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STABILITY EVALUATION OF TIERED RETAINING WALLS SUPPORTING AN ISLAMIC BOARDING SCHOOL DORMITORY IN SOLOK CITY

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ABSTRAK

This study evaluates the stability of tiered gravity retaining walls supporting an Islamic boarding school dormitory in Solok City, Indonesia. The investigation was motivated by observed ground deformation, surface erosion, and damage to structures located near the slope. Subsurface conditions were characterised using cone penetration test data from two investigation points, CPT-1 and CPT-2. The CPT results were interpreted to establish soil stratigraphy and estimate the geotechnical parameters required for numerical analysis. A two-dimensional finite element model was developed using the Mohr–Coulomb constitutive model, incorporating the existing slope geometry, soil layers, dormitory loads, groundwater conditions, and retaining wall dimensions designed in accordance with SNI 8460:2017. Slope stability was evaluated using the shear strength reduction method. The existing slope produced a factor of safety of 2.43, indicating a relatively high stability margin against deep-seated failure. After the addition of the tiered retaining walls, the factor of safety increased to 2.60, corresponding to an improvement of approximately 7%. The results indicate that the retaining walls improve stability by supporting the stepped ground and restricting lateral soil movement. However, the relatively small increase suggests that the overall response remains primarily governed by the soil properties and slope geometry. Since both calculated safety factors exceeded 2.0, the observed damage was inferred to be more closely associated with shallow surface erosion and local soil loss during rainfall rather than global slope failure. These erosion processes were not explicitly modelled and represent a limitation of the study. Effective drainage and erosion protection are therefore essential to complement the proposed retaining wall system.

Kata kunci : finite element method; gravity retaining wall; slope stability;

1. INTRODUCTION

Retaining walls are essential geotechnical structures used to retain back soil and maintain differences in ground elevation, particularly in areas where buildings are constructed on sloping terrain. In this study, the development of an Islamic boarding school, a retaining wall plays an important role in protecting the building platform and supporting facilities from lateral soil movement and slope instability. The performance of the retaining wall is therefore directly related to the safety and serviceability of the Islamic boarding school complex. Failure of the wall may result in excessive ground deformation, foundation settlement, cracking of buildings, disruption of access, or even partial collapse of the surrounding facilities.

The shear strength parameters of the retained soil, particularly cohesion and the internal friction angle, are among the most important factors governing the stability of a retaining wall. These parameters determine the soil's resistance to shear deformation and directly influence the magnitude of lateral earth pressure acting on the wall. Their effects are especially significant in cement–soil retaining walls and gravity retaining walls, where stability largely depends on the interaction between the wall mass, the foundation soil, and the retained backfill (Song and Yan, 2016). Lower values of cohesion or internal friction angle may increase the risk of sliding, bearing-capacity failure, and overall slope instability. Therefore, reliable soil parameters should be obtained through appropriate field investigations and laboratory testing rather than relying solely on generalized values.

The unit weight of the soil behind the retaining wall also has a considerable influence on stability. A higher soil unit weight produces a greater vertical overburden stress and, consequently, increases the lateral earth pressure exerted on the wall. In the case of a retaining wall supporting an Islamic boarding school complex, this pressure may be further increased by surcharge loads from facilities constructed behind or above the wall. The combined effects of soil self-weight and structural surcharge must therefore be carefully considered in evaluating sliding, overturning, bearing capacity, and global stability (Seo *et al.*, 2023; Singh, Gupta and Kumar, 2026).

Groundwater conditions represent another critical factor affecting retaining-wall performance. A rise in groundwater level increases hydrostatic and pore-water pressures behind the wall causing reduce of the soil effective stress and shear strength. In addition, poor drainage systems exacerbate instability by increasing soil moisture and reducing effective stress. Optimized drainage is critical for mitigating infiltration-induced failures (Luo, Wei and Ding, 2013; Khan *et al.*, 2025). These conditions can affect in reducing the factor of safety against sliding, overturning, and global instability (Khan *et al.*, 2025; Rajabian and Vahedifard, 2025).

On the other hand, Earthquake-induced forces significantly affect sliding and overturning stability, with soil properties (e.g. cohesion and friction angle) playing a major role in seismic conditions (Nimbalkar, Pain and Annapareddy, 2020). Earthquake loads can significantly impact the stability of retaining walls through increased lateral earth pressures, ground motion effects, and potential failure mechanisms such as sliding and overturning. Stiffer walls exhibit better deformation control and stability under dynamic loads (Zhu *et al.*, 2026). Proper drainage, reinforcement, and adherence to seismic design codes are essential for enhancing the resilience of retaining walls against earthquake loads.

