



Stability Analysis of Slopes with Weak Interlayers Considering Dynamic Construction Processes and Variable Dip Angles of Low-Angle Discontinuities

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Abstract. Based on the engineering case of a gently inclined bedding rock slope containing weak interlayers, this study summarizes the engineering characteristics of weak interlayers and preliminarily determines that the slope failure mode is bedding slip-tensile cracking, with the weak interlayer being the primary factor affecting slope stability. Numerical analysis was conducted to evaluate the stability of both vertical-cut and slope-cut excavations with varying structural plane inclinations. The results indicate that unloading through excavation improves slope safety but disrupts the original stress equilibrium, reduces the beneficial self-weight load of the overlying soil, releases initial slope stress, and increases tangential displacement. The intersection zone between the excavated slope surface and the weak structural plane constitutes a post-excavation weak area. Compared to vertical excavation, slope cutting significantly enhances the stability factor across different inclination angles. The study reveals that the stability of gently inclined bedding slopes with weak interlayers is inversely correlated with the thickness and dip angle of the weak structural layer as well as the self-weight of the overlying rock and soil mass. For the studied slope, the structural plane exhibits a sensitive inclination range of 19° – 30° , within which the slope is prone to developing rear-edge tensile cracks as the angle increases. After slope cutting, the shear stress distribution follows a similar decreasing trend as the inclination angle varies from 9° → 14° → 19° , with the self-weight of the sliding mass above the weak interlayer becoming the dominant factor influencing the rear-edge shear resistance. When the dip angle of the weak structural plane is less than 14° , slope stability is primarily governed by the geomechanical properties of the rock-soil mass and boundary conditions.

Keywords: Gentle dip; Dynamic construction; Weak interlayer; Varying dip angles; Slope stability

1 Introduction

In recent years, the stability issues of gently inclined bedding rock slopes have gradually gained significant attention within China's geotechnical engineering community.^[1]

[8] Numerous gently inclined bedding rock slopes containing weak interlayers have demonstrated severe failure consequences, as exemplified by the 2015 highway landslide in Guiyang City. This geohazard caused significant tilting damage to two transmission towers on the mountain slope, resulting in instantaneous rupture of 220 kV high-voltage cables. In slope engineering practice, the most critical scenario involves dip-slopes where the bedding plane orientation aligns with the slope face, particularly when weak interlayers are present. The stability concerns become especially pronounced when such gently inclined dip-slopes contain weak structural planes or undergo stress redistribution due to engineering excavation. These landslide masses typically exhibit bedrock dip angles below 15° , classifying them as characteristic gently inclined dip-slopes. Current engineering practice lacks precise angular boundaries for defining dip-slopes, though conventionally, gently inclined slopes refer to those with bedrock dip angles $\leq 30^\circ$. Slopes where the intersection angle between the slope face and bedding plane is $< 30^\circ$ are universally identified as dip-slopes. Several scholars have derived closed-form solutions correlating weak plane inclination angles with critical slope height and safety factors for rock slopes containing weak structural planes. Through case studies, these solutions have been visually demonstrated to establish quantitative relationships between the aforementioned parameters.^[9] While extensive research has been conducted internationally on the stability of slopes with soft rock strata, systematic investigations specifically addressing gently inclined rock slopes containing soft rock layers remain notably scarce.^{[10]-[14]}

The gently inclined bedding rock slope exhibits internal stratification that is essentially parallel to the dominant structural planes within the slope mass, with relatively low dip angles. Under the combined influence of self-weight and external factors, the rock-soil mass above the weak structural plane develops a driving force that exceeds the resisting force along the weak plane, triggering progressive sliding along the weak structural plane and ultimately leading to overall slope instability. The characteristic failure process manifests as follows: under external influences such as unloading, rainfall, or slope excavation, relaxation or tension cracking occurs along weak structural planes within the internal rock mass, creating significant stress concentration on excavated slope surfaces. Initial sliding typically initiates at outcrops of weak structural planes, subsequently generating substantial tensile stress concentration within the slope body. Given the inherently low tensile strength of rock masses, when the driving force generated by the sliding mass exceeds the actual resisting force of the rock, the sliding mass readily undergoes overall movement toward free surfaces. This process leads to the formation of tension cracks in the rear slope region and establishes shear boundaries around the sliding mass. Once these rear tension cracks and shear boundaries develop, the sliding mass becomes increasingly prone to shear breakout along the weak structural planes within the slope, ultimately resulting in sliding-tension failure of the slope.

