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Experimental study of stemming applicability in underground hard rock mining
Badania eksperymentalne możliwości zastosowania przybitki w górnictwie podziemnym skał zwięzłych

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Abstract: *In this paper, results of experimental studies of stemming applicability for hard rock underground mining are presented. Different stemming materials were examined, including clay, sand, cement slurry, adhesive charge and two types of montage foam. The results of the small scale investigations were evaluated based on the Trauzl lead block test and indicated that cement slurry and clay stemming produced the greatest expansion. Therefore, due to relatively small differences in expansion and the semi-liquid form of the former, the latter was tested underground. However, in situ tests of clay stemming did not provide clear conclusions confirming or rejecting its usefulness for improvement of blasting effectiveness.*

Streszczenie: *W artykule przedstawiono wyniki badań eksperymentalnych dotyczących możliwości zastosowania przybitki w kopalniach podziemnych skał zwięzłych. Przeanalizowano różne rodzaje przybitek, w tym glinę, piasek, zawiesinę cementową, ładunek klejowy i dwa rodzaje piany montażowej. Wyniki badań stanowiskowych ocenione z wykorzystaniem metody bloku ołowianego Trauzla wykazały, że zawiesina cementowa oraz przybitka gliniana spowodowały największe wydęcie. Dlatego też, z uwagi na stosunkowo niewielkie różnice i półpłynną postać pierwszej, druga z nich została przebadana pod ziemią. Wyniki badań przybitki glinianej in situ nie wykazały jednak jednoznacznie jej przydatności w poprawie efektywności robót strzałowych.*

Keywords: *blasting, stemming, working capacity, underground mining*
Słowa kluczowe: *roboty strzałowe, przybitka, zdolność do wykonania pracy, górnictwo podziemne*

1. Introduction

Stemming is the material, which is placed between the explosive charge and the outer end of the blasthole in order to confine the gases from detonation, which are crucial in performing the fragmentation and movement of the burden material [1]. As stated by Zhang *et al.* [2], unstemmed blasts result in the loss of at least 25%

of explosive energy in fragmentation, compared with stemmed blasts. Thus, blast performance may be improved, when suitable lengths of inert material are packed into the blasthole, which also may reduce the cost of blasting. According to Oates and Spiteri [3], it is recommended to always stem the blastholes. The general aim of stemming is minimizing the loss of energy, thereby improving rock fragmentation as well as reducing fly-rock and oversize boulders [4]. The stemming length (S_L) depends on many factors such as rock type or blasthole diameter, as well as local mining and geologic conditions. However, it should not be less than the assumed burden. Generally, the following relationship can be applied for S_L calculations [5]:

$$S_L = (20 \text{ to } 60) \times D \ [\text{m}] \tag{1}$$

where: D – blasthole diameter [m].

Where the length of stemming is insufficient, explosive energy can vent prematurely with fly-rock risk increases. In turn, excessive length of stemming significantly reduces this energy, but there is no direct correlation between stemming length and excessive air blast and ground vibration [6]. Since the stemming length is strongly dependent on site conditions, it should always be verified on the basis of post-blast evaluation. Nevertheless, the optimum length of stemming is directly related to the following factors [7]:

– strength of rock,
– charge diameter,
– charge energy,
– burden,
– presence of water,
– fly-rock considerations,
– geologic conditions (e.g. fractures).

Various stemming materials are currently used in mining, including clay, sand, fly ash or rock cuttings. As stated by Maram and Uttarwar [8], sand is the best stemming material enabling an effective confinement of the high-pressure stress produced by blasting. In turn, Reddy *at al.* [9] found that blasting with clay as a stemming material gives a good muckpile profile which helps in loading of excavators, which was also proved by Shi *et al.* [10]. Similar conclusions were drawn by Cevizci [11], who verified the applicability of plaster stemming in mining. For decades, many researchers have been trying to find the optimal stemming material [12-14]. However, rock cuttings are still most commonly used in open-pit mining due to their availability at the hole collar [15]. Another solution is the application of stemming plugs, which are becoming more popular due to environmental, technical and economic advantages [16]. They are available in many variants, such as air plugs, stemming plugs, small inflatable balloons, plaster of Paris packings, cement concrete, and grouting. Rehman *et al.* [17] stated that the economic benefits of using stemming plugs are considerable enabling significant reductions in blasting costs.

