

Analysis of Retaining Wall Using Plaxis 2D

¹Sneha K T V, ²Murshid M, ³Neeraj N K, ⁴Riya Rasheed, ⁵Vinaya p

¹Assistant professor, ^{2,3,4}UG Final year student

^{1,2,3,4}Department of Civil Engineering,

^{1,2,3,4}St Thomas College of Engineering and Technology, Kannur, India

Abstract: Particularly during the monsoon season when intense rainfall triggers frequent landslides. The present study focuses on the design and analysis of a cantilever retaining wall intended to prevent slope failure at Valiyannur, where a residential property located adjacent to a steep laterite soil slope (approximately six metres high) has been adversely affected by soil movement. The project aims to provide a safe and economical retaining structure capable of resisting the lateral earth pressures and maintaining long-term slope stability. The stability of soil slopes in hilly regions of Kerala has become a major concern.

The design of the cantilever retaining wall was initially performed using conventional analytical methods based on Rankine's earth pressure theory. The structural dimensions were determined considering stability against overturning, sliding, and bearing failure. Subsequently, numerical analysis was carried out using PLAXIS 2D, a finite element software widely employed in geotechnical engineering, to model the wall-soil interaction and to assess deformation, stress distribution, and the overall factor of safety. The comparison between analytical and numerical results provided valuable insights into the performance of the retaining wall under realistic loading and boundary conditions.

The outcome of this study demonstrates that the proposed cantilever retaining wall is adequate to ensure slope stability and prevent further damage to nearby structures. The analysis highlights the importance of numerical modelling in verifying traditional design approaches and in enhancing the safety and reliability of retaining wall systems constructed in laterite soil environments.

Keywords - Retaining wall; laterite soil; slope stability; PLAXIS 2D; finite element analysis; earth pressure; Valiyannur; geotechnical design; landslide prevention.

1. INTRODUCTION

The stability of natural slopes is a major concern in many parts of Kerala, particularly in regions composed of laterite soil formations. In Valiyannur, recurring instances of soil movement and minor landslides have been reported during heavy monsoon rainfall. The affected area includes a residential property located close to a steep laterite slope of approximately six metres in height. During the rainy season, excessive infiltration of water into the soil mass weakens the bonding of laterite particles, leading to reduced shear strength and progressive failure of the slope. The absence of an adequate retaining structure has resulted in soil displacement towards the residential compound, causing damage to boundary walls and posing a potential threat to the safety of the occupants and the stability of the building foundation. Conventional slope protection methods, such as surface drainage or vegetative cover, have proven insufficient in mitigating the movement of soil under intense rainfall conditions. Therefore, a more robust and permanent engineering solution is required to stabilise the slope and prevent further erosion or sliding. The challenge lies in designing a retaining structure that is both structurally safe and economically viable, while accurately reflecting the real behaviour of laterite soil under various stress conditions. Traditional analytical design methods provide only an approximate understanding of soil pressure and wall stability. Hence, there is a need for advanced numerical modelling to assess the soil-structure interaction more realistically. To address this problem, the present study proposes the design and analysis of a cantilever retaining wall at the Valiyannur site, using PLAXIS 2D finite element software. This approach enables the detailed evaluation of earth pressure distribution, wall deformation, and overall factor of safety, thereby ensuring a reliable and sustainable solution for slope stabilisation in laterite soil conditions.

1.1 Scope of the work

The scope of this project encompasses both the analytical design and numerical analysis of a cantilever retaining wall intended to stabilise a six-metre-high laterite soil slope located at Valiyannur. The study focuses on developing a safe, practical, and cost-effective retaining structure that can prevent slope failure and protect nearby residential structures from damage caused by soil movement during the monsoon season. The analytical part of the study involves determining the dimensions of the cantilever retaining wall using conventional design principles and earth pressure theories such as Rankine's or Coulomb's methods. The design includes stability checks against overturning, sliding, and bearing capacity failure, ensuring the structure satisfies standard safety requirements prescribed in relevant design codes. The numerical part of the work is carried out using PLAXIS 2D, a finite element analysis (FEA) software widely used in geotechnical engineering. The software is employed to simulate the wall-soil interaction, evaluate stress and deformation behaviour, and verify the analytical design. The analysis considers the realistic soil parameters of laterite, boundary conditions, and loading conditions to obtain a more accurate understanding of the wall performance under both dry and saturated states. The project is limited to two-dimensional analysis and does not include dynamic effects such as seismic loading or time-dependent consolidation behaviour. However, the study aims to bridge the gap between traditional design methods and advanced numerical analysis, thereby demonstrating the effectiveness of PLAXIS 2D as a modern design tool for geotechnical structures. In summary, the scope of the work includes site evaluation, characterisation of laterite soil, analytical design of the retaining wall, finite element modelling using PLAXIS 2D, comparison of results, and formulation of recommendations for safe and sustainable slope stabilisation.

