DRILLING AND BLASTING OPERATIONS FOR REHABILITATION OF ROCK QUARRY BRESTANICA FOR THE CONSTRUCTION OF WASTEWATER COLLECTOR

ID 107

Stjepan ŽGANEC, Milan H. ZABUKOVEC

Minervo, Ljubljana, SLOVENIA
info@minervo-lj.si

ABSTRACT

Exploitation of raw mineral material like building rocks has a consequence of permanently destroying or damaging the natural environment.

Rehabilitation of rock quarries and surface mines means returning them to their original or natural state. Rehabilitation of abandoned quarry Brestanica is a positive example how to turn damaged environmental site into use and restore it to more natural state. Having in mind that disposal of various wastes represent permanent issue, the abandoned quarries are not sufficiently exploited for this purpose.

Preparations of abandoned quarry for useful purpose include rehabilitation, protection of surroundings during blasting, building operations and objects for wastewater purification. Since there are buildings in the vicinity of the quarry, it was crucial to carefully monitor blasting and its impact with seismic measurements.

The protection of working plateau, road and railroad was achieved with construction of protection channel, embankment and wood fence along the railroad tracks.

Key words: drilling, blasting, protection, seismic.

INTRODUCTION

Drilling and blasting during rehabilitation of abandoned rock quarry Brestanica (Figure 1.) were carried out under difficult and complex working conditions. The rock quarry is located 100 meters high above the existing road which is only 30 meters far from the blasting site. To protect the road and railroad from falling and sliding of blasted material, the embankment and prefabricated protective fence were constructed along the railroad. In the final stage of rehabilitation, protective wall was built on the slopes of the rock quarry and protective channel and embankment on the bottom to protect wastewater collectors from possible fall of rock blocks from the top and from the slopes of the quarry. Coordination with Road and Railroad Maintenance authority was needed since the work site is only 30 m far from Krško-Brestanica road and Krško-Zagreb railroad. Secure and careful blasting and monitoring with blasting-seismic measurements were employed to protect surrounding houses, secure and careful blasting and monitoring with blasting-seismic measurements were employed.

Figure 1.: Rock quarry Brestanica

GEOLOGICAL CHARACTERISTICS OF BRESTANICA ROCK QUARRY

Rock quarry is on the left hill of Sava river between Brestanica and Krško. Dolomite beds in the quarry are from Triassic geological period. Detailed examinations determined unique dolomite structure of the quarry and its chemical composition. There is no particular stratification on the quarry site. The layers of predominantly massive dolomite have angle of about 40° towards north-east. Observed gaps and gap systems lay towards north-west that is towards north under the angle of about 75° and westward under the angle of about 80°. The gaps are filled mainly with 1-3 cm thick milonite and rarely with clay. Gap planes are smooth to rough and moderately wavy. Petrographical analysis determined that dolomite has grey colour and fine grained structure.

OBSERVATION AND SCANNING OF THREATENED OBJECTS IN THE CLOSE PROXIMITY

The position of quarry is very unfavourable because its height is only 100 meters above the road and 30-40 meters distant from the road. It is located immediately along the road Krško-Brestanica and in parallel with flow of Sava River and railroad. The rock quarry and its immediate surrounding are shown on Figure 1. For blasting alone it was necessary to build protective channel, embankment along the road and strong prefabricated fence made of iron frame and 5 cm thick wooden elements along the railroad tracks to stop rock blocks that could escape embankment and channel (Figures 2 and 3). For monitoring of buildings located directly in the endangered zone during the blasting, the closest buildings were inspected. The quarry is located along the straight road between the houses. The most endangered house was the house located on Krško's side, being 120 meters distant from the blasting site. On the other side, towards Brestanica, the closest house was 180 meters apart from the blasting site. Besides those two houses, eight more houses along and behind quarry were also being monitored. Pictures were taken from inside and outside facades, walls and gaps in ceilings and floors. Blasting started after competition of filming and listing of the facilities description.

Figure 2.: Embankment between rock quarry and the road.

Figure 3.: Road, railroad tracks and prefabricated protective fence located along the rock quarry.

DIMENSIONING OF PROTECTIVE CHANNEL AND EMBANKMENT

Protective embankment was needed for protection of Krško-Zagreb road and railroad during drilling and blasting operations. Protective channel and embankment were needed for protection from possible falling of the rock blocks from the slopes towards workers working on construction of collectors and later in wastewater purification work phase (Figure 6 and 7). As in this case we can not mathematically define rock fall as free body fall or some straight-line accelerated or slow motion on the slope we can, to some extent, approximate the fall as accelerated motion on the upper steep part of the slope and slow motion on the lower part of mild slope.

Acceleration in the upper part:

$$a_1 = \sin(\alpha_1) - k/r \cos(\alpha_1) \quad (1)$$

Slowing down on the bottom part:

$$a_2 = \sin(\alpha_2) - k/r \cos(\alpha_2) \quad (2)$$

k – coefficient of rolling friction,
r – block radius.

Kinetic energy is the most frequent parameter used for the description of rock drifts. Every shift of solid body down the slope contains components of translational and rotational motions.

$$E_{kin} = E_{kin\,tran} + E_{kin\,rot} = \frac{mv^2}{2} + \frac{I\omega^2}{2} \quad (3)$$

m – mass (kg),
v – velocity (m/s) at the impact moment,
I –moment of mass inertia (kgm^2),
ω – angle velocity (s^{-1}) mass, m = ρV,

m – mass of rock block (kg),
ρ – specific density (kg/m^3),
V – volume (m^3)
velocity, v = s/t

v – velocity (m/s),
s – distance (m),
t – time (s).

