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Comparative Study on the Design of Different Types of Retaining Walls Using Software Tools

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ABSTRACT

Retaining walls are used to hold back soil and keep the ground stable in places like roads, bridges, and basements. This study compares three common types of retaining walls — Gravity, Cantilever, and Counterfort — by designing them in STAAD.Pro using the same soil and loading conditions. The designs follow IS 456:2000 and other related codes. The comparison is based on bending moments, shear forces, stability, and material use. The study shows that gravity walls are suitable for small heights, cantilever walls work well for medium heights, and counterfort walls are best for taller walls. Using software also makes the design easier and more accurate.

Keywords: Retaining Wall, Gravity Wall, Cantilever Wall, Counterfort Wall, STAAD.Pro, IS Codes.

INTRODUCTION

Retaining walls are very important structures in civil engineering because they help hold back soil when the ground level changes. These walls prevent the soil from sliding or eroding and are seen in many places such as highways, bridge abutments, basements, embankments, gardens, and hillside areas. Their main purpose is to keep the soil stable and protect nearby structures from damage. If retaining walls are not properly designed, the soil behind them can move, which may lead to cracks in buildings, road failures, or even complete collapse of a slope.

Different types of retaining walls are used in construction depending on the height of the wall, soil type, available land space, and the cost of construction. The three most used types are Gravity Retaining Walls, Cantilever Retaining Walls, and Counterfort Retaining Walls.

A gravity retaining wall depends mainly on its own self-weight to resist pressure from the soil. These walls are usually made of plain concrete or stone masonry and are simple in design. They are mostly preferred for small-height retaining structures.

A cantilever retaining wall is made of reinforced concrete and consists of a vertical stem and a base slab. In this type of wall, the bending action of the stem and base helps resist soil pressure.

Cantilever walls are more economical and efficient for medium-height walls and are widely used in modern construction.

A counterfort retaining wall is like a cantilever wall but includes additional thin vertical concrete slabs called counterforts at regular spacing. These counterforts tie the stem and base slab together, reducing bending moments and making the wall suitable for larger heights. Counterfort walls are chosen when the wall height is large, as they save material and reduce overall cost.

In earlier times, these design calculations were done manually using formulas from soil mechanics and structural engineering. While manual design methods work, they take a lot of time and there is a chance of calculation mistakes, especially when the structure is large or the loading conditions are complex.

Today, with advancements in digital technology, engineers use software tools to design and analyze retaining walls more easily and accurately. Software like STAAD.Pro, AutoCAD, and Geo5 helps engineers model the wall, apply loads, and study how it behaves under different conditions. Using software reduces calculation errors and gives clear visual outputs like bending moment diagrams, shear force diagrams, and displacement profiles. These tools also allow engineers to make quick changes in dimensions and material properties to study different design options.

This project focuses on a comparative study of different types of retaining walls by designing them using software tools. All walls are analyzed using the same soil properties, wall height, surcharge load, and other conditions. This helps in making a fair comparison among gravity, cantilever, and counterfort retaining walls.

The comparison includes parameters like lateral earth pressure, bending moments, shear forces, factor of safety against sliding and overturning, base pressure, and material requirements. By studying these results, engineers can understand how each type of wall performs and which wall is more suitable for a particular height and site condition.

Software-based analysis also helps in optimizing the wall design by reducing unnecessary material usage. For example, STAAD.Pro gives detailed results that show exactly where reinforcement is required and how much bending moment or shear force acts at different parts of the wall. This helps engineers choose the most economical design that still meets safety requirements.

This study also helps students and engineers understand the practical aspects of retaining wall design. It shows how different wall types behave under the same conditions, how the factor of safety changes with wall configuration, and how cost varies depending on reinforcement and concrete quantity. Learning these concepts helps in selecting the most efficient retaining wall type for real-life projects, ensuring safety and economy.

LITERATURE REVIEW

Sajika S. R. [1] emphasizes the use of STAAD.Pro software for analyzing and designing retaining walls under static conditions. It compares manual and software-based results, showing that STAAD.Pro ensures higher accuracy, quicker analysis, and reliable safety checks for overturning, sliding, and bearing capacity, leading to efficient and economical retaining wall designs suitable for practical engineering applications.

Rameesha K. [2] analyzing the stability and performance of a retaining wall constructed in the Kuranchery region using GEO5 software. The study evaluates sliding, overturning, and bearing capacity under different soil and load conditions. It concludes that GEO5 provides accurate, efficient, and realistic analysis results, helping engineers ensure the safety and cost-effectiveness of retaining wall designs.

