Studying rock slope stability for the northwestern plunge of Hamrin Anticline fold / North Iraq

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ABSTRACT

The research aims to study rock slope stability for the northwestern plunge of hamrin anticline fold north Iraq in (4) stations in the fatha formation. A survey of the rocky slopes was carried out, which included the engineering descriptions at each station. The study showed that the slopes in the studied stations are classified depending on the relationship of the direction of the strike slopes with the strike of layers to the type of parallel, orthogonal and oblique side types. Through the field study, it was found that the most common occurrence is rockfall, followed by toppling and then wedge sliding and that the probability to occur is rockfall, followed by toppling and then plane sliding and wedge sliding.

Keywords: Fatha Formation, Slope Stability, Toppling, Wedge Sliding

1-Introduction:

The stability of rocky slopes is one of the important problems facing the geologist as his complementary work to the civil engineer, and these problems exist in the form of landslides on the slopes on which roads and railways are based, as well as when building roads for the passage of vehicles and railways or when making designs for digging tunnels, dams and others (Al-Obaidi, 2005). And landslides can be defined as a movement of the land mass (rock and debris of other ground materials) towards the bottom of the slope as a result of its influence by several factors, and the collapse in the rock mass occurs when the stress in the rock mass is greater than its resistance, and therefore slopes are the basis for the occurrence of all land manifestations (Small & Clark, 1982). . The main types of landslides that occur on rocky slopes are (plane slip, wedge slip, toppling, rotational slip, and rockfall) (Hoek and Bray, 1981), as shown in Figure (1).

