STABILITY ANALYSIS OF A ROAD CUT SLOPES IN AZMUR MOUNTAIN, NORTHEAST IRAQ

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ABSTRACT

Engineering geological study was carried out to evaluate the slope stability of a road cut in a tourism area, north of Sulaimaniya Governorate. The study involved geotechnical evaluation of the area including engineering and petrophysical tests.

Two formations are exposed in the studied area, Cretaceous in age. These are Kometan and Balambo formations, both of them consist mainly of bedded limestone. The area is affected by tectonic uplift due to Alpine Orogeny, forming two set of joints of NE – SW and NW – SE directions.

For the first time, direct shear test is introduced to get the most important parameters concerning slope stability (cohesion and friction angle). For station No.(1) sliding is more possible along planes of tectonic joints (J_1), while that of station No.(2) sliding is along bedding planes. Both slopes are considered unstable, where planner sliding is dominant especially in the second station.

تحليل استقرارية المنحدرات لطريق في جبل أزمر ، شمال العراق

أزهار علي غالب الخطيب و آرسين أوهانيس كابيكيان

المستخلص

تم أعداد دراسة جيوهندسية في منطقة جبل أزمر، شمال شرق محافظة السليمانية لتقييم استقرارية منحدرات طريق سليمانية – جوارتة. شملت الدراسة تقييم جيوتكنيكي للموقع مع أجراء فحوصات ميكانيكية وبترو فيزيائية. يتكشف في المنطقة تكوينان هما: تكوين بلامبو وتكوين كوميتان والعائدان للعصر الطباشيري ويتكونان بشكل رئيسي من حجر كلسي جيد التطبق.

تأثرت المنطقة بحركات الرفع التكتوني بسبب الحركات الالبية مما أدى إلى تكون أثنين من مجاميع الفواصل ذات اتجاه شمال شرق – جنوب غرب وشمال غرب – جنوب شرق. تم استخدام جهاز فحص القص المباشر للصخور للمرة الأولى في الشركة العامة للمسح الجيولوجي و التعدين في دراسات من هذا النوع والذي بواسطته يتم الحصول على معاملي القوة القصية للفواصل (قوة التماسك وزاوية الاحتكاك). بينت الدراسة عدم استقرارية المنحدرات حيث أنها معرضة لانزلاق من النوع المستوي وخاصة في المحطة الثانية.

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INTRODUCTION

Two locations along road cuts have been studied in Azmur Mountain, Sulaimaniya Governorate, to evaluate their stability. There is no previous works concerning the stability of slopes in this area. The studied area was selected on the bases of a large scale slope stability found through field work executed in this area during the year 2004. Two formations are exposed in the studied area, Cretaceous in age. These are Kometan and Balambo formations. The strength parameters (Cohesion **C**, angle of internal friction φ) of the discontinuities were measured using direct shear box device, for analyzing the road cut slopes stability, in the above locations. Six samples were collected for mechanical and petrophysical tests namely: Uniaxial compressive strength, direct shear test, porosity, water absorption. Climatic data shows that the mean annual maximum temperature is 25^{o} C, the mean annual relative humidity is 48%, and the average annual rainfall is 775 ml (Abdullah, 2001).

LOCATION

The studied area is situated on the northeastern flank of Azmur Mountain, Sulaimaniya Governorate in Northeast of Iraq, approximately 8 Km from Sulaimaniya town (Fig.1), with the following coordinates:

$$\text{Long. } 45^{o}\ 27'\ 00'' - 45^{o}\ 28'\ 00''$$
$$\text{Lat. } 35^{o}\ 38'\ 00'' - 35^{o}\ 39'\ 00''$$

