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Original Research Article

IMPACT OF WATER QUALITY ON CONCRETE MIX AND HARDENED CONCRETE PARAMETERS

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Abstract

The subject of the present article is the evaluation of the use of different water types in the production of concrete mix and C20/25 class concrete (assuming the same composition). Taking as an example a selected Subcarpathia-based concrete production plant, equipped with a process water management system, the research analysed the quantity-quality parameters of drinking water, sewage water, and groundwater and evaluated them for their accordance with mixing-water quality standards. It should be emphasised that the majority of specifications recommend the use of drinking water for concrete production. The paper presents the results of research which analysed the impact of water quality on selected properties of concrete mix and concrete (consistency; compressive strength after 7, 14, and 28 days; density). The results obtained confirmed the findings of the research on the suitability of recycled water for concrete production.

Keywords: concrete compressive strength, mixing water, ready-mixed concrete, sewage water

1. INTRODUCTION

Due to its major impact on the environment, the building industry is closely linked to the notion of sustainable development. The building industry:

- uses over 40 per cent of global energy production,

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- is the cause of about 35 per cent of global greenhouse gas emissions,
- accounts for about 50 per cent of the total mass of processed materials.

The building industry uses enormous quantities of raw materials. For instance, annual concrete production worldwide requires 20 billion tons of aggregate, 1.5 billion tons of cement, and 0.8 billion tons of water [1].

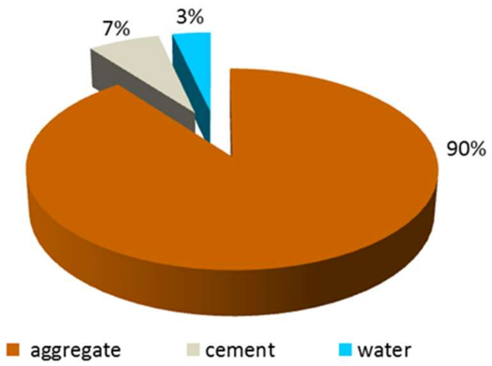

Fig. 1. Percentage of raw materials used in global concrete production [1]

With respect to the principles of sustainable construction, ready-mixed concrete production plants should apply the following practices [2-16]

- reducing the use of natural resources and energy consumption,
- reclaiming and reusing materials (recycling),
- using energy from natural resources and renewable sources.

Alongside production and sales, the protection of natural resources is currently one of the most important goals of a socially responsible company. Concrete production plants have long been implementing solutions and technologies that do not cause harm to our planet's natural resources. Production plants establish objectives that aim to minimise the environmental impact of their business activities. One such task is to reduce the use of drinking water for production purposes and implementing a special water-saving system is one of the steps to achieving the set objectives. For a concrete production plant, however, this remains difficult to achieve as there are specific requirements that determine the quantity of water necessary for the concrete binding process. Therefore, excessive water saving could lead to deterioration of the product's compressive strength. This is why concrete production plants aim not to minimise the use of water but rather to obtain it from a source other than the water supply system. The first alternative is to modify the production process by replacing drinking water with groundwater; another solution is to use sewage water.

Water has an important role in the production of concretes and mortars (as mixing water) and in cement binding processes by helping to obtain the appropriate consistency of concrete or mortar; it is also essential for the curing of concrete or mortar in the process of hardening [17-19]. During the technological process, cement and aggregate quality control is regularly carried out, whereas water quality control remains neglected.

2. SEWAGE WATER IN THE PRODUCTION OF READY-MIXED CONCRETE

Sewage is the main source of waste generated by concrete production plants. It is generated as a result of the cleaning of machines used for concrete mix production and transport and during the disposal of concrete mix residues. One might, therefore, consider its further use in production as a substitute for drinking water [20,21]. However, a major problem is posed by the quality of untreated water, which is polluted with a number of chemical compounds [22]. The pollution, including the presence of sulphates, phosphates, zinc, lead, and suspended solids, coupled with high alkalinity, makes it impossible for untreated water to be disposed of into the municipal sewage system. This problem can be resolved by building an in-house sewage treatment unit, but not without generating high investment costs [21]. A more cost-effective solution, implemented in ready-mixed concrete production plants, is to reuse the recycled, post-production water as mixing water [3,8,20,21,23-26].