However, stemming is not always used in hard rock excavation in underground mines and tunnelling. This means that most horizontal or upward-drilled blastholes are not stemmed or are stemmed using plastic plugs only. This is in order to reduce the time spent by shotfirer in the area of the firing. The use of stemming for horizontal short hole blasting is time-consuming and much more expensive, especially when blasting is conducted in several locations at the same time. On the other hand, as stated by Devendar and Uttarwar [18], stemming may be used to maximize the effectiveness of an explosive at the face and minimize the magnitude of the elastic waves which propagate down the entry and reduce unnecessary discharge. Moreover, since commercial explosives are a major source of pollution containing some toxic and harmful gases, the application of stemming in underground mines appears to be justified, especially those which are able to completely neutralize harmful gases [19]. Apart from energy utilization and the environmental point of view, stemming in underground mines would enable the use of smaller quantities of explosives to achieve the same blasting results when using packaged explosives. In such cases, one or two cartridges of explosive may be replaced by one cartridge of stemming, so the total cost of explosives is lower. Improvements in fragmentation may also be expected, which can lead to lower downstream handling costs.

In this paper, results of experimental studies of stemming applicability for hard rock underground mines, is presented. Six different stemming materials were analyzed, including clay, sand, cement slurry, adhesive charge and two types of montage foam. The results of the small scale investigations were evaluated based on the Trauzl lead block test and compared to the expansion produced without stemming. These indicated that both cement slurry and clay stemming produced the greatest expansion. Therefore, the former was then tested in large scale trials underground.

2. Materials and methods

The subject of the research were the stemming materials widely used in the mining industry, i.e. clay, sand and cement slurry. Three alternative materials were also tested, including adhesive charge and two types of commercial montage foams. To evaluate the importance of stemming in mining, the results were compared to those produced by detonation of unstemmed explosive material. Each tested material varied in density, which ranged from 0.055 to 2.24 g/cm^3, as shown in Table 1.

Table 1. Densities of tested stemming materials

Type of material	Density [g/cm^3]
Cement slurry	2.24
Clay	2.05
Sand	1.51
Adhesive charge	1.92
Non-flammable montage foam	0.064
Rapid curing expanding foam	0.055

Cement slurry, having the highest density value, was made by mixing water with barite aggregate. Such a high-density mixture is called heavy concrete and is used mainly in civil engineering. Clay stemming with the trade name OT-1 was delivered by Wanika Sp. z o.o. It is designed for tight filling of blastholes before detonation of the explosive with the aim of safer and more effective blasting. It is used for both the traditional (manual) and pneumatic loading of blastholes. Sand stemming was formed from dry fine-grained compacted sand with a grain size smaller than 1 mm. Another tested stemming with relatively high density was the adhesive charge used for rock bolt installation in underground mines manufactured by DSI Schaum Chemie. Finally, two low-density montage foams were tested, including Sika Boom-420 Fire foam and FM710 foam. The former is a single-component and fireproof expanding polyurethane foam manufactured by Sika Poland Sp. z o.o. The second is a two-component, rapid curing, high yield, expanding polyurethane foam manufactured by Tremco illbruck Sp. z o.o. suitable for general gap filling, bonding and insulation applications.

Since full-scale field blasting is much more expensive and time-consuming than small-scale model blasts, research was conducted at the Central Mining Institute – National Research Institute's test site in Mikołów, Poland. The results of the investigations were evaluated using the Trauzl lead block test [20, 21], which is the oldest method for explosive performance testing still widely used. It is based on determining the expansion capacity produced by the detonation of a 10 g foil-wrapped sample of explosive in a cylindrical lead block. The height and diameter of the block is 200 mm. The explosive sample is loaded into a hole with a diameter of 25 mm and depth of 125 mm located in the centre of a solid block. In principle, the hole is then filled up with sand, but in this case with different stemming materials. The sample is initiated using a 0.65 g PETN detonator. By measuring the volume of the cavity produced by the detonation, explosive power/strength is obtained. The resulting expansion is compared to that produced by 10 g of picric acid acting as a reference charge. Detonation of this charge at 15 °C results in a cavity of 310 cm^3.

