GEOLOGICAL CHARACTERICS OF THE TERRAIN IN THE NERETVA RIVER BED'S PART REGULATION AREA

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Treated area in this paper starts from the barrage point of the HPP Jablanica dam, from P98 until the bridge of Bukov pod, P77. Due to regulation of spillway and dam bottom outlet, as well as bed's part regulation directly beneath the dam and output organs, geological recognition of the terrain has been performed with geological mapping of the river's bed and slope sides. The space in which is considered the regulation of spillway, as well as bed regulation is made of Lower Triassic rocks, magmatic rocks of Gabbros and of river deposit like gravel, sand, large and fine-grained crushed stones. In hydrogeological sense, the terrain which has been made of rock masses like Verfene schist seria, Gabbros and Quaternary sediments, has various hydrogeological characteristics and functions. Rocks with cracking porosity make Gabbros massive, those with cracking-bursting porosity are Verfene schist rocks, and rocks with intergranular porosity make Quaternary sediments of river deposits, diluvia and proluvial deposits in slopes and side river flows.

In engineering-geological sense, depends on tectonically damage, these rock masses suffered changes in sense of physical-mechanical characteristics. Thus Gabbros, according to its engineering-geological characteristics represents connected, hard, stony rocks pervious to close-surface decay. Verfenic sediments, in lithological view, represent complex of shale feldspars, layered limestones and marls, marl limestones and alevrolites, and as such, they have various physical-mechanical characteristics. Feldspars belong to half-stoned silicate rocks, and limestones belong to the group of stoned carbonate crystal-kind and crypto-crystal-kind rocks. Quaternary rocks in view of river deposit are represented by unconnected rocky masses of changeable petrographic and granulometric composition. In half-connected rocky masses there belong conglomerates and clays from slope sides of the river flow and side tributaries.

Key words: *regulation, bed, river, spillway regulation, geological characteristics, hydrogeological, engineering-geological.*

GEOGRAPHICAL POSITION

The researched terrain is situated in the Central Bosnia region. Access to the dam in a downstream part is possible from direction of Jablanica, where highway towards the dam is detached and continues towards Prozor. Access to the left river side is possible over the Bukov pod bridge and further partially by local way and by the Neretva River abandoned bed.

The Neretva River valley stretching direction in the observed area is north-south. Terrain is highland area.

In hypsometric regard, the terrain in space of the dam and valley bottom of the Neretva River abandoned bed is on the highest elevation such are Čeharski vrh 827 m above sea

level and Oskoruša 781 m above sea level. In the area of Bukov pod at the bridge, the lowest observed height is 230 m above sea level where planned bed regulation is supposed to end. Vegetation cover is very poor and undeveloped concerning the fact that the terrain is quite devastated due to gabbro exploitation.

GEOLOGICAL STRUCTURE AND TECTONIC CONSTITUTION OFTHE TERRAIN

Wider area of the Neretva River bed is made of sediments of Lower Trias (T_1^2)-verfene, magmatic sediments of gabbro (n) and Quaternary sediments (Q).

Lower Trias sediments - verfene (T_1^2) represent the oldest products in the subject area. Those are clastic-carbonate sediments, shales, clays, alevrolites, marls and scuds of marl limestones. The whole set is characterized with rotation of various lithological parts. Older verfenic parts were made of clay-marl rocks and in younger ones participation of carbonate substance dominates. Macroscopically, in the whole set can be asserted the presence of bituminous material as well, which gives the set characteristic grey-black appearance.

Gabbro (n) appears in several varieties and has the shape of laccolite. Inside the massive, rock varieties are stated as follows:

1 biotitic-amphibolic gabbro which forms about 53 % of total mass;
2 amphibolic gabbro builds about 17 % of the massive
3 norite (hypersthene) gabbro which forms about 18 %
4 normal gabbro and olivine gabbro are more subordinated and they form about 6 %.

