WOLLO UNIVERSITY
KOMBOLCHA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL,ARCHITECTURE AND WATER ENGINEERING

REINFORCED CONCRETE STRUCTURE-II
CHAPTER FOUR RETAINING WALLS AND INTRODUCTION TO PRESTRESSED CONCRETE, WATER RETAINING STRUCTURES
TARGET GROUP WRIE THIRD YEAR.

Contents

- Introduction to Retaining Structures
- Meaning of Retaining Walls
- Types of Retaining Walls
- Geometry of Retaining Walls
- Analysis and Design of Retaining Walls
- ✓ Stability Analysis
- ✓ Design

Introduction

- Retaining structures include all types of wall and support systems in which structural elements have **forces imposed by the retained material**.

Retaining Walls

- Retaining walls are usually built **to hold back soil mass to retail soil** which is unable to stand vertically by themselves. However, retaining walls can also be constructed for **aesthetic landscaping purposes**.

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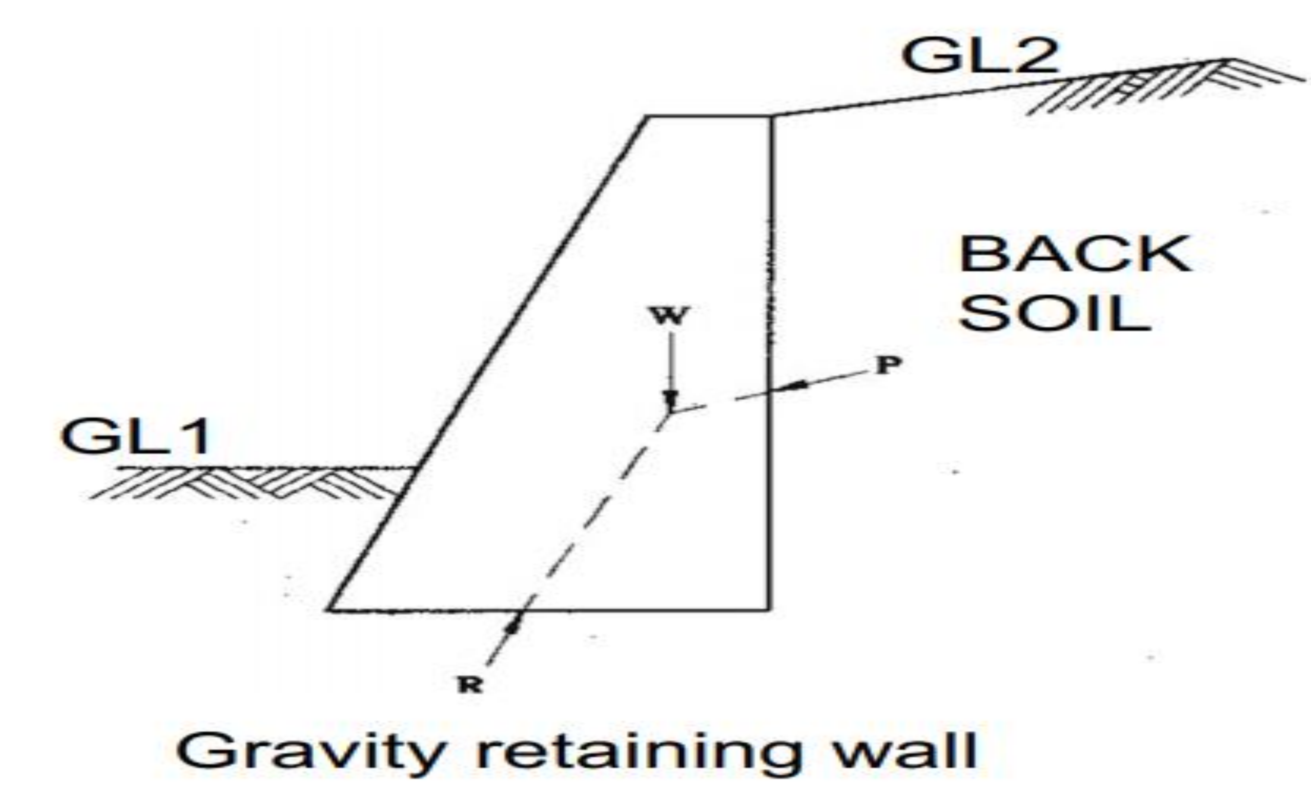

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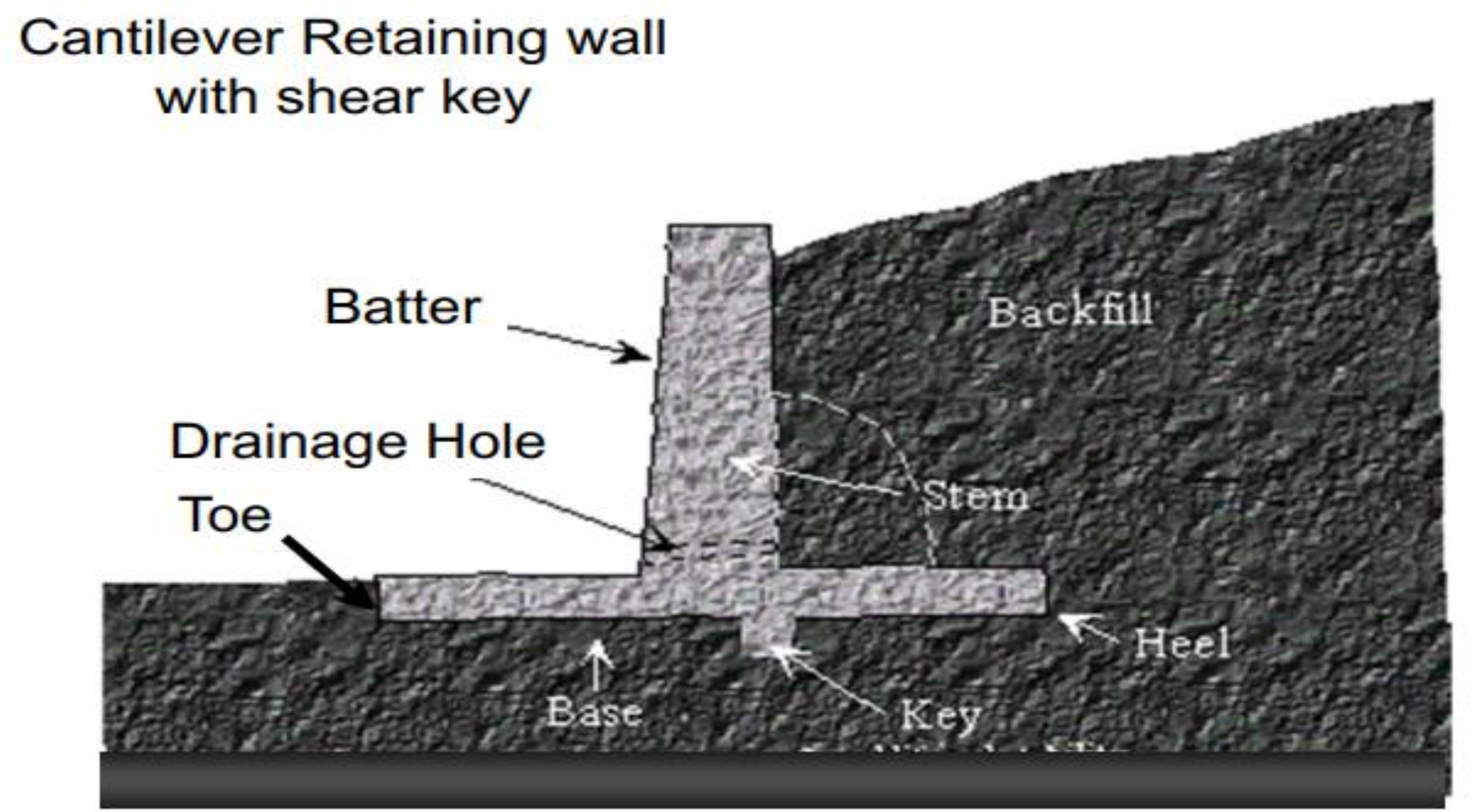
- 

Cantilever Retaining wall with shear key
Batter
Backfill
Drainage Hole
Toe
Stem
Heel
Base
Key

4.2 Common Types of Retaining Wall

1. **Gravity Wall**
2. **Cantilever Wall**
3. **Counter fort Wall**
4. **Buttress Wall**

Gravity Wall

- ✓ Made of **plain concrete** or **stone masonry.**
- ✓ It's Stability depends on **it's weight.**
- ✓ **Trapezoidal in section** with the base projecting beyond the face and back of the wall.
- ✓ Economically used for walls less than **6m high**.

