THE POSSIBILITY OF USING TREATED WASTEWATER IN CEMENT MORTAR

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***Abstract*— this study deals with the effect of different types of treated wastewater on properties of strength of mortar such as compressive and flexural strength with respect to Tap Water (TW). Mortar mixes using Primary, Secondary and Tertiary treated wastewater (PTWW, STWW, TTWW) and tap water were cast and tested after various curing ages(2,7, 28 days).The variables in this study are the mixing and curing water by using different grades of cement. All the remaining constituents and parameters are to remain constant. The results indicate that mortar made with TTWW and STWW at curing time up to 28 days has no significant negative effect on mortar's compressive and flexural strength. Conversely, using PTWW as mixing water led to a reduction in the mortar's compressive and flexural strength up to 27% and 33% respectively. In addition, using treated wastewater results, a significant increase in the initial and final setting time of up to 11%. The chemical composition of wastewater is affecting the mortar compressive and flexural strength under many considerations like; hydration process and the properties of mortar in the future; durability of mortar. A comparison between parameters obtained for mortar samples prepared with treated wastewater and those prepared with tap water indicated that wastewater reuse would be a good alternative for tap water consumption reduction in the mortar industry.**

Keywords: Mortar, Treated wastewater, Tap water, Compressive strength, Flexural strength

I. INTRODUCTION

A water crisis is a well-known worldwide problem concerning water resources related to human demand. The construction industry appears to be responsible for consumption of huge amounts of water [1]. The concrete and cement mortar industry has a serious impact on the environment with regard to consumption of water. Therefore, we need to find an alternative source of freshwater in the cement mortar industry. Moreover, large quantities of fresh water are used for cement mortar mixing, curing and washing aggregates. So, if we can use the treated wastewater for construction industry, we can save a lot of freshwater. Chemical limits for water for concrete and mortar construction, suggested by different codes indicate that many types of non-potable water can be used for construction [2]. Therefore, efforts towards wastewater reuse have lately gained worldwide consideration and attention in both the agricultural and industrial fields [3]. The results of an investigation regarding the use of treated wastewater for concrete and cement mortar mixing suggested that such water can be used as mixing water in concrete and cement mortar without any harmful effects [4]. It has also been found that pond or lake water having low contents of silt, organic matter, or other impurities has little or no adverse effect on concrete properties [5]. M.Kanitha et al [2] studied the effects of raw and treated wastewater as water for mixing concrete. Therefore, the focus of this study is to consider the applicability of reusing the treated wastewater in the mortar industry since some wastewater water is found to be suitable as the concrete and cement mortar mixing water. This paper presents the results of a laboratory study using treated wastewater as mixing water for cement mortar. Four types of water (Primary, Secondary and Tertiary treated wastewater and tap water) are first sampled from a treated wastewater plant. Their quality is analyzed in the laboratory and compared with the ECP code and specification [6]. The effects of water type on setting time and compressive strength of mortar are studied. The results of compressive strength of cement mortar after replacement of 100 % tap water with tertiary treated wastewater in mortar mixing as well as curing in tertiary wastewater is found to be in range of 87-94% of normal cement mortar, which satisfies ASTM C-94 norms [7]. The water quality showed that TTWW is suitable for cement mortar production according to permissible limits of mixing water for mortar while PTWW and STWW are not. The present study confirms the feasibility of using TTWW in cement mortar. Moreover, compressive strengths of test samples are less than the reference samples but they are well within the limits as per code ECP 203-2020. In conclusion, this study has shown that TTWW is a potential alternative for tap water in the cement mortar industry.

II. Materials and Methodology

A. Treated Wastewater

Three types of treated wastewater were collected from wastewater treatment plants for test program experiments. The first sample represents the Primary Treated Wastewater (PTWW), while the second sample represents the Secondary Treated Wastewater (STWW), and the third sample represents the Tertiary Treated Wastewater (TTWW). Tap Water (TW) was used as control for test program experiments.

B. Raw Material Preparation and Testing

B.1. Aggregates

The properties of the raw materials used in preparing cement mortar mixtures were tested in a laboratory according to Egyptian standards [6]. These materials include fine aggregate and cement. Regarding mortar mixtures, one type of fine aggregates was used in the preparation of mortar. The physical properties of aggregates are shown below in Table I.

Table I. Fine Aggregate Sieve Analysis Results

IS Sieve Size(mm)	Percentage of passing (%)
2	0
1.6	7±5
1	33±5
0.5	67±5
0.016	87±5
0.08	99±1

B.2. Cement

Four types of Ordinary Portland cement (OPC, CEM I) manufactured by Egypt cement factory companies were used in preparing mortar mixtures. Helwan cement 32.5 N, Helwan cement 42.5 N, National cement 42.5 N, and National cement 52.5 N were used. The chemical properties of the cement used are shown in Table II.