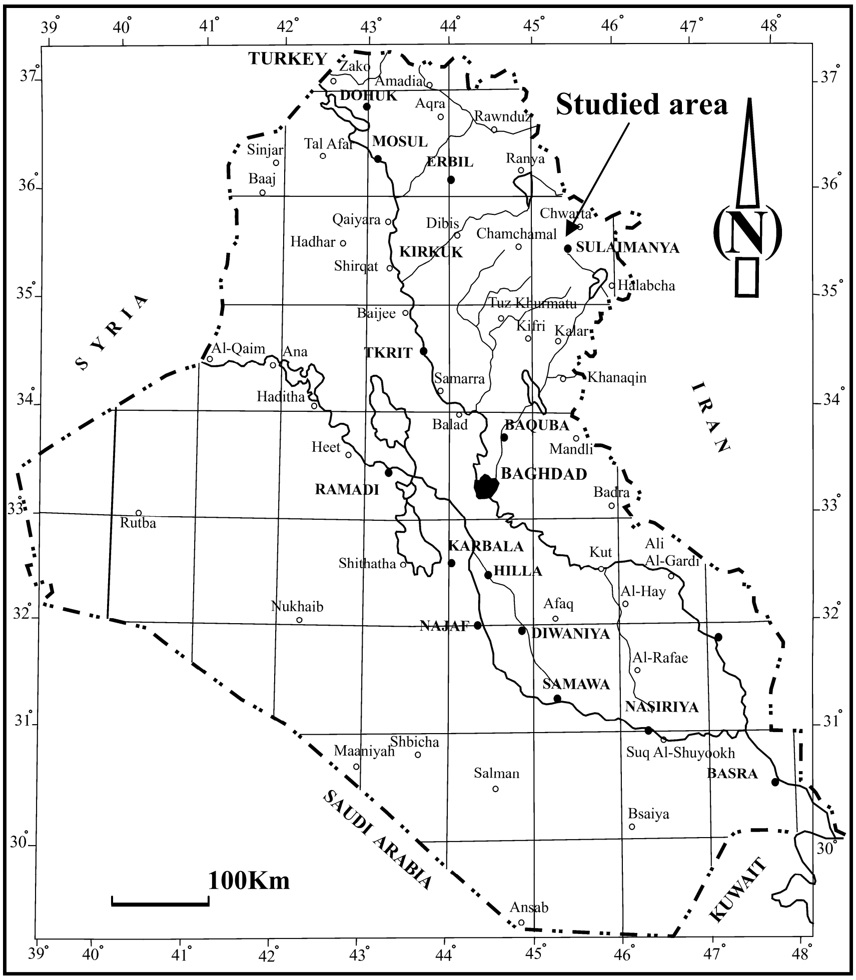


Fig. 1: Location map of the studied area

GEOLOGIC SETTING

According to a most recent study of the area (Ma'ala *et al*., 2004), the area is considered as a Foreland Zone, which includes carbonate rocks represented by well bedded, hard and highly jointed, limestones interbedded with green marl (Balambo Formation) and highly jointed, hard, limestones (Kometan Formation). These formations were deposited in deep marginal basin in Continental Shelf (Fig.2). As a result to the continental collision during Mio – Pliocene, the sediments were subjected to intensive lateral compression, forming Azmur Mountain (anticline) with local and minor structural association. The Azmur anticline formed by mechanism of flexural folding under the effect of tectonic horizontal main stress, it has been considered as a complex Alpine Fold of Zagros Folding system. The highest point in the studied area is 1464 m, while the lowest point is about 1300 m (Fig.2) (Ma'ala *et al.*, 2004).

Geomorphologically, the landscape of the area is represented by the extension of Azmur Mountain as the main conspicuous feature in the area. Valleys are of sub parallel type and of V-shape. Expected mass movements are planner sliding and debris slide. The main geomorphologic units in the area are:

Units of Structural – Denudational origin
Units of Denudational origin
Units of Depositional – Fluviatile origin
Units of Evaporitic origin

METHODOLOGY

The work included the following aspects:

- **Description of the stations**

Station No. (1): It is located about 3.0 Km from the Police station (Fig.2). Upper part of Kometan Formation is exposed in this station, which consists of well bedded, grey color, fine crystalline, hard, highly jointed limestone. It forms steep scarp inclined 85º towards the east, discontinuity surfaces are planner, rough and filled by clay. Two set of joints were noticed, the first is of NE – SW direction, while the second is of NW – SE direction (Fig.3 and Table 1).

Station No. (2): It is located about 1 Km from the Police station (Fig.2) on the northeastern limb of Azmur anticline. The exposed formation is Balambo, which consists of alternation of ammonitiferous marly limestone, and green, soft marl of thickness ranging from (1.0 – 5.0) cm (Ma'ala *et al.*, 2004). There are numerous fallen limestone blocks in front of the slope toe, over a total front of more than 100 m. It is obvious that the rock mass failed in kind of planner slide. Two sets of joints were observed in this locality, the first one is of NE – SW direction and the second is of NW – SE direction (Fig. 4 and Table 1).

- **Field measurements**

Gradient of slopes with strike and dip and spacing of discontinuities were measured to obtain block size indices, B-index, and Jv-index, as follows:

Spacing of each discontinuity set is plotted vice number of observations of the spacing on a semi-log chart.

