



ISSN: 0067-2904

The Effect of some discontinuities on rock Slope Failure in Some Selected Sites in Bammo Anticline

Aya Ali Hameed*, Manal Shakir Alkubaisi

Department of Geology, College of Sciences, University of Baghdad, Baghdad, Iraq

Abstract

Field studies of the slopes of Bammo anticline, in Northeast of Iraq, was carried out in five selects stations, where rock slopes and the discontinuities were surveyed in these stations and its relationships with failures were determined. The field work was revealed the abundance of rock slope failures, the dominant types are rock fall and toppling.

Slope stability assessment was carried out by stereographic projection was made using software (GEOrient 9.5.0), the slopes were classified according to (Al-Saadi, 1981), and the rocks were described in engineering terms according to (Anon, 1972) depending on field data. The study also revealed that the factors affecting slope stability in the study area were slope angle, height, dip of strata, and discontinuities.

Some remedial measures are suggested for the unstable slopes, and the most important removal of the detached block.

Keywords: Slope stability, Bammo Anticline, Stereographic projection, Discontinuities.

تأثير الانقطاعات على انهيار المنحدرات الصخرية في مناطق مختارة من طية بامبو المحدبة

اية علي حميد*, منال شاكر الكبيسي

قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

أجريت دراسات ميدانية على المنحدرات الصخرية لطية بامو المحدبة ، في شمال شرق العراق ، لخمسة محطات مختارة ، حيث تم مسح المنحدرات الصخرية والانقطاعات في هذه المحطات وتم تحديد علاقاتها مع حالات الانهيار. اوضح العمل الميداني عن وجود وفرة انهيار منحدرات الصخور ، وأنواع الانهيارات الغالبة هي سقوط الصخور والانقلاب.

تم اجراء تقييم استقراريه للمنحدرات بواسطة الاسقاط الفراغي باستخدام برنامج (Georint 9.5) . كما وتم تصنيف المنحدرات وفقا لتصنيف (Al-S aadi, 1981) , ووصف الصخور هندسيا وفقا ل(Anon, 1972) اعتمادا على البيانات المسجلة حقليا. كما قد بينت الدراسة ان العوامل التي تؤثر على استقرارية المنحدرات ضمن منطقة الدراسة هي ميل المنحدر، الارتفاع، ميل الطبقات، والانقطاعات. وتم اقتراح بعض التدابير العلاجية للمنحدرات الغير المستقرة واهمها ازالة الكتل المعرضة للانهيار

1- Introduction

Slope failure is a geologic process that included down slope movement of rock masses under the influence by many factors (such as; gravity, discontinuities presence, weather ... etc.). The instability

*Email: Aya.ali19951617@yahoo.com

of the most important problems and risks facing the geologist in its work complementary to the work of the civil engineer, where these problems appear frequently in the form of landslides in the slopes [1-3]. The study area is located in the Kurdistan Region, about 35km southeast of Darbandikhan town at the extreme Northeastern Iraq. It is located between latitudes ($35^{\circ} 05' 06'' - 35^{\circ} 07' 07''\text{N}$) and longitude ($45^{\circ} 42' 32'' - 45^{\circ} 44' 15''\text{E}$) such as Figure-1.