The orientation and dip angle of weak structural planes significantly influence slope stability in engineering practice. When the weak structural plane is parallel to the principal compressive stress direction of the slope, shear and tensile stress concentrations occur at the endpoints or stress-blocked zones of the interlayer, leading to tensile cracks or shear failure on both sides. Conversely, when the weak structural plane is perpen-

pendicular to the principal compressive stress direction, the interlayer endpoints may develop stresses either perpendicular or parallel to the plane, which generally enhances the overall stability of the system. In cases where the weak structural plane intersects obliquely with the principal compressive stress direction, tensile stresses dominate at the interlayer endpoints or stress-blocked zones, while shear stresses become the primary factor causing overall shear failure along the weak structural plane. When multiple weak structural planes converge toward the principal compressive stress direction, stress concentrations intensify at the intersections due to combined tensile and compressive stresses, ultimately leading to large-scale slope deformation and instability.

2 Evolution Mechanism of Weak Interlayers

The formation and evolution mechanism of weak interlayers in slopes is closely related to their long geological history and is influenced by various factors such as weathering, water, and external forces. Different geological histories result in different formation and evolution patterns of weak interlayers. For gently inclined layered rock slopes, the genesis of weak interlayers is related to the long-term sedimentary process of rock layers. Mohammad Azarafza et al. introduced the Q-slope classification system, which provides preliminary predictions for the stability assessment of rock slopes by applying simple assumptions that tend to reflect different failure mechanisms^[15]. In the mountainous areas of Southwest China, layered structures often develop several weak interlayers composed of rock materials such as mudstone, shale, or claystone. Sometimes, these weak interlayers, together with internal fractures or joint surfaces of the rock mass, form separation surfaces of the rock mass, which then become unstable and fail after long-term creep deformation. To some extent, the failure mechanism of rock slopes is inseparably linked to the geological evolution history of weak interlayers. For specific gently inclined bedding rock slopes, the evolution mechanism of weak interlayers needs to be determined based on local geological history data combined with on-site exploration and analysis.

Chinese scholars Zhu Sinan and Wang Sen have done a lot of work on the evolution mechanism of weak interlayers. Taking Jiweishan landslide in Chongqing as an example, Zhu Sinan clarified the geological background, deformation history and formation mechanism of the landslide on the basis of detailed investigation of on-site geological data, and found that the main control factor of creep deformation was caused by the strength attenuation of weak layer and karst zone. On this basis, the material foundation, sedimentary environment and evolutionary characteristics of the weak interlayer are explored, and the typical interlayer evolution stage of the slip zone is from the primary soft rock evolution to the interlayer shear zone and finally to the slip zone. He described in detail the evolution of mineral components, physical properties, chemical properties, microstructure and connection types of the weak interlayer, and summarized the evolution model of the weak interlayer of Jiweishan from the initial structure, overlying pressure and water-rock interaction to the formation of primary soft rock through physical and chemical interaction, and the destruction of microstructure and then the for-

mation of intercambial shear zone. After a long period of physicochemical and microbial interaction, it evolved into a slip zone^[16]. Wang Sen pointed out that the key factor to control bedding landslide is the evolution process of mudred interlayers in a large number of bedding rock slope slide cases in a certain area of Nanjiang County, and to grasp the strength change of soft interlayers under the action of long-term groundwater is the core to prevent such rock slope slide^[17]. The typical formation stage of argillated interlayer is also obtained, namely sedimentary soft rock → tectonic shear → mud-containing shear fracture zone (groundwater water chemistry) → argillated interlayer, which is basically consistent with the research results of Zhu Xianan. This shows that although they are different weak interlayers, the factors related to the formation mechanism and evolution mechanism of interlayers and the evolution process of interlayers show certain regularity.

It can be seen that the formation of weak interlayer is the result of the combined action of time and multiple internal and external factors, and the weak structural plane formed in the slope determines the stability of the bedding rock slope to a large extent. It is necessary to explore the influence of the thickness, dip Angle and related properties of the interlayer on the stability of the bedding rock slope. Based on the above, and combined with the engineering examples of low-dip bedding rock slope, the author takes a low-dip bedding rock slope with weak interlayer as an example to analyze the relationship between dynamic construction, Angle of low-dip, characteristics of weak interlayer and slope stability.

