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Slope Stability Assessment of The Garin Majjed Archeological Village Area, East of Yemen

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ABSTRACT

The stability assessment of sedimentary rock slopes of the area surround Garin Majjed archeological village which lay on cuesta shape hill in Wadi Dawa'an - East of Yemen was carried out. All important factors affecting slope stability in the area such as differential weathering, rainfall and runoff, sewage, discontinuities trends and inclinations, slope face orientation, and mechanical properties of rocks and joints filling materials were evaluated. Direct shear test of joints filling materials showed that the friction angle (Φ) values range between 11˚ and 31˚ and cohesion (C) Values between 0.00 and 0.5 MPa. The compressive strength (cσ) values of the nodular limestone rocks is 66 MPa and for shaley marly sandstone it is 12 MPa. It was found that rock fall is the main mode of failure in the area, while secondary toppling and/ or plane sliding are probable to occur. Some remedial measures are proposed to protect the slopes like erect well seal drainage path, supporting the toe of the dip slope and the overhanging parts, as well as grouting of joints by convenient filling material.
Keywords: Slope Stability, Garin Majjed, Archeological Village, Cuesta shape, Yemen.

1. INTRODUCTION

The study area is located at Wadi Leimen, the western tributary of Wadi Dawa'an which is 600 km to the south – east of Sana'a city; capital of Yemen (Fig.1). Wadi Leimen is U-shape Wadi to mountainous area with hot dry climate. The annual average temperature ranges between 9°- 42°c and the annual precipitation ranges between 50-150 mm/year (Al-kharasane, 2005) with a considerable vegetative cover.

This research aims to evaluate the slope stability of the area surrounding Garin Majjed archeological village which is one of the most important tourist villages (Photo.1) in Wadi Dawa'an (Ben Slman, 2007 and General Tourism Authority, 1999).

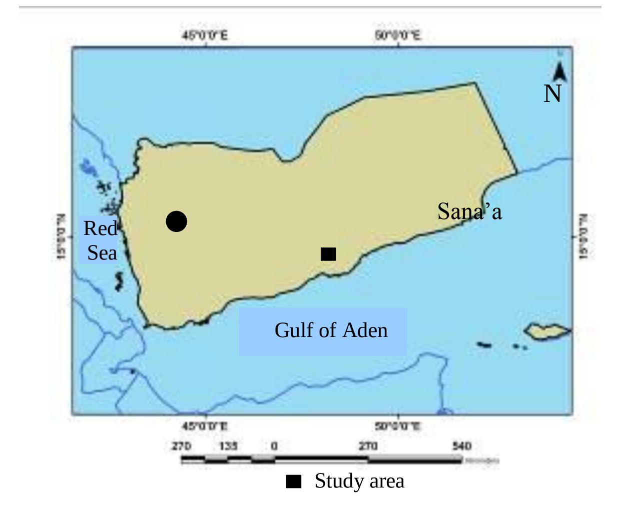


Figure (1): Yemen map showing the location of study area.

Photo (1): Side view of Garin Majjed archeological village. Photo direction south-east

The important factors affecting slope stability in the study area were evaluated. These include differential weathering and erosion, rainfall and runoff, sewage, discontinuities trends and inclinations, slope face orientation, engineering characteristics of rocks and their discontinuities as well as determining the type and direction of failures.

The engineering characteristics of the rock mass and discontinuities were described according to the geological society engineering group working party (Anon, 1972). The relationship between slopes faces and beds attitude are classified according to Al-Saadi's slope classification (AL-Saadi, 1981). The inclination of slope (or dip of strata) is indicated by two numbers, the one to the left (three digits) represents the direction and the one to the right (two digits) represents the dip angle. The symbol (OH) is used for overhanging slopes.

Stereographic projection was carried out to show the relationship between slope faces and discontinuities using Rock Pack III computer program.

The laboratory tests include performing a compressive strength test for 6 samples of nodular limestone and shaley marly sandstone as well as shear box test for 5 samples of discontinuities filling materials to estimate the two shear strength parameters; friction angle (Φ) values and cohesion (C) values. The tests are carried out in the laboratory of the ministry of public works & highway in Sana'a.

2. GEOLOGY OF THE STUDY AREA

The study area is located to the east of the Arabian shield as a part of the Arabian shelf (Beydoun et al., 1998). It is affected by faults and joints which associated with the opening of the Gulf of Aden since Oligo- Miocene. The dominant trends of these geological structures are NW-SE and NE-SW (Fig. 2).

