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DRILLING AND BLASTING PROCEDURES OPTIMIZATION TO OBTAIN CONDITIONED MINING MASS IN THE VARIABLE STRENGTH MONOLITHIC LIMESTONES EXTRACTION

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Abstract. An expert assessment of the drilling and blasting works actual parameters compliance with the standard blasting project at the Verbka-Pivdenna quarry in the Khmelnytskyi region was carried out. It was found that the actual parameters of drilling and blasting work partially do not correspond to those proposed in the "Standard Project for Blasting Works Using the Method of Borehole and Burrow Charges at the Verbka-Pivdenna Quarry."

In this regard, ways of adjusting the actual blasting operations parameters in accordance with the standard project, taking into account the strength properties and limestone structure, are indicated. In particular, it is proposed to assess the limestone fracturing influence on the explosion destruction nature, as well as to clarify their strength according to the M.M. Protodiakonov scale for individual sections of the massif, since these rock properties significantly affect its fragmentation. This will make it possible to carry out a scientifically based calculation of the specific explosives consumption used for crushing limestone and obtain the required the rock mass crushing quality at the Verbka-Pivdenna quarry.

To achieve high-quality explosive preparation of crushed rock mass in isotropic monolithic rocks, such as limestones, a good result is provided by the use of a checkerboard drilling grid on the blasting block and switching of downhole charges according to a diagonal scheme. The use of such a scheme for connecting explosive charges significantly reduces the oversized fractions volume due to a reduction in the spall cracks number and ensures more uniform crushing of the rock by explosion.

It is necessary to adjust the borehole charges location in the increasing its area direction. This will ensure a reduction in the specific explosives consumption used to destroy the massif and, as a result, reduce the destroyed rock recrushing.

In the future, the results of this work should be used to develop adjusted parameters for drilling and blasting operations at the Verbka-Pivdenna limestone quarry, which will allow achieving high quality crushing and the required condition of the blasted rock mass.

Keywords: drilling and blasting, limestone, typical project, fracturing, quality of grinding, geological structure, rock strength.

1. Introduction

The Verbetsk limestone deposit is located in the Khmelnytskyi region, Kamianets-Podilskyi district, near the village of Verbka, 3.5 km from the Nizhyn railway station, Kamianets-Podilskyi, which is 12 km south of the deposit.

From a geological point of view, the limestones of this deposit are represented by the so-called Medobors or Tovtras [1]. These are highly dissected, rocky limestone ridges. They begin in the west from the sources of the Zbruch River and extend far to the southeast – to the cities of Kamianets-Podilskyi and Khotyn, and then continue towards Moldova.

This is a rocky arc-shaped ridge, the height of which reaches 443 meters near the Pidkamin town. This ridge rises 60-65 meters above the surrounding plain. Tovtry is a barrier reef of the Miocene sea, formed by bryozoans, membranoporous and shelly limestones. The surface of the tovtras is usually free of Quaternary deposits, so their irregularities stand out sharply in the relief with rocky and karst forms that have a rather picturesque appearance.

The length of Medobor reaches 250 km, and the width is 15-20 km. The tovtras shape is diverse: sometimes they rise in the elongated shaft form, sometimes they

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have the form of individual cone-shaped hills, and sometimes they resemble atolls.

The most common form is ridges in the elongated shafts form up to 0.5 km wide. Their surface is mostly wavy, and the slopes are convex.

The large Transnistrian part of the Podolian Plateau is distinguished by certain features: it is strongly and rather densely dissected by deep canyon-like valleys of the left tributaries of the Dnister. The valleys are 200 m deep, their slopes are steep, and their bottoms are narrow. The rivers flowing here are mountainous in nature: their beds and banks are rocky, the bottom is uneven, and the current is fast.

Weathered and eroded limestone exposed on the slopes of the valleys form rocks of various shapes - in the form of columns, pillars, giant mushrooms or chaotic accumulations of large blocks. The Podolian Plateau within Transnistrian consists of separate narrow, long, and parallel meridionally oriented strips. The surface of its watershed is covered with loess everywhere and has a predominantly flat or undulating mountainous character.

