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80 YEARS OF DAMS CONSTRUCTION - THE KEY STRUCTURES OF HYDRO SYSTEMS IN REPULIC OF MACEDONIA

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ABSTRACT

This year we celebrate a significant jubilee – 80 years of dam engineering in Republic of Macedonia. Planning, design, construction and maintenance of dams are among the most responsible civil engineering works. The first dam in R. Macedonia, arch dam Matka, at the canyon of Treska River, near the city of Skopje, was built in 1938. Construction of this dam and its appurtenant structures marks the beginning of dam engineering in Republic of Macedonia. At present, in 2018, we can proudly state that dam constructors in R. Macedonia are worthy heirs and prolongers of the noble work of the first dam designers, dating to 1938. Confirmation of such statement is the fact that 45 dams with regional importance and over 110 embankment dams with local importance are the key pillar of the present water economy infrastructure. Republic of Macedonia is located in the central part of the Balkan Peninsula, and it covers an area of 25,713 km2 with a population of about 2.1 million. With over 150 built dams of basically all types (embankment and concrete dams, gravity and arch dams) categorized as "large dams" by ICOLD criteria, Republic of Macedonia, proportionally to its size, is located right at the top of dam engineering in Europe.

Key words: embankment and concrete dams, gravity and arch dams

1. INTRODUCTION - MATKA, THE FIRST DAM IN R. MACEDONIA

This year we celebrate a significant jubilee – 80 Years of Dam Engineering in R. Macedonia. Back in 1938, the first dam in R. Macedonia was built – Matka arch dam. By construction of the dam and the appurtenant structures, at the exit of the canyon of river Treska close to the city of Skopje (figure 1), was created reservoir Matka (figure 2). By completion of the construction works on the hydropower plant located in the base of the dam, the power use of river Treska commenced. The Matka dam Design was prepared by academician Miladin M. Pecinar (1893-1973), figure 3, one of the pioneers in the development of contemporary "Hydraulic Engineering" in Yugoslavia. At this occasion, here below a brief overview of the rich biography of academician Pecinar is presented, which by his noble work has indebted in great deal the Civil Engineering profession in R. Macedonia.

Miladin Pecinar graduated in Belgrade at the Technical Faculty, department of Civil Engineering, in 1921. In 1925 Pecinar created its own bureau for designing of water structures, where as he designed the following hydropower plants that were later constructed: Perukachko Vrelo on river Drina (1927), Chechevo (1929), Novi Pazar (1930), St. Andreja with the arch dam Matka (1938), Temshtica (1939), Crn Timok (1940). In that period, before World War II, in several mandates, Pecinar was vice president of the Association of Yugoslavian engineers and architects. In 1946 he became president of the Yugoslav section of the International Commission on Large Dams (ICOLD). In 1948 he was elected as professor at Chair of Hydraulic structures at Civil Engineering Faculty within the Technical University in Belgrade. As the most appreciated expert in field of hydrotechnics before, during and immediately after the World War II, Pecinar was elected as very first professor on the course "Hydraulic structures". On the XI World Conference on Energy in 1957, he was general rapporteur on the topic of the complex use of water resources. In 1959 he was elected as writing member for the Serbian Academy of Science and Arts (SASA) and later in 1963 was elected as Academy full member. He got retired in 1963 as full time professor at the Civil Engineering Faculty in Belgrade.

Fig. 1. Canyon Matka on the river Treska in 1935, before construction of the arch dam

Fig. 2. Downstream face of Matka dam, the first dam in R. Macedonia, built in 1938

It is worth noting that Pecinar for each hydropower plant that he designed, he also designed the appurtenant structures of the dam as well as the hydropower derivations. Aside from his ingenuity and enormous hydrotechnical talent, the greatness of academician Pecinar was also in combining experts of different

