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Assessment of Rock Slopes Stability Located on the Banks of the Khanas Dam Reservoir in the Nineveh Governorate, Northern Iraq.

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ABSTRACT

A detailed study is conducted on the stability of the rock slopes at the two banks of the Khanas Dam reservoir located in the southeastern Sheikhan anticline, -Nineveh Governorate. The study includes seven stations distributed in both banks. The field survey is accomplished to determining the attitude of slopes and discontinuities of the rock blocks belonging to the Pilaspi Formation in the study area. The stability of the rock slopes is evaluated using Dips v: 6.008 program which uses kinematic analysis to predict potential structural failures (plane sliding, wedge sliding, flexure toppling and direct toppling), and SMARTool-v205 program used to determines the degree of the stability for each mode of failure. From the stability analysis results, it is found that there is possible occurrence of direct toppling at stations (SR1, SR2, SR3 and SL1), wedge sliding at stations (SR1, SR2, SR3, SL2 and SL3), flexural toppling at stations (SL1) and plane sliding at station (SR1). A program to evaluate the (slope mass rating shows the values of discrete (Slope Mass Rating SMR) and (Continuous Slope Mass Rating, (CSMR). At worst case, the lowest values for the slope mass rating of wedge sliding are in the stations (SR2 and SR3), where they range between (13-19) for discrete and (6-20) for continuous. While the highest wedge sliding values are in the stations (SL2 and SL3). In the discrete, they range between (44-46) and in continuous (CSMR), they range between (38-46). As for the direct toppling and in the worst condition in the spillway station, they are (44) in discrete and (48) in continuous, but the highest values are in the stations (SR2, SR3, SL1). They range between (51-61) in the discrete, and between (48-60) in continuous (CSMR), while the flexural toppling, is found at one station in (SL1) for the discrete (44) and continuous (47), and the plane sliding at the first station (SR1) for discrete status is (9), while in the continuous (CSMR) is (15).

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تقييم استقرارية المنحدرات الصخرية الواقعة على ضفاف خزان سد خنس في محافظة نينوى – شمال العراق

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الملخص

أجريت دراسة تفصيلية حول استقرارية المنحدرات الصخرية الواقعة على ضفتي خزان سد خنس والواقع في الجزء الجنوبي الشرقي من طية الشيخان- محافظة نينوى. تضمنت الدراسة سبع محطات متوزعة على كلا الضفتين. وتضمنت الدراسة مسحاً ميدانياً شمل تحديد وضعية المنحدرات والانقطاعات لمنطقة الدراسة، والمتمثلة بالكتل الصخرية التابعة لتكوين بلاسبي. تقييم استقرارية المنحدرات الصخرية باستخدام برنامج (Dips-v6.008) للتحليل الحركي للتنبؤ بالانهيارات التركيبية المحتملة (الانزلاق المستوي، الانزلاق الاسفيني، الانقلاب الانثنائي والانقلاب المباشر) واستخدام برنامج (SMARTool-v205) لتحديد درجة الاستقرارية لكل نمط من انماط الانهيار. نتائج تحليل الاستقرارية اوجدت احتمالية لحدوث انقلاب مباشر في المحطات (SR1, SR2, SR3 and SL3)، وانزلاق اسفيني في المحطات (SR1, SR2, SR3, SL2 and SL3)، وانقلاب انثنائي في المحطة الاولى (SL1)، وانزلاق مستوي في المحطة الاولى (SR1). حيث ان البرنامج (SMARTool-v205) قيم تصنيف كتلة المنحدر في الحالة المنفصلة (SMR) وفي الحالة المستمرة (CSMR) في اسوأ حالة، فان اقل قيمة لتصنيف كتلة المنحدر في حالة الانزلاق السفيني هي في المحطات (SR2 وSR3) حيث ان المدى ما بين (13- 19) في الحالة المنفصلة و (6-20) في الحالة المستمرة، بينما اعلى قيمة للانزلاق الاسفيني كانت في المحطات (SL2 وSL3)، ففي الحالة المنفصلة يتراوح المدى ما بين (44-46) وفي الحالة المستمرة المدى يتراوح ما بين (46-38)، اما بالنسبة للانقلاب المباشر في اسوأ حالة هي في محطة المسيل المائي في الحالة المنفصلة (44) وفي الحالة المستمرة (48)، بينما اعلى قيمة كانت في المحطات(SR2 و SR3 و SL1)، فالمدى في الحالة المنفصلة يتراوح ما بين (51-61) وفي المستمرة يتراوح ما بين (60-48)، بينما يقع الانقلاب الانثنائي في محطة واحدة في الضفة اليسرى وهي المحطة الاولى(SL1)، ففي المنفصلة القيمة هي (44) وفي المستمرة (47) وبالإضافة الى الانزلاق المستوي في المحطة الاولى الضفة اليمنى (SR1) حيث ان الحالة المنفصلة كانت القيمة (9) اما في الحالة المستمرة فكانت (15).

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Introduction

The stability of rock slopes is one of the very important topics in engineering geology due to the importance of evaluating and knowing the stability of the mountainous area, on which many engineering facilities are built, such as building, roads, cut of rocks in mines, tunnels, and construction in all its material importance and its impact on human life (Qadir and Syan, 2021). Therefore, studying the stability of rock slopes in the study area is of great importance, especially in studying the stability of the rock slopes overlooking the reservoir as well as the spillway area toward the downstream area.

The study area is located in northern Iraq within Nineveh Governorate and in the northeastern part, especially in the Sheikhan district. Its limited coordinates are between latitudes (36° 55' 301" and 36° 45’ 150") N and between longitudes (43° 25' 09.11" and (43° 25' 36.888") E as shown in Figure (1).

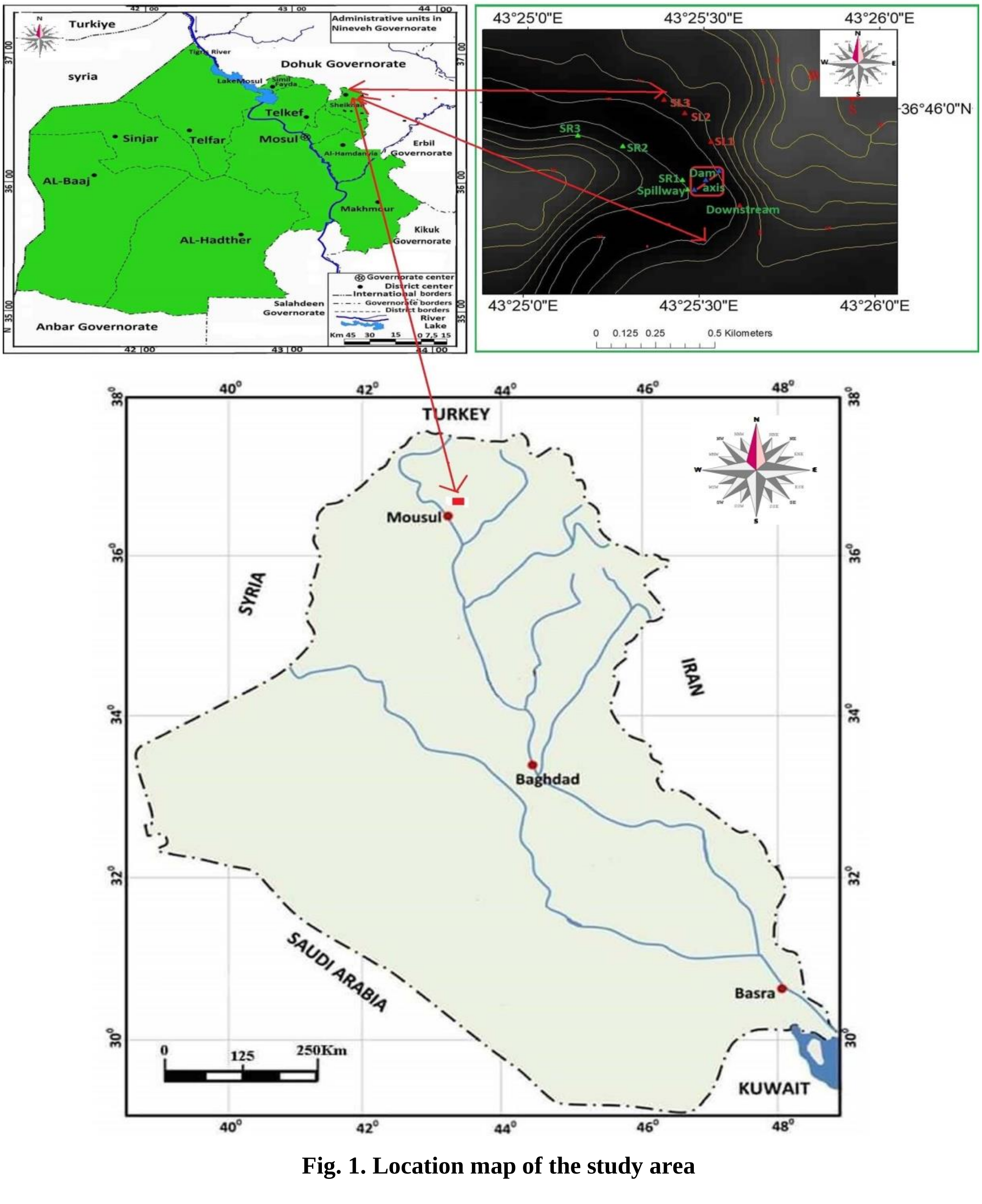


Fig. 1. Location map of the study area

A stability study is conducted for the exposed rock masses on the slopes overlooking the Khanas Dam reservoir. Seven stations are chosen, which distributed along both banks, four on the right bank represented by (Spillway station, SR1, SR2 and SR3) and three on the left bank include (SL1, SL2 and SL3) as shown in Figure (1).

