CERIS Civil Engineering Research and Innovation for Sustainability

WATERCRETE – Performance of concrete with recycled water from wastewater treatment plants

Summary

Water scarcity is currently a serious problem worldwide. According to the United Nations (UN), the global population, which reached 8 billion people in 2022, is expected to reach approximately 10 billion people by 2050. This exponential population growth places additional pressure on water resources and the construction industry. Globally, about 30 billion metric tonnes of concrete are produced annually, requiring around 1 billion metric tonnes of freshwater for its production (Atakan et al., 2016). Because it is the most widely used construction material worldwide, concrete has a considerable ecological footprint. Therefore, there is an increasing need to adopt sustainable practices in concrete production, such as using recycled materials to reduce its environmental impact.

The project "WATERCRETE - Performance of concrete produced with recycled water from wastewater treatment plants" aims to analyse the performance of concrete produced with water from wastewater treatment plants in the following sequence: a) characterization of several treated waters from two different wastewater treatment plants; b) production and characterization of concrete with water obtained after secondary treatment; c) production and characterization of concrete with recycled water obtained in accordance with Decree-Law no. 119/2019 (classifying recycled water from "A" to "E"); d) proposal for classifying water from wastewater treatment plants for subsequent use in concrete.

This project falls under two thematic strands: "Product Development in Civil Engineering Industries", as it aims to develop a new sustainable material to be used in the construction industry; "Response to Natural and Societal Changes", as it intends to propose a process for developing new infrastructures to supply treated wastewater for the production of concrete (similar to what already exists for irrigation).

Hence, to promote the conservation of water resources and mitigate water scarcity in high--demand regions, the use of non-potable water such as seawater, concrete mixer wash water, wastewater, and treated wastewater (TWW), emerges as an alternative to freshwater However, it is essential to ensure that concrete produced with non-potable water meets the necessary conditions for use, including a good mechanical and durability performance. In this context, the present research intended to evaluate a set of properties characterizing the behaviour of concrete produced with secondary treated wastewater (STWW) and tertiary treated wastewater (TTWW). Furthermore, as there is a consensus on the use of recycled aggregates (RA) in concrete production, the study also examined the performance of concrete mixes produced with both TTWW and RA from construction and demolition waste (CDW).

This research intended to study the effect of incorporating TTWW in concrete produced with natural aggregates (NA) (PW-0) and with 50% of RA (PW-50). In summary, for mixes with NA, considering their overall performance, it was concluded that TTWW (BCA and BCB) from the Beirolas WWTP has the biggest potential for application. Moreover, the results (Figure 1) showed that using more advanced TTWW does not lead to a significant improvement in concrete behaviour. Furthermore, the use of Alcântara's WWTP TTWW (ACA and ACB) indicated that even when coming from the same source, the type of treatment applied can alter water characteristics, making it less suitable for concrete production. Regarding the use of RA, it was observed that incorporating TTWW has a slightly different effect on mixes with or without RA, particularly in terms of mechanical performance. However, similar to mixes with NA, no significant improvements were identified with the use of higher treatment levels. Lastly, for STW from Beirolas (BCS) and Alcântara (ACS), it was noted that its incorporation has a more noticeable negative effect on concrete durability, both in mixes with NA and RA.

Type of water	Variation of compressive strength at 28 days [%]		Variation of tensile strength at 28 days [%]		Variation of modulus of elasticity at 91 days [%]		Variation of water absorption by immersion at 28 days [%]		Variation of carbonation depth at 28 days [%]		Variation of chloride diffusion coefficient at 28 days [%]	
	PW-0	PW-50	PW-0	PW-50	PW-0	PW-50	PW-0	PW-50	PW-0	PW-50	PW-0	PW-50
PW	**44.3 MPa**	**35.5 MPa**	**3.4 MPa**	**2.8 MPa**	**45.0 GPa**	**36.2 GPa**	**11.5%**	**15.0%**	**4.0 mm**	**5.2 mm**	**16.5 $\times10^{-12}$ m^2/s**	**22.7 $\times10^{-12}$ m^2/s**
BCA	2.4	-1.4	-0.4	-6.6	0.0	-2.0	-5.2	-3.3	-15.7	-10.1	-8.4	-3.4
BCB	2.2	-4.4	-2.2	-16.9	-0.7	-3.4	-6.6	-2.8	-6.7	-8.1	-9.1	-5.6
BCS	-0.2	0.5	-7.6	-20.4	-2.1	-1.0	0.2	-6.0	6.5	11.3	6.8	-4.5
ACA	1.0	-5.8	-11.2	-3.8	-0.8	-2.6	0.0	-1.0	2.5	-4.4	4.6	-7.8
ACB	-0.4	0.0	-14.9	-12.5	-1.3	-2.8	2.5	-5.8	-10.2	-6.6	-4.1	-4.3
ACS	-2.4	1.4	-36.6	-25.7	0.1	-4.4	1.7	-2.7	3.7	10.8	45.4	0.2

Figure 1. Comparison between the hardened concrete properties of TTWW and STW mixes.

Project Reference

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Leading Institution

CERIS – Civil Engineering Research and Innovation for Sustainability (Portugal)

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Project Website

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