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SUBSTRUCTION FROM SPRAYED (TORKRET) CONCRETE IN A FUNCTION OF INSURANCE OF MAIN TRANSPORTATION FACILITIES IN MINES TREPČA - LEPOSAVIĆ

PODGRADA OD PRSKANOG (TORKRET) BETONA U FUNKCIJI OSIGURANJA GLAVNIH TRANSPORTNIH PROSTORIJA U RUDNICIMA TREPČA - LEPOSAVIĆ

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Abstract: *This paper represents the possibility of application of sprayed concrete in a combination with another type of substruction in the rehabilitation of existing underground facilities and building new ones. Therefore, in this paper the particular attention is paid to sprayed concrete production for application in different conditions, and the calculation method of substruction parameters. Considering the complexity of maintenance and construction of underground facilities, the very important and crucial is the selection of appropriate technologies for foundation and sub-structures.*

Key words: *sprayed concrete, underground facilities, substruction calculation*

Apstrakt: *Rad prikazuje mogućnost primene prskanog betona u kombinaciji sa nekom drugom podgradom pri sanaciji postojećih podzemnih prostorija i građenju novih. U radu se posebna pažnja poklanja tehnici spravljanja prskanog betona, mogućnost primene istog u različitim uslovima rada, kao i načinu proračuna parametara podgrade. Imajući u vidu složenost održavanja i gradnju podzemnih prostorija, od vrlo važnog i presudnog značaja je izbor odgovarajuće tehnologije izrade i načina podgrađivanja istih.*

Ključne reči: *prskani beton, podzemne prostorije, proračun podgrade*

1 INTRODUCTION

Maintenance of transportation facilities in mines with underground mining represents a serious problem and requires considerable material resources for daily supporting and providing secure environment. This work is related to the implementation of sprayed concrete in the insurance and repairement of major transportation facilities in the mines of Crnac and Belo brdo. Mines Crnac and Belo brdo belong Kopaonik Ore District and they produce ores of Pb and Zn. Located at an altitude of about 1000 m

1 UVOD

Održavanje transportnih prostorija u rudnicima sa podzemnom eksploatacijom stvara ozbiljan problem i zahteva znatna materijalna sredstva za svakodnevna podgrađivanja i osiguranje prostorija. Ovaj rad se odnosi na primenu prskanog betona pri osiguranju i sanaciji glavnih transportnih prostorija u rudnicima Crnac i Belo Brdo. Rudnici Crnac i Belo Brdo pripadaju Kopaoničkoj rudnoj oblasti i u njima se proizvodi ruda Pb i Zn. Nalaze se na nadmorskoj visini od oko 1000 m i pripadaju

and belonging to the hilly-mountainous type of mines that are opened by undermine system at different levels of high altitude. Type of mining and other geological conditions are dictated by the manner of opening and developmant of both deposits, so we have a huge number of premises that are necessary to be fulfilled for normal functioning of the pits Belo Brdo and also Crnac.

For the purposes of transportation of mineral raw materials in Belo Brdo, there are approximately 10 km long transportation facilities, while in the pit Crnac there are about 6 km transport facilities of various cross-sections. The main transport facilities are generally sub-constructed in segments by permanent and temporary substructions, and there are sections that are not substructed and in these sections there are loose pieces of rocks which are tending to ruin.

In early 60 ties of the last century a modern construction technology of underground facilities based on the application of sprayed concrete was involved. In the mining practice, sprayed concrete substruction has been implemented as stand-alone or in combination with another substruction. So, there are very often applications of a combination of:

- Sprayed concrete + anchors
- Sprayed concrete + steel net
- Sprayed concrete + anchors+ steel net
- Sprayed concrete +steel frame+ steel net

Which of the following forms of construction will be applied, it depends exclusively on the impact of which the substruction will be exposed. Sprayed concrete is applied independently only in favorable geological and hydrological conditions, in the stable temperature regimes and the premises at which the minor strain contours occured.

2 CONSTRUCTIVE FORMS OF SUBSTRUCTIONS

According to its purpose substructions of sprayed concrete can be protective and supporting.

Protective substruction is a thinner layer of sprayed concrete applied across the whole surface of opening contours. The thickness of protective layer ranges from several mm to 5-7 cm. The thickness of the layer depends entirely on local conditions and roughness contours. This

brdsko-planinskom tipu rudnika koji su otvoreni sistemom potkopa na različitim visinskim nivoima. Tip orudnjenja i drugi geološki uslovi su diktirali način otvaranja i razrade oba ležišta, tako da postoji veliki broj prostorija koje su neophodne za normalno funkcionisanje jama u rudnicima Belo Brdo i Crnac.