Table II. Cement Chemical Analysis

Constituents	Helwan 32.5 N	Helwan 42.5 N	National 42.5 N	National 52.5 N
	Percentage (%)	Percentage (%)	Percentage (%)	Percentage (%)
Silicon Dioxide (SiO2)	18.75	21.19	20.35	20.62
Aluminum Oxide (Al2O3)	2.73	3.63	4.78	4.74
Ferric Oxide (Fe2O3)	2.52	3.13	3.58	3.49
Calcium Oxide (CaO)	59.60	61.05	62.94	63.78
Magnesium Oxide (MgO)	1.27	1.47	1.52	1.46
Potassium Oxide (K2O)	0.25	0.32	0.40	0.20
Sodium Oxide (Na2O)	0.29	0.42	0.41	0.27
Sulfur Trioxide (SO3)	2.09	3.08	2.20	2.50
Residue	81.3	1.50	0.56	0.54
Chlorides (Cl-)	0.09	0.11	0.55	0.06
Loss on Incineration	11.29	4.90	3.29	2.23

C. *Experimental Work for Mortar*

Details of the experimental test program are given in Table III. After the preparation of control mix (using tap water), three types of treated wastewater were utilized for separate mixes. The other components of mixtures were kept constant as those in the control one except for water/cement type, which was added to each mix to obtain the same workability as the control mix. A standard mixer was used in the mixing process. After mix preparation, it was filled in the moulds and compacted by a Jolting table, and after that, the moulds were covered with glass plates and kept in standard conditions until the next day. After 24 h of casting, samples were taken out from moulds and stored for curing in a water tank under standard temperature 20 ºC. For each mortar mix, 18 prisms (40 mm x 40 mm x 160 mm) were cast. Each six prisms were tested after various curing times (2, 7 and 28 days). Fresh cement mortar properties were tested directly after mix preparation such as initial and final setting time. Generally, initial setting is the time elapsed from adding water to the cement until the time at which the needle cannot penetrate more than 6 to 2 mm from the bottom of the vicat's mould and final setting is the time elapsed from adding water to the cement until the time at which the needle cannot penetrate more than 0.5 mm from the top of the vicat's mould. The compressive strength was evaluated according to ECP-203 [6]. The specimens were tested at 2, 7, and 28 days of age, and the average of three specimens at each age was calculated in order to compare the results of the different mixes that were prepared. Six samples were collected randomly at various cross sections from each mortar mixture at curing age 28 days. Each slide dimension was 40 mm x 40 mm.

TABLE III. Experimental Test Program (Phase I and II) – Flexural Strength and Compressive Strength

Group number	Cement Type	Cement Grade	Water Type	Time (days)	number of specimens	Total number of specimens
G1 and G2	**Helwan CEM I**	32.5	**PTWW STWW TTWW TW**	2 7 28	3 3 3	18
				2 7 28	3 3 3	18
	Helwan CEM I	42.5		2 7 28	3 3 3	18
				2 7 28	3 3 3	18
G3 and G4	**National CEM I**	42.5	**PTWW STWW TTWW TW**	2 7 28	3 3 3	18
				2 7 28	3 3 3	18
	National CEM I	52.5		2 7 28	3 3 3	18
				2 7 28	3 3 3	18
Total Specimens						144

E. *Test Set-up and Instrumentation*

Compressive tests were done by using a compression-testing machine with a capacity of 2,000 kN. The load was measured by using a 2,000-kN-capacity load cell. The loading was applied through the displacement control method at a rate of 0.005 mm/s.

III. Test Results and Discussion

A. Treated Wastewater Quality

Mixing water quality plays an essential role in the preparation of cement mortar/concrete. Tap water can be used as mixing water for cement mortar/concrete production. Furthermore, some water types that are not suitable for drinking may be fit for cement mortar/concrete making. Table IV, shows that the TSS concentration of PTWW (72 mg/L), STWW (10.0 mg/L) and TTWW (3.0 mg/L) were below the tolerated limit of suspended fine particles in mixing water (2000 mg/L) according to the Portland Cement Association (PCA). However, a suspended solid of 50,000 mg/L is still tolerated in case of reusing of wastewater from mixer washout operations. The results also showed that the TDS concentrations of PTWW, STWW and TTWW (765,810 and 897 mg/L) are lower than the maximum permissible concentration (2000 mg/L). The values of chloride and PH are under the maximum permissible limits [6].

