Rock Slope stability of the Pilaspi Formation Rocks in the Bina Bawi Anticline at Darbandi Gomaspan / Erbil- Iraq

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Abstract

This research included study of stability of rock slopes for Pilaspi formation in Bina bawi anticline at Darbandi Gomaspan area in Erbil, by selecting four stations on the outcrops of Pilaspi formation on the south western limb of the anticline. Detail surveying of rock slopes were carried out in each station with engineering describtion and classified according to (1) (2). The study revealed that the type of rock slopes were oblique lateral and parallel type according to the relationship of the strike of beds with the strike of the slopes, and concordant, right emergent according to (3) classification.

The unconfined compressive strength values of the rocks calculated indirectly from point load test which ranged between (55.677-59.311)MPa for Limestone and (34.734)MPa for marly limestone. The type of the rocks were strong to moderately strong respectively according to (4). The average value of Tensile strength (σt) for limestone is 15.45 MPa/m2 and 7.12MPa/m2 for Marly Limestone. Also the fracture analysis was performed using stereographical projection. The types of failure in the study area were rock fall, toppling and rock rolling. The factors affecting the stability of the rock slopes were evaluated which included presence of discontinuities in the rock, over hanging slopes, differential weathering and cutting rocks for different purposes for example roads and road widen.

Introduction

Increase of establishment of cities and highways, roads and road widening affect the rock slopes especially in mountainous region and leads to increasing of unstable rock slopes if left without protection methods.

The predictions of slope stability in soil or rock masses play an important role when designing for dams, roads, tunnels, excavations, open pit mines and other engineering structures. (5) and (6). The main objectives of slope stability analysis are finding endangered areas, investigation of potential failure mechanisms.

The stability of man-made rock slopes is greatly influenced by the orientation of the discontinuities in the rock mass. (7).

The present study carried out in the rocks of Pilaspi Formation (Late Eocene) which mostly deposited in a carbonate ramp environment with low topographic patchy reef, back reef and lagoon (8).

The Pilaspi Formation is one of the main rocks which forms high ridges and core of anticlines such as Permam, Bina Bawi, Haybat sultan and Bazian anticlines. These mountains and anticlines extent from the northwest to southeast and most of high ways and roads in north Iraq cross these ridges, most of the rock fall occurres in these areas especially the roads between Shaqlawa-Erbil, Koya-Dokan and Bazian-Sulaimaniyah,

This study aims to assess the slope stability of Limestone of Pilaspi Formation in Gomaspan valley and indicate the type of rock failures and discus the causes affecting the rock stability such as the activities of constructions of main and secondary rocks across the anticlines and ridges in the area .

Location of study area:

Gomaspan area is located about (28)km East of Erbil with accordance 44° 20′ 00″ E and 36° 16′ 30″N . The site is located along the road between Erbil-Koya and Shaqlawa road, which is within the south western limb of Bina Bawi anticline. Figure(1).

