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Comparative Analysis of Cantilever Retaining Wall With And Without Column-Beam System

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Abstract - *Retaining Walls are essential in civil engineering projects, stabilizing soil, preventing erosion, and mitigating landslides. The successful design and analysis of retaining walls necessitate a deep understanding of soil mechanics, structural engineering principles, and the behaviour of different wall configurations. Among these configurations, the Cantilever Retaining Wall stands out due to its simplicity and effectiveness in resisting lateral earth pressures. However, when dealing with taller retaining walls, incorporating a column beam system can yield more economical outcomes. This research aims to comprehensively analyse cantilever retaining walls with and without a column-beam system. The research involves manual calculations and analysis using the STAAD Pro software and Excel spreadsheets for design optimization. The study strictly adheres to the guidelines outlined in the Indian Standard IS 456:2000 for reinforced concrete structures, ensuring compliance with industry standards. The research undertakes a comprehensive examination and design of both the Cantilever Retaining Wall (CRw) and the Column Beam Cantilever Retaining Wall (CBCRw) for a span of 35 meters and heights ranging from 3 meters to 9 meters, including their respective footings. By evaluating the construction cost of walls, this study concludes that CBCRw is more economical than the CRw.*

Key Words: Cantilever Retaining Wall, Column-Beam System, Stability, STAAD Pro, IS 456:2000, CRw, CBCRw

1. INTRODUCTION

A retaining wall serves as a construction element that is responsible for supporting and restraining soil or other substances at different elevations. It finds widespread application in the construction industry, serving to prevent erosion, control slopes, and create level surfaces on uneven ground. Retaining walls can be found in a variety of settings, including residential, commercial, and infrastructure projects.

The primary objective of a retaining wall is to withstand the lateral pressure exerted by the retained soil or substances. In the absence of a retaining wall, the natural tendency of soil is to move downward due to the force of gravity. This movement can result in slope instability, erosion, and potential damage to nearby structures or areas. By constructing a retaining wall, the soil is effectively confined and prevented from sliding or collapsing.

When designing a retaining wall, several factors need to be considered, including the type of soil being retained, the height and slope of the wall, drainage conditions, and anticipated loads and forces acting upon the wall. Engineers and architects employ principles of structural analysis to determine the appropriate dimensions, reinforcement, and construction techniques necessary to ensure the stability and durability of the retaining wall.

Use of retaining walls in basements opens a world of possibilities for space utilization and expansion. For Residential, commercial, or institutional purposes, these walls play a vital role in creating functional, safe, and attractive below-ground spaces.

1.1. TYPES OF RETAINING WALLS

• Gravity Retaining Wall

- Rely on their weight to withstand soil pressure.
- Constructed using dense materials like concrete or stone.
- Suitable for retaining moderate heights.
- Not economical for design.

• Semi-gravity Retaining Wall

- Min. reinforcement to be used in the wall to reduce the size of the wall.

• Cantilever Retaining Walls.

- Made of reinforced concrete & Designed with a base slab and a vertical stem.
- Relatively economical for design.
- Suitable for retaining moderate to high heights.

• Counterfort / Buttressed Retaining walls.

- Have additional vertical supports called counterforts on the backside of the wall to help distribute the lateral forces and provide extra stability.
- Suitable for higher retaining wall heights.

2. COLUMN-BEAM CANTILEVER RETAINING WALL

In CBCRw, Columns are introduced at the spacing of 3.5 m and Beams at a 4.5 m span. Both types of walls are analysed with the help of designed Excel spreadsheets and STAAD Pro software. The analysis results of the STAAD Pro software for all the heights were taken individually and compared with the analysis results of both types of retaining walls. The STAAD Pro output is then used in the Excel program to design it by the Limit state method. The quantities of Concrete and Steel were calculated with the help of a designed Excel sheet and compared the results.

Moment values along the "X" direction are less as compared to the "Y" direction in CRW's, still minimum steel as per code is provided based on the cross-sectional area of the wall.

By the introduction of columns & Beam in the stem, the "Mx" value is increased. Later certain moments are transferred to the columns. However, Columns are designed and provided in excess as compared to regular cantilever retaining walls still economy is achieved by saving reinforcement in the stem.