A total of 24 samples were prepared, including 3 samples for each type of stemming, 3 for picric acid and 3 for unstemmed sample. The schematic of the lead block used in the experiments and the cavity produced by detonation of an explosive are shown in Figure 1. In turn, Figure 2 shows the lead blocks and foil-wrapped sample of explosive with detonator. In this research, Emulinit GM1 explosive was used. It is a chemically sensitized packaged emulsion explosive intended for use in underground and open-pit mines as a rock blasting explosive and may be described by the following parameters, according to the technical data sheets:

- density: 1.05–1.25 g/cm^3,
- velocity of detonation: 4,000 m/s,
- specific energy: 897 kJ/kg,
- Relative Weight Strength: 70%,
- heat of detonation: 3,449 kJ/kg,
- gas volume: 904 dm^3/kg.

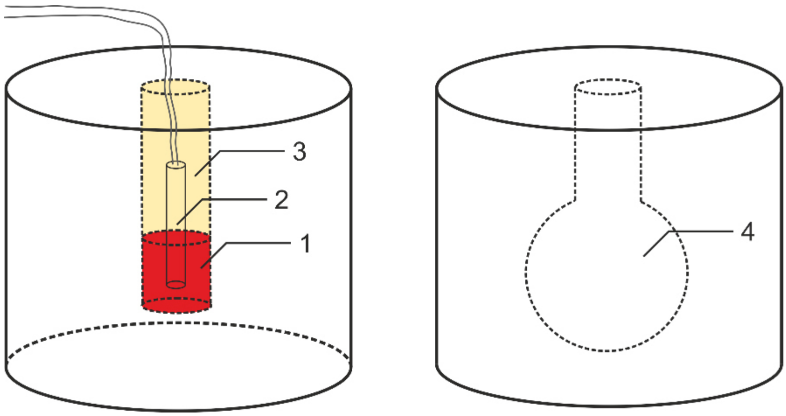

Figure 1. Schematic of the Trauzl test (left) and cavity produced by detonation (right): 1 – explosive sample, 2 – detonator, 3 – steming, 4 – cavity produced by detonation

Figure 2. Foil-wrapped explosive sample with detonator (left) and blocks before the test (right)

The difference between the initial internal volume of the block was then compared to the increases in volume produced by the explosive. The performance of explosive ("strength" or "power") is expressed as a percentage in relation to the reference sample, i.e. picric acid. The testing procedure is described in the national standard [22].

3. Results

Expansion of the lead blocks for each stemming material was determined based on the firing of three samples and presented graphically as the increase in the volume of the cavity in relation to the cavity produced by 10 g of picric acid. Results are presented in cubic centimetres as one average value from three samples (Figure 3) in relation to density of a given material. The uncertainty in the mean value is also presented.
The greatest expansion for the tested materials was observed for cement slurry which resulted in an internal volume of 395.7 cm^3. Somewhat lower expansions were produced for clay and adhesive charge and amounted to internal volumes of 374.5 and 353.2 cm^3, respectively. Particularly good results were also achieved for compacted sand, which is widely used in open-pit mining to stem vertical blastholes.
Expansion volumes produced by the two remaining stemming materials, i.e. two types of montage foam, were relatively low. The results for those materials showed slightly higher expansions than those produced without stemming, indicating that stemming material density is a key factor affecting the high-pressure confinement.
Dispersion in expansion of the lead blocks for the tested materials was relatively low and varied from 2 cm^3 for adhesive charge to 9 cm^3 for cement slurry. The calculated coefficient of determination (R^2) for these reached almost 0.99, which can be interpreted as a very strong and almost perfect correlation between the cavity volume produced and density of the stemming material.

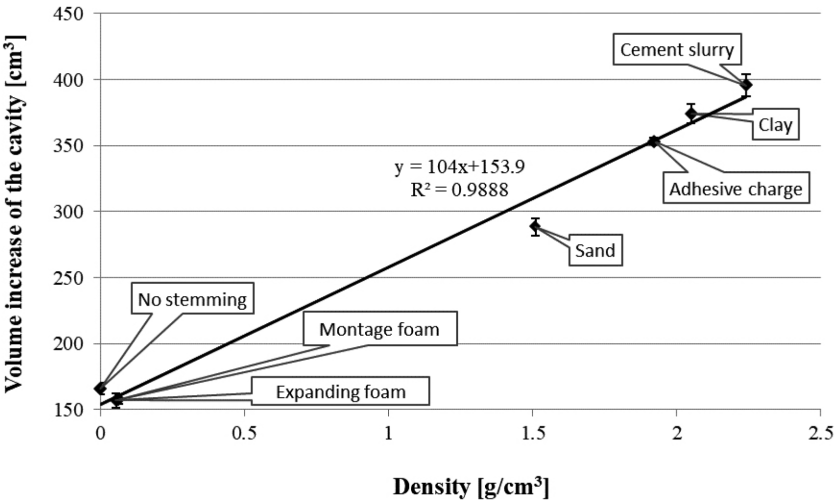

Figure 3. The relation between lead block expansion and density of stemming material