These coordinates for all stations are projected onto the contour map using the ArcGIS 10.6.1 program for the study area in the UTM unit, as shown in the upper right part of Figure (1). and Table (1), which shows the coordinates

Table. 1: Shows the Coordinates for all stations

Spillway station	Easting	X= 359374	Northing	Y=4069758
SR1	Easting	X= 359353	Northing	Y=4069803
SR2	Easting	X= 359100	Northing	Y=4069959
SR3	Easting	X= 358910	Northing	Y=4070008
SL1	Easting	X= 359493	Northing	Y=4069931
SL2	Easting	X= 359461	Northing	Y=4070177
SL3	Easting	X= 359274	Northing	Y=4069931

Justification of the study: Studying the rock slopes is considered very important because it poses a danger to tourists, as it is a touristic area, and to the people who live there near the bank, such as sheep shepherds, as well as its impact on the roads leading to the dam body. The recent floods affected the Khanas Dam, uprooting and destroying rock blocks and bulldozing them from the spillway area towards the downstream area. The fall of rock block reduces the volume of the lakes reservoir and thus leads to the generation of waves, which have a significant impact on the banks and dam.

The aim of the study is to evaluate the rock slopes using the Dips v6.008 program of kinematic analysis to determine the type of possible failure, and using the SMARTool-v205 program to determine the degree of stability for each mode of failure. There are many previous studies related to slope stability such as Al-Talib (2021), who studied and evaluated the environmental effects of landslides at selected sites in Dohuk, northern Iraq. The study included tourist areas near the city of Dohuk, specifically from Besiri valley towards the Dohuk dam. The result of the evaluation showed the area is geometrically unstable and at risk of failure. Faraj (2021), studied assessment of Rock Slope Stability along Bazian- Basara Main Road, Sulaymainyah, NE Iraq. The study showed that the vertical rock slopes formed due to road construction have greatly affected the stability of the slope. Abdullah (2021), studied the stability of the rock slopes on the right bank of the Tigris River in the Hajjah region, Salah Al-Din Governorate, the result evaluation showed that the most possible types of failure are toppling and rock falls. Zaraq (2020), assessed the stability of the slope in the southwestern limb of the Kosret anticline in the Dokan area, and the results of the analysis showed evidence of the failure of rock blocks along the main road that connects Dokan to Quesangaq in Erbil and the road that connects the city and the residential neighborhood of Dokan. Badowi (2023), evaluated and analyzed the stability of the banks of Badush Dam- in Nineveh Governorate. The results of the evaluation identified several types of possible failure, represented by rock falls at several stations, as well as the direct toppling, in addition of plane sliding, which will greatly affect the stability of the banks in the future. Fattah *et al.,* (2023), studied of the structural analysis and evaluated the stability of the slopes in selected locations at Shurshirin valley, Zurbatiyah region, eastern Iraq. The result of the assessment determined that most of the rock slopes appear dangerous along this valley.

Geology of the study area

It is considered one of the most important factors affecting the stability of exposed rock masses on slopes. It includes each of geomorphology and stratigraphy and structure of area. In terms of geomorphology, the Gomel River, which takes its stream perpendicular to the axis of the fold from the northern limb of the fold at the village of Rakawa and continues to enter the center of the fold and deviating near the archeological area represented by Khanas area, where high rises and high plateaus were formed on the sides of the rock masses represented by the slopes of the Pilaspi Formation and Gercus Formation. There are several transverse valleys perpendicular to the river stream and parallel to the axis of the fold. In terms of stratigraphic, the exposed rocks are represented by the Gercus Formation that consist of sand and red clay and small pieces of rock without stratification, and Pilaspi Formation, which consists of limestone in addition to recent deposits (Ahmed, 1980; Al-Hemdy, 2007). The Pilaspi Formation consists of fine – grained micritic limestone through examining thin slides for the rocks in each station. The dam is located on the southern limb. In this area, there is an overlap between Gercus and Pilaspi formations, which are located on the shoulders. Gercus Formation is older than Pilaspi Formation, and then continuous within the basin of the reservoir lake. Therefore, the Gercus Formation represents the core of the lake or reservoir. Where the age of Gercus Formation is (Early – Middle Eocene), while the age of the Pilaspi Formation is (Middle-Late Eocene). As the tectonic situation of the study area, it is located in an unstable continental shelf area, within the foothill’s subzone according to tectonic divisions of (Bolton, 1959; in Al-Daoudi, (1989); Numan,1997; Jassim and Goff,2006; Fouad,2012) having the trend of the Taurus Mountains Range. The Sheikhan folds are considered an asymmetrical in the both limbs Al-Khatony, (2009). During this study, on the other side of the geological section is taken perpendicular to the fold axis and extending from the southeastern limb in Khanas area and extending to northwestern limb in the village of Rakawa as shown on Khatony and modified according to the (Khanas- Rakawa) section on the map, the fold is distinguished by the fact that the average reading for the status of the bedding planes (dip direction/ dip amount) in its southern limb is (170°/30°), while the average reading of the northern limbs for the attitude of bedding planes(dip direction and dip amount) is (347°/45°). Through the aerial images of Google Earth, and as mentioned by Al-Khatony, (2009) by preparing a map of the region, the Sheikhan anticline is a fold with two tapering plunges, the first in its eastern part and the other in the western part as in Figure (2).

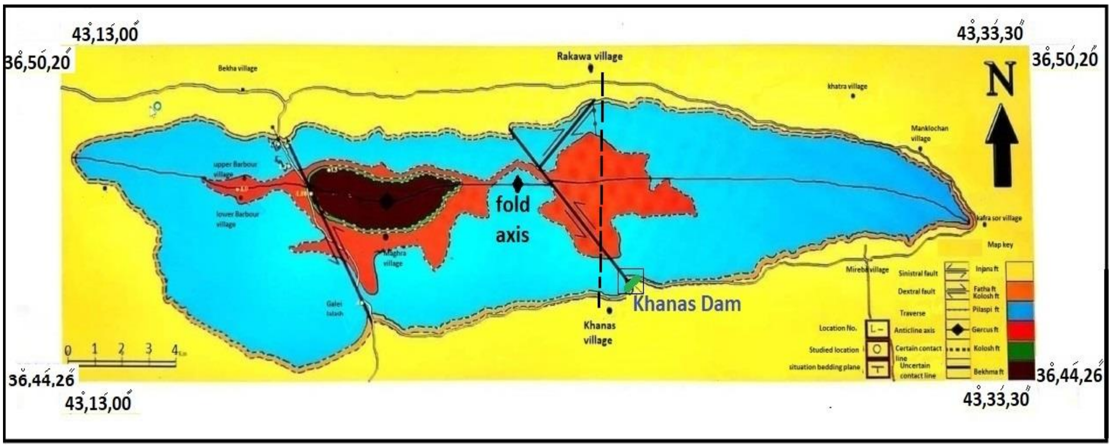


Fig. 2. A structural and geological map of the Sheikhan Anticline (AL-Khatony,2009)

Methodology

During the field work, the largest amount of information's is collected, represented by the stations that are chosen on both right and left banks. It involves collecting readings of bedding planes attitudes represented by (dip direction and amount) of rock masses, determining the joints present on the exposed rocks and determining the volumetric joint, and then finding the rock quality designation (RQD) and the geotechnical analysis for rock masses to find the uniaxial compressive strength (USC) according to Palmstrom, (2005), and the joint conditions and condition of ground water. This is to find value of Rock Mass Rating (RMR), which will enter with account Slope Mass Rating (SMR),then we work on entering these joints that were taken from the rock block, clarifying them, and determining their quality through spatial projection, through the (Dips Program) and used in the program of (Kinematic analysis) to determine the type of movement of failure or sliding that is exposed and expected to happen in the future for these blocks over time, which is represented by four types of sliding as follows (planar sliding, wedge sliding, flexure toppling, and direct toppling). After entering, read the discontinuities represented by bedding plane attitude (dip direction/ dip amount) and joints, and determine the type of movement. We then move to the final stage which is the evaluation stage through the (SMART Program v6-2005) to determine the type of potential failure as for (planar sliding) or (Wedge sliding) and enter the slope attitude represented by dip direction of slope and dip amount of slope) and then enter the major rock mass rating basic (RMR_b), and then we chose the paragraph in the program represented by method excavation and chose to it (blasting or mechanical), we will get on the parameter of (SMR), and get on the evaluations and the description of Slope Mass Rating discrete (SMR) classes according to Romana, (1985) and then status self-according (Tomas *et al.*, 2007) for continuous Slope Mass Rating (CSMR). as shown in Figure (3).

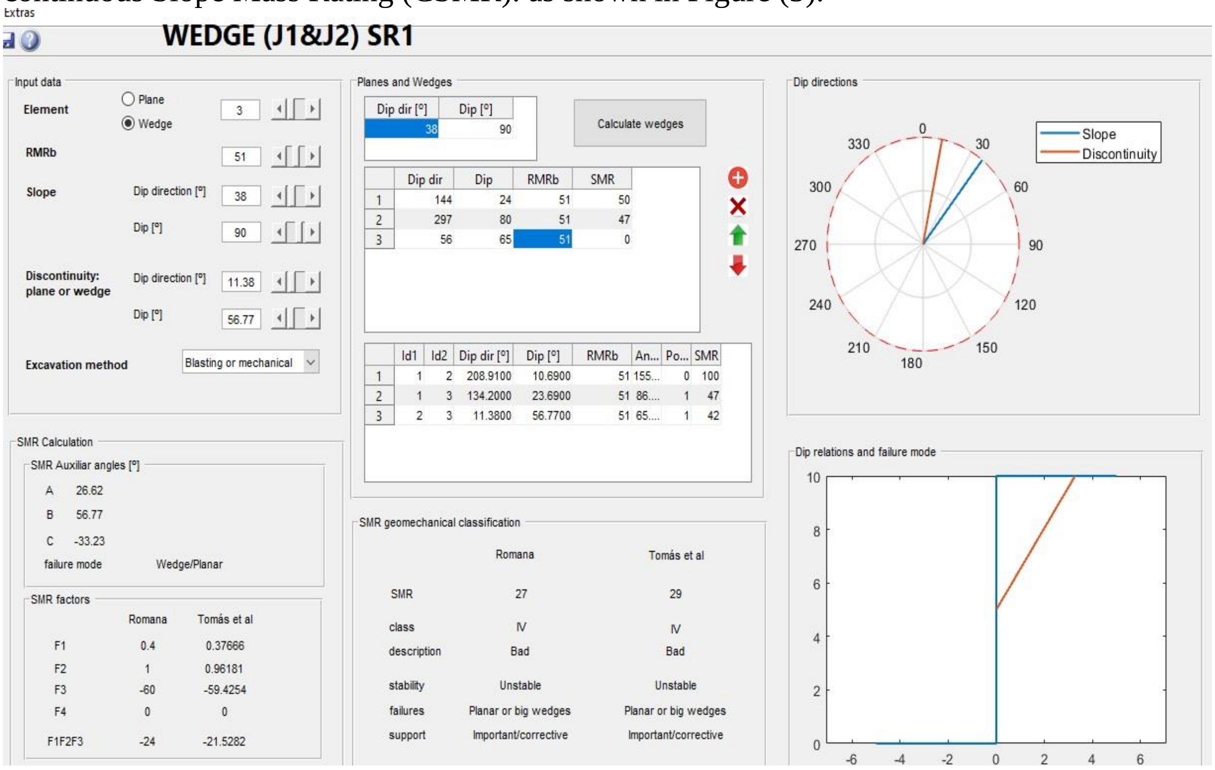


Fig. 3. Assessment of the rock slope stability at station (SR1) in the right bank, showing wedge sliding between (J1&J2) for both discrete-SMR and continuous (CSMR), using SMARTool-v205.

