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MEASUREMENT IN BLAST HOLE STEM AND INFLUENCE OF STEMMING MATERIAL ON BLASTING QUALITY

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Abstract

Paper presents results of blast hole stem materials, that were conducted to assert best stem materials for surface blasting in quarry of technical / construction stone. Blasting has been performed with equal explosives and test-minefield parameters (length of the stem, volume of the explosive charge, mine-drill depth, and angle) on various sites / quarry. Results are guidelines in materials to be chosen in surface blasting of quarry works, adding to quality of mining works and reduction of costs.

Sažetak: U radu su dani rezultati ispitivanja materijala čepova minskih bušotina. Ona su obavljena sa ciljem određivanja najbolje vrste materijala za čepljenje minskih bušotina prilikom površinskog miniranja u kamenolomima tehničko-građevnog kamena. Miniranje je izvedeno sa jednakim eksplozivom i parametrima pokusnog minskog polja (ista duljina čepa, eksplozivnog punjenja, duljina bušotine, kut nagiba minske bušotine) za miniranja na pojedinim kamenolomima. Rezultati ispitivanja daju smjernice u korištenju materijala čepa pri površinskim miniranjima u kamenolomima tehničko-građevnog kamena, što pridonosi kvaliteti izvedenog miniranja i preko optimalnih bušačo-minerskih parametara smanjuje troškove eksploatacije.

Introduction

Blasting is a technological process used in mining for acquiring of mineral raw-materials, and for profiling of underground structures and tunnels. Blasting of explosive charge in blasting hole creates significant amount of energy released, shock-wave of great force in explosive and surrounding rock-formation and gases of high temperature and pressure. Blasting is considered successful when gas-energy produced by blasting is held in blast-hole long enough to create web of cracks in rock-formation and discharge of materials. Also, amount of energy needs to be sufficient to surpass strength of rock-formation and assures controlled movement of materials. If blasting parameters meet requirement, majority of energy is used to crush and discharge materials, while inadequate parameters result in surplus oscillation of ground and air (shock-wave in ground and air) and greater discharge of material. Blast energy reduction is a key factor of control for size and nature of oscillation produced. Test-blasts are required to successfully determine amount of explosive charge, stem size and drill parameters (diameter of the

hole, placing of the holes and size of discharge). For understanding of the stem and its role in the process, underground or surface, knowledge of the processes in hole during blasting is required. Parameters involved are: amount and type, blasting-technical characteristics of explosives, detonation method, and geometry of the blast-field and in uence of blasting to rock-formation. For optimal usage of explosive energy and reduction of unnecessary discharge, blast-holes need to be stemmed with adequate inert materials, from explosive charge to mouth of the hole.

Underground blasting, where distance between holes is lesser, where rock-formation levels and is under in uence of previous blasting shock-waves, stem holds explosive charge in holes. Experience, both lab and field, proves that optimal stem increases efficiency of blasting up to even 300%. Stem usage in underground construction and tunnelling by blasting is considered hindering factor in velocity of process and is mostly avoid in praxis, but testing has proven that 300% increase in efficiency of usage of energy, so that delays in explosives charge

production are compensated by savings in explosives and possible reduction in blasting cycles. Stems are characterised by; type of blasting (surface, underground, special blasting), shape (patronized, powder), material (discharged material, gravel, crushed rock of different fractions, dirt, clay, water, water-based gels, air, mineral clay, polyurethane foam, etc), method of stemming (hand or machine). For surface blasting, stems used most are discharged material, gravel, crushed rock of different classes.

Test of various granulated stems under equal blasting conditions

Stem Material

Optimal stem type test were conducted in two technical / construction rock quarry's ("Ivanec" and "Očura") in test-fields of 5 blast-holes. Classes used for determination of optimal fraction were:

- Discharged blast-holes material, classes of: 4; 4/8; 8/16; 16/32.

Class 16/32 material is shown on figure 1. In table 1 are densities of used classes.



