

# INNOVATIVE RETAINING WALL SYSTEM FOR ENHANCED SAFETY AND ECONOMY

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## Abstract

A retaining wall is a structure designed to resist the lateral pressure exerted by soil, water, or both, especially where elevated soil needs support above stable ground. For low heights, gravity retaining walls are commonly used, relying on their own weight for stability. However, as wall height increases, gravity walls become uneconomical due to the large size and volume of materials required. For medium heights, cantilever retaining walls—typically L- or inverted T-shaped—offer better material efficiency, with thinner stems supported by a base slab. Yet, they become risky for higher walls, as minor foundation defects or scouring at the toe can lead to structural failure and an uneconomical design. In such cases, counterfort retaining walls are preferred. These walls use vertical supports (counterforts) placed at regular intervals on the soil-facing side to reduce bending moments and increase stability. Though effective for tall walls, counterfort designs are complex, labor-intensive, and require skilled workmanship. This paper presents a new type of retaining wall that has been developed by combining the principles of both gravity and cantilever designs. It consists of parallel double walls connected by tie members, spaced vertically at regular intervals. Three-dimensional analysis shows a significant reduction in stress, making this design more economical and safer. Additionally, it does not require skilled labor and allows for faster construction than counterfort walls.

**Keywords:** Retaining wall, Gravity, Cantilever, Counterfort, Double wall

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## 1. Introduction

A retaining wall is one of the most common civil engineering structures used to sustain lateral pressure exerted by retained materials such as soil, water, or both. It is required when the elevations on either side differ. Generally, retaining walls for low heights are constructed using stone masonry, either dry or with mortar. As the height increases, the thickness must also increase to maintain stability. Sometimes retaining walls become necessary due to insufficient space on sloping land, where it is required to create space for roads or other structures by cutting the slope, thus making a retaining wall essential.

There are different types of retaining walls, and their selection depends on height requirements as well as economy. The materials used for retaining walls also vary according to the type of wall. Stone masonry is commonly used for low-height walls, while gabion walls

are typically used in areas with more flexible or unstable soil, such as landslide-prone regions. Similarly, Reinforced Cement Concrete (RCC) retaining walls are among the most common types for greater heights due to their strength and cost-effectiveness. However, proper design and skilled construction are essential for RCC retaining walls to perform effectively. Special types of retaining walls include Mechanically Stabilized Earth (MSE) panels, steel sheet piles, and others. The shapes of RCC wall sections are selected based on site requirements, such as L-type or inverted T-type sections. These types of sections are typically used for medium-height cantilever retaining walls. Cantilever walls (Figure ??) are popular because they are relatively easy to design and construct. However, if construction quality is not maintained or if there is carelessness during implementation, these walls can fail to retain the backfill material. Failures of cantilever retaining walls are commonly observed in the field. Additionally, for greater heights, cantilever walls become uneconomical and riskier. In such conditions, counterfort retaining walls are constructed (Figure 1b). In this system, vertical walls

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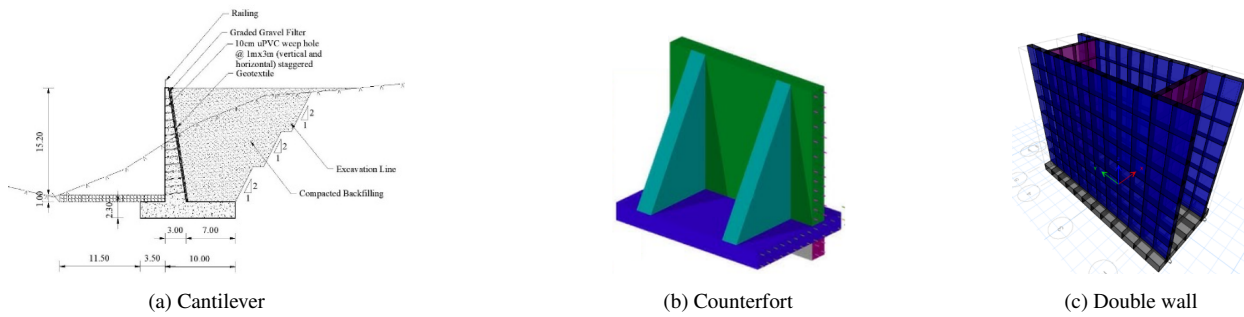


Figure 1: Different types of RCC retaining wall

Table 1: Comparison of retaining walls for headworks

Particulars	Cantilever	Counterfort	Double Wall
Concrete Quantity	22,385 m <sup>3</sup>	18,674 m <sup>3</sup>	15,420 m <sup>3</sup>
Rebar Quantity	3,258 MT	1,559 MT	1,220 MT
Cost Rs. (RCC only)	780,153,616	519,123,033	420,968,760
Design	Normal	Complex	Simple
Risk to Failure	More	Normal	Less
Construction	Normal	Difficult	Simple
Time Required	Normal	More	Less

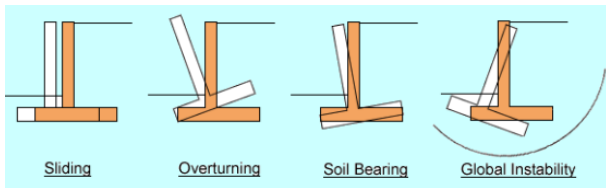


Figure 2: Different failure mechanisms in a retaining wall

act as the main supports against the retained material, while counterforts—inclined supports placed normal to the vertical face—are provided at regular intervals on the soil-facing side to reduce bending moments and enhance stability.