This study aims to evaluate the stability and performance of the retaining wall supporting the Islamic boarding school buildings under various conditions. The analysis focuses on determining the influence of soil shear strength parameters, including cohesion and internal friction angle, soil unit weight, structural surcharge loads, and groundwater level to evaluate the global stability of the retaining wall and surrounding soil mass supporting the Islamic boarding school complex. The analysis is conducted to determine the overall factor of safety against potential deep-seated failure surfaces involving the retaining wall, backfill soil, foundation soil, and adjacent slope

2. RESEARCH METHOD

The research was conducted through six sequential stages (Figure 1) to evaluate the stability of tiered retaining walls supporting an Islamic boarding school dormitory in Solok City. The first stage involved identifying the main geotechnical problems at the site. Field evidence, such as slope movement, ground cracks, retaining wall distress, and damage to nearby structures, was reviewed to define the research problem. The study objectives were then established, focusing on evaluating wall stability, identifying the critical failure mechanism, and determining the factors contributing to instability.

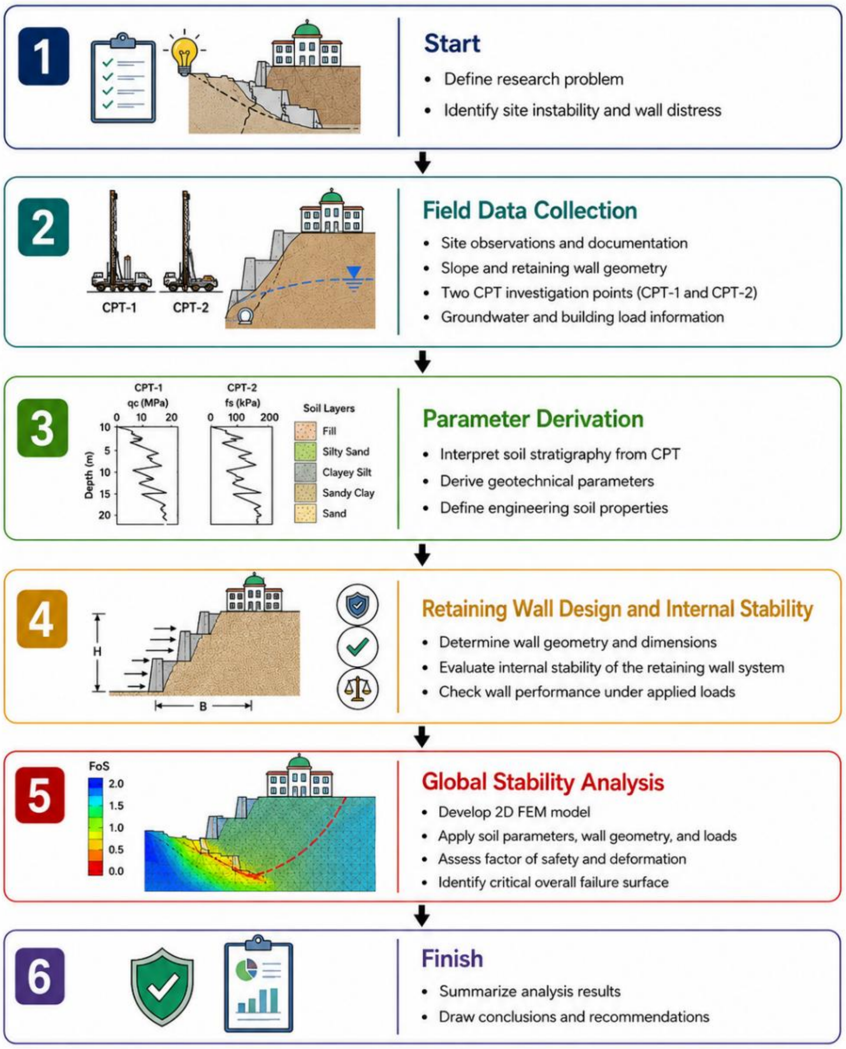


Figure 1. Research flow chart

Field investigations were carried out to obtain the data required for analysis. The activities included site observations, photographic documentation, and measurements of the slope and retaining wall geometry. Information on wall height, spacing, foundation depth, slope profile, groundwater conditions, drainage, and building loads was collected. Subsurface conditions were investigated using two cone penetration test points, CPT-1 and CPT-2, selected to represent the soil conditions along the analyzed slope section.

The CPT data were interpreted to determine soil stratigraphy and estimate engineering properties. Cone resistance, sleeve friction, and friction ratio were used to identify different soil layers and their thicknesses. Relevant geotechnical parameters, including unit weight, cohesion, internal friction angle, Young's modulus, Poisson's ratio, and undrained shear strength, were estimated using established empirical correlations. Conservative values were adopted to account for uncertainties associated with CPT-based parameter interpretation.

The dimensions and performance of each retaining wall were then evaluated. Earth pressure, groundwater pressure, soil weight, building surcharge, and other external loads were considered. Stability checks included resistance against sliding, overturning, and bearing capacity failure. The interaction between the retaining wall tiers was also considered because the upper walls may increase the load acting on the lower walls. This stage determined whether the individual retaining wall components had sufficient local stability. The overall slope–wall system was analyzed using a two-dimensional finite element model. The model incorporated the surveyed geometry, interpreted soil layers, wall properties, groundwater conditions, and building loads. Soil behavior was represented using an appropriate constitutive model, such as the Mohr–Coulomb model. The factor of safety was calculated using the shear strength reduction method. The analysis also produced displacement, deformation, stress, and shear strain patterns. These results were used to identify the critical failure surface and evaluate whether instability could extend through several retaining wall tiers or beneath the dormitory building.