Various sources report similar dimensioning for protective channels and embankments. Many use reference from HIGHWAY RESEARCH RECORD 17 – Stability of Rock Slopes (Ritchie A.M. 1963). Table 1. shows dimensions of protective channels and embankments at various angles.

Table 1.: The relationship between slope height and angle and dimensions of protective channels and embankments (1-slope height, 2-protective channel width, 3-depth of protective channel).

Slope angle: approximately vertical		
1	2	3
4.57 – 9.15	3.05	0.91
9.15 – 18.3	4.57	1.22
> 18.3	6.1	1.22

Slope angle: 73° – 76° (0.25 : 1 do 0.3 : 1)		
4.57 – 9.15	3.05	0.91
9.15 – 18.3	4.57	1.22
18.3 - 35	6.1	1.83
> 35	7.62	1.83
Slope angle: 63° (0.5 : 1)		
4.57 – 9.15	3.05	1.22
9.15 – 18.3	4.57	1.83
18.3 - 35	6.1	1.83
> 35	7.62	2.44
Slope angle: 53° (0.75 : 1)		
4.57 – 9.15	3.05	0.91
9.15 – 18.3	4.57	1.22
> 18.3	4.57	1.83
Slope angle: 45° (1 : 1)		
4.57 – 9.15	3.05	0.91
9.15 – 18.3	3.05	1.52
> 18.3	4.57	1.83

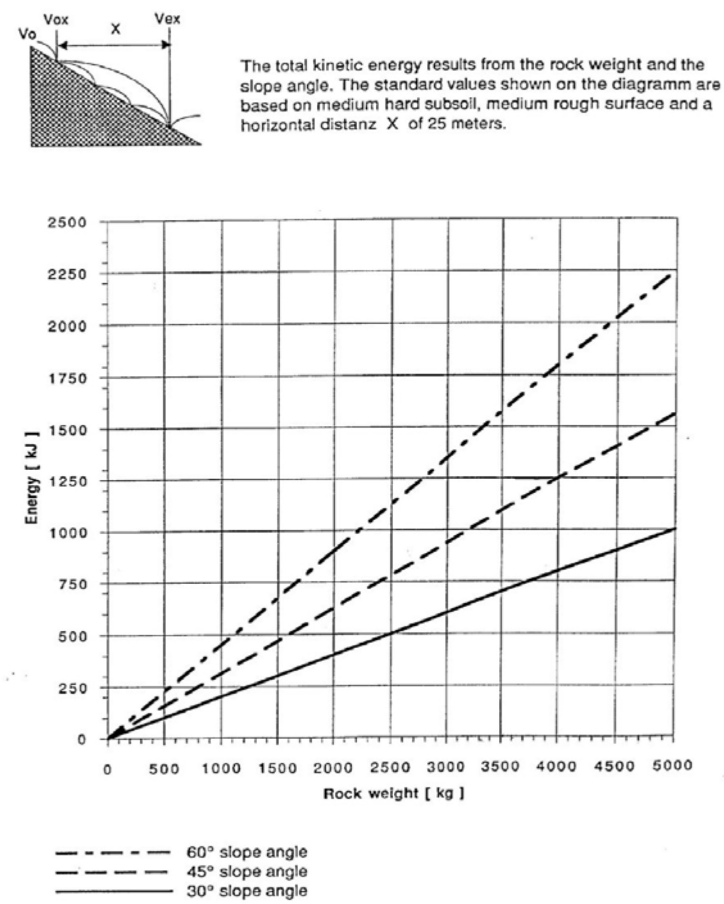

Figure 4.: Energy-weight diagram.

We accepted rock block energy relationship from the leaflet of GEOBRUGG Company (Figure 4.). Using this source we calculated that rock block with mass of 4000 kg on the slope of 45º has energy of 1250 kJ and velocity of 25 m/s.

