Engineering and geological conditions of dam construction

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Abstract. The article presents studies of the engineering-geological conditions of dam construction, consisting of the structure of river valleys and slopes, conditions of rock occurrence, geotechnical and filtration properties of rocks, and geological conditions of the dam construction site. A classification of valley types with schemes, classification of rocks about the location of dams, and types of tectonic structure of valleys about the construction of dams are presented. Conclusions are drawn about the most favorable and unfavorable conditions for the construction of dams.

1 Introduction

Engineering-geological conditions for the construction of dams are made up of [1, 2]:
1) Conditions for the stability of the structure's foundation about settlement and shear.
2) Filtration conditions at the dam site (under the dam and in the abutments) from two points of view:

a) Filtration rates and hydrodynamic pressure arising during filtration (questions of the influence of filtration on the properties of rocks at the base and at the junctions of dams - dissolution, suffusion, buoyancy);

b) Values of filtration flow discharge downstream (questions of the influence of filtration on the water balance of the reservoir).

The above conditions are determined by a combination of several circumstances, of which the most important are: 1) the structure of river valleys, 2) the conditions for the occurrence of rocks, 3) the geotechnical and filtration properties of rocks. The structure of river valleys is very diverse and is directly dependent on the geological history of the valleys [3].

The narrowing and widening of the valleys are essential for the design of dams and reservoirs since, generally speaking, the most advantageous location of the dam is the narrowing of the valley, which reduces the amount of construction work, the most advantageous location of the reservoir is the expansion of the valley, which increases the capacity of the reservoir. The narrowing and widening of the valleys in some cases are due to the development of channels and the descent of individual lakes; in others - to various

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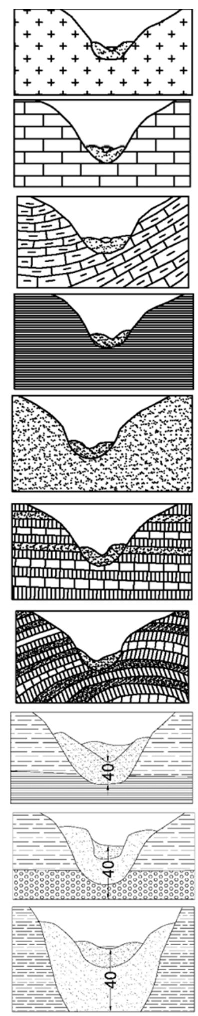
erosion of rocks; in the third - to some accumulative processes occurring in the valley. Valley narrowings can occur due to the accumulation of alluvial fans, landslides, landslides, etc. Establishing the cause of the narrowing of the valley is of great practical importance since, in some cases, the narrowed sections can be contraindicated for engineering and geological reasons for the construction of dams (narrowings associated with collapses, landslides, etc.).

Most of the valleys are overdeepened; in other words, alluvial deposits lie at their base. The thickness of the latter significantly affects the engineering-geological conditions for the construction of dams and the research methodology.

With low alluvium thickness (less than 5-6 m), the dam can be based on bedrock since removing sediment from under the dam's base in these conditions will not present any particular difficulties. The study of the properties of bedrock comes to the fore.

Table 1 gives a classification of engineering-geological types of valleys.

Table 1. Scheme for classifying valley types

I Valleys in bedrock, sediment thickness does not exceed 5-6 m	1 Rock formations	A. Homogeneous	a) non-dislocated occurrence	Insoluble rocks; Soluble rocks Insoluble rocks;	
		B. Overlapping	b) dislocated occurrence		
	2 Non-rock rocks	A. Homogeneous	a) water resistant		
			b) water-permeable		
		B. Overlapping	a) non-dislocated occurrence		
			b) dislocated occurrence		
II Valleys of alluvial and deluvial sediments	1 Sediment capacity less than 40 m	A. The bedrock is waterproof	Homogeneous sediments Heterogeneous sediments		
	1 Sediment capacity less than 40 m	B. Water-permeable bedrock			

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With an average thickness of alluvium, the dam is usually based on alluvial deposits, but its foundation, with the help of sheet piles, can be associated with bedrock if the latter are represented by clays or rocks close to them in properties. In the presence of alluvium of medium thickness, it is equally important to investigate alluvial deposits and underlying bedrocks.

