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## 80 YEARS OF DAM ENGINEERING 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 exit of the canyon of river Treska in nearby of 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.

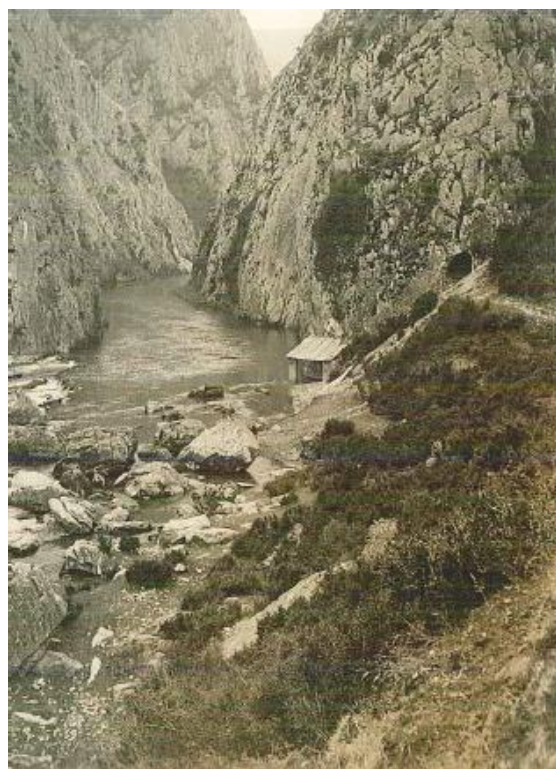


Figure 1. Canyon Matka on the river Treska in 1935, before dam construction



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

Miladin Pecinar finished elementary school in the village of Ljubish, his birth place, and graduated in high school in Uzhice in 1912. He continued his education in Belgrade at the Technical Faculty, department of Civil Engineering. In March 1918, he took a break from the studies in Belgrade and has transferred to the Applied School for Civil Engineers in Rome. After the end of World War I, in 1919 Miladin continued its studies in Belgrade, and in graduated in 1921. The first years after graduation was employed at the Ministry of Civil Engineering, in the General directorate for water. 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) but also and other hydropower systems, that were not built. In that period, in several mandates, Pecinar was vice president of the Association of Yugoslavian engineers and architects.

After World War II, Pecinar was employed at the Ministry of Civil Engineering and the Yugoslav hydro meteorological facility. 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 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. In 1960, he wrote the book "Hydraulic structures – dams", containing very few formulas and plenty sketches and drawings, that happens to be the most favorable way for transferring of his great individual experience in designing and building of these most complex civil engineering structures. He got retired in 1963 as full professor at the Civil Engineering Faculty in Belgrade.

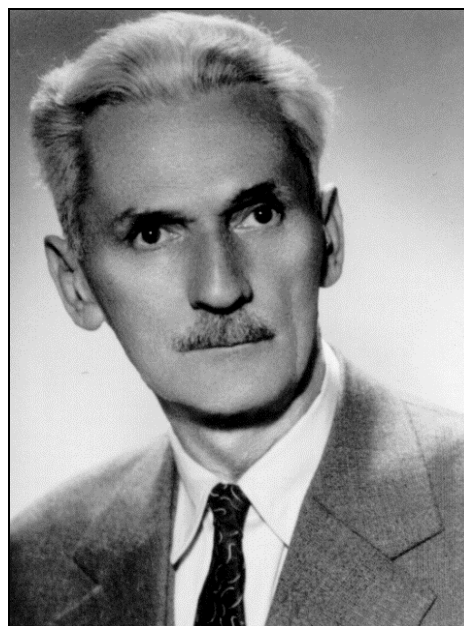


Figure 3. Academician Miladin M. Pecinar, (1893-1973)

It is here by to be noted that Pecinar for each hydropower plant that has designed, also designed and the appurtenant structures of the dam as well and hydropower derivations. Aside his ingenuity and enormous hydrotechnical talent, the greatness of academician Pecinar was also in combining experts of different 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 dam in Europe (Denia dam in Spain was the first). In addition, Matka dam was the highest arch dam in the Kingdom of Yugoslavia, but also and the boldest arch dam in Yugoslavia in XX century, with slender coefficient equal to 0.054.

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 from 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 small fill (embankment) dams with local importance. 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 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.

