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Impact of Geological Structures on Rock Slope Stability in The NW Nose (Plunge) of Surdash Anticline, Sulaimaniya/ NE Iraq

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Abstract

The road network in Surdash anticline is considered as an important road network connecting lower Dukan town with the touristic upper Dukan town . Dukan lake plays an important role in the social and economic activities of Dukan town and the surrounding areas.

For assessing the stability of the rock slopes in the area, 9 stations were selected along the upper Dukan road on both sides of Surdash anticline, and their stability was evaluated by the kinematic analysis using DIPS V6.008 software.

Kinematic analysis of the studied stations shows thatplanar sliding is possible in stations No. 1, 2, 3 and 8, while wedge sliding is possible in station No. 5, 6, 7 and 9b. The other stations (No. 4and 9a) are stable. Tectonic structures played an extra paradoxical role in the stability of the rock slopes and the type of failure. In most of the selected stations , the geological structure had a negative role, which supported or promoted the failure in the study area. However, in few stations , it had a positive role and converted the slope from unstable to stable conditions. In addition, the presence of incongruent minor syncline folds, especially in the SW-limb of the major anticline, led to the occurring of wedge sliding instead of plane sliding.

Keywords: Kinematic Analysis ,Landslide ,Slope Stability ,Surdash anticline ,Joint sets , DIPS v6.008

تاثير التراكيب الجيولوجية على استقرارية المنحدرات الصخرية لطية سارة في منطقة الغطس الشمالي الغربي، السليمانية/. شمال شرق العراق

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الخلاصه

ان شبكة الطرق في طية سارة تعتبر من شبكات الطرق المهمة والتي تربط مدينة دوكان السفلي مع مدينة دوكان العلوي السياحية ، و تلعب دورا كبيرا في النشاطات الاجتماعية والاقتصادية لمدينة دوكان والمناطق المحيطة بها. تم اجراء تقويم هندسي لاستقرارية المنحدرات الصخرية في هذه المنطقة و تم اختيار (9) محطات في المنحدرات الصخرية على طول طريق دوكان العلوي وعلى جانبي طية سورداش لتقويم استقرارية هذه المنحدرات الصخرية بطريقة التحليل الكينماتيكي باستخدام برنامج DIPS V6.008 . وقد بين التحليل الكينماتيكي امكانية حصول الانزلاق المستوي في المحطات 1،2،3و 8.اما بالنسبة للانزلاق

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الاسفيني فامكانية حدوثه ممكنة في المحطات 6،7و9- ب . اما بقية المحطات (4،5 و 9أ) فتكون فيها المنحدرات مستقرة. ان البنية التركيبية تلعب دورا متناقضا وبشكل متزايد في استقرارية المنحدرات الصخرية وفي نوع االانزلاق . في معظم المحطات التي تم اختيارها فان التراكيب الجيولوجية كان لها دور سلبي مما يؤدي الى تفعيل الانزلاق ، او دور ايجابي مما يؤدي الى تغيير حالة عدم الاستقرار الى حالة الاستقرار بالاضافة الى هذا فان تواجد الطيات الثانوية المقعرة المتعارضة مع الطيات الرئيسية في الجناح الجنوبي الغربي للطية الرئيسية ادى الى حصول الانزلاق الصخري الاسفيني بدلا من الانزلاق المستوي.

1-Introduction

The landslides, or other interchangeably used terms, , such as slope failure, mass movement and so on , are defined as the history of a mass movement that comprises pre-failure deformations, failure itself. and post failure displacements [1]. Also, it describes the processes that involve downward and outward movements of earth materials including rocks and soils that result in slope modifications [2].

The slopes on which the landslide is taking place are either naturally existing or as a result of man-made activities, where man-made slopes (especially rock slopes) are created by highway or motorway constructions in the mountainous region and by the excavation of surface mining such as stone quarries , open pits… etc.[3].

The landslide along road cuts are caused by different geologic and geometric factors such as engineering and lithological properties of rocks (uniaxial compressive strength, slope material, slake durability , amount and type of clay minerals… etc). Slope characteristics includes slope angle, joint structure, ground water , seepage, and surface runoff …etc.. Rock mass characteristics include the presence of discontinuities such as joints, bedding planes, faults, foliations, and their characteristic such as roughness, discontinuity spacing, infilling material nature , orthogonal blocks formed by the discontinuities …etc., climate , ground water conditions, and rainfall history [4-7].

There are different methods for estimating and evaluating the stability of rock slopes, including limit equilibrium analysis , rock mass classification, kinematic analysis and other methods [8-10].

Kinematic analysis is a geometric method that employs the angular interactions between discontinuity planes to evaluate the possibility and failure types in a jointed rock mass. Usually, the kinematic analysis by utilizing the stereographic projection method is carried out before performiing an elaborated study, mostly in all slopes stability analyses [3].

The rock slope may fail in one of the four known modes of failure; plane, wedge, circular and toppling, depending on the consideration that the main cause behind slope failure in the road cuts is the presence of not preferred oriented discontinuities which act as planes of failure with respect to the slope face [11].

2-Location of the study area

The study area is located in Sulaimaniya governorate, Kurdistan region, NE Iraq, about 60Km to the northwest of Sulaimaniya city (Figure-1). It lies between longitudes E 44° 57' 30'' and E 44° 55' 10'' and latitudes N 35° 57' 30''and N 35° 55' 50'', and includes 9 stations that represent rock slopes and distributed as follows: Stations No. 1, 2, 3,4 and 5 are located within the NE-limb of Surdash anticline , station No.6 is located at the nose of the anticline , while the others (Stations No. 7, 8 and 9a &b) are located within the SW limb of Surdash anticline (Figure-1).

The study area represents the northwest plunge part of Surdash double-plunging anticline that is extending in the northwest-southeast trend.

According to a previous study [12], all stations represent a concordant slope in which the slope has the same orientation as the bedding planes, except stations No.4 and 7, which are disconcordant slopes . All of the studied stations are located within the Kometan Formation.

