

Techno India NJR Institute of Technology
(Approved by AICTE, New Delhi and Affiliated to Rajasthan Technical University Kota (Raj.))

Lab manual

Water and Earth Retaining Structures Design

Semester: VI Year: III (2023-24)

Name of faculty: Dr. Kuldeep Swarnkar

Email ID: Kuldeep.swarnkar@technonjr.org

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RAJASTHAN TECHNICAL UNIVERSITY, KOTA Syllabus

3rd Year - VI Semester: B.Tech. (Civil Engineering)

6CE4-24: WATER AND EARTH RETAINING STRUCTURES DESIGN

Credit: 1
OL+OT+2P

Max. Marks: 100(IA:60, ETE:40)
End Term Exam: 2 Hours

Assignments/ Exercises on the following topics:		
SN	CONTENTS	Hours
1	Continuous Beams: Analysis and Design of continuous beams using coefficients (IS Code), concept of moment redistribution	4
2	Curved Beams: Analysis and design of beams curved in plan.	4
3	Circular Domes: Analysis and design of Circular domes with u.d.l. & concentrated load at crown.	4
4	Water Tanks and Towers: Water Tanks and Water Towers-design of rectangular, circular and Intze type tanks, column brace type staging.	10
5	Retaining walls: Analysis and design of Cantilever Retaining Walls: Introduction to counterfort and buttress type retaining walls, their structural behaviour and stability analysis.	6
	TOTAL	28

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.1: Introduction]

Introduction

Retaining walls are structures used to retain earth or water or other materials such as coal, ore, etc; where conditions do not permit the mass to assume its natural slope. The retaining material is usually termed as backfill. The main function of retaining walls is to stabilize hillsides and control erosion. When roadway construction is necessary over rugged terrain with steep slopes, retaining walls can help to reduce the grades of roads and the land alongside the road. Some road projects lack available land beside the travel way, requiring construction right along the toe of a slope. In these cases extensive grading may not be possible and retaining walls become necessary to allow for safe construction and acceptable slope conditions for adjacent land uses. Where soils are unstable, slopes are quite steep, or heavy runoff is present, retaining walls help to stem erosion. Excessive runoff can undermine roadways and structures, and controlling sediment runoff is a major environmental and water quality consideration in road and bridge projects. In these situations, building retaining walls, rather than grading excessively, reduces vegetation removal and reduces erosion caused by runoff. In turn, the vegetation serves to stabilize the soil and filter out sediments and pollutants before they enter the water source, thus improving water quality.

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

Different Types of Retaining Structures

On the basis of attaining stability, the retaining structures are classified into following:

1. Gravity walls :

Gravity walls are stabilized by their mass. They are constructed of dense, heavy materials such as concrete and stone masonry and are usually reinforced. Some gravity walls do use mortar, relying solely on their weight to stay in place, as in the case of dry stone walls. They are economical for only small heights.

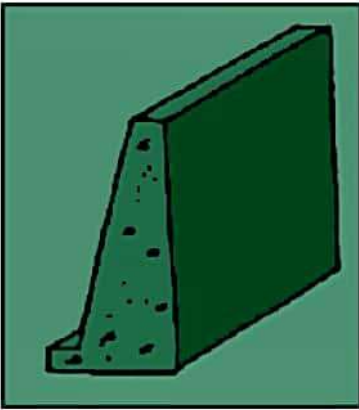


Fig 6.1 Gravity wall



Fig 6.2 Dry Stone Gravity Wall

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

2. Semi Gravity Retaining Wall

These walls generally are trapezoidal in section. This type of wall is constructed in concrete and derives its stability from its weight. A small amount of reinforcement is provided for reducing the mass of the concrete. This can be classified into two:

- Cantilever retaining wall
- Counter fort retaining wall

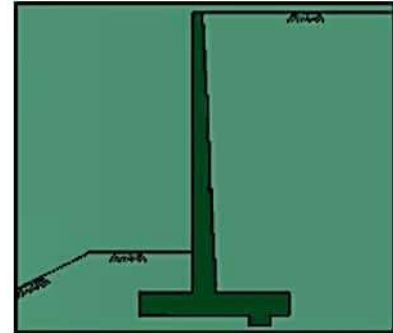


Fig 6.3.Semi Gravity Retaining Wall

■ Cantilever retaining wall

This is a reinforced concrete wall which utilises cantilever action to retain the backfill. This type is suitable for retaining backfill to moderate heights (4m-7m). In cross section most cantilevered walls look like "L"s or inverted "T"s. To ensure stability, they are built on solid foundations with the base tied to the vertical portion of the wall with reinforcement rods. The base is then backfilled to counteract forward pressure on the vertical portion of the wall. The cantilevered base is reinforced and is designed to prevent uplifting at the heel of the base, making the wall strong and stable. Local building codes, frost penetration levels and soil qualities determine the foundation and structural requirements of taller cantilevered walls. Reinforced concrete cantilevered walls sometimes have a batter. They can be faced with stone, brick, or simulated veneers. Their front faces can also be surfaced with a variety of textures. Reinforced Concrete Cantilevered Walls are built using forms. When the use of forms is not desired, Reinforced Concrete Block Cantilevered Walls are another option. 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 perpendicularly from the vertical surface into the slope. The bars or strips, sometimes called "deadmen" 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.

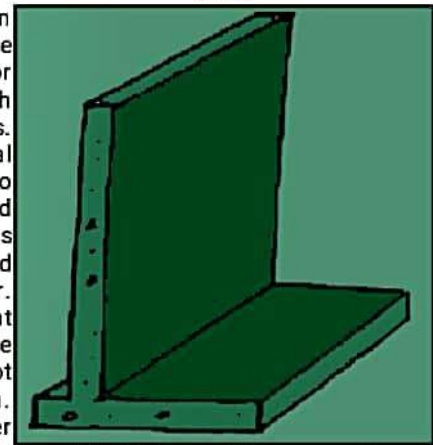


Fig.6.4 Cantilever wall

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Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

■ Counterfort retaining wall

When the height of the cantilever retaining wall is more than about 7m, it is economical to provide vertical bracing system known as counter forts. In this case, both base slab and face of wall span horizontally between the counter forts.

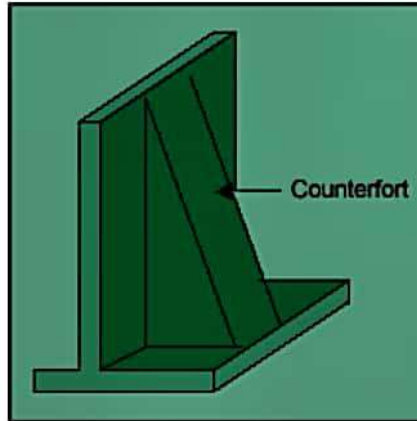


Fig. 6.5 Counter fort retaining wall

3. Flexible walls: there are two classes of flexible walls.

- A. Sheet pile walls and
- B. Diaphragm wall

A. Sheet Pile Walls

Sheet piles are generally made of steel or timber. The use of timber piles is generally limited to temporary structures in which the depth of driving does not exceed 3m. for permanent structures and for depth of driving greater than 3m, steel piles are most suitable. Moreover, steel piles are relatively water tight and can be extracted if required and reused. However, the cost of sheet steel piles is generally more than that of timber piles. Reinforced cement concrete piles are generally used when these are to be jettied into fine sand or driven in very soft soils, such as peat. For tougher soils, the concrete piles generally break off. Based on its structural form and loading system, sheet pile walls can be classified into 2 types: (i) Cantilever Sheet Piles and (ii) Anchored Sheet Piles

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Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

1. Cantilever sheet pile walls:

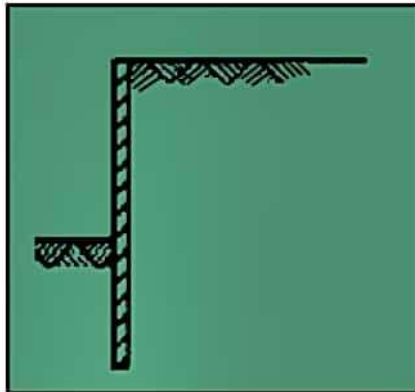


Fig. 6.6. Cantilever sheet pile wall

Cantilever sheet piles are further divided into two types:

- **Free cantilever sheet pile**

It is a sheet pile subjected to a concentrated horizontal load at its top. There is no back fill above the dredge level. The free cantilever sheet pile derives its stability entirely from the lateral passive resistance of the soil below the dredge level into which it is driven.

