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Effect of Using Tertiary Treated Wastewater from Nablus Wastewater Treatment Plant (NWWTP), On Some Properties of Concrete

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Abstract: ***This research paper aims at presenting the effect of using tertiary treated wastewater from Nablus Wastewater treatment plant (NWWTP) on some properties of concrete. The research idea have both environmental and economic aspects. The use of tertiary treated wastewater in partial replacement of potable water in concrete mixtures, will save substantial amount of potable water for domestic use. The research variables are water cement ratios (w/c) = 0.5, 0.6 and 0.7, replacement ratios (30%, 60%. and 100%); and curing ages at 7, 14 and 28 days. Different concrete properties were investigated such as compressive strength, natural absorption and workability (Slump). The tests results of concrete cube samples were compared for both types of water, at different replacement ratios and curing ages. The general trend of test results revealed increase in maximum compressive stress of concrete made with w/c=0.5, 0.6, and decrease at w/c=0.7. The recommended replacement ratio of tertiary treated wastewater in concrete mixtures would be 30% to 40%.***

Keywords: Tertiary treated wastewater, concrete, workability, compressive strength, absorption

I. INTRODUCTION

Recently many wastewater treatment plants has been established or planned to be established in Palestinian. In 1998, Nablus Municipality and the German government signed an agreement through KfW to establish a waste water treatment plant (NWWTP). The plant was designed to treat 14,000 m^3 / day and 8.0 tons of BOD5 per day. The plant is located approx. at 12 km West of Nablus City, near Beit Leed village junction. The wastewater is collected from Zawata, Beit Eba, Beit Wazan, Deir sharaf and Quzin. The water is collected by gravity after the implementation of relevant sewerage networks. Currently the capacity of NWWTP is about 10,000 m^3/day. Part of the treated waste water is used in agriculture for irrigation. With reference to the Ministry of agriculture by-law 34-2012 the treated wastewater quality of NWWTP has Grade (A). In the year 2017 about three millions nine hundred and sixty three thousands (3,963,000 m^3) cubic meters of wastewater were treated. Four projects of reuse of treated waste water in agriculture has been implemented in 2017 to 2018, and the total amount of treated wastewater used in the four projects was only about 233 m^3/year [Abu Ghosh, et.al. 2018]. To

Figure (1): Nablus Wastewater Treatment Plant (NWWTP) year [Abu Ghosh, et.al 2019].

guarantee sustainability of NWWTP, and ruse of maximum amount of tertiary treated wastewater, it's important to investigate different industries in which the treated wastewater may be reused, beside agriculture. One potential reuse will be in the production of ready mix concrete. The ready mix concrete industry in Palestine, is considered one of the largest consumer of potable tap water, beside the stone cutting industry. Currently there are more than 60 ready mix concrete plants distributed in the West Bank, and many of them are suffering from potable water shortage which cost about US$1.5 per cubic meter. Therefore, this research projects aims to investigate the potential utilization of the tertiary treated wastewater from NWWTP in concrete production. The reuse of treated tertiary wastewater in concrete industry will contribute to the sustainability and better management of both the water sector and concrete industry at the same time.

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Substantial quantities of potable water, saved for concrete industry, will be available for domestic use. Figure (1) shows Nablus Wastewater treatment plant (NWWTP). [Abu Ghosh, et.al 2019].

II. OBJECTIVES AND IMPORTANCE

The main objectives of this research is to investigate the effect of reuse of tertiary treated wastewater form NWWTP in partial replacement of potable water, on properties of concrete. The research is important because it will contribute to the sustainability and better management of water sector and concrete industry in Palestine.