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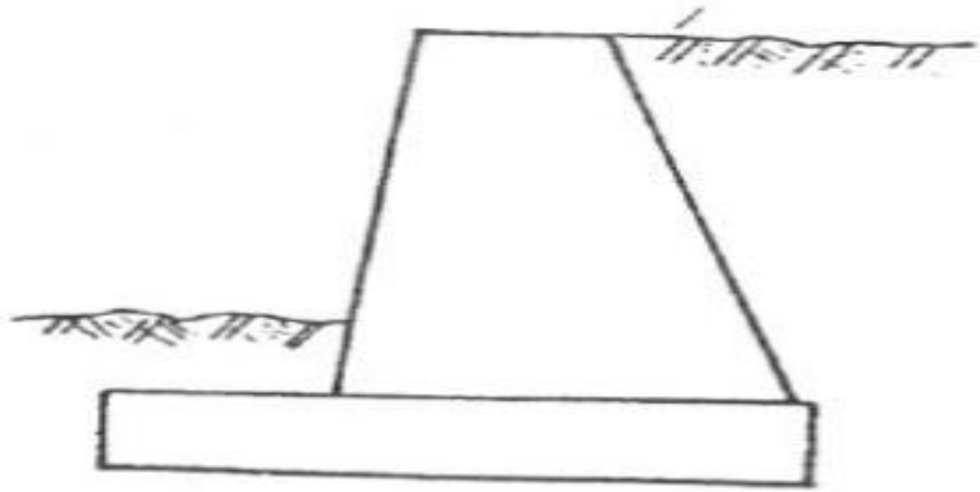


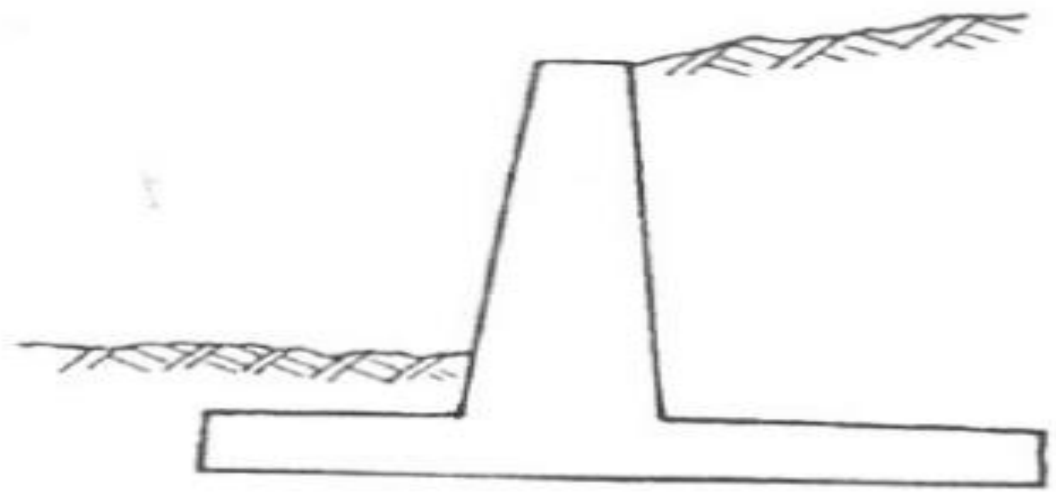
I. GRAVITY WALL

Cont….

Cantilever Wall

- ✓ Made of **Reinforced concrete material**.
- ✓ **Inverted T-shape** in section with each projecting portion acting as cantilever.
- ✓ **Utilizes cantilever action** to retained mass behind wall.
- ✓ Economically used for walls **height 6-7.5 m** .

Cont….



2. CANTILEVER WALL

Cont….

Counter Fort wall

- ✓ Made of **reinforced concrete** material.
- ✓ Consists of **cantilever wall** with **vertical brackets** known as **counter forts** placed **behind face wall**.
- ✓ Ordinarily used for walls height **greater than 6m.**

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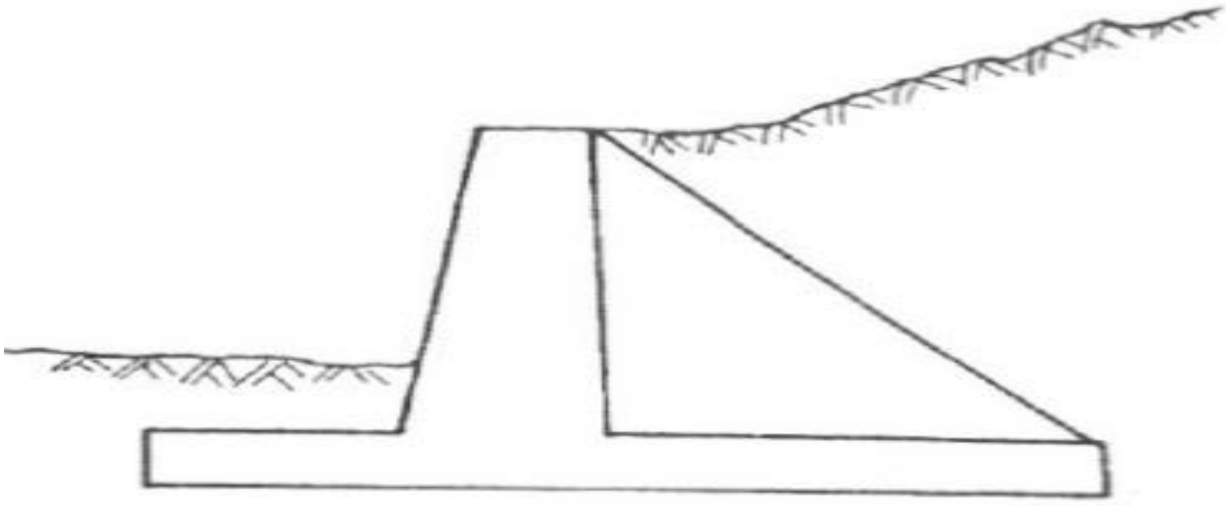

3. COUNTER FORT WALL

Cont….

Buttress Wall

- ✓ Same as **counter fort except the vertical brackets are on the opposite side of the backfill**.
- ✓ Not commonly used because of the exposed brackets (Buttresses).

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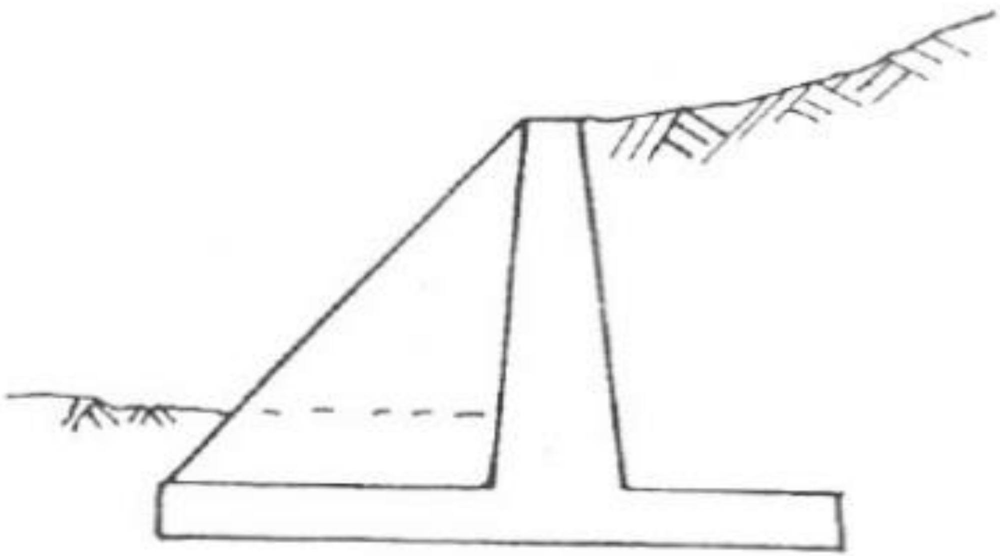