- **Cantilever Sheet Pile Wall with Backfill**

A cantilever sheet pile retains backfill at a higher level on one side. The stability is entirely from the lateral passive resistance of the soil into which the sheet pile is driven, like that of a free cantilever sheet pile.

2. Anchored sheet pile walls

Anchored sheet pile walls are held above the driven depth by anchors provided at a suitable level. The anchors provided for the stability of the sheet pile, in addition to the lateral passive resistance of the soil into which the sheet piles are driven. The anchored sheet piles are also of two types.

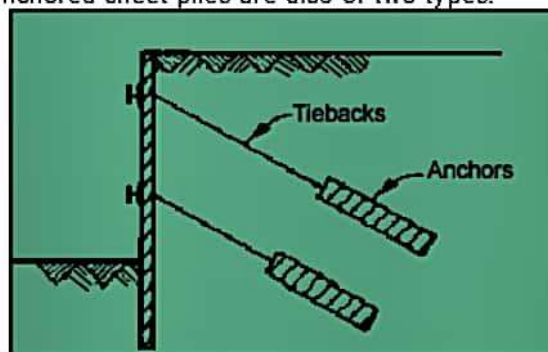


Fig. 6.7. Anchored sheet pile wall

- **Free earth support piles.**

An anchored pile is said to have free earth support when the depth of embedment is small and the pile rotates at its bottom tip. Thus there is a point of contraflexure in the pile.

- **Fixed earth support piles.**

An anchored sheet pile has fixed earth support when the depth of embedment is large. The bottom tip of the pile is fixed against rotations. There is a change in the curvature of the pile, and hence, an inflection point occurs.

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

B. Diaphragm Walls

Diaphragm walls are commonly used in congested areas for retention systems and permanent foundation walls. They can be installed in close proximity to existing structures, with minimal loss of support to existing foundations. In addition, construction dewatering is not required, so there is no associated subsidence. Diaphragm walls have also been used as deep groundwater barriers through and under dams.

Diaphragm walls are constructed by the slurry trench technique which was developed in Europe, and has been used in the United States since the 1940's. The technique involves excavating a narrow trench that is kept full of an engineered fluid or slurry. The slurry exerts hydraulic pressure against the trench walls and acts as shoring to prevent collapse. Slurry trench excavations can be performed in all types of soil, even below the ground water table. Cast in place; diaphragm walls are usually excavated under bentonite slurry. The construction sequence usually begins with the excavation of discontinuous primary panels. Stop-end pipes are placed vertically in each end of the primary panels, to form joints for adjacent secondary panels. Panels are usually 8 to 20 feet long, with widths varying from 2 to 5 feet. Once the excavation of a panel is complete, a steel reinforcement cage is placed in the center of the panel. Concrete is then poured in one continuous operation, through one or several tremie pipes that extend to the bottom of the trench. The tremie pipes are extracted as the concrete raises in the trench, however the discharge of the tremie pipe always remains embedded in the fresh concrete. The slurry, which is displaced by the concrete, is saved and reused for subsequent panel excavations. When the concrete sets, the end pipes are withdrawn. Similarly, secondary panels are constructed between the primary panels, and the process continues to create a continuous wall. The finished walls may cantilever or require anchors or props for lateral support.