$$\text{B-index} = \frac{S_1 + S_2 + S_3}{3}$$

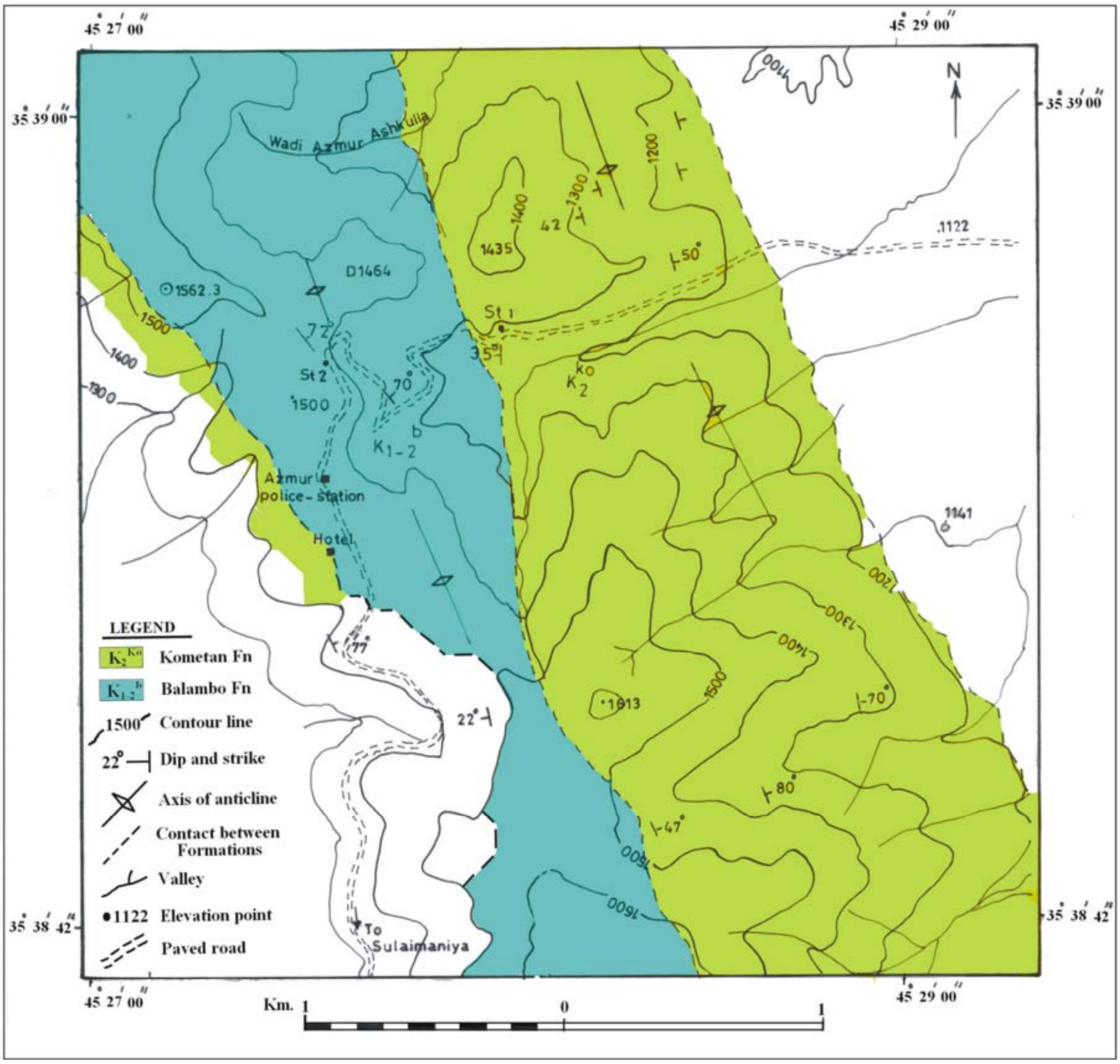


Fig. 2: Geological map of the studied area (after Ma'ala *et al.*, 2004)

Where $\mathbf{S_1}$, $\mathbf{S_2}$, $\mathbf{S_3}$, represent the model spacing of bedding and tectonic joints, respectively.

$\mathbf{S_1}$ **model** in station No.1 and $\mathbf{S_2}$ **model** in station No.2 show two model values due to presence of two accumulations of spacing observations.

Increasing of **B-index** value indicates larger blocks.

$$\text{Jv-index} = \frac{n_1}{ds_1} + \frac{n_2}{ds_2} + \frac{n_3}{ds_3}$$

Where:

$\mathbf{n_1}$, $\mathbf{n_2}$, $\mathbf{n_3}$, represent the number of spacing observations of bedding, tectonic joints (J_1 and J_2), respectively.

$\mathbf{ds_1}$, $\mathbf{ds_2}$, $\mathbf{ds_3}$, represent the summation of spacing for the sets in the same order above (Figs.5 and 6).

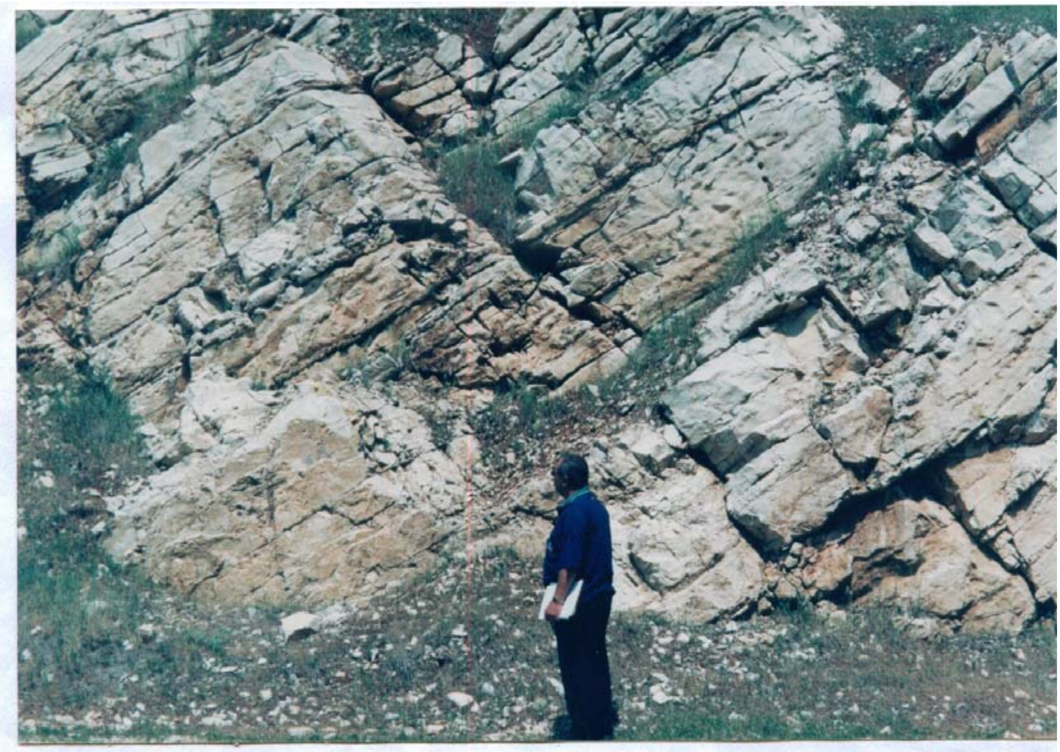
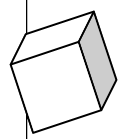
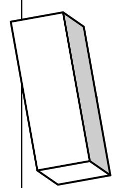