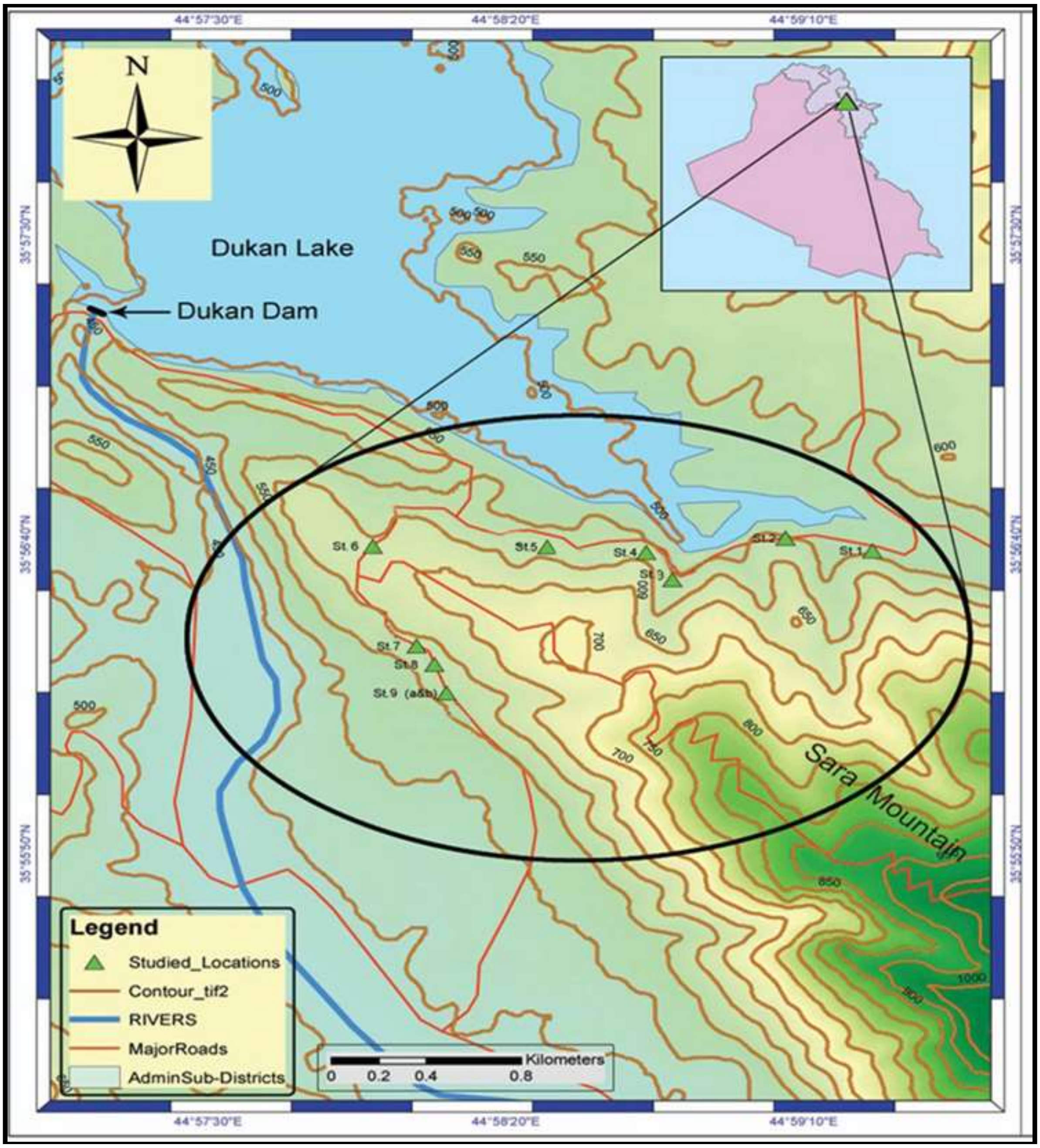

Figure 1- Topographic map showing the location of the studied area including the locations of the studied stations.

3-Materials and Methods

In this study, 9 stations in rock slopes (1,2,3,4,5,7,8and ,9a and b) were selected . They are distributed along the Upper-Dukan road on both sides of Surdash anticline in the NE plunge. The possibility of failure occurrence was assessed in these stations by kinematic analysis using DIPS v6.008 software to analyze the stability and determine the slope failure type, which were used by many researchers in assessing rock slopes stability. The input data were the attitude of the geological discontinuities (dip direction /dip) of bedding planes, joints, and faults as well as the slope face. The data were taken by field work from the 9 selected stations along the Upper Dukan road, as illustrated in table 1, using the Swedish Silva compass. After that, the gathered data were plotted on an equal area stereonet and a kinematic analysis was performed by using DIPS v6.008 software to analyze the stability and to determine the type of slope failure and the direction of discontinuity or line of intersection of discontinuities on whichthe failure will take place. Also the roles of minor folds and faults on the rock slope stability were determined. The slope faces attitude (dip directions/ dip) were used to draw the daylight envelopes. Friction angles of discontinuities were evaluated from the field by the tilting test [13], which was equal to 32° for most of the stations, except in stations no.2 and 3 (20 °) and station no.7 (30°).

Table 1- Attitude of slope face, bedding planes , joints and faults in the selected stations.

St.no.	Slope (S) Dip Dir/dip (average)	Bedding plane (So) Dip Dir/dip (average)	Join set (J1) Dip Dir/dip (average)	Joint set (J2) Dip Dir/dip (average)	Joint set (J3) Dip Dir/dip (average)	Joint friction Angle (f)
1	016/45°	015/37°	159/69°	221/67°	095/82°	32°
2	018/80°	012/24°	098/82° 284/88°	014/78° 192/84°	141/70°	20°
3	035/75°	019/24°	073/87°	279/86°	155/76°	20°
4	028/83°	300/38° 120/27°	050/86°	140/80° 146/75°	——	32°
5	028/65°	045/23	175/67°	265/82°	——	32°
6	320/75°	322/5°	242/86°	314/81°	360/78°	32°
7	220/70°	L.S.170/38° R.S.250/38°	060/64° 210/73°	324/66° 276/86°	—— ——	30°
8 (upper unsta. part)	236/75°	220/40°	202/79°	260/80°	080/80° (J4) 125/80° (Fault)	32°
9b Syncline	240/70°	220/23° (Left .limb) 256/22° (Right .limb	092/71°	340/74°	008/75°	32°
9a Anticline	240/70°	280/38°(Left .limb) 236/28° (Right .limb	092/70°	190/68°	225/85°	32°

-Station No.1

The rock mass was intersected with four discontinuities sets (a bedding plane and three joint sets), as illustrated in Table-1 , Figure-2 and plate 1.

Kinematic analysis revealed that the plane sliding occurred on the bedding plane (So) towards 015°, which in turn acts as basal release surface during sliding(Figure-2a), while J1, J2 and J3 act as lateral release surfaces.

The upper remaining parts of the slope are also unstable due to the presence of tension cracks and opening of joint sets and, thus, they are expected to fail in the future .

Wedge sliding occurs due to the presence of a pole of the intersection line between So and J3 in the critical area of wedge sliding (pink area), but wedge sliding is not possible because the direction of So is located within the slope direction and plunge direction of the intersection (I (So,J3)), as shown in Figure-2b, this idea was emphasized by [13]&[14].

Flexural toppling was not occurring because no poles were located in the critical area (pink area) defined for flexural toppling (Figure-2c), while no direct toppling occured .

In spite of the presence of basal plane (So) and three critical intersections in the critical area of the direct toppling (Figure-2d), direct toppling is not possible to occur because the suitable dimensions of blocks (width and height) for toppling are not existing in reality (Plate 1).

Plate1- General view for station no.1. Photo was taken in the SW-direction.