Due to the fairly good results obtained for the clay stemming and in view of the relatively easy process of blasthole loading when using clay, this stemming material was selected for testing in large scale trials underground. Since the blastholes in mines are not fully charged with explosive and/or stemming, additional studies were carried out prior to these trials, in which internal expansion of the lead blocks was determined in relation to the length of stemming column. For this purpose, four cases were evaluated, including full clay stemming, then 70%, 30% and then no stemming (Figure 4). The latter is never used in the Trauzl test since the explosive would always be covered with sand, but the Authors' intention was to reflect mining conditions.

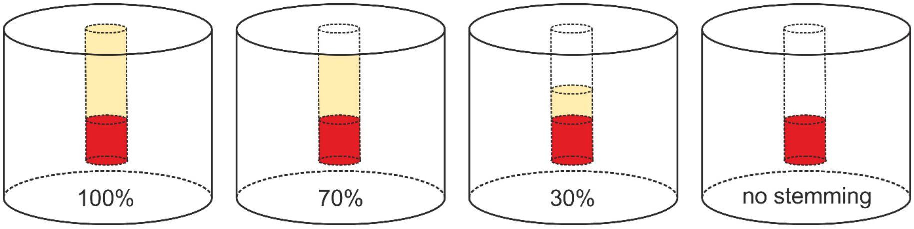

Figure 4. Analyzed lengths of stemming column for clay

Results are very favorable from the economical point of view. As shown in Figure 5, the trend line is polynomial and there is only a minor difference in internal expansion of the lead blocks when using 70% and 100% of clay stemming. The resulting increase in expansion was almost the same. Bearing in mind the uncertainty of the test method, it can be concluded that results are the same. The difference in the cavity volume between the 30% and 70% of stemming is slightly higher than 10%, which means that even 30% of stemming may confine the gases from the detonation, which in turn may help to improve fragmentation of rocks in mines.

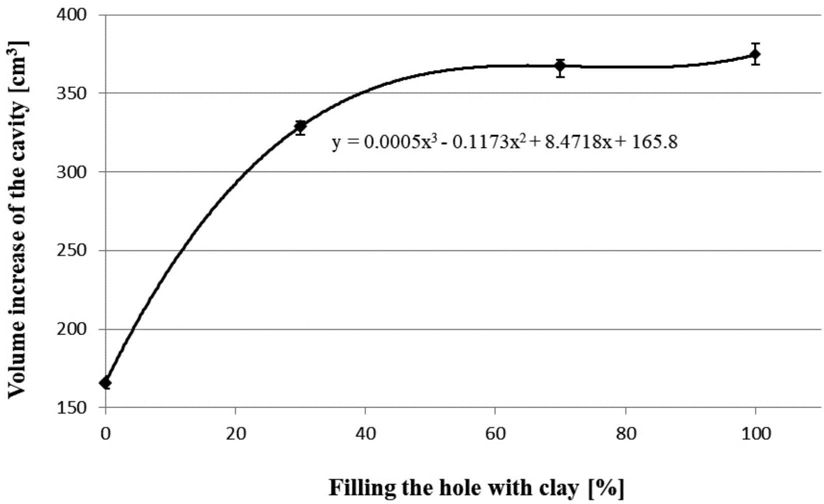

Figure 5. The relation between lead block internal expansion and length of stemming column

The final stage of research consisted of testing the effectiveness of stemming in hard rocks underground. For this purpose, six cuts were blasted, from which three were stemmed and another three unstemmed. A cut is a group of blastholes drilled in the center of the mine face parallel to the excavation to create a second free face towards which the rock can break and be ejected. It was assumed that blasting is effective when a cut is able to produce an opening to the full depth (same like the length of blastholes). A parallel hole cut was used in this test with two empty holes as shown in Figure 6.