The final stage involved summarizing and interpreting the results. The calculated factor of safety and deformation patterns were compared with observed field damage to assess the reliability of the model. The controlling factors of instability were identified, and conclusions were drawn regarding the performance of the retaining wall system. Recommendations were then proposed, including wall strengthening, drainage improvement, surcharge reduction, slope reinforcement, or deformation monitoring.

2.1. Research location

This study was conducted at the dormitory complex of Warsatul Anbiya, located in Solok City, West Sumatra Province, Indonesia (see Figure 2). The study area is situated on sloping terrain developed for educational facilities and student accommodation. To support land development and maintain differences in ground elevation, a tiered retaining wall system was constructed at several levels along the slope. The retaining walls are intended to resist lateral earth pressure and maintain the stability of the dormitory building area located adjacent to the slope. Field observations identified indications of ground movement, surface slope failure, and damage to nearby structural elements. These conditions highlight the need to evaluate the stability of the tiered retaining wall system by considering the slope configuration, wall geometry, soil properties, groundwater conditions, and loads imposed by the dormitory buildings. Geographically, the study area is located at approximately -0.7698993271554275, 100.63831184244037 with an elevation of about 421 m above mean sea level.

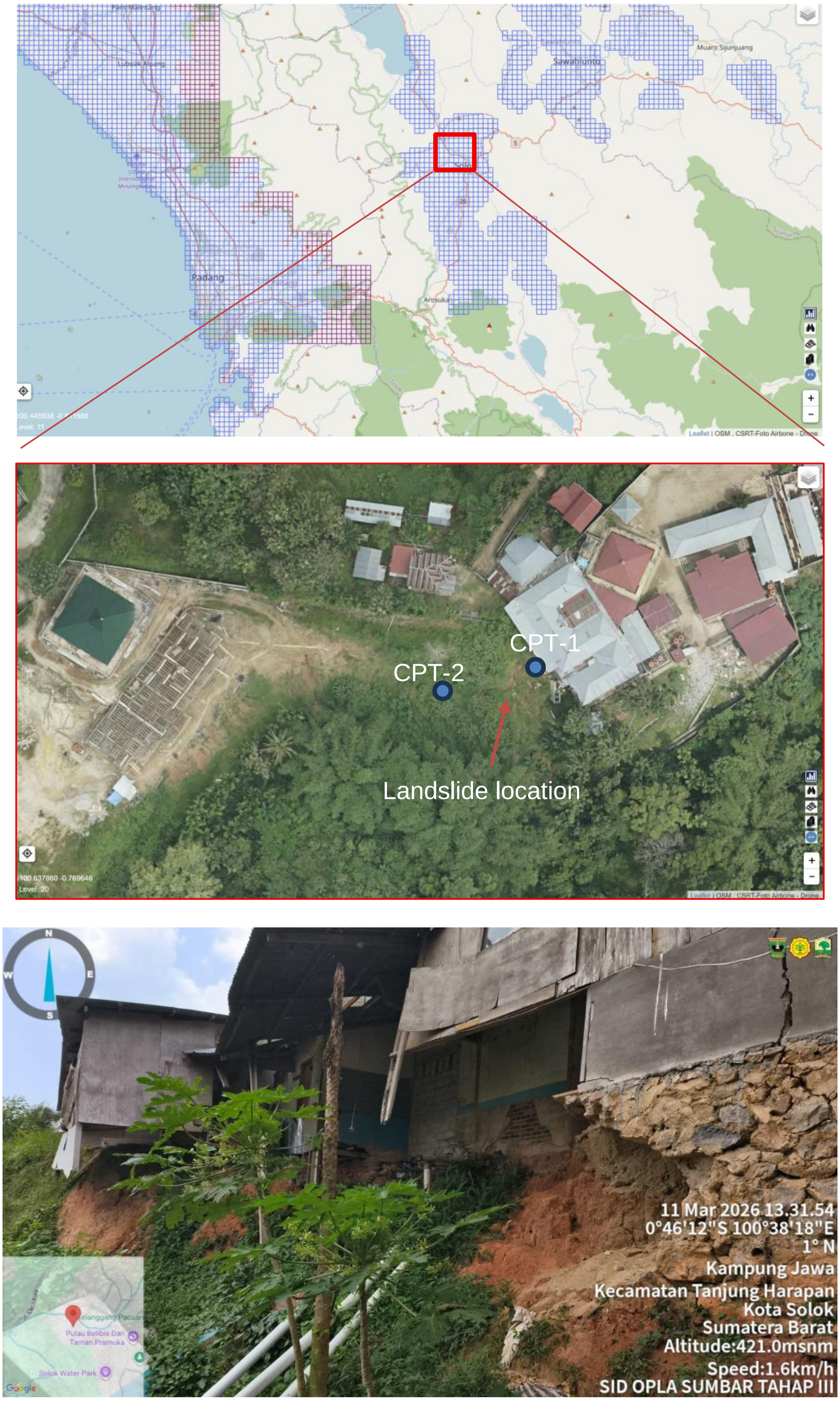


Figure 2. The situation of research location

2.2. Research Data

The data used in this study consisted of field survey data, retaining wall geometry, and subsurface soil information. The field survey was conducted to determine the existing ground profile, slope inclination, retaining wall positions, and elevation differences between the wall tiers. The geometrical data included the height, width, spacing, and foundation depth of each retaining wall, as well as the distance between the retaining walls and the dormitory buildings.

