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ROCKMASS QUALITY AT THE FOUNDATION AREA OF THE SIMONOS PETRA MONASTERY, IN MOUNT ATHOS - GREECE.

SUMMARY

Simonos Petra Monastery is a historical building of the 13th century lying at the south-western coast of Athos peninsula that consists part of a seismically very active region. In the present investigation the geomechanical conditions of the Monastery foundation area are studied, regarding the classification of the rock-mass and the analysis of the rock slope stability. The quality of the rockmass was determined using the Bieniawski classification method. The results of the above elaboration were also used for plotting sketches of rockmass quality and stability of the foundation area, in order to establish the more rational way for conservation

RESUME

Le Monastère de Simonos Petra est un bâtiment historique, du 13ᵉ siècle, situé sur la cote sud-occidentale du presque île Athos, qui fait partie d'une region de sismicité active. Dans cet étude les conditions géotecniques dans la zone de fondation du monastére ont été étudiées par classification de la rochemasse et analyse de la stabilité des pentes. La qualité de la rochemasse a été determinée par la méthode de Bieniawski. Les resultats de l'elaboration ci-dessus ont été aussi utilisés pour faire les plans de qualité et de stabilité de la rochemasse, pour que la méthode de conservation la plus rationaliste soit utilisée.

1. INTRODUCTION

Foundation rock stability conditions are of particular interest, especially in regions like the Mediterranean Basin, where tectonic conditions are very active. In this framework a particular area of Mount Athos was studied by means of the geotechnical conditions at the sites where many important monasteries are built. Simonos Petra Monastery was used as a good example to provide the influence of the tectonic conditions existed to the stability of the building.

Mount Athos peninsula is located in Northern Greece and belongs administratively directly to the Patriarchate of Constantinople. It is an area of great historical and religious interest, where only Monasteries for men are built. Many, probably active, neotectonic faults, of N-S and E-W directions, traverse the area, causing damage to the Monasteries.

Simonos Petra Monastery was built up around 1257 AD, on an isolated and uplifted rock (altitude 305 m) at the S/SW site of the peninsula (Fig. 1).

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It was burnt down several times, so as only the lower parts of the construction, near the rock base is of that age. The western part of the present building was built in 1590 AD while the eastern part in 1890 AD (KADAS, 1989).

The area was investigated by means of geomechanical rockmass classification and slope stability analysis. The interpretation of the collected data determined the probable surfaces of sliding that can be activated under specific conditions and loading. The activity of important discontinuities was also investigated, with in situ measurements, using specific instruments, such as strainmeters and extensionmeters, so as to determine their probable relationship with the existed neotectonic faults.

2. GEOLOGY

The broader study area geologically belongs into the Serbomacedonian zone, an old massif. It consists of palaeozoic or older two mica gneisses, plagioclase - microcline gneiss, marbles and amphibolites, as well as mesozoic intrusion (biotite granite with transitions into biotite hornblende granite-granodiorite). Sills and dykes of leucocratic aplitic muscovite-granite are frequent.

Normal faults (N-S and E-W) and typical extension joints and open fractures, which post date the ductile deformation, characterise the neotectonic

