Assessment of Replacing Wastewater and Treated Water with Tap Water in Making Concrete Mix

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ABSTRACT

This work carried out to assess the strength of concrete using treated water and wastewater in concrete mix as a comparison with the strength of concrete made by tap water. The compressive and splitting strength were measured for each type of water and the results show that; using wastewater and treated water decrease the strength of the samples of cubs and cylinders; were the average reduction for compressive strength of cube is (7.3%) and for splitting cylinder strength is (9.7%) for treated water. But using wastewater gives an average reduction of compressive strength of cube about (23.2%), and for splitting cylinder strength about (23.1%). The performance requirements in British Standards and AASHTO T26-79 requires that the compressive strength of concrete cubes made of untreated water not to be less than 90% of cubes made with tap water; according to these specification the treated water could be used in concrete mix. The chemical composition of wastewater is affecting the concrete strength under many considerations like; hydration process, steel corrosion and the properties of concrete in the future; durability of concrete.

KEYWORDS: Assessment, Tap water, Wastewater, Treated water, compressive strength, splitting strength.

INTRODUCTION

Fresh water is a precious and scarce commodity in all arid regions such as Jordan and many other countries. However, non-fresh water supplies including many kinds of water such as waste water and treated water which exist in abundant quantities in these regions [1].

The Hashemite Kingdom of Jordan is suffering from an increasing demand for water due to the rising number in population, at the same time there are a very limited resources for water supply. It is one of the crucial equations that can not find an appropriate balance. Thus Jordan is facing a future of very limited water resources. Re-use of treated wastewater is an important issue in housing, schools, roads and many other civil works policy [1].

Water is needed as a component in concrete mixtures. It is primarily needed for the hydration process of cementations materials and for curing. It is also needed for road construction projects, where it is used as mixing water for compaction and for dust control [2].

Treated water and wastewater is considered as a non-conventional water resource and is one of the current alternatives to use it in the construction of such projects and many other works. It has been estimated that this water resource contributes in 70 million cubic meters (MCM) per year which could be a good source of water if managed properly on sustainable basis to ensure environmental protection [3].

In addition to, Jordan suffers from a low irregular rainfall. The annual average rainfall ranges widely from 50 to 600 mm in different parts of Jordan, but an average of 104 mm due to the higher evaporation that means the precipitation ratio is low. Hence the ground water has a poor renewable source. Although of such a dramatic fact, but Jordan depends on underground water for its water resources and share more than 54% of its usage. The underground water resources contribute with 70% of the total supply for the country [1, 4].

In this work, the researcher is trying to find a solution to the treated and wastewater as the replacing to the tap water in making concrete mix. Also to figure out the effect of using treated water and wastewater on the compressive strength of concrete mixtures and the possibility to use it as a mixing water to decrease economically using tap water on concrete mixes in Jordan.

WATER QUALITY

Water quality has been a matter of concern in civil engineering construction and most specifications require the use of potable; tap water because its chemical composition is known and well regulated. In some situations where tap water is not readily available, many water types which are unacceptable for drinking may be satisfactorily used in concrete, road construction and other applications. The performance requirements in British Standards and AASHTO T26-79 are the time of setting and the compressive strength [5]. A note in the British Standard requires that the compressive strength of concrete cubes made of untried water not to be less than 90% of cubes made with tap water. The note also states that water that results in a strength reduction of up to 20% can be acceptable, but the mixture proportions should be adjusted as appropriate. The physical and chemical requirements in the standards refer to dissolved salts and solids in suspension. AASHTO T26-79 prescribes test methods for the pH value in water as well as testing for Chloride, Sulfate, Organic and Inorganic contents [5].

CONCRETE QUALITY

Concrete is an intimate mixture of bonding material like; cement, lime, polymers, etc, fine aggregate, coarse aggregate and water. When water is added to the dry mixture of bonding materials and aggregates, it forms a plastic mass which can be easily molded to the desired shape and size. After stipulated time, the molded mass hardens and becomes a solid mass. Concrete has completely different properties when it is in the plastic state and when hardened. Concrete in the plastic stage is also known as green concrete. Concrete must be tested in either states; plastic and stiff, for workability, segregation, bleeding, harshness, strength, durability and permeability [6].

THE MIXING MATERIALS

The used materials in making concrete mixes must be tested; so as for aggregate specific gravity, unit weight, absorption, impact and crushing value should be stated clear. Table 1 present the characteristics of the used aggregates.

Table 1: Characteristics of aggregate

Aggregate size	Bulk S.G (SSD)	Crushing value	Impact value	Value of unit weight(kg/m³)	Absorption (%)
Coarse	2.61	25.6% < 30% (ok)	17.3% <30% (ok)	1466 kg/m³	2%
Medium	2.62			1513 kg/m³	1.92%
Fine	2.46			1703.9 kg/m³	1.63%

Ordinary Portland cement of Jordan; grade 42.5 N/mm^2, with Specific Gravity of 3.15 been used.

In reality, the silicates in cement are not pure compounds, but contain minor oxides in solid solution. These oxides have significant effect on the atomic arrangement, crystal form and hydraulic properties of the cement.