Intrusion of this magmatic rock is post-anisian age. Upper limit has not been determined yet. It is only known that gabbro has perforated verfenic layers. Intrusion thus formed is post-consolidation caught by intensive tectonic movements so the border on mapped part of the terrain has gabbro-verfene tectonic character. In the narrower part of the dam especially are often varieties of amphibolic (basic plagioclase +augite) and biotitic (basic plagioclase + biotitic) gabbros.

Quaternary deposits are the youngest products usually unconnected or slightly connected rocks with locally spreading. They are made of slightly connected conglomerates which are situated on the left side of the Neretva River upstream from Jablanica where they mostly form eroded terraces of diluvia age. They are made of rounded fragments mainly of carbonate composition and subordinated of gabbro and verfenic rocks.

Alluvial deposits in the Neretva Valley and its tributaries are made of sands, gravel and clay of various compositions.

Concerning flood character of tributaries in this area, on their moths in the Neretva currently abandoned bed, thick proluvial deposits have been formed where sediments with various roundness and granulation are presented. Those are mostly sediments with origin from verfene and gabbro massive. Alluvial-diluvia covering was formed almost in the whole area with thickness that only locally exceeds the thickness of 1m, and which was built from verfenic small crushed stones that shred into clay, crushed stones, and gabbro's gruss.

In a structure-tectonic means, the wider area of the observed space is from southwest limited by tectonic unit of high karst, and from northeast by tectonic unit of the inside

Dinarides. Only a small part inside that unit has been caught by intensive tectonic movements for the time of multiphase collection.

Intensive tectonic movements were especially manifested in the set of verfenic sediments (T_1^2). Due to their physical-mechanical characteristics, verfenic rocks behave like very plastic masses under high pressures. That is reflected through many gathers registered in the terrain, and which move from centimetre to hectometre sizes. Limestone scuds in clay-marl rocks partially behaved like hard masses, so they often have irregular position in view of lentil-like and irregular shapes of accumulation in set of shale feldspars and marls. Such intensive tectonic movements have caused forming, beside plicative ones and yet very often flattened and upturn structures, stronger rupture break structures and tectonic deformations of lower layer – crack systems.

Registered faults, as well as assumed ones, have almost north-south stretching direction with tendency of binding towards northeast so generally, they cut verfenic shale set vertically. Verfene set stretching direction is dinaric in general, northwest-southeast.