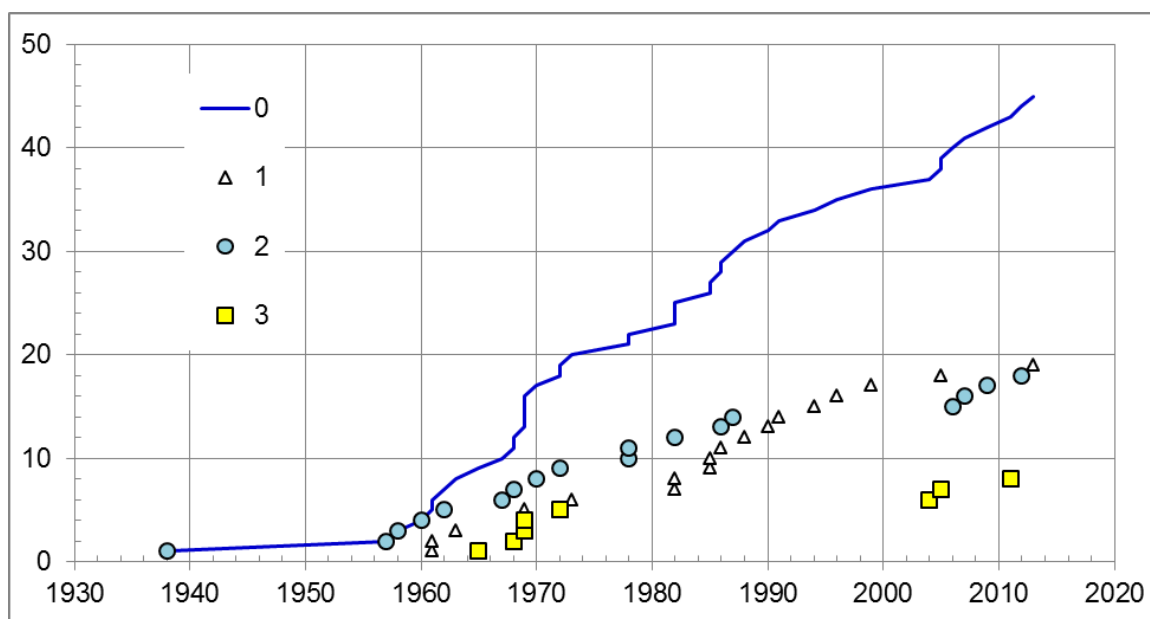


Figure 4. Dynamics of construction of large dams in R Macedonia, for 45 hydro-systems of regional importance. (0) in total, (1) low,  $H < 30$  m, (2) medium,  $H < 80$  m, (3) high,  $H < 150$  m

The latest built dam in R Macedonia is double curved arch dam St. Petka on river Treska, with structural height of 64 meters, constructed in 2012, figure 5.



Figure 5. St. Petka arch dam on river Treska, constructed in 2012

In the past period in R Macedonia practically all dam types are built, in correlation that is common worldwide. According to the material type for dam construction (figure 6), 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 (Prilep dam). In case of fill dams, according to

the local material, equally are constructed - 17 earthfill and 17 rockfill dams. From the rockfill dams, mostly represented are earth-rock dams (impermeable element of natural clay material) and only 2 are rockfill dams (with artificial impermeable element). Such dams are Loshana dam, constructed in 2006 (with geomembrane facing) – first of such type in ex-Yugoslavia, and Knezhevo dam (figure 7), built in 2011 (with asphaltic core), first of such type in southeastern Europe. These two dam cases in most eclectic manner show the boldness and inventiveness of the present generation of hydrotechnics professionals in R Macedonia.

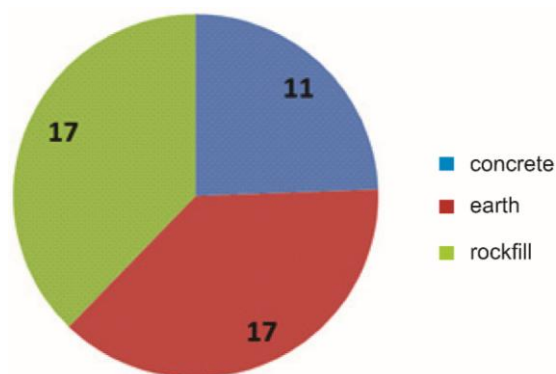


Figure 6. Division of large and important dams built in R Macedonia, according to the material type for construction



Figure 7. Rockfill dam Knezhevo with asphalt core, on river Zletovska, built in 2011 with structural height of 82 m



Figure 8. 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, built in 2006 with structural height of 126.0 m, figure 8. However, the highest fill dam

in R Macedonia is tailings dam Topolnica of mine Buchim, Radovish, completed in 2015, with crest-to-downstream-toe height of 141.2 m. According to the structural height of the important and large dams in R Macedonia, figure 9, 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.

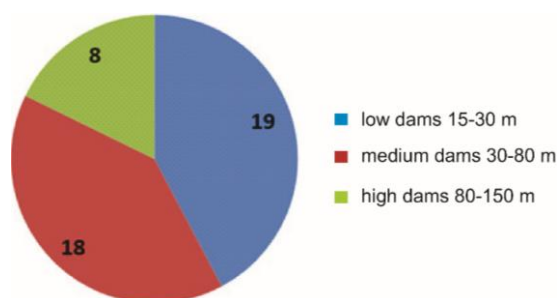


Figure 9. Division of large and important dams in R Macedonia, according to height