The limestones structure here is quite diverse. Mostly, these are oolitic limestones of varying strength, which transition into loose sandstone. Along with this, there are shelly limestones (villages of Liadova, Pyliava, and Berezhne) and bryozoan limestones (district of the city of Letychiv, villages of Verbka, Holovchyntsi, Riv, Lopatyntsi, Brailiv, etc.). The latter participate in the forming of the second eastern reef ridge. Mossy (membranoporous) limestones come in two varieties: light, porous, similar to pumice, and dense, heavy, partially recrystallized.

The standard project for blasting works using the method of borehole and blasthole charges at the Verbka-Pivdenna quarry (hereinafter referred to as the “Standard Project”) involves the use of modern explosives and means of their initiation for crushing limestone with charges approved for permanent use by the State Industrial Inspectorate of Ukraine. During the development of the “Standard Project”, the geological and hydrogeological characteristics of the deposit, the range of explosives used in open-pit (quarry) blasting operations, as well as the necessary equipment for drilling operations, in particular the drilling of vertical and inclined boreholes were taken into account.

It should be emphasized that the geological variability of different type’s limestones in this area, their location in space, and the nature of secondary changes caused by weathering and recrystallization inevitably lead to changes in their strength properties (strength coefficient according to the M.M. Protodiakonov scale).

Therefore, certain difficulties should always be expected when mining these rocks by explosive method. That is, if the features of the geological structure and changes in physical and mechanical (strength) properties are not properly taken into account in the “Standard Project” of blasting works using the method of extended borehole charges and in the “Passports of drilling and blasting works”", this will necessarily affect the quality of the preparation of the rock mass after the explosion. In particular, it is possible that the mining mass is not densely piled up, there is an increased yield of oversized and excessively crushed fractions, poor quality of the ledge base processing, etc.

5Such phenomena were observed for some time at the Verbka-Pivdenna quarry.

In this regard, in order to achieve the required rock crushing quality, an expert assessment was conducted of the actual drilling and blasting works parameters compliance with the "Standard Project" at the Verbka-Pivdenna limestone quarry.

In the future, the results of this work should be used to develop adjusted parameters for drilling and blasting operations at the Verbka-Pivdenna limestone quarry, which will allow achieving high crushing quality and the required condition of the blasted rock mass.

Below are the main features of a typical project for blasting using the borehole and blasting charges method at the Verbka-Pivdenna quarry.

The project was developed by the production and technical department of PJSC "Zakhidvybuhprom" on the basis of a subcontract for the blasting works performance (drilling and blasting works, mining plan and field development project). This "Standard Project" is used to prepare passports for mass explosions for crushing rock mass, forming ledge bases and other blasting operations provided for by quarry development technology.

The purpose of the work is to assess the compliance of the drilling and blasting operations actual parameters with the conditions and requirements provided for by the "Typical Project" for the "Verbka-Pivdenna" quarry, taking into account the geological structure, fracturing and limestones strength properties. Based on this assessment, it is planned to develop adjusted drilling and blasting parameters that will ensure high quality of the rock mass crushing, effective use of explosives, and optimization of the mining process.

2. Methods

The problem considered in this work is the non-compliance of the blasting operations actual parameters with the conditions set forth in the "Typical Project" for the "Verbka-Pivdenna" quarry. During operation, it was discovered that the geological deposit structure, in particular, the fracturing, different strength and limestones structure, were not always properly taken into account in the project documentation. This usually leads to such negative consequences as inefficient the mining mass grinding, excessive oversized forming or too crushed fractions, low-quality the ledge sole processing, as well as an increase in the explosives consumption.

A key aspect of the problem is that the typical project is based on weighted averages of the physical and mechanical rocks properties, without taking into account their local variability, fracturing, and weathering degree. This reduces the blasting efficiency prediction accuracy and affects the technical and economic production process indicators.

In the global practice of the mining industry, drilling and blasting operations are constantly being improved in order to increase the rock crushing efficiency. The main focus is on obtaining fractions suitable for further technological processing and minimizing the substandard material proportion. In Ukraine, many mineral deposits that are developed in an open-pit manner are exploited using the drill-blast method. In works [2-8], rational drilling and blasting parameters were analyzed and substantiated, that aimed at optimizing the boreholes location, the explosives type, and the initi-

ation method to improve the massif fragmentation quality.

