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Stability Analysis of an Over-Tilted Slope in a Granite Quarry: the Role of Joint Spacing

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Abstract

This paper presents the case study of a stability analysis of an over-tilted (inverse) slope in an ornamental granite quarry. Based on traditional small quarrying practices and due to space constraints, the SW slope was carved following the occurrences of highly persistent joints that were dipping around 80º counter-slope. Experience dictates that this sort of slopes tends to be unstable, at least in case of average to low quality rock masses. In this way, a stability analysis was due to analyze slope stability. The good quality granite rock mass in the slope was characterized, joint data was recorded and laboratory testing was done to estimate the main significant parameters involved in the study and the geometry of the slope. A stability analysis of the slope was performed by means of the calculations of safety factors against toppling. These calculations have been done contemplating various possibilities regarding the occurrence of joints and its spacing, which was found to be the most relevant parameter controlling stability.

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Keywords: Rock slope; Stability analysis; Toppling; Rock joint spacing

1. Introduction

This paper presents the case study of a stability analysis of an over-tilted (inverse) slope in a granite quarry. Due to space constraints of the quarry located in a hill slope, the SW end of the quarry happens to be parallel to a set of highly persistent joints that were dipping around 80º counter-slope. Therefore, as shown in Fig. 1, large parts of

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the slope are overt-tilted, that is, the slope is inverse –dips more than 90º– in these areas. In such situations, the local mining regulations enforce the owner to carry out a slope stability study appropriately justifying the stability of the slope. In this paper, the authors presents the most relevant topics of this geomechanical study, together with some considerations regarding the actual occurrence of instability toppling phenomena in rock slopes.

Fig. 1. General view of the general quarry slope roughly 40 m high.

1.1. Brief description of the quarry and mined stone

The quarry is located in the municipality of Tui in NW Spain. Fig. 1 shows a general view of this exploitation. The quarry activity is mining local slightly weathered granite, whose commercial name is 'Silvestre Moreno'. Quarry production tends to be around 100,000 m3 per year according to market evolution. Final products of the quarry are granite blocks, semi-blocks and ashlar masonry; appropriate descriptions of these products are provided below. The exploitation method is quarrying using black powder to cut the rock following the typical three weakness directions and recently diamond wire has been introduced in the quarry to make precise vertical cuts in the stone, improving recovery levels in the extraction of the ornamental rock.

The rock quarried can be defined as an alkaline two-mica granite moderately weathered. Grain size is average 5 mm and it is averagely composed by quartz (22 %), microcline (42 %), plagioclase albite (23%), muscovite (6 %) and biotite (7%). From a structural scope, this is a post-kinematic (post-Variscan or post-Hercynian) granite batholite, and therefore it has not suffered large tectonic stresses. A number of rock mechanics tests in this kind of granites were performed in the past and their results presented elsewhere [1, 2].

The attempt to obtain larger, and therefore more profitable, ornamental granite blocks, means that the primary goal is to extract primary blocks of the largest size possible, to be subsequently squared off to obtain parallelepiped blocks that are transported to the gang-saw for sawing into slabs.

In general terms, a block suitable for sawing in the gang-saw has the following characteristics: length 1.90-3.30 m, width 1.00-1.80 m and height 0.90-1.60 m. The slabs that are obtained after sawing will normally be 2-3 cm thick and surface area will be as large as possible so as to permit the production of large pieces. Next down the scale in terms of ideal quarry product size is the semi-block; although this may not have the ideal minimum block measurements indicated above, after sawing it will be of a size that is both commercially acceptable and economically viable. When the natural fracturing of the rock mass is such that it is impossible to obtain blocks or semi-blocks, smaller sized particles - greater than 15 cm thick, 42 cm high and of variable length - can be extracted for sale as ashlar and rubble masonry [3].

In the studied quarry due to its geographical situation far from large towns, the rest of material is carried to a waste dump. In other quarries, having available crushing equipment and located close to consumption areas, the remaining material is typically crushed into a number of suitable sizes, sold to the aggregate market.

Average annual rainfall for a return period of 100 year has been quantified in 165 l/m^2 by regional records and