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Some hydraulic models and analogues for solving spatial lateral and bottom seepage through earth dams

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Privileged way and its significance for stability of protective dams and levees

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I

Some hydraulic models and analogues for solving spatial lateral and bottom seepage through earth dams

The principles of the methods of analogies and basic rules of their application for ground water study have been known for some time. Experimental technique itself has been improved in the course of time and consequently the scope of soluble problems has increased. The development of the methods of analogies is continuing generally in dependence on the progress in various scientific branches, especially in electronics and numerical mathematics. The significance of hybrid procedures increases, using partly the principles of methods of analogy and partly numerical calculations by means of digital technique.

Into the vast number of soluble problems fall also heterogeneous problems of water seepage through earth dams. In space conditions it is a complicated phenomenon, the study of which is possible by means of modelling. In these cases, like at the classical hydraulic models, it is also difficult to achieve full physical similarity. Therefore we select from all acting effects only the deciding ones and establish necessary criteria for them.

One of the oldest experimental techniques is the application of sand models fed by water. This methods has advantages and disadvantages. Many of these disadvantages can be eliminated, or at least suppressed, by transition to a pervious medium consisting of glass or ceramic globules. We choose their diameter with regard to the sort of liquid admitted into the mass of globules. Besides we respect at this choice the condition of flow law. The extent of the band of partly saturated zone over free water level is regulated by the choice of globule diameter, liquid viscosity and also by the choice of material the globules are made of. Another possibility is given by surface finish of globules.

Spatial flow along earth dams is usually characteristic, even at stationary flow, by its complicated geometrical configuration. The identification of its position in adequate globule models is possible in this way that over the created free level those globules are removed which are unsaturated by water or only partly saturated. Hydroisohypses can be obtained by direct measuring of the denuded area.

At unstationary flow point identification of the position of free level is possible by means of various transmitters.

In more complicated cases the influence of deformability of natural pervious medium is also respected and is simulated in globule analogues by inside placing hydraulic capacities. These are discretized elements constructed on the principle of concentrated parameters of continuous medium.

The flow through the subsoil of the dam is often of spatial character, too. The investigation can be facilitated by

so called spectral method. This method is based on the study of flow in an analogue with very simplified boundary conditions. We suppose they are time-independent zero. We realize a source of constant abundance in a certain point of the space. In the analogue we determine the time course of increase of total volumes of liquid flowing into the source and flowing off over individual boundaries. These data are sufficient for calculating in the given point the function necessary for determination of piezometric hight, influenced by other arbitrarily complicated boundary conditions.

The suggested procedure can be mathematically based by the theory of Green's function and has the advantage that a great part of the solution is of numerical character so that it is possible to perform the calculation by digital computers.

The realization of the experimental part of the solution can have a few variants. We showed two of these variants on the example of seepage study under river dams. The disposition using underpressure has many advantages. In this way it is simply possible to achieve uniform outflow from the source. At the same time discharge of the analogue occurs in such a manner that its preparation for next test is simple and quick.

The suggested spectral method principle has a more general character and is applicable even for problems of observing ground water flow by means of other analogues, for example by means of electrical RC networks. In this case we realize nodal current sources and measure time behaviour of voltage drop on small electric resistors at the boundaries. The results are again worked out by digital procedures.

The spectral method is applicable in cases describing systems of linear partial differential equations. On some examples we also indicated possibilities of applicability for approximative solution of nonlinear problems.

In general we may say that tendency of return to hydraulic models and analogues can be observed in the analogue technique. Their advantages are evident in cases when spatial development of free level and spatial flow are studied in configurations that are analytically hardly definable. Complications can arise by leakage problem mainly in cases when its existence is not unquestionable in the whole observed space.

As example can serve the problem of spatial draw-down in earth dams and in lateral slopes. The results of the solution are basis for analysis of the time effect of pore pressures in the sealing elements.

As another example can serve the calculation of the magnitude of seepage losses.

We admit that many colleagues do not consider seepage losses as essential part of the total hydraulic balance of the reservoir. We should like, however, to point out that underestimation is generally not justified. So e.g. Czechoslovakia lies in the distribution area of great rivers and earth dams are built up on streams that are little aqueous. Water management which is limiting factor of living conditions has therefore its specific aspects.