Table IV. Water quality analysis

Parameter	PTWW	STWW	TTWW	TW	Tolerable limits
PH	7.3	7.4	7.5	7.8	>7
Total dissolved substance	765	810	897	250	2000 ppm
Total suspended solids	72	10	3	0	-
Total solids	837	820	890	250	5000 ppm
Biological oxygen demand	146	4	2	-	-
Chemical oxygen demand	136	51.2	21	0	-
Alkalinity	200	223	222	60	600 ppm
Sulfates	147.2	162	189	70	3000 ppm
Chlorides	178	233	250	90	500 ppm
Phosphates	6.3	5.2	4.1	0	100 ppm

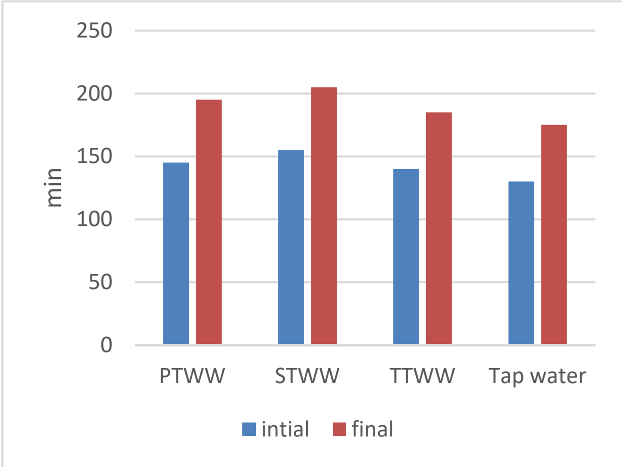
B. Effects of Treated Wastewater on Cement Paste

The results presented in table V and Figure 1 show that the initial/final setting time of cement paste mixed with PTWW, STWW and TTWW were up to +5 and +30 min compared to control, respectively.

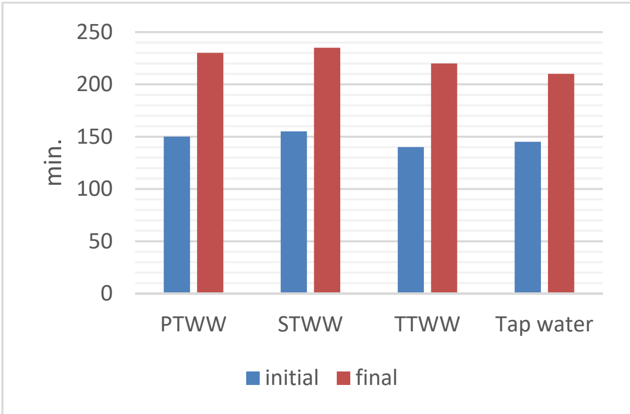
Table V. Initial and final setting time

Cement Type	Initial / Final setting time (min)	PTWW	STWW	TTWW	TW
Helwan 32.5 N	Initial setting time	145	155	140	135
	Final setting time	195	205	185	175
Helwan 42.5 N	Initial setting time	150	155	140	145
	Final setting time	230	235	220	210
National 52.5 N	Initial setting time	180	175	165	160
	Final setting time	240	245	240	230

These results are in harmony with ASTM C94[7] requirements on initial and final setting time where the initial setting time of cement paste made with the questionable water must not be more than 60 min earlier than that made with the same cement using TW. Shekarchi et al [10] and Ghusain et al [9] reported that the dissolved salts could increase the initial setting time up to +70 min in case of using treated wastewater on cement paste.



Helwan 32.5 N



Helwan 42.5 N

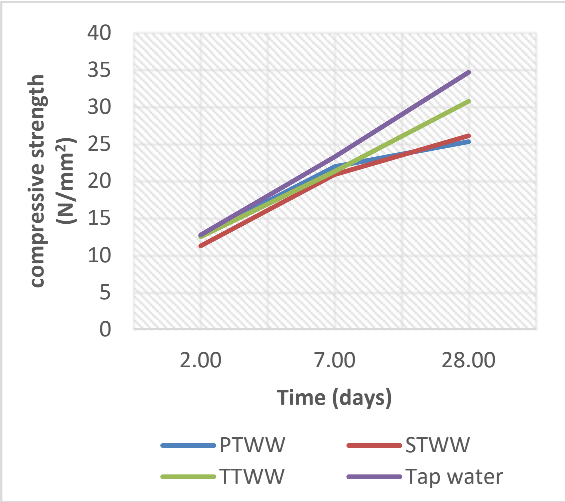
National 52.0 N

Fig. 1 Comparison between initial / final setting time of for different mixing water types using different cement grades