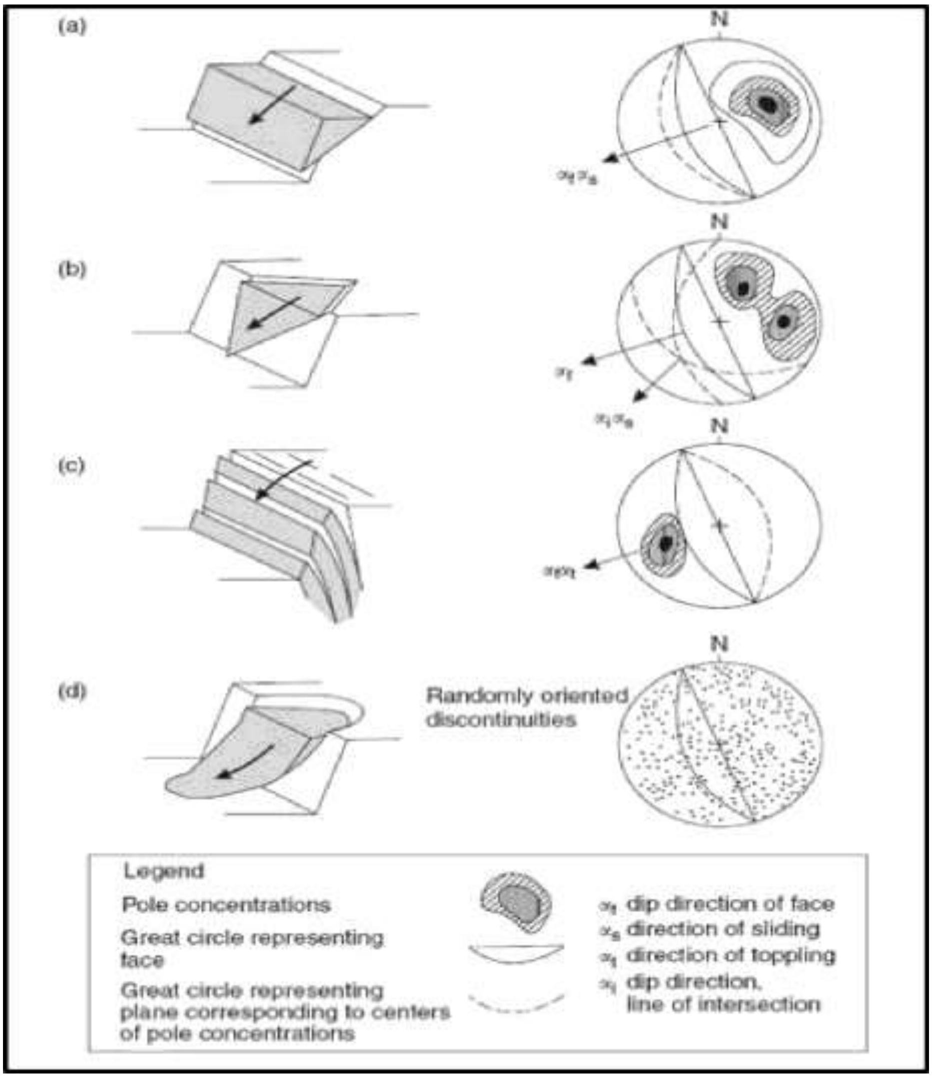


Figure (1) represents the main types of collapse according to (Hoek and Bray, 1981), (a) planar slip, (b) wedge slip, (c) toppling, (d) rotational slip

2- Research Problem:

Due to the multiplicity of accidents of landslides and the consequences of these accidents many risks may result in human and material losses or may lead to the closure of the road and the partial or complete disruption of traffic. Therefore, a study of the stability of the slopes is required to contribute to providing information on the risks caused by the slopes.

3- Research Importance:

1- To learn about landslides and their mechanism of occurrence and what are the most at-risk sites in the study area for the occurrence of such accidents so that we can reduce their risks and educate citizens about the dangers of landslides.

2- Due to the lack of stability studies for the rocky slopes in the study area.

4- Research Aims:

Knowing the types of collapses (occurring and possible) in the field.

5- The location of the study area:

The study area is located in the north of Iraq, about (50 km) to the northeast of the city of Tikrit. The study area is limited between longitudes (43°34'12") (43°33'36") east and latitudes (35°03'20") (35°02'48") north, as shown in Figure No. (2).

