Summer 8-2022

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Amany G. Micheal Prof.
The British University in Egypt, amany.micheal@bue.edu.eg

Haidy Abdel Salam
pg.haidy91830015@bue.edu.eg

Gouda Ghanem
Helwan University

PAPER • **OPEN ACCESS**

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To cite this article: A Micheal *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1056** 012046

IOP Conf. Series: Earth and Environmental Science 1056 (2022) 012046 doi:10.1088/1755-1315/1056/1/012046

Implementation of Secondary and Tertiary Treated Wastewater in Concrete Manufacturing

A Micheal[1, *], H Abdel Salam[2] and G M Ghanem[3]

[1] Centre for advanced Materials, the British University in Egypt, Cairo, Egypt
[2] Faculty of Engineering, the British University in Egypt, Cairo, Egypt
[3] Civil Engineering Department, Faculty of Engineering, Helwan University, Cairo, Egypt

[*] Corresbonding Author Email: amany.micheal@bue.edu.eg

Abstract. Water scarcity is a problem that faces many regions. In a developing and arid country like Egypt, the need for freshwater is exponentially increasing. This research is an evaluation of the recycled wastewater to be used in concrete manufacturing. The treated wastewater is blended with potable water with percentages of 25%, 50%, and 100%. The mixture of the two types of water is used in concrete mixing and curing. Control specimens with pure potable water are cast for comparison. The setting time for Ordinary Portland Cement is tested using the different water mixes. The hardened concrete is tested in compression and flexural at age of 7 days and 28 days. The results show that the treated wastewater may delay both the initial and final setting. The phenomenon is more pronounced in secondary treated wastewater. For the compressive strength, both treatment regimens can be safely used. The flexural strength is reduced at late ages.

Key words: treated wastewater, mixing water, curing.

1. Introduction

The construction industry responsible for the consumption of huge amount of fresh water. Approximately 150 litres water is required for every 1m^3 of concrete. The use of water in construction industry is not limited to concrete mixing but it extends to cleaning of equipment, aggregate washing, and concrete curing. The quality of mixing and curing water is a vital factor in producing concrete with high strength and good durability. Different specifications are set for mixing water qualities [1], [2] & [3]. An overview on the quality of concrete mixing water according to different codes can be found in the work of Babu et all [4].

One of the promising areas for saving water is to use treated wastewater in concrete manufacturing. Many researchers contribution in this field are available in literature. The published experimental programs range between checking the effect of using wastewater on cement paste properties, fresh concrete properties and hardened concrete properties mainly strength. The effect on cement setting can be found in the work of Babu and Raman [4]. Samples of cement pastes mixed with tab water and designated as control specimen, Primary treated water (PTW), Secondary Treated water (STW), and Tertiary treated water (TTW) gave initial setting time of +70, +47, and +38 minutes respectively compared to that of control, where they give +30 and +75, and +45 minutes respectively for final setting time. Different chemical compounds are observed in the XRD test compared with the compounds observed in the samples mixed with distilled water. Same observation of increased initial and final setting time is mentioned in the work of Shaikh and Inamdar [6].

The amount of soluble sulfates in the mixing water is of great importance that will affect the C3A hydration [7] & [8]. For cement soundness, Tang and Gartner [7] stated that no significant

differences between using PTW, STW, and control in the context of the maximum expansion in Le Chatelier test.
For properties of fresh concrete that implement treated wastewater, Tang and Gartner [7] carried out an experimental investigation on the slump of concrete mixed using PTW, STW and tab water. The results reveal that using PTW and STW leads to a decrease in slump by 4 and 1cm respectively, compared to the tab water control mix. This is attributed to the fact that PTW and STW have a higher amount of total dissolved solids that may lead to decrease in the concrete slump value.

For hardened concrete properties, focus is drawn on the compressive strength. according to ASTM C94 [1], the compressive strength at 7 days of standard mortar cube mixed with treated water should not be less than 90 percent than that of cubes constructed with tap water. As for the flexural strength, it does not have any requirements in the standards. In the work of Shekarchi M. et al [9], when STW was used, a decrease of 10 percent occurred to the compressive strength at age of 7 days and flexural strength at 28 days. On the other hand, and when TTW is used, the compressive strength at 7 days and the flexural strength at 28 days increase by 15 percent.