The problem urgency is exacerbated by the need for rational use of resources, minimizing environmental impact, and ensuring stable crushing quality. That is why there is a need to conduct an expert assessment of the actual drilling and blasting parameters compliance, as well as to develop adjusted technological solutions adapted to the quarry specific geological conditions.

3. Results and discussion

Mining-geological and mining-technical conditions, as well as existing production conditions at the Verbetsk limestone deposit. The water level in blast boreholes can reach 1 m. The overlying rocks, which are up to 6 m thick, are represented by a vegetative layer, loam and loose limestone. The height of the overlying ledges reaches 6 m.

Mining operations are carried out by loading the rock mass with an E-2003 mechanical shovel with a bucket capacity of 2.5 m^3 and a maximum scooping height of 8 m. The mountain ledges height varies from 9 to 13 m, and the ledges inclination angle is 80°. According to the concluded contract, the maximum conditional size of blasted rock piece by the largest dimension is 0.7 m, and the oversized fractions percentage output is 15 %. The strength coefficient *f* according to the M.M. Protodiakonov scale is 6.

The annual mined rock mass volume is 150,000 tons. The initiating method downhole explosive charges are electric, combined. Equipment used for drilling: BTS-150, Atlas Copco Rock 460 drilling rigs; boreholes diameters – 115, 130 and 150 mm. The boreholes drilling direction is vertical. According to the "Standard Project", the drilling and blasting parameters calculation was carried out taking into account the conducting mass explosions experience in the quarry and scientific achievements in the explosives field.

Explosives types used in blasting operations. The Verbka-Pivdenna quarry uses explosives and their initiation means that are approved for permanent use by the State Mining Inspectorate of Ukraine, namely:

- For wet boreholes – gramonite 50/50, cartridge ZARS-1, THF cartridge charges, Anemix, Anemix P, igdanite;
- For partially wetted boreholes – Gramonite 50/50, Gramonite 79/21C, cartridge ZARS-1, THF cartridge charges, Anemix, Anemix P, Igdanite;
- For dry boreholes – gramonite 79/21, gramonite 79/21C, ZARS-1, THF charges, Anemix, Anemix P, igdanite;
- For the intermediate initiators manufacture – industrial-type TNT bombs T-400G, ZTP-800, TP-200, TP-400, etc., ammonite cartridges No. 6ZhV, THF cartridge charges, Anemix P cartridges;
- To initiate explosive charges – ED-8Zh electric detonators, DSHE-9, DSHE-12 detonating cords;
- Non-electric initiation systems (Nonel) – “Impulse”, “Prima ERA”, etc.

Ammonite No. 6ZhV was taken as the standard explosive when calculating the

charges mass. In the replacing the design charge event or part of it with another explosive, the modified charge mass is multiplied by the conversion factor specified in the "Standard Project".

The "Standard Project" also contains sections on methods for detonating borehole charges from industrial explosives and explosives manufactured directly at the blasting site using NSI or detonating cords connected to intermediate initiators, as well as designs of borehole charges recommended for use in the Verbka-Pivdenna quarry in accordance with the instructions for their formation. In addition, charges calculations with corresponding examples for charges in water-saturated rocks, paired-close charges, calculations for determining a typical charges series, the ledge forming base for boreholes with a diameter of 115, 130 and 150 mm, as well as examples of boreholes used for the ledge base forming for downhole charges with a diameter of 42 mm are provided.

The "Standard Project" contains schemes for switching the blast network with deceleration intervals for rocks with different degrees of blockiness, calculation of the electric blast network, sections on organizing the preparation and conduct of blasting work, as well as the procedure for admitting workers to the quarry after a mass explosion and occupational safety measures during blasting work in the event of emergencies.

The dangerous zones radii calculation due to the rock fragments scattering, seismically dangerous distances to objects requiring protection, and the dangerous zone under the influence of an air shock wave are also provided. Important sections are highlighted separately, including: typical procedure and work organization on the failed charges elimination; explosive oversized rocks crushing with appropriate safety measures.