D.R. Dhamdhere [3] presents the structural design and analysis of a reinforced concrete retaining wall using modern engineering methods. It focuses on checking stability against overturning, sliding, and bearing failure, and determining suitable reinforcement detailing. The study concludes that using software-based analysis improves accuracy, reduces material wastage, and ensures a safe, stable, and economical retaining wall design for real-world applications.

Unmesh M Tayade [4] examines how changes in key design parameters such as wall height, backfill properties, and base thickness affect the stability and safety of cantilever retaining walls. The study concludes that proper selection of these parameters greatly influences bending moments, shear forces, and overall cost efficiency, ensuring a safe and economical design.

In the paper "Advanced Structural Analysis And Optimization Of Retaining Walls With ANSYS", the authors Deore S.M. [5] focuses on performing an advanced structural analysis and optimization of retaining walls using ANSYS software. The study aims to evaluate the structural behavior, stability, and material efficiency of different types of retaining walls—particularly gravity, cantilever, and counterfort walls—under various soil and loading conditions.

Authors Syed Raheel Ahmed [6] focuses on analyzing the effect of various infill wall materials on the behavior of framed structures. Using structural analysis software, the study compares frames with brick masonry, concrete block, and lightweight infill walls under similar loading conditions. Key parameters such as lateral displacement, storey drift, stiffness, and load-carrying capacity are evaluated. The results show that the type of infill wall significantly influences the overall performance of the structure. Brick masonry and concrete block infill increase stiffness and reduce deflection, while lightweight materials improve economy but offer less rigidity. The paper concludes that the proper selection of infill material enhances both the strength and cost-effectiveness of framed structures, contributing to safer and more efficient building designs.

METHODOLOGY

This study follows a structured and practical research approach to analyze and compare different types of retaining walls using STAAD.Pro. A mixed-method design is used, where both quantitative calculations and qualitative observations help in understanding the behavior of gravity, cantilever, and counterfort retaining walls. The process begins with collecting relevant data from literature, focusing on previous design methods, soil behavior, and the performance of different wall types. This literature review helps form a strong theoretical base.

After that, a representative imaginary site is selected to reflect common field conditions faced in civil engineering projects. The necessary geotechnical data such as soil density, angle of internal friction, bearing capacity, and backfill conditions are finalized. These parameters form the basic input for calculating earth pressure and other loads acting on the walls. Load estimation includes self-weight of the structure, lateral earth pressure, and surcharge loads to simulate realistic field conditions.

Once the design parameters are ready, each retaining wall type is modeled individually in STAAD.Pro. The software is used to create geometry, assign material properties, define supports, and apply loads. STAAD.Pro then performs the structural analysis to obtain bending moments, shear forces, displacements, and stress distribution. Multiple iterations are carried out to ensure that the model behaves realistically and that the design meets safety and stability requirements.

The results of all three wall types are recorded and compared to study their behavior under identical conditions. Differences in structural performance, reinforcement requirement, and overall cost are highlighted. The methodology concludes with interpreting the analysis results, identifying the most economical wall type, and giving suggestions for future improvements in retaining wall design.