To help in water saving efforts in arid country as Jordan, Ghrair and Al-Mashaqbeh [10] investigated the use of Primary and Secondary Treated Wastewater (PTW, STW) in concrete manufacturing. They reported that STW is a better alternative for concrete and mortar as no negative effect on the compressive strength and setting time is observed. Conversely, using PTW as mixing water decreased the compressive strength up to 19.6%. Same comment can be found in the work of Swami et al [11]. Al Jabri et al [12] investigated the effect of using wastewater collected from car washing stations in concrete mixing. They concluded that there is no significant effect on the strength and absorption but it is suspected to have long term effect on concrete durability and steel corrosion.

El Nawawy and Ahmed [13] investigated implementation of treated wastewater from El Doha water treatment plant in concrete mixing. The chemical analysis if the water effluent revealed that it is not compatible most codes. They suggest mixing this water with tab water to improve their properties. Their results show that the treated water impacted negatively the concrete strength and cannot be used unless it is blended with tab water with percentage around 40%.

2. Water treatment methods

Wastewater is one of the types of polluted water resulting from different human activities and their multiple uses of water for many purposes. Wastewater is classified into two major categories; black water and grey water. Black water is discharged from toilet and kitchen water and it contains mainly organic matter, Nitrogen, and Phosphorous. Grey water results from recreational water, washing water and laundry water and it occupies 60-80% of sewage water.

The treatment of wastewater starts by the primary treatment process (PTW). The main objective of PTW is to remove large size of floating matter. It signifies the split-up of liquid and solids by the means of gravity settling. After the Primary Treatment about 40%-60% of the suspended solids and 30%-40% of the biological matters are omitted [14]. The key features of the Secondary Treatment stage (STW) are the use of biological processes to oxidize the organic matters and to dispose the oxidized materials using sedimentation. Purification using Ozon or Chloride is also a part of this process. The resulting water is 80-90% clear from the solid particles and 90 to 99% from harmful bacteria. Nowadays many countries adopt the Tertiary Treatment on wastewater (TTW) which involves more purification of Secondary Treated water to reduce the content of biological content and suspended matters. The Tertiary or advanced treatment results in more efficient water that can be used in purposes that need more efficient water than that results from Secondary Treated. Whatever the adopted treatment regimen, the quality of resulting water is assessed in the context of the content of the total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BODS), chemical oxygen demand (COD), total phosphorous (T-P), Ammonia (NH3), Chloride (Ci^-), and, finally, Escherichia coli bacteria.

3. Methodology

In Egypt, the water scarcity is becoming an urgent matter nowadays [15]. On the other hand, the water treatment plants are spreading in Egypt exponentially. In this research an attempt is made to implement wastewater effluent in concrete manufacturing. The wastewater is obtained from a water treatment plant located in El Shorouk City located on Cairo-Suez Desert Road. The effluent is obtained after the completion of both secondary and tertiary treatment processes. Properties of the used secondary treated wastewater effluent is shown in Table 1.

Table 1. Chemical composition of secondary treated water.

Day	PH	Temp	TS	TSS	TDS	COD	BOD5	D.O.
28-11-2020	7.4	23.2	580	25	555	37	-	4.5
29-11-2020	7.44	21	437	32	405	43	29	4.8
30-11-2020	7.35	20.2	436	26	410	37	-	4.7
1-12-2020	7.39	21.5	478	18	460	45	-	5.0
2-12-2020	7.33	21.3	475	25	450	43	-	5.2

Where:

BOD5: Biological oxygen demand
TS : Total solids
COD: Chemical oxygen demand
TDS : Total dissolved solids
TSS: Total suspended solids

One of the most significant parameters is the pH value which most of codes require to be not less than 7 to ensure suitable alkalinity of concrete medium. This is satisfied in the effluent used in concrete mixing and curing according to Table 1. Several tests are conducted on concrete made using both secondary and tertiary treated wastewater. The results are compared with concrete mixes made with tab water. The cement content in the mix is 350 kg/m^3 and the water/cement ratio is 0.45. The ratio of coarse aggregate to fine aggregate is 2:1. The coarse aggregate is lime stone with NMA of 19mm and the fine aggregate is sand.

Three percentage to replace tab water with either secondary treated or tertiary treated wastewater; 25%, 50%, and 100%. The type of water used for mixing is used for curing as well. For example, concrete mixed with water of 50% secondary treated wastewater is cured in the same mix of tab and treated water. For concrete compressive strength determination, samples of cubes of dimensions 15.8x15.8x15.8 cm according to the Egyptian Standards ECP 203 (2017) are used. The compressive strength test is conducted at age 7 and 28 days. Another test is performed to determine the concrete flexural strength. The specimens are concrete beams with length 600mm, span 500mm, section 100mmx100mm. The failure load is determined and the flexural strength is calculated using the relation:

4. Results

4.1 Cement setting time

The initial and final setting time tests are performed using the different blending percentages stated above. The test is conducted according to ESS 373/1991 [16]. The setting time are shown in figures 1 and 2 for initial and final setting time respectively.

