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Justification of the Method for Determination the Optimum Performance of Limestone Quarry for Steel and Cement Production

Vladimir Viktorovich Ivanov, Sergey Aleksandrovich Sidorenko and Andrey Aleksandrovich Sidorenko

National Mineral Resources University, Russia, 199106,
Saint-Petersburg, Vasilievsky Island, 21 line, 2

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In work the major industries which using carbonate raw materials are considered. The factors affecting difference in demand for calcareous raw materials are defined. The dependences of prime cost of mineral and the specific revenue of its realization from productivity of quarry limestone allowing analyzing the difference in demand for productivity are presented.

Key words: Open-cast mining, Limestone, Productivity quarry, Pit productivity, Prime cost, Mineral raw materials.

The annual increase in the pace of construction in Russia, the implementation of a number of major long-term projects of the government of the Russian Federation, requiring huge amounts of construction materials, suggests that the demand for non-metallic minerals will increase[1].

Calcareous rocks are the raw materials consumed by various industries and agriculture[2, 3]. Various kinds of raw materials are registered in the State Registers of Useful Minerals Reserves, such as "Fluxing limestone", "Carbonaceous raw materials for the chemical industry", "Carbonaceous raw materials for sugar refining and pulp-and-paper industries"[4].

One of the most valuable types of carbonate raw materials are the limestones used as the basic flux in ferrous and nonferrous metallurgy and by alumina production[5,6]. In alumina production from nepheline ores limestone is used as one of charge material and also for desiliconization the aluminate mud[7].

For production of cement the raw mix consisting for 80–85% from low-magnesian carbonate breeds, for 15–17% from clays and a small amount of pozzolon (a molding, bergmeal, diatomite) is used[8].

In a form of a bedding of mineral products all carbonate deposits, including deposits of flux limestone and raw materials for cement production, are presented by sheetlike or pod-like forms of deposits[9].

Open-cast mining of flat seams of limestone with slides of restricted power has the specifics, and technological schemes of conducting mining operations when developing such deposits have the features. Limestone belongs to group of semi-rocky rocks, and development of breeds of given group demands preliminary preparation of the massif for digging-out by drilling-and-blasting, mechanical or in a different way[10, 11].

* To whom all correspondence should be addressed.

The performance of the mining enterprise is one of the main parameters of a quarry that determine economic performance opencast mining of any mineral deposits[12].

The performance quarry determined by the amount of rock mass produced in a quarry in a unit of time, it is set in weight or volume units and is usually calculated in shift, day, month or year. In the open pit mining of mineral deposits are distinguished performance quarry on minerals on overburden, or a whole rock mass. In order to transition from a quarry performance by rock mass performance quarry minerals are used stripping ratio, defined as the ratio of volume or mass of overburden to the volume or mass of minerals extracted from the depths in the open pit mining of mineral deposits.

MATERIALS AND METHODS

The performance quarry on minerals is influenced by many technical and economic factors. Chief among these is the need of the economy in minerals, the selling price of commercial products, the cost of minerals including repayment costs notch rock - quarry waste, as well as the geological conditions of the deposit, the amount of reserves, the method stripping of deposit , the system development and other.

Two main groups of methods of determination of productivity of pits - on mining and economic factors are applied in the design of open pits[13]. Productivity can be determined by the speed down of mining operations or due to the placement of the loading equipment on the work front. Quite often the performance calculated by the speed down, checked for reliability by the arrangement of the equipment, or vice versa[14].

Method of determining the performance quarry on minerals depending on the speed reduction of mining operations is one of the methods for determining the approximate performance of quarries for minerals on the stage of preliminary calculations prior to the implementation of the project. The method is based maximum intensity decrease mining (treatment) works, the area of mineral resources involved in the development at the same intensity, losses and dilution of minerals. Guidelines for the implementation of the method are given for solving a specific example in the conditions close to reality. The performance quarry on minerals is directly proportional to the rate of reduction of mining operations, executed by the area of minerals and should take into account the volume of losses and dilution of minerals.

Lowering the mining operations are taken into account: - the use of rail transport - 8.6 meters in the year; - when using the car and conveyor transport - 10-15 meters in the year. During construction, quarry using road transport reduction reaches 45-55 meters in the year.

The performance quarry on minerals can also be determined from the condition of the possible deployment of excavators for mining front. At the same time the number of quarry face is determined based on the scheme of mining operations. Method of determining the performance quarry on minerals, based on the arrangement of production equipment, is also indicative method. This technique is fundamental to determining the design capacity of the mining company engaged in the development of horizontal and shallow mineral deposits. In the method is based on the rational allocation of production equipment for quarry work areas. Performance mining company engaged in the development of an open field, on minerals determined by the total production capacity of all excavation and loading and excavation and transporting units simultaneously involved in the mining operations in his quarry.

