Case Study
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STABILITY ANALYSIS OF ROCK BLOCKS WITH ENTIRE SPHERE STEREOGRAPHIC PROJECTION BASED ON THE BLOCK THEORY: A CASE STUDY FOR A TUNNEL ENTRANCE PROJECT

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ABSTRACT

This paper presents a static equilibrium kinematic analysis of rock performed in the tunnel entrance project using entire sphere stereographic projection under block theory. The objective of this study is to improve the predictive analysis of rock masses in terms of stability in rock masses area. Different key blocks with failure modes are determined. The conventional upper hemisphere stereographic projection is also employed for comparative analysis. Based on the findings, it was concluded that the planar failure is not probable in the case of the kinematic and block theory method in the tunnel entrance area. However, the wedge failure is more probable in both cases of analysis and the number of possible slide blocks in the case of kinematic analysis was found to be less than in the case of block theory; In these conditions, the support system should be provided for the reasons of safety. The comparative analysis shows that the results of block theory analysis are close to reality and provide more precision on the stable and unstable block than the results of kinematic analysis; Moreover, the block theory method using the entire sphere stereographic projection provides more precision on the sliding angle than the use of one sphere stereographic projection. Based on this study, the tunnel entrance is more stable for the dip slope face equal to 45 and not probable for slope face 60˚ and 85˚; but these results were limited in the case of stability analysis under gravitational loading.

Keywords: Entire Sphere Stereographic Projection, Block Theory, Rock Masses, Rock Failure, Tunnel Entrance Project

1. INTRODUCTION

Usually, the failure mechanism in the fractured rock mass is mixed with relative spatial position; after the establishment of the failure mechanism, the complete analysis of stability or the appropriate design support system for the unstable block can be performed. The presence of discontinuities impacts the stability of rock mass; indeed, by the intersection between them near the basement surface, these discontinuities create different rock blocks in term of shapes and sizes Warburton (1981), Azarafza et al. (2016). Several analytical approaches have been developed the last four decades; among of these approaches, the kinematic analysis using stereographic projection and block theory method constitute the most used in the rock, civil, and mining engineering; these methods obtained success because of its simplicity and resolution speed. However, block theory method has been improved by many authors. Into discontinuous rock mass, the margin of the free surface may largely affect by the inner neighbouring block. Previously, considering the Goodman and Shi (1985) approach, Wibowo (1997) focused on these secondary blocks and observed that they were similar to the traditional one. However, Wibowo (1997) found that some the first batch key blocks have been removed, leading to the creation of some new free surfaces. Additionally, using BLOCKS program, the progressive failure analysis for underground excavation was also assessed recently by Thompson (2002). On the other hand, some other researchers Yarahmadi-Bafghi and Verdel (2003) have also studied the effect of the adjacent blocks related to removable blocks thanks to 2D key group method. It is worth noticing, the dangerous key blocks are mostly associated with the top or the walls of the underground chamber. These issues can be deeply investigated by the classical theory. However, in most of the cases, the associated concave of free plane or excavation surfaces are common. Mostly, the presence of non-convex blocks is evident where the free plane are complex combinations. Li et al. (2012) considered this aspect and through the classical block theory, they analysed the multifaced blocks with concave association of free planes. They found that the association of convex block led to the non – convex block. From their study, Li et al. (2012) proposed a criterion of finiteness and removability in the case of non – convex blocks. Moreover, an algorithm for validation of some cases of non – convex have been designed and concluded for effectiveness, the feasibility, and the importance of this theory. It is important to note that it is now possible to conduct the analysis of the progressive failure using the key block method extended in three dimensions as recently did Noroozi et al. (2011). In fact, the key block method is capable to show more than one batches of the blocks without taking into account the interaction between the blocks in those batches. Others researches that extended the key block analysis including the prediction analysis block sizes or support design have been widely carried out by authors such as Windsor and Thompson(1992) and Windsor (1997), Thompson (2002) and Thompson and Windsor(2007) and Fu and Ma (2014). For example, Fu and Ma (2014) numerically modelized the rock mass into three dimensions for better designing the rock mass supports.

The previous research aforementioned were conducted considering only the one sphere stereographic projection Figure 1a, no study related to the using of entire sphere stereographic projection Figure 1b was found in the literature. It is worth noticing, as previously mentioned, all those studies are related with the block theory Goodman and Shi (1985). Therefore, in the purpose of improving the predictive analysis of the rock's failure modes, this research suggests the use of entire sphere stereographic projection Figure 1b to conduct the static equilibrium analysis of rock blocks. More importantly, this research is limited to the underground excavation projects, and the diversion tunnel entrance project in the Nam Phoun Hydropower project presented by Mboussa et al. (2019) and Mboussa and Sun (2022) represents is the unique case of study considered.

