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# CONSTRUCTIONAL AND OPERATING SAFETY OF THE BLAST-FILL DAMS

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Peculiarities of the blast-fill dams erection technology predestine specific approaches to their safety assessment during the design and construction.

First of all, in contrast to the hydraulic projects with “traditional” types of dam, those that include blast-fill dams, contemplate construction of the spillway and powerhouse in advance, before dam erection. Explosions used for such dam construction provide significant seismic effect on these structures and on the host rock massif. It can cause either their destruction or failures of natural and artificial slopes at the dam site and in its vicinities. The latter is especially important since blast-fill dams are constructed, as a rule, in narrow gorges whose slope stability could be at a marginal state. Seismic shaking can lead to their failure or to growth of weaknesses that can facilitate decrease of their stability.

Slope stability assessment should be performed at the initial stages of the design as far as its results allow suggesting measures that guarantee safe and secure work of the hydraulic complex. For example, slope stability studies performed for the design of the Kambarata-1 & 2 HPP at the Naryn River in Kyrgyzstan showed that several tens of thousands cubic meters of rock can collapse from the slope above the Kambarata-2 power house intake due to seismic shaking. To prevent such unfavourable effect hazardous slope was flattened. It was also found out that several millions cubic meters of rocks could fell from the left bank of the river downstream from the Kambarata-1 dam site. Such rockslide can block the river and inundate the powerhouse. Since it was practically impossible to stabilise this slope, the artificial channel was designed to guarantee free water flow downstream of the dam site.

To insure the stability of the host massive where powerhouse and spillway should be placed they are usually located within the slope opposite to that which should be exploded. They can also be located at the knowingly safe distance from charges.

Blast-fill dams operating safety can be assured by following special standards of the materials that are used for dams construction, of dam foundation and of structures dimensions. Hereafter we discuss them in more details. However, we must note that these standards summarise experience gained during construction and operation of the “purely” blast-fill dams up to 100-120 m high and can be strictly utilised for such dams only.

The first requirement concerns rocks or soils that are used as construction material. They must be weathering-prone, that means that the initial properties of the exploded rock mass must not change during dam lifetime. Such types of rocks as siltstone, mudstone, sandstone and conglomerate with clayey and carbonate-clayey cement and some varieties of shale and gneiss undergo fast and intensive weathering. Within several months or first years they turn into sand or rock debris. Intensive weathering is typical of rocks from fault zones as well. Weathering leads to significant changes of the density and strength of the constructed dam and of its filtration properties. It is practically impossible to predict rate and value of these changes as well as their consequences. It’s most likely, however, that the latter will be negative. For example, decrease of size of the blasted rock fragments – the most evident effect of weathering, leads to the increase of the dam fill density that can reduce its permeability. In some cases it can lead to uncontrolled rise of water level and dam overtopping. We should take into account that weathering can be non-uniform. It facilitates formation of the density heterogeneity, which, in its turn, create high filtration gradients and can cause piping and internal erosion.

It is well known that characteristics of blast-fill dams, especially their filtration properties strongly depend on the material and on its density (KORCHEVSKY & PETROV, 1989; BLAST FILL DAMS, 2000). Generally, grain-size composition of blasted rock mass is governed by the style and extent of rock fracturing and can be predicted with high reliability (KOLICHKO, 1988). Grain-size adjustment, namely increase of fines content, can be performed by blasting. Though it is widely used for mining, during large explosions that are used for dam construction such method can not be realised.

Upper parts of dams up to 8-10 m thick are friable. With depth dam fill density increases. It is especially evident at the upper one third of such structures (KORCHEVSKY & PETROV, 1989; BLAST FILL DAMS, 2000). The prevailing values of blast-fill dam material density are near to the density of rolled rockfill of the “traditional” embankment dams. Permeability values of the blast-fill dams vary from $6\times10^{-1}$ to $6\times10^{-2}$ cm/s depending on their composition (BLAST FILL DAMS, 2000).

