Journal of Al-Azhar University Engineering Sector

Vol.17, No. 63, April 2022, 528 - 538

INFLUENCE OF USING TREATED WASTEWATER ON PROPERTIES AND STRENGTH OF REINFORCED CONCRETE MIXTURE AND ITS DURABILITY

Mohamed A. E. Halawa [1*], Saeed A. M. Al-Sheikh [1]

[1] Civil Engineering Department, Higher Institute of Engineering at 15th May, Cairo, Egypt

*Corresponding author's E-mail: mohamed.34911@yahoo.com

Received: 15 Oct. 2021   Accepted: 6 Feb. 2022

ABSTRACT

Population increasing led to increase of water consumption, so providing suitable alternatives was an important to serve water. In this study reuse treated wastewater (TWW) in concrete is possible. Water samples were used as primary, secondary, tertiary treated wastewater and treated grey water to compare final results with mixture of concrete using the fresh water (FW) as a control sample. This paper examines the influence of burn tests by using TWW in process of curing concrete cubes. The results of this study verified using tertiary TWW as mixing water achieves strength better than the fresh Water. The results confirm the possibility of using TWW in reinforced concrete mixture; however, in buildings exposed to fire and high temperatures, it is recommended not to use any treated wastewater as mixing water.

KEYWORDS: Treated wastewater; curing concrete cubes; Reinforced concrete; Tertiary treated wastewater and compressive strength.

تأثير استخدام مياه الصرف المعالجة على خصائص ومقاومة ومتانة الخرسانة المسلحة

محمد أشرف عزالدين حلاوة[1]*، سعيد أحمد محمود الشيخ[1]

[1] قسم الهندسة المدنية، المعهد العالي للهندسة بمدينة ١٥ مايو، القاهرة، مصر

* البريد الإلكتروني للمؤلف الرئيسي: mohamed.34911@yahoo.com

الملخص العربي:

نظراً للزيادة السكانية الهائلة والتي أدت إلى زيادة الاستهلاك المائي، لذا كان من المهم توفير بديل مناسب للحفاظ على المياه العذبة. في هذه الدراسة نستنتج أن استخدام مياه الصرف المعالجة يصبح ممكناً في الاستخدام الإنشائي. العينات المستخدمة في هذه الدراسة كماء خلط في خلطة الخرسانة المسلحة تم تجميعها من المياه المعالجة معالجة ابتدائية والمياه المعالجة معالجة ثانوية والمياه المعالجة معالجة ثلاثية وكذلك المياه الرمادية والتي يتم تجميعها من صرف الأحواض دون المرحاض ومقارنة تلك النتائج بخليط من الخرسانة المسلحة تم استخدام ماء عذب به كماء خلط. كما تهدف هذه الدراسة إلى مدى تأثير الحريق على المياه المعالجة. أثبتت هذه الدراسة أن استخدام المياه المعالجة معالجة ثلاثية تحقق مقاومة للخرسانة أفضل من

نظيرتها التي تستخدم الماء العذب كماء خلط، ولكن في المنشآت المعرضة للحريق وللحرارة العالية نوصي بعدم استخدام أي نوع من المياه المعالجة بأنواعها المختلفة كماء خلط.

الكلمات المفتاحية : مياه الصرف المعالجة، مكعبات الخلطة الخرسانية، الخرسانة المسلحة، المياه المعالجة معالجة ثلاثية، مقاومة الضغط.

1. INTRODUCTION

Concrete industry contains about 75 % aggregate, 25 % paste of cement contains 10 % water. In Egypt, concrete industry uses huge amounts of fresh water. Large amounts of potable water are used for cement mortar and washing aggregate. The water shortage problem is the most substantial problem faces a lot of societies. For these reasons, reuse of treated wastewater (TWW) is one of the significant alternatives in water resources management [1]. In the construction part, potable water is recommended for the compressive strength for industry of concrete [2]. Concrete is the main material in industrial life and plays a significant role in civil engineering [3]. Egypt suffers from water shortages due to population increasing [4]. Accordingly, other sources instead of fresh water should be used in concrete industry. So using treated wastewater in construction industry can save a lot of the fresh Water in Egypt [5]. Nile River contains a lot of pollutions from several resources, such as agricultural activities [6]. Using TWW in concrete industry may effect on corrosion of reinforcing. Impurities in wastewater (chlorides, sulfates, solids and micro-organisms) may effect on strength [7].