Although effective for tall walls, counterfort designs are complex, labor-intensive, and require skilled workmanship. As an alternative to counterfort walls, a double-wall system has been developed (Fig. 1c). This system consists of two vertical parallel walls connected by tie walls, creating a box-like enclosure that is filled with locally available riverbed material or other types of soil. This paper specifically discusses this type of double-wall system. The system is easier to construct, simpler in design, and more economical, which is demonstrated through the following examples.

## 2. Design Principle of Retaining Wall

The design principle of a retaining wall consists of two parts: the sub-structure and the super-structure. The sub-structure design is primarily based on principles of equilibrium. It includes ensuring safety against overturning, sliding, and excessive bearing pressure (Figure 2). Under weak soil conditions, global stability must also be checked. The sub-structure design generally remains the same for all types of retaining walls, whereas the design of the super-structure varies depending on the wall type. For gravity retaining walls, no super-structure design is required. For cantilever and counterfort retaining walls, however, the structural design of the super-structure becomes essential.

Key design considerations include the characteristics of the retained soil and the effects of hydrostatic pressure. Hydrostatic pressure does not need to be considered in dry stone masonry or gabion walls because water can freely drain through them. In other types of retaining walls, hydrostatic pressure becomes a crucial design factor, although it can be reduced or eliminated by providing adequate weep holes.

The design principle of a cantilever retaining wall is relatively simple, but the base slab is the most critical component. Any negligence in construction quality at the base can lead to serious structural risks.

A counterfort retaining wall consists of a vertical stem, counterforts, and a base slab. In practice, each component

Table 2: Comparison of retaining walls for desander

Particulars	Cantilever	Counterfort	Double Wall
Concrete Quantity	33,789 m <sup>3</sup>	29,941 m <sup>3</sup>	30,225 m <sup>3</sup>
Rebar Quantity	4,878 MT	3,885 MT	2,878 MT
Cost Rs. (RCC only)	1,043,418,155	876,413,039	769,925,647
Check of Stability (H/B = 2.5)	No need	No need	No need
Design	Normal	Complex	Simple
Risk to Failure	More	Normal	Less
Construction	Normal	Difficult	Simple
Time Required	Normal	More	Less