3 Engineering Overview of a Gently Inclined Bedding Rock Slope Project

There is a gently sloping bedding rock slope in southwest China, and a sewage treatment plant is planned to be built at the foot of the slope, which is located in a subtropical humid monsoon climate. The annual average precipitation is 1163.6mm, and most of the precipitation is 700.3mm from May to August every year. The climate is mild, with an average annual temperature of 15°C. The site belongs to the "U" type bank of the structural dissolution denudation remnant mound, the topographic slope is greater than 30°, the terrain is relatively steep, and the overall is high in the northwest and low in the southeast. The elevation of the terrain is between 1217.036 and 1243.778m, and the relative elevation difference is about 26.74m. The slope area is low mountain and hilly landform with vegetation covering the surface.

According to the regional geological data, exploration results and drilling, the underlying bedrock is the muddy dolomite of the middle Triassic Songzikan Formation. Formation occurrence: the inclination is 115 degrees, the inclination is about 14 degrees, the rock mass is relatively broken, the joint cracks are relatively developed, and the structural plane is very poor. Two groups of joints are mainly developed on the site, the occurrence group is $185^{\circ}\angle 87^{\circ}$, 2 ~ 3 pieces per meter, the group is $276^{\circ}\angle 86^{\circ}$, 1 ~ 2 pieces per meter, and the degree of argillous cementation of the joint surface is poor. The site is covered with quaternary cultivated soil with an average thickness of 0.40m.

The underlying bedrock is the muddy dolomite of the middle Triassic Songzikian Formation, of which the average thickness of strongly weathered muddy dolomite is about 1.2m. Medium weathered argillaceous dolomite, rock mass structural plane 2 to 3 group developed, spacing about 0.1 ~ 0.4 m, the degree of structural plane bonding is very poor.

In terms of hydrogeology, the proposed site is located in a gentle slope area with high elevation and easy drainage, which is a non-accumulation area of surface water and does not exist. The ground water discharge condition of the site is good (because there is a river on the east side of the site about 50m away from the site), so the water level of the ground water does not change much in dry and wet periods, and the ground water will not affect the slope. There is no active fault passing through the site and its vicinity, no adverse geological effects such as collapse, debris flow and goaf, and no karst collapse and funnel phenomena on the surface of the site.

The slope project is linear, the total length of the slope is about 120m, the vertical height is 9.75 ~ 36.55m, generally 23-28m, there is no building on the top of the slope, but the slope damage will endanger pedestrians and buildings at the foot of the slope, and the damage consequences are very serious. The slope strike is about 90° , the occurrence of rock strata $115^\circ \angle 14$, the Angle between the occurrence of rock strata and the slope strike is 25 degrees, the slope is a forward slope, the occurrence of slow dip. The slope is high, the rock joint cracks are developed, rock fall may occur, and the slope stability is poor. The design elevation of the site is 1213.00m. After the excavation of the site, a permanent slope with a vertical height of 9.75 ~ 36.55m will be formed on the west side of the site, which has certain slope conditions.



Fig. 1. Characteristics of Rock Mass and Discontinuities.

Based on the field characteristics and rock mass types of the slope, preliminary stability calculations and evaluations were conducted (Figure 1). The site plan of the slope

is shown in Figure 3. Stereographic projection analysis was performed using statistically measured joints from the highest section of the investigated slope. For this analysis, the representative left side of section A-A' was selected with a designed slope gradient of 1:0.75. The results indicate that the slope is potentially susceptible to sliding along the combination of bedding planes and Joint Set 1. The stability of the slope is predominantly controlled by the bedding planes, with the likely failure mode being a slip-tension crack failure pattern along the bedding surfaces.



Fig. 2. Argillized Weak Interlayer.

The preliminary support design adopts the strategy of maximum slope cutting combined with intercepting drainage measures, utilizing an integrated system of anti-slide piles + prestressed anchor cables + rock bolts + shotcrete with wire mesh. During initial construction, deformation cracks approximately 60mm wide appeared at the slope crest (location shown in Figure 3). The weak interlayers identified in preliminary exploration exhibit thicknesses of 5-20mm (Figure 2). Due to significant variation in the occurrence of outward-dipping structural planes, these clay-softened interlayers demonstrate pronounced randomness and concealment characteristics, making it challenging to obtain accurate computational parameters during preliminary investigations. Slope stability is predominantly controlled by the orientation of outward-dipping structural planes and their shear strength parameters.

