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DETERMINING THE STRESS OF ROCK MASSIF***

Abstract

Defining the stress rock massif is essential for design of underground facilities and methods of mining in the mines. Assessment the value of stress state of rock massif and rock strength in the various loads allows rational design. This is of particular importance when sizing columns, determining the extent of excavation, the cross-sections of underground rooms in problems with rock bursts and others. This paper briefly gives the basic methods of determining the rock massif stress as part of a study that is aimed to facilitate development of engineering-geological and geomechanical model of the rock massif along the tunnel route under the flotation tailing dump Veliki Krivelj and underground facilities in Jama Bor as the numerical analysis could be applied of the stress-strain state of rocks around the built facilities.
Keywords: *stress of rock massif, "in situ" measuring of stress, probe for stress measuring*

INTRODUCTION

To solve the problem of stability of built room, in addition to knowledge of the theory of elasticity, it is necessary to know the stresses acting in the rock massif, the properties and composition of the massif. Experimental studies have shown that the stress state of the rock massif is very complex. At relatively shallow depths of exploitation, the additional stresses are sometime, due to the stress concentration at the measuring point, up to 20 times higher than predicted by calculation based on the weight of the rocks (the effect of gravitational forces only). With increasing depth of exploitation, the stress also increases in the rock massif, and thus the importance of studying this problem.

The primary stress state refers to the undisturbed rock massif. Based on previous studies and conducted measurements the primary stress in the world, and using a well-known theory, it was concluded that the vertical component of the primary stress in most cases depends on the force of many lying masses in comparison to the observed point in the earth's crust, Figure 1.

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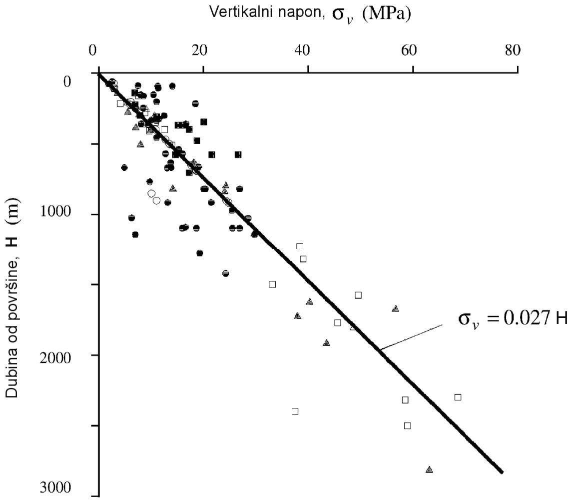

Figure 1 *Measurevertical stress for the needs of design in mining in the world (by Hoek-Brown, 1978)*

It is represented by equation:

$$\sigma_V = \gamma \cdot H$$

where:

σv - vertical component of normal stress;

γ - bulk density in natural state *(on average 27 kN/m^3)*

H - depth of the observed place from surface.

The size of horizontal component of stress has influenced by tectonics, residual stresses due to erosion, gravity, morphology of rocks themselves. It starts from the engineering-geological conditions in general, and then the properties of each lithologic members, the presence of water, the temperature, the tectonic movements that have occurred or are still ongoing. From the point of hydrostatics, the vertical and horizontal components are equal or nearly equal, so that the ratio of the horizontal and vertical stresses in the rock massif "k" can be represented by the following equation:

$$k = \frac{\sigma_H}{\sigma_V} \approx 1$$

where:

k - coefficient of horizontal and vertical stress ratio in the rock massif,

σ_V - vertical component of normal stress

σ_H - horizontal component of normal stress.

