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Designing of Loft Retaining Wall & Comparison with other Types of Retaining Walls

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ABSTRACT

Retaining wall structures are used for holding back earth material. The various reasons are for constructing the retaining walls, like preventing erosion, aesthetic purposes. The main purpose of a retaining wall is to separate two different levels of soil or ground when there is a need for a change in elevation. Retaining walls plays an important role in protecting the structures from collapsing and natural problems such as soil erosion. Earth retaining structures include cantilever retaining wall, sheet pilings, bulkheads, basement walls, and special types of retaining wall. The special types of walls include counter fort retaining wall, buttress retaining wall, and retaining wall that rest on piles etc. Loft retaining wall can be considered as a special type of retaining wall. A loft retaining wall is an uncommon type of retaining wall. The pressure relief shelf towards the backfill side of retaining wall helps to decrease the total earth pressure on the stem which results in increasing the overall stability of the wall. Lofts are horizontal platforms, which are constructed monolithically with the stem of wall, and extend into the backfill at right angles, throughout the length of the retaining wall. A number of such shelves is constructed at regular spacing along the height of the wall. The concept of providing loft on the backfill side of retaining wall reduces the total earth pressure on the wall, due to which it reduces the thickness of the wall and ultimately gives more economical design. The parametric study is carried out to find the effect of number of lofts, width of lofts, loft position and variation in the length of loft, etc.

Keywords: Retaining wall, Loft retaining wall, Total earth pressure, backfill. Economical design.

Introduction

Retaining walls are vital structures in civil engineering, serving to hold back soil and prevent erosion. They are crucial in various applications, from landscaping to infrastructure projects, providing stability and support to slopes and vertical grade changes. Traditional retaining wall designs, such as gravity walls and cantilever walls, have been widely used but are limited in their maximum height and can be costly to construct, particularly for taller walls.

In recent years, there has been a growing interest in innovative approaches to retaining wall design that offer improved efficiency and cost-effectiveness. One such approach is the use of loft retaining walls, which incorporate horizontal platforms, or "lofts," into the backfill material behind the wall. These lofts are constructed monolithically with the wall stem and extend into the backfill at right angles, providing additional support and reducing the lateral earth pressure on the wall.

The concept of loft retaining walls is based on the principle of reducing the total earth pressure on the wall, thereby allowing for a more economical design. By strategically placing lofts at regular intervals along the height of the wall, engineers can optimize the wall's stability and reduce the amount of construction material required. This can lead to significant cost savings, especially for retaining walls with large heights or lengths.

This research paper aims to explore the design and performance of loft retaining walls compared to traditional retaining wall designs. The study will investigate the effects of various loft parameters, such as the number of lofts, their width, and their position, on the stability and cost-effectiveness of the wall. The research will also include a comparative analysis of loft retaining walls and other types of retaining walls, such as gravity walls and cantilever walls, to determine the advantages and disadvantages of each design.

Through this research, we hope to provide valuable insights into the potential of loft retaining walls as a cost-effective and efficient solution for retaining wall design. By understanding the factors that influence the performance of loft retaining walls, engineers and designers can make informed decisions when selecting retaining wall systems for their projects, ultimately leading to more sustainable and economical infrastructure development.

Retaining wall is a structure that holds or retains soils behind the retaining wall. Usually, retaining walls can be built by materials like: concrete, timber, rocks or boulders. Retaining wall is majorly used as a separator between soils that have different elevation. A retaining wall is structure which is constructed to retain lateral earth pressure of soil. The main function of retaining wall is to stabilize hill slide and control erosion. Retaining walls are mainly provided in construction of Roads, Embankment, Bridge abutments, basement in building etc, as shown in Fig.1.1.

The forces acting on retaining wall are -

Resisting forces

Driving forces

Earth pressure

Lateral earth pressure

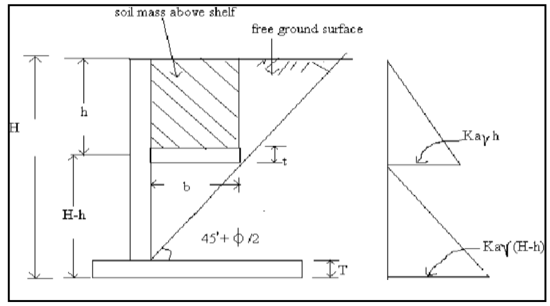

Fig 1 Roadside Retaining Wall

Fig 2 Retaining Wall with loft

Besides the self-weight, the main predominant force for analysis and design of the retaining wall is lateral earth pressure. The lateral earth pressure behind the wall depends on the angle of internal friction and the cohesive strength of the retained material, as well as the direction and magnitude of movement of the stems. Its distribution is typically triangular, least at the top of the wall and increasing towards the bottom. The earth pressure could push the wall forward or overturn it if not properly analyzed. Retaining walls are encountered and constructed in various fields of engineering such as roads, harbors, dams, subways, railroads, tunnels, mines and military fortifications.

