Proceedings of the International Conference on Mining, Material and Metallurgical Engineering
Prague, Czech Republic, August 11-12, 2014
Paper No. 61

The Applicability of Underground Mining Methods in Limestone Quarries of Western Taurus

Mete Kun, Baran Tufan
Department of Mining Engineering, Dokuz Eylül University
Izmir, Turkey
mete.kun@deu.edu.tr; baran.tufan@deu.edu.tr

Nejat Kun
Department of Geological Engineering, Dokuz Eylül University
Izmir, Turkey
nejat.kun@deu.edu.tr

Abstract **-**Turkey is one of the world leaders in the production and trading of natural stones for a decade, especially with rich calcium carbonate originated marble reserves. The marble quarrying in Turkey gathered around three main regions with production of more than 700 type of limestone, marble, travertine and other decorative stones with different colors and patterns. These regions can be listed as Aegean, Mediterranean and Central Anatolia. The Mediterranean Region stands out with light colored limestone which is in demand nowadays. The underground mining becomes a preferable alternative regarding the increasing production capacity, increasing transportation cost due to deepening open pits, necessity of selective production and occurrence of waste problems. The operating parameters are investigating regarding these difficulties in limestone quarries applying room and pillar method in Southern Turkey (Western Taurus). The internal parameters of the related rock sample is investigated and revealed by laboratory tests and experiments. The parameters are applied to a two dimensional model suitable for underground mining and applicable to related quarry to form the room and pillar geometry. The results gathered by modeling are compared to the underground quarry survey results and the safety factors for the underground openings (rooms) and pillars are evaluated in comparison. This study clarifies the importance and accuracy of modeling in mining applications by evaluating and comparing the modeling results with the real situation. In addition, an optimum room and pillar design is proposed related to the investigated quarry.

Keywords**:** Limestone, Underground Mining, Room and Pillar, Modelling.

1. Introduction

The underground mining becomes a preferable alternative regarding the increasing production capacity, increasing transportation cost due to deepening open pits, necessity of selective production and occurrence of waste problems. This alternative brings the necessity of determining the room and pillar mining method parameters for a limestone quarry in Beydaglari Autochthonous located in south-western Turkey. The observed roof cracks and rock falls create a risky condition in the currently operating limestone quarry, planned and initiated quarrying without any modelling studies in advance. The modelling of the related quarry for a safer application of room and pillar method is aimed in this study.

1. 1. Regional Geology

One of the two existing belts in south-western Anatolia is the Menderes Massive with metamorphic rock formations in the north and secondarily the Taurus Belt in the south. The Taurus Belt is classified into 3 different rock formations from north-west to south-east labelled as Lycian Nappes in the north, Beydaglari Autochthonous in the centre and Antalya Nappes in the south (Özgül, 1976; Poisson, 1977). The Lycian Nappes are formed by ophiolitic melange, partly flysh formation and limestone with different sizes and ages (Senel et al., 1981). In recent studies, the Lycian Nappes are also named as Kütahya-Bolkardagi Belt (Göncüoglu, 2007; 2011). The northern part of Beydaglari Autochthonous and the southern part of Finike-Elmali region are formed by plated, old upper cretaceous limestone. The investigated limestone quarries are located in those zones (Fig. 1).

The southern part of Beydaglari Autochthonous shows similar specifications with Lycian Nappes however the researchers sort the zone as a different and complicated formation. The formation of limestone blocks can be observed with ophiolitic melange and flysh facies (Fig. 2). The natural stone in the vicinity is named as “Limra” and mined from neritic limestone quarries in southern Beydaglari Autochthonous. The natural stone “Limra” is in fact a homogeneous fossiliferous limestone and light cream in colour.