Figure 1 16/32 Class Material

Slika 1. Frakcije materijala za čepljenje

Table 1. Density of classes used in stemming

Tablica 1. Zapreminska masa frakcija korištenih za čepljenje

Class (mm)	Discharged Material	4	4/8	8/16	16/32
Sample volume (dm ³)	1	1	1	1	1
Sample Mass (kg)	1.766	1.716	1.609	1.430	1.383
Density (kg/dm ³)	1.766	1.716	1.609	1.430	1.383

Blasting-technical qualities of explosive used in test-blasting

"Ivanec" quarry test-blasts were conducted with emulsion explosive "EMUNIT", manufacturer "Elmech Razvoj", for both primary and secondary charges.

An "Očura" quarry blast was with "ELMULEXAL" explosive of "Elmech Razvoj", and for secondary charge powder ANFO explosive was used.

"Emunit" is emulsion explosive of secondary heavy-ANFO explosive type and is sensitized with glass micro

spheres and ammonium nitrate granules to produce hot-spot. Its purpose is in civil usage in surface and underground blasting of methane and coal-dust free conditions and in wet blasting due to its water-resistance. It is white, pasty material, packed in PVC patroness of 70 mm diameter / 2.600 g weight.

Table 2. Characteristics (declared) of explosives used

Tablica 2. Deklarirane karakteristike korištenih eksploziva

Explosive	ANFO	Emunit	Elmulexal
Velocity of detonation (m/s)	2700	4862	5200
Density (g/cm ³)	0,882	1.201	1.15
Detonation temperature (°C)	2190	2050	2057
Heat of explosion (kJ/kg)	3600	3650	3120
Gas Volume (l/kg)	1050	920	910
Oxygen Balance (%)	1,5	-1.5	0.7

ANFO explosives are mixture of nitrates and fuel. Basic material for its production is ammonium nitrate with addition of oils, especially mineral oils, with or without aluminium powder to increase energy and efficiency of explosive. ANFO explosive is used in combination with emulsion, plastic and other stronger explosives.

“Elmulexal” is emulsion explosive of secondary type. Aluminium powder is one of its components for increase of energy and efficiency, and is used for blasting of hardest rock, for special construction and underwater works. Comes in patroness of 60 mm diameter / 1.714 g weight. Characteristics (declared) of explosives are given in Tab. 2.

Test I – “Ivanec” quarry

Velocity of detonation was measured in 5 blast-holes. Stem material changed, other parameters equal. Blasting Parameters:

Drill Angle	70°,
Drill Diameter	86 mm,
Drill Depth	13.5 m,
Stem Depth	3.8 m,
Distance between Holes	3 m,
Burden	2.7 m.

Initiation system – non-electric detonator “Crodet” with 500 ms delay time. Firing retarder for each hole – 25 ms. Drill depth, stem length and number of cartridge (charging mass) were parameters monitored. Each hole was stemmed with different material.

Geometry of charging is given in table 3. On figure 2 is schematic view of blasting field. Figure 3 presents charge of blast hole.

Table 3 Drill parameters and explosive charge in “Ivanec” quarry

Tablica 3. Bušačko minerski parametri minskih bušotina u kamenolomu Ivanec

Hole No.	Hole Depth (m)	Stem Length (m)	Stem Class (mm)	No. of cartridge
1	13,5	3,8	– 4	26
2	13,5	3,8	4/8	25
3	13,5	3,4	8/16	26
4	13,6	3,8	16/32	27

