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Study the Effects of Using Different Water Types on the Mechanical Properties of Concrete

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ABSTRACT

The issue of water sustainability is a major topic due to the lack of water sources and the scarcity of drinking water, so the search for alternatives began. In this paper, the effect of using three water sources will be studied (the tap water (as control reference mix.), the Tigris River, and the Pepsi Company factory). To study the physical and chemical properties, and the effect of this water on the concrete mixture, and for each source the concrete mixture was placed in cube molds and cylinders. Put the concrete mixture in a water basin for curing. Compression and splitting tests are performed at intervals of (7-28-90) days to evaluate these mixtures. From the results it was found that the compressive and splitting strength of concrete for tap water, Tigris River and Pepsi factory, which was recorded at the age of 7 days, the compressive strength of cubes was an average of 18.5 MPa, 19 MPa and 13 and the splitting strength was an average of 1.5 MPa and 1.4 MPa and 0.5 MPa, respectively, at the age of 28 days, which were recorded at 32.1 MPa, 28 MPa, and 16.4 MPa, respectively, and the splitting strength was 3 MPa, and 2.7 MPa, and 1.5 MPa, respectively, and at 90 days they were 36 MPa, 32 MPa, and 18 MPa, respectively, and the splitting strength was 3.2 MPa, 3 MPa, and 1.7 MPa respectively also was observed a decrease in compressive strength and splitting by more than 40% for Pepsi Baghdad company factory wastewater samples. Finally, the drinking water and the water of the Tigris River was suitable for making concrete mixtures

Keywords: concrete mixture, recycled water, river water, sand, cement.

INTRODUCTION

Water is an essential element in life, and due to climatic changes and the lack of rainwater, the depletion of these natural resources has increased and thus will lead to a shortage of fresh water, and one of the most important industries that consume large amounts of water is the concrete industry [Miller, 2018; Larsen, 2016] Thus the quantity and quality of water is required to be looked into very carefully. The strength and durability of concrete is reduced due to the presence of chemical impurities in water. In the manufacturing process, drinking water is always used in the concrete mixing process [Dakkak, 2020]. Nevertheless, in the context of this study, water is a crucial component of concrete; it combines chemically with cement in a process known as cement hydration to generate concrete with the appropriate characteristic strength [Akeem, 2013]. Water used in the mixing process influences the workability qualities of concrete and defines the needed water-cementitious content ratio, which influences the durability and strength properties of the concrete mixture. In addition to the amount of water used, the purity of the water has a considerable impact on the durability, strength, workability, and setting time properties of both fresh and hardened concrete [Alaneme, 2020]. After completely mixing concrete materials with water, the usage of various water sources, such as the water of the Tigris River and the waste water from the soft drink factory in Baghdad, was tested to determine the influence of the water's constituents on concrete's resistance. The use of impure water in the production of concrete may lead to issues with setting and premature structural failure. And has been discovered [Abrams, 1924] that impurities in water samples used to mix concrete might reduce its strength, particularly its compressive strength. In a similar manner, water used for curling concrete may reduce its strength [Smith, 1976]. Impurities and harmful compounds that are mostly introduced from the water used to mix concrete are likely to interfere with the hydration process, preventing aggregates and matrices from bonding effectively. Sometimes, the contaminants impair the aggregate's durability [Neville, 1995]. The purpose of this research is to determine the viability of using various natural water sources for recycling, i.e. as an alternative to drinking water, including river water (Tigris River) and sewage water (Baghdad Soft Drink Factory). Whether it has been treated or not, and comparing these two sources to municipal tap water, will serve as the standard. And understanding the impact of these two water sources on the compressive and tensile strengths of concrete

Table 1. Chemical composition of cement

Compound composition	By weight %	Limits of Iraqi Specification No.5:1984
Lime	61.34	-
Silica	19.51	-
Iron oxide	3.92	-
Alumina (Al_2O_3)	4.91	-
Magnesia oxide	2.18	<5.0
Sulfate	1.26	<2.8
Loss on Ignition	1.4	<4.0
Lime saturation factor	0.89	0.66–1.02
Insoluble residue	0.97	<1.5
Main Compounds (Bogue´s equation) %by weight of cement		
Tricalcium silicate	48.45	-
Dicalcium silicate	32.33	-
Tricalcium aluminate	4.82	-
Tetracalcium aluminoferrite	4.81	-

Note: *Chemical assessment was performed at National Center for Construction Laboratories and Research.