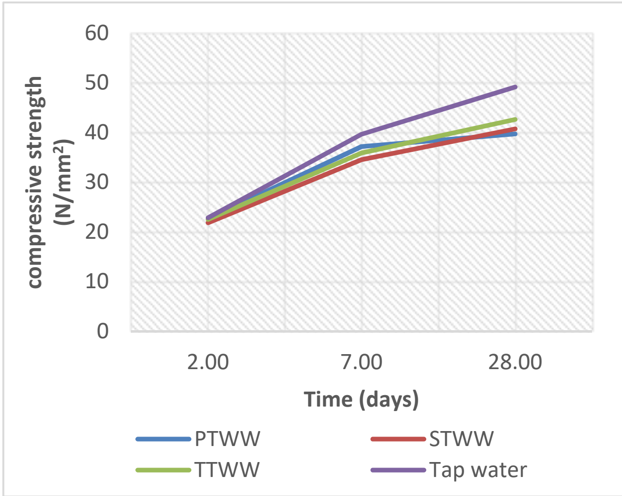
Table V and Figure 1 shows the initial and final setting time of cement mortar made with different types of treated wastewater and potable water using different cement grades. The results for cement mortar grade 52.5 containing different types of treated wastewater (PTWW, STWW and TTWW) were within (+20, +15 and +5 min.) for initial setting time compared to that of control made with PW and (+10, +15 and +10min.) for final setting time which satisfy ECP-203 requirements [6].

C. Effects of Treated Wastewater on Mortar Properties

The results shown in Figure 2 appear that mortar made with TTWW and STWW at curing time (2, 7, and 28 days) has a slight reduction effect on the mortar's compressive strength. On the other hand, using PTWW as mixing water led to reduction in the compressive strength at curing time (2, 7, and 28 days). This could be due to the effect of organic contents, which may have contributed to mortar strength reduction.



HELWAN 32.5 N



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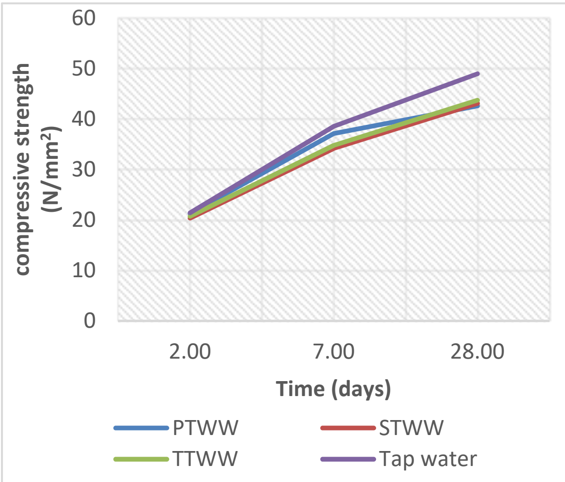

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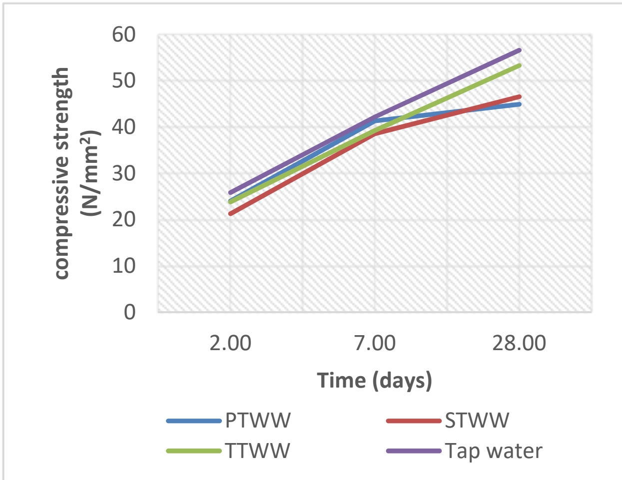

NATIONAL 52.0 N

Fig. 2 Influence of PTWW, STWW and TTWW on mortar compressive at various wet curing age

Mortar relative strength index (RM) can be defined as the ratio of the compressive strength of mortar to the control specimen. Tables IV and V represent the mortar RM of mixes using PTWW, STWW and TTWW at the wet curing ages of 2,7, and 28 days. The relative index in Tables VI and VII indicate that using PTWW and STWW as mixing water for mortar production led to a reduction in the compressive strength between 12% and 27%, while addition of TTWW led to a slight decrease in RM at curing age (28days) 6%. According to the ASTM C109[7], water is suitable for production cement mortar if mortar which was made with it has strength at 7 days curing time that is equal or less than 10% reduction compared to control samples made with tap water.

Table VI. Compressive strength of Helwan Cement

Cement Grade	Water Type	Age of Curing (days)	Average load (KN)	Average stress (N/mm^2)	Relative Strength Index (%)
HELWAN CEMENT GRADE (32.5)	TW	2	20.39	12.74	--
		7	37.23	23.26	--
		28	55.44	34.65	--
	PTWW	2	20.22	12.63	-1.0
		7	35.11	21.94	-6.0
		28	40.50	25.31	-27.0
	STWW	2	18.01	11.26	-12.0
		7	33.41	20.88	-10.0