Assuming that the rock is elastic and continuous environment, Terzaghi concluded that the rock is deformed by the effect of vertical stress, and the result of that is deformation in horizontal direction. Horizontal deformation is prevented by the presence of surrounding rocks, and by the theory of elasticity, it follows:

$$\sigma_H = \frac{\nu}{1-\nu} \cdot \sigma_V$$

where:

ν - Poisson's ratio

Of the newest approaches was given by Sheorey (1994). He developed an elastic-static-thermal stress model of the Earth. He proposed a simplified equation with which it is possible to estimate the ratio of horizontal and vertical stresses.

$$k = 0.25 + 7 \cdot E_h \cdot \left(0.001 + \frac{1}{H}\right)$$

where:

E_h - mean value of deformation module of lying masses measured in horizontal direction, GPa

H - depth of the observed place from surface, m

A graphical presentation of this equation is shown in Figure 2. It should be noted that the curve showing the ratio of stress k is also the same with the other authors who measured the stress "in situ", among others, Hoek and Brown (1978), Harget (1988) and others.

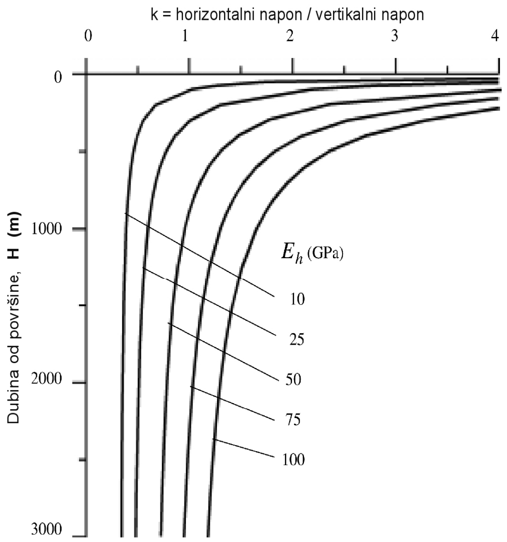

Figure 2 *Ratio of horizontal and vertical stress for various deformation modules based on the Sheorey equation*

In any case, it should be noted that there is no theoretical approach that would fully satisfy the needs of analyzing the primary stress state. Such complex solutions are still required in the experimental study. Thus, the collected and processed data have led to the establishment a relatively realistic legality between these two components. In practice, it is recognized that the values of horizontal component are determined based on the following relationships:

$$\sigma_H = k \cdot \sigma_V$$

where:

- for rock massives that behave elastically:

$$\sigma_H = \frac{\nu}{1-\nu} \cdot \sigma_V$$

- for rock massives that behave plastically:

$$\sigma_H = \frac{1-\sin\varphi}{1+\sin\varphi} \cdot \sigma_V$$

where:

φ - angle of internal friction

ν - Poisson's ratio

However, it should be noted that it can be concluded from the all stated above that data on components of the primary stress, despite all theoretical considerations, can be only defined in the field by direct measuring "in situ" [1].

The secondary stress states occur, mainly, as the result of human activities in the rock, which disrupts the natural balance and leads to changes in the intensity and redistribution of the primary stress state.

In addition, on the basis of theoretical and experimental research, three characteristic zones of the secondary stress can occur in the rock massif:

- Zone of released stresses (plastic zone),
- Zone of increased stresses (elastic zone),
- Intact zone (zone of the primary stresses).

In the case of the secondary stress state, in addition to the above mentioned factors for the primary stress state, the new influential factors are added such as: the quality of rock material, size and shape of the underground facility, as well as the manner and speed of execution the works. These factors have the greatest impact on the character of stress changes; however, it should be always kept in mind that the changes that occur in rock material have progressive character. If these changes are not prevented on time or intentionally prolonged, it can lead to unintended consequences - demolitions.

PROBLEMS RELATED TO THE MEASURINGOF STRESS "IN SITU"

There are at least three main areas of difficulties when measuring the stress of rock massif. They must be understood in order to create an optimal plan of measuring, and more importantly correctly interpret the measuring results.

Those areas are:

a) interaction of stress - rock massif,
b) measurement methodology, and
c) reduction of data - calculation.