4 Numerical Simulation of Stability Considering Dynamic Construction and Variable Dip Angles of Structural Planes

4.1 Parameter Selection and Numerical Model Establishment

The numerical model was established using Midas GTS NX software with dimensions of 241 m in length and 63 m in height to minimize computational errors and ensure

alignment with actual engineering conditions. The geotechnical materials were simulated using 2D plane strain elements. A 20 mm-thick weak interlayer was incorporated at elevation 0.000 m based on field observations, while water seepage effects were neglected. To guarantee computational accuracy, the mesh around the weak structural plane and adjacent geotechnical materials was refined. The model boundaries were constrained at the base and both sides to simulate realistic slope conditions. Only the self-weight stresses of the vertically excavated slope and cut-slope configurations were considered as loading conditions. The Mohr-Coulomb constitutive model was adopted for both rock and soil materials, with geomechanical parameters presented in Table 1. Based on the engineering background, tension cracks were observed at the rear edge during preliminary construction following a 26.33 m vertical excavation. Subsequent geological review identified the presence of argillized weak interlayers. Accordingly, the numerical model compares two working conditions: Vertically Excavated Slope: post 26.33 m vertical excavation state. Cut Slope: final configuration after slope cutting following vertical excavation. The natural slope was excluded from stability analysis as field assessments confirmed its stable condition.

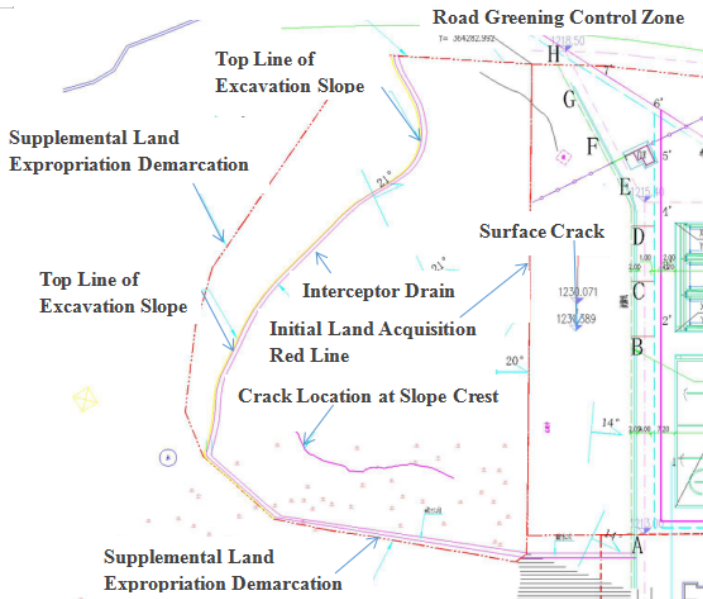


Fig. 3. Site Plan of the Slope.

Table 1. Physico-mechanical Parameters of Rock and Soil Mass.

	Weak-layer Dolomite	Argillaceous Dolomite
Cohesion c /kPa	26.8	200
Internal friction angle $\varphi / (^\circ)$	11.2	30
Elastic modulus E /MPa	1000	17000
Poisson's ratio μ	0.25	0.27

Unit Weight γ ($\text{kN} \cdot \text{m}^{-3}$)	26.51	26.51
Note: The parameters for weak-layer dolomite were determined through field tests, while those for argillaceous dolomite outside the weak layers were referenced from Nie Kailiang et al.'s experimental research on argillaceous dolomite in the Guiyang area [18]. These correspond to the rock mass compressive strength of 30.65 MPa to 34.86 MPa and an elastic modulus of 17,000 MPa as specified in this project's investigation report, with other values derived from the survey report.		

4.2 Comparative Analysis of Numerical Simulations Before and After Slope Cutting

A numerical model was established based on the original slope profile and the designed slope profile.

Table 2. Comparison of Numerical Simulation Results Between Vertical Excavation Slope and Cut Slope.

Working Condition	Vertical Excavation Slope	Cut Slope
Safety Factor	0.85	2.24
Maximum Tangential Displacement (m)	0.22	0.65
Maximum X-Displacement (m)	0.0038	0.0047
Maximum Y-Displacement (m)	-0.1	+0.39/-0.19
Maximum Shear Stress (kN/m^2)	429.3	701.1

Conclusions based on comparative analysis of numerical results (Figures 4-7 and Table 2):

① The safety factor increased from 0.85 (post-vertical excavation) to 2.24 (post-slope cutting), indicating that the resisting force was less than the driving force after vertical excavation but exceeded it after cutting, demonstrating that material removal improved slope stability.

