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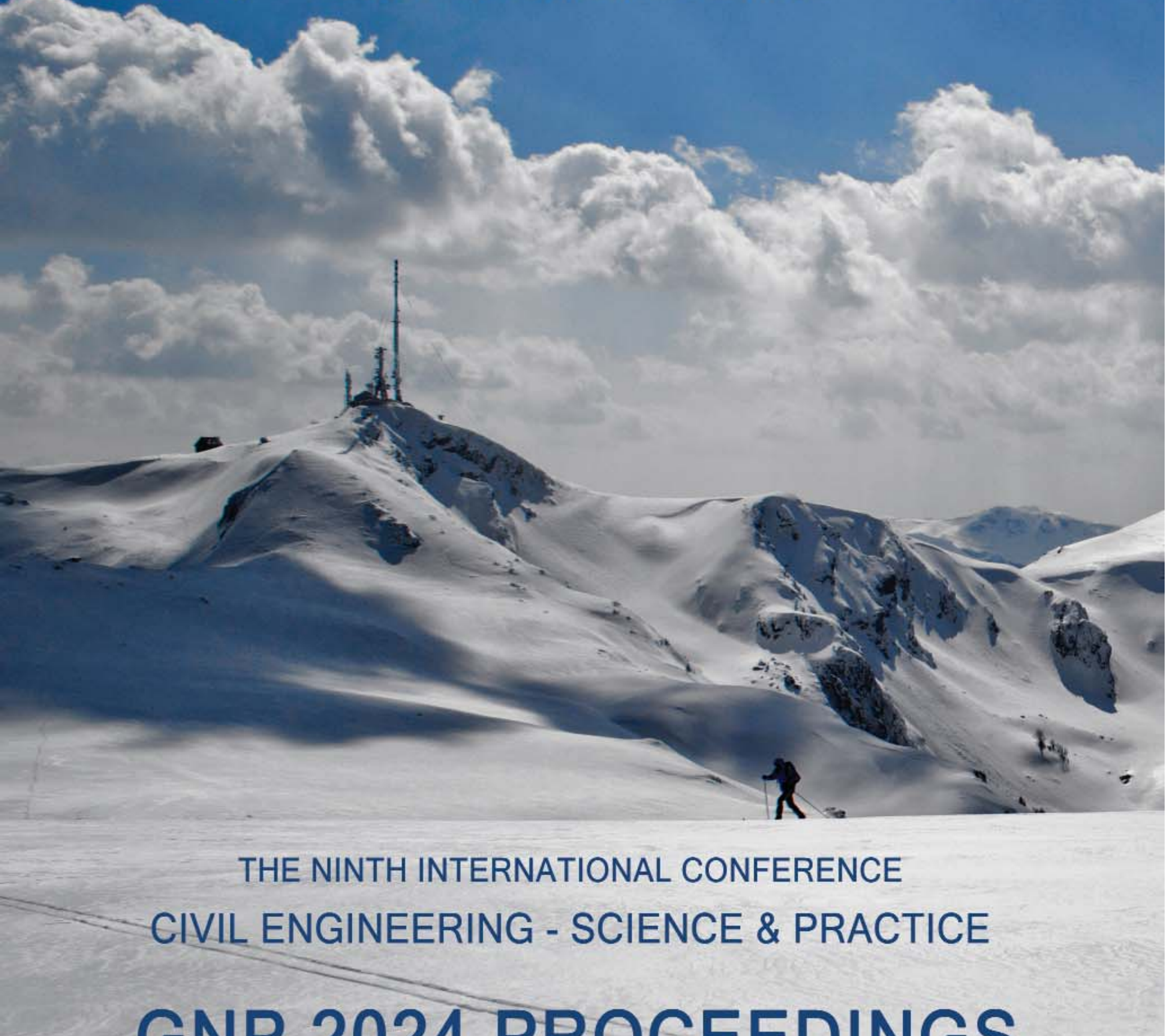

