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1.Abstract

A large number of types of retaining devices are currently available but their limitations, recommendations and guidelines are must be considered to choise any type of retaining wall , and choising the methods of designing atype of retaining wall .[1]

When designing and building a retaining wall, there are a variety of factors to consider, regardless of whether it's intended for residential or commercial use. The same standard of care should be applied to walls as a bridge since they are both structures. Depending on the application and your experience, you may wonder what style of wall will work best for the site, how deep the footing needs to be buried, if it needs reinforced, or even what material is best for the location.

Before you begin designing your wall and choosing the aesthetics, you need to understand the location and environmental factors that can make your wall fail. Building a retaining wall takes advanced planning and careful layout in order to avoid it becoming a hazard or collapsing. This report looks or shows some types of retaining wall . Also this report guide anyone to have knowledge about elements of retaining wall , how begin to design the elements to be constructed save retaining wall and the main factors effect on retaining wall frailer .[2]

Key Words: Retaining Wall, Design Retaining Wall, and Back fills, Stability, Earth pressure

2.Introduction

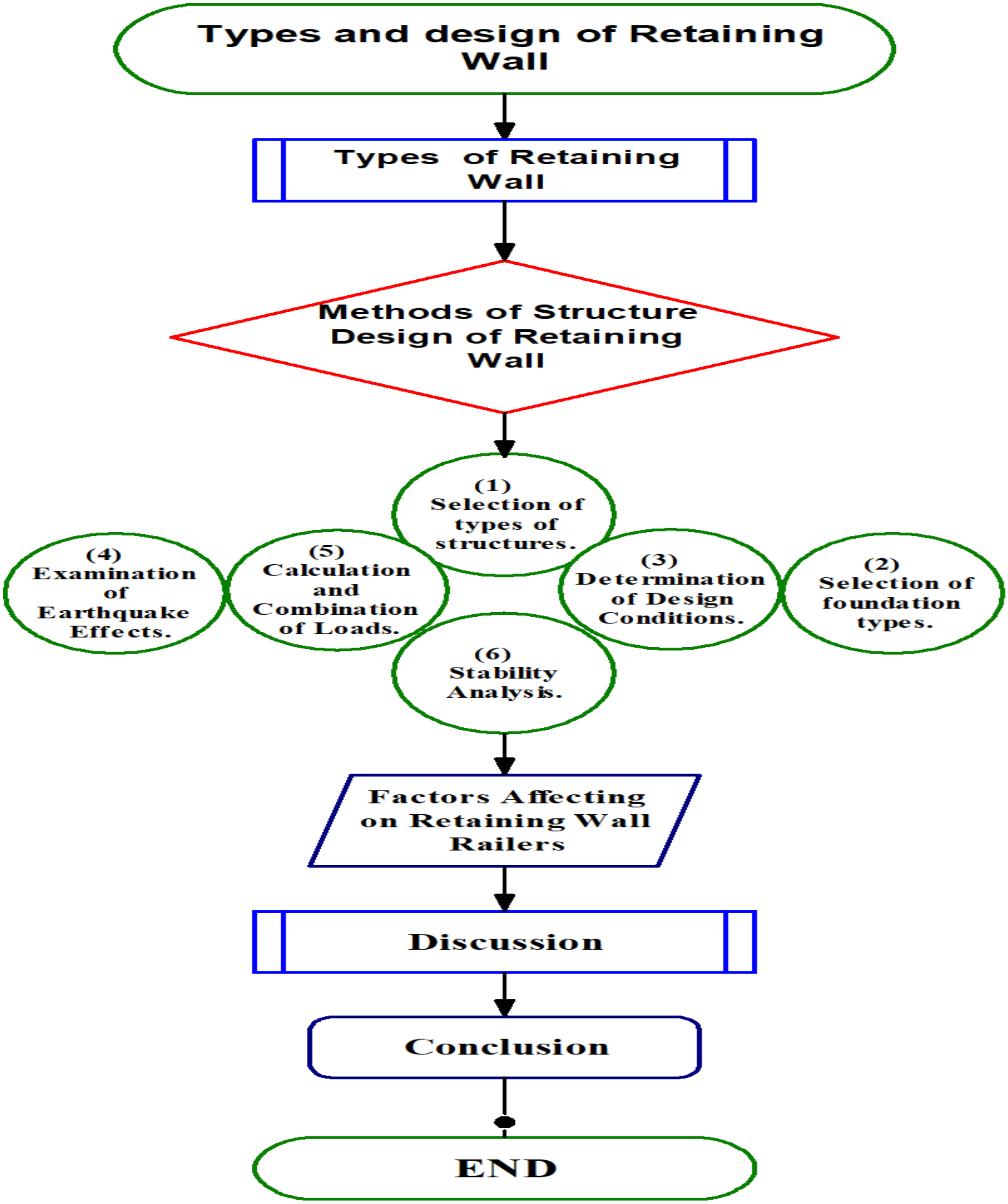
Retaining walls are structures constructed to support earth or water or other materials such as coal, ore, etc. The retaining material is usually called as backfill. The main objective of retaining walls is to stabilize hillsides and protect it from erosion. At any place if soils are unstable, steep slopes are there, or heavy runoff is present, retaining walls are used to stop erosion. Excessive runoff can wash out roadways and structures, and protecting sediment runoff is a big environmental and water quality consideration in transportation projects like road and bridge projects. In these scenario constructing retaining walls, reduces removal of vegetation and reduction in erosion caused by runoff. Again soil will get stabilized by the vegetation. Sediments and pollutants gets filter out before they enter the water source, in this way improving water quality. The supported material exerts a force on structures and this leads to overturning and sliding effect on it. Along with the self-weight, earth pressure is the majorly acting force for analysis and design of the retaining wall. Cohesive strength of soil and angle of internal friction are very important factors on which the lateral earth pressure depends. Earth pressures distribution is generally triangular, minimum at top of the wall and increasing towards the bottom of wall. This push force can either overturn or push forward the wall if not properly analyzed.

Few more factors are also there which are to be considered while analyzing like the wall location, its position relative to other structures and the availability of space. Another one to be considered is required wall height and the ground topography, both before and after construction. Then the conditions of ground, the ground water table and tidal conditions, ground movement's extent of acceptance during construction and in life of structure and the effect of the earth retaining structure's movement on existing or proposed structures and services, external live loading; g) the materials availability; required life and maintenance. [3]

3. Objective of the report:

- To representing the variouse types of retaining wall,
- To define or explain the proceders of designing the retaining wall.

4. **Method of The Work :** Figuer 1.

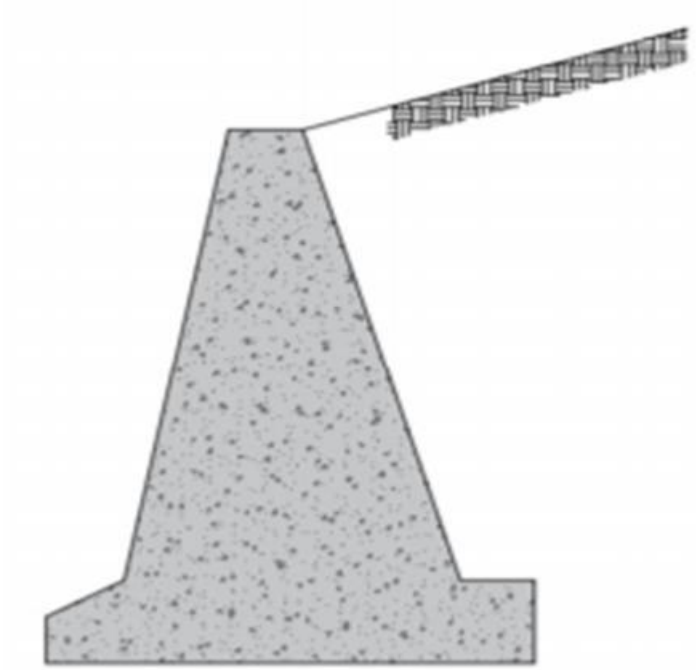


Figuer 1. **Method (model) of The Work**

5. **Tyypes of retaining wall : [4]**

Classification of Retaining Structures On the basis of attaining stability as follows:

1. **Gravity walls:** Gravity walls are stabilized because of their mass. They are constructed of dense, heavy materials like concrete and stone masonry and they are generally reinforced structures. Some of gravity walls uses mortar, depending only on their weight to remain in place, as in the case of dry stone walls. They are economical for only small heights.



Figuer 2. **Gravity Retaining Wall**

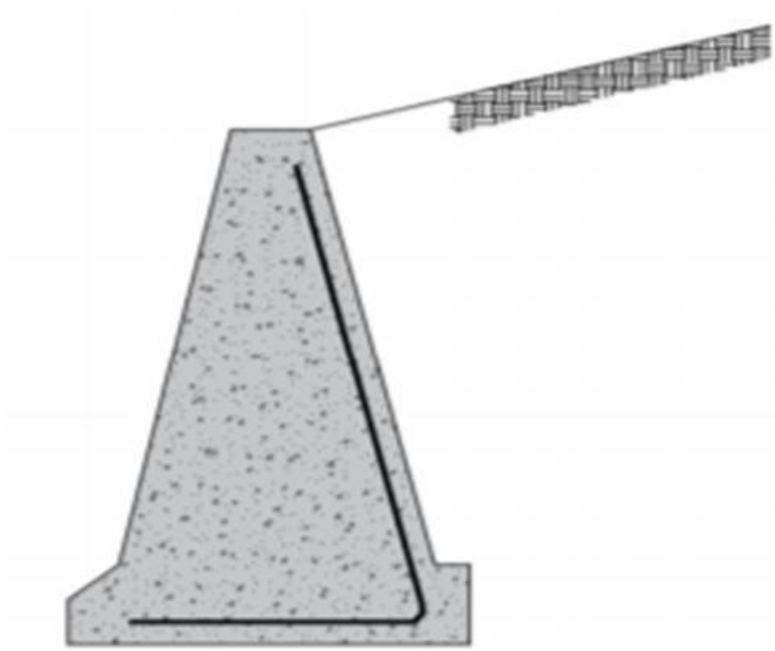
2. Semi Gravity Retaining Wall These are the reinforced concrete walls in which lateral earth pressure is resisted by structural action of its members. The base of the wall is extended into the backfill on the heel side and is known as heel slab. The backfill over the heel slab provides significant additional lateral stability to the wall. The back of the wall on the heel side is also given a slope. This increases the width of the wall with depth, similar to the increase in lateral earth pressure with depth.