Some factors to consider are - the material of the foundation, water content in soil, soil being landfilled, pressure from the soil's surface, friction provided from the retaining wall, etc. With these factors, we could estimate and design the size, materials, and the strength needed to build the retaining wall. The engineering essence of retaining wall is to keep the retained soil in certain shape and prevent it from falling (stability), or to restrain the deformation of the wall and the backfill to maintain its service function (serviceability). Lateral earth pressure generated by retained backfill on the wall and relevant soil / wall deformations are two main facets of engineering design and analysis of retaining walls

Methodology

The methodology for this research paper involves a comprehensive analysis of loft retaining walls, focusing on their design, performance, and cost-effectiveness compared to traditional retaining wall designs. The study will utilize theoretical calculations and Excel-based optimization to analyse the effects of various loft parameters on the stability and cost of the walls.

Selection of Parameters: The study will consider a range of parameters for the loft retaining walls, including the number of lofts, their width, and their position along the height of the wall. These parameters will be varied to assess their impact on the wall's stability and cost.

Design of Loft Retaining Walls: Using the selected parameters, the study will design loft retaining walls of varying heights and lengths. The design will include determining the dimensions of the lofts, the thickness of the wall, and other relevant details to ensure structural stability.

Stability Analysis: The stability of the loft retaining walls will be analyzed using established principles of soil mechanics and structural engineering. Factors such as the factor of safety against overturning, sliding, tension, and bearing failure will be considered to assess the walls' overall stability.

Cost Analysis: The cost of constructing the loft retaining walls will be calculated based on the design parameters and prevailing construction rates. The study will compare the cost of constructing loft retaining walls to that of traditional retaining walls to evaluate their cost-effectiveness.

Comparative Analysis: A comparative analysis will be conducted between loft retaining walls and other types of retaining walls, such as gravity walls and cantilever walls. This analysis will consider factors such as stability, cost, and ease of construction to determine the advantages and disadvantages of each design.

Excel-Based Optimization: To optimize the design of the loft retaining walls, an Excel-based optimization tool will be developed. This tool will allow for the input of various parameters and will automatically calculate the optimal design for the desired stability and cost-effectiveness.

Sensitivity Analysis: A sensitivity analysis will be conducted to assess the impact of uncertainties in input parameters on the design and cost of the loft retaining walls. This analysis will help identify the most critical parameters affecting the walls' performance.

Through this methodology research aims aims to provide valuable insights into the design and performance of loft retaining walls, highlighting their potential as a cost-effective and efficient solution for retaining wall design in civil engineering project.

3. Result

The theoretical calculation on stability of retaining walls are as shown in Table.

Table 1 - Result of retaining wall without loft

Sr. No.	Types of Retaining Walls	FOS of overturning	FOS of sliding	Concrete (m3)
1	Gravity wall	3.27	1.65	2368
2	RCC Counterfort retaining wall	3.56	1.786	6143.31

COST (DSR RATES)

The amount of retaining walls is calculated by accounting the rates of various item from DSR as shown in Table

Table 2 -Cost of retaining wall without loft

Sr. No.	Types of Retaining Walls	Particulars	Quantity	Rate (Rs.)	Per	Amount (Rs.)
1	Gravity wall	Plain Cement Concrete	4750	4647.00	m3	22073250
2	RCC Counterfort retaining wall	Reinforced Cement Concrete	2772.5	5551.00	m3	15112598

Design and cost results of counterfort retaining wall with loft by using excel

After fixing position of loft, optimization of retaining wall is done to minimize the size, following Table shows optimized dimensions of retaining walls.

