An Idea of Multi-Functional Storage Reservoirs in Mountain Regions

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Abstract: *The paper presents possibilities of construction of multi-functional reservoir in mountain regions, especially those with soft rocks. Construction of relatively small reservoir instead of big ones and taking the area configuration into account allows eliminating expensive embankments and insists to construction of cofferdams. The cofferdam can be formed of the occurring rock eluvium. Such idea was analyzed for the south of Poland. At present we can observe the climate changes accompanied by increase of the weather dynamics and unusual intensity of extreme phenomena. Mineralogical composition of rocks or their eluvia occurring in the considered area is usually not taken into account while forecasting of such phenomena. The proposed tests on determination of the eluvium areas especially susceptible to formation of mud avalanches in the mountains sites.*

Keywords*: flysch eluvium, reservoir, rock eluvium , mud avalanches , swelling*

I. INTRODUCTION

The climate variation has been observed recently. They are accompanied by increase of the weather dynamics and unusual intensity of extreme phenomena. Precipitations are very intense and they are accompanied by landslides and mud avalanches, or long-lasting droughts. A lack of suitable retention causes a fast flow of discharge water to the seas. Mineralogical composition of rocks or their eluvia occurring in the considered area is usually not taken into account while forecasting of such phenomena. Colloidal activity, a state of colloidal bonding and crystallization strongly influence formation of avalanches, strength of the mixtures and reversibility of their reactions with participation of clay minerals.

Polish water resources are rather poor in comparison with other European countries. 1600 m^3 falls to one person in a typical year; in a dry year it is below 1450 m^3 [1]. In Spain such number is twice higher, and for all Europe this number equals to 4500 m^3. Retention ability of Polish reservoirs equals to 6% of the mean flow of the surface water per year. Moreover, it does not prevent against periodical excess of deficit of water. Our water resources vary at different seasons and their distribution is not uniform. The Podkarpacie region, especially its mountain part, belongs to the regions where the water resources are the most poor. Only 20% of all the underground water of that region occur in its mountain part. In this region there is a lack of rich aquiferous layers because of an unique geological structure, i.e the laminar Carpathian flysch. It is water-permeable (there are no faults and dislocations), so in this region there are very good conditions for small flood pools. Such conditions allow for high surface flows which can be significantly slowed down owing to renaturization of the flows and so-called “small retention”. The program of “small retention” gives the best results in mountain and forest areas, for example the Bieszczady mountains in the south of Poland. “Small retention” satisfies most requirements connected with ecological methods of water economics, and if it is correctly realized, it can help in improvement of natural values of ecosystems [ ]. The Podkarpacie region belongs to the mountains range of the Carpathian arc and the fall before the Carpathians. The region is very diversified considering its configurations and geological structure. Such diversification influences hydrography, climate, soils, flora and fauna etc.

Intense precipitations in the summer are very important for the idea of construction of flood pools. The mountain part of the region belongs to the Carpathian climate with thermal conditions varying depending on the site height.
Geological and hydrogeological conditions of the region in its mountain part are really suitable for the flood pools. The eastern Carpathians are built of flysch formations, weathered in their top layer. The eluvia usually occur as dust or dust clays. The external part of the massif contains flysch formations (Fig. 1), i.e. sandstone, mudstone, menillites, etc. [14].

Fig. 1. Outcrops of the Carpathian Flysch

The Bieszczady Mountains are the area where there are very good conditions for the considered reservoirs because of favourable tectonics and its effects. It appears from the tests realized in the Podkarpacie region it appears that the eluvia occurring under the surface are of a high volume, and from mineralogical tests it results that they are suitable for location of reservoirs because they guarantee the maximum tightness. Thus, construction of small earth dams or rock-fill dams probably will not require application of additional sealing elements. The eluvium of suitable parameters will play that role. The eluvia in the layers located just under the surface usually occur as dust or dust clays.

