Combine technology in construction of transport tunnels

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Abstract. Article reviews the questions of using the combine technology in construction of transport tunnels with mechanized mining, taking into account the standard being developed, which establishes characteristic features and procedures of classifying the tunnels in public roads. Restrictions in connection to environmental safety of transport activities are specified. It was suggested, along with tunnelling machines of selective effect, to use reloaders with reciprocated motion of traction transporting units and with variable geometry of transporting elements.

1. Introduction
Over the last years, the countries with developed mining industries pay great attention to making mine roadways and transport tunnels with the help of tunnelling machines of selective effect [1-4].

Presently, there’s a standard developed which is stating characteristic features and procedure of classifying tunnels in public roads, typical design and technology solutions, requirements to construction materials and products, devices and systems supporting safety operation. The developed classification is intended to designate the tunnels while projecting them, constructing, reconstructing, doing major repairs, and operating [5].

It’s suggested to distinguish tunnels according to the features of general characteristics, specifics of structural design and technical characteristics. The group of general characteristics includes the following features: positioning in relation to topographic relief; seismic activity in the area of construction; depth of construction; building method; driving direction. The group of characteristics related to specifics of structural design includes the following features: quantity of tiers and passages; cross-sectional shape; type of lining and entry-exit. The group of technical characteristics consists of the following features: cross-sectional sizes; length; longitudinal profile; profile in plan; total number of lanes; width of traffic line.

System of classification establishes the subdivision of tunnels according to forms, classes, types and groups in conformity with location, structural design and technical characteristics. Classification stipulates the subdivision of tunnels till the level enabling to identify constructive, structural and technical
characteristics. Classification of tunnels in public roads includes the categories, which are distinguished according to the following features: form – layout towards topographic relief; class – by seismic activity in the area of construction; type – depth of construction; group – by structural design. Typical sizes of tunnels are defined according to the parameters of technical characteristics: length and clearance to obstructions across the width. Depending on length, the tunnels are divided into long and short ones. According to the cross-sectional sizes, the tunnels are divided into tunnels of small cross section (up to 20 m²), of medium cross section (from 20 to 50 m²), of large cross section (more than 50 m²).

Research task – is developing the technology of constructing transport tunnels with the usage of environmentally safe methods.

2. Problem-solving methods

To solve the task set, it’s suggested to use the combine technology of tunnel construction with mechanized mining, which is used in a broad range of rocks. In particular, there is one renowned experience of using domestic tunnelling machines KP-25 and KP-200T in LLC “Tonneldorstroy” while constructing transport tunnels in Sochi city. In rocks with uniaxial compression strength \( \sigma_{cs}=60 \text{ MPa} \) it’s possible to use the method of low ledge, wherein the dense profile is pushed in advance of the lower part at the length of 30 - 50 meters. Transportation of subsoil, installation of temporary lining, and erection of lining are made in equivalent to regular mining working practice. Stability of surrounding mass is violated to a considerably lesser degree than in drill and blast method, because in the process of cutting during mechanical destruction of rocks by the executive element of a tunnelling machine, the dynamic impact is reduced. In connection to this, the danger of falling ground and ground surface subsidence is essentially eliminated. Creation of quite smooth contour of groove is ensured with minimum overbreaks, which leads to reduction of loading, transport operations and consumption of concrete for erection of lining in comparison to drill and blast tunnelling method. Also, the benching method is used in tunnel construction, with profile area of more than 120-130 m² and height of more than 10m, mainly in hard rocks (uniaxial compression strength 80 - 100 MPa) [6].

Tunnelling machines of selective action are designed for mechanized development workings of coal pits, ore mines, and also of tunnels when constructing underground facilities. The usage of tunnelling machines allows to combine in timings the basic, the most difficult and heavy works (destruction of face and further gathering of rock mass), which gives opportunity to increase in 2 – 2.5 times the speed in development of workings and working efficiency, to reduce the cost of headworks and to considerably facilitate and secure the work of heading men against danger. Along with that, in tunnelling machine method of mining, the stability of mine works increases considerably, because the adhesion of subsurface rocks in the massive is violated in degree lesser than in drilling and blasting works, which reduces the expenses for roadway maintenance.

