Without Fly Rock Blasting Technology of Railway Reconstruction

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Abstract. The paper considers the problem of hard rock blasting in confined space of railway reconstruction with widening of side-hill cuts or shelves. To ensure reliable blasting without fly rock to construct the secondary railway tracks, it is proposed to use a combination of borehole cushioned charge construction in overdrilling, large delays in explosive initiation, as well as installation of permeable convertible shelters from elastic elements.

1. Introduction

According to a large-scale program of the Far East transport system development, by 2020 the growth of traffic up to 66.8 million tons per year is planned additionally to the 2012 level. It is planned to increase the carriage capacity of the BAM (Baikal - Amur Mainline) section by 1.38-2.13 times, traffic capacity – by 1.6-2.6 times [1] The traffic growing volumes will require construction of secondary tracks, development of stations and junctions, reconstruction of the defective and deformable railway roadbed of the active railway on the eternal permafrost [2]. In the process of the BAM construction [3], the railway builders used the blasting methods of earth excavation for development of cuts in rock and permafrost soils in the BAM Eastern section. So, in the Tynda-Urgal section 48% of the embankments (25.5 mln m³) were constructed from rock grounds extracted in rock quarries or excavations, 38% of excavations (13.4 million m³) were developed in rock formations, and 29% – in permafrost soils. During the construction of the Urgal-Komsomolsk-on-Amur section 59% of the excavations volume (2.429 million m³) were in the rocky soils. The total volume of permafrost and rocky soils loosening in this section was more than 8 mln. m³ [4]. Therefore, for the reconstruction of the entire BAM Eastern section, the large-scale explosive works are planned for destruction of hard rocks for excavations or shelves widening on the slope near the active railway track. When the trains are moving, blasting is carried out in special allocated breaks – technological "windows", under the special project. The project should include the measures and works to ensure the continuity and safety of railway operation, as well as preservation of existing facilities [5]. The works for protection of engineering constructions from the scattered rock fragments and explosion seismic action, and the exploded rock debris cleaning after the explosion, elimination of possible engineering networks and constructions damage occupy 75-80% of the allocated "window" time. The efficiency of the work management under these conditions is extremely low. Moreover, the flying rock fragments significantly damage the environment. Therefore, it is necessary to develop such technologies of
blasting under confined space conditions, when good quality of loosening is acquired with the least negative impact on the railway constructions and environment.

2. Materials and methods.

The analysis of this problem has allowed to propose the following scheme of non-damage blasting for slope rock loosening in the process of the secondary railway tracks construction: use of specially constructed blast holes; use of hole-after-hole blasting with large slowing-down; sheltering of explosion sites by gas-permeable mats.

For the construction of the secondary track in the hard rock excavation (Figure 1), it is suggested to apply the developed and tested by the authors method of explosive loosening of hard rocks under confined space conditions [6]. It is based on a combination of borehole charges construction with air cushion in overdrilling with gas-permeable transformable shelter from elastic elements [7].

![Figure 1. Cross section of the rock excavation widening for a secondary track: I – an existing track axis; II – designed track axis; 1 - tamping; 2, 3, 4 – air gaps; 5, 6 – explosive (E) charge](image)

The following technology is suggested using as an example the normal height slopes (up to 5 m). The explosive holes with a diameter of 80-100 mm drilled parallel to the slope with overdrilling up to 1.0 m. The explosive hole charge is divided by an air gap (3) into the upper (5) and lower (6) parts. With the same grid of wells location, the use of air-gap charges in comparison with solid charges allows to improve significantly the quality of rock crushing. This is achieved by increasing the explosion duration and the height of the charge column with a corresponding decrease of tamping length. Thus the explosive ratio decreases in hard-crushed rocks by 8-10 %, and in easy- and medium-crushed rocks – by 18-20 %. The destruction of the formation behind the last row of the holes is reduced by 1.3-1.6 times. The latter is especially important in transport construction, where it is necessary to ensure long-term safety of new cut slopes. In the upper part of the hole a combined tamping 1 is installed, consisting of an expanding concrete cone and a crushed stone charging part, wedging a cone in the hole. To reduce the length of the tamping for rock destroying at the wellhead, an air gap 2 was set between it and the explosive (E) charge. Such tampings are well retained in the hole and securely lock the detonation products.