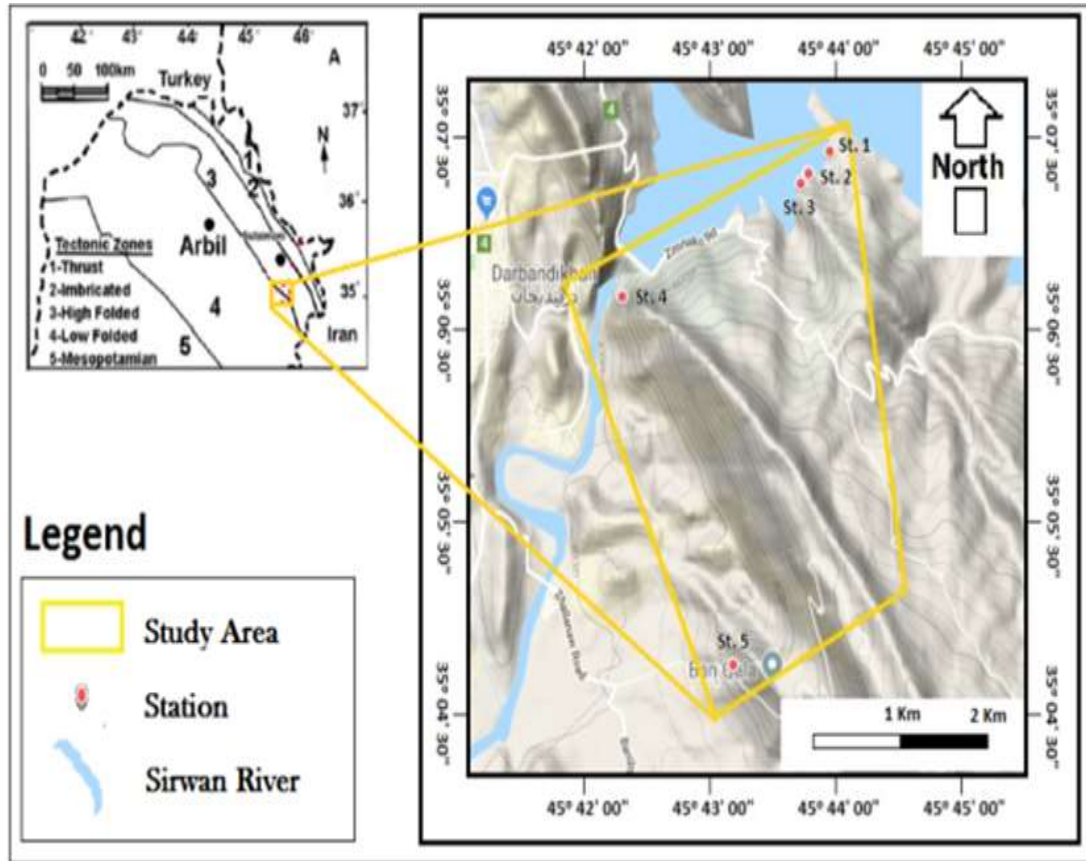


Figure 1-location map of the study area and selected sites

2- Aims of the study

The main purpose of this study is to evaluate the slope stability in the area to determine failure types of past failures and those are likely to occur in the future, and their relationship with existing discontinuity types.

3- Methodology

This study included three stages, these are; field work, laboratory, and office works. In the field stage general structural and engineering survey was carried out in relation with slope stability assessment at five stations in different sites of Bammo anticline. Laboratory test included (point load test) for twelve rock samples from three sites within PilaSpi formation to determine the compressive strength of the rocks indirectly. Office work involved the representation and analysis of field data on Schmidt Net of stereographic projection through using the software programs GEOrient for windows Ver.9.5.0.

4- Stratigraphy of the study area

Depending on the Previous studies of [4- 6], there are five formations exposed in the study area, these are; Kolosh Fn. ((Middle Paleocene) which consists mainly of claystone, shale, siltstone, and sandstone [7], Sinjar Fn. (Late Paleocene), consisting of thickly bedded-massive limestone [6], Gercus fn. (Early Eocene) which is composed of alternation of claystone, siltstone, and rare sandstone [5], PilaSpi Fn. (Late Eocene) composed of limestone with chalky marl and chert nodules in its upper part, whereas the lower part is represented by bituminous, poorly fossiliferous limestone [5], and Fatha Fn. (Late Miocene) that is represented by a very thick alternation of Gypsum, claystone, marly limestone, and sandstone with interbeds of limestone [8]

All the five stations that were selected in this study lie in PilaSpi and Gercus formations.

5- Tectonic and Structure of Study Area

Tectonically, the study area is part of the Zagros folds – thrust belt and it represents the tectonic boundary between High Folded and Low Folded Zones within unstable shelf of Iraq [9].

Structurally, Bammo anticline represents Northwest-Southeast trending, Asymmetrical, Double plunging, and Sub-rounded hinge. The crest of this anticline is highly eroded to a level that led to exposure of the early Cretaceous rocks [10].

6- Climate of the study area

The climate of the study area is characterized by heavy rain fall during the winter and especially in (January, February, and March) months, while it is very rare in Summer, as the annual precipitation rate reaches (600 mm), and the average monthly temperature of the area is (4.8° c) recorded in January, as for the highest temperature was (32.6° c) as a monthly average recorded during July. [11]

7- Slope stability assessment of the study area

Five stations were chosen in this study in order to analyze the slope stability in the area based on discontinuity types. The unconfined compressive strength (σ_c) of the rock strata in the failure sites was found indirectly by the point load test. Engineering geological description of rocks at all stations was carried out according to [12, 13].

The symbols used to represent the data on the stereographic projection are based [14] as in Tables-(1, 2).

Table 1-Symbols Use d in Stereographic Projection [14]






Symbol	Description	Symbol	Description
G.S 	Cyclographic trace (great circle) of a general slope	R.m	Rock mass
S.S 	Cyclographic trace of a side slope	L.S	Left side slope
OH or VS 	Cyclographic trace of vertical slope (VS) or overhanging slope (OH)	R.S	Right side slope
		L.s	Lower slope
S ₀ 	Cyclographic trace of mean orientation of bedding plane (S ₀)	U.s	Upper slope
		L.p	lower part
S ₁ , S ₂ 	Pole to joint plane, joint sets	U.P	Upper part

Table 2-Symbols of Types of Failure and Photo Direction Used and Represented on Stereogram, [14]

Types of failure	Symbol	
	Possible	present
Toppling		
Rock fall		
Plane sliding		
Granular disintegration		
Rolling		
Slumping		
Photo direction		

8- The selected stations:

- Station No.1

This station lies SE of Darbandikhan dam, It's lies (4.5 km) SE of Darbandikhan town, at latitude (35° 07' 19.7" N) and longitude (45° 43' 57.1"E), Its exposed at the northeastern limb of Bammo anticline, within Pila Spi Formation. The slope at this station is (30m) height, (55m) long along its trend, and its inclination is (307/72). The average dip of bedding plane is (068/70).