Figure 1

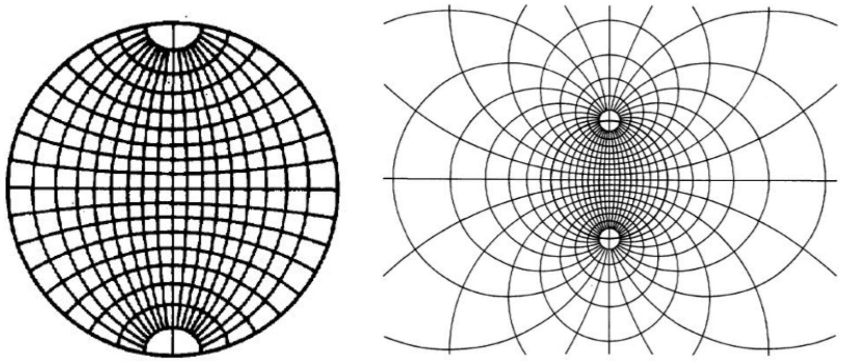

Figure 1 Stereonet with References Spheres (a) One Sphere Projection (b) Entire sphere (Goodman and Shi 1985)

2. MATERIAL AND METHOD

2.1. GEOLOGY OF THE STUDY AREA

Figure 2

Figure 2 Location Map of Nam Phoun Hydropower Project

The study area is this study consist of the diversion tunnel project situated at the Nam Phoun River in the North-western of Laos Figure 1, located with the geographic coordinates such us 18˚27'48".23N and 101˚28'04.45" E Mboussa et al.(2019), Mboussa and Sun (2022). The stratum of the tunnel project is a part of Indo – China stratigraphic region range from middle Paleozoic to Cenozoic – Quaternary period. The rock united including sedimentary, metamorphic, and igneous rocks.

Moreover, the Devonian and early Carboniferous (cPz2) are mostly characterized by marine limestone and Shale and the rocks are slightly metamorphic. The rocks from Carboniferous, Permian, and Earl Triassic (vPz3) are extrusive rock and intrusive rock. The materials aged from Triassic to Cretaceous (Mz1) are mostly continental sediments which mostly appear to be thin-bedded sandstones, partially containing thin coal seams. The bed rock is mostly composed of Tuff, tuffaceous sandstone, and tuffaceous slate (cPz2); however, the overburden is typically comprised of alluvial – eluvial deposit Mboussa and Sun (2022).

2.2. KINEMATIC ANALYSIS

Kinematic analysis is one of the best technics used in rock area to perform the static equilibrium analysis of rock block. This technic is described as a displacement of body except the reference the forces that cause them Stead and Wolter (2015). In this study, the analysis as presented by Hoek and Bray (1981) was applied. Moreover, in this research data related to stability analysis published by Djohn et al. (2019) were included for comparison purposes. In order to conduct this research, the slope face Dip angle of the tunnel entrance was varying for 45˚, 65˚ and 85˚. This is in the aim to appreciate the results of analysis according to the main purpose of this study. Therefore, the upper hemisphere stereographic projection in the respect to plane sliding and wedge failure sliding in the tunnel entrance was realized using the Rocscience program Dip.v.6.0 Inc. Rocscience (2014). The different orientation of joints set in the study area are presented in the Table 1. Therefore, the results of these analysis are presented in Figure 5 and Figure 6.

Table 1

Table 1 Orientation of Joint's Family

Joints	Dip (in degree)	Dip Direction
J_1	64	155
J_2	26	124
J_3	65	354
Free surface 1	45	110
Free surface 2	65	110
Free surface 3	85	110

2.3. BLOCK THEORY ANALYSIS

The block theory analysis was conducted according to the criterion as described by Goodman and Shi (1985), chapter 9. The keys block under self – weight was considered. The main tools of the key block method are the using of vectors analysis through mathematical equations and the stereographic projection technic by determining failure modes and evaluate the stability rock blocks. Therefore, every rock block which not fulfil these conditions correspond to the block type V or (a) (infinite block, Figure 4).

2.3.1. VECTOR ANALYSIS

In the vector analysis, the equation of each joint's plane $AX + BY + CZ = D$ Equation 1 is established as following:

$$AX + BY + CZ = D \quad \text{Equation 1}$$

The unit vector is represented by the Equation 2 such us:

$$\hat{n}_p = (A, B, C) \quad \text{Equation 2}$$

With the constants A, B and C the coordinate of the unit vectors of joints plane and free surfaces were computed according to the Equation 3 following:

$$A = \sin\alpha \sin\beta$$
$$B = \sin\alpha \cos\beta$$
$$C = \cos\alpha \quad \text{Jianyong et al. (2015)} \quad \text{Equation 3}$$

The results of these computations are presented by the Table 2. Moreover, according to the theorem of removability Goodman and Shi (1985), all block satisfying the following Equation 4 and Equation 5 are considered as removable.

