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Assessment of Cantilever Retaining Wall with Shelves and Design by Using Staad-Pro Software

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ABSTRACT

Retaining walls are structures designed to bound soils between two different elevations; therefore they are mainly exposed to lateral pressures from the retained soil plus any other surcharge. Competent design of retaining walls can maximize land use and substantially increase property value. This article discusses the required steps in the design of either concrete or masonry un-piled cantilever retaining walls. Our software STAAD-PRO will be used to support the discussion. Retaining walls serve as rigid structures to support soil masses laterally, allowing soil to different levels on both sides. Various types of retaining walls exist, such as gravity walls, cantilever walls, counter fort walls, anchored walls, piled retaining walls, and buttress walls. the stem is the vertical member holding the backfill, the Toe *is the portion of the footing at the front of the wall, the heel is the portion of the footing at the backfill side, and the* shear key *projects down under the footing. The images below show the geometry of a typical cantilever retaining wall.*

Keywords: *buttress walls, counter fort walls, gravity walls, Retaining walls, STAAD-PRO,*

1. INTRODUCTION

1.1. GENERAL

The purpose of a retaining wall is to resist the lateral pressure exerted by soil when there's a desired change in ground elevation that exceeds the angle of repose of the soil. Retaining walls serve as rigid structures to support soil masses laterally, allowing soil to be retained at different levels on both sides. Various types of retaining walls exist, such as gravity walls, cantilever walls, counter fort walls, anchored walls, piled retaining walls, and buttress walls. Among these, the cantilever wall is the most common and cost-effective for heights up to 6 to 8 meters. The focus of the current project is to design an economically optimal cantilever retaining wall section, ensuring stability against overturning, sliding, excessive foundation pressure, and water uplift. To achieve this, the walls are designed with safety factor of 1.55 against lateral sliding and overturning. Stability assessment is based on the provided section, andtheprojectinvolvesanalyzingnumerousretaining wall sections to identify the most economic design. These walls commonly support earth, coal, replies, and water, making optimize on crucial for cost-effectiveness. The primary force acting on retaining walls is lateral earth pressure, which can lead to bending, sliding, and overturning of the wall. Proper design and installation of retaining walls must account for the tendency of retained material to move due to gravity, resulting in lateral earth pressure. This pressure depends on factors like the angle of internal friction (φ), cohesive strength (c) of the soil, and the direction and magnitude of the retaining structure's movement.

1.2 TYPESOFRETAININGWALL

1. Gravity retaining wall
2. Cantilever retaining wall
3. Gabion retaining wall
4. Counter-fort retaining wall
5. Anchored retaining wall
6. Piled retaining wall

1.3 THE NEED OF RETAINING WALL WITH RELIEF SHELVES

Retaining walls are an integral part of almost all infrastructure projects, to support vertical back fills. Rigid on-yielding retaining walls are made usually as gravity retaining walls. These gravity retaining walls are bulky in size. There may be situations where high retaining walls are required to resist the lateral earth pressure. However, massive gravity walls may not be viable due to economic and space constraints. Also, in some cases, sufficient yielding of rigid cantilever retaining walls may not be permitted due to site constraints, and these walls need to be designed for higher earth pressures, than the active earth pressures. One alternative to tackle such issues is to reduce the lateral thrust on the wall. There are many techniques available to reduce the earth pressure, such as use of light weight backfill, inclusion of compressible geo-foam, provision of relief shelves. A retaining wall with pressure relief shelves is one of the least explored techniques to reduce the earth pressure on retaining walls. Although these types of walls have already been constructed at several places, their working mechanism, and lateral earth pressure calculation procedure is still immature for these retaining walls. Hence, present study is aimed to understand the behavior of such walls and to explore the effectiveness of relief shelves.

2. LITERATURE SURVEY

Yun Que et al. (2022) [1] This study investigates a unique type of retaining wall, the cantilever retaining wall with a long relief shelf, focusing on failure when the wall rotates at its base. Through finite-element limit analysis, it identifies failure patterns: initial failures at the wall heel, followed by a third failure surface at the shelf's end.