Geometric classification of joints

Joints in rock masses are classified according to their relationship with three tectonic axes (a, b and c). The (a-axis) represents the dip of the layer, the (b-axis) represents the strike of the layer, and the (c- axis) is perpendicular to them, according to the Figure (4) as follows:

Set joints: they include three types of joints (ab), (ac) and (bc). These mentioned three types are called set joints as they are parallel to two axes and intersect the third.

(*ab-set joints*): The joints that are parallel to the dip of the layer, as well as parallel to the strike of the layer, are called bedding plane joints and are called (ab- set). The joints that are parallel to the dip of the layer (that is, they are perpendicular to the bedding plane) and perpendicular to the strike of the layer, are called (*set joints-ac*). As for the joints that are perpendicular to the dip of the layer and parallel to the strike of layer, they are called (*bc- set joints*). The other joints that intersect two axes and are parallel to the other axis are called system joints. According to Hancock, (1985), they are as follows: (hko-system) these joints are present on the surface of layer, where they cut two axes (a) and (b) axis and are parallel to (c – axis) it is either acute around (a) or acute around (b)(hko>a) or (hko>b). As for the joints that intersect the (b-axis) and (c-axis) and are parallel to(a-axis), they are called (okl-system).They are found in the area of layer thickness and are either acute around (b) or acute (c) (okl>b) or (okl>c).As for the third type, it intersects the (a-axis) and intersect (c-axis) and parallel to the (b-axis), it is called (hol- system) either acute about (a) or acute about (c) (hol>a) or (hol> c). This type of joints is found in the hinge area of the folds.

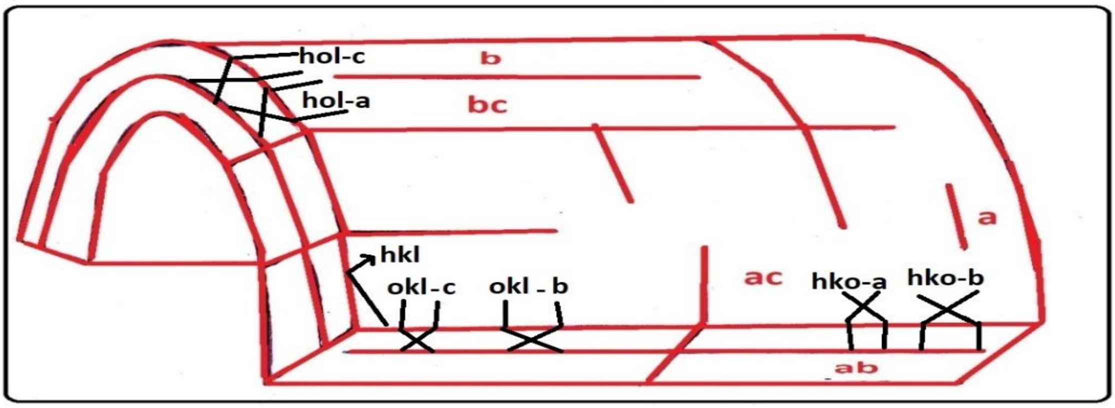


Fig. 4. Engineering model between the joints of sets and systems with tectonic axes according to Hancock, (1985).

During the stage, the joints on the rock blocks are projected after projecting the attitude of the bedding plane for the rock block represented by (dip direction/ dip amount), and then projecting the attitude of the slope. The three-dimensional stereographic engineering drawing of the station located on the right bank of the dam represented by the spillway station, first, second, and third stations are projected (Figure 5) (Plate 1). Then the same process took place by projecting the joints on the rock block of the left bank of the dam, by projecting the layer attitude of these blocks and projecting the slope attitude of the following stations the first, second, and third stations, as shown in the Figure (6) Plate (2).

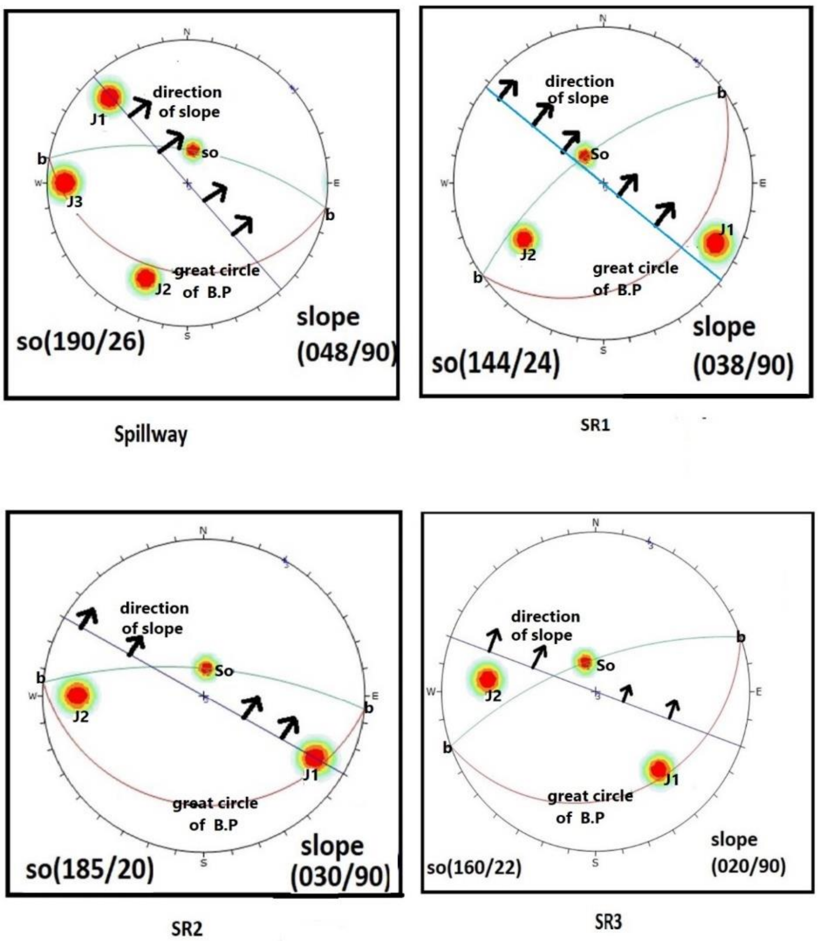
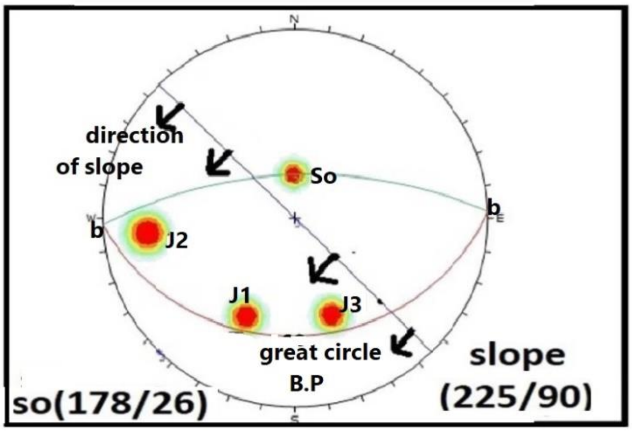
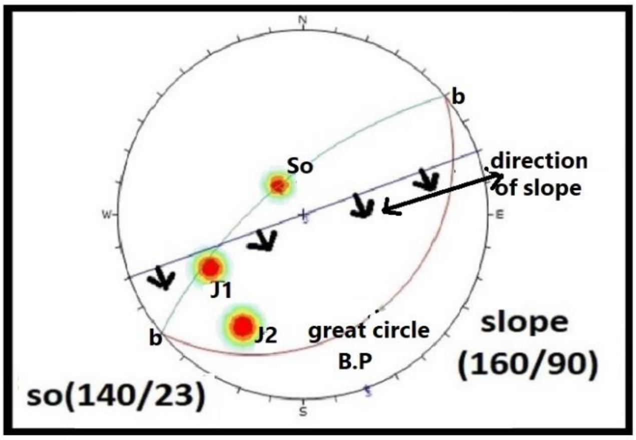


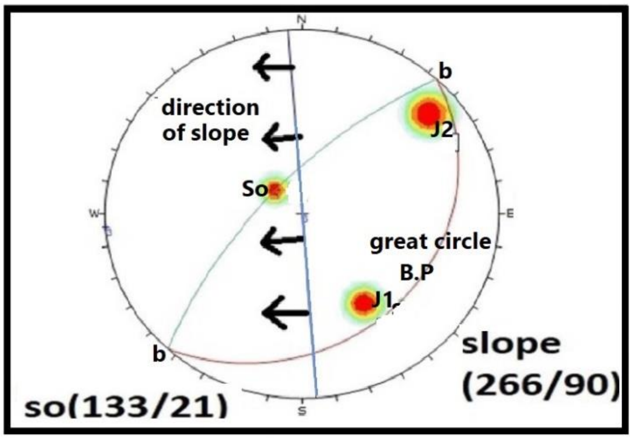
Fig. 5. Stereographic projection of stations located on the right bank. The photography direction at each station is (southwestern). So: represented dip direction of bedding plane. b: represented to strike of bedding plane, (J1, J2, and J3) represented for discontinuities, B.P: bedding plane.