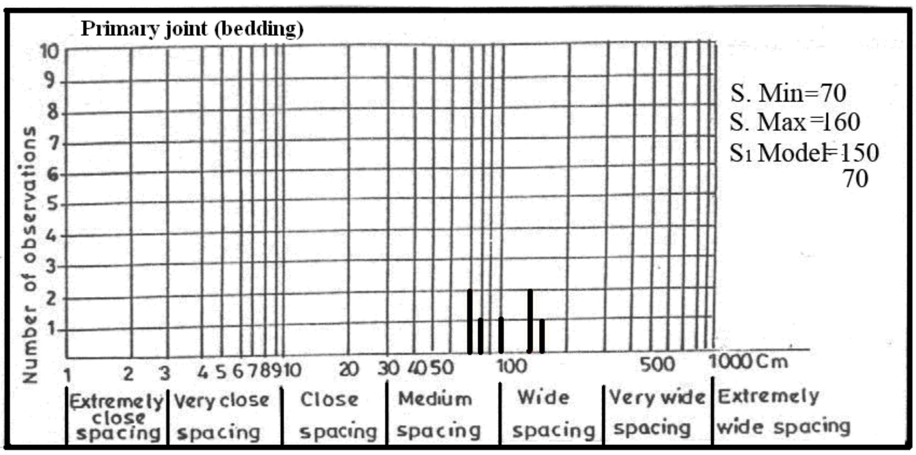
Fig. 3: Station No.(1)

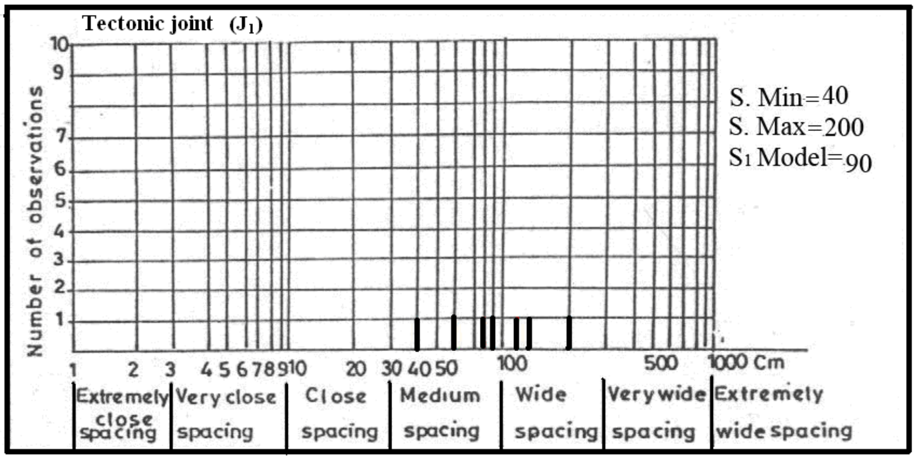
Fig. 4: Station No.(2)

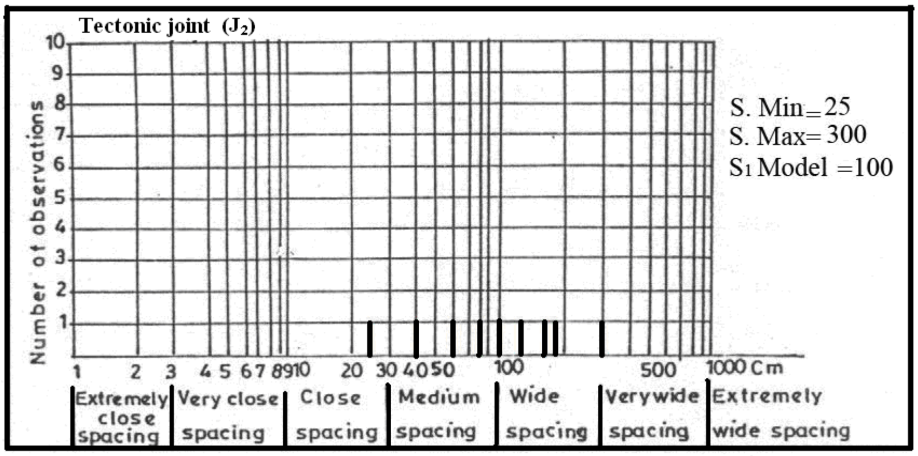
Table 1: Field and Laboratory Geotechnical Results

Station No.	Dominancy of joint sets	Discont		Spacing of discont (cm)			Direction and amount	Block size		Block Shape	Petrophysical tests (Av.)		σc	Direct Shear test		
		Strike	dip	Min.	Max.	Av.		B-index (cm/ J)	Jv-index (J/ m)		Po (%)	W. a. (%)	MPa	C MPa	φ^{o}_{P}	φ^{o}_{r}
1	Primary bedding B	NS	35ºW	70	160	150 70										
	tectonic J_1	N72ºE	85ºSE	40	200	100	N85°E/85°E	113 87	2.7 Large Block			0.772	29.4	0	35	32
	tectonic J_2	N28ºW	66ºNE	25	300	100										
2	Primary bedding B	N38ºW	72ºNE	10	60	25	N38°W/72°E									
	tectonic J_1	N18ºE	84ºSE	30	200	170 60		42 78	4.19 Medium Block			0.195	41.4	0	29	20
	tectonic J_2	N58ºW	60ºNE	20	60	40										