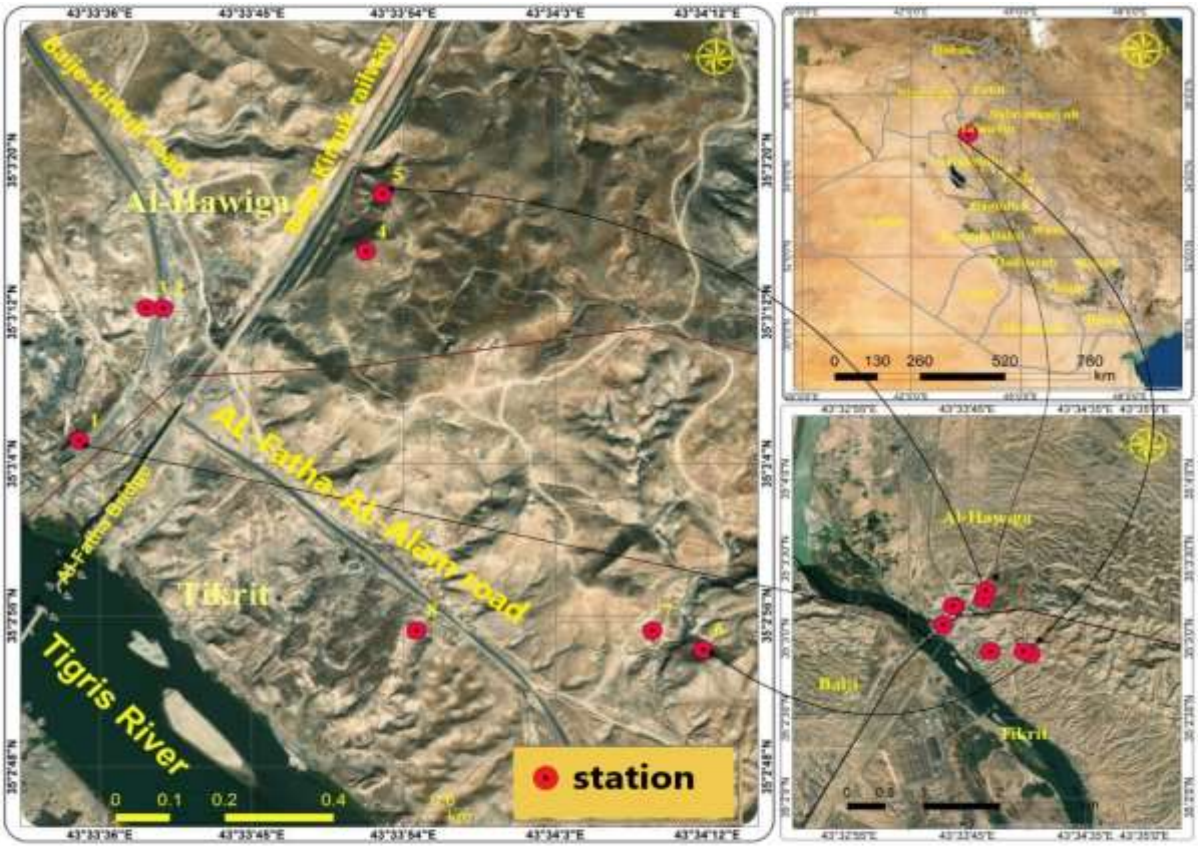


Figure (2) shows the locations of stations in the study area

6- Geology of the study area:

6-1 Formation Exposed

The formation of the fatha is revealed in the study area

6-1-1 Fatha Formation

The formation appears in the form of thick layers of limestone, gypsum, marly stone, and layers of clay stone in succession and its age is the middle Miocene (Kazim et al., 2009), (Belen et al, 1959), and the formation of the fatha is one of the widespread and important formations in Iraq (Al- Juboury, et al, 2001), due to the presence of thick layers of evaporated rocks that form as a cover for most of the geological structures in which oil is located in the north and northeastern regions of Iraq, in addition to the importance of its use in industrial and construction works (Al-Sawaf, 1977.

6-2 Tectonics of the study area

The study area is located within the low folds of the secondary zone (Hamrin-Makhool) as a result of the collision of the Arabian plate with Iranian and Turkish, which is formed from the second phase of the alpine movement (Fouad, 2012).

6-3 Geomorphology of the study area

The study area is characterized by the presence of the cuesta phenomenon, where the layers tend at an angle less than the slope of the slope, and the presence of a drainage pattern of parallel and semi-parallel type, which consists of limestone rocks, and there are valleys of two types, the first type is called transverse valleys, which is directed in a vertical direction to strike of the layers and type the second is called the strike valleys, which are directed in a parallel direction to the strike of the layers.

7-Research Methodology:

This study was conducted in four stages:

7-1 information collecting stage

At this stage, all information about the study area was collected through access to research, reports, publications, aerial photographs, and topographical and geological maps of the study area, which are used during the fieldwork stage.

7-2 fieldwork stage

Fieldwork was carried out in two phases:

The first stage includes making an exploration round of the study area and defining stations for the rocky slopes in the study area.

The second stage includes the following steps:
1- Determining the coordinates of the stations' locations using a GPS device.
2- Measure the width and height of the slope with a tape measure.
3- Measure the position (angle and direction of inclination) of the slope, and the attitude (angle and direction of inclination) of the discontinuities (for layers and joints).
4- The engineering description for rock according to the report proposed by the working group of the engineering group of the Geological Society of London (Anon, 1972, 1977)
5- A detailed survey of the discontinuities in terms of their types and status (direction and angle of inclination), frequency, shape, and extent of aperture.
6- Determining the types of collapses occurring and possible in the field.
7- Collect representative samples for each station of the study area to conduct laboratory tests.