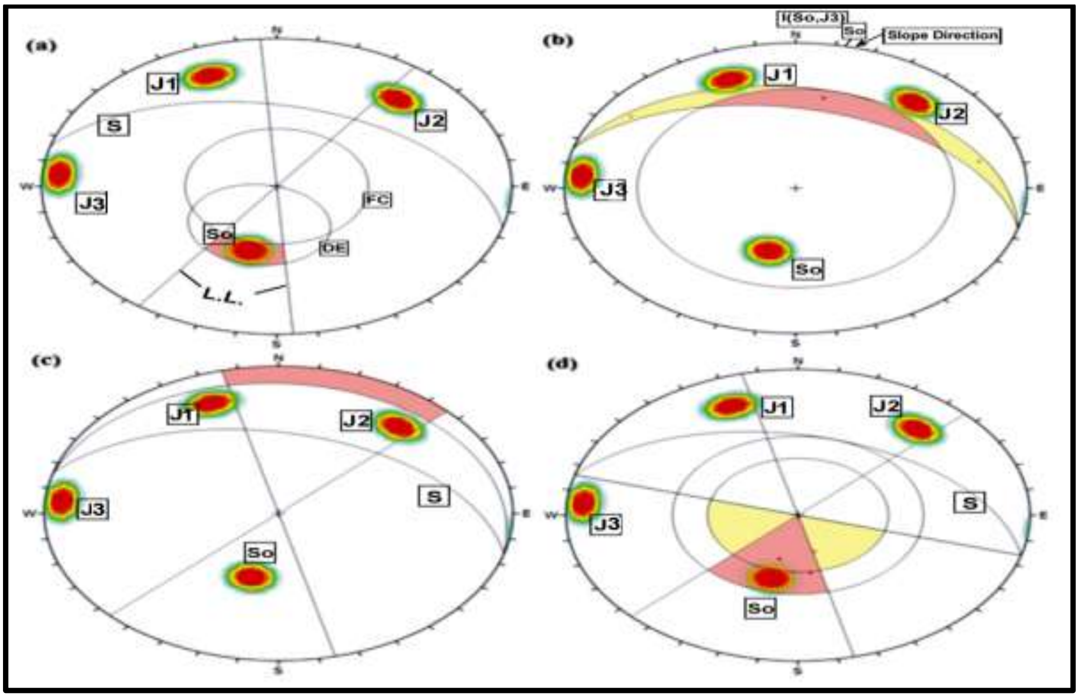

Figure 2- Kinematic analysis for stationNo.1:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2, J3 is joint set no.2 is , slope face is(S),bedding plane is (So) ,lateral limits are (L.L), FC is friction cone, DE is daylight envelope and the line of the intersection of the discontinuities is (I).

-Station No.2

Four discontinuities (a bedding plane and three joint sets) are intersected with the rock mass of this slope, as shown in Figure-3 and plate 2 .From the kinematic analysis , it was clear that plane sliding occurred on the bedding plane (So) towards 020°, which in turn acts as basal release surfaces during sliding, while J1 and J3 act as lateral release surfaces and J2 acts as a back release surface. Occasionally, plane sliding may occur on J2 (J2 and slope face have the same dip direction), as illustrated in Figure-3a. Two tension cracks run parallel to J2 with lengths of about 9m and 20m, extending along J2 and defined rock blocks. These blocks are stable at the present time but they are expected to fail in the future in the form of high angle - plane sliding, according to a previous study. In spite of the presence of 6 poles of intersection , the most suitable intersection for the wedge sliding to occur is between J2 and J3 (I(J2 & J3)), as shown in Figure-3b. Figure-3c shows that the pole of J2 (hol$_3$ type) is located within the area of potential flexural toppling, but it does not occur because the J2 of hol3 type is alternated by the J2 of hol4 type which hinders the occurring of flexure toppling. No direct toppling occurs in spite of the presence of two basal planes (So& J2) and three critical intersections in the critical area of direct toppling (Figure 3-d), because the suitable dimension of the blocks (width and height) for the toppling are not existing in the field. In other words, the stereographic projection is not able to identify the block dimension but it only gives the possibility of failure types.

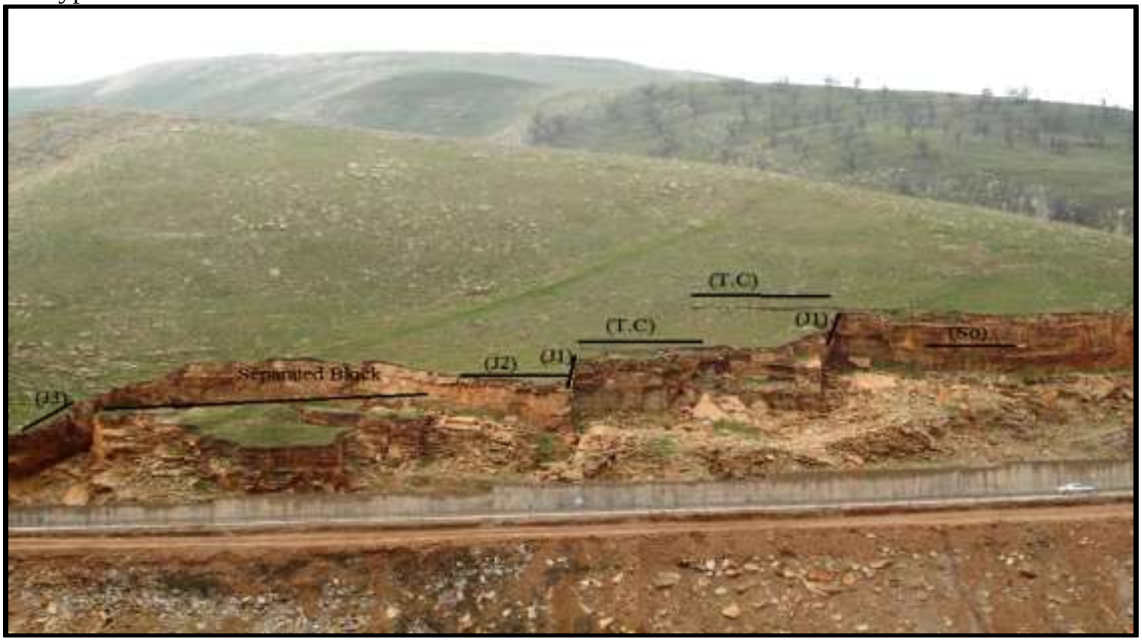

Plate 2- Front view showing the Bedding plane (So), Joint set No. 1 (J1),Joint set No.2(J2) , joint set No.3(J3) and tension cracks (T.C) along J2 in station No. 2 .Photo direction is SW.

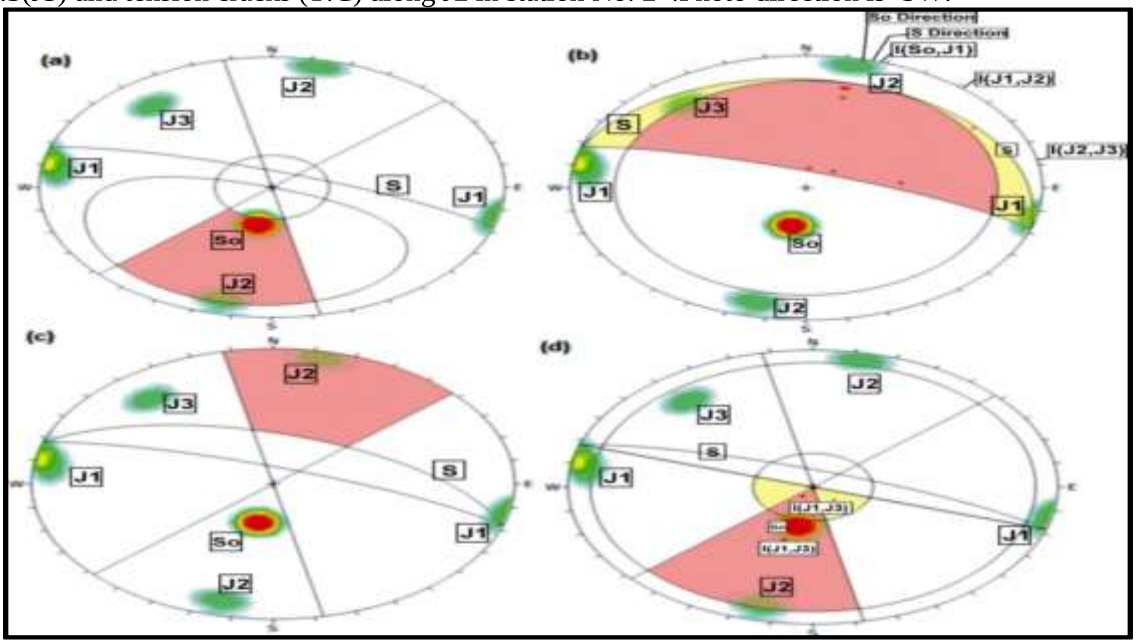

Figure 3- Kinematic analysis for station No.2:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2, J3 is joint set no.3 ,slope face is (S),bedding plane is (So) and the line of the intersection of the discontinuities is (I).