4. BUTTRESS WALL

Geometry and Common proportions

1) Gravity Wall

Min. H:V = 1:50

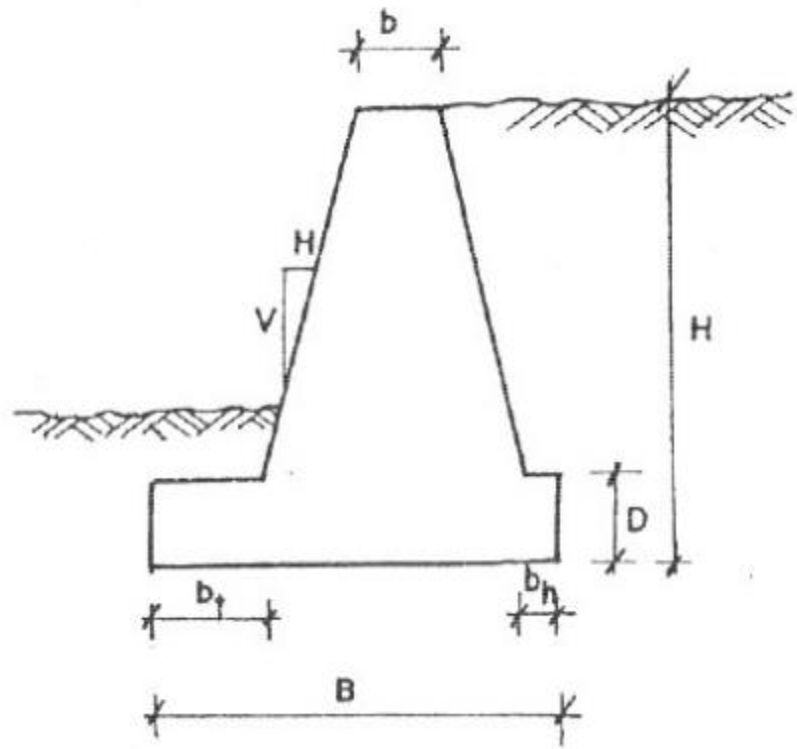
b = 30cm to H/12

D = H/8 to H/6

b_h = 10 to 15cm

b_t = D/2 to D

B = 0.5H to 0.7H



Cont….

2 Cantilever Wall

min. h : V = 1:50

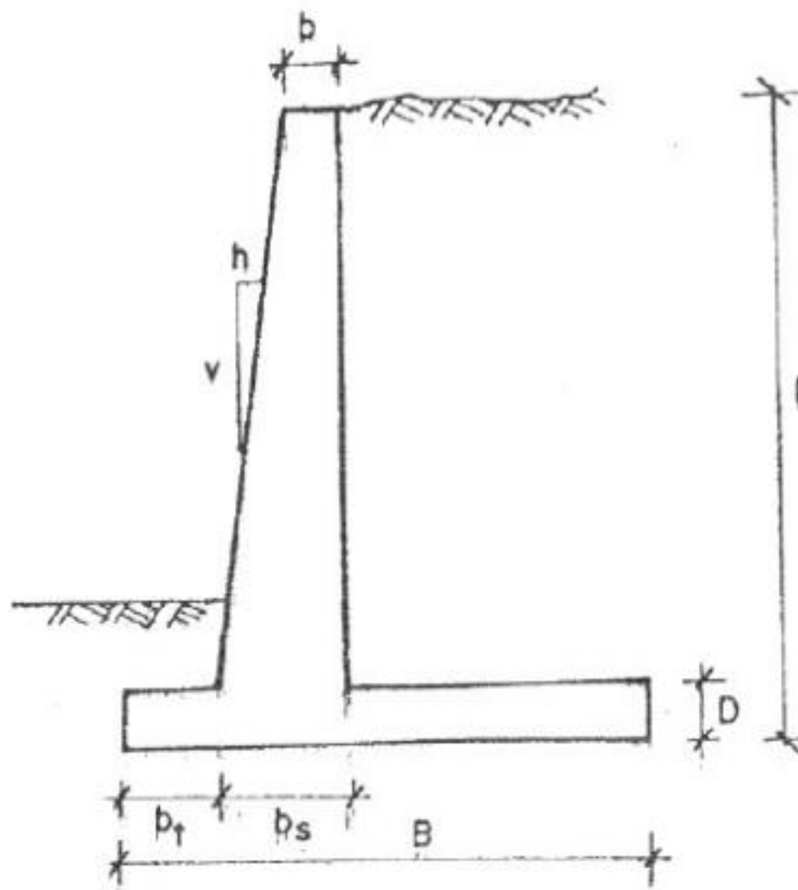
b = 20 to 30 cm

D = H/12 to H/10

b_s = H/12 to H/10

b_t = B/3

B = 0.4 H to 0.7 H



Cont….

3) Counter fort wall

Min. H:V = 1:50

$b = 20$ to $30\,cm$

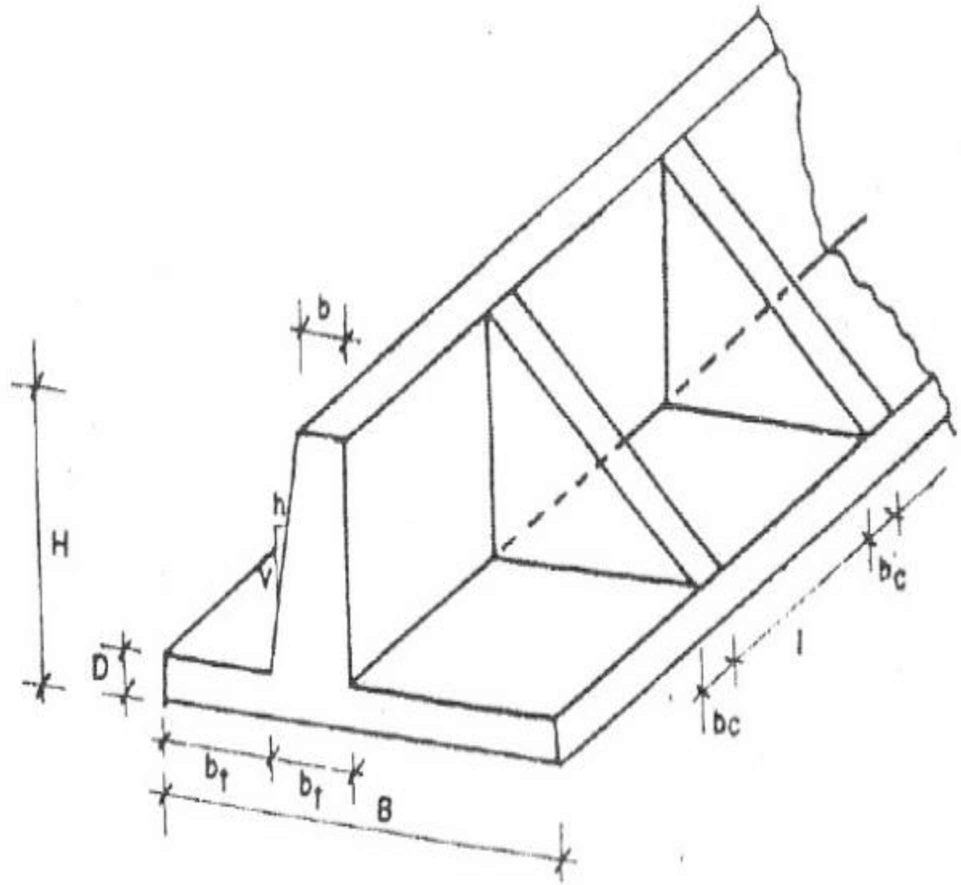
$D = b_s = H/14$ to $\frac{H}{12}$

$b_t = H/14$ to $H/12$

$B = 0.4H$ to $0.7H$

$b_c \geq 20cm$

$l = 0.3H$ to $0.6H$



Analysis and Design of Retaining Walls

Analysis and Design of Cantilever Retaining Walls

- ✓ Retaining walls shall be designed to withstand lateral earth and water pressures, surcharge loads, the self-weight of the wall.