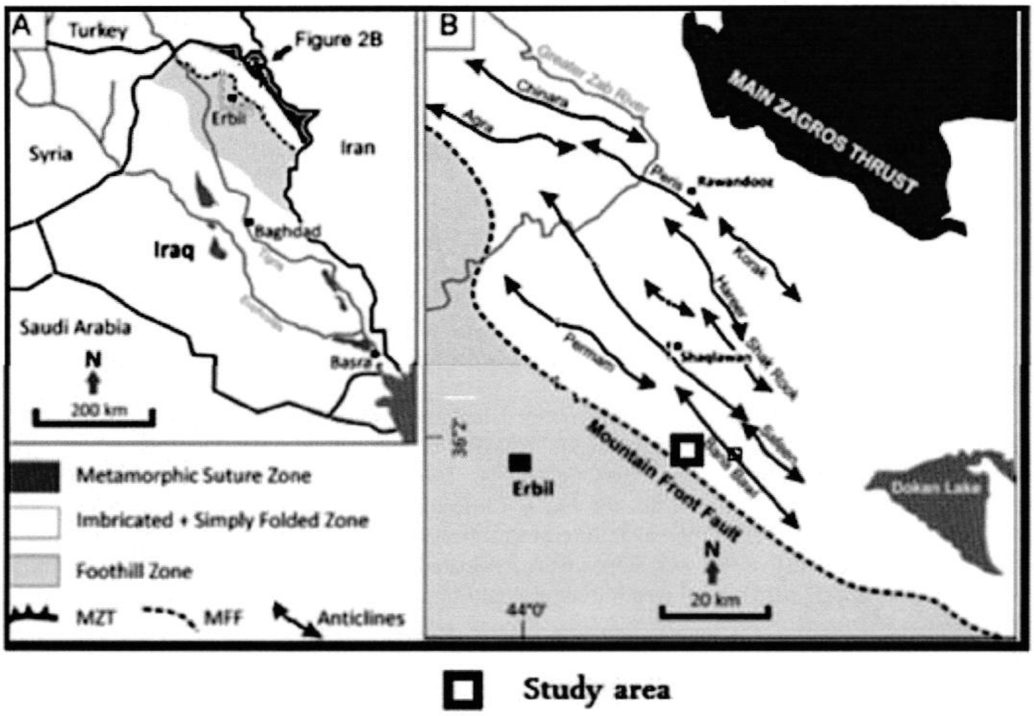


Figure -1- Location map of the study area with the tectonic units in the northeastern of Iraq . MZT=Main Zagros Thrust, MFF=Mountain Front Fault. (modified from (9),(10)and(11).

Geology of the area

Based on the tectonic divisions of Iraq after (12), the study area is located within the high folded zone which is in the area of anticlines form northwest-southeast trending folds over an exposed distance of more than 70 km, with wavelengths varying between 6 km (Safeen Anticline), 7 km (Permam Anticline) and 8 km (Bina Bawi Anticline). Bina Bawi anticline is the major structure in the study area, its average trend is NW-SE, and its northern limb (back limb) dips 20° NE, while the southern limb(forelimb) dips40° SW ,The hinge line reveals a double – plunging fold, with beds dipping approximately 22 degree and 32 to the SE and NW around the SE and NW fold hinges, respectively. The overall structure expression shows the anticline to be approximately 40 Km long. The Pirmam Anticline represents the NW continuation of the Bina Bawi Anticline, which together may form one gigantic anticline that is over 75Km long.(13).

Along the fold limbs, Late Cretaceous to Tertiary sediments are exposed, consisting of competent lithology, such as well bedded to massive limestones, dolostones and sandstones, intercalated with incompetent lithology, such as marls and claystones.

Quaternary deposits typically fill in low-lying areas where weaker lithology are more deeply eroded (13). Geomorphology of the study area shows that the area is structurally affected by the dipping beds which represents the southwestern limb of Bina Bawi anticline with rock discontinuities and faults as well as climatically the area is wet and frozen in winter which leads to the frozen water in the rocks discontinuities. The Gomaspan Valley cuts the limestone outcrops as consequent stream and leads to fracture widen.

The following formations are exposed in the vicinity of the studied area :

Gercus Formation (Middle Late Eocene)

The formation consist of red clastic rock, which are mainly of claystone, siltstone and sandstone, with a different layer of conglomerate at upper part. The main rock type of this formation is the claystone which is ridish brown, brown in color, soft and fragmentede to small chipses, occasionally the claystone is silty and very rarely sand grains could be seen.

The sandstone are less aboundant than the claystone and occur at thin beds. The thickness of the formation is varies along Shaqlawa area, at Sork mountain is about 110 m. (14).

Pila Spi Formation (Late Eocene)

The formation forms continuous high ridges with very common flat iron morphology, the formation consist mainly of limestone, which are crystalline, dolomitic and clayey or chalky, the color is white creamy, light gray and yellowish white, well bedded, the thickness of the individual bed ranges from less than 0.4 m to 1.5 m, hard to very hard occasionally the limestone is fossiliferous. Fossils are mainly Foraminifera and Gastropods. The thickness of the formation is about 90 m, the lower contact is unconformable with Gercus Formation.(12)(14), Table 1 and Figure 2.

Table -1- The stratigraphy of the studied area (11).

Period	Tectonic history	Epoch		Formation/ Mech. behavior
Neogene	Compression and continental collision	Holocene		Flood plain deposits / Residual soil and polygenetic deposits
		Pleistocene		Slope and alluvial fan deposits / River terraces
		Pliocene		Bai Hassan (Upper Bakhtiari) Formation
				Mukdadiyah (Lower Bakhtiari) Formation
		Miocene	Late	Injana (Upper Fars) Formation
			Middle	Fatha (Lower Fars) Fm. **
			Early	
Paleogene		Oligocene	Late	
			Early	
		Eocene	Late	Pila Spi Formation
			Middle	Avanah Fm.
			Early	Gercus Formation *
				Avanah Fm.