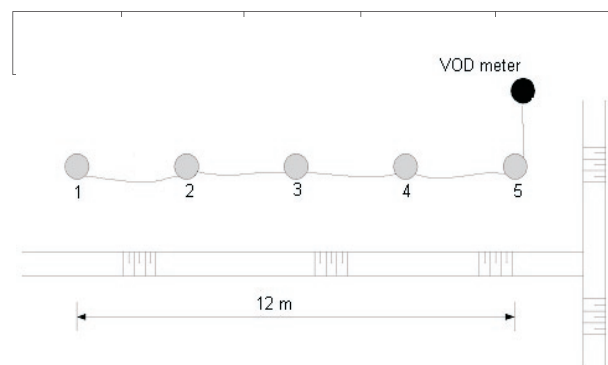


Figure 2 Blasting Field Schematic

Slika 2. Shematski prikaz minskog polja i postava mjerenja

1. Stem
2. “EMUNIT” explosive charge ř70/2600
3. Non-electric Detonator
4. VOD Measurement Cable
5. Shock Tube

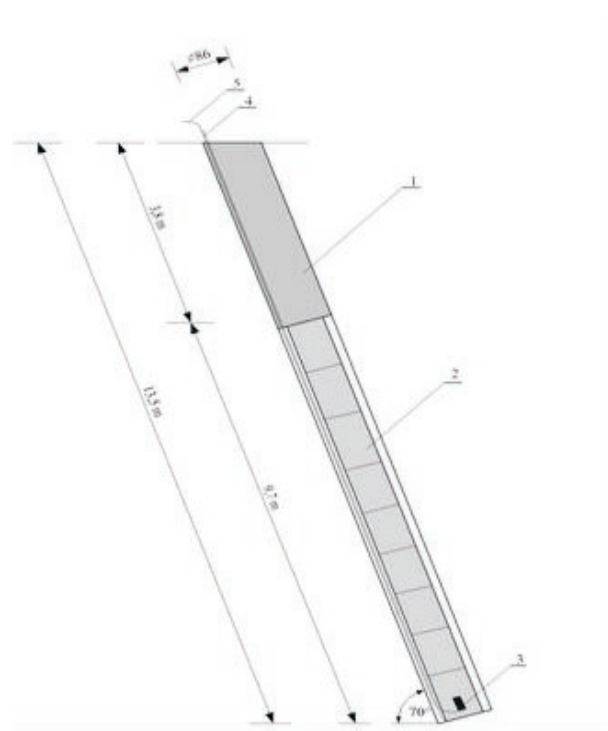


Figure 3 „Ivanec“ quarry, Blast Hole Schematics

Slika 3. Presjek minske bušotine- kamenolom Ivanec

“Očura” Quarry – Test II

Detonation velocity was measured in 5 blast-holes. Stem material was different, while other parameters stayed same. “Elmulexal” ø60/1714 g explosive was used as primer cartridge for ANFO explosive making rest of explosive charge.

Drill Parameters:	Angle	70°,	ms. Blast-hole length, stem length and ANFO explosives
	Diameter	90 mm,	volume were parameters monitored. Holes were stemmed
	Depth	24 m,	with different material.
	Stem length	4,5 m,	Charging data are given in table 4. On figure 2 is
	Distance between holes	5 m,	schematic view of blasting field. Figure 5 presents charge
	Burden	5 m.	of blast hole.

Non-electric detonator "Crodet" with 500 ms retarder was initialising element. Detonation retardation was 42

1p – one cartridge
25kgA – 25 kg of ANFO explosive
UP – primer cartridge

Table 4 Drill parameters and explosive charge in "Očura" quarry

Tablica 4. Bušačko minerski parametri minskih bušotina u kamenolomu Ivanec

Hole No.	Hole Depth (m)	Blast hole explosive charge	Measured Hole Length (m)	Stem Length (m)	Stem Class (mm)
1	24	24kgA+UP+95kgA	21	4,5	- 4
2	24	24kgA+UP+90kgA	21	5	4/8
3	24	24kgA+UP+95kgA	21	4,5	8/16
4	24	24kgA+UP+100kgA	21	4,5	16/32
5	24	24kgA+UP+100kgA	21	4,5	Discharged material

Velocity of detonation measurement in blasting holes

VOD (velocity of detonation) measurement is crucial parameter, based on which we interpret retardation (decrease in velocity) of shock-wave in specific stem. Stem with highest retardation has best energy retention and discharged material prevention. Detonation velocity is measured with "VODMate InstanTel Inc". Adequate measurement cable, equipment and connector were used with VODMate instrument.