Tunnelling machine method of doing mine roadway is the most progressive, because it combines the basic operations in time, and mining works flow as an uninterrupted process. Existing tunnelling machines mechanize the processes of face destruction and placing of rock break on reloaders, which are installed behind tunnelling machines, and further, into transport. With all the diversity of boom-type roadheader, produced in the world, structurally they have many common elements. Structural-designing schemes of the machines, belonging to considered class, have practically one and the same composition for the majority of models.

Among national tunnelling machines of selective effect, the serial roadheader machines 1GPKS, 1GPKS-PV, KP21, SM130, and also the experienced samples KP200, KP200T, KPYU-50 found the broadest use. According to constructive features, all tunnelling machines can be referred to three classes: light, medium and heavy. Let us give short characteristics on the example of tunnelling machines, manufactured by OJSC «Kopeysk machine-building plant» (figure 1).
The first representative of standard series is road header 1GPKS of light class, which is geared to mechanized breakage and loading of rock mass in roadway of any form (apart from circular one) in the range of cross sections from 7 to 17 m² in driving with angles of slope ± 12° angle wise and in case of rocks with uniaxial compressive strength $\sigma_{cs} \leq 70$ MPa and abrasivity up to 15 mg.

Road header KP21 is representative of the standard series of medium class, which is designed for mechanized breakage and loading of rock mass (± 12°). Road header can drive workings of arched, trapezoidal and rectangular forms of cross-section varying from 10 to 28 m², in coal and rocks having uniaxial compression strength $\sigma_{cs} \leq 100$ MPa and abrasivity index 15 mg.

Representative of the heavy class is road header KP200. It’s engineered for mechanized breakage and loading of rock mass while horizontal and inclined drivings of rectangular, trapezoidal and arched forms, with cross-section from 14 to 39 m² by coal and rocks with upper limit of uniaxial compressive strength $\sigma_{cs} \leq 120$ MPa and abrasivity index up to 18 mg.

On basis of road header KP200, the road header of heavy class KP200Т was created, which is used for mechanized breakage and loading of rock mass while horizontal driving and inclined one (± 12°) of mine roadways with arched, trapezoidal and rectangular forms of cross-section varying from 18 to 52 m² by coal and rocks with upper limit of uniaxial compressive strength $\sigma_{cs} \leq 120$ MPa and abrasivity index up to 18 mg.

The basic factor of increasing the speed of roadways development is rational and well-managed organization of managing transport machines, which are used for timely transfer of rocks and delivery of necessary quantities of auxiliary materials to mine working place. In certain mining-and-geological and mine technical conditions there’s possibility of different combinations of forms and methods of organizing transportation of rock mass and auxiliary cargo, securing speedy mine workings.

It should be noted that the considerable part of construction works are carried out in restrained urban conditions. This imposes certain limitations on technologies under use from the point of view of ecological safety. This is directly referred to the ways of transporting the rock mass, which is formed in the process of mine workings, outside of inhabited localities. This restriction induces long distances of transportation that is accomplished in public roads, and as consequence – usage of haulers, poorly adapted for use in reviewed sets of shaft-sinking and tunnelling equipment under consideration. In connection to this, a need arises for developing and validating the loading of mentioned means of transportation directly in drifting face for ensuring further transportation of destroyed material.
3. Results and discussions

Let’s analyse the results received. Process of loading and transportation of rock mass in a number of situations, especially when constructing transport tunnels, has significant dissimilarity – cyclicity. It’s connected with time spent for change of batch transports - motor vehicles.

Let’s consider this thesis in more detail.