7-3 laboratory work stage

The following test was performed:

1- Unconfined compressive strength: (4) samples of limestone rocks were prepared for the stations in the study area in a cylindrical shape (core models). The test was carried out according to the standard specification (ASTM-D, 2938-95., 2004), and it was classified according to (Anon, 1977), the results of the test are shown in Table (1)

Table (1) Results of the unconfined compressive strength of limestone models, and their classification according to (Anon, 1977)

Classification by (Anon,1977)	**σc1 Mpa**	**Cσ Mpa**	**F KN)(**	**L/D**	**D/L**	**D)mm(**	**L)mm(**	**Station no.**	**Rock type**	**Sample status**
Moderately strong	14.294	14.48	34.4	0.94	1.06	55	50	ST1	**limestone**	**Natural state**
Moderately weak	11.400	12.21	29	0.75	1.32	55	40	ST2		
Moderately strong	13.330	13.77	32.7	0.86	1.15	55	46	ST3		
Moderately weak	10.057	10.57	25.1	0.81	1.23	55	43	ST4		

2- Direct shear: The test was conducted on one sample of marl stone for station no. (2) to find the angle of friction and cohesion of the marl, after preparing the sample for test, it was checked according to the standard (ASTM, D-3080-03,2004), and the results of the test are shown in Table (2)

Table (2) Results of tests (liquidity limit, plasticity limit, and plasticity index)

plasticity index	**plasticity limit**	**liquidity limit**	**lithology**	**Station no.**
30.08	14.88	44.96	Marley Stone	2

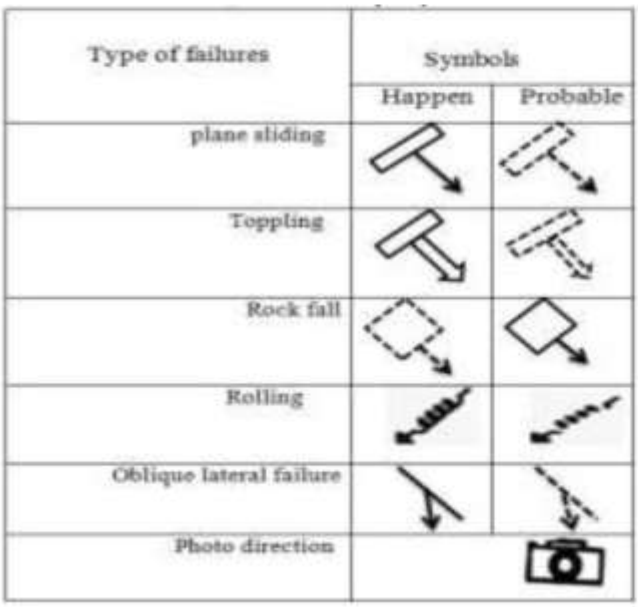
7-4 office work stage

This stage includes an analysis and interpretation of field and laboratory information to identify possible collapses using the (stereonet) program, which requires the use of data from the situation (slope and discontinuities).

8-symbols used to represent information:

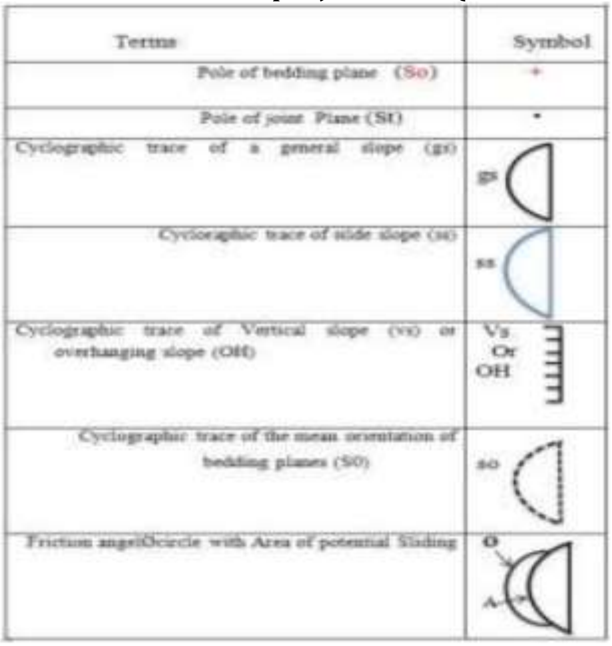
The symbols were used to represent the collapses and an understanding of the stereonet diagram shown in Tables (3) and (4), (Al-Saadi, 1981)