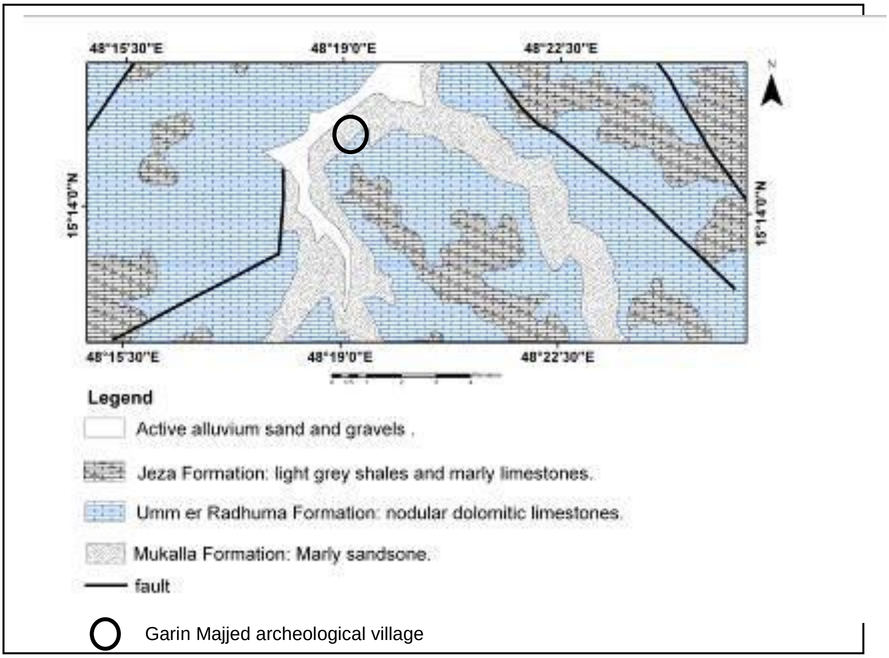


Figure (2): Geological map of study area (Modified after Robertson Group, 1990)

The Garin Majjed archeological village stands above cuesta shape hill with a dip (back) slope of 295°/30°, scarp- overhanging slope (090°/OH) and Southern side slope of 180°/80°-OH° (photo2 & Fig. 3). The average dip of contact between two rock units of the cuesta is 270°/26°. The upper part of the cuesta shape belongs to the Umm er Radhuma Formation (Upper Paleocene) which consists mainly of yellow and grey nodular limestone with some marl while the basal part belongs to Mukalla Formation (Cretaceous) which consists mainly of sandstone with some shale, silt and marl. Jeza formation (Early Eocene) outcrops to the east, south and west of study area. This formation belongs to Hadramawt Group and consists of a series of yellow and pink papery shales with beds of marl and limestone (Beydoun et al., 1998).

3- ROCK MASS DESCRIPTION AND SLOPE STABILITY ANALYSIS

The Cuesta shape rock mass outcrop in Garin Majjed archeological village area consists of two rock units as mentioned before (Figure 2). In the upper part, a 12 m thick layer is exposed. It is grey, fine grained, very thickly bedded, moderately to very widely spaced joints, slightly weathered, nodular LIMESTONE, strong with uniaxial compressive strength (σc) of 66 MPa. The 5 m thick layer in the lower part of slopes is light yellowish brown, fine to medium grained, very thinly bedded, closely spaced joints, moderately to highly weathered, shaley marly SANDSTONE moderately weak with compressive strength (σc) of 12 MPa.

The limestone layers are cut by two main cracks, one in the attitude of 285°/62° and the other with attitude of 005°/86°. Stereographic projection of these two main cracks is shown on Figure 4D. The horizontal sandstone layers are cut by three sets of joints, S1, S2 and S3. The average dip of S1 joints is 265°/87° and the joints spacing are of >3 m. The persistence is about 2 m on the bedding planes and slope surfaces. The joints are almost close. The average dip of S2 joints is 205°/90° and the spacing ranges between 0.25-0.60 m while the persistence ranges between 0.20-0.40 m on the bedding planes and they are almost close. The average dip of S3 joints is 113°/90° and the spacing ranges between 0.20-0.40 m, their persistence ranges between 0.20-0.70 m on the bedding planes and they are almost close. Stereographic projections of S1, S2 and S3 are shown on Figures 4 A and C.