MATERIALS AND TESTS

All materials used in experimental work are detailed in the following paragraphs, with mention of the physical and chemical characteristics and respective standards.

Cement

Ordinary Portland Cement (OPC) type (I) of (Almass) which was manufactured in Sulaimanya, Iraq, is used in this study. The cement is packed in paper bags conforming to the requirements of the Iraqi Standard Specifications (No. 5:1984). Table 1 and Table 2 show the most important cement properties.

Fine aggregate

The research used the typical sand of the AL-Ukhaider region in (Karbala, Iraq), which fits the standards of Iraqi Standard Specification (No. 45: 1984-Zone II) as seen in Figure 1. Sand is a readily available, affordable material that contributes to reduce the cost of a specific concrete mixture. Table 3 displays the findings of the fine aggregate sieve study. Table 4 displays the chemical and physical characteristics of fine aggregate.

Coarse aggregate

Figure 2 shows the usage of gravel with a maximum size of 12.5 mm from the AL-Nibaee region (AL Anbar, Iraq). Table 5 presents the sieve analysis of natural coarse aggregate under Iraqi Standard Specification (No. 45: 1984).

Water mixture

The three types of water sources were used (tap water, Tigris River water, and sewage water for the Pepsi factory), where the first sample was taken from the tap water directly, and the second

Table 2. Physical properties of cement

Physical properties	Test result	Limits of Iraqi specification No. 5:1984
Specific surface area, Fineness Blaine method (m/kg)	262	>230
Setting time by Vicat´s method Initial setting (min) Final setting (min)	 167 244	 >45 <10 hrs
Soundness using auto clave (%)	0.3	<0.8

Note: *Physical assessment was performed at National Center for Construction Laboratories and research.

Figure 1. Fine aggregate

Figure 2. Natural coarse aggregate

Table 3. Sieve analysis of fine aggregate (Zone II)

Sieve size (mm)	% passing by weight	Limits of iraqi specification No. 45:1984 (Zone II)
9.5	100	100
4.75	96	90–100
2.36	90.5	75–100
1.18	78.5	55–90
0.6	55.4	35–59
0.3	21.6	8–30
0.15	6.5	0–10
Pan	0	-

Table 4. Fine aggregate physical properties

Physical properties	Test result	Limits of iraqi specification No. 5:1984
Specific gravity	2.44	-
Sulfate content (%)	0.08	≤ 0.5%
Absorption (%)	2.87	-
Particles finer than 75 mm sieve (%)	2.45	< 5%
Modulus of Fineness	2.5	-

Table 5. Sieve analysis of coarse aggregate

Sieve size(mm)	% passing by weight	Limits of iraqi specification No. 45:1984
19	100	100
12.5	96	95–100
9.5	44	30–60
4.75	4.4	0–10

sample was taken from the Tigris River from the Al-Qurayat area in Baghdad city at a depth of half a meter, while the third sample was collected from the waste of the Pepsi Co. factory from the final tank, before discharging to wastewater network. All these samples were collected in a polyethylene bottle capacity 5 gallons to test these parameters (temperature, pH, EC, TDS, salt, turbidity, DO, Cl, SO_4, O_2, acidity, and alkilnity) according to standard method (2000). The three water sources were used in the concrete mixtures. A constant water-cement ratio (w/c) of 0.45 was used in the concrete mixture.

Preparation of materials and specimens

Three mix groups are cast with a mix ratio of (1:1.7:2.8) (cement : sand: gravel) and w/c ratio of 0.45 for the purpose of testing and evaluating the effect of different water sources as describe in table (6) on the properties of concrete. The details of the mixes are as follows:

- group one – is considered as the reference group it used tap water, and it is adopted as a measure to compare the test results for the rest of the groups;
- group two – used water taken from Tigris River;
- group three – used water of the Baghdad Factory for soft drinks.

Concrete specimens

Standard concrete specimens were cast to investigate the properties of concrete, where the average of three specimens were adopted for each results. The dimensions of specimens prepared in this investigation are shown in Table 7 and Figure 3. After cleaning and lubricating the inside surfaces of the steel molds to avoid concrete adhesion after hardening, the concrete mixtures were poured into the steel molds until they were completely filled with compaction and then left for about 24 hours. As indicated in Figure 4, a 100 cm by 150 cm vibrating table was utilized to improve the strength and durability of concrete, which rely on adequate compaction.

