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Perspective Technology of Open-Pit Mining of Limestone and Dolomite

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Abstract: This study describes the technology of limestone and dolomite mining which can be used both for deposits with a simple geological structure and for deposits that have an internal overburden-substandard rock lying in the form of lenses and interlayers in strata of minerals that cannot be contoured during exploration and the calculation of reserves due to its non-systemic spread. To date in quarries equipped with a large fleet of various types of equipment, the main technical and economic indicators (productivity, profitability of the enterprise and so on) are rising at an insufficiently high rate. In most cases, this is impeded by the inconsistency between the mining, loading, transporting and auxiliary equipment with the engineering conditions of mining which leads to a low degree of use of such equipment and weak mechanization of auxiliary processes and subsequently causes reduction in quality of the extracted raw materials and technical and operational parameters of the enterprise in general. Therefore, creation of new technological schemes for exploitation of limestone and dolomite deposits with the use of powerful, unified, mobile equipment for mining is of great practical importance for many enterprises.

Key words: Technology, ripper, excavator, horizon, bench, blasting operations, production costs

INTRODUCTION

When using traditional blasting technology, the internal overburden of low capacity is not developed separately but is removed with minerals which subsequently causes an additional load in processing of the rock mass in the crushing and sorting factory.

Analysis of the mining and technical conditions of limestone and dolomite deposits shows that one of the ways to increase the efficiency of mining operations includes use of mobile equipment both in mining and stripping which include rippers, hydraulic hammers and milling combines that provide a non-blasting exploitation. (Argimbaev and Kholodjakov, 2013; Fomin *et al.*, 2013; Kaerbek and Maya, 2016).

A wider use of milling combines which are based on the technology of thin-layered excavation allows to mine the rock mass selectively, reducing the operational losses of minerals while increasing the overall output of products and the stability of the slope of the quarry's side (Kornev *et al.*, 2000).

The timing of the operations (as measured by us) which are necessary for the smooth work of the milling combine, points out to the low efficiency of its use in limestone deposits, the combine stopped or changed its location about 60% of its operating time (Fig. 1).

Operation of this type of mining equipment will allow to carry the crushing process to the quarry, eliminating

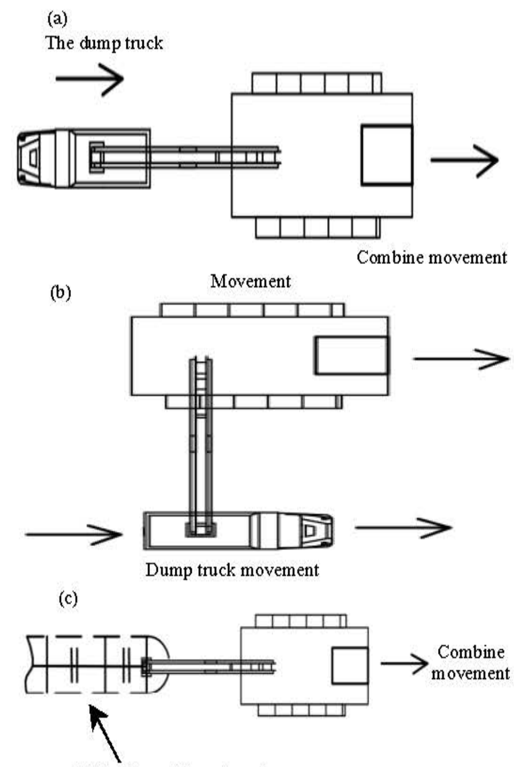

Fig. 1: Scheme of work of a milling combine; a, b) With the loading of the mineral into the dump truck and c) Off-loading of the mineral into the dump

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oversize, however by reducing the length of the site to be worked out, there is a need for frequent distances and the preparatory work for leveling the operating platform also increases.

