University of Belgrade
Technical Faculty in Bor,
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Institute Bor

54th International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:
Ljubiša Balanović
Dejan Tanikić

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović

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APPLICATION OF THE NUMERICAL METHOD IN THE DEFINITION OF A SUBSTRATE OF CIRCULAR CROSS SECTION

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Abstract:
Looking at the stages of development of the shape of the cross-section of the horizontal room of the pit, it can be concluded, regardless of their diversity, that at the base of all shapes, trapezoidal, vaulted and circular shapes, with appropriate combinations, appear as basic shapes.
When applying the Phase ^{2} software , a circular cross-section of the room was used. In order to define (design) the tunnel lining in the case of a circular cross-section, the geomechanical data of the example provided by the software producer Phase ^{2} was used .

Keywords: circular cross section, finite element method, Phase2 v 8.0

1. INTRODUCTION

The dependence between geometric and physical quantities in continuum mechanics is established on elements of differentially small dimensions. The very continuity of those dependencies, by expanding from that infinitesimally small hot spot to the entire observed area, gives differential equations, which define the task with appropriate boundary conditions. We know the primary state of stress σ_{ij}^0which depends only on the coordinates. Secondary state of stress - occurs due to the opening of the hole. We are familiar with Kirsch's solution of the state of stress in an infinite plate in the case of a circular opening [1] (Figure 1).

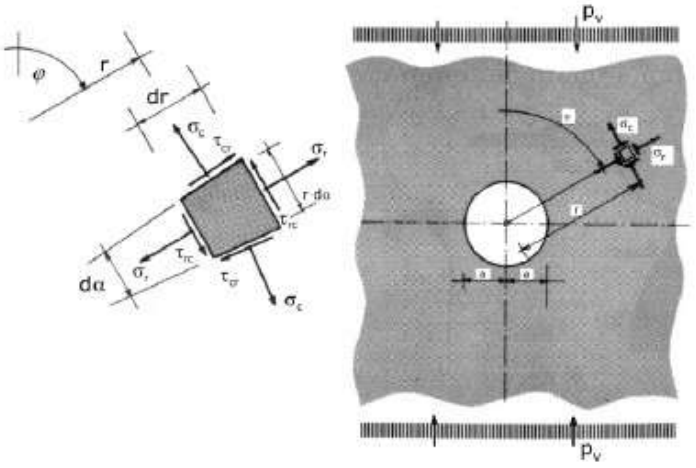

Figure 1 - The case of a circular opening in an infinite plate

Analytical solution of secondary stress or stress concentration for the case of vertical pressure only p_v, is shown by the following expression:

$$\sigma_r = \frac{p_v}{2}\left[1 - \frac{a^2}{r^2} + \left(1 - \frac{4a^2}{r^2} + \frac{3a^4}{r^4}\right) \cdot cos2\varphi\right]$$

$$\sigma_t = \frac{p_v}{2}\left[1 + \frac{a^2}{r^2} + \left(1 + \frac{3a^4}{r^4}\right) \cdot cos2\varphi\right]$$

$$\tau_{rt} = \frac{p_v}{2}\left[1 + \frac{2a^2}{r^2} - \frac{3a^4}{r^4}\right] \cdot sin2\varphi$$

Solving planar and spatial problems is therefore based on solving differential equations.

When solving the continuum problem with the assumed constitutive connection, it is necessary to simultaneously satisfy the conditions of the equation:

a) equilibrium conditions
b) continuity conditions
c) conditions on the contour and others.

2. CONSTRUCTION OF UNDERGROUND SPACE OF CIRCULAR CROSS SECTION IN INFINITELY ELASTIC ENVIRONMENT

This problem considers the case of an underground room with a circular cross-section, diameter 1m, which is made in an ideally elastic medium. It is assumed that the hydrostatic pressure is applied, the value of which is 30 MPa. Figure 2 shows the configuration of the model, including the limit values [2] , while Table 1 shows the material properties and other parameters.