Table 2 illustrates the standard specifications of tap water according to the ASTM & World health organization (WHO).

Table 2: Tap water standard specifications

	ASTM specification of tap water	World health organization
T.D.S	500 mg/L	1000 mg/L
T.S.S	-	-
pH	6.5 – 8.5	6.5-8.5
COD	-	-
BOD	-	-

Table 3 illustrates Mutah University tap water specifications, where; the TDS, pH, COD, BOD and Cl_2 concentrations are tabulated.

Table 3: Mutah University tap water specifications

Chemical composition and physical properties	Tap water
T.D.S (total dissolved solid)	320 mg/L
T.S.S(total suspended solid)	-
pH	7.6-7.9
COD	3-4 mg/L
BOD	-
Cl2	48 mg/L

Table 4 presents the chemical composition and physical properties of the domestic treated water of Mutah University treatment plant. This treated water uses for irrigation purposes.

Table 4: Chemical composition and physical properties of treated water

Chemical composition and physical properties	Treated water
T.D.S(total dissolved solid)	600 mg/L
T.S.S(total suspended solid)	<30 mg/L
pH	6.9-7.2
COD	(50-70) mg/L
BOD	<10 mg/L
Cl2	3 mg/L

Table 5 illustrated the chemical composition of the waste water of Mutah University campus.

Table 5: Mutah University waste water chemical composition.

Chemical composition and physical properties.	Wastewater
T.D.S(total dissolved solid)	800 mg/L
T.S.S(total suspended solid)	(200-600) mg/L
pH	(6.6-7.3)
COD	(1400-1600) mg/L
BOD	(250-800) mg/L

According to ASTM, two molds been used in testing concrete samples; where the standard (15 x 15 x 15) cm cubes were used for compression tests and the standard **(**15 x 30) cm cylinders were used for splitting samples. Figure 1 present the two molds respectively.

Figure 1: The testing molds

THE MIX DESIGN

Three groups of concrete mixes been prepared; where the first group prepared using tap water, the second group prepared using treated water and the third group prepared using waste water.

Each mold been filled with concrete for three layers and compact each layer by standard rode (25 times). The W/C ratio was stated to 0.5 based on the ASTM standards. The samples left to dry for 24-hours then curing started until 28 days in tap water. Figure 2 and 3 illustrated.

Figure 2: Prepared cub sample

Figure 3: prepared cylinder sample

TESTING SAMPLES

The prepared samples been tested for compression and splitting based on the ASTM specifications. Samples were tested after 1, 7, 14, 21, and 28 days of curing in tap water. Figure 4 present the compression and splitting machines.

Figure 4: The compression and splitting machines respectively

RESULTS AND ANALYSIS

Figure 5 present the relation between curing time and the compressive strength of concrete cubes made by different water types.

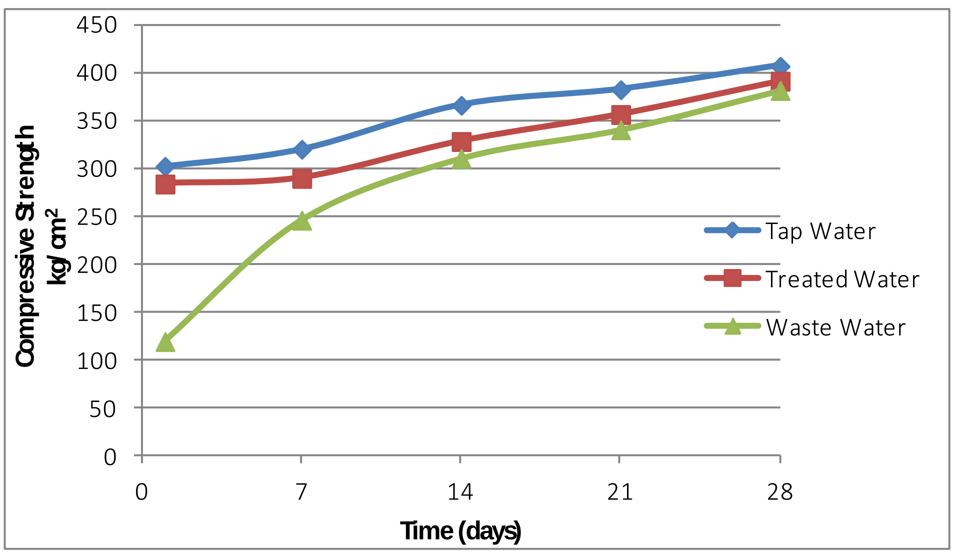

Figure 5: Compressive strength of concrete cubes.

Figure 6 present the relation between curing time and the splitting strength of concrete cylinder made by different water type.