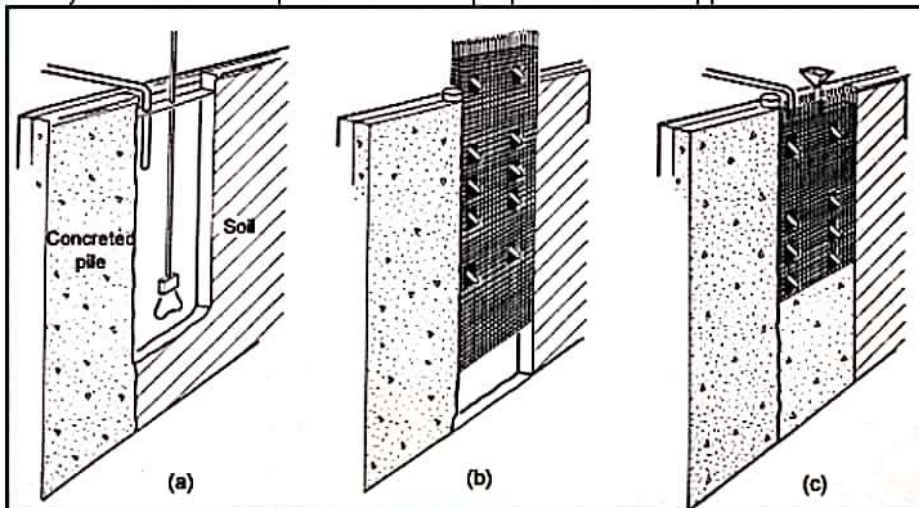


Fig. 6.8. Construction Stages of a Diaphragm Wall using Slurry Trench Technique.

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

4. Special type of retaining walls

■ Gabion walls

Gabion walls are constructed by stacking and tying wire cages filled with trap rock or native stone on top of one another. They can have a continuous batter (gently sloping) or be stepped back (terraced) with each successively higher course.

This is a good application where the retaining wall needs to allow high amounts of water to pass through it, as in the case of riverbank stabilization. It is important to use a filter fabric with the gabion to keep adjacent soil from flowing into or through the cages along with the water. As relatively flexible structures, they are useful in situations where movement might be anticipated. Vegetation can be re-established around the gabions and can soften the visible edges allowing them to blend into the surrounding landscape. For local roads, they are a preferred low-cost retaining structure.

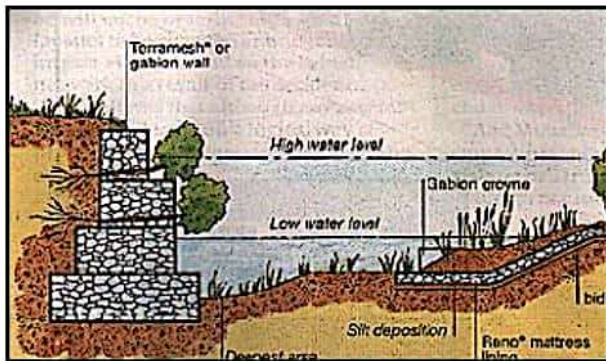


Fig. 6.9 (i) Gabion Wall



Fig.6.9 (ii) Gabion Wall

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Lecture 26 : Introduction [Section 26.2 : Different Types of Retaining Structures]

■ **Crib walls**

Crib walls have been made of 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 usually quite large and can be out of scale and character with the surrounding landscape. In addition, heavy construction equipment is required to lay the courses, possibly impacting sensitive areas. It can be used for moderate heights of 4m to 6m

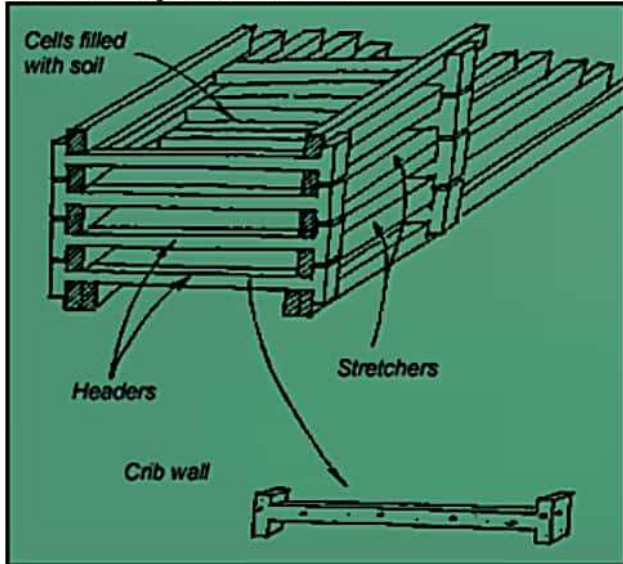


Fig. 6.10 (i) Crib wall



Fig. 6.11 (ii) Crib wall

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.3 : Design Requirement for Gravity walls]

Fig. 6.12a shows a typical trapezoidal section of a gravity retaining wall.