Table 3 - Design Results of Counterfort Retaining Wall with Loft by using Excel

Counterfort Retaining Wall with Loft

Height of Retaining Wall	**8 m**		**12 m**			**16 m**			**20 m**		
Thickness of Loft (m)	**0.4**		**0.5**			**0.6**			**0.8**		
Number of Loft	**1**	**2**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Width of Loft (m)	**2.15**	**2.15**	**3.77**	**3.77**	**3.77**	**4.65**	**4.65**	**4.65**	**5.91**	**5.91**	**5.91**
No. of Counterfort	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
Spacing of Counterfort (m)	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Base width of RW (m)	**4**	**3.3**	**6.5**	**5.5**	**4.8**	**8**	**6.7**	**5.9**	**10**	**8.5**	**7.4**

Earth Pressure (kN/m2)	**145.82**	**97.37**	**288.271**	**192.48**	**144.59**	**547.31**	**365.46**	**274.53**	**844.15**	**563.66**	**423.42**
MO (kN.m)	**583.89**	**412.78**	**1622.92**	**1147.32**	**885.03**	**4245.7**	**3001.5**	**2315.29**	**8132.5**	**5749.2**	**4434.9**
FOS for overturning	**2.1**	**2.02**	**2.8**	**2.84**	**2.8**	**2.23**	**2.22**	**2.24**	**2.27**	**2.32**	**2.34**
FOS for sliding	**2.06**	**2.55**	**2.38**	**3.01**	**3.51**	**2.13**	**2.67**	**3.14**	**2.14**	**2.73**	**3.21**
Eccentricity (m)	**0.601**	**0.53**	**0.55**	**0.45**	**0.407**	**1.07**	**0.913**	**0.797**	**1.31**	**1.07**	**0.929**
qmax (kN/m2)	**264.69**	**273.96**	**294.038**	**291.98**	**295.69**	**486.39**	**490.93**	**489.97**	**597.62**	**588.68**	**585.66**
qmin (kN/m2)	**13.64**	**5.06**	**96.67**	**99.45**	**96.42**	**52.623**	**49.27**	**51.22**	**71.74**	**82.01**	**86.21**
Amount (Rs.)	**664027**	**710388**	**1466717**	**1582106**	**1754611**	**2483574**	**2609710**	**2859001**	**3905109**	**4186673**	**4603289**

Table 4 - Analysis of Retaining Walls

Retaining Walls

Type of Retaining Wall	**Gravity Retaining Wall**	**Counterfort Retaining Wall**	**Counterfort Retaining Wall with Loft**		
Height of Retaining Wall	**20 m**	**20 m**	**20 m**		
Thickness of Loft (m)	**-**	**-**	**0.8**		
Number of Loft	**-**	**-**	**1**	**2**	**3**
Width of Loft (m)	**-**	**-**	**5.91**	**5.91**	**5.91**
Number of Counterfort	**-**	**5**	**13**	**13**	**13**
Spacing of Counterfort (m)	**-**	**5**	**2**	**2**	**2**
Base width of RW (m)	**16**	**16**	**10**	**8.5**	**7.4**
Earth Pressure (kN/m^2)	**66.6 kN/m at 10m from base** **1198.8 KN/m at 6.67m from base**	**1728**	**844.15**	**563.66**	**423.42**
M_O (kN.m)	**8661.99 kN.m**	**13824**	**8132.5**	**5749.2**	**4434.9**
FOS for overturning	**3.27**	**3.56**	**2.27**	**2.32**	**2.34**
FOS for sliding	**-**	**1.78**	**2.14**	**2.73**	**3.21**

Eccentricity (m)	**-**	**0.8447**	**1.31**	**1.07**	**0.929**
q_{max} (kN/m^2)	**-**	**470.44**	**597.62**	**588.68**	**585.66**
q_{min} (kN/m^2)	**-**	**244.1**	**71.74**	**82.01**	**86.21**
Amount (Rs.)	**22073250**	**15112598**	**3905109**	**4186673**	**4603289**

4. Conclusion

From above study we concluded that:

Proper selection, number, location, and dimensions of loft can considerably reduce the total contact pressure below the base slab and making the retaining wall much safer in bearing capacity failure mode.

Lofts are susceptible to modify the wall movement of the retaining wall depending upon its width and location along the height of the wall.

The provision of the loft to the wall can lead to significant improvement in the stability of the retaining wall to carry the static surcharge loading on the backfill surface compared to a wall without a loft.

Designing of economical loft retaining wall for reducing lateral earth pressure and to increase the stability of retaining wall.

Each counterfort retaining wall of height 8 m, 12 m, 16 m & 20 m are compared without loft & with loft on the basis of number of lofts, thickness of loft, earth pressure & cost.

The provision of 2 number of loft results in reduced earth pressure, base width and cost of retaining wall as compared to the provision of 1 loft.

The counterfort retaining wall with loft is economical as compared to counterfort retaining wall without loft.

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