The vertical wall (known as stem), the heel slab, and the toe slab act as cantilevers fixed at their junction and spanning to the other end. The stem is subjected to lateral earth pressure, causing bending away from the backfill. The heel slab and the toe slab are subjected to resultant upward soil pressure from the bottom and bend upward.

Reinforcement is therefore provided on the tension side, that is, vertically on the backside of the stem and horizontally at the bottom of the heel slab and the toe slab.

The weight of a cantilever retaining wall is significantly less than that of a gravity retaining wall and therefore requires only lighter foundations.

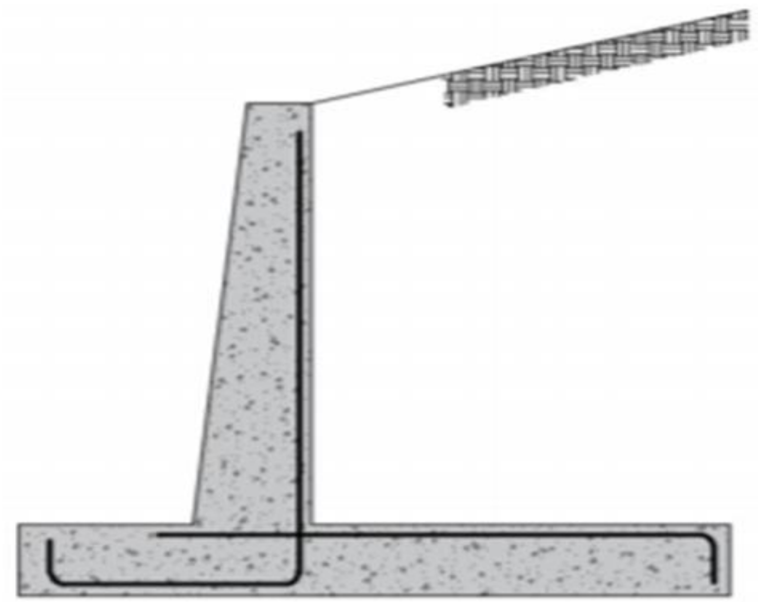
Cantilever retaining walls are suitable for retaining the backfill to moderate heights of 4-7 m. In cross section, most cantilevered walls look like “L”s or inverted “T”s. Where foundation soils are poor, earth tieback retaining walls are another choice. These walls are counterbalanced not only by a large base but also by a series of horizontal bars or strips extending out from the vertical surface into the backfill. The bars or strips, sometimes called “dead- men” are made of wood, metal, or synthetic materials, such as geotextiles. Once an earth tieback retaining wall is backfilled, the weight and friction of the fill against the horizontal members anchors the structure.



Figuer 3. **Semi Gravity Retaining Wall**

There are two sub types Cantilever retaining wall and Counter fort retaining wall.

2.1. **Cantilever retaining wall:** When the height of a cantilever retaining wall is more than about 7 m, it is economical to provide a vertical bracing system, known as counterforts, on the backfill side above the heel slab. The counterforts are triangular beams of variable depth and uniform width, connecting the heel slab and the stem, provided at a regular spacing along the length of the wall. This type of wall is most suitable up to 4m to 7m heights.

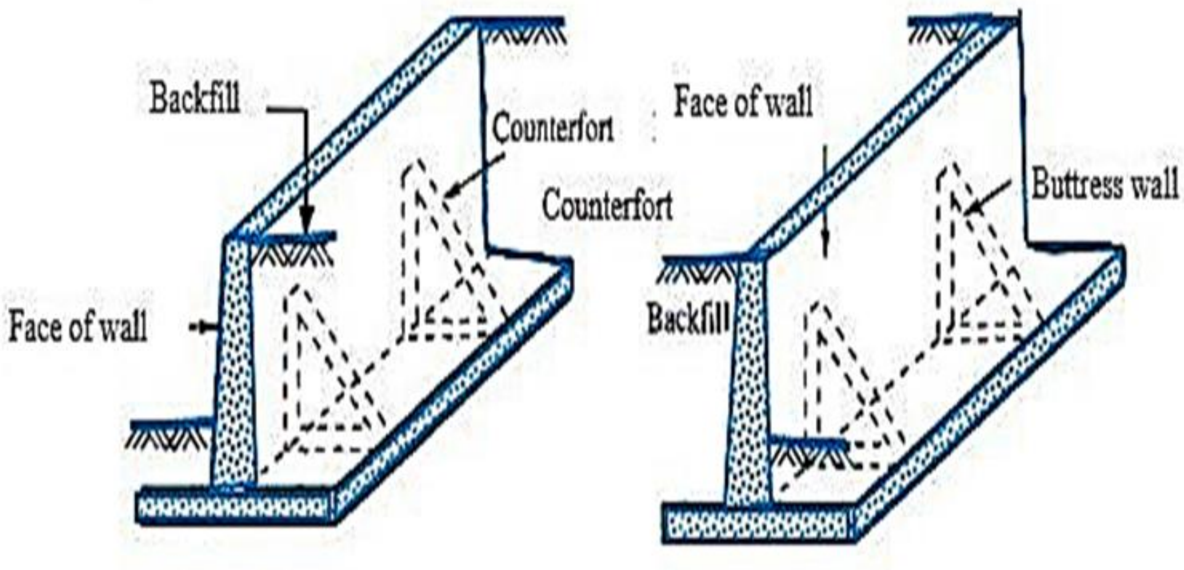


Figuer 4. **Cantliver Retaining Wall**

The stem and the heel slab act as continuous slabs spanning horizontally along the length of the wall between the counterforts. The use of counterforts reduces the bending moment due to earth pressure and hence the size and reinforcement of the stem and the heel slab. Counterforts are subjected to tension due to the action of lateral earth pressure of the backfill on the stem.

2.2. **Counter fort retaining wall:** When the triangular beams are placed on the front side of the retaining wall, instead of on the backfill side under certain situations, the retaining wall is known as buttressed retaining wall, and the triangular beams are known as buttresses, instead of counterforts. The structural action of the stem is the same as in a counterfort retaining wall. These are provided when cantilever retaining wall’s height is greater than nearly 7m.

However, the heel slab acts as a cantilever slab as in a cantilever retaining wall. The toe slab acts as a continuous slab spanning along the length of the wall between the buttresses. Buttresses are subjected to compression due to lateral earth pressure of the backfill on the stem and that due to upward soil pressure on the toe slab.



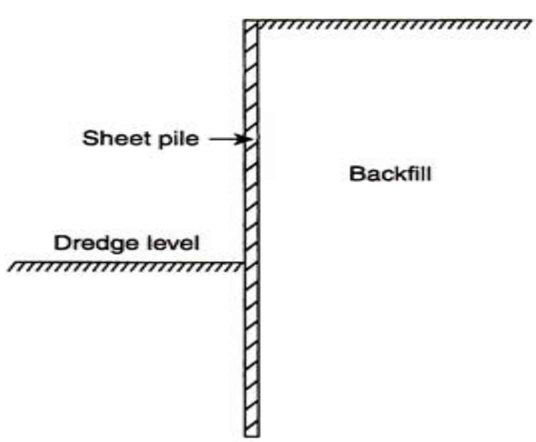
Figuer 5. **Counter Retaining Wall**

5. **Flexible walls:** are further having two types Sheet pile walls and Diaphragm walls.

3.1. Cantilever Sheet Pile:

The cantilever sheet pile derives its support from the embedment into the underlying soil below the dredge level. Hence, the design of cantilever sheet piles involves determination of the depth of embedment of the sheet pile to ensure its lateral stability.

In the case of anchored sheet piles, additional lateral support is provided by means of anchor rods fixed to the sheet pile near the top and anchored suitably. The lateral stability of anchored sheet piles is derived both from the embedment into the soil below the dredge level as well as by the support provided by the anchor or tie rod.



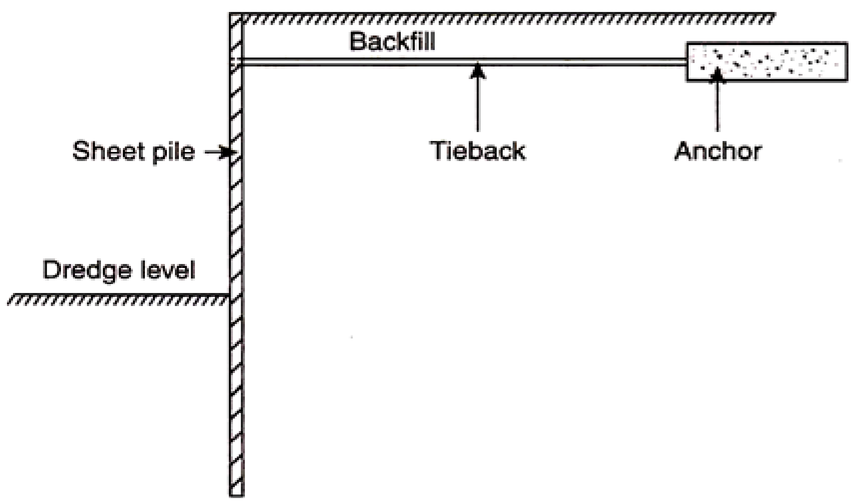
Figuer 6. **Cantiliver Sheet Pile Retaining Wall**

3.2. Anchored Sheet Pile:

In the case of anchored sheet piles, additional lateral support is provided by means of anchor rods fixed to the sheet pile near the top and anchored suitably, as shown in Fig. 16.12. The lateral stability of anchored sheet piles is derived both from the embedment into the soil below the dredge level as well as by the support provided by the anchor or tie rod.

The design of anchored sheet piles involves determination of the depth of embedment as well as the force (tension) in the anchor rod. The depth of embedment depends on the depth of soil to be retained above the dredge level and the type and properties of the backfill and the underlying soil below the dredge level.

The anchorage is provided by means of an anchor or tieback at or near the head of the wall. More than one set of anchors or tiebacks can be used. Provision of anchorage increases wall stability and enables taller walls to be built. In the case of cantilever sheet pile walls, if the deflection at the top point of the sheet pile wall is very large, then settlement of soil takes place at the top just behind the sheet pile wall. The anchors are provided to reduce excessive deflections.