Za potrebe transporta mineralne sirovine u jami Belo Brdo postoji oko 10 km, dok u jami Crnac postoji oko 6 km transportnih prostorija različitog poprečnog preseka. Glavne transportne prostorije su uglavnom podgrađene u segmentima trajnom i privremenom podgradom, a postoje i deonice koje nisu podgrađene i na tim deonicama ima stena koje su sklone zarušavanju.

Početkom 60-tih godina prošlog veka uvodi se savremenija tehnologija građenja podzemnih prostorija, zasnovana na primeni prskanog betona. U rudarskoj praksi podgrada od prskanog betona primenu je našla ili kao samostalna ili u kombinaciji sa nekom drugom podgradom. Veoma često se koriste sledeće kombinacije:

- Prskani beton + sidra
- Prskani beton + čelična mreža
- Prskani beton + sidra + čelična mreža
- Prskani beton + čelični okvir + čelična mreža

Koji od navedenih konstruktivnih oblika će biti primenjen, to zavisi isključivo od uticaja kojima će podgrada biti izložena. Prskani beton se primenjuje samostalno, isključivo u povoljnim geološkim i hidrogeološkim uslovima, pri stabilnim temperaturnim režimima i kod prostorija kod kojih su deformacije konture neznatne.

2 KONSTRUKTIVNI OBLICI PODGRADE

Prema svojoj nameni podgrada od prskanog betona može biti zaštitna i noseća.

Zaštitna podgrada predstavlja tanak sloj prskanog betona koji je nanešen po čitavoj površini iskopne konture. Debljina zaštitnog sloja kreće se od nekoliko mm do 5-7 cm. Debljina sloja zavisi isključivo od stanja u kom se nalazi stenska masa i hrapavosti konture. Ova vrsta

type of substruction is intended solely for surface protection of rock mass from moisture loss and decay, and connecting the smaller pieces of rocks and preventing their relegation and dropout. This substructure is shown to be effective in the insurance underground facilities made in solid rocks [1].

Supporting substructions

With increasing thickness of the supporting layer of sprayed concrete can be achieved the same effect as the setting of concrete podgrade. Given that in the sprayed concrete substructions, bonding concrete mixtures with rocks is 2-2.5 times better than in monolitnog concrete, and mechanical properties are also better, so with the smaller thickness of applied layer of sprayed concrete the same effects are achieved.

In case of need for this kind of substructions in supporting weaker rocky materials, sprayed concrete is strengthened with wire mesh and reinforcement bars so it can withstand considerable external loads. Substruction of sprayed concrete advantages, over the concrete substruction are bigger capacity and facter construction of underground facilities. Lack of this procedure, compared to the monolithic concrete substructions is significantly greater mixture scattering.

In the production of sprayed concrete substructure, it is necessary to keep in mind that the area on which concrete is applied to uneven, and for the flat final sbstructure concrete surface, it is necessary to make some previous settlements, which is achieved by applying of flattening layer, and only after that comes the supporting application layer [1].

Depending on the construction of the sprayed concrete substruction it can be independent or combined.

Independent substruction is used in cases when the premises operate or are made in solid and stable rocks, where strain contours do not cross the border at which the destruction occurs when the concrete stability maintenance does not need any additional funds (Figure 1).

Combined substruction of sprayed concrete is applied in weak and unstable rocks, as well as in

podgrade isključivo je namenjena površinskoj zaštiti stenske mase od gubitka vlage i raspadanja, kao i povezivanja manjih komada stena i sprečavanju njihovog ispadanja i osipanja. Ovakva podgrada pokazala se efikasnom kod osiguranja jamskih prostorija izrađenih u dovoljno čvrstim i neispucalim stenama [1].

Noseća podgrada.

Sa povećanjem debljine nosećeg sloja prskanog betona može se postići isti efekat kao i kod postavljanja betonske podgrade. S obzirom da je kod podgrade od prskanog betona vezivanje betonske smeše sa stenom 2-2,5 puta bolje nego kod monolitnog betona, kao i da su mehaničke karakteristike ovakve smeše bolje, to se u praksi i kod manjih debljina nanetog sloja prskanog betona postižu isti efekti.

U slučaju potrebe za ovakvom vrstom podgrade u slabije nosećim stenskim materijalima, prskani beton se ojačava sa armaturnom mrežom i armaturnim šipkama, zbog povećanja izdržljivosti spoljašnjih opterećenja. Prednost podgrade od prskanog betona, nad istom takvom betonskom podgradom, osim veće nosivosti, ogleda se i u većoj brzini gradnje podzemnih prostorija. Nedostatak ovog postupka, u odnosu na gradnju monolitnim betonskim podgradama ogleda se u znatno većem rasturu smese.