An air cushion 4 is arranged in the overdrill, allowing to achieve a directional displacement of the blasted mining mass without lifting it upwards, reducing the seismic impact of the explosion. Danger of rock movement decreases, in addition, in the air cushion charges the action of a double shock wave in the lower part of the hole creates favorable conditions for a better separation along the ledge bottom. Further researches of rock pieces flying reducing during blasting, made by the authors, showed, that mechanical explosion action is demonstrated not only in crushing and destruction of rocks, but also in degradation at remote distances from the charge [8]. In this area the explosion stress waves cause the development of existing microdefects, microfractures, increasing their concentration, weakening of intergranular and intercrystal bonds. The rock mass changes its strength and deformation properties, passes into a new state, called pre-destroyed [9, 10, 11]. In works [12, 13, 14] on the basis of the analysis of microfractures development, the peculiarities of an explosive wave impact on rock in the area of rock elastic deformation were studied. It is proved that at the front of the wave, radial and circumferential stresses are first compressive (negative), but then both radial and circumferential stress become tensile (positive). The studies of the rock pre-destruction zone during explosions [15] showed that in this zone the speed of elastic waves passage is reduced, indicating
weakening connection between the individual rock elements. The radius of the predestruction zone, estimated by the change of the elastic waves speed, can 30-100 times exceed the radius of the explosive cavity, i.e. the zone is the most large-scale area of changes in the rock mass. When varying deceleration values to ensure the safety of blasting seismic effects, it was established that the best result was shown by a group of 150, 200 ms decelerations [16]. When no more than four rows of wells are exploded, always no more than one explosive charge per deceleration unit is exploded. Also, these decelerations allow to minimize simultaneous blasting of charges, associated with the error of the initiation system. The scheme of blasting blocks with holes of 100 mm diameter, located over a 2×2 m grid (Figure 2), was accepted for the investigation of the case under study. Blasting was carried out using a non-electric initiation system (NIS), for example, RIONEL. The 150 and 200 ms deceleration between the holes of the surface network was specified, and the initiation of the downhole network was 750 ms. The initiation of the surface network of borehole charges of the block was carried out from the hole 1.

![Figure 2. Diagonal scheme of charge initiation.](image)

Experimental mass explosions carried out in the quarries of AO Urgalugol, OOO Albinsky Rudnik, OOO AVT-Amur showed that there was almost no rock movement, because the detonation products did not blow out from the well, but penetrated the cracks formed at short-deceleration in the rock of the explosive block, contributing to their development. It was also noted that the large pieces of rock mass often break down in the face under the excavator bucket operation, which confirms the significant fracturing during long-term multiple action of stress waves in the "compression-stretching" mode. This wave action is possible only with such large deceleration intervals [17]. Deceleration of 150 ms and more makes it possible to break out each hole (hole-after-hole blasting) not to open cracks, as with 40-80 ms decelerations, but to a free surface, that allows to form a rock mass collapse with relatively calm surface and reduce its height, while maintaining the crushing quality. During the long-term application of the increased deceleration intervals, it was found that the quality of crushing remains high even without tamping, and there is practically no throw of the rock mass outside the block [18, 19].

Figure 3 a, b shows a video image of the experimental mass explosion of the block at the Pokrovsky mine. The block was divided into two approximately equal parts: one part (right) – with boreholes tamping with cuttings, the second part – without tamping. The block was blown up with the use of NIS RIONEL. Deceleration between the holes of the surface network was performed by the device RIONEL X: in a row - 200 ms, between the rows - 150 ms. Initiation of the downhole network is performed by the RIONEL MS-30 device with a deceleration of 750 ms. The frame-by-frame scanning of video recording of the explosion allowed to establish a regular decrease of the emission amount from the wells without tamping and from the wells with tamping as the explosion was developing in time and space. The height of the dust-gas outburst is consistently reduced at the wells without tamping from 29.5 m at the wells 1 and 3 (exploded after 40 and 2920 ms from the explosion start) to 13 m at the wells 4 and 5 (exploded after 4680 and 6480 ms from the explosion start).
start), and up to 6 m at the well 9, exploded after 7920 ms (Figure 3c). The wells with a tamping have height of stemming material outburst higher, but with the same pattern: from 35 m at the well 2, exploded after 2520 ms from the explosion start, to 10 m at the wells 4 and 5, exploded after 3880 ms from the explosion start (Figure 3d). This is due to the fact that in the process of explosion of the first cut hole, the pre-destruction zone will pass through the vicinity of nearby wells, and before the explosion of subsequent wells the tension wave generates cracks in full volume of cracking and pre-destruction zones in the compression and stretching phases. Thus, it is enough time for fractures formation in the zones of wells without tamping and from the wells with tamping to full disclosure. Tension waves are absorbed in the fracture zone of the blasted wells.