at the project site.

1.2 Significance of the study

Slope instability and landslide occurrences have become increasingly common in Kerala's hilly regions, particularly during the monsoon season. The study holds significant importance as it addresses a real-world geotechnical challenge at Valiyannur, where a residential property is endangered due to the instability of a six-metre-high laterite soil slope. By providing a systematic approach to slope stabilisation through the design of a cantilever retaining wall, this project contributes both practical and academic value. From a practical standpoint, the study proposes an engineering solution that ensures the safety of residential structures and reduces the risk of property loss caused by slope failure. It also demonstrates the application of cost-effective and easily constructible retaining wall systems suitable for medium-height slopes. From an academic perspective, the study bridges the gap between traditional analytical design and advanced numerical modelling by employing PLAXIS 2D for finite element analysis. This integration enhances the understanding of soil–structure interaction, deformation behaviour, and stability performance under realistic site conditions. Furthermore, the outcomes of this project can serve as a reference for future geotechnical designs in areas with similar soil and climatic conditions. It underscores the necessity of incorporating modern computational tools in civil engineering design to achieve more reliable and sustainable infrastructure solutions in vulnerable terrains like those found across Kerala.

2. METHODOLOGY

The site investigation at Valiyannur was carried out to understand the topography, soil conditions, groundwater condition, and slope instability. The approximately 6 m high slope was found to consist mainly of laterite soil, with signs of surface erosion and minor soil movement during the monsoon. Field observations, photographs, and sketches were used to document the slope profile, vegetation, drainage, and nearby residential structures. Soil samples were collected and tested in the laboratory for moisture content, specific gravity, compaction characteristics, direct shear strength, and unconfined compressive strength. The results provided the necessary geotechnical parameters for the retaining wall design and analysis. Numerical analysis was then performed using PLAXIS 2D to evaluate the behaviour of the laterite soil and proposed cantilever retaining wall. The slope and wall geometry were modelled based on the site conditions, and the laboratory-derived soil parameters were assigned to the model. Appropriate boundary conditions, loading conditions, and staged construction were considered. The analysis was used to assess soil–structure interaction, deformation, settlement, earth pressure, and the overall stability of the proposed retaining wall.

3. NUMERICAL ANALYSIS IN PLAXIS 2D

The slope stability analysis was carried out in Plaxis 2D using a plane strain model developed from the actual site geometry. The soil domain extends 40 m horizontally and 8 m vertically, with a 30 m long horizontal crest from the left boundary up to the start of the slope face. From this point, the ground surface descends along an inclined slope toward the right side and terminates on a 2 m high berm/bench that represents the toe-level ground portion of the site. The subsurface profile was idealized as a two-layer system consisting of an Upper Soil layer with a thickness of 3 m overlying the Lower Soil layer, which continues across the full model width and forms the foundation beneath the slope.