		28	41.76	26.10	-25.0
	TTWW	2	20.10	12.50	-2.0
		7	34.10	21.31	-8.0
		28	49.21	30.75	-12.0
HELWAN CEMENT GRADE (42.5)	**TW**	2	36.55	22.84	--
		7	63.42	39.64	--
		28	78.60	49.13	--
	PTWW	2	36.20	22.63	-1.0
		7	59.48	37.18	-6.0
		28	63.50	39.69	-20.0
	STWW	2	34.95	21.84	-4.0
		7	55.23	34.52	-13.0
		28	65.15	40.72	-17.0
	TTWW	2	36.00	22.50	-4.0
		7	57.42	35.89	-10.0
		28	48.20	42.62	-13.0

Table VII. Compressive strength of National Cement

Cement Grade	**Water type**	**Age of curing (days)**	**Average load (KN)**	**Average stress (N/mm^2)**	**Relative Strength Index (%)**
NATIONAL CEMENT GRADE (42.5)	TW	2	34.20	21.38	--
		7	61.64	38.53	--
		28	78.30	48.94	--
	PTWW	2	33.95	21.22	-1.0
		7	59.32	37.08	-4.0
		28	68.1	42.56	-13.0
	STWW	2	32.55	20.34	-5.0
		7	54.65	34.16	-12.0
		28	68.9	43.06	-12.0
	TTWW	2	33.10	20.69	-3.0
		7	55.58	34.74	-10.0
		28	69.60	43.69	-11.0
NATIONAL CEMENT GRADE (52)	TW	2	41.34	25.84	--
		7	67.50	42.18	--
		28	90.53	56.58	--
	PTWW	2	38.40	24.00	-7.0
		7	66.10	41.31	-2.0
		28	71.82	44.89	-20.0
	STWW	2	34.01	21.26	-18.0
		7	61.67	38.54	-9.0
		28	74.45	46.53	-18.0
	TTWW	2	38.10	23.81	-8.0
		7	62.78	39.24	-7.0
		28	85.25	53.28	-6.0

Overall compressive strengths and flexural strengths of mortar was found to be in the range of 87-94% and 69%-99%, respectively of normal concrete, after replacing tap water with tertiary wastewater. Overall compressive strengths and flexural strengths of mortar was found to be in the range of 75-88% and 68%-98%, respectively of normal concrete, after replacing tap water with secondary wastewater. Overall compressive strengths and flexural strengths of mortar was found to be in the range of 73-87% and 67%-93%, respectively of normal concrete, after replacing tap water with primary wastewater. The relative strength index indicates that using PTWW as mixing water for mortar production led to a significant reduction in the compressive strength by up to 27%. The water quality showed that TTWW is suitable for mortar production according to permissible limits of mixing water for mortar while PTWW and STWW are not.

C. Flexural strength test results

Flexural strength of cement mortar is assessed at age of 2, 7 and 28 days. Three specimens were used for each mixing water type. There is no recommendation for flexural strength in standards. The flexural strength test results of cement mortar using Helwan cement grade (32.5) and different types of water illustrated in table VIII and figure 3. For PTWW and STWW the reduction in flexural strength at ages 2, 7 and 28 days exceed more than 15 percent. Meanwhile, in using TTWW, the reduction of flexural strength in early ages (2 days) is less than 4 percent but at ages 7, 28 days exceed more than 12, 31 percent, respectively.

Table VIII. Flexural strength of Helwan cement grade (32.5)

Water type	Age of curing (days)	Average load (KN)	Average stress (N/mm^2)	Relative Strength Index (%)
TW	2	1.50	3.52	--
	7	2.61	6.12	--
	28	3.70	8.67	--
PTWW	2	1.24	2.91	-17.00
	7	2.10	4.92	-20.00
	28	2.47	5.80	-33.00
STWW	2	1.22	2.86	-18.00
	7	2.23	5.23	-15.00
	28	2.51	5.88	-32.00
TTWW	2	1.44	3.38	-4.00
	7	2.30	5.39	-12.00
	28	2.53	5.93	-31.00