Table 6. Group of water

Group	Details source of water
Group one	Tap water (control)
Group two	Water of Tigris River
Group three	Water of the Baghdad factory for soft drinks

Table 7. Test type, and dimensions of specimens

Type of test	Dimensions of specimen
Compressive strength of concrete	Cube of 150 mm
Splitting tensile of concrete	Cylinder of 100×200 mm

Mixing and casting

The mixing operation is essential for achieving the necessary workability and homogeneity of the concrete mix. Concrete was mixed in a laboratory mixer with a volume of 0.1 m^3 as shown in Figure 5. Before starting to mix it is essential to maintain the mixer smooth, humid, and clear of the water. The mixing procedure was carried out as described in the following items according to ACI 211 [Hamad, 2019; ACI, 2005]:

1. Add the coarse and fine aggregate into the mixer and dry-mixed for 3 minutes.

Figure 3. Types of specimens

Figure 4. Vibrating table

2. Add the binder materials (cement) to the mixture and continue for 2–3 minutes.
3. Adding 60% of mixing water to the mixture with slowly mixed for 3 minutes to make a homogenous distribution.
4. Adding the remaining 40% of the mixing water is added gradually to the mix. The total mixing time is 5–8 minutes.
5. Finally, the concrete was removed, cast, cured, and tested for concrete properties.

This method was chosen according to the limitations of mixing adopted by other researchers [Li, 2016; Said, 2017].

Curing

The process of pouring samples according to the requirements of the test. The number and types of samples are clarified in Table 7. The samples were kept for 24 hours and taken out of the molds and placed in a water tank filled with water and the samples were completely immersed, where they are treated with the same source of water for each sample, for example, samples from the source of the Tigris River are treated In the water with the same river water, as well as the tap water samples are treated with the same water. Also, the water samples of the Baghdad Factory for Soft Drinks are treated with the same laboratory water, meaning that the mixing water for each sample is the same as the treatment water. in it for a period of 7, 28 and 90 days, taking into account the compensation for the lack of water due to evaporation. They were then taken out of the tank and placed in an accessible location at room temperature prior to the testing process. Figure 6 shows the processing process.

Quantities of materials

The mixing ratio by weight of the control mixture is (1 : 1.7 : 2.8) (cement : sand : gravel) and the water content is 0.45 w/b, while the mixing weight per cubic meter are:
1) 390 kg/m^3 cement
2) 672 kg/m^3 sand
3) 1085 kg/m^3 gravel

Figure 5. Mixing and casting of concrete

Table 8. Number and types of specimens

Parameter	Mix	Group one	Group two	Group three	Total
Model type	Cube	9	9	9	27
	Cylinder	9	9	9	27

Figure 6. Curing process

Experimental tests

Compressive strength and splitting tensile tests are adopted for the purpose of evaluating concrete properties. Figure 7 shows the machine that was used for Compressive Strength test (ELE – ADR Touch) with a capacity of 2000 KN used to investigate compressive strength for each specimen [Sahan, 2021]. This strength was derived from the average of three cubes of 150×150×150 mm tested according to *(*BS 1881-116:1983*)*. The tests were carried out at the ages (7-28-90) days. The compressive strength of concrete cubic samples

Splitting tensile strength

Splitting tests are well-known indirect tests used to determine the tensile strength of concrete, also known as the split tensile strength of concrete.

Figure 7. Compressive strength testing machine

The test consists of delivering a compressive line load and opposing generators to a horizontally positioned concrete cylinder between the compressive platens. This splitting was calculated from the mean of three 100×200 mm cylinders tested in accordance with [PN-EN 1008:2004], as seen in Figure 8. The examinations were conducted at ages (7-28-90) days.