J/ m = Joint / m, Po = Porosity, W.a. = Water absorption



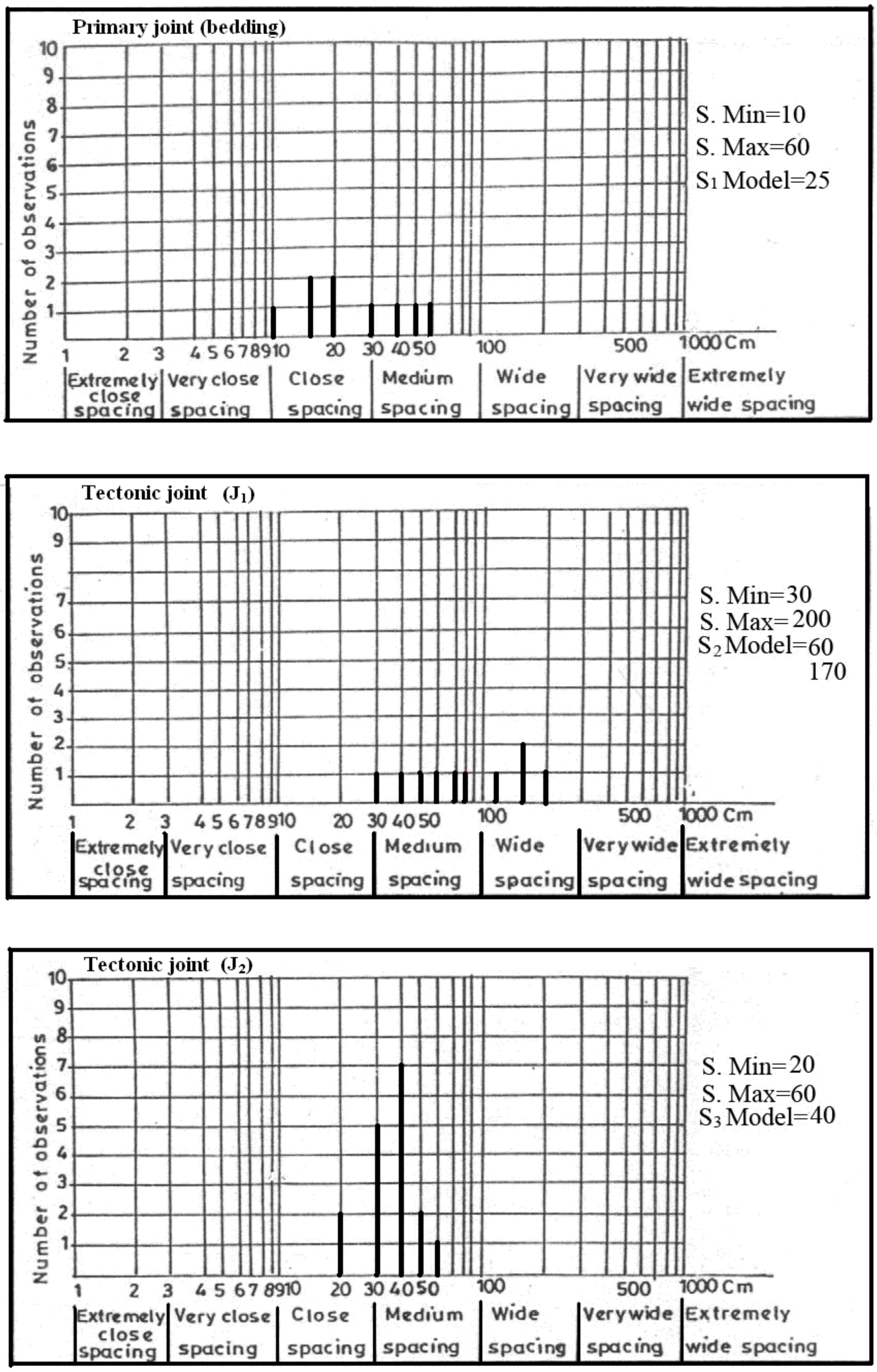




$$\text{Block size (B-index)} = \frac{S_1\text{ model} + S_2\text{ model} + S_3\text{ model}}{3} = 113.87\ \text{cm/ joint}$$

$$\text{Block size (B-index)} = \frac{n_1}{ds_1} + \frac{n_2}{ds_2} + \frac{n_3}{ds_3} = \frac{7}{7.8} + \frac{7}{7.1} + \frac{9}{10.85} = 2.7\ \text{J/ m}$$

Fig. 5: Histograms showing model, minimum and maximum spacing of station No.(1)



$$\text{Block size (B-index)} = \frac{S_1\text{ model} + S_2\text{ model} + S_3\text{ model}}{3} = 42.78\ \text{cm/ joint}$$

$$\text{Block size (B-index)} = \frac{n_1}{ds_1} + \frac{n_2}{ds_2} + \frac{n_3}{ds_3} = \frac{9}{2.6} + \frac{10}{18.5} + \frac{17}{8.9} = 5.9\ \text{J/ m}$$

Fig. 6: Histograms showing model, minimum and maximum spacing of station No.(2)

Block size is classified according to **Jv-index** (Table 2), hence the block size for stations No.(1) and No.(2) is considered as a large and medium blocks, respectively.