With a large thickness of alluvium (40 m or more), it becomes very difficult to connect with bedrock using sheet piles. In this case, the engineering-geological properties of bedrock at the base of alluvium require much less attention or may not be studied at all (the exception is karst rocks). Geotechnical studies of alluvial deposits should establish the work of these deposits in the dam's base, filtration studies - the feasibility of taking measures to combat seepage (in particular, by laying sheet piles). Their nature (rocky, non-rocky rocks) should be established for bedrocks, which determines the possibility of driving sheet piles into these rocks, and the permeability of rocks, which determines the expediency of driving sheet piles.

The structure of the slopes of the valleys. In addition to the thickness of alluvial deposits at the base of the valley, the structure of the valley slopes has a significant impact on engineering and geological conditions. [4, 5] If there are terraces in

In the valley, it is essential to establish from the types (erosive, accumulatively superimposed, accumulatively nested, socle), without which it is impossible to correctly compose geological profiles and correctly interpolate geotechnical and filtration survey data. So, for example, in the presence of nested terraces, the data of an experimental pumping performed on one of the terraces cannot be extended to another terrace, even if the marks of the studied reservoirs coincide, while in the presence of superimposed terraces, this is quite possible.

The role of alluvial deposits composing the sides of the valley is twofold. If the permeability of alluvium is less than that of bedrock, then the presence of alluvial terraces improves the engineering-geological conditions of the dam; otherwise, these conditions worsen.

Of the other alluvial formations involved in the structure of the slopes of river valleys, deluvial formations are of significant importance. Since deluvial deposits are the product of washing particles from the slope, they are mainly represented by fine-grained rocks, which usually have less water permeability than bedrock. Therefore, the presence of deluvium on the slopes helps to reduce seepage losses at the dam site. Conditions for the stability of deluvium on the slopes in the upper and lower pools are different. In the upstream, the filtration currents are directed deep into the massif; in the downstream, the filtration currents are directed towards the earth's surface. Therefore, upstream, the hydrodynamic pressure “presses” the deluvium against the bedrock; on the contrary, downstream, the hydrodynamic pressure can cause the phenomenon of sliding of the deluvium, which is dangerous for the dam. Thus, the optimal conditions (from the point of view of engineering and geological) of the dam section are the presence of a deluvial cover upstream and its absence downstream. Suppose the watersheds and the upper parts of the valley's slopes are composed of sandy loamy bedrock, and the lower part of the slopes are clayey. In that case, it may turn out that the deluvium of sandy loamy rocks will have greater water permeability than the bedrock of the lower part of the slopes to which the dam adjoins. In such cases, the presence of talus worsens the engineering-geological conditions of the dam (without talus, filtration losses bypassing the dam will be less, all other things being equal; in addition, talus may slip along the clay surface).

2 Conditions of occurrence of bedrock

The composition and conditions of bedrock occurrence determine, in all cases, the engineering-geological conditions (filtration, stability) of the areas where the shoulders of the dam adjoin. The exception is when there are alluvial terraces of large width, in which the arms of the dam are cut. Of particular importance are the bedrocks of the slopes in the construction of arch dams since, in this case, a significant part of the hydrostatic pressure experienced by the body of the dam from the side of the reservoir is transferred to the areas where the shoulders of the dam adjoin.

The properties and conditions of occurrence of bedrocks in the foundation of dams are of greater importance the closer the surface of bedrocks lies to the surface of the earth.Геологические условия места возведения плотины. Enlarged categories of rocks that can be distinguished in terms of stability conditions at the base and at the junctions of dams are shown in Table 2 [6-8]. It indicates those deformations and disturbances in the occurrence of rocks that may occur during the construction of the dam due to the pressure of the dam body (vertical component), water pressure on the dam body (horizontal component), slope trimming, and filtration.

Table 2. Classification of rocks in relation to location of dams

Classification of breeds and characteristic representatives				The nature of possible deformations at the base of dams	The nature of possible deformations in the dam junctions	The nature of water permeability
I.Rocky	1.Insoluble	A.Not cracked	Deep rocks, cemented sedimentary rocks	Rocks that are quite stable, with the exception of the weathering zone, where the rocks acquire a semi-horizontal character	Collapses	Rocks are water resistant except for the weathering zone
		B. Fractured	The same rocks that have undergone tectonic disturbances;			Rocks are permeable through cracks distributed more or less evenly in the rock thickness