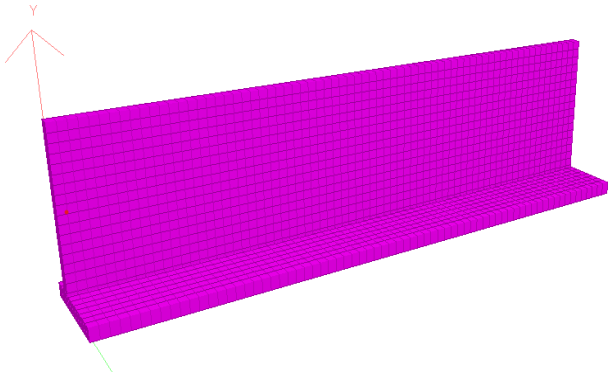

Fig -1: Simple Cantilever Retaining Wall (CRw)

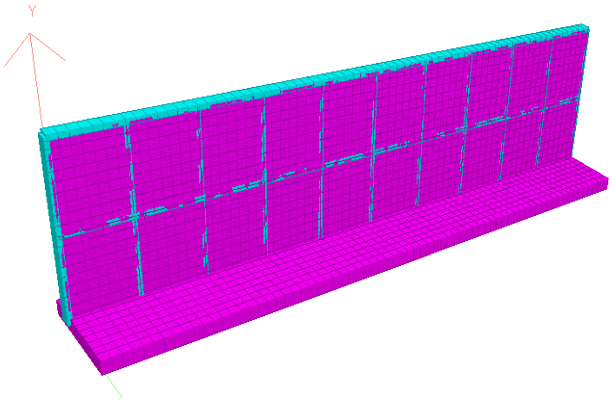

Fig -2: Column Beam Cantilever Retaining Wall (CBCRw)

3. METHODOLOGY

The research methodology integrates manual calculations of the cantilever retaining wall, analysis by STAAD Pro software, and preparation of Excel design spreadsheets. By adhering to the guidelines outlined in IS 456:2000, this study contributes to an enhanced understanding of efficient design approaches for retaining walls.

The length of the wall is taken as 35 m. CRw of height 4.5 m is manually analyzed by taking all the necessary checks as per the IS 456:2000 code i.e., overturning check, stability check, tension & shear check, & check for bearing pressure. and prepared the designed Excel spreadsheets program.

Analysis of the model: -

The following model is analyzed by the STAAD Pro software.

1. Cantilever Retaining wall, CRw

   (Height 3 m, 4.5 m, 6 m, 7.5 m & 9 m)

2. Column Beam Cantilever Retaining wall, CBCRw
   (Height 3 m, 4.5 m, 6 m, 7.5 m & 9 m)

In CBCRw, Columns are introduced at the spacing of 3.5 m and Beams at a 4.5 m span. Both types of walls are analysed with the help of designed Excel spreadsheets and STAAD Pro software. The analysis results of the STAAD Pro software for all the heights were taken individually and compared with the analysis results of both types of retaining walls. The STAAD Pro output is then used in the Excel program to design it by the Limit state method. The quantities of Concrete and Steel were calculated with the help of a designed Excel sheet and compared the results.

Table -1: Data Assumed for model analysis.

Data Assumed for model analysis	
The angle of repose (Φ)	30°
Density of soil (Y)	18 kN/m^3
Co-efficient of friction between concrete and soil (μ)	0.45
Active Earth Pressure (ka)	1/3
Length of wall	35 m
Use M-20 & Fe-415 steel	
The backfill is horizontal	

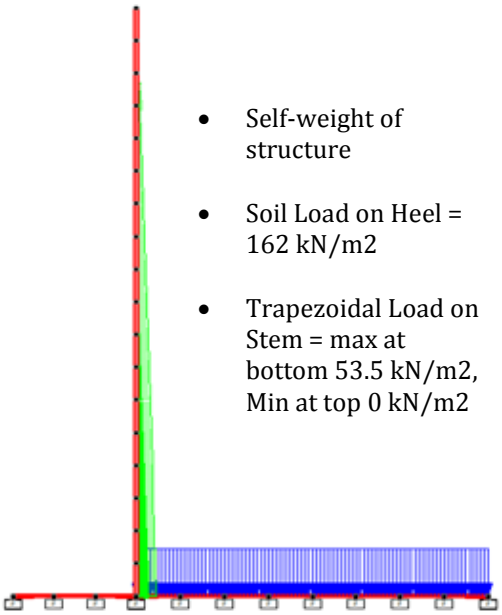

Fig -3: Loading on retaining wall.

Table -2: Properties at different heights.