Table (3) illustrates the symbols used to represent the types of landslides on a chart, the stereonet projection, modified of (AL-Saadi, 1981)



Type of failures	Symbols	
	Happen	Probable
plane sliding		
Toppling		
Rock fall		
Rolling		
Oblique lateral failure		
Photo direction		

Table (4) shows the types, poles, and great circles used to represent the field information on the scheme of the stereonet projection of (AL-Saadi, 1981)



Terms	Symbol
Pole of bedding plane (So)	+
Pole of joint Plane (St)	•
Cyclographic trace of a general slope (gs)	gs
Cycloraphic trace of slide slope (ss)	ss
Cyclographic trace of Vertical slope (vs) or overhanging slope (OH)	Vs Or OH
Cyclographic trace of the mean orientation of bedding planes (SO)	so
Friction angel/Ocircle with Area of potential Sliding	O A

9-Evaluation of the stability of the rocky slopes in the study area:

Four stations of rocky slopes were studied in the study area and the assessment of the probability of the occurrence of types of landslides using field information obtained through the field survey was as follows:

9-1 Station no.1

This station is located in the northwestern part of the Hamrin convex fold, according to the coordinates N (35° 03'09) and E (35'33° 43), and it consists of a slope whose attitude is (240°/OH-90°)) with a height of about (4m) and a width of about (2m), and the type of slope is of a parallel type where the value of the angle of deviation is (d = 10°), plate (1), the attitude of the layers is (250°/05°), and the limestone layer has a compressive strength of (14.294) MPa.

In the limestone layer, there are two sets of joints, the first set (set1) with a frequency (2 per 2m) and an attitude (212°/80°), and the second set (set2) with a frequency (3 per 2.5 m) and an attitude (264°/89°).

Through the field survey, it was found that the collapse of the type of rockfall and the occurrence of the collapse of the toppling type, and the expected collapse of the type of toppling collapse and rockfall, due to the presence of the vertical and hanged slope, which leads to the cohesion between the discontinuity being zero (0) and the fall of the rock mass towards the bottom of the slope with the effect of the weight of the rock mass, and the occurrence and possible rockfalls were represented in the spatial projection diagram shown in Figure (3)

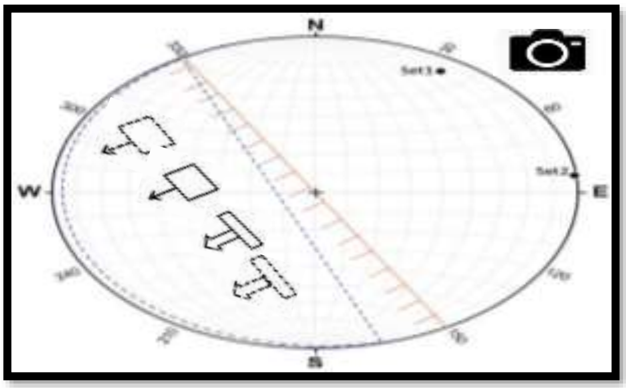


Fig.3: diagram showing the relationship between the slope and the layers and discontinuities, as well as the failure types of station No. (1), the direction of photography (north-east).