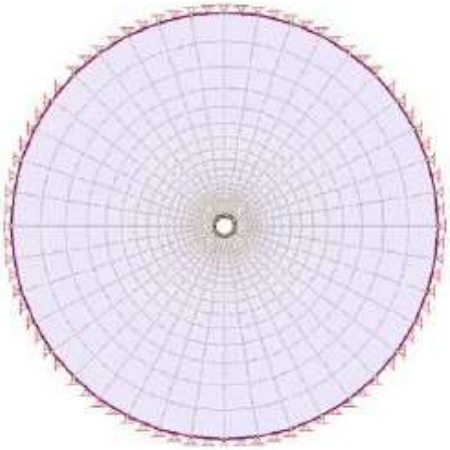

Figure 2 - Room model of a circular cross-section in an infinitely elastic medium in the **Phase ^{2} program**

Table 1 - Model parameters

Parameter	Value
Jung's modulus (E)	10000 MPa
Voltage field (p_1, p_2)	30 MPa
Poisson's ratio (ν)	0.2

This model in the ***Phase ^{2} program*** uses a radial grid with 840 8-node quadrilateral elements with a fixed outer boundary that is 21m from the center of the room. The room is divided into 40 segments.

2.1 Substructure of underground rooms in an elastic environment

In this example, an account is given of solving the problem of the occurrence of axial force and bending moment in the rock mass in subgrade, during the construction of mining rooms with a circular cross-section, in an ideally elastic environment. Figure 3 shows the model, which was applied in the ***Phase*** ^{2} ***program*** , which defines the support as an elastic thick-walled lining in both phases, during bending and peripheral deformations.

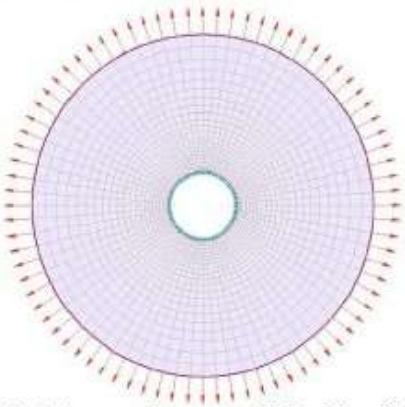

Figure 3 - Model of the finished mining room that was applied in **Phase** ^{2}. The support is shown in blue

The relevant parameters of the model are given in Table 2. The model uses a radial mesh with 1680 4-node quadrilateral elements. The underground room and support are divided into 80 segments; substructure elements are simplified using the Euler-Bernoulli equation. The finite element method is used along the outer boundary.

Table 2 - Characteristics of rock material and subgrade

Parameter	Value
Horizontal voltage (σ^0_{xx})	30 MPa
Vertical stress (σ^0_{yy})	15 MPa
Jung's modulus (E)	6000 MPa
Poisson's ratio (ν)	0.2
Characteristics of the support	
Young's modulus (E_s)	20000 MPa
Poisson's ratio (ν_s)	0.2
Thickness (h)	0.5 m
Diameter (a)	2.5 m

In order to calculate the tunnel deformations, Vlachopoulos and Diederichs met from over the numerical method of finite elements in plastic zones at total displacements [3]. The layout of the model is given in Figure 4. All calculations are made for the condition when the internal pressures in the tunnel are equal to zero.

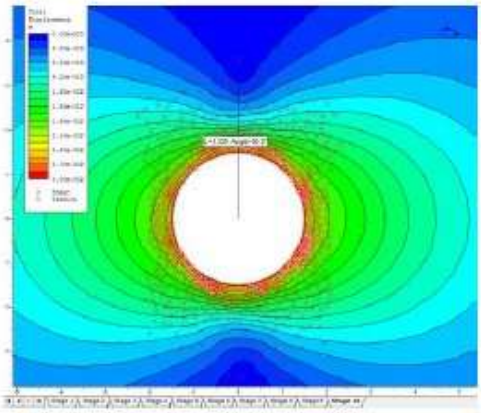

Figure 4 - Total displacements in the tenth phase at maximum media stresses with the distance to the plasticity zone where the displacement is equal to zero. R_p=3,339 m

After that, the selection of the support and concrete that will satisfy the balance system and the safety factor of 1 is approached; 1.2 and 1.4 for the given condition. The choice of substructure and concrete is given in Figure 5.

