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THE RESEARCH ON THE TECHNICAL STATE OF RETAINING WALLS OF HYDRO SCHEMES IN THE JONAVA DISTRICT

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There are 12 ponds in the Jonava district territory and 3 ponds in the Rukla military base territory. All dams in the district were built in 1978–1989 for irrigation, recreation, fisheries, runoff control or other purposes. 8 earth dams located in the Jonava district were selected for the research. Research aim and objectives:
to assess the state of retaining walls of Jonava district dams;
to investigate and assess the state of the Jonava district dams;
to assess the changes in the concrete strength of concrete and reinforced concrete retaining walls of Jonava district dams.
Methods used to investigate the state of the dams: documentation analysis; visual method; non-destructive method to determine the concrete strength (instrumental), the state was assessed according to the standard methodology specified in the technical construction regulation STR 1.03.07:2017. Based on the investigations' results, the state of the flood spillway outlet structures (retaining walls) of the hydro schemes of Beržai, Lokys, Šveicarija and Užusaliai ponds in the Jonava district deteriorated the most, with a score of 8.1–9.2. According to the technical state assessment (carried out following STR 1.07.03:2017) results, reconstruction works are necessary for the Beržai, Lokys, Šveicarija and Užusaliai hydro schemes in the Jonava district, and repair works are necessary to eliminate the defects and damage in the hydro schemes of the Jonava city ponds I–IV. Based on the investigations' results, it was found that the concrete of the retaining walls of the Beržai, Užusaliai, Jonava I and II hydro schemes has weakened the most, at least by one strength class, when comparing the results of investigations done in 2017 and 2020 with the results of 2023 investigations. In the other hydro schemes, the concrete of the retaining walls weakened less.

Keywords: *retaining wall, concrete deterioration, technical state.*

INTRODUCTION

Between 1950 and 1990, 414 of large and small dams with various types of flood spillways (FS) were built in Lithuania. The most common types of flood spillways used in Lithuania are (Damulevičius & Vyčius, 2008; Chen, 2015): 1) overflow flood spillways, 2) pipe flood spillways with simple, bucket, trench, shaft, and tower heads, and 3) side channels. In Lithuanian hydro schemes, mainly pipe spillways with tower ("shaft") heads are constructed. For hydraulic analogy reasons, such a head is usually called a shaft and the entire spillway is called a shaft spillway. Overflow and pipe flood spillways in Lithuania are designed, constructed, and maintained following the requirements of the regulatory documents (STR 2.02.06:2004; STR 2.05.05:2005; STR 2.05.15:2004; STR 1.03.07:2017).

Defects and damage are often observed during the construction and use of hydraulic structures.

The primary sources and causes of deterioration in structures and buildings are (Onazi et al., 2018; Abdulazeez, 2022) human, faulty construction, chemical, faulty materials, atmospheric, faulty systems, structural defects, faulty design, moisture, cleaning, fire, and vandalism.

As defects and damage in reinforced concrete structures are caused by a variety of reasons, the diagnostic methods used vary (Onazi et al, 2018; Šadzevičius et al, 2015).

The diagnostic methods used to investigate reinforced concrete structures can be divided into five main groups (Kaplan & Skoloud, 2016; Shah et al, 2023):

- visual methods,
- methods for determining the physical properties of concrete and steel,
- methods for determining the degree of corrosion disruption of concrete and steel,
- methods for determining the position of reinforcement,
- load test structures, respectively, methods of registering immediate response of the structure to achieved static or dynamic loads.

In this article, presented data and analysis are confined to the compressive strength of concrete retaining walls (RW) and technical state.

The purpose of these investigations, based on research in the field, is to determine the actual compressive strength values of concrete used in the RWs and assess the technical state according to noticed defects and deteriorations.

Research objectives:

to assess the state of retaining walls of dams in the Jonava district;

to investigate and assess the state of the dams in the Jonava district;

to assess the changes in the concrete strength of concrete and reinforced concrete retaining walls of dams in the Jonava district.

RESEARCH METHODS

The object of the research work

In the Jonava district, there are 12 dams and ponds in the territory of the district and 3 dams and ponds in the territory of the military base in Rukla (Manual of ponds in Lithuania, 2017). Of the 15 ponds, only three are larger than 10 ha, the others range from 1.0 to 7 ha. All the dams in the district were built in the Soviet era between 1978 and 1989 for irrigation, recreation, fisheries, runoff control or other purposes.