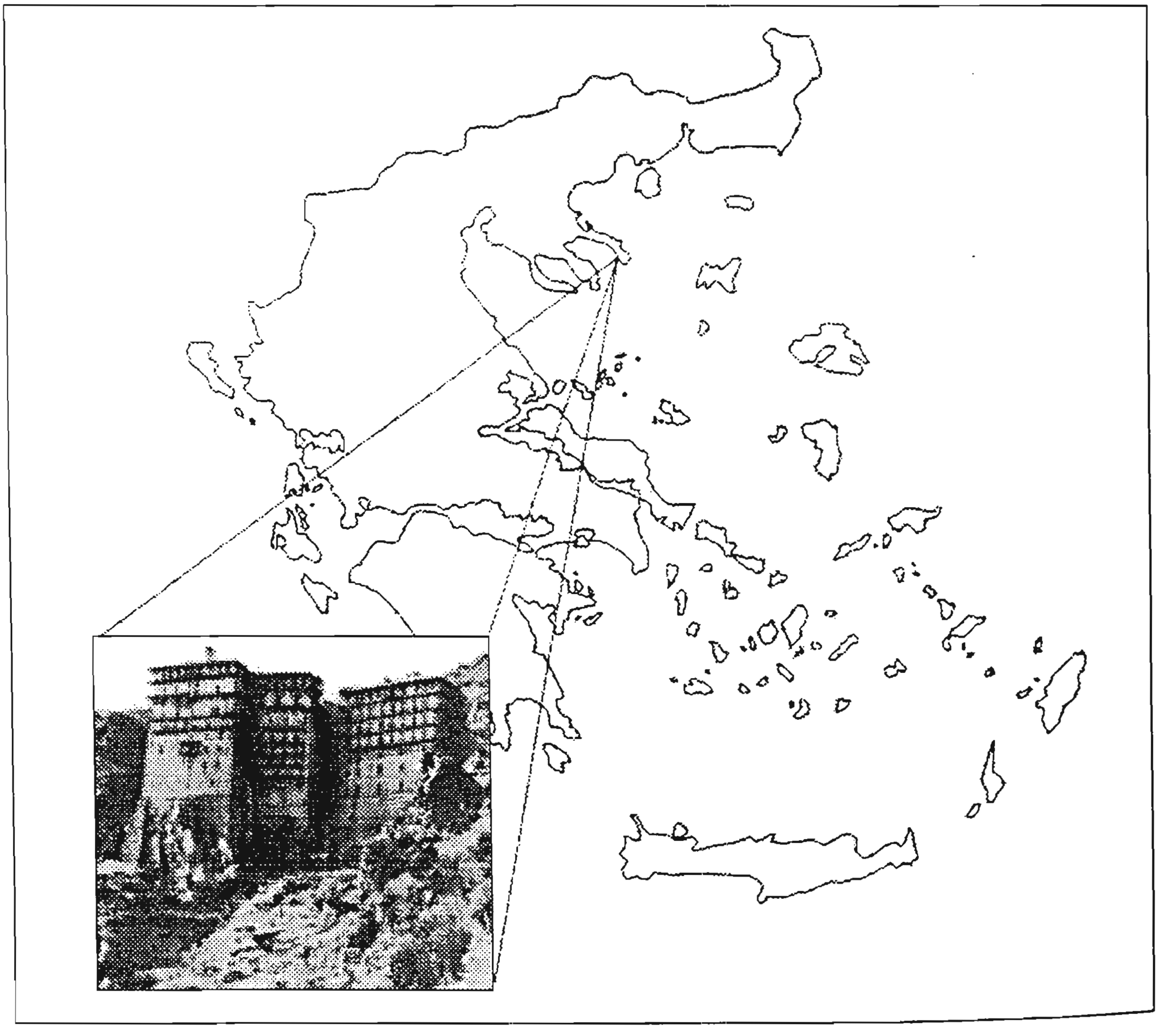

Fig. 1 - Location of the Simonos Petra Monastery.

pattern of the area. Polished steep fault surfaces in the granite, mainly uneroded, striated mirrors, rock faults, open cracks establish the neotectonic, if not active, tectonic regime.

The change of the opening in tectonic structures of the above directions, in the foundation area, ensure their influence on the stability of the Monastery.

3. ROCKMASS QUALITY

Many important faults of E-W and N-S general directions are occurred in the area. A medium to closely spaced net of joints, with rough surfaces, is related to the above tectonic directions. From a first point of view, these discontinuities could cause unstable geotechnical conditions to the rockmass, especially at the slopes of the construction area (Fig. 2).

Widely spaced joints, of eastern dip direction, are occurred too. Their aperture is usually narrow. Joints are usually unfilled. Although some fractures are filled with breccia of granite or rather with soil.

The rockmass quality was investigated at several representative sites, and a geomechanical classification was performed using the BIENIAWSKI (1974) method (Tables 1 and 2, Fig. 3).

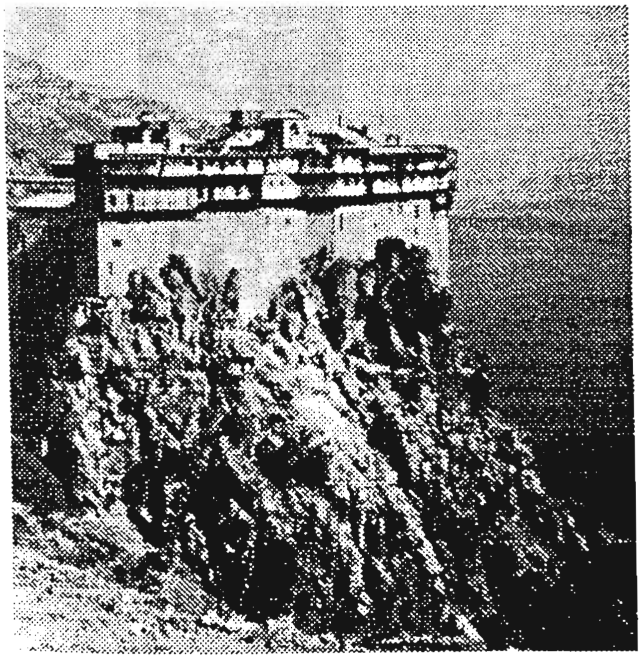

Fig. 2 - The rockmass where the monastery is constructed.

