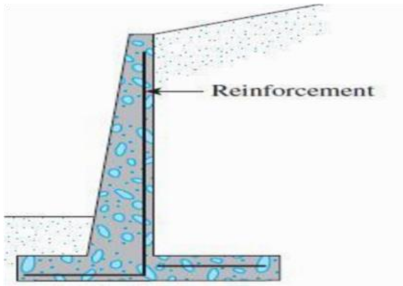

Fig: 1.7c: Cantilever retaining walls

(d) Counterfort retaining walls

Counterfort retaining walls (Figure 1.7d) are similar to cantilever walls. At regular intervals, however, they have thin vertical concrete slabs known as counterforts that tie the wall and the base slab together. The purpose of the counterforts is to reduce the shear and the bending moments.

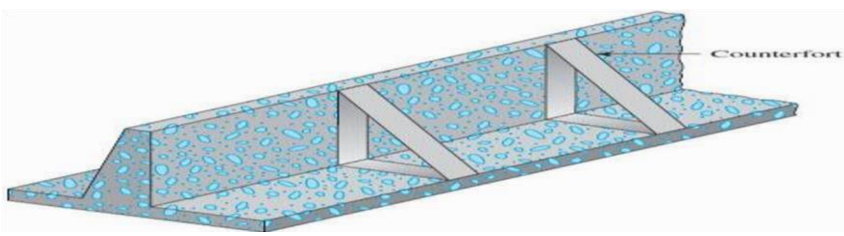

Fig: 1.7d: Counterfort wall

Fig: 1.7d: Counterfort wall

To effectively construct retaining walls, an engineer needs understand the basic parameters of the soil maintained behind the wall and the soil beneath the foundation slab (unit weight, angle of friction, and cohesiveness). Knowing the qualities of the soil behind the wall enables the engineer to plan the lateral pressure distribution. A traditional retaining wall is designed in two stages:

First, the structure as a whole is tested for stability using the lateral earth pressure. The structure is inspected for overturning, sliding, and bearing capacity problems. Second, each structural component is examined for strength, and the steel reinforcement of each component is determined. A retaining structure may fail to work satisfactorily because to structural failure, soil failure, or undesirable deformations. The following are the general factors of stability to be examined;

- The structure should not collapse. The disturbing moments on the structure should not outnumber the restoring moments, and the ground's bearing capacity should not be surpassed.
- The structure must not sag.
- The horizontal disturbing force must be smaller than the resistance to sliding on the foundation, and the overall stability of the soil around the structure must be preserved.

  Excessive wall or ground deformation should not develop to the point that surrounding structures or services reach their final limit state.

- The ground pressure should not overstress any section of the structure in order to prevent structural members, including the wall itself, from failing in bending, shear, or tension/compression.
- It is critical to avoid water accumulating behind the retaining wall.
- Weep holes should be provided to drain the backing materials suitably.

3.2 Importance of Weep Holes in Retaining Walls

Retaining walls are made to withstand pressures from the retained materials, surcharge pressures from the passage of cars, loads from the foundations of nearby buildings on their backfills, seismic loading, and other forces. Accurate estimations of earth pressures are essential for safe and affordable designs since they may be vulnerable to catastrophic failures during earthquakes due to abrupt spikes in lateral loads, pore pressure rises, and other factors. Reducing the overall lateral force acting on the walls is necessary to successfully manage the cross section of retaining walls.

This can be achieved by adding a compressible inclusion between the wall and the backfill; numerous materials, including geofoam, tire chips, granulated rubber-soil mixture, soil bags, glass fiber, cardboard, and hay, have been examined for this purpose. While cardboard and hay eventually decompose, glass fiber is incredibly compressible, which is usually surprising given their material nature. Expanded polystyrene geofoam is a material that exhibits predictable stressstrain behavior, has a high strength-to-density ratio, is resistant to weather, light in weight, safe for the environment, inexpensive, and easily moldable or prefabricated (Horvath, 1994).

3.3 Monitoring of installed Retaining walls

According to Wikipedia, the instrumentation setup for wall monitoring retaining walls includes detecting lateral earth pressures on the retaining wall, quantifying geofoam inclusion deformation, and determining the wall tilt. The sensors employed are earth pressure sensors, laser-based displacement transducers, and slope inclinometers. It is vital to ensure that the wall does not distort when subjected to at-rest lateral earth pressures. As a result, obtaining the slope profile of the wall becomes critical, for which slope inclinometers are used.

