University of Belgrade
Technical Faculty in Bor,
Mining and Metallurgy
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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SELECTION OF ANCHOR TYPE USING AHP METHOD

Dragan Šabaz[1], Miloš Stojanović[1], Dejan Petrović[2]

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Abstract
Underground drift construction in underground mines affects the disturbance of the balance that prevails in the primary rock mass. In such an environment, there is a redistribution of stress in the rock medium and the formation of a secondary field stress around the underground drift. Importance of the supporting underground drifts is reflected in the fact that only by installing an optimal support structure, safe conditions can be ensured for the continuation of work. Total installation costs and required installation time can be highly rationalized by choosing the right type of support. Comparison and ranking of anchors in this paper was carried out according to different criteria: stability of the drift, required installation time and costs of support installing. In order to evaluate the precision of the obtained results and to ascertain whether the prescribed support structures imparted requisite safety to the subterranean enclosure, stability analysis was created utilizing Rocscience Phase software. Selection of the optimal type of anchor according to the above criteria was carried out using the Analytic Hierarchy Process (AHP) method. The analysis and evaluation of the obtained results according to the specified criteria was performed using the Expert choice software.

Keywords*: underground mining, drift support, anchor type, AHP method*

1. INTRODUCTION

The natural balance that prevails in the rock mass is disturbed by the construction of underground mining objects. It is necessary to mitigate the resulting changes and establish a state of equilibrium similar to the one that existed before [1]. By installing an appropriate support structure, conditions are created for uninterrupted and safe utilization of the underground objects.

Application of modern techniques and technology in the support installation process, the reliability, stability and speed of constructing of underground objects are increased. In mines around the world, the implementation of anchoring system has proven to be a highly effective method of support. Anchoring system represent a network of embedded anchors within the rock mass, designed to increase the load-bearing capacity of the surrounding portion of the rock mass around the excavated underground object [2].

A universal procedure for selecting elements of anchoring system does not exist yet. For this reason, this paper presents a methodology for selecting the optimal anchor type that can be used in the construction of different shapes and dimensions of the underground objects. The methodology involves comparing and ranking anchors according to several important criteria: stability of the drift, required installation time and costs of support installing.

The adopted shape and size of the cross-section of the drift (dimension 5,3×5,3 m) and the technical characteristics of different anchor types (Swellex, Split Set and SN) were used to define parameters of anchoring system. A stability analysis of underground drift was conducted using the Rocscience Phase 2 software, considering the different anchor type. The time required for installation supporting elements was calculated, after considering all the individual operations involved in the support process.

Additionally, the total installation costs for supporting of 1 m of the underground drift were determined by considering the individual prices of the supporting elements. The results obtained according to the given criteria are shown in Table 1.

Table 1 – The input data for AHP method is defined in accordance with the criteria

Criteria	Parameters	Swellex	Split Set	SN
Supporting system	Anchor diameter (cm)	4,10	3,90	2,00
	Anchor length (m)	3,00	2,80	2,80
	Load-bearing capacity (t)	9,00	7,00	13,00
	Number of anchors in a row (com)	12	16	8
	Wire mesh	100×100×8		
	Thickness of shotcrete (cm)	5	4	6
Stability of the drift	Minimum displacements (mm)	3,00	3,30	2,60
	Maximum displacements (mm)	7,70	8,00	7,40
Installation time	Total installation time (min)	83,51	101,61	124,23
Costs of support	Anchor (din)	12.461,54	10.467,69	14.030,80
	Wire mesh (din)	7.959,69	7.959,69	7.959,69
	Shotcrete (din)	6.242,76	4.995,50	7.498,51
	Total costs (din)	26.663,99	23.422,88	29.489,00

The selection of the optimal type anchor based on the mentioned criteria was performed using the Analytical Hierarchy Process (AHP) method. Method involves evaluating the weight of the criteria and evaluating the types of anchors according to the criteria. The analysis and evaluation of the obtained results according to the mentioned criteria were performed using the Expert Choice software.

2. APPLICATION OF THE AHP METHOD IN THE PROCESS OF SELECTING SUPPORTING ELEMENTS

The AHP method is multi-criteria decision-making method that is used to solve complex problem, which consist of goals, criteria and alternatives. This method enables the interactive creation of a problem hierarchy, which serves as preparation for decision making. Pairs of criteria and alternatives are compared, a synthesis of all comparisons is made and the weight coefficients of all in the hierarchy are determined. The sum of weight coefficients for elements at each level of the hierarchy is 1. For the comparison of individual criteria or alternatives, the Saaty's scale is used, which consists of nine numerical ratings [3]. Decision maker uses ratings to distinguish the intensity of the relationship between the two elements. A hierarchical structure of the multi-criteria decision-making model was created based on the given criteria and alternatives (Figure 1).