Plate.1: Front view of station No. (1)

9-2 Station no.2

This station is located in the northwestern part of the Hamrin convex fold, and at the following coordinates: N (35°03'12) and E (40'33°43'), and its altitude is above sea level (139m), It consists of a slope with a height of about (7m) and a width of about (25 m), and its attitude (222°/OH-90°), plate (2), and the attitude of the layers in this station (017°/10°), and the slope is of a lateral oblique type where the value of the deflection angle is (d=25°), and the limestone layer appears with fine grains in light color, with a thickness of about (1m) and with a weak compressive strength with a moderate value of (11.400) MPa.

The limestone layer is cut by two sets of joints, the first set (set1) with attitude (284/88) and frequency = (3 per 2.5m), and the second set (set2) with attitude (185/78) and frequency =(3 per 2m), and the internal friction angle (Ø=33°). Field-survey, it appears that the collapse is of rockfall and overhang because the slope is vertical to the overhanging due to the presence of a weakly weathering-resistant marl layer, whose cohesion resistance is (C=13.21) kPa and its internal friction angle (Ø=21°), which led to the release of the weight from the center of the supports and the cohesion between the interruptions became zero, which leads to the overturning of the rock mass. The cohesion between the discontinuities is zero (0), and the occurrence and possible failures were represented in the spatial projection diagram, Figure (4).

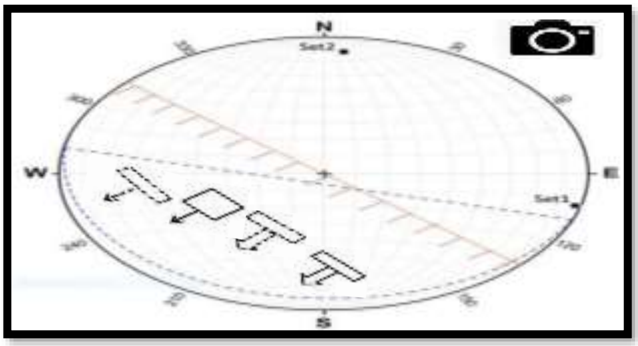


Fig.4: diagram showing the relationship between the slope and the layers and discontinuities, as well as the failure types of station No. (2), the direction of photography (north-east).

Plate.2: Front view of station No. (2)

9-3 Station no.3

This station is located in the northwestern part of the Hamrin convex fold, at the following coordinates: N (03°16'35) and E (43°33'39'), and its height is from sea level (139m). It consists of a slope with a height of about (8 m) and a width of about (30 m), and its attitude (064°/OH-90°), plate (3), and the attitude of the layers in this station (240°/07°), the plate, and the type of the slope is of the parallel type because the angle of deviation is (d=4°), and the limestone layers appear with fine grains in a light color and with a thickness of about (3.5m), and with a moderately strong compressive strength of (13.330) MPa.

The limestone layer is cut by two sets of joints, the first set (set1) with an attitude (014°/80°), frequency =(4 per 2m), and the second set (set2) with an attitude (104°/83°), frequency =(3 per 2m), and the value of the internal friction angle (Ø=31°). In the field, it appears that the collapses occurring in it are of the type of rockfall, and the collapses that are expected to occur are of the wedge slip type and the type of rockfall, due to the presence of the vertical and overhanging slope (OH) and when the cohesion between the discontinuities becomes zero (0) the mass is allowed to fall down the slope due to the weight of its weight, and the occurrence and possible collapses were represented in the spatial projection diagram, Figure (5)