Structural properties of rock massif affect any method of stress measuring. The impact of natural properties of the rocks is analyzed on the existing stress field before the start of measuring.

The degree of disturbance the stress field depends on the size of studied site. It may be regional, local or at the level of measuring point size. This means that disturbance of stress field will come from the impact of faults, major discontinuities, fractures and cracks, and even of micro-cracks. As the result of these disorders, it is normal to expect that the value of "in situ" stress is highly variable when measured along one direction through the rock massif.

In engineering practice, the general requirement is knowledge of the total stress state as well as its variations in a particular location, which is the sum of all local impacts. It is far easier to measure the local stress field than to isolate only, for example, tectonic stress component of undisturbed rock massif. All this must be borne in mind when making a measurement program and making interpretation of measured values.

Measurement in a discontinuous rock massif is far more sensitive because it is measured in larger volume in order to eliminate the local irregularities of stress field. Dispersion the measuring results is reduced by increasing the mass volume of measurement area. This leads to the concept of a representative elementary volume [2].

Therefore, it is necessary to understand a degree of expected dissipation the measured stress values. This means that in development the program for stress measuring of rock massif, these factors must be taken into account as they affect the results. The key problem lies in the use of information on the structure of rock massif and other relevant data in order to get a realistic view on stress field.

In addition to dissipation the measuring results due to the natural factor, it must be borne in mind that the applied measuring technique also has an impact.

ANALYSIS OF SOME MEASURING METHODS

The most common way of measuring the stress of rock massif consists in measuring the deformation of massive by disburdening. So, the stress of rock massif is determined indirectly. It is necessary to have a measured size (deformation) and legality of its link with stress. In the majority of cases, the Hook's law is used, because it is assumed that in the first moments of mass disburdening, the greatest part of deformation is "fall of" to the elastic:

$$\sigma = \varepsilon \cdot E$$

where:

σ - stress, MPa

ε - deformation, μmm/mm

E - elasticity modulus, MPa.

This means that the stress can be calculated by the modulus of elasticity and measured deformation. In fact, it is the basis of most methods of determining the stress of rock massif.

Selection of method and measuring instruments

Measuring methods that meet minimum requirements are reduced to the principle of disburdening a part of rock massif with incorporated instrument and measuring:

a) deformation of drill hole sides,
b) deformation of drill hole bottom, and
c) hydraulic fracture.

Deformation of drill hole sides

Instruments for measuring the deformations of drill hole sides are in the shape of probe, which can be cemented by volume in a drill hole, or only in contact over some parts with a drill hole side. The first type consists of so-called instruments soft type - deformometers, and the other probes that are used repeatedly and moved by depth of drill hole; their bodies are typically made of metal or hard plastic, and the measuring detail both of measuring tape or some of inductive sensors. In addition to these two types, there are probes with optical tapes (photoelastic tapes - Photostress gage).

Deformation of drill hole bottom

Instruments for measuring the deformations at the bottom of drill hole are known under the name "Doorstoper". All of these instruments for monitoring the changes in the rock massif deformation caused by disburdening, use various types of sensors. The main task of the sensors is to convert the changes of mechanical sizes (μmm/mm) into an electrical signal (millivolt - milliamp), which can then be registered by sensitive electronic instruments.

Hydraulic fracture

The instrument that uses the principle of hydraulic fracture of rock massif, is one of reliable instruments, which is particularly important because there is no need for special preparation the measuring points for its use.

SELECTED SYSTEM FOR MEASURING THE MASS STRESS

Having primarily in mind the problems with procurement some of commercial instrument for measuring the stress in mass, the instruments can be used that are designed and made in some scientific organization, faculty or institute. These instruments are based on known theoretical principles of stress measuring as well as the experiences gained in the past period of exploration.

According to the set objective of the Project and required physical-mechanical and stress-deformation testing of rocks along the route of the new tunnel under the flotation tailing dump Veliki Krivelj in Bor as well as the underground facilities in Jama Bor, a special probe-transmitter was made.

