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Use of Waste Water Sludge in Concrete Mixes with Treated Water

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ABSTRACT: The aim of this study is to find a solution for the large volume of sludge produced in the wastewater treatment plants in Jordan in order to decrease the environmental pollution in the air , as well as to assess the strength of sludge concrete using treated water in concrete mix as a comparison with the strength of sludge concrete made by tap water. Many researchers have been trying to find suitable solutions to solve part of wastewater sludge problem. One of these solutions is to use sewage sludge in construction field (as the interlock bricks as an example of non structural elements made with sludge concrete) [1]. According to the results findings, no significant strength loss was observed when low organic dry sludge was used in making sludge concrete cube specimens as additive . The compressive strength of sludge concrete for treated water was compared with the strength of sludge concrete made by tap water. The results show that; using sludge concrete mixes decrease the strength of cube about (9.3%) when treated water was used .

KEWORDS: Sludge, Concrete, Additive , Tap water, Treated water, Compressive strength.

I. INTRODUCTION

The main objective of this research is to study the effect of using wastewater sludge in concrete mixes in non-structural elements. The wastewater treatment plants equipments concentrate impurities in wastewater into solid form and then separate these solid from liquid ;[2]. The source of sludge in wastewater treatment plant varies according to plant type and its method of operation. Small amount comes from chemical precipitation, screening, grinder and filtration device[3] . The successful use of sludge will help in reducing the environmental and health problems related to the bad handling of sewage sludge at wastewater treatment plants ; [4] . In addition to the above mentioned objective of this research is that : Jordan is facing a future of very limited water resources. Re-use of treated wastewater is an important issue in many civil works policy. Water is needed as a component in concrete mixtures. It is needed for the hydration process of cementations materials and for curing. Treated water 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.

II. THE MIXING MATERIALS

II.1 Dry Sludge : Sludge with low organic material and high sand content .

The current sewage sludge produced in Amman wastewater plant (Al-kherbe Al-Samra Plant) is exposed to the sun for a long period of time and then accumulated and transferred to dumping sites. The dumping sites are sandy dunes near plants. Figure (1) illustrates a sample of this type of sludge which distributed on sand dunes around plant. The organic material content (weight loss at 550oC) varied between 11%-13%. The moisture content of sludge (weight loss at 105 ^{o}C) varied between 20%-25%.

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Figure (1): Low organic sewage sludge shape

The grain size distribution of sludge was determined in same way of aggregate. The granulometry of this type after drying and manual grinding is shown in Table (1) and Figure (2).

Table(1) : Sieve analysis of low organic sludge

Sieve size (mm)	Sieve #	Sample % Passing
76	3"	100
50	2"	100
37.5	11/2"	100.0
25	1"	100.0
19	3/4"	100.0
12.5	1/2"	100.0
9.5	3/8"	100.0
4.75	#4	90.6
2.36	# 10	79.2
1.18	#16	68.7
0.600	#25	59.5
0.300	#40	31.9
0.150	#100	5.5
0.075	#200	2.2

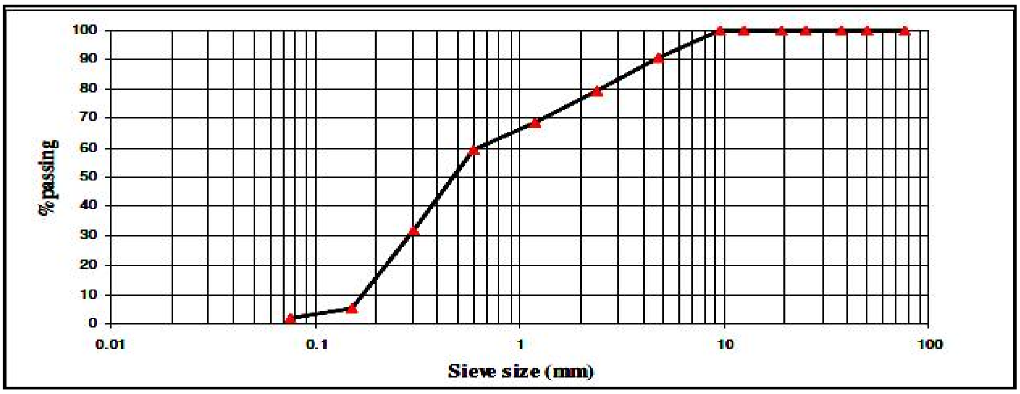

Figure (2): Grain size distribution of low organic sludge

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II.2 Aggregate:

Three size of coarse aggregate were used : (a) Aggregate with maximum size 25 mm (b) Aggregate with maximum size 19 mm (c) Aggregate with maximum size 9.5mm (d) Natural sand with maximum size 600µm .The most important aggregate properties which needed to prepare concrete mixes are:

• Specific gravity: The determination of specific gravity of coarse and fine aggregate was done according to ASTM C 127;[5] and ASTMC128;[6] respectively. The aggregate specific gravity was calculated at dry condition, see Table (2).

Table (2): Aggregate specific gravity

Aggregate type	Specific gravity ;Gs (dry)
25mm	2.68
19mm	2.59
9.5mm	2.52
sand	2.66

• Unit weight: The unit weight or bulk density of aggregate is the weight of aggregate per unit volume. ASTM C 29 procedure was used to determine aggregate bulk density, see Table(3).

Table (3): Aggregate Dry unit weight

Aggregate type	Dry unit weight γ_{dry} (kg/m3)
25mm	1435
19mm	1505
9.5mm	1485

• Absorption: ASTM C127 was used to determine coarse aggregate absorption and ASTM C128 for fine aggregate, see Table (4).

Table (4): Aggregate absorption

Aggregate type	Absorption (%)
(25mm)	1.12
(19mm)	2.42
(9.5mm)	3
Sand	0.5

• Grain size distribution : The sieve analysis of aggregate includes the determination of coarse and fine aggregate by using a series of sieves. ASTM C136;[7] procedure was used to determine the sieve analysis of coarse aggregate as shown in Table (5) and Figure (3).

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Table (5): Sieve analysis of aggregate with maximum size 25mm

Sieve size (mm)	Sieve #	Sample % Passing
76	3"	100
50	2"	100
37.5	11/2"	100.0
25	1"	98.2
19	3/4"	46.7
12.5	1/2"	3.3
9.5	3/8"	1.4
4.75	#4	1.1
2.36	# 10	1.1
1.18	#16	1.1
0.600	#25	1.0
0.300	#40	1.0
0.150	#100	0.9
0.075	#200	0.7

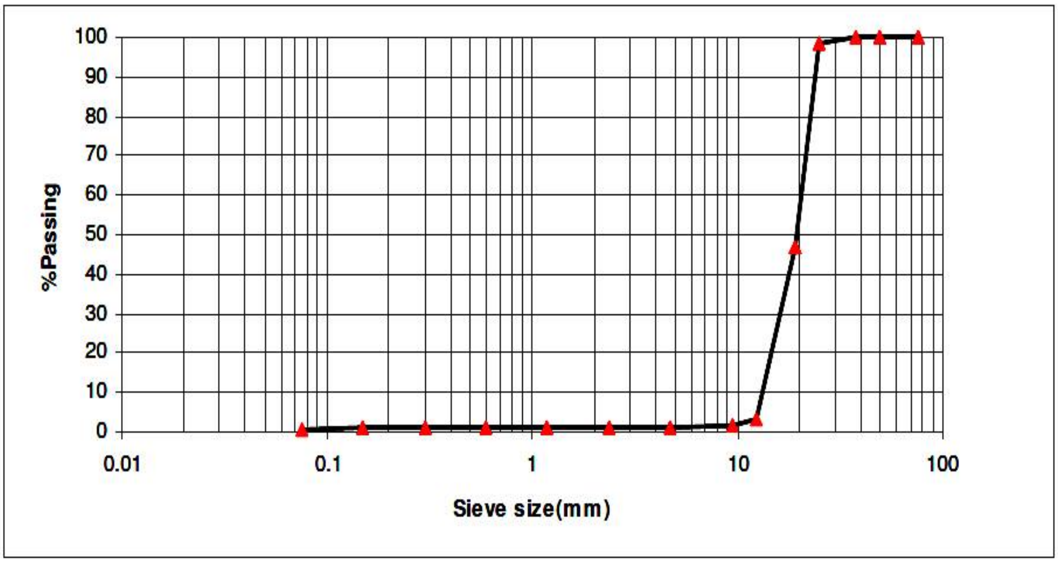

Figure (3): Sieve analysis of coarse aggregate with maximum size 25 mm

II.3 Cement :

Ordinary Portland cement of Jordan; grade 42.5 N/mm2 , with Specific Gravity of 3.15 been used . The cement was obtained from local concrete manufacture and kept in dry location ;[8].