$$BP = JP \cap EP \neq \text{empty} \quad \text{Equation 4}$$

$$JP \subset SP \quad \text{Equation 5}$$

Table 2

Table 2 Vectors Coordinates of Joint Set and Free Surface

Vector	**Unit Normal Vector $\hat{n}_p$**		
	X	***Y***	***Z***
$\hat{n}_1$	0.36859	0.82790	-0.4226
$\hat{n}_2$	0.34634	-0.24248	-0.57376
$\hat{n}_3$	-0.38608	0.82795	0.90630
Free surface 1	0.66446	-0.241844	-0.34202
Free surface 2	0.85165	-0.30997	-0.34201
Free surface 3	0.93611	-0.340718	-0.34202

2.3.2. STEREOGRAPHIC PROJECTION

This approach supposes that the blocks are stiff, and all discontinuities or joints are cohesionless, dry, and entirely persistent; the blocks' lateral restrictions and tensions are not taken into account. Due to these factors, the technique only identifies the kinematic modes that are feasible for a given slope angle, not the genuine kinematic behaviour within the unstable rock mass Gischig (2011) . The Figure 3 illustrate the stereographic projection of a joint plane on the upper hemisphere case. The upper and lower half spaces of the joint's plane P_i $(i = 1 - n)$ is represented by Ui and Li. However, these half spaces can be represented by the binary digit. Consequently, the half spaces above the plane Pi, the corresponding number is 0 for Ui and the number 1 correspond to the Li, representing the half space below the plane Pi. The coordinates of the cercle are determined by the following Equation 6 and Equation 7:

$$C_x = R \tan \alpha \sin \beta \qquad \text{Equation 6}$$

$$C_y = R \tan \alpha \cos \beta \qquad \text{Equation 7}$$

Where, α the dip angle, β the dip direction of a discontinuity plane and R the radius of the circle. For more detail on the stereographic construction is presented by Goodman and Shi (1985). However, in this paper the upper hemisphere stereographic was considered for projection and analysis.

Figure 3

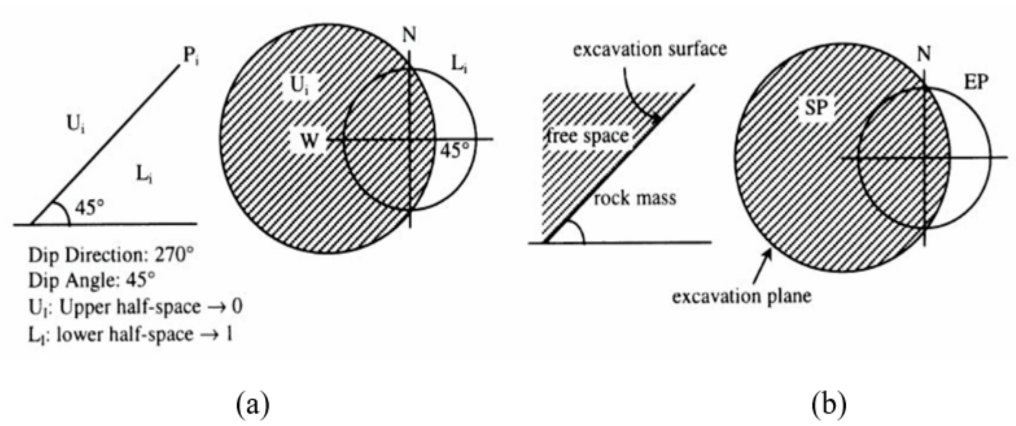

Figure 3 Stereographic Construction on Upper Hemisphere, (A) Discontinuity, (B) An Excavation Plane Um and Kulatilake (2001)

2.3.3. ENTIRE SPHERE STEREOGRAPHIC PROJECTION

The process used to conduct the entire sphere stereographic projection was the same as the traditional analysis, but the difference is focused on the sphere of projection. The set of joints presented in the Table 1 was projected on the stereo – plot presented in the Figure 1(b).

Table 3

Table 3 Characteristic of the Projection on the Entire Sphere		
Stereographic Projection	**Center of Coordinate**	**Radius(cm)**
Reference circle	*C (0,0)*	1.7
Projection plan 1	*C (1.4, 3.3)*	4.2
Projection plan 2	*C (0.6, - 0.4)*	1.8
Projection plan 3	*C (-0.3, 3.7)*	4.2
Projection slope face dip 45˚	*C (1.53, -0.58)*	2.42
Projection slope face dip 65˚	*C (3.27, -1.23)*	4.04
Projection slope face dip 85˚	*C (17.14, - 6.60)*	21.25

The characteristic of each projection, mean the center and the radius of each circle presented in the Table 3 were determined using the Equation 6 and Equation 7 following:

2.3.4. SEPARATION OF BLOCKS

Block theory method defined fives types of blocks in rock masses according of the discontinuity's families in presence illustrated in the Figure 4.