THE NINTH INTERNATIONAL CONFERENCE

CIVIL ENGINEERING - SCIENCE & PRACTICE

GNP 2024 PROCEEDINGS

Kolašin, March 2024

UNIVERSITY OF MONTENEGRO

FACULTY OF CIVIL ENGINEERING

THE NINTH INTERNATIONAL CONFERENCE

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GNP 2024 PROCEEDINGS

KOLAŠIN, 5-9 MARCH 2024

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THE 9th INTERNATIONAL CONFERENCE
"CIVIL ENGINEERING – SCIENCE AND PRACTICE"

GNP 2024 – Kolašin, Montenegro, 5-9 March 2024

Zlatko Zafirovski[1], Pero Cvetkovski[2], Vasko Gacevski[3], Ivona Nedevska Trajkova[4], Riste Ristov[5], Slobodan Ognjenovic[6], Marijana Lazarevska[7]

STABILITY ANALYSIS OF PORTALS IN TUNNELS

Abstract

At this paper will be reviewed stabilization and rehabilitation of cuts and portals of railway tunnel. Usually, tunnels are performed in rock areas and there is always need from stabilization and temporary protection during performing and its use. Tunnel's cuts are located at the entrances and exits of the and stabilization but as most common method is with galvanized wire mesh, shotcrete and barriers.

During every construction works appears changes in some parts of rocks massive and new deformations. In order to avoid appearance of deformations, in slopes anchors need to be installed. Installation of geotechnical anchors is method with drilling, insertion of anchors and injection. In that way the stabilization of the slope is achieved, where anchors help the rock massive to keep his load. Anchors with pulling force transmit the force in health rock mass. Anchors can be used and with other types of protection for better and longer stabilization of slopes.

In this paper will be reviewed stabilization of cuts and portals of tunnel in Republic of Croatia, which had need of stabilization. The process consists of making design (schemes) for stabilization, and then checking and verifying the solutions with software analysis and directly on site. The purpose of this paper is to emphasize the importance of stabilization of slopes and of portals too. In Republic of North Macedonia, the use of protective measures is still low, but it should be increased especially in the area of transport infrastructure.

Keywords

Tunnels; portals; rockfall; landslides; protection; stabilization; rehabilitation.

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1. INTRODUCTION

The protection of the slopes/cuts and tunnel portals is one of the most important construction tasks in the construction of tunnels, both during construction and during long-term exploitation. In general, the protection of these parts is the same as the stabilization of slopes along the route. When starting to stabilize or rehabilitate a certain position, a variety of tests, analyzes and hazard assessments should be done first [1, 2, 3].

In this paper, unstable slopes, rockfall and rockfall protection will be presented. The following will be singled out as protective measures: road mesh (net); shotcrete; barrier; anchors.

As part of this paper, the protection of slopes and portals at the Plavche Draga tunnel, Republic of Croatia has been done. In the development of the analysis, the assumed stabilization schemes are first inserted, and then they are confirmed by their dimensioning. As different methods of protection, three types of protection are distinguished, namely: TYPE 1 - Rehabilitation of the portal slope with shotcrete, anchors and reinforcing mesh, TYPE 2 - Rehabilitation of the portal slope of a tunnel with protective mesh for a controlled rockfall, TYPE 3 - Rehabilitation of the portal slope of a tunnel with a double mesh protective net for a controlled rockfall with anchors and galvanized cables.

The quality control and assurance are based on the following measures: design quality assurance measure, performance quality assurance measure, general safety measures at work.

2. ROCK SLOPE STABILITY

During any engineering intervention on a rock mass, whether it is work in excavations, foundations or a hydrotechnical facility, there is a need for a certain degree of stability on the slopes of the rock mass. In the case of a structure built in a section, it is inevitable that rockfalls will occur along the slope during construction or after the completion of the construction of that part [4].

The inclination of the slopes can be vertical or inclined (oblique), depending on the conditions of the slope and the conditions for the needs of the object to be insured.

In geotechnics, the term slope stability is used when solving two basic types of engineering problems, namely:

- Design of artificial slopes in a cut or in an embankment, due to the construction of new structures in the rock mass and soil, geometry which is determined by the safety factor of a possible rockfall from the slope,
- Analysis of the stability of an existing slope of the rock mass or ground, a slope that is potentially unstable, a slope on which there is an occurrence of rockfalls or a slope on which it is necessary to carry out certain interventions.