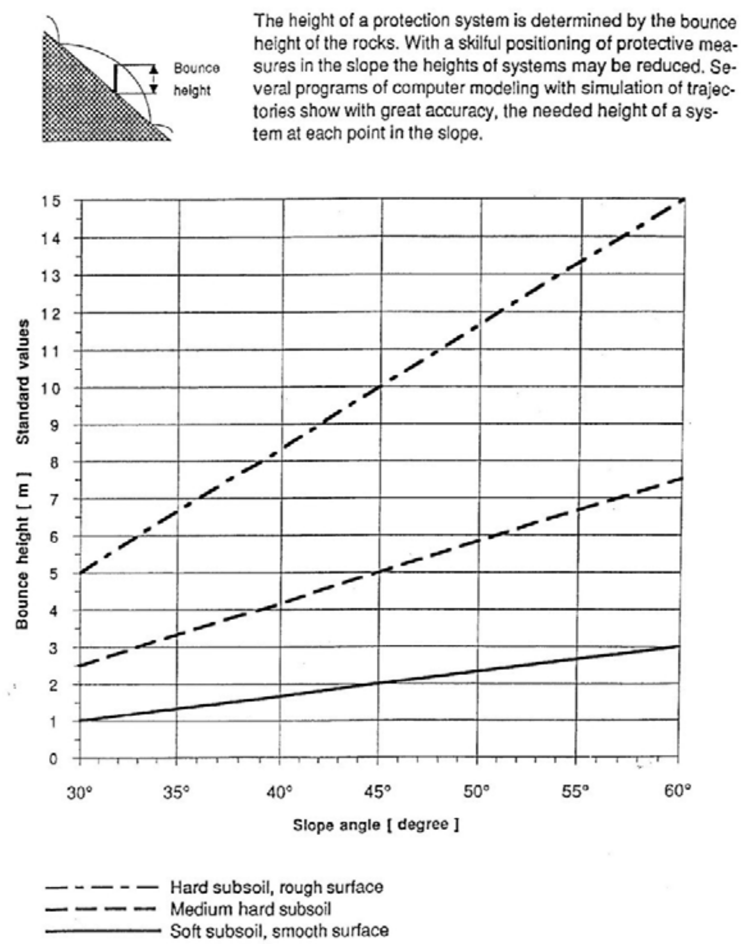

Figure 5.: Bounce height and slope angle diagram.

The same source (Figure 5) reports data about rock blocks bounce height (for angle of 45º on soft subsoil bounce height is up to 2 m, and on medium hard subsoil is up to 5 m.) In our presented case, due to the terrain, it is possible to achieve bounce height up to 5 m, for which minimal height from the bottom of channel up to the top of embankment needs to be 5 m.

Figure 6.: Embankment and channel between rock quarry and wastewater collectors. Total height of channel and embankment is 8 m.

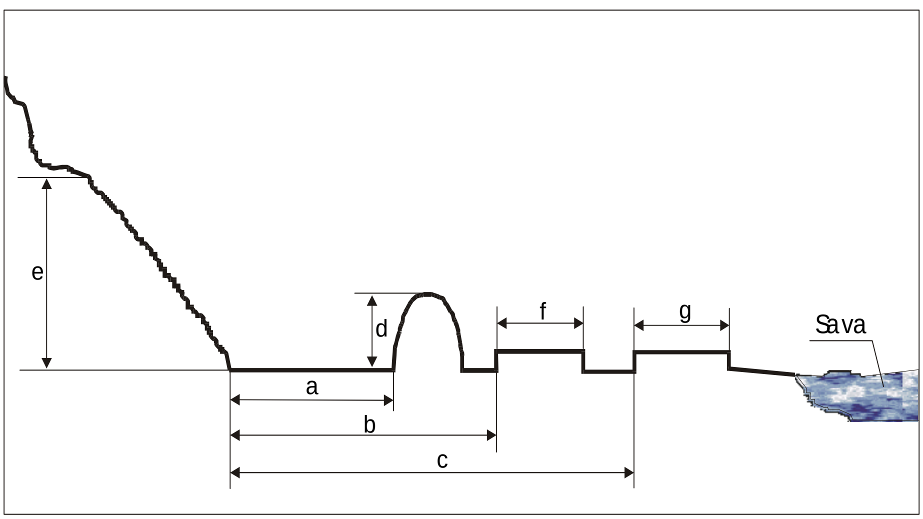

Figure 7.: Protective embankment and channel parameters:
a- the distance between embankment and blasting site (20 m)
b- the distance between road and blasting site (30 m)
c- the distance between railroad and blasting site (40 m)
d- embankment height (7 m)
e- rock quarry height (100 m)
f- road
g- railroad

Figure 8.: Collector construction.

EXPLOSIVES

For the activation of explosives in boreholes, electrical detonators were used (Austin Detonator s.r.o., type; Insensitive Electric detonators, millisecond delay numbers 1 – 30). We used Polonit V patronized explosive (Istrochem a.s., Bratislava) and Amonal V (KIK, Kamnik). Part of blasting fields were used for experimental use of explosive Heavy ANFO (ANFO strengthen 10% emulsion), carried out on the site by mobile unit of Minervo company, who besides this work also performed drilling and blasting. The borehole diameter was 76 mm, which is at the same time critical diameter for the use of AFNO explosives.

Testing of explosives on the terrain

In order to verify the properties of explosions made on the terrain, we carried out the testing and measured detonation velocity in borehole. The measurement was performed by instrument for the measurement of detonation velocity Microtrap (MREL). Obtained data (detonation velocity) are shown on the diagram in Figure 9.

SEISMIC MEASUREMENTS AND RESULTS

Seismic measurements were performed on the object about 120 m far from the blasting field, the house at the address Sotesko 32 on one side and on the other side on the house at the address Cesta izgnancev 2, which has distance of about 180 m from the blasting site.

In the beginning phase the measurements were also performed behind the rock quarry, but first data showed that their continuation was not necessary. According to results and observations after first ten to fifteen measurements, it was determined that the measurements were necessary only at the object approximately 120 m distant from the blasting site.