Generally speaking, in the flysch formations of the Podkarpacie region there are no advanced aquiferous layers. The minimum surface permeability is also an effect of mineralogical structure of the surface layers. Under moderate swelling, illite minerals seal the site surface and increase intensity of the surface flow. In a consequence, even relatively low precipitations cause a flood situation at many water-courses and rivers in the Poskarpacie region. Thus, construction of multi-functional pools of small retention on the limited areas protects the water-courses of the Podkarpacie region against the results of floods. The proposed idea increases pure water resources, influences beauty of the region. It also changes geotechnical conditions and improves stabilization of slopes, protects against landslides.

The proposed idea seems to be reasonable because in 1995 in Japan 360 such reservoirs were built in the mountains, and the country was protected against floods. At the same time, suitable amount of water was delivered for rice growing (Japan is an important exporter of rice at present).

Let us note that the considered pools are located in the mountains, and the cofferdams baffling the valleys are made of soil concrete because of a large amount of montmorillonite in the rock eluvia. In the past in Andalusia the Moor engineers built the reservoirs used for the purposes of agriculture, and this area of Spain developed very quickly. Let us remember that the proposed pools should be supplied by water flowing from the eastern Carpathians being an enclave of unique environmental conditions.

Water-bearing character of the flysch rocks is connected with their slots – it results from their low porosity, i.e. from 0.02 to 0.1. The flow in the interporous spaces is difficult because of their small dimensions; moreover they are filled with the weathered illite fraction, susceptible to shrinkage and swelling, decreasing water absorbability of the flysch, sometimes to zero. Water absorbability gets worse as the depth of layer deposits rises. Resources of underground water is very low, there are no water-bearing layers. Water is stopped and occurs only in the cracked rocks. Under such conditions, precipitation waters can easily flow to the water-courses, and next to the fall before the Carpathians where they supply the reservoir of underground waters. From that reservoir they flow through the underground gutters to the basin of the Dniestr River. Minimal surface permeability is also an effect of mineralogical structure of surface layers, i.e. illite and smectite minerals. Because of swelling, these minerals seal the surface and increase intensity of the surface run-off. In a consequence, even relatively small amount of precipitations cause floods at many rivers and water-courses of the Podkarpacie region.

Climate variation causes serious rain-storms which are very dangerous for inhabitants of the Podkarpacie region. Such storm took place on the 26th July, 2005 near locality Zagórz. Some villages were flooded in a very short time. The mentioned above example of Japan also proves that the proposed solution seems to be reasonable.

II. THE PREDICTED KINDS OF FLOOD POOLS

Rational management of water resources in the Podkarpacie region requires minimization of their variation at time and space (periods of drought and flood). Thus, retention must be developed in the area of the basin. Construction of small multi-functional pools is recommended. In management of each pool one function here is usually dominating (flood protection, touristic, ecological or energy function and so on), and other tasks are assigned as that main function. In practice, there are pools satisfying two or three main economic tasks at the same time depending on local needs. .

There is no one official classification of flood pools. So-called “small retention” includes all the microreservoirs, and small pools positively influencing the environment [10]. Small pools are usually of total volume to 0.1 of million m^3 and the maximum swell height 5 m. They are built one by one, or in a cascade system [12]. All the cascade is usually used for energetic purposes. The systems of small retention pools are proposed instead of one big reservoir. In Bieszczady mountains there are many river valleys (Fig.2) which are good places for the proposed flood pools. In the past many people lived in those valleys, at present they uninhabited.

According to the proposed concept, reservoirs – depending on their location – can be flood pools, equalizing tanks, they can also be auxiliary reservoirs near big flood pools [3]. Some reservoirs should play the role of flow reservoirs formed as a result of partition of water-courses. Dry reservoirs are also provided as anti-flood protection. They will be accumulate the flowing eluvium or organic products.

Fig. 2. An exemplary site for a reservoir in the Bieszczady Mountains

In the considered region, the intense precipitations, of big slopes of the ground and the flysch substrate cause intense run-off of the weathered flysch layer, sometimes being like an avalanche. The rubble occurring in the reservoirs and flumes of water-courses causes that they become more and more shallow. Thus, construction of dry reservoirs is. In the considered area there are unusual conditions of flysch weathering, especially biological weathering. Such conditions are a result of rich afforestation. Generally speaking, in the considered region plan dry reservoirs it will be possible to plan dry reservoirs where will be accumulate the flowing weathered eluvia or organic products. Such places will be the programmed enclave of the intense development of flora and fauna and, we can also expect favourable humus processes.