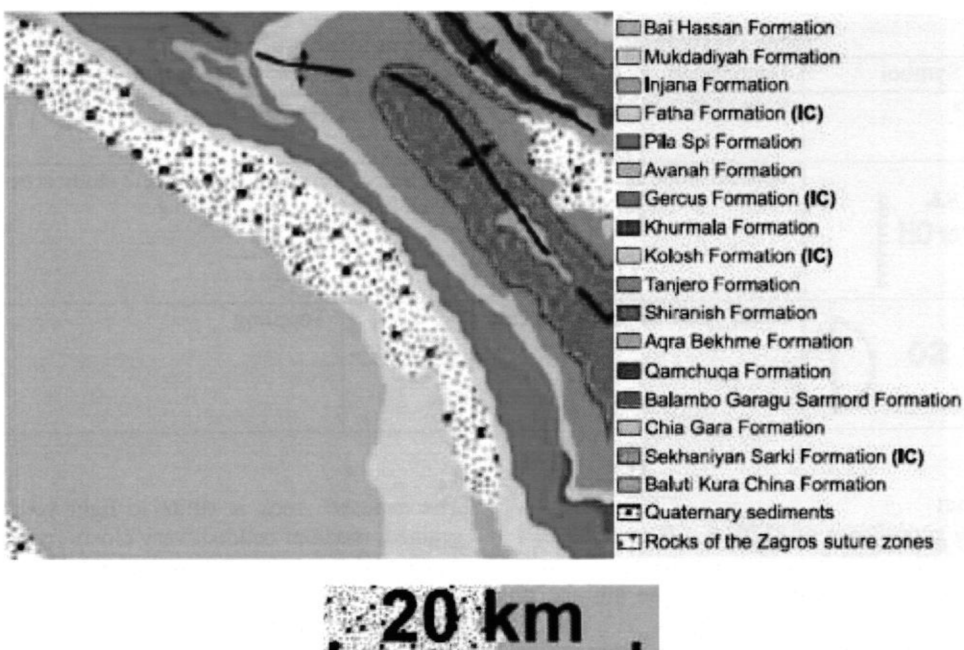


Figure 2 Geological map of the studied area and district (11and(15)).

Methods

This study included field work for assessing the Limestone rock slope stability and determining the failure type by :

1- Determining the angle and attitude of the slope, slope height and wide along the slope strike.

2- Determining the attitude of the limestone beds.

3- Describing the rocks according to (1)and (16).

4- Describing the attitude, frequency, aperture, spacing and length of discontinuities .

5- Indicating the type of dominant failures that happened or probably to be happen.

6- Collecting rock samples for the point load test and tensile strength test in the laboratory.
7- Taking photographs of the stations for documentation.
Four stations were selected on the southwestern limb of the Bina bawi Anticline on the outcrop of Pilaspi formation to indicate the type of slopes and assessment of the rock slope stability Figure (3). Samples were taken from the rock outcrops in the selected stations for point load test. Also the data obtained from the field survey were plotted stereographically to all the bedding plane, slope surfaces and discontinuities. Symbols used on stereogram are in Table (2).

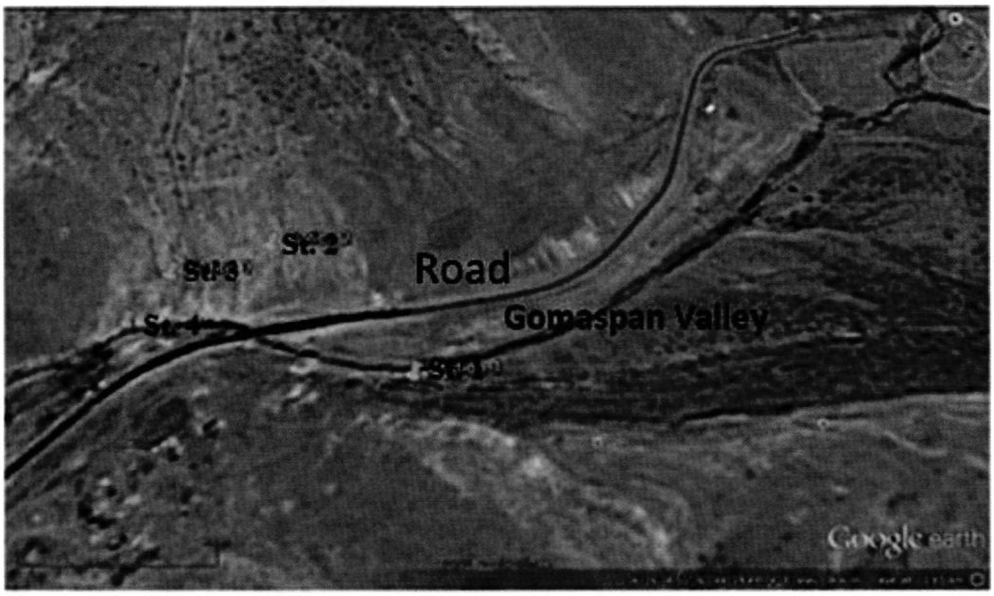
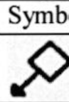


Figure (3) Location of the stations (From Google Earth Image).