The 8 dams investigated in the Jonava district have shaft spillways (except the Lokys one (overflow) and dam IV of the Jonava city, which has a circular overflow). The investigated hydraulic structures fall into consequence classes CC1 and CC2, depending on the materials used in their construction, the pressure height, and the foundation soil.

The following methods of structural diagnostics have been used to investigate the evolution of the damage and state of the hydro schemes in the Jonava district:

1. documentation analysis;
2. visual method;
3. non-destructive method to determine the concrete strength (instrumental).

Documentation analysis: design (working drawings, construction projects) and other archival documentation (maintenance logbooks, pond maintenance rules, inspection reports) were analysed.

Visual surveys are inspections of the site carried out by an experienced specialist, who also takes the necessary measurements and carries with him/her the basic instruments: a sheet of paper, a pen, a ruler, a tape measure, a calliper, and a camera. These tools were used to determine the location of the damaged structures, the type of damage, and the geometric characteristics of the damage in terms of area and depth.

Instrumental tests were carried out using a calibrated elastic rebound device, the Schmidt hammer, which was checked on a reference anvil before and after the tests. An elastic rebound computerised device, Silver Schmidt N, was also used. The rebound hammer was struck 10 to 12 times at specially prepared areas on the structure following the methodology given in LST EN 12504-2:2021 standard. Dry areas of the concrete surface were selected for testing. The concrete was struck in such a way that the distances between the marks in the concrete were at least 30 mm. The average compressive strength f_c of the concrete of the reinforced concrete structures was determined from special device calibration curves. After statistical processing of the test results (using the MS EXCEL computer program), assessment of the statistical indicators (coefficient of variation ν, mean square deviation σ) and following standards LST EN 13791:2019 and LST EN 206:2014, the characteristic (95% guaranteed) compressive strength f_{ck} was determined based on the compressive strength obtained by the non-destructive method, and based on this strength, the concrete compressive strength class C was selected according to the technical construction regulation STR 2.05.05:2005.

The technical state of the Jonava district hydro schemes was assessed using points according to the methodology presented in the technical construction regulation STR 1.03.07:2017. The state was assessed using defectiveness (risk) points according to a ten-point system (0 – ideal state, 10 – element is in the state of emergency), per the assessment criteria specified in Annex 5 to STR 1.03.07:2017.

RESEARCH RESULTS AND DISCUSSION

Results of the assessment of the technical state of retaining walls

In this paper, the data and analysis of reinforced concrete retaining walls of 8 functioning hydro schemes are presented.

In 2017–2023, after performing the technical state investigations of the retaining walls of the hydro schemes in the Jonava district ponds Beržai, Lokys, Šveicarija, Užusaliai, Jonava city ponds I–IV, the following main damages of the reinforced concrete elements were found: damage to the surface layer of the concrete in the abutments of the downstream apron, signs of concrete carbonation, bio-corrosion, cracks; partially decayed upper part, holes, corrosion of the reinforcement, weak concrete, broken corners, insufficient protective concrete layer.

Based on the observed damages of the elements, per the assessment criteria specified in Annex 5 to STR 1.03.07:2017 and following the methodology presented in STR 1.03.07:2017, the technical state of the hydro schemes in the Jonava district has been assessed by points. The defectiveness points for the retaining walls of the hydro schemes and the overall defectiveness points for the assessment of the technical state of the hydro schemes in the Jonava district are shown in Figure 1.