Basic Actions

- ✓ Earth Pressure (P)
- ✓ Surcharges
- ✓ Weight of water

Cont….

Earth Pressure (P)

- ✓ Earth pressure is the pressure exerted by the retaining material on the retaining wall. This pressure tends to deflect the wall outward.

Types of earth pressure

1. Active earth pressure or earth pressure (Pa)

- ✓ Active earth pressure tends to deflect the wall away from the backfill

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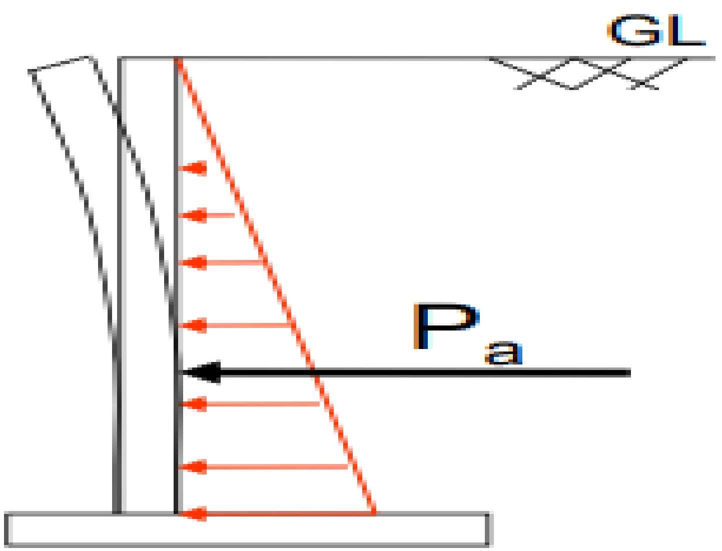


Variation of Earth pressure

Cont….

Passive earth pressure (Pp).

- ✓ Passive earth pressure tends to deflect the wall to wards the backfill.

Factors affecting earth pressure

- ✓ Earth pressure depends on type of backfill, the height of wall and the soil conditions

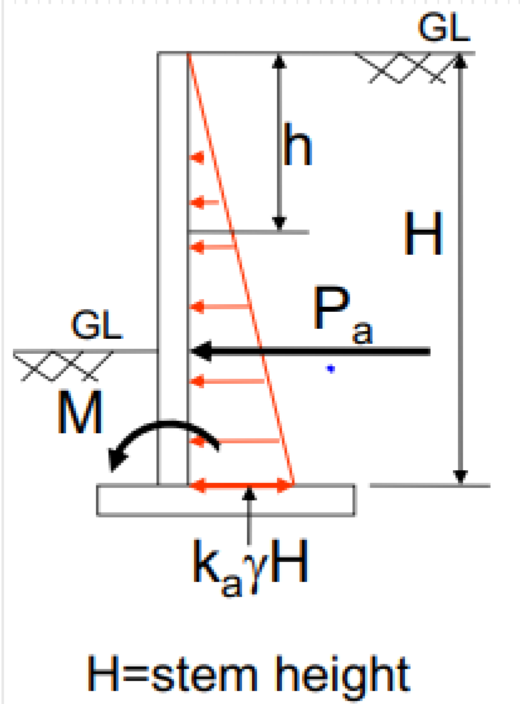
Soil conditions: The different soil conditions are

- Dry leveled back fill
- Moist leveled backfill
- Submerged leveled backfill
- Leveled backfill with uniform surcharge
- Backfill with sloping surface

Analysis for dry back fills

- Maximum pressure at any height, p=ka*Y*h
- Total pressure at any height from top,pa=1/2[ka*Y*h^2]
- Total Bending moment at bottom,

M =[ka*Y*H3]/6



Cont….

- Where, ka= Coefficient of active earth pres
- ka = (1-sinφ)/(1+sinφ)=tan2φ
  = 1/kp, coefficient of passive earth pressure
- φ = Angle of internal friction or angle of repose
- Y=Unit weight or density of backfill.

Stability of Retaining Walls

- ✓ Retaining walls should be design to provide adequate stability against sliding, overturning, foundation bearing failure and deep foundation failure. In short
  - **It should not overturn**
  - **It should not slide**
  - **It should not subside**, i.e. Max. pressure at the toe should not exceed the safe bearing capacity of the soil under working condition

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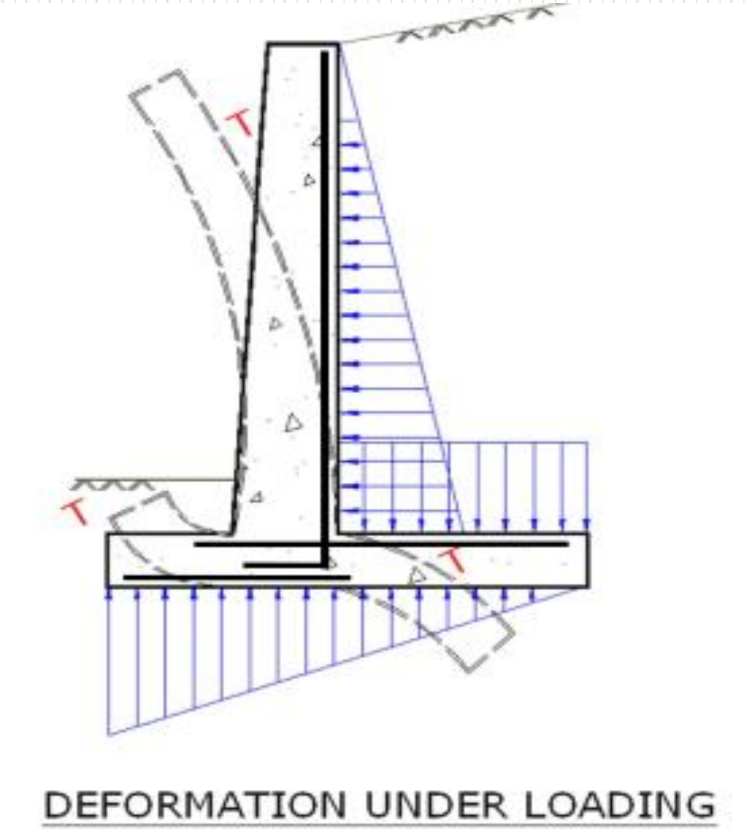
- Behavior or structural action

✓ Behavior or structural action and design of stem, heel and toe slabs are same as that of any cantilever slab.