The probe acts as a hydraulic cushion and it is permanently installed in the side of the room. The probe is placed into a special metal box with other measuring technique [3].

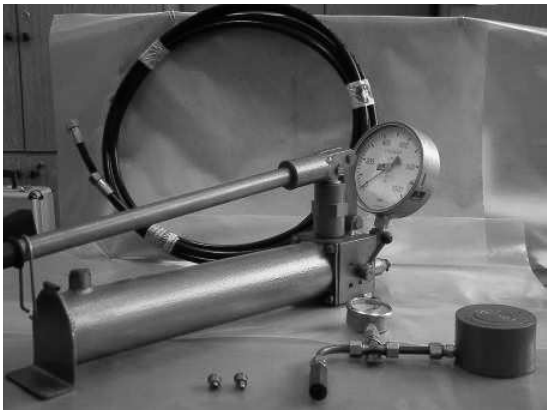

Figure 3 *Measuring probe with additional tools for measuring the stress states*

This equipment is of domestic production, made of local materials in the Mining and Metallurgy Institute in Bor (MMI). It can be applied in various mining and construction structures and, if necessary, it can be serially produced in various measuring ranges.

CONCLUSION

In contrast to most branches of structural engineering in which the engineer-designer is able to choose the construction material with a known initial stress state, the mining engineer has no ability to choose the location of construction, and mechanical properties and initial stress state in his construction material are unknown.

Due to this fact, definition and measuring the stress state in the vicinity of underground facilities becomes of primary importance for their design in each lithological environment.

The mentioned research enables development of engineering-geological and geomechanical model of rock material of the new tunnel route and modeling the designed rooms in the underground mine Jama Bor as the numerical analysis of the stress-strain states of rocks around the facilities could be applied.

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ODREĐIVANJE NAPONA STENSKOG MASIVA[***]

Izvod

Definisanje napona u stenskoj masi je od bitnog značaja za projektovanje podzemnih objekata i metoda otkopavanja u rudnicima. Procena vrednosti naponskog stanja stenskog masiva i otpornosti stena na razna opterećenja omogućuje racionalno projektovanje. Ovo ima poseban značaj kod dimenzionisanja stubova, određivanja raspona otkopa, poprečnih profila podzemnih prostorija, kod problema gorskih udara i dr.

U ovom radu se, u najkraćim crtama, daju osnovni postupci o određivanju napona stenskog masiva kao deo istraživanja koje ima za cilj da omogući izradu inženjersko-geološkog i geomehaničkog modela stenskog masiva duž trase tunela ispod flotacijskog jalovišta Veliki Krivelj u Boru kao i podzemnih objekata u Jami Bor, kako bi se mogla primeniti numerička analiza o naponsko-deformacionom stanju stena oko izgrađenih prostorija.

***Ključne reči:** napon stenskog masiva, merenje napona „in situ“, sonda za merenje napona*

UVOD

Za rešavanje problema stabilnosti izrađene prostorije, pored poznavanja teorije elastičnosti, neophodno je znati i napone koji deluju u stenskom masivu, svojstva i sastav masiva. Eksperimentalna istraživanja su pokazala da je naponsko stanje stenskog masiva vrlo složeno. Na relativno malim dubinama eksploatacije, dopunska naprezanja su nekad, zbog koncentracije napona na mernom mestu i do 20 puta veća nego što to predviđa proračun na osnovu težine stena (uticaj samo gravitacionih sila). Porastom dubine eksploatacije raste i napon u masivu, a time i važnost izučavanja ovog problema.

Primarno naponsko stanje se odnosi na neporemećen stenski masiv. Na osnovu dosadašnjih ispitivanja i izvršenim merenjima primarnih napona u svetu, a koristeći poznate teorije, došlo se do zaključka da vertikalna komponenta primarnih napona u većini slučajeva zavisi od sile više ležećih masa u odnosu na posmatranu tačku u zemljinoj kori, slika 1.