III. LITERATURE REVIEW

Manjunatha M. (2017) , presented results of experimental study on reuse of treated wastewater in concrete production. Potable water and treated wastewater were used to prepare concrete mixtures and for curing. The result showed that the treated wastewater is suitable and could be used in concrete production at permissible limits. The results showed no big differences exist between concrete cubes made of both treated wastewater and portable water. The initial and final setting time of cement mixing treated wastewater is within the IS limit. Workability is good and the compressive strength increased by using treated wastewater in concrete mixtures, at the end of 7 days curing. Al-Joulani (2015), reported results of the effect of different types of wastewater on some concrete properties. The author investigated workability, natural absorption, splitting tensile strength and compressive strength. The results of using treated wastewater in concrete mixtures showed minor reduction (11%) in compressive strength after 28 curing. Kucche, M.K., et. al. (2015), reported review of the literature on the effect of quality of mixing water for making concrete. The authors compiled the allowable limits of physical and chemical impurities in mixing water, and their test methods from different countries standards. The authors concluded that using non-traditional mixing water in concrete making influenced the reaction process and therefore, the setting time, compressive strength and also lead to softening of concrete. ATA Olugbenga (2014), conducted a series of tests to investigate the effect of different types of mixing water from different sources on compressive strength of concrete. The results revealed that the sources of water used in mixing concrete have a significant impact on the compressive strength of concrete. The results suggested using river water in concrete production where potable water is scarce. Al-Ghusain I and Mohammad J. Terro, (2003), evaluated the suitability of using of treated wastewater for concrete mixing in Kuwait. Among different types of water such as tab water (TW), preliminary treated wastewater (PTWW), secondary treated wastewater (STWW), and tertiary treated wastewater (TTWW), the authors found that using tertiary treated wastewater, of the type produced from wastewater treatment plants in Kuwait, to be suitable as mixing water with no adverse effects on concrete properties.

Rakesh A. More and S.K. Dubey, (2014), conducted a research on utilizing wastewater in concrete production, and concluded the following:

1) The concrete made with different qualities of water, such as ground water, packed drinking water, waste water etc. have compressive strength at 7- and 28 – day not less than 90 percent of the compressive strength of reference specimens made with potable water. (Except Waste water specimen for 7- day)

2) When using wastewater at constant water – cement ratio of 0.5, there was about 20% less 7- day compressive strength compared to reference specimen.

3) When using packed drinking water as mixing water, the compressive strength obtained for concrete was 13.5% more than the strength of concrete cubes made with potable water.

(4) When using bore water (ground water) as mixing water, the compressive strength of concrete was 5% less compared to reference concrete specimen.

Hummaira Kanwal et al. (2017), reported results on the effect of using wastewater (WW), treated wastewater (TWW) and treated sewage (TS), on compressive strength of concrete, as compared with concrete made using fresh water (FW). The tests results showed that workability were between 25-50 mm, but the ultimate compressive strength of concrete made with wastewater (WW) was decreased and the strength of concrete made with treated wastewater and treated sewage (TWW, TS) at the age of 28 days do not change significantly.

Sameer N. S. et. al. , (2016), presented experimental results of replacement of potable water by treated wastewater in concrete mixing. Water samples used were primary treated wastewater (PTWW), secondary treated wastewater (STWW) and tap water (TW). The results for PTWW, STWW and TW suggested that STWW is appropriate for using in construction industry.

IV. METHODOLOGY

1- Inventory and data collection about reuse of treated wastewater in concrete production
2- Preparation of concrete mix design and materials proportioning.
3- Preparation of different concrete batches with different w/c ratios (using potable water).
4- Preparation of different concrete batches at different w/c (using wastewater for NWWTP).
5- Conducting workability test (slump test) for all concrete batches made with both type of water.
6- Casting sufficient concrete samples, (10 x 10 x 10 cm), and curing them for 7, 14 and 28 days.
7- Testing the concrete samples for compressive strength after different curing time.
8- Testing concrete cubes after 28 days curing for natural absorption.
9- Analysis and comparison of tests results of concrete made with the two types of water.