SL1



SL2



SL3

Fig. 6. Stereographic projection of stations located on the left bank. Photography direction SL1 (Northeastern), SL2 (Northwestern), SL3 (East-West). So: represented dip direction of bedding plane. b: represented to strike of bedding plane, (J1, J2, and J3) represented for discontinuities, B.P: bedding plane.

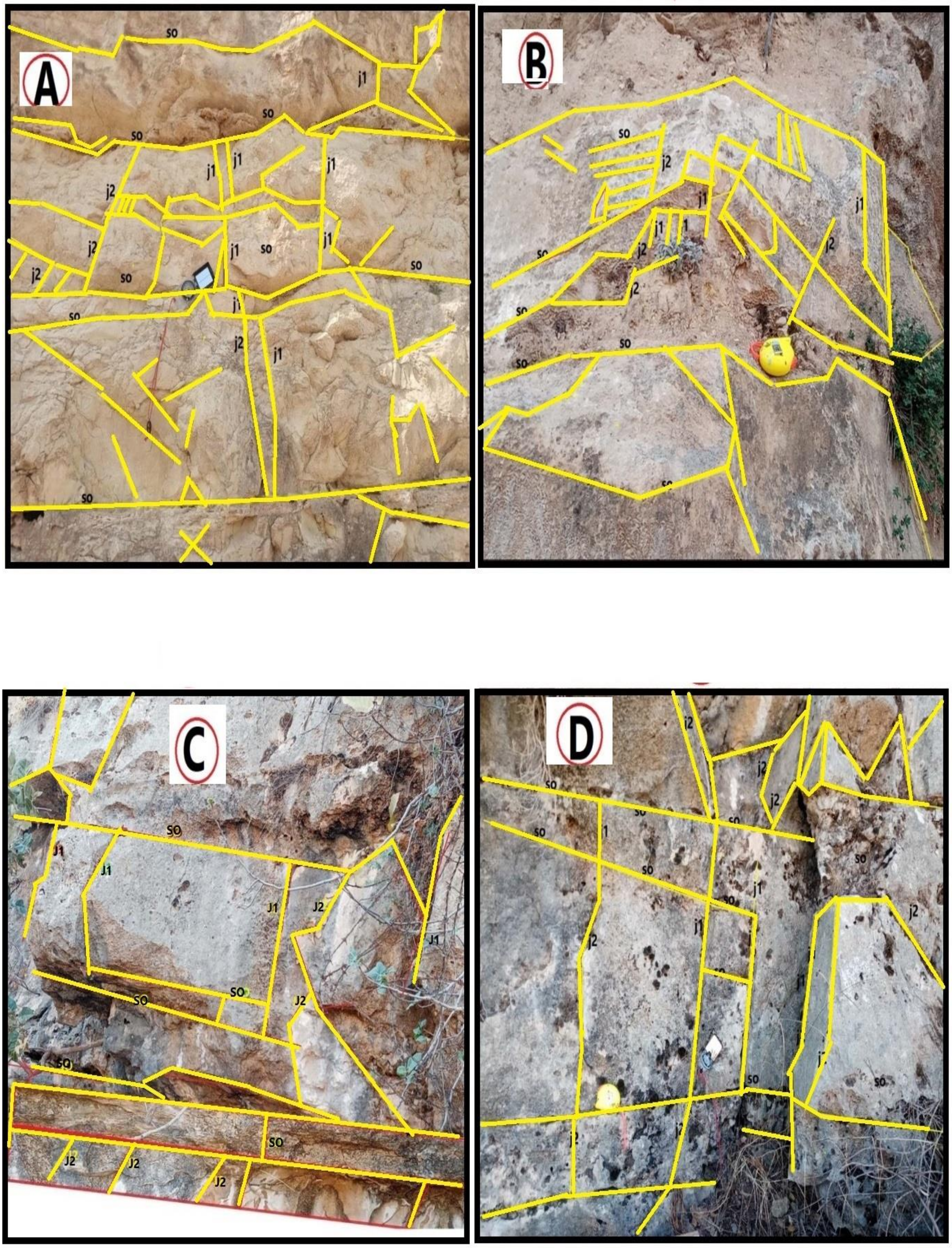


Plate 1: Pictures of the rock blocks located on the right bank of the dam, where (A) represents the spillway station, and (B) is the first station (SR1), and (C) is the second station (SR2), and (D) is the third station (SR3).

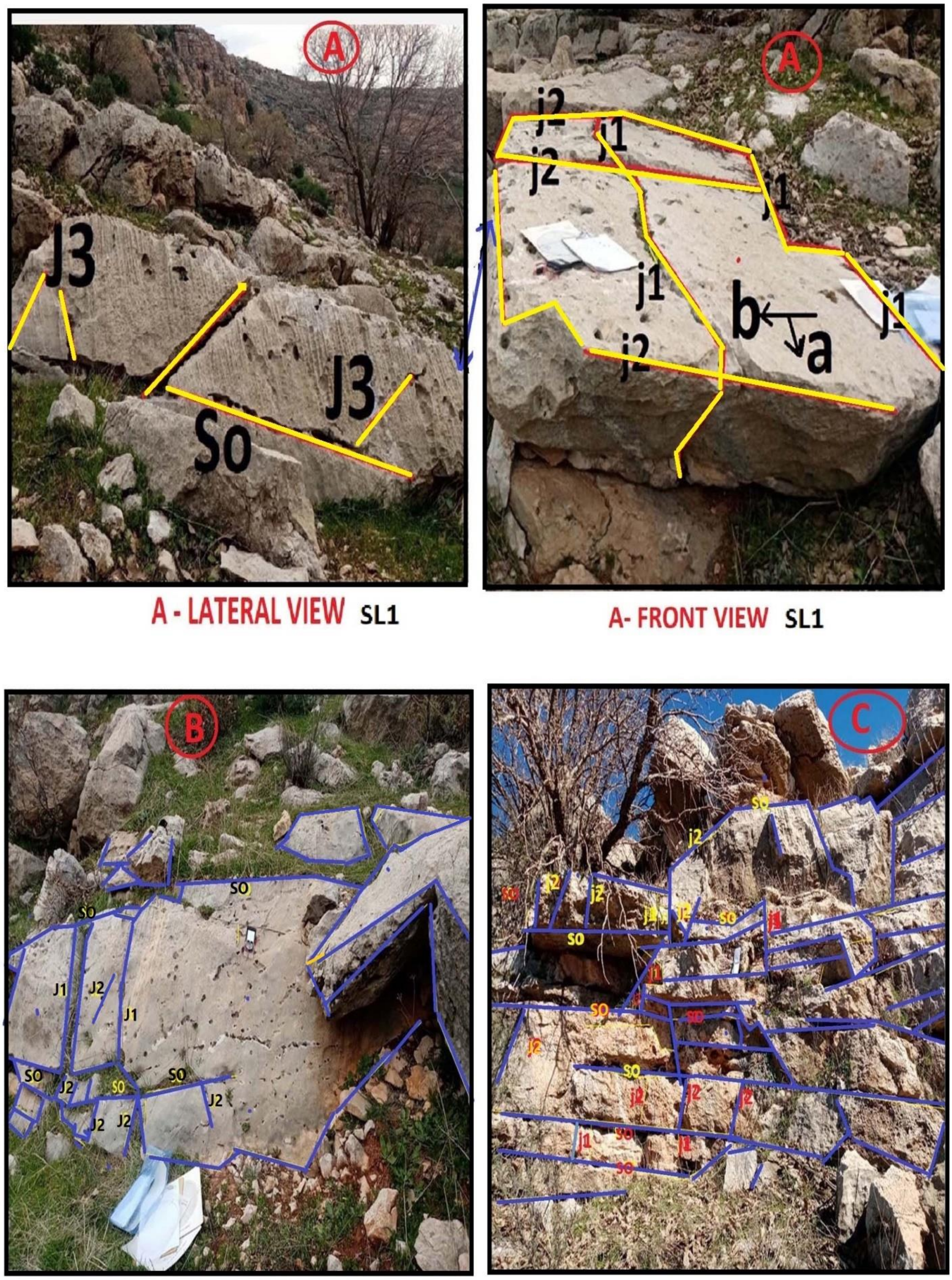


Plate 2: Pictures of the rock blocks located on the left bank of the dam, where (A) represents the first station (SL1) through two front and lateral view of the rock block, (B) the second station (SL2) and (C) the third station (SL3).