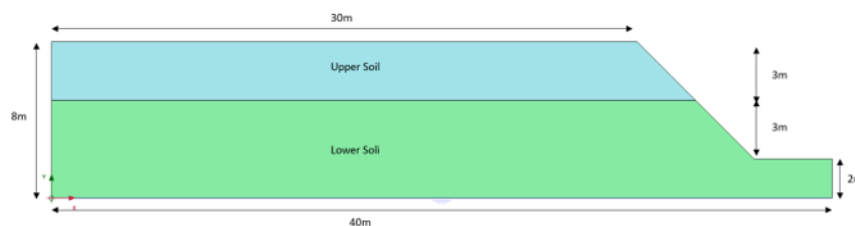


Fig 1 : Model Dimensions

3.1 Material Properties

In this study, the Lower Soil layer was modelled in Plaxis 2D using the Mohr–Coulomb (drained) constitutive model, and the key “mandatory” parameters were defined to ensure the software can simulate both deformation and stability realistically. The unit weights (γ_{unsat} and γ_{sat}) are required to generate the self-weight of the soil and to account for changes in effective stress when groundwater conditions are considered. The stiffness parameters (E'_{ref} and ν) control the stress–strain response of the layer and govern predicted displacements and the overall deformation pattern of the slope. The shear strength parameters (c'_{ref} , ϕ' , and ψ) are essential for defining the soil's failure resistance and are the primary inputs used in the strength reduction (ϕ – c reduction) procedure to compute the global factor of safety and the likely failure mechanism. Together, these properties provide Plaxis with the minimum necessary information to calculate stress distribution, pore-pressure-dependent effective stresses (in drained behaviour), deformations, and slope stability performance of the lower layer.

Group	Parameter	Unit	Value	Group	Parameter	Unit	Value
General	Soil model	—	Mohr–Coulomb	General	Soil model	—	Mohr–Coulomb
General	Drainage type	—	Drained	General	Drainage type	—	Drained
Unit weights	γ_{unsat}	kN/m ³	17.0	Unit weights	γ_{unsat}	kN/m ³	18.0
Unit weights	γ_{sat}	kN/m ³	18.0	Unit weights	γ_{sat}	kN/m ³	19.0
Stiffness	E _{ref}	kN/m ²	15.00E3	Stiffness	E _{ref}	kN/m ²	25.00E3
Stiffness	ν	—	0.25	Stiffness	ν	—	0.23
Strength	c _{ref}	kN/m ²	4.0	Strength	c _{ref}	kN/m ²	8.0
Strength	ϕ'	°	20	Strength	ϕ'	°	25
Strength	ψ	°	0	Strength	ψ	°	0

Table 1 : Upper layer soil properties

Table 2 ; Lower Layer Soil Properties

3.2 Boundary Condition and Loading

Model boundaries (essential fixities): The bottom boundary is fully fixed ($U_x = 0$, $U_y = 0$) to prevent rigid-body motion, while the left and right vertical boundaries are roller supports ($U_x = 0$, U_y free) so the soil can settle vertically but cannot move sideways at the edges. Initial Phase (Gravity loading): The analysis starts with Gravity loading in staged construction ($\Sigma M_{\text{weight}} = 1.0$) to generate the initial geostatic stress condition due to self-weight of the two soil layers. Deformation Phase (Plastic): A Plastic deformation phase is run starting from the initial phase to obtain realistic stress redistribution and slope deformations under self-weight (and staged activation). FoS Phase (Safety): Finally, the Safety calculation (ϕ –c reduction) is used with incremental multiplier settings to reduce soil strength until failure, giving the global Factor of Safety and the expected failure mechanism

3.3 Meshing

Meshing is the process of dividing the soil domain into many small finite elements (in Plaxis 2D, mainly triangular elements) so that the program can numerically compute stresses, strains, pore pressures, and displacements throughout the slope. In this study, a fine finite element mesh was generated to represent the real slope geometry and the two-layer soil profile accurately. The mesh was kept more refined in critical regions such as the slope face, crest, and toe/bench area, where stress concentration and the development of a potential slip surface are most likely during loading and failure. Using a fine mesh is important because it improves the accuracy of deformation and stress predictions, enhances numerical stability, and provides a clearer and more reliable failure mechanism and Factor of Safety outcome in the strength reduction (FoS) analysis.