Untreated wastewater is a hazard to the environment [8]. The sewage collected from houses and commercial buildings is called residential or domestic wastewater [9]. The sewage collected from houses is called domestic wastewater. Wastewater treatment consists of three main phases; preliminary, biologically, and tertiary treatment. Wastewater treatment plants contain concentrated impurities. The first stage is called primary treatment; suspended matters were removed from sewage effluent. The second stage is called secondary treatment; settleable solids and suspended organic were removed. Tertiary treatment is a third stage of wastewater treatment that can achieve levels of water purification [10]. Grey water is water collected from baths [11].

Using admixture of treated water effluent and fresh water in the concrete industry with a percentage of 20% and 80%, consequently, provided that strength reduced compared with specified in various codes [12]. Many studies have assessed using wastewater in concrete mixtures on a lab scale. A lot of studies concluded the possibility of using TWW in concrete [13]. The results concluded that the use of TWW in this paper succeeded in being used in the concrete industry [14]. Using TWW in concrete treatment and cement mortar is possible according to the standard specifications codes [15].

Using TWW from WWTP in Kuwait for the concrete industry has been investigated. Based on the mechanical testing results, tertiary TWW was appropriate for the concrete industry [16]. Using TWW from biological or secondary stages in Tehran to product samples of concrete at 28- day was more than 90% at compressive strength of the control sample of potable water [17]. Using TWW in mixing water with the concrete industry led to a major decrease in the strength of compressive by up to 16.2%. In a final conclusion, using secondary treated wastewater is a good alternative instead of the fresh Water in concrete industry [18].

2. MATERIAL AND METHODS

2.1 Samples from Zenien Wastewater Treatment Plant (WWTP)

Zenien WWTP is located in Giza Governorate, Egypt. Zenien WWTP is accomplished by 4 basic techniques; physical, mechanical, biological, and chemical. Zenien WWTP consists of 12 primary settling tanks, 36 aeration tanks and 12 secondary settling tanks, and an odor control system as shown in **Fig. 1.** Three samples of TWW were collected from Zenien WWTP in addition to a fourth sample of grey water. Sample No. (1), was collected from the primary clarifier is called primary TWW (PTWW). The second sample was collected from final clarifier is called secondary TWW (STWW). Sample No. (3), was collected from tertiary TWW, and final sample No (4) represent treated grey water (TGW). Samples were collected and moved to the laboratory.

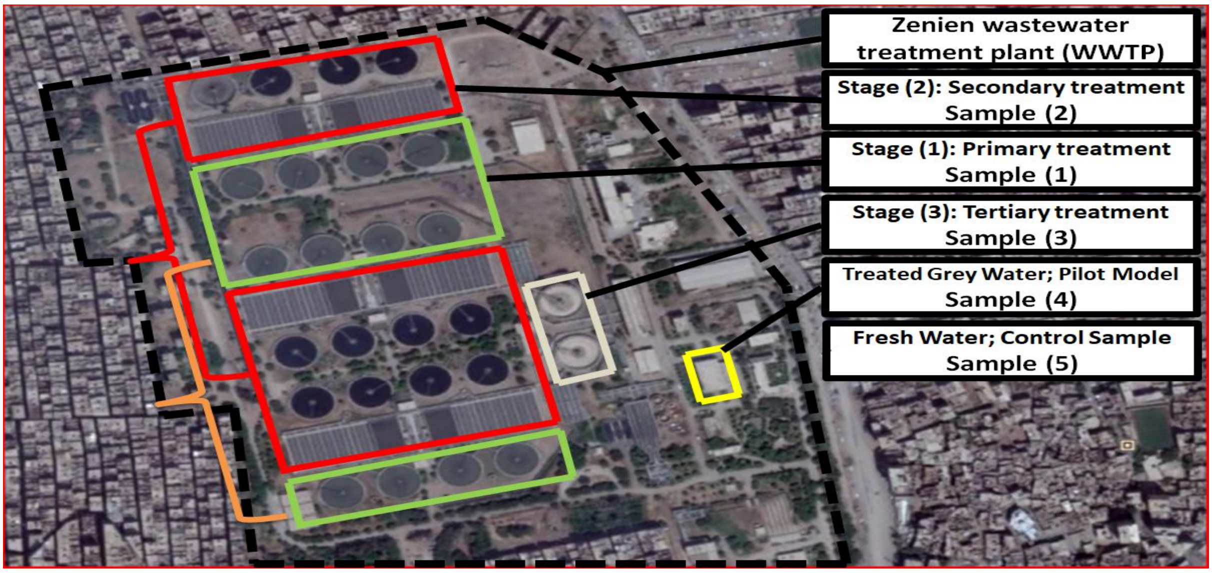

Fig. 1: Stages of Zenien wastewater treatment plant (WWTP)