The rocks at this station consist of reddish brown to greenish brown, fine grained, the thickness of bedding is ranging between (3cm - 308cm), widely spaced joints, moderately to highly weathered, Extremely strong ($\sigma_c=225$ MPa), LIMESTONE.

The rocks are cut with three sets of joints(S_1 , S_2 , and S_3) which were analyzed by stereographic projection and occurred to be (hkl_1 , hkl_2 , and hkl_3) respectively as shown in [plate 1], the (S_1) set has an average dip (142/63°), spacing range between (20 cm – 80 cm), with persistence range between (60 cm – 120 cm), the (S_2) set has an average dip (227/83°), spacing range between (95 cm – 105 cm), and persistence range between (27 cm – 40 cm), the (S_3) set has an average dip (340/37°), spacing range (40 cm – 85 cm), with persistence range about (36 cm).

S_1 (hkl) would act as lateral Release Surface (LRS), S_2 (hkl) would act as back Release Surface (BRS) and S_3 (hkl) would act as Basal Surface (B.S) of plane sliding and rockfall occurred, such as [plate1, Figure-2.



Plate 1 front view of the slope of the station one

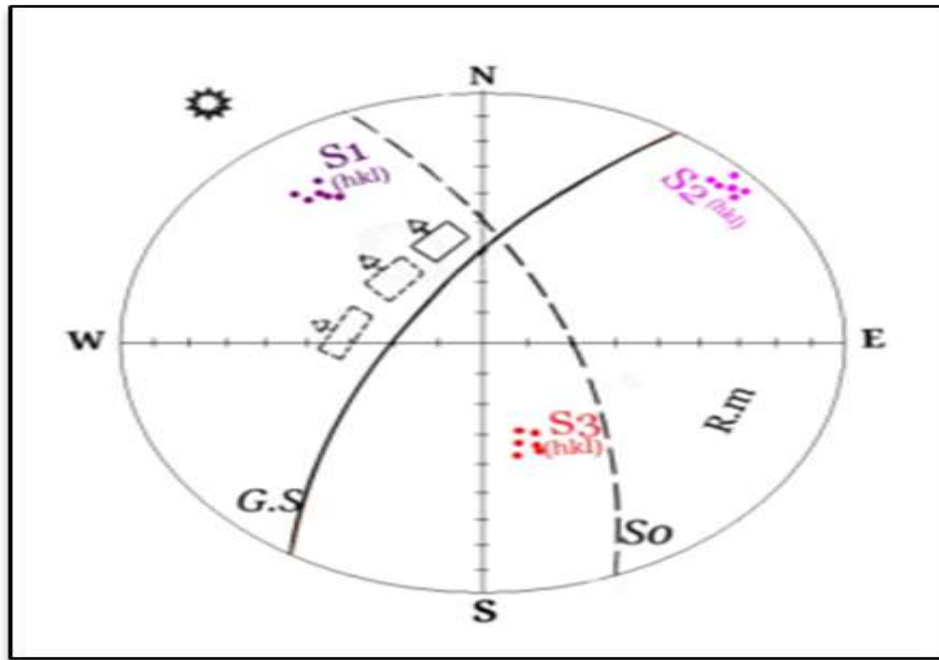


Figure 2-Stereographic projection of discontinuities and types of failure of station one.

• Station No.2

This station lies SE of Darbandikhan dam, at latitude ($35^{\circ} 07' 7.6''$ N) and longitude ($45^{\circ} 43' 50.6''$ E), its exposed at the northeastern limb of Bammo anticline, within Pila Spi Formation. The slope at this station is (8m) high, (80m) long along its trend, and its inclination is (042/88). The average dip of bedding plane is (040/86).

The rock in this site is composed of greenish grey, very fine grained, the thickness of bedded is range (10cm-40cm), highly discontinuity and moderately widely spacing, moderately weathered, very weak (failed in point load test) LIMESTONE.

This slope cut by three sets of joints in (S_1 , S_2 , and S_3) which were analyzed by stereographic projection and occurred to be S_1 (hko acute about b), S_2 , and S_3 (hko acute about a) as shown in [plate 2], the (S_1) set has an average dip ($323/62^{\circ}$), spacing range between (50 cm – 80 cm), with persistence range between (48 cm – 85 cm), the (S_2) set has an average dip ($142/32^{\circ}$), spacing range between (25 cm – 115 cm), and persistence range between (27cm – 70 cm), the (S_3) set has an average dip ($132/86^{\circ}$), spacing range (40 cm – 85 cm), with persistence range between (34 cm – 104cm).

S_2 would act as Lateral Release Surface (L.R.S) and S_1 would act as Basal Surface (B.S) of toppled block along the bedding plane. The probable types of failure to occur in the future are toppling too, such as (Figure-3).