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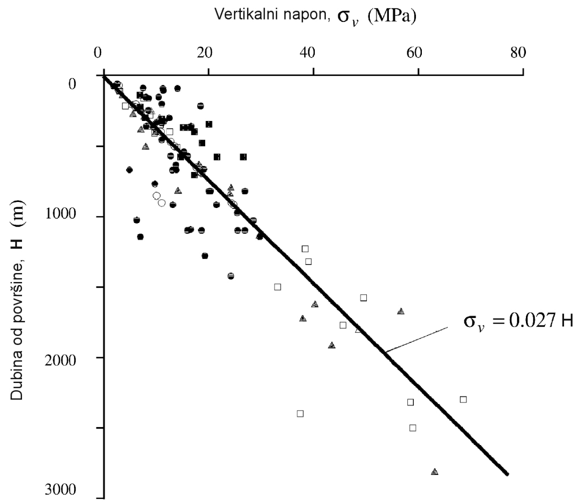
[***] *Ovaj rad je proistekao kao rezultat projekta 33021 „Istraživanje i praćenje promena naponsko deformacijskog stanja u stenskom masivu „in-situ“ oko podzemnih prostorija sa izradom modela sa posebnim osvrtom na tunel Kriveljske reke i Jame Bor“, koga finansira Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije.*



Sl. 1. *Izmereni vertikalni napon za potrebe projektovanja u rudarstvu u svetu (po Hoek-Brown-u, 1978)*

Predstavlja se jednačinom:

$$\sigma_V = \gamma \cdot H$$

gde su:

σ_v - vertikalna komponenta normalnog napona;

γ - zapreminska težina u prirodnom stanju *(u proseku 27 kN/m³)*

H - dubina posmatranog mesta od površine.

Na veličinu horizontalne komponente napona značajan uticaj imaju tektonika, zaostali naponi usled erozije, gravitacija, morfologija samih stena. Polazi se od inženjersko-geoloških uslova u celini, zatim od svojstva svakog litološkog člana, od prisustva vode, od temperature, tektonskih pokreta koji su se dogodili ili još uvek traju. Sa stanovišta hidrostatike, vertikalne i horizontalne komponente su jednake ili približno jednake, tako da koeficijent odnosa horizontalnog i vertikalnog napona u stenskoj masi "k" može da se predstavi sledećom jednačinom:

$$k = \frac{\sigma_H}{\sigma_V} \approx 1$$

gde su:

k - koeficijent odnosa horizontalnog i vertikalnog napona u stenskoj masi,

σ_v - vertikalna komponenta normalnog napona,

σ_H - horizontalna komponenta normalnog napona.

Polazeći od pretpostavki da je stena elastična i kontinualna sredina, Terzaghi je zaključio da se stena dejstvom vertikalnog napona deformiše, pa je posledica toga deformacija u horizontalnom pravcu. Horizontalna deformacija je sprečena prisustvom okolnih stena, a po teoriji elastičnosti proizilazi:

$$\sigma_H = \frac{\nu}{1-\nu} \cdot \sigma_V$$

gde je

ν - Poissonov koeficijent

Jedan od najnovijih prilaza je dao Sheorey (1994). On je razvio elasto-statičko-termički model napona Zemlje. Predložio je pojednostavljenju jednačinu sa kojom je moguće proceniti odnos horizontalnog i vertikalnog napona.

