



## **Rockfalls in Eocene flysch rock mass: geomechanical aspects of remediation of abandoned quarries in Central Dalmatia**

Goran Vlastelica and Predrag Mišćević

University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia (goran.vlastelica@gradst.hr)

Flysch is a typical example of heterogeneous rock mass with layers of different mechanical properties. Even though they are formed by sedimentation and originally were horizontal, since flysch was suitable for tectonic shaping, layers that are often bent or inclined at various dip angles from 0 to 90 degrees can be encountered.

While for homogeneous rock masses the process of weathering and erosion on cut slope is relatively predictable, and it can be well described by mathematical models of recession, for heterogeneous profiles this task is significantly more complex and sometimes unpredictable. Flysch members which are more resistant to weathering, depending on the dip and dip angle of the layer, usually remain for longer time on the slope face and overhang like a "console". When the console becomes sufficiently long, the bending moment separates the blocks create rockfall that threatens the space below the slope. At the same time less resistant members, which are previously eroded form under or above more resistant members, create an scree (talus) at the bottom of the slope, thus making a very specific slope profile of different ground properties and relatively rapid changing of geometry of the slope. Even though talus material restitution parameters are favourable (it consists mainly of disintegrated marl), because of its quasi stable nature, talus is prone to sliding in case of extreme loading conditions. Additional considerations about loading and calculation of stability to sliding are made, considering its build-up and environmental influences (rainfall, earthquakes, etc.).

Therefore, as a typical example of this situation, an abandoned quarry in flysch rock mass was selected, as it is intended to be reused as a recreation area. On the eastern side of the quarry slopes are up to 50 meters high and inclined more than 70 degrees, with large sandstone layers overhanging on the top. Considering that a solution with minimum investment was requested, that would ensure both maximum space for recreation area, and sufficient safety factor for rockfall hazard, multiple scenarios and types of remediation measures were investigated. Detailed survey by terrestrial laser scanner was made to ensure detailed profiles for 2D kinematic analysis, as well as to detect the erosion intensity and rate of scree accumulation at the bottom of the slope. Ground parameters necessary for kinematic analysis of future rockfalls were obtained by retrograde analysis of previously detected rockfalls on this and couple of other sites in the nearby area. Finally, a solution with two level gabion barriers was tested which, in combination with periodical monitoring, provides the maximal usable space within budget constraints.