APPLİCATİON OF GENETİC ALGORİTHM TO DEVELOP A NEW İNDEX TO DETERMİNE THE CUBOİD PRODUCTİVİTY OF DİMENSİON STONE QUARRİES AND FİND THE OPTİMUM CUTTİNG DİRECTİON

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Abstract: Due to the lack of a criterion such as grade, it is difficult to decide for the extraction of a stone quarry. On the other hand, the goal of optimization in quarries is to produce blocks in shapes of standard rectangular cuboids. In this research, an index is defined called Cubic Productivity Ratio (CPR) that classifies the quarries in terms of the geometric grade of the blocks into three categories: good, moderate, and poor. In addition, by applying cutting planes and comparison of CPR values for different directions, the optimum cutting direction can be determined. This index was implemented in Ask Travertine Quarry, Mazandaran Province, Iran, and its value was calculated to be 22%, which places the quarry in a poor level in terms of block geometric quality. The optimal direction was found at N60w, indicating that in order to get the most yield, the current direction should be adjusted 35 degrees to the north. With that being done, the average volume of blocks will be 241.63 cubic meters, the average dimensions of the cuboids will be 2.93 (m) × 2.4 (m) × 2.25 (m), and the amount of marketable cuboids will be 53369.14 cubic meters, which will result in a revenue of about 130 billion IRR, according to the current sales price of raw blocks.

Keywords: Dimension stone quarry, Rectangular cuboid, Genetic algorithm, Cubic Productivity Ratio, Optimum cutting direction.

INTRODUCTION

In order to plan for the extraction of natural reserves, the quality of the ore and the materials should be evaluated before extraction, which is usually based on the estimation of a single-variable indicator such as the grade. But identification of this indicator, and the division of blocks are two major challenges in the process of planning the quarries (Tercan and Özçelik 2000). In metal mines, the amount of metal content is important, which is expressed in terms of grade; but in dimension quarries, other factors, such as the shape and size of the product, affect income, because the economic production of building stones depends on the appearance of rocks and the possibility of producing slab blocks (Ashmole and Motloung 2008). Therefore, the index that is supposed to be introduced as a substitute for the grade in the quarries must be an appropriate representative of the geometric quality of the blocks.

In 1999, Taboada et al. presented an index for the classification of granite blocks, using a multivariate analysis technique. Also in 2012, Alade et al. introduced a volumetric index of the modified joints for the suitability of the granite outcrops, which should not be higher than 1.7 per m for economic production. However, the volume density of the joints is a general criterion that is most suitable for building underground spaces such as tunnels. Many researchers have been investigating the size of the in-situ blocks (such as Stavropoulou 2014). But the block volume alone cannot be the right criterion for deciding on the geometric quality of the blocks, because a high result may be calculated for the size of a block, but it lacks the characteristics of a standard block for extraction.

In the literatures, there is no comprehensive index for determining the geometric quality of the blocks, while the production of regular blocks is of great importance in terms of facilitating stone processing and reducing waste. So, in this research, a CPR index was defined using a program

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coded by the genetic algorithm using MATLAB software. Then, the amount of cuboids in the blocks, and thus the amount of marketable blocks were calculated. In addition, by applying cutting planes and comparing the CPR index in various directions, the optimal cutting direction was found, in order to increase the productivity. At the end, the performance of this indicator was evaluated in a travertine quarry.

METHODS

It was necessary to define a volume parameter, the volume of the largest surrounded cuboid, or VISC, which is the volume of the largest rectangular cuboid that can be placed within a block. Different patterns of discontinuity will make blocks with various sides (planes) and shapes. It's difficult to calculate VISC in complex shapes. Ulker and Turanboy 2009 used a genetic algorithm to determine the maximum volume of this rectangular cuboid. However, they did not provide an indicator to determine the cuboid productivity capacity or the optimal cutting direction. In this research, 3DEC software was used to identify the blocks resulting from collision of the joints. Then, the coordinates of the vertices of the blocks were input to the program coded based on the genetic algorithm in MATLAB software.