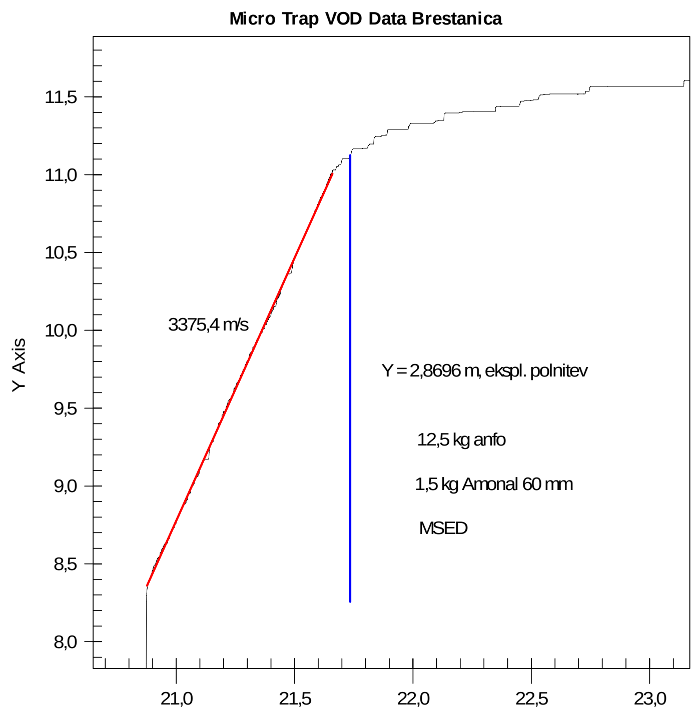

Figure 9.

The measurements were performed using the instrument Nomis Seismographs, Minigraph 7000. The first, closest measurement site was approximately 120 m distant from the blasting site. Second measurement site was approximately 180 m distant from the blasting site.

Blasting was performed in small blasting fields (31 boreholes) with the use of millisecond electrical detonators in a number series that is with the delays of 0 to 30. Blasting was performed with powder explosive Amonal. Table 3 shows the parameters and results of measurements for the closest measurement site 2 (about 120 m) and Table 2 shows data for the farthest measurement on site 1 (about 180 m). Data presented in tables are three measurements for each measurement site.

Table 2.: Presentation of parameters and measurement data for the more distant site 1 (about 180 m).

Measure ment no.	Borehole depth [m]	Explosive charge [kg]	Lid [m]	Air impact [dB]	Radial comp. [mm/s]	Vertical comp. [mm/s]	Transfer comp. [mm/s]	Vector sum [mm/s]
1	6.5	12	3.5	110	1.14	1.14	0.76	1.28
2	6.5	14	3.0	113	2.28	1.65	1.77	2.41
3	6.5	14	3.0	107	1.90	1.39	1.65	2.15

Table 3.: Presentation of parameters and measurement data for the closest measurement site 2 (about 120 m).

Measure ment no.	Borehole depth [m]	Explosive charge [kg]	Lid [m]	Air impact [dB]	Radial comp. [mm/s]	Vertical comp. [mm/s]	Transfer comp. [mm/s]	Vector sum [mm/s]
1	6.5	12	3.5	101	3.04	2.03	3.10	4.10
2	6.5	14	3.0	105	2.54	1.52	1.27	2.80
3	6.5	14	3.0	102	3.42	3.24	2.66	3.55

CONCLUSION

From the seismic measurement results it was established that the blasting effects were inside the range of tolerable values according to DIN standards. There was no dispersion of blasted material on the surrounding objects. Dimensions of protection measures, like protective channel, embankment and prefabricated protective fence were properly designed and there were no penetration or falling of rock blocks from the top of the rock quarry down onto the road or railroad.

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VRTALNO MINERSKA DELA PRI SANACIJI KAMNOLOMA BRESTANICA ZA IZDELAVO KOLEKTORJA ODPADNIH VOD

ID 107

Stjepan ŽGANEC, Milan H. ZABUKOVEC

Minervo d.d., Ljubljana
info@minervo-lj.si

POVZETEK

Izkoriščanje mineralne surovine – gradbenega kamna ima pogosto za posledico trajno uničenje ali poškodovanje naravnega okolja.

Sanacija kamnolomov in površinskih kopov je vsaj delno vračanje v prvotno ali naravno stanje. Sanacija oziroma sanacijska dela za spremembo namembnosti opuščenega kamnoloma Brestanica je pozitiven primer kako poškodovan okoliš spremeniti v koristnega in bolj naravnega. Glede na to, da je stalen problem odlaganje različnih odpadkov, se zapuščeni kamnolomi premalo koristijo v ta namen.

Sanacija, zaščita med izvajanjem minerskih del, zaščita pri izvajanju gradbenih del kot tudi zaščita za objekte, ki čistijo odpadne vode so sestavni del celote pri spremembi namembnosti opuščenega kamnoloma. Zaradi objektov v bližini kamnoloma je potrebno pazljivo miniranje in kontrola vplivov miniranja s seizmičnimi meritvami.

Zaščita delovnega platoja, ceste in železniške proge se izvaja z izdelavo zaščitnega kanala, nasipa in lesene ograje ob sami železniški progi.

Ključne besede: vrtanje, miniranje, zaščita, seizmika.

UVOD

Vrtalno minerska dela pri izvajanju sanacije opuščenega kamnoloma Brestanica (slika 1) so se izvajala v izredno težkih in zahtevnih pogojih. Sama lega kamnoloma in višina, ki je znašala preko 100 m nad lokalno cesto ter nepostredna bližina le te od prvih minskih polj, so narekovala izvajanje del pod posebnimi pogoji. Zaradi nevarnosti padca posameznih kosov minirane kamnine na cesto in železniško progo, je bil izdelan varnostni nasip in postavljena montažna lesena zaščitna ograja ob železnici. V končni fazi sanacije je bila izdelana zaščitna etaža na brežini kamnoloma, pod njo na platoju pa zaščitni kanal in nad njim nasip z namenom zaščite kolektorja odpadnih voda pred padanjem kosov kamenine iz brežine kamnoloma. Med samim izvajanjem vrtalno minerskih del je bila potrebna stalna koordinacija z družbo za vzdrževanje ceste in družbo za vzdrževanje železnic, kajti razdalja med deloviščem in cesto Krško – Brestanica in železniško progo Zidani most – Zagreb, je znašala zgolj 30m. Zaradi neposredne bližine objektov, je bilo potrebno izvajati pazljivo miniranje ter spremljanje seizmičnih učinkov miniranja

Slika 1.: Kamnolom Brestanica.