A general the "Typical project for blasting works using the method of borehole and blasting charges at the Verbka-Pivdenna quarry" analysis allows us to conclude that it was developed at a fairly high technical level, taking into account the mass explosions experience in quarries and modern scientific achievements in the explosives field. It meets the relevant regulatory documents requirements and Ukraine regarding labour protection and safety rules legislation when handling explosive materials for industrial purposes [9-12].

At the same time, an analysis of the drilling and blasting operations the actual parameters compliance with the "Standard Design" of blasting operations at the Verbka-Pivdenna limestone quarry showed the following.

According to the "Standard Design" for drilling rock blocks subject to explosive crushing, it is recommended to use a square (rectangular) or vertical or inclined borehole explosives charges checkerboard arrangement with a lower location of the UNS-S type device with a T-400G intermediate initiator or ZTP-800 and ZTP-1200 checker (Fig. 1-3).

In addition, various typical intermediate detonators designs for dry and partially moistened rocks have been proposed for the use of Anemix P type cartridged emulsion explosives.

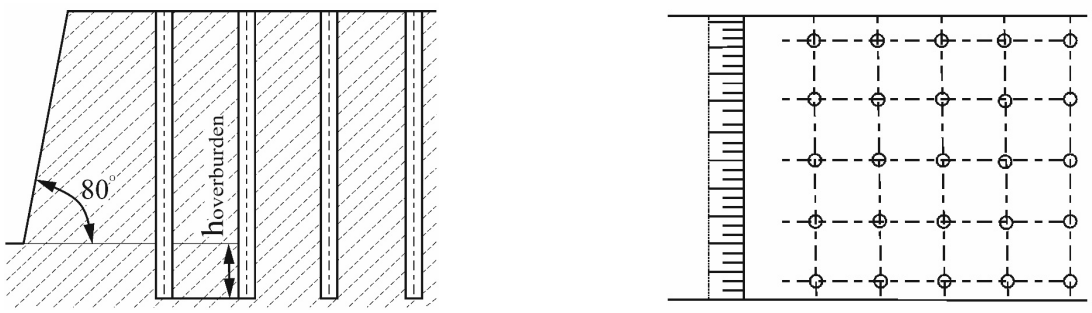


Figure 1 – Typical square (rectangular) arrangement of boreholes in the Verbka-Pivdenna quarry according to the "Standard Design"

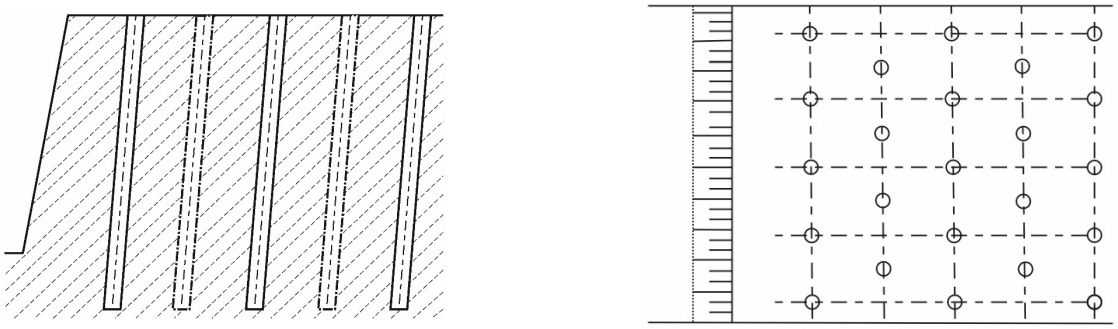
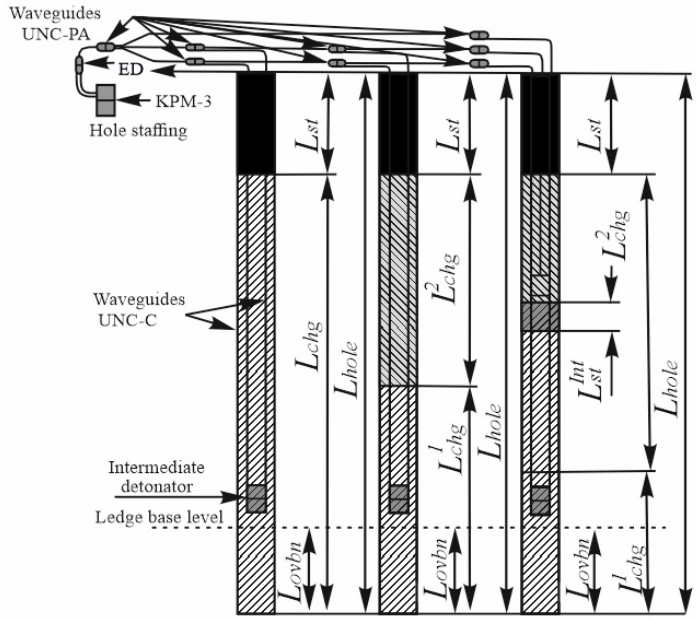