Figure 4

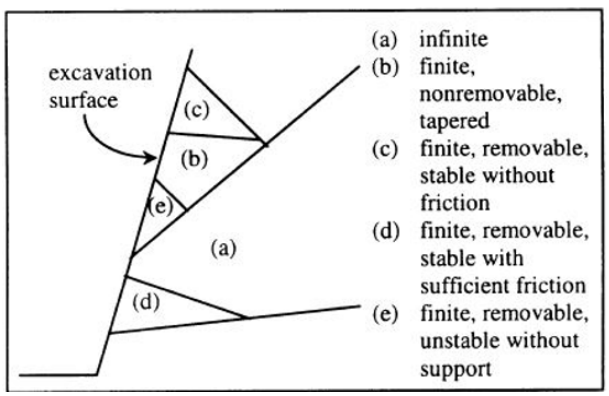

Figure 4 Different Types of Blocks at Excavation Surface Cut, (a) Block Type V, (b) Block Type IV, (c) Block Type III, (d) Block Type II, and (e) Block Type I

In the aim to separate the infinite blocks from the finite blocks in this paper, the joint sets planes, and excavations surfaces (slope faces) were plotting on the stereo – plot according to upper hemisphere one sphere stereographic projection firstly, and on the entire sphere stereographic projection secondly. For the case of traditional analysis, the analysis and computations were possible through the VisKBT program developed by Shi, and the results are illustrated in the Figure 7, Therefore, the joint pyramid, the mode of the plan, the frictions forces, the coefficient of safety, and the sliding direction were obtained. However, in the case of entire sphere, some computations and analysis were conducted with respect to the equilibrium equations of removable blocks and the results are presented in the Figure 8. The joints pyramid, the sliding mode, the factor of safety and the frictions forces were determined; hence, the tapered blocks (type III) were separate from the potential and key blocks (type II and I) according to the theorem of removability.

3. RESULTS

Static equilibrium analysis of rock masses in the case of a diversion tunnel entrance was conducted in this paper. The object of this paper was to assess the stability of a tunnel entrance by using the entire sphere stereographic projection based on the block theory method. Therefore, in order to compare with the traditional kinematic analysis and block theory, some previous published data obtained in the Nam Phoun dam site project were also introduced (Djohn et al., 2019). In order to separate the different block, the VisKBT developed Shi was used. The key findings are presented and discussed in term of comparative analysis.

3.1. ROCK FAILURE MODE

3.1.1. PLANE SLIDING

The results of planar failure analysis with respect to the variation of slope face dip are shown Figure 5. The Figure 5(a) show the intersections of joints J1 and J3 denoted I1,3, the intersection between J1 and J2 denoted I1,2 and the intersection between J2 and J3 denoted I2,3. Moreover, I1,3 plunges to 65˚E, I1,3 plunges to 255°W and I2,3 plunges to 238°W. The joints J1, J2 and J3 intersect the excavation surface (free surface) with 33% of possible planar sliding. The same result is observed in the two other case, mean for the slope dip face of 65˚ and 85˚, illustrated in Figure 5(b) and Figure 5(c). However, the difference can be observed in the potential failure zone; consequently, more the dip of slope face is great more the failure zone increase.