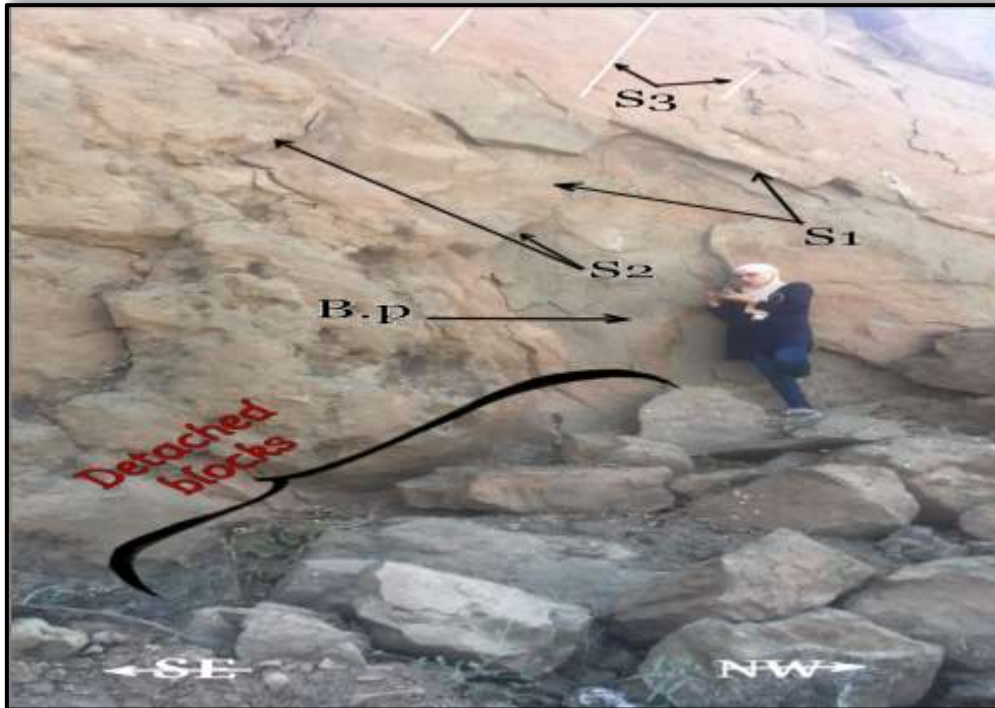


Plate 2-the slope at station No.2 of Side view showing discontinuities

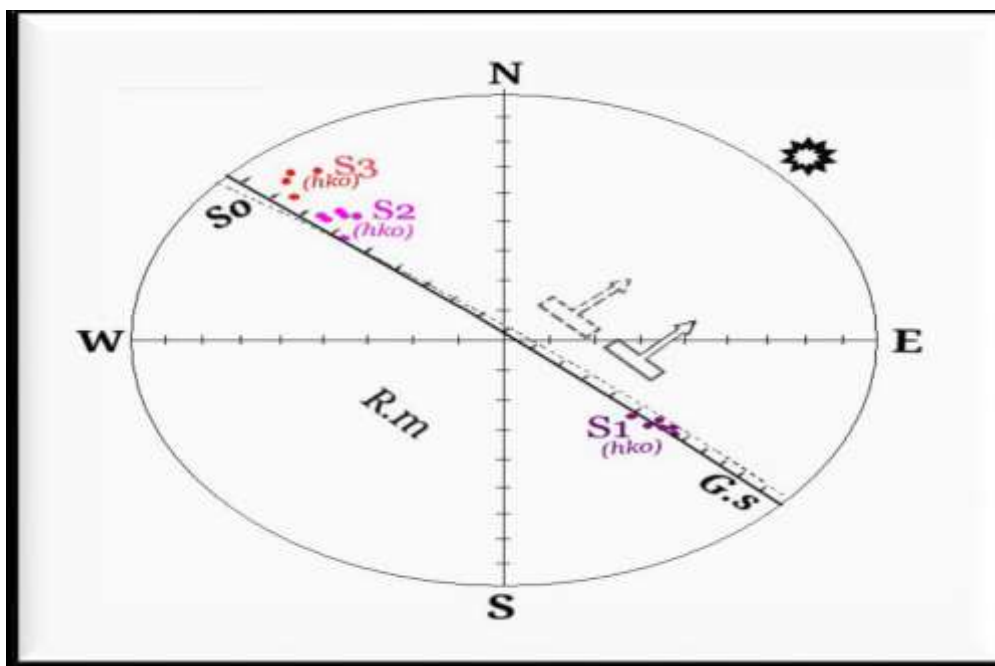


Figure 3-Stereographic projection of discontinuities and types of failure.

• Station No.3

This station lies SE of Darbandikhan dam, at latitude (35° 07' 7.6" N) and longitude (45° 43' 37.7" E), its exposed at the northeastern limb of Bammo anticline, within pilaSpi Formation. The slope at this station includes two slopes; the first is (9m) high, (18m) long along with its trend, and its inclination is (285/70), the second is (12m) high, (68m) long along its trend, and its inclination is (260/65). The average dip of bedding plane is (058/80).

