Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 191 (2017) 646 – 655

Procedia Engineering

www.elsevier.com/locate/procedia

Symposium of the International Society for Rock Mechanics

A Parametric Study Using Numerical Modelling to Assess the Stability of Marble Quarries

Ahmet Turan Arslan[a,*], Bayram Kahraman[a], M. Kemal Özfırat[a], Thomas Frühwirt[b], Kemal Yıldızdağ[b], Halil Köse[a]

[a]*Faculty of Engineering, Dokuz Eylul University, İzmir, 35160, Turkey*
[b]*Faculty of Rock Mechanics/Rock Engineering, TU Bergakademie Freiberg, Freiberg, 09599, Germany*

Abstract

Marble quarries, are located at 3 km southeast of the city of Afyon İscehisar. The marble bed is lens shaped has a thickness of 300 meters. İscehisar is on south of the city center and marble bed extends through NW-SE direction for 6 km long and 1.5 km wide. Present base elevation of İscehisar marble quarry is at 1020 m and it is planned to be excavated down to 980 m elevation. The aim of this study is to determine the stability deep slopes at maximum depth (> 90 m) using numerical modelling. In the finite element method, generalized Hoek-Brown and Mohr-Coulomb failure criteria together with a jointed rock mass model are used. In marble quarries, particularly in this locations, the rock mass is severely affected by sliding blocks, caused by four intersecting joint sets. Stability analysis were conducted under static and dynamic conditions using Phase2 V.9.016 software. Shear Strength Reduction (SSR) technique that is built into the software used to determine the failure mechanisms and to suggest and the necessary controls to ensure the stability of the slopes.

Peer-review under responsibility of the organizing committee of EUROCK 2017

Keywords: Open pit mine; Mohr-Coulomb parameters; Generalized Hoek-Brown Criterion; Finite element method; Slope stability

1. Introduction

Slope stability is one of the most important critical and mostly studied subjects of open pit mining. This is because of the fact that slope instabilities can cause.

* Corresponding author. Tel.: +90-232-301-7273; fax: +90-232-453-0868.
E-mail address: ahmet.arslan@deu.edu.tr

Peer-review under responsibility of the organizing committee of EUROCK 2017
doi:10.1016/j.proeng.2017.05.228

Slope stability is controlled by many factors such as the local geological conditions, natural seismic activities, ground water table and changes in pore pressures. The aim of the study is to determine the stability of deep slopes at maximum depth using numerical modelling (> 90 m). The stability analyses were conducted using the methodology suggested by Hoek et al. [1] and Hoek [2] using the generalized Hoek-Brown parameters. In dynamic loading analyses, both Hoek-Brown and equivalent Mohr-Coulomb parameters were used [3–7]. The equations recommended by Sofianos and Halakatevakis [3] were used to obtain the equivalent Mohr-Coulomb parameters for the rock masses that have GSI value of more than 25. Sofianos [4]; Sofianos and Nomikos [5] suggested that when estimating the equivalent Mohr-Coulomb parameters, the lower stress limit of a rock is changed to be equal to the biaxial tensile strength, cohesion (c) and friction angle (ϕ) values obtained from these equations were compared with estimated c and ϕ. Li et al. [6] suggested a rock slope sensitivity table using the equivalent Mohr-Coulomb parameters and Hoek-Brown failure criterion in a limit-equilibrium analysis. They indicated that the factor of safety values of slopes (higher than 45°) obtained from stability tables using the equivalent Mohr-Coulomb parameters are somewhat higher due to the intervals wherein geometric discrepancy of curves from these two methods are high. Therefore, they concluded that Mohr-Coulomb curves and Hoek-Brown criterion cannot be integrated into one approach and then they proposed two different equations for slopes (with overall slope angles of $\geq$ 45°) that estimate minimum principal stress values. Nekouei and Ahangari [7] claimed that Hoek-Brown criterion is not reliable due to the low correlation coefficient values using Mohr-Coulomb parameters and Hoek-Brown criterion in slope stability tables proposed by [6, 9].

2. Geology of marble quarries

The surface rocks named Afyon Metamorphics are mostly originated from sedimentary rocks and underwent metamorphosis during intermediate to high temperature and pressure. Consisting of different lithologies, they are divided into sub-groups called upper and lower Metamorphics. The uppermost unit on the metamorphic foundation is the Iscehisar marble (Fig. 1). These marble formations are originally limestone (carbonate) and show different geological characteristics in colour, grain size and mineralogical composition so that they are divided into three different formations. During the metamorphism, rocks in that region were exposed to diverse deformation processes and temperatures. They have been folded and bended through plastic deformations. Structural analyses revealed that marbles in this region had been affected by at least three different folding phases [10]. Subsequent to metamorphism, brittle deformations occurred. Marbles in this region is believed to contain joints with different orientations [10].

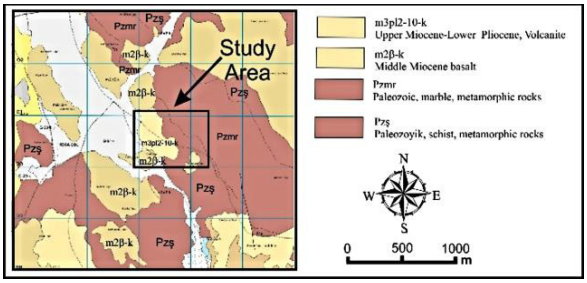

Fig 1. Marble quarries and near surroundings in the geological map.

Metamorphism of Afyon rocks was active until the Palaeozoic era (appr. 400 million years B.C.) and after that they were overlained by sedimentary rocks. Such as Degirmendere recrystallized limestone, Elmacik polygenic conglomerates and Gözsüzlü limestone are those sedimentary rocks which were not affected by metamorphism. Moreover, lava flow and pyroclastic serials were also observed in this region [10].