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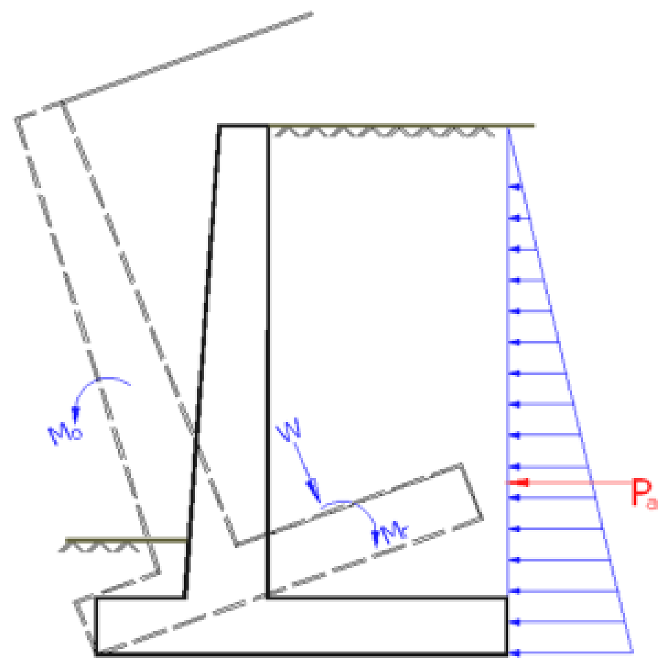
Overturning stability

- Factor of safety against overturning
$= MR / MO \geq 1.5$ for granular back fill and ≥ 2 for cohesive back fill
Where,
MR =Stabilizing moment or restoring moment
MO =overturning moment

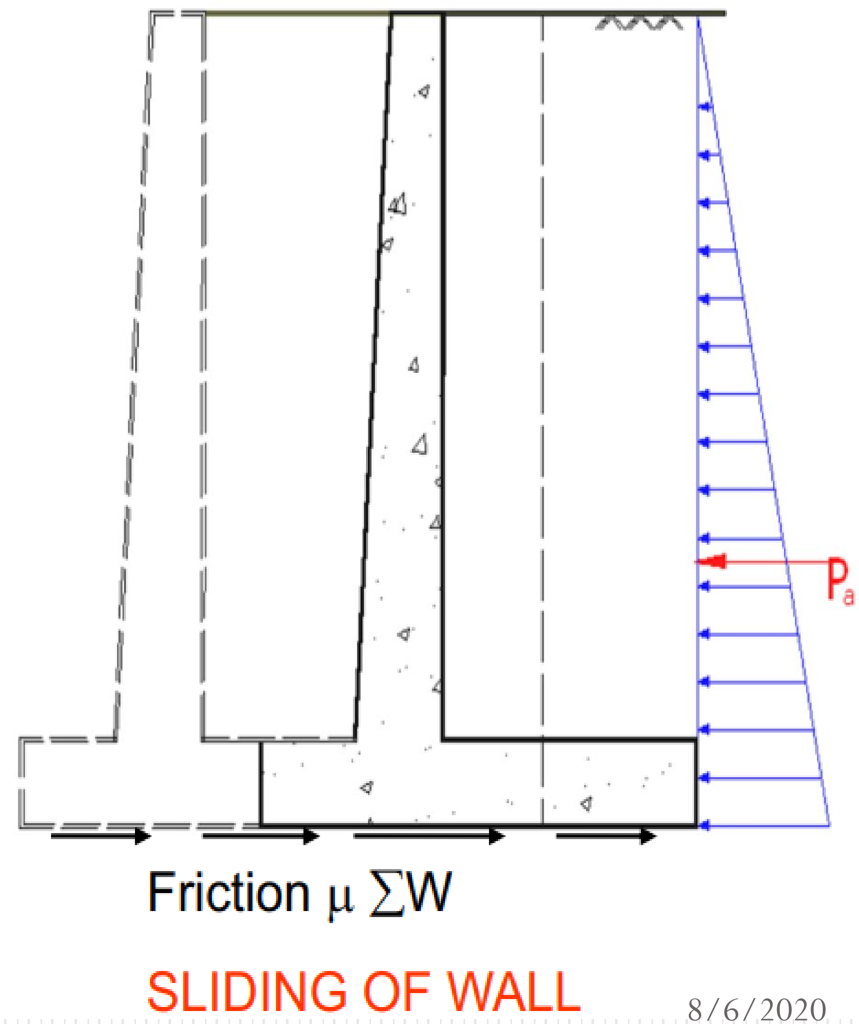


OVERTURNING OF WALL

Cont….

Sliding Stability

- ✓ FOS against sliding = Resisting force to sliding/Horizontal force causing sliding = $\mu * W/Pa \geq 1.5$ for granular back fill and ≥ 2 for cohesive back fill .



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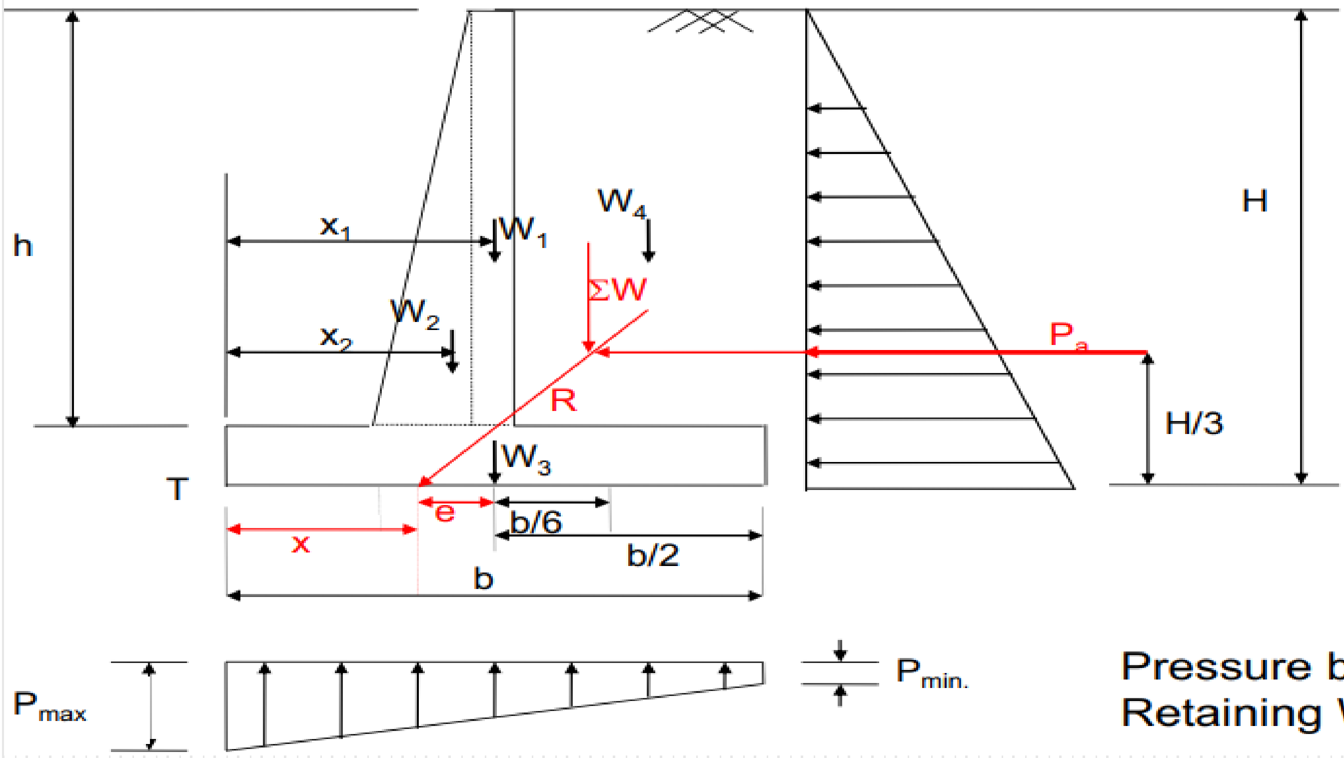
Foundation Stability

Maximum pressure at the toe



Pressure below the Retaining Wall

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Pressure at Heel and Toe

Minimum pressure at heel= $P_{min} = \frac{\sum W}{b}\left[1 - \frac{6e}{b}\right]$ >Zero.

Maximum pressure at toe= $P_{max} = \frac{\sum W}{b}\left[1 + \frac{6e}{b}\right]$ < SBC of soil.