② The maximum tangential displacement after cutting (0.65 m) was three times greater than after vertical excavation (0.22 m). While cutting enhanced stability, the excavation altered the original stress equilibrium, reduced beneficial overburden pressure, released initial stresses, and consequently increased tangential displacement.

③ The instability of the vertically excavated slope primarily originated from the free boundary at the upper part of the potential sliding surface. After cutting, the intersection between the new slope face and weak structural planes became the most vulnerable zone, from which the failure surface propagated.

④ Figures 4-5 show negligible deformation differences at the boundaries of the 14°-inclined, 20 mm-thick weak interlayer in the vertically excavated slope. The post-cutting failure surface developed as a circular arc rather than following the weak interlayer, confirming that stability depends on interlayer thickness. Thicker interlayers reduce stability, validating both the decision not to conduct stratified measurements initially and the scientific basis of the "50 mm threshold for stratified measurement" specified in the "Technical Code for Geological Exploration and Sampling of Construction Projects."

⑤ The maximum shear stress after cutting was 1.6 times that after vertical excavation. Figure 6 shows minimal maximum shear stress concentrations only at weak layer exposures in the vertically excavated slope, while Figure 7 demonstrates vertical distribution of maximum shear stress from top to bottom near the rear slope surface exposure after cutting. This indicates that excavation-induced unloading caused sliding-tension cracking, concentrating shear stress at the slope rear - consistent with field observations of 50-60 mm tension cracks during early construction and confirming a sliding-tension failure mode post-cutting.

⑥ All slope displacements occurred tangentially along structural planes.

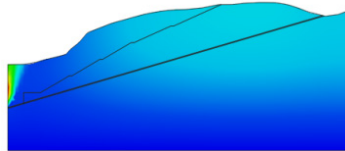


Fig. 4. Total Displacement Contour of Vertical Excavation Slope Model.

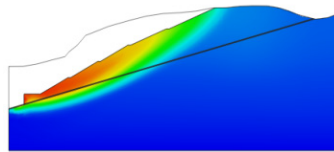


Fig. 5. Total Displacement Contour of Cut Slope Model.

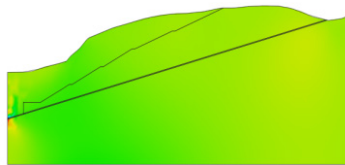


Fig. 6. Shear Stress Contour of Vertical Excavation Slope Model.

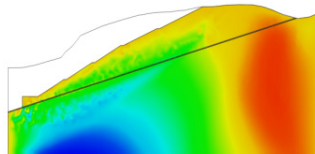


Fig. 7. Shear Stress Contour of Cut Slope Model.

4.3 Comparative Analysis of Numerical Simulations for Gently Inclined Structural Planes with Varying Dip Angles

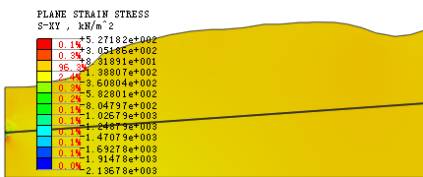
Numerical models were established based on various dip angles of weak structural planes in the vertically excavated slope, with analysis results as table 3.

Table 3. Stability Factors from Numerical Simulation of Different Dip Angles in Structural Planes After Vertical Excavation

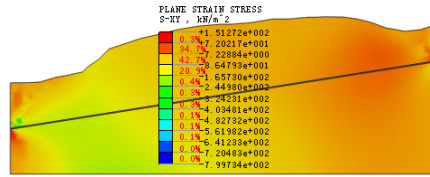
Dip Angle 4°	0.87
Dip Angle 9°	0.86
Dip Angle 14°	0.85
Dip Angle 19°	0.78
Dip Angle 24°	0.70
Dip Angle 30°	0.70

Based on the analysis of Table 3, Figure 8, and numerical calculation results of different dip angles in gently inclined weak structural planes after vertical excavation, the following patterns and conclusions are obtained:

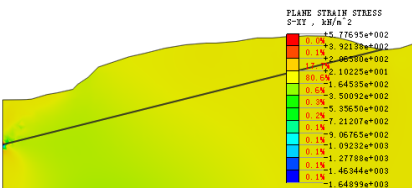
- ① The slope stability factor gradually decreases with increasing dip angle of structural planes. When the angle is $\leq 14^\circ$, the stability factors are relatively close, indicating that the presence of thinner weak interlayers has limited impact on slope safety, which is primarily determined by geotechnical properties and boundary conditions.
- ② After reaching 24° within the gently inclined range, stability factors tend to converge, showing that although the dip angle increases, the unit weight of overlying rock/soil decreases, reducing driving forces and resulting in only minor sliding at boundary areas.
- ③ Significant variations in stability factors occur during the 14° - 24° transition, identifying this as the critical range affecting post-excavation slope safety, where stability decreases progressively with increasing angle.
- ④ Shear stress contours show that when dip angles increase from 19° to 30° , vertical stress distribution becomes pronounced along the slope rear, indicating tension crack development and sliding-tension failure mode, with more evident failure at higher angles.
- ⑤ Notably, the 9° dip angle exhibits more concentrated shear stress than 14° , particularly at frontal/rear structural plane intersections, suggesting greater overlying mass weight at 9° makes it less stable than 14° .



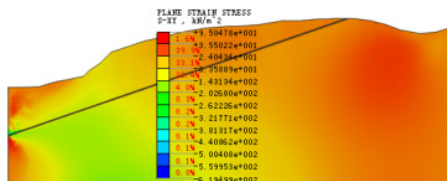
(a) Dip Angle 4°



(b) Dip Angle 9°



(c) Dip Angle 14°



(d) Dip Angle 19°

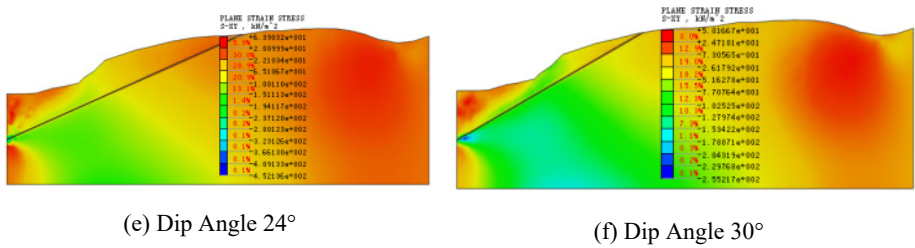


Fig. 8. Shear stress contour plots from numerical simulations of slopes with different dip angles after vertical excavation.

Numerical models were established based on different dip angles of weak structural planes in the cut slope. Due to the removal of upper rock and soil layers during cutting, only three working conditions with dip angles of 9°, 14°, and 19° were analyzed. The following patterns and conclusions were obtained by combining Table 4, Figures 9-10, and numerical calculation results of different dip angles in gently inclined weak structural planes:

① The stability factors of the slope under the three working conditions were relatively close, indicating that the stability of the cut slope is similar within a certain range of gently inclined angles. This is because when the dip angle is small, the heavier sliding mass above the weak layer increases the sliding tendency of the upper rock mass. As the dip angle increases, the weight of the upper rock mass gradually decreases, reducing the sliding tendency. Overall, slope stability is inversely correlated with the dip angle of weak structural planes and the self-weight of the overlying rock mass.

② Compared to the vertically excavated slope, the stability factors of the cut slope with different dip angles were significantly improved, demonstrating that material removal is a reasonable slope treatment method for this project.

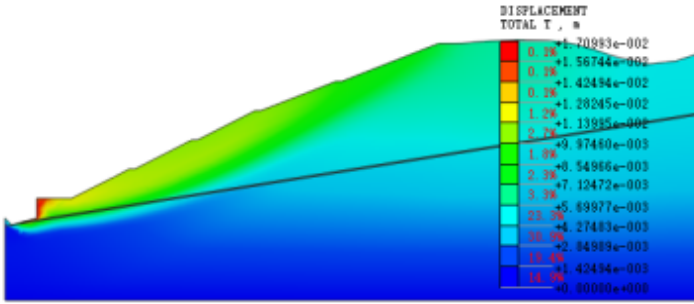
③ Comparing the shear stress contours of different dip angle models after cutting (Figure 10), it was found that as the dip angle increases, the shear stress distribution in all three working conditions shows a similar decreasing pattern, with stress mainly concentrated at the rear edge of the slope. This indicates that for this slope, the increase in dip angle after cutting does not significantly contribute to the shear stress at the rear edge, which is primarily influenced by the self-weight of the overlying sliding mass. The greater the self-weight of the overlying rock and soil mass, the more likely tension cracks will develop at the rear edge.