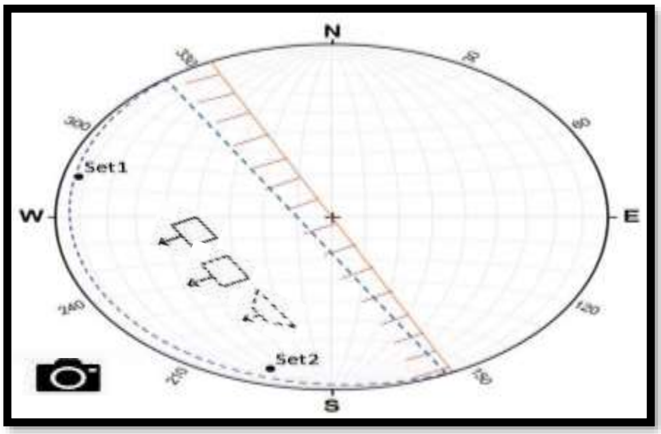


Fig.5: diagram showing the relationship between the slope and the layers and discontinuities, as well as the failure types of station No. (3), the direction of photography (south-west).

Plate.3: Front view of station No. (3)

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9-4 station no.4

9-4 Station no.4

This station is located in the northwestern part of the Hamrin convex fold, at the following coordinates: N (35° 03'19) and E (52°33° 43'), with a height above sea level (160 m). It consists of a slope with a height of about (7m) and a width of about (15m), and its attitude (300°/OH-90°), plate (4), and the attitude of the layers in this station (040°/10°), and the type of slope is of the orthogonal type where the value of the deflection angle is (d=80°), and the limestone layers appear with fine grains, with a thickness of about (3m), and with a moderate compressive strength of (10.057) MPa.

The limestone layer is cut by two sets of joints, the first set (set1) with an attitude (330°/90°), frequency = (4 per 2m), and the second set (set2) with an attitude (210°/68°), frequency =(4 per 2m), and the value of the internal friction angle (Ø=31°). In the field, it appears that the collapses that occur in it are of the type of rockfall and toppling collapse, and the collapse that is expected to occur is of the type of toppling collapse, and it is expected that the rockfall of the blocks at the top of the slope will be overhanging slope when the cohesion between the discontinuities becomes zero (0). Occurring and possible collapses in the spatial projection diagram, Figure (6)

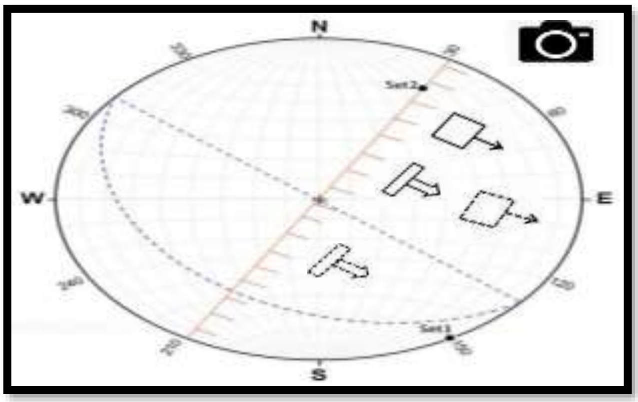

Fig.6: diagram showing the relationship between the slope and the layers and discontinuities, as well as the failure types of station No. (4), the direction of photography (north-east).

Plate.4: Front view of station No. (4)

10-Results and Discussion:

After an engineering geological survey of the stations in the study area was conducted and the types of possible collapses of the stations in the study area were determined, it was found that in the field the collapses were of the rockfall type, and then the direct toppling and then the plane slip and that the collapses that are possible to occur are of the toppling type and then the falling rock and then wedge slip and plane slip.

11- Conclusions:

1- The type of rocky slopes in the study area were of the type (parallel, orthogonal and lateral oblique).

2- Through field study, it was found that most of the rocky slopes consist of two parts (the upper part) with high resistance to weathering represented by limestone rocks and (the lower part) being less resistant and affected by weathering processes, which are represented by the Marley rocks.

12- Recommendations:

1- Conducting a recent (tectonic and seismic) study of the study area, which is important for the stability of the rocky slopes.

2- Placing warning signs alerting passersby of the danger of landslides along unstable slopes.

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