Figuer 7. Anchored **Cantiliver Sheet Pile Retaining Wall**

The following are the different types of anchorages used for anchored sheet piles:

a. Tie rods with deadman.

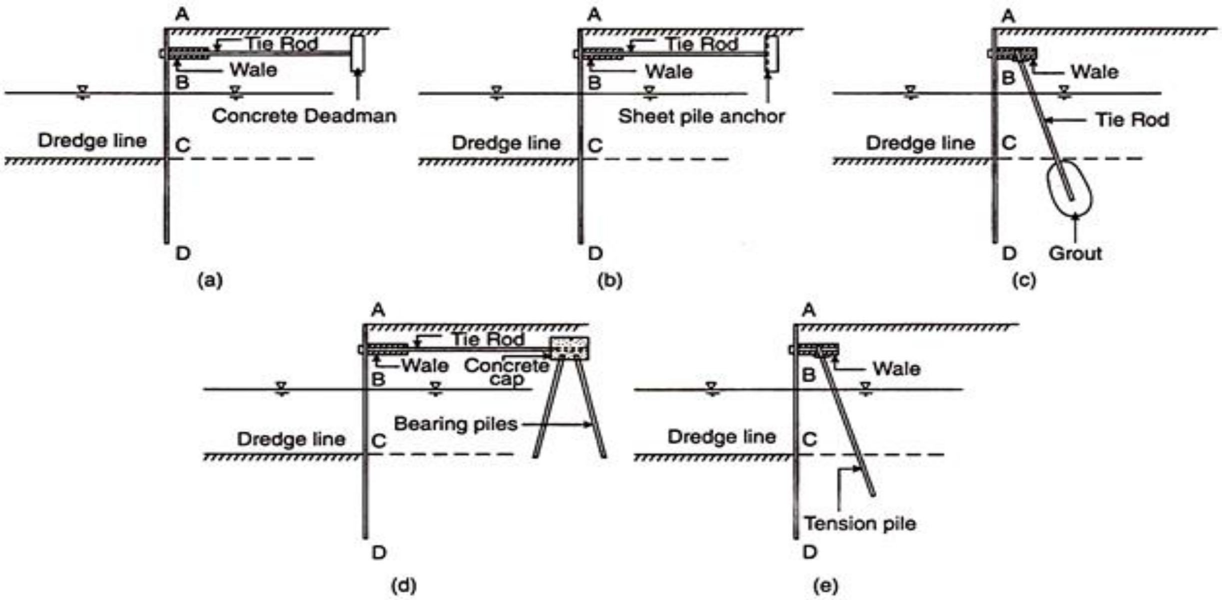
b. Tie rods with anchor walls.

c. Tie rods with grout anchor.

d. Tie rods with bearing piles.

e. Anchorage with tension piles.

Figuer 6. **Cantiliver Sheet Pile Retaining Wall**



Figuer 8. **Different Types of Anchorages Sheet Pile Retaining Wall**

4.Special type of retaining walls: these are Gabion walls and crib walls.

4.1. Gabion wall: These are made by stacking and tying wire cages filled with trap rock or native stone on top of one another. They can have a continuous batter or be stepped back with each successively higher course.

Figuer 9. **Gabion wall Retaining Wall**

4.2. Crib walls: These are prepared with various materials including wood, concrete and even plastic. The cribs are made of interlocking headers and stretchers that are stacked like the walls of a log cabin. Crib walls are generally enough big.

Retaining walls have some potential applications as follows:

a) To maintain the stability of the foot part of a slope after being distressed.

b) To prevent small-scale shallow collapse and toe collapse of large-scale slope failures.

c) To support slope fattening and berm fills.

d) To function as a foundation for other slope protection works such as crib works.

e) To catch rock fall mater in order to protect vehicles from rock.

f) To provide road space especially where right of way is limited.

6.Method of Structural design of retaining wall :

(1) Selection of types of structures.

(2) Selection of foundation types.

(3) Determination of Design Conditions.

(4) Examination of Earthquake Effects.

(5) Calculation and Combination of Loads.

(6) Stability Analysis.

1.Sellection of types of structures.

There are many types of structures for retaining walls and the selection of type of structures are dependent mainly on the topographical and geological conditions at the place of the wall construction, work conditions, purpose of retaining wall, and height of walls.

2.Sellection of foundation types

The types of foundations for a retaining wall are principally classified into spread foundations and pile foundations. The preferable type of foundations for a retaining wall are spread foundation in view of their movement together with the bearing stratum and the filling material at the back. In some cases, if surface layer is soft, spread foundations can also be used with the replacement or improvement of the soft layer. Pile foundations are used when the application of spread foundations are difficult.

3. Determination of Design Conditions.

The parameters for shear strength of soil are generally obtained from either unconfined compression test or the triaxial compression test. The empirical relationship with N value can be used to obtain parameters of soils as follows:

3.1. Parameters for shearing strength of soil

*** Cohesion c of clayey soils (C).**

$c = 6N \sim 10N$ (kN/m2)

***Internal friction angle φ of sandy soil**

$\varphi = 15 + 15N \leq 45°$ N>5

3.2. Unit weight of soil

The unit weight of soil γ (kN/m3) used for the calculation of earth pressure is obtained from laboratory of soil samples. If it is difficult to conduct soil test.

3.3. Allowable bearing capacity of ground.

The allowable bearing capacity of ground is, in principle, determined by conducting an in-situ test (standard penetration test). When it is difficult to conduct an in-situ test for retaining wall.

3.4. Friction angle φB and cohesion cB between foundation base and ground.

When the shear parameters c and φ of the bearing stratum are obtained by soil test, the friction angle of the foundation base φB is determined to be φB =φ for cast-in-place concrete retaining wall and φB =2/3φ for precast concrete retaining wall.

4. Examination of Earthquake Effects

In many countries such as Japan, the effects of earthquakes need to be considered when designing retaining walls higher than 8 meters. Accordingly, it is suggested that analysis of stability against earthquake should be made for retaining wall of up to 8 m in height when the importance of retaining wall and the difficulty of it restoration demand such analysis..

5. Calculation and Combination of Loads.

There are various types of loads and forces acting on retaining wall, which are:

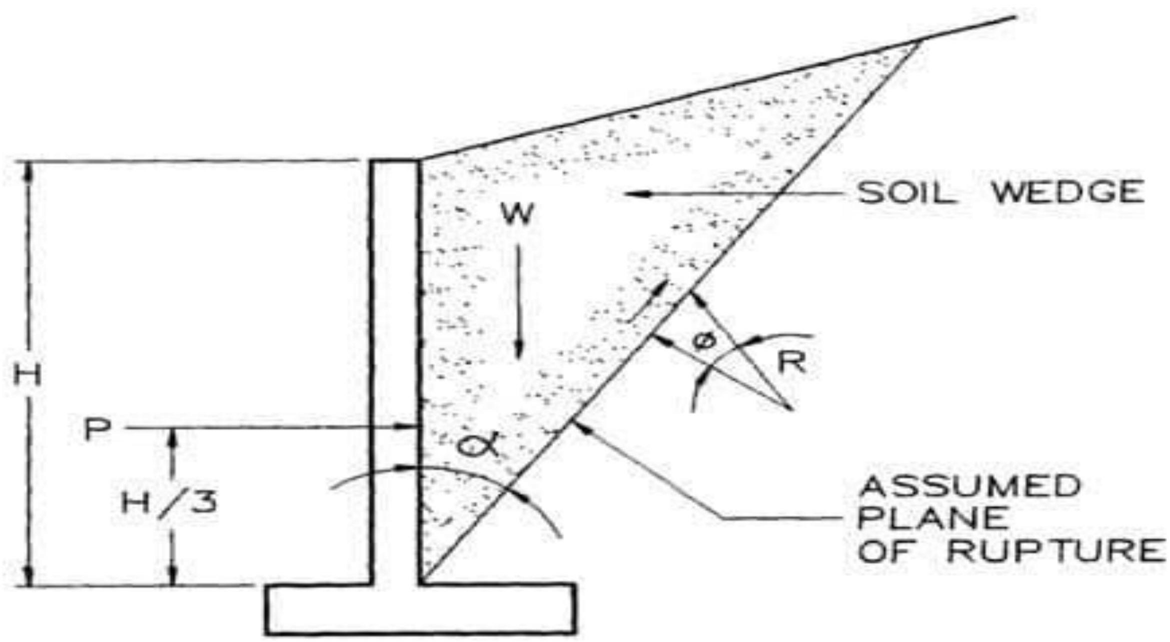
1. Lateral earth pressure
2. Surcharge loads
3. Axial loads
4. Wind on projecting stem
5. Impact forces
6. Seismic earth pressure
7. Seismic wall self-weight forces

Retaining wall design could include any or all of loads and forces which are explained in the following sections:

1. Lateral Earth Pressure Acting on Retaining Wall: [5]

The main purpose of retaining wall construction is to retain soil that is why soil lateral earth pressure is major concern in the design. Sliding soil wedge theory is the basis for most of theories by which lateral earth pressure is computed.

The wedge theory suggests that a triangular wedge of soil would slide down if retaining wall was removed suddenly and the wall has to sustain this wedge soil. Figure 1 shows free body lateral forces acting on retaining walls Figuer 10.



Figuer 10. **Retaining Wall**

Free body of lateral forces acting on retaining wall

Coulomb and Rankin equations are two major formulas which are used to compute lateral earth pressure:

The **Coulomb** method of Lateral Earth Pressure Calculation:

This equation takes backfill slope, friction angle at wall face, rupture plan angle, and internal friction angle into consideration:

Coulomb equation :

Active earth pressure $P_a = \frac{1}{2} K_a \gamma H^2$

$$K_a = \frac{\sin^2(\alpha+\emptyset)}{\sin^2\alpha \sin(\alpha+\delta)\left[1+\sqrt{\frac{\sin(\emptyset+\delta)\sin(\emptyset-\beta)}{\sin(\alpha-\delta)\sin(\alpha+\beta)}}\right]^2} \rightarrow \text{Equation 1}$$

And

$$K_{a\,horizontal} = \cos\delta K_a \rightarrow \text{Equation 2}$$

Passive earth pressure $P_p = \frac{1}{2} K_p \gamma H^2$

$$K_p = \frac{\cos^2(\emptyset+\theta)}{\cos^2\theta \cos(\delta-\theta)\left[1+\sqrt{\frac{\sin(\delta+\emptyset)\sin(\emptyset-\beta)}{\cos(\delta+\theta)\cos(\beta-\theta)}}\right]^2}$$

Where:

Ka: Coefficient of active pressure

$\emptyset$: Angle of internal friction

β: Angle of backfill slope

δ: Angle of friction between soil and wall (2?3 $\emptyset$ to 1?2 $\emptyset$ is assumed)

α : Slope angle of the wall which is measured from horizontal (equal to 90 degree for vertical wall)

Furthermore, in the case of flat level backfill soil, considering zero friction at soil-wall interface, and soil-sidewall is vertical, the **coulomb equation** is reduced to the following:

Ranking equation:

$$K_a = \frac{(1-\sin\emptyset)}{(1+\sin\emptyset)} \rightarrow \text{Equation 3}$$

The Rankine method of lateral earth pressure calculation

This equation, which derived by William Rankine, is the development of coulomb formula. The Rankine method does not take the friction between wall and soil into account.