The rock in this site is composed of light to dark grey, very fine grained, the thickness of bedded is range (10cm-75cm), closely space widely joint, moderately weathered, Extremely strong ($\sigma_c = 382.5$ MPa) LIMESTONE.

This slope cut by two sets of joints in (S_1 & S_2) which were analyzed by stereographic projection and occurred to be (hkl_1 , and hkl_2) respectively as shown in [plate 3], the (S_1) set has an average dip ($220/39^\circ$), spacing range between (2 cm – 80 cm), with persistence range between (10 cm – 200 cm), the (S_2) set has an average dip ($307/86^\circ$), spacing range between (4 cm – 20 cm), and persistence range between (10 cm – 200 cm). Joints S_1 (hkl) act as back Release Surface (BRS), and joints S_2 (hkl) act as lateral Release Surface (LRS) during sliding. There is another failure type in the same rock mass. It is rock fall because of the slope steep and fracturing of the rock mass. The probable types of failure to occur in the future are rock fall, toppling and sliding, as shown in Figure-4.

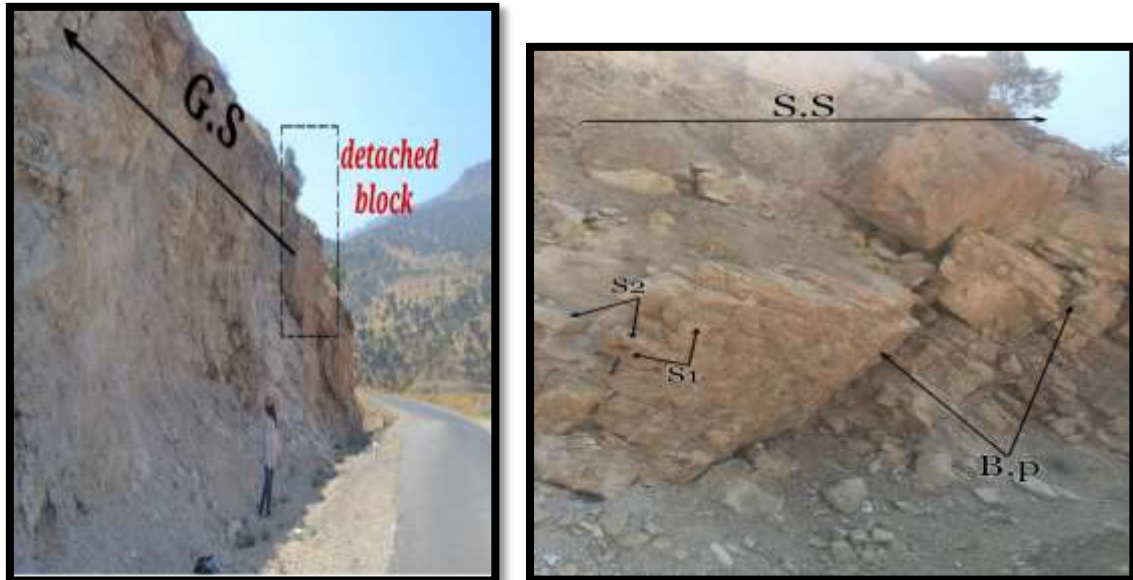


Plate 3-the general and the second slope at station No.3 of Side view showing discontinuities.

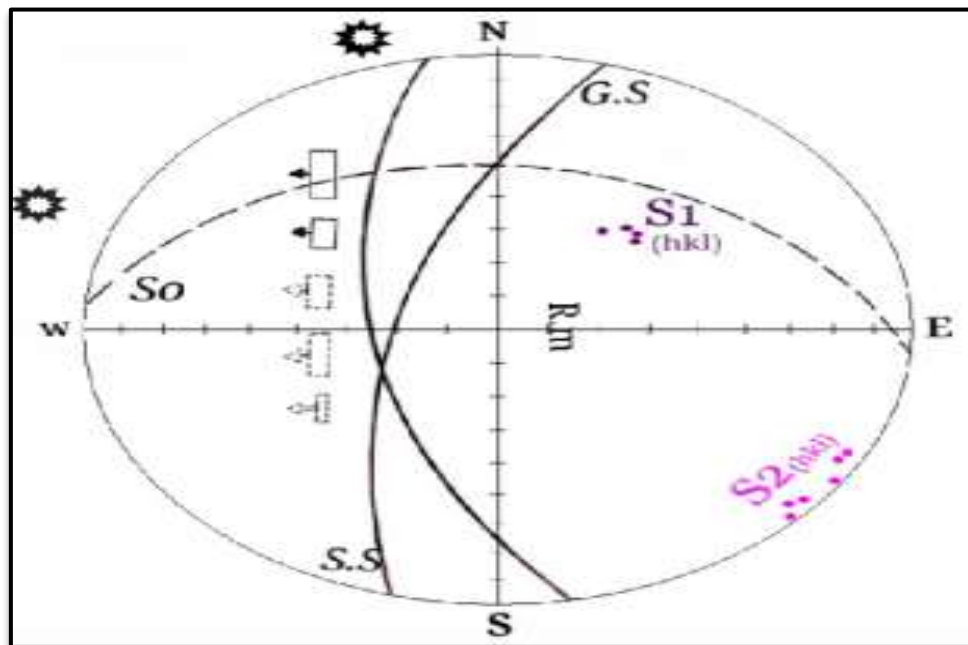


Figure 4-Stereographic projection of discontinuities and types of failure.