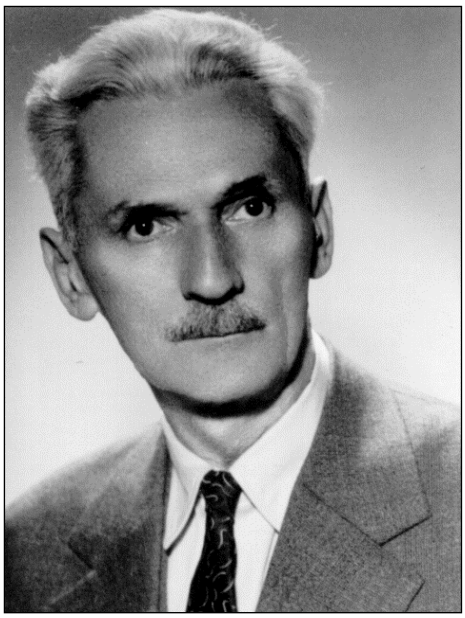

Fig. 3. Academician Miladin M. Pecinar, (1893-1973)

profiles thus creating both compatible and economically optimized structures, confirmed by Matka dam – a unique type of structure worldwide by many parameters. Accordingly, for the most important dam in R. Macedonia – Matka dam, the best experts at that time from various fields were in charge. Namely, the static stability analysis was made by Miodrag Marinkovic (later a professor at the Civil Engineering Faculty in Belgrade). Supervisor for concrete works was Djordje Lazarevic (later a professor at the Civil Engineering Faculty in Belgrade and full member of the Serbian Academy of Science and Art). Pavle Vukicevic was contractor of the dam (later a consultant at company Energoprojekt, Belgrade). Such approach by Pecinar resulted in building the Matka dam as "Penna Beff" type, second construction of such a dam in Europe (Denia dam in Spain was the first). In addition, Matka dam was the highest arch dam in the Kingdom of Yugoslavia (1918-1941), but also and the boldest arch dam in Yugoslavia in XX century, with slender coefficient equal to 0.054.

2. DYNAMICS OF LARGE DAMS CONSTRUCTION IN R. MACEDONIA

At present, in 2018, we can proudly state that dam constructors in R. Macedonia are worthy heirs and prolongers of the noble work of academician Pecinar, dating back to 1938. Confirmation of such statement is the fact that the key pillar of the our present water

economy infrastructure are 45 dams with regional importance, 4 of which are tailings dams, and over 110 embankment dams with local importance. The hydro systems with dams are mostly multipurpose, serving for irrigation, electricity production, flood control, water supply and guaranteed ecological discharge. With over 150 built dams of basically all types (embankment and concrete dams, gravity and arch dams) categorized as "large dams" by ICOLD criteria, shows that R. Macedonia, proportionally to its size, its located right at the top of dam engineering in Europe. It should be noted that the most significant water structures are designed and built by domestic companies, which is the best proof that in this period of eight decades was created well-known and respected Macedonian hydrotechnical school.

The central spot in the progress and improvement of the widely respected Macedonian school for Dam Engineering holds the Chair of Hydraulic Structures at Faculty of Civil Engineering in Skopje, created by establishment of the Technical Faculty in Skopje in 1949. The greatest merits for the development of the Chair of Hydraulic Structures belong to the following: Chair founder, prof. Bratislav Subanovic, that lectured the first classes in courses "Utilization of Water Power" and "Hydraulic Structures" in the so far away 1950 and was the head of the Chair until 1965; his heirs, prof. Mihajlo Serafimovski (retired since 1987), leading by great number of applicative works and designs, prof. Nikola Durned (retired since 2001) and prof. Dr. Ljubomir Tanchev (retired since 2010) – a person with the greatest scientific contribution to the Chair [Tanchev, 2014] and a professor that I had the privilege to be my teacher in the "world of dams".

According to the dynamics of large dams construction in R. Macedonia, regarding the 45 hydro-systems with regional importance (figure 4), we can divide three periods with different intensity of construction of dams: (1) the period of 60-ies of XX century or "gold period" for dam construction, (2) the last decade of XX century – period of great stagnation, in which period are built very few small fill dams and (3) first two decades of XXI century – period of intensifying dam construction by various and also new dam types. By the chart on figure 4, it can be stated that R. Macedonia has a solid tradition and continuity in designing and building dams that is required for proper knowledge transfer from one generation of hydrotechnics engineers to another and maintenance of high quality of work of the engineering companies in the field of Dam Engineering.