III. APPLICATION OF FLYSCH ELUVIA FOR CONSTRUCTION OF COFFERDAMS

From the investigations on landslides in the Podkarpacie area it appears that the eluvia existing under the site surface are of a large thickness. From mineralogical tests it results that such eluvia are very good for location of reservoirs because they provide the maximum tightness. Thus, construction of small earth dams will not require additional sealing elements. This role should be played by a layer of eluvium of suitable parameters.

Experience obtained while investigations on marl eluvia as well as the elaborated test methods were applied for investigations of he Carpathian flysch and dust soils occurring in the river terraces, grounds of loess massif, illite clays and baidelite clays [4,5]. These grounds are susceptible to moisture changes accompanied by shrinkage and swelling as well as petrification. This property is strictly connected with presence of illite in mineralogical composition of the considered media. Even a very small amount of that mineral influences joints of the basic minerals.

The samples prepared of eluvium shales were tested and next the obtained results were compared with the results obtained for the samples from river valleys treated as the accumulated sediment of the flysch eluvium [5]. The test were carried out in order to estimate usability of flysch eluvia for construction of cofferdams by identification of clayey minerals. Differentiation of these minerals is important because the contents of smectite groups exerts an unfavourable influence on setting and hardening of ground concrete [11]. As for the considered ground media, their basic geotechnical parameters were tested and special attention was paid to swelling tests allowing to distinguish clayey minerals. Before the swelling tests, physical, chemical and strength tests as well as mineralogical tests of the considered media were carried out [4, 6]. Recognition of the grounds was based on chemical and mineralogical compositions by means of fluorescence, X-ray difractommetry and scanning microscopy. Moreover, derivatographic analysis was realized. Recognition of microstructure of the clays with so-called hidden swelling parameter were carried out by means of scanning microscopy. The mentioned tests of chemical composition (Fig.3) show the presence of potassium which occurs only in illite. It was proved by tests realized by means of the scanning electron microscope (SEM).

The tests of flysch swelling, swelling clay or the media with so-called hidden swelling parameter used the method described previously [8]. This method allows for cheap tests of flysch eluvia and estimation of their usability. Identification of illite in the flysch eluvium allows to qualify it as a material for construction of cofferdams because of moderate shrinkage and swelling as well as favourable petrification and sealing properties. Moreover, the proposed tests could help in selection of places for reservoir location into taking a proper tightness of the ground account.

Presence of illite being an aluminosilicate responsible for eluvium petrification allows for application of flysch chips and flysch eluvia for construction of earth cofferdams sccording to the proposed construction of multi-functional pools in the Bieszczady Mountains [3]. In Japan, the flood pools were located in the mountains and the cofferdams in the valleys were the ground-concrete is made. The eluvia occurring in Japan contain montmorillonites, so formation of cofferdrams is difficult, because it is necessary to add much cement to the eluvia. It is also necessary to take care of ground-concrete because of formation of scratches caused by shrinkage of montmorillonite [13].

Construction of cofferdrams using flysch chips and flysch eluvia is considered for each reservoir in Bieszczady, depending on its geological structure. Of course, a suitable amount of clayey minerals for petrification and sealing is necessary. If there are no enough illite minerals in the eluvium, we must consider a solution using geotextiles and sealing foils for cofferdrams, and materials offered by such firms as Tensar International Corporation, Ten Cate Geosynthetics and Geobrugg.

IV. THE PROPOSED TESTS FOR DETERMINATION OF THE ELUVIUM AREAS ESPECIALLY SUSCEPTIBLE TO FORMATION OF MUD AVALANCHES IN THE MOUNTAINS SITES

Experience obtained in the while works on marl eluvia [2,4,7], and the elaborated test methods were used during tests of Carpathian flysch and dust soils occurring in river terraces generated as a result of the eluvia accumulation [5,11].