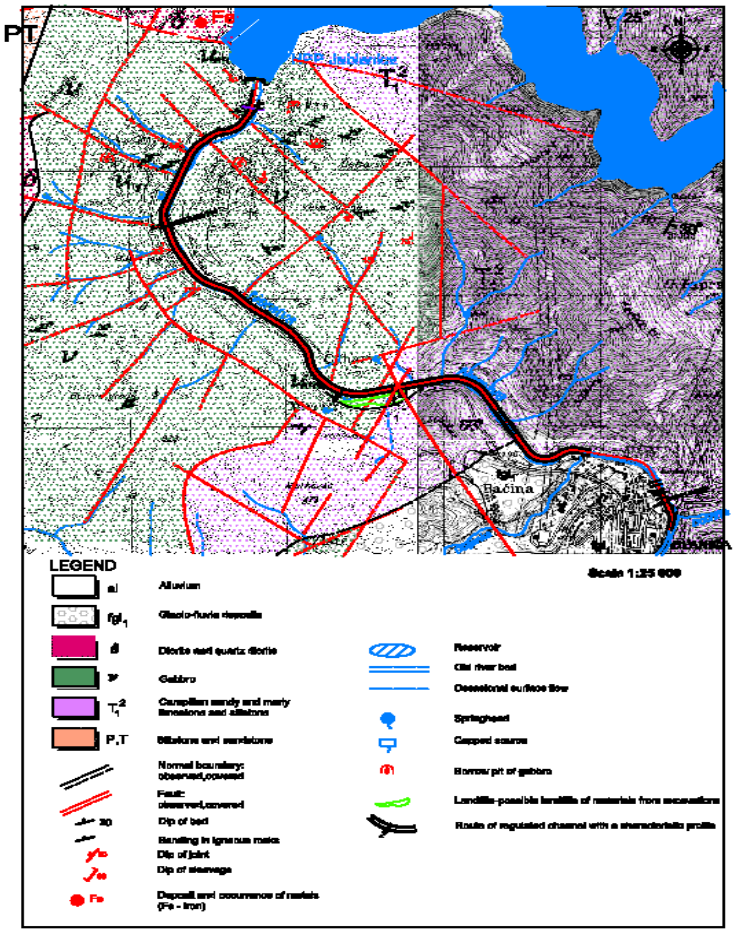

Fig. 1. Geological map.

The middle size of dip angles amounts $10\text{-}30^0$. Azimuths of dip angles are mostly oriented towards northeast. Local deviations of stretching direction and of fall of the whole set are very often, what is normal, concerning intensive tectonic movements with which the set was overtaken (higher collection phases of Alpine orogenesis) as well as plasticity of the whole set.

On the base of so far known data, the border verfene-gabbro, have fault character in the whole area. The whole gabbro massive in the vicinity of the dam, in its close-surface part has been significantly cracked. Cracks are consequences of various factors: from magma contractions to the insolation process and part of gabbro massive into blocks with various shapes.

HYDROGEOLOGIC CHARACTERISTICS OF THE TERRAIN

Geological structure of this terrain is made of rocks with various hydrogeological characteristics and the rocks can be sorted out like:

1 slightly permeable rocks with crack porosity

2 slightly to impermeable rocks with crack-split porosity and

3 very permeable rocks with intergranular porosity

Rocks with crack porosity make gabbro massive. Gabbro massive was significantly cracked in parts close to surface. It contains water in cracks and has characteristic of hydrogeological collector and yet in higher hypsometric parts with conductivity function, and in parts with the level fall of lake and the Neretva River, it has the function of collector and reservoir. Wider observed space, starting from barrier place of the Jablanica dam all to Čehari in downstream part, in geological sense are made of magmatic rocks – gabbro which in hydrogeological sense are represented by slightly permeable rocks to impermeable rock masses. However, local conditions, such are stronger discontinuity, connection among open cracks, spatial hypsometric position, and special existence of the formed Jablanica lake are conditioned that these rocks partially have also function of hydrogeological collectors with crack type of porosity – conductors and reservoirs.

Rocks with crack-split porosity are verfenic shale rocks (T_1^2) which have been significantly cracked in their close-surface parts, so the water-bearing horizon is formed in it at depth of couple of meters at most. Linkage and disaggregation of cracks is relatively small, so that water-bearing horizon is not continuous in a wide area, and its drainage is done over small number of springs. Larger spring is registered in a contact between verfene and gabbro in Čehari, with capacity of several l/s at maximum outlet. Observed in the whole, verfenic shale set, partially gabbro as well, have characteristics of hydrogeological isolators, and especially in deeper parts.

Rocks with intergranular porosity are quaternary age represented by conglomerates, gravels, sands, clay and crushed stones. Permeability is very changeable. If participation of clay material is dominant in them, then they are almost impermeable to slightly permeable.

Mostly, those are eluvia, diluvia and proluvial coverings. Bed and river terraces are made of river deposits of gravel, sands, and blocks and crushed stones which in hydrogeological sense make very permeable rock masses. They are situated along the whole river bed with changeable thickness of one to several tens of meters. As the exploitation of gabbro is performed at slope sides, it comes to uncontrolled disposal of waste parts down the slope, and thus to the river bed as well. This material is artificially deposited and as such, it participates and makes the rock complex being the one with intergranular porosity. Those are mainly blocks and crushed stones of degraded gabbro.