According to the on-site observations carried out at the 82-m high Nanshui blast-fill dam in China, dam body density increases with time. Correspondingly its crest sets. During the first year this setting was up to 70-80% of the overal 5-years set that was 1.7% of the dams height (BLAST FILL DAMS, 2000). Similar processes are going on at the embankment dams which compaction was performed by use of the "traditional" technologies. Relative set of such structures is up to 0.8-1.9% of their height and this process lasts for 9-11 years (MACEDO-GOMES *et alii*, 2000; ZHENGGUANG, 2000; *Comparative* -…, 2001). The peculiar feature of the "traditional" dams' deformation is the presence of lateral component, which is, most likely, due to their rather narrow profile. Dam deformations practically do not change physical properties of its body and this circumstance allows expecting that blast-fill dam characteristics also will not change with time.

Thus, using the prognosis of the grain-size composition of the blasted rock mass it is possible to forecast physical properties of the dam. The following limitations are evident for the water-retaining blast-fill dams:

– Dam's crest should be at least 12-15 m higher than the designed reservoir water level;
– Blast-fill dams composed of massive or thick-layered rocks with weak fracturing, which are designed on the rivers with small water discharge, can be ineffective without additional antifiltration measures due to their high permeability. Such "ineffective" dam can be exemplified by the natural blockage on the Yagnob River in Tajikistan composed of blocks of massive limestone.

One of the problems of the ensuring the blast-fill dam safety is connected with the preparation of their foundations. It is especially important since filtration through such dams is often concentrates at their bases. Infiltration coincides with the most permeable part of dam foundation or with that part of the dam-basement conjugation, which is located far from charges. If there are piping-prone deposits at the dam foundation, concentrated water flow may cause the internal erosion. Presence of buried trees at the dam's foundation can be hazardous as well, since wood putretaction will increase the porosity of the dam-foundation boundary zone and, thus, its permeability. What about bedrock, even those types subjected to various weathering processes do not pose any threat as far as their physical and filtration properties are better than those of the blasted dam fill. Therefore, foundations' preparation can be reduced to the removal of the piping-prone units, characterised by the higher permeability than the dam body and also to the removal of trees if they are widely distributed over the dam site.

Blast-fill dams higher than 150-180 m differs from the lower ones, first of all, by their internal structure. It can be derived from the study of large-scale rockslide dams, which are considered as natural analogues of large blast-fill dams (KOLICHKO & FIL, 1976; STROM, 1994).

Such features are characterised by the presence of large dense "cores" composed, depending on the mechanism of emplacement, either of the intensively comminuted overconsolidated debris or by shattered rock massif retaining its initial structure. Rock avalanches are characterised by intensive rock crushing during their motion and high extent of debris consolidation. It results in the formation of dense crushed debris characterised by low permeability and rather high mechanical properties.

Such core composed of crushed debris was found at the Karakul rockslide dam more than 200 m high in the Central Tien Shan. Its scar rises for more than 250 m above the dam surface. Rockslide that occurred in the strong thick-layered limestone, blocked the Karasu River just at its mouth and formed a lake more than 100 m deep. At present it is filled by the alluvial deposits. Small springs are observed only at the dam base. After lake infilling the dam was overtopped and a new riverbed have been formed at the frontal part of the blockage.

The Usoy blockage in the Central Pamirs seems to be the typical case of rockslides with the core composed of rock massif that retained its initial structure. Rockslide 2.2 $km^3$ in volume blocked the Murgab River and formed the Sarez Lake up to 500 m deep. Seepage takes place only through the uppermost 100 m thick blocky part of the dam.

One can expect that high blast-fill dams will form secure water-retaining structures. For such dams the requirements for the preparation of their foundations can be simplified, since descending rock mass of such volume can "bulldozer" loose material from valley bottom up to the bedrock. At the same time such dam crest elevation above the designed reservoir level should be about 10-15% of the entire dam height.

The above considerations on the internal structure and characteristic features of high blast-fill dams are hypothetical since no one so high blast-fill dam has been erected yet.

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