-Slope site No.3

In addition to the bedding plane (So), there are three discontinuities, namely Joint set No.1 (J1), Joint set No.2 (J2) and Joint set No.3 (J3) which is a random joint set that has a spacing of more than 5 m (Plate-3).

From Figure-4a, it is clear that a planar sliding occurred on the bedding plane (So) due to the presence of bedding plane poles in the potential plane sliding area shaded with pink color and in the direction of 048°. The sliding J1 & J2 act as oblique release surfaces according to a previous study, while J3 acts as a lateral release surface. The presence of a Claystone bed with a thickness of about 4cm, interbedded with limestone beds, played a role in accelerating the planar sliding.

The wedge sliding is not occuring, despite the pole of the intersection line between So & J2 which is located in the shaded area (pink color, Figure-4b), because the direction of So is located within the critical zone of the slope direction and the plunge of the intersection line (I (So,J2)). No flexural toppling occurs due to that no poles of any joint sets are located in the shaded area (pink color) of the critical zone of flexural toppling (Figure-4c). Direct toppling is not occuring due to the nonexistence of critical intersections that release blocks in the shaded area with pink color for the critical zone of the direct toppling (Figure-4d). The presence of the slope of station No.4 on the SW limb of the minor fold (anticline) and the road-cut method gave rise to the instability of the slope and induced the landslide (Plate 3a and b).

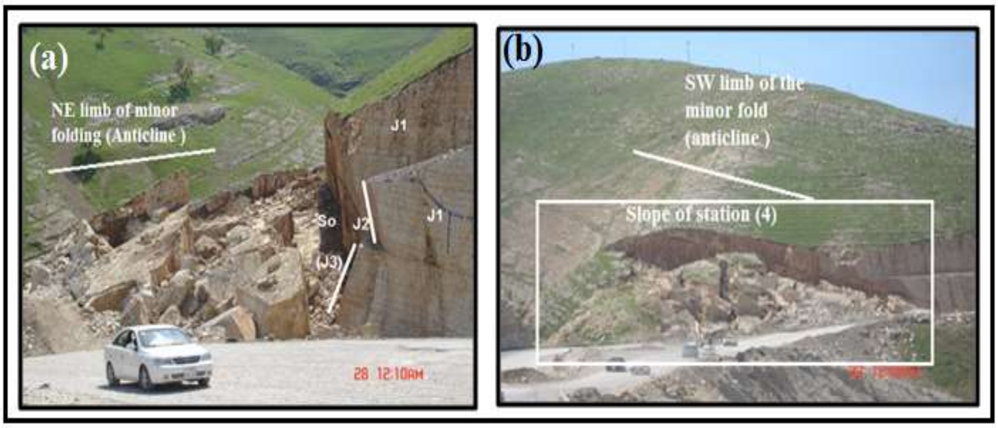

Plate 3a- Bedding plane(S0) , joint sets one (J1), joint set tow (J2) and joint set three (J3). The photo was taken in the direction SW**.** 3b shows the slope of station No.3 which is located at the SW limb of the minor anticline .

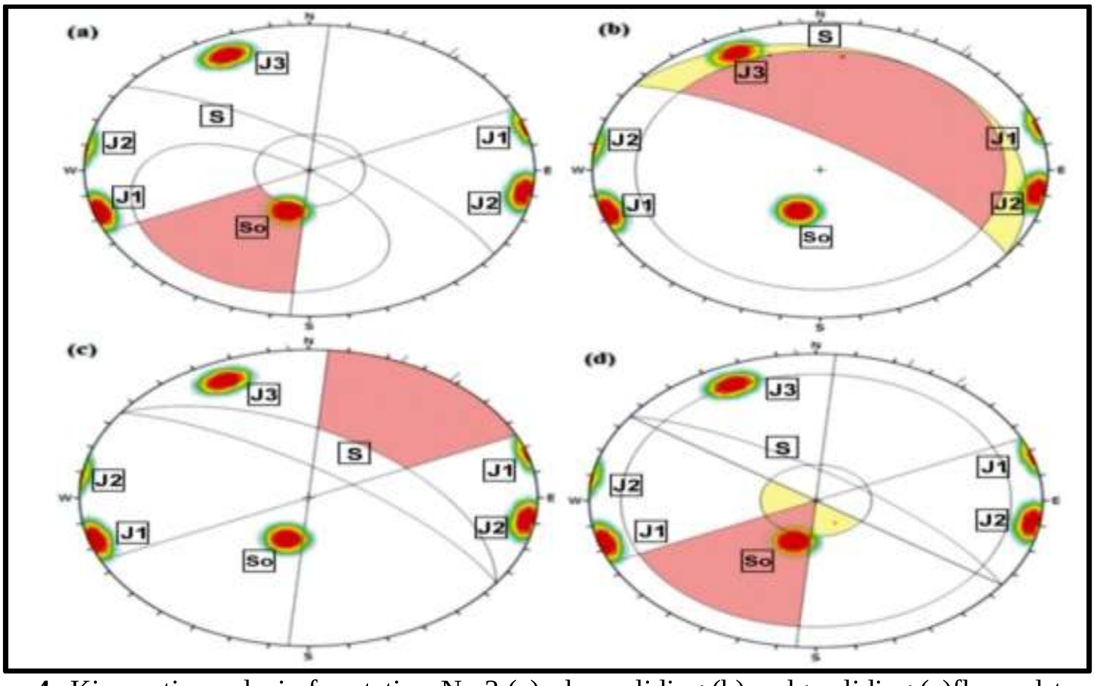

Figure 4- Kinematic analysis for station No.3:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2, J3 is joint set no.2,slope face is (S),bedding plane is (So) and the line of the intersection of the discontinuities is (I).

Slope site No.4

In this station which is shown in plate 4 , there is a minor recumbent fold with an average dip of the two limbs 300/38^o and 120/27^o. Kinematiclly, the slope of this station was analyzed and revealed that the planar sliding is not occuring on any discontinuities (Figure-5a). The occurrence of wedge sliding has a very low probability in the direction of the plunge of line of intersection between bedding plane (So) and joint set (J1) (I (So,J1)) in the critical area of potential wedge sliding (pink area) (Figure -5b), because the plunge direction (323°) of the intersection line is very far from the free face of slope direction (28°). No flexural toppling was observed because no poles are located in the critical area of flexure toppling (purple area) (Figure-5c). The direct toppling will not occur in spite of the presence of many critical intersections in the critical area of direct toppling (Figure-5d, due to presence of basal planes of bedding plane (So) in the slope direction and due to unsuitable dimension of blocks (width and height) for toppling in the field . The presence of a recumbent fold in the slope of this station increased the stability of the slope, inspite of the presence of the cavities that resulted from the dissolution of Limestone rock by fluids (rainfall) which in turn may cause slope failure if the cavities size increases in the future.