GEOLOŠKE ZNAČILNOSTI KAMNOLOMA BRESTANICA

Opuščeni kamnolom Brestanica se nahaja na levem bregu reke Save med Brestanici in Krškim. Na tem območju je nahajališče dolomita iz obdobja triasa. Podrobnejše analize so pokazale značilno strukturo ležišča in značilno kemično zgradbo dolomita. Na območju kamnoloma ni opaziti izrazite slojevitosti. Generalni nagib plasti pretežno masivnega dolomita se giblje okrog 40° proti severovzhodu. Posamezne razpoke in sistemi razpok, ki so opazne predvsem v zgornjem delu kamnoloma, padajo v smeri severozahoda, oziroma proti severu pod kotom 75° in proti zahodu pod kotom 80°. Razpoke so večinoma zapolnjene z milonitom debeline 1 do 3 cm. Redkeje je opaziti zapolnitev posameznih razpok z glino. Stene razpok so gladke do hrapave. Vse so rahlo valovite. Petrografska analiza je potrdila drobnozrnat dolomit svetlo sive barve.

PREGLED IN POPIS OBJEKTOV V OGROŽENEM OBMOČJU

Za izvajanje miniranje ima kamnolom izrazito neugodno lego, saj se dviga ca. 100 m nad cesto in železnico, medtem ko je od ceste oddaljen zgolj 30 do 40 m. Nahaja se neposredno ob stari cesti Krško – Brestanica vzporedno s tokom reke Save in železniško progo. Kamnolom in ožja okolica sta nazorno prikazana na sliki 1. Zaradi potencialnih nevarnosti, ki jih prinaša miniranje, je bilo potrebno izdelati varovalni kanal in nasip ob cesti ter montažno čvrsto ograjo iz jeklenih nosilcev in lesenih plohov debeline minimalno 5 cm ob železniški progi z namenom zaustavitve morebitnih kamnitih blokov, kateri bi prebili nasip ob cesti (slika 2, 3). Zaradi ugotovitve dejanskega stanja objektov v ogroženem območju je bil opravljen podroben popis objektov. Najbližji in najbolj ogrožen stanovanjski objekt je bil v oddaljenosti ca. 120 m ob cesti proti Krškem. Na drugi strani je bil najbližja stanovanjska hiša oddaljena ca. 180 m v smeri ob cesti protiu Brestanici. Poleg teh dveh objektov je podroben popis zajel še osem drugih objektov ob kamnolomu ter zadaj za kamnolomom. Popis je zajemal pregled zunanjih in notranjih sten ter pregled stropov in tal. Zabeležene in arhivirane so bile vse vidne razpoke in druge deformacije na objektih. Po opravljenem popisu in ugotovitvi ničnega stanja se je pristopilo k vrtalno minerskim delom.

Slika 2.: Nasip med kamnolomom in cesto.

Slika 3.: Cesta, železniška proga in varovalna ograja.

DIMENZIONIRANJE VAROVALNEGA JARKA IN NASIPA

Osnovna naloga varovalnega nasipa je zaščita ceste in železniške proge Zidani most – Zagreb pri izvajanju vrtalno minerskih del. Varovalni jarek in nasip je potreben zaradi varovanja pred možnostjo padca posameznih blokov kamenine iz brežine kamnoloma na ožje gradbišče kolektorja, kot tudi kasneje ko bo kolektor že v funkciji čiščenja odpadnih voda (slika 6 in 7). Padec posameznega kosa kamenine zaradi različnih pogojev in naklonov brežine ni mogoče definirati kot prosti padec nekega telesa ali kot linearno pospešeno oz. pojemajoče gibanje po brežini. Padec posameznega kosa kamenine lahko opišemo kot pospešeno gibanje na zgornjem strmem delu brežine in pojemajočem gibanju v spodnjem delu kamnoloma, kjer so nakloni brežine blažji.

V zgornjem delu pospeševanje:

$$a_1 = \sin(\alpha_1) - k/r \cos(\alpha_1) \quad (1)$$

V spodnjem delu pojemanje:

$$a_2 = \sin(\alpha_2) - k/r \cos(\alpha_2) \quad (2)$$

k – koeficient trenja kotaljenja
r – polmer bloka kamenine

Najpogosteje lahko posamezni premik bloka kamenine opišemo s kinetično energijo. Vsak premik telesa po brežini vsebuje komponente rotacijskega in translacijskega gibanja.

$$E_{kin} = E_{kin\,tran} + E_{kin\,rot} = \frac{mv^2}{2} + \frac{I\omega^2}{2} \quad (3)$$

m – masa (kg),
v – hitrost (m/s) v trenutku udarca,
I – moment (kgm^2),
ω – kotna hitrost (s^{-1})

masa, $m = \rho V$
m – masa bloka kamenine (kg),
ρ – specifična gostota (kg/m^3),
V – volumen (m^3)