If the power of the mineral and the length of the scope of work changes significantly as movement front of mining operations in the received direction, the possible performance quarry stages is determined by periods of development.

Performance quarry opportunities for mountain company engaged in the development of mineral deposits by open way, is the upper limit of this indicator, but it can be limited, and sometimes determine the transport capacity (carrying capacity of transport communications) or economic factors (planned needs in the produced raw materials, as well as amortization period of capital investment, and so on).

As a possible career performance on minerals usually take a minimum of three values

determined by the performance of career possible rate deepening quarry (for steeply dipping deposits) at maximum speed movement ledge (for horizontal and shallow pools), the performance of the mining excavator and the minimum service life career.

Limit the production capacity of the quarry mining engineering and economic factors: - carrying capacity of transport communications, the intensity of mining operations, the number of mining dredges; specific and absolute capital costs of career, cost and selling price of commodity products, land rent for the area occupied by the enterprise, mining rent and others. Freight and transport communications quarry working levels with a surface provided by the system ramps highway. The most intense portion of the transport communications in a quarry is usually located in the upper levels, as through the upper exit system is opened quarry congresses held almost the entire rock mass quarry, in connection with the data section of the route is the limiting overtake. When making transportation system performance quarry on the rock mass can not exceed the carrying capacity of the bounding haul. Carrying capacity limiting haul depends on the actual weight of goods transported in the blood vessels, the ratio of non-uniformity of the daily traffic and bandwidth limiting haul. In turn, the bandwidth is determined by the limiting haul transport in day time laden progress on limiting the stretch, the empty travel time by limiting the stretch, and other factors.
Set the number of vehicles passing through the vessels limiting stage during the day is determined by the carrying capacity on minerals, waste rock and rock mass, that is practically determined by transport conditions possible performance career on minerals, waste rock and rock mass.

Defining performance career on economic factors based on the known value of the customer's needs in the produced at the quarry minerals.

Career Performance Minerals also be determined taking into account the normal life of the mining enterprise (normal amortization period of capital investments) and balance reserves of mineral in the final pit outline. Career Performance Minerals should be chosen such as to ensure a minimum period of existence career. Optimal performance career on minerals can be determined by technical and economic calculations, taking into account the cost of transportation of minerals to the consumer and its consumption by the customer. Optimization criterion is minimal given the costs of production and transportation of commercial mineral because of its quality.

In addition to defining projects possible performance career on minerals should be indicated as possible to achieve it and the duration of the period of stable production of raw materials.

Determine the performance of quarry host rocks is usually performed on the basis of careful analysis of schedule mining operations performed in the project in accordance with the established procedure of mining operations and set performance quarry minerals.

By the mining group quarries, that is if there is a part of the mining enterprise several quarries performance of each of them and order of involvement in the development determined by scheduling.

Reliability of the made design decisions increases during the using of several methods and the accounting of the greatest possible number of factors of the open pits determining productivity.

The choice of methodical approach option is the first step to develop a technique of optimum productivity determination[15].

Demand characterizes interrelation between productivity of open pits and the market price of mineral raw materials. Reaction of demand for price variance for mineral raw materials can be diverse. When this reaction is insignificant or isn't observed at all, it is possible to speak about inelastic demand. On the other side, if demand reacts to the price change strongly, it is characterized as elastic. In this case it is necessary to use such indicator as price demand elasticity[16].

Similarly income elasticity of demand is determined: it shows, how the quantity of demand for limestone increase if the revenue increases by one percent. Both indicators allow to predict the demand change through time. For example, if it is possible to define elasticity

coefficient of demand pretty exactly, from estimated dynamics of size of the income probable development of dynamics of demand is established.

For determining of demand for limestone matters not only the market price, but also a price for the replacing and supplementing types of raw materials. Besides, positive or negative impact on demand can affect on changing in valuable estimates of consumers of the mineral raw materials, and it can affect on changing of size of their revenue too.

The function which correlates any planned productivity of an open pit (Ap) to the expenses connected with production of the volume of limestone (Z_X), is the costs function[17]. It is possible to develop of the deposit with the minimum cost only in a point of a minimum of unit costs. Unit costs are the expenses carried on unit of the mining ore. ($Z_Y = Z_X / A_P$).

In certain cases the price can be below expenses, in this case the mining and realization of mineral won't be stopped. Such situation is justified at refusal of a covering of constant expenses. Accounting loss in this case belong for the last periods since they are caused by unprofitable investments during the current period.