Chauhan et al. (2021) [2] this study examines statically loaded walls with multiple relief shelves retaining dry cohesion less backfill It employs mechanics and bending theory to develop a novel closed-form solution that addresses the joint between relief shelf and wall stem. This solution evaluates shear force, bending moment, and deflection at any wall section, offering designing sights for optimal relief shelf width.

Chauhanetal.(2021)[3]This study investigates retaining wall stability ,comparing relief shelf designs to conventional cantilever walls. Combining limit analysis and finite element method, it evaluates the performance of these walls under incremental, uniformly distributed surcharge loading.

Kalemci et al. (2020) [4] This article aims to optimize the design of a light weight cantilever reinforced concrete retaining wall with a shear key using the Grey Wolf Optimization(GWO) algorithm implemented in MATLAB. The optimization technique mimics grey wolf hunting behaviour.

Chauhan et al. (2018) [5] This study is motivated by a wall failure incident in Hyderabad, India, focusing on a 3D rigid cantilever wall subjected to static analysis within cohesion less soil. The research investigate show relief shelf width and position impact displacement, deflection, settlement, and earth pressure. FLAC 3D software is employed for analysis.

Chauhan et al. (2016) [6] Cantilever retaining wall with pressure relief shelves is considered one of the special types of retaining walls. The concept of providing pressure relief shelves towards the backfill side of a retaining wall reduces the total earth pressure on the wall, which results in reducing the thickness of the wall andultimately to get an economic design.

Balwan et al. (2011) [7] studied the earth retaining structures cost is major cost in any infrastructural developmental project. Saving in earth retaining structure influences the project cost.The use of gravity wall coupled with loft gives excellentcombination, resulting into about 40% cost saving.

3. STRUCTURE CONFIGURATION

3.1 MODEL DESCRIPTION

To achieve the objectives, 14 m retaining wall is analysed using Staad pro. Analysis and design have been carried out by considering the stated properties of cohesion less backfill and also height of backfill to be retained for cantilever retaining wall and cantilever retaining wall with relief shelf. The tentative dimensions for cantilever retaining wall are adopted based on prevailing thumb-rules. Klein's method is used to calculate lateral earth pressure in the retaining wall with shelves. Parameters used in modelling and section of wall are discussed below.

Following are the parameters used in the modelling:

1. Height of wall to support backfill = 14 m
2. Unit weight of soil (γ) = 20 kN/m3
3. Bearing capacity of soil (qf) = 300 kN/m2
4. Angle of internal friction = 300

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5. Coefficient of friction between base slab and soil = 0.55

6. Unit weight of reinforced cement concrete = 25 kN/m3

7. Grade of concrete: M 25

8. Grade of steel: Fe 500

3.2 SECTION OF RETAINING WALL

Following are the section details:

1. Width of base slab (B) = 7 m, 6.5 m and 6 m are used in this study. (Width of base slab should be within 0.4H to 0.7H)

2. Thickness of stem at top of retaining wall (T) = 0.30 m

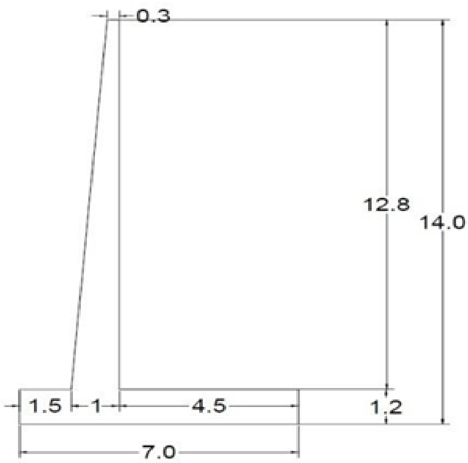
3. Thickness of stem at intersection of stem and base sla (Ts) = 1 m (Thickness of intersection should be within H/12 to H/8)