Continuation of table No. 2

Classification of breeds and characteristic representatives				The nature of possible deformations at the base of dams	The nature of possible deformations in the dam junctions	The nature of water permeability
II.Semi - permanent	2.Soluble		Limestone, marble, dolomite	Roof collapses of voids (dips) as a result of dissolution	Dips, collapses	Water permeability is very high
	1.Soluble	A. Sulphate	Gypsum, anhydrite	Sinkholes, softening of gypsum-containing rocks, swelling (anhydrite), shear	Sinkholes, landslides	The waters move through a complex system of karst voids
		B. Carbonate	Chalk, marl	Softening, plastic deformation, shear. In some cases , failures		Water permeability is very diverse
	2.Insoluble		"Weak" sandstone, opoka	Disintegration of sandstones, softening (opokovidnye clays), shiftDisintegration of sandstones, softening (opokovidnye clays), shift	Landslides	
III.Non - rock	1. Discon-nected	A. Large-porous	Pebbles, gravel	Shift		Filtration coefficient > 50 m/day
		B.Fine – pored	Sand	Suffusion (in heterogeneous sands), buoyancy shift; draft quickly fading	Buoyancy and suffusion	Filtration coefficient 50-1 m/day
	2. Connected	A. Sandy-clay	Sandy loam, heavy and light loam	Buoyancy, draft of various sizes, protrusion, shift	Bulging, landslides	Filtration coefficient 1-0.05 m/day
			Loesslike loams	Draft catastrophic character, shift	drawdowns, landslides	
		B. Clay	Clay	Swelling, plastic deformation (tightening during precipitation), shear	Landslides	Filtration coefficient < 0.05 m/day

The degree of homogeneity of bedrock is an essential feature of the classification of engineering-geological conditions of dams. With the homogeneity of the rock, the research and design of dams are greatly simplified. Exploration work should, in this case, establish the thickness of the weathering zone under the alluvial deposits and on the slopes of the valley.

The number of experimental and laboratory work, in this case, is also minimal since the subject of the study is one breed.

When rocks are interbedded, the engineering-geological conditions become more complicated, and the bedding conditions become most important. When interbedding rocks (whether bedrock or alluvial formations), a concentrated hydrodynamic pressure can occur that adversely affects the foundation rocks and directly on the dam foundation.

With a horizontal occurrence, the heterogeneity manifests itself only in the vertical direction, while in the horizontal direction, the series of layers is isotropic. Therefore, with a horizontal occurrence and sustained thickness of the plates, the bearing capacity and resistance to shearing conditions of rocks are approximately the same throughout the entire area of the dam. Definitions of geotechnical and filtration properties of rocks can be easily interpreted; the exploration system is simple.

During the deployment of layers, the engineering-geological conditions of dams are very diverse and depend on the tectonics of the area where the dam is located.
Various cases of the location of dams about tectonic elements are given in Table 3 [6-8].

Table 3. Types of tectonic structure of valleys in relation to construction of dams

Dam locations			Fragmentation breeds	Filtration conditions to the downstream (when alternating waterproof and permeable layers)
Valleys along strike	Anticlinal		Decreases	Direct filtration downstream in bedding planes
	Synclinal			
	Monoclinal			
Valleys across strike	Anticlinal		Decreases	Filtration currents cross formations due to their significant fragmentation
	Synclinal			The same as for anticlinal valleys. In addition, filtration directly on the permeability of the layers emerging upstream and downstream
	Monoclinal	Layers fall into direction of the river		Filtration can occur only in the case of a small dip angle
		The layers are falling backwards		Filtration in the absence of fragmentation of rocks does not occur

3 Conclusion

Ceteris paribus (about the composition of the rocks), the most favorable for the construction of dams are: from the valleys directed along the strike - monoclinal valleys, and from the valleys that cut the layers across the strike - those areas where the layers fall upstream of the river, as well as areas of consonant fall at a large angle of the latter. The least favorable position of dams is in the axial sections of the folds, especially the anticlinal ones.

Particularly unfavorable are areas that have undergone disjunctive dislocations. Such areas are characterized by a large fragmentation of rocks. Significant water leaks and even water breakthroughs downstream are possible along separate fault fractures. Therefore, discharge sites are contraindicated for the construction of dams, especially in seismic areas. Only not in those areas where disjunctive dislocations are very ancient or in those areas that are currently tectonically calm, the presence of these dislocations does not significantly affect the engineering and geological conditions of dams.

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