



## COMPARISON BETWEEN DIFFERENT METHODS FOR ROOM AND PILLAR DESIGN IN UNDERGROUND HARD ROCK MINING

Expert paper  
DOI: 10.5937/RGD240015J

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**Abstract:** *Designing a mine using room and pillar mining method (R&P) represents complicated task. Choosing the dimensions of pillar is a very sensitive subject, since it is directly connected with room stability and exploitation factor of ore body, because some part of ore body stays in pillars. This paper will compare multiple ways to correctly calculate dimensions of pillar and rooms, so that room stability wouldn't be endangered and, at the same time, to excavate as much ore body as possible, to enhance efficiency.*

**Key words:** A MINE USING ROOM, PILLAR MINING METHOD, HARD ROCK

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### INTRODUCTION

Mining methods can be split into 3 main categories: room and pillar mining methods, backfill mining methods and caving (stopping) mining methods. Goals of all mining methods are to ensure safety of people and to ensure the highest efficiency possible. For that to be achieved, in R&P methods, pillars are left as a support holding rock mass and ensuring its stability by redistributing stress. Backfill methods imply that there is some material that is filled into excavated space, which then can act as a stress receiver. Caving or stopping methods just let ore body and rock mass to cave under natural stress, by undercutting. [1]

Room and pillar mining method has been used for the last 150 years at least all over the world (Mexico, Poland, USA etc.). It is low cost, versatile and safe method. The distribution of pillars doesn't have to be equal to all sides, they can be distributed

unevenly, so that the richer parts of the ore body can be excavated, and the poorer part can be left in the pillars (Figure 1). When this method is applied it is essential to correctly determine the dimensions of pillars and span of chambers. Excavation can be done as a horizon mining or mining with vertical or horizontal slices (Figure 2). [2]

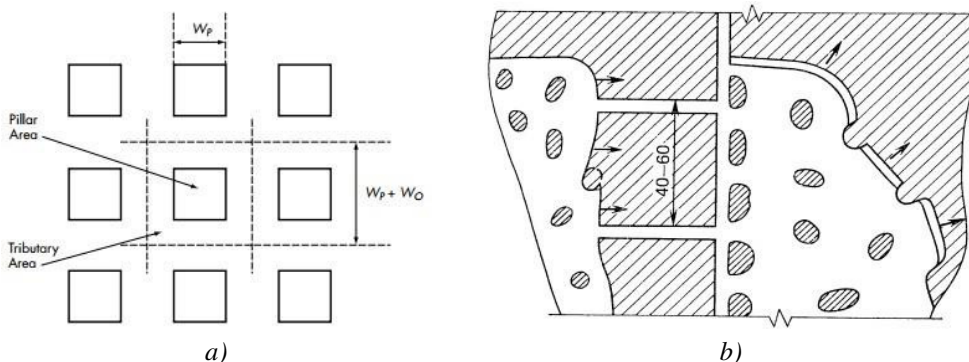


Figure 1, Evenly (a) and unevenly (b) distributed pillars in a mine [1, 3]

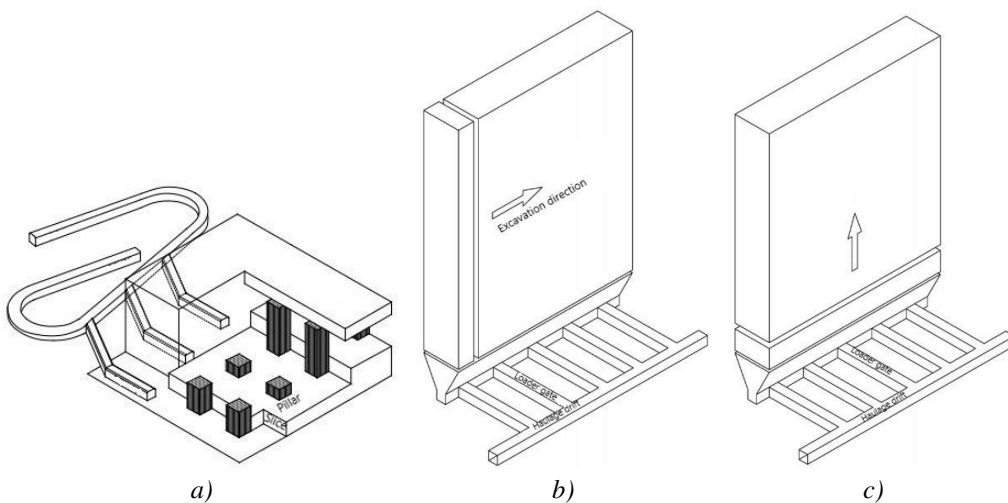


Figure 2, Horizon mining (a), mining with vertical (b) or horizontal (c) slices

PILLAR DIMENSIONING

During the years, the need for more accurate ways to dimension pillars, both to provide higher safety and efficiency resulted in more research and more equations for this use. For the last couple of years, programs are developed, such as Phase and FLAC 3D to ensure the best possible prediction of pillar stability considering given specifications of rock mass.