ENGINEERING-GEOLOGICAL CHARACTERISTICS OF THE TERRAIN

Verfenic sediments, which are situated downstream from the place of Čehari, take part in geological structure and tectonically they are divided from gabbro massive. These rocks have been made of shale feldspars, layered limestones and marls, marl limestones and alevrolites, so they have also very different physical-mechanical characteristics. On the base of engineering-geological characteristics, feldspars belong to the group of half stony silicate rocks, and limestones, which belong to the group of stony, carbonate, crystal and crypto-crystal rocks, have the most favourable physical-mechanical characteristics. These rocks replace each other in the terrain in view of coot like, laminated, and thin-layer parts with thickness of several mm like, for example, coot shale feldspars all until several tens of cm like marl limestones and limestones. That is why their engineering-geological characteristics should be observed complexly, like addition of single characteristics of all mentioned lithological parts, and they are treated like engineering-geological complex. Layering is an important characteristic of verfenic rocks, because according to inter-layer surfaces, they are divided into coots, plates, and thinner layers. Besides layering, schistosity is clearly expressed, which is parallel to layering and is characterized with plan-parallel orientation of coot minerals in marls and alevrolites. In limestones, schistosity is less noted. When performing works in these stones, one can expect clear detaching of rock in plate coots and thinner layers.

Discontinuity is also expressed in verfenic complex and the most intensive one is in fault zones where rocks are totally crushed and as such, with very bad physical-mechanical characteristics. In these zones the content of clay substance is often increased, and the circulation of underground water is more intensive as well. Smaller cracks and splits are most often full with calcite, but they do not weaken the rock mass in fault zones and zones of longer and deeper cracks which separate the massive into blocks. On the whole, discontinuity of verfenic rocks, concerning the regulation is not so intensively expressed that it could cause barriers at works except in fault and stronger crack zones.

Special kind of discontinuity, cleavage, sporadically is clearly observed and manifested as a system of splits and smaller cracks under certain angle compares to layering, depends on the part of structure it has been registered.

Beside these characteristics, verfenic rock complex is characterized with clear expressed anisotropy of physical-mechanical characteristics concerning various lithological articles in it. The compression strength as well, significantly varies depends on composition and tectonic damage of the rock, and it goes from several tens of kg/cm^2 in close-surface parts of feldspars until around 1000 kg/cm^2 in limestones.

With decay of these rocks, clayish crushed stones are formed with very unfavourable physical-mechanical characteristics, and as they are submissive to decay, more often that

process is developed until the depth of few meters, and in combination with discontinuity it causes the forming of landslides and unstable slopes.

The area of the dam barrier place and downstream part of the terrain has been made of magmatic formations of gabbro, called Jablanica's gabbro. According to its engineering-geological characteristics, gabbro belongs to the group of stony rocks. That is silicate, massive, completely crystallized rock with granular structure. In a narrower dam space, biotitic and amphibolic gabbro varieties are especially often, with its parallel textures on which some more important cracks also originated, better said, the whole group of parallel cracks.

Observing structural-texture characteristics of the total gabbro mass, one can conclude that it is quite monotonous. Those are almost rocks with middle grain size, only sometimes with larger pegmatite differentions. Their texture in greatest part is massive, and rare parallel and yet especially in varieties of amphibolic and biotitic gabbros. Here shaly gabbro is often noticed, which, when amphibolic varieties are about, then turns into amphibolic shales.

In the very vicinity of the dam, there have been noticed narrow zones of shaly gabbro which has been grussificated after. Grussificated gabbro is noticed as well along spherical cracks which detach round blocks. It is general appearance that gabbro is disintegrated on the surface, what is manifested with making of gruss and later humus as well. Especially large groups of gruss we can find in rim parts of gabbro in which the dam has been situated. From that have arisen famous difficulties around slope mending above the dam on the left riverside. On open profiles one can follows the „mechanism" of grussification which is developed from the rim parts of spheroid blocks towards inland.

According to engineering-geological classifications, gabbro is sorted in solid, stony rocks which have compression strength cca 1800-2000 kg/cm^2. Gabbro is silicate, massive totally crystallized rock with granular structure. According to sources, allowed weight is from 15-40 kg/cm^2. Resistance at notching marked with „f" according to F.P. Savremenski amounts 10-20.