While using a small park of cars and existence of considerable transportation distance, the tunnel-boring machine is forced to be idle waiting for the next car. Expanding of the automobile park leads to an increase of cost value of works and doesn't exclude non-production losses of time spent for shunting operations during exchange. Indicated peculiarities do not allow using reloaders in the transport chain effectively. It’s possible to ensure continuity of loading process and increasing the effectiveness of work performance with the help of using transfer bunker, which, during the time of waiting for the vehicle, serves as accumulator of rock mass, coming from roadheader, but in the process of loading the vehicle, it becomes both, the accumulator and reloader at the same time (figure 2).

![Figure 2. Technological scheme of doing mine works when constructing transport tunnels.](image-url)

At this point, transfer bunkers, designed for ensuring uninterrupted work of combine systems as a part of batch-operated hauling equipment, are well known. Transfer bunker BP-15 with tonnage of 15 t, developed by OJSC «Kopeysk machine-building plant» can serve as an example.

Structures of reloaders with reciprocated motion of traction transporting units and with variable geometry of transporting elements can serve as the basis for transfer bunker, as a component of tunnelling machinery and equipment in construction of vehicular tunnel. Reloaders are differentiated by simplicity of design (absence of gear groups, chainless structure), servicing ease, possibility of transporting firm, large, abrasive rocks and designed for transporting rock mass from loading machine, which is located in face area, into the train of carriages, given for loading without additional shunting at the interchange point.

Authors developed principal structural schemes of transfer bunkers at the level of Russian Federation patents; selection methods of its structural parameters were validated [7]. Figure 3 presents some technical solutions of transfer bunkers. With an aim of increasing work efficiency and effectiveness of transporting bulk and lump materials at the expense of exclusion from structure of transporting elements, which are used for filling chute with material, conveyor was developed, and it has flight, chute, transporting element, tailgate, actuation cylinders and elements of driving gear control, including spreaders, where the chute is connected with flight hingedly, with possibility, in course of work, to change its angle of slope in relation to horizon by means of actuation cylinder for chute elevation, and chamber of cylinder, kinematically connected with tailgate, is attached with pressure indicator, which is giving signals to spreader controlling actuation cylinder of chute elevation. Such technical solution allows ensuring its balanced load due to gravitation force. Pressure indicator secures balanced, automatic load of chute with the loaded material by means of change in its angle of slope depending on load intensity applied to the tailgate from the side of loaded material.
Development of structure and selection of its parameters are possible only on the basis of studying working processes and predicted patterns of forming productiveness of all machines from transport chain «head-road machine – transfer bunker – truck».

Let us analyse the further transport chain. During construction of tunnels, in the function of transport means, dumptrucks got the widest distribution. Lack of data about opportunity of using reloaders in tunnel construction in combination with batch-operated transport vehicles, sets the task of modelling the works of shaft-sinking and tunnelling equipment complex, and this, in its turn, requires the following: development of technological schemes for carrying out development heading with the usage of transfer bunker; selecting structural schemes of transfer bunker; development of methodology related to selecting its basic structural parameters.

4. Conclusion
To sum up, it’s necessary to make conclusion that the creation of transfer bunker, geared to multiple changing conditions of heading works, represents the task difficult to accomplishment, and it’ll be reasonable and doable for some range of mining-and-geological and mining-engineering conditions coupled with the equipment of the most common types, used in the area located near a heading. For making loading of rock mass into dumptruck with the help of transfer bunker, the following technological schemes can be realized:

- placing of transfer bunker along the axis of heading with installing it on mono-rail (figure 4, a);
- placing of transfer bunker along the axis of heading with installing it on frame (figure 4, b);
- placing of transfer bunker next to the roadway wall (figure 4, c).

![Figure 3. Structural schemes of transfer bunkers.](image)

![Figure 4. Options of schemes for placing the transfer bunker in face.](image)
Analysis of technological variants and requirements applied to them, allowed to establish that the selection of option for the transfer bunker placement in face, should be made according to the condition of framing of tunnelling equipment into cross-section of roadway; along with that, mining conditions of doing heading and technological scheme of placing equipment in face influence the selection of transfer bunker structural scheme.

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