The subsurface soil conditions were investigated using cone penetration testing at two investigation points, designated as CPT-1 and CPT-2 (Figure 2). The CPT locations were selected to represent the soil conditions along the critical section of the slope and retaining wall system. The test results consisted primarily of cone resistance, sleeve friction, and friction ratio values recorded with depth. These parameters were used to identify variations in soil resistance and to interpret the subsurface soil stratification at the study site.

The CPT data were used to estimate the thickness and engineering characteristics of the soil layers. Soil behaviour types were interpreted based on the relationship between cone resistance and friction ratio. The measured cone resistance was also used to assess the relative consistency or density of the soil and to estimate relevant geotechnical parameters through established empirical correlations. The interpreted parameters included soil unit weight, undrained shear strength for cohesive soils, and friction angle for granular soils. Because these parameters were derived indirectly from CPT results, the selected values were evaluated conservatively and adjusted according to the observed site conditions.

Structural and loading data were incorporated into the stability model. The loads considered included the self-weight of the retaining walls, the weight of the retained soil, surcharge loads, and loads transmitted by the dormitory buildings. Building loads were obtained from available structural information or estimated based on the building configuration, number of storeys, foundation type, and functional use. The interpreted soil profile from CPT-1 and CPT-2, together with the retaining wall geometry, groundwater conditions, and applied loads, was subsequently used to develop the geotechnical stability model and determine the factor of safety and critical failure mechanism.

2.3. Slope Stability Analysis

The stability of the slope and tiered retaining wall system was evaluated using the finite element method (FEM). This method was selected because it enables the simultaneous modelling of the soil mass, retaining walls, groundwater conditions, and structural loads. Unlike conventional limit equilibrium methods, FEM calculates the stress–strain behaviour of the soil and does not require the potential failure surface to be defined in advance. Therefore, the critical failure mechanism can develop naturally according to the geometry, soil properties, boundary conditions, and loading conditions incorporated into the numerical model.

A two-dimensional numerical model was developed based on ground profile, retaining wall geometry, and interpreted subsurface conditions obtained from the two CPT investigation points. The stratigraphy and thickness of the soil layers were established by correlating the CPT-1 and CPT-2 profiles along the analysed cross-section. The engineering properties assigned to each soil layer included unit weight, cohesion, internal friction angle, Young’s modulus, and Poisson’s ratio. These parameters were estimated using established correlations with CPT cone resistance and friction data. Conservative values were adopted to account for uncertainties associated with the indirect interpretation of soil parameters.

The soil behaviour was represented using an appropriate constitutive model, such as the Mohr–Coulomb model, which describes soil strength in terms of cohesion and internal friction angle. The retaining walls were modelled as structural elements with material properties representing their stiffness, unit weight, and strength. Interfaces between the retaining walls and the surrounding soil were incorporated where required to account for possible relative movement and reduced shear resistance along the soil–structure contact surfaces. The dormitory building load was represented as a distributed surcharge or structural load applied at the corresponding position on the slope.

Boundary conditions were defined to prevent horizontal displacement along the lateral boundaries and both horizontal and vertical movements along the bottom boundary of the model. The model boundaries were placed sufficiently far from the retaining walls and potential failure zone to minimise their influence on the calculated response. Mesh refinement was applied around the retaining walls, building foundations, changes in soil layers, and areas where high stress concentration or significant deformation was expected. A mesh sensitivity evaluation was performed to ensure that the numerical results were not significantly affected by the selected element size.

The analysis was conducted through several calculation stages representing the initial stress condition, retaining wall construction, soil placement or excavation, building loading, and groundwater conditions. The initial geostatic stresses were generated based on the soil unit weight and lateral earth pressure coefficient. The retaining walls and structural loads were subsequently activated according to the assumed construction sequence. The groundwater level was introduced into the model to calculate pore-water pressure and effective stress within the soil mass. Where groundwater information was limited, several groundwater scenarios were analysed to assess its influence on slope stability.