Discontinuity is one of important characteristics of gabbro which in great measure impacts geomechanical characteristics as well as hydrogeological function of these rocks. Cracks which are consequences of several of factors, from magma contraction to insolation process, divide gabbro mass into bodies with different shapes. The greatest importance for specific area have cracks which set out blocks of spherical shape and along which grussification is the most intensive. Thus detached blocks represent the most instable parts of gabbro mass in geotechnical sense, and gruss drainage opens the ways to water, and enable water fluidity in larger quantities.

Quaternary rocks such are conglomerates, gravel, sand clay and crushed stones, belong to the group of half-connected and unconnected rocks, and engineering-geological characteristics vary depends on degree of consolidation, clearness, water influence and so. In the observed space of river bed, important are sediments of river deposits and slope crushed stones. They are situated as larger accumulation in the river bed and as such they become problem in regulation of larger flow at activation of flow fields and with that, undisturbed outlet when water level is higher. That's the purpose this regulation has been planned for.

Engineering-geological conditions on the regulation of the Bukov pod bed-dam-bridge

With elaborate working out for the Main project the treated area is covered, started from the barrier place of the hydroelectricity (HE) Jablanica dam, from P98, st. 5+487,66-P105, st. 5+745; from P98, st. 5+487,66 all to the Bukov pod bridge, P77, st. 4+357,47. The area was treated with aim of spillway and basic dam outlet regulation, and regulation of the part of bed just beneath the dam and exit organs.

In geological structure of this area gabbro sediments participate as magmatic rocks and Quaternary sediments.

Petrographically viewed, rock massive is built of biotitic gabbro, with granular structure and homogenic texture.

Physical-mechanical characteristics of gabbro are:

Volumetric weight g= 27 kN/m^3

Compression strength to 2800 kp/cm^2

A characteristic of gabbro is great wear resistant. Ejaculation of rock is in form of bank and parallelepiped.

Genetic origin of cracks is from ejaculation and tectonic movements. There prevail two directions of crack stretching: northeast-southwest and northwest-southeast and they fall steep under the angle of 80-85^0. The size of cracks gape moves from 1 to 10 cm and somewhere they are even larger. Larger cracks are mainly tectonic origin and they permeate deep into the rock massive and are filled with crushed, grussificated and clayish material.

Cracks cut rock mass into blocks of various sizes. Size and number of cracks, as well as the composition of fill, are very unfavourable appearances, in our case in the place of spillway, because overflowed jet easily irrigates the fill so the blocks are created, easily segregated from basic rock mass by the jet energy.

In summer 1975, spillway deflation was done in order to examine the condition in the spillway area. Then, numerous cracks and division on blocks were noticed, as well as the rest material at the bottom.

Quaternary sediments mostly build the river bed in sense of river deposit and gabbro crushed stones which were deposited and accumulated in the river bed. Those are unconnected rocks with changeable petrographic and granulometric composition and equable physical-mechanical characteristics. Basically, they lie at the bottom of river as well as slopes. Thickness of deposits moves from 4 to 9 m, most often 4-6 m.

The Jablanica dam is arch-gravitation type, building height of 80 m and with overflow on the top of dam.

After dam was built, the spillway was not specially constructed but left so that overflowed jet forms natural spillway place in the very abandoned river bed. When the dam was finished, it was approached to organizing of erosion impact of overflowed jet in the spillway area. During 1995 permanent profiles were set for measuring of soil erosion in the spillway and the first measures were performed then. Due to lasting and frequent jets, in that year measures were not possible to be performed in complete. Since that year up today systematically and regular measures have been performed in the bed, in the spillway area, and after every long lasting jet.