If the market prices of mineral raw materials are established below a minimum of unit costs of production ($P < (Z_X / A_P)^{min}$) production in quarry has to stop, and the open pit can be supported in working order during half a year, waiting for improvement of a situation in the market of raw materials and growth of the price[18].

The market price determines the price of the limestone extracted on the open pit and its productivity can increase until the maximum marginal costs don't reach the level of this price. In the circumstances maximizing profit of an open pit at the adaptation of its productivity to the limestone market price on the mineral raw materials market is possible.

RESULTS AND DISCUSSION

By the way of determination of optimum performance of an open pit taking into account demand for limestone it is possible to apply the principle of limitation to determination of optimum productivity of open pits. The principle of limitation says that for establishment of an optimum it is necessary to compare the differential costs arising when the productivity of an open pit grows with value of the mineral mining in addition. In general, the revenue from an augmentation of the received value has to be not less than differential costs from increase in productivity.

In such a way, marginal costs ($\Delta Z_X / \Delta A_P$) are a value of increasing of operating costs for the purpose of increasing the pit productivity. The marginal revenue ($DRev / \Delta A_P$) is a value at which the aggregate revenue in result of single increase in productivity of quarry limestone.

Annual profit from development of the deposit.

$$OP_C = Rev - Z_X,$$

where Rev - a gross annual revenue of realization of the mineral mining in quarry; Z_X - total operating costs (cumulative expenses).

Optimum performance of a market mechanism assumes that competitors can't have essential impact on the limestone price separately. Such situation sometimes is possible when a lot of subjects are in the market and nobody has decisive advantages, i.e., for example, there are no such mining enterprises which have productivity providing a considerable share of the offer of the market.

In reality it is necessary to consider a set of the factors influencing functions of supply and demand. For that reason exact matching of productivity changes and the prices changes at empirical estimates is very problematic. Excess of the offer or excess demand have to conduct to the price changes with the purpose of corrective of supply and demand. Actually the price changes often accidental and don't cause immediate reaction from the mining enterprises - competitors of the limestone market. There is a certain danger of that quantity supplied can adapt to the prices, differ from equal[19].

Nevertheless, and in the markets of mineral raw materials in the medium-term and long-term plan decisive action to supply and demand on the price change is observed. Not so quick reaction of the market of mineral raw materials often is even a certain advantage as business doesn't reach sudden market fluctuations and productivity of open pits like it takes place at

the raw exchange markets. Not airways the market mechanism conducts to balance. There is a probability of that demand-and-supply curves won't be crossed. It means, in this case supply and demand can't define price formation: there is no such market price of mineral raw materials which would carry out the information and regulating functions. The state intervention can prevent corrective of supply and demand .The establishment of the price of limestone by certain competitor of the market or small group of competitors defined as monopolistic behavior, in principle is incompatible with functions of the market price mechanism.

Considerable increase in consumption of limestone reduces the relative amount of fluctuation in prices and allows realizing the volumes extracted in open pits over quantity demanded that leads to restriction of the periods when it is necessary to reduce productivity of pits - subjects of the market of mineral raw materials.

It was shown above that the increase in productivity of open pits leads to cutting of prime costs if the economy from increase in productivity exceeds increase in costs of size of under-amortization. Such decrease in prime cost happens until rates of increase under-amortization start increasing sharply in connection with a under-amortization of active part of the fixed funds which service life makes 10 - 15 years. It leads to an optimum on a prime cost minimum. In the conditions of market model of economy the minimum of prime cost isn't correct criterion for determination of optimum productivity of open pits.

The analysis of influence of market factors on productivity of open pits has two levels:

1. Level of the mining enterprise (quarry, groups of pits, mining systems).
2. Level of the market of the considered type of mineral raw materials.

It is necessary to understand the relation of percentage change of volume of realization of the extracted mineral to percentage change of market price as elasticity of a demand curve. Elasticity of a demand curve is described by a slope of curve graphically.

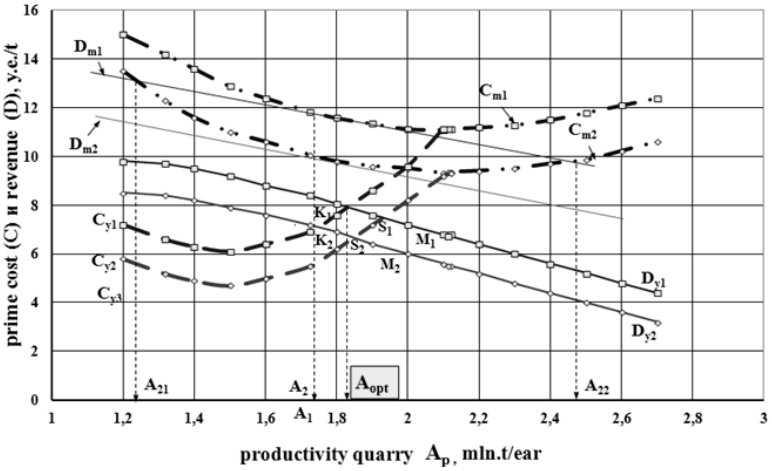
Relative change of prime cost (C_Y) is the relation of a difference of total annual operating costs to a difference of annual production rates of quarry limestone[17]

$$C_y = \frac{\Delta(C_i A_i)}{\Delta A_i}$$

where C_i - cost of production of mineral accounting repayment of overburden works; A_i - the annual production rate of a pit on mineral.