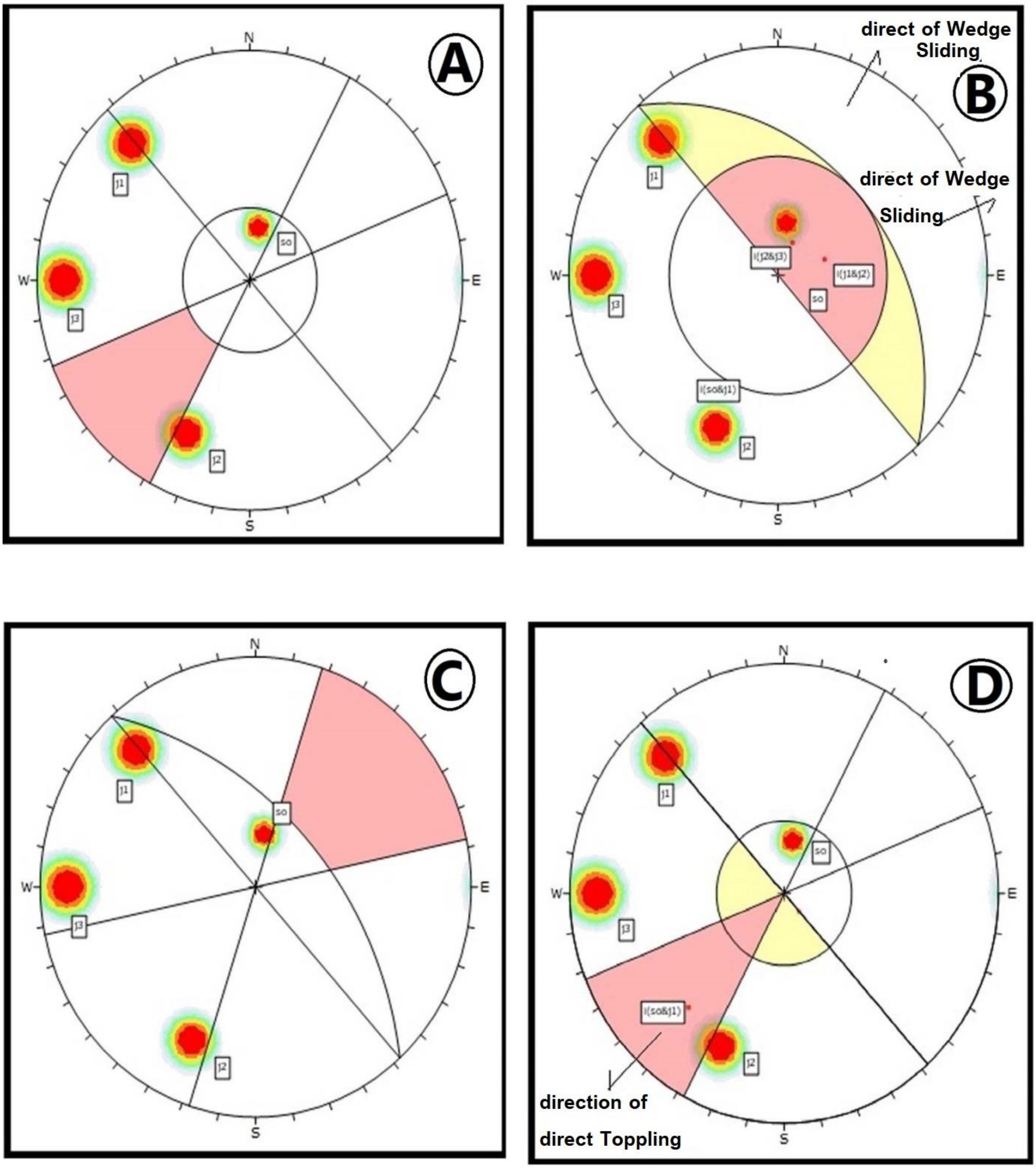


Fig. 7. Kinematic analysis of a spillway station with an attitude of slopes (048/90) A: There is no possibility of planar sliding. B: There is a possibility of wedge sliding. C: There is no possibility of flexure toppling. D: There is a possibility of direct toppling

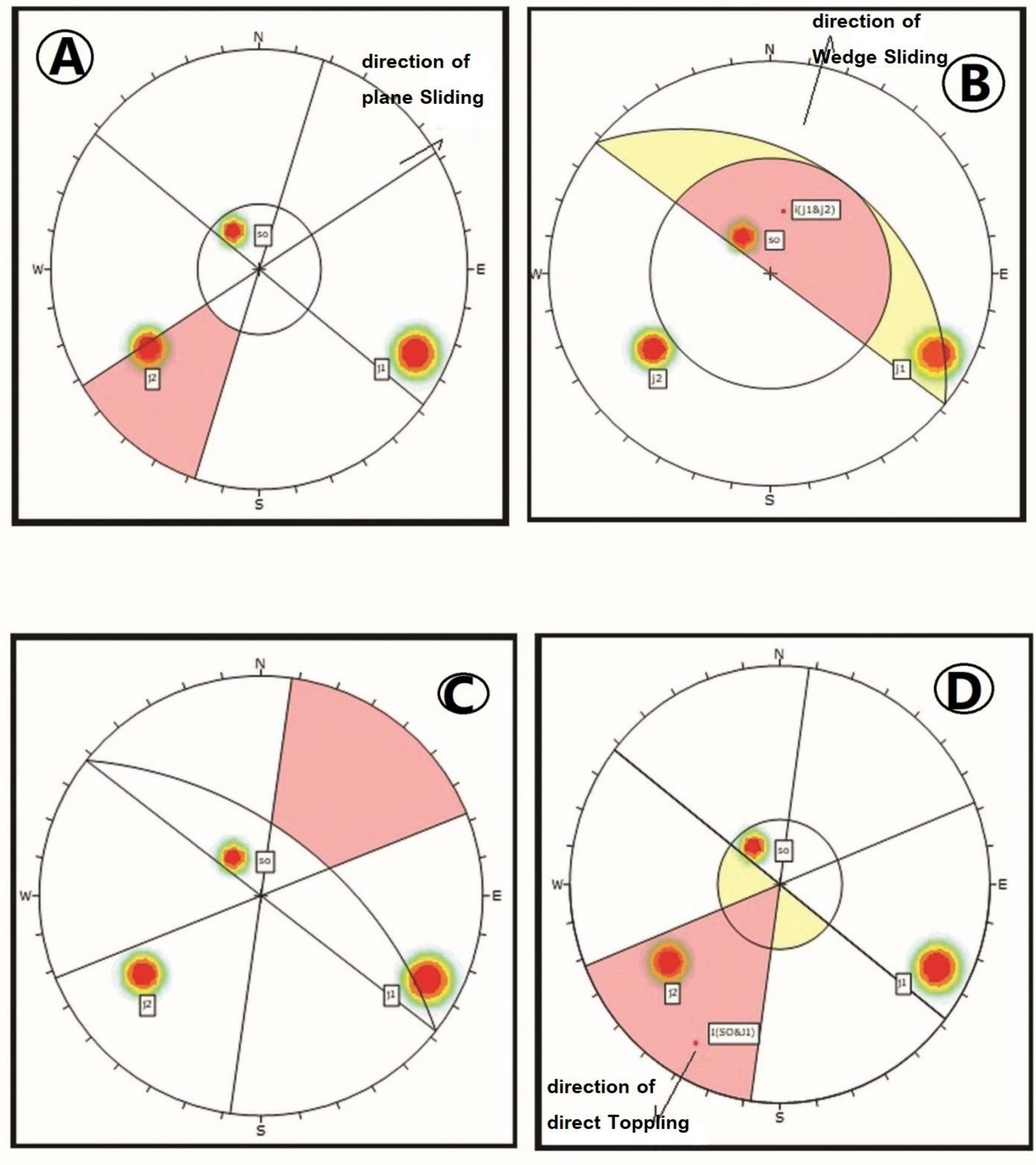


Fig. 8. Kinematic analysis for the first station (SR1) with attitude of slopes (038/90), A: There is a possibility of planar sliding. B: There is a possibility of wedge sliding. C: There is no possibility of flexure toppling. D: There is a possibility of direct toppling

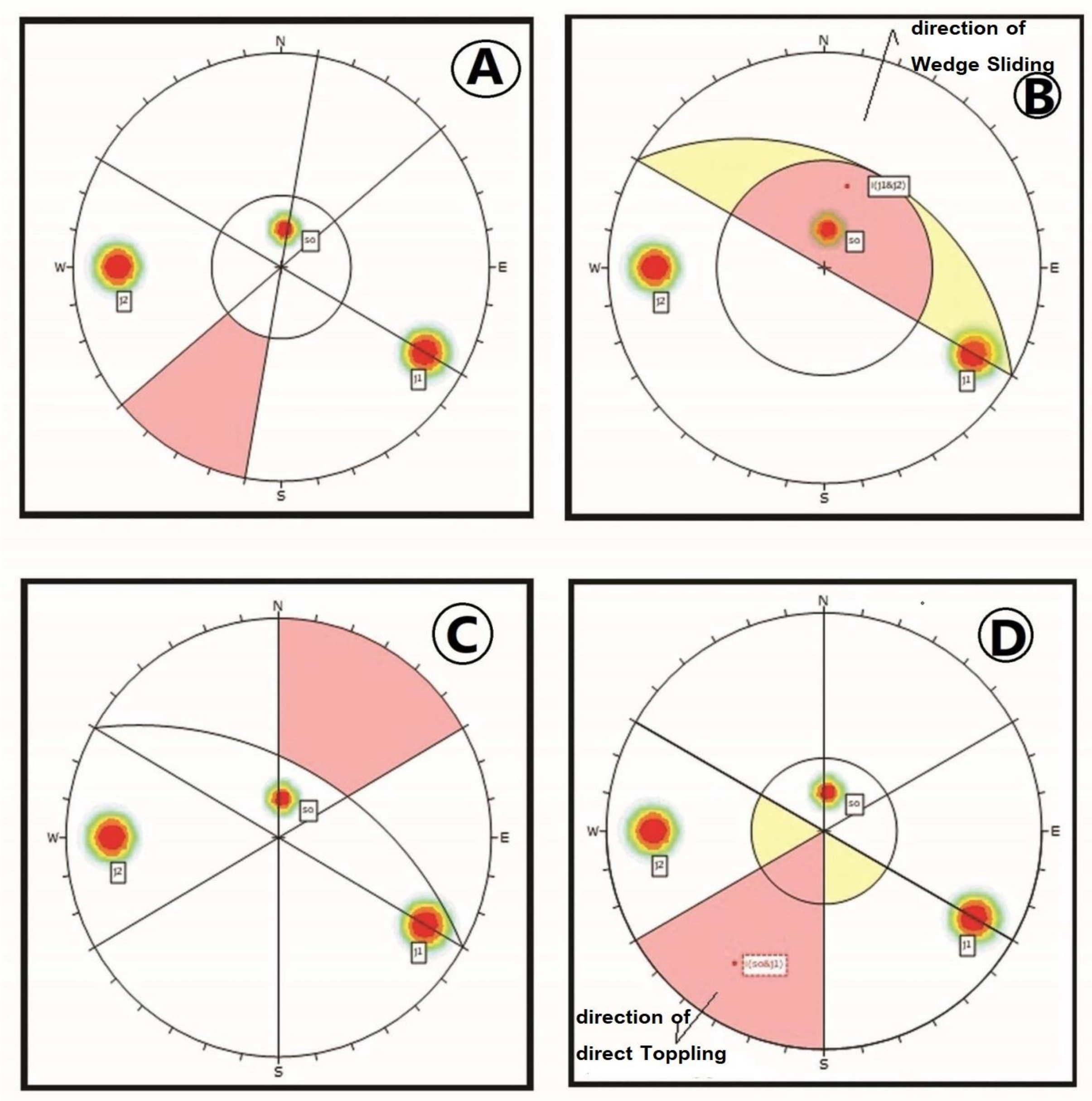


Fig. 9. Kinematic analysis of the second station (SR2) with an attitude of slopes (030/90) A: There is no possibility planar sliding. B: There is a possibility of wedge sliding. C: There is no possibility of flexure toppling. D: There is a possibility of direct toppling.