Properties at different height							
L= 35m	Stem	Foundation		Column		Beam	
Ht.	Thick (m)	Width (m)	Thick (m)	B (m)	D (m)	B (m)	D (m)
3.0	0.30	1.80	0.25	0.30	0.45	0.25	0.375
4.5	0.40	2.80	0.30	0.30	0.55	0.35	0.375
6.0	0.45	3.00	0.40	0.30	0.60	0.40	0.375
7.5	0.55	4.50	0.50	0.38	0.70	0.50	0.375
9.0	0.65	5.50	0.75	0.375	0.75	0.65	0.375

4. RESULTS AND COMPARISON

Following Fig 4 & 5 shows the variation in the moment along the Y direction for CRw and CBCRw type retaining walls for the height of 9 m.

In CBCRw columns are provided at the span of 3.5 m along the length and Beam at the span of 4.5 along the height.

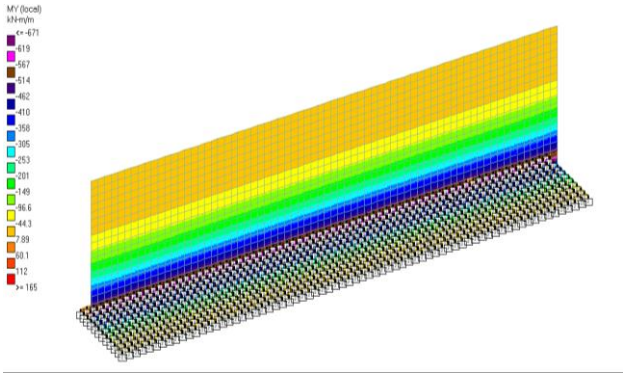

Fig -4: Moment Variation in CRw.

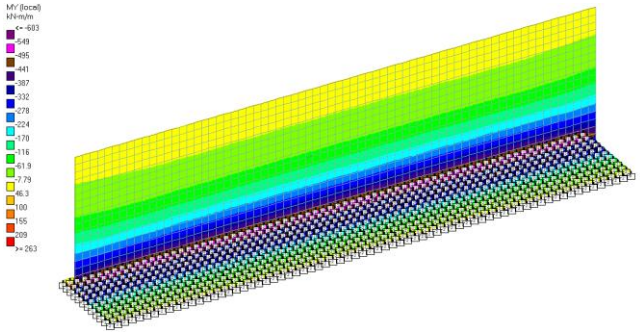

Fig -5: Moment Variation in CBCRw.

Table 3 shows the comparison of moment along Y direction at different height from 3 m to 9m for both the type of retaining wall i.e., CRw and CBCRw

Table -3: Max. Stem moment at different heights.

Max. Stem moment at different heights		
Length= 35	CRw	CBCRw
Height	My	My
3.0 m	42 KN-m	38 KN-m
4.5 m	136 KN-m	122 KN-m
6.0 m	324 KN-m	291 KN-m
7.5 m	422 KN-m	379 KN-m
9.0 m	671 KN-m	602 KN-m

Table 4 shows the comparison of concrete & steel quantities for both the type of retaining wall i.e., CRw and CBCRw of different heights from 3 m to 9m.

Table -4: Comparative Quantities

Comparative Quantities				
Length= 35	CRw		CBCRw	
Height	Concrete (m3)	Steel (kg)	Concrete (m3)	Steel (kg)
3.0 m	47.25	2882	48.08	2644
4.5 m	92.40	5636	93.32	5132
6.0 m	136.50	8327	138.81	7635
7.5 m	223.13	13611	227.11	12491
9.0 m	349.13	21297	352.84	19406

5. CONCLUSIONS

Based on the study carried out, the following conclusions are drawn:

The manual results of the bending moment of the retaining wall with and without column beam have been compared with STAAD Pro results.

1. Distribution of pressure below the footing (strip type) varies on the addition of columns.

2. Maximum reduction in the moment along the Y axis is about 10% by providing a column beam system at 3.5 m intervals.

3. The overturning moment gets reduced due to the provision of columns.

4. The steel is reduced by providing a Column Beam system to the cantilever retaining wall.

5. Increase in column and beam size, decreasing the moment in the stem but can be increased up to a certain size taking the economy factor into account.

6. It is observed that the saving in cost of construction is 10-15% by the provision of a column Beam over the conventional cantilever retaining wall. There is about a 10% saving on steel.

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