Figure 5

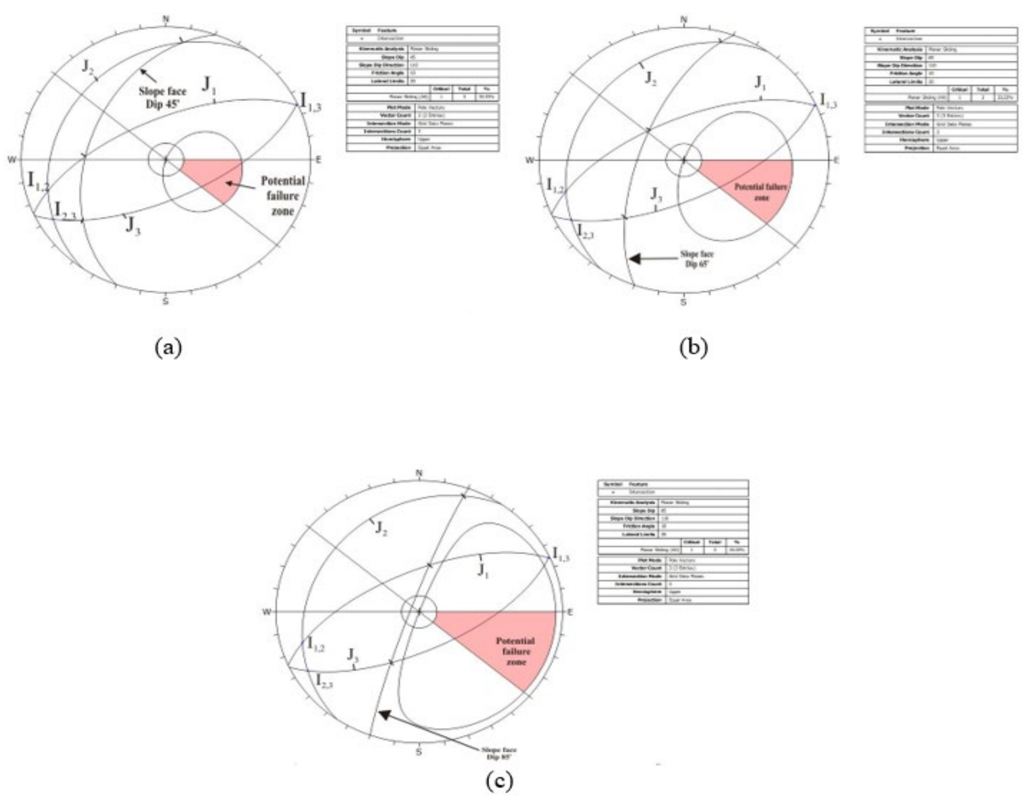

Figure 5 Kinematic Analysis, Planar Sliding, Upper Hemisphere Stereographic Projection. (a) Slope Face Dip Angle 45˚, (b) Slope Face Dip Angle 65˚, (c) Slope Face Dip Angle 85˚.

3.1.2. WEDGE SLIDING

Figure 6 present the result of wedge sliding analysis performed in the tunnel entrance face. This is shows three intersections points I1,2, I1,3 and I2,3 of joints set with 66,6%. Two intersections are critical, precisely I1,2 and I2,3, but I1,3 is not critical. These intersections constitute the possible direction of wedge sliding failure; the intersections I1,2, I1,3 and I2,3 plunge respectively to 255°W, 65°E and 240°W Figure 6(a), Figure 6(b) and Figure 6(c). For the slope dip face of 65° and 85°Figure 6 (b) and Figure 6(c), the difference can be observed in the potential failure zone; therefore, the failure zone increases proportional to the increase of slope face angle.

Figure 6

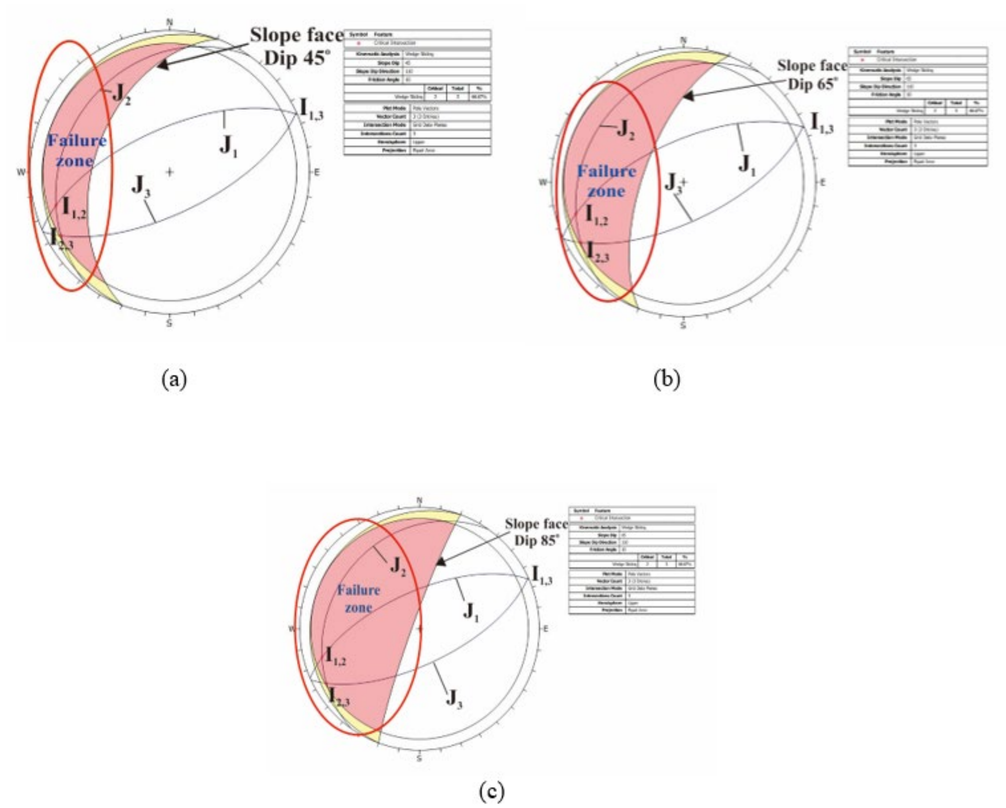

Figure 6 Kinematic Analysis, Wedge Sliding, Upper Hemisphere Stereographic Projection (A) Slope Face Dip Angle 45°, (B) Slope Face Dip Angle 65°, (C) Slope Face Dip Angle 85°

3.2. KEYS BLOCKS ANALYSIS

The block theory analysis results in this research were conducted according to traditional stereographic projection and the entire sphere stereographic projection. These results are based on the three main joint set orientations Table 1 applying firstly the computer program VisKBT developed by Shi and through the projection on the entire sphere stereo – plot secondly. The identification of detachable blocks for the slope face dip direction 110 for the tunnel entrance under gravitational loading is shown in Figure 7 and Figure 8. This was conducted by stereographic projection approach using the VisKBT program Figure 7 and entire sphere stereographic projection Figure 7 when the dip of the free surface is 45° Figure 7(a) and Figure 8(a). For the different variations of the slope's face dip (45°, 65°and 85°), the stereographic projection in both cases shows eight visible regions corresponding to joints pyramid noted JP such as 000, 100, 010, 110, 001, 101, 011, 111. These results are presented in tables 3.3, 3.4, and 3.5. The frictions forces of these JPs are respectively 0.09120, - 0.01478, - 0.0353, 0.84182, 0.2628, -100, 0.8317 and 1; Moreover, the corresponding safety coefficient of these Joint pyramid are: 0.69, 1.05, 1.10, 0.07, 0.37, 100, 0.08 and 0. In addition, the coordinates of sliding direction of each joints pyramid are also presented in the Table 4.