- $X = \sum M / \sum W$,
- $\sum M$ = sum of all moments about toe.
- Eccentricity of the load = e = (b/2-x) < b/6

.Design

- ✓ The analysis and design of retaining walls includes the following Steps

1. Estimation of primary dimensions of the wall, then these dimensions should be checked
2. Checking external stability of the walls (sliding of retaining walls, overturning stability and bearing stability)
3. For reinforced concrete retaining walls main and secondary reinforcement must be calculated.
4. Detailing of reinforcement if it is reinforced concrete retaining walls

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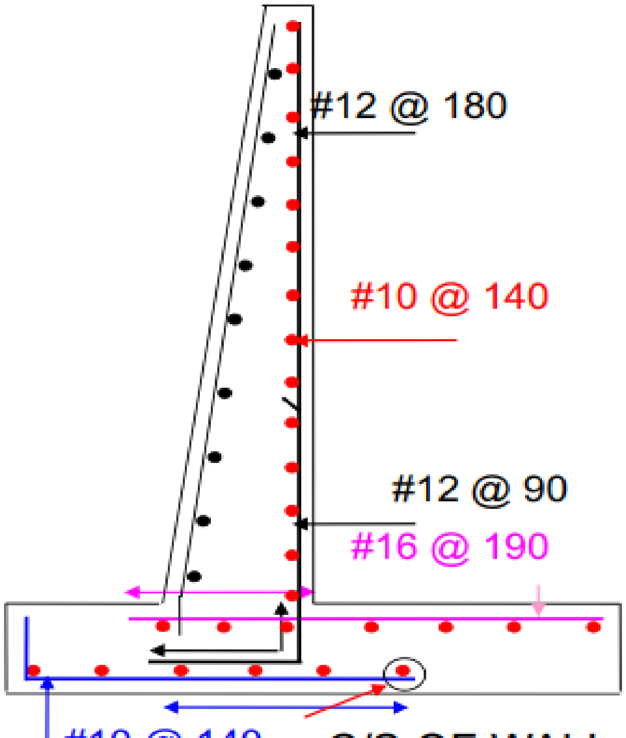
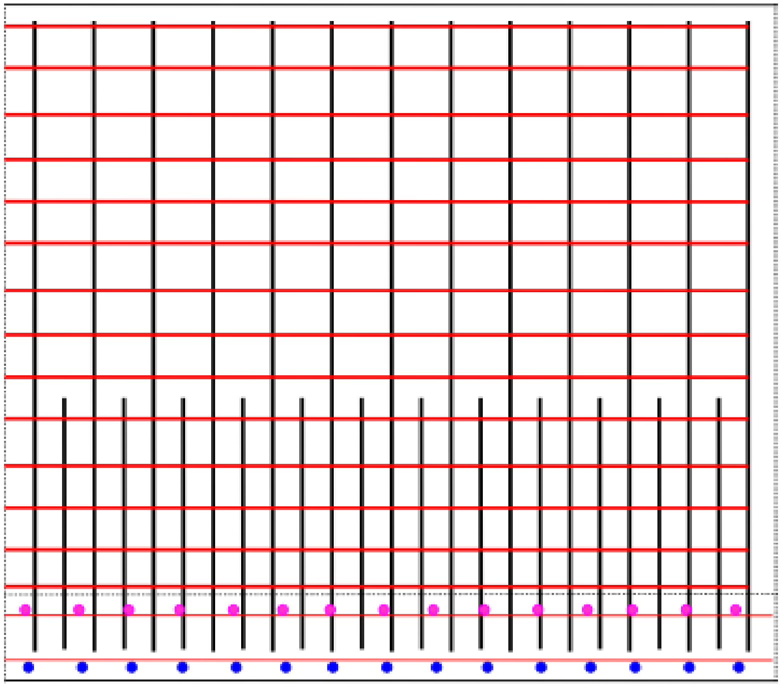
Drawing and detailing



C/S OF WALL

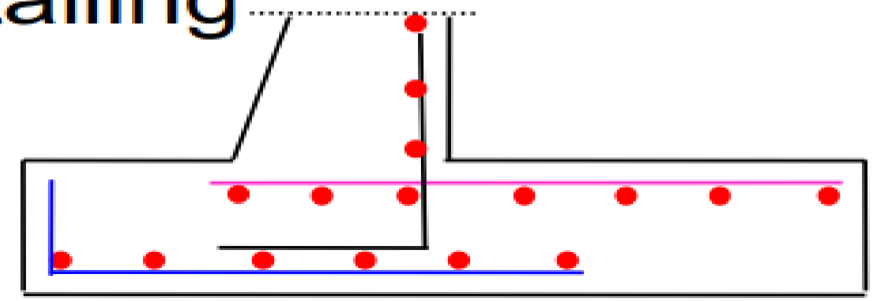


L/S ELEVATION OF WALL

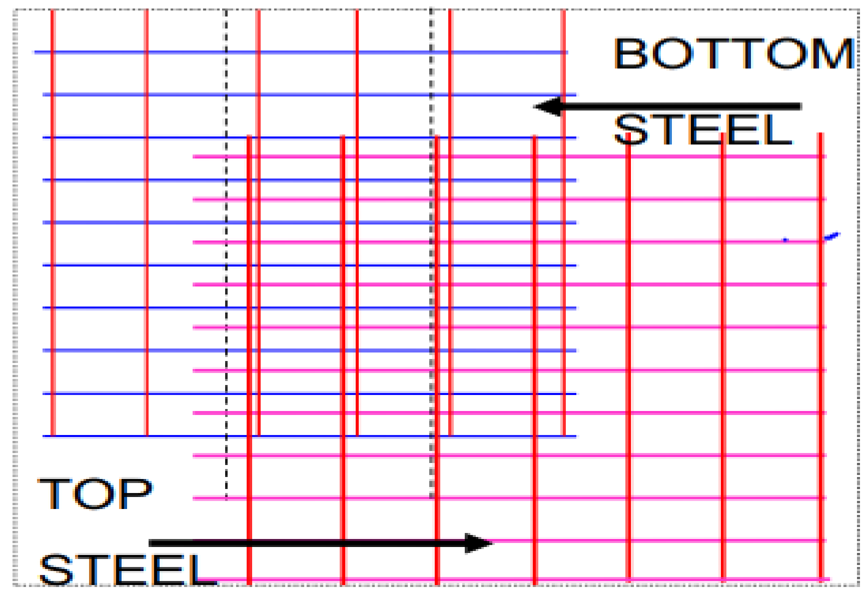
Cont….

Drawing and detailing

BASE SLAB DETAILS



PLAN OF BASE SLAB



INTRODUCTION TO PRE STTRESSED CCONCRETE

Prestressed concrete is a material that has had internal stresses induced to balance out, to a desired degree, stresses due to externally applied loads.

- Since tensile stresses are undesirable in concrete structural members, the objective of prestressing is to create compressive stresses (prestress) at the same locations as the tensile stresses within the member so that the tensile stresses within the member so that the tensile stresses will be diminished or will disappear together

INTRODUCTION

- The elimination of tensile stresses within the concrete will result in members that have fewer cracks or are crack-free at service load levels
- This one of the advantages of prestressed concrete over reinforced concrete
- Prestressed concrete also have other advantages
- Because beam cross sections are primarily in compression, diagonal tension stresses are reduced and the beams are stiffer at service laods.
- Also , sections can be smaller, the following must be considered:

Cont…

Some of the items that must be considered when using prestressed concrete:

1. The higher unit cost of stronger materials,
2. The need for expensive accessories,
3. The necessity for close inspection and quality control, and
4. In the case of precasting, a higher initial investment in plant,

DESIGN APPROACH AND BASIC CONCEPT

- The normal method for applying prestress force to a concrete member is through the use of steel tendons
- There are two basic methods of arriving at the final prestressed member:
  - Pre-tensioning and
  - post-tensioning

Cont…

- ***Pre-tensioning***
  - Pretension can be defined as a method of prestressing concrete in which the tendons are tensioned before the concrete is placed
  - This operation, which may be performed in a casting yard, is basically a five-step process.
    1. The casting tendons are placed in a prescribed pattern on the casting bed between two anchorages. The tendons are then tensioned to a value not to exceed 94% of the specified yield strength , but not greater than the lesser 80% of the specfied

Cont...

tensile strength of the tendons and the the maximum value recommended by the manufacturer of the prestressing tendons or anchorages

2. If the concrete forms are not already in place, they may then be assembled around the tendons.
3. The concrete is then placed in the forms and allowed to cure. Proper quality control must be exercised, and curing may accelerate with use of steam or other methods. The concrete will bond to tendons.