Genetic Algorithm

Genetic algorithm is one of the most common evolutionary algorithms to search for optimum points in very complex environments and imitates the natural evolution of living organisms. In general, genetic algorithms consist of components such as chromosomes, populations, and fitness functions. Each chromosome represents a possible solution to the problem. The chromosomes itself (solutions) consist of a constant number of genes (variables). In genetic algorithms, genetic operators are used during reproduction. With the effect of these operators on a population, the next generation of the population is generated. Selection, crossover and mutation operators are most commonly used. This program was coded based on genetic algorithm using MATLAB software, in order to identify the largest cuboid in 3D space. Six genes were considered for each chromosome, representing the two-cornered coordinates of the cuboid. The fitness function was defined to calculate the volume of the cuboid. The significant point in the program coding was that the generated cuboids must be in range of the intended block. To avoid this problem, Point in Polyhedron Test (PPT) had to be performed on every point generated. In this research, the triangulation method had been used for a lower time order, i.e. polygon decomposes into triangular prisms. For this purpose, the Delaunay Triangulation had to be applied. The general process of the program was that an initial population was made up of chromosomes (solutions), all of which were subjected to PPT, and their fitness was calculated. Then the main part of the program started. Chromosomes from the initial population were selected by the Roulette method, to apply crossover and mutation operators. The crossover operator used two parent chromosomes to create two children. The selection of genes to be obtained from each parent was done by Uniform Method. The mutation used a single parent to create a child. Here, the mutation was carried out by the Swap Method. In the next step, the initial population was merged with the population derived from the crossover, and the mutation was sorted from highest to lowest according to the fitness. This cycle continued until the stop criteria, which is the number of generation, is met.

The greater the number of initial populations and the number of generations, the better final solutions are obviously obtained; but the time of resolution is also increased. Other primary parameters in the genetic algorithm are the probability of crossover (Pc) and the probability of mutation (Pm), which are expressed in percentages, completing each other. Therefore, the parameters of the genetic algorithm, such as the initial population, the number of generations, and the probability of the crossover must be determined in such a way that the highest value of the fitness function is obtained. Therefore, the random values for parameters of population, number of generations and probability of crossover were input to the program, and the amount of fitness function was calculated in each scenario. After this sensitivity analysis, initial population was 30. The number of generation considered to be 70, and Pc was 0.9. At the end, the dimensions and volume of the largest surrounded cuboid (LSC) placed inside the block were printed on the output, and is shown to the user in form of a (Fig. 1).

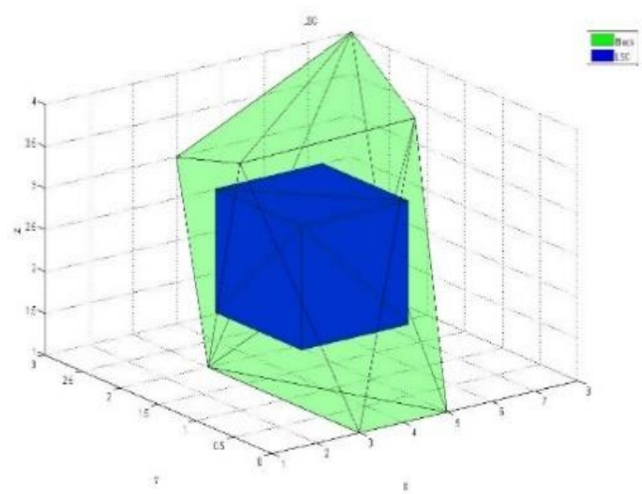

Fig 1. Output of the program showing the LSC inside a block

Cuboid Production Ratio

According to Eq.1, the cuboid production ratio (CPR)) is defined as the ratio between the volume of the cuboids and the volume of the blocks. When this ratio is closer to 100, the blocks will be more regular, producing less waste.

$$CPR = \sum V_{lsc} / \sum V_b \times 100 \quad (1)$$

where V_b is the volume of the in-situ block and V_{lsc} is the volume of the largest surrounded cuboid.

An important point in stone extraction is determining the direction of the working face and the distance between the cutting planes, which acts as a discontinuity plane. By using the program, it was possible to examine the different cutting directions and intervals so that their optimal values were determined according to the highest rate of CPR. It was then possible to estimate the amount of extraction (ER), which is the total volume of cuboids inside the blocks, after applying the directions and cutting planes, but not all extracted blocks are able to be sold. Blocks of less than 1 cubic meter are considered as waste. Therefore, the parameter of AMC can be calculated from Eq.2. Given the uncertainties that may occur during extraction, a safety factor of 0.8 must also be taken into account. Then, the quarry income is calculated by multiplication of AMC, specific gravity of stones and the price of raw blocks.

$$AMC = (ER - \sum (V_c < 1)) \times SF \quad (2)$$

Where, AMC is the amount of marketable cuboid, ER is the extractable reserve, V_{lsc} is the cuboid size inside the block, and SF is the safety factor.

