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Comparative Study of Relief Shelves and Anchored Cantilever Retaining Wall

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Abstract - *Earth retaining structures are provided to support the vertical or nearly vertical face of the soil. Retaining wall is the most common earth retaining structure. The objective of this study is to suggest the viable option available for the construction industry with considering cost optimization is the need of the hour. Retaining walls are designed to restrain against the lateral earth thrust while keeping its original position intact. Use of relief shelf and anchored retaining wall proves to be an effective tool to reduce the bending moment and increase the stability of retaining wall. A study has been made to compare various types of retaining wall. This study presents a lucid model of cantilever retaining wall, Relief Shelf Retaining wall and Anchored Retaining wall having different cases. This work studies the different types of retaining walls where a comparative study of these walls have been carried out with the help of finite element software SAP-2000. Typically, Cantilever Retaining Wall, Relief Shelf Retaining Wall and Anchored Retaining wall can be compared on the basis of Maximum Moment and top wall displacement criteria. Accordingly, the results will be evaluated.*

***Key Words*: Cantilever retaining wall, single anchor, double anchor, single shelf, double shelves, SAP 2000, etc.**

1. INTRODUCTION

Retaining wall plays a pivotal role in earth retaining structures. For higher height of retaining wall one can go for various special types of retaining wall such as relief shelf and anchored retaining wall. From the past studies it was observed that the cantilever retaining wall and counterfort retaining wall proves to be uneconomical solution for the higher height of retaining structures. From past studies, it was observed cantilever and counterfort type of retaining wall extremely uneconomical for the height more than 6 m susceptible to heavy dead loads, and in some cases, lead to collapse of the structure. Hence, to improve the economy in such type of structure, a control solution has been proposed in the form of relief shelves retaining wall and anchored retaining wall.

1.1 Modelling

1.1.1 Modelling of Cantilever retaining wall with relief shelf

The model for relief shelf cantilever retaining wall using thick shell element is modelled using SAP-2000. All the models are having the same data and c/s dimensions except the different parameters of models as grouped in Table 3 which is varying in each case for parametric study. Dimensional properties for different types of models are as shown in Table 1. Properties of soil like dry density, modulus of elasticity, angle of internal friction, Poisson's ratio, and safe bearing capacity of soil and properties of concrete like grade of concrete are as shown in Table 2.

Table -1: Geometry of Retaining Wall

Structural Elements	Dimensions
Height of Retaining Wall	10.0 m
Width of Toe Slab	2.0 m
Width of Heel Slab	3.0 m
Thickness of stem (t_s)	0.5 m
Thickness of footing slab	0.8 m
Width of Relief Shelf	1.0 to 3.0 m
Thickness of Relief Shelf	0.1 to 0.5 m
Depth ratio (h_1/H)	0.1 to 0.8

Table -2: Material Properties

Property	Soil	Retaining Wall
Density	20 kN/m^3	25 kN/m^3
Modulus of Elasticity	20 N/mm^2	25000 N/mm^2
Angle of internal friction	30^o	-
Safe bearing capacity	180 kN/m^2	-
Poisson's Ratio	0.5	0.2

For cantilevers with one pressure relief shelf and two pressure relief shelves, the wall is analyzed. The first rack is at depth h_1 from the top of the wall, and the second is at depth h_2 from the bottom of the wall. The model discernment in Figure 1.1 is demonstrated.

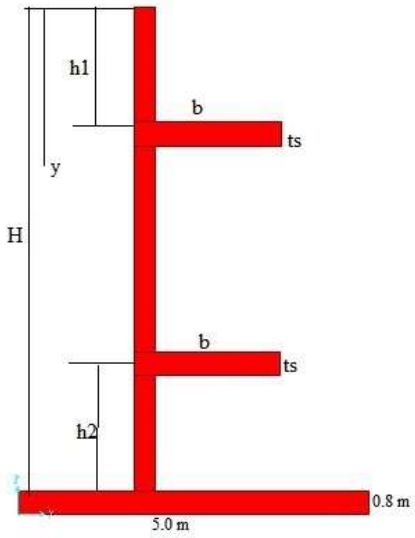

Fig -1.1.1: Discretization of the Model

Figure 1.1.2 and Figure 1.1.3 shows the sketch of modelled cantilever retaining wall with one relief and two shelves retaining wall using thick shell element in SAP-2000.