④ Comparing the numerical analysis results before and after cutting, the post-cutting results show more regular patterns due to the designed slope profile being systematically modified from the original vertical excavation.

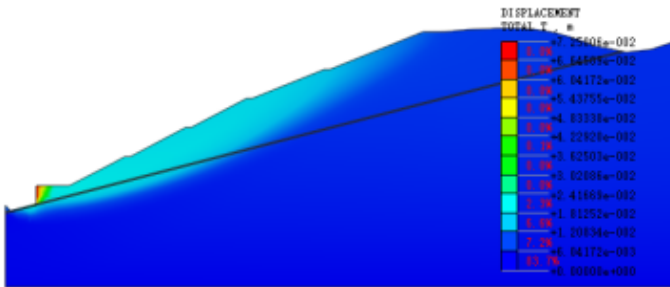
These conclusions confirm the theoretical analysis results, showing that gently inclined bedding rock slopes with weak interlayers mainly fail through a sliding-tension mode.

Table 4. Stability Factors from Numerical Simulation of Different Dip Angles in Structural Planes After Slope Cutting

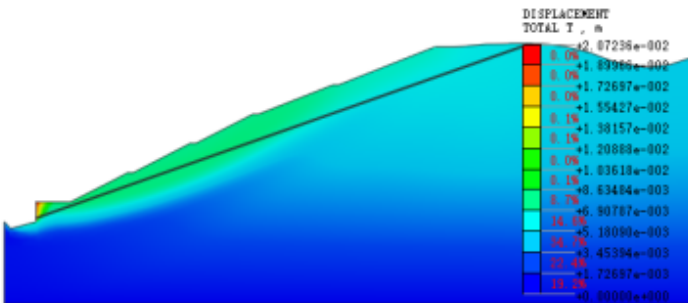
Dip Angle 4°	0.87
Dip Angle 9°	0.86
Dip Angle 14°	0.85



(a) Dip Angle 9°

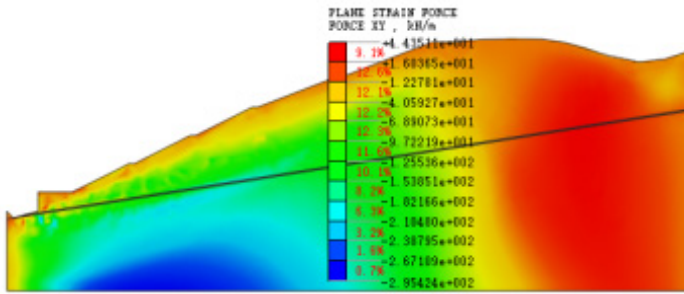


(b) Dip Angle 14°

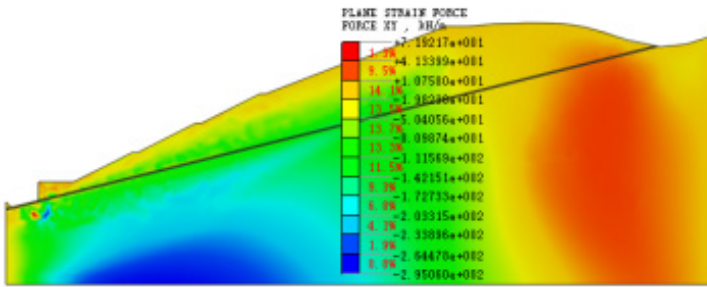


(c) Dip Angle 19°

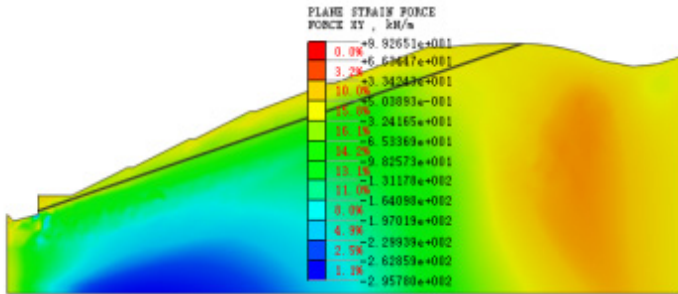
Fig. 9. Total displacement contour plots for different dip angles after slope cutting.