II.4 Water :

a. Tap water : Potable without any salts or chemical was used in the study according to ASTM & World health organization (WHO) and Jordan T.W. classifications; [9], as shown in Table (6).

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Table (6): Tap water standard specifications

Chemical composition and physical properties	ASTM specification of tap water	World health organization
T.D.S (total dissolved solid)	500 mg/L	1000 mg/L T.S.S
T.S.S (total suspended solid)	---	------
Ph	6.5 – 8.5	6.5 – 8.5
COD	-----	-------
BOD	-----	-------

b. Treated water : This treated water uses for irrigation purposes. The chemical composition and physical properties of the domestic treated water of Zarqa treatment plant , are shown in Table (7)

Table (7): 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)	<30mg/L
Ph	6.9-7.2
COD	(50-70) mg/L
BOD	<10mg/L
$C1_2$	3 mg/L

III. MIX PREPARATION

According to ASTM, one mould been used in testing concrete samples; where the standard (10 x 10 x 10) cm cubes were used for compression tests . Dry sludge was added to concrete mix as fine sand at percent various from 0-10%. One control mix design A0 was prepared to investigate the influence of dry sludge , and waste water on concrete properties. Mix A0 was designed with a targeted compressive strength 300kg/cm^2.

The present study concentrated on developing the most straightforward mix design and preparation techniques to produce concrete containing sewage sludge with acceptable properties in fresh and hardened states. The influence of sludge on concrete properties was studied by preparing several concrete mixes involving different types, and amount of sludge. The use of low organic sludge as additive and sand replacement was carried out as follow :

a) Prepare concrete cube specimens containing 0%, 2.5%, 5% and 10% of dry sludge by cement weight as an additive with tap water.
b) Prepare concrete cube specimens containing 0%, 2.5%, 5% and 10% of dry sludge by cement weight as an additive with treated water , as shown in Table (8).

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Table (8): Low organic sludge as additive to mix A0 :
1. With Tap Water 2. With Treated Water

Batch name	Sludge content by weight (kg) in 1m^3
A0	Zero sludge content (Control mix), s/c=0
A-A2.5	2.5% of cement content of mix A0 as additive sludge. (s/c) = 2.5%, s= 7.75kg/m3
A-A5	5% of cement content of mix A0 as additive sludge. (s/c) = 5%, s= 15.5kg/m3
A-A10	10% of cement content of mix A0 as additive sludge. (s/c) = 10%, s= 31kg/m3

The above mentioned groups prepared using : 1. Tap water 2. Treated water and each mould been filled with sludge 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.

IV. EQUIPMENT AND TESTING PROCEDURE

IV.1 Compressive strength

All batches were prepared, cured, and their compressive strength was determined after 7 , 28 and 90 day. According to ASTM, two moulds been used in testing concrete samples; where the standard (10 x 10 x 10) cm cubes were used for compression tests .

The compressive strength was calculated by dividing the failure load by average cross sectional area. The average value of the three specimens was considered as the compressive strength of the experiment. The compressive strength machine in Material Lab at Zarqa University was used for determining the maximum compressive load carried by concrete cube as shown in Fig. (4) below.

Figure (4): The compression machine

IV.2 Density : The same cube specimens which used to determine compressive strength were used to determine the density in the same procedure .

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IV.3 Workability : Slump test was conducted to asses the workability of fresh control concrete and concrete containing sludge, see Fig. (5). The slump test was carried out according to ASTM C143, [10].

Figure (5): Slump value determination

V. TEST RESULTS AND ANALYSIS

V.1 Control mix properties

As mentioned before one control mix (A0) was prepared to investigate the effect of dry sewage sludge on concrete properties, see Table (9).