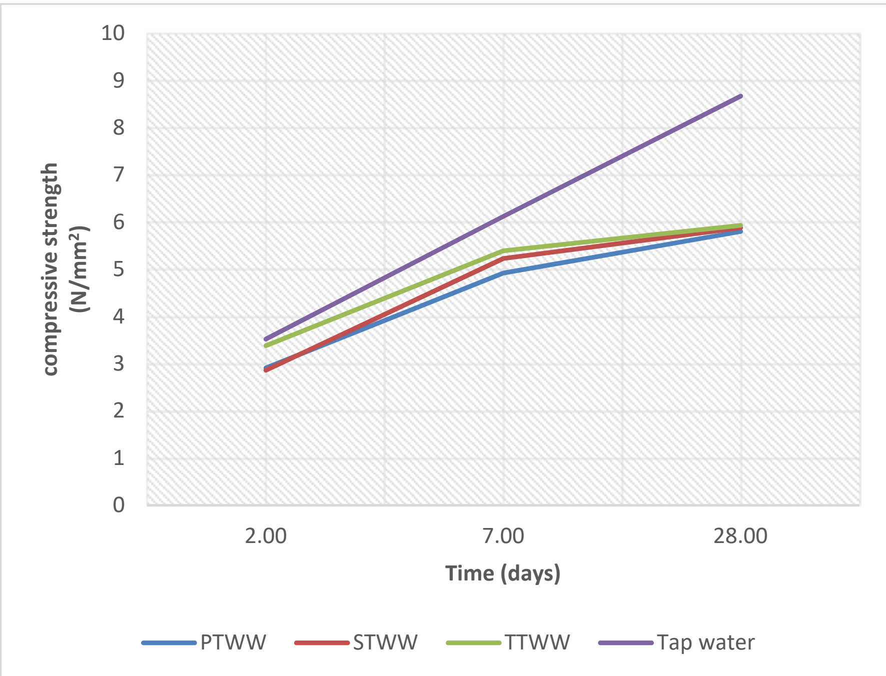

Fig.3 Comparison between flexural Strength for different mixing water types using Helwan cement grade (32.5)

The flexural strength values of cement mortar using Helwan cement grade (42.5) and different types of water are shown in Table IX and figure 4. It can be observed that the flexural strength tended to decrease with using different types of treated water in a manner similar to that observed for compression strength. This probably due to the similar results mentioned for the compressive strength. This could be due to the existence of the fine polymeric particles, which may affect the direct contact of water - cement thus eliminates the hydration of the cement components mainly the Dicalcium silicate and Tricalcium silicate to form CSH, which is responsible for the development of concrete strength. It observed that at early ages 2 and 7 days for PTWW, STWW and TTWW the reduction in flexural strength is less than 10 %, while the flexural strength reductions at late ages (28days) exceeds 20 %.

Table IX. Flexural strength of Helwan cement grade (42.5)

Water Type	Age of curing (days)	Average Load (KN)	Average stress (N/mm^2)	Relative Strength Index (%)
TW	2	2.20	5.16	--
	7	3.12	7.31	--
	28	3.91	9.16	--
PTWW	2	2.00	4.69	-10.00
	7	2.85	6.68	-9.00
	28	3.15	7.38	-25.00
STWW	2	2.11	4.95	-5.00
	7	2.90	6.80	-8.00
	28	3.16	7.40	-20.00
TTWW	2	2.13	4.99	-3.00
	7	3.00	7.03	-4.00
	28	3.27	7.66	-20.00

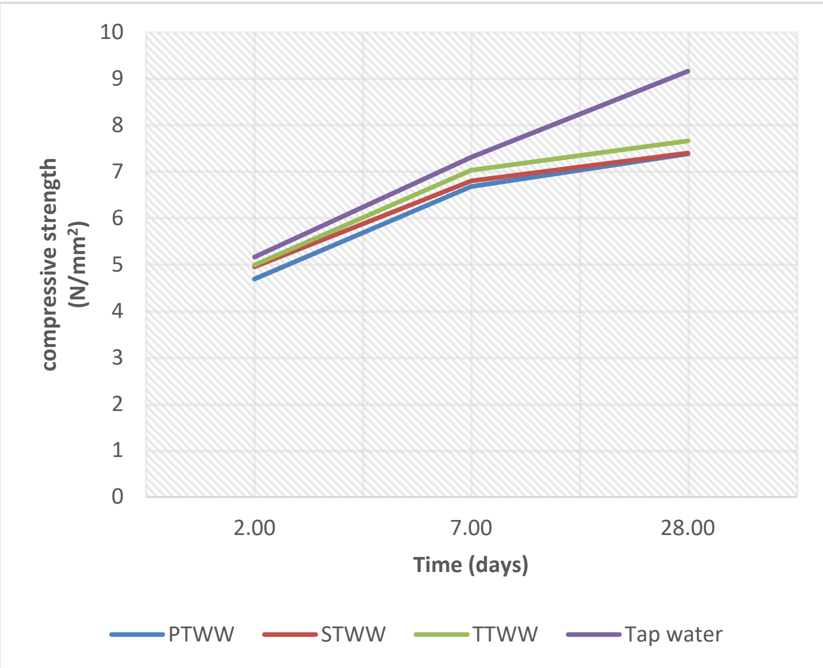

Fig.4 Comparison between flexural Strength for different mixing water types using Helwan cement grade (42.5)

The flexural strength test results of cement mortar using National cement grade (42.5) and different types of water illustrated in table X and figure 5. Based on test results the reduction of the flexural strength of mortar in all cases was observed. It should be noted that at early ages 2 and 7 days for PTWW, STWW and TTWW the reduction in flexural strength is less than 7 %, while the flexural strength reduction at late ages (28days) exceed 15 %.