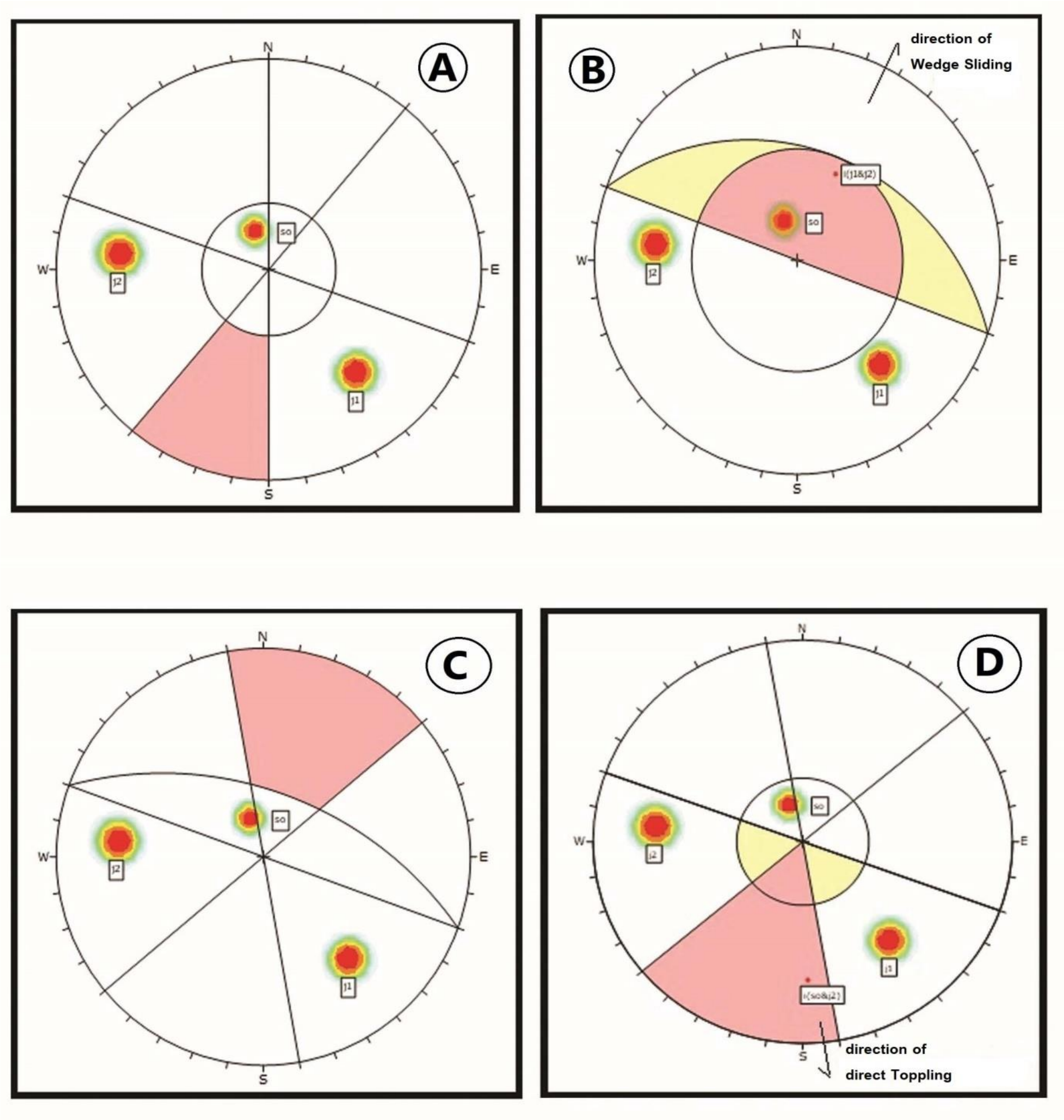


Fig. 10. Kinematic analysis for the third station (SR3) with an attitude of slope (020/90), A: There is no a possibility of planar sliding. B: There is a possibility of wedge sliding. C: There is no possibility of flexure toppling. D: There is a possibility of direct toppling.

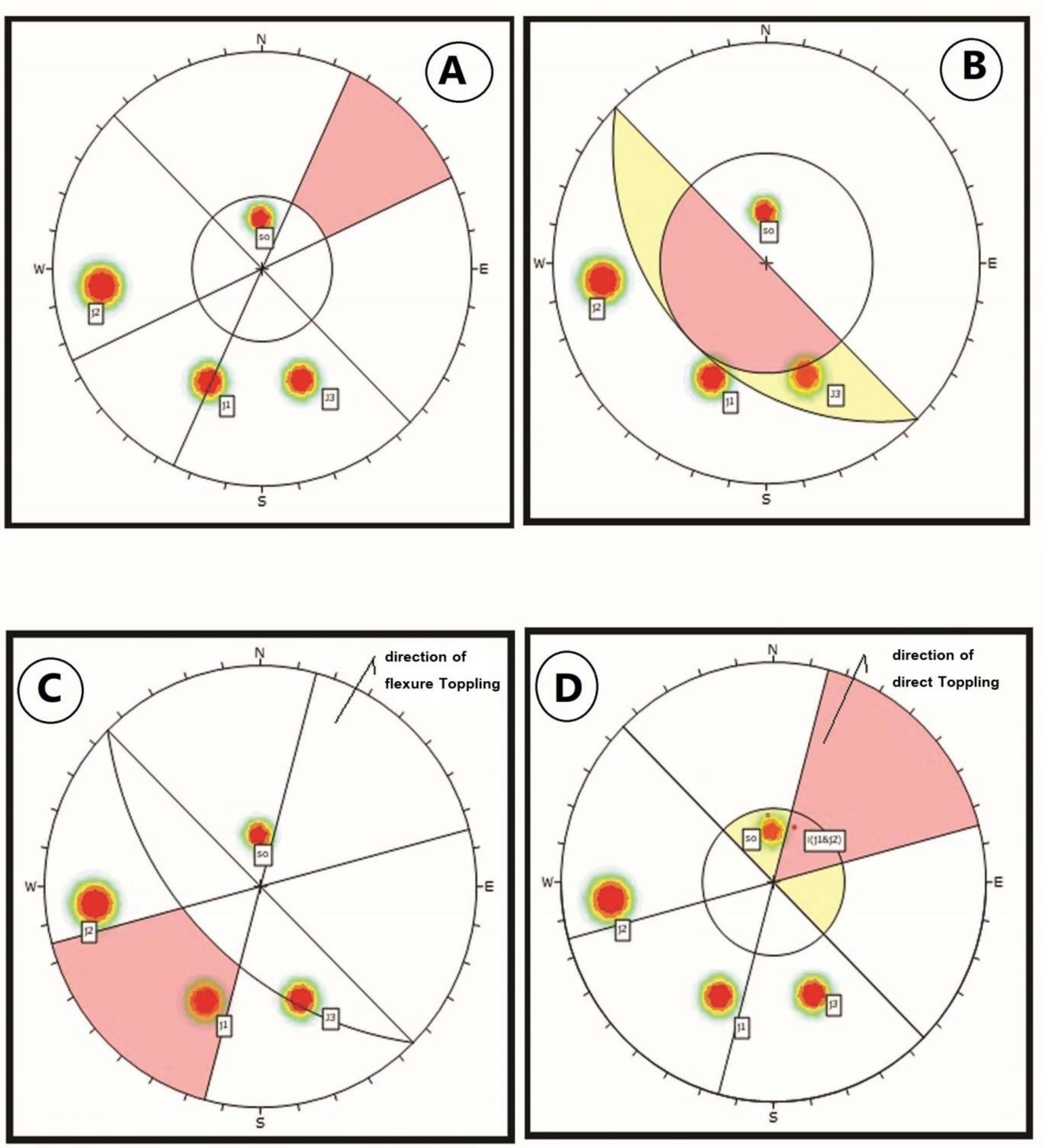


Fig. 11. Results of the Kinematic analysis of the first station (SL1) with an attitude of slopes (225/90) A: There is no possibility of planar sliding. B: There is no a possibility of wedge sliding. C: There is a possibility of flexure toppling. D: There is a possibility of direct toppling.