However, in engineering practice, especially in Serbia, equations are still used, and, with newer methods of calculations, the question rises, what equations are more applicable and precise? For this, couple of examples will be used, with rock and ore body

specifications given in the table 1. For comparability on how different methods impact calculations, only depths will change, other specifications are identical for all cases. For first case calculations will be shown, for the others just the end results will be shown.

*Table 1, Specifications of rock and ore body*

Specification	Value		
	Case 1	Case 2	Case 3
Ore body angle	0° (horizontal)		
Ore body depth (mm)	250000	350000	500000
Ore body thickness (pillar height) (mm)	25000		
Ore body volumetric weight (N/mm <sup>3</sup> )	2.75 · 10 <sup>-5</sup>		
Above rock volumetric weight (N/mm <sup>3</sup> )	2.55 · 10 <sup>-5</sup>		
Safety coefficient	1.4		
Compressive rock strength (N/mm <sup>2</sup> )	70		
Tensile rock strength (N/mm <sup>2</sup> )	7		
Opening width (mm)	10000		
Assumed pillar width (mm)	10000		
Q classification	7		

The first method was firstly recommended by Tournaire in 1884, and has been developed by L.D. Ševjakov. The method is assuming some value is known for opening width and uses it to calculate pillar width, which then uses to calculate the safety condition [4].

When the pillars are square shaped, pillar width is calculated:

$$a = \frac{A}{\sqrt{\frac{\sigma}{k_s \cdot H \cdot \gamma} - \frac{h \cdot \gamma_1}{H \cdot \gamma} - 1}}$$

Where:

- $a$  – pillar width (mm)
- $A$  – opening width (mm)
- $\sigma$  – compressive strength (70 N/mm<sup>2</sup>)
- $k_s$  – safety coefficient (1.4)
- $h$  – pillar height (mm)
- $H$  – ore body depth (mm)
- $\gamma$  – above rock volumetric weight (N/mm<sup>3</sup>)
- $\gamma_1$  – ore body volumetric weight (N/mm<sup>3</sup>)

Since it is an older equation, different measurement units are used.

Assuming that pillar width is unknown, it can be calculated:

$$a = \frac{10000}{\sqrt{\frac{70}{1.4 \cdot 250000 \cdot 2.55 \cdot 10^{-5}} - \frac{25000 \cdot 2.75 \cdot 10^{-5}}{250000 \cdot 2.55 \cdot 10^{-5}} - 1}} = 5615.8 \text{ mm} = 5.62 \text{ m}$$

Opening stability check is calculated as a confirmation of a correct value of pillar width.

For opening to be stable, condition must be met:

$$\sigma_{imax} < \sigma_i$$

Where:

$\sigma_{imax}$  – maximal tensile strength

$\sigma$  – rock tensile strength

Maximal tensile strength is calculated as a:

$$\sigma_{imax} = \gamma \cdot H \cdot \sigma_x + \frac{3 \cdot \gamma \cdot A^2}{4 \cdot h_1} - n \cdot \gamma \cdot H$$

Where:

$\sigma_x$  – corrective factor of tensile strength (Figure 3)

$h_1$  – roof length supported by bolts (adopted 1.5 m)

$n$  – lateral stress coefficient (for hard rock it is adopted 0.5)

Since it is known ratio of  $h_1/2r$  ( $2r = a + A$ ), and it is equal to  $1.5/15.62 = 0.096$ , and it is known ratio of  $a/2r$  ( $2r = a + A$ ), and it is equal to  $5.62/15.62 = 0.36$ , then graphically can be determined value of  $\sigma_x = 0.9$  (Figure 3).

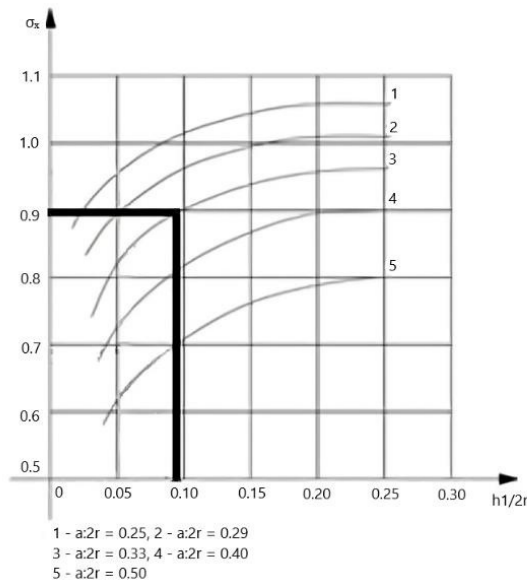


Figure 3, Graph for defining  $\sigma_x$

Taking these parameters into equation, the value of  $\sigma_{imax}$  is:

$$\sigma_{imax} = 2.55 \cdot 10^{-5} \cdot 250000 \cdot 0.9 + \frac{3 \cdot 2.55 \cdot 10^{-5} \cdot 10000^2}{4 \cdot 1500} - 0.5 \cdot 2.55 \cdot 10^{-5} \cdot 250000$$

$$\sigma_{imax} = 3.825 \frac{N}{mm^2}$$

Criteria that must be met for an opening to be stable:

$$\sigma_{imax} < \sigma_i$$

$$3.825 < 7$$

With this method, it is concluded that workings are stable with pillar width of 5.62 m and opening width of 10m.

The next method is tributary area method and is used for horizontal and flat ore bodies on shallow depth, like this one in the example [1, 5].

The first characteristic to determine is Q classification or rock mass classification. This is consisted of many factors, but some general value is adopted here. From graph made by Hutchinson and Diedrichs in 1996, maximal length value of unsupported room can be determined (Figure 4).

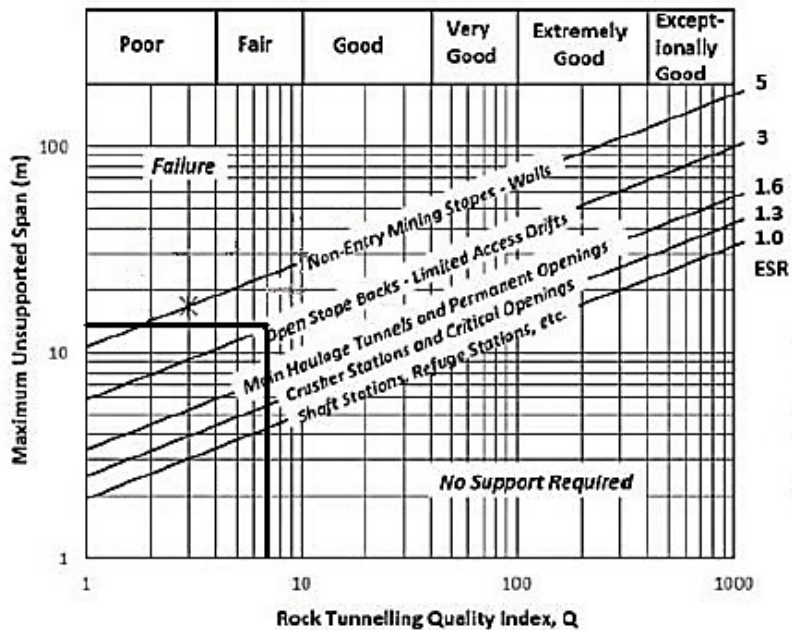


Figure 4, Hutchinson and Diedrichs graph

From the graph, the maximum unsupported span is around 14 meters, so it will be adopted 10 as an opening width.

Pillar load from roof rock mass can be calculated with the equation:

$$\sigma_p = \gamma \cdot H \cdot \left(1 + \frac{A}{a}\right)^2 = 25.5 \frac{\text{N}}{\text{mm}^2}$$

The ratio  $\sigma_p/\sigma_c$  is  $25.5/70 = 0.36$ . When that is added to the graph made by Lunder and Pakalnis [6], the result is:

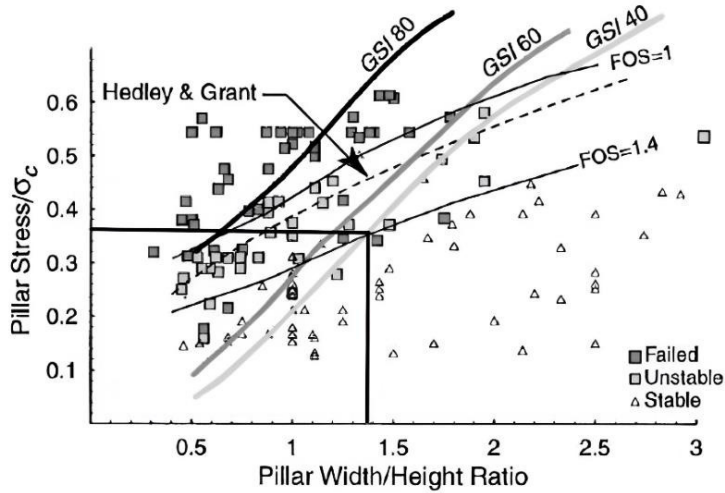


Figure 5, Lunder and Pakalnis graph

This means that ratio  $a/h = 1.4$ , which means that for this ore body, pillar with height of 25 meters will be stable if it has width of 35 meters.