VODMate is measuring velocity continuously, giving real-time detonation velocity data for explosive used and helping to optimise blast effect. Computer software calculates data received and with analyses, achieved detonation velocity and boundaries between explosives in hole could be determinate. Instrument also monitors shock-wave velocity in stem.

Measurement Schematic in Blast-hole is given on figure 5.

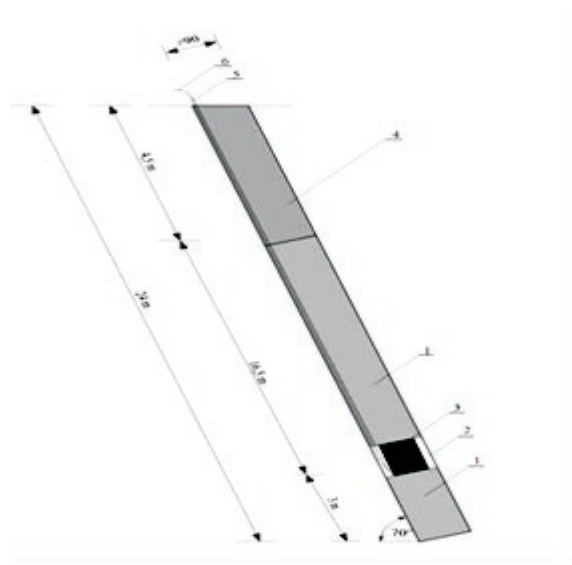


Figure 4 „Očura“ quarry, Blast Hole Schematics

Slika 4. Presjek minske bušotine- kamenolom Očura

1. ANFO
2. nonelectric detonator
3. primer cartridge ELMULEXAL- a
4. stem
5. measurement cable
6. shock tube

VODMate operates on measurement of change in electric resistance in measurement cable, where constant power supply is secured. During detonation, explosives detonation front advances and shortens (melts) measurement cable. Based on known specific electric resistance per m of cable, instrument measures total electric resistance in time frame and calculate cable length. Detonation velocity is calculation from measured values.

Upon selection of charges in test-holes, measuring equipment is selected. Primer cartridge is equipped with coaxial measurement cable. Primer cartridge is lowered

to the bottom of hole, and is charged with pre-determined amount of explosives. Uncut measurement cable is

lowered in all test-holes. Primer cartridge is placed on the bottom of bore hole.

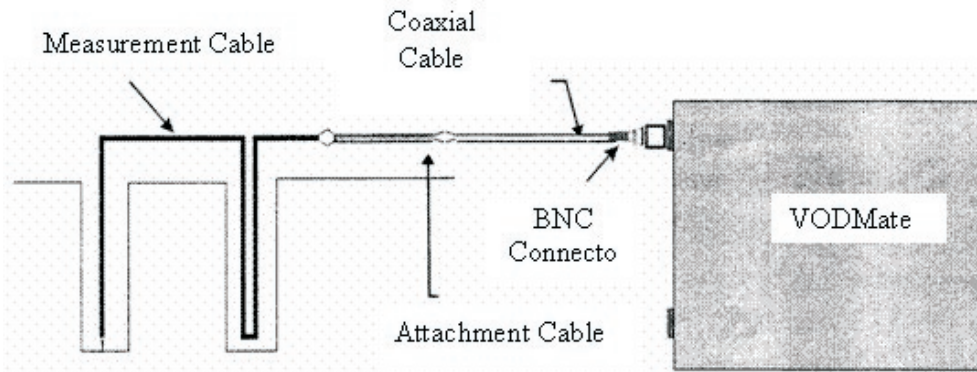


Figure 5 VODMate Measurement Schematic

Slika 5. Shematski prikaz mjerenja VOD kontinuiranom metodom



Figure 6 Primer cartridge

Slika 6. Udarna patrona

Measurement results

Table 5 gives velocity of detonation for specific holes. Table 6 presents measured Shock-wave velocity in stems.