2.2 Properties of Materials Used In Concrete Mixes

2.2.1 Mixing water

The criteria for approval of using TWW in the concrete industry are based on physical and chemical testing results. Physical and chemical tests refer to remaining suspended and dissolved matters in treated wastewater which have an effect on compressive strength. Five types of water samples were used in this study; four types of wastewater from Zenien WWTP (primary, secondary, tertiary treatment and grey water) and a sample of FW to be a control sample. Analyzing chemical and physical properties of wastewater is shown in **Table 1**.

Table 1: Physical and chemical properties of treated water

Sample No.	Type of Treatment	Chemical composition and physical properties of treated water						
		PH (Unit)	Temp. (^{o}c)	TSS** (mg/l)	BOD*** (mg/l)	COD**** (mg/l)	TDS***** (mg/l)	Chloride (mg/l)
World health organization*		6-8	24-28	< 2000	< 10	< 50	< 1000	< 2000
1	PTWW	7.2	26.9	89	87	180	177	138
2	STWW	7.4	26.6	14	12	29	25	124
3	TTWW	7.2	26.4	1	2	6	2	21
4	TGW	7.6	26.1	31	44	69	54	129
5	FW	7.8	25.4	0	0	1	0	28

*** World health organization (WHO): permissible limits according to ASTM C94 [19].**
**** Total suspended solids (TSS): it is the dry-weight of suspended particles that are not dissolved in wastewater sample.**
***** Biochemical oxygen demand (BOD): represents the amount of dissolved oxygen (DO) consumed by biological organisms when they decompose.**
****** Chemical oxygen demand (COD): it is the amount of oxygen consumed when the water sample is chemically oxidized.**
******* Total dissolved solids (TDS): it is the inorganic salts and small amounts of organic matter present in solution in water.**

2.2.2 Ordinary Portland cement

Cement used in this experiment was ordinary Portland cement (OPC). OPC from Helwan Factory in Cairo was used.

2.2.3 Fly ash

Analyzing properties and chemical analysis OPC and fly ash play an important role in the concrete industry, as shown in **Table 2**.

Table 2: Chemical composition and physical properties of (ordinary Portland cement & fly ash)

Description	ordinary Portland cement	Fly ash
	Value	Value
Physical properties:		
1- specific Gravity	3.15 t/m^3	2.68 t/m^3
2- Fineness passing 45µm%	90 %	81.7 %
Chemical analysis:		
1- Silicon Dioxide (S_iO_2)	17 : 25 %	40.9 %
2- Aluminum Oxide (Al_2O_3)	3.0 : 8.0 %	18.6 %
3- Magnesium Oxide (M_gO)	0.10 : 4.0 %	1.01 %
4- Titanium Oxide (T_iO_2)	---	0.85 %
5- Alkalis	0.40 : 1.25 %	---
6- Sulphur trioxide (SO_3)	2.75 %	0.87 %

2.2.4 Aggregate

Aggregates are grout material to increase concrete strength. Aggregates consist of fine aggregate and coarse aggregate (4.75 mm & 20 mm) in size.

2.2.4.1 Coarse aggregate

Crushed dolomite of 19 mm maximum size was used as a coarse aggregate with specific gravity 2.69 t/m^3. Surface area 2.367 cm^2, and a crushing factor is equal to 17.78 %.

2.2.4.2 Fine aggregate

Local natural sand is used as a fine aggregate with modulus of fineness of 2.65, specific gravity is 2.70 t/m^3, absorption = 81%, and voids ratio of 31.7%.

2.2.5 Super-plasticizer

Workability improving by using Addicrete BVS is a super plasticizer concrete admixture for high range water reduction. This had 3 % from cement weight according to: [ASTM C 494 type G], [EN 934-2] and specification Egyptian requirements [ES 1899].