The concept, stability of slopes is not fully determined, because for any slope of the rock mass or ground, the stability in use over a long period of time cannot be fully guaranteed at an assumed constant level of reliability. Climatic, hydrological and tectonic conditions, as well as human activity can affect the stability of artificial and natural slopes over the years [5].

In operation, rocks and unstable rock slopes are usually the result of an unwanted and critical condition of the slopes. The appearance of a discontinuity indicates the appearance of an unstable rock mass. Conditions of stress on the rock mass that exceed their strength cause a landslide and collapse of the rock mass from the slope.

Violation of the stability of the rock mass is a result of the application of various blasting methods and explosives during work on a certain route. By making cuts, detonation cracks, seismic stresses and other deformations from explosions occur. These deformations in certain conditions can cause the slopes of the breached route to collapse, cause conditions of instability, expand the already existing unstable slopes and form new cracks in the depth of the massif [6].

Cutting of rock slopes is most often encountered in construction due to the needs of some constructions or in mining during open mining of mineral resources.

The stability of the slopes that have been formed are of special importance in the construction of structures with a long-time character, such as roads, railways or other types of infrastructure facilities (shafts, tunnels, bridges, etc.) [7, 8].

3. REHABILITATION OF THE ENTRANCE AND EXIT PORTAL SLOPE OF A TUNNEL

Plavča Draga tunnel with a total length of 237,02 m is located on the Oshtarije-Knin-Split Predgradze railway, Croatia from km. 34+523,53 to km. 34+761,55 between Plashki railway station and Blata railway station.

The route of the railway is made in a section with two portals, with a length of 116 m on the western side and 73 m on the eastern side. The approximate height of the cut on the western side is 4,0 m to 11,0 m (south side) and from 10,0 m to 17,0 m (north side), and the approximate height of the eastern entrance is from 3,0 to 12,0 m (north side) and from 4,0 m to 10,0 m (south side).

Figure 1. View of the portal slope

Excavations on the slopes were carried out with a slope of 3:1-5:1 without a berm, following the line of the field, which is in accordance with the way the works were carried out in 1918 (Figure 1).

The portal slope is performed in live rock without protection parts. The protection is made with concrete walls on undermined, collapsed parts of the slope, but zones that later suffered deformations are registered and their development is expected. In accordance with the agreed obligations, investigative works were carried out, which included a detailed classification of the rock mass and the way it affects the mechanical resistance and stability of the structure.

Investigative works are based on the current situation of the tunnel, with:

- Geodetic recording of tunnel and portal slope,
- Engineering-geological mapping of a developed tunnel profile.

3.1. REHABILITATION TYPES

In the conducted analyses, the standard value characteristics of the supporting elements were used. Support assemblies represent expensive interventions and materials, the application of which improves the stability and maintains the load-bearing capacity of the rock mass. The foreseen remedial elements are placed in places where there is a bad influence on the safety of railway traffic.

TYPE 1 - Rehabilitation of portal slope with shotcrete, anchors and reinforcing mesh

Due to the slope and the height of the slope at the entrance and exit of the tunnel, which are performed without berms and due to increasing the durability of the construction to prevent rockfall, protection with shotcrete, mesh and anchors is applied.

TYPE 2 - Rehabilitation of portal slope with protective mesh for controlled rockfall

A steel mesh type 8x10 is provided. The mesh will be placed on parts of cuts, where the height is not greater than 5 m. It is installed on the surface of the cut, with reinforcement above the cut and loading of the lower end with concrete weights.

TYPE 3 - Rehabilitation of portal slope with double mesh protection for controlled rockfall with anchors and galvanized cables

This type of protection is placed on the parts of the slope where the height is more than 5m. The double-braided mesh is installed after or before the anchors are drilled, and before the steel plates are installed. After the installation of the network, and after that the steel plates are installed, the installation of the cable can be carried out, and thus this type of rehabilitation ends.

3.2. ANALYSIS

Regarding the need for the rehabilitation of the precuts of the Plavche Draga tunnel, and based on a field visit and a visual review of the situation of the portal slopes from the engineering-geological mapping, an analysis of protective measures was made in the SWEDGE computer program. With this program, calculations were made for wedge formation and rockfall stability.