Table (2) symbols used in the stereographical projection (3).

Symbol	Description	Symbol	Description
•	Pole of discontinuity plane		Rock fall
V.S. or OH	vertical slope or overhanging	S1, S2,S3	Joint systems in the study area
SO	Great circle of bedding plane		Toppling

Station One:
This station coordinates of 452814 E and 3637991 N with elevation 809.5m above sea level. The beds attitude is N50W and dips 22°SW. The attitude of slope is N20E (020/OH).
And the height from the ground level is(16)m. upper part is over hanging slope of limestone rock and the lower part of the slope is about (4)m high with 40° slope, its wide is (27)m. of Gercus formation rocks which consists of shelly siltstone with sandstone bed where the Gomaspan valley is located on.The type of slope is parallel (d=20°),right emergent and discordant according to the classification of (3).
The exposed rock is white to light yellowish, fine grained, medium bedded, very closly spaced, slightly weathered, LIMESTONE and strong.
There are three types of discontinues, the first set of the joints attitudes is joints with attitude S60W/50NW, S55E/45NE and N10E/80SE. The joints spaces ranges (1-2)cm. The main type of the failure is rock fall because of the differential erosion which Gercius Formation is less resistance than Pilaspi Formation and led to overhanging slope while the cohesion through the discontinuities is zero. Figure (4).

A

B

Plate 1. Station 1. A. Slope view in the South direction. B. General view of slope and Gomaspan valley is filled of rock fall aggregates and accomulated down in the valley

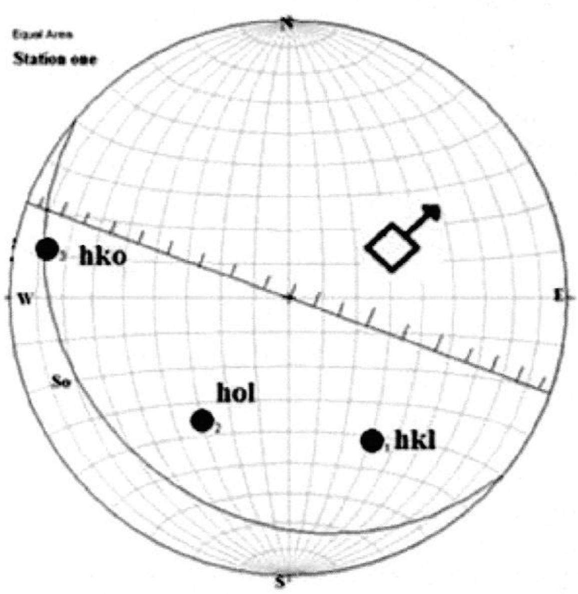


Figure (4) Stereogram shows the relationship between slope, bedding and discontinuities at station one

Station Two:
This station is on the southwestern limb of the Bina Bawe anticline as shown on Plate (3). The station coordinate is determined by GPS with UTM system which is 442220E and 3637991N altitude 815.3m above sea level. The attitude of slope is N40W and slope direction OH/SW, about (4) m high and (30)m wide.

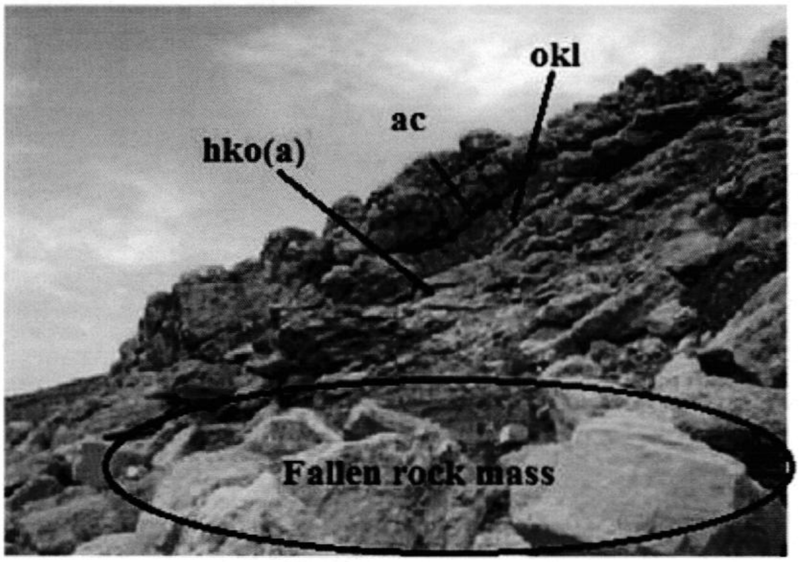


Plate 3 Frontal view of Station 2(photograph direction is to the North).

