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Impact of weathering on slope stability in soft rock mass

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ABSTRACT

Weathering of soft rocks is usually considered as an important factor in various fields such as geology, engineering geology, mineralogy, soil and rock mechanics, and geomorphology. The problem of stability over time should be considered for slopes excavated in soft rocks, in case they are not protected against weathering processes. In addition to disintegration of material on slope surface, the weathering also results in shear strength reduction in the interior of the slope. Principal processes in association with weathering are discussed with the examples of marl hosted on flysch formations near Split, Croatia.

1. Introduction

Weathering of soft rocks has been studied in various fields including geology, engineering geology, mineralogy, soil and rock mechanics, and geomorphology. However, the relationship between influence of weathering and slope instability (i.e. landslides, rockfalls, and surface erosion) is still not well understood.

Surface degradation processes and local landslides occur frequently on slopes excavated in soft rocks. As a result, safety of facilities at the bottom of these slopes is threatened and the cost of maintenance and/or supporting is usually significantly high. At the same time, the stability of facilities located at the top of such slopes is also submitted to increasing risk. The excavation work in these geomaterials (mostly clayey rocks, such as marl, siltstone, mudstone, shale, claystone, etc.) can be performed only with use of heavy machinery (rock breaker) or explosives, as well as in other types of rocks. However, in a relatively short time after excavation, the excavated slope in marl is exposed to influence of atmospheric agents during that period, e.g. a couple of months, then rock deterioration process starts both on the slope surface and the rocks inside. These processes can be observed on many natural slopes and on cuts excavated in flysch formations in the region of Dalmatia, Croatia, which were formed in the Eocene epoch and usually consisted of marl as the main soft rock component.

Information about marl strength at all phases of slope exploitation is of utmost importance for any stability analysis of cuts and slopes in this geomaterial. To provide data for analysing the strength deterioration of rocks, there should be a possibility to test degraded materials. Weathering processes fragmented marl samples into smaller pieces, thus the fragmented sample is very difficult to be operated with and to be installed into a testing device. For the solution of this problem, additions to the standard test procedure were used (Miščević and Vlastelica, 2009). Additions refer to the standard procedure of a direct shear test method (ISRM suggested methods for determining shear strength in 1974) enabling the tests of deteriorated samples. Results of this procedure will be presented and discussed.

The main scope of the presented study is to identify the main influences of weathering on slope stability in marl formation, present some basic engineering observations or previous experiences on known examples of observed slopes in this material, and propose solutions associated with those observations for future projects and studies. Also, it is important to emphasise the necessity of proper engineering solutions that prevent the development of the weathering process, which can lower the potential of slope instability and the maintenance cost.

2. Weathering

An example of surface deterioration induced by weathering of a natural slope, situated on the Adriatic Highway in the Podstrana municipality, is presented in Fig. 1. Here we can see a developed

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Fig. 1. Marl degradation on the surface of a cut slope on the Adriatic Highway (Podstrana municipality).

Fig. 3. Landslide along the coastal cliff in flysch formation (Duilovo, Split).

process of marl degradation on the slope surface, with accumulation of detached fragments at the bottom of the slope. The understanding of the degradation process such as that in this example is of great interest to many engineers, as these processes lead to reduced stability of such slopes and hence to higher maintenance costs.

Examples of impact of weathering processes on stability of unprotected cuts can be found on many locations in these geomaterials. For instance, such situations are quite frequently reported in the vicinity of Split when excavations are made in flysch rock mass. The landslide formed several months after excavation at the building site of the Medical School in Trstenik, Split is shown in Fig. 2. Fortunately, the landslide occurred during the night, therefore the lives of workers at the bottom of the foundation pit were not endangered.

An example of landslide at natural cliff in flysch formation along the coast is shown in Fig. 3. The sliding process is usually continuous if it is not interrupted by remediation works, a kind of instability that is quite frequent along the coastline near the town of Split. The material deposited at the bottom of the slope is carried away by the sea and thus the space is liberated for the next “sliding phase”.

A formation of greater sandstone blocks at a natural cut in flysch formation, caused by weathering of marl, is shown in Fig. 4. The weathering rate of sandstone layers within the flysch formation is not the same as that of marl. It could be stated that the sandstone is almost unchanged in the engineered time scale. Because marl is significantly influenced by weathering around the sandstone layer, it disintegrates quickly and is gradually removed by the action of gravity and precipitation (Neiman, 2009; Admassu et al., 2012), i.e. we can witness here the process of differential weathering. Sandstone layer outcrops remain on the slope as a kind of “cantilever” and when the length of this overhang becomes sufficient, the blocks detach due to bending action. Resultant rockfall poses a serious threat to the zone at the bottom of the slope.

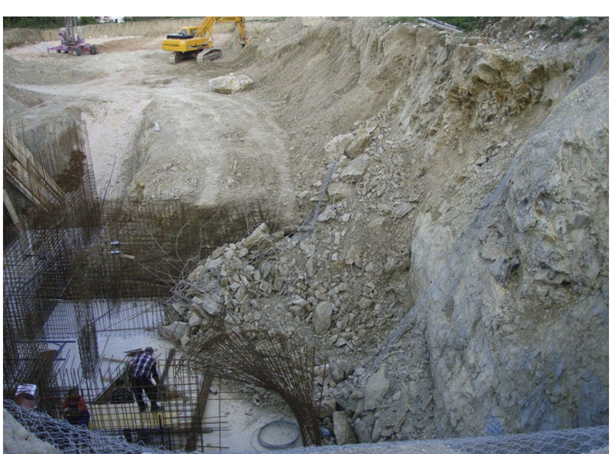

Fig. 2. Collapse of slope in foundation pit excavated in marl (Trstenik, Split).

Fig. 4. “Cantilever” of harder sandstone layer on the slope (differential weathering along the slope).