2.3 Materials, Samples Preparation and Testing

Mix proportions that were selected for this experiment are given in **Table 3** for reinforced concrete preparing. Five reinforced concrete mixtures were prepared. Each of them contains nine concrete cubes (150 * 150 * 150 mm) for compression test, nine concrete cylinders (100 * 200 mm) for tensile test and nine concrete reinforced beam samples (150 * 150 * 500 mm) for bending test. One hundred thirty five samples of reinforced concrete mixtures were prepared for the age of concrete was 7, 28 and 56-day for all tests as shown in **Fig. 2**.

Table 3: Mix proportions and water-to-cement (w/c) ratios for concrete mixtures

Cement	Sand	Coarse Aggregate	Water (l)	W / C ratio
350	700	1400	180	0.55

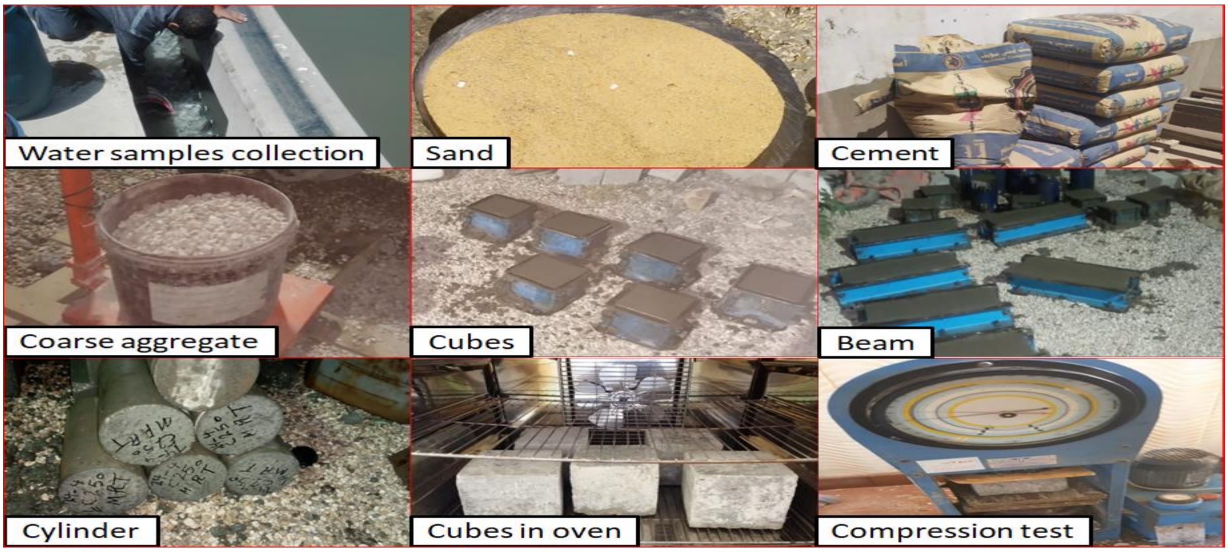

Fig. 2: Materials, Samples preparation in laboratory

2.4 Laboratory Testing Program

Test of compressive strength is a destructive test of concrete which can categorize the capability of concrete material to repel loads. Tensile strength of concrete was casted by mixing each types of water of same w/c ratio and tested under a compressive testing machine according to IS standard. Flexural strength of concrete were prepared by beams were casted to check the flexural strength of concrete. **Fig. 3** illuminates the flowchart of the steps of experimental work and the simulation model.