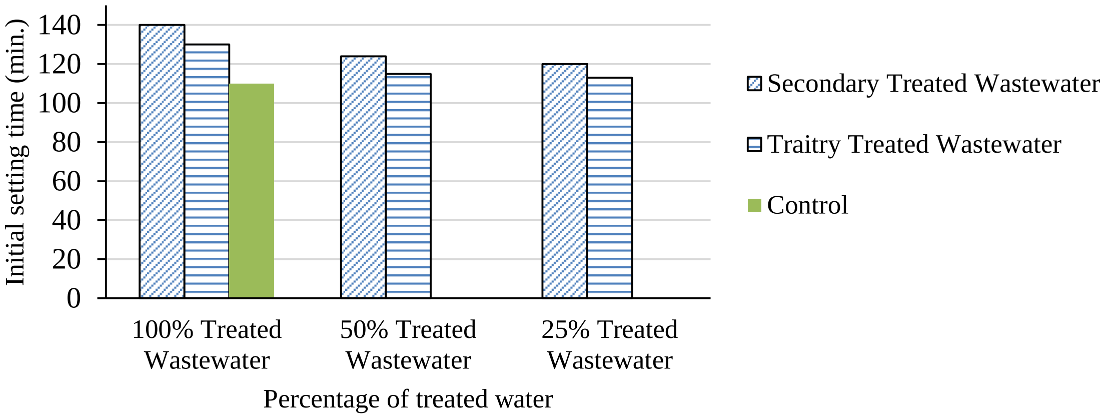

Figure 1. Initial setting time for different wastewater percentages.

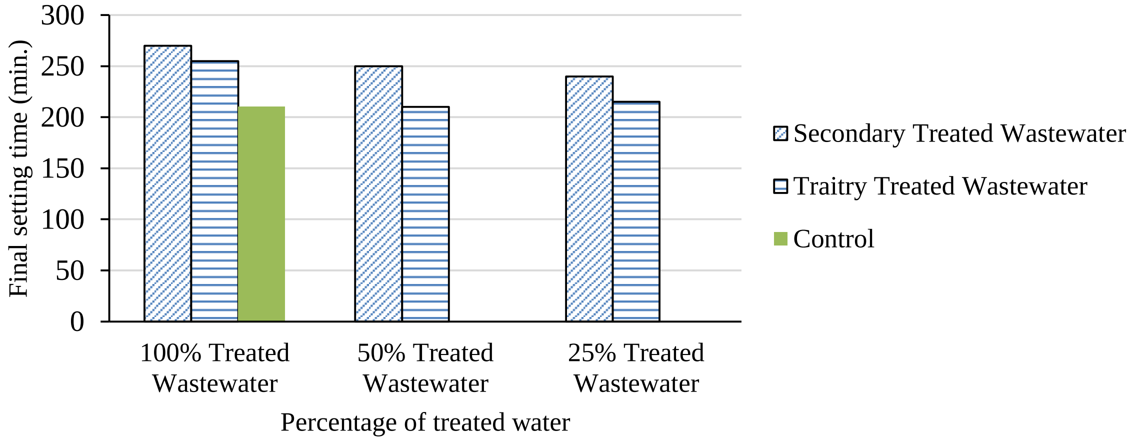

Figure 2. Final setting time for different wastewater percentages.

The trend of the results shows that there is an increase in the setting time for both secondary and tertiary waste water. The increase in more pronounced for the secondary treated water. The percentage increase in the setting time are shown in Table 2.

Table 2. Percentage increase in initial and final setting for different percentage of wastewater.

% Blending	STW		TTW	
	Initial Setting	Final Setting	Initial Setting	Final Setting
0 % (Control)	----	----	----	----
100% wastewater	+27.27	+28.57	+18.18	+21.43
50% wastewater	+12.73	+19.05	+4.55	+0.00
25% wastewater	+9.09	+14.29	+2.73	+2.38

4.2 Compressive strength

Figure 3 shows the comparison of compressive strength for different concrete mixes at age of 7 days and using the curing regimen stated before. It can be concluded that no significant change or reduction in the strength of concrete using blended water of both tab water and treated water. Both the STTW and TTTW shows good results. The same comment can be said about the compressive strength after 28 days as shown in figure 4.