The first embankment dam, constructed in R. Macedonia, is Mavrovo dam, near Gostivar, with structural height of Hs = 62 m, built in 1957, figure 5. The most important dams in R. Macedonia from the golden period of dams construction [YUCOLD, 1970] are: several rock-fill dams with clay, two on River Crn Drim, Globochica, near Struga, Hs = 94.5 m, built in 1965 and Shpilje, near Debar, Hs = 112 m, built in 1968, figure 6, Tikvesh, near Kavadarci, on Crna River, Hs = 114 m, built in 1968 with hydraulic compaction (the highest embankment dam in ex Yugoslavia), figure

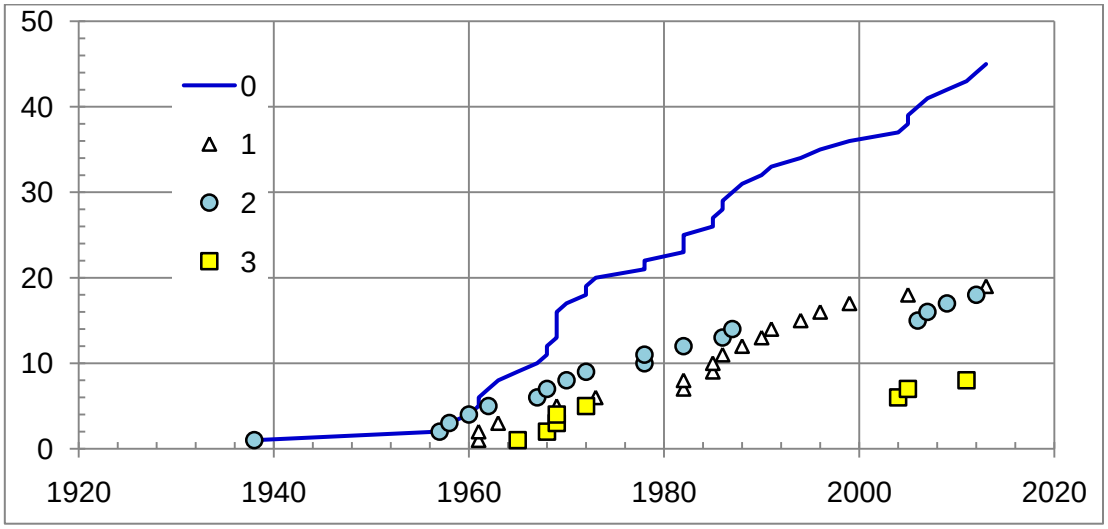

Fig. 4. Dynamics of construction of large dams in R. Macedonia, for 45 hydro-systems of regional importance. (0) in total, (1) low, H < 30m, (2) medium, H < 80m, (3) high, H < 150m

7, Kalimanci, near M. Kamenica on river Bregalnica, Hs = 95 m, built 1969, Prilep buttress dam, Hs = 36 m, built in 1967, figure 8 and Glazhnja, near Kumanovo, arch dam Hs = 81 m, built in 1972, figure 9.

Fig. 5. Mavrovo dam, constructed in 1957, first embankment dam in R. Macedonia

Fig. 6. Upstream slope of Shpilje dam, constructed in 1969

Fig. 7. Downstream slope of Tikvesh dam, constructed in 1968, the heighest embankment dam in ex Yugoslavia

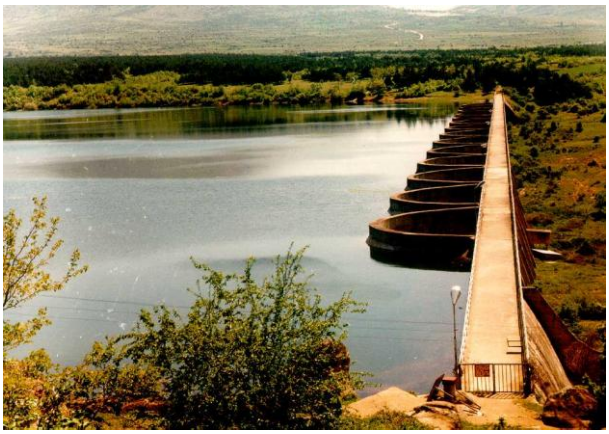

Fig. 8. Priplep dam, constructed in 1967, the unique buttress dam in R. Macedonia