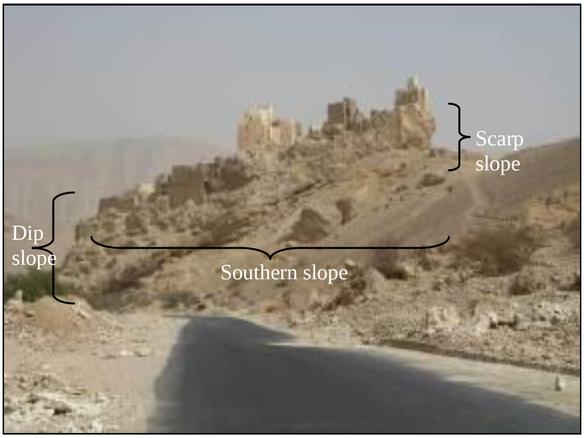


Photo (2): Side view of cuesta shape showing different slopes around the village. Photo direction to the north.

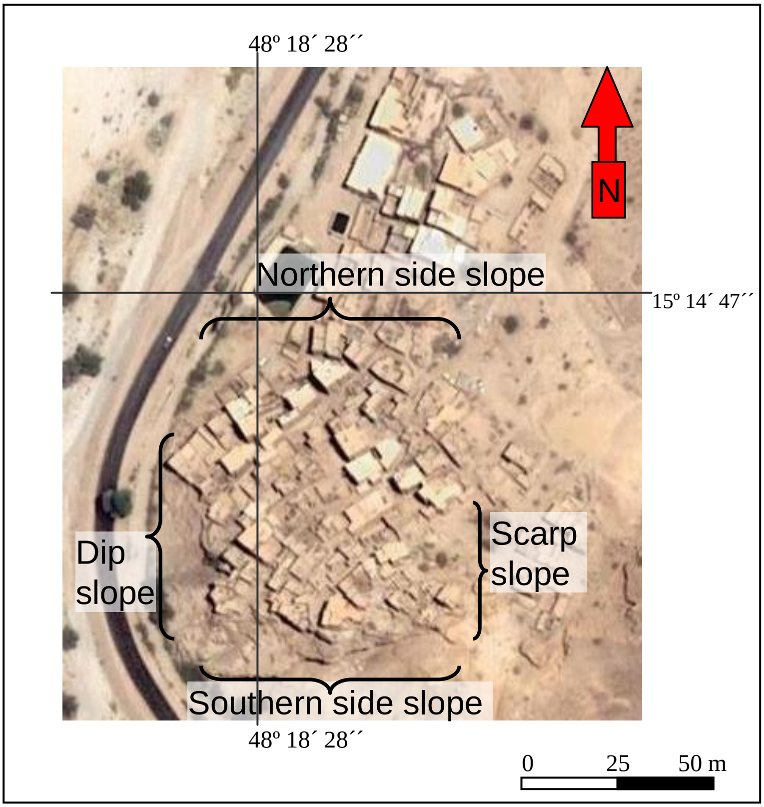
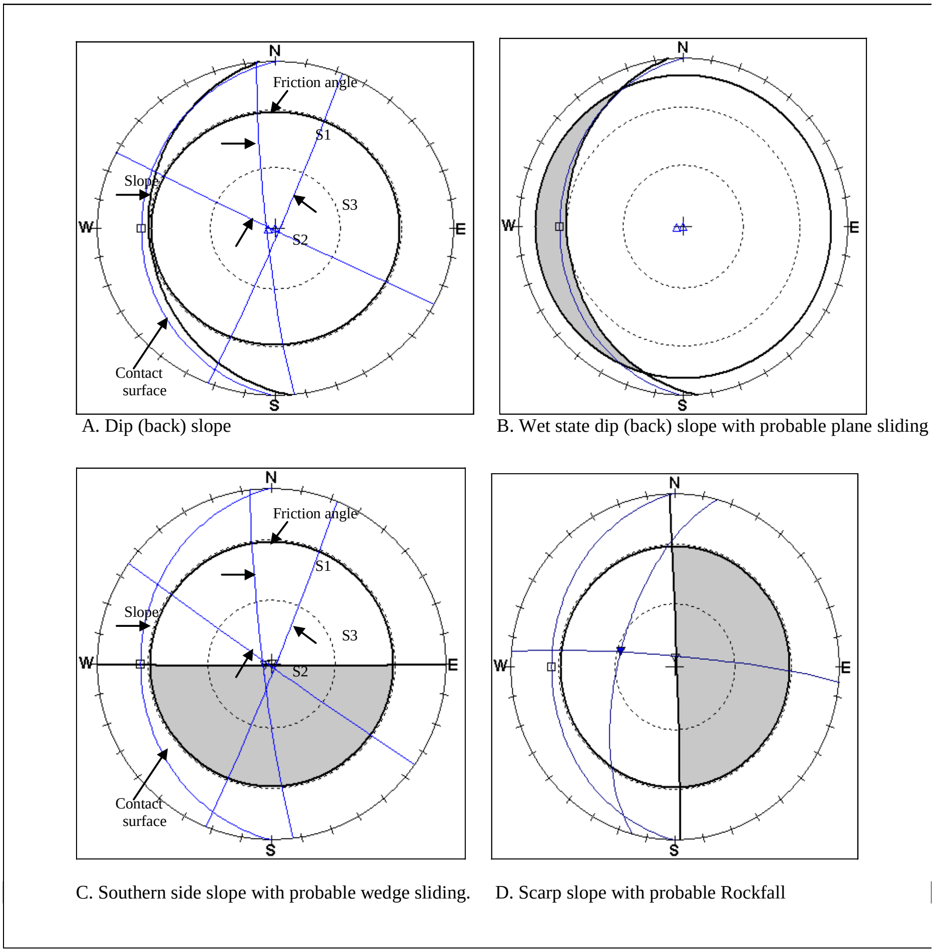