Plate 4-Frontal view showing the slope of station No.4 with Joint sets No.1(J1), No.2(J2) and bedding planes of minor fold (recumbent) , which is located at the SW limb of the minor anticline.

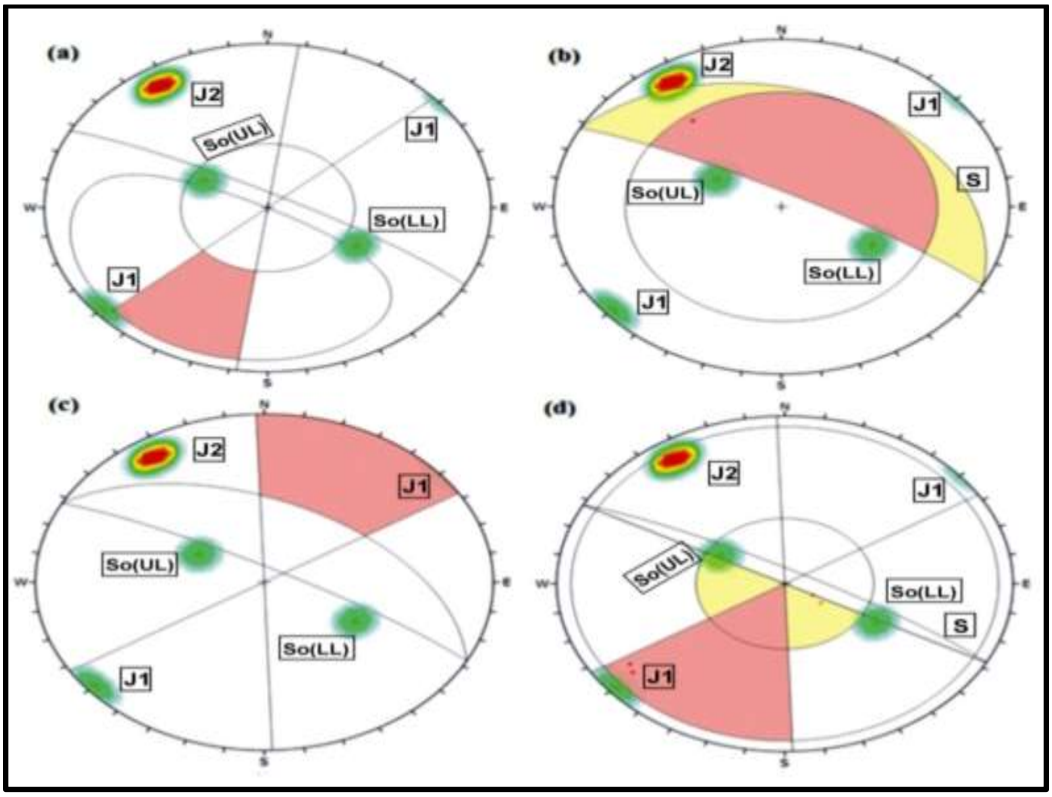

Figure 5- Kinematic analysis for station No.4:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2,slope face is (S),bedding plane is (So) , the line of the intersection of the discontinuities is (I) ,Upper limb of minor fold (UL) and lower limb of the minor fold(LL).

-Station No.5

Tow discontinuities cut the rock mass of this slope (Joint set No.1 (J1) and Joint set No.2 (J2)), in addition to the bedding plane (So) (Plate 5).The planar sliding is not taking place at this slope because the pole of So is out of the shaded area (shaded with pink) which represents the critical zone for the planar sliding (Figure-6a). Wedge sliding is not occurring because there are no intersection line poles between joint sets in the shaded area (colored with pink, Figure -6b). No Flexural toppling is found due to the absence of poles of joint sets in the shaded area (pink color) for the critical zone of flexural toppling (Figure-6c). Figure-6d shows the occurrence of a direct toppling due to the presence of basal plane (So) and pole of intersection line between J1 and J2, but in reality it does not occur because the required height for direct toppling is not available in the field, where in this case the height reflects the bedding thickness. Hence, the slope of this station is stable, except for the presence of rock fall from the upper parts of the slope .

Plate 5-Frontal view showing the slope of station No.5 with Joint sets No.1(J1), No.2(J2) and bedding planes (So . Photo direction is SW.

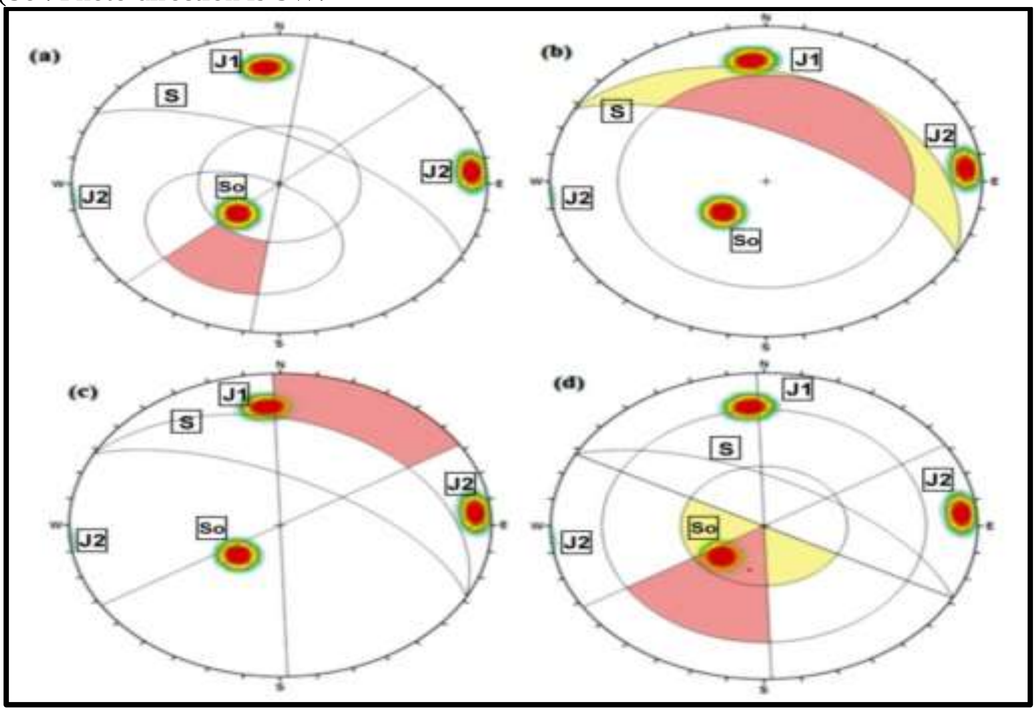

Figure 6- ,Kinematic analysis for station No.5:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2,slope face is (S),bedding plane is (So) .

-Station No.6

This slope is located at the axis of the NW plunge of Surdash anticline and the rock mass of the slope of this station was intersected by three discontinuities (Joint set No.1 (J1) , Joint set No.2 (J2) Joint set No.3 (J3)) and a bedding plane, as in plate 6.

The planar sliding is not occurring because the poles of the bedding plane (So) are out of the defined area (critical zone) for the plane sliding, as in Figure-7a.

Wedge sliding may occur in the upper parts of the slope, in the plunge direction of line intersection of discontinuities the J1 and J2 (318°), as shown in Figure-7b. It can be estimated that the size of the potential blocks from the wedge sliding will be small because of the low spacing of joint sets and the small thickness of the beds.