Operation of the milling combine is complicated by various inclusions, interlayers or clay lenses which in the autumn and spring periods (because of the great humidification of the operating platform), complicates movement of equipment (the drive train would slip) and the extracted rock would stick to the loading conveyor belt. At negative temperatures, a complete stop of the equipment is observed. Extraction of hard rocks leads to increased wear of the cutters which increases the time to replace them and reduces productivity (Shpanskiy and Buyanov, 1996; Yakubovskiy *et al*., 2014; Kaerbek and Ivanova, 2016).

Therefore, creation of powerful and super-powerful bulldozers and improvement of the designs of modern rippers over the past 5 years has significantly expanded the scope of mechanical loosening which is now considered as one of the highly efficient production processes in open mining.

MATERIALS AND METHODS

The study focuses on using a ripper bulldozer at limestone and dolomite quarries. In Russia and abroad, progressive manufacturing and improvement of rippers is explained by many advantages as compared with the existing methods of loosening. Therefore, in open-pit mining where drilling and blasting are the main methods of loosening of rocks, rippers allow to eliminate some of the shortcomings inherent in blasting (the seismic effect and damaging effect of rock fragments during projection), reduce losses and dilution of mineral due to layered separate excavation of rocks with various quality characteristics, significantly reduce the cost of loosening (more than 1,5-2 times) as well as improve work safety and capacity (Kovalevskiy and Argimbaev, 2016).

RESULTS AND DISCUSSION

Technological schemes using ripper bulldozers are better as compared to other schemes (drilling and blasting and excavating). However, successful operation of a ripper requires certain conditions: appropriate physical and mechanical properties of the rocks, sufficient exploitation area to ensure proper scope of work, correct choice of a bulldozer with a blade, a ripper type, a ripper tip.

The technology of mechanical loosening is determined by the final designation of the material being developed. If rocks need only be removed, the size of individual pieces of the rock mass does not matter too much. Such material as overburden or rocks which are removed during road construction, usually do not find further application, so, the reduction in size is required only to improve the conditions of development and adaptation to the parameters of loading and transport equipment.

The rock mass transported by a bulldozer does not require significant crushing and its size is not limited. It is sufficient to have several working passages to bring the material to dimensions suitable for bulldozing.

Before the start of loosening, it is necessary to make several test runs on each new site, changing the depth of penetration of the ripper tooth and the bulldozer's speed. This will help to determine the direction of bedding and resistance of the rock mass to destruction. Routes of the bulldozer's movement during loosening should be outlined, so that, the ripper does not cross the transport infrastructure.

The operating platform of loosening must be constantly cleaned which reduces equipment wear and breakage. An insignificant amount of loose material and small rocks ensures coupling of the bulldozer's tracks with the ground and a sufficient pulling force and excessive pulling creates a slip. When you exit the loosening area of a more solid difference, it is developed immediately without leaving the following passages. The loosening site should have an area sufficient to ensure the productivity of the ripper and transport equipment for at least half a shift. Frequent hauling of machines and changing the type of work will lead to low use of equipment over time and create potential dangers in a quarry.

In average rock, the optimum distance between the passages is a distance of about half of the bulldozer track (about 1.2 m). This ensures creation of a strip of crushed material with a width of about 1.5-1.8 m. Intensive crushing and smaller lumpiness are observed in the area of passage of the working body in the rock and a large one-along the outer perimeter. Therefore, to obtain a more uniform lumpiness, the next ripper pass is advisable near the outer perimeter of the previous pass. By reducing the distance between the ripper passages, it is possible to achieve a reduction in lumpiness and conversely to increase it, the distance should be made large. Therefore, with mechanical loosening, the lumpiness of the rock mass can be controlled.

To increase the effectiveness of loosening (wherever possible), you should try to use the weight of the bulldozer and loosen it downhill. Additional weight and pulling force when loosening downhill can increase the ripper's productivity up to 25-40%.

Loosening should be carried out in a direction perpendicular to a series of vertical cracks crossing an array of rocks. Work in the direction of propagation of cracks leads to a reduction in the ripper's productivity.