Cont…

4. When the concrete attains a prescribed strength, normally within 24 hours or less, the tendons are cut at their anchorages. Since the tendons are now bonded to the concrete, as they are cut from their anchorages the high prestress force must be transferred to the concrete. As the high tensile force of the tendon creates a compressive force on the concrete section, the concrete will tend to shorten slightly. The stresses that exits once the tendons have been cut are often called the stresses at ***transfer***. Since there is no external load at this stage, the stresses at transfer include only those due to prestressing forces and those due to the weight of the member.

Cont…

5. The prestressed member is then removed from the forms and moved to a storage area so that casting bed can be prepared for further use

- Pretensioning members are usually manufactured at a casting yard or plant that is somewhat removed from the job site where the members will eventually be used.
- In this case, they are usually delivered to the job site ready to be set in place
- Sometimes, a casting yard may be built on the job site to decrease transportation costs.

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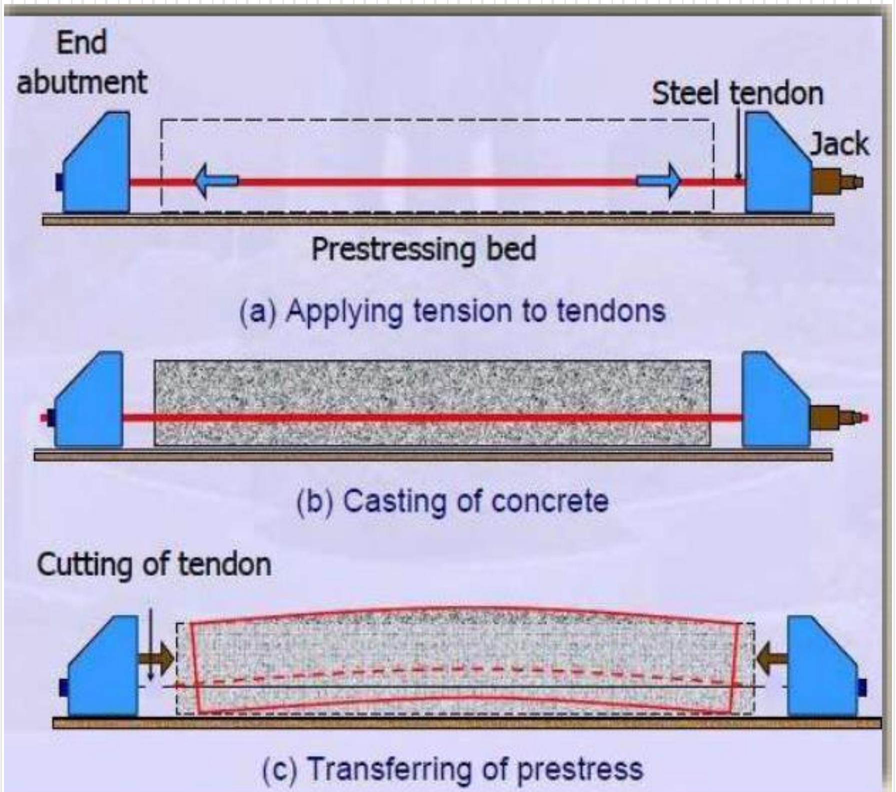
- Figure below shows the various stages in the manufacture of a precast, pretensioned member.



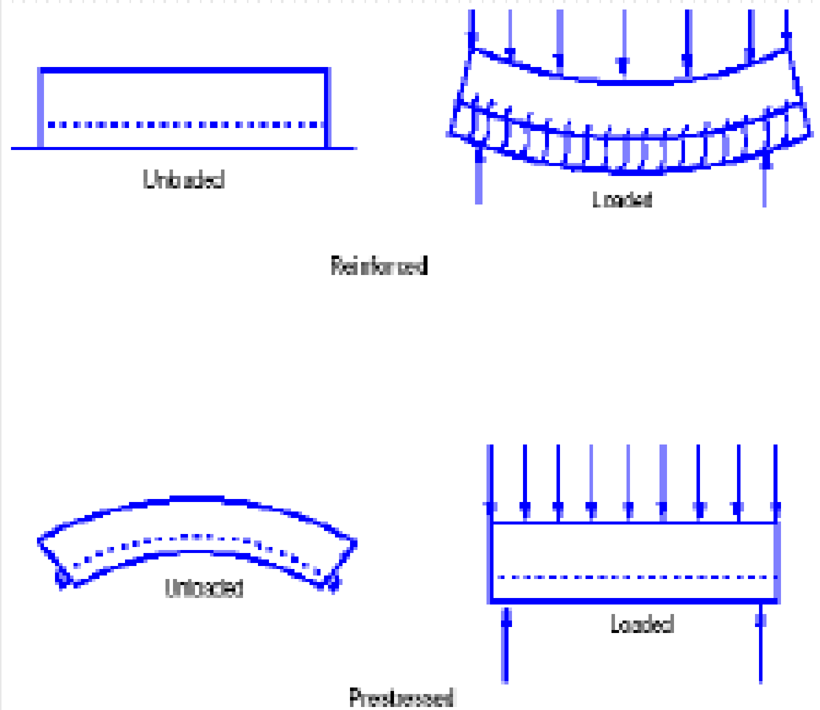


Fig: Prestresing action

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Pre-tensioned Concrete Beam

Cont…

- ***Post-tensioning:***
  - May be defined as a method of prestressing concrete in which the tendons are tensioned after the concrete has cured.
  - The operation is commonly a six-step process:

1. Concrete forms are assembled with flexible tubes(metal or plastic) placed in the forms and held at specified locations.
2. Concrete is then placed in the forms and allowed to cure to a prescribed strength
3. Tendons are placed in the tubes. In some systems, a complete tendon assembly is placed in the forms prior to the forms prior to the placing of concrete.

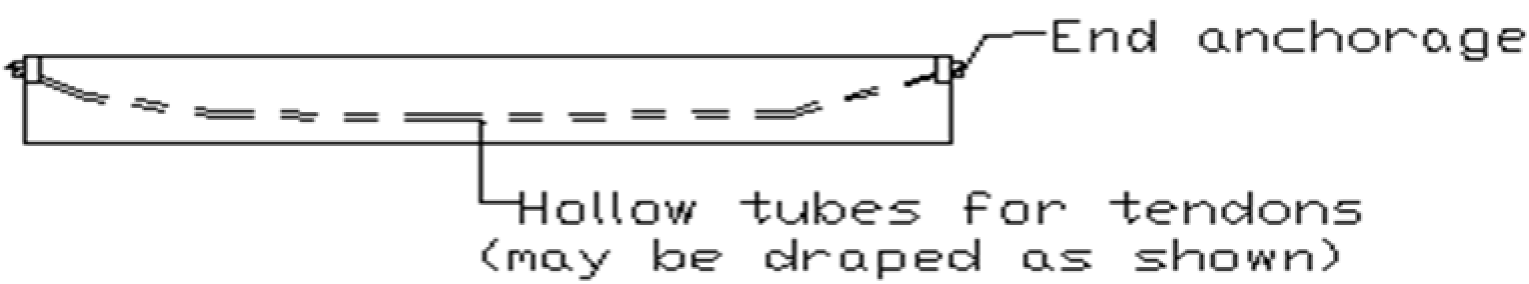
Cont…

4. The tendons are tensioned by jacking against an anchorage device or end plate that, in some cases, has been previously embedded in the end of the member. The anchorage device will incorporate some method for gripping the tendon and holding the load.

5. If the tendons are to be bonded, the space in the tubes around the tendons may be grouted using a pumped grout. Some members use unbonded tendons.

6. The end anchorage may be covered with a protective coating.

- Although post-tensioning is sometimes performed in a plant away from the project, it is most often done at the job site, particularly for units too large to be shipped assembled or for unusual application



Post-tensioned Member

STRESS PATTERNS IN PRESTRESSED

Concrete Beams

- The stress pattern existing on the cross section of a prestressed concrete beam may be determined by superimposing the stresses due to the loads and forces acting on the beam at any particular time.
- the following sign convention can be adopted:
  - Tensile stresses are positive(+)
  - Compressive stresses are negative (-)
- Since a crack-free cross section at service load level can be assumed, the entire cross section will remain effective in carrying stress.