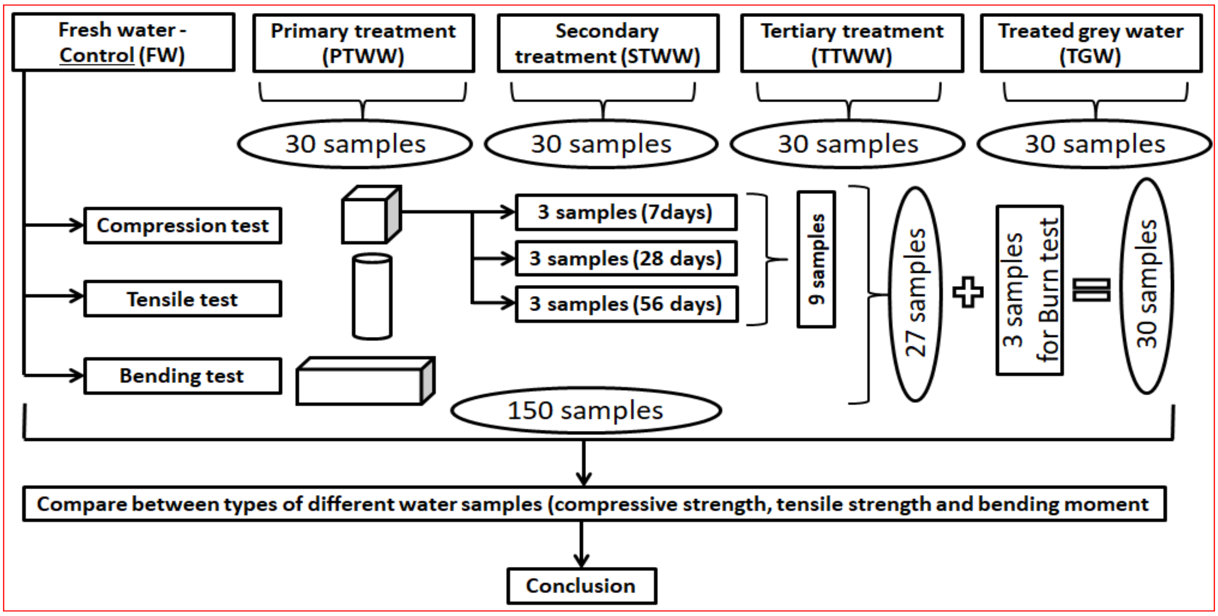

Fig. 3: The Work Program Flow Chart

3. RESULTS AND DISCUSSION

3.1 Compressive Strength Results

The results illustrated in **Fig. 4** indicate that concrete mixture made with TTWW at curing time (7, 28, and 56 days) has a significant increasing of up to (4.0 %, 5.0 % & 2.4 %) consequently compared with concrete mixture made with fresh Water . However, at 56 days, there is a significant increase at compressive strength. Using (PTWW, STWW & TGW) directed to a decrease values at curing different time because of the effect of organic contents.

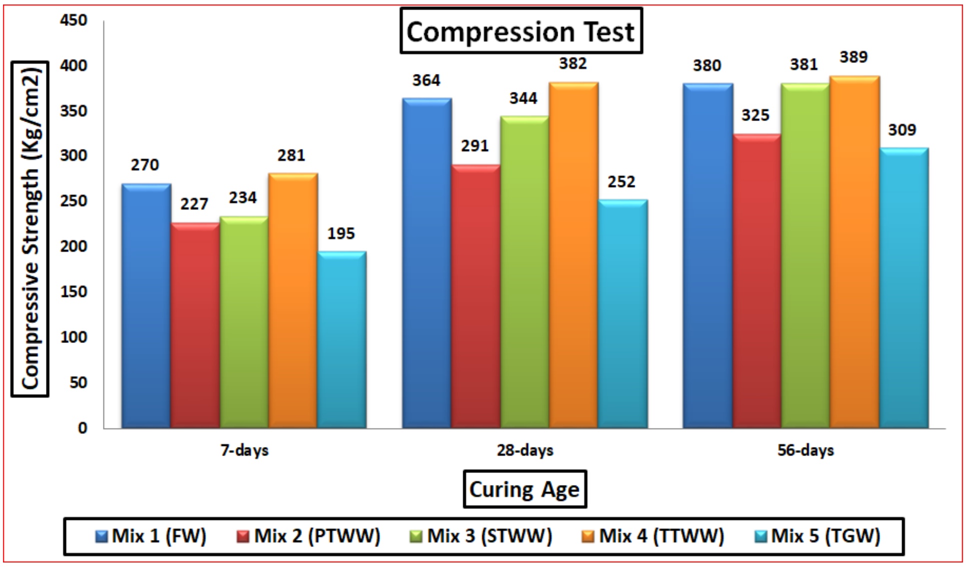

Fig. 4: Influence of different types of Treated wastewater on Concrete compressive strength at various curing age

3.2 Tensile Strength Results

In tension test, the tensile strength with concrete mixed by TTWW at curing time (7, 28, and 56 days) has an increase of up to (3.8 %, 8.8 % & 7.9 %) respectively compared with concrete mixture made with fresh water as shown in **Fig. 5**. At the curing age of 28 days, it shows a high increase in tensile strength. Using (PTWW, STWW & TGW) led to a reduction in the tensile strength at different curing time.