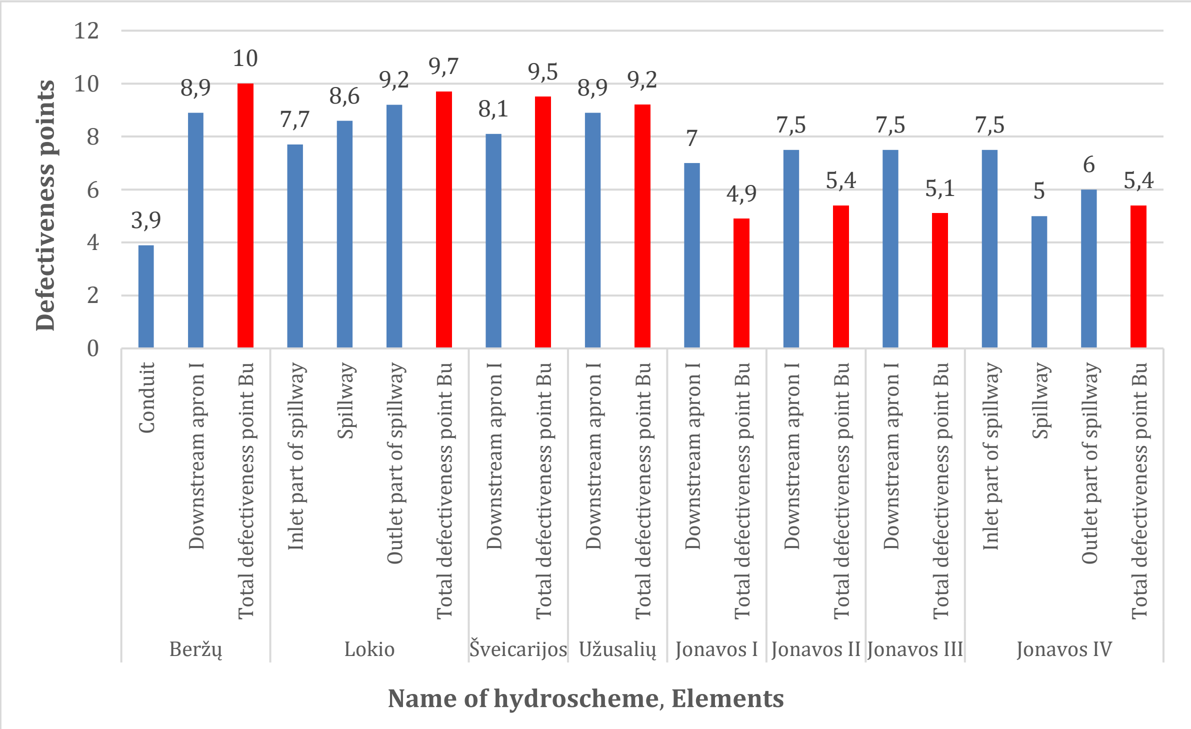

Fig. 1. Defectiveness score B_u for the individual structures of the downstream apron of the investigated hydro schemes and for the assessment of the overall technical state of the hydro scheme.

Based on the results of the investigations presented in Figure 1, the deterioration of the state of the flood spillway outlet structures (retaining walls) was found to be the most severe, with a score of up to 9.2 at the Lokys hydro scheme. Significant deterioration (8.9 points) was also recorded in the structures of the downstream apron of the other hydro schemes (Beržai and Užusaliai). According to the results of the investigations, the structures of the Šveicarija dam (8.1 points) and Jonava city dams I–III (7.5 points) are the closest to the critical limit of 8.1 defectiveness score (characterising very poor condition).

The overall assessment score B_u for the technical state of the hydro schemes of Beržai, Lokys, Šveicarija and Užusaliai ponds in the Jonava district is 9.2 to 10.0. According to STR 1.07.03:2017 "Procedures for technical and operational supervision of structures. Procedure for formation of new real estate cadastre objects" point 81.3, if the overall score of the technical state of the hydro scheme is between 8.1 and 10.0, its state is assessed as very bad (emergency), i.e., there are significant defects in the element that make its further operation impossible, and the collapse of the entire structure is possible.

The overall assessment score Bu for the technical state of the hydro schemes of the Jonava city ponds I–IV is 4.9 to 5.4. According to STR 1.07.03:2017 "Procedures for technical and operational supervision of structures. Procedure for formation of new real estate cadastre objects" point 81.3, if the overall score of the technical state of the hydro scheme is between 4.1 and 6.0, its state is assessed as satisfactory, i.e., there are defects in the element that have a negligible impact on its strength, reliability, and durability.

According to the results of the technical state assessment (carried out per STR 1.07.03:2017), reconstruction works are necessary for the Beržai, Lokys, Šveicarija and Užusaliai hydro schemes in the Jonava district, and repair works are necessary to eliminate defects and damage in the hydro schemes of the Jonava city ponds I–IV.

Results of the assessment of the concrete compressive strength of retaining walls

The location of the 8 hydro schemes in the Jonava district which were investigated in 2017–2023, the median compressive strength f_c, mean square deviation σ and minimum class of compressive concrete of the retaining walls are presented in Table 1.

Table 1. The results of compressive strength assessment of retaining wall elements in hydro schemes at the Jonava district in 2017, 2020, and 2023.