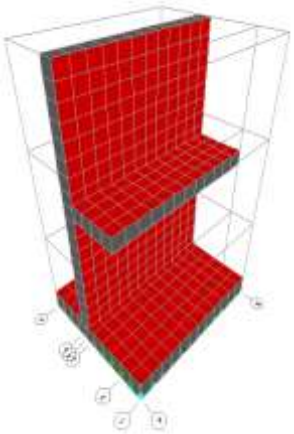

Fig. -1.1.2: Schematic 3D Model of Cantilever retaining wall with one shelf

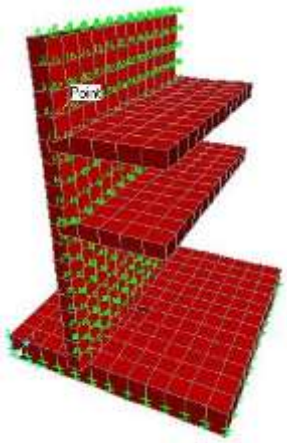

Fig. -1.1.3: Schematic 3D Model of Cantilever retaining wall with two shelves

Table -3: Details of different Models

Models' Group Model	Model
Group (1)	Retaining wall without shelves
	Single relief shelf, h_1/H= 0.7, b= 2 m, ts= 0.5 m
	Two relief shelves, h_1/H= 0.3, h_2/H= 0.3, b= 2 m, ts= 0.5 m
Group (2)	Single relief shelf, h_1/H= 0.7, b= 2m, ts= 0.1, 0.2, 0.4, 0.5 m
	Single relief shelf, h_1/H= 0.7, b= 1, 2, 3 m, ts= 0.2 m
	Two relief shelves, h_1/H= 0.3, h_2/H= 0.3, b= 2m, ts= 0.1, 0.2, 0.4, 0.5 m
	Two relief shelves, h_1/H= 0.3, h_2/H= 0.3, b= 1, 2, 3 m, ts= 0.2 m
Group (3)	Single relief shelf, b= 2m, ts= 0.2m, h_1/H= from 0.1 to 0.9

Analyses and discussions

Table -4: Comparison of results for Without Relief Shelf and With Relief Shelf

Sr. no.	Description	Without Relief Shelf	With Single Relief Shelf	With Double Relief Shelves
1	Moment in wall	1321.56 kN-m	862.40 kN-m	770.43 kN-m
2	Top wall Displacement	155 mm	122.4 mm	99.1 mm
3	FOS against sliding	1.02	1.85	2.05
4	FOS against Overturning	2.04	2.46	2.60
5	Reduction in Moment	-	34.73%	41.07%

It is observed that providing a single shelf and double shelves decreases the resulting bending moment by about 34.73% and 41.07% compared to a cantilever retaining wall without shelves.

From the above discussions the following conclusions can be made as follows:

- This work provides information on the impact of attaching racks to a retaining cantilever wall.
- The attachment of racks to the retaining system showed that the complete lateral earth stress decreases. This reduction makes the retention structures more stable and lowers the bending moment.
- A parametric study examined the efficiency of the shelving rigidity and position on the lateral earth pressure distribution, top wall displacement movement and maximum bending moment.
- The project also concludes the optimized width and thickness of the relief racks. The racks reduce the peak bending moment and the top wall displacement of the wall considerably. This reduction in side stress improves the stability of the retaining system.
- Retaining Wall with relief shell leads to decrease in Moment in the wall as well as increases the stability of wall.

1.1.2 Modelling of Cantilever retaining wall with single and double and anchor

For walls of more than 6 m height, anchored retaining wall is generally suggested. The necessary depths of penetration and cross sectional region of the retention wall were reduced by means of anchor cables. For the design of wall retenders, many successive operations, like lateral pressures and force on the wall, penetration depth and pressure on the wall were required. A numerical parametric study on single and double anchor retaining walls subject to sandy retaining of different types was performed using a Finite Element Program from SAP 2000. As illustrated in Figures 1.2.1 and 1.2.2, the typical wall segments of the one and double anchored retaining wall.