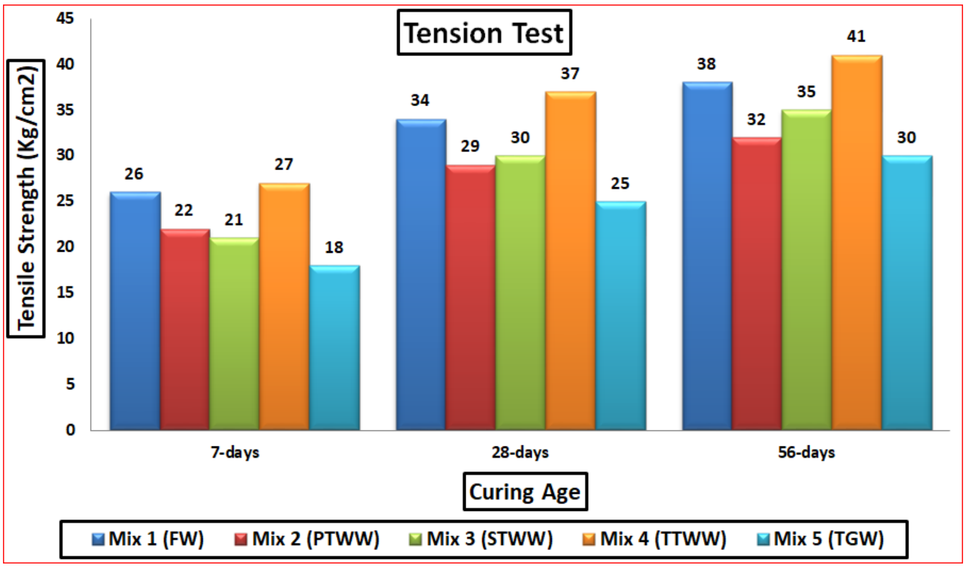

Fig. 5: Influence of different types of Treated wastewater on Concrete tensile strength at various curing age

3.3 Flexural Strength Results

In flexure test, strength with concrete mixed by TTWW at curing time (7 & 28) days has an increase of up to (2.8 % & 6.7 %) consequently compared with a concrete mixture made with fresh water as shown in **Fig. 6**. At the curing age of 56 days, it shows that no a significant effect between TTWW and fresh water. Using (PTWW, STWW & TGW) directed to a reduction in the flexural strength at different curing time.

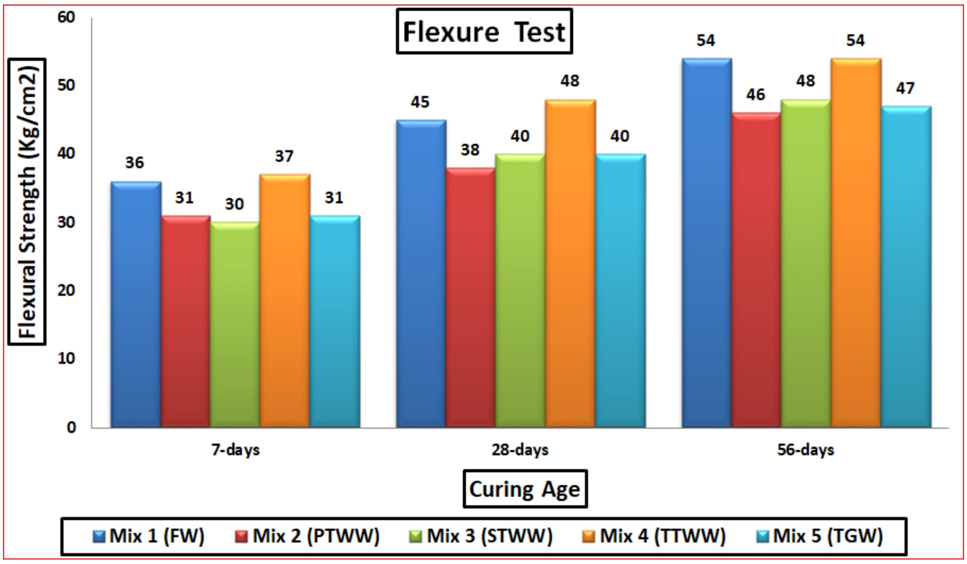

Fig. 6: Influence of different types of Treated wastewater on Concrete bending at various curing age

3.4 Burn Test Results on Compressive Strength (Durability of Concrete)

In this experiment, the durability of concrete was tested by a burn test on concrete cubes and showed the burn effective on compressive strength of concrete cubes as shown in figure

(7). Using (PTWW, STWW, TTWW and TGW) led to a significant decrease in compressive strength at 28 days compared with a concrete mixture made with fresh water. After burn concrete cubes in oven at 100 oc for one hour, **Fig. 7** showed a significant reduction in compressive strength by using all different types of treated wastewater compared with concrete cube mixture made with fresh water. Using (STWW & TTWW) as mixing water has a large reduction factor (68 %) between compressive strength before the burn test and after the burn test.