II

Privileged way and its significance for stability of protective dams and levees

Protective dams erected along rivers are usually in action during transient time, mainly during floods. They are, however, of great significance because they protect valuable riverside territories. In Czechoslovakia there exists fairly extensive protective system along the Danube. The dams are erected on thick layers of pervious gravels and sands. The dam body itself is relatively stable. In the subsoil, however, there occur displacements resulting into ruptures from time to time.

During a flood the area at the foot of the dam is overflooded and this development is accompanied by changes of the position of ground water level under the dam and its hinterland. A good indicator is time development of the pressure line drawn at the lower border of the cover on which the dam is situated and under which usually sands and then gravels can be found. Water effluxes arise behind the dam in the case that the pressure line overtops terrain level behind the air foot of the dam. The position of the effluxes is predestinated by local failures of the cover. For penetration of water into the failure high incoming gradients are characteristic which are the cause of filtrative deformations. Their existence is proved by lifting of sand, i.e. transport of loosened material.

Unilateral inflow of ground waters is the cause of assymetrical penetration of water into the failure. Therefore material is also loosened assymetrically. The off-transport of sand grains in the contact area between cover and subsoil gives rise to tortuous tubes, the heads of which proceed against the flow of ground water, i.e. towards the foot of the dam. These tubes are called privileged ways because they are preferential ways for water (due to their high perviousness) and preferential transport of loosened material.

We have also proved the existence of privileged ways experimentally in a sand model with glass wall with an outlet hole (Fig. 1). This hole was situated in the contact level between sand and clay filling. After opening of the outlet hole first a privileged way arose (Fig. 1 a) which in the plan view had for example the form of Figure 1 c. After some time it developed so that a sand layer broke through into it from below (Fig. 1 b).

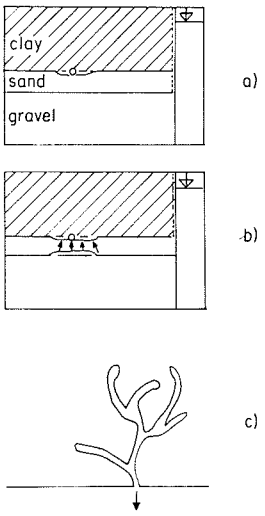
Precondition of genetical development of privileged way is the possibility of material transport through the tube. For study reason we examined conditions of transportability in two variants. The first one assumed longitudinal uniform water inflow only along the tube (Fig. 2 a). The

second one assumed only inflow into the head of the tube (Fig. 2 b). For concrete conditions we calculated hydraulic conditions of the transport of fine sand through the tube in dependence on its diameter, transported grain and perviousness of material in neighbourhood of the privileged way. Comparison with natural conditions showed that the scheme in Figure 2 a corresponds to limiting states determined at catastrophic ruptures.

The stability of dams is judged according to theoretical and empirical rules. Under the later group fall especially the criteria of Bligh, Lane. The criterion of transportability shows another development trend. The most dangerous case is arising of a privileged way in sands, under which there is coarse gravel. The more pervious is this material, the broader must be the footing of the dam. In addition to that, arrangement of a blanket at the foot of the dam is recommended, which impedes proceeding of the head of the privileged way. It is substantial for the general scheme of the dam, including adjoined blanket and drainage, that it must create such pressure conditions that can prevent rupture into the privileged way.

Dams without supplemental outfit are potentially endangered mainly for that reason that genetical development of privileged ways proceeds inconspicuously. Every flood facilitates extension of the privileged way. In an unexpected moment, afted a number of repeated floods, undesirable catastrophe occurs.

We are aware of the fact that the described view on the stability of dams is very unusual. Therefore we do not consider our conception to be solely and generally correct. Nevertheless we make no doubt of its acceptability in conditions in which we had possibility to study the course of catastrophes. We should be very happy if the abovesaid ideas would help in investigation of the given problematics in other countries, too.



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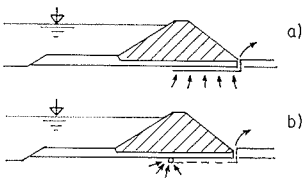

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