Table (2): Classification of block size according to (Jv-Index), (I.S.R.M, No.110, 1975)

Jv-Index(J/m)	Description	Jv-Index(J/m)	Description	Jv-Index(J/m)	Description
< 1	Massive	3 – 10	Medium block	> 30	Very small block
1 – 3	Large block	10 – 30	Small block		

- **Laboratory tests:**

The following laboratory tests were carried out:

Uniaxial compressive strength: for both stations the rocks are classified as "moderate", according to Edge (1968).

Porosity: the samples of both stations are characterized by "excellent" rock type (Fatouhi, 1985).

Water absorption: station No. (1) samples are characterized by very low water absorption value (0.19%), which declare its insignificant effect on the stability, however the same could be said for station No.(2).

Direct shear test: for the first time this test was conducted in GEOSURV, in which two halves of jointed rock samples were sheared against each other to get the most important parameters concerning slope stability (C and φ) (Fig.7). For both stations, joints were of in-cemented type and hence cohesion (C) is proposed to be equal to zero, both peak and residual angles of internal friction were calculated. For samples of station No.(1) it is relatively of high values, the internal angle of friction (φ_p)=35º, (φ_r)=32º and this could be explained by slight to moderate weathering degree of joint walls, besides their roughness. While in samples of station No.(2) values of (φ_p) and (φ_r) are remarkably lower than their equivalents at station No.(1), due to moderate weathering degree and planner smooth joint walls beside presence of green marl between bedding planes, which make station No.(2) less stable than station No.(1).

EVALUTION OF THE STATIONS

Station No. (1)

The samples are characterized by rough joint surfaces, slightly to moderately weathered, with little or no filling materials, aperture of the joints is 20 mm near the surfaces and almost zero inside the rock mass. Stereographic projection (Figs.8 and 9) of the discontinuities shows that the probable sliding is of planner type along secondary joint planes (J_1), which forms the slope. From the aforementioned data, it is obvious that the slopes in the station seem to be stable, mainly due to roughness of joint planes and relatively slight weathering degree. However according to Hoek and Bray (1977) the most probable movements are sliding and toppling because the probable sliding plane is dipping about 84º SE.

Station No. (2)

It is characterized by planner and smooth joint surfaces, including bedding planes, moderately weathered with thin interbedded green marl of thickness not exceeding few centimeters. Stereographic projection (Figs.8 and 9) of the discontinuities shows that sliding along bedding planes is the most probable case, which is very obvious in the field.

Due to the aforementioned data, beside the high dip amount (72° NE) of the bedding planes towards the probable sliding directions and relatively low value of (φ_p) with considerable low value of residual friction angle, the station is considered as highly unstable. (Figs. 7 and 8).