Prilikom izrade noseće podgrade od prskanog betona, neophodno je imati u vidu da je površina na koju se nanosi beton neravna, te da bi se dobila što pravilinija završna površina betonske podgrade, nužna je predhodna obrada u cilju poravnanja svih neravnina, što se postiže nabacivanjem izravnavajućeg sloja, pa tek posle toga dolazi nanošenje nosećeg sloja [1].

U zavisnosti od konstrukcije, podgrada od prskanog betona može biti samostalna ili kombinovana.

Samostalna podgrada koristi se u slučajevima kada se prostorije rade, ili su urađene u čvrstim i stabilnim stenama, kod kojih deformacije konture ne prelaze granicu kada dolazi do razaranja betona i kada za održavanje stabilnosti nisu potrebna nikakva dopunska sredstva (Slika 1).

Kombinovane podgrada od prskanog betona primenjuje se u slabim i nestabilnim stenama,

cases when there is a threat from swoop down from the roof or sides. In such cases, the purpose of reinforcement of rock mass surrounding the underground facilities, it is necessary first to install the anchor, either alone or in combination with wire mesh, then apply a layer of sprayed concrete [7]. Sprayed concrete, depending on the thickness and purpose can serve as a protection of the bearing structure (Figure 2). In cases where the rock mass are unstable and prone, and requires setting up temporary substructures after excavation, the combined substructure of steel frame and sprayed concrete is applied (Figure 3).

kao i u onim slučajevima kada preti obrušavanje iz krova ili iz bokova. U ovakvim slučajevima, u cilju ojačanja dela stenske mase koja okružuje podzemnu prostoriju, neophodno je prvo ugraditi sidra, bilo samostalno ili u kombinaciji sa armaturnom mrežom, pa zatim naneti potreban sloj prskanog betona [7]. Prskani beton u zavisnosti od debljine i namene može poslužiti kao zaštita nosećem delu konstrukcije (Slika 2). U slučajevima kada je stenska masa nestabilna i sklona obrušavanju, i zahteva postavljanje privremene podgrade, odmah posle izrade iskopa, koristi se kombinovana podgrada od čeličnih okvira i prskanog betona (Slika 3.)