TABLE 1 - Geomechanical classification of the rockmass, according to the Bieniawski method (1974).

SITE	W,X	U,V	T,T1	O,N
Strength of intact rock material	7	4	4	7
R.Q.D.	13	17	17	17
Spacing of discontinuities	10	8	10	15
Condition of discontinuities	0	25	30	25
Ground water	10	10	10	10
Total	40	64	71	74
Rating adjustment for joint orientation (slopes)	-5	-25	-5	-5
Total score	35	39	66	69
Rock mass class	IV Poor	IV-III Poor-Fair	II Good	II Good

TABLE 2 - Geomechanical classification of the rockmass, according to the Bieniawski method (1974).

SITE	Q,Q1, P,P1	R,S	K,K1,L	M,M1
Strength of intact rock material	7	4	4	7
R.Q.D.	17	17	17	13
Spacing of discontinuities	10	10	8	8
Condition of discontinuities	25	25	10	20
Ground water	10	10	10	10
Total	69	66	49	58
Rating adjustment for joint orientation (slopes)	-5	-5	-5	-5
Total score	64	61	44	53
Rock mass class	II Good	III-II Fair-Good	III Fair	III Fair

According to the above investigation, the southern part of the foundation area presents a poor to fair rockmass quality, corresponds to the most unstable part of the monastery. Furthermore, an engineering geological sketch of the surrounding area, with faults and joints, expressed by the jointing degree, given in Figure 4, verifies the above observations.

Field measurements were interpreted statistically and the results were plotted in equatorial stereonets (Fig. 5). Slope direction as well as daylight envelope (DE) of joints that rise on the corresponding slope face are given in the stereonets in order to determine plane failures. The intersections of joint sets that determine probable wedge failures, are also given for representative sites, using the tests proposed by MARKLAND (1972), HOCKING (1976) and HOEK and BRAY (1981). A friction circle (FC) with probable, general phi=30° was also plotted in every stereonet for this purpose.

The wedge and plane failures that could produce sliding were interpreted and the factors of safety (F) were calculated for each case (Fig. 6). According to the above interpretation, the wedges created at the points C and E of Fig. 5, on the western slope of the foundation area, gave factors of safety higher than 1 (Fig. 6). On the other hand, the factors of safety calculated for the failures determined at the points J1, J2 and I of Fig. 5, on the southern slope of the foundation area, take values from 0.48 to 0.98, creating unstable conditions in the area (Fig. 6). The factors of safety were calculated for the sec seasons, without having taken in mind the water content of the fractures, during humid periods. This parameter lower the calculated factors of safety, creating more unstable conditions, especially during winter where freezing phenomena of the water are occurred.

The geometry, roughness, water pressure, external forces and other engineering characteristics of the discontinuities are not the only causes for the