V. MATERIALS PROPERTIES

Mixing Water:

Mixing water is the main ingredient in concrete mixtures. Mixing water has different purposes, such as wetting surfaces of aggregates so that better adhesion between cement paste and aggregates is ensured. Also, water is necessary to impact workability to concrete to facilitate placing in the desired position. Finally, mixing water is needed for the hydration of cementing material to set and harden during the period of curing.

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The ASTM C94 stipulate that the appropriate water for concrete mixing is potable water. The water must be free of chloride, sulphate and salts and is also free from harmful substances such as oils, grease, acids, alkalis, organic matters, cork and other substances that have a reverse effect on concrete properties such as resistance to fracture and durability. Other types of water which not fit for drinking may be suitable for concrete making provided that they satisfy the acceptance criteria set by ASTM C94. Compressive strength at 7 days curing must not be less than 90% of the reference concrete made with potable water (Test method ASTM C 109 or T106A). The setting time of concrete must not be earlier than 1 hour or later than 1:30 hour using the ASTM C191 or T 131 test methods respectively.

Effects of Impurities in Mixing Water:

Excessive impurities in mixing water affect setting time and concrete compressive strength efflorescence (deposits of white salts on the surface of concrete), staining, corrosion of reinforcement, volume change and reduced durability. Table (1), present the effect of some impurities on concrete properties.

Table (1): Effect of some impurities on concrete properties [12]

Impurity	Effects
Alkali carbonate and bicarbonate	Acceleration or retardation of setting time. Reduction of strength
Chloride	Corrosion of steel in concrete
Sulphate	Expansive reactions and deterioration of concrete. Mild effect on corrosion of steel.
Iron salts	Reduction in strength
Miscellaneous inorganic salts (zinc, copper, lead, etc)	Reduction in strength and large variations in setting time
Organic substances	Reduction in strength and large variations in setting time
Sugar	Severely retards the setting of cement
Silt or suspended particles	Reduction in strength
Oils	Reduction in strength

In this research, the tertiary treated wastewater (TTW) from Nablus wastewater treatment plant (NWWTP), is used for concrete production. The treated wastewater is tested frequently by special certified laboratory, to ensure conformity with the standard limits. Table (2) shows some properties of the (TTW) from NWWTP, and Table (3) present the quality and limiting values of the tertiary treated wastewater standards and the class categories. It should be noted that the TTW form Nablus Wastewater Treatment Plant (NWWTP) is classified as class A.

VI. EXPERIMENTAL WORK

The experimental work was based on preparing different concrete batches at the Palestine Polytechnic University (PPU) laboratories. The concrete batches were prepared at three different water cement ratios w/c = 0.5, 0.6, and 0.7.
The reference concrete batch was made by using potable water. More than 12 other concrete batches were prepared at the same w/c ratios by using TTW collected form NWWTP, in partial or full replacement of potable water. At each w/c ratio 4 replacement ratios of wastewater (0%, 30%, 60% and 100%), were used in substitute of potable water. The constituents of the different concrete batches are shown in Table (4). Compressive test setup and the mode of concrete failure are shown in Figure (2).

Table (2): Properties of Tertiary treated wastewater of NWWTP

Test	Result	Method
Total Suspended Solids (TSS)	< 2.0 mg/L	StMe
Fecal Coliforms	Nil /100ml	ISO
Total Dissolved Solids (TDS)	811 mg/L	StMe
Nitrate Nitrogen (NO3-N)	8.83 ppm	StMe
Chloride	159.15 ppm	CIA
Sulfates (SO4)	51.32 ppm	CIA
Sodium (Na)	161.0 ppm	ICP
Magnesium (Mg)	16.64 ppm	ICP
Calcium (Ca)	88.6 ppm	ICP
Sodium Adsorption Ratio (SAR)	4.12	ICP
PO4-P	9.28 ppm	StMe
Aluminum (Al)	0.052 ppm	ICP
Manganese (Mn)	0.009 ppm	ICP

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Table (3): Quality of Tertiary treated wastewater from NWWTP, [Abu Ghosh et. Al. 2018]