Figure 7

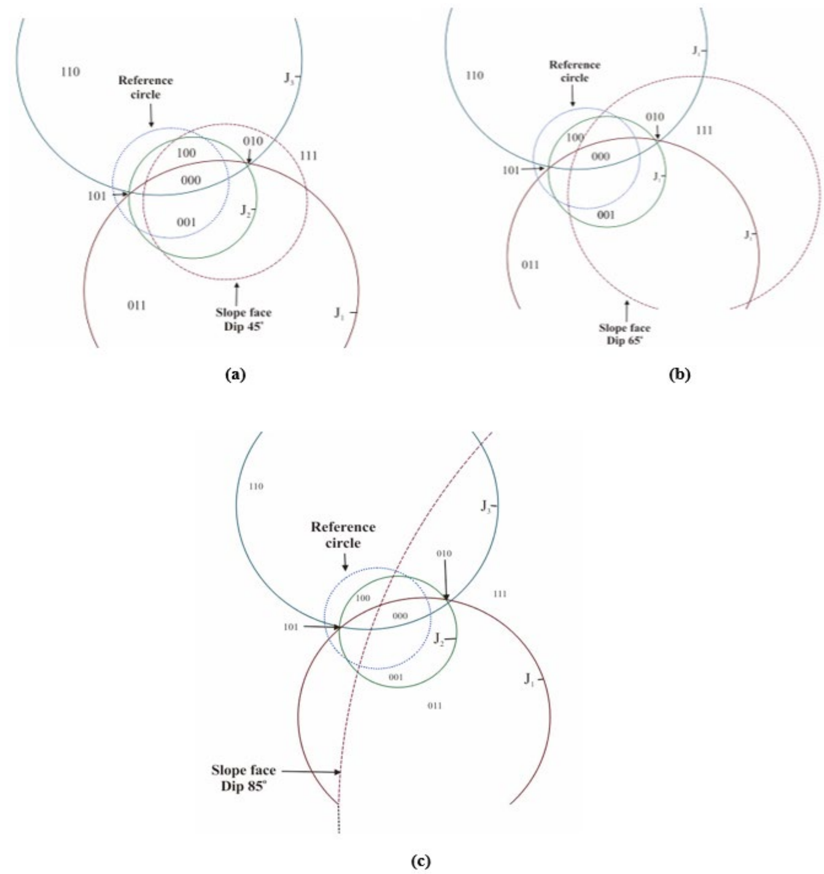

Figure 7 Identification of Removable Blocks in the Dam Site using Stereographic Projection Technic on Joints Combination J_1 J_2 J_3 (A) Slope Face Dip Of 45°, (B) Slope Face Dip Of 65°, (C) Slope Face Dip of 85