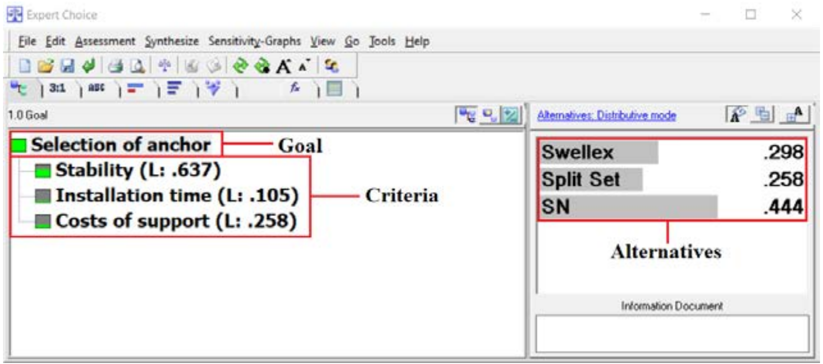

Figure 1 – The hierarchical structure of the multi-criteria decision-making model

The criteria are evaluated by importance and then compared in pairs based on Saaty's scale. After that, the weight of the criteria is determined and consistency is checked (Figure 2).

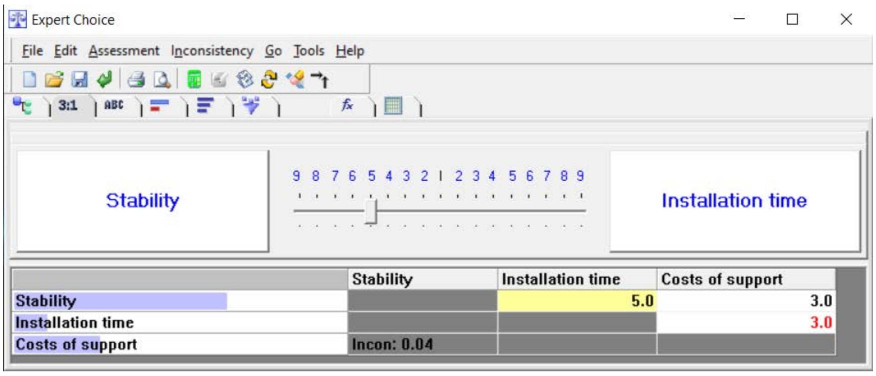

Figure 2 – Pairwise comparison of criteria

Value for pairwise comparisons of criteria is entered into the software, a consistency ratio is obtained (CR ≤ 0,10). This achieves a more objective assessment of the importance of criteria. In this case, the stability criterion is the most important, followed by cost of support, and finally installation time. The consistency level is below the threshold value, which means that the evaluation is correct.

After defining the weight coefficients of the criteria, it is necessary to define the final hierarchical level of alternatives. The formation of alternatives is carried out by selection in the main Expert Choice window, under the Alternative distributive mode (Figures 3,4,5). By comparing pairs of alternatives based on specified criterion, the weight coefficient of the alternative is determined, based on the data presented in Table 1.

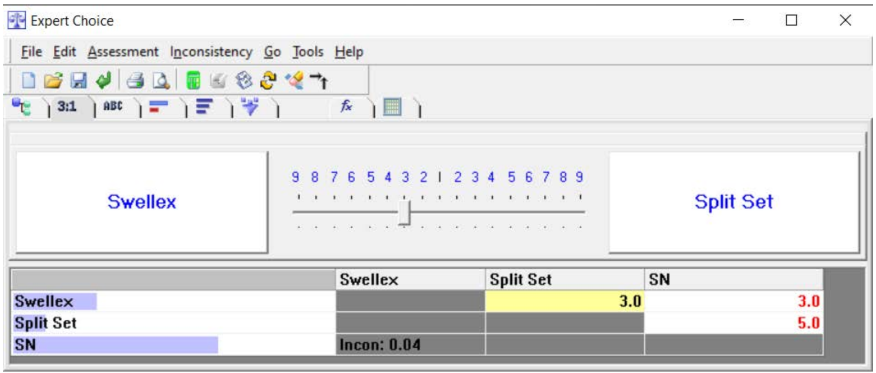

Figure 3 – Pairwise comparison of alternative based on the criterion of stability