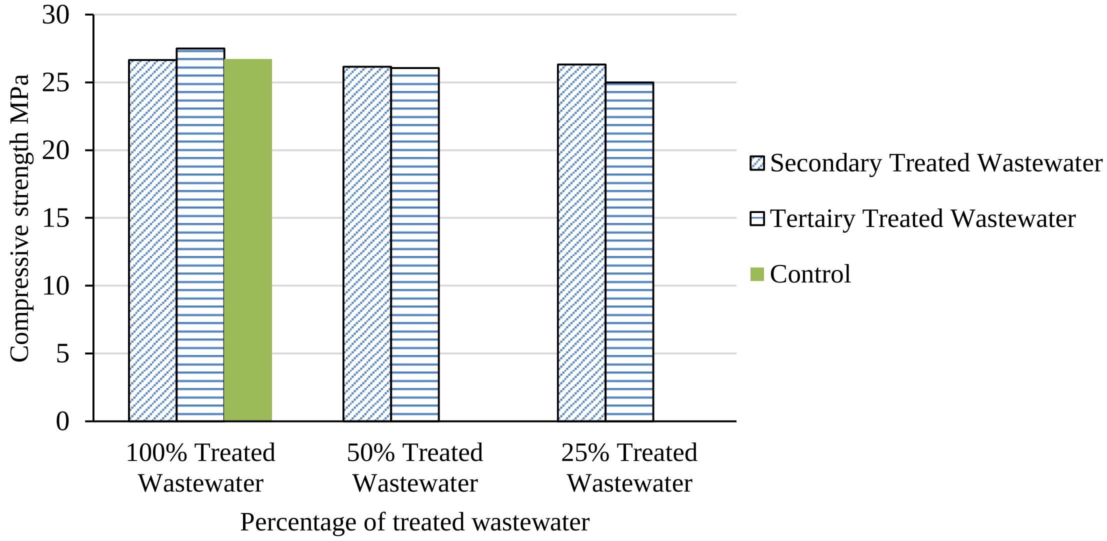

Figure 3. Compressive strength of concrete cube specimens at age of 7 days.

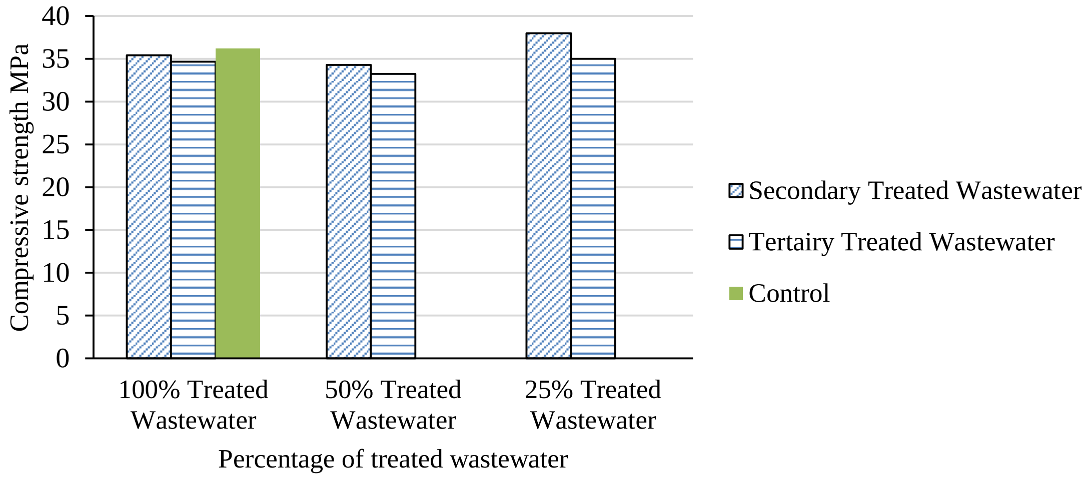

Figure 4. Compressive strength of concrete cube specimens at age of 28 days.

4.3 Flexural strength

The other mechanical test conducted in this experimental program is the three-point flexural strength test. The results are shown in figures 5 and 6 for 7 and 28 days respectively. For early ages, the tertiary treated wastewater show better performance but as hardening goes on and at age of 28 days, the control specimens takes the lead. The reduction in the flexural strength for STW is 41.8% , 29.5% and 18.9% for blending percentages of 100%, 50% and 25%. For the TTW the reduction is 40.6%, 47% and 34.2% for same blending percentages.