The samples prepared from the shale eluvia were tested and compared with the samples from the river valleys, treated as the accumulated sediment of the flysch eluvium. The basic geotechnical parameters of the considered ground media were tested. Special attention was paid to swelling tests allowing to identify clayey minerals. At present, the author is engaged in works connected with the causes of mud avalanches formation. In such cases, hydraulic conditions and influence of mineralogical composition should be taken into account. Tests of susceptibility of the soft rocks for formation of the mud avalanches could be limited to drawing of eluvium samples occurring at the slope. The samples should be subjected to swelling tests by means of the method given in the some previous papers [4,8,11]. This simple method allows to identify clayey minerals responsible for swelling, occurring in the rocks. While tests we use the presence of endothermic maxima – the temperature points at which the heated sample loses contents of bound water. The author found that minerals from the groups of monmorillonite and illite (causing swelling) lost that water at the temperature up to 200 degrees, and kaolinite – at 600 degree. Thus, the comminuted eluvium sample prepared to the standard swelling test and free from water, subjected to the swelling test manifests swelling up to tens %. Under such conditions, the kaolinite sample swells up to some %. Let us remember that montmorillonites soak to 700%, while kaolinite soaks to 90%.

4.1 THE PROPOSED METHOD OF EXAMINATION OF CLAY MINERALS

Application of the method of swelling ability test, given in the author's earlier works [2,4,8] was proposed as method of determining the content of illite and smectite minerals. It has been prooved so far that it is just these minerals that are responsible for moisture changes, extreme strength parameters and processes of petrification and maximum moisturizing. Tests were carried out on the material taken from the deposit of different breakups, and samples were grouped in accordance with the diameter of sieve meshes. With the method of successive trials, it has been found that the most stable and real results are obtained by conducting the tests in the following way [11]:

1. The material undergoes a preliminaryair-drying in the case of water content so that in can be sifted through the of Ø=0.76 mm
2. the material thus prepared is subjected to moisture content near to the plasticity limit(during the trial of roller bursts at the first or second instant) and is subjected to working (just like a typical "dough")
3. forming the material into the "cake" – like shape of 10 mm in height
4. then , samples with the diameter Ø=50mm and 65 mm and the height of 10 mm and 20 mm are cut by means of a ring
5. the samples thus prepared are weighed and dried in a drier at a temperature of 200 C for the period from two hours until reaching constant weight
6. after drying and cooling process the samples are weighed to determine their water content
7. the samples are subjected for the examination of swelling minerals in the apparatus testing unbounded swelling
8. After swelling has been defined the final moisture is determined.

The considered test informs us about the amounts and kinds of swelling minerals in the point of sampling. Thus, we get also the data concerning ability of the tested rock medium to water stoppage and moisture degree, as well as the maximum moisture occurring under natural conditions.

Fig.3.Examples of rocks samples after the investigation

After swelling, the sample moisture is the maximum moisture, under which we get the worst numerical values of the strength parameters. Under such conditions, landslides are possible. In our analysis, soft rocks are treated as mixtures containing much clayey minerals. In the case of occurrence of greater contents of montmoryllonite, greater amount of moisture is present and it is accompanied by fluidization and formation of mud avalanches. Similarly, content of the swelling minerals in higher parts of mountains causes their collecting in the rock slots. Then, possibility of landslides and rock falls increases.

The swelling investigations were preceded by physical, chemical and strength tests of the considered media. Recognition of such soils were based on tests of chemical and mineralogical composition by means of fluorescence and X-ray diffraction method. Moreover, derivatographic analyses were performed. Tests of clay structure with so-called swelling parameter were realized by means of scanning microscopy(SEM) utilization of SEM, derivatogram method, fluorescence, diffraction method,.

Simple analyses and tests according to the discussed swelling tests allow to identify sites which can be easily subjected to mud avalanches and rock falls. Such information are very useful for the site management.