RESULTS AND DISCUSSION

Water test results

Chemical analysis results for three water samples. (Drinking water, Tigris river water and waste water of the Baghdad Factory for Soft Drinks), it was noted that the waste water of the Baghdad Factory for Soft Drinks contains the highest concentrations, as shown in Table 9. The results showed that tap water contains the lowest chemical concentrations compared to the water of the Tigris River And the waste water of the Baghdad factory. All results of the Tigris River water are within the standard specifications. generally, the presence of sulfates and chlorides and the acidic function have an effect on the concrete mix, increasing sulfate can reduce the content of calcium and magnesium. Hexavalent chromium (Cr^{6+}) is in cement due to its strong reducing ability. A major issue is how sulfur salts affect the corrosion of steel reinforcement in reinforced concrete structures. the chlorides that may cause

Figure 8. Splitting testing machine

Table 9. Results of the water tests

Parameters	Tap water	Tigris River	Wastewater of Pepsi factory	Max. allowable values in PN-EN 1008[BS 1881, 1983]
pH	7.54	7.31	7.6	≥ 4
Temp. C°	17	13.7	20	
TDS mg/l	500	572	1614	
Salt mg/l	410	425	864	
Cond. ms	740	864	1614	
Turbidity NTU	347	5.7	34.3	
O_2 %	54.6	21.8	34.2	
DO mg/l	5.15	2.27	54.4	
CL^-	11.2	9.2	35	500
Acidity	Trace	Trace	Trace	
Alkail mg/dm³	Trace	Trace	240	1500
SO_4	175	136	220	
Acidity				
Alkail mg/dm³	Trace	Trace	1500	
SO_4	160	430	250	500

corrosion in inert materials such as stainless steel and aluminum. The pH scale is an important parameter for determining the alkalinity of concrete. The most severe damage to concrete is caused by or as a result of low alkalinity level, which lowers the pH of concrete The most serious concrete damages are brought on by or result from a decline in the alkalinity level, which lowers the pH of the concrete.

Results of compressive strength and splitting tensile strength

The compressive strength, splitting strength, and lifespan of concrete created with Tigris River and wastewater of Pepsi factory are graphed to help explain the differences in compressive strength and splitting with age. This is ilustrated in Figures 9 and 10.

Table 10 and Figure 9 show that the compressive and splitting strength of concrete cubes and cylinders in tap water and Tigris River water increased significantly with age and this goes a long way to depicting the suitability of fresh water and river water for use in concrete production. With concrete production there was a gradual increase in compressive and splitting strength as it was recorded at 7 days of age, compressive strength 18.5 and 19 MPa and splitting strength 1.5 and 1.4 MPa, and at 28 days of age it was recorded 32.1 and 28 MPa, and splitting resistance 3 and 2.7 MPa At the age of 90 days, the highest compressive strength was recorded at 36 and 32 N/mm^2 and