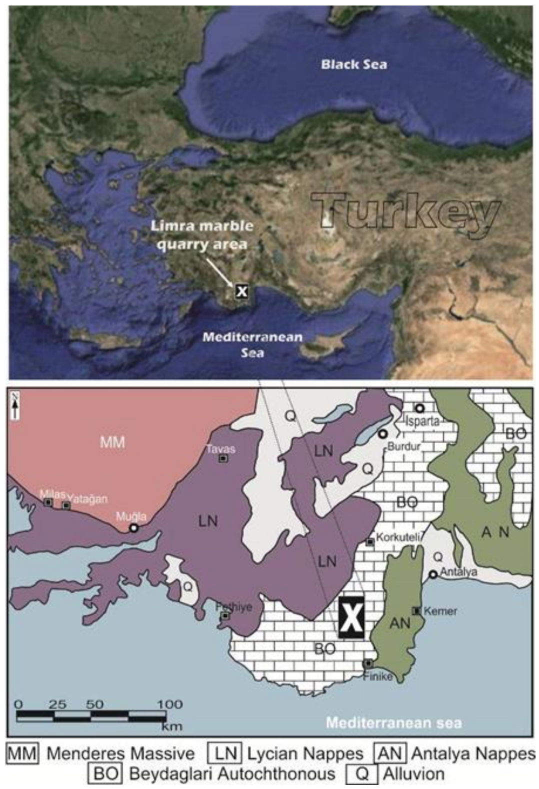

Fig. 1.The location map of the investigated area and the geology of its vicinity (revised from Özgül, 1976).

Fig. 2. The photographic displays of Lycian (A) and Antalya (B) Nappes in the region.

2. Experimental Study

A detailed laboratory study is the first and most important stage in enhancing open pit and underground mining methods, production in deeper elevations, designing underground openings through rock or ground. The inner parameters of rock specimens gathered by laboratory or insitu work are significant inputs especially in determining the production or excavation method. Hence, the rock specimens gathered from the limestone quarry applying an underground mining method were studied in the laboratory and the measurements of hardness, unit weight, water absorption, porosity, uniaxial compressive strength (UCS), etc. were practiced on 10 to 15 specimens and listed in Table 1 with standard deviations.

Table 1. Laboratory test results for characterization of Limra

Specification	Unit	Value
Hardness	mohs	3
Unit Weight	gr/cm^3	2.42±0.025
Density	gr/cm^3	2.72±0.008
Porosity	%	10.64±0.11
Water ab. by weight	%	3.22±0.064
Water ab. by volume	%	7.14±0.072
UCS	MPa	42±1.29
UCS after freezing	MPa	30±2.15
Young's modulus	MPa	44300
Poisson's ratio	-	0.41
Cohesion	MPa	7.6

3. Field of Study and Numerical Modelling

There are different approaches to determine the dimensions of rooms and pillars with different design parameters in the quarries applying room and pillar mining method. These approaches can be listed as determining the pillar parameters by empirical equations and numerical modelling depending on experimental results involving evaluations of rock mass classifications and formulations. At the present time, more accurate and advantageous results come forward with numerical modelling upon rock mass stability criterion and empirical equations (Nicieza et al., 2006).

The room and pillar underground production method is applied in Limra marble quarry because of selective production and thick overburden (70-75 m) although the use of wire cutting and chain saw cutters become almost classical in Limra production for decades.

The pillar dimensions of the underground quarry in production is 9x9x5 m (WxHxL) with room dimensions of 15x15x5 m. The maximum cutting length of the previously used chain saw cutter is the determining factor in pillar height estimation since the design is not based upon a new investment. The cracks formed in the roof and subsidence of 20 cm can be clearly observed in the operational underground quarry with 8500 m^3 of production till today (Fig. 3). The alternative cause of these fractures and cracks were investigated with a detailed geological study and no faults, fractures or joints were observed in the region.

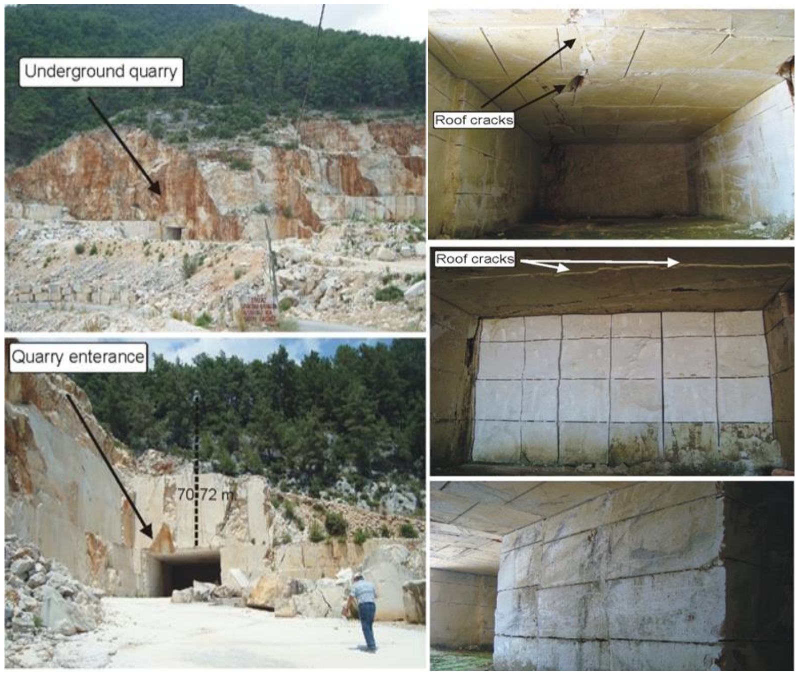

Fig. 3. Underground marble quarry and cracks observed on roofs.