4. Thickness of base slab (Tb) = 1.2 m (Thickness of base slab should be within H/12 to H/10)

5. Projection of base slab towards toe = 1.5 m (Projection must be within range of

0.20 B to 0.40 B)

6. Thickness of relief shelf = Base slab thickness / 2 = 1.2 / 2 = 0.6 m Where, B = Width of Base Slab (m)



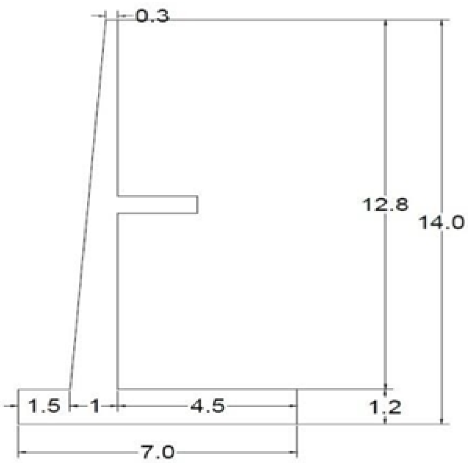


Figure 3.1 Section of retaining wall

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4. RESULT AND DISCUSSION

4.1 Result for Staad - pro models

Cantilever retaining walls without shelves are included within this group 1. Base width variation is carried out here. The model for cantilever retaining wall with base width 7m is shown in figure Thus, the analysis is carried out in Staad pro as described.The analysis of cantilever walls with varying base widths (7 m, 6.5 m, and 6 m) using Staad Pro indicates that as the base width decreases, the stability of the wall progressively diminishes.

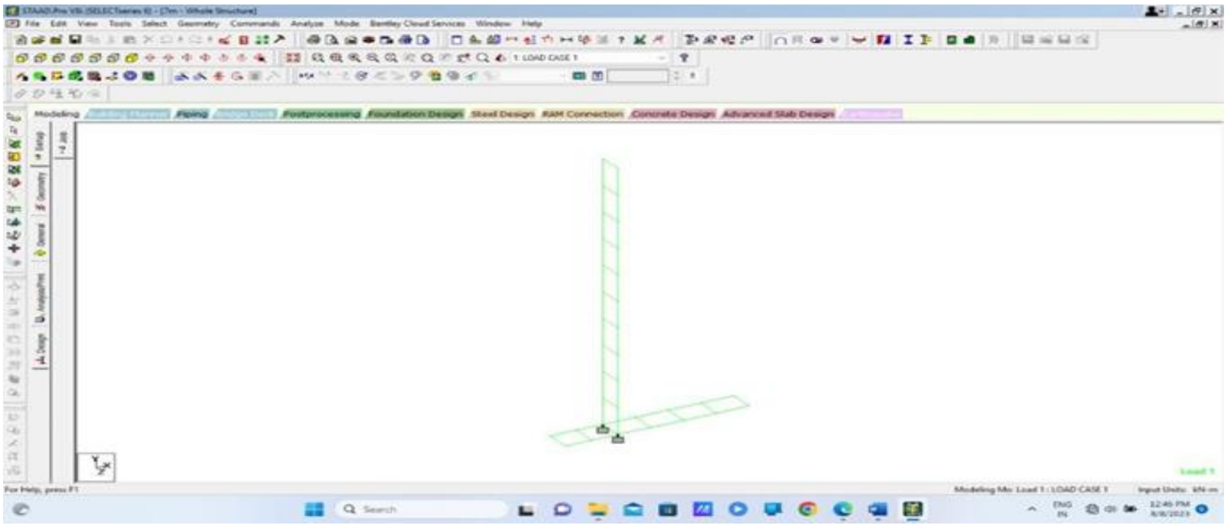


Figure 4.1 Geometry of cantilever retaining wall with base width 7 m in Staad pro