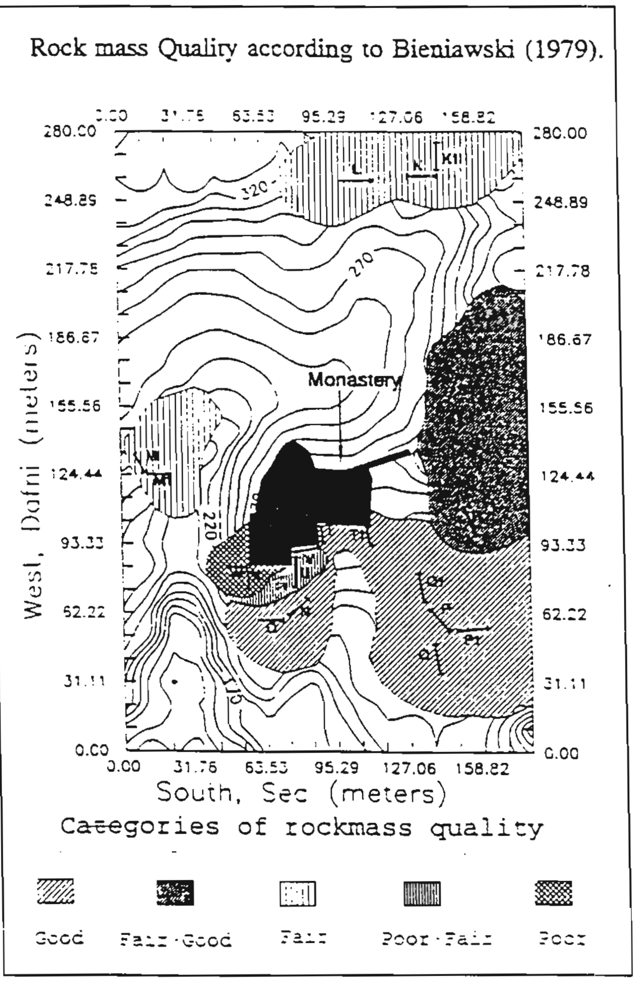

Fig. 3 - Sketch of the monastery surrounding area with zones of similar rockmass quality (Q, P, ...: sites of investigation).

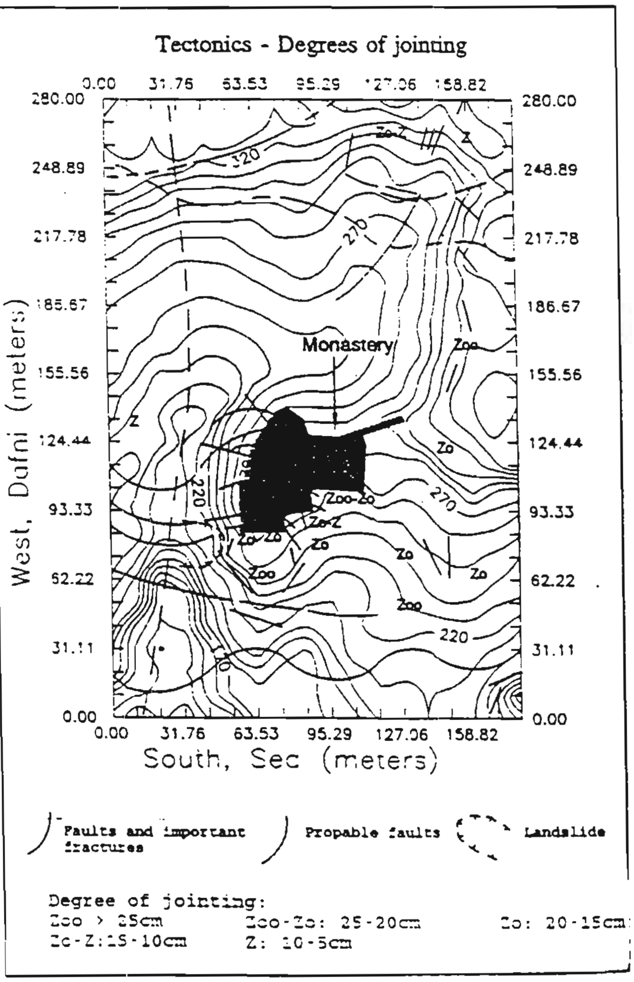

Fig. 4 - Sketch of the surrounding area with important faults and joints. Joints are expressed by the jointing degree.

instability of the rockmass. The tectonic structures determined in the broader area could also affect the foundation rockmass. In this framework an important neotectonic fault or megajoint of SW dip direction (216°/80°) devides the rockmass in two halves at the site C, decreasing the safety of the Monastery. A similar probable fault (200°/80°) also exists at the site E. Small faults also affect at the southern part of the Monastery. Furthermore, an important fault of N-S direction, cut the building near by its western wall, causing also damage both to the building and the foundation rock. After June 1993, the opening of these discontinuities is measured, in every three months, in order to determine recent tectonic creep. Until to now, only three different measurements have been made, so no definitive result can be extracted. Although an opening change of 0.08 mm/year was already measured, using a DEMEC gauge N. 4711, of W.H. Mayers and Son (Windsor) Ltd. with error 0.002 mm.

4. CONCLUSIONS

The site investigation at Simonos Petra Monastery gave the following results: The rock-hill, where the Monastery is built, is traversed by important neotectonic faults and joints, mainly of E-W and N-S general directions, affecting the stability of the foundation rockmass. The quality of the rockmass was described using the Bieniawski method. According to this elaboration a sketch of similar quality zones was plotted. Furthermore a slope stability analysis was performed with the determination of important unstable wedge and plane failures. The factors of safety of these failures were calculated resulting values lower than 1. Both investigations shown that the rockmass, in the southern part of the monastery, is very low and of limited stability, causing damage to the monument.