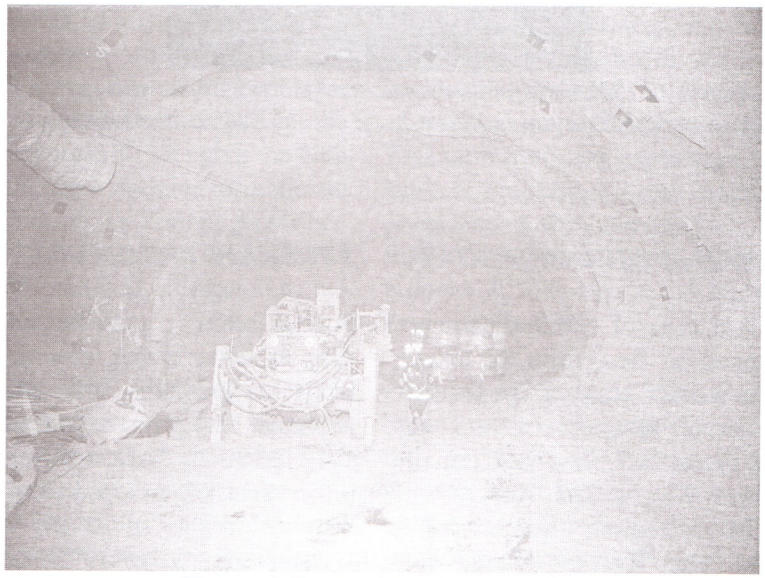

Figure 1 Sprayed concrete coating
slika 1 Obloga od prskanog betona

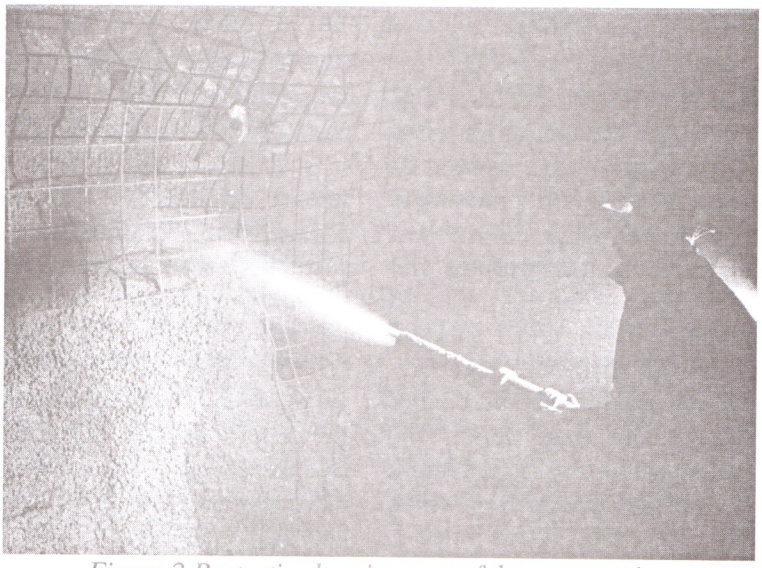

Figure 2 Protective bearing part of the construction
slika 2 Snimak zaštitnog nosećeg dela konstrukcije

Figure 3 Image of the combined substructure of steel frame and sprayed concrete
slika 3 Snimak kombinovane podgrade od čeličnih okvira i prskanog betona (1)

3 SPRAYED CONCRETE AND ITS APPLICATION

Sprayed concrete is a type of concrete that are released by high-speed air flow from the nozzle and deposited to the surface areas of the facility. The first application of sprayed concrete was reported in 1912th in the U.S., and in Germany after the First World War, called "Torkret" or schpritz concrete. In our region, these concretes appeared in 1950th, titled "Torkret" for the first time in hydraulic tunnels, and later at other facilities. And today, we kept the name "torkret" for layer thickness up to 5cm [4].

There are the two production procedure for sprayed concrete:"dry" and "wet" process. Dry process of sprayed concrete production is when the dry mixture is transported to a reinforced rubber tube nozzle (nozzles) where the mixture is added water under pressure, while in the wet process, wet mixture of cement, aggregates and water is transported by pipes in the air stream to the nozzle (nozzles), where the air under pressure is added. In the dry production procedure, optimum humidity of dry mixture should be 2 to 5% to avoid lifting cement dust during the operation. Adding water at the dry procedure is performed by worker-nozzler over a ring which has a radial drilled holes [4].

In wet process, water is more accurate dosed and the mixture is homogenous-it is better mixed,

3 PRSKANI BETON I NJEGOVA PRIMEN

Prskani beton je vrsta betona koji se vazdušno strujom velike brzine izbacuje iz mlaznice–dizne izbija na površinu tela prostorije na koju nabacuje. Prva primena prskanog betona se pojav 1912. godine u SAD, a u Nemačkoj se primenju posle I svetskog rata pod nazivom"Torkret" ili šp beton. Kod nas su se ovi betoni pojavili 50 godina, pod nazivom "Torkret" prvo kod izra hidrotehničkih tunela, a kasnije i kod dru objekata. I danas se kod nas zadržao naziv "Torkr za debljinu sloja do 5cm [4].

U praksi su u primeni dva postupka proizvod ovog betona: "suvi" i "mokri" postupak. S postupak izrade prskanog betona je onaj pri koj se suva smeša transportuje armiranim gume cevima do mlaznice (dizne) gde se toj sm dodaje voda pod pritiskom, dok se kod mok postupka, mokra smeša cementa, agregata i v transportuje cevima u vazdušnoj struji do mlazn (dizne), gde joj se dodaje vazduh pod pritisk Pri tome, kod suvog postupka rada, optim vlažnost suve smeše treba da iznosi 2 do 5% d se izbeglo dizanje cementne prašine pri r Dodavanje vode kod suvog postupka vrši rad mlazničar preko jednog prstena koji ima zrak izbušene otvore [4].

Mokrim postupkom voda se tačnije dozi smeša je homogenija-bolje izmešana,

while in the dry process, the installation of a mixture with smaller hydraulic factor (0.35 -0.40) and greater length of the transport (up to 200 m) is enabled, but it requires great skill and experience of workers, especially nozzlers [3]. By the dry process it can be installed 6.0 m^3/h of concrete, and in the wet process there can be loaded up to 10-15m^3/h of sprayed concrete.

Sprayed concrete is performed according to the project, whereby the previous testing and quality control of performed works must be implemented. Concrete is applied in layers, ie. With discontinuity, one layer comes first, and the second and so on, depending on the projected total thickness of the concrete. This is because new layers are tightly adherent to previous, that increases water impermeability and new layer covers the possible occurrence of cracks in the previous layer. Sprayed concrete can give the high strength of the pressure and straining of concrete and well above the mark of our current prescribed standards, thereby lining thickness (layer of sprayed concrete) is significantly reduced, compared to the thickness of the classical concrete.