Application of the model in a real quarry

Ask Travertine Quarry with a measured resource of 500 thousand tons is located in the south of the Damavand Mountains, near the Abask village in Mazandaran Province, Iran. Although the access is available from two sides, because of the greater ease, the quarry was opened westward by a ramp from the road. Annually, 11,000 tons of pale yellow travertine is extracted from this quarry. The current cutting direction is S85W.

Findings and *Argument*

Joint studies were carried out by Scan-line method, and 55 joints were recorded with a point on each joint, using a GPS device. The resulted Rose diagram showed that two major sets of joints can be identified in general, with specifications of S49W / 60W, and S37E / 78W. In the next step, the joints were modelled for a 300(m) ×200(m) ×11(m) rock mass in 3DEC software, which produced 1498 blocks (Fig. 2). Then, the coordinates of the vertices of the blocks created from the intersections of the joints were input to the program. Finally, the CPR value was 22%. Cutting planes with a spacing of 1.8 m and azimuths 0-170 degrees were applied to the initial block model. The highest CPR parameter was obtained on azimuth 30° and equalled 20.21% (Table 1). If the quarry is extracted in that direction, the average volume of blocks will be 241.63 cubic meters, the average dimensions of the cuboids will be 2.93(m)×2.4(m)×2.25 (m), and the amount of marketable cuboids will be 53369.14 cubic meters, which will result in a revenue of about 130 billion IRR, according to the current sales price of raw block. The optimum cutting direction obtained to be on azimuth 30°, showing that the strike of direction is either S60E or N60W. The quarry is not accessible toward S60E, therefor the optimum strike will be N60W. The current cutting strike, as mentioned before, is S85W. As a result, the current direction should be adjusted by 35° northward in order to gain the utmost production.

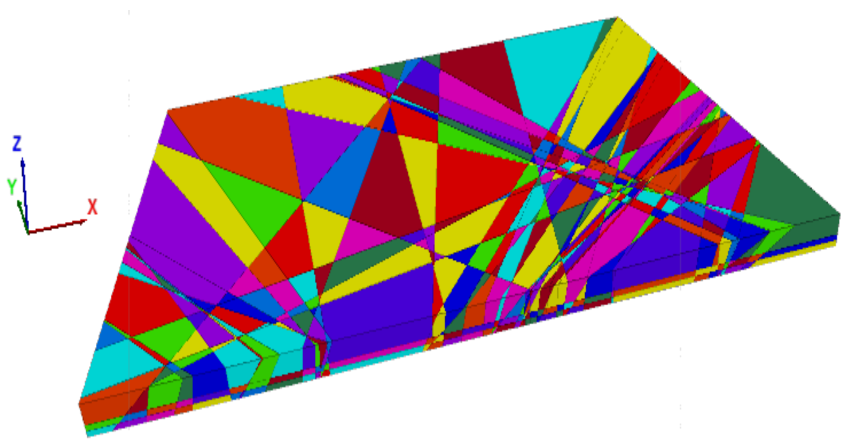

Fig. 2 The rock mass block model in 3DEC

Table 1 CPR values for various cutting directions

Direction	CPR	Direction	CPR
0	17.74	90	17.46
10	18.93	100	16.43
20	19.37	110	17.57
30	20.21	120	18.31
40	17.81	130	18.93
50	17.33	140	19.02
60	15.85	150	18.26
70	16.04	160	17.89
80	17.38	170	17.38

CONCLUSIONS

By recognizing and eliminating the defects of traditional quarrying, it is possible to minimize the problems during extraction, and increase the profitability, which is only possible by proper extraction of the mine. Until now, no suitable parameter for assessing the cuboid productivity capacity of a quarry had been proposed. The ratio of cuboid capacity and determination of optimal extraction has a great impact on the economics of a quarry. The CPR ratio can be used to plan for production in quarries. By applying different cutting planes on the rock mass block model and comparing the obtained values, the optimal cutting direction will also be determined. The amount of CPR ratio for Ask Quarry was 20.21%. The optimum cutting direction was achieved along the N60W. The successful performance of the CPR for Ask Quarry proved the high potentials of this index for more applications in stone industry.

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