The average bedding plane attitude is N60W/34SW with dip angle 34°.Figure(5).The type of slope is oblique lateral because (d=40°), left emergent, concordant according to(3) classification.
The beds are white to light yellowish, fine grained, bedded, spaced joints, weathered, chalky or marly Limestone and strong.
The beds are cut by three sets of joints. Mode of failure is rockfall and the rock mass rolling on the slope face.
Some of the joints plane filled with secondary calcite.

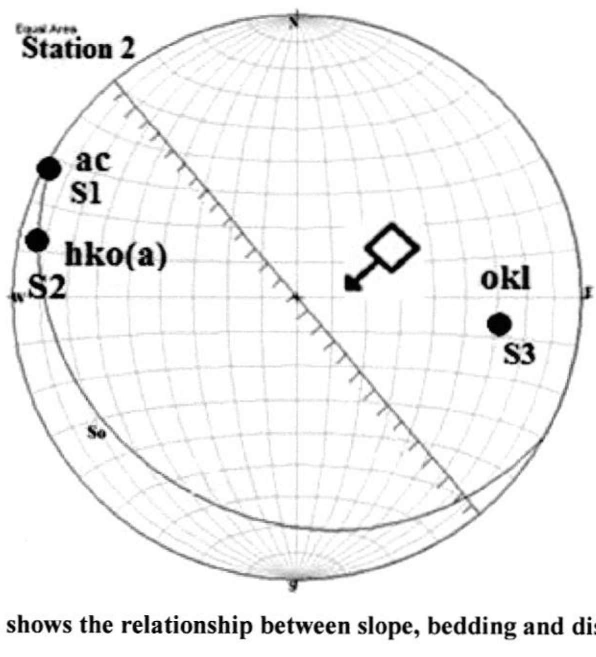


Figure (5) Stereogram shows the relationship between slope, bedding and discontinuities at station two.

Station Three:

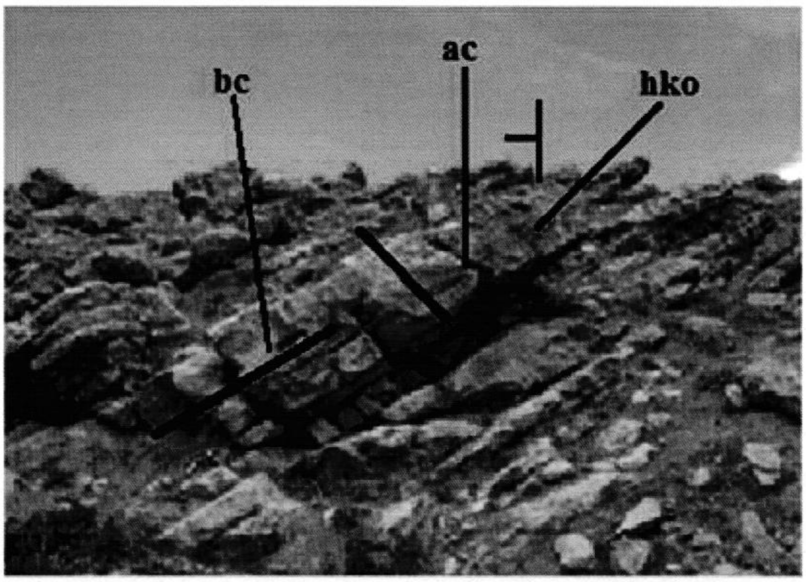
This stations coordinate is 441432E, 3628835N and the elevation is about 833m. The attitude of the Slope is EW/ OH in S direction. The height of the slope is about 30m, and 18m wide. plate(4)

The beds attitude is N52W/ 35°SW. The type of slope is oblique lateral (d=38°),left emergent and concordant according to(3) classification.

The exposed rock is white to grey, fine grained, medium bedded, very closely spaced, highly weathered, LIMESTONE and strong.

There are three types of discontinues, the first set of the joints attitudes is joints with attitude S40W/88NW, S50E/36NE and NS/60E and bedding plane joints. The joints spaces is about (5) cm. The main type of the failure is toppling and probable toppling will occur when the cohesion equals zero, Figure (6).

The slope rock consist of massive beds with average of thickness (80-120)cm including marl beds with thickness about (5-15)cm , limestone bed thickness is about 35 m with white colour .highly weathered.