Surface on which the first layer of sprayed concrete is applied, immediately before the start of concreting must be released of unbonded and weakly bonded pieces of rocks (to the background sound) and carefully washed, and the impurities and water arrears must be completely removed. Sprayed concrete can not be applied to surfaces that are frozen, porous and soggy, all irregularities (bumps and dents) should be pre-processed so as not to create diskontuitete in the lining thickness. Thanks to the positive properties of the concrete it is very suitable for carrying out renovation works and strengthen of the structures [3].

Sprayed concrete layer formation takes place in the following way: from the nozzle at high speed (100 m/s) concrete mass was rejected and and strikes the surface on which a layer of sprayed concrete should be formed. Fine particles (cement, and fine grained sand) hit less on the surface of the substrate (and also less of them were declined), being deposited on the surface, entering into all the pores, cracks and irregularities, while the larger particles (aggregates), were being reflected from the surface. Thus, the first formed layer was cement layer (1 - 2mm) and for the further work, smaller grains were being injected, and than, with increasing layer thickness and larger aggregates, so that the loss of material due to the

kod suvog postupka, omogućena je ugradnja smeše sa manjim vodocementnim faktorom (0,35 - 0,40) i većom dužinom transporta (do 200 m), ali zahteva dobru obučenost i iskustvo radnika, posebno mlazničara [3]. Pri suvom postupku može se ugraditi oko 6,0 m^3 /h betona, a kod mokrog 10-15 m^3/h betona.

Prskani beton se izvodi prema projektu, pri čemu se moraju sprovesti predhodna ispitivanja i kontrola kvaliteta izvedenih radova. Beton se nanosi u slojevima tj. sa radnim prekidima, prvo jedan sloj, pa na njega drugi i tako redom, zavisno od ukupne projektovane debljine betona. Ovo se radi iz razloga što novi slojevi čvršće prijanjaju za predhodni, čime se postiže veća vodonepropustivost, a novi sloj pokriva eventualnu pojavu prslina u predhodnom sloju. Prskanim betonom postižu se visoke čvrstoće na pritisak i zatezanje i one mogu biti znatno iznad propisanih našim standardima, što kao posledicu ima smanjenje debljine obloge (sloja prskanog betona) u odnosu na debljinu pri korišćenju klasičnog betona.

Površina na koju se nanosi prvi sloj prskanog betona, mora, neposredno pre početka betoniranja biti očišćena od nevezanih i slabo vezanih komada stena (sve do zdrave podloge) i brižljivo oprana, a nečistoća i zaostala voda moraju biti potpuno odstranjeni. Prskani beton ne sme da se nanosi na površine koje su zamrznute, porozne i raskvašene, a sve neravnine (udubljenja i ispupčenja) treba predhodno obraditi kako ne bi stvarale diskontinuitete u debljini obloge. Zahvaljulući svojim pozitivnim svojstvima ovaj beton je vrlo pogodan za izvođenje sanacija i radova na ojačanju konstrukcija [3].

Formiranje sloja prskanog betona odvija se na sledeći način: iz mlaznica velikom brzinom (oko 100 m/s), izlazi betonska masa i udara po površini, na kojoj treba da se formira sloj prskanog betona. Pri tome, sitnije čestice (cement i vrlo sitan pesak) udaraju slabije o površinu podloge (pa se manje i odbijaju), slažu se na površini, ulazeći u sve pore, neravnine i pukotine, dok se krupnije čestice (agregati), po udaranju o podlogu odbijaju. Tako se prvo obrazuje cementni sloj debljine 1 - 2 mm. Pri daljem radu, u njega se nabacivanjem utiskuju prvo sitniji, a zatim, sa povećanjem debljine sloja i krupniji agregati, tako da se gubitak materijala, usled

impact refusal of (waste, bounce) decreases, but still retains. The goal is achieved when less materials was lost by scattering, with preserved demanding properties of sparayed concrete [3].

Sprayed concrete application area is related to the characteristics of rock mass deformation and deformative properties of the layer of sprayed concrete.