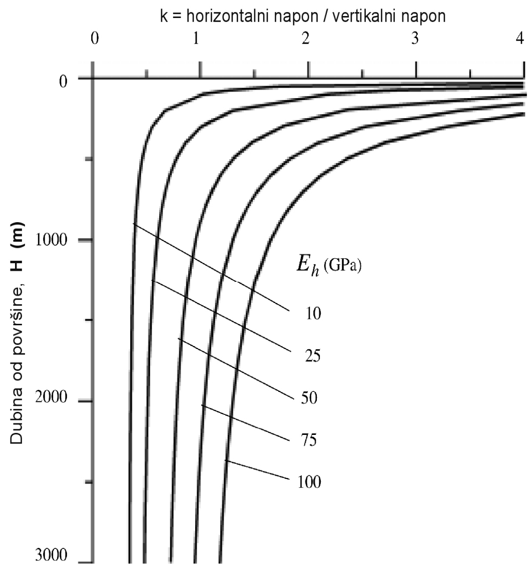
$$k = 0{,}25 + 7 \cdot E_h \cdot \left(0{,}001 + \frac{1}{H}\right)$$

gde su:

E_h - srednja vrednost modula deformacije višeležećih masa merene u horizontalnom pravcu, GPa

H - dubina posmatranog mesta od površine, m

Grafički prikaz ove jednačine dat je na slici 2. Treba napomenuti da kriva koja prikazuje odnos napona k je slična i sa drugima autorima koji su merili napon »in situ«, između ostalih, Hoek i Brown (1978), Harget (1988) i drugi



Sl. 2. *Odnos horizontalnog i vertikalnog napona za različite module deformacija bazirane na Sheorey-ovoj jednačini*

U svakom slučaju treba reći da ne postoji ni jedan teoretski pristup koji bi u potpunosti zadovoljio potrebe za analiziranjem primarnog naponskog stanja. Takva kompleksna rešenja su dalje tražena u eksperimentalnom istraživanju. Tako prikupljeni i obrađeni podaci su doveli do uspostavljanja relativno realne zakonitosti između ove dve komponente. U praksi je prihvaćeno da se veličina horizontalne komponente određuje na osnovu sledećih veza:

$$\sigma_H = k \cdot \sigma_V$$

gde je:

- za stenske mase koje se ponašaju elastično:

$$\sigma_H = \frac{\nu}{1-\nu} \cdot \sigma_V$$

- za stenske mase koje se ponašaju plastično:

$$\sigma_H = \frac{1-\sin\varphi}{1+\sin\varphi} \cdot \sigma_V$$

gde su:

φ - ugao unutrašnjeg trenja,

ν - Poissonov keoficijent.

Ipak, treba reći da se iz svega do sada rečenog može zaključiti da podatke o komponentama primarnog napona je, pored svih teorijskih razmatranja jedino možemo odrediti na terenu, direktnim merenjem "in situ".[1]

Sekundardna naponska stanja javljaju se, uglavnom, kao rezultat čovekovog delovanja u steni, čime se narušava prirodna ravnoteža i dolazi do promene inteziteta i preraspodele primarnog naponskog stanja.

Pri tome se, na osnovu teoretskih i eksperimentalnih istraživanja, u stenskom masivu se mogu javiti tri karakteristične zone sekundarnih napona:

- Zona oslobođenih napona (plastična zona),
- Zona povećanih napona (elastična zona),
- Intaktna zona (zona primarnih napona).

U slučaju sekundarnog naponskog stanja, pored već nabrojanih faktora za primarno naponsko stanje, dodaju se novi uticajni fakori kao što su: kvalitet stenskog materijala, veličina i oblik podzemnog objekta, kao i način i brzina izvođenja radova. Ovi faktori najviše utiču na karakter promene napona s'tim što, uvek treba imati na umu da su promene koje se dešavaju u stenskom materijalu progresivnog karaktera. Ukoliko se ove promene ne spreče na vreme ili svesno produže, može doći do neželjenih posledica – zarušavanja.

PROBLEMI VEZANI ZA MERENJE NAPONA "IN SITU"

Postoji najmanje tri glavne oblasti teškoća kod merenja napona stenske mase. One se moraju razumeti da bi se napravio optimalni plan merenja, a što je još važnije korektno interpretirali rezultati merenja.