![Characteristic frames of the explosion video image (a - 2,000 mc after explosion start; b) - after 7000 ms) and the dynamics of emissions from wells without tamping (c) and with tamping (d)](image)

Figure 3. Characteristic frames of the explosion video image (a - 2,000 mc after explosion start; b) - after 7000 ms) and the dynamics of emissions from wells without tamping (c) and with tamping (d)

The impact of each pulse causes a certain number of violations as a result of the development of existing in rock violations under the direct compression wave impact, and the formation of new ones in places of stress concentration, dislocations, weakened strength, etc. at the impact of the stretching wave, changing the compression wave after a certain time interval. At large deceleration intervals there is a necessary time for fractures germination at full depth, corresponding to a quasistatic stage of destruction under the expanded action of the detonation products of subsequent charges. Multiple repetition of alternating compressive and stretching stresses leads to fractures opening, and due to this, along the edge of the block with formation of a smooth slope of the ledge and absence of disturbances behind a separation line with good crushing quality. Thus, it was found that the quality of crushing remains high, and spreading the rock mass outside the block is virtually absent, when well-after-well blasting with large decelerations, in terms of without fly explosion, is used.

When constructing the secondary railway tracks, it is proposed to take advantage of the above improvements in a complex manner. Reliable without rock fly blasting is provided by a combination of the borehole charges construction with an air cushion in the overdrilling, applying the large decelerations, as well as installation of gas-permeable transformable shelters from elastic elements, worn tires from heavy-duty dump trucks can be used for this purpose.
The method of without fly explosive loosening of rocks using gas-permeable shelters was tested in the process of construction of the Amur highway (Chita - Khabarovsk) on the by-pass of Teploozyorsk settlement. A videogram of one of the experimental mass explosions is presented in Figure 4.

![Videogram of the experimental mass explosion development](image)

3. Results

The experimental block had 32 wells with a diameter of 110 mm and a depth of 6 m (including 1.0 m overdrilling). The wells were located in three rows on the selected ledge height of 5 m. Distance between rows of wells and wells in the row was 3 m, up to the edge of the ledge – 2 m. The total volume of the blasted block by the passport was 1440 m³, and the shelter area – 340 m², the average specific consumption of explosives per block was 0.65 kg/m³. The wells were dry, the explosive was grammonite 79/21, the total consumption of explosive per block was 596 kg.

The Belaz vehicle tires, about 280 kg, were used as a shelter. The tires were laid on a Rabitz grid with a 50x50 mm cell, overlapping behind a block edge on 2.3... 2.5 m coaxially above each well. Besides, to protect the object on the slope of the blasted ledge, the additional 20 tires were laid. All tires were equipped with a 6 mm diameter wire binding and were tied together by chains in a single mat. Under the vehicle tires shelter more than 350 thousand m³ of rock mass was successfully blown up. There was no movement of the exploded rock mass pieces.
A new technology of blasting under constrained conditions was developed on the basis of the above research. Thus, to provide reliable without rock fly blasting for construction of secondary railway tracks, the following complex solution is proposed: 1) to use a combination of the hole charges construction with an air cushion in the overdrilling; 2) to use large decelerations during the initiation of explosives (150-200 ms); 3) to install gas-permeable transformable shelters from elastic elements, the worn tires of heavy dump trucks can be used. All of this allows not to make operations for protection of the railway superstructure, utility network and engineering railway constructions and minimize the size of the “window” allocated. Thus, the application of the new technology allows to solve most problems of operating railways reconstruction with minimum expenses.

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