Figure (3): Satellite image showing the areal distribution of slopes in study area, (Google earth).

The areal distribution of slopes in the study area is shown in Figure 3. It can be divided into four main slopes. These are:

(i) Dip (back) slope
The slope is close to the main road as shown on Photo 2. It is 45 m high and 60 m long parallel to its trend. The slope inclination is 295°/30° with average dip of 270°/26° and it is daylighting at right part. According to Al-Saadi's slope classification this slope is parallel slope with 15° divergence angle and left emergent concordance (Fig. 4A & B),

(ii) Scarp slope
This slope is 15 m high and 20 m long parallel to its trend. The slope inclination is 088°/OH° with average dip of 270°/26° (fig. 4D). According to Al-Saadi's slope classification, it is a parallel slope with 02° divergence angle, right emergent and disconcordance.



A. Dip (back) slope

B. Wet state dip (back) slope with probable plane sliding

C. Southern side slope with probable wedge sliding.

D. Scarp slope with probable Rockfall

Figure (4): Stereographic projections showing the relationship between slopes (thick great circles), (□)contact surface, (▲) cracks, (△) joints S1, S2 & S3, and area of potential sliding for friction angle of 31° & 11°.

(iii) Southern side slope

The slope is 45 m high and 60 m long parallel to its trend. The slope inclination is 180°/80°-OH°) and the average dip of contact between the two rock units of the cuesta shape is 270°/26° (Fig. 4C). According to Al-Saadi's slope classification, it is orthogonal slope with 90° divergence angle.

(iv) Northern side slope

The slope is 45 m high and 60 m long parallel to its trend. The slope inclination is 360°/23° with average dip of 270°/26°. According to Al-Saadi's slope classification, it is orthogonal slope with (90°) divergence angle (AL-Saadi, 1981).

4- RESULTS AND DISCUSSIONS

The laboratory tests include performing of compressive strength as well as shear box tests. The average compressive strength of fresh to slightly weather nodular limestone (σ_c) is 66 MPa which indicate strong rock. This value decrease rapidly by weathering resulting from seasonal rainfall and runoff as well as from local sewage. For fresh to slightly weather shaley marly sandstone, the average compressive strength is 12 MPa. This value indicates moderately weak strength rock. Evaluation of the two shear strength parameters namely friction angle (Φ) and cohesion (C) for unconsolidated filling materials of discontinuities indicate $\Phi = 31^\circ$ and C = 0.22 MPa under 16 % moisture content and $\Phi = 11^\circ$ and C = 0.013 MPa. under moisture content of 29%. This mean that the friction angle of unconsolidated materials with more moisture content is smaller than sliding plane (contact surface) inclination which has dip of 26°

The discontinuities dissected the upper back slope as well as the exfoliation weathering of limestone help rainfall and sewage to penetrate inside the rock mass and reach the jointed marly sandstone. This resulting in disturb slope stability of the area. The scarp slope and southern side slope are strongly affected by this action; therefore, rockfall failure is dominant. Stereographic projection indicates wedge sliding along southern side slope but due to moderately wide spaceof joints, the rockfall occurs instead of wedge sliding for small rock fragments.