Slope inclinometers are geotechnical instruments that measure horizontal displacements along various sites of a borehole; they are made up of two major parts: grooved casings and the probe. The casings are to be inserted in boreholes within the stem of the wall in the field model. These boreholes run from the top to the bottom of the wall and are built by inserting vertical pipes of appropriate sizes into the wall during the concrete pouring process. Lowering the probe along the casing yields the wall tilt profile. Pipes that are significantly larger in diameter than the outside diameter of the inclinometer must be installed so that the casings may be grouted firmly into place while maintaining verticality. Figure 1.8 depicts an example of an inclinometer probe. Potentiometers, strain gauges, and other similar devices can be used to easily measure deformation of geofoam in small scale models. However, in a full scale model, physical contact with the geofoam part is extremely impossible, making quantifying the deformation along the section a considerable difficulty. Laser distance sensors are optoelectronic sensors used for non-contact displacement and distance measurements. Most laser displacement sensors work on the time-offlight or phase comparison principles. Figure 1.8 depicts a typical Laser-based Displacement Sensor.

Lasers from the devices will be targeted on a reflecting screen positioned at the end of the geofoam layer through already supplied holes with clear line of sight in the research, and the distance from the sensor to the end of the geofoam may be calculated based on the transducer output. Successive readings from holes along the height of the retaining walls over time will then provide information on geofoam deformation at various locations.

Fig 1.8: slope inclinometers (Wikipedia).

3.3 Importance of Weep Holes in Retaining Walls

Retaining walls are designed to withstand pressures from retained materials, surcharge pressures caused by automobile traffic movement or loads from adjacent building foundations on their backfills, seismic loading, and so on. They may also be subject to catastrophic failures during earthquakes due to abrupt increases in lateral loads, pore pressure increases, and so on, making accurate estimate of earth pressures crucial for safe and cost-effective designs. To successfully control the cross section of retaining walls, the total lateral thrust acting on the walls must be reduced.

This can be accomplished by inserting a compressible inclusion between the wall and the backfill; several materials have been investigated for this purpose, including geofoam, tire chips, granulated rubber-soil combination, soil bags, glass-fiber, cardboard, and hay. However, their material behavior is frequently surprising; glass fiber is extremely compressible, whereas cardboard and hay biodegrade over time. Expanded Polystyrene Geofoam is a material with predictable stress strain behavior, a high strength to density ratio, is weather resistant, light weight, environmentally safe, cheap, and easily moulded or prefabricated.

3.4 Proportioning of Retaining Walls

When building retaining walls, an engineer needs to make some assumptions about their size, which is known as Proportioning; these assumptions allow the engineer to test trial sections of the walls for stability. If the stability tests produce unfavorable findings, the portions might be altered and retested. The approximate proportions of various retaining wall components that can be employed for initial checks are shown in Figure1.9.

Note that the top of the stem of any retaining wall should not be less than about 0.3 m (≈12 in) for proper placement of concrete. The depth, D, to the bottom of the base slab should be a minimum of 0.6 m (≈2 ft). However, the bottom of the base slab should be positioned below the seasonal frost line.

For good concrete placement, the top of the stem of any retaining wall should not be less than around 0.3 m (12 in). D should be a minimum of 0.6 m (2 ft) to the bottom of the base slab. The bottom of the base slab, however, should be placed below the seasonal frost line.

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The general proportion of the stem and base slab in counterfort retaining walls is the same as in cantilever walls. However, the counterfort slabs may be 0.3 m (12 in) thick and separated at 0.3H to 0.7H Centre-to-Centre distances (Robert et al., 2013 and Dhamdhere et al., 2018).

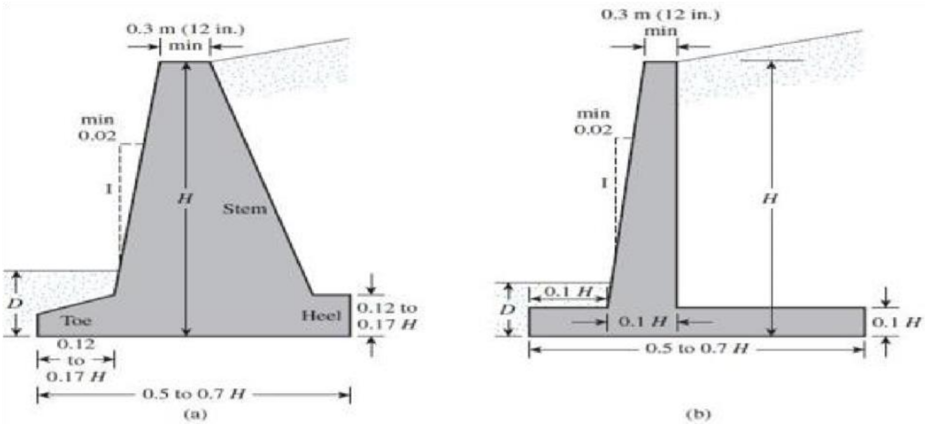

Fig 1.9: Approximate dimensions of various components of retaining walls for initial stability checks (After Dhamdhere et al., 2018).