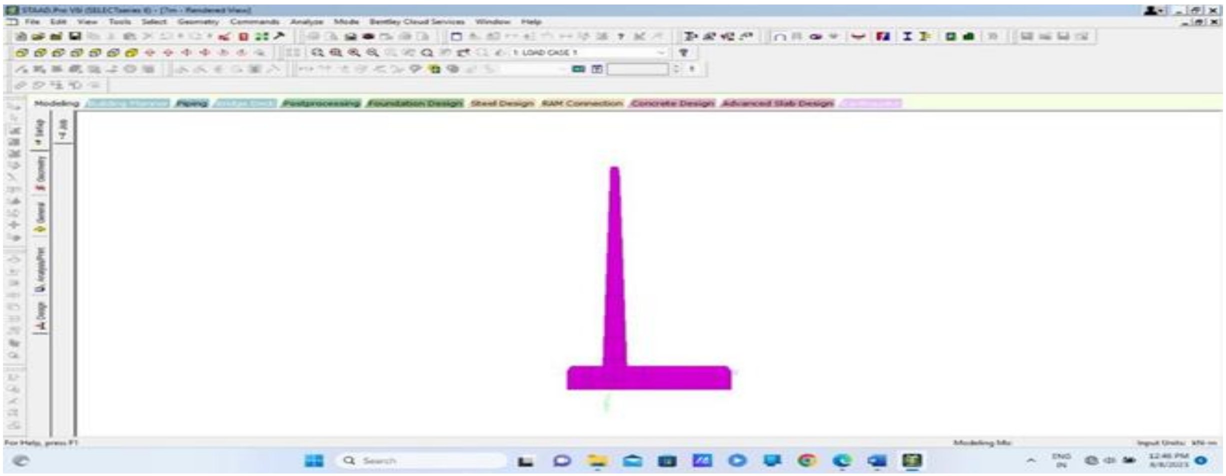
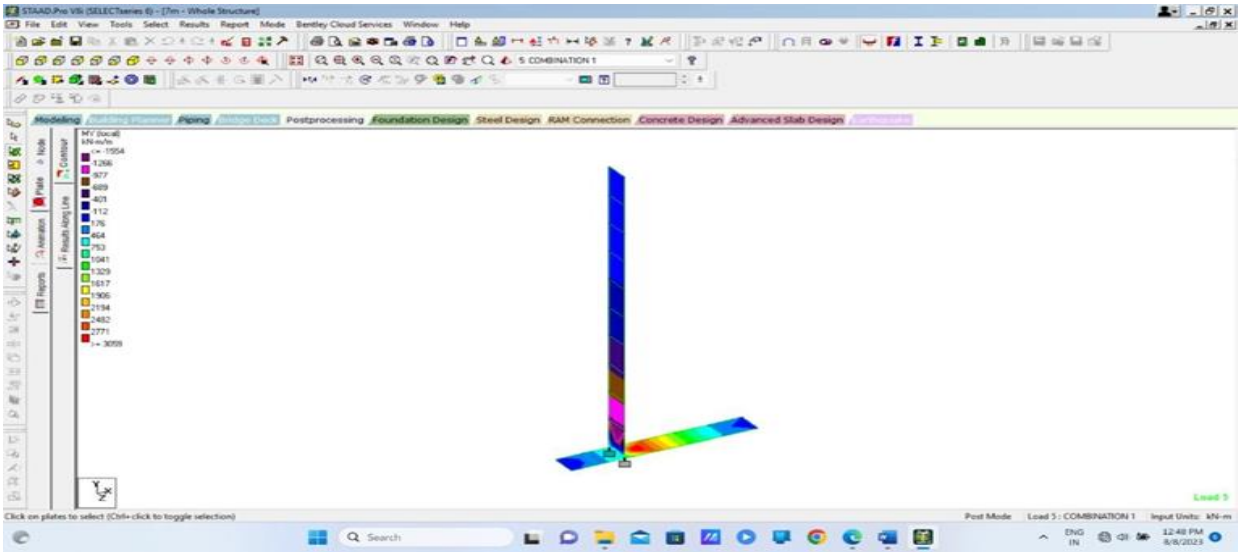


