# SLOPE INSTABILITIES IN PROTECTED HISTORICAL SITES. THE CASE OF THE MONASTERIES OF MOUNT ATHOS, IN N. GREECE

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The monuments need protection particularly in regions like the Mediterranean basin, where the seismotectonic regime is active, and the geomechanical conditions are complex. Phenomena like, settlement and slope movements as well as earthquakes and tectonic activity contribute to the damage of the historical buildings. The ground water activity is also an important factor, especially in cases where monuments are buried in the soil or they are founded on steep slopes.

The methods used for the stabilization of the slopes can be classified in the following categories: a) change of the slope geometry to decrease the driving forces or to increase the resisting forces, b) control of surface water infiltration to reduce seepage forces, c) control internal seepage to reduce the driving forces and to increase material strength, d) provide retention to increase the resisting forces.

The more common used drainage methods are related to the construction of deep wells, vertical drains, subhorizontal drains, drainage galleries, interceptor trench drains and relief trenches.

The various methods of retaining hard rocks slopes are the following: a) concrete pedestale, b) rock bolt for jointed masses, c) bolts and concrete straps for intensely jointed masses, d) cable anchors to increase support depth, e) wire mesh to constrain falls, f) impact walls to deflect or contain rolling blocks, g) shotcrete to reinforce loose rock, with bolts and drains, h) shotcrete to retard weathering and slaking of shales. In soil slopes, the various types of retaining walls are classified into a) gravity walls, b) non gravity walls (basement walls, bridge abutment, anchored concrete curtain wals), c) rigid walls (concrete walls) and d) flexible walls (gabion walls).

In the present paper, the Monastries of Simonos Petra, Dionisioy, Grigoriou, St. Paul, Stavronikita and Koutlomoussi, in Mount Athos (N. Greece), were investigated by means of the geotechnical failures and the intervention methods proposed or used. Mount Athos peninsula is an area of great historical and religious interest, where only Monasteries for men are built. Administratively, the area belongs directly to the Patriarchate of Konstantinople.

The instabilities observed at the sites of the Monasteries in Mount Athos are mainly related to the presence of active faults and the geometry of the tectonic discontinuities, in relation to the active seismotectonic regime. The groundwater activity also decreases the shear strength of the rockmass at the foundation area. The description of building stones, degradation forms and mortars as well as the quantitative determination of their physico-mechanical properties are necessary for estimating their deterioration and proposing appropriate measures for their protection.

The Monastery of Simonos Petra is located on the SW coast of Mount Athos peninsula. It was built around 1257 AD by the Blessed Simon. It was burned down several times and consequently only the lower parts of the construction, close to the rock base are of that age. The western part of the present building was built in 1590 AD while the eastern part was built after the fire of 1891 AD.

The Monastery is built on an isolated and uplifted rock (altitude: 305 m), at the S/SW side of the mountain. The construction presents a particularity caused to the morphology of the rock-hill. The slopes of this rock are steep and the difference of altitude between the lower and higher points is more than 90 m. The rockmass consists of a typical, coarse grain, dark colour granite, that belongs to the Serbomacedonian mass.

The area is very fractured and is traversed by joints of various directions. Many important faults cut the studied area in E-W and N-S general directions. These discontinuities can cause unstable geotechnical conditions, especially at the slopes of the construction area. These instability phenomena are related to the neotectonic conditions of the broader area.

A slope stability analysis was performed with the determination of important unstable wedge and plane failures and the calculation of their factors of safety, using both field measurements and laboratory tests results (Christaras et al., 1994)

In order to protect this rockmass a net bolts is necessary to be applied, in the sites where the approach is possible. Grouting could be used only in the cases where the material is very broken and the discontinuities open. All the protection techniques have to respect the environment.

The Koutloumoussi Monastery was built in the 11$^{th}$ century, on the upper part of a gently sloping hill, of SE direction. Geologically, the area consists of mica schist presenting well-developed schistosity planes, dipping parallel to the slope face. The bedrock is covered by a 5-6 m thick weathered mantle (fine grained material) underlain by a 6-8 m thick transitional zone of strongly fractured and altered rock.

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The slip plane was identified at a depth of aprox. 10 m, at the contact between the weathered mantle and the strongly jointed bedrock. The inclination of the slipe plan was estimated as $5^{o}$-$6^{o}$ downslope.

For the stabilisation of the sliding mass, a retaining structure consisting of reinforced concrete piles with anchored bulkhead was proposed (Bandis & Tzaros, 1988).

The Stavronikita Monastery was built in the $11^{th}$ cendury, on the tope of a rock-hill at the North-East coast of Athos peninsula. The building is founded on a strongly fractured rockmass. Geologically the material is gneiss. Two dominate joint sets of N-S and E-W directions cut the rockmass creating important slab and wedge failures, as well as toppling phenomena. An important N-S fault causes damage to the wall of the North side of the monument. In order to retain this fractured rock mass, a pattern of anchored rock-bolts was used. The weathered mantle was stabilised using a pattern of piles of 10 m length (Bandis & Schinas, 1997).

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