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BLAST-FILL DAMS CONSTRUCTED BY PIN-POINT BLASTING AND BY ARTIFICIAL ROCK AVALANCHES

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The new, untraditional way of dam erection by use of large explosions, that have been developed in the XX Century, required the extensive natural studies and modelling to validate possibility of the bulk of blasted rock utilisation as a structure which properties can be predicted beforehand. It is not surprising that this technology was utilised at a greatest extent in the USSR and China – countries with planned economy, which could perform expensive large-scale natural experiments funded by the state budget.

Besides study of the constructed dams and embankments (the Medeo debris flow storage dam in Kazakhstan, the Baipaza HPP dam in Tadjikistan, the Ak-su embankment in Dagestan) the most detail investigations have been carried out at the experimental Burlykia and Uch-Terek dams erected on the Naryn River tributaries. Methods of the blast-fill dams geotechnical and filtration-piping characteristics prediction were elaborated on the basis of these investigations. It was found that:

- density of the bulk of compressed rock debris that collapsed from a reasonable height is higher than that of the traditionally erected embankment dams;
- grain-size composition of blast-fill dam body results both from rock crushing by the explosion and from its compression during the collapse. At a first stage it depends, mainly, on natural fracturing of rock massif. At the second stage – on the compression forces, which cause relative motion of rock fragments, their additional crushing and formation of fines that fill the skeleton pores;
- rock crushing due to its compression depends on the initial grain-size composition. Uniform-sized debris undergoes intensive crushing, while mixtures in which amount of fines is equal to pores volume practically remain intact. Thus, processes of debris crushing and compression are self-regulating - they attenuate as grain-size composition reaches its optimum;
- shearing of the weakest parts on rock fragments surface by compression increases the skeleton strength and decreases dams deformability;
- permeability of the blasted rock mass is determined by its density and by content of fines (particles smaller than 5 mm) which, in their turn, determine pores dimensions. During the initial impoundment of the reservoir some transfer of fines occur within the blockage that lead to the formation of the reverse filters and to the decrease of seepage;
- the blockage that underwent large compression stress has large safety factor with respect to the natural seismic effects.

In spite of favourable technical characteristics of the blast-fill dams, these structures are interesting from the economical point of view. In the remote mountainous areas use of large-scale explosion that combines all operations of the constructional material excavation, transportation, floating and compaction in one can decrease the construction time and cost, required efforts, cargo transportation, and also need in the expensive materials and in powerful mechanisms. It is especially efficient with the increase of dam height and, thus, their volumes, which is incommensurable with the capacity of modern load-haul-dump machines.

Dams constructed by use of large explosions can be divided into two main groups. The first one includes the dams that have special water-retaining elements (diaphragm, filters, drainage, areal or deep pressure grouting, etc.). Their erection requires construction of the offtake tunnels and cofferdams. The second group includes homogeneous dams that have spread profiles and low filtration gradients and do not require any special measures for dam body-basement transition and water offtake. If necessary, permeability of such homogeneous dam can be reduced by its upstream face mudding with fines. It is obviously that maximal economic effect of blast technology utilisation can be achieved for the dams of the second group.

Seismic effect of blasting on the structures constructed beforehand, which are located most often on the opposite bank of the river, usually does not exceed the background seismicity typical of the region and does not require any special measures for their strengthening.

It should be noted that utilisation of pin-point blasting is effective for rather small dams up to 60-80 m high only. For the higher dams amount of explosives increases at a rate of 3.5-4.0 in proportion to the crater depth that makes such explosion inexpedient both by the explosives cost and by its seismic effect on the structures.

Erection of larger blast-fill dams is possible, however, on the basis of the approach proposed by M.A. Sadovsky, according to which the explosion is considered just as a trigger that releases the potential energy of rocks resting high above valley bottom. Their further emplacement in the form of rock avalanche is governed by gravity force only. Such dams could be named "blast-rockslide" dams.

Possibility of this technology utilisation is proved by the presence of numerous natural rockslide dams that block mountainous rivers. Many of them have been eroded later on by the overtopping water, but those where the inflow is balanced by the filtration still keep safe. They can be exemplified by the Usoi and Yashilkul blockages in the Pamirs, by the Karasu natural dam in the Tien Shan and by many others. Rather small filtration discharge through these dams that have high water head (up to several hundreds meters) and absence of piping testify their low permeability and high suffosion strength.

The Usoy dam is up to 700 m high. Thus, practically there are no limitations of the height of such dams. What about geotechnical properties of such dams' bodies, we can assert that they will change positively with the increase of dam dimensions. It can not be excluded that construction of the homogeneous blast-rockslide dams with elongated profiles is possible not only in the seismically active regions, but moreover, at the sites with active faults that can be ruptured and where the "traditional" dam construction is avoided.

The developed technology of rock slope failure includes the consecutive (upward) exploding of linear charges located along the designed sliding surface. The amount of explosives is calculated just to provide rock massif ripping and its initial push. To prevent debris spreading along the river valley after rock avalanche collision with the opposite slope, small "cofferdams" should be erected beforehand by pin-point blasting at the up- and downstream limits of the designed dam.

Such technology decreases the total amount of the required explosives more than two times in comparison with the pin-point blasting, which, along with the delay of blasting of different charges excludes hazardous seismic effect on the HPP structures and surrounding infrastructure.

The most favourable topographic conditions for the blast-rockslide dam erection are at the curved gorge with slope steepness not less than 40-45º. Its plan crookedness allows to focus the collapsing rock debris from the exploded concave slope and to decrease length of the spillway and headrace-tailrace tunnels that are constructed at the opposite side of the valley concurrently with blast preparation.

The fundamentally new in blast-fill and blast-rockslide dams construction is the rejection of the effort to ensure absolute water impermeability of the dam body traditional of the hydraulic engineering. It is obvious for the dams constructed for debris flow protection and for transportation. For the water retaining irrigation dams the filtrating discharge is not spilled if it does not exceed minimal discharge record of water use and, as a matter of fact, is the same controlled discharge that have to pass through the spillway. The same relates to the obligatory sanitary drawdown to the tailwater pools of the barrages.

But for hydraulic projects designed for the electricity production, filtration discharge through the homogeneous dam leads to the decrease of the production. Therefore their erection is expedient on the high-water rivers where relative loss of energy production due to filtration is small and does not exceed several percents, while more than 90% of rivers power budget can be utilised for minimal cost. In such cases the decrease of energy loss by the increase of dam impermeability, with a help of its colmatage for example, should be economically effective.

Results of the extensive investigations were used for the design of the Kambarata-1 and 2 HPP on the Naryn River in Kyrgyzstan. The project of the 275 m high blast-rockslide dam of the HPP-1 with the designed volume of 112 millions cubic meters seems to be the most interesting. The total amount of explosives that should be used for its erection was up to 220 thousands tons. The expected filtration rate through the dam body at the maximal reservoir water level was estimates as 5% of the Naryn River mean annual flow. The calculated cost of the project with blast-rockslide dam was 22% and 32% lower than that of the project with the traditional dam types – the embankment and the concrete one correspondingly. Unfortunately realisation of the project was stopped after breakdown of the USSR due to shortage of funding.

We should note that transportation of large amount of the explosives and their accumulation in the coyote-holes requires a lot of time. In case of the Kambarata-1 dam it will take 4 years. At present political situation (terrorism escalation) it should be undoubtedly considered as a negative factor. We hope, however, it is not forever.