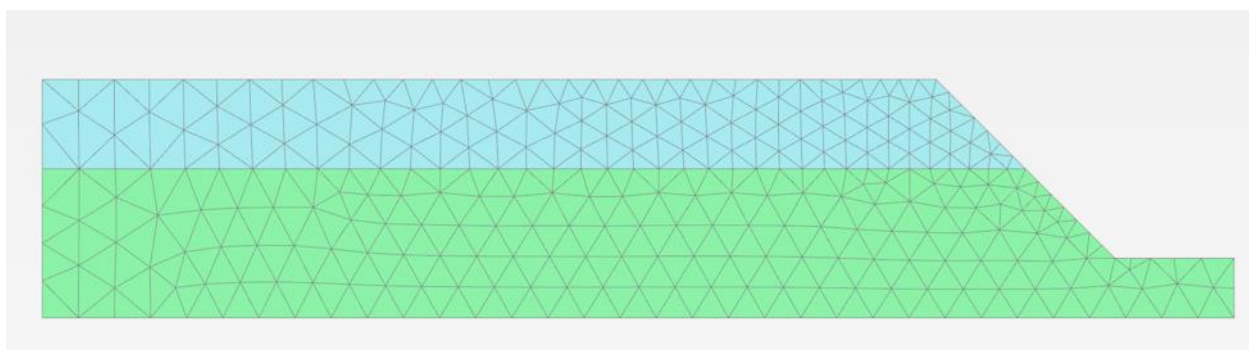


Fig 2 Meshing

4. RESULT AND DISCUSSION

4.1 Soil Displacement and FoS Without Retaining Wall

The figure presents the deformed shape (deformed mesh) of the slope obtained from the deformation phase in Plaxis 2D. For clear visualization, the deformation is scaled by 500 times, while the actual displacement values are relatively small. The deformation is mainly concentrated near the crest and upper part of the slope face, where the maximum displacement is about 1.675×10^{-3} m,

indicating this as the most critical movement zone under self-weight loading. In contrast, the deeper foundation region shows minimal distortion, suggesting that the deformation is largely localized within the slope mass rather than affecting the entire domain.



Figure 1 Deformed Shape

This contour plot presents the total displacement magnitude ($|u|$) of the slope obtained from the deformation phase in Plaxis 2D, with the deformed shape scaled by 500 for better visibility. The colour scale indicates that displacement values are generally low across the soil mass (dominant blue region), while a clear concentration of movement develops near the upper portion of the slope face close to the crest, where the highest stress redistribution occurs under self-weight loading. The maximum displacement is approximately 1.675×10^{-3} m, and the displacement progressively reduces with depth and toward the left side of the domain, showing that the deeper foundation remains comparatively stable. Overall, the displacement pattern highlights the critical deformation zone likely to initiate shear strain development and supports interpretation of the failure mechanism in the subsequent FoS (strength reduction) analysis.

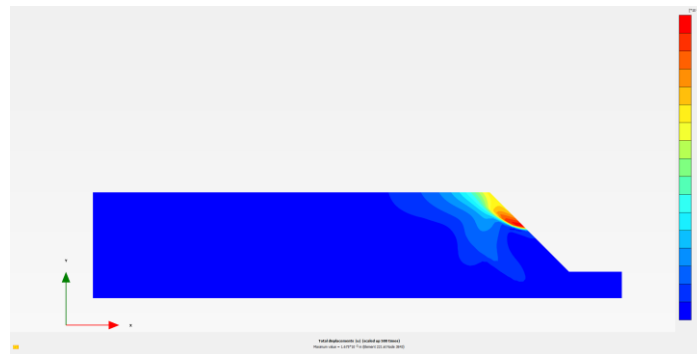


Figure 2 Total deformation

The strength reduction (FoS) analysis for the slope without a retaining wall converged to a Factor of Safety of approximately 1.07. The FoS-time step curve shows a short initial overshoot (peaking around ~ 1.14), which is a typical numerical transient during the early stages of the safety calculation. After this, the result stabilizes and remains nearly constant at ~ 1.07 , confirming the final converged safety value for the slope under gravity (self-weight) loading.

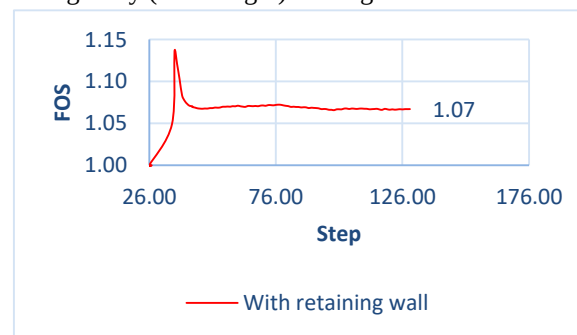


Figure 3 FOS Curve

This figure shows the FoS (strength reduction) failure mechanism for the slope without a retaining wall, where the analysis converged to a Factor of Safety of 1.07. The coloured band concentrated near the upper slope/crest region indicates the critical zone of plastic deformation and shear strain localization, which governs the initiation of instability. The remainder of the soil mass remains mostly in the low-response range (blue), confirming that the failure mechanism is localized rather than a deep-seated global slide. Overall, the result suggests the slope is marginally stable under self-weight loading, with potential failure initiating near the crest and propagating along the slope face as strength is reduced.