Erosion process was the fastest in period 1955-1957 and then it was discussed the need of building a bench in spillway with aim of raising the water in already created stilling basin, in order to decrease erosive jet impact. However, the results of later observations and measures pointed out that the erosion process in the spillway bottom got normal flow of grow, so it was left to develop normally, but with regular control. After lasting jets in period

1955-1957 measured depth of water in created stilling basin amounted already 5 m, which means that energy of overflowed jet performed deepen of the bottom until elevation 195. In that period 4 flow fields worked at the same time.

Area in which the spillway was formed is part of abandoned river bed of the Neretva River, beneath the dam. Width of the bed amounts approximately 50 m. The bottom of the spillway then was covered by the river deposit thickness 8-9 m, composed of river rounded fragments of larger size and partially stony material left from the dam scoop. Original bottom was situated on elevation 200 and basic rock, on which deposit lied, is situated between elevations 191 and 192. The position of basic rock is determined on the base of foundations of basic outlet which was funded in a rock. Visiting the terrain in downstream part of basic outlet, on the right side of the bed, gabbro outcrops are perceived as well.

In 1995 were set 18 measuring profiles on the spillway to monitor erosion actions of overflowed jet. Later, because of need, there were added 3 more, so from then on, measures have been taken on 21 profiles. Measuring profiles include the bed's length of 75.30 m.

At drafting of this elaborate, in the phase of visiting the terrain as well as working out of project documentation, it was determined that condition on the terrain has been changed in compare to the previous study. The river bed is quite damaged in the area of basic outlet. It is estimated that thickness of deposit is less for 2-3 m. Concerning that jets were done in January and March 2013, small fractions in this part were carried away, while the larger ones with blocks and gabbro pieces were stayed. Small fractions are presented in downstream part of the bed between P92 and P89. In downstream part until the **Bukov pod** bridge, along with filtration of the river flow, there are visible some larger gabbro fractions in shape of pieces and rounded fragments of the same. Concerning the vicinity of outcrops along the bed, here is to expect less thickness of the river trailing deposit. On the left slope until the bed, along the whole flow there is deposited material from the nearby quarry. In case this material would be still deposited, there is the danger that it fills the bed as well, what additionally makes moving of large waters difficult and with that also movement of trailing deposit towards downstream part.

CONCLUSION

Treated area in this paper starts from the barrage point of the HE Jablanica dam, from P98 until the bridge of Bukov pod, P77. Due to regulation of waterfall spot and basic dam taphole, as well as bed's part regulation river Neretva directly beneath the dam and output organs, geological recognition of the terrain has been performed with geological mapping of the river's bed and slope sides. The space in which is considered the regulation of waterfall spot, as well as bed regulation is made of Lower Trias rocks, magmatic rocks of Gabbros and of river deposit like gravel, sand, large and fine-grained crushed stones.

In hydrogeological sense, the terrain which has been made of rock masses like Verfene schist seria, Gabbros and Quaternary sediments, has various hydrogeological characteristics and functions.

In engineering-geological sense, depends on tectonically damage, these rock masses suffered changes in sense of physical-mechanical characteristics.

After building the HE Jablanica dam, a spillway was formed in the abandoned bed, which deepens the bed after lasting jets. In a distance of cca 50 m from bounce of overflowed jet, also stilling basin was formed with 5 m depth, and the energy of overflowed

jet performed deepening of the bottom until elevation 195 (since 1955 to 1957). The process of deepening still continued but with less intensity. In the aim of removal of the river drift and deposited one from slope, deposits in the river bed, according to GN 200 belong to II, III, and subordinated to IV category in proportion 25%:40%:30%. As in this bed there exist also large blocks of gabbro, the ones should be chopped up or deposited on slopes as side-fort. For such materials is predicted usage of explosive means or machines which break this rock mass, and which suit to VII category of excavation. After removed deposit, it is to expect that these excavations will be performed in the basic rock mass of gabbro. Excavations in this rock mass would be performed in the VII category.

Depot which is predicted from P44-P55 is situated in the expanded river terrace on the right river side. In present conditions this part of the terrain is situated behind elevation of the regulated bed, on sleek part. As depot, it is possible if not endangers the existing regulated bed.

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