This makes it a conservative way for designing retaining walls. The Rankine lateral earth pressure equation is the same for both zero-wall friction and level backfill soil:

$$K_a = \cos\beta \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\emptyset}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\emptyset}} \rightarrow \text{Equation 4}$$

$$K_{a\,horizontal} = \cos\delta K_a \rightarrow \text{Equation 5}$$

Where:

β: Backfill slope angle

$\emptyset$: Internal friction angle of soil

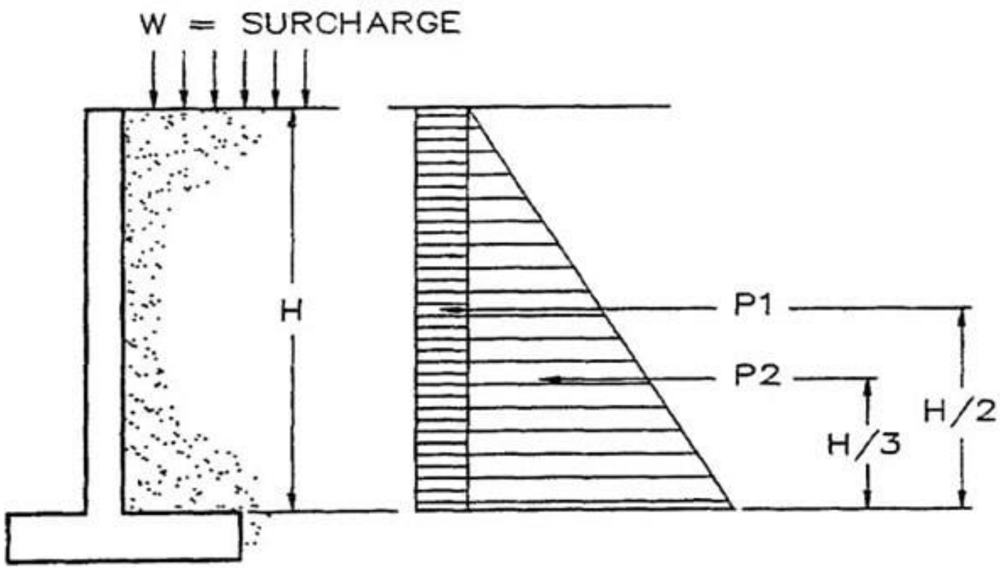
Rankine equation is rearranged when backfill is level as:

$$K_a = \tan^2\left(45 - \frac{\emptyset}{2}\right) = \frac{1-\sin\emptyset}{1+\sin\emptyset} \rightarrow \text{Equation 6}$$

2. Surcharge loads Acting on Retaining Wall

Surcharge loads acting on retaining wall are additional vertical loads that used to the backfill soil above the top of the wall. It can be either dead loads for example sloping backfill above the wall height or live load which could result from highway or parking lot, paving or adjacent footing.

Live load surcharge is considered when vehicular actions act on the surface of backfill soil at a distance which equal or less than the wall height from the wall back face. Active pressure from uniform surcharge is explained in the Figure 11.



Figuer 11. Showing sarcharge pressure

$P_1=K_a WH$ -> Equation 7

$P_2=0.5K_aH^2$ ->Equation 8

Where:

γ: is the density of soil

W: is the uniform surcharge load

H: is the height of the wall

There are various types of surcharge loads such as:

- Highway surcharges
- Backfill compaction surcharge
- Adjacent footing surcharge

3. Axial Forces Acting on Retaining Wall

Overturning resistance on retaining wall is provided by axial loads. There are different types of axial load that will be discussed in the following sections:

a) Vertical loads on the stem

These loads might be resulted from beam reactions, bridge, or lodger and applied to the stem directly.

For most critical conditions, it is not necessary to consider live load from dead load separately because axial live load on the stem increases resisting moments and soil bearing pressure.

Point vertical loads on walls are considered to be spread downward in a slope of two vertical to one horizontal. Consequently, there will be rather low compressive stresses at the base of the wall, girder reactions on walls is an example of vertical point load.

Moreover, bearing stresses that directly under girder or beams reactions must be checked in addition to take eccentricity into account with respect to the stem centerline since it influences stability and design of the stem.

Finally, it is worth mentioning that, un-conservative results might be produced by acting live loads at negative eccentricity toward backfill.

b) Soil weight

It is the weight of the soil above toe and heel of the retaining wall.

c) Structural weight

It includes weight of the footing and stem which added to the bearing pressure of the soil and help stability against sliding and overturning.

d) Vertical component of active pressure

It is another vertical load, resultant earth pressure action line is at an angle from horizontal provided that backfill soil is sloped.

The angle is equal to the backfill slope angle according to Rankine formula and is the same as soil-stem friction angle according to coulomb formula. This inclined active pressure has two components includes horizontal and vertical.

The latter is employed as added sliding resistance, decrease soil pressure, and increase withstand against overturning.

4. Wind Forces on Projecting Stem

Wind pressure generates an overturning force when retaining wall is exposed and extends above grade. Common formula used to compute wind pressure is as follow:

$$F=0.0026V^2 \text{ -> Equation 9}$$

Where:

F: wind pressure

V: Velocity of the wind

According to ASCE 7 design wind pressure (F) is calculated using the following simplified formula:

$$F=q_z\, G G_f \quad \text{-> Equation 10}$$

Where:

G: is the gust factor (0.85 can be used)

G_f: Commonly taken as 1.2

q_z: is the velocity pressure at mid height and can be calculated using the following formula:

$$q_z=0.613 K_z\, K_{zt}\, K_d\, V^2 \quad \text{-> Equation 11}$$

Where:

K_z: wind directionality factor, can be determined in section 26.6 of ASCE 7-10

K_{zt}: Velocity pressure exposure coefficient, can be determined section 26.6 of ASCE 7-10

K_d: Topographic factor see section, can be determined 26.6 of ASCE 7-10

V: Basic wind speed in m/s

5. Impact loads Acting on Retaining Wall

Design retaining wall for car bumper might be necessary when the wall extends above grade and parking area is close to it. When retaining wall is designed for impact loads, the stem should be checked at equally spaced points along stem length from top to the bottom as impact load spread at the greater length of the stem. Moreover, use slope of two vertical to one horizontal for spreading impact load.[6]

6.Stability of Retaining Wall

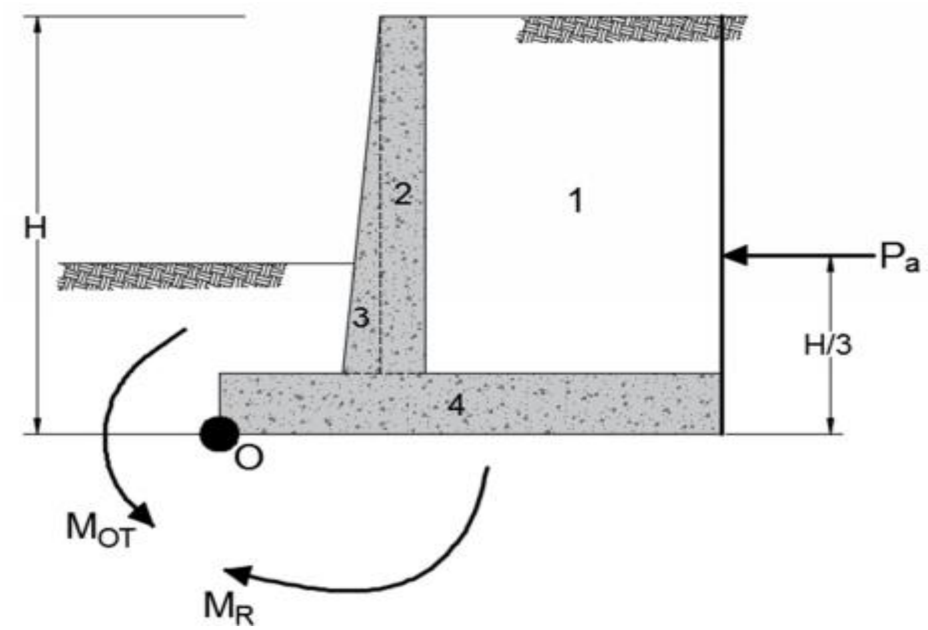
A retaining wall may be fail in any of the following:

1. It may overturn about its toe.
2. It may slide along its base.
3. It may fail due to the loss of bearing capacity of the soil supporting the base.
4. It may undergo deep-seated shear failure.
5. It may go through excessive settlement.

We will discuss the stability of retaining wall for the first three types of failure (overturning, sliding and bearing capacity failures).