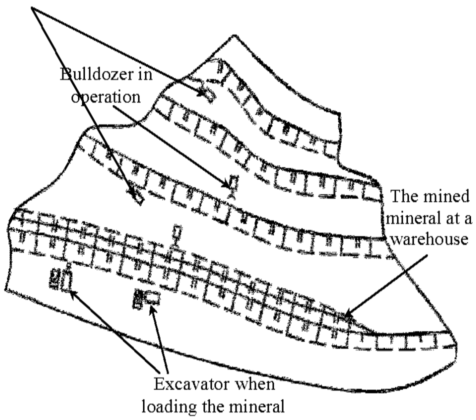

Fig. 2: Scheme of exploitation using a bulldozer and an excavator

Table 1: Comparative characteristics of technical and economic indicators of drilling and blasting loosening and mechanical loosening

Indicators	Loosening: Drilling and blasting	Mechanical
Total costs (USD/h)	48.500	30.000
Capacity (tons/h)	100.000	227.000
Costs per unit of output (USD/ton)	0.485	0.131

It is necessary to plan the use of the ripper bulldozer when moving materials, maintaining the roads, loading bunkers and also as a pusher when loading scrapers. This will increase the machine utilization rate and reduce per unit costs of the material being developed.

With the transition from drilling and blasting to the mechanical loosening, the equipment's fleet in the quarry is reduced. Mechanical loosening provides less lumpiness of the material which allows to improve productivity of the loading and crushing equipment. By reducing, the distance from the face to the plant (cancellation of the restriction in respect of the explosive zone), the productivity of transport operations increases.

Table 1 provides comparative characteristics of technical and economic indicators of drilling and blasting loosening and mechanical loosening.

The system of open-pit exploitation of limestone and dolomite deposits with the use of a bulldozer and an excavator (longitudinal-concave with the fan-shaped advancement of the faces), presented in Fig. 2 will significantly improve labor productivity and reduce mining costs.

This scheme includes three upper production horizons, the fourth (lower) horizon is the loading horizon. Bulldozers work on the mining horizons. Each machine captures a part of the blown rock with its blade, delivers this load to the edge of the escarpment and drops it down. On the lower horizon, another bulldozer is doing the same operation with the rock. Excavators which operate on the loading horizon, load the mined minerals into railcars or dump trucks.

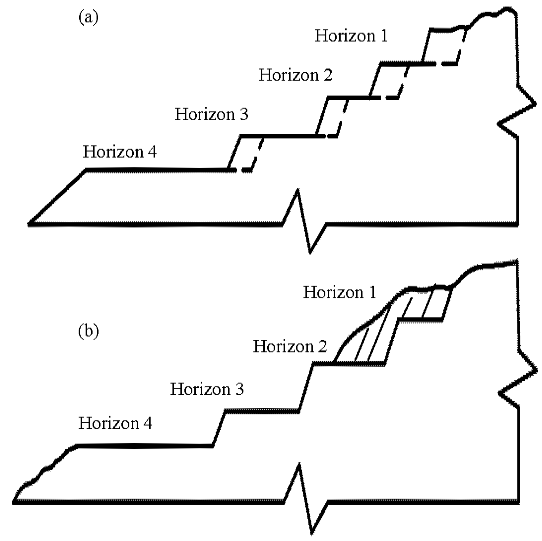

Fig. 3: Scheme of blasting operations: a) Before blasting and b) After blasting

With the fan-like advancement of the faces, the width of the operating platforms on the horizons increases as the faces advance. This means that the distance that the bulldozer moves from the face to the escarpment slope also increases. And with an increase in this distance, the output of the machine decreases. Therefore, the distance to which the bulldozer moves the rock must not exceed 40 m.

It should be emphasized that a small distance from the face to the slope of the escarpment as well as the uniform advancement of all the escarpments is a precondition for success of the used mining method. Return of the bulldozer to the place of loading should be carried out in reverse. Moving forward 1st gear and backward movement (without load) 2nd gear.