Fig. 9. Glazhnja dam, constructed in 1972, the highest arch dam in R. Macedonia

In the past period of 80 years in R.Macedonia, practically all dam types have been built, in correlation that is common worldwide. According to the material type for dam construction (figure 10), 11 are concrete (24.4%) and 34 are embankment dams. Regarding the concrete dams, according to the structure, 8 of them are arch dams, 2 are massive dams and 1 is buttress dam. In case of fill dams, according to the local material, equally are constructed - 17 earth-fill and 17 rock-fill dams. From the rock-fill dams, mostly represented are earth-rock dams (impermeable element of natural clay material) and only 2 are rock-fill dams (with artificial impermeable element). Such dams are Loshana dam, near Delchevo, [Petkovski L., Paskalov T., 2003.], constructed in 2006 (with geomembrane facing) – first of such type in ex-Yugoslavia (figure 11), and Knezhevo dam, near Probishtip (figure 12), built in 2011 (with asphaltic core), first of such type in southeastern Europe [Petkovski L., 2007.06]. These two

dam cases in most obvious manner show the boldness and inventiveness of the present generation of hydrotechnics professionals in R. Macedonia. The latest significant large dam, built in R. Macedonia is double curved arch dam St. Petka on river Treska, Hs = 64 meters, constructed in 2012, figure 13.

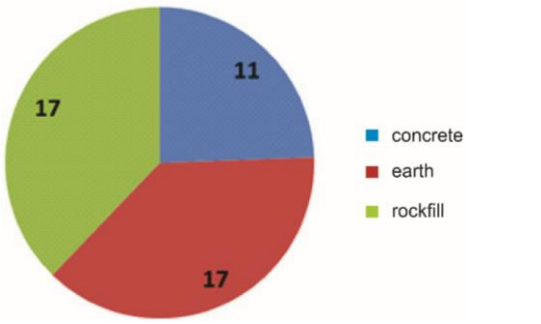

Fig. 10. Division of large and important dams built in R. Macedonia, according to the material type for construction

Fig. 11. Rock-fill dam Loshana with geomembrane facing, built in 2006, Hs=45 m

Fig. 12. Rock-fill dam Knezevo with asphalt core, on river Zletovska, built in 2011, Hs= 82 m

Fig. 13. St. Petka arch dam on river Treska, constructed in 2012

Fig. 14. Upstream view of Kozjak dam, highest earth-rock dam in R. Macedonia

The highest dam creating water reservoir in R. Macedonia is earth-rock dam Kozjak on river Treska [Petkovski L., Tanchev L., Mitovski S., 2007.06], built in 2006 with structural height of 126.0 m, figure 14. However, the highest fill dam in R. Macedonia is tailings dam Topolnica of mine Buchim, Radovish, [Petkovski L., Mitovski S., 2018.04] completed in 2015, with crest-to-downstream-toe height of 141.2 m, figure 15. According to the structural height of the important and large dams in R. Macedonia, figure 16, we have mostly low dams (less than 30 m) and medium high dams (30 to 80 m) – all in all, total of 19 and 18 respectively, and high dams (80 to 150 m) are total of 8 (or 17.8%), while extremely high dam (height more than 150 m) is not yet constructed in R. Macedonia.

Fig. 15. Tailings dam Topolnica of mine Buchim, with recultivated downstream slope

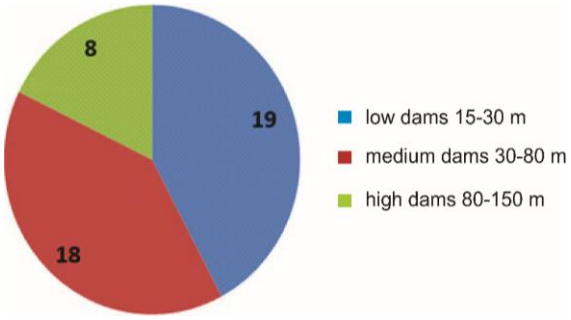

Fig. 16.Division of large and important dams in R. Macedonia, according to height

3. CURRENT PROJECTS FOR LARGE DAMS IN R. MACEDONIA

The current projects for important dams in R. Macedonia are: (1) Shtuchka dam, figure 17, rock fill dam with geomembrane facing (GFRD) in seven stages, [Petkovski L., Mitovski S., 2015.06] near Strumica, for the tailings of mine Ilovica, Hs = 207 m, in the phase of preliminary design, (2) Slupchanska Dam, figure 18, near Kumanovo, concrete faced rock-fill dam (CFRD), Hs = 54 m, in the phase of basic design, (3) Otinja dam, figure 19, rock-fill dam with central clay core [Petkovski L., 2005.08], near Shtip, Hs = 30 m, in the phase of Review of the Basic design, which is planned for construction in 2020, (4) Orizarska dam, figure 20,