The program is based on the following assumptions:

The block is formed through two discontinuities, excavation face, clean surfaces or with the possibility of a crack,

Movement occurs along the length of the formed block, as a non-deformable rigid body,

The surface discontinuities are completely flat,

Discontinuities can be found anywhere on the considered site.

Only two structural planes can be analyzed simultaneously. If several cracks appear, it is necessary to consider all their mutual combinations (Figure 2, 3).

The results from the analysis are shown in table 1 for geotechnical unit 4.

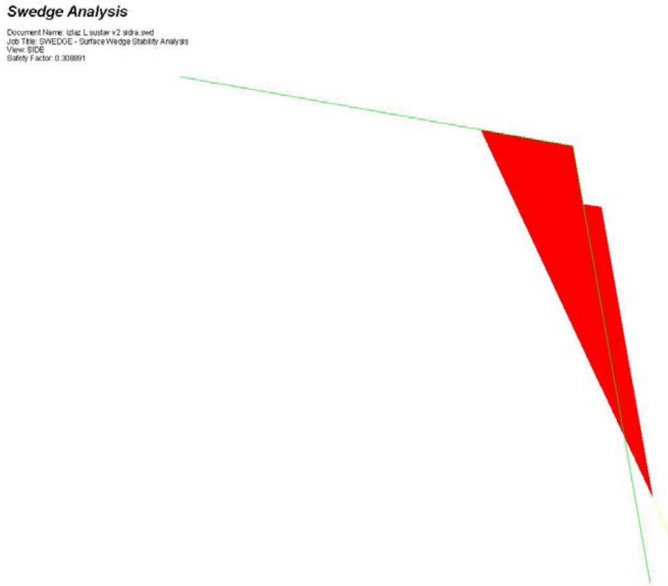

Figure 2. Calculation model cross section

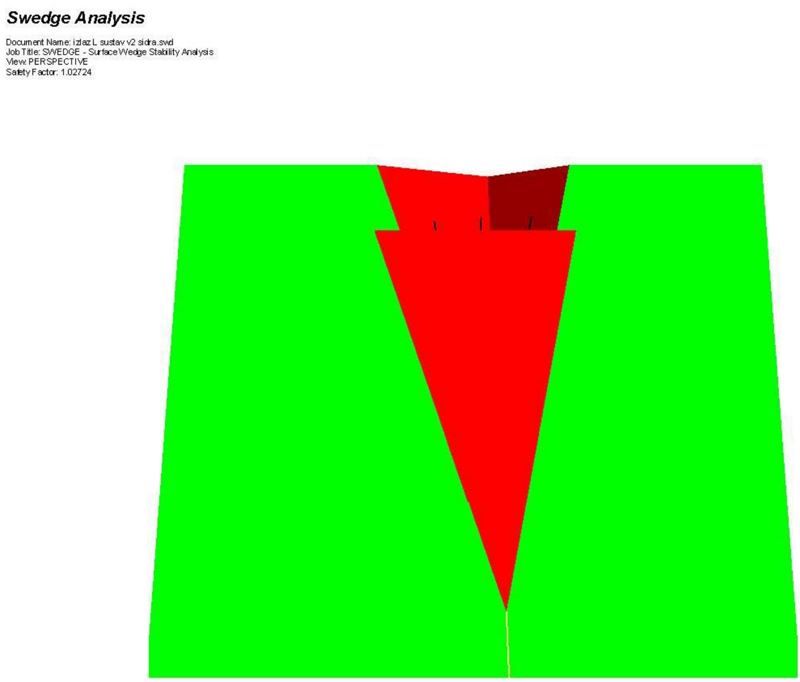

Figure 3. Calculation model longitudinal profile

Table 1. Results from the stability analysis

Num.	Mark of the model	Calculation model	Situation	Fs- before rehabilitation	Fs min	Fs	Note
4	PM-4-1	Block 4, slope orientation 225/80	Slope stability in a cut without protection, least favorable discontinuity orientation	0,57	1,00	2,98	Anchors of distribution at 2x3m – passive anchors, L=9 m Ø32 and L= 6 m Ø25,