This technological scheme may include the use of drilling and blasting operations for loosening with a reduction in the volume of transshipment operations performed by the bulldozer (Fig. 3).

Drilling of wells on horizon 1 is not carried out for the entire 40 m width of the operating platform but only for a 28 m strip adjacent to the slope of the escarpment. The strip, 12 m wide, adjacent to the deposit, remains untouched. As a result of blasting, the rock from the 28 m strip collapses on horizon 2 lying and there remains a 12 m wide block from horizon 1, serving as a sort of protective berm. At the second stage of operation, the rock above horizon 1 is drilled. When it is blown up, only a part of it (about 30%) stays on the 1st horizon; the overwhelming mass (about 70%) slides directly to horizon 2. Such a sequence of explosions will allow a 70% reduction in the volume of transshipment.

It is known that in excavation the size of the collapse should not exceed twice the height of the escarpment, otherwise, the rock will form a thin layer and the excavator will have to collect it from a larger area. But with bulldozer mining, it is better to have the blast throw the rock as far as possible from the massif that is as close as possible to the slope of the escarpment while the width of the collapse should be equal to the triple height of the escarpment.

Successful implementation of this scheme largely depends on the operators of bulldozers. They must meet a number of requirements: to deliver at least 90% of the rock of the dump capacity per each passage to the slope of the escarpment, to maintain an even surface of the operating platform, to keep the machine in a working condition. In order to prevent, the blade from bulldozing in the ground, along which the bulldozer moves, cutting off the “chips” from the site, damaging its horizontality and overloading of the machine, it should be placed 2-3 cm from the site surface. The bulldozer’s blade should be inserted into the face at an angle of “cutting” at 50-60° to the face line.

If the bulldozer enters the face with the right side, then the blade should be installed, so that, its right edge

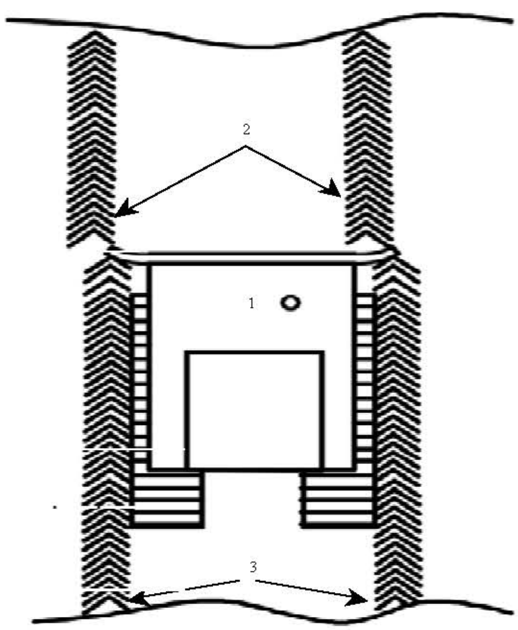

Fig. 4: Scheme of the bulldozer movement that ensures minimal losses of load during its movement: 1: Bulldozer; 2: Rolls remaining from the previous passage and 3: Newly formed rolls

is placed 2-5 cm in front of the left edge. If the cutting goes to the left, the blade should be beveled, so that, its left edge protrudes in front of the right edge.

When the rock is heavily crushed from the blast, the dump is set, so that, its right edge “outperforms” the left only by 2-3 cm. During the movement of the load, the bulldozer forms rolls of crumbled material on both sides of its path which increases rock losses. In order to reduce losses of the load during transportation, the scheme shown in Fig. 4 should be used.

CONCLUSION

Introducing the above technology of open-pit exploitation of limestone and dolomite deposits with the use of sufficiently powerful rippers in combination with new types of quarry bulldozers and loaders will allow increasing the labor productivity 1.5-2 times and reduce mining and loading costs as well as the costs of rock delivery 1.2-1.5 times.

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