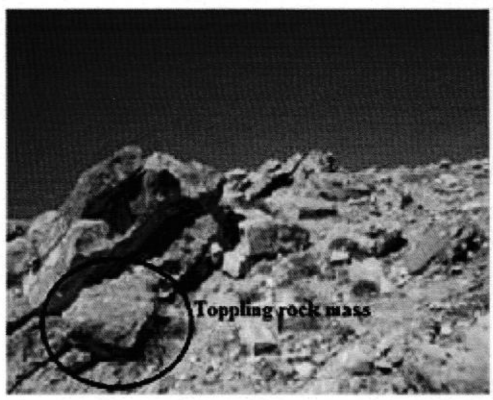


Plate 4. Station3 Photograph direction is N40W direction

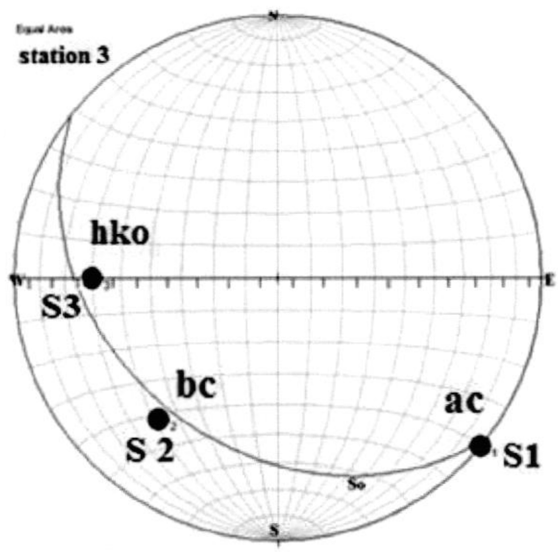


Figure (6) Stereogram shows the relationship between slope, bedding and discontinuities at station 3 .

Station Four:
This station is located on 441021E and 3621873N on the southwestern limb of the Bina Bawi anticline as shown on Plate (5). The stations elevation is about 810m above sea level. The attitude of slope is N80W and slope direction (190/OH) , about (12)m high and (25)m wide.

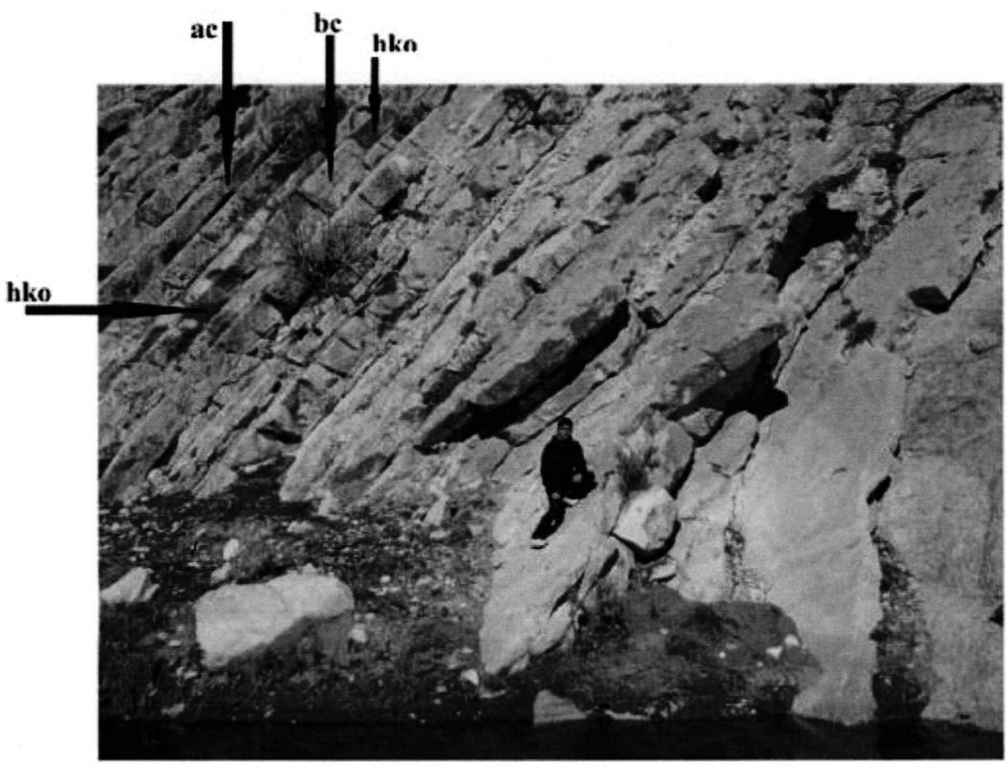


Plate (5) Frontal view of slope at station three.