Relative variation of the revenue from realization of 1 t of ore (R_Y) is the relation of a difference of revenues of realization of mineral to a difference of annual production rates of quarry limestone.

$$R_y = \frac{\Delta(P_i A_i)}{\Delta A_i}$$



Pic. 1: Schedules of dependence of production costs and the revenue from pit productivity on limestone for its two sorts

where P_i - the price of 1 t of mineral upon sale of the corresponding volume in the market of this type of mineral raw materials.

For complex structure limestone deposits fluctuations of quality of mineral depending on layers and the area of a deposit, and depending on sites of the fulfilled pits are indicative. Depending on the chemical and fractional composition of raw materials for the production of fluxes of ferrous metallurgy parts on marks and grades [20]. Dependence of production cost (C) from quarry limestone production (A_p) for various kinds of mineral is presented in picture 1. For the markets of mineral raw materials of the most typical the situation characterized by down-ward demand curve during market development. The maximum of the net current discounted profit or net current value of the limestone realized for all term of mine development is reached when fractional increase of the prime cost and fractional increase of the revenue are equal.

The schedules of dependence of mineral prime cost and the specific revenue of its realization from quarry limestone productivity allow analyzing influence of shift in demand for productivity. (picture1). At the size of the prime demand corresponding to the right line D_{m1}- the average revenue from realization, pit mining with flux limestone, will be profitable only with an annual production rate on mineral A_1 = 1,75 million tons/year (point of intersection of a straight line D_{Y1} and the average revenue and curve of average cost C_{m1}). Working off of other sites of the open pit, with limestone for cement production, will be profitable with a productivity within A_{21} = 1,25 million tons/year and A_{22} = 2,55 million tons/year (points of intersection of a straight line D_{Y1} of the average revenue and curve of average cost C_{m2}). For the considered pit sites the value of optimum productivity will correspond to points of intersection of curves of relative change of the revenue D_{Yi} and relative change of prime cost C_{mi}, a point of K, S.

At falling-off in demand for the extracted mineral from the level of D_{Y1} characterized by a straight line to the level expressed to a straight line of D_{Y2}, working off of sites of a pit with flux limestone will be unprofitable. Productivity, providing profitability of sites of a pit with limestone for cement production, will make A_2 = 1,75 million tons/year (a point of intersection of a straight line of the average revenue D_{Y2} and curve of average cost C_{m2}).

Falling-off in demand will lead to reduction of value of optimum productivity of an open pit, according to shift of relative increase in the revenue of D_{Y2}, and will move from K_1 point to point K_2, moving on curve C_{Y1} (for pit sites with flux limestone) from S_1 point in S_2 point, moving on curve C_{Y2} (for pit sites with limestone for cement production).

Falling-off in demand for limestone will lead to reduction of range of possible pit productivity, from the profitability of development of the deposit point of view, determined by shift of a curve of demand and its elasticity, and also it compels to intensify the development of the deposit .In this case optimum value of productivity of the considered pit sites, by criterion a maximum of the net present value (NPV) of the limestone realized for all term of working off of a deposit, or by criterion a maximum of the net present discounted profit, is reached only by the way of decrease in volumes of mining operation.

CONCLUSIONS

Optimum productivity of a pit, taking into account demand and sorts of mineral, designing of open-cast mining of the complex structure deposit, it is necessary to determine by criterion a maximum of the net present value of limestone realized for all term of mine development.

Determination of pits productivity taking into account demand should be carried out by the principle of irreducibility, where under for evaluation of an optimum the differential costs coming out because of increasing in a pit productivity are compared to the value of overproduced limestone.

Predicting terms of pits exploitation requires studying and the analysis of a tendency of demand in the market of mineral raw materials.

One of decline of falling demand in the limestone market is slow finishing of mining operations on small and low-grade deposit. Sharp

changes of demand in the markets of limestone don't allow to intensify mine development quickly and it can explained by relative inertness of mining operations so it is necessary to consider designing of open-cast mining of calcareous deposits, as well as determining of productivity of pits and terms of mine development.

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