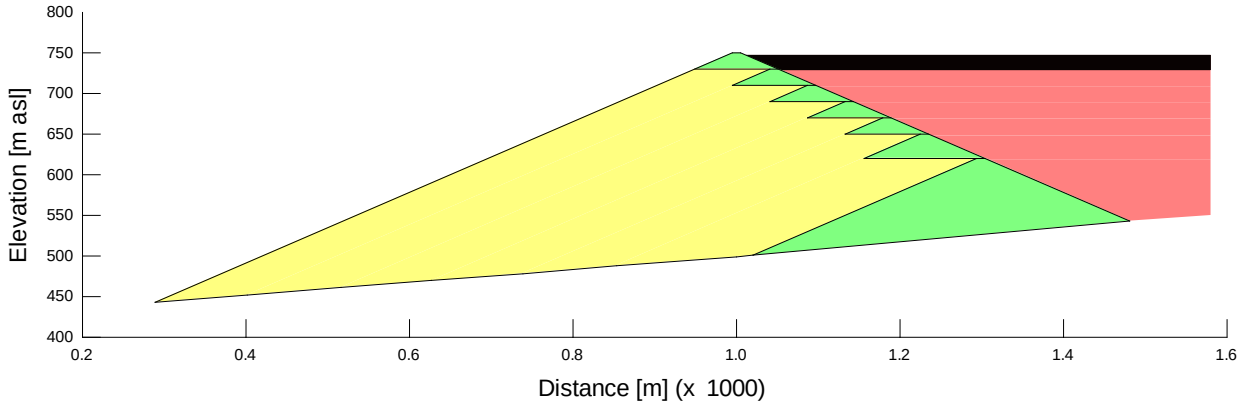

Fig. 17. Shtuchka dam, Strumica, H1 = Hs = 207 m, GFRD in 7 stages

rock-fill dam with geomembrane facing (GFRD), near Kochani, [Petkovski L., Mitovski S., 2013.05] Hs = 81m, with Reviewed Basic design, which is planned for construction in 2019 and (5) Konsko dam, near Gevgelija [Petkovski L., Tančev L., Mitovski S., 2013.10], Hs = 80 m, figure 21, rock-fill dam asphalt core (ACRD), construction is started in July, 2018, figure 22.

The Contractor of the dam Konsko, selected by the Investor – Ministry of Agriculture, Forestry and Water economy of R. Macedonia, is the company Serka-Akely Joint Venture, from Turkey. This could be an excellent example how to increase the competition, extend the transfer of knowledge and practice, and finally and to improve the Dam Engineering in South East Europe.