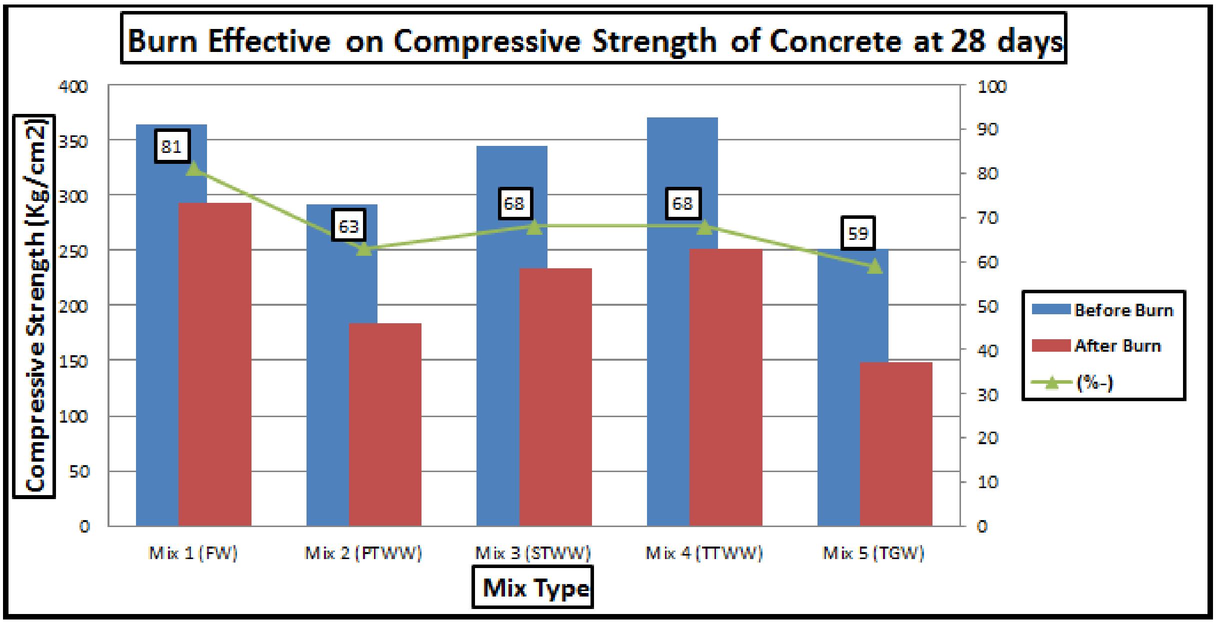

Fig. 7: Burn effective on compressive strength of concrete by using different types of Treated wastewater at 28 days

4. CONCLUSIONS

The results of laboratory analysis of using four types of TWW samples from Zenien WWTP as mixing water and compared with the fresh water as mixing water indicate that:

1) In the compression test, different types of treated wastewater (PTWW, STWW and TGW) gave strength less than the strength that was mixed with the fresh water after 28 days by (-25.1%, -5.8% & -44.4%).
2) In the tension test, different types of treated wastewater (PTWW, STWW and TGW) gave strength less than the strength was mixed with the fresh water after 28 days by (-17.2%, -13.3% & -36.0%).
3) In the flexure test, different types of treated wastewater (PTWW, STWW and TGW) gave strength less than the strength was mixed with the fresh water after 28 days by (-18.4%, -12.5% & -12.5%).
4) Using (PTWW, STWW & TGW) led to a significant reduction in different types of strength tests at different curing time.
5) Using TTWW achieves strength better than fresh water by (4.9%, 8.8%, and 6.7%) at 28 days.
6) Using TTWW instead of fresh water as mixing water provided a lot of quantity of water in Egypt.
7) Based on the experimental burn test reported; using (STWW & TTWW) as mixing water

has a large reduction factor (68 %) between compressive strength before the burn test and after the burn test.