Computing, with Blast Ware III software, of VOD diagram reveals data open for interpretation, and can be computed upon detonation velocity in blasting-hole, hole depth, explosive charge length or stem length in hole. Correct ascertain of start and

finish of detonation front influence, shock-wave area in hole and in stem, and middle value of velocity of detonation in specific interval.

Small change in angle of axis or dependence of measurement cable length per time, velocity value can

change significantly. Following general axis angle, differences in measured intervals are in 100 m/s range, or app. 2,5% error in detonation velocity. Detonation velocity diagrams are analysed and median value determined according to axis angle.

Figure 7 presents VOD measurement characteristic diagram and figure 8, Segment of measurement for hole 1, Test I, Stem material class-4.

Table 1 VOD of explosive used

Tablica 5. Brzina detonacije korištenih eksploziva

Explosive type	Detonation velocity in Holes (m/s)					Declared Detonation velocity (m/s)
	1	2	3	4	5	
EMUNIT	4725	4815	4739	4567	4719	4862
ANFO	3642	3590	3660	3705	3528	2700
ELMULEXAL	Used as primer cartridge					5200

Table 6 Velocity of shock wave in stems

Tablica 6. Brzina udarnog vala u čepovima

Hole No.	Stem Type (mm)	Velocity (m/s)	
		Measurement I	Measurement II
1	- 4	665	433
2	4/8	966	634
3	8/16	1663	1218
4	16/32	476	393
5	Discharged Material	1331	923

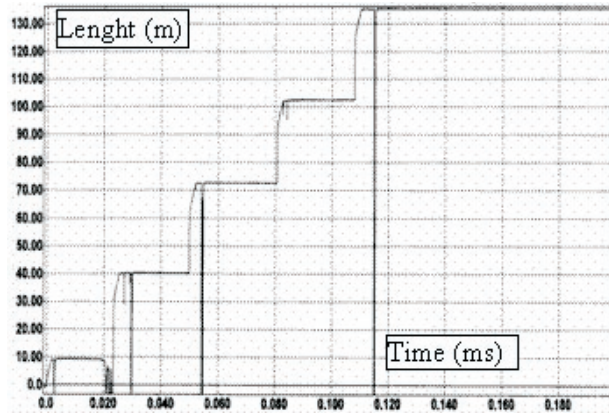


Figure 7 VOD measurement diagram

Slika 7. Dijagram mjerenja VOD

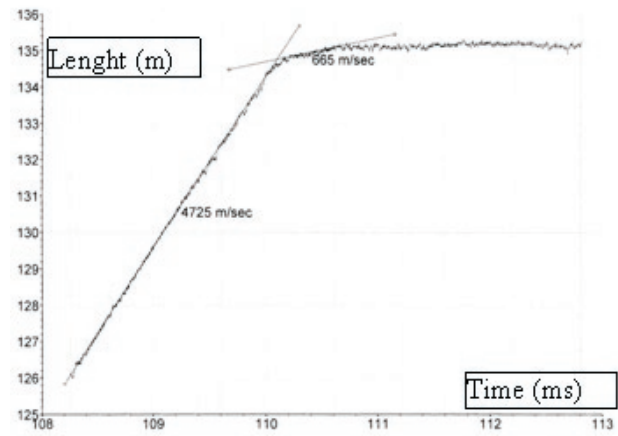


Figure 8 Hole no. 1, Test I, Stem class -4

Slika 8. Bušotina br. 1, Ispitivanje I, Frakcija -4

Blasting Video Analysis

Tape analysed is of FUJI S500 digital camera, 320x240 resolution, and 33 frames/7sec. In "VirtualDub 1.4.8" software, drill positions are determined inside blast-field with stem discharge height visible for specific holes. Hole no. 3, stemmed with granulation

8/16, has highest discharge, confirming detonation velocity interpretation that this particular granulation presents lowest stemming quality. Next highest discharge / lowest quality are 16/32. This granulation was asserted as best for stemming using previous interpretation of detonation velocity results. Location of holes in blasting-field are given on figure 9.