STRESS PATTERNS IN PRESTRESSED

Concrete Beams

- The entire cross section will be used in the calculation of centroid and moment of inertia.
- For illustration purposes, a rectangular cross section will be used.
- **Example 1**

  For the section shown in the figure, determine the stresses due to prestress immediately after and also the stress at midspan when member is placed on a 6m simple span. Use C-50 and assume that the concrete has attained a strength of C-40 at the time of transfer. Use a central prestressing force of 500KN.

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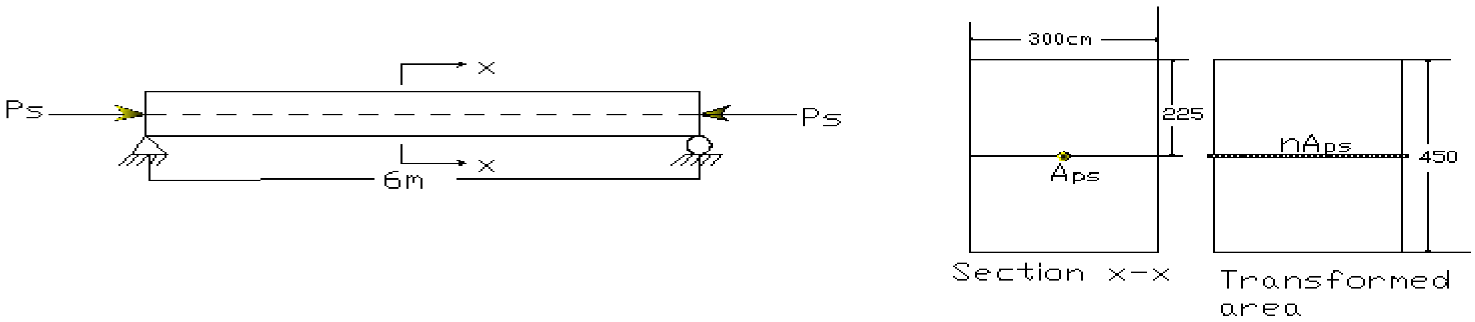
Concrete Beams

Example 1(cont'd)



Step-1 compute the stress in the concrete at the time of initial prestressing force Ps applied at the centroid of the section and assumed acting will be unifrom over the entire section. Thus,

$$f = Ps/Ac = -500/(0.3*0.45) = -3704 KN/m^2$$

Cont…

Concrete Beams

Step-2 Compute the stresses due to the beam dead load:

Weight of beam, DL=(0.3*0.45)*25=3.375KN/m

Moment due to dead load, $M_{DL}=wl^2/8$=15.2KN-m

$Ig=bh^3/12=0.3*0.4^3/12=1.6*10^{-3}$

Dead load stresses:f=Mc/I=(15.2*0.225)/(1.6*10^{-3})= $\pm$2,137.5KN/m

Step-3 Compute the stresses due to prestress plus dead load:

F(initial prestress+DL)=-3704 $\pm$2,137.5

=5,841.5

=-1566.5

These stresses are shown in stress summation diagram of figure

Cont…

Concrete Beams

These stresses are shown in stress summation diagram of figure 4

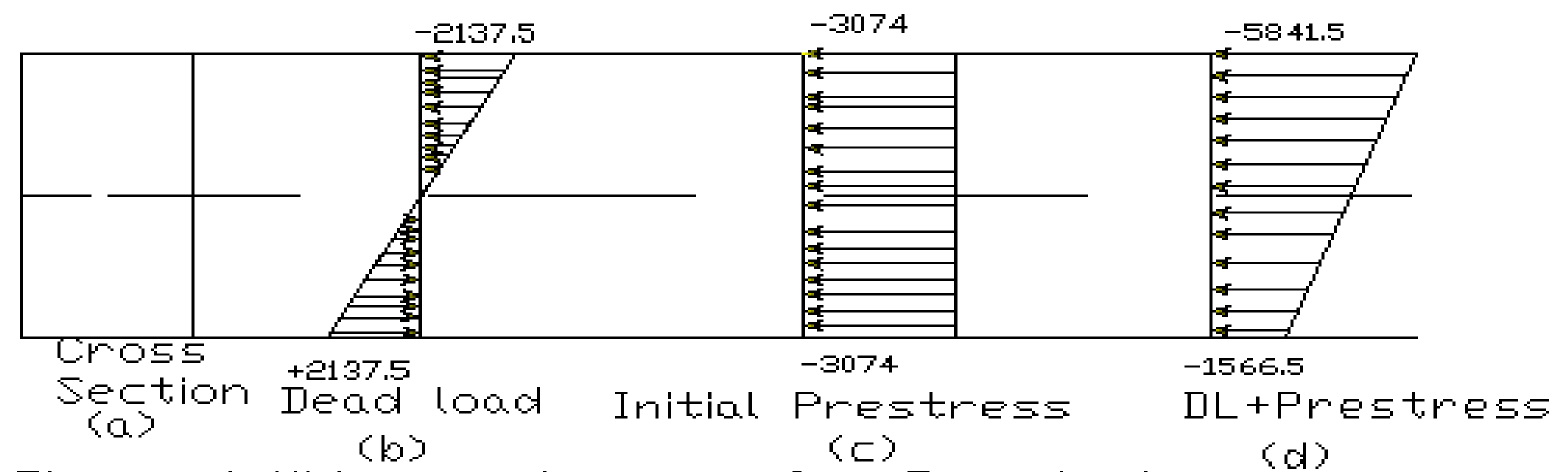


Figure-4 Midspan stresses for Example-1

Cont…

Concrete Beams

-Notes:

- The stress due to the DL moment in the bottom of the beam have been completely canceled out and compression exists on the entire cross section.
- A limited additional positive moment may be carried by the beam without resulting in a net tensile stress in the bottom of the beam.
- This situation may be further improved on by lowering the location of the tendon to induce additional compressive stresses in the bottom

Cont...

Concrete Beams

-Notes(cont'd)

- This example reflects two stages of the prestress process.
- The transfer stage occurs in a pretensioned member when the tendons are cut at the ends of the member and the prestres force has been transferred to the beam(figure-1)
- When the beam in this problem is removed from the forms (picked up by its end points), dead load stresses are introduced, and in this second stage, both the beam weight (dead load) and the prestress force are contributors to the stress pattern within the beam.

Cont…

- This stage is important because it occurs early in the life of the beam (sometimes 24 hours of casting)' and the concrete stresses must be held within permissible values as specified in ACI Code, section 18.4
- If the prestress force were placed below the neutral axis in this example, negative bending moment would occur in the member at transfer, causing the beam to curve upward and pick up its dead load.
- Hence for simple beam such as this, causing the prestress force is eccentric, the stress due to the initial prestress would never exits alone without the counteracting stresses from the dead load moment.

Cont…

PRESTRESSING STEEL

- The most commonly used steel for pretensioned concrete is in the form of a seven-wire, uncoated, stress-relived strand having a minimum tensile strength (fpu) of 250,000psi or 270,000psi.
- Prestressing steel does not exhibit the definite yield point characteristic found in the normal ductile steel used in reinforcing steel.(

Cont....

- The yield strength for prestressing wire and strand is a "specific yield strength" that is obtained from the stress-strain diagram at 1% strain, according to ASTM.
- Nevertheless , the specified yield point is not as important in prestressing steel as is the yield point of ductile steel.
- It is a consideration, however, when determining the ultimate strength of a beam.
- The analysis of flexural stresses in a prestressed member should be performed for different stages of loading, that is
  - the initial service load stage, which includes dead load plus stresses before losses;
  - The final service load stage, which includes dead load plus, prestress plus live load after losses.

- the initial service load stage, which includes dead load plus stresses before losses;
- The final service load stage, which includes dead load plus, prestress plus live load after losses; and
- The ultimate strength stage, which involves load and under strength factors.

Analysis of Rectangular Prestressed Concrete Beam

- Generally, checking of presterssed members is accomplished at the service load level based on unfactored loads.
- The ultimate strength of a member should be checked, however, using the same strength principle as for non prestressed reinforced concrete members.

THANK YOU FOR YOUR ATTENTION