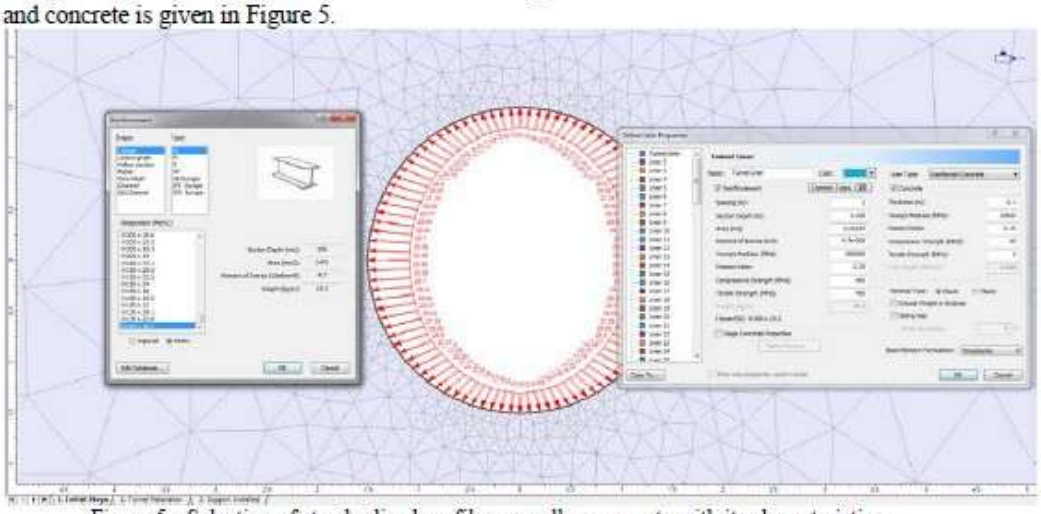

Figure 5 - Selection of standardized profiles as well as concrete with its characteristics.

After selecting the approach, the safety factor is checked, which is shown in Figure 6. In case the support, concrete or both do not meet the safety factors, the selection is made until the desired balance is reached.

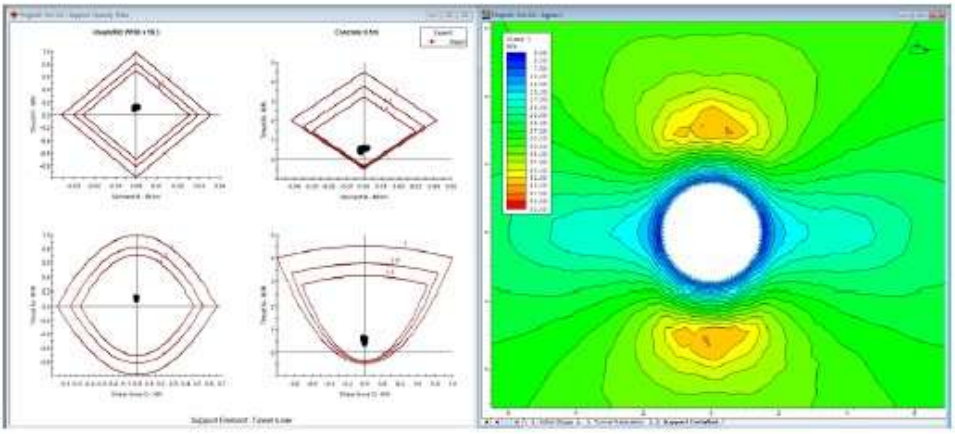

Figure 6 - Showing a good support selection

3. CONCLUSION

Based on all the analyses, the theory was confirmed that, if possible, it is most practical to apply a circular cross-section of the room, especially in weaker environments.
In terms of software, the standardized substructure is mainly considered. It is common in practice that for each specific case, the selection of subgrade and concrete recipe is subjected to tests. The substructure is standardized and its selection is considered by the moment of inertia and twisting as well as the force it can resist. When choosing cement, it is necessary to be guided by the conditions to which the subgrade will be exposed, as well as the function intended for it. Thus, when making a concrete lining from sprayed concrete, in solid and stable environments, it is possible to use Portland cement of standard quality. When applying sprayed concrete on the walls of the room immediately behind the front of the work site, and with weak and unstable rocks, it is necessary to use fast-setting cements or normal Portland cement with the addition of a setting accelerator.

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