•Station No.4

This station lies adjacent to Darbandikhan dam and to power station ,It's lies(2km) SE of Darbandikhan town, at latitude ($35^\circ 06' 36.1''$ N) and longitude ($45^\circ 42' 19.5''$ E), It is considered a very high station. It's exposed at the hinge zone of Bammo anticline, within Pila Spi Formation. The

slope at this station is (9m) high, (18m) long along its trend, and its inclination is (285/70). The average dip of bedding plane is (238/38).

The rock in this site is composed of light to dark grey and green sometimes, fine to very fine grained, the thickness of bedded is range(180cm-460cm), very widely space, moderately to highly weathered, LIMESTONE.

This slope cut by two sets of joints in (S_1 & S_2) which were analyzed by stereographic projection and occurred to be (hol acute about c, and bc) respectively as shown in [plate 4], the (S_1) set has an average dip ($249/64^\circ$), spacing range between (30 cm – 700 cm), with persistence range between (40 cm – 500 cm), the (S_2) set has an average dip ($061/55^\circ$), spacing range between (40 cm – 200 cm), and persistence range between (8 cm – 250 cm). Joints S_1 act as lateral release surfaces (LRS), and joints (S_2) act as lower release surface (LRS) during plane sliding and another type of failure is rockfall because the slope steep and fracturing of rock mass such as Figure-5. And this station is very dangerous because they cause great damage to the dam.