Figure 4.2Rendering view of cantilever retaining wall without relief shelf



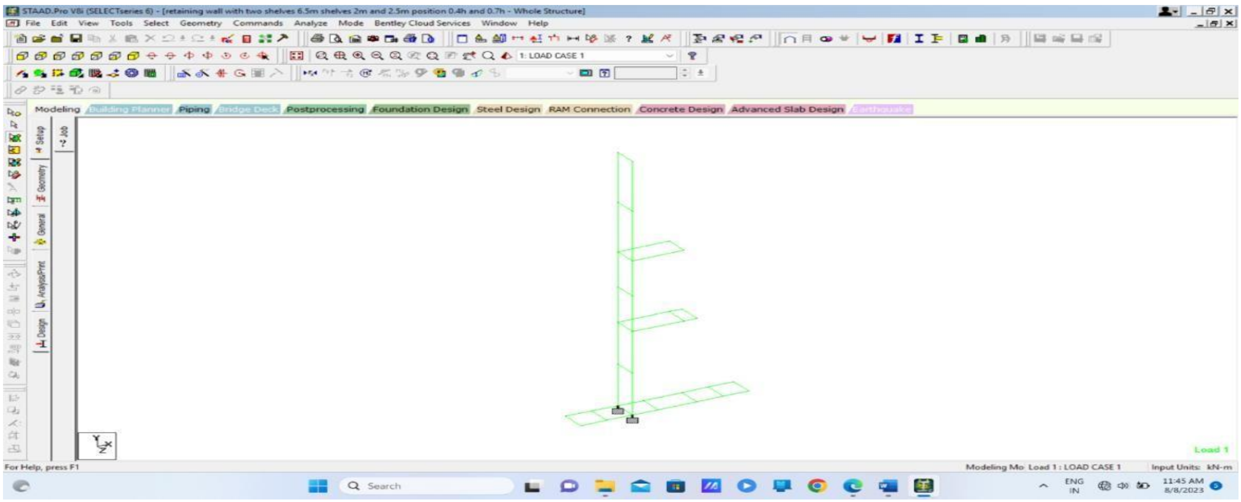


Figure4.3Stressdistribution diagramofcantileverretaining wallwithoutshelf

Figure 4.4 Geometry view of cantilever retaining wall with 7m base width, 2m shelf and 2.5m shelf width at position 0.4h and 0.7h