(a) Dip Angle 9°



(b) Dip Angle 14°



(c) Dip Angle 19°

Fig. 10. Shear stress contour plots for different dip angles after slope cutting.

5 Conclusion

This study focuses on typical gently inclined bedding rock slopes, investigating a case in Guizhou Province containing weak interlayers. Using Midas GTS NX numerical

analysis software with an elastic-perfectly plastic model based on limit equilibrium theory, we examined stability after vertical excavation, post-excavation stability, and stability with varying dip angles of weak structural planes. Key findings:

① The engineering characteristics of weak interlayers in bedding rock slopes were analyzed. Based on geological conditions, geotechnical properties, slope features and rock mass types, the slope failure mode was preliminarily identified as bedding slip-tension, with weak interlayers being the primary factor affecting stability.

② Numerical simulations were conducted on vertical and cut slopes with different structural plane dip angles. Results show: Unloading through excavation improved slope safety, excavation altered the original stress equilibrium, beneficial overburden weight was reduced, initial stresses were released, tangential displacement increased, the intersection between cut slope surface and weak structural planes represents the most vulnerable zone. Stability factors significantly increased after cutting compared to vertical excavation, demonstrating the effectiveness of unloading as a treatment method.

③ In summary, the stability of this gently inclined slope containing weak interlayers demonstrates an inverse correlation with three key parameters: thickness of weak structural layers, dip angle of structural planes, and self-weight of overlying rock/soil mass above the interlayer. Specifically, slope stability decreases with increasing interlayer thickness, steeper dip angles, and greater overburden weight.

④ For vertically excavated slopes: the 19° - 30° range represents sensitive dip angles. Vertical shear stress distribution becomes distinctly pronounced along the rear slope, tensile cracks readily develop at the slope crest, the slope exhibits a sliding-tension failure tendency that intensifies progressively with increasing dip angle.

⑤ For cut slopes: shear stress displays a similarly decreasing distribution pattern across dip angles of 9° → 14° → 19° , stress primarily concentrates vertically along the rear slope region, increased dip angle post-cutting shows limited influence on rear-slope shear stress, the self-weight of overlying sliding mass dominates the shear resistance at the slope rear, heavier overburden mass significantly increases the probability of tensile crack development, post-cutting rear-slope shear stress distribution demonstrates more regular patterns compared to pre-cutting conditions.

⑥ About stability thresholds, when dip angles are $<14^{\circ}$, thin weak interlayers have negligible impact on safety. Slope stability becomes governed by geotechnical properties and boundary conditions. The 14° - 24° range constitutes critical dip angles for vertically excavated slopes, showing: progressive stability reduction with increasing angle, gradual decrease in safety factors. At 9° dip angle, the overburden weight exerts more detrimental effects on stability than the dip angle itself.

⑦ Based on the research conclusions derived from this actual engineering case, the following slope engineering practices should be implemented: timely site investigation, conduct comprehensive field surveys, Perform detailed exploration of concealed geological issues. Instability mode identification, adopt appropriate analytical methods to determine potential failure mechanisms. Engineering implementation, emphasize dynamic design approaches, implement real-time data monitoring systems and ensure slope stability throughout project lifecycle.

6 Deficiency and Prospect

The article analyzes the stability of gently inclined bedding rock slopes containing weak interlayers under dynamic construction conditions and various structural plane dip angles, yielding significant conclusions. However, due to multiple objective factors, this study still has certain limitations that require further research for refinement:

① The numerical analysis did not consider the effects of seismic activity and water seepage on slope stability and progressive failure characteristics after cutting. These adverse factors should be incorporated into reinforcement measures for practical engineering applications.

② While utilizing geological survey and field test data, the study focused on the primary weak structural layer without accounting for the influence of other joints and fractures on slope stability. Given the geological complexity, there may exist unquantified intersecting joints and fractures that cross-cut rock masses.

③ The analysis of different dip angles for weak structural planes did not investigate how varying thicknesses of weak layers at the same dip angle affect slope stability.

④ The numerical analysis employed only simplified 2D plane models assuming a single sliding surface, whereas actual conditions may involve multiple potential slip surfaces or complex combinations. Further research is needed to incorporate these more complicated scenarios into stability assessments.

In summary, the stability of gently inclined bedding rock slopes remains a complex subject requiring continuous investigation. The current findings, while valuable, highlight several areas where additional research could provide more comprehensive understanding and practical applications.

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