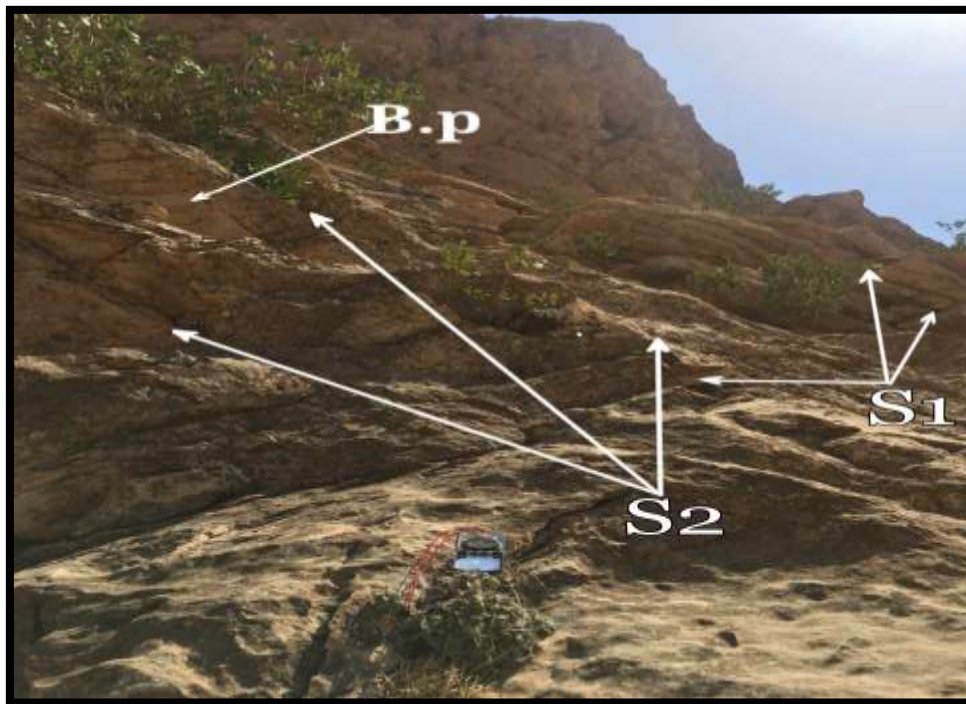


Plate 6-the slope at station No.4 of Side view showing discontinuities

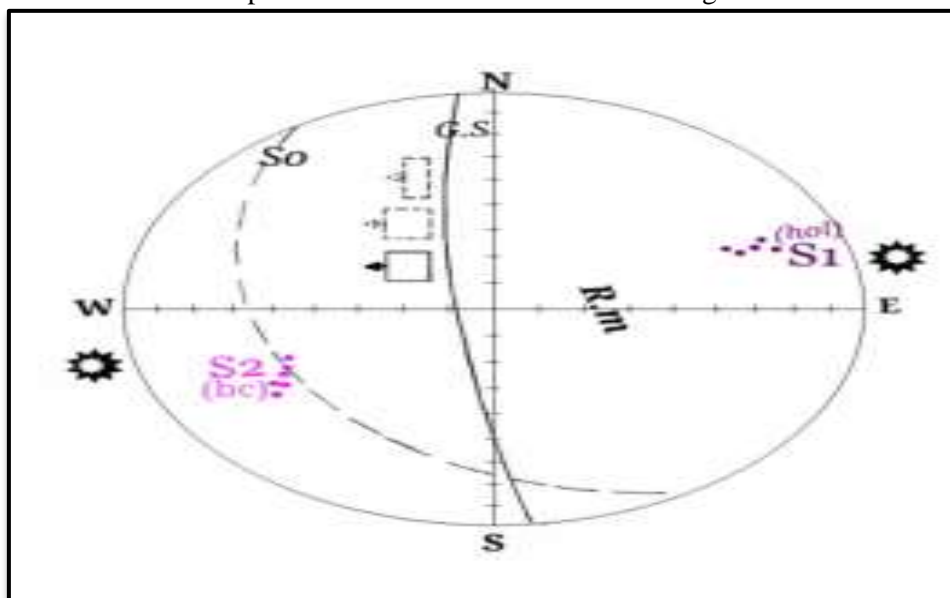


Figure 5-tereographic projection of discontinuities and types of failure.

Station No. 5

This station lies SW of Darbandikhan lake, it's lies(2.30Km)E of Zhallanaw Mosque, at latitude ($35^{\circ} 04' 45.3''$ N) and longitude ($45^{\circ} 43' 10.5''$ E), Its exposed at the northwestern limb Bammo anticline, Locally called Galeno castle ,within Pila Spi and Gercus Formation . The slope at this station is (20m) high, (210m) long along its trend, and its inclination is ($242/90$ -OH). The average dip of bedding plane is (178/14).

The outcrop layers in this site are composed of light to dark grey with brown to greenish , coarse to fine grained, the thickness of bedded is range(200-800cm), widely spaced joint, moderately to highly weathered, LIMESTONE.

This slope cut by two sets of joints in (S_1 & S_2) which were analyzed by stereographic projection and occurred to be (hkl, and bc) respectively as shown in [plate 5], the (S_1) set has an average dip ($217/85^{\circ}$), spacing range between (20 cm – 200 cm), with persistence range between (180 cm – 370 cm), the (S_2) set has an average dip ($357/73^{\circ}$), spacing range between (20 cm – 280 cm), and persistence range between (80 cm – 770 cm). Joints S_1 (hkl) act as back release surfaces (BRS), and joints S_2 (bc) act as lateral release surface (LRS) of toppled block and another type of failure rockfall along the slope because it is vertical to overhanging (OH) and rolling rock, the probable types of failure may occur are plane sliding to detached blocks, toppling, as well as rockfall and rolling to the rock failure as Figure-6.