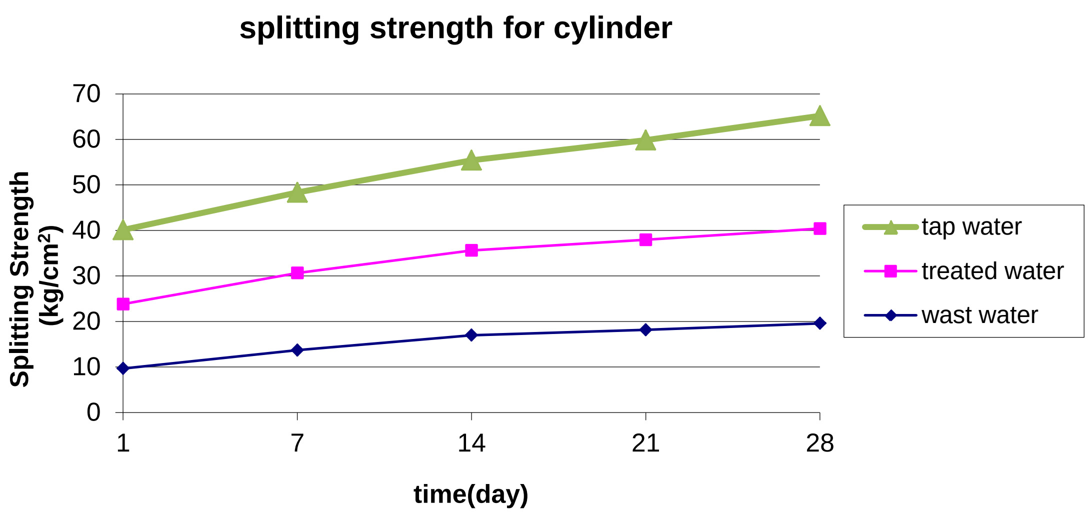

Figure 6: Splitting strength of concrete cylinder

Figure 5 and 6 illustrates that the compressive and splitting strength of concrete decreases when the treated and wastewater been replaced by tap water for mixing. The chemical composition of treated water is not so far from the chemical composition of tap water, but very far from the waste water. The results showed that the treated water could be used instead of tap water based on the ASTM specifications. The compressive and splitting strength obtained by treated water is not less than 90% of the strength obtained from tap water that gives good results of using the treated water of Mutah University treatment plant.

Using wastewater in making concrete mix; the strength decreases more than using treated water, the chemical compositions in table 5 shows that; the value of BOD, COD, and TSS is very high and more than the limits of ASTM C94 requirements that reflects the effect of chemicals on concrete compressive and tensile strength. These elements found in wastewater do more effects on the durability and resistance of concrete in the future because it affects the chemical reaction of the main cement constituents which are C_2S, C_3S, C_3A, and C_4AF.

Wastewater tends to reduce the compressive strength of concrete during the hydration process. The wastewater transforms to unstable compounds such as mono sulfate aluminates, and finally dissolves. As a result; there are additional pores in the concrete matrix, which eventually causes the decrease in strength, also make a weaker bond between aggregate and cement paste which yield the lower compressive and tensile strength of concrete[1].

The resistance of sulfuric acid attack the wastewater has a negative effect on the acid resistance. The reaction between calcium hydroxide $Ca(OH)_2$ in concrete and sulfuric acid (H_2SO_4) yields a soluble product of calcium sulfate or gypsum $CaSO_4 \cdot H_2O$ as a layer on the surface of concrete, that lead to lose bonds and the layer is prone to leaching and deterioration.

The resistance of hydrochloric acid attack; that the wastewater has a negative effect on the resistance to hydrochloric acid attack. The reaction between calcium hydroxide $Ca(OH)_2$ in the concrete and hydrochloric acid HCL forms calcium chloride $CaCl_2$ which is a soluble product that make the concrete more susceptible to leaching and deterioration due to the acid attack. In comparison with hydrochloric acid, sulfuric acid attack is more damaging to concrete as it combines an acid attack and a sulfate attack.

The high quantity of BOD, and COD on wastewater make the concrete mix unsatisfactorily to use as a reinforced concrete because the more effect on the corrosion of steel.

CONCLUSION AND DISCUSSION

1- Using treated and waste water will decrease the strength of the concrete. Because the high amount of COD, BOD, TDS, and TSS in water affect cement compounds; C3S, and C2S, which are responsible for the strength.

2- Using waste water; the strength decreases more than using treated water in making concrete. The amount of COD, BOD, TSS, and TDS in wastewater is greater than that in treated water.

3- It is good to use the treated water in making concrete mix, because compressive strength of concrete is not less than 90% of that concrete made by tap water, the results show that the average percent of compressive and splitting strength made by treated water was 92.7%, 90.3% respectively.

4- The chemical composition and physical properties of treated water is approximately within the limits according to the ASTM performance requirements, and the difference between the results of compressive strength of treated water and tap water is less than 10%, so there is no problem in using the treated water as mixing water.

5- Using the treated water in making concrete mixes will decrease the consumption of using tap water in making the mix; this economically considered good because Jordan suffers from very limited resources and need it for population growth in the future instead of making concrete.

6- The composition of waste water make it unsatisfactorily to use it in concrete mix because it’s negative effect on concrete behavior and steel, and the concrete made by wastewater shows no resistance to the acids attack so it can't be used as a mixing water.

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