MODELLING IN STAAD PRO

- Cantilever Retaining Wall

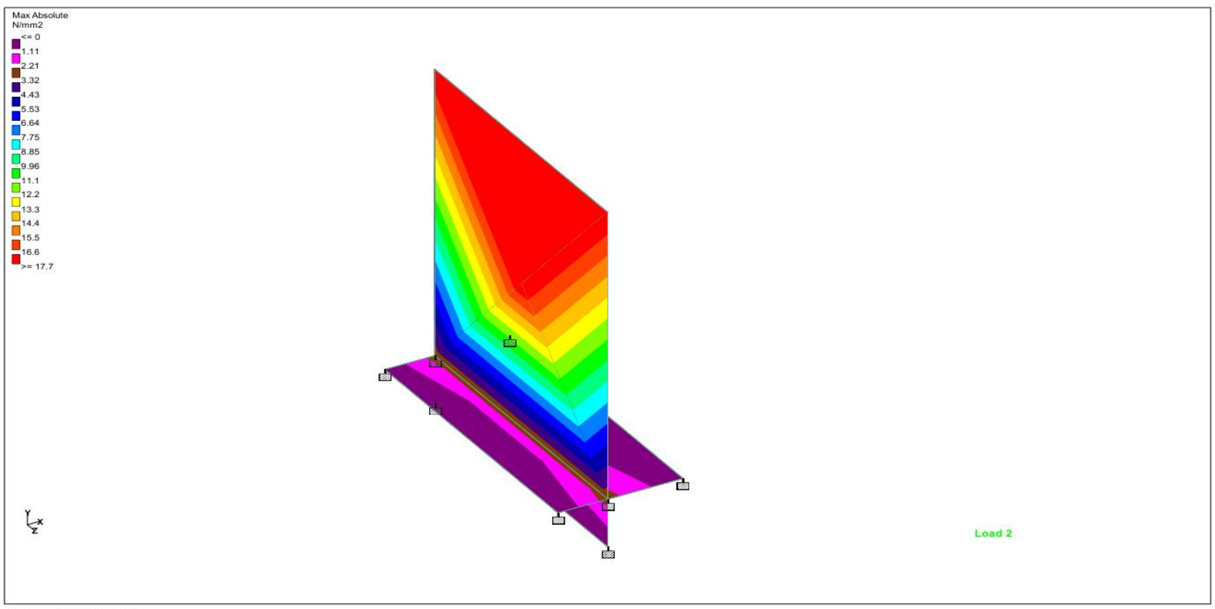
  Create Wall Geometry- Connect nodes

Nodes	X	Y	Z
1.	0.000	0.000	0.000
2.	0.000	6.000	0.000
3.	0.000	6.000	6.000
4.	0.000	0.000	6.000
5.	1.500	0.000	0.000
6.	1.500	0.000	6.000
7.	-1.000	0.000	0.000
8.	-1.000	0.000	6.000
9.	0.000	-1.000	0.000
10.	0.000	-1.000	6.000

- Plate Thickness

PROP	Node A (cm)	Node B (cm)	Node C (cm)	Node D (cm)	Material
1.	40.000	40.000	40.000	40.000	CONCRETE
2.	20.000	20.000	15.000	15.000	CONCRETE

- Design Conditions for Retaining Wall For the site conditions:
  - Selected wall height (H): 6.0 m (from finished ground level to footing level).
  - Soil unit weight (γ): 18 kN/m³ (backfill).
  - Angle of internal friction (φ): 30°.
  - Allowable bearing capacity (SBC): 180 kN/m²
  - Surcharge load (q): 10 kN/m² uniformly distributed on backfill
  - Concrete grade: M25 (fc = 25 MPa).
  - Reinforcement grade: Fe500
  - Stem thickness (top): 300 mm
  - Base slab thickness: 500 mm



MAX ABSOLUTE

DESIGN RESULTS & COMPARISON

From the STAAD.Pro analysis, each wall behaved differently under the same soil and load conditions. The gravity wall showed the highest bending moments and shear forces because it depends mainly on its own weight. This made it safe but very uneconomical due to more concrete usage.

The cantilever wall performed better, with reduced bending and shear compared to the gravity wall. It required moderate reinforcement and was comparatively economical. For medium wall heights, the cantilever wall provided a very good balance of strength and cost.

Parameter	Gravity Wall	Cantilever Wall	Counterfort Wall
Max Bending Moment	Highest	Medium	Lowest
Max Shear Force	Highest	Medium	Lowest
Reinforcement Required	Very high	Medium	Low
Stability	Good	Good	Very Good
Cost	High	Lowest	Medium
Best Suitable Height	Below 4 m	4–7 m	Above 7 m

The counterfort wall showed the best performance with the lowest bending moments and shear forces. The counterforts significantly reduce the stem bending, making it the most structurally efficient. The reinforcement required was the lowest among the three walls. However, due to more formwork and construction complexity, the cost was slightly higher than the cantilever wall.

CONCLUSION

This comparative study shows that no single retaining wall type is perfect for all situations. Each wall performs best in a specific height range. For the given imaginary site with a 6 m height, the Cantilever Retaining Wall is the most economical and structurally balanced option. It offers good stability, moderate reinforcement, and lower material cost compared to the other two walls.

Gravity walls are suitable for small heights but become uneconomical as height increases. Counterfort walls are ideal for higher walls above 7 meters due to their excellent load-carrying behavior and reduced bending moments. Using STAAD.Pro helps achieve accurate results and reduces manual errors, making it a valuable tool for modern structural design.

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