The forces acting on the wall per unit length are:

- Active Earth pressure P_a .
- The weight of the wall (W_c)
- The Resultant soil reaction R on the base. (or Resultant of weight W_c & P_a). Strike the base at point D. There is equal and opposite reaction R' at the base between the wall and the foundation.
- Passive earth pressure P_p acting on the lower portion of the face of the wall, which usually small and usually neglected for design purposes. The full mobilization of passive earth pressure not occurs at the time of failure so we not consider it. If we consider it then it shows resistance against instability. So if we ignore it then we will be in safer side.

First decide which theory we want to apply for calculating the active earth pressure. Normally we calculate earth pressure using Rankine's theory or Coulomb's Earth pressure theory.

For using Rankine's theory, a vertical line AB is drawn through the heel point

(Fig 6.12-b). It is assumed that the Rankine active condition exist along the vertical line AB. While checking the stability, the weight of the soil (W_s) above the heel in the zone ABC should also be taken in to consideration, in addition to the Earth pressure (P_a) and weight of the wall (W_c).

But Coulomb's theory gives directly the lateral pressure (P_a) on the back face of the wall, the forces to be considered only P_a (Coulomb) and the Weight of the wall (W_c). In this case, the weight of soil (W_s) is need not be considered.

Once the forces acting on the wall have been determined, the Stability is checked using the procedure discussed in the proceeding section. For convenience, the section of the retaining wall is divided in to rectangles & triangles for the computation of the Weight and the determination of the line of action of the Weight.

Module 6 : Design of Retaining Structures

Lecture 26 : Introduction [Section 26.3 : Design Requirement for Gravity walls]

For a safe design, the following requirement must be satisfied.

■ No Sliding

Horizontal forces tend to slide the wall away from the fill. This tendency is resisted by friction at the base.

$$F.S._{sliding} = \frac{\sum \text{Resisting Force } (\sum V)}{\sum \text{Sliding Force } (\sum H)} > 1.5 (\text{for Stability}) \quad (\text{General})$$

$$F.S._{sliding} = \frac{[\mu \cdot \sum W] + P_p \cdot \cos(\delta)}{P_a \cdot \cos(\delta)}$$

$$F.S._{sliding} = \frac{\mu \cdot W_c + \mu \cdot [P_a \cdot \sin(\delta)] + P_p \cdot \cos(\delta)}{P_a \cdot \cos(\delta)} \quad \therefore [\mu = \tan(\delta)] \quad (\text{Coulomb})$$

μ = Coefficient of friction between the base of the wall and soil (= $\tan \delta$).

$\sum W$ = Sum of the all vertical forces i.e. vertical component of inclined active force.

A minimum factor of safety of 1.5 against sliding is recommended.

■ No Overturning

The wall must be safe against overturning about toe.

$$F.S._{Overturning} = \frac{\sum M_R}{\sum M_o} \geq 1.5$$

$$F.S._{Overturning} = \frac{W_c \cdot l_1 + P_a \cdot \sin(\delta) \cdot l_2 + P_p \cdot \cos(\delta) \cdot l_3}{P_a \cdot \cos(\delta) \cdot l_4}$$

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Lecture 26 : Introduction [Section 26.3 : Design Requirement for Gravity walls]

■ No Bearing Capacity Failure and No Tension

First calculate the line of action of the Resultant force (e) from centre of the base.

(No Tension will develop at the heel)

$$\bar{X} = \frac{[\sum M_R] - [\sum M_0] \text{ (net moment)}}{\sum V \text{ (vertical force)}}$$

$$\text{Therefore } [e = \frac{B}{2} - \bar{X}] \leq \frac{B}{6}$$

The pressure at the toe of the wall must not exceed the allowable bearing capacity of the soil. The pressure at the base is assumed to be linear. The max. Pressure at the Toe & min at the Heel is given by:

$$P_{(max)} = \frac{\sum V}{B} \left(1 + \frac{6e}{B} \right) \quad P_{min} = \frac{\sum V}{B} \left(1 - \frac{6e}{B} \right)$$

$P_{(max)}$ should be less than the Safe bearing capacity(q_{allow}) of the soil & $P_{(max)}$ should not be Tensile in any case. Tension is not desirable. The tensile strength of the soil is very small and tensile crack would develop. The effective base area is reduced.

$$F.S. \text{ bearing capacity} = \frac{q_{allowable}}{P_{max}} \geq 2.5$$