6.Stability of a retaining wall should be analyzed on the following five considerations:[4]

6.1. Stability on overturning, typically about the toe of a wall: Figuer 12.



Figuer 12. Showing Over Turning Case

The horizontal component of active force will causes overturning on retaining wall about point O by moment called “overturning moment” $M_o = P_a \times H/3$ This overturning moment will resisted by all vertical forces applied on the base of retaining wall:

1. Vertical component of active force Pa if exist).

2. Weight of all soil above the heel of the retaining wall.

3. Weight of each element of retaining wall.

4. Passive force (we neglect it in this check for more safety). Now, to calculate the moment from

these all forces (resisting moment) we prepare the following table:

Force = Volume × unit weight but, we take a strip of 1 mlength

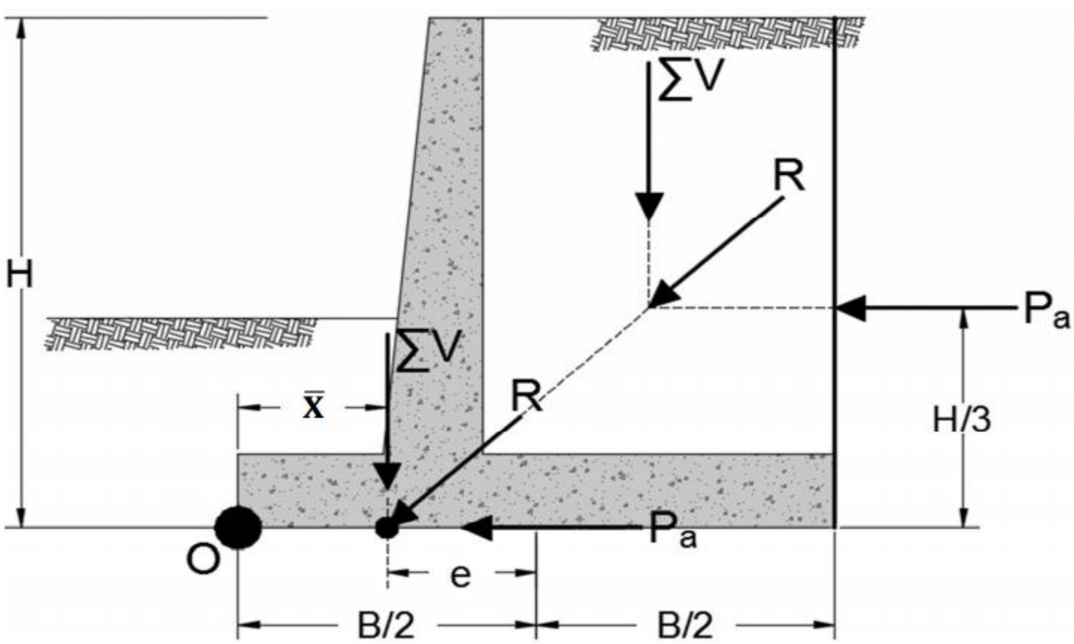
→ Force = Area × unit weight

Table.1. arrangement table for overturning calculation

Section	Area	Weight/unit length of the wall	Moment arm measured from O	Moment about O
1	A_1	$W_1 = A_2 \times \gamma_1$	X_1	M_1
2	A_2	$W_2 = A_2 \times \gamma_c$	X_2	M_2
3	A_3	$W_3 = A_2 \times \gamma_c$	X_3	M_3
4	A_4	$W_4 = A_2 \times \gamma_c$	X_4	M_4
		$P_{a,v}$(if exist).	B	M_V
$\sum$		$\sum V$		$\sum M = M_R$

γ_1 = unit weight of the soil above the heel of RW

$$FS_{OT} = \frac{M_R}{M_{OT}} \geq 2$$



Figuer 13. Showing Eccentricity bar.

The resultant of all forces acting on the structure should fall within the middle third of the structure base.

$$M_O = \sum V \times \bar{X}$$

$$M_R - M_{OT} = \sum V \times \overline{X} \rightarrow\rightarrow \overline{X} = \frac{M_R - M_{OT}}{\sum V}$$

$$e = \frac{B}{2} - \overline{X}$$

$$e = \frac{B}{2} - \frac{\sum Mr - \sum Mo}{\sum V}$$

Where:

e= Acting range of resultant (m)

d= Acting point of resultant (m)

∑V= Sum of vertical loads acting on base slab (kN/m)

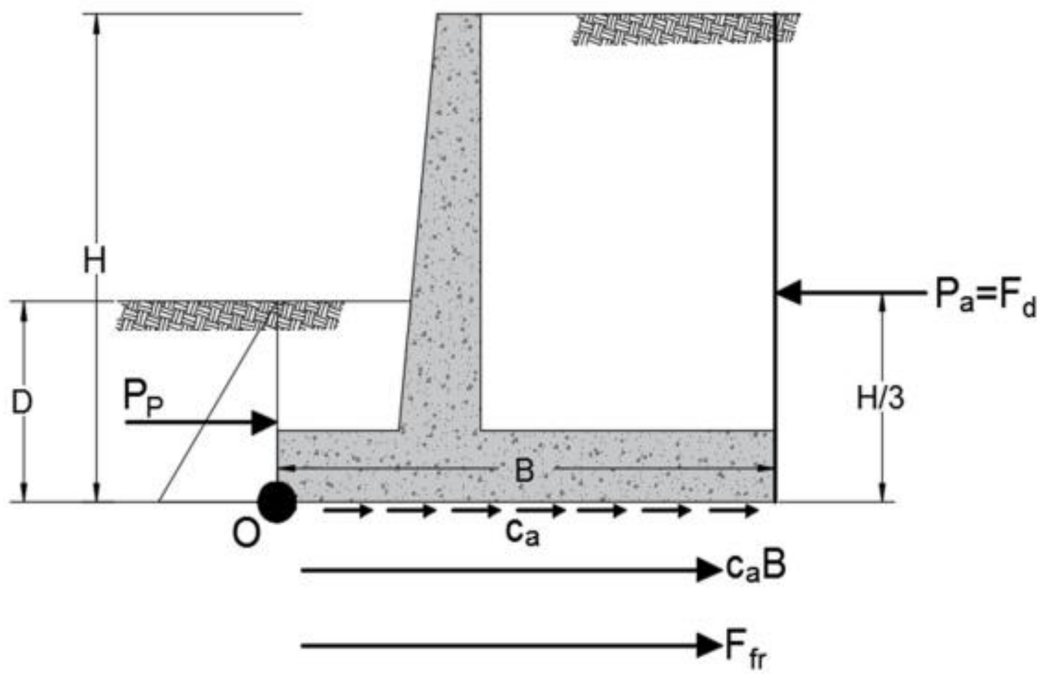
∑Mr= Resistant moment for base slab (kNm)

∑Mo= Overturning moment for base slab (kNm)

B= Width of base slab (m)

6.2. Stability on sliding between the base of the wall and its foundation ground

The safety factor against sliding will be as follows:[4]



Figuer 14. Showing sliding case

$$Fs = \frac{\sum V \times \mu + c \times B}{\sum H}$$

Where:

Fs: Factor of safety for sliding

∑V= Sum of vertical loads acting on base slab (kN/m)

∑H= Sum of horizontal loads acting on base slab (kN/m)

μ= Friction coefficient of base slab (from Table)

c= Cohesion of base slab or sand bags (kN/m2)

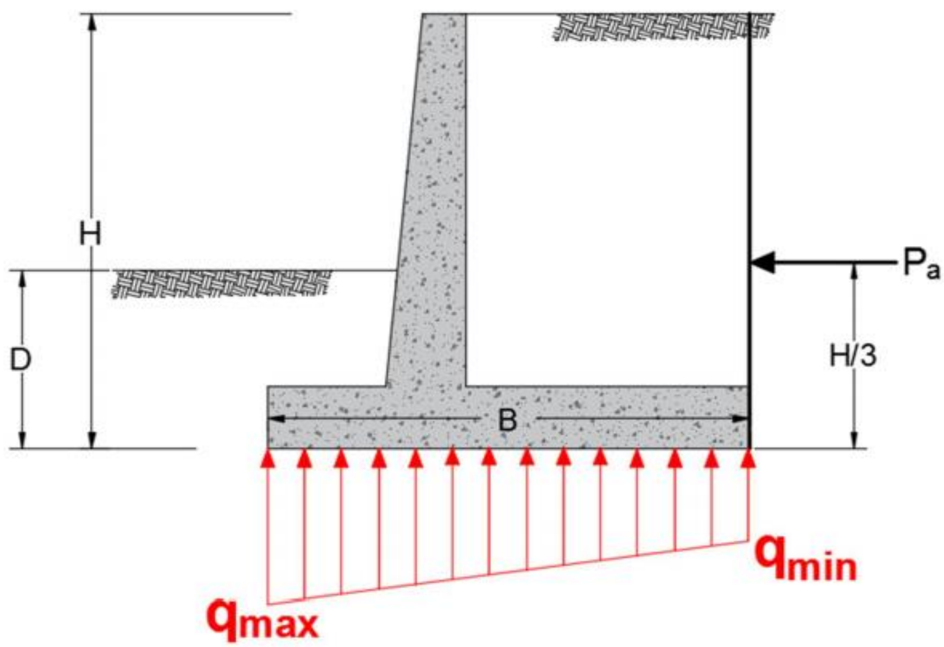
B= Width of base slab (m)

Factor of safety against sliding:

$$FS_S = \frac{F_R}{F_d} \geq 2 \text{ (if we consider } P_P \text{ in } F_R)$$

$$FS_S = \frac{F_R}{F_d} \geq 1.5 \text{ (if we dont consider } P_P \text{ in } F_R)$$

6.3.Stability on bearing capacity of the foundation ground and its settlement



Figuer 15. Showing Bearing Capasity

Eccentricity in B-direction and retaining wall can be considered strip footing

If $e < \frac{B}{6}$

$$q_{max} = \frac{\sum V}{B \times 1}\left(1 + \frac{6e}{B}\right)$$

$$q_{min} = \frac{\sum V}{B \times 1}\left(1 - \frac{6e}{B}\right)$$

If $e > \frac{B}{6}$

$$q_{max,new} = \frac{4 \sum V}{3 \times 1 \times (B - 2e)}$$

Now, we must check for q_{max}:

$q_{max} \leq q_{all} \rightarrow q_{max} = q_{all}$ (at critical case)

$$FS_{B.C} = \frac{q_u}{q_{max}} \geq 3$$

$$q = \leq q_a = \frac{q_u}{Fs}$$

Where:

q= Bearing capacity of the ground (kN/m2)

qa= Allowable bearing capacity of the ground (kN/m2)

qu= Limiting bearing capacity of the ground (kN/m2)

Fs= Factor of safety for bearing capacity of the ground , FS = (3 - 4) for bearing capacity

$q_u \Rightarrow$ Gross ultimate bearing capacity

$((q_u)_{net} = q_u - q) \Rightarrow$ Net ultimate bearing capacity

$q_{all} \Rightarrow$ Gross allowable bearing capacity

$(q_{all})_{net} \Rightarrow$ Net allowable bearing capacity

$Q_u \Rightarrow$ *Gross* Ultimate load.