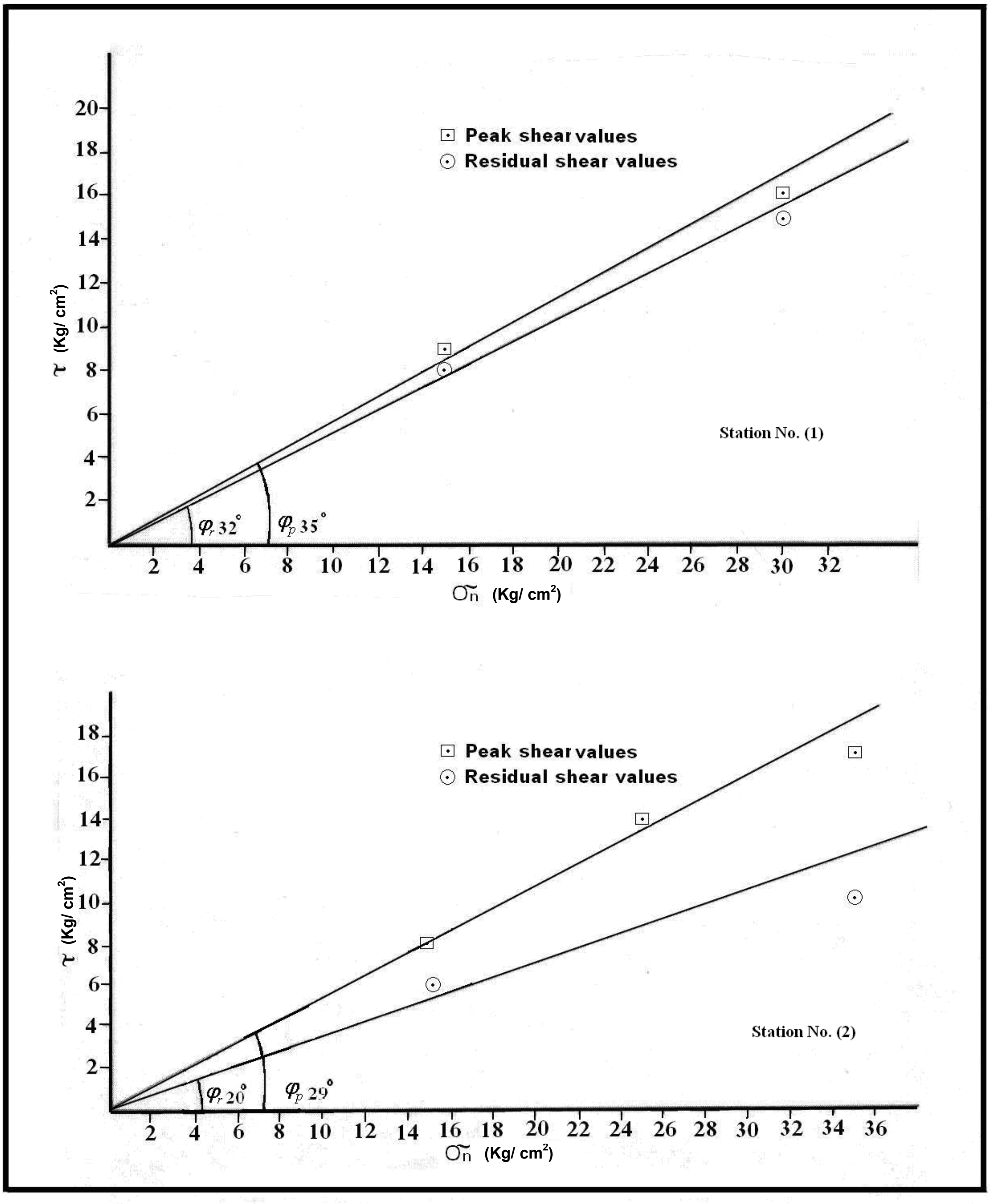


Fig. 7: Direct shear box test results for station Nos. (1 and 2)

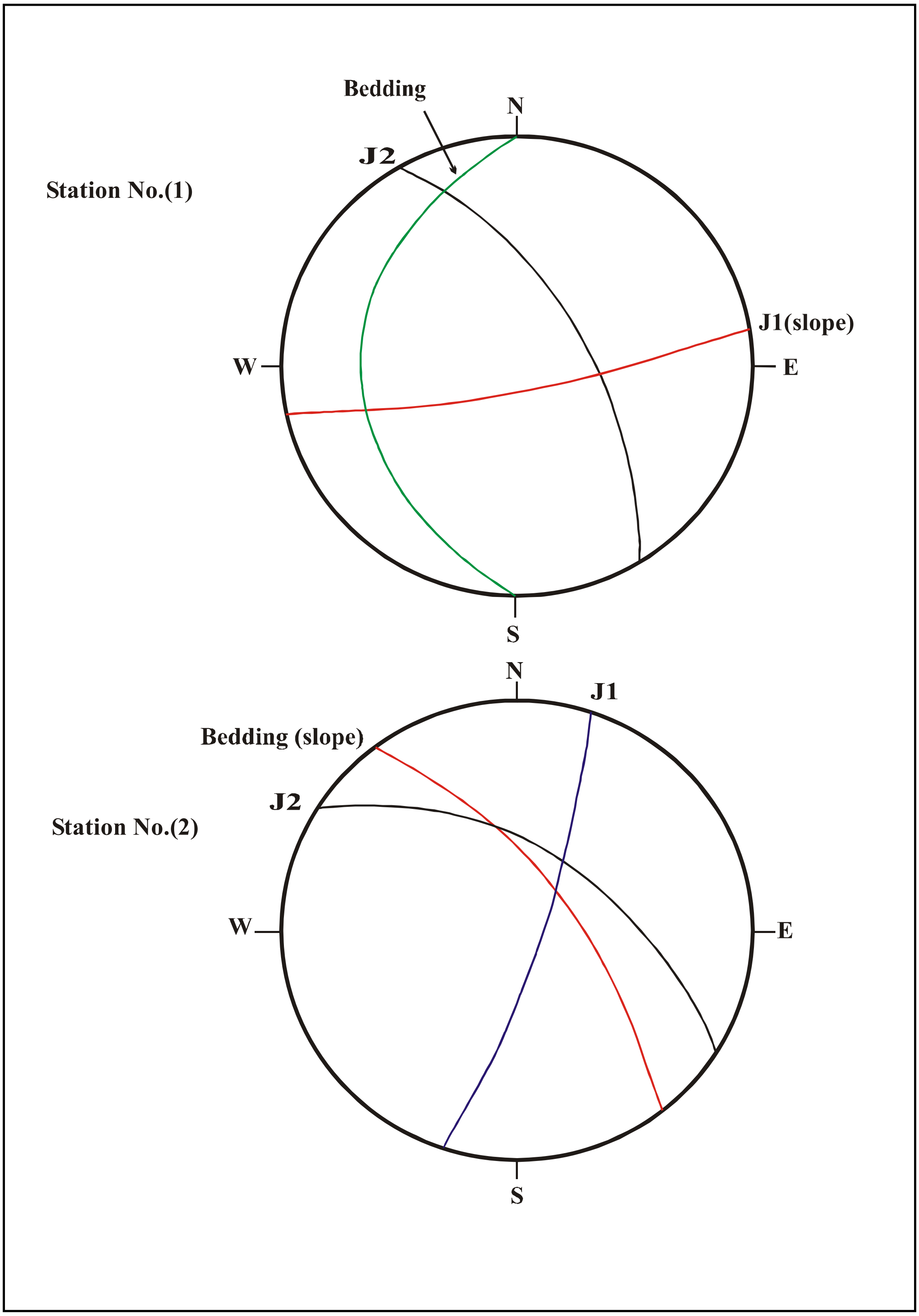


Fig. 8: Stereographic projection of discontinuities for station Nos.(1 and 2)