Nr.	Name of the hydro scheme	Main structures	Median compressive strength of concrete f_{cm}, MPa		Mean square deviation σ		Class C of concrete strength	Class C of concrete strength
1	2	3	4		5		6	7
	BERŽAI, years of investigation		**2020**	**2023**	**2020**	**2023**	**2020**	**2023**
		Downstream apron right retaining wall	18.2	15.3	6.6	7.0	C16/20	C12/15
		Downstream apron left retaining wall	14.0	9.0	6.8	4.0	C12/15	C8/10
	LOKYS, years of investigation		**2020**	**2023**	**2020**	**2023**	**2020**	**2023**
		Downstream apron right retaining wall	11.3	10.4	4.5	4.5	C8/10	C8/10
		Downstream apron left retaining wall	12.5	13.7	3.2	4.8	C12/15	C12/15
		Upstream apron right retaining wall	12.0	11.3	3.7	7.2	C8/10	C8/10
		Upstream apron left retaining wall	12.1	9.6	4.7	4.0	C8/10	C8/10
	ŠVEICARIJA, years of investigation		**2020**	**2023**	**2020**	**2023**	**2020**	**2023**
		Downstream apron right retaining wall	11.5	10.5	4.8	4.9	C8/10	C8/10
		Downstream apron left retaining wall	12.0	11.7	4.3	6.8	C8/10	C8/10
	UŽUSALIAI, years of investigation		**2020**	**2023**	**2020**	**2023**	**2020**	**2023**
		Downstream apron right retaining wall	17.3	11.0	6.4	6.0	C16/20	C8/10
		Downstream apron left retaining wall	17.5	12.7	5.9	5.8	C16/20	C12/15
	JONAVA I, years of investigation		**2017**	**2023**	**2017**	**2023**		
		Downstream apron right retaining wall	22.9	19.0	6.7	7.7	C20/25	C16/20
	JONAVA II, years of investigation		**2017**	**2023**	**2017**	**2023**		
		Downstream apron left retaining wall	26.0	20.0	9.3	12.9	C25/30	C16/20
	JONAVA III, years of investigation		**2017**	**2023**	**2017**	**2023**		
		Downstream apron right retaining wall	38.8	31.0	17.2	12.0	C35/45	C30/37
		Downstream apron left retaining wall	20.0	18.5	9.3	12.3	C16/20	C16/20
	JONAVA IV, years of investigation		**2017**	**2023**	**2017**	**2023**		
		Upstream apron right retaining wall	39.3	38.8	14.1	17.0	C35/45	C35/45
		Upstream apron left retaining wall	25.3	23.5	10.0	10.7	C20/25	C20/25
		Downstream apron right retaining wall	15.0	13.0	7.8	10.0	C12/15	C12/15
		Downstream apron left retaining wall	19.5	19.0	13.0	6.8	C16/20	C16/20

Based on the results of investigations presented in *Table 1*, it was found that in the Jonava district hydro schemes, the concrete of the retaining walls of the Beržai, Užusaliai, Jonava I and II hydro schemes has weakened the most, at least by one strength class, when comparing the results of investigations done in 2017 and 2020 with the results of 2023 investigations. In the other hydro schemes, the concrete of the retaining walls weakened less.

Figure 2 shows the results of the concrete tests of the retaining walls of the downstream apron of the hydro schemes of the Beržai, Lokys, Šveicarija, Užusaliai, Jonava city I–IV ponds in the Jonava district for the period 2017–2023.