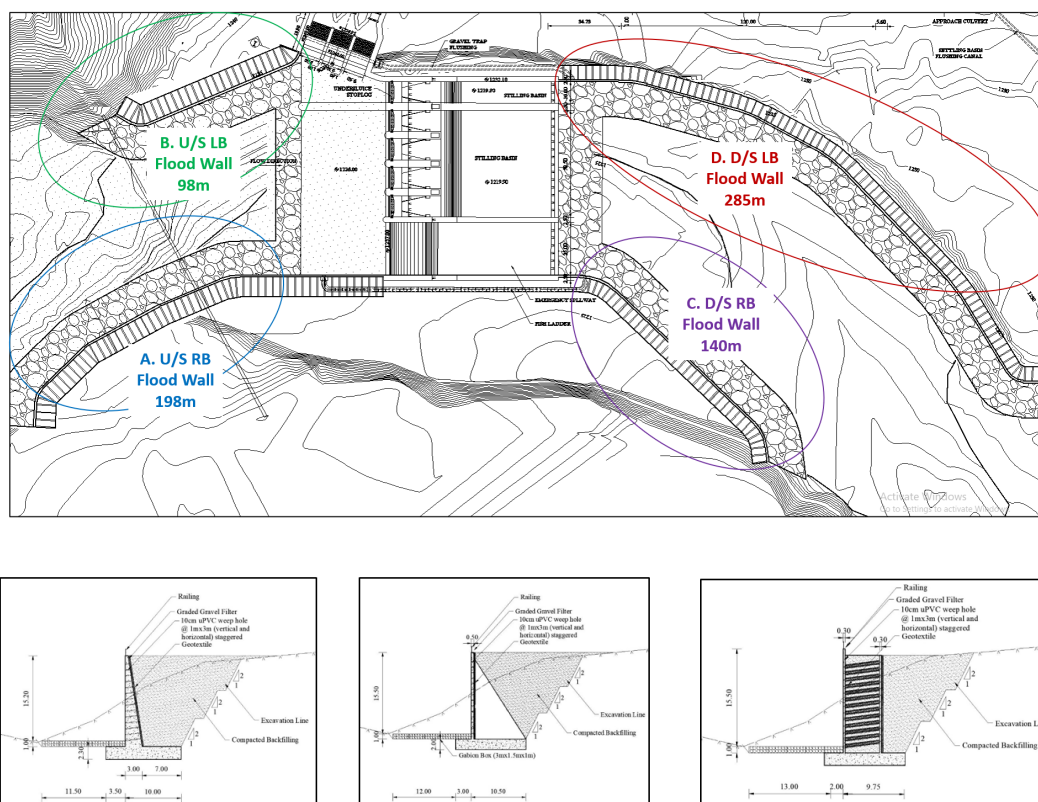


Figure 3: Headworks design and types of RCC retaining wall

is often designed independently, which can make the overall design conservative. Counterfort walls require heavy reinforcement, are difficult to construct, and demand skilled labour, making them more time-consuming than conventional cantilever walls. For greater heights, they also become uneconomical.

To address the challenges and high cost associated with cantilever and counterfort systems, an alternative retaining wall configuration can be used: a vertical double-wall system connected by tie walls. For example, a repeated 10 m long double wall connected with tie walls spaced 6

m apart in plan, with 2 m cantilever projections at each end, can be filled with locally available material inside the box. The design of this system is simpler than that of counterfort walls and functions similarly to a gravity wall at the super-structure level. This results in enhanced safety, lower cost, and easier construction.

### 3. Case Study

For comparison among cantilever, counterfort, and double-wall systems, a case study from the headworks

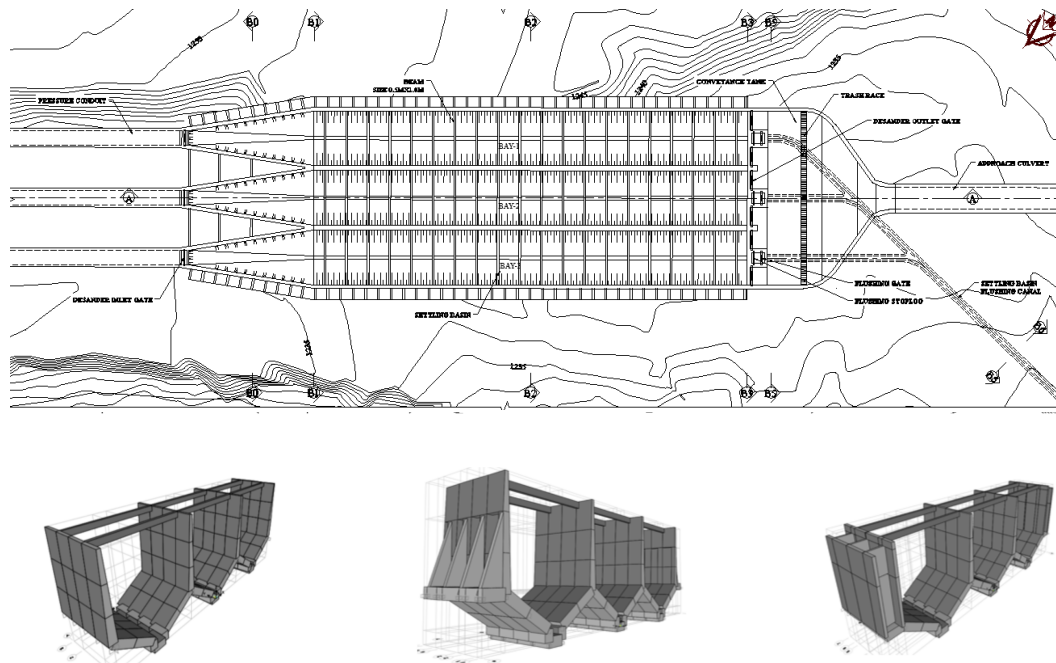


Figure 4: Desander basin design and types of RCC retaining wall

protection walls of a hydropower project is considered (Figure 3). The upstream protection walls required lengths of 98 m on the left bank and 198 m on the right bank based on the site topography. Similarly, downstream walls of 285 m on the left bank and 140 m on the right bank were designed, and all three wall types were compared for these conditions.

After completing the design and quantity estimation, the cost, construction time, and various risk factors related to potential failure were evaluated. The required construction duration was also compared, and the results are presented in Table 1.

From Table 1, it is evident that the costs of the counterfort wall and the double-wall system are 33.50% and 46.05% lower than the cantilever wall, respectively. Beyond cost alone, the double-wall system also offers significant advantages in design simplicity, reduced risk of failure, easier construction, and shorter construction time. Overall, it provides benefits in almost every aspect compared to the other wall types.

A similar comparison was carried out for the desander basin (Figure 4) in the same project, evaluating the side walls that retain the earth using different wall types. In this case as well, the double-wall system proved economical, with cost reductions of 16.01% and 26.21% compared to the cantilever wall.

#### 4. Conclusion

An innovate retaining wall system was demonstrated for enhanced safety and economy by using examples of two scenarios- comparison of Cantilever, Counterfort, and Double Wall RCC retaining walls for headworks and desander basin of a hydropower project. Both cases showed that the double-wall system proved economical than the other two.

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