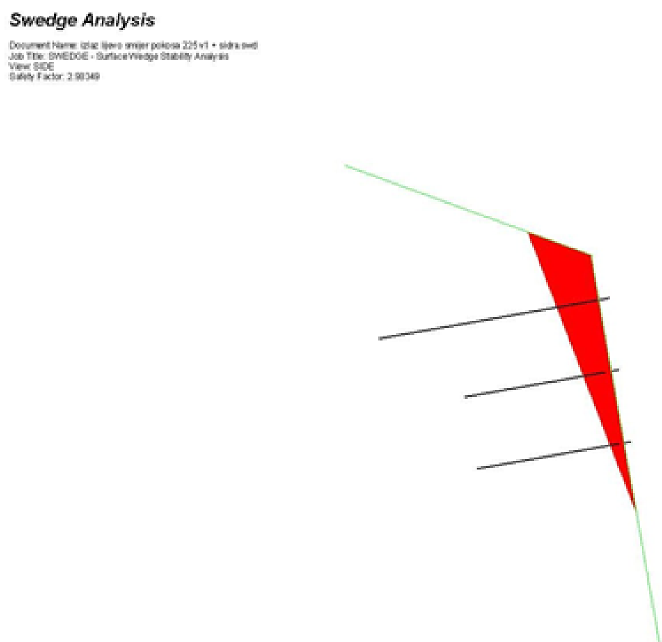

Figure 4. SWEDGE analysis cross section with anchor protection

Analysis Results:

Analysis type = Deterministic Safety Factor = 2,98349

Wedge height (on slope) = 11 m

Wedge width (on upper face) = 2,84562 m

Wedge volume = 10,1447 m^3

Wedge weight = 26,3762 tones

Stability analysis of wedges forming critical discontinuity pairs of the above slopes made with selected computational models with valid engineering-geological characteristics of rock slope. The selected calculation models also show the real geometry of the slope, size, arrangement and state of discontinuity, all based on data obtained from engineering-geological works for the indicated object. In the mentioned analyses, data were obtained on the minimum slip safety factors for assumed slip-prone surfaces, i.e. wedges formed along expressed and recorded discontinuities.

Variant solutions included a stability check before and after slope rehabilitation. For all proposed variant solutions, satisfactory calculation factors for landslide reliability were achieved, where Fs=1 (Fs – Factor of safety) was requested. Stability of the slope with the specified safety factors can only be realized with the correct performance of the intended protection (Figure 4).

With the performed stability analyzes and based on the calculations, it can be concluded that the predicted state of the slope of the cut satisfies the stability criteria in the context of calculation assumptions. Figure 5 shows the performed portal protection.

Figure 5. View of the performed portal protection at the Plavce Draga tunnel

4. CONCLUSION

The study and analysis of problems such as rockfalls and landslides is of special importance, primarily for the purpose of protection against unwanted consequences. During a certain construction project in a section, the need to protect the slopes arises over time.

In this paper, certain types of protection, as well as stabilization of portals and tunnel slopes, are discussed. Some slopes do not require sophisticated landslide block velocity simulations. It is enough to have adequate data for the location and for the place we are analyzing, and by using basic calculation data we can arrive at the simplest solution for stabilization. For this particular slope the type 1 rehabilitation with shotcrete, anchors and reinforced mesh gave high factor of safety and was implemented on site.

Before starting the design for the stabilization of slopes, first of all, appropriate data about the slope should be collected, such as the inclination of the slope, the material from which the slope is made, the occurrence of discontinuity, etc. Apart from the necessary basic data for a specific slope, the visit to the location that needs to be stabilized is most important. During the visit to the location, the accuracy of the data is determined and an assumed stabilization scheme should be made, which will be a guide in the design and dimensioning of the protection [9, 10].

Analyzing a cut in the rock mass comes down to the correct choice of protective measures in order to obtain a stable geometric slope. On the basis of conducted geotechnical research, a geotechnical calculation model is implemented, which is needed to conduct a stability analysis [11, 12].

If there is a possibility, the stabilization of the slope can be done in time during excavation work in the field, it turns out to be the most economical stabilization due to the easily accessible places and the easier access to work. If timely, specific work activities for the stabilization of the slopes are not undertaken, the consequence may be material losses, human casualties and the need for greater financial resources for its stabilization.

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