Te oblasti su:

a) interakcija napon - stenski masiv,
b) metodologija merenja i
c) redukcija podataka, proračun.

Strukturna svojstva stenskog masiva utiču na bilo koju metodu merenja napona. Analizira se uticaj prirodnih svojstava stene na postojeće naponsko polje pre početka merenja.

Stepen poremećaja naponskog polja zavisi od veličine izučavanog lokaliteta. On može biti regionalni, lokalni ili na nivou veličine mernog mesta. To znači da će do poremećaja naponskog polja doći od uticaja raseda, glavnih diskontinuiteta, pukotina i prslina, pa čak i od mikroprslina. Kao rezultat ovih poremećaja normalno je i očekivati da je vrednost "in situ" napona vrlo promenljiva kada se meri duž jednog pravca kroz stensku masu.

U inženjerskoj praksi, opšti zahtev je znanje ukupnog naponskog stanja kao i njegove varijacije na određenoj lokaciji, koja je ujedno i zbir svih lokalnih uticaja. Daleko lakše je meriti lokalno polje napona nego izolovati samo npr. tektonsku komponentu napona neporemećenog stenskog masiva. Sve ovo se mora imati u vidu kada se pravi program merenja i vrši interpretacija izmerenih veličina.

Merenje u diskontinualnoj stenskoj masi daleko je osetljivije jer se meri u većoj zapremini u cilju eliminisanja lokalnih neregularnosti naponskog polja. Rasipanje rezultata merenja se smanjuje povećanjem zapremine masiva merne oblasti. To vodi ka konceptu reprezentativne elementarne zapremine. [2]

Zato je potrebno razumeti stepen očekivanih rasturanja merenih vrednosti napona. To znači da se pri izradi programa merenja napona stenske mase mora voditi računa o ovim faktorima jer će oni uticati na rezultate. Ključni problem se sastoji u korišćenju informacija o strukturi stenske mase i drugih relevantnih podataka kako bi se došlo do realne slike o naponskom polju.

Pored rasipanja rezultata merenja zbog prirodnih faktora mora se imati u vidu da i primenjena merna tehnika ima uticaja.

ANALIZA POJEDINIH METODA MERENJA

Najčešći način merenja napona stenske mase sastoji se u merenju deformacija masiva rasterećenjem. Znači, napon stenske mase određuje se indirektno. Potrebno je imati neku izmerenu veličinu (deformaciju) i zakonitost njene veze se naponom. U većini slučajeva koristi se Hook-ov zakon, jer se pretpostavlja da u prvim momentima rasterećenja masiva, najveći deo deformacija "otpada" na elastične:

$$\sigma = \varepsilon \cdot E$$

gde su:

σ - napon, MPa,

ε - deformacija, μmm/mm,

E - modul elastičnosti, MPa.

To znači de se preko modula elastičnosti i izmerene deformacije može izračunati napon. U suštini to je osnova većine metoda određivanja napona stenske mase.

Izbor metode i instrumenata za merenje

Metode merenja koje ispunjavaju minimum zahteva svode se na princip rasterećenja dela stenskog masiva sa ugrađenim instrumentom i merenju:

a) deformacija bokova bušotine,
b) deformacija dna bušotine i
c) hidraulički lom.

Deformacija bokova bušotine

Instrumenti za merenje deformacija bokova bušotine su u obliku sondi, koje mogu biti ucementirane po obimu u bušotini ili samo u kontaktu preko pojedinih delova sa bokom bušotine. Prvu vrstu čine instrumenti tzv. mekog tipa - deformometri, a drugu sonde koje se koriste više puta i pomeraju po dubini bušotine, tela su im po pravilu od metala ili tvrde plastike, a merni detalj ili od mernih traka ili je to neki od induktivnih davača. Pored ova dva tipa imamo i sonde sa optičkim trakama (foto-elastične trake - Photostress gage).