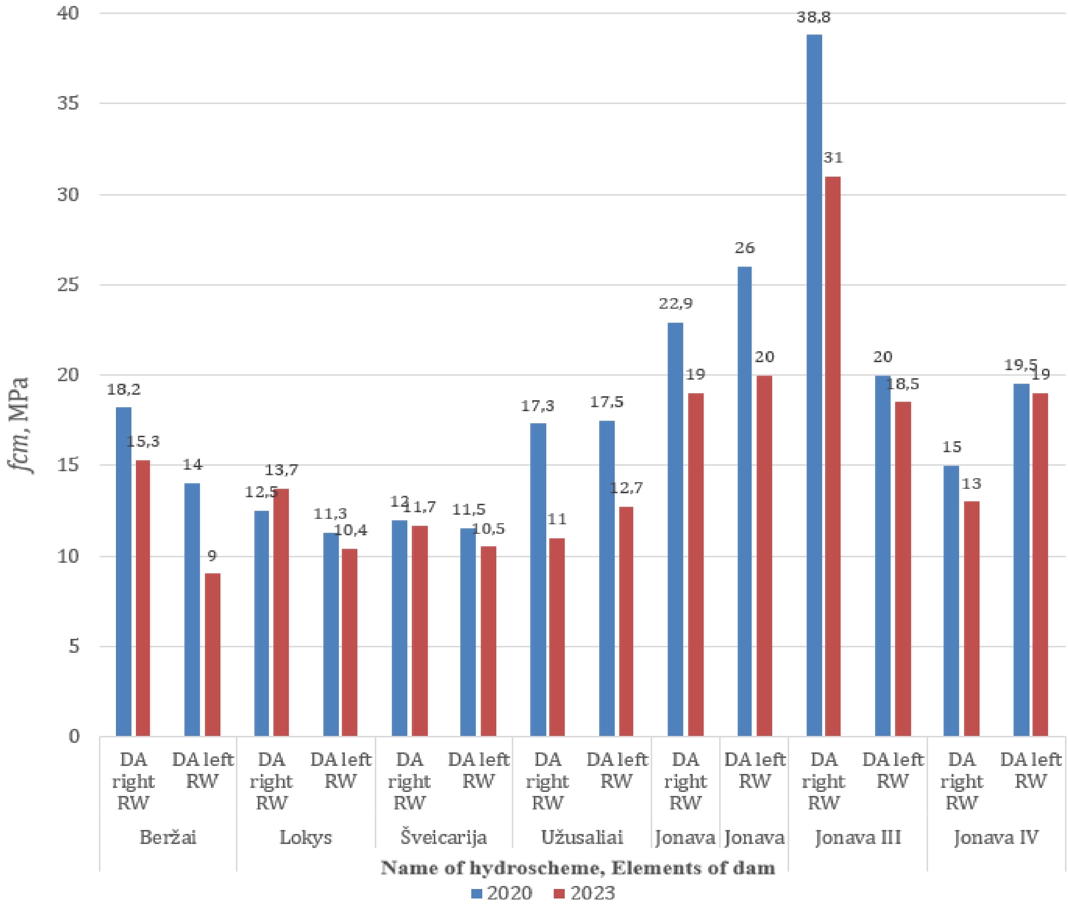

Fig. 2. Results of strength tests on the retaining walls of the DA of hydro schemes.

Based on the results of the investigations presented in Figure 2**,** we found that:

In 2023, the highest minimum compressive strength of concrete is found in the Jonava city hydro scheme IV, which is 38.8 MPa and corresponds to concrete class C35/45. The lowest minimum compressive concrete strength is 9 MPa and it was found in the Beržai hydro scheme (Jonava district), corresponding to concrete class C 8/10.

According to the current standard LST EN 13791:2019 for structures subjected to moderately humid and cyclically wet and dry environments during use and Table 1 of STR 2.05.05:2005 (Annex 3), the recommended minimum compressive strength class of concrete is C30/37. Based on the research data, it was found that only the concrete strength of the reinforced concrete structures of the retaining walls on the right side of the Varnaka River in the Jonava city III pond is higher than the recommended strength and the compressive strength class of the structures meets the requirements, while the concrete of the retaining walls of the downstream apron of the other hydro schemes investigated does not comply with the current requirements.

CONCLUSIONS

Based on the results of the investigations, the state of the flood spillways outlet structures (retaining walls) of the hydro schemes of Beržai, Lokys, Šveicarija and Užusaliai ponds in the Jonava district deteriorated the most, with a score of 8.1–9.2.

The overall assessment score B_u for the technical state of the hydro schemes of Beržai, Lokys, Šveicarija and Užusaliai ponds in the Jonava district is 9.2–10.0. The overall assessment score B_u for the technical state of the hydro schemes of the Jonava city ponds I–IV is 4.9–5.4. According to the results of the technical state assessment (carried out following STR 1.07.03:2017), reconstruction works are necessary for the hydro schemes of Beržai, Lokys, Šveicarija and Užusaliai in the Jonava district, and repair works are necessary to eliminate the defects and damages in the hydro schemes of ponds I–IV of the Jonava city.

Based on the results of the tests, it was found that in the Jonava district hydro schemes, the concrete of the retaining walls of the Beržai, Užusaliai, Jonava I and II hydro schemes has weakened the most, at least by one strength class, when comparing the results of investigations done in 2017 and 2020 with the results of 2023 investigations. In the other hydro schemes, the concrete of the retaining walls weakened less. The concrete strength of the reinforced concrete retaining wall structures of the downstream apron of the Jonava district hydro schemes is below the recommended strength and the compressive strength class of the structures does not comply with the requirements (except the Jonava city dam No III).

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