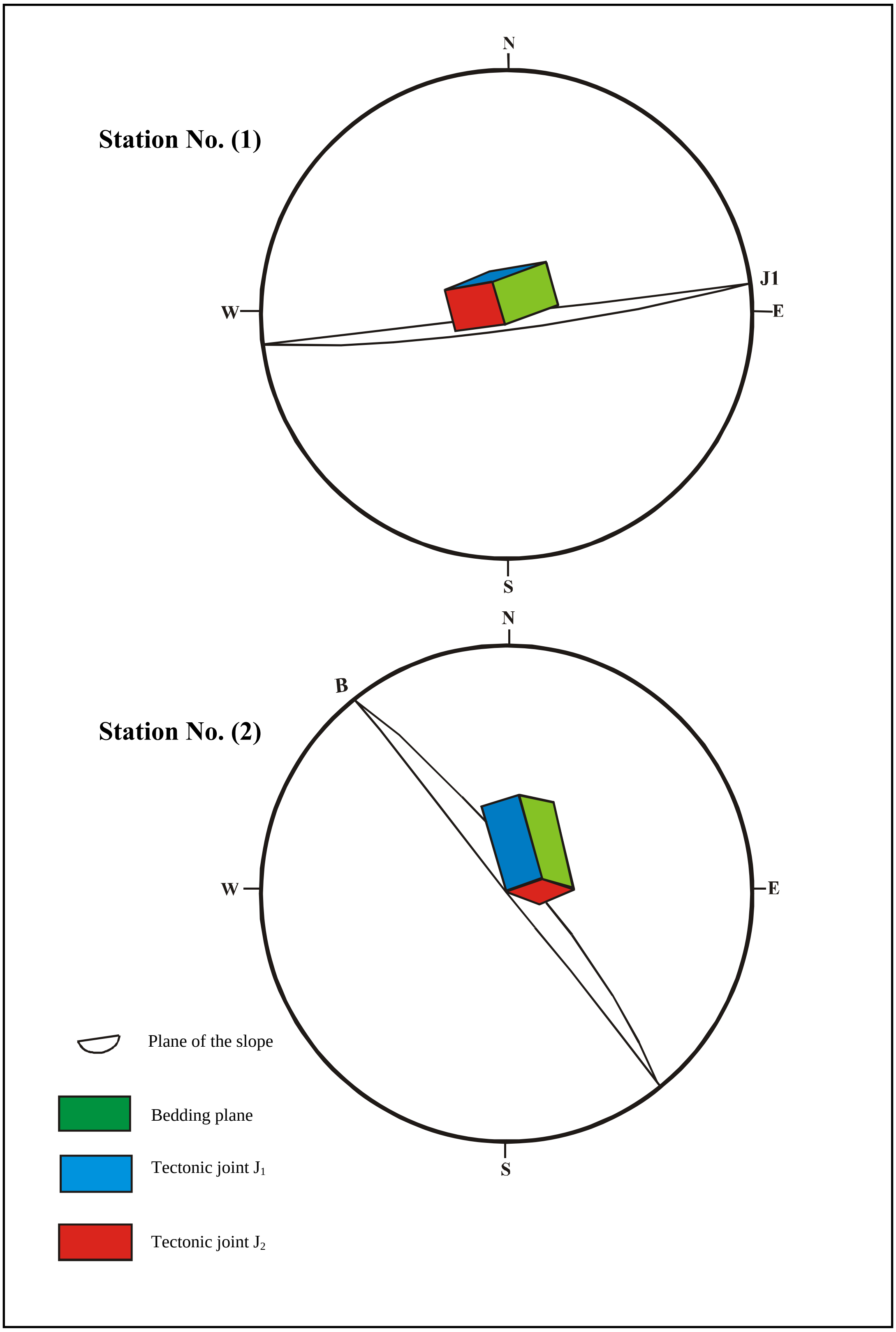


Fig. 9: Stereographic projection of discontinuities for station Nos.(1 and 2)

CONCLUSIONS

- The slope in station No.(1) is more stable relative to station No.(2), because the slope of the latter one is bedding slope.
- Presence of thin marl horizons interbedded with limestone beds in station No.(2), reduces highly the shear strength parameters of the bedding plane, which is considered as the most probable sliding surface.
- Partial failure of the down slope in station No.(2) makes the rock beds at the upslope in a critical position, (Fig.4).
- High dip amount of sliding plane for stations No.(1 and 2), (85º and 72º, respectively) is much higher than their corresponding values of internal friction angles (φ_p) (35º and 29º) and in this case the planner sliding is more possible.
- The slope in station No.(2) is a natural slope, while that in station No.(1) is a man made, hence, it is logic and predictable that the weathering processes along sliding planes are more intense and active in station No.(2) than that in station No.(1).
- Station No. (1): As the slope is recently exposed, no remarkable slide have been seen in the field except some upslope blocks, which are susceptible to fall down slope, in future.
- Value of φ_p of station No.(1) is greater than that of station No.(2) and the difference between values of φ_p, φ_r in station No.(2) is more greater than that in station No.(1), where it decrease about one third and that is due to difference in weathering degree and roughness of joint surfaces, in both stations.

RECOMMENDATIONS

- Using in situ shear test in order to get representative value of shear strength parameters besides the effects of roughness, undulation, irregularities and filling materials on shear strength.
- Removing the upslope blocks, which are in critical position and liable to fall in future, especially in station No.(1).
- Retaining walls seem to be the more perfect remedial procedure in station No.(2).

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