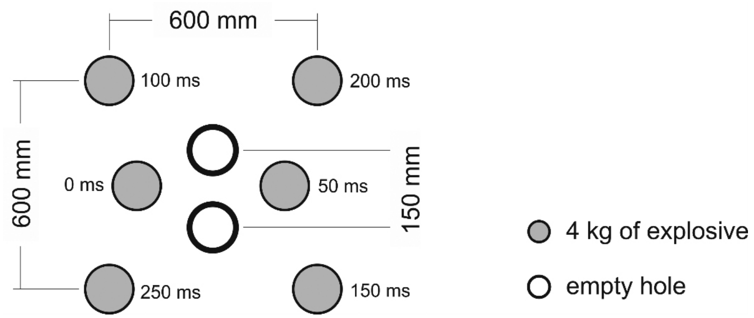

Figure 6. Drilling and firing pattern of the cut

All cuts were located in the sidewalls in a relatively soft dolomite stratum. The diameter of the blastholes was 51 mm and the length was approximately 300 cm. The same explosive was used as in the small-scale tests, i.e. Emulinit GM1, cartridged emulsion explosive. The mass of each charge was 1 kg and the total mass per hole was 4 kg (24 kg per cut in total). Explosives were initiated using non-electric detonators with a 50 ms time interval from 0 to 250 ms. Blastholes were fully stemmed using packaged clay stemming as shown in Figure 7.

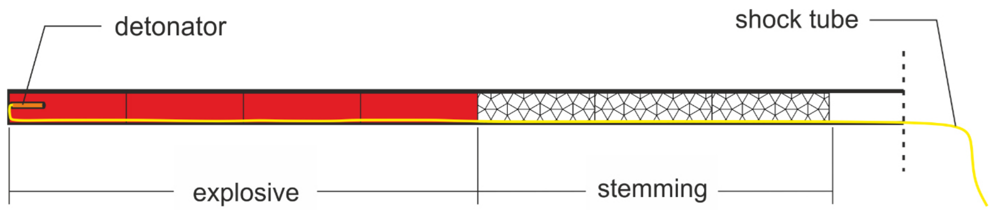

Figure 7. Charging pattern of blasthole

The results of these tests were evaluated by measuring the full depth and the total volume of the produced opening. The average depth was 285 ±10 cm, while the average volume was about 1 m^3. Due to heterogeneity of the dolomite stratum at the test site and probably the low precision of drilling caused by the dimensional and technical limitations of the drill rig, there were no significant differences observed between both cases, and it was difficult to determine if stemming can improve the effectiveness of blasting. However, it should be noted that overall the results were very good, since an opening on a full depth was produced in each case, but it was not possible to compare them. It seems that comparison of stemming effectiveness is difficult to determine based on cut blasting only, and it should rather be evaluated on the basis of full face blasting supplemented by fragmentation analysis. Another solution, to be verified, could be the evaluation of the blasting effect when the total mass of explosive is reduced instead of the stemming length being increased.

4. Discussion

Results have shown that effectiveness of stemming determined by the internal expansion of the lead blocks produced by detonation of explosive sample is strictly related to the density of the stemming material. Thus, cement slurry and clay stemming, which are characterized by the highest density, produced the greatest expansion. This means that the density of the stemming is a key factor affecting the cavity volume. It can therefore be assumed that higher density materials will provide even greater effectiveness in blasting. The relationship between the volume of the produced cavity and density of the stemming is almost linear, however, increases in density may result in a flattening of the curve.

The cement slurry demonstrated the greatest expansion, although its application in mining is limited to vertical blastholes due to its semi-liquid form. The cement slurry used was made from two components and tested before solidification. However, some problems may occur after the cement solidifies as in the case when the explosive charge in the blasthole has partly or completely failed to explode as planned, since removal of stemming may cause serious problems. Clay stemming in turn showed quite similar results. Relatively high density leads to comparable internal expansion of the lead blocks. Due to its packaged form, it may be used for both vertical and horizontal blastholes. The price is also competitive compared to other stemming materials, achieving similar effects.

Even though the adhesive stemming material is the most expensive, it does not provide the greatest internal expansion. Since it is supplied in a flexible packaged form and never solidifies, it may also be used for both vertical and horizontal blastholes. Another advantage of the material, similar to clay, is its ability of pneumatic loading, what can speed up the performance of blasting works. Satisfactory results were also observed when using sand as stemming. This is undoubtedly a cost-effective solution, but again limited to vertical blastholes. The produced expansion is acceptable, however, sand cannot be compacted enough to achieve similar expansion like other high density materials. It may therefore be assumed that drill cuttings, which are commonly used for stemming in open-pit mines are a good and low-cost alternative to sand.