There are numerous technological solutions for the recycling of production sewage which consist of the separation of washings and their treatment for reuse in concrete production. Particular recycling systems differ mainly in the construction of these separators.

3. MIXING WATER

Drinking water, lake and river water, and production sewage water might be used as mixing water, provided that they meet the standards set out in PN-EN 1008:2004. Mixing Water for Concrete [19]. Sewage water [2,3,7,8,14,21,23,24,26,27] has an impact on the microstructure [2,3,7,10,11,14,20,21,25,26,28-30] and the physico-mechanical properties of concrete mixes and mortars. Concretes made with sewage water are characterised by a slightly lower compressive strength than concretes made with tap water/drinking water [8,21]. Specimens made with recycled water show 4 per cent lower compression strength than those made with drinking water. Using recycled water reduces the concrete water capillary absorption and mortar microporosity [21,30].

4. INDIVIDUAL INVESTIGATIONS

The aim of the research was to apply different water types in the production of concrete mixes and concrete. In the first stage of the research, groundwater and sewage water were evaluated in terms of compliance with PN-EN 1008 [18,19]. This phase consisted of a preliminary (organoleptic) and a detailed assessment. The detailed water assessment investigations involved an extensive chemical analysis whose results are presented in Table 1.

Table 1. Quantity-quality parameters of analysed water with values as set out in PN-EN 1008

Index	Drinking water	Groundwater	Sewage water	Max. allowable values as set out in PN-EN 1008 [21]
Chlorides [mg/dm^3]	150	175	210	500
Sulphates [mg/dm^3]	40.8	75.2	132.4	2000
Alkalis [mg/dm^3]	Trace	Trace	598	1500
Sugars [mg/dm^3]	-	-	<0,001	100
PO_4 [mg/dm^3]	0.22	0.57	0.78	100
NO_3 [mg/dm^3]	0.45	0.89	1.45	500
Lead [mg/dm^3]	Trace	0.002	0.022	100
Zinc [mg/dm^3]	Trace	0.07	0.132	100
pH value [pH]	8.2	6.6	10.2	≥ 4
Density [g/cm^3]	1.001	1.001	1.028	-
Total suspended solid [mg/dm^3]	-	-	270	-

Groundwater and sewage water meet the required standards, yet the results for sewage water significantly differ from those for drinking water and groundwater. Most sewage water properties appear on the low side of allowable values as set out in PN-EN 1008 [19].

Sewage water density amounts to 1.028g/cm^3, exceeding the value of 1.001 g/cm^3. Thus, in accordance with Table A.1 of PN-EN 1008 [19], water quantity was adjusted due to the presence of suspended solids. Concrete mix consistency was evaluated as S3.

The next stage of the research consisted of a compressive strength test of a cubic specimen of side 150 mm after 7, 14, and 28 days. Averaged results of the compressive strength test are presented in Table 2 and Fig. 2.

Table 2. Results of the compressive strength test

Type of water	Compressive strength f_{cm} [MPa]								
	after 7 days			after 14 days			after 28 days		
	Test value	Average	Range	Test value	Average	Range	Test value	Average	Range
Drinking water	25.4	25.2	0.9	28.9	30.8	3.0	39.5	39.5	1.1
	24.6			31.7			39.1		
	25.5			3.,9			40.2		
Groundwater	23.9	24.8	3.2	25.6	28.3	5.2	37.7	36.3	2.4
	26.8			28.6			35.8		
	23.6			30.8			35.3		
Sewage water	17.7	17.7	1.7	21.1	23.1	4.1	28.5	26.3	4.4
	18.5			25.2			24.1		
	16.8			23.1			26.4		

The concrete slump test is an on-the-spot test to determine the consistency as well as fluidity of fresh concrete. This test plays a vital role in ensuring immediate concrete fluidity in a construction project. According to the *PN-EN 206: 2014 Concrete - specification, performance, production and conformity standard*, workability for all fresh concrete mix is classified as S3 category (table 3).