No flexural toppling was observed due to the nonexistence of any discontinuity poles in the area shaded with pink color defined for the critical zone for flexural toppling (Figure-7c).

The direct toppling is not occurirng, in spite of the presence of basal plane (So), because there is no pole of intersection to release the blocks (Figure-7d) and there are no suitable dimensions that are required for direct toppling to occur.

Small rock-falls may occur in the upper parts due to the slope steepness.

Plate 6 - Frontal view showing the slope of station No.6 with Joint sets No.1(J1), No.2(J2) ,Joint set No.3(J3) and bedding planes (So) . Photo direction is SW.

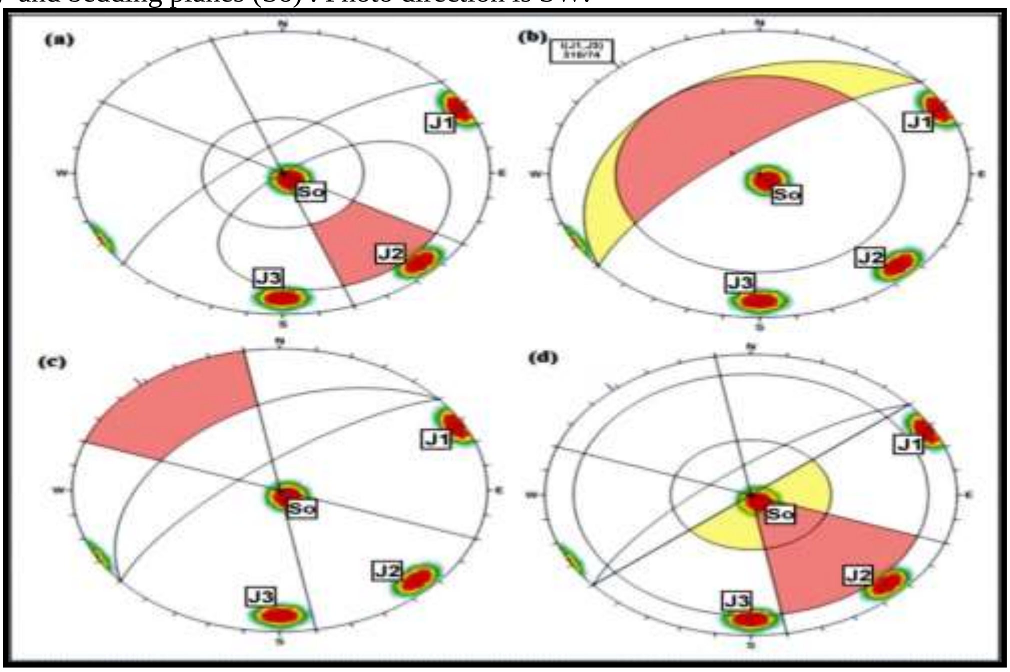

Figure 7- Kinematic analysis for station No.6:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2,slope face is (S),bedding plane is (So) and the line of the intersection of the discontinuities is (I).

-Station No.7

This slope is a minor fold (Syncline). Both syncline limbs are intersected with tow joint sets in addition to the bedding plane which is considered as a discontinuity, as shown in plate 7 and Figure -8 . No poles of any discontinuities are located in the potential area of plane sliding , so the planar sliding is not occurring, as shown in Figure-8a. Wedge sliding occurred on the bedding planes (So) of both limbs of small incongruous syncline in the direction of 210° (Figure-8b). The possibility of flexural toppling is existing about J1 in the left limb, as in Figure-8c, but it does not occur because of the persistence of J1 with a depth which defines block height as very small, so it does not promote flexural toppling. The possibility of direct toppling (Figure-8d) is due to the presence of the basal plane (So) and the pole of intersection line (I (J1, J2), but in reality it does not occur because the basal plane (So) of the right limb and the critical intersection (I (J1, J2)) are for joints in the left limb. In spite that the kinematic analysis revealed the presence of the wedge sliding, but the slope is stable at the present time .

Plate 7- Frontal view showing the slope of station No.7 with Joint sets No.1(J1), No.2(J2) of each limb of the syncline and bedding plane (So) .Photo direction is NE.

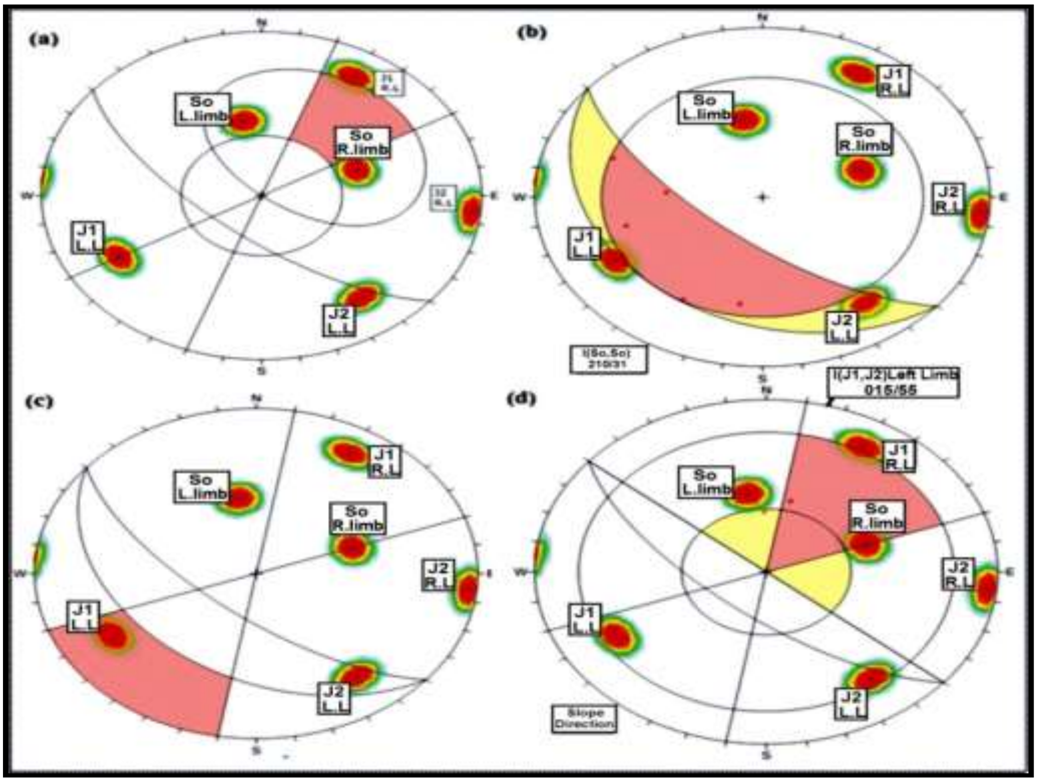

Figure 8- Kinematic analysis for station No.7:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2,slope face is (S),bedding plane is (So) and the line of the intersection of the discontinuities is (I).

-Station No.8

The slope of this station is intersected by 3 discontinuities, namely Strike – slip fault , Joint set No.1(J1) , and Joint set No2.(J2), in addition to the bedding plane (So) ,(Plate 8).

From the results of kinematic analysis (Figure-9a), a planar sliding occurred along the bedding plane (So), which plays a role as a sliding surface plane (Basal release surfaces) . The strike –slip fault J2 will act as lateral release surfaces , while J1 will act as back release surfaces.