Quality of the treated water (NWWTP) with comparison of reuse standard (34/2014)

Maximum limits for chemical and biological properties	KfW reuse project sampled 14/8/2017	USAID reuse project sampled 18/5/2017	Quality of Tech. Spec 34-2014			
			High Quality (A)	Good Quality (B)	Medium Quality (C)	Low Quality (D)
(BOD$_5$) mg/l	14.8	5	20	20	20	60
suspended solids (TSS) mg/l	<2	6	30	30	30	90
FC (Colony/100ml)	Nill	2	200	1000	1000	1000
(COD) mg/l	45.3	25	50	50	100	150
Dissolved Solids (TDS) mg/l	975	820	1200	1500	1500	1500
pH	7.74	7.54	6–9	6—9	6–9	6–9
Fat, Oil, & Grease mg/l	4	4	5	5	5	5
Phenol mg/l	-	BDL	0.002	0.002	0.002	0.002
MBAS	-	<10	15	15	15	25
NO3-N ppm	BDL	2.46	20	20	30	40
NH4-N mg/l	1.3	1.4	5	5	10	15
Total nitrogen	6.6	11.06	40	40	40	40
CL ppm	260.82	239.38	400	400	400	400
SO$_4$ ppm	88.73	97.40	300	300	300	300
Na ppm	177	197	200	200	200	200
Mg ppm	26.2	21.9	60	60	60	60
Ca ppm	74.7	82.28	300	300	300	300
SAR	5.37	5.33	5.85	5.85	5.85	5.85
PO$_4$-P ppm	16.3	11.93	30	30	30	30
Al ppm	0.10	0.05	5	5	5	5
Cu ppm	0.035	0.013	0.2	0.2	0.2	0.2
Fe ppm	0.113	0.07	5	5	5	5
Mn ppm	BDL	0.04	0.2	0.2	0.2	0.2
Ni ppm	0.054	BDL	0.2	0.2	0.2	0.2
Pb ppm	0.03	0.03	0.2	0.2	0.2	0.2
Se ppm	BDL	BDL	0.02	0.02	0.02	0.02
Cd ppm	0.01	BDL	0.01	0.01	0.01	0.01
Zn ppm	0.08	0.16	2	2	2	2
Cn ppm	BDL	BDL	0.05	0.05	0.05	0.05
Cr ppm	<0.04	BDL	0.1	0.1	0.1	0.1
Hg ppm	<0.05 ppb	0.44 ppb	0.001	0.001	0.001	0.001
Co ppm	BDL	BDL	0.05	0.05	0.05	0.05
B ppm	0.15	0.066	0.7	0.7	0.7	0.7
Ag ppm	BDL	1				
E. coli (Colony/100ml)	Absent	Absent	100	1000	1000	1000
Nematodes (eggs/L)	Absent	Absent	1>=	1>=	1>=	1>=

BDL = below detection limit

Table (4): Concrete batches constituents

Water Type , Replacement %, (w/c Ratio)	Portland cement type 1 (kg/m^3)	Tab Water (kg/m^3)	Tertiary treated WW (kg/m^3)	Fine Aggregate (Sand) (kg/m^3)	Coarse Aggregate (Crushed limestone) (kg/m^3)
Tap W (0.5)	347	174	0	896	956
Tap W (0.6)	309	185	0	896	956
Tap W (0.7)	279	195	0	896	956
SW30 (0.5)	347	121	53	896	956
SW30 (0.6)	309	130	55	896	956
SW30 (0.7)	279	137	58	896	956
SW60(0.5)	347	69	104	896	956
SW60(0.6)	309	74	111	896	956
SW60(0.7)	279	78	117	896	956
SW100 (0.5)	347	0	174	896	956
SW100 (0.6)	309	0	185	896	956
SW100 (0.7)	279	0	195	896	956

Figure (2) : Setup of compressive test and mode failure of samples made with TTW from NWWTP

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VII. EXPERIMENTAL TESTS RESULTS

Slump Test Results:

Table (5) shows the slump test results of concrete batches with different type and replacement ratios of TTW from NWWTP. The results showed gradual increase in slump at w/c = 0.6 and 0.7, and different replacement ratios of TTW, but remain almost constant at w/c=0.5.