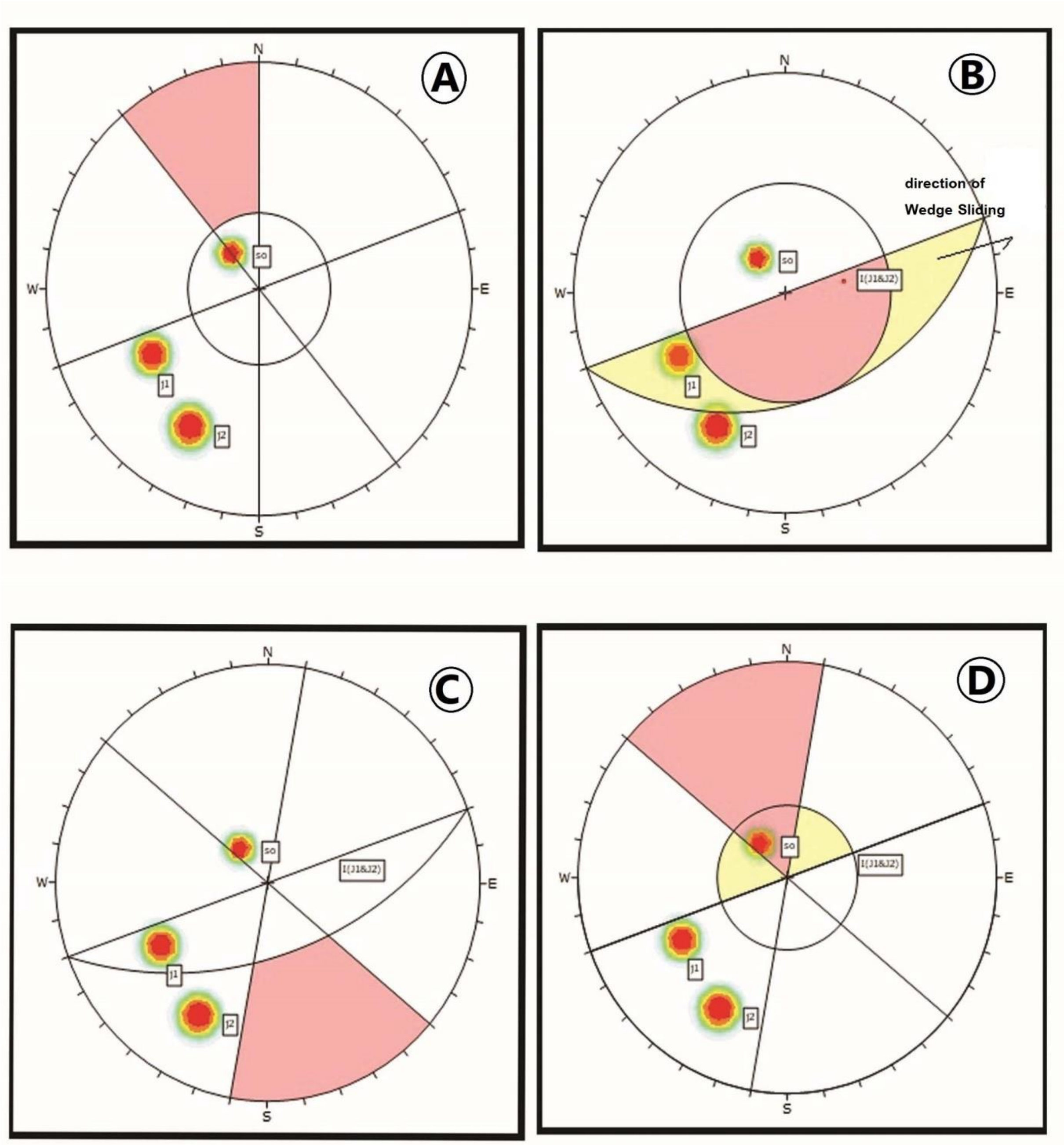


Fig. 12. Kinematic analysis for the second station (SL2) with an attitude of slope (160/90), A: There is no a possibility of planar sliding. B: There is a possibility of wedge sliding. C: There is no possibility of flexure toppling. D: There is no possibility of direct toppling.

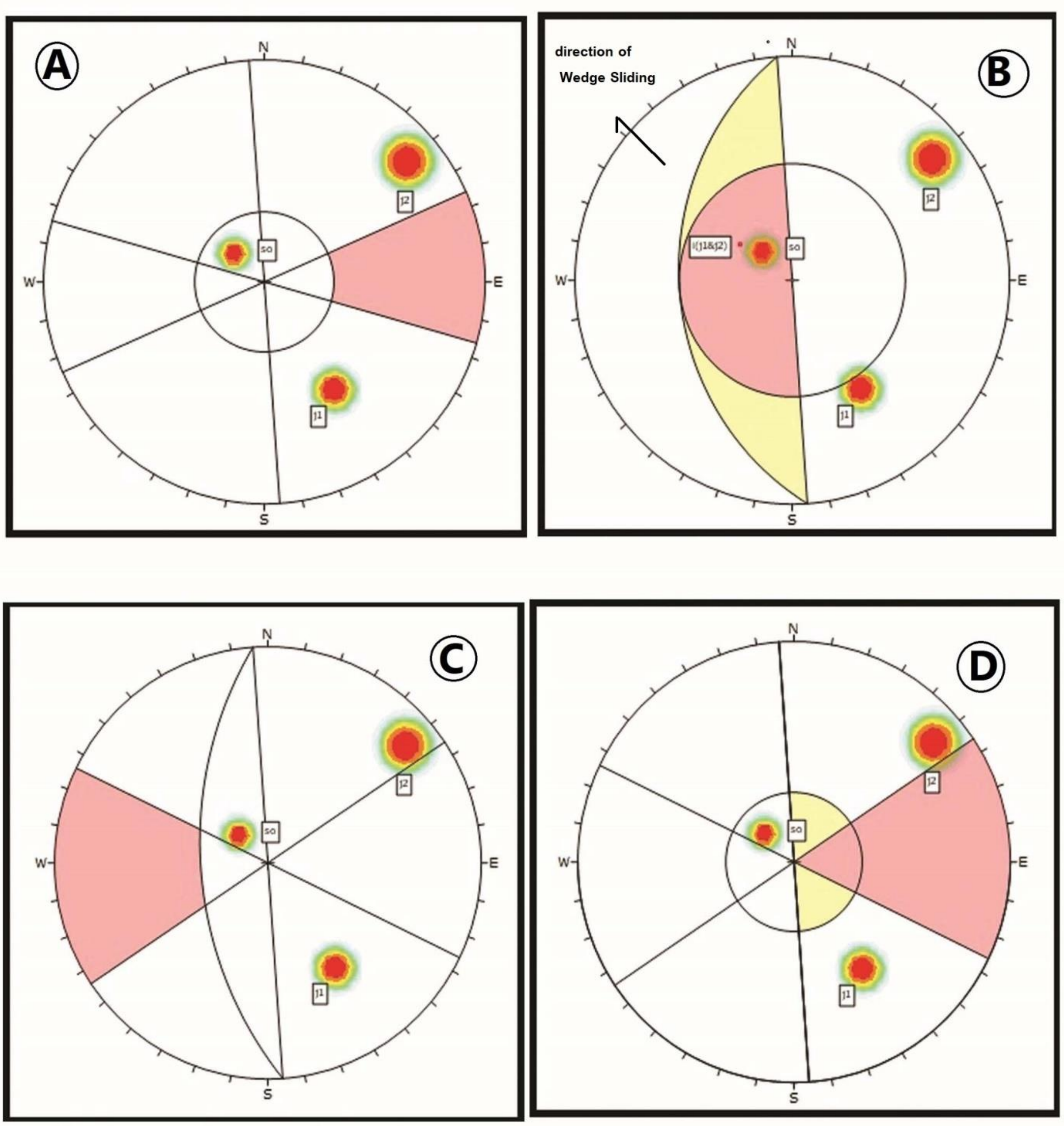


Fig. 13. Kinematic analysis of the third station (SL3) with an attitude of slopes (266/90) A: There is no possibility of planar sliding. B: There is a possibility of wedge sliding. C: There is a possibility of flexure toppling. D: There is no a possibility of direct toppling.

Slope Mass Rating (SMR)

It is a rock mass classification system developed by Romana, (1985). By adding the basic Rock Mass Rating ($RMR_{b\ (89)}$) to the semi-quantitative definition of the effect of the direction of discontinuities in rock slopes through continuous function (Tomas et al., 2007). The basic rock mass classification plays an important and effective role in calculating the Slope Mass Rating. The classification of the rock mass (RMR) includes the collection of all field data, such as attitude (dip direction/dip amount) for all different discontinuities, Compressive strength is extracted through the use of uniaxial compressive strength on cylindrical rock samples of known length and diameter. In addition to the Rock Quality Designation, the distance between the discontinuities, condition of discontinuities, and condition of ground water. The average distance between discontinuities is calculated according to Bieniawski, (2011). The Rock Quality Designation (RQD) is calculated according Palmstrom, (2005) using volumetric joints. The number of discontinuities per unit volume according to the following equation:

RQD = 110 – 2.5 (J. V) ……………. (Palmstrom, 2005).

The Slope Mass Rating index is calculated by applying four adjustment factors to Rock Mass Rating which are (F1, F2, F3, and F4). These factors depend on both of the excavation method and the engineering relation that exists between the slope and the discontinuities effected by the rock mass (Romana,1985; Riquleme *et al.,* 2016).

Where the Slope Mass Rating Index is calculated through equation:

$$SMR = (RMR_b + (F1 \times F2 \times F3) + F4.$$

For continuous slope mass rating adjustment factors, F1, F2, and F3 are calculated as follows according to equations proposed by Tomas *et al.,* (2007):

$$F1 = (16/25) – (3/500) \text{ Arc tan } [(1/10) (|A| - 17)].$$

Where $|A| = |\alpha i - \alpha s|$ for planar sliding failure.

$|\alpha i – \alpha s|$ for wedge failure.

$|\alpha j - \alpha s|$- 180) for toppling failure.

Where (αi, αj, αs) are the directions of the dip of the joint and slope and plunge of intersection line between two joint planes.

F2= (9/16) + (1/195) Arc tan [(17/100) B-5] for planar and wedge failure).

F2 = 1 (For toppling failure).

Where (B) equal to dip (ßJ) of joint for planar and toppling failure and the dip of the plunge of the intersection line for wedge failure.

F3 = - 30 + (1/3) Arc tan (C) For planar and wedge failure.

F3= - 13 + (1/17) Arc tan for toppling failure.

Where (C) is the angular difference between the dip of the joint and slope (ßj-ßs) for a wedge. For toppling, C is defined as a sum of the dip of the joint and slope (ßj-ßs).

F4 refers to the adjustment factor for the excavation method of the rock slope.

Where the stability classes and values of slope mass rating and rock mass description, condition of the stability, type, and probability of failure are given in the following table which given by Romana, (1985) are also applicable for continuous Slope Mass Rating Classification Table. 2.

Table 2: Description of slope mass rating (SMR) classes (Romana, 1985)

Classes→	V	VI	III	II	I
SMR	0-20	21-40	41-60	61-80	81-100
Description	Very bad	bad	Normal	Good	Very good
Stability	Completely unstable	Partially unstable	Partially unstable	Stable	Completely stable
Failure	big planar soil - like	Planar or big wedge	Some joints or many wedge	Some blocks	none
Failure probability	0.9	0.6	0.4	0.2	0

Table 3: Dip direction/Dip amount of slope face, bedding planes, joint sets, and Friction angle at the stations (Rock slopes) of the study area.