Expansion produced by both montage foams were relatively low and only slightly higher than that produced without stemming. Such materials, due to their significant expansion properties, are able to fully fill the blasthole. However, due to low density, they cannot confine the gases from such dynamic events as detonation and improve the blasting effect. Since the application time of foam is relatively short, it is reasonable to develop a pump unit and pumpable high-density stemming for mining which will enable a reduction in the time of blasting and increase the efficiency.

Tests of internal expansion of the lead blocks in relation to the length of stemming column, have shown that even 30% of stemming gives promising results and may confine the gases from the detonation. However, this applies to high-density stemming materials only. It means that there are no grounds for blasthole stemming up to the collar if no methane and/or coal dust explosion hazard are observed. Stemming may of course confine the toxic gases but does not affect the blasting result.

Underground tests of clay stemming did not provide clear conclusions confirming or rejecting its usefulness in improving blasting effectiveness. Thus, additional tests involving full face blasting should be carried out.

5. Conclusions

- Experimental results of the lead block expansion test, produced by stemmed explosive samples have proved that the use of stemming to confine the energy from the detonation and hence improve the blasting effect, is justified. Results have shown that expansion increases with increases in the density of stemming material. Effective confinement of the energy released in the detonation may be achieved when the density of the stemming is close to 2 g/cm^3. Application of such a high-density stemming material can contribute to a reduction of the amount of explosive in blastholes instead of an increase in stemming column length. This is particularly important in underground mines from the ventilation point of view, since reducing the amount of explosive will directly translate to a potential reduction in post-blast fumes and toxic gases.
- The use of low-density stemming gives similar results to those obtained without stemming. Even though they are able to fully fill the blasthole and minimize the channel effect, the produced expansion is very low. In turn, application of a shorter column of stemming when using high-density stemming material may confine the energy from detonation, and play an important role in blast fragmentation. Shorter stemming columns may be used in underground mines when methane and/or coal dust explosion hazard are not observed.
- Analysis confirmed that among the analyzed stemming materials, cement slurry and bulk sand may only be used in vertical blastholes, basically in open-pit mines. However, the role of stemming in surface

mining, apart from increased confinement inside the hole and better utilization of blast explosive energy in the rock, is a reduction of backbreaks, fly-rock, and ground vibrations. In turn, in underground mines, where relatively short blastholes are used, stemming may have a much stronger effect on blasting results. Nowadays, due to difficult mining conditions underground, blasters are exposed to a wide range of hazards, so the time of blasting operations should be limited to a minimum. Thus, most blastholes underground are not stemmed or only plastic plugs are used. This provides room for action in the field of development of novel stemming materials with parameters similar to clay. Such a stemming, on one hand, should be flexible, and on the other, should be characterized by high density to minimize the channel effect. The challenge for the mining industry also lies in the development of pumpable high-density stemming for bulk emulsion explosives, which will enable a reduction in time and an increase in the effectiveness of blasting.

References

[1] Armstrong L.W. *The Quality of Stemming in Assessing Blasting Efficiency*. Master thesis, University of New South Wales, **1994**.

[2] Zhang Z.X., Hou D.F., He Z. Laboratory Experiment of Stemming Impact on Rock Fragmentation by a High Explosive. *Tunn. Undergr. Space Technol.* **2020**, *97* paper 103257; https://doi.org/10.1016/j.tust.2019.103257.

[3] Oates T.E., Spiteri W. Stemming and Best Practice in the Mining Industry: A Literature Review. *J. South. Afr. Inst. Min. Metall.* **2021**, *121*(8): 415-426; http://dx.doi.org/10.17159/2411-9717/1606/2021.

[4] Zhang Z.X., Qiao Y., Chi L.Y., Hou D.F. Experimental Study of Rock Fragmentation Under Different Stemming Conditions in Model Blasting. *Int. J. Rock Mech. Min. Sci.* **2021**, *143* paper 104797; https://doi.org/10.1016/j.ijrmms.2021.104797.

[5] *Safe and Efficient Blasting in Underground Metal Mines – Manual.* Melbourne: Orica Mining Services, **2010**.

[6] Mpofu M., Ngobese S., Maphalala B., Roberts D., Khan S. The Influence of Stemming Practice on Ground Vibration and Air Blast. *J. South. Afr. Inst. Min. Metall.* **2021**, *121*(1): 1-10; http://dx.doi.org/10.17159/2411-9717/1204/2021.