Table (5): Slump test results for potable water and TTW at different w/c and replacement ratios

Type of Mixing Water	w/c , (%)	Slump , (cm)
Potable tap water (0%)	0.5	0.4
	0.6	5.5
	0.7	7
Tertiary treated Water , (30%)	0.5	0.5
	0.6	6.5
	0.7	11
Tertiary treated Water (60%)	0.5	0.5
	0.6	7
	0.7	12.5
Tertiary treated Water (100%)	0.5	0.5
	0.6	8
	0.7	15.5

Compressive Strength Test Results

Table (6) present the results of all compressive strength tests. The results revealed that at w/c=0.5, the maximum compressive stress increases at all ages and replacement ratios. However at w/c=0.6 the compressive stress increased after 14 and 28 days, but reduction was observed at 7 days curing. When using w/c=0.7, the maximum compressive stress decreases at all ages and replacement ratios.

Table (6): Max compressive stress for concrete made with potable water and TTW from at different w/c and replacement ratios

w/c %	Age (days)	% Replacement water: 0 %	30 %	60%	100 %	Replacement Ratio of TTW: 30 %	60 %	100 %
		Max. Compressive Stress (MPa)				(change in max. stress) increase (+) or decrease (-)		
0.5	7	18.3	21.1	30.35	24.5	15.30	65.85	33.88
	14	26.3	25	33.5	28.6	-4.94	27.38	8.75
	28	36.4	29.4	36.1	39.9	-19.23	-0.82	9.62
0.6	7	20.95	20	20.75	16.5	-4.53	-0.95	-21.24
	14	21.45	24.5	23	25	14.22	7.23	16.55
	28	22.6	27.5	28.6	31.4	21.68	26.55	38.94
0.7	7	14.9	16.45	11.6	12.35	10.40	-22.15	-17.11
	14	16.6	19.1	14	13.45	15.06	-15.66	-18.98
	28	25.6	23.6	19.5	18.85	-7.81	-23.83	-26.37

Figures (3, 4 and 5) present linear regression of the variation in maximum compressive strength of concrete samples made with potable water and TTW from NWWTP at different w/c and replacement ratios. The results recommend reuse of the TTW from NWWTP, in concrete mixtures, up to 60% replacement of potable water (at w/c=0.5 and 0.6). However, it is not recommended to use TTW in concrete mixtures (at w/c=0.7), because of the gradual decrease in maximum compressive strength at 7, 14 and 28 days curing.

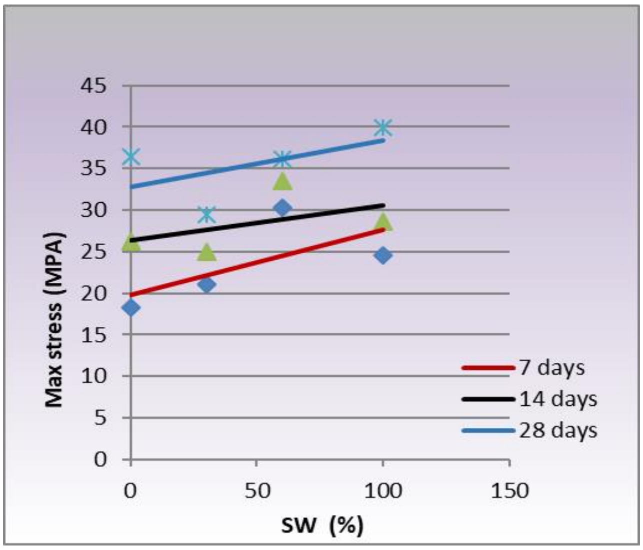

Figure (3): Max compressive stress of concrete at different replacement ratios and curing time for tertiary wastewater (w/c=0.5)