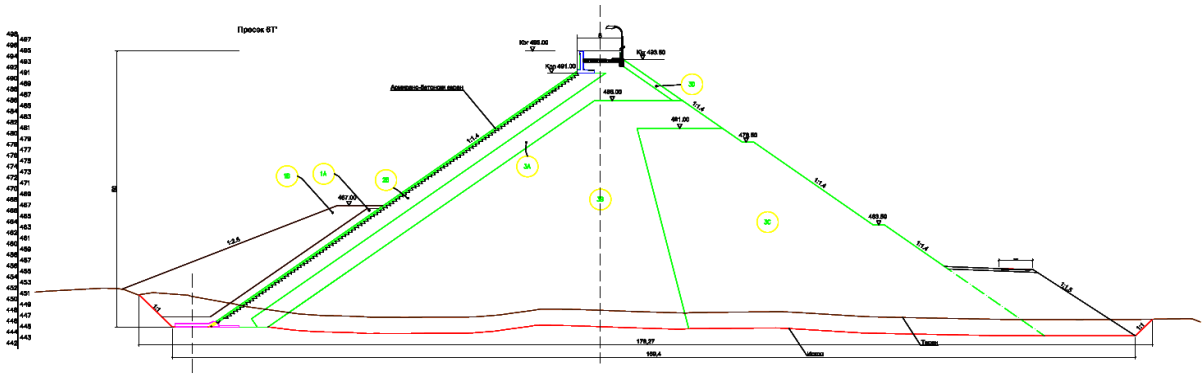

Fig. 18. Slupchanska dam, Kumanovo, CFRD, Hs = 54 m

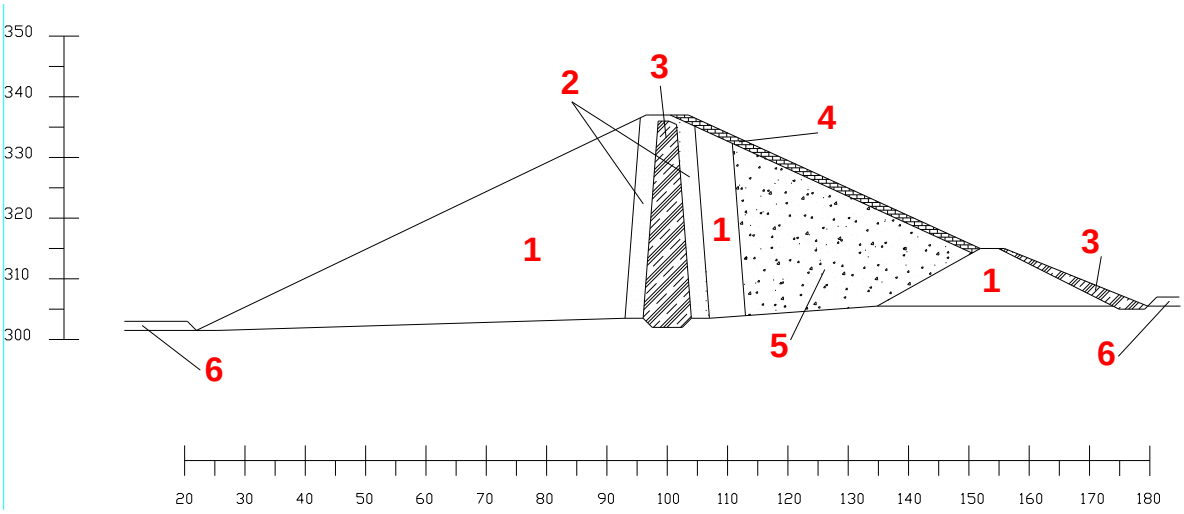

Fig. 19. Otinja dam, Shtip, rock fill with clay core, Hs = 33.5 m, 1 - gravel (downstream shoulder, transition zones, upstream cofferdam), 2 - sand (filters), 3 - clay (core of dam, screen of cofferdam), 4 - masonry stone (upstream slope protection), 5 - stone-fill (upstream shoulder), 6 - alluvial deposit in riverbed

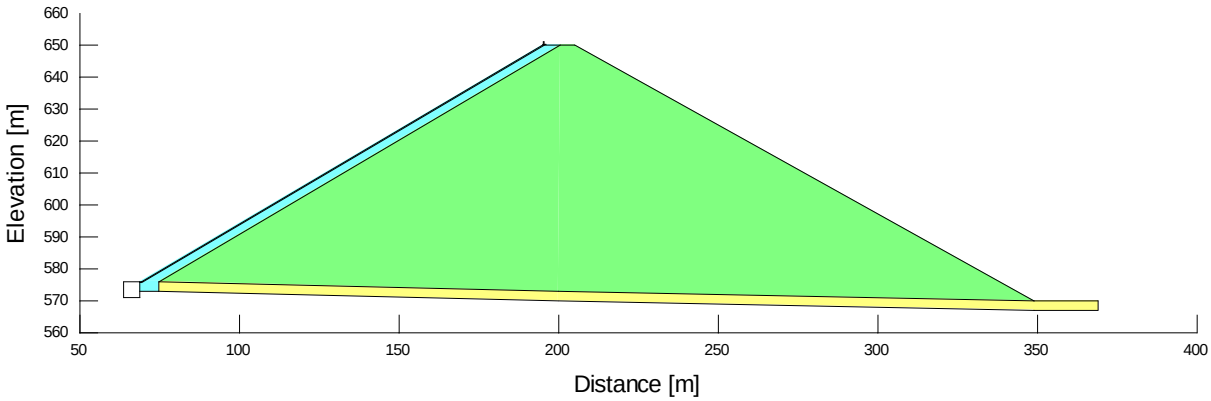

Fig. 20. Rechani dam, Kochani, GFRD, Hs = 81 m, (1) foundation: deposit in the river bed, (2) filter: sub-layer of the upstream facing of geomembrane, (3) shell: rock-fill