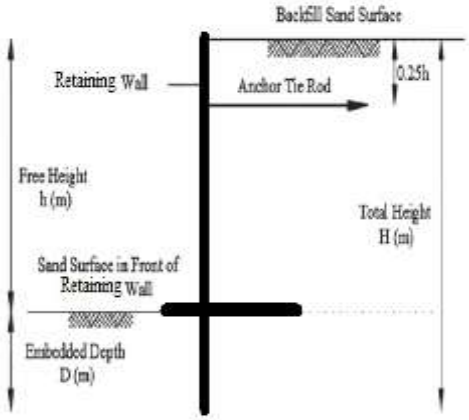

Fig. -1.2.1: Typical wall section of single anchored retaining wall

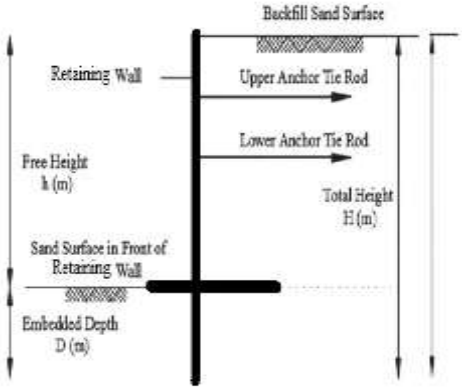

Fig. -1.2.2: Typical wall section of double anchored retaining wall

Schematic model of single and double anchored retaining wall is as shown in Figure 1.2.3 and Figure 1.2.4 respectively.

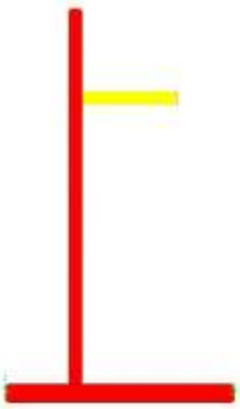

Fig. -1.2.3: Schematic model of single anchored retaining wall

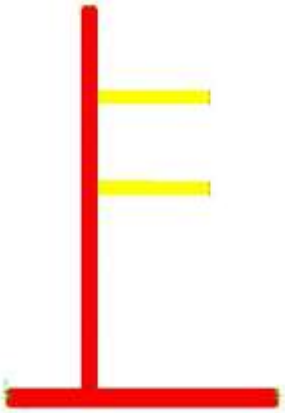

Fig. -1.2.4: Schematic model of double anchored retaining wall

Analyses and discussions

Table -4: Comparison of results for single and double anchored retaining wall

Sr. no.	Description	Without Anchor	With Single Anchor	With Double Anchor
1	Moment in wall	1321.56 kN-m	962.40 kN-m	870.43 kN-m
2	Top wall Displacement	155 mm	117 mm	108 mm
3	FOS against sliding	1.02	1.75	1.95
4	FOS against Overturning	2.04	2.16	2.40
5	Reduction in Moment	-	27.17%	34.14%

It is observed that providing a single anchor and double anchor decreases the resulting bending moment by about 27.17% and 34.14% compared to a cantilever retaining wall without shelves.

For the various cases studied under consideration, the anchored forces developed in the lower anchor rods are always greater than those developed in the upper anchor rods. The reason for this is that the lower anchor force consists of the reaction to an upper span common with the upper anchor and a larger lower span supporting a higher lateral pressure. However, the upper anchor force consists of a smaller reaction to the upper common span and the upper cantilever portion of the retaining wall where the lateral pressure has relatively small value.

2. COMPARISION OF RESULTS

In the present study different types of retaining wall were analysed. From the above study following results are developed.