Figure 4 FOS Diagram

4.2 Construction of Retaining Wall (Plate Element)

A retaining wall is constructed to provide lateral support to the soil mass near the sloping region and to control soil movement under self-weight and water actions. The wall is modelled as a plate element, which represents a thin structural member capable of resisting axial forces and bending moments. The plate is positioned along the slope face location shown in the geometry, with an effective retained height of approximately 4 m from the reference ground/water level down to the wall base. A 1 m freeboard is maintained at the top as indicated in the figure, while a 2 m base/toe length is considered to improve stability against sliding and overturning. Soil–structure interaction is simulated by assigning an interface along the wall–soil contact so that realistic frictional behaviour, possible separation, and relative slip can occur between the wall and surrounding soil. After activating the wall in this construction stage, the model is used to evaluate the structural response of the wall (bending moments, shear forces, and lateral deflection) and the corresponding deformation pattern in the retained soil, including any potential failure mechanism developing near the slope and wall base.

The retaining wall is defined as an isotropic plate element, meaning its stiffness is taken as the same in the plate's principal directions (direction 1 and 2). The key stiffness inputs provided are the axial stiffness and bending stiffness, which control how the wall resists in-plane forces and out-of-plane bending due to soil and water pressure. The axial stiffness (EA_1) is assigned as 2.0×10^9 kN/m, representing a very stiff wall in compression/tension along its length. The Young's modulus (E_1) is given as 11.55×10^9 kN/m², which describes the material's elastic rigidity (typical of a stiff structural material such as concrete/structural-grade wall idealization). The wall's flexural stiffness (EI) is set to 5.0×10^6 kN·m² per metre width, which governs the wall's ability to resist bending moments and therefore directly affects predicted wall deflection and bending moment distribution under lateral earth pressure. The Poisson's ratio (ν) is taken as 0.0, which means lateral strain coupling is neglected in the plate behaviour (often acceptable for simplified plate modelling when the focus is mainly bending response).

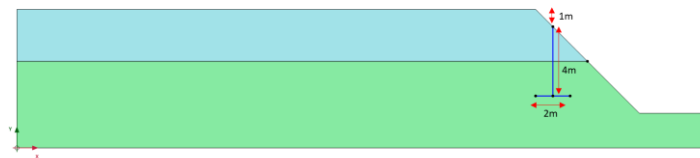


Figure 5 soil slope with retaining wall

4.3 Soil Displacement and FoS With Retaining Wall

The displacement field is largely very small across the main soil mass, as indicated by the dominant dark-blue region, which represents near-zero movement away from the wall zone. A clear deformation concentration develops around the retaining wall and the adjacent sloping face, where the contour colours change from blue to green/yellow and finally orange/red. This indicates that soil movement is localised near the wall–slope interface rather than spreading through the entire domain.



Figure 6 Deformation with a retaining wall

The maximum total displacement occurs close to the wall toe / lower interface region along the slope, where the red zone appears. This pattern suggests that the retained soil is pushing laterally and downslope under self-weight (and water influence, if applied), causing the largest deformation demand at the wall's embedded/base region and the nearby potential shear band zone.

Output shown: Total displacements $|u|$

- Maximum value $\approx 0.1317 \times 10^{-3}$ m (≈ 0.0001317 m = 0.132 mm)

- The displayed deformation shape is scaled up (5.00×10^3 times) for visibility, meaning the real deformation is small but the plot exaggerates it to show the mechanism clearly.

Interpretation

Overall, the retaining wall is effectively restricting global soil movement, but a local deformation zone forms around the wall base and slope face, which is the critical area to check further using: interface stresses / mobilised shear, wall bending moment and shear, and (if applicable) safety factor/strength reduction results.