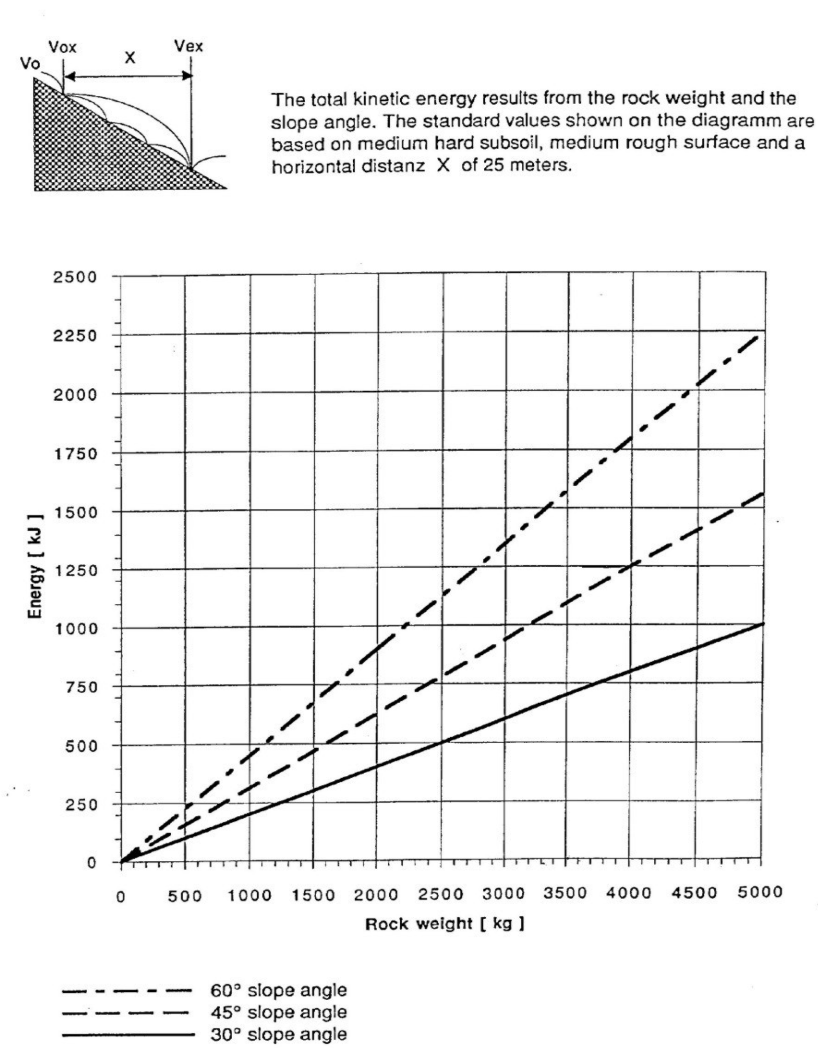
hitrost, $v = s/t$
v – hitrost (m/s),
s – razdalja (m),
t – čas (s)

Razni viri navajajo zelo podobne podatke o dimenzioniranju varovalnih jarkov in nasipov. Pri tem se jih večina sklicuje na HIGHWAY RESEARCH RECORD 17 – Stability of Rock Slopes (Ritchie A.M. 1963). Za različne naklone brežine so prikazane dimenzije varovalnih jarkov in nasipov v tabeli 1.

Tabela 1.: Razmerje med višino in nagibom brežine varovalnega jarka in nasipa (1-višina brežine, 2-širina varovalneg jarka, 3-globina varovalnega jarka).

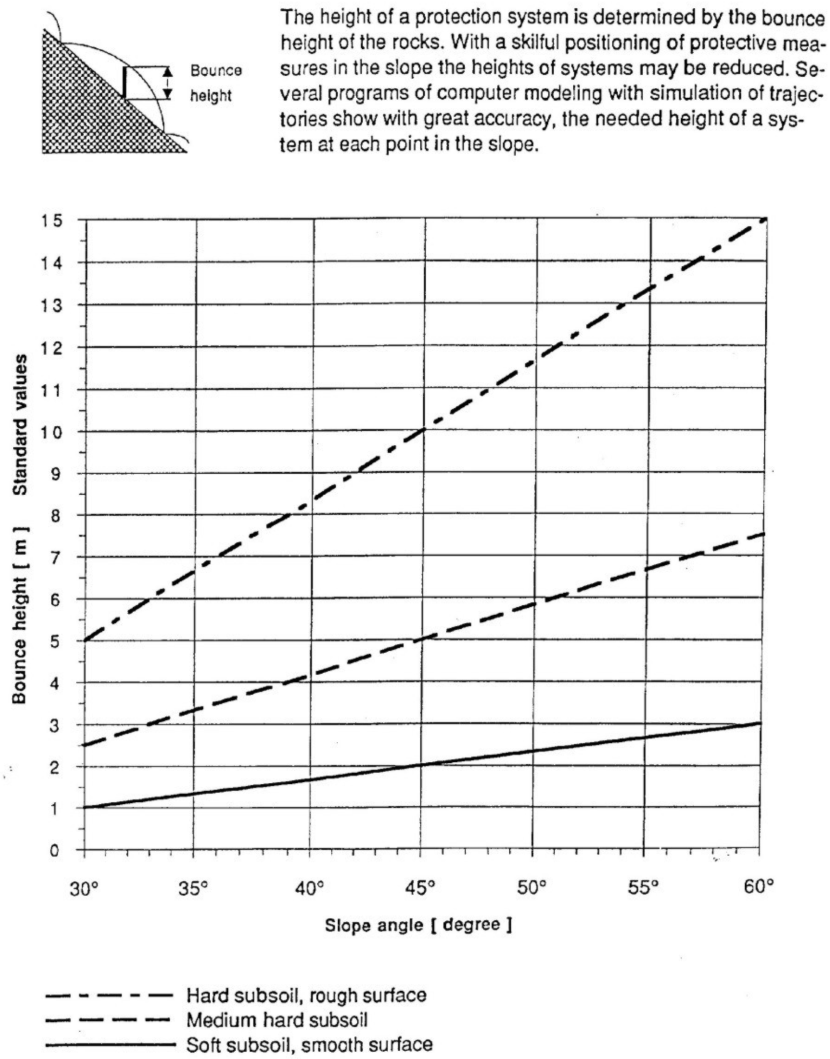
Nagib brežine: približno navpično		
1	2	3
4,57 – 9,15	3,05	0,91
9,15 – 18,3	4,57	1,22
> 18,3	6,1	1,22
Nagib brežine: 73° – 76° (0,25 : 1 do 0,3 : 1)		
4,57 – 9,15	3,05	0,91