According to the research made by many authors, it can be concluded that for the substructure made only by sprayed concrete, without reinforcement by anchors and nets, the conditions for application, can be determined, based on criteria related to the relationship between the size of deformation (U) and mining width of the facility (l). The condition is fulfilled if:

$$\frac{U}{l} \leq 0{,}014 \qquad (1)$$

where U - roof deformation to the deformation in substruction,
l - mining with of the facility

This condition will be satisfied if:

$$\frac{\gamma \cdot H}{R_p} \leq 0{,}30 \qquad (2)$$

that means that if the relation $\frac{\gamma \cdot H}{R_p} \leq 0{,}30$, then the sprayed concrete without reinforcement is applicable for the substruction. However, if $\frac{\gamma \cdot H}{R_p} \geq 0{,}30$, then the lining should be reinforced by anchors and nets.

4 LAYER THICKNESS OF SPRAYED CONCRETE CALCULATION (d)

Since the contours of underground facilities, to which a sprayed concrete was applied were irregular (have expressed roughness), and the layer of concrete applied no regular geometric shape, the calculation of the thickness of applied layer of sprayed concrete is matter of a very complex calculation [2].

udara odbijanja (otpad, odskok) smanjuje, ali dalje se zadržava. Cilj je da gubitak bude š manji, uz očuvana zahtevna svojstva prskan betona [3].

Oblast primene prskanog betona vezana je deformacione karakteristike stenske mase deformacione mogućnosti nabacanog slo prskanog betona.

Prema istraživanjima mnogih auto konstatovano je, da za podgradu od prskan betona, bez ojačanja sidrima i mrežom, se mog odrediti uslovi primene na osnovu kriterijum vezanog za odnos između veličine deformaci (U) i iskopne širine prostorije (l). Uslov ispunjem ukoliko je:

$$\frac{U}{l} \leq 0{,}014 \qquad (1)$$

gde je: U - deformacija krovnine do pojave deformacija u podgradi,
l - iskopna širina prostorije

Ovaj uslov biće zadovoljen ako je:

$$\frac{\gamma \cdot H}{R_p} \leq 0{,}30 \qquad (2)$$

što znači da ukoliko je odnos $\frac{\gamma \cdot H}{R_p} \leq 0{,}30$, tad je moguće za podgrađivanje koristiti prska beton bez ojačanja. Međutim, ukoliko $\frac{\gamma \cdot H}{R_p} \geq 0{,}30$, tada oblogu treba ojačati sidrim ili mrežom.

4 PRORAČUN DEBLJINE SLOJA OD PRSKANOG BETONA (d)

S obzirom na to, da su konture podzemn prostorija, na koje se nanosi prskani beto nepravilne (imaju izraženu hrapavost), to i sl nanetog betona nema geometrijski pravil oblik, pa je proračun debljine nanetog slo prskanog betona skopčan sa veoma složeni proračunom [2].

For these reasons, all calculations related to the thickness of layers of concrete are mainly related to the considerations that rely on the results obtained in the study of behavior of these structures in natural conditions on site (5).

Iz tog razloga svi proračuni debljine sloja betona uglavnom su vezani za razmatranja koja se oslanjaju na rezultate koji su dobijeni prilikom izučavanja ponašanja ovakvih konstrukcija u prirodnim uslovima [5].

There are several theories for the calculation of sprayed thick layer of concrete. In this paper, we will consider the proposed calculations by Lejbedzona, Rapcevica at al.. [2]. They proposed the calculation of the required layer thickness of sprayed concrete in case of substruction combined with the anchors, the most widely used method based on the theory of thin plates evenly loaded, because just a calculation of a thin layer of concrete on a smaller area (limited anchors) is relational to the above methods. Research performed by Lejbedzon, Rapcevic and others, has shown that conditions in the boards relying on a number of supports corresponds to the combined substruction of sprayed concrete and anchors and are indentical [6].

Postoji više teorija za proračun debljine sloja od prskanog betona. U ovom radu su korišćena istraživanja Lejbedzona, Rapcevica i dr [2]. U ovim istraživanjima, za proračun potrebne debljine sloja prskanog betona, za slučaj kombinovane podgrade sa sidrima, koristi se metoda zasnovana na teoriji oslanjanja tankih ploča opterećenih ravnomerno raspoređenim teretom. Upravo, tanki sloj betona, na jednoj manjoj površini (ograničenoj sidrima), po uslovima rada, odgovara navedenoj metodi. Istraživanja koja su izveli Lejbedzon, Rapcevic i drugi, pokazala su, da su uslovi koji vladaju kod ploče oslonjene na veći broj oslonaca, što odgovara i kombinovanoj pogradi od sidara i prskanog betona, identični [6].