4.0 Case Histories

4.1 Analysis of the Dewarwadi Retaining Wall's Static Stability

A stability study check on the semi-gravity wall of the PCC was carried out by Vijayakumar et al. (2015) in Dewarwadi hamlet, close to Vaijanath temple, 19.7 kilometers from Belagavi district, Karnataka, India (fig. 1.9). The Dewarwadi Gram Panchayat oversaw the construction of the wall in 2009. The dimensions of a typical retaining wall are: length = 25.50 m, top width = 0.55 m, height = 3.98 m, base slab width = 2.65 m, and foundation depth = 1.46 m. There are 6 weep holes with a diameter of 100 mm and 26 holes with a diameter of 50 mm.

The safety factors for bearing failure, skidding, and overturning were established. Additionally, because the existing wall is of the semi-gravity type, Rankine's theory is used to calculate passive resistance in the foundation soil and Coulomb's theory is used to calculate active earth pressure due to backfill (Vijayakumar et al., 2015). The study's findings led to the following conclusions.

- The current retaining wall is secure since it exceeds the necessary values of 1.5-2, 1.5-2, and 3. Additionally, the average factors of safety for overturning, sliding, and bearing failure are 4.56, 9.62, and 3.10, respectively. The wall is therefore big and ineffective.
- The dimensions of the suggested retaining wall are: stem top width=0.2 m, stem bottom width=1.1 m, base slab width=2.72 m, base slab thickness=0.68 m, heel projection=0.62 m, and toe projection=1 m. Overturning, sliding, and bearing failure each have safety factors of 3.684, 6.970, and 5.140.
- When compared to the current wall, the projected wall used 41.5% fewer materials.

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Fig. 2.0: Existing Retaining wall at Dewarwadi (Vijayakumar *et al.,* 2015)

4.2 Design and Analysis of Retaining wall by Dhamdhere

A cantilever and relieving platform retaining wall with different heights from 3 to 10 meters and an SBC of 160 KN/m2 was evaluated and designed by Dhamdhere et al. in 2018. Comparative analyses of cost, economy, bending moment, and stability against overturning and sliding between the two retaining walls were shown in the final product. The relieving platform is located at the midpoint of the retaining wall, and the following design parameters are used: length of relieving platform kept equal to the length of heel slab; thickness of relieving platform considered onefourth of base slab thickness; angle of friction (): 35o; coefficient of active earth pressure (Ka): 0.27; and coefficient of passive earth pressure (Kp): 3.6.

The foundation's height or depth ranges from 3 to 10 meters, with 0.5-meter intervals. The soil's bearing capacity ranged from 100 KN/m3 to 200 KN/m3 at intervals of 10 KN/m. 18 KN/m3 is the weight of soil, while 25 KN/m3 is the weight of concrete. concrete grade M25; Fe500 steel grade. The retaining wall design incorporates the following stability evaluations: The factor of safety against sliding was decided to be larger than 1.5, and the factor of safety against overturning was chosen to be greater than 0 and less than the soil bearing capacity. The eccentricity of the resulting reaction force was determined to be between 0 and the base width of 6. The IS456:2000 code was used to calculate the reinforcement spacing as well as the highest and lowest reinforcement percentages. The maximum shear stress limits in various parts depend on the concrete grade set in the IS456:2000 code. The relieving platform retaining wall, he concluded, is less expensive, more stable than the cantilever retaining wall, and does not have the heel component's bending moment.

5.0 CONCLUSION

To support soil slopes that are vertical or almost vertical, retaining walls are a type of building. For building and environmental experts worldwide, the frequent breakdown of these walls raises serious environmental problems. Geotechnical professionals must assess the size of the lateral ground forces behind the wall. It is believed that the soil behind the wall (known as the backfill soil) is on the verge of failing and adheres to some failure criteria, such as the Mohr-Coulomb failure criterion, in order to accurately calculate the magnitude of this lateral earth pressure. The sort and extent of wall movement, the type of backfill used, the effective unit weight of the backfill soil, the position of ground water, the drainage situation in the backfill, the ground surcharge, and the application of the ground surcharge are some of the factors that affect lateral earth pressure. Maintaining stability is very important while building is underway. Earth pressure sensors, laser-based displacement transducers, and slope inclinometers should be used to monitor failure in already-built retaining walls. Potentiometers and strain gauges make it simple to measure geo-foam deformation in small-scale models.

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