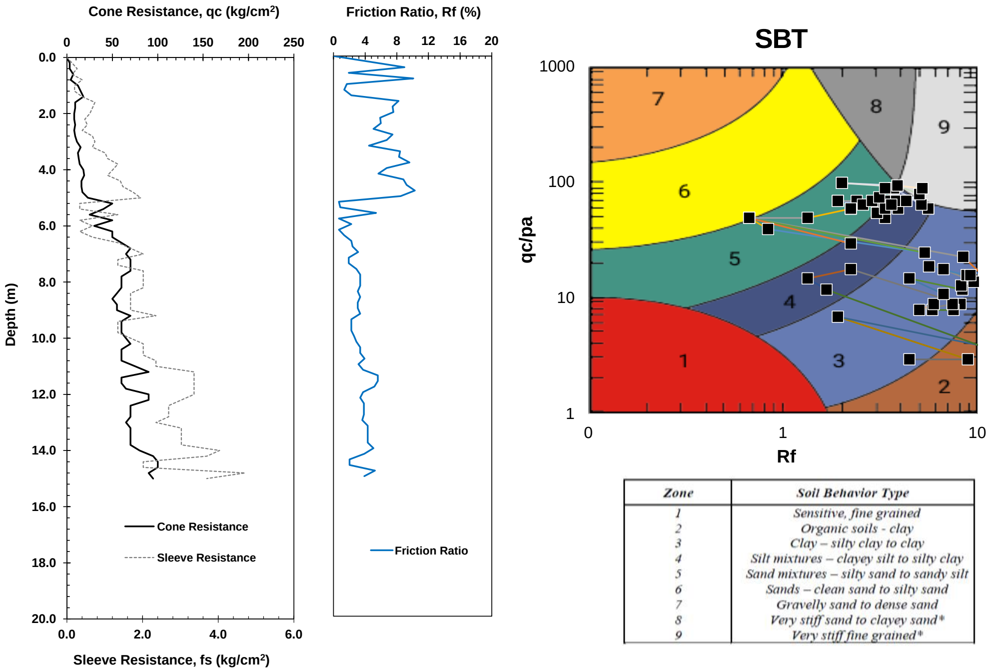
The factor of safety was determined using the shear strength reduction technique. In this approach, the soil shear strength parameters were progressively reduced until the numerical model was unable to reach equilibrium and a continuous failure mechanism developed. The strength reduction factor at failure was interpreted as the factor of safety of the slope and retaining wall system.

3. RESULT AND DISCUSSION

3.1. Soil Characteristics

The CPT-1 profile (Figure 3) indicates relatively weak, fine-grained soil in the upper layer. From the ground surface to approximately 5 m depth, cone resistance remains low, while the friction ratio is relatively high and variable. Based on the soil behavior classification chart, this interval is predominantly associated with clayey silt, silty clay, and sand–silt mixtures, corresponding mainly to Zones 3, 4, and 5. These characteristics suggest soft to medium-consistency soil with comparatively low stiffness and shear resistance.

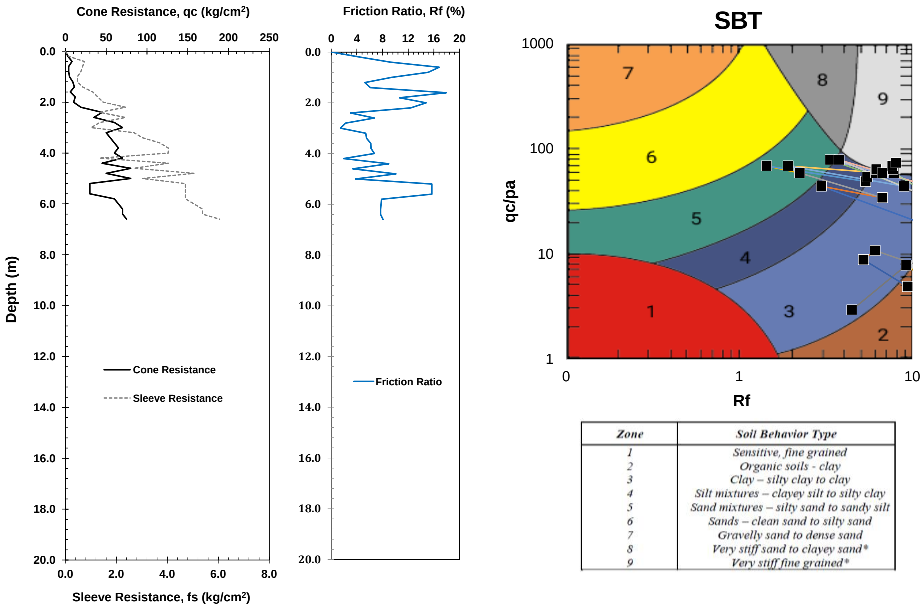
At depths greater than about 5–6 m, the cone resistance generally increases and the friction ratio decreases, indicating a transition toward denser and more granular material. The interpreted soil behavior is dominated by silty sand, sandy silt, and mixed clay–silt layers, with several points extending into cleaner sand and clayey zones. The higher cone resistance recorded between approximately 10 and 15 m suggests improved soil strength and stiffness. Overall, CPT-1 reveals a heterogeneous subsurface profile, consisting of weaker fine-grained soil near the surface and progressively stronger silty to sandy soil at greater depths.



Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils - clay
3	Clay – silty clay to clay
4	Silt mixtures – clayey silt to silty clay
5	Sand mixtures – silty sand to sandy silt
6	Sands – clean sand to silty sand
7	Gravelly sand to dense sand
8	Very stiff sand to clayey sand*
9	Very stiff fine grained*

Figure 3. Soil behavior type based on CPT-1

On the other hand, the CPT-2 profile (Figure 4) indicates relatively weak and heterogeneous soil conditions within the investigated depth of approximately 6.5 m. From the ground surface to about 2 m depth, the cone resistance is generally low, while the friction ratio is relatively high and variable. The soil behavior classification points are concentrated mainly in Zones 3, 4, 5, and 9, indicating mixtures of slity clay, silt mixtures, sand mixtures, and very stiff fine grained soil. The high friction ratio in the upper interval suggests a significant fine-grained component, whereas the low cone resistance reflects relatively low penetration resistance and limited stiffness.



Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils - clay
3	Clay – silty clay to clay
4	Silt mixtures – clayey silt to silty clay
5	Sand mixtures – silty sand to sandy silt
6	Sands – clean sand to silty sand
7	Gravelly sand to dense sand
8	Very stiff sand to clayey sand*
9	Very stiff fine grained*

Figure 4. Soil behavior type based on CPT-2

Between approximately 2 and 6.5 m depth, the cone resistance gradually increases, particularly below about 4 m, while the friction ratio remains variable. The interpreted soil behavior is dominated by Zones 4 and 5, with several points extending into Zones 2, 3, 6, and 9. This suggests alternating layers of silt mixtures, sand–silt mixtures, clayey soil, and locally denser sandy material. The increasing cone resistance toward the termination depth indicates improved strength and stiffness at greater depth. Overall, CPT-2 shows a layered subsurface profile composed mainly of fine-grained to mixed silty-sandy soils, with stronger material encountered below approximately 4–5 m.

3.2. Geometry Model and Input Parameter

The proposed site design shown in the Figure 5 was used as the primary reference for developing the numerical model. It illustrates the arrangement of the dormitory buildings on stepped ground supported by tiered retaining walls at different elevations. The building positions, ground profile, wall locations, and relative elevation differences were simplified into a representative two-dimensional cross-section for the finite element analysis. The structural loads from the dormitory buildings were incorporated into the model as equivalent surcharge loads, while the retaining walls and surrounding soil layers were represented according to their specified geometries and material properties. This modelling approach enabled the interaction between the buildings, retaining walls, and supporting slope to be evaluated under the proposed site configuration.

Figure 5. The proposed design for model geometry

Figure 6 presents the two-dimensional finite element geometry used to evaluate the stability of the study area. The model consists of two principal soil layers, represented by different colours. The upper cyan layer represents the near-surface soil or fill material, whereas the lower beige layer represents the underlying soil deposit with different engineering properties. The ground surface was modelled according to the surveyed slope profile, including the level ground at the slope toe, the inclined section, and the upper platform supporting the dormitory area.

Figure 6(a) represents the existing site condition, while Figure 6(b) shows the modified model incorporating two-tiered retaining walls, represented by the green structural elements. The walls were positioned at different elevations to support the stepped ground profile and reduce lateral soil movement. The thin grey lines indicate the original or intermediate ground geometry used during the construction-stage modelling. Both geometries were analyzed to compare the existing slope response with the condition after the retaining wall system was introduced, particularly in terms of factor of safety, displacement, and critical failure mechanism.

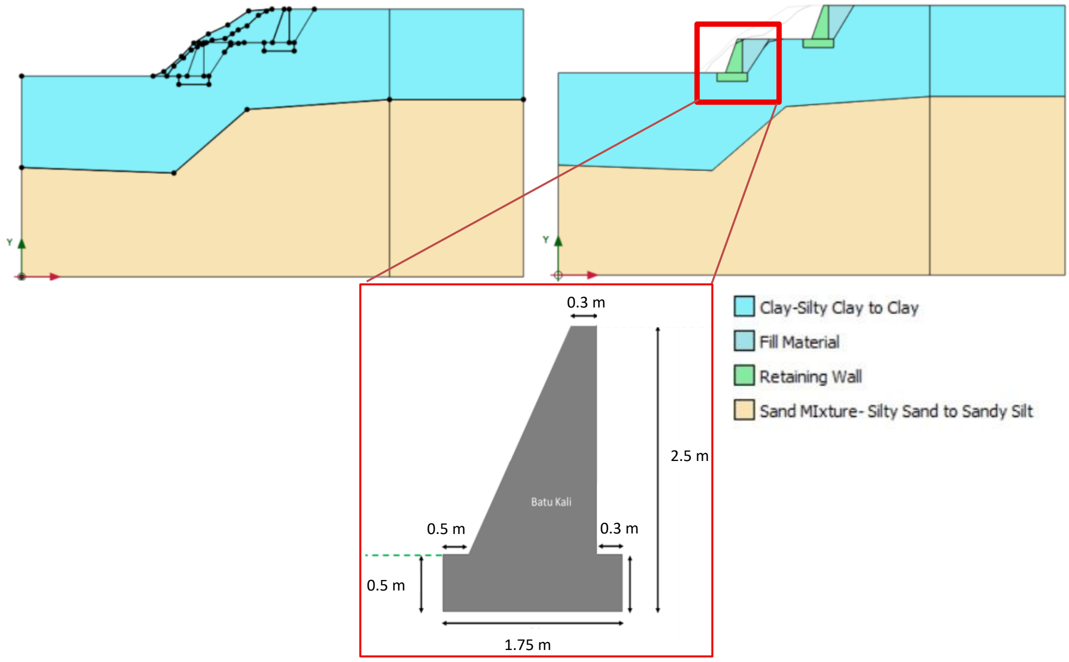


Figure 6. Geometry model of a) existing condition, b) end of construction, c) geometry of retaining wall