In spite of the presence of many poles of intersection lines between joint sets in the critical zone of the wedge sliding (Figure-9b), there is a low possibility of wedge sliding only along the intersection line of J2 and J4 (Fault plane (I(J4,J2)) in the direction of 192°.

There is a possibility of flexural toppling J3, as shown in Figure-9c, but it is not happening because of the persistence of J1 with depth which defines the block height as very small , so it does not promote flexural toppling .

In spite of the presence of the basal plane (So) in the critical zone of the direct toppling (Figure-9d), it does not occur due to the absence of critical intersection (Purple area) .

Also, the oblique toppling does not occur because of the persistence of J1 and J3 which is very small and non- repeating.

Plate 8- Frontal view showing the slope of station No.13 with Joint sets No.1(J1), No.2(J2) of each limb of the syncline and bedding plane (So) .Photo direction is NE

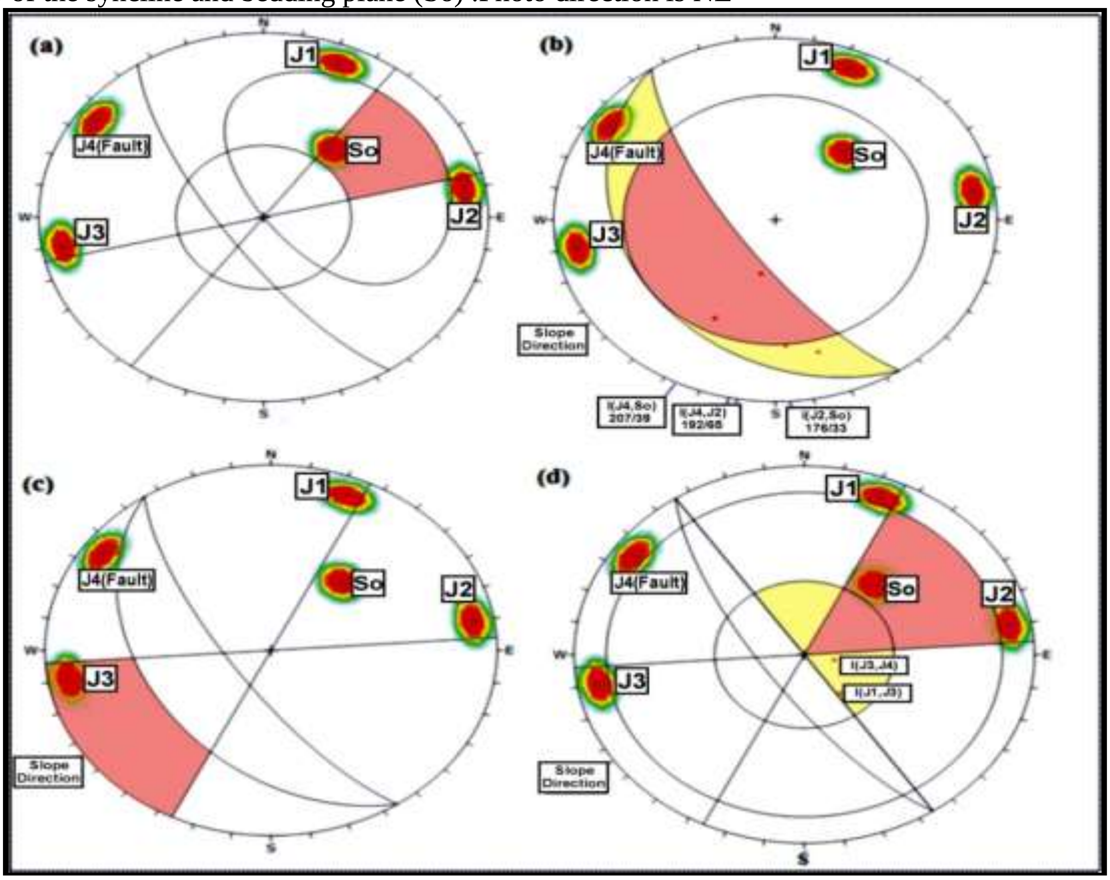

Figure 9- Kinematic analysis for station No.8:(a) plane sliding,(b)wedge sliding,(c)flexural toppling and (d) direct toppling .WhereJ1 is joint set No.1, J2 is joint set no.2,J3 is joint set no.3slope face is (S),bedding plane is (So) and the line of the intersection of the discontinuities is (I)

-Station No.9

This slope consists of left and right sides. The rock mass of the left side consists of a minor fold (Syncline). Both blimbs of the syncline were intersected by two discontinuities (Joint set No.1(J1) and Joint set No.2(J2)) besides the bedding plane (So) (Plate 9a and Figure-10).

In the left side there is no planar sliding because the poles of the bedding plane (So) are out of the critical area of planar sliding. Also, there is no wedge sliding (Figure-10a and 10b) for the same reason. Flexural toppling is not occurring because there are no poles of line of intersections of any tow discontinuities, in addition to the absence of basal plane (bedding plane) in the critical area of planar sliding (Figure-10c) . Figure-10d shows the possibility of direct and oblique toppling, but in reality it does not occur because the persistence of J1 , J2 & J3 has a depth (height of blocks, perpendicular to bedding plane) which is very small for these types of failure to occur. Thus, this sloe is stable at the present time in spite of the presence of a minor fold.

In the right side of the slope, there is a minor fold (An anticline). The rock mass of the right side of the slope of station No.9 was cut by 2 discontinuities (Joint set No.1 (J1) and Joint set No.2 (J2)) for each limb of the anticline, as shown in plate 9b and Figure-11. From kinematic analysis, it can be concluded that there is no planar sliding on the bedding plane (So), as shown in Figure-11a, because the poles of the bedding planes of the anticline are out of the critical area of the planar sliding. The wedge sliding occurs in the direction of the plunge of I (So , J2) but not along the direction of the plunge of I (So , J3) as in Figure-11b. There is no flexural toppling or direct toppling because the conditioning factors are not available (Figure-11c and Figure-11d).

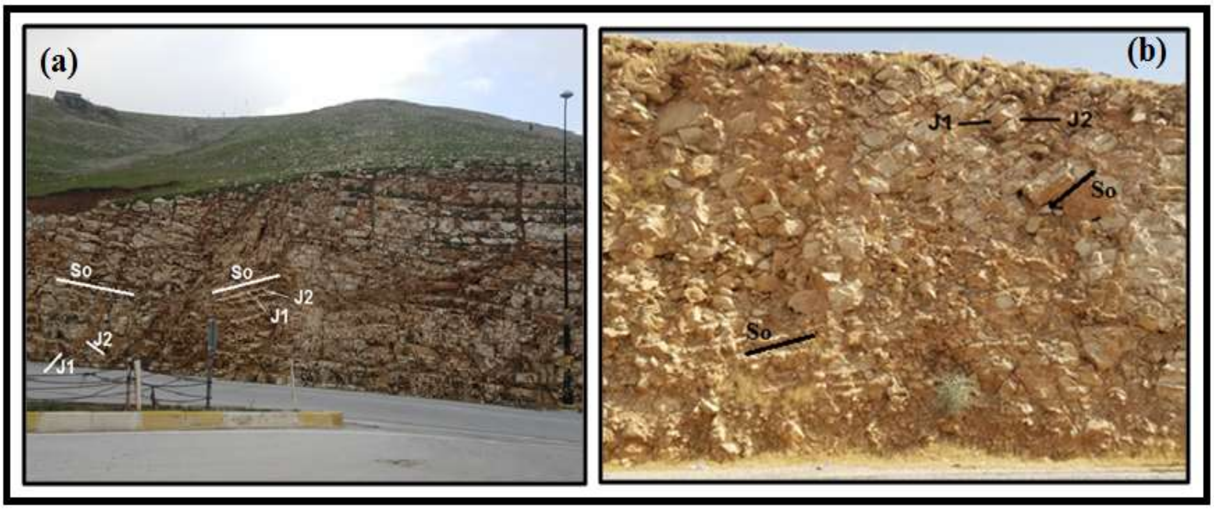

Plate 9- (a) Frontal view showing the slope of left side of station No.9 with Joint sets No.1 (J1)and No.2 (J2) of each limb of the syncline and bedding plane (So). Photo direction is NE. (b) Frontal view showing the slope of right side of station No.9 with Joint sets No.1 (J1), No.2(J2) and bedding plane (So). Photo direction is NE.