Table(9): Concrete Mix Properties (A0)

Parameter	Mix (A0)/ B300
Target compressive strength (28 day)	300
Water/ cement ratio	0.54
28 day compressive strength result (kg/cm2)	Prismatic = 396
90 day compressive strength result (kg/cm2)	Prismatic = 484
28 day density result (kg/m3)	2454
90 day density result (kg/m3)	2420
Slump result (cm)	4

V.2 Compressive strength results

The compressive strength of mix A0 with various percentage of dry low organic sludge as additive in Tables (10) , (11) ,and (12) respectively. The results of the compressive strength of concrete mixes are also presented in Figures (6) ,and (7) respectively . According to the compressive strength test results, the existence of this Type of sludge in concrete mixes as additive has limited adverse effect on compressive concrete strength due to low organic content.

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Table (10) : Compressive strength (kg/cm2) of mix A0 with sludge as additive
[With Tap Water].

Curing Age	Mixes with different sludge content			
	A0	A-A2.5	A-A5	A-A10
7	296	292	297	327
28	396	421	399	419
90	484	479	450	475

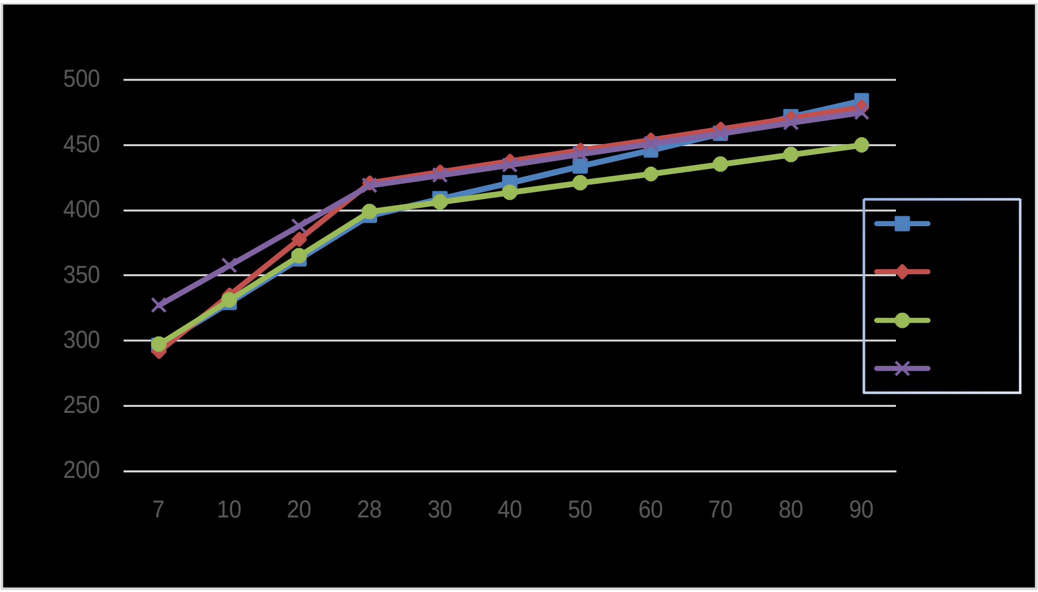

Figure (6): Relation between compressive strength and curing age for concrete with additive sludge content (0%, 2.5%, 5%, 10%)- [With Tap Water].

Table (11) :Compressive strength (kg/cm2) of mix A0 with sludge as additive
[With treated Water].

Curing Age	Mixes with different sludge content			
	A0	A-A2.5	A-A5	A-A10
7	268	265	269	298
28	359	382	362	380
90	439	434	408	431