9,15 – 18,3	4,57	1,22
18,3 - 35	6,1	1,83
> 35	7,62	1,83
Nagib brežine: 63° (0,5 : 1)		
4,57 – 9,15	3,05	1,22
9,15 – 18,3	4,57	1,83
18,3 – 35	6,1	1,83
> 35	7,62	2,44
Nagib brežine: 53° (0,75 : 1)		
4,57 – 9,15	3,05	0,91
9,15 – 18,3	4,57	1,22
> 18,3	4,57	1,83
Nagib brežine: 45° (1 : 1)		
4,57 – 9,15	3,05	0,91
9,15 – 18,3	3,05	1,52
> 18,3	4,57	1,83



Slika 4.: Diagram energija – masa.

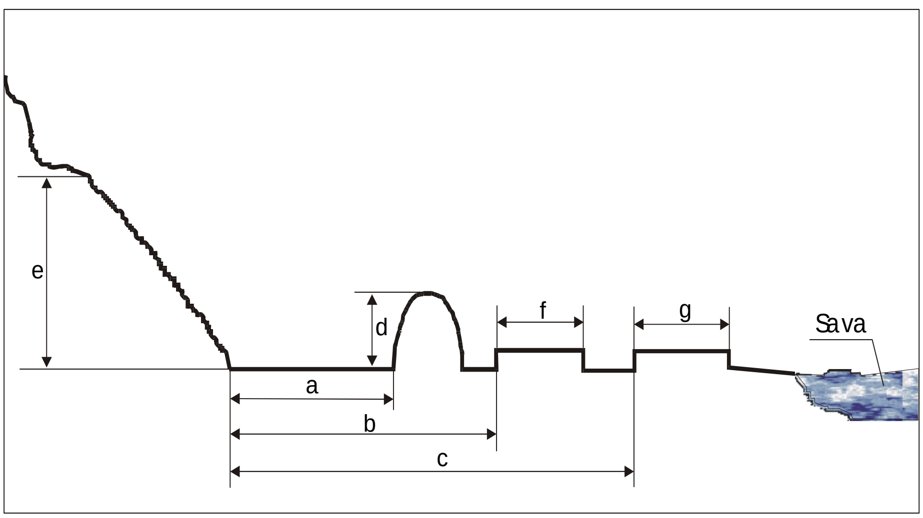
Energijo blokov kamnine smo prevzeli iz prospekta družbe GEOBRUGG (slika 4). Iz prospekta je razvidno, da ima blok mase 4.000 kg na brežini 45º energijo 1.250 kJ in hitrost 25 m/s.



Slika 5.: Diagram odboja in nagiba brežine.

Isti vir navaja (slika 5) podatke o višini odbijanja blokov kamnine (za brežino 45º na mehki podlagi odbijanje do 2 m, na srednje trdi podlagi do 5 m). V našem primeru je zaradi vrste podlage mogoč odboj posameznih blokov do 5 m. Sledi, da jue potrebna minimalna višina od dna varovalnega jarka do vrha nasipa minimalno 5 m.

Slika 6.: Nasip in jarek med brežino kamnoloma in kolektorjem odpadnih vod. Skupna višina jarka in nasipa je 8 m.



Slika 7.: Parametri varovalnega jarka in nasipa:

a- razdalja med nasipom in minskim poljem (20m)
b- razdalja med cesto in minskim poljem (30m)
c- oddaljenost železniške proge od minskega polja (40m)
d- višina nasipa (8m)
e- višina kamnoloma (100m)
f- cesta
g- železniška proga

Slika 8.: Izdelava kolektorja odpadnih vod.

UPORABLJENA RAZSTRELILNA SREDSTVA

Za aktiviranje razstrelilnih polnitev v vrtini so bili uporabljeni električni detonatorji. (Austin Detonator s.r.o., tipe; Insensitive Electric detonators, milisecond deley numbers 1 – 30). Kot razstrelivo se jevečinoma uporabljalo patronirano razstrelivo Polonit V (Istrochem a.s., Bratislava) in Amonal V (KIK, Kamnik). Poskusno so bile uporabljene tudi razstrelilne mešanice (ANFO ojačan z 10% emulzije), izdelane na licu mesta z mobilno mešalno enoto družbe Minervo d.d. Premer vrtin je bil 76 mm, kar je blizu kritičnega premera uporabe ANFO razstreliv.