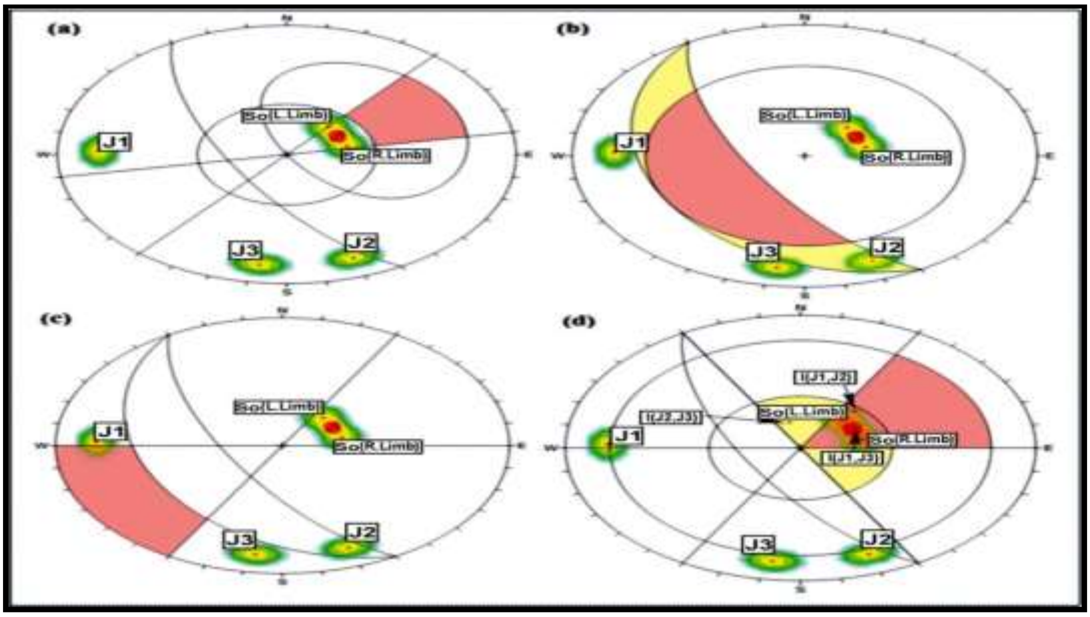

Figure 10- The kinematic analysis of left side of station No.9 shows the possibility of failure types,(a) planar sliding, (b) wedge sliding, (c) flexural toppling, (d) direct toppling.

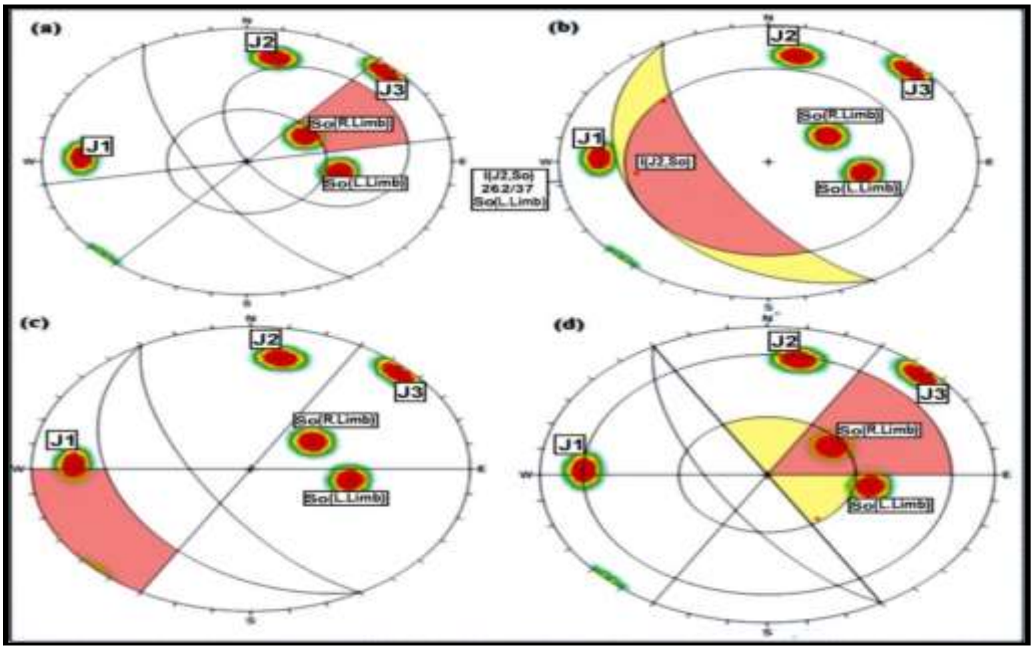

Figure 11- The kinematic analysis of right side of station (9) , shows the possibility of failure types ,(a)planar sliding ,(b) wedge sliding ,(c) flexural toppling ,(d)direct toppling.

Conclusions

1. Kinematic analysis of the studied stations shows that planar sliding is possible in stations No. 1, 2, 3 and 8. Wedge sliding is possible in stations No. 6, 7 and 9b. Stations of rock slope No. 4, 5 and 9a are stable.
2. Field work revealed that the planar sliding that occurred on the bedding plane in slope sites No. 1 , 2 and 3 is characterized by large blocks and a huge volume of slided- limestone rock masses.
3. The majority of planar sliding in station No.1 is due to steep dip angle of sliding surface, high height of the slope, and the presence of few tension cracks in the slope, indicating the opening of joints and promoting sliding.
4. The majority of planar sliding in stations No. 2 and 3 is due to the presence of a thin layer (3-4c of soil (marly sand in slope site No.2 and clay in slope site No.3) between planes at the sliding surface. The kinematic analysis does not take into account the dimension of failure blocks. In other words, it gives only the possibility of failure type and, hence,so in the case of toppling failure the interpreter must be aware of the required block dimension for the occurring, or not, of toppling in the actual slope.
5. Minor geological structure are present in both limbs of Surdash anticline (NE plunge) , but the presence of these structures (Fold and Fault) are more common at the SW limb. Some of these minor structure were responsible for increasing the stability, as in Station No.4, while in Station No.7, wedge sliding will occur on the bedding planes (So) of both limbs of small incongruous syncline in the direction of 210°.In Station No.9, in the right side of the slope, wedge sliding occurred in the direction of the plunge of the line of intersection between the bedding plane (So) of limb of anticline and the join set No.2. Normal faults act as triggering factor as in stations No.8 and 9.b.
6. Stylolite structure present in most of the stations increased roughness of the bedding planes and, hence, supported the stability of slopes.

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