The northern side slop is rather stable. Although the dip (back) slope is stable at present, it may reach a critical state of secondary toppling (Hoek, E. & Bray, J.W., 1981) or plane sliding in the future if toe cutting by rabid differential weathering resulting from surface sewage and seasonal rainfall and runoff continue.

Because this village is one of the most important tourist villages in Wadi Dawa'an, and due to its heritage value, it is necessary to take some construction measures to treat the instability problem of the dip (back) slope, southern side slope and scarp slope. The following treatment may achieve:

1- Removing the unstable blocks which are liable to fall in the scarp slope.
2- Erecting well seal drainage conduit.
3- Supporting the toe of the dip (back) slope and the overhanging part of the southern side slope by retaining wall.
4- Grouting of discontinuities by convenient filling material like cement in order to increase the cohesion of the different parts of the rock mass and to prevent water infiltration to the lower part of the slope.

5- CONCLUSIONS

1- Weathering is the dominant cause of failure in the study area and most of discontinuities help to separate the rock blocks out of the slope.
2- The northern side slop is rather stable.
3- Rockfall is the main mode of failure that occurs in scarp and southern side slopes.
4- Sliding and/ or toppling are the probable mode of failure in dip (back) slope.
5- The treatment must be applied with well aspect.

6- ACKNOWLEDGEMENT

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7- REFERENCES

AL-Saadi, S.N., 1981, A Method for Mapping Unstable Slopes with Reference to the Coastline of S.W. Dyfed, Wales, Unpub. PhD. Thesis, University of Bristol. 252P.

Anon, 1972, The preparation of Maps and Plans in Terms of Engineering Geology, Quarterly Journal of Engineering Geology, Vol.5, No.4, PP;293-382.

Al-kharasane, M., 2005, index of agriculture climate in Yemen (1881-2004), (in Arabic).

Ben Slman, S., 2007, Rhythm of life in Wadi Dawa’an, Dar Hadramout publishing co., 248p (in Arabic).

Beydoun, Z.R., As-Saruri M.A.L., EL-Nakhal, H. AL-Ganad, I.N. Baraba, R.S., Nani, A.S.O., AL-Aawah M.H., 1998, International Lexicon of Stratigraphy Vol.III, ASIA, Republic of Yemen, IUGS and Ministry of Oil and Mineral Resources Sana'a, R.Y., 2nd ed., 245P.

General Tourism Authority, 1999, tourism surveying result (1996-1999), part 4, Hadramout, Suqatra, Almahra, 28P. (in Arabic).

Hoek, E. & Bray, J.W., 1981, Rock Slope Engineering, 3rd. ed., Institution of Mining and Metallurgy, London, 358P.

Robertson Group plc, 1990, Geological map of Yemen, scale (1:250000) Sayun, sheet 15J, Ministry of oil & mineral resources, Sana’a, Republic of Yemen.

تقييم استقرارية المنحدرات الصخرية
في منطقة قرية قرن ماجد الأثرية – شرق اليمن

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ملخص

في هذه الدراسة تم تقييم إستقرارية المنحدرات الصخرية المحيطة بقرية قرن ماجد الأثرية و التي تقع على مرتفع من الصخور الرسوبية بشكل الكويستا في وادي دوعن - شرق اليمن. إذ تم تقييم جميع العوامل المؤثرة في عدم الإستقرارية في المنطقة مثل التجوية التفاضلية، سقوط المطر والسيول، الصرف الصحي، اتجاه و ميل الانقطاعات، اتجاه و انحدار وجه المنحدر، و الصفات الميكانيكية للصخور و المواد المالئة للانقطاعات. أظهرت نتائج فحص القص المباشر للمواد المالئة للفواصل أن قيم زاوية الاحتكاك الداخلي (Φ) تتراوح بين 11° و 31° و قيم التماسك (c) بين 0.00 و 0.5 ميقاباسكال. أما قيم المقاومة الانضغاطية فكانت 66 ميقاباسكال للصخور الجيرية العقدية و 12 ميقاباسكال للصخور الرملية المارلية الطفلية. خلصت هذه الدراسة إلى أن نمط السقوط الصخري هو الانهيار السائد في المنطقة كما توجد احتمالية لحدوث انهيارات من نوع الانقلاب الثانوي و / أو الانزلاق المستوي. بناءا على نتائج هذه الدراسة تم اقتراح عدد من الإجراءات الوقائية لحماية منحدرات منطقة الدراسة مثل إنشاء قنوات تصريف مبطنة، تدعيم أساس سفوح منحدر الميل و الأجزاء المعلقة و حقن الفواصل بمواد مالئة مناسبة.