$$\Rightarrow q_{all} = \frac{q_u}{FS}$$

$$\Rightarrow (q_{all})_{net} = \frac{(q_u)_{net}}{FS} = \frac{q_u - q}{FS} = q_{all} - \frac{q}{FS}$$

FS = (3 – 4) for bearing capacity

7. Example design of cantliver reinforcedconcre:

Example1 : Chek for stability.

solution:

H' = 0.7+6+2.6 tan10

=7.185m

calculating Pa :

Pa = $\frac{1}{2}\gamma$.H2.Ka

Ka = cosα $\frac{cos\alpha - \sqrt{(cos^2\alpha - cos^2\emptyset)}}{cos\alpha + \sqrt{(cos^2\alpha - cos^2\emptyset)}}$

α=10° ; ∅=30

Ka=0.35

Pa=1/2 * 18*7.158^2*0.35

Pa=161.4 KN/m

Ph = Pa cosα=158.95 KN/m

Pv = Pa sinα = 28.03 KN/m

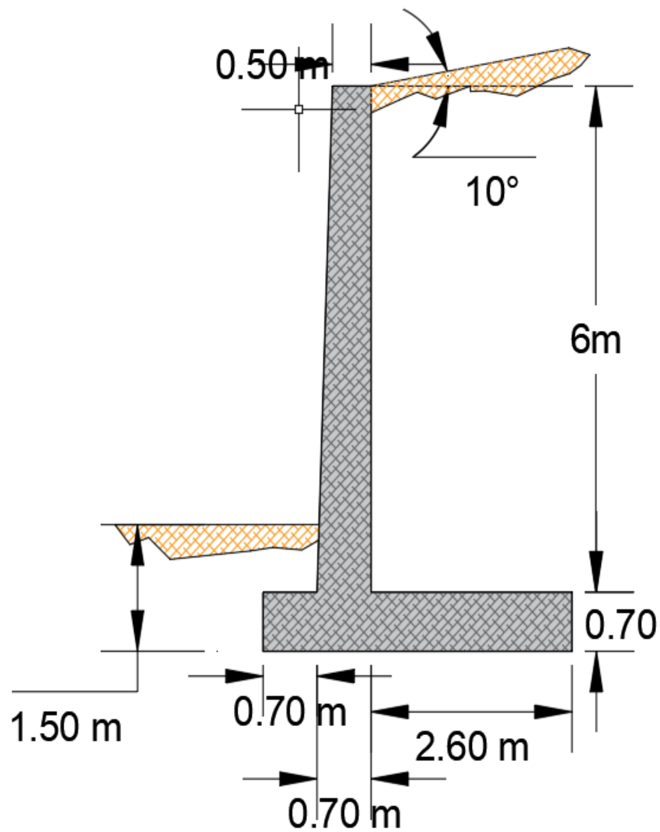
section 1 :

Area = 0.5 * 6 = 3

weigh = A*γ = 3*24=72

distance to C = 1.15m

resisting moment =82.8 KN.m/m



Figuer 16. Example Sketch to Design

section 2 :

Area = 0.5*0.2*6 = 0.6

weigh = 14.4

distance to C = 0.833

resisting moment = 12

section 3 :

Area = 0.7*4 = 2.8

weigh = 67.2

distance to C = 2

resisting moment = 134.4

section 4 :

Area = 2.6*6 = 15.6

weigh = 280.8

distance to C = 2.7

resisting moment = 758.16

section 5 :

Area = 2.6*0.458*0.5 = 0.595

weigh = 10.71

distance to C = 3.13

resisting moment = 33.52

Pu :

weigh = 28.03

distance to C = 4

resisting moment = 112.12

Σv = 470.45 KN

ΣM = 1128.98 KN.m/m

$FOS_{\text{against overturning}} = \frac{Mr}{Mo} > 2$

$M_o = P_h * \frac{1}{3}H = 158.95 * \frac{1}{3} 7.158 = 379.25$ KN.m/m

$FOS = \frac{1128.95}{379.25} = 2.98 > 2$ O.K

$FOS_{\text{against sliding}} = \frac{\Sigma V\ tan\delta' + BCa + Pp}{Ph}$

$tan\delta' = tanK_1\phi_2 = \frac{2}{3} * 24 = 16$

$Ca = K_2C_2 = \frac{2}{3}*40 = 26.66$

$P_p = \frac{1}{2} K_p \gamma_2 D_2^2 + 2C_2\sqrt{Kp}\, D$

$K_p = \tan^2(45+\frac{\emptyset 2}{2})$

$K_p = 2.37$

we get P_p = 235 KN/m

FOS = $\frac{(470.45\tan(16)+4*26.66+235}{158.95}$ = 2.99 > 1.5 it is O.K

FOS $_{\text{against B.C failure}}$ = $\frac{\text{Q allowable}}{\text{Qtoe}} > 1$

check for e ; $e<\frac{B}{6}$; $e=\frac{B}{2}-\frac{\Sigma Mr-Mo}{\Sigma V}=\frac{4}{2}-\frac{1128.98-379.25}{470.45}$ = 0.406

B/6 = 4/6 = 0.66

e<B/6 O.K

$q_{toe} = \frac{\Sigma V}{B}(1+\frac{6e}{B})$ = 189.238 KN/m²

$q_{heel} = \frac{\Sigma V}{B}(1-\frac{6e}{B})$ = 45.99 KN/m

Example.2 figure 16.

Design a cantilever retaining wall (T type) to retain earth for a height of 4m. The backfill is horizontal. The density of soil is 18kN/m3. Safe bearing capacity of soil is 200 kN/m2. Take the co-efficient of friction between concrete and soil as 0.6. The angle of repose is 30°. Use concrete 20 Mpa, and Fe415 steel. [7]

Solution

Data: h' = 4m, SBC= 200 kN/m2 , g= 18 kN/m3 , µ=0.6,

φ=30°

Depth of foundation To fix the height of

retaining wall [H] H= h' +Df

$$D_f = \frac{SBC}{\gamma}\left[\frac{1-\sin\varphi}{1+\sin\varphi}\right]^2$$

= 1.23m say 1.2m , Therefore H= 5.2m

Thickness of base slab=(1/10 to1/14)H

0.52m to 0.43m, say 450 mm

Width of base slab=b = (0.5 to 0.6) H

2.6m to 3.12m say 3m

Toe projection= pj= (1/3 to ¼)H

1m to 0.75m say 0.75m

Provide 450 mm thickness for the stem at the base and 200 mm at the top

Design of stem

Ph= ½ x 1/3 x 18 x 4.752=67.68 kN

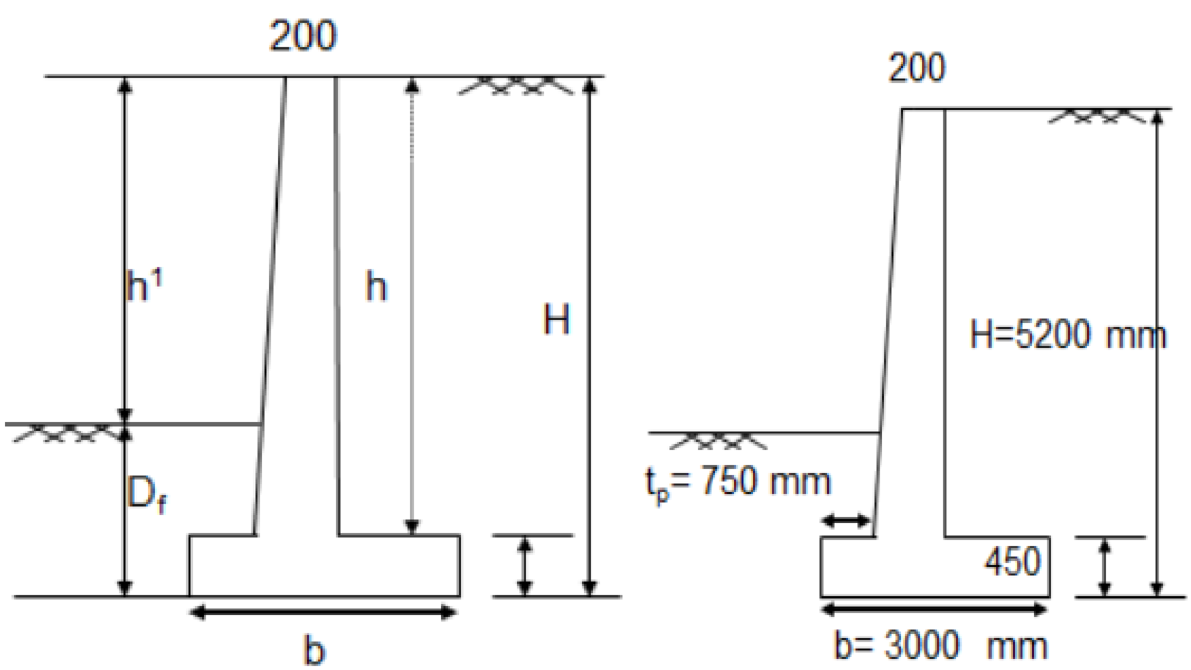
M = Ph h/3 = 0.333 x 18 x 4.753/6 = 107.1 kN-m

Mu= 1.5 x M = 160.6 kN-m

Taking 1m length of wall,

Here d=450- eff. Cover=450-50=400 mm)

To find steel



Figuer 17. Example Sketch to Design

$$\rho = \frac{0.85f'_c}{f_y}\left(1-\sqrt{1-\frac{2.35M_u}{\emptyset bd^2 f'_c}}\right), \quad \rho = \frac{0.85f'_c}{f_y}\left(1-\sqrt{1-\frac{2.61M_u}{bd^2 f'_c}}\right) \; here, \emptyset = 0.9$$

Where:

ρ: steel ratio. $\rho = \frac{A_S}{bd}$

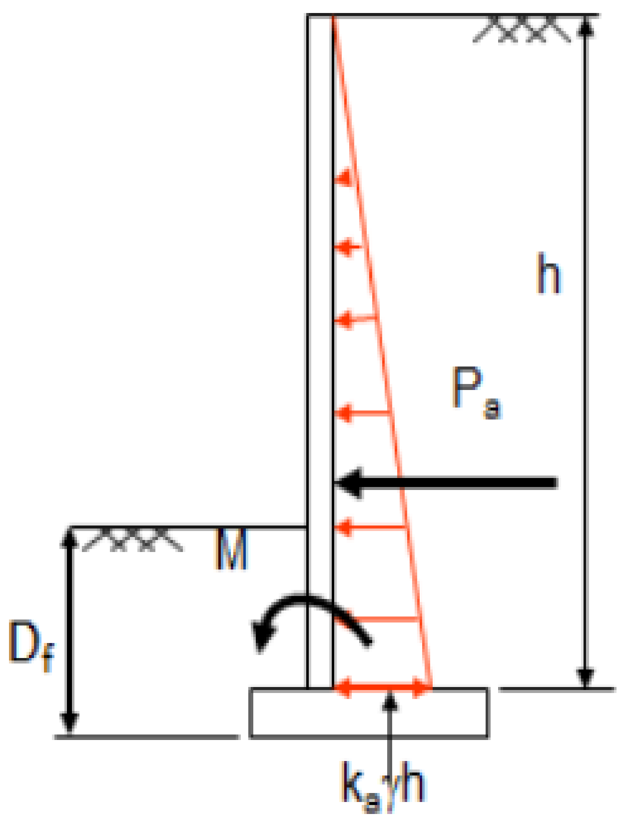
Mu: ultimate applied bending moment, N.mm

b: width of compression zone, width of section, mm

d= effective depth of section, mm

f'c: compressive strength of concrete, cylinder test, at 28 days, MPa

fy: yield strength of reinforcing steel, MPa

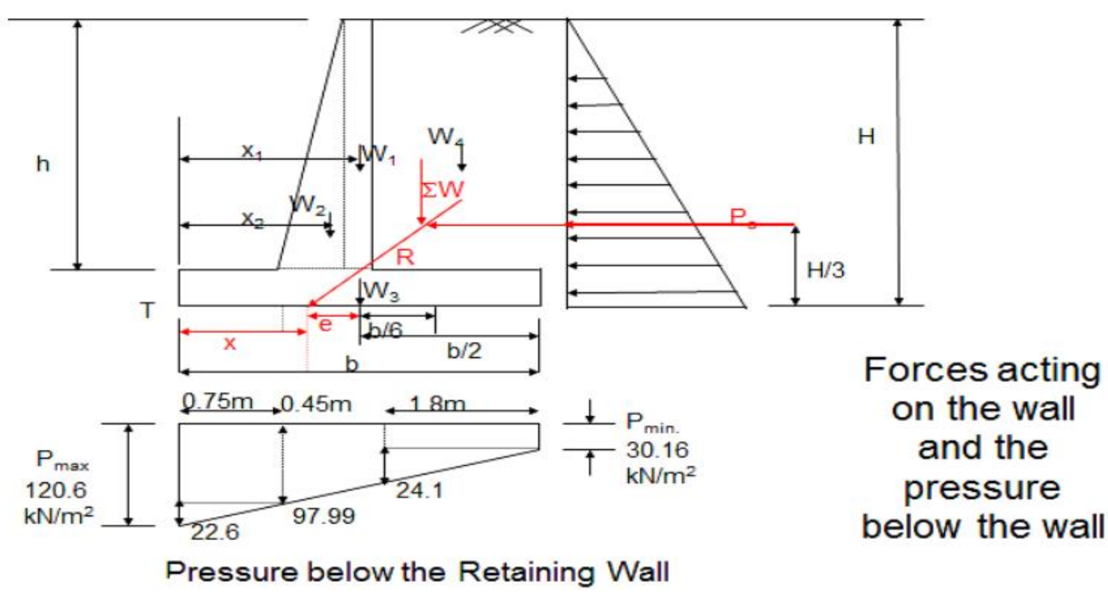


Figuer 18. Show Active Pressuer

ρt =2.78X10-3
Ast= 0.00278x1000x400 = 1112 mm2
#12 @ 90 ok
Ast provided= 1266 mm2 [0.32%] Secondary steel for stem at front
0.12% GA = 0.12x450 x 1000/100 = 540 mm2
#10 @ 140 < 450 mm and 5d ok
Distribution steel = 0.12% GA = 0.12x450 x 1000/100 = 540 mm2
#10 @ 140 < 450 mm and 5d ok
Stability analysis .Figuer 17.

Table.2. arrangement table for moment calculation

Load	Magnitude, kN	Distance from A, m	BM about A kN-m
Stem W1	0.2x4.75x1x25 = 23.75	1.1	26.13
Stem W2	½ x0.25x4.75x1x25 = 14.84	0.75 + 2/3x0.25 =0.316	13.60
B. slab W3	3.0x0.45x1x25=33.75	1.5	50.63
Back fill, W4	1.8x4.75x1x18 = 153.9	2.1	323.20
Total	**ΣW= 226.24**		**ΣM_R=413.55**
Earth Pre. =P_H	P_H =0.333x18x5.2^2/2	H/3 =5.2/3	**M_O=140.05**



Figuer 19. Show Forces Acting on The Wall

Check for overturning

FOS = ΣMR/ MO= 413.55/140.05= 2.95 >1.55 safe

Check for Sliding FOS = μ ΣW/ PH= 2.94 >1.55 safe

Check for subsidence

X=ΣM/ ΣW= (413.55-140.05)/226.24=1.20 m > b/3 and e= b/2 -x = 3/2 - 1.2 = 0.3m < b/6

Pressure below the base slab

Pmax= ΣW/B(1 +(6 e/B)= (226.24/3)(1+6X0.3/ 3) , Pmin= ΣW/B(1 -(6 e/B)

PMax=120.66 kN/m2 < SBC, safe

PMin = 30.16 kN/m2 > zero, No tension or separation, safe

Table 3.arrangement table for moment calculation

Load	**Magnitude, kN**	**Distance from C, m**	**BM, $M_{C,}$ kN-m**
Backfill	153.9	0.9	138.51
Heel slab	0.45x1.8x25 = 27.25	0.9	18.23
Pressure dist. rectangle	30.16 x 1.8 =54.29	0.9	-48.86
Pressure dist. Triangle	½ x 24.1 x1.8=21.69	1/3x1.8	-13.01
Total Load		**Total**	**ΣM_C=94.86**

Design of heel slab

Mu= 1.5 x 94.86 =142.3 kNm

Pt=0.245%

Ast= 0.245x1000x400/100 = 980 mm2

#16@ 190

Ast provided= 1058mm [0.27%]

Distribution steel

Same, #10 @ 140

Design of toe slab

Table.4. arrangement table for moment calculation calculation

Load	**Magnitude, kN**	**Distance from C, m**	**Bending moment, $M_{C,}$ kN-m**
Toe slab	0.75x0.45x25 =	0.75/2	-3.164
Pressure distribution, rectangle	97.99x0.75	0.75/2	27.60
Pressure distribution, triangle	½ x22.6 x1.0.75	2/3x1=0.75	4.24
Total Load at junction		**Total BM at junction**	**ΣM=28.67**

Mu= 1.5 x 28.67 =43 kN-m

Pt=0.085% Very small, provide 0.12%GA

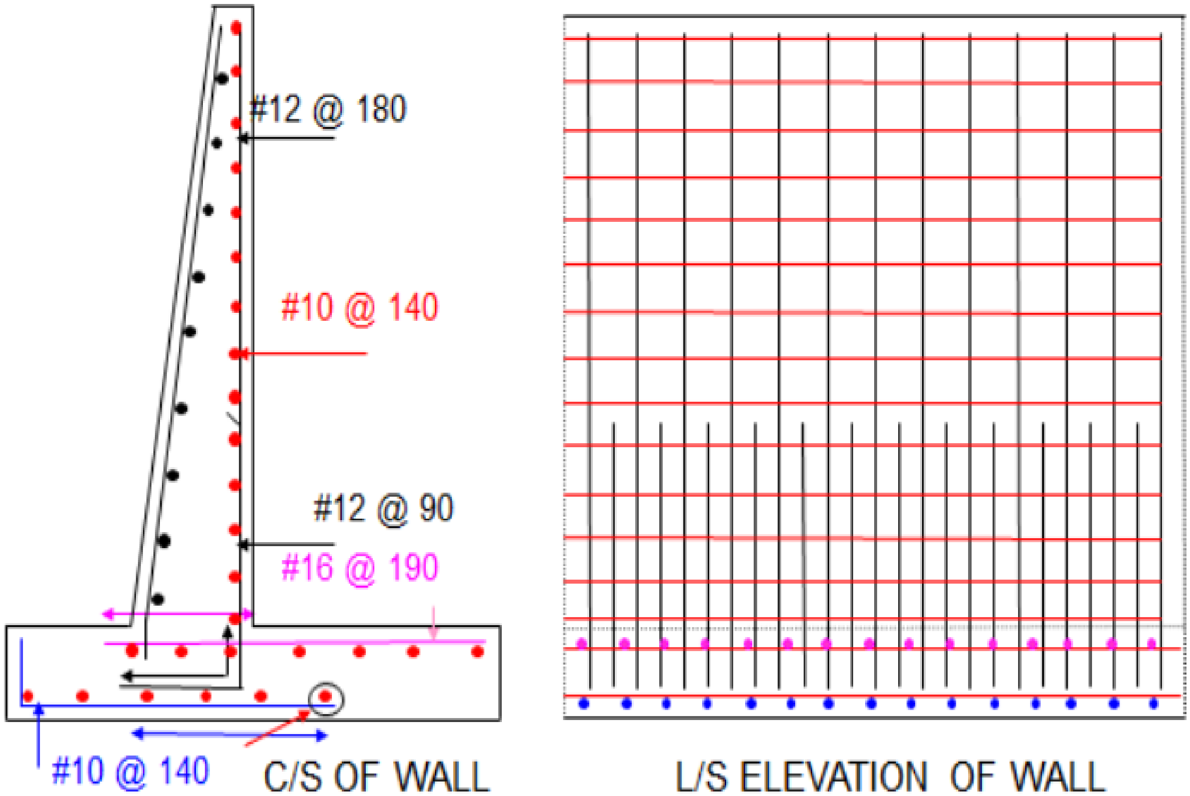
Ast= 540 mm2

#10 @ 140

Development length:

Ld=47 φbar =47 x 10 = 470 mm

Drawing and Detailing



Figuer 20. Detail Drawing of Reinforcement of Retayning Wall

8.Factores affecting on Retaining Wall Failure:[8]

Following the common causes for retaining wall failures:

1. Improper reinforcement placement
2. Saturated backfill
3. Weep holes that do not weep
4. Design error
5. Calculation error
6. Unanticipated loads
7. Mistakes in utilizing software
8. Detailing errors
9. Foundation issues
10. Inadequate specifications and notes
11. Shoddy construction
12. Retaining wall age

Following are the explanation of various causes for retaining wall failure:

1.Retaining Wall Failure due to Improper Reinforcement Placement:

Reinforcement size, depth, and spacing should be checked when wall stem exhibits sign if issues such as cracking and extreme deflections. Reinforcement size and depth can be determined either by devices for example magnetic field measuring pachometer.