VI. CONCLUSIONS

6.1. Suitable geological (soft rocks) structure allows for cheap construction of reservoirs. Dislocations and fault fissures filled with weathering materials because of their mineralogical structure, i.e. swelling minerals cause self-sealing of the bottom. A lack of water-bearing layers eliminates uncontrolled outlet of water to the ground.

6.2. Distinct improvement of protection against floods is an advantage of the proposed solution (see the mentioned solution in Japan). At present, intense precipitations are transported to water-courses and rivers because they cannot percolate to the ground (it is favourable for reservoir structure).

6.3. Water supply for inhabitants of a given region and water collecting in reservoirs can be very important in the future. Large amount of water of high quality should be a valuable good. Water resources could influence future development of many regions.

6.4. Construction of the considered reservoirs is rather cheap because it is possible to introduce unified earth cofferdrams using ground-concrete as a construction material.

6.5. Introduction of the considered reservoirs could help in generation of new places of employment (construction and service, tourists' service)

6.6. Some reservoirs could be used in energetics.

REFERENS

[1] Bogacz – Rygas M : (2007) Aspekty ekologiczne stosowania nowych rozwiązań odprowadzania wód opadowych i ich zagospodarowanie(in polish),. Wavin Metalplast-Buk.Kielce.

[2] Jaremski J.:(1994) Influence of physical and chemical processes occurring in eluvium of the Opole marls and their influence on the geotechnical parameters, Proceedings of the 7th International Congress IAEG, Lisboa , A.A Balkema, 859-868.

[3] Jaremski J.:(2007) O niektórych aspektach budowy wielofunkcyjnych zbiorników retencyjnych w części górzystej województwa podkarpackiego. Cywilizacja i żywioły, (in polish), seria: Monografie Instytutu Meteorologii i Gospodarki Wodnej, Warszawa.

[4] Jaremski J.:(1995) Proposal for a method determining value of the maximum swelling of soil by example of the Opole marls eluvium and illite clays. Proc. of 8th Int. Cong. on Rock Mechanics, Tokyo, A.A.Balkema.

[5] Jaremski J.:(2004) The influence of changes of weathering water content on the formation of landslides in the Carpathian Flysch. Proc. of 9th Australia New Zealand Conference on Geomechanics, Auckland – February 2004, New Zealand Geotechnical Society Inc.

[6] Jaremski J,:(2005), The influence of physical and chemical processes occurring in the weathered Opole marls on the geotechnical parameters, Publishing House of Rzeszów University of Technology, 2005,p. 98.

[7] Jaremski J.(1991), Creep property of Opole marls weathering on the base of the model laboratory research and the research " in situ" , Proceedings of the 7th International Congress on Rocks Mechanics, Aachen, A.A. Balkema, 1991, 269-273.

[8] Jaremski J :(1994) Proposal for method of stating the value of maximum swelling of the soil on the example of Opole marls eluvium. Proc. 3th Int. Conf. on Trop. Resid. Soils., Maseru, A.A.Balkema,

[9] Jaremski J :(1990) Analysis of swelling of marl eluvium of water infiltration. Proc. 6th Int. Cong. IAEG. Amsterdam, A.A. Balkema, Rotterdam.

[10] Jaremski J.:(2010) Aspekty geotechniczne w ochronie zasobów wodnych województwa podkarpackiego. Inżynieria Morska i Geotechnika (in polish), nr. 1. Gdańsk 2010.

[11] Jaremski J.:(2010), Influence of moisture changes on physico - chemical processes and geotechnical parameters in soft rocks, Studia Geotechnica et Mechanica, Vol. XXXII, No. 1, 2010

[12] Mioduszewski W.:(2008) Mała retencja w lasach elementem kształtowania i ochrony zasobów wodnych. Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej R. 10. Zeszyt 2 (18) (in polish) .

[13] WAKIZAKA Y.:(1994) Influence of montmorillonite group Bering aggregates on concrete. 7th International IAEG Congress, A.A. Balkema 1994, s. 3285-3294.

[14] Zabuski L., Thiel K., Bober L.(1999), Landslides in Polish Carpathian Flysch, (in polish), IBWN PAN, Gdańsk, p. 172.