The gravity retaining wall (Figure 6c) used in the analysis was constructed from stone masonry and proportioned in accordance with the Indonesian geotechnical design standard, SNI 8460:2017. The wall has a total height of 2.5 m, a base width of approximately 1.75 m, a base thickness of 0.5 m, and a top width of 0.3 m. The base extends approximately 0.5 m beyond the inclined face and 0.3 m beyond the vertical rear face. This trapezoidal configuration provides sufficient self-weight and base area to resist lateral earth pressure while improving the wall's resistance to sliding, overturning, and excessive foundation pressure.

The Table 1 presents the material properties used in the finite element analysis for two natural soil layers, the fill material, and the retaining wall. The soil materials were represented using the Mohr–Coulomb model, with parameters including unit weight, shear strength, internal friction angle, Poisson's ratio, and Young's modulus, while the retaining wall was modelled as a linear-elastic material. Layer 1 represents a cohesive soil under undrained conditions, whereas Layer 2 and the fill are primarily characterized by frictional strength. Differences in strength and stiffness among the materials were incorporated to simulate their stress–strain behavior and evaluate the deformation and overall stability of the slope–retaining wall system.

Table 1. Input parameter

Parameter	Unit	Clay-Silty Clay to Clay	Sand Mixture-Silty Sand to Sandy Silt	Fill Material	Retaining Wall
Material Model	-	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Elastic Linear
Unit weight*, γ	kN/m^3	17.71	19.67	17	-
Undrained Shear Strength*, c_u	kN/m^2	61.85	-	5	-
Internal Friction*, ϕ	°	-	30.72	33	-
Poisson ratio**, υ	-	0.45	0.4	0.4	-
Young's Modulus**, E	kN/m^2	12370.62	37666.66	19200	90000

*Robertson and Cabal (2010) **Bowles (1984) Hakam (2008)

3.3. Model Output and Stability

The finite element analysis after the installation of the tiered gravity retaining walls resulting a safety factor of 2.60, indicating that the proposed slope–wall system remains stable under the modelled soil and loading conditions. The concentration of deformation or shear strain is mainly distributed from the lower wall area toward the upper slope, forming a curved potential failure zone within the near-surface soil layer. However, the retaining walls restrict lateral soil movement and provide additional resisting forces, preventing the critical zone from developing into an overall slope failure.

Compared with the existing slope condition, which had a safety factor of 2.43, the retaining wall system increased the safety factor by 0.17, or approximately 7%, to 2.60. This improvement demonstrates that the proposed walls enhance overall stability by supporting the stepped ground and restricting deformation near the slope face. The increase is smaller than that reported from other research, who found that cantilever retaining-wall reinforcement increased the safety factor from 1.16 to 1.56, or approximately 34% (Hastuty and Pambudi, 2020). This difference may be attributed to variations in the initial slope stability, wall type and dimensions, slope geometry, soil properties, and loading conditions. In the present study, the relatively modest increase is reasonable because the existing slope was already stable; therefore, its overall behaviour remains strongly controlled by the geometry and properties of the surrounding soil mass. The retaining walls should consequently be combined with adequate drainage, proper foundation preparation, and construction quality control, while their resistance to sliding, overturning, and bearing-capacity failure should also be verified separately.

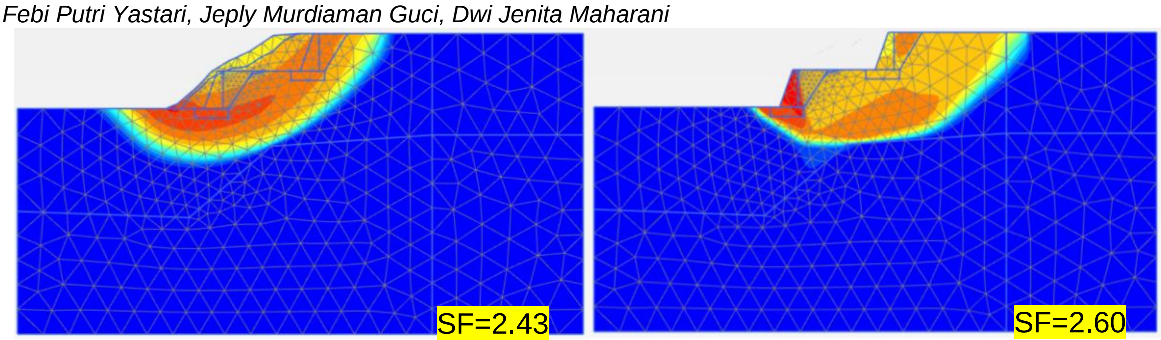


Figure 7. Stability model of : a) exsisting condition, and b) end of construction