The greatest loadings are observed on the supporting points (in our case these are embedded anchors). The Maximum bending moment can be determined by formula:

Najveća opterećenja se javljaju na mestima oslonaca (u našem slučaju mesta gde su ugradna sidra). Maksimalni momenat savijanja može se odrediti po obrascu:

$$M_{max}= \frac{q \cdot l_0^2 (1+\mu)}{4\pi} \cdot \ln \frac{l_0}{l_1}, \text{(Nm)} \qquad (3)$$

$$M_{max}= \frac{q \cdot l_0^2 (1+\mu)}{4\pi} \cdot \ln \frac{l_0}{l_1}, \text{(Nm)} \qquad (3)$$

where q – is equaly distributed load
M – Poason coefficient for concrete mass building the sprayed concrete layer
l_1 - half of the flat washer width (l_1= 10 cm)
l_0 – distance between anchors.

gde je: q – ravnomerno raspoređeno opterećenje
M – koeficijent Poasona betonske mase koja izgrađuje sloj prskanog betona
l_1 - polovina širine podložne pločice (l_1 = 10 cm)
l_0 – rastojanje između sidara.

Considering the yeld strength of the sprayed concrete and φ – internal friction angle, the authors proposed formula for sprayed concrete layer thickness calculation which could carry the load:

Uzimajući u obzir čvrstoću prskanog betona na zatezanje i φ – ugao unutrašnjeg trenja stene, autori su dali obrazac za proračun debljine sloja od prskanog betona koji može da nosi opterećenje:

$$d = 0{,}78 \cdot l_0 + \sqrt{\frac{l_0 \cdot \gamma}{2tg\varphi \cdot \sigma_z^{Pb}} \cdot \ln \frac{l_0}{l_1}} \text{ (cm) } (4)$$

$$d = 0{,}78 \cdot l_0 + \sqrt{\frac{l_0 \cdot \gamma}{2tg\varphi \cdot \sigma_z^{Pb}} \cdot \ln \frac{l_0}{l_1}} \text{ (cm) } (4)$$

If there is a joint work of concrete and rock considered, it is possible to propose formula by the analogy to composite intel:

Ako se uzme u obzir, zajednički rad betona i stene, moguće je, po analogiji sa slučajem složene grede dati obrazac:

$$d = \frac{l \cdot E_{Pb}}{E_{Pb} + E_{St}} + \sqrt{\frac{l_0 \cdot \gamma}{2tg\varphi \cdot \sigma_z^{Pb}} \cdot \ln \frac{l_0}{l_1}} \text{ (cm) } (5)$$

$$d = \frac{l \cdot E_{Pb}}{E_{Pb} + E_{St}} + \sqrt{\frac{l_0 \cdot \gamma}{2tg\varphi \cdot \sigma_z^{Pb}} \cdot \ln \frac{l_0}{l_1}} \text{ (cm) } (5)$$

where: E_{Pb} and E_{St} – are elasticity modules od sprayed concrete and rock

According to Rapćenc and Miljanović, sprayed concrete elasticity module (E_{Pb}) depends of aging time expressed in hours, so this parameter could be calculated by the following formulas:

For the concrete aged 6 to 11 hours:
$E_{Pb} = -130{,}75\ t^{1{,}803}$, (MPa)

For the concrete aged 11 to 51 hours:
$E_{Pb} = -16657{,}84 + 11036{,}11 \ln(t)$, (MPa)

For the concrete aged 51 to 480 hours:
$E_{Pb} = -15610{,}53 + 3070{,}34 \ln(t)$, (MPa)

where t is (time in hours).

If the sprayed concrete layer thickness is calculated , than the carrying capacity of this layer can be calculated by:

$$P_{Pb} = \frac{\sigma_p^{Pb} \cdot f_i \cdot d}{k_s \cdot r \cdot \sin\alpha \cdot \cos\alpha}, \text{(kPa)} \qquad (6)$$

where σ_p^{Pb} - pressure strength of the sprayed concrete achieved after certain period of time, and according to Rapćenc it is:

$$P_p^{Pb} = 1{,}004{,}286 \cdot t^{0{,}733}, \text{(kPa)} \qquad (7)$$

where: f_i – coefficient caculated by:
$f_i = 1{,}3794\ t^{-0{,}4436}$

for the concrete age of 24 h $f_i = 0{,}337$

for the concrete age of 72 h $f_i = 0{,}207$

d – concrete lining thickness
k_s – safety coefficient
r – semi diameter of mining facility.

It is possible to reach the orientation value of the sprayed concrete thickness, depending of substruction construction if the strength coefficient by Protođakonovu (f) is known, and also width of the facility, according to the diagrams presented on Figure 4.

gde su: E_{Pb} i E_{St} – moduli elastičnosti prskanog betona i stene.