The beds attitude is N58W /54°SW, so the type of slope is oblique lateral (d=22°), left emergent and concordant according to (3) classification.
The exposed rock is Succession of massive beds of grey limestone interbedded by thin lamina of marl or marly limestone, fine grained, medium bedded, very closely spaced, slightly weathered, LIMESTONE and strong.
There are three types of discontinues, the first set of the joints attitudes is joints with attitude N50W/90, N25E/90 and S35w/90. The joints aperture is about (1-4)cm. The main type of the failure is toppling and rock fall and afterward rolling. Figure (7).

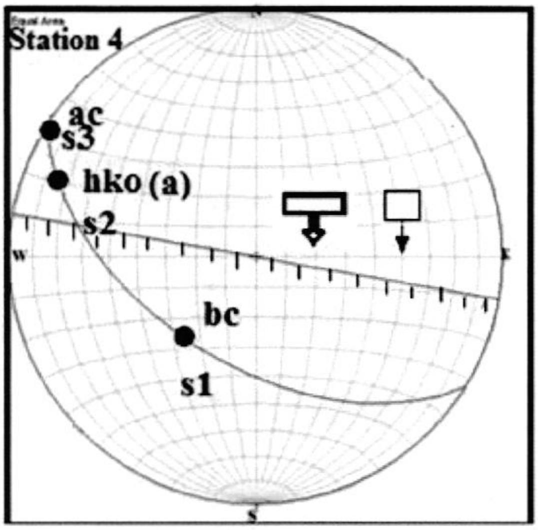


Figure (7) Stereogram shows the relationship between slope, bedding and discontinuities at station four.

On the top of this station slope a fault is recognized as shown in plate (6) which consider as a normal fault which noticed an obvious change in amount of the beds angle of dipping.

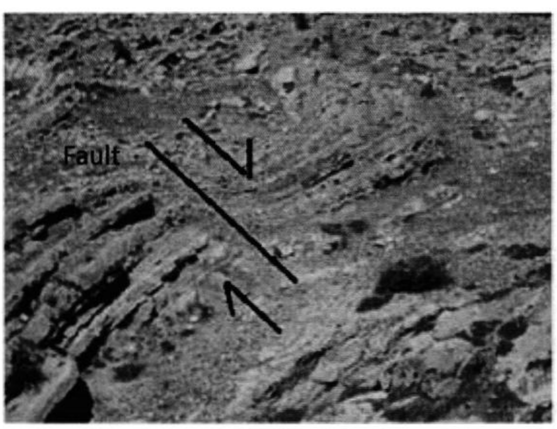


Plate (6) The normal fault.

Table (3) The attitude and classification of the discontinuities in the study area

Station	Joint set	Strike	Dip	Set or System
1	1	S60W	50NW	Hkl
	2	S55E	45NE	Hol
	3	N10E	90	Hko
2	1	N28E	90	Ac
	2	S60W	50NW	Hkl
3	1	S40W	88NW	Ac
	2	S50E	36NE	Bc
4	1	N50W	36NE	Hko
	2	N25E	80SE	Hko
	3	S35W	90	Ac

Point Load Test

This test has a great importance in rock mechanics and engineering geology as an indirect measure of the UCS, and it was regarded as a standard test by the international society of rock mechanics in 1973 (17). The point load test involves the compressing of a rock sample between conical steel plates until failure occurs. Three irregular lump samples of Limestone rocks were prepared for point load test in the engineering Laboratory of Applied Geology Department the results are in Table (2) σc is the compressive strength of the rock according to (17)and (18).

Is(50)=f*F/De2

Is (50) = Point load strength index of a specimen of 50mm diameter.

f= Size correction factor.

Is=Point load strength index

F= (De/50)0.45 F=Force at failure D=Thickness of the specimen

σc= K Is(50)

De=Equivalent core diameter which is given by:

De= √ ((4A) / π) for the axial, block or irregular lump tests

Where K=14+o.17d K is the index - to – strength conversion factor

σC=22.5 Is(50).

Table (4) Values of compressive strength according to Point Load Test.