Nevertheless, both calculated safety factors exceed 2.0, indicating that the overall slope has a relatively high global stability margin under the conditions represented in the numerical model. Therefore, the observed site instability is unlikely to have resulted from a deep-seated global failure mechanism. Instead, the recorded slope damage is presumed to be associated with shallow surface erosion and local soil loss during rainfall, particularly where surface runoff and drainage are inadequately controlled. Such rainfall-induced erosion processes could not be explicitly represented in the present finite element model. Accordingly, the retaining walls should be complemented by effective surface and subsurface drainage, erosion protection, proper foundation preparation, and adequate construction quality control, while their resistance to sliding, overturning, and bearing-capacity failure should also be verified separately.

4. CONCLUSION

This study evaluated the stability of a tiered gravity retaining wall system supporting an Islamic boarding school dormitory in Solok City using CPT-based soil interpretation and finite element analysis. Subsurface conditions were characterised from two investigation points, CPT-1 and CPT-2, which indicated heterogeneous soil layers consisting mainly of fine-grained and mixed silty–sandy materials. The interpreted soil parameters, surveyed slope geometry, retaining wall dimensions, groundwater conditions, and building loads were incorporated into the numerical model. The existing slope produced a factor of safety of 2.43, indicating a relatively high stability margin against deep-seated failure under the modelled conditions. Following the installation of the tiered retaining walls, the factor of safety increased to 2.60, representing an improvement of approximately 7%. The retaining walls therefore enhanced slope performance by restricting lateral soil movement and supporting the stepped ground configuration. However, the modest increase indicates that overall stability remains strongly influenced by the geometry and engineering properties of the surrounding soil mass. Since both safety factors exceeded 2.0, the observed site damage was unlikely to have resulted from a deep-seated global failure mechanism. The instability was instead presumed to be associated with shallow surface erosion and local soil loss during rainfall, which were not explicitly simulated in the present finite element model. Consequently, the proposed retaining wall system should be complemented by effective surface and subsurface drainage, erosion protection, proper foundation preparation, and adequate construction quality control. Separate checks against sliding, overturning, and bearing-capacity failure are also required to ensure the satisfactory performance of each retaining wall..

REFERENCES

Bowles, J.E. Foundation Analysis and Design, 5th ed. Singapore: The McGraw-Hill Companies, Inc, 1984

Hakam, A. Rekayasa Pondasi. Padang: BiG Padang, 2008.

Hastuty, I. P., & Prambudi, R. (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). *IOP Conference Series: Materials Science and Engineering, 851*(1), 012021. https://doi.org/10.1088/1757-899X/851/1/012021

Khan, M.I. et al. (2025) 'Usage of permeability ratio to check the stability of a pile-soil model with retaining wall support – Huizhou slope failure as a case study', International Journal of Geo-Engineering, 16(1), p. 7. Available at: https://doi.org/10.1186/s40703-025-00238-4

Luo, Y.-N., Wei, Y.-X. and Ding, Z.-F. (2013) 'Analysis of main influence factors on stability of cutting retaining wall', Journal of Railway Engineering Society, 30(5), pp. 23–26.

Nimbalkar, S., Pain, A. and Annapareddy, V.S.R. (2020) 'A Strain Dependent Approach for Seismic Stability Assessment of Rigid Retaining Wall', Geotechnical and Geological Engineering, 38(6), pp. 6041–6055. Available at: https://doi.org/10.1007/s10706-020-01412-4

Rajabian, A. and Vahedifard, F. (2025) 'Probabilistic Stability Analysis of Retaining Walls with Unsaturated Backfill', International Journal of Geomechanics, 25(12). Available at: https://doi.org/10.1061/IJGNAI.GMENG-11393

Robertson, P.K., Cabal, K.L. Guide to Cone Penetration Testing for Geotechnical Engineering. GREGG, 2010.

Seo, S. et al. (2023) 'Geotechnical factors influencing earth retaining wall deformation during excavations', Frontiers in Earth Science, 11. Available at: https://doi.org/10.3389/feart.2023.1263997.

Singh, J., Gupta, S. and Kumar, S. (2026) 'Stability Assessment of T-Type Retaining Wall Under Gravity Loading Using Optum G2', in, pp. 207–217. Available at: https://doi.org/10.1007/978-981-95-2588-1_18.

Song, X.-H. and Yan, H.-H. (2016) 'Analysis of stability of masonry slope based on cusp catastrophe theory', Yantu Lixue/Rock and Soil Mechanics, 37(12), pp. 3499–3505.

Zhu, Y. et al. (2026) 'Experimental Study on Working Performance of Reinforced Soil Retaining Wall under Vehicle Dynamic Load', Geotechnical Testing Journal, 49(1), pp. 84–98. Available at: https://doi.org/10.1520/GTJ20240231.