For all cases, the calculated results from both methods are given in the Table 2.

Table 2, The calculated results from both methods

	Case 1	Case 2	Case 3
Ševjakov	a = 5.62 m; A = 10 m	a = 7.4; A = 10 m	a = 10.35; A = 10
Tributary area method	a = 35 m; A = 10 m	a = 60 m; A = 10 m	a = 55; A = 6 <sup>1</sup>

These values are shown in Figure 6.

<sup>1</sup> If the same input parameters were used, the calculation can't be done, because the value can't be found on Figure 5. It is needed to lower the opening width to 6 m.

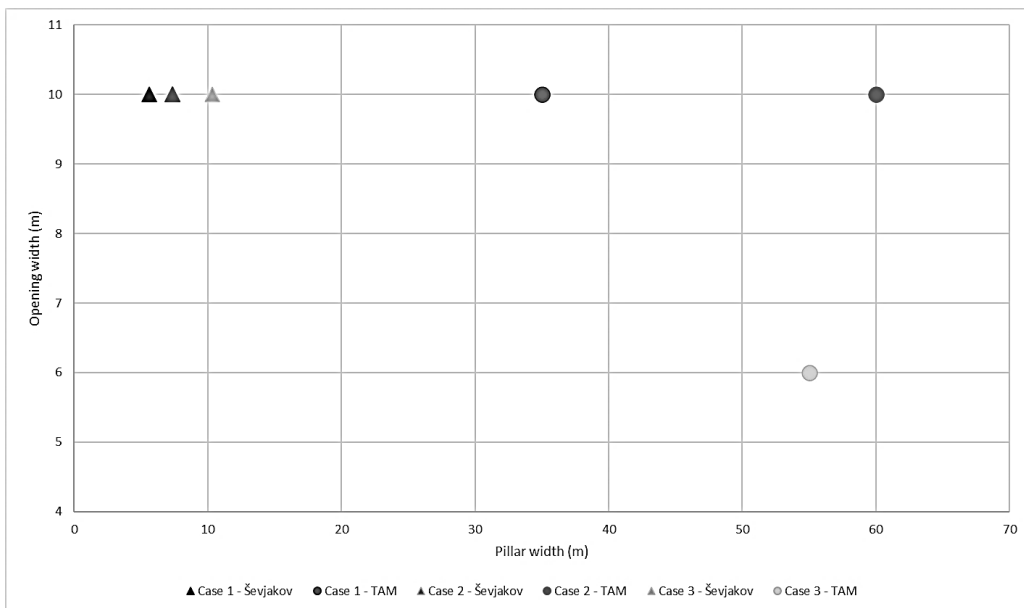


Figure 6, Values from Table 2

CONCLUSIONS

In this paper, multiple ways to calculate R&P widths are shown on multiple cases. The example used for rock mass and ore body specification is arbitrary, but with a strong foundation in information about excavated ore bodies around the world. The first method of calculating dimensions of room and pillars dates from the first half of 20<sup>th</sup> century. It can be concluded that pillars with 5.62 m width and 25 m height are sufficient enough to not fail with 10 m openings at depth of 250 m. However, with newer equations, the conclusion is that pillar with height of 25 meters must be wide 35 meters to support opening of 10 meters. The major difference can be seen in the results of these 2 equations. As an engineering practice, safer route is always taken, so in this case bigger pillars would be safer option. That would arise the question of profitability and exploitation and should the excavation method change, especially in cases 2 and 3 when the pillars are even wider, with the same width of openings.

As seen on Figure 6, for the same opening width, difference between pillar widths is very small when using Ševjakov’s method (2-3 m) and maximum size of pillar is 10.35 m, at depth of 500 m. When using tributary area method, pillars are a lot wider (35 m compared to 5.62 m). Additionally, width is drastically increasing with depth increasing (25 m), compared to the previous case. In the case 3, opening width had to be lowered to 6 m, because the result couldn’t be calculated with opening width of 10 m.

The major difference between methods is that the tributary area method is using actual Q classification of rock mass, that includes fissures and their state into consideration. That means that extensive work must be done to properly classify rock mass, so that the

input values are relevant and can be used to precisely determine maximum and minimum width of room and pillars.

These are empirical equations and methods, and they must be used carefully with background knowledge of rock mass management and risks associated with it. The methods used in this paper could have been developed for different conditions, f.e. deeper ore bodies or coal mines, so the best method to determine R&P dimensions is by using software mentioned before, so that the inputs are customizable for a specific case.

#### ACKNOWLEDGEMENT

The authors from Faculty of Technical Sciences in Kosovska Mitrovica would like to thank the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for funding the scientific research work, contract no. 451-03-65/2024-03/200155, realized by the Faculty of Technical Sciences in Kosovska Mitrovica, University of Pristina.

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