Table 3. The concrete slump test (the slump cone test)

Type of water	Slump values [mm]	Classified category
Drinking water	117	S3: 100-150 mm
Groundwater	134	
Sewage water	139	

Table 4 shows densities for *concrete with all types of water.*

Table 4. Density of concrete

Type of water	Density of concrete [kg/m^3]					
	after 7 days			after 28 days		
	Test value	Average	Range	Test value	Average	Range
Drinking water	2253	2288	68	2238	2254	45
	2321			2283		
	2291			2240		

Groundwater	2178	2220	84	2190	2277	158
	2262			2294		
	2219			2348		
Sewage water	2296	2214	34	2329	2286	130
	2316			2329		
	2230			2199		

5. DISCUSSION

All results from the laboratory tests of the obtained concretes and concrete mixes are of lower values than those set out in PN-EN 1008. Having measured the impact of sewage water on the compressive strength of concrete after 7, 14, and 28 days, it was established that compressive strength lowered by 29.8 per cent, 25 per cent, and 33.4 per cent, respectively when compared to the concretes made with drinking water (Fig. 2). The results of the compressive strength test meet the criteria for the assumed compressive strength class C25/30. It should be emphasised that the sewage water used in the research was sampled in the concrete production plant on a regular production day.

For concretes made with groundwater, differences in compressive strength amounted to 2–8 per cent, remaining within the limits of the typical variability of concrete properties.

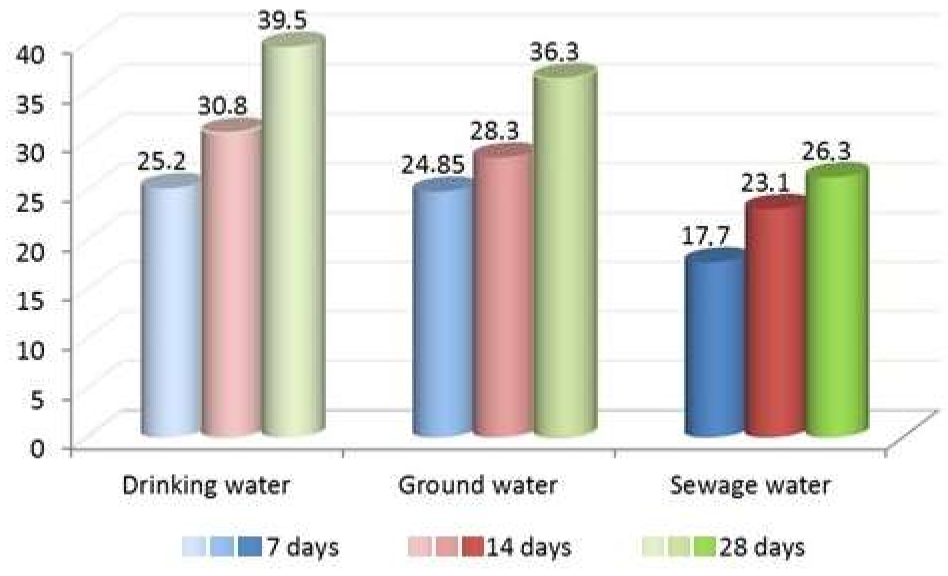

Fig. 2. Averaged results of compressive strength test

6. CONCLUSIONS

The sewage water used in the research proved to have an impact on the quality properties and parameters of both concrete mix and hardened concrete with the sewage water parameters appearing on the low side of allowable values.

Following a water quantity adjustment resulting from the presence of suspended solids in the sewage water, no significant impact of sewage water on concrete mix consistency was found. Consistency was evaluated as S3.

On the other hand, it was found that sewage water has a major impact on the compressive strength of concrete, which impact is clearly noticeable after 7, 14, and 28 days, and the values obtained are about 1/3 lower than the values obtained for concretes made with drinking water. This is probably the result of higher porosity; an increase in aeration under the effect of sewage water considerably affects the compressive strength of hardened concrete.

Groundwater has a significantly lower impact on the decrease in compressive strength, with the difference not exceeding 9 per cent. Thus, concretes made with tap water/drinking water and groundwater reach comparable levels of compressive strength.

The presented results may constitute the basis for further research that would include an evaluation of the changes in concrete workability over time, the evaluation of the impact of recycled water on concrete durability, and the evaluation of concrete and concrete mix physico-mechanical properties such as porosity. Today, as both global and regional drinking water resources become scarcer, this type of research gains in importance since it allows us to minimise the use of drinking water for technological and industrial purposes and, therefore, contributes to countering water deficiency. It is certainly in line with the long-term strategy for sustainable natural resource management.

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