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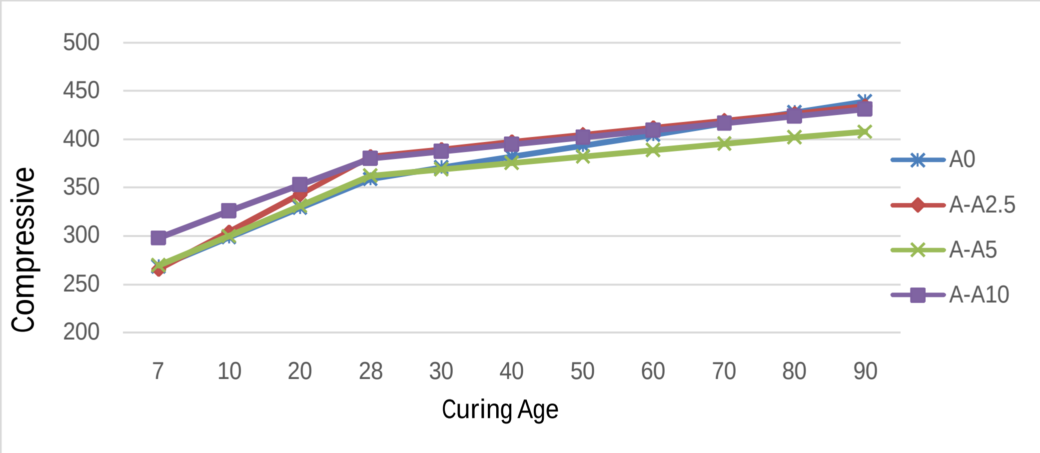

Figure (7): Relation between compressive strength and curing age for concrete with additive sludge content (0%, 2.5%, 5%, 10%)- [With treated Water].

Table(12): Relative strength of mix A0 contained additive sludge

Additive sludge (%)	Relative strength (28 day)	Relative strength (90 day)
0	1	1
2.5	1.06	0.99
5	1	0.93
10	1.06	0.98

V.3 Density results : The density of concrete cubes decreased as sludge content increased, as is shown in Tables (13-a) and (13-b) and Figures (8) and (9) .

Table (13-a): Average density (kg/m^3) of mix A0 contained additive sludge.
[With Tap water]

Curing period	Mixes with different sludge content			
	A0	A-2.5 A	A-A5	A-A10
7	2451	2395	2399	2378
28	2454	2414	2412	2410
90	2420	2405	2388	2367

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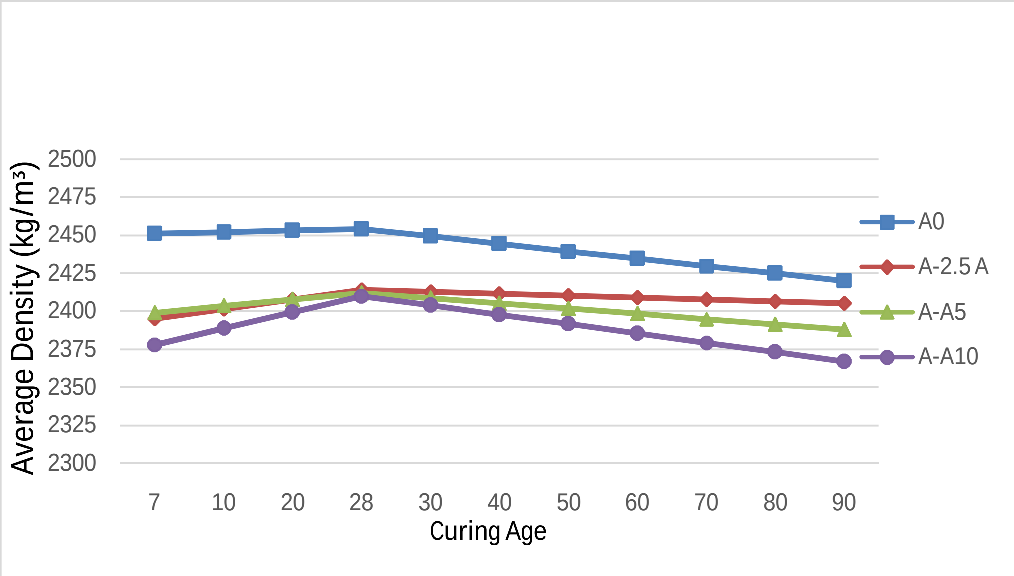

Figure (8): Relation between density and curing age for different additive sludge content (0%, 2.5%, 5%, 10%). . [With Tap water]

Table (13-b): Average density (kg/m3) of mix A0 contained additive sludge. [With treated water]

Curing period	Mixes with different sludge content			
	A0	A-2.5 A	A-A5	A-A10
7	2223	2172	2175	2157
28	2226	2190	2188	2186
90	2195	2181	2166	2147