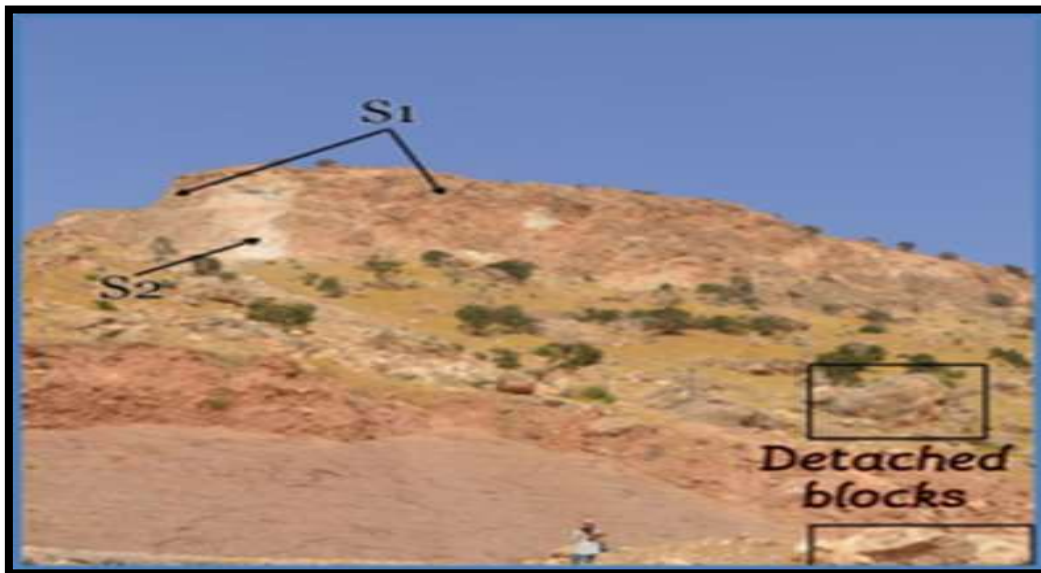


Plate 5- the slope at station No.5 of front view showing discontinuities

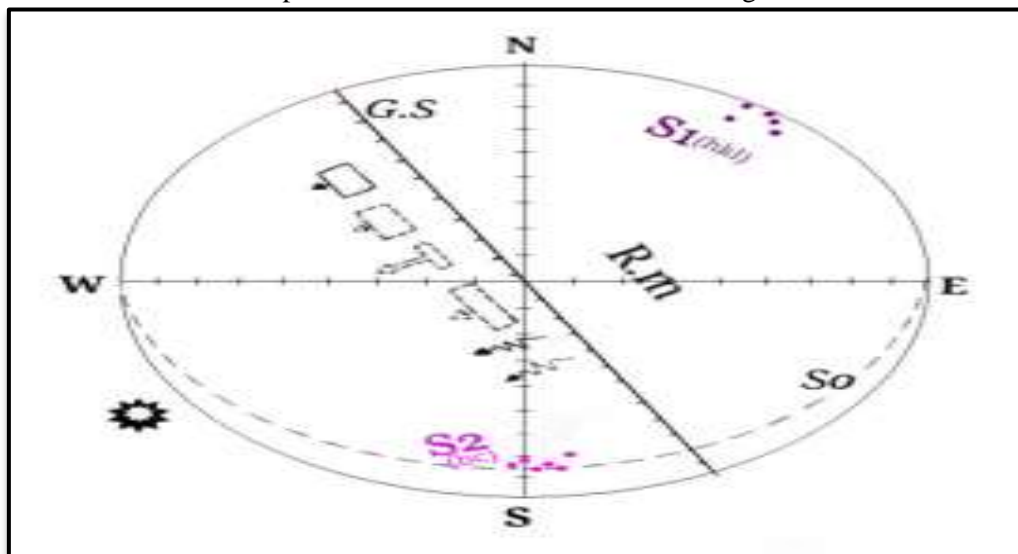


Figure 6-Stereographic projection of discontinuities and types of failure.

9- Conclusions

1- The joints existing in the study area are classified according to the relationship between the discontinuities and the tectonic axes; the most abundance in first degree is (hkl, hko) and in second degree is (bc, hol).

2- The failures type can be determined by the type of discontinuities play various roles in rock masses and their relationship with each other and with the layers within the slope.

10- Recommendations

The following remedial measures are proposed to stabilize slopes:

1- Removal of the unstable hanging blocks which are liable to toppling in the critical cases.

2- All slopes undergo different types of failure (toppling and rock fall); the detached blocks from slopes move to down slope during failure and causing human and economic damages; therefore, it is recommended to construct retaining walls to protect the slopes and reduce the hazard.

11- Reference

1. Hoek, H. and Bray, J.W. **1981**. *Rock Slope Engineering*, 3rd Edition, Institution of Mining and Metallurgy, London, 358 p.
2. Ramamurthy, T. **2008**. *Engineering in Rocks for Slopes*, Foundation and Tunnels. New Delhi, 357 p.
3. Small, R. J. and Clarck, M. J. **1982**. *Slope and weathering*, Cambridge University, Great Britain, p112.
4. Buday, T. **1980**. *The Regional Geology of Iraq*. Vol: 1 Stratigraphy and Paleogeography. Publications of GEOSURV, Baghdad. 445 p.
5. Jassim, S. Z., Al-Shaibani, S.IQ. and Ajina, T.M. **1975**. Possible Middle Eocene block movements in the Darbandikhan area, Northern Iraq ; 1.Geol. Soc. Iraq. Special Issue,pp. 139-145.
6. Karim, K. H. **1997**. Stratigraphy of Sartaq-Bamo Area, Northeastern Iraq, Journal of Iraqi Geological Society, **2**(4): 493 -509.
7. Al-Hashimi, H. A. J. and Amer, R. M. **1985**. *Tertiary microfacies of Iraq*. D. G. geol.Surv. invest. Public, Baghdad, 56 p.
8. Karim, K. H. **2011**. Basic Principles Description of stratigraphy, tectonics and boundary conditions of the some Rock units in Iraq and Kurdistan during Cretaceous and Tertiary. Public, 30 p. <https://www.researchgate.net/publication/272089839>
9. Budy, T. and Jassim, S. z. **1984**. Final report and the regional geological survey of Iraq; Unpubl., Report, S.O.M. Library, Vol. 2, tectonic, Framework.
10. Al-Balany, I., Q. and Salar, G., S. **2018**. Darbandikan district natural landscape study for the purposes of sustainable tourism development. *Journal of Garmin university*, **5**(4): 179-199. <https://doi.org/10.24271/garmian.408>
11. Geo. Sur. **2007**. State Company of Geological Survey and Mining, the Geology of Sulaimaniya Quadrangle, NI-38-3(G.H.M.-10), Scale 1:25000, Republic of Iraq, 36p.
12. Anon, **1972**. The preparation of maps and plans in terms of engineering geology., *quarterly jou . of eng. Geo.*, **5**: 293- 382.
13. Anon, **1977**. The Description of Rock Masses for Engineerin Purposes. *Quart. Jour. of Enging. Geol.* **10**: 355 – 388.
14. Al-Saadi, S.N. **1981**. A Method for Mapping Unstable Slopes with Reference to the Coast Line of S.W. Dyfed, Wales, Unpub. PhD. Thesis, University of Bristol, 252 pp.