Rock Type	Sample	D(cm)	P(KN)	σ MPa	Avearge σ MPa	Term according to(2)
Limestone	1	4.5	4.5	46.35	55.677	Strong
	2	4.4	5.8	61.376		
	3	4.2	5.3	59.306		
Limestone	1	4.2	4.1	45.878	59.311	Strong
	2	4.2	6.3	70.496		
	3	3.5	4.4	61.5668		
Marly Limestone	1	5	1.8	16.38	34.734	Moderatly strong
	2	4.5	3.6	37.088		

Tensile strength(σ t)

This test carried out in the mechanical engineering laboratory in the engineering college / Tikrit University. Three circle plate samples of limestone rocks were prepared Figure (8) Table (5) and loaded through the samples diameter between the plates of loading machines, which caused failure in the samples. (19)

$\sigma t = 2F/3.14DT$

σt =Tensile strength (Kg/cm2)

$F = Vertical\ load.$

D= Diameter of the plate sample (cm).

T= Sample thickness (cm).

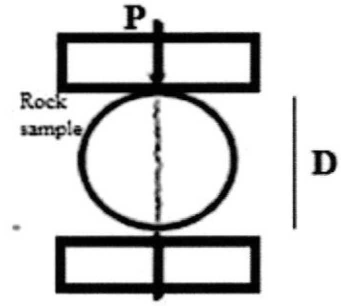


Figure (8) Sample for tensile strength test.

Table (5) Test values of tensile strength and Classification of rock samples according to (4).

Station	Rock Type	Diameter (cm)	Thickness(cm)	σT MN/m2	Term
1	Limestone	5.5	2.5	15.77	Very High
2	Limestone	5.5	2.8	14.32	Very High
3	Marly Limestone	5.5	2.5	7.12	High

Conclusions

Studying the rock slope stability of the studied area the following are concluded:

1. The studied area is effected by structural, climatically and geomorphological condition because Gomaspan Valley cuts the Limestone outcrop as consequent stream this leads to fracture widen by frozon water. .
2. The slopes in the studied area are over hanging and influenced by the fractures which cause falling rock masses and accumulated in the valley as well as on the road.
3. The slops type are oblique lateral, parallel, concordant and disconcordent, right, left emergent.
4. The average values of unconfined compressive strength for Limestone rock ranges (55.677-59.311)MN/m2 and Marley Limestone (34.734)MN/m2 which is strong to moderately strong respectively. According to (4), the average value of(σ t) for Limestone and Marly Limestone are 15.o45MPa/m2 and 7.12MPa/m2 respectively.
5. The modes of failure are affected by presence of discontinuities which acts as release surface which led to rock fall, Toppling and then rolling on the slope surface.

Recommendation

1. Detail structural and engineering geological study.
2. Preventing to build residual construction near the valley banks and on area on the top the slopes because of instability of the slopes.
3. Surveying more stations in the area.
4. Determining Φ and C of the marl beds between the Limestone beds.
5. Fixing warning signs on the road and using the suitable method for preventing dangerous slopes.
6. Preventing the valley blockage which results from fallen rock masses affects the water flow in the valley and on the road.

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أستقرارية المنحدرات الصخرية لصخور تكوين البلاسبي في طية بناباوي المحدبة في دربندي كومه سبان في أربيل/ العراق

امیرة اسماعيل حسين

قسم علوم الارض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

تناول البحث دراسة أستقرارية المنحدرات الصخرية لتكوين البلاسبي في طية بناباوي في منطقة دربندي كومه سبان في اربيل من خلال اربع محطات متوزعة على مكاشف تكوين البلاسبي في الجناح الجنوبي الغربي من الطية .تم اجراء مسح شامل للمنحدرات الصخرية ووصفها هندسيا وتصنيفها حسب (1)و(2)بينت الدراسة بان المنحدرات الصخرية من نوع جانبي الانحراف والمتوازي حسب علاقة الطبقات مع مضرب المنحدر ومن نوع المتوافق ذو بروز يميني حسب تصنيف(3) ،ومن قيم المقاومة الانضغاطية غير المحصورة من خلال فحص حمل النقطة لصخور الحجر الجيري تراوحت (55.677-59.3111)ميكا باسكال و لصخور الحجر الجيري المارلي (34.734) ميكاباسكال تبين ان صخور المنطقة تكون ذات مقاومة عالية الى عالية باعتدال حسب (4)، ومعدل قيمة σT للحجر الجيري 15.045ميكاباسكال بينما للحجر الجيري المارلي 7.12 ميكا باسكال. بعد تحليل البيانات من خلال اسقاطها على المخطط الفراغي المجسم تبين بان الانهيارات من نوع السقوط الصخري والانقلاب ثم الدحرجة على سطح المنحد. وتبين بان السبب الرئيسي للانهيارات هي بسبب الانقطاعات داخل الصخور و التجوية التفاضلية والمنحدرات العمودية وقطع الصخور لاستخدامات انشائية وشق الطريق أو توسيعها.