The stability analysis indicates a Factor of Safety (FoS) = 1.29 for the slope reinforced with the plate retaining wall. The contour pattern highlights that the soil mass away from the slope remains in a stable condition (dark blue), while a potential failure zone is concentrated mainly in the upper sloping region near the wall and along the slope face (green → yellow → orange → red). The highest intensity (red region) appears close to the upper slope crest, indicating that this area experiences the greatest mobilization of shear strength and is the most critical part of the slope in terms of instability.

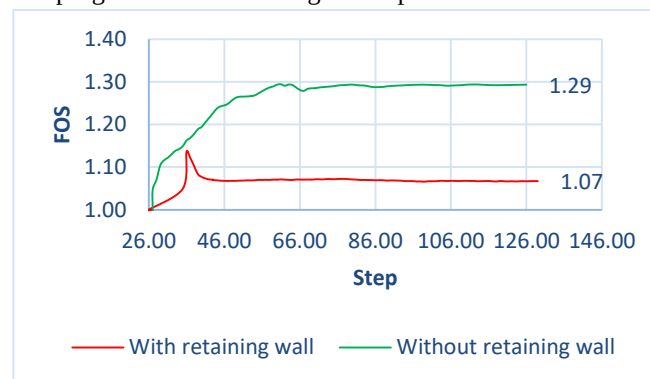
The presence of the retaining wall changes the deformation/stability mechanism by restricting movements near the wall base and toe, forcing the critical shear zone to develop more towards the upper slope rather than forming a deep, global sliding surface. Overall, a FoS of 1.29 suggests the slope is marginally stable, meaning it is stable under the current conditions but with limited reserve strength; any increase in surcharge load, rise in water level, reduction in soil strength, or seismic effect could reduce the safety margin.



Figure 9 FoS in retaining wall

Discussion

Slope stability was evaluated using the strength reduction method by comparing the Factor of Safety (FoS) for two cases: with retaining wall and without retaining wall. The results show two distinct safety levels. One condition achieves a higher safety margin of approximately FoS = 1.29, indicating that the slope has a better reserve shear strength and is generally stable under the applied conditions. The other condition remains at a lower value of approximately FoS = 1.07, which represents a marginally stable slope close to failure. This lower FoS implies that the slope is more sensitive to external influences such as rainfall infiltration, rise in groundwater level, surcharge loading, or reductions in soil strength parameters. Overall, the configuration with the higher FoS provides improved slope stability and reduced likelihood of progressive failure along the slope face.



5.CONCLUSION

The slope stability study shows two different safety conditions, with the Factor of Safety (FoS) values reaching 1.07 for the lower-stability case and 1.29 for the higher-stability case. This indicates that the configuration achieving FoS = 1.29 provides a noticeably safer slope, with greater reserve shear strength and a reduced likelihood of failure compared to the case that remains near FoS = 1.07, which is considered marginally stable. When the improvement is quantified, the FoS increases from 1.07 to 1.29, giving an approximate 20.6% increase in slope stability. Overall, the higher FoS condition demonstrates better performance in controlling slope deformation and resisting shear failure, whereas the lower FoS condition may become unstable if external effects such as rainfall, groundwater rise, or surcharge loading occur.

6. REFERENCES

1. Vicario Jose Fernando Souhoka, Hamkah, Penina T Istia. (2024)-Stability Analysis of Cantilever Type Soil Retaining Wall Using Plaxis Method on Waipia-Saleman Road Section of Seram Island.
2. Rahul R. Kshatriyaa, Pramod S. Satheb, Pooja S. Kankarejc (2022)-Analysis and Behavior of Retaining Wall on Black Cotton Soil by Using Software 'PLAXIS 2D'.
3. N Ika Puji Hastuty and Rizky Prambudi (2020)-Analysis of slope stability by the planning of cantilever retaining wall reinforcement using the application of Plaxis (case study: substation Panyabungan sta 0+060).
4. Sandip M Chavan, Dr. Vijay Sharma (2017)-Behaviour of retaining wall in black cotton soil.The findings shows retaining walls in black cotton soil are vulnerable to cracking, tilting, and structural distress.
5. Vinay Bhushan Chauhan, Satyanarayana Murty Dasak (2022)-Behavior of Rigid Retaining Walls with Relief Shelves.

Copyright & License:

© Authors retain the copyright of this article. This work is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.