[7] *Blaster's Handbook.* (Stiehr J.F., Ed.) Cleveland: International Society of Explosives Engineers, **2011**.

[8] Maram D., Uttarwar M.D. Application of Stemming Systems and Materials in Underground Excavations - A Critical Review. *Int. J. Innov. Res. Sci. Eng. Technol.* **2020**, *9*(2): 14010-14021; http://www.ijirset.com/upload/2020/february/upload/2020/february/11_2_Application.PDF.

[9] Reddy S., Tripathi A.K., Parida S. Influence of Stemming Material on Performance of Blasting. *PalArch's J. Archaeol. Egypt/Egyptol.* **2020**, *17*(7): 9797-9809; https://archives.palarch.nl/index.php/jae/article/view/3968.

[10] Shi X., Zhang Z., Qiu X., Luo Z. Experiment Study of Stemming Length and Stemming Material Impact on Rock Fragmentation and Dynamic Strain. *Sustainability* **2023**, *15* paper 13024; https://doi.org/10.3390/su151713024.

[11] Cevizci H. A New Stemming Application for Blasting: A Case Study. *Rem: Rev. Esc. Minas* **2013**, *66*(4): 513-519.

[12] Qiu X., Shi X., Zhang S., Liu B., Zhou J. Experimental Study on the Blasting Performance of Water-Soil Composite Stemming in Underground Mines. *Adv. Mater. Sci. Eng.* **2018**, paper 3523509; https://doi.org/10.1155/2018/3523509.

[13] Ko Y., Shin C., Jeong Y., Cho S. Blast Hole Pressure Measurement and a Full-Scale Blasting Experiment in Hard Rock Quarry Mine Using Shock-Reactive Stemming Materials. *Appl. Sci.* **2022**, *12* paper 8629; https://doi.org/10.3390/app12178629.

[14] Li R., Xu S., Li Z., Suorineni F.T., Zhu G. Development and Testing of Self-Swelling Cartridge For

Use as Stemming Material in Open-Pit Blasting – A Quarry Case Study. *Int. J. Rock Mech. Min. Sci.* **2023**, *170* paper 105503; https://doi.org/10.1016/j.ijrmms.2023.105503.
[15] Cevizci H., Ozkahraman H.T. The Effect of Blast Hole Stemming Length to Rockpile Fragmentation at Limestone Quarries. *Int. J. Rock Mech. Min. Sci.* **2012**, *53*: 32-35; https://ui.adsabs.harvard.edu/link_gateway/2012IJRMM..53...32C/doi:10.1016/j.ijrmms.2012.04.005.
[16] Choudhary B.S., Rai P. Stemming Plug and its Effect on Fragmentation and Muckpile Shape Parameters. *Int. J. Min. Miner. Eng.* **2013**, *4*(4): 296-311.
[17] Rehman A.U., Emad M.Z., Khan M.U. Improving the Environmental and Economic Aspects of Blasting in Surface Mining by Using Stemming Plugs. *J. South. Afr. Inst. Min. Metall.* **2021**, *121*(7): 369-378; http://dx.doi.org/10.17159/2411-9717/1573/2021.
[18] Devendar M., Uttarwar M.D. Investigation Into the Effect of Stemming on Blast Performance in Underground Excavations – A Model Study. *Helix* **2020**, *10*(1): 43-50; https://doi.org/10.29042/2020-10-1-43-50.
[19] Tverda O., Kofanova O., Kofanov O., Tkachuk K., Polukarov O., Pobigaylo V. Gas-Neutralizing and Dust-Suppressing Stemming of Borehole Charges for Increasing the Environmental Safety of Explosion. *Latv. J. Phys. Tech. Sci.* **2021**, *58*(4): 15-27; https://doi.org/10.2478/lpts-2021-0030.
[20] Afanasenkov A.N. Strength of Explosives. Trauzl Test. *Combust. Explos. Shock Waves* **2004**, *40*(1): 119-125.
[21] Dobrilovic I., Dobrilovic M., Suceska M. Revisiting the Theoretical Prediction of the Explosive Performance Found by the Trauzl Test. *Def. Technol.* **2024**, *36*: 163-174; https://doi.org/10.1016/j.dt.2023.08.013.
[22] *Explosives – Determination of Explosive Strength in a Lead Block*. (in Polish) PN-C-86037:2000, **2000**.

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