Deformacija dna bušotine

Instrumenti za merenje deformacija na dnu bušotine su poznati pod imenom "Doorstoper". Svi ovi instrumenti za praćenje promena deformacija stenskog masiva, izazvanih rasterećenjem, koriste senzore raznih vrsta. Osnovni zadatak senzora je da pretvore promene mehaničkih veličina (μmm/mm) u električni signal (milivolt - miliamper) koji se zatim može registrovati osetljivim elektronskim instrumentima.

Hidraulički lom

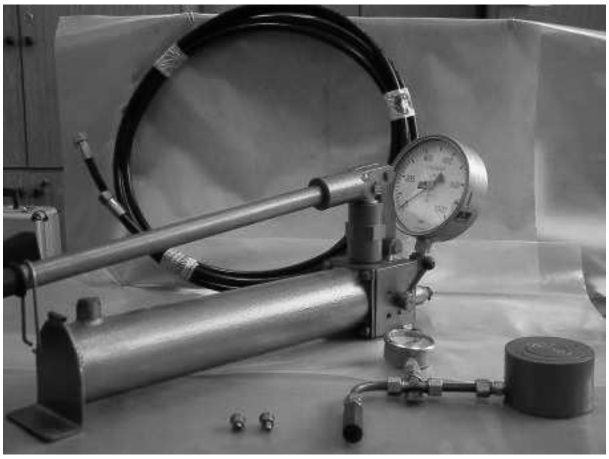
Instrument koji koristi princip hidrauličkog loma stenske mase, je jedan od pouzdanih instrumenata, a što je naročito važno, jer za njegovu upotrebu nisu potrebni specijalne pripreme mernih mesta.

ODABRANI SISTEM ZA MERENJE NAPONA MASIVA

Imajući prvenstveno u vidu probleme oko nabavke nekog od komercijalnih instrumenata za merenje napona u masivu, mogu se upotrebiti instrumenti koji su konstruisani i izrađeni u nekoj naučnoj orga-nizaciji, fakultetu ili institutu. Ovi instru-menti su bazirani na poznatim teoretskim principima merenja napona kao i na iskust-vima stečenim u ranijem periodu istra-živanja.

Shodno postavljenom cilju Projekta i potrebnih fizičko-mehaničkih i naponsko-deformacionih ispitivanja stena duž trase novog tunela ispod flotacijskog jalovišta Veliki Krivelj u Boru kao i podzemnih objekata u Jami Bor, izrađena je specijalna sonda-transmiter.

Sonda ima ulogu hidrauličnog jastuka i trajno se ugrađuje u bok prostorije. Sonda se smešta u specijalni metalni sanduk sa ostalom mernom tehnikom.[3]



Sl. 3. *Merna sonda sa dodatnim alatima za merenje naponskih stanja*

Ova oprema je domaće proizvodnje, izrađena od domaćih materijala u Institutu za rudarstvo i metalurgiju u Boru (IRM). Može se primenjivati u raznim rudarskim i građevinskim objektima i po potrebi se može serijski proizvoditi u različitim mernim opsezima.

ZAKLJUČAK

Nasuprot većini grana konstruktivnog inženjerstva u kojima je inženjer- projektant u mogućnosti da bira konstruktivni materijal sa poznatim početnim stanjem napona, rudarski inženjer nema mogućnost izbora lokacije gradnje, a mehaničke karakteristike i početno naponsko stanje u njegovom konstruktivnom materijalu su nepoznati.

Zbog ove činjenice definisanje i merenje naponskog stanja u okolini podzemnih objekata postaje od primarnog značaja za njihovo projektovanje u svakoj litološkoj sredini.

Navedena istraživanja omogućavaju izradu inženjersko-geološkog i geomehaničkog modela stenskog materijala trase novog tunela i u modeliranju projektovanih prostorija u Jami Bor, kako be se mogla primeniti numerička analiza o naponsko-deformacionom stanju stena oko izgrađenih objekata.

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