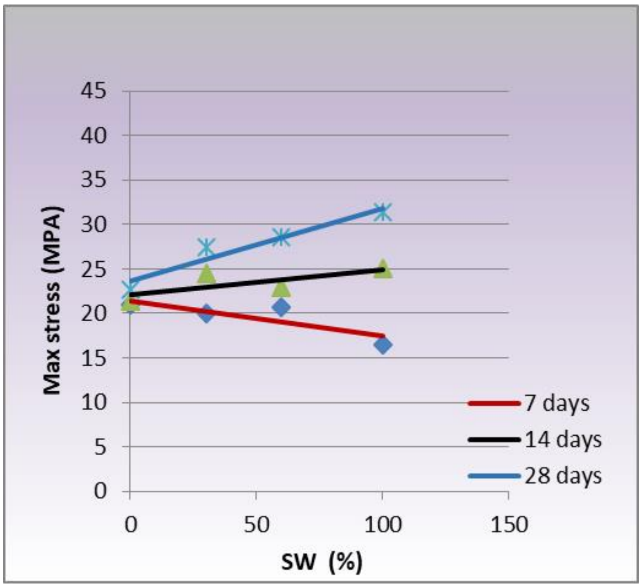

Figure (4): Max compressive stress of concrete at different replacement ratios and curing time for tertiary wastewater (w/c=0.6)

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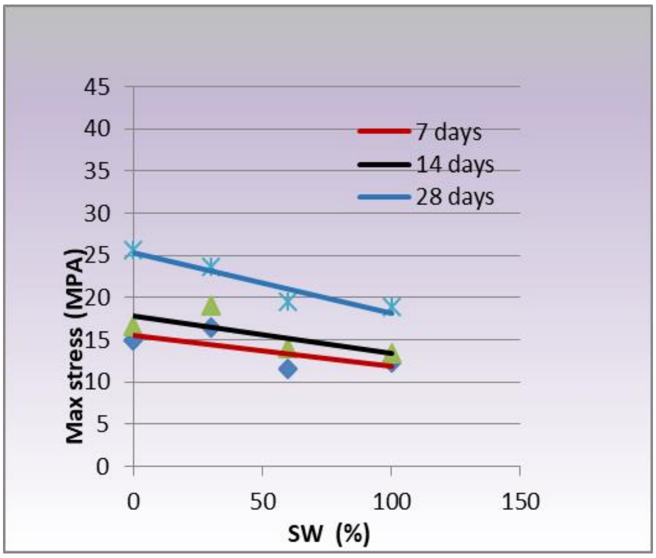

Figure (5): Max compressive stress of concrete at different replacement ratios and curing time for tertiary wastewater (w/c=0.6)

Absorption Test Results

Table (7) shows the absorption rate of concrete samples produced by potable water and TTW from NWWTP after 28 days curing. There are no significant changes in absorption at any replacement ratio of the potable water with TTW, in concrete mixtures.

Table (7): Natural absorption of concrete samples produced by using potable water, and TTW, at different w/c and replacement ratios

Type of Mixing Water	w/c (%)	Absorption rate after 28 days (%)
Potable tap water (0%)	0.5	3.01
	0.6	3.28
	0.7	3.83
Tertiary treated Water (30%)	0.5	3.86
	0.6	3.26
	0.7	4.08
Tertiary treated Water (60%)	0.5	2.62
	0.6	3.4
	0.7	4.03
Tertiary treated Water (100%)	0.5	2.67
	0.6	3.49
	0.7	3.77

VIII. CONCLUSION AND RECOMMENDATIONS

1-The results showed that reuse of tertiary treated wastewater (TTW) from NWWTP in concrete production, (at w/c=0.5 and 0.6) has increased the maximum compressive strength by increasing replacement ratio (30%, 60% and 100%) after 14 and 28 days curing. The increase varied from 10% to 39%.