Prema Rapćencu i Miljanoviću, modul elastičnos prskanog betona (E_{Pb}) zavisi od vremena starenj izraženog u časovima, tako da se ovaj parameta može proračunati sledećim obrascima:

Za starost betona od 6 do 11 časova:
$E_{Pb} = -130{,}75\ t^{1{,}803}$, (MPa)

Za starost betona od 11 do 51 čas:
$E_{Pb} = -16657{,}84 + 11036{,}11 \ln(t)$, (MPa)

Za starost betona od 51 do 480 časova:
$E_{Pb} = -15610{,}53 + 3070{,}34 \ln(t)$, (MPa)

gde je t (vreme u časovima).

Ako se na ovakav način proračuna debljina sloj prskanog betona, tada je nosivost ovog sloj moguće proračunati po obrascu:

$$P_{Pb} = \frac{\sigma_p^{Pb} \cdot f_i \cdot d}{k_s \cdot r \cdot \sin\alpha \cdot \cos\alpha}, \text{(kPa)} \qquad (6)$$

gde je σ_p^{Pb} - čvrstoća na pritisak prskanog beton koja se postiže posle određenog vremena i izvodi po Rapćencu i iznosi:

$$P_p^{Pb} = 1{,}004{,}286 \cdot t^{0{,}733}, \text{(kPa)} \qquad (7)$$

gde je: f_i – koeficijent koji se proračunava po obrascu: $f_i = 1{,}3794\ t^{-0{,}4436}$

za starost betona od 24 časa $f_i = 0{,}337$

za starost betona od 72 časa $f_i = 0{,}207$

d – debljina betonske obloge
k_s – koeficijent sigurnosti
r – poluprečnik iskopa prostorije.

Do orjentacione vrednosti debljine prskano betona, u zavisnosti od konstrukcije podgrade moguće je doći ako je poznat koeficijer čvrstoće po Protođakonovu (f) i širin prostorije, za šta su pogodni dijagram prikazani na slici 4.

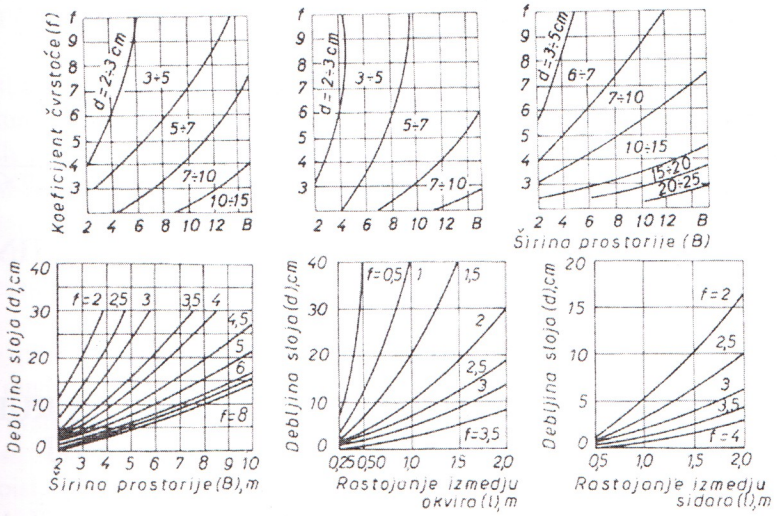

Figure 4 Lining thickness vs strength coefficient (f) and premisses width, and lining thickness vs substruction construction

Slika 4 Dijagrami zavisnosti debljine obloge od koeficijenta čvrstoće f i širine prostorije i zavisnost debljine obloge od konstrukcije podgrade

5 CONCLUSION

In a very solid and stable rocks it is usually sufficient to achieve static convinient form, so the surrounding part of rock massive accept loading and protect the contour from the deformation and destruction. However, in the weak and unstable rocks as well in the solid rocks exposed to high internal stresses, this is not possible, and in order to prevent or reduce deformations and to prevent occurrence of landslide in underground facilities the various type of substructions were built.

5 ZAKLJUČAK

U veoma čvrstim i stabilnim stenama, najčešće je dovoljno podzemnoj prostoriji dati statički najpovoljniji oblik, pa da deo stenske mase koja okružuje prostoriju na sebe primi opterećenje i sačuva konturu od neželjene deformacije i razaranja. Međutim, u slabim i nestabilnim, kao i u čvrstim stenama izloženim velikim unutrašnjim naprezanjima, ovo nije moguće, te se u cilju sprečavanja ili smanjenja deformacije konture i onemogućavanja pojave zarušavanja u podzemnim prostorijama ugrađuje različita vrsta podgrade.

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