8) According to the burn test, a significant reduction in compressive strength for using all different types of treated wastewater compared with concrete cube mixture made with fresh water.
9) The results confirm the possibility of using TWW in reinforced concrete mixtures compared with the results of using fresh water; but in especially the buildings exposed to fire and high temperatures, it is recommended not to use any treated wastewater as mixing water.

ACKNOWLEDGMENT

This research work was conducted within the material laboratory in the institute of engineering at 15th May – Helwan – Egypt. Authors really would like to thank the institute of engineering at 15th May and Zenien wastewater treatment plant for their institutional and technical support.

REFERENCES

1. I. Mariolakos, Water resources management in the framework of sustainable development, Desalination 213 (2007) 147–151.
2. Taha R, Al-Harthy AS, and Al-Jabri KS, Use of production and brackish water in concrete. Proceedings International Engineering Conference on Hot Arid Regions (IECHAR 2010), March 1-2, Al-Ahsa, Kingdom of Saudi Arabia, pp. 127-132.
3. V.S. Pallapu, B.J.N. Satish, K.H. Reddy, Mechanical and microstructural properties of concrete subjected to temperature, Mat. Today. J., https://doi.org/10.1016/j.matpr.2020.05.606.
4. M. Goher, M.H. Ali, S. Elsayed, Heavy metals contents in Nasser Lake and the Nile River, Egypt: An overview, Eg. J. of Aqu. R. 301-312, https://doi.org/10.1016/j.ejar.2019.12.002.
5. Ramkar A.P, Ansari, Effect of Treated Waste Water on Strength of Concrete, 2018, U.S.A.
6. Z. S. Aboulnaga, Water pollution challenge and its impact on Egypt’s life an overview, Mans. Univ. J., 2017.
7. Kosmatka, S. H. & Panares, W. C., Natural Capitalism-Creating the Next Industrial Revolution, Little Brown Co., 1995.
8. Metcalf E, Inc., Wastewater Engineering: Treatment, sixth ed., Disposal and Reused, 2004, McGraw-Hill.
9. Viessman, W. J. & Hammer, M. J., Water Supply and Pollution Control, Harper and Row, 1985, New York.
10. C. Nilsson, H. Dahlström, Treatment and Disposal Methods for Wastewater Sludge in the Area of Beijing, China, Master Thesis. Published, 2005, Lund University, Sweden.
11. Al-Jayyousi Odeh R., Grey water reuse: towards sustainable water management. European conference on desalination and the environment, the fresh Water for all, Malta, vol. 156(1–3). European Desalination Society, International Water Association; 2003. p. 181–92, 2003, published in desalination, Elsevier.
12. El-Nawawy, O. A., Use of treated effluent in concrete mixing in an arid climate, Cement and Concrete Composite, 1991, 13: 137-41.
13. V.S. Pallapu, B.J.N. Satish, K.H. Reddy, Mechanical and microstructural properties of

concrete subjected to temperature, Mat. Today. J., https://doi.org/10.1016/j.matpr.2020.05.606.
14. Saricimen, H., Shameem, M., Barry, M., and Ibrahim, M., Testing of treated effluent for use in mixing and curing of concrete, 2009.
15. Saricimen, H.; Shameem, M.; Barry, M.; Ibrahim, M., Testing of Treated Effluent for Use in Mixing and Curing of Concrete. Available online: http://eprints.kfupm.edu.sa/1745/1/91-104 (accessed on 11 May 2016).
16. Al-Ghousian, I. & Terro, M., Use of treated wastewater for concrete mixing in Kuwait, Kuwait Journal of Science and Engineering, 2002, Vol 30, Issue 1: 213-28.
17. N. Mehrdadi, A. Akbarian, A. Haghollahi, Using domestic treated wastewater for producing and curing concrete, J. Environ., 2009, Stud. 35 (50) 129–136 (in Farsi).
18. K.S. Al-Jabri, A.H. Al-Saidy, R. Taha, A.J. Al-Kemyandi, The effect of using wastewater on the properties of high strength concrete, in: The twelfth East Pacific conference engineering and construction, procedia engineering, vol. 14, 2011, pp. 370-378. [17] S. Tsimas, M. Zervak.
19. World Health Organization (WHO), 2006. Guidelines for the Safe Use of Wastewater, Excreta and Greywater. World Health Organization, Geneva.