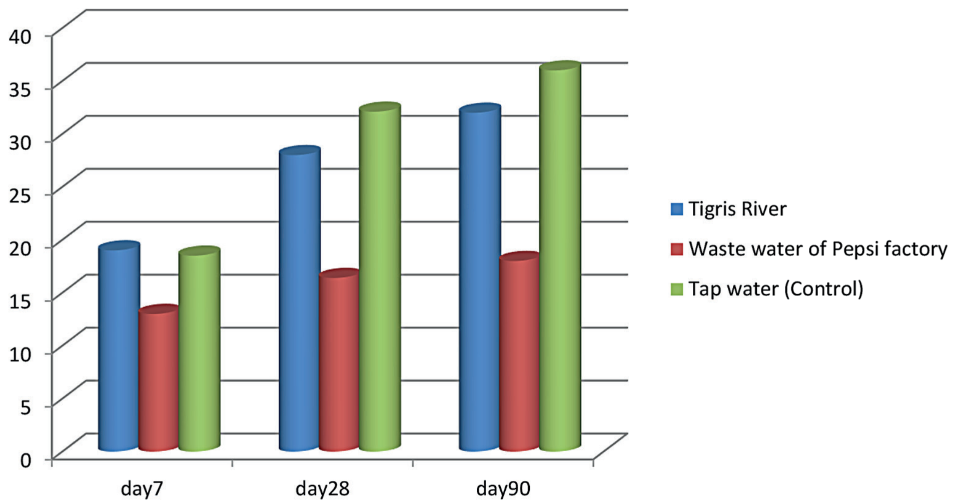

Figure 9. Graph of compressive strength against age of concrete

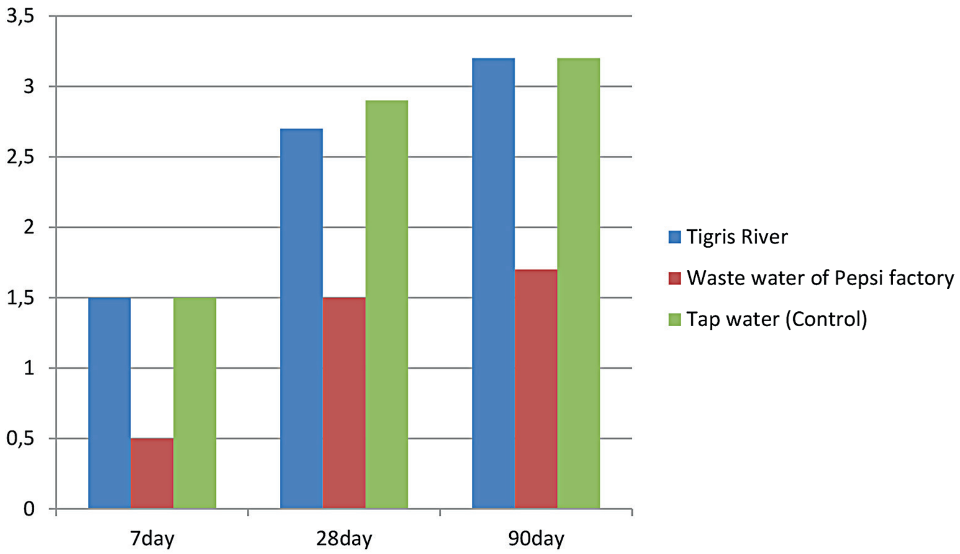

Figure 10. Graph of splitting tensile strength against age of concrete

Table 10. Results of the compressive strength and splitting tensile strength

Details source of water	Source of water	Water percentage	Compressive strength MPa			Tensile strength MPa		
			7 Days	28 Days	90 Days	7 Days	28 Days	90 Days
Tap water (Control)	-	0.45	18.5	32.1	36	1.5	3	3.2
Tigris River	natural	0.45	19	28	32	1.4	2.7	3
Wastewater of the Pepsi factory	Recycle water	0.45	13	16.4	18	0.5	1.5	1.7

the splitting strength was 3.2 and 3 MPa. It was discovered from Table 10 and Figures 9 and 10 that the compressive and splitting strength of concrete specimens produced with water from Pepsi-Baghdad Factory, where low compressive strength was recorded at the age of 7 days, compressive strength 13 N/mm^2 and splitting tensile strength very small, at the age of 28 days 16.4 MPa was recorded and the split strength was 1.5 MPa. With age the compressive strength increased, but in a very little way, at the age of 90 days, the highest compressive strength was recorded at 18 MPa and split resistance 1.7 MPa and the presence of elements such as Na, K, Ca and Cl helped to increase the hydration rate, which facilitated the early increase in compressive strength, but later it witnessed a sharp stabilization due to declining quantities.

One of the most important reasons for the increase in the compressive resistance of tap water and Tigris River water is due to the lack of salts, where the percentage of salts in tap water was 410, and the percentage of salts in the water of the Tigris River was 572, where the percentage of salts was low compared to the percentage of salts of waste water from Baghdad Factory for soft drinks, where the highest percentage was recorded 864 salts, where notice that the increase in the percentage of salts causes a decrease in the compressive resistance. As for turbidity, where tap water recorded a turbidity rate of 3.47, while the Tigris River water had a turbidity rate of 18, and the highest turbidity in Baghdad water for soft drinks recorded a turbidity rate of 34.3, where the increase in turbidity affected the lack of resistance to compression and splitting of concrete. Likewise, the percentage of chloride in the water affected the strength of the concrete, as each decrease in the percentage of chlorides increased the resistance to compression and splitting of concrete.

CONCLUSIONS

According to established results in this work the following facts can be found. The use of Tigris River water in concrete production including mixing and curing is good as tap water, where the results provide very close concrete strength values. For early ages concrete strength (at 7 days) specimens mixed and cured with Tigris River shows higher strength values in compare with other water scours examined in this work. Due to higher concentrations of salts, sulfate and some other impurities Pepsi Baghdad company factory wastewater provides the lower concrete strength values in compared with concrete mixed and cured with tap water and Tigris River waste water. From the foregoing, it was concluded that the waters of the Tigris River in the Al-Qurayat area can be used in concrete mixtures

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