Figure 2 – Typical staggered arrangement of boreholes at the Verbka-Pivdenna quarry according to "Standard Project"

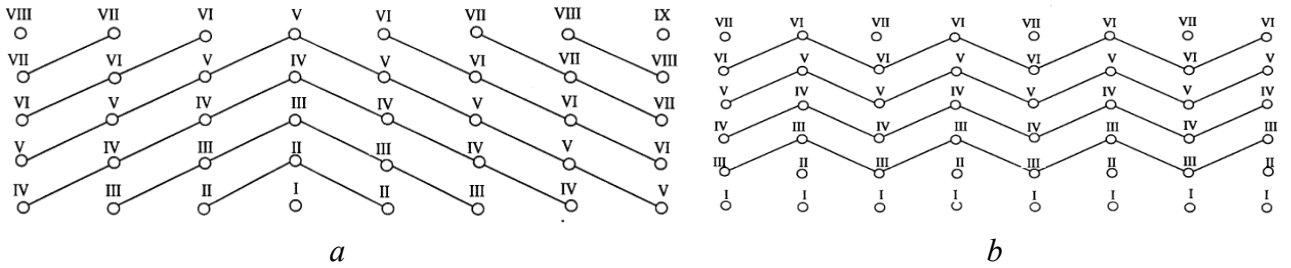


L_{hole} – borehole length, L_{ovbdn} – overburden length, L_{chg} – charge length,
L_{1chg} – length of water-resistant explosives, L_{2chg} – length of non-water-resistant explosives,
L_{st} – length of the driving, L_{intst} – length of the intermediate driving

Figure 3 – Recommended designs of borehole charges at the Verbka-Pivdenna quarry according to a typical project

According to the “Standard Design”, it is recommended to use diagonal schemes of short-delay detonation (SDD) of borehole charges using the “Impulse” non-electric initiation system, as well as wedge initiation schemes using UNS-PA-25 and UNS-PA-40 devices. In addition, some SDD schemes have been proposed, namely: “wedge cut” and “combined scheme with increased resistance values along the bottom of the boreholes first row ledge” (Fig. 4, *a*, *b*). With the purpose of the drilling and blasting works actual parameters compliance expert assessment with the standard blasting project at the Verbka-Pivdenna limestone quarry, 19 drilling and blasting work passports were analyzed.

The main attention was paid to such parameters as the ledge height, the explosive boreholes number on the block, the boreholes grid dimensions and its geometric parameters (checkerboard, rectangular, square, etc.), as well as the boreholes explosive charges the connection schemes.



a *b*

a – wedge cut; *b* – combined scheme with increased resistance values along the ledge base

Figure 4 – Limestones short-delayed blasting schemes at the Verbka-Pivdenna quarry according to the “Standard Project”

These drilling and blasting parameters typically directly or indirectly affect the quality of rock fragmentation and the quality of slope base preparation. An analysis of the data provided compliance in the blasting passports used at the Verbka-Pivdenna quarry with the “Standard Design” shows the following.