Table X. Flexural strength of National cement grade (42.5)

Water Type	Age of curing (days)	Average Load (KN)	Average stress (N/mm²)	Relative Strength Index (%)
TW	2	2.24	5.25	--
	7	3.20	7.50	--
	28	3.98	9.33	--
PTWW	2	2.20	5.16	-2.00
	7	3.16	7.41	-1.00
	28	3.46	8.11	-15.00
STWW	2	2.15	5.04	-4.00
	7	3.00	7.03	-7.00
	28	3.48	8.16	-14.00
TTWW	2	2.18	4.99	-5.00
	7	3.10	7.27	-4.00
	28	3.51	8.23	-13.00

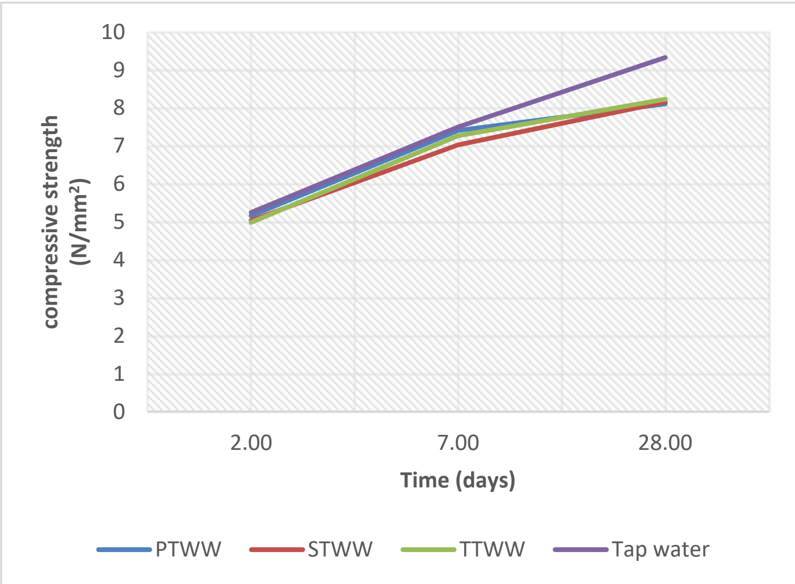

Fig.5 Comparison between flexural Strength for different mixing water types using National cement grade (42.5)

The Flexural characteristics of the treated wastewater mortar have been affected by replacing tap water with treated wastewater. Flexural strength minor decreases when TTWW used with National cement grade (52.5) in mortar mix. At initial days strength reduces but at later stage strength increases. The flexural strength test results of cement mortar using National cement grade (52.5) with different types of water were illustrated in table XI and figure 6. It observed that at early and late ages (2, 7 and 28 days) for PTWW, the reduction in flexural strength is less than 7 %. Meanwhile, in using STWW and TTWW, the reduction of flexural strength in early ages (7 days) is less than 1 percent but at age 28 days less than 2 percent. In this study, all the flexural strength values were considered acceptable since they range from18 to 22% of the measured compressive strength values (Tables 8 and 9).

Table XI. Flexural strength of National cement grade (52.5)

Water Type	Age of curing (days)	Average Load (KN)	Average stress (N/mm^2)	Relative Strength Index (%)
TW	2	2.40	5.63	--
	7	3.42	8.01	--
	28	4.20	9.48	--
PTWW	2	2.29	5.37	-5.00
	7	3.25	7.61	-5.00
	28	3.80	8.91	-7.00
STWW	2	2.30	5.39	-4.00
	7	3.37	7.90	-1.00
	28	3.95	9.26	-2.00
TTWW	2	2.35	5.50	-2.00
	7	3.41	7.99	-0.00
	28	3.98	9.33	-1.00

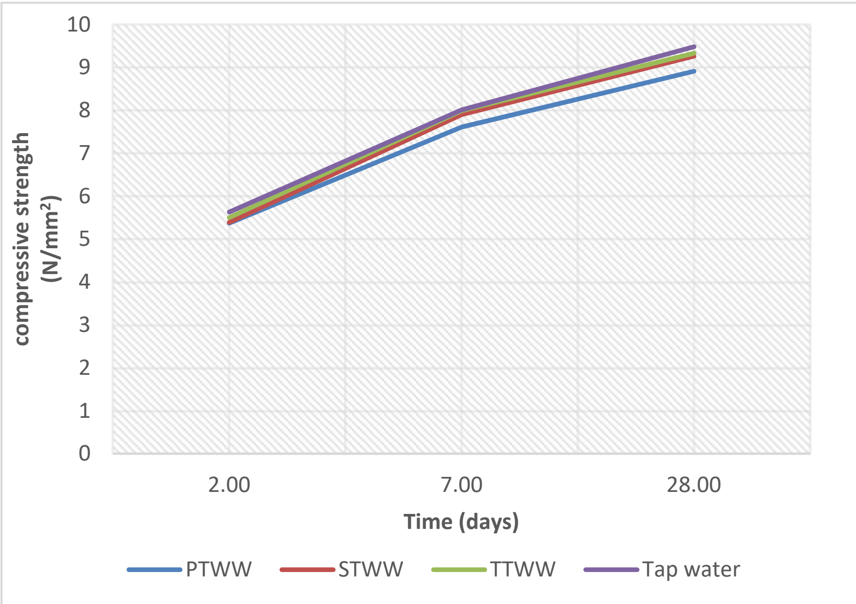

Fig.6 Comparison between flexural Strength for different mixing water types using National cement grade (52.5)

CONCLUSIONS

Based on the results of the study the following conclusions can be drawn out.