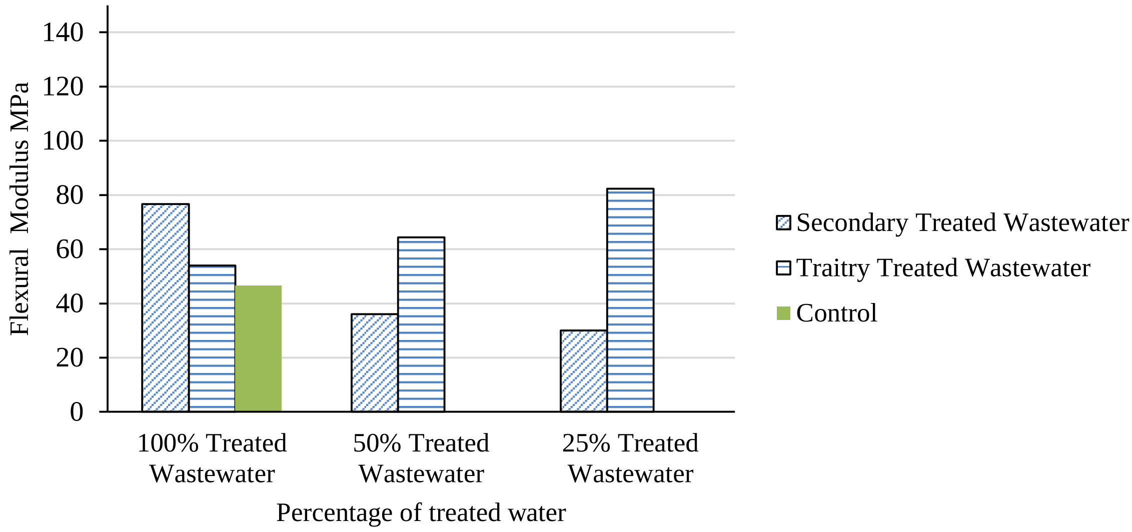

Figure 5. Flexural modulus at age of 7 days.

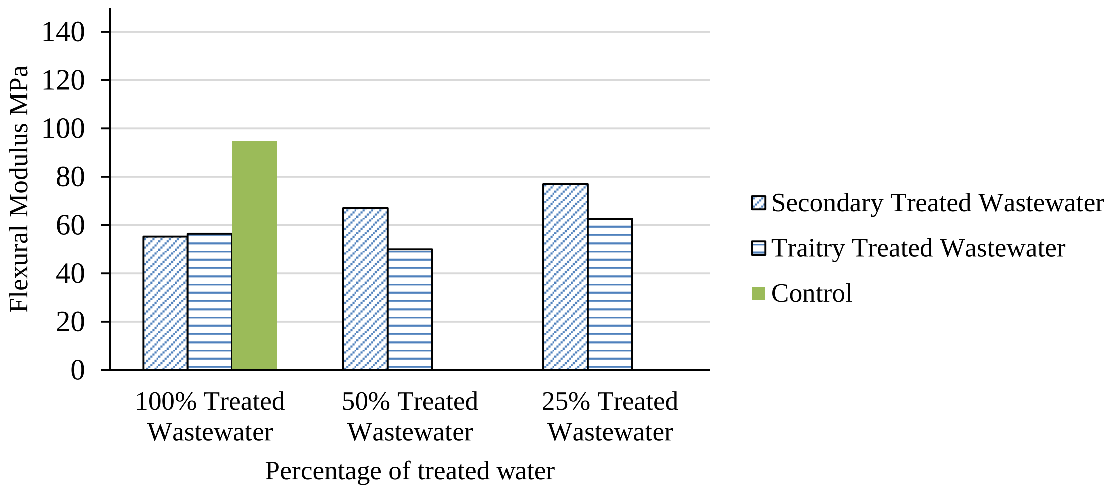

Figure 6. Flexural modulus at age of 28 days.

5. Conclusion

Implementation of treated wastewater in concrete mixing and curing is tested. Two water treatment regimens are used; secondary treated and tertiary treated water. The mixing and treatment water is a mix between tab water and treated water with percentages of 25%, 50% and 100%. The results are compared with control specimens of 100% tab water. The tests include the initial and final setting time, compressive strength and flexural strength. The results show increase in both initial and final setting time which is more pronounced in the secondary treated water. For the strength, no significant reduction can be observed in the compressive strength. For the flexural strength, the treated water shows some enhancement for the early age but for late ages, the control specimen shows better performance.

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