1. The working ledge height varies significantly, and the difference between the minimum and maximum values of this parameter reaches 5 m with a 2.2 m average value. With an average working ledge height of 12.4 m, these fluctuations are 40 %. This is too large a value and indicates an extremely low quality of the ledge processing sole during previous massive explosions.

2. The average boreholes number per block is 15, which is insufficient.

3. The quarry mainly uses a two-row scheme for blasting rock blocks. Three- or four-row blast boreholes arrangement is almost never used. This scheme of rock blocks destruction, which will be crushed by the explosion energy, limits the advantages of short-delay blasting and leads to unsatisfactory mass explosions results, namely: uneven crushing and poor the ledge base processing quality.

4. The plans for the blast holes location in the rock blocks being blasted do not include diagrams for switching explosive charges. Because of this, it is virtually impossible to predict the outcome of a massive explosion. In addition, it is unknown how many charges detonate simultaneously in a group, which makes it difficult to

assess the explosion seismic impact. Also, the diagrams lack scale, which makes it impossible to determine the distance between the boreholes in the rows and the distance between the rows themselves (Fig. 5, *a*, *b*).

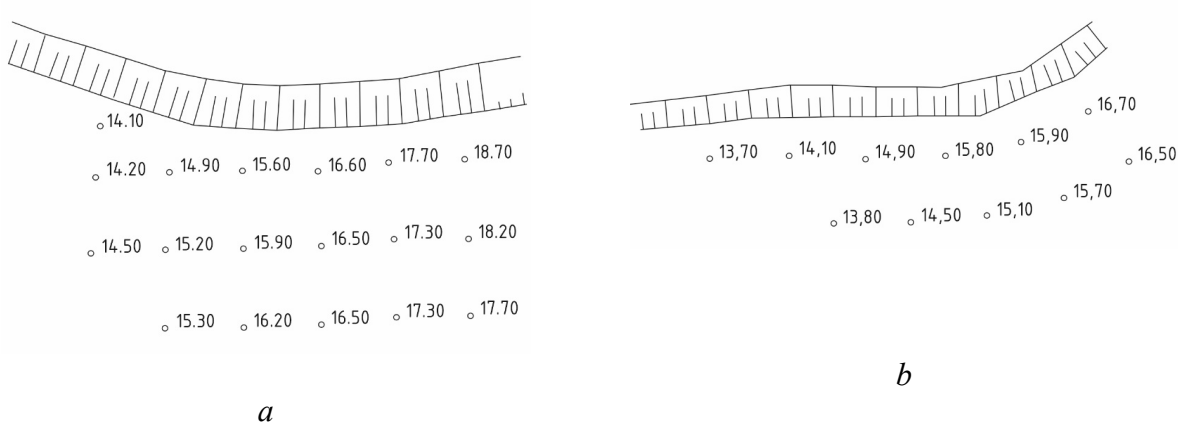


Figure 5 – Real layouts of blast boreholes at the Verbka-Pivdenna quarry during mass explosions on 01/25/2022, horizon+273 (*a*) and 05/31/2022, horizon +285 (*b*).

Thus, as an expert assessment result of the drilling and blasting works the actual parameters compliance with the “Standard Project” for blasting works at the Verbka-Pivdenna limestone quarry, the following was established.

The actual parameters of drilling and blasting work, or some of them, do not fully correspond to the blasting work parameters specified in the “Standard Project" for blasting work using the borehole charges method”: This is the main reason for the low rock mass quality during mass explosions in a quarry, namely: a significant the crushed rock proportion does not meet the requirements accepted under the contract between the contractor and the customer. In particular, the crushed rock oversized proportion piece exceeds 15 %, and the volume of over crushed rock is over 30 %.

In view of this, it is necessary to adjust the actual parameters of blasting works in accordance with the “Standard Project”, taking into account the structural and strength properties of limestones.

Considering the limestones of the Verbetsk deposit in general from the view point of their fractured-tectonic structure the influence and mining characteristics on the destruction nature under explosion energy action, the following should be noted.

This limestone massif is a mountain range that arose not as a result of tectonic processes, but due to the vital living organisms’ activity – coral polyps. Therefore, such a limestone massif consists of practically monolithic isotropic rocks without cracks, with the exception of isolated seismoclases - artificial cracks formed under the industrial explosions influence (Fig. 6).