2.1 Variation of bending moments

Table -5: Bending moment variation

Sr. No.	Description	Moment in the wall (kN.m)
1	Cantilever wall Without Shelf (CWWS)	1321.56
2	Cantilever Wall with Single Shelf (CWSS)	862.40
3	Cantilever Wall with Double Shelf (CWDS)	770.43
4	Single Anchor Cantilever Wall (SACW)	962.40
5	Double Anchor Cantilever Wall (DACW)	870.43

Above table can be graphically studied as shown in Figure 2.1

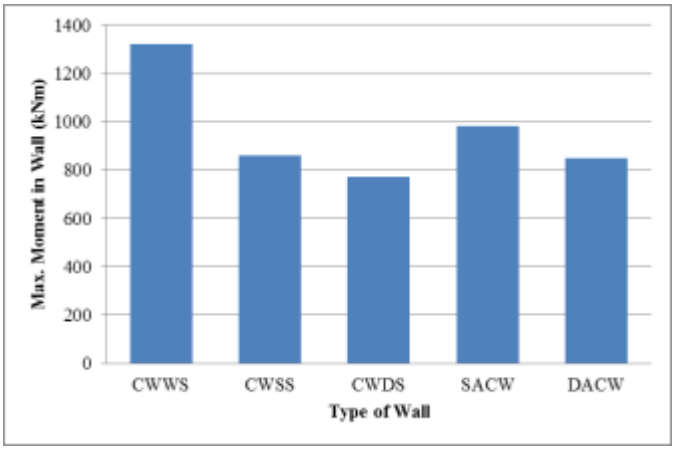

Fig. -2.1: Bending Moment variations of various types of Retaining Wall

2.2 Variation of Displacement values of wall at top

Table -6: Top Wall Displacement

Sr. No.	Description	Displacement of stem at top (mm)
1	Cantilever wall Without Shelf (CWWS)	155
2	Cantilever Wall with Single Shelf (CWSS)	122.4
3	Cantilever Wall with Double Shelf (CWDS)	99.1
4	Single Anchor Cantilever Wall (SACW)	117
5	Double Anchor Cantilever Wall (DACW)	108

Above table can be graphically studied as shown in Figure 2.2

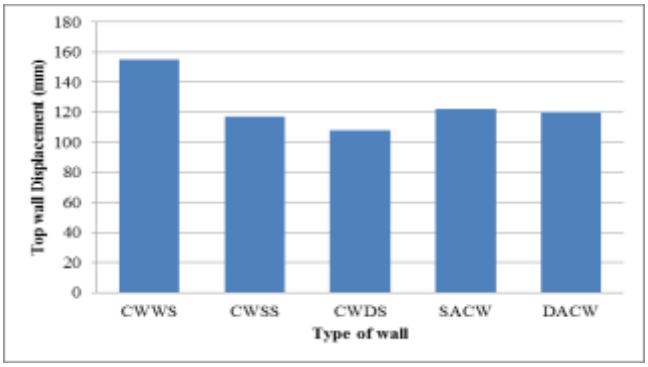

Fig. -2.2: Top wall displacement variations of various types of Retaining Wall

From the above bar chart in Figure 2.1 the maximum bending moment in the wall is decreased 41.07% for double relief shelves as compared to the simple cantilever retaining wall, while it decreased by 34.12% in case of single relief shelf cantilever retaining wall. It is also observed that providing a single anchor and double anchor decreases the resulting bending moment by about 27.17% and 34.14% compared to a cantilever retaining wall without shelves. From chart in Figure 2.2 the top wall displacement is found to be least for the double relief shelves. Thus it is clear from the above study that the double relief shelves will be the most economical for the design as well as stability point of view.

3. CONCLUSIONS

- The provision of relief shelves and anchoring the wall leads to the reduction of lateral thrust and leads to the more stable retaining structure.
- Location, width and thickness of the pressure relief shelves are the key factors for deciding the provision of relief shelf as they should generate least top wall displacement and the least maximum bending moment in the structure to achieve the economy.
- From all the cases studied top wall displacement and the maximum bending moment in the wall were found to be least in Double relief shelves cantilever retaining wall.
- Anchoring can be one of the alternative technique for economical design of wall as relief shelves retaining wall are difficult to construct on site.

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