Figure 8

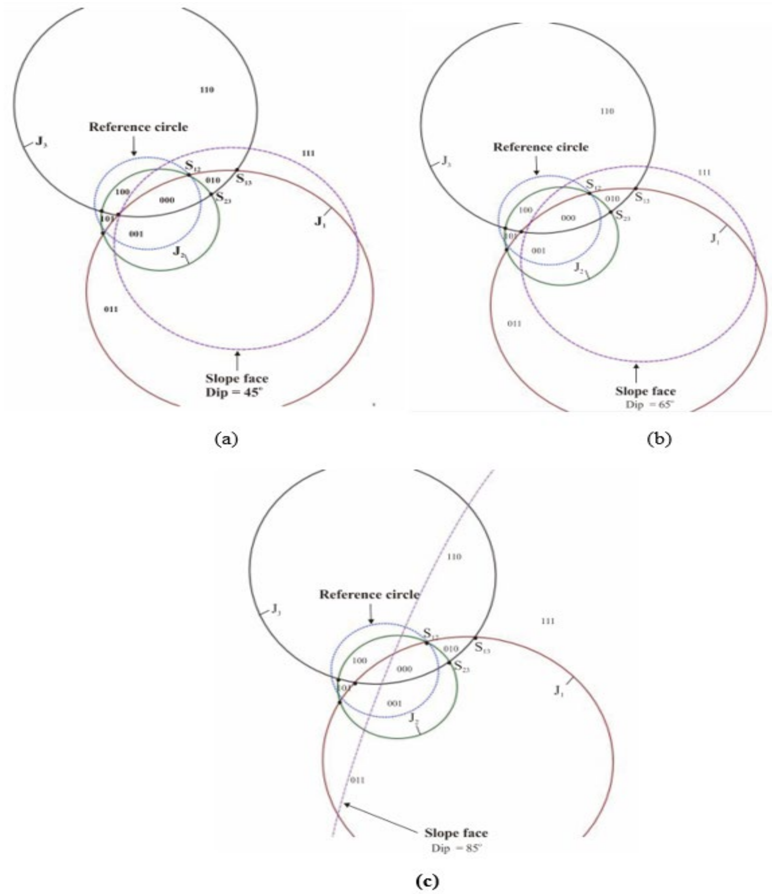

Figure 8 Identification of Removable Blocks in the Dam Site using Entire Sphere Stereographic Projection Technic on Joints Combination J_1 J_2 J_3 (A) Slope Face Dip Of 45°, (B) Slope Face Dip of 65°, (C) Slope Face Dip of 85

Table 4

Table 4 Results of Block Theory Analysis in the Tunnel Entrance Project

Slope Face Dip/Dip Dir. (◦)	Joint Pyramid Code (JP)	Types of Blocks	Frictions Forces	Safety Coefficient	Coordinates Vectors of Sliding Direction *(X, Y, Z)*
	000	Key	0.09120	0.69	(0.93, 0.215, -0.298)
	100	Potential	-0.01478	1.05	(0.922,0.267, -0.281)
45/110	010	Potential	-0.0353	1.10	(0.911, 0.232, -0.34)
65/110	110	Key	0.84182	0.07	(-0.035,0.405, -0.914)
85/110	001	Key	0.2628	0.37	(0.742, -0.52, -0.423)
	101	Stable	-100	1.00	(0, 0, 0)
	011	Key	0.8317	0.08	(0.172, -0.386,-0.906)
	111	Key	1	0	(0, 0, -1)

4. DISCUSIONS

4.1. STATIC EQUILIBRIUM KINEMATIC ANALYSIS

Firstly, the following requirements should typically be achieved for any stability analysis in fractured rock mass using kinematic analysis for potential planar failure mode depending on the gravitational loading: a) The sliding plane must be parallel to the free surface with an angle more or less than 20˚; b) the dip angle of the free surface must be greater than the dip angle of the failure plane; c) the friction angle of the sliding plane must be less than this plane; d) the upper end of the failing surface should cross the upper of free surface; e) and the clearance surface that provides insignificant resistance to sliding must be present in the rock mass to define the lateral limits of sliding. Otherwise, it can be possible that failure takes place on the plane including the convex edge of a failure slope Kulatilake et al. (2011), Djohn et al., 2019.

In the case of wedge sliding, the failure can happen according to the requirement such as:

1) Discontinuities or joints intersections vector should fall within the critical wedge region and,
2) The fiction angle of the joint or discontinuity plane must be less than intersection line angle.

According to the results of kinematic analysis Figure 5, the intersections I1,2, I2,3 and I1,3 is outside of the potential failure zone; However, the plunge of I1,3 is stiff than the free surface in the dip slope face 45˚ Figure 5(a) and more significant than the friction angle. These results indicate that 3 planar sliding could be possible with 1 critical block at 33,33%, but the probability is not enough even if the potential damage zone increase when the slope face dip face is 65˚ and 85˚, illustrated in the Figure 5 (b) and Figure 5(c).

However, the results of Figure 6 indicate, that three wedge failure sliding with two critical blocks is more possible at 66%; intersections I1,2, and I2,3 is situated in the potential failure zone. Moreover, by increasing the dip slope face of the whole slope as presented in Figure 6(b) and Figure 6(c), the probable damage zone is more significant than when the slope face dip is 45˚.

4.2. KEYS BLOCK ANALYSIS

The above requirements are also applied for block theory analysis with additional specific conditions which are the existence of the removable block created by the intersection of joint planes and the lateral free plane; moreover, the rock mass should be the key block. In the case of block theory, the analysis of the eight regions of block appearing in both cases of stereographic projection Figure 7 and Figure 8 allowed for the separation of the different types of blocks. Indeed, the number of joints pyramid visible on the projection in relation to the number of set of joints planes (n) according to Goodman and Shi (1985) expressed by Equation 8 such as:

$$N_R = n(n-1) + 2 \qquad \text{Equation 8}$$

The Equation 8 means that if n increase (n>4), the visible regions appearing on the projection increase and generally the analysis becomes uninteresting; Indeed, the number of plans induce by the complex blocs becomes higher and make the analysis more complex. But, when n=3 which was consider in this study, the shape of block is a tetrahedron issue from three discontinuities or joints planes and one free surfaces plane Goodman and Shi (1985), Kulatilake et al.(2011).