Typically, for rock massifs consisting of monolithic isotropic rocks, the adjusting drilling and blasting parameters task to improve the rock mass preparation quality is not difficult, unlike significantly anisotropic rocks, which contain several systems of cracks with varying intensity degrees and opening in the so-called fractured-fault network form. This phenomenon is mainly igneous rocks characteristic, such as, for example, granites [7, 13].

Figure 6 – The Verbka-Pivdenna quarry mining site (horizon +273)

Therefore, adjusting the drilling and blasting procedures, in addition to adhering to the existing parameters specified in the "Standard Project", comes down to specifying the dimensions and the grid geometry of blasting boreholes, the rows number with charges, and their design in individual the rock block sections being blasted.

Changing the solid charge design for blasting crushing isotropic limestones with a charge with an inert gap (air gap or sealing composed material), is associated with a sharp decrease in the limestone strength according to the M.M. Protodiakonov scale. According to the "Standard Project", the strength coefficient of limestone f on this scale is 6. However, the physical and mechanical properties of limestone studies (compressive strength $\square_{st}$, Young`s modulus of elasticity E), carried out by us using a fifty-ton hydraulic press P-50 on cubic rock samples with an edge size of 40 mm, was established the following.

In general, the limestone massif of the Verbetsk deposit consists of two varieties: dense dark gray and gray rocks, among which the so-called loose white limestones are sometimes found. Therefore, the average value of the strength limit under uniaxial compression σ_{st} for limestones selected from the middle and northern part of the working ledge allows them to be classified as fairly strong rocks (dark limestone). At the same time, the average strength value according to the M.M. Protodiakonov scale is f = 9-10.

At the same time, there are areas on the working ledge with so-called "loose" limestone, the average strength of which is only 0.7, i.e. less than one. Such limestone samples, when loaded on a press, crumble into small aggregates with a large amount of fine dust.

The results obtained are shown in Table 1.

It should be noted that identifying areas with loose limestone of low strength f = 0.7 in quarry conditions, for example, using geological mapping, is extremely difficult, very expensive (requires drilling of geological exploration boreholes with a very dense grid), and therefore practically impossible.

Table 1 – Results of research on the limestones strength characteristics at the Verbka-Pivdenna quarry

Characteristic	Dense limestone dark gray	Dense limestone gray	Loose limestone
Uniaxial compression strength σ_{st}, MPa	103.19	98.86	7.5
Average of the elasticity modulus value *E,* MPa	4052	3998	426
Average strength value according to the M.M. Protodiakonov scale, *f*	10	9	0.7

* – The values of physical and mechanical characteristics are averaged based on five tests.

However, according to the recommendations of the Institute of Geotechnical Mechanics NAS of Ukraine, it is quite possible to establish the loose limestone boundaries areas on the block that is planned to be blasted during the drilling of blast boreholes based on the results of their drilling speed. The greater the speed of rock drilling in this sections of the quarry, the lower the strength of the rock. Typically, in such boreholes, it is necessary to form explosive charges with dispersion using an inert gap (air or filled with material, for example, a stemming). To achieve conditioned explosive preparation of crushed rock required condition mass in isotropic monolithic variable strength rocks, such as limestones of the Verbetsk deposit, it is proposed to use a checkerboard drilling grid on the blasting block and connection downhole charges according to a diagonal scheme.

In areas of loose limestone, it is necessary to use dispersed charges in accordance with the requirements of the “Standard Project”. The use of such a scheme for connecting solid and dispersed downhole explosive charges will significantly reduce the volume of oversized fractions due to a reduction in the number of spall cracks and will ensure more uniform crushing of the rock by explosion.

After implementing the recommendations of the Institute of Geotechnical Mechanics NAS of Ukraine on optimizing the drilling parameters and blasting operations to obtain conditioned rock mass during the variable strength monolithic limestones extraction at the Verbka-Pivdenna quarry, the oversized fractions proportion decreased almost twice and is no more than 8 %. The volume of recrushed rock decreased from 30 % to 10-12 %. Currently, the quality of the blasted rock mass at the quarry meets the Customer's requirements.