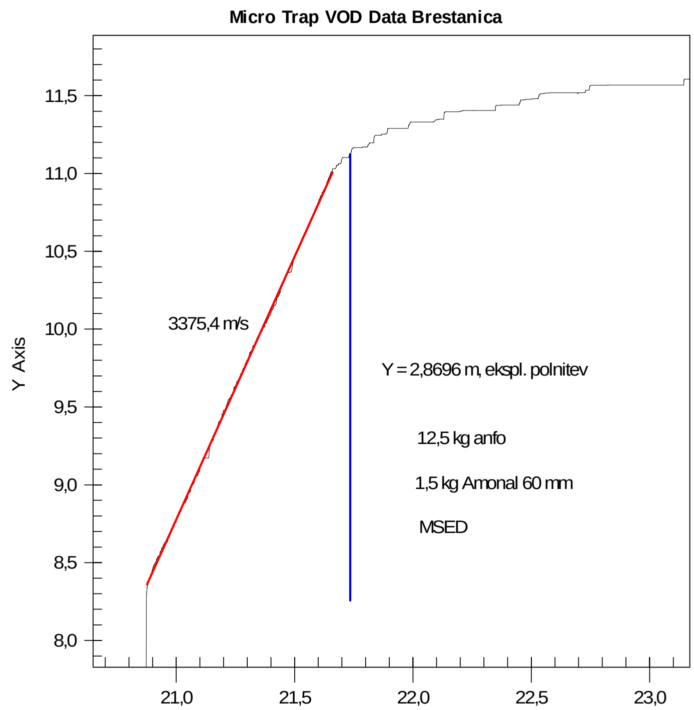
Testiranje razstreliva na mestu uporabe

Zaradi kontrole lastnosti razstrelilnih mešanic izdelanih na mestu uporabe je bilo opravljeno testiranje- meritve detonacijske hitrosti v vrtini. Meritve so bile izvedene z instrumentom za merjenje detonacijske hitrosti Microtrap (MREL). Rezultati meritev so razvidni iz diagrama prikazanega na sliki 9.

SEIZMIČNE MERITVE IN REZULTATI

Seizmične meritve so se stalno izvajale na najbližjem stanovanjskem objektu, na naslovu Sotesko 32 oddaljenem ca. 120 m in najbližjih minskih polj in ca. 180 m oddaljenemu objektu na drugi strani na stanovanjski hiši Cesta izgnancev 2, oddaljeni ca. 180 m od minskega polja. Na ostalih popisanih objektih so se izvajale občasne kontrolne seizmične meritve.

Za seizmične meritve so bili uporabljeni seizmografi proizvajalca Nomis Seismographs, tipa Minigraph 7000. Razdalja prvega merilnega mesta je bila ca. 120 m od lokacije miniranja. Drugo merilno mesto je bilo oddaljeno ca. 180 m od minskega polja.



Slika 9.

Vsa miniranja so bila izvedena z malimi minskimi polji (31 vrtin) z uporabo milisekundnih električnih detonatorjev v seriji številk oz. zakasnitev od 0 do 30. Za polnitve se je uporabljalo praškasto razstrelivo Amonal V.

Parametri minskega polja in rezultati seizmičnih meritev za najbližje merilno mesto (cca. 120 m) so prikazani v tabeli 3. Za drugo merilno mesto na stanovanjskem objektu oddaljenem ca. 180 m pa so rezultati prikazani v tabeli 2. V tabelah so prikazani karakteristični rezultati treh meritev na vsakem merilnem mestu.

Tabela 2.: Prikaz parametrov minskega polja in rezultatov meritev za merno mesto MM1.

Meritev št.	Globina vrt. [m]	Polnitev [kg]	Čep [m]	Zračni udar [dB]	Radial. komp. [mm/s]	Vertikal. kompo. [mm/s]	Transfer. komp. [mm/s]	Vektor vsota [mm/s]
1	6,5	12	3,5	110	1,14	1,14	0,76	1,28
2	6,5	14	3,0	113	2,28	1,65	1,77	2,41
3	6,5	14	3,0	107	1,90	1,39	1,65	2,15

Tabela 3.: Prikaz parametrov minskega polja in rezultatov meritev za merno mesto MM2.

Meritev št.	Globina vrt. [m]	Polnitev [kg]	Čep [m]	Zračni udar [dB]	Radial. komp. [mm/s]	Vertikal. kompo. [mm/s]	Transfer. komp. [mm/s]	Vektor vsota [mm/s]
1	6,5	12	3,5	101	3,04	2,03	3,10	4,10
2	6,5	14	3,0	105	2,54	1,52	1,27	2.80
3	6,5	14	3,0	102	3,42	3,24	2,66	3,55

ZAKLJUČEK

Iz rezultatov seizmičnih meritev je razvidno, da so vrednosti hitrosti nihanja znotraj dovoljenih vrednosti po DIN normah. Pri samem miniranju ni prihajalo do prekomernega razmeta odminiranega materiala. Zaščita-varovalni jarek in nasip ter varovalna ograja so bili dimenzionirano pravilno. Nikoli ni prišlo do preboja ali preskoka posameznih blokov kamenine z brežine kamnoloma na cesto ali železniško progo.

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