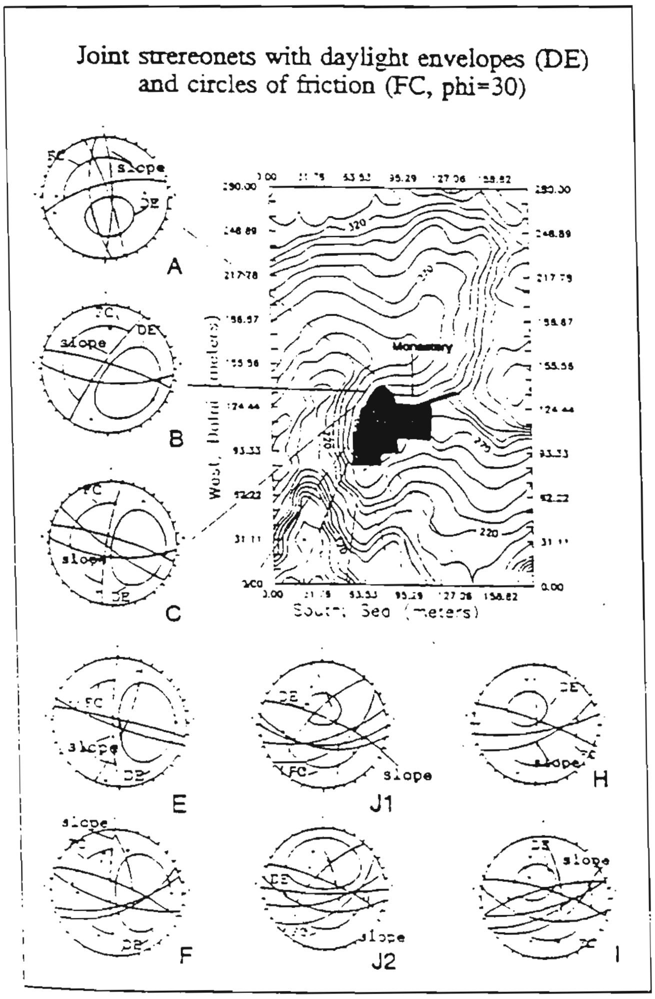

Fig. 5 - Plane and wedge failures at the foundation area of the monastery (Christaras & Moropoulou, 1994).

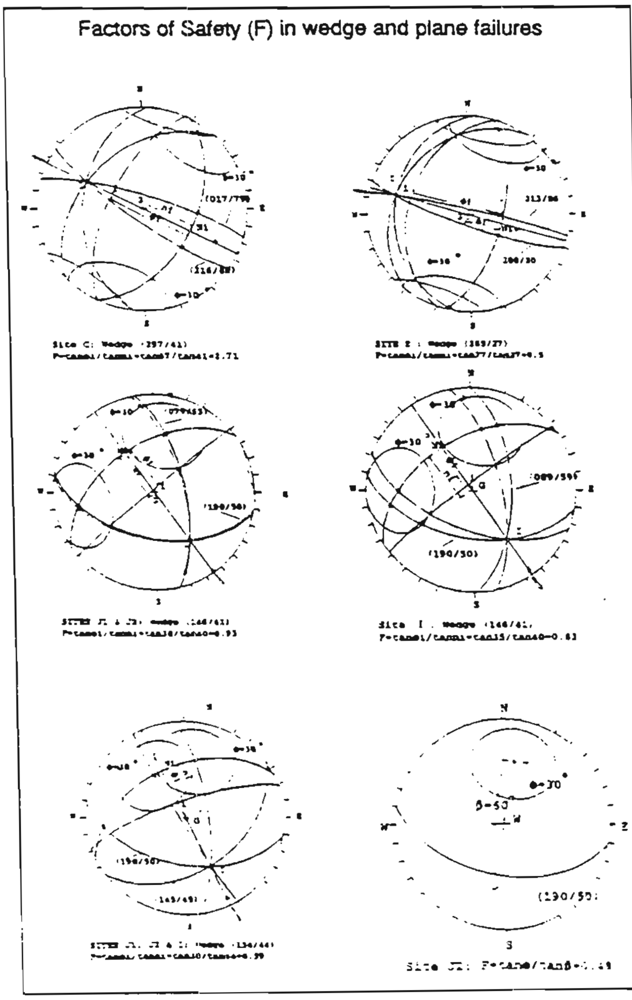

Fig. 6 - Factors of safety (F) at representative sites around the building (Christaras et al., 1994).

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