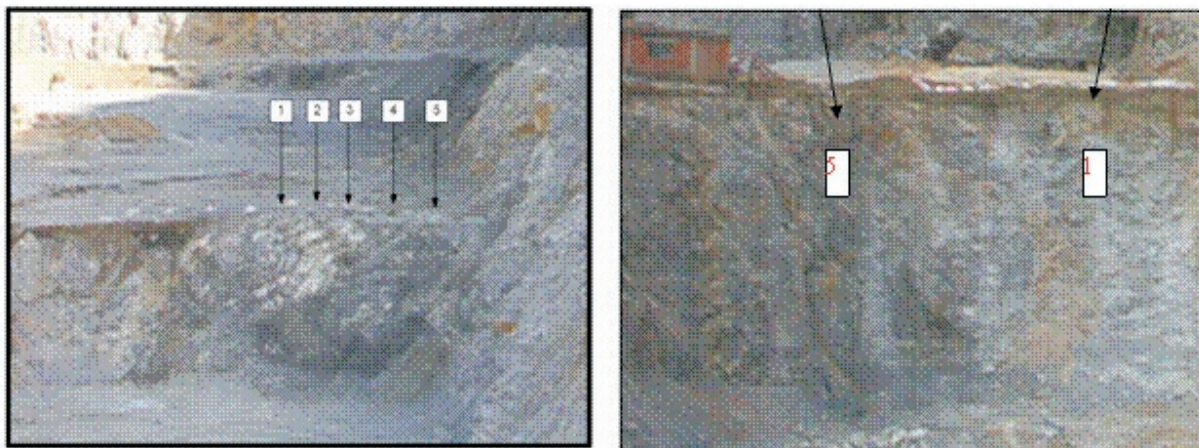


Figure 9 Holes location

Slika 9. Pozicija bušotina u minskom polju

Analysis of blasting in “Očura” quarry shows that no stem discharge occurred. Reason for it is use of non-electric initiation system that doesn't destroy stem, and stem over-dimensioning. Stem material (fraction) is relevant with border-line stem length, as seen in “Ivanec” quarry. Further inspection of blasting field revealed that part of material surrounding stem was also not discharged. Figure 10, hole stemmed with 16/32 fraction material left in hole after blasting.



Figure 10 Hole stemmed with 16/32 fraction

Slika 10. Minska bušotina čepljena frakcijom 16/32 nakon otpucavanja

Conclusion

Video-tape interpretation of “Ivanec” quarry blasting revealed that 8/16 and 16/32 materials used for stemming were discharged from hole while stayed intact. “Očura” quarry test produced no discharge in both tests.

Detonation velocity measurements in hole gives conclusion that best suited material for stemming in technical / construction quarries is 16/32 fraction, which produced lowest shock-wave velocity inside the

stem. Usage of this fraction allows reduction of stem length without loss of explosive energy. This results in increase in explosive charge and geometrical parameters of mining, or lesser no. of holes for same amount of discharged material.

8/16 proved to be least favourite stem material, with shock-wave velocity of over 1.200 m/s. Material most frequently used is discharged material.

Shock-wave velocity is dependant also upon explosives type. In “Ivanec” quarry, “Emunit” explosive was used, producing greater detonation velocity than ANFO explosive used in “Očura” quarry. Greater detonation velocity in explosive charge results in greater shock-wave velocity in stem. So “Očura” quarry measurements revealed for separate fractions lesser shock-wave velocity in stem.

Stem type depends on needs or conditions in which blasting is performed and of fractioned material disponibility and desired blasting effects. 16/32 fraction is recommended in all cases, dependant only to supply economics.

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