4. Conclusions

1. An expert assessment of the drilling and blasting procedures actual parameters compliance with the standard project at the Verbka-Pivdenna limestone quarry was found that these parameters, or some of them, do not fully correspond to the parameters specified in the “Standard Project” for blasting works using the borehole method and explosive charges at this quarry. Because of this, there is an extremely low rock fragmentation quality under the explosion energy action, that is, there is excessive the rock mass crushing, an increased yield of oversized fractions, and a low working ledge sole processing quality.

2. Taking into account the Verbetsk deposit limestones geological structure peculiarities, which are developed by the open-pit method, namely the absence of tectonic cracks and physical and mechanical isotropy rock properties, to improve quality it is necessary to adhere to the requirements proposed in the "Standard Project". It is necessary to adjust the boreholes charges grid in the direction of increasing its area. This will ensure a reduction in the consumption of specific energy explosives used to destroy the massif and, as a result, will reduce the destroyed rock re-crushing.

3. Adjustment of the blasting procedures actual parameters in accordance with the “Standard Project” and the recommendations of the Institute of Geotechnical Mechanics of the NAS of Ukraine, namely, taking into account the low rocks strength in loose limestone areas mining by using explosives dispersed charges, made it possible to obtain the required the rock mass crushing quality at the Verbka-Pivdenna quarry.

Conflict of interest

Authors state no conflict of interest.

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ОПТИМІЗАЦІЯ ПАРАМЕТРІВ БУРОПІДРИВНИХ РОБІТ ДЛЯ ОТРИМАННЯ КОНДИЦІЙНОЇ ГІРНИЧОЇ МАСИ ПРИ ВИДОБУТКУ МОНОЛІТНИХ ВАПНЯКІВ ЗМІННОЇ МІЦНОСТІ

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Анотація. Проведено експертну оцінку відповідності фактичних параметрів буровибухових робіт типовому проєкту проведення вибухових робіт на кар'єрі «Вербка-Південна» в Хмельницькій області. Було встановлено, що фактичні параметри буропідривних робіт частково не відповідають тим, що запропоновані у «Типовому проєкті проведення вибухових робіт методом свердловинних та шпурових зарядів на кар'єрі «Вербка-Південна».

У зв'язку з цим зазначено шляхи коригування фактичних параметрів вибухових робіт відповідно до типового проєкту, з урахуванням міцнісних властивостей і структури вапняків. Зокрема, пропонується оцінити вплив тріщинуватості вапняків на характер руйнування вибухом, а також уточнити їхню міцність за шкалою М.М. Протодьяконова для окремих ділянок масиву, оскільки ці властивості породи істотно впливають на її подрібнення. Це дасть змогу здійснити науково обґрунтований розрахунок питомої витрати вибухових речовин, що використовуються для подрібнення вапняків, і отримати необхідну якість дроблення гірничої маси на кар'єрі «Вербка-Південна».

Для досягнення високоякісної вибухової підготовки дробленої гірничої маси в ізотропних монолітних породах, таких як вапняки, хороший результат забезпечує використання шахової сітки буріння на блоці, що підривається, та комутація свердловинних зарядів за діагональною схемою. Застосування такої схеми з'єднання вибухових зарядів значно зменшує обсяг негабаритних фракцій завдяки зменшенню кількості тріщин розшарування і забезпечує більш рівномірне дроблення породи вибухом.

Потрібно скоригувати сітку розташування свердловинних зарядів у напрямку збільшення її площі. Це забезпечить зменшення питомої витрати вибухових речовин, що використовуються для руйнування масиву, і, як наслідок, знизить повторне подрібнення зруйнованої породи.

У майбутньому результати цієї роботи мають бути використані для розробки скоригованих параметрів бурових і вибухових робіт на вапняковому кар'єрі «Вербка-Південна», що дозволить досягти високої якості дроблення та необхідного стану підривної гірничої маси.

Ключові слова: буропідривні роботи, вапняки, типовий проєкт, тріщинуватість, якість подрібнення, геологічна структура, міцність породи.