2-There was reduction in max. Compressive stress between 16 to 26%, when using TTW from NWWTP, for replacement ratio of 60% and 100% respectively, (w/c =0.7, and 28 days curing).

3-There was no significant change in slump when TTW used in partial replacement of potable water at w/c=0.5 and 0.6. However, slump was increased from 70 mm for potable tap water to 110 mm, 125 mm and 155 mm at replacement ratios of 30% , 60% and 100%, respectively.

4-sThere was no significant change in natural absorption of concrete, when using TTW at any replacement ratio of potable water.

5-From linear regression of the experimental results, it may be recommended to reuse TTW, in concrete mixtures, at replacement ratio not more than 40% of potable water, with w/c = 0.5 and 0.6.

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REFERENCES

1- ASTM C-94 (1996), Standard Specification for Ready Mix Concrete, American Society of Testing and Materials.

2- ATA Olugbenga, (2014), Effects of different sources of water on concrete stress: A case study, Civil and Environmental Research Vol. 6 No.3.

3- Al-Jabri K. S. et al. (2011), Effect of Using Wastewater on The Properties of High Stress Concrete, Elsevier Proceeding Engineering 14 , pp. 370-376.

4- Bassam Mahasneh, (2014) Assessment of replacing wastewater and treated water with potable tap water in making concrete mix, The Electronic Journal of Geotechnical Engineering Volume 19 PP 2379-2386.

5- Hummaira Kanwal et al., (2018) , Effect on Compressive Strength of Concrete Using Treated Wastewater for Mixing and Curing of Concrete, Mehran University Research Journal of Engineering and Technology, ISSN (p): 0254-7821, e-ISSN: 2413-7219, V. No. 37, No. 2, 445-452. http://oaji.net/articles/2017/2712-1520877446.pdf

6- Ibrahim Al-Ghusain and Ibrahim Terro (2003) Use of treated wastewater for concrete mixing in Kuwait, Kuwait J. Sc. Eng. 30 (1).

7- Kucche, M.K., S. Jamkar, and P. Sadgir, (2015), Quality of water for making concrete: a review of literature. International Journal of Scientific and Research Publications, V-5, Issue-1.

8- Manjunatha. M (2017), An Experimental Study on Reuse of Treated Waste Water in Concrete – A Sustainable Approach International Journal of Latest Engineering and Applications (IJLERA), ISSN:2455-7137,V. No. 2, Issue – 07, PP 124-132, http://www.ijlera.com/papers/v2-i7/15.201707377.pdf

9- Mixing Water for Concrete Effects of Impurities in Mixing Water, http://site.iugaza.edu.ps/malqedra/files/Lecture-42.pdf

10- Nabil M. A. Al-Joulani (2015), Effect of Waste Water Type of Concrete Properties, International Journal of Applied Engineering Research ISSN 0973-4562, Vo. 10, No. 19, Pp 39865-39870

11- Rakesh A. More (2014), Effect of Different Types of Water on Compressive Stress of Concrete, International Journal of Emerging Technologies, 5 (2): 40-50.

12- Sameer N. Shinde, Ranjeet N. Patil, and Nitesh B. Thikare , (2016), An Experimental Study of Replacement of Potable Water by Treated Wastewater in Concrete Mixing, International Journal of Pure and Applied Research in Engineering and Technology (IJPRET), V. 4(9):221-227.

http://www.ijpret.com/publishedarticle/2016/4/IJPRET%20-%20Civil%20113.pdf

13- Suleiman Abu Ghosh, Yousef Jaffal, Samer Bitar and Mohammad Homeidan, (Feb. 2019), Monthly Report of Nablus Wastewater Treatment Plant-in Arabic (NWWTP).

14- Suleiman Abu Ghosh et. al. (2018), Wastewater Treatment Plant-Nablus West, Annual Report for Operation and Reuse of year 2017, http://wwtp.nablus.org/wp-content/uploads/2018/02/Final-2017-report-20-2-2018.pdf

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