Two-dimensional (2D) mining software is used to determine the crack formations in the roof of the production zone by actual production parameters (Fig. 4).

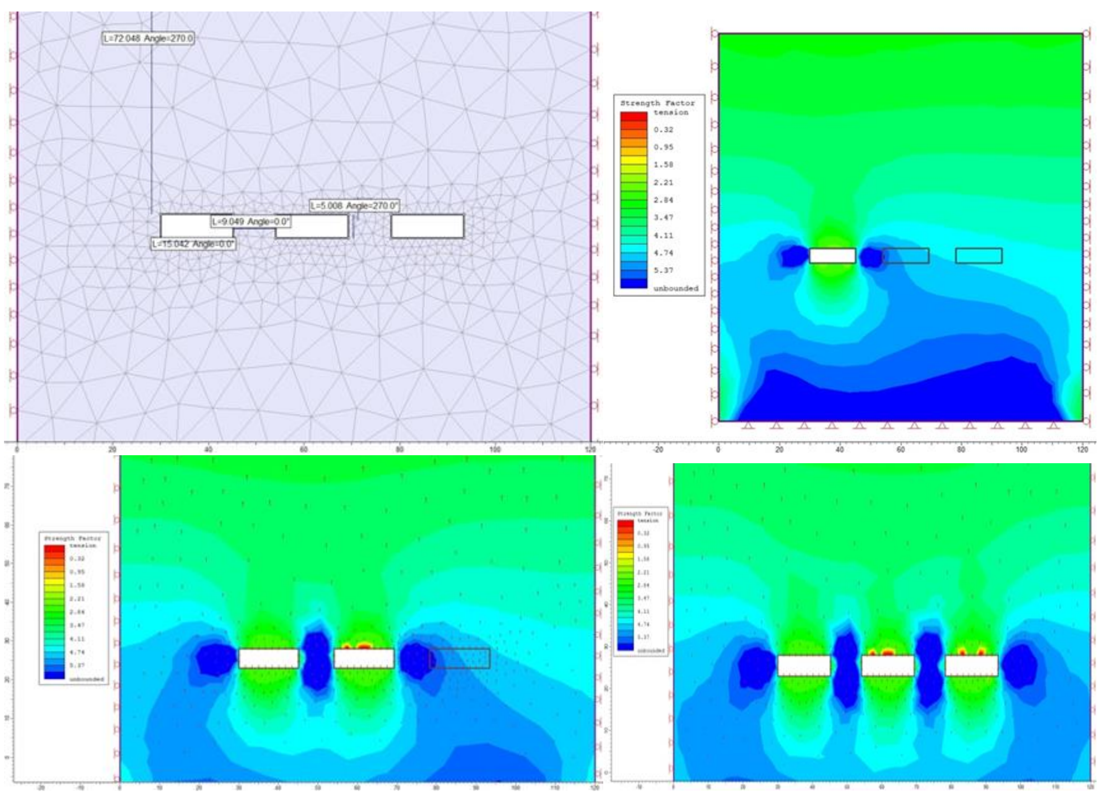

Fig. 4. The distribution of safety factors over the rooms and pillars by production model.

The model formed in 3 stages with the exact same dimensions of the production method and quarry operations allowed to determine the zones where strength factor is below 1 especially for the production rooms of 2 and 3. These zones are represented as red in color in Fig. 4. The zones where the safety factor is below 1 are expected to have failures and risky conditions due to these failures. Therefore, the operating underground quarry is remodeled by resizing only the rooms and pillars in defiance of the use of same machinery pool (chain saw cutter) and production convenience. The determining factor in determination of room and pillar sizes in both production and modeling phases is the specifications of the chain saw cutter. A chain saw cutter has 5 meters of working length, hence in planning stage, the height have to be 5 meters and the room depth should be 5 or multiples of 5 meters regarding the duration and ease of production. Besides, the producing company desires to maintain or enhance the ratio of production capacity (R_v) to pillar volume left (P_v) as 2.78 with the existing room and pillar dimensions. The geometry to maintain the safest working environment satisfying the optimum production capacity is modelled in Figure 5 under these circumstances.