This device is used to determine reinforcement position and depth up to around 100 mm with acceptable accuracy or to achieve more accurate measurement. This device can also locate steel bars and chip out concrete to find out the precise reinforcement size and depth.

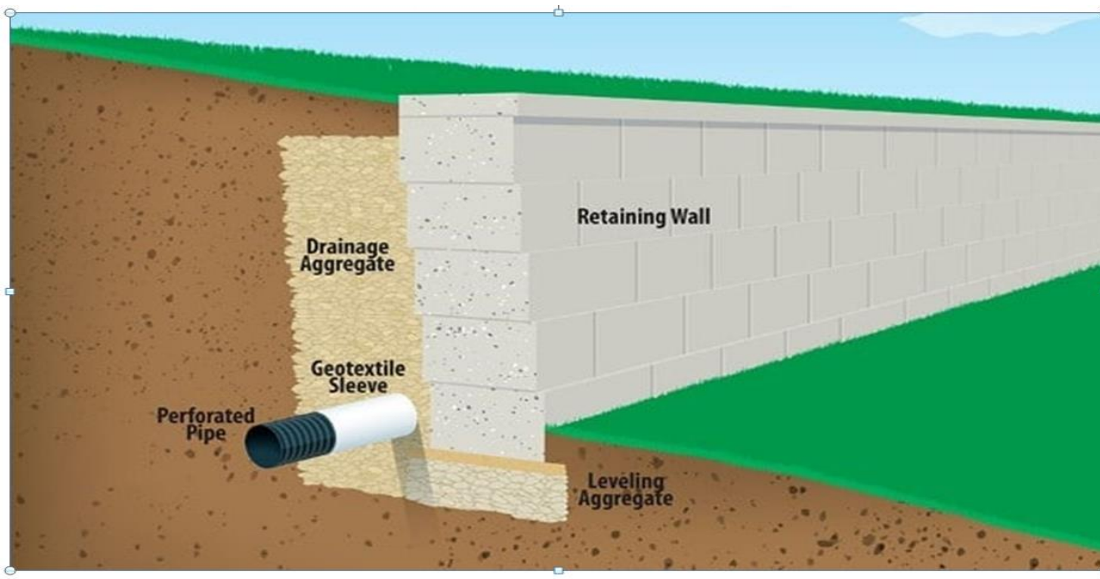
Surprisingly, there are situations where reinforcement was installed in wrong wall side that might be resulted from contractor error or detailing error.

After actual steel reinforcement size, depth, location, and sometimes testing stem concrete strength by taken core sample, back design computation is employed to estimate actual design capacity then provide remedial measures.

2.Retaining Wall Failure due to Saturated Backfill

It is assumed that backfill is granular and well drained during the design of retaining wall. Pressure against the wall is substantially increased if surface water is permitted to infiltrate into the backfill.This can be avoided by grading backfill surface that direct water away from the wall or by diverting water to disposal through drainage channels close to the retaining wall.

Furthermore, poor backfill such as those containing clay swells and lead to increase pressure considerably. Finally, crushed and pea gravels are examples of good backfill that provide proper drainage and avoid creating pool water behind the wall.

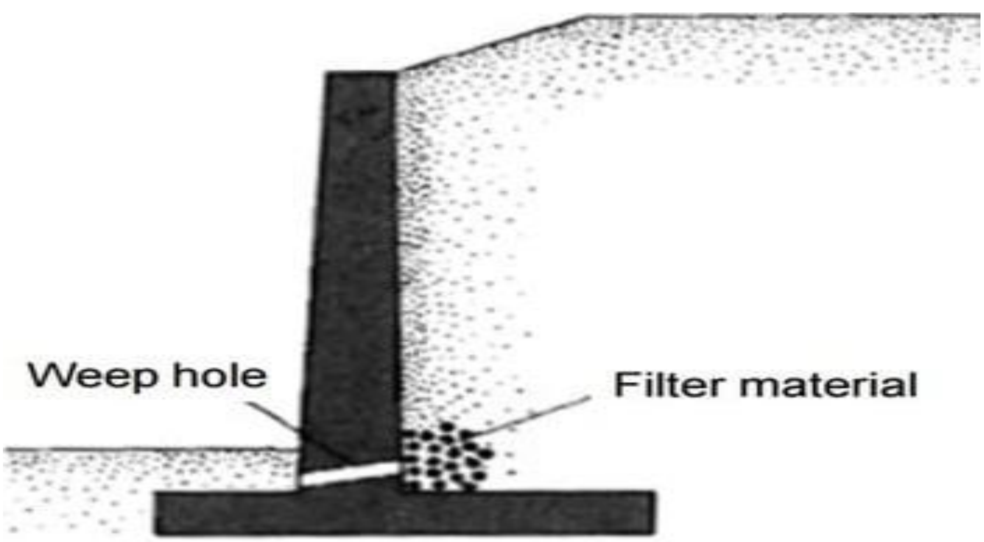


Figuer 21. Showing Dranage Aggregate

3.Retaining Wall Failure due to Weep Holes that do not Weep Figuer 22.

Due to lack of filters, for instance line of gravel or crashed stone positioned along the base of the wall weeds turn into clogs and create problems for water draining.

In masonry retaining wall, weep hole is made by removing mortar at the side joints and distance between weeps is around 80 cm. Weep hole in reinforced concrete retaining wall is at least 7.5 cm in diameter and spacing should not be more than 1 m or it can be specified by the designer.



Figuer 22 . Showing Weep Hole

4.Design Error Resulted from Misinformation

Retaining wall failures due to design errors are rather exceptional case provided that an experienced structural designer carried out wall design. Nonetheless, there are situations where designers are provided with inadequate or faulty information that can be extremely detrimental.

5.Retaining Wall Failure due to Calculation Errors

These errors could be noticed easily by experienced designer. However, there are possibilities when new designer carry out the computation and it is extremely significant to double check the design. This can avoid costly fixing of the wall after construction.

6.Unanticipated Loads

It is client to designer information issues so it is essential to have good communication between different people who involve in the design. Unexpected loads might be resulted from a surcharge that designer did not about it. Moreover, it could have been a steeper slope backfill or wind load.

7.Mistakes in utilizing software

Designers need to input data precisely and familiar with capabilities, outputs, and limitation of the program when a software is employed for designing. Moreover, it is recommended to check and perform quick calculations for verification especially when there is doubt about outputs.

8.Retaining Wall Failure due to Detailing errors

Detailing should be clear, conforming design calculation and prevent doubtful interpretation. Vague detailing could lead to inaccurate reading of information for instance there were cases that dowel extended 0.15 m instead of 0.6 m into the stem.

9.Foundation Issues

There are guidelines for foundation design that designer can use with the help of site investigation report, but there could be cases where this investigation is not provided.
Lack of site investigation could lead to foundation problems because Codes restricted soil bearing and designers should use conservative values. Additionally, designers should be aware about compressible soil, backfill material, water table, and other factors that might decrease sliding resistance or lead to large differential settlement.

10.Inadequate specifications and notes

If discrepancies come across between site conditions and drawings, or unexpected conditions is encountered the engineer should be contacted to for the steps to be followed. If there are conflicts between standards and details, the most restricted must govern.

Finally, all changed instructions must be conformed and affected parties should be informed. These measures are taken avoid problems that could lead to detrimental effect on the retaining wall.

11.Retaining Wall Failure due to Poor Construction

Poor construction practices might be due to unscrupulous or inexperienced contractor works that is carried out as per standards and specified plans.Inadequate mortar, or grouting, or improper steel reinforcement placements are compelling examples of poor construction. it is recommended to understood construction requirement and conditions and review the plan properly.

12.Retaining Wall Failure due to Age

When a retaining wall is stood for about fifty years or more without showing distress indication, therefore there are possibilities that it may stand for another fifty years or more in the future and will not need to take any actions. However, this is not the case in seismic regions, or adding new surcharges, or drainage change above the wall, so maintenance or seismic evaluation would be suitable to verify whether the wall can take new loads or withstand another earthquake.

9.Discussion :

There are many type of Retaining walls. Constructed from brick or stone block walls and plain concrete or reinforced concrete, made to prevent damage from erosion or surface runoff on angled or elevated property. They may be used on residential or commercial property to prevent water and soil from shifting and changing the landscape.

Residential retaining walls are most often used to protect exposed basements from the effects of erosion. With enough time and rain, soil can block basement doors and windows if not restrained by a retaining wall.

Houses on top or below high hills also benefit from retaining walls. For homes on top of hills, retaining walls keep the foundation from shifting. For homes at the bottom of a hill, a retaining wall will keep loose soil from building up around the house. Different placement of a wall will provide different results for your .

Commercial retaining walls provide functional support and aesthetic appeal to business properties. When constructing a new building, retaining walls help keep the area level by controlling the grading

In this report we worked to represent the types of retaining wall and precedes of designing the cantilever retaining wall.

Several factors will determine how high your retaining wall will be. Some walls may only need to be 2 feet high while others on commercial land might exceed 40 feet. It will depend on your property and how much protection you need the wall to provide. Our experts will determine the right size for your retaining walls.

10. Conclusion

Various systems are implemented to support laterally the soil. Retaining walls might face failure because of sliding, overturning, and bending. Gross pressure and its point of application plays vital role in its failure. Coulomb's method and Rankine's method used to evaluate the lateral earth pressure on retaining wall for static condition. The retaining wall with relieving platform is safer against overturning and sliding as compared to cantilever retaining wall. In the gravity type of walls the sequence of construction is a also a important factor to be considered in the design. compared to cantilever retaining wall. In the gravity type of walls the sequence of construction is a also a important factor to be considered in the design.

In general the collapse mode of reinforcement concrete Cantilever retaining walls are flexural failure. Wall damage result of soil forces effect on structure in earthquake, which lead to cracking and finally crashing of the structure.[9]

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