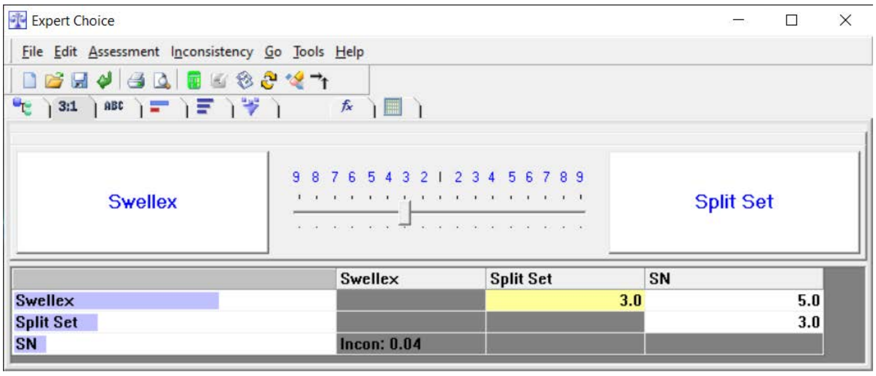

Figure 4 - Pairwise comparison of alternative based on the criterion of installation time

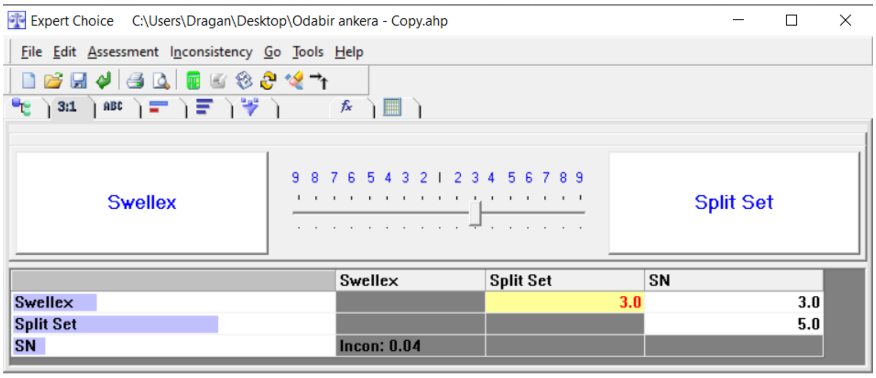

Figure 5 - Pairwise comparison of alternative based on the criterion of costs of support

Based on the previous figures, it is evident that the consistency coefficient is satisfactory in all cases (0,04 ≤ 0,1). According to the stability criterion SN anchors have proven to be the best choice, while for the installation time criterion Swellex anchors are preferred. The lowest costs were achieved using Split Set anchors.

Considering the obtained results of the relationship between alternatives and criteria, it can be conducted that SN anchors have proven to be the best solution for supporting (Figure 6).

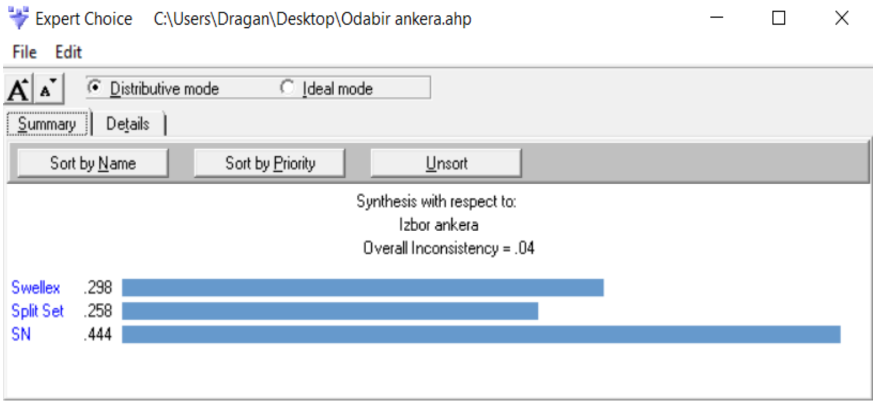

Figure 6 – Comparison of anchors based on three criteria

3. DISCUSION AND CONCLUSION

The selection of the optimal type of anchor for support is complex process. In order to facilitate this decision, the paper presents the application of the analytic hierarchy process (AHP) method. The weight of the criteria has been evaluated and the types of anchors have been evaluated according to these criteria. Based on the results obtained through this method, it has been concluded in the specific case, that using SN anchors achieves the best results for support an underground drift. Therefore, by applying the presented methodology for anchors selection, it significantly influences cost reduction, construction time, and achieves the necessary stability.

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