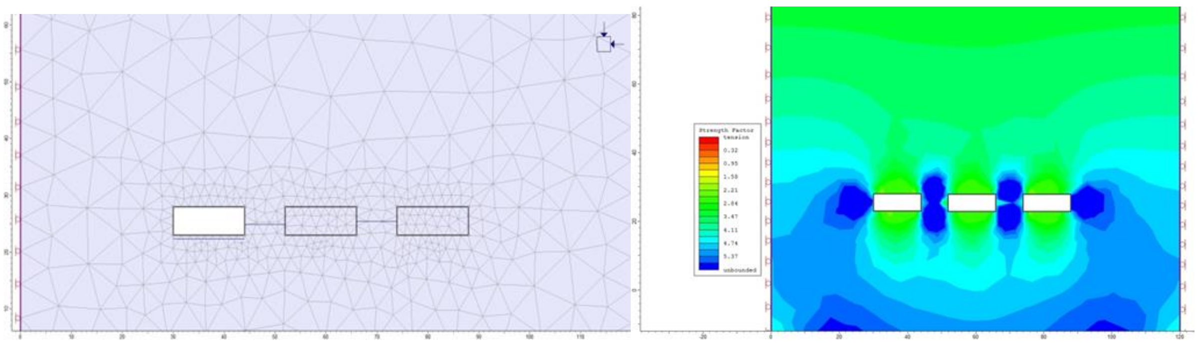

Fig. 5. The remodeled room and pillar geometry and distribution of safety factors (Room size: 14x14x5, Pillar size: 8x8x5).

4. Conclusion

The operating parameters of an producing underground marble quarry of Limra, in Beydaglari Autochthonous in southern Turkey, by room and pillar method is investigated. The evaluation is based on field observations, measurements and numerical modeling studies. The existing production geometry is revealed to be risky due to observed cracks and subsidence up to 20 cm in the roof of the rooms. In addition, rock falls due to failures threatens the security of the working area.

The underground quarry of Limra is remodeled regarding the factors mentioned. The ratio of R_v/P_v is tried to be maintained, even enhanced while applying different production geometries. The optimum room and pillar geometry among 10 different geometries is found to be 14x14x5 m for the room and 8x8x5 m for the pillars. The stated geometry brings forward a R_v/P_v ratio of 3.06 enhanced from 2.78 where no zones with values below 1 for both stress intensity and safety factor are observed.

In conclusion, it is revealed that the field and modeling studies should be carried out simultaneously in application of underground mining methods to weak rocks (UCS=42 MPa) in the planning stage.

Acknowledgements

The authors gratefully acknowledge the contribution of Dokuz Eylül University Scientific Research Projects Coordination Unit with projects of 2012.KB.FEN.024 and 2013.KB.FEN.022.

References

Göncüoglu, M.C. (2007). Geology of Kütahya-Bolkardag Belt – Menderes massive colloquium (in Turkish). In Extended Proceedings of International Symposiums on Menderes Massive Colloquium; Proc. intern. symp: Izmir, 5-10 November 2007. Izmir, Turkey, 39-43.

Göncüoglu, M.C. (2011). Geology of Kütahya-Bolkardag Belt (in Turkish). In Ergun Gökten (ed.), *The Journal of mineral research and exploration*, Ankara, 142, 227-282.

Nicieza, G.C., Fernandez, A.I.M., Diaz, M.A., Vigil, A.E.A. (2006). A comparative analysis of pillar design methods and its application to marble mines. *Rock Mech. Rock Engineering* 39(5): 421-444. Vienna: Springer.

Özgül, N. (1976). The basic geological characteristics of Taurus (in Turkish). In The bulletin of geological companies in Turkey, Ankara, 19, 65-75.

Poisson, A. (1977). Recherches géoloques dans les Taurides occidentales (Turquie) (in French). Publication of Université de Paris Sud (Orsay), Paris, France, 1-795.

Senel, M., Serdaroglu, M., Kengil, R., Ünverdi, M., Gözler, Z. (1981). The geology of south-western Taurus. The Journal of mineral research and exploration, 95-96: 13-43.