Therefore, the analysis of the results indicates that JP 000, 110, 001, 011, and 111 correspond to the key blocks (type I). This is can be explained by their safety coefficients respectively 0.6, 0.07, 0.37, 0.08, and 0 which are less than 1, moreover, the frictions forces of these JPs are greater than zero; This is mean that these JPs are not stable in the conditions of the given slope angle and require the support. The JP 100 and 010 correspond to the potential key block (type II) with the safety coefficients respectively 1.05 and 1.10. However, the JP 101 with the friction forces equal to -1.00 and the safety coefficient of 1.00 is stable and cannot move; this is corresponding to the infinite block or block-type IV and V. The analysis of sliding mode of each JP shows that wedge sliding is possible for JP 000, JP 110, JP 001, JP 011, and JP 111; Therefore, the JP 000, JP 110 and JP111 can slide on S13, and the sliding direction of JP 001 and 011 are respectively S23, S12. For the potential key block JP 100 and JP 010, the wedge failure could be possible according to the simultaneous sliding direction S12 and S13. However, the sliding angle of each JPs is determined directly on the stereo – plot in the case of entire sphere stereographic projection Figure 8, Therefore, the JP 000, JP 110 and JP111 can slide under 70˚, the JP 001 slide under 80˚ and the JP 011 slide under 50˚. These sliding angles corresponds respectively to the sliding directions S13, S23 and S12 or S21.

4.3. COMPARATIVE ANALYSIS BETWEEN STATIC EQUILIBRIUM KINEMATIC ANALYSIS AND BLOCK THEORY ANALYSIS

The comparative analysis performed between the static equilibrium analysis and the block theory is based on the results obtained. Generally, the existence of the free lateral plane is expected with possible plane failure in static equilibrium kinematic analysis. But this is cannot be applied in the block theory which requires the presence of the key block (type I) in addition to the existence of the lateral release planes Kulatilake et al. (2011). Expected to these reasons, the possibility of plane failure occurring in kinematic analysis it is not possible in the block theory analysis in the dam site. Moreover, the JP 101 which is stable (type IV category) in the block theory analysis could slide under kinematic analysis; Consequently, the number of wedge failures in the block theory analysis seems higher than those obtained under static equilibrium kinematic analysis. Some stable block in kinematic analysis seems unstable in the case of block theory. According to the aforementioned analysis, it seems that the results of key blocks analysis are more real than the results of the equilibrium traditional kinematic approach. The findings of the analysis of the key block using both approaches, precisely the entire sphere projection, and the traditional stereographic projection provide the same results concerning the number of the regions appearing on the projection, the number of key blocs (type I), the number of potential key blocks (types II) and the number of stables block (type IV). However, the analysis of the entire sphere shows some blocks more visible than for the traditional analysis such as the JP 020 and 011. Moreover, under the analysis of the entire sphere stereographic projection, the angle of intersection which determine the sliding angles of keys blocks is obtained directly on the stereo - plot. But, in the traditional analysis, the sliding angle should be determined by computing through the sliding direction coordinates, because the intersection between two planes gives a line; therefore, this intersection line plunge according to a given angle which should be determined. In these conditions, the analysis of the entire sphere gives more precision than the traditional analysis. In general, the right bank slope dam site in the Nam Phoun hydropower project presents some instabilities which require some reinforcement. The variation of the slope face angle from 45˚ to 85˚ has no more influence on the stability of the dam area; However, the dam site is more stable for the dip slope face equal to 45˚.

5. SUMMARY

In this chapter, the results and discussion of the static equilibrium analysis of rock blocks were presented. The stability analysis of rock mass was performed on the diversion tunnel entrance area of the Nam Phoun hydropower project in Laos. The objective of this study was to predict the failure mode which can occur around the tunnel entrance for safety. The geometric features of rock mass in the tunnel entrance site were obtained from the filed investigation data. The predominant dip direction of the joint's families and the bedding plane in the tunnel entrance site seem to be South - East. To accomplish this task, the equilibrium kinematic analysis through the entire sphere stereographic projection based on the block theory was suggested. In addition, the conventional kinematic analysis and the traditional block theory were also applied for the reason of comparative analysis; These analyses were conducted with the respect to planar and wedge sliding failure. Based on the finding, it was found that the planar failure is not probable in the case of the kinematic and block theory method in the tunnel entrance. However, the wedge failure is more probable in both cases of analysis, and the number of possible slide blocks in the case of kinematic analysis was found less than in the case of block theory; The comparative analysis shows that the results of block theory analysis are close to reality and provide more precision on the stable and unstable block than the results of kinematic analysis; Moreover, the block theory method using the entire sphere stereographic projection provides more precision on the sliding angle than the use of one sphere stereographic projection. In the case of this study, the dam area of the Nam Phoun hydropower station project seems more stable for the dip slope face of 45˚; the probable failure surface is greater in the case of the dip slope face of tunnel entrance equal to 65˚ and 85˚. In these conditions, the support system should be provided for the reasons of safety view the quality of rock masses environment. However, these analytical results were limited in the case of stability analysis under gravitational loading; Therefore, more research and investigation should be conducted with widespread discontinuity data for the entire sphere stereographic projection.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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