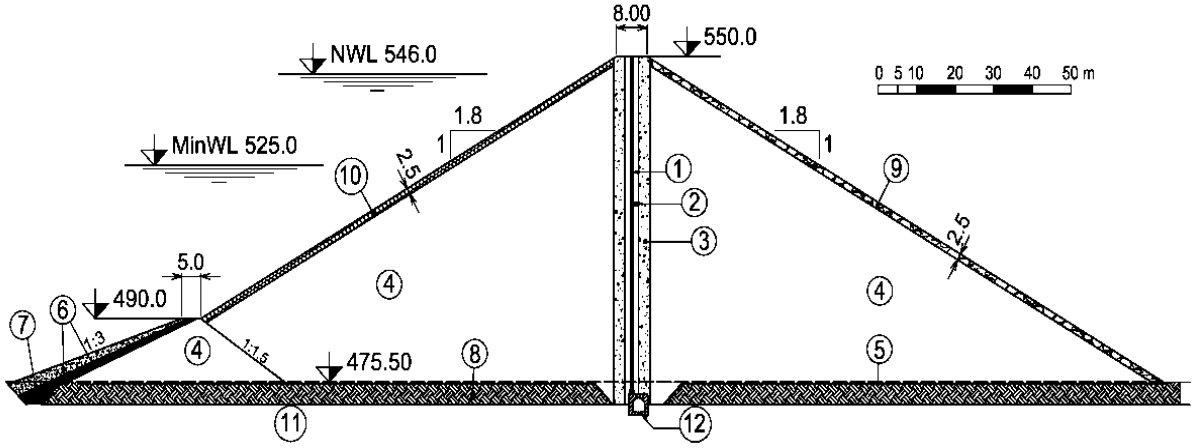

Fig. 21. Konsko dam, Gevgelija, ACRD, Hs = 80 m, (1) asphalt core, (2) fine transition, (0-60) mm, (3) coarse transition, (0-250) mm, (4) rock-fill, grains to 700 mm, (5) removed humus layer, (6) cofferdam filter from river gravel, (7) cofferdam clay facing, (8) river deposit, (9) protection of the downstream slope, (10) rip-rap for protection of the upstream slope, (11) rock foundation (12) grouting gallery

Fig. 22. Ceremony at the beginning of the construction of Konsko dam, on 21st of July 2018

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ОСАМДЕСЕТ ГОДИНА ИЗГРАДЊЕ БРАНА - КЉУЧНИХ ОБЈЕКАТА ХИДРОСИСТЕМА У РЕПУБЛИЦИ МАКЕДОНИЈИ

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Резиме

Ове године прослављамо важан јубилеј - 80 година Инжењерства брана у Републици Македонији. Планирање, пројектовање, изградња и одржавање брана спадају међу најодговорније грађевинске радове. Прва брана у Републици Македонији, лучна брана Матка, у кањону реке Треске, у близини града Скопја, изграђена је 1938 године. Пројектант бране је инж. Миладин Пећинар, касније академик САНУ. Изградња ове бране и њених пратећих објеката означава почетак Инжењерства брана у Републици Македонији. Тренутно, у 2018 години, са поносом можемо рећи да су градитељи бране у Републици Македонији достојни наследници и настављачи племенитог рада првих пројектаната и извођача брана из 1938 године. Потврда овог закључка је чињеница да су кључни стуб наше садашње водопривредне инфраструктуре 45 брана од регионалног значаја и преко 110 насутих бране од локалног значаја. Република Македонија се налази у централном делу Балканског полуострва и заузима површину од 25.713 км^2, са популацијом од око 2,1 милиона. Са више од 150 изграђених брана, практично свих врста (насуте и бетонске, гравитационе и лучне), категорисаних као "велике бране," у складу са критеријума ICOLD-а, Република Македонија, сразмерно својој величини, налази се у самом врху Инжењерства брана у Европи.

Кључне речи: насуте и бетонске бране, гравитационе и лучне бране

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