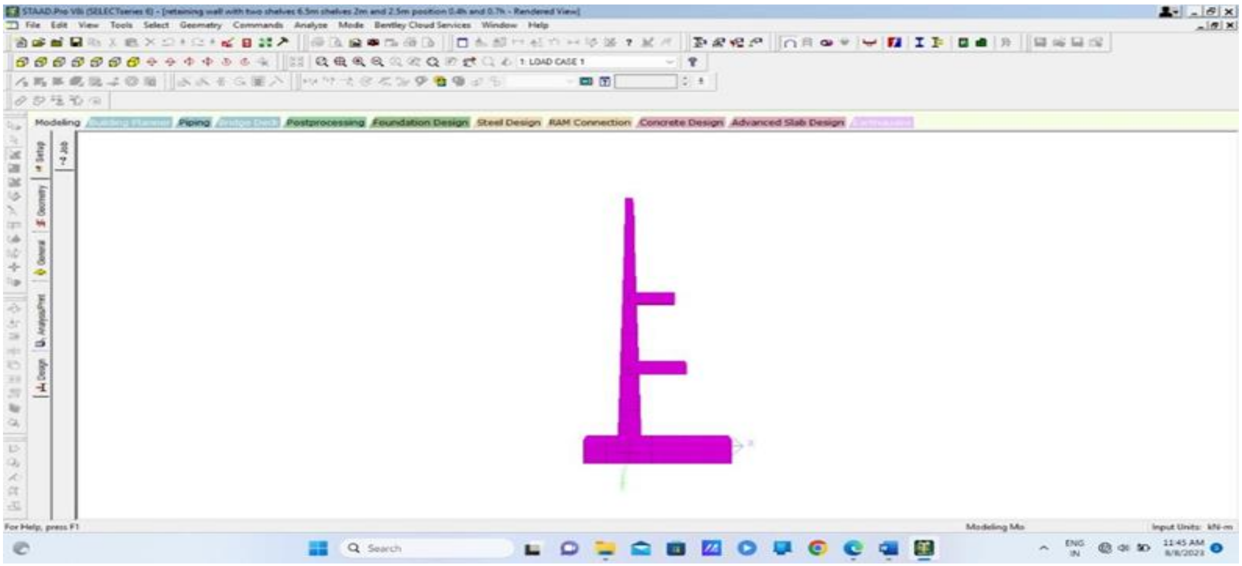


Figure 4.5Rendering view of retaining wall with two relief shelves

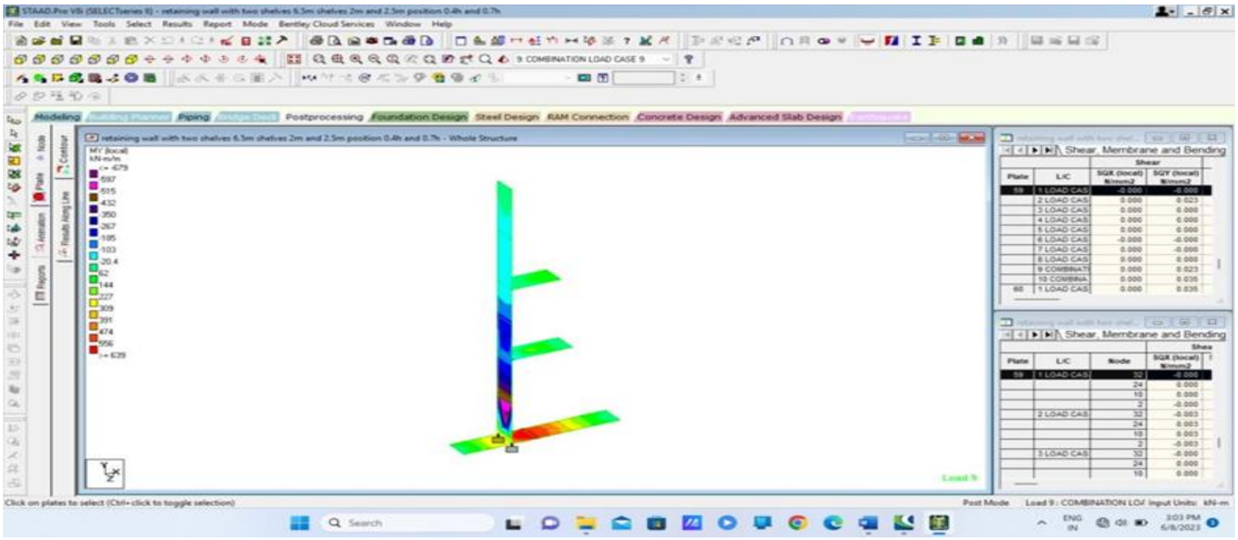


Figure4.6Stressdistributiondiagramofretaining wallwith tworelief shelves

4. OUTCOMES AND CONLUSIONS

The conclusions made for the results of the analytical work carried out on retaining wall with shelves are enumerated as follows.

1. Adding shelves to retaining walls reduces lateral earth pressure, enhancing stability and reducing bending moments.
2. Optimal single shelf location lies between 0.4h to 0.5h, considering lateral earth pressure, bending moments, and deflection.

3. Top node deflection mainly depends on shelf location, decreasing from 0.1h to 0.5h and increasing from 0.6h to 0.9h.
4. Providing a 3.5 m shelf at 0.5h reduces stem deflection by about 95% compared to a shelf-less wall. Bending moment at stem bottom decreases from 0.1h to 0.5h.
5. A single shelf at 0.4h reduces resulting bending moment by around 70%.
6. Increasing shelf width rises bending moment at shelf end and displacement but reduces stem bottom bending moment.
7. Stability conditions are met as long as shelf width stays below the rupture plane; extending beyond the rupture surface is recommended.
8. Allowable shelf width should increase from top to bottom, and it's linked to the width of the shelf below.
9. Using two shelves for a 14 m wall enhances stability and increases the factor of safety against sliding and overturning.
10. Combining shelves of 1.5 m and 2 m widths at 0.35h and 0.55h minimizes bending moments and deflection.
11. For shelves of 2 m and 2.5 m widths at 0.35h and 0.65h, the optimum solution reduces bending moments by about 78% and node displacement by about 90%.

Providing shelves to the retaining wall leads to decrease in the lateral earth pressure and that helps it the retaining wall to decrease the bending moment at stem bottom and decrease node displacement. Thus, retaining wall with shelves can be considered as an effective solution of the high retaining walls according to the study.

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