Stations	Slope dip direction/ dip amount	Bedding plane dip direction/dip amount	Set 1 (J1) dip direction/ dip amount	Set 2 (J2) dip direction/ dip amount	Set 3 (J3) dip direction/ dip amount	Friction Angle ϕ
Right bank						
Spillway station	048°/90°	190°/26°	137°/78°	024°/72°	90°/82°0	35°
SR1	038°/90°	144°/24°	297°/80°	065°/65°	--------	33°
SR2	030°/90°	185°/20°	300°/77°	090°/77°	--------	37°
SR3	020°/90°	160°/22°	320°/65°	96°/70°	--------	35°
Left bank						
SL1	225°/90°	178°/26°	026°/60°	084°/75°	340°/57°	37°
SL2	160°/90°	140°/23°	060°/60°	28°/69°	--------	37°
SL3	266°/90°	133°/21°	327°/60°	230°/80°	--------	35°

Table 4: Results of discrete slope mass rating (SMR), Using SMAR Tool software.

Station No.	RMR_b	Type of failure	Failure direction	F1	F2	F3	F4	F1. F2. F3	SMR Value	SMR Class /Stability
spillway	50	(b) W.S. (j1&j2). (b) W.S. (j2&j3). (d) D.T. (So, &j1).	(b) 72.62 (b) 25.26 (d) 221.95	(b) 0.4 (b) 0.4 (d) 0.85	(b) 1 (b) 1 (d) 1	(b) -60 (b) -60 (d) -6	(b) 0 (b) 0 (d) 0	(b) -24 (b) -24 (d) -5.1	(b) 26 (b)26 (d) 44	(b) IV/Un.sta (b)IV/ Un.sta (d)III/P.sta
SR1	51	(a) P.S (J2) (b) W.S. (j1&j2) (d) D.T. (So, &j1)	(a) 56 (b) 11.38 (d) 208.91	(a)0.7 (b)0.4 (d)0.85	(a) 1 (b)1 (d) 1	(a) -60 (b) -60 (d) 0	(a) 0 (b) 0 (d) 0	(a) -42 (b) -24 (d) 0	(a) 9 (b) 27 (d) 51	(a) V/Un.sta (b) IV/ Un.sta (d) III/P.sta.
SR2	61	(b)W.S. (d) D.T. (So, &j1)	(b)15.59 (d) 214.21	(b) 0.7 (d) 1	(b) 1 (d) 1	(b) -60 (d) 0	(b) 0 (d) 0	(b) -42 (d) 0	(b) 19 (d) 61	(b)V/C.Un.sta (d) III/Sta.
SR3	57	(b) W.S. (j1&j2). (d) D.T. (So, &j1)	(b) 25.15 (d) 177.96	(b) 0.85 (d) 0.4	(b) 0.85 (d) 1	(b) -60 (d) -6	(b) 0 (d) 0	(b) -43.35 (d) 2.4	(b)13 (d) 54	(b)V/C.Un.sta (d) III/P.sta.
SL1	62	(c) F.T. (J1) (d) D.T (J2&J3)	(c) 26 (d) 21.56	(c) 0.7 (d) 0.4	(c) 1 (d) 1	(c) -25 (d) -25	(c) 0 (d) 0	(c) -17.5 (d) -10	(c) 44 (d) 52	(c)III/P.sta. (d)) III/p.sta
SL2	55	(b) W.S. (J1&J2)	(b) 79.07	(b) 0.15	(b)1	(b) -60	(b) 0	(b) -9	(b) 46	(b)III/P.sta
SL3	53	(b) W.S. (J1&J2)	(b) 303.71	(b) 0.15	(b) 1	(b) -60	(b) 0	(b) -9	(b) 44	(b)III/P.sta

Where the symbol a= (P.S.) is represented by planar sliding, b= (W.S.) represented by the wedge sliding, c= (F.T) Represented by the flexural toppling, and d= (D.T.) is represented by (direct toppling), (F1, F2, F3, F4) represented to correction factors for SMR, (Un.sta) represented (unstable), (P.sta) represented (Partial stable), (C.Un.sta) represented to (completely unstable)

Table 5: Results of continuous slope mass rating (CSMR), Using SMARTool software

Station No.	RMR_b	Type of failure	Failure direction	F1	F2	F3	F4	F1. F2. F3	SMR Value	SMR Class /Stability
spillway	50	(b) W.S. (j1&j2). (b) W.S. (j2&j3). (d) D.T. (So, &j2).	(b) 72.62 (b) 25.26 (d) 221.95	(b) 0.41616 (b) 0.4703 (d) 0.92558	(b) 0.97429 (b) 0.9837 (d) 1	(b) - 59.27 (b) -58.940 (d) -1.225	(b) 0 (b) 0 (d) 0	(b) 24.0317 (b) -27.269 (d) -1.1338	(b) 25 (b) 22 (d) 48	IV/Un.sta (b) b) IV/ (Un.sta (d) III/P.sta
SR1	51	(a) P.S (J2) (b) W.S. (j1&j2) (d) D.T. (So, &j1)	(a) 56 (b) 11.38 (d) 208.91	(a) 0.60574 (b) 0.37666 (d) 0.87006	(a) 0.97591 (b) 0.96181 (d) 1	(a) -59.236 (b) -59.42 (d) -0.563	(a) 0 (b) 0 (d) 0	(a) -35.017 (b) -21.5282 (d) -0.49277	(a) 15 (b) 29 (d) 50	(a)V Un.sta (b)IV/ Un.sta (d) III/P.sta
SR2	61	(b) W.S. (d) D.T. (So, &j1)	(b) 15.59 (d) 214.21	(b) 0.72712 (d) 0.95188	(b) 0.92995 (d) 1	(b) -59.554 (d) -0.802	(b) 0 (d) 0	(b) -40.270 (d) -0.7639	(b) 20 (d) 60	(b)V/C.Un.sta (d) III/P.sta
SR3	57	(b) W.S. (j1&j2) (d) D.T. (So, &j1)	(b) 25.15 (d) 177.96	(b) 0.93904 (d) 0.47951	(b) 0.89584 (d) 1	(b) - 59.60 (d) -1.0506	(b) -0 (d) 0	(b) -50.14 (d) - 0.5037	(b) 6 (b) 56	(b)V/C.Un.sta (d) III/P.sta
SL1	62	(c) F.T. (J1) (d) D.T (J1&J2)	(c) 26 (d) 21.56	(c) 0.57214 (d) 0.44331	(c) 1 (d) 1	(c) -25.584 (d) -58.38	(c) 0 (d) 0	(c) -14.6379 (d) -11.34	(c) 47 (d) 50	(c) III/P.sta (d)) III/p.sta
SL2	55	(b) W.S. (J1&J2)	(b) 79.07	(b) 0.15334	(b) 0.96557	(b) -59.39	(b) 0	(b) -8.7937	(b) 46	(b) III/P.sta
SL3	53	(b) W.S. (J1&J2)	(b) 313.71	(b) 0.25464	(b) 0.96411	(b) -59.4	(b) 0	(b) -14.58	(b) 38	(b)IV/Un.sta

Where the symbol a= (P.S.) is represented by planar sliding, b= (W.S.) represented by the wedge sliding, c= (F.T) Represented by the flexural toppling, and d= (D.T.) is represented by (direct toppling), (F1, F2, F3, F4) represented to correction factors for SMR, (Un.sta) represented (unstable), (P.sta) represented (Partial stable), (C.Un.sta) represented to (completely unstable)

Conclusion

Through the kinematic analysis program of Dips (version 6.008). For the initial evaluation of the types of failures, is also time - saving and its results facilitate the evaluation of stability by classifying the slope mass system. It shows the possibility of a plane sliding at the first station (SR1), which is located on the right bank. The possibility of wedge sliding occurring at the following stations (spillway, SR1, SR2 and SR3) which are located on its right bank. And the stations (SL2, SL3) are located on the left bank. The possibility of flexure toppling occurs in the first station of the left bank. The results of the SMARTool-version205 program show that the classification value is continuous (CSMR) and in its worst condition.

1- The lowest value for the wedge sliding in the stations are located on the right bank. represented by (Spillway, SR1, SR2, SR3), whose values range from (13 to 27) in the discrete status according to Romana, (1985), while in the continuous status according to Tomas *et al.*, (2007), they range from (6-29), which means that the rock block located within the fourth category (IV) to fifth category (V) (very bad/Completely unstable to bad/ Partially unstable). The high values of wedge sliding range between (44-46) in discrete status and located within the third category (III) (normal /Partially unstable) and between (38-46) in continuous status located within the third category (III) and fourth category (IV) from (bad/Partially unstable to normal/ Partially unstable) in the stations SL2 and SL3 in the left bank.

2- Flexural toppling value in the first station (SL1) on the left bank is (44) in the discrete status, which is located within the third category (III) (normal/Partial unstable) and in the continuous status (47), which is also located in the third category (III) (normal/Partial unstable).

3- Plane sliding appear in only one case, which is in the first station (SR1) right bank, and its value is (9) in the discrete, which is within the fifth category (V) and is (very bad/ Completely unstable). And also in the continuous status, the value is (15) which is also located within the fifth category (V) of (very bad /Completely unstable).

4- Direct toppling direct appears in the stations (Spillway, SR1, SR3) and (SL1), their values range from (48-61), which are located in the second category(II) and third category (III), which (normal/Partially unstable to good / stable) this is in the discrete status, while in the continuous status, the results appear from (48-60), which are located in the third category (III). It is considered (normal/Partially unstable).

Recommends

1- It is suggested to treat the spillway station with reinforced concrete, to reduce the effect of the rocks at this station on the water descending towards the downstream.

2- Conducting treatments for some unstable stations, such as consolidation and support, especially stations near the dam body and the lake.

3- Conducting a stability study on the rock slopes in other areas of the lake and suggest the necessary treatments to reduce their impact on the lake.

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