1. Using Primary, Secondary and Tertiary treated wastewater decreased the compressive strength and flexural strength of the mortar.
2. Setting times are found to significantly increase in all treated wastewater of mixing water when compared with tap water.
3. It is good to use the tertiary treated wastewater in making mortar mix, because compressive strength of mortar is not less than 90% of that mortar made by tap water.
4. The relative strength index indicates that using PTWW as mixing water for mortar production led to a significant reduction in the compressive strength and flexural strength by up to 27% and 33%, respectively.
5. Overall compressive strengths and flexural strengths of mortar was found to be in the range of 87-94% and 69%-99%, respectively of normal concrete, after replacing tap water with tertiary wastewater.
6. Overall compressive strengths and flexural strengths of mortar was found to be in the range of 75-88% and 68%-98%, respectively of normal concrete, after replacing tap water with secondary wastewater.

7. Overall compressive strengths and flexural strengths of mortar was found to be in the range of 73-87% and 67%-93%, respectively of normal concrete, after replacing tap water with primary wastewater.
8. The water quality showed that TTWW is suitable for mortar production according to permissible limits of mixing water for mortar while PTWW and STWW are not.
9. The initial setting time of cement paste performed with TTWW, STWW and PTWW was increased by 5, 15 and 20 min, respectively.
10. The final setting time of cement paste performed with TTWW, STWW and PTWW was increased by 10, 25 and 20 min, respectively.
11. The present study confirms the feasibility of using TTWW in cement mortar. Moreover, compressive strengths of test samples are less than the reference samples but they are well within the limits as per code ECP203-2020.
12. In conclusion, this study has shown that TTWW is a potential alternative for tap water in the cement mortar industry.

REFERENCES

[1] Stamatis, T. and Monika, Z. "Reuse of waste water from ready-mixed concrete plants", Management of Environmental Quality. An International Journal.pp.7-17, Vol.22 No. 1, 2011.
[2] Rajesh, T. and Parag, A. "Influence of Grey Water as Mixing Water on Properties and Strength of Cement", International Journal of Technology Enhancement and Emerging engineering Research. Vol.3 Issue 05, 2015.
[3] Metcalf and Eddy "Wastewater Engineering: Treatment, Disposal and Reuse. Third Edition, McGraw-Hill.
[4] Omar, A. and Shamim, A."Use of Treated Effluent in Concrete Mixing in an Arid Climate", Cement & Concrete Composites 13.1991.
[5] Troxell, G. E., Dams, H. E., and Kelly, J. W. Composition properties of concrete. 2nd Ed., McGraw Hill, Inc., New York, N. Y. 1968.
[6] ECP 203, Building Code Requirements for Structural Concrete. Egypt, Cairo. 2020.
[7] ASTM C94. Standard Specification for ready-mixed concrete. 1992.
[8] Samorn Muttamara, "Water characteristics", Resources, Conservation and Recycling 16, 1996.
[9] J.Terro & Al-Ghusian, "Use of Treated Wastewater for Concrete Mixing in Kuwait", Kuwait J. Sci. Eng. 30, Kuwait, 2003.
[10] M.Shekarchi, "Use of biologically Treated domestic Wastewater in Concrete", Kuwait J.Sci.Eng.39 (2B) pp.97-111, 2012.
[11] Tay, H. "Use of Reclaimed Wastewater for Concrete Mixing. Journal of Environmental Engineering". pp 1156 – 1161, 1987.
[12] Ghazaly, N. and Lay K. "Effect of Impurities in Mixing Waters on Cement/ Concrete Blocks Compressive Strength". Paper presented at National Seminar on Advances in Environmental Control Technology. University Technology Malaysia. pp 18–19, 1993.
[13] Friedler, E. "The Jeezrael Valley Project for Wastewater Reclamation and Reuse", Israel. Wat. Sci. Tech. 40(4-5): pp 347 – 354, 1999.
[14] Cebeci, O. Z. and A. Saatci. "Domestic Sewage as Mixing Water in Concrete". ACI Materials Journal. Sept.-Oct., pp 503 – 506. 1989.
[15] APHA. Standard Methods for Examination of Water and Wastewater. New York: American Public- Health Association/American Water Works Association/Water Environment Federation, 1992.