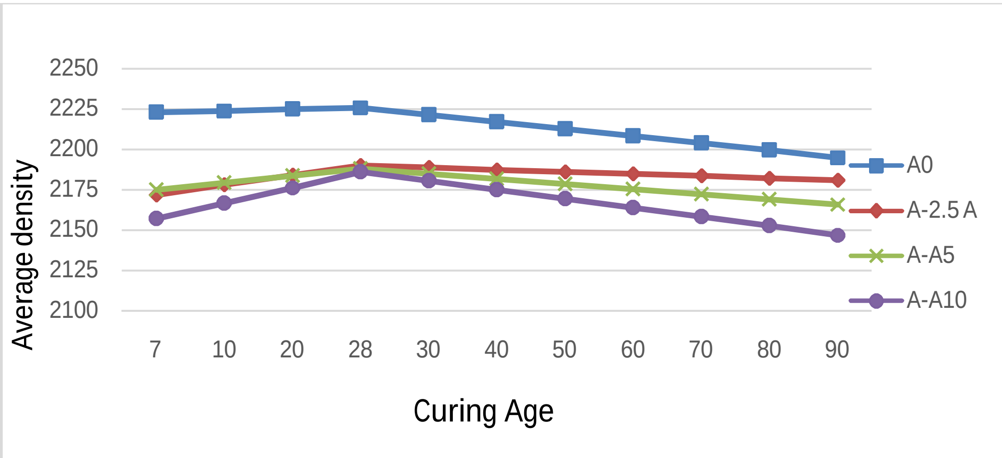

Figure (9): Relation between density and curing age for different additive sludge content (0%, 2.5%, 5%, 10%). .[With treated water]

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Finally it is very important to do some comparisons between compressive strength of concrete mix A10 with sludge as Additive using different water, these results can be seen in Table (14) and Figure (10).

Table (14): Comparison between Compressive strength (kg/cm2) of mix A10 with sludge as Additive using different water.

Curing Age	Water type	
	Tap water	Treated water
7	327	298
28	419	380
90	475	431

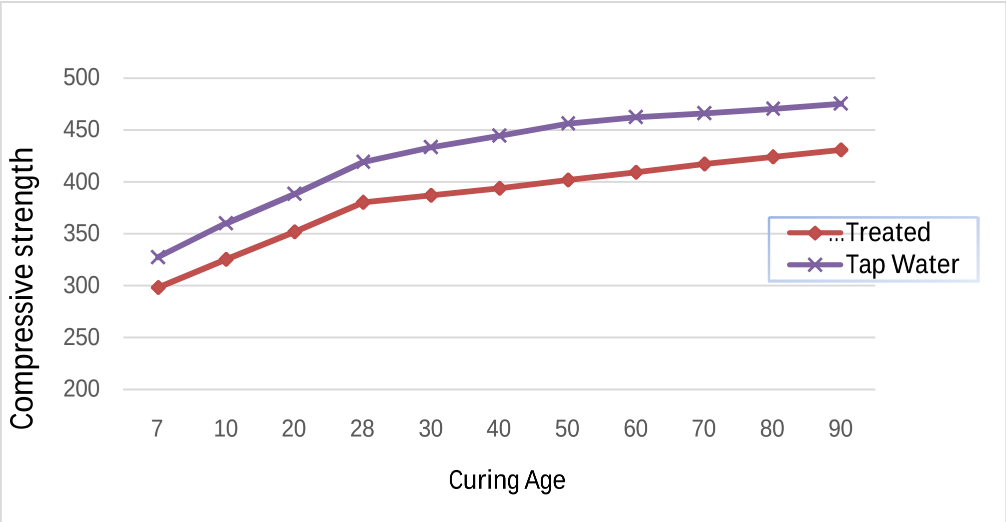

Figure (10): Comparison between Compressive strength (kg/cm2) of mix A10 with sludge as Additive of Tap water and Treated water.

It is also very important to do some comparisons between density of concrete mix A10 with sludge as Additive using different water, these results can be seen in Table (15) and Figure (11).

Table (15) Comparison between density and curing age for additive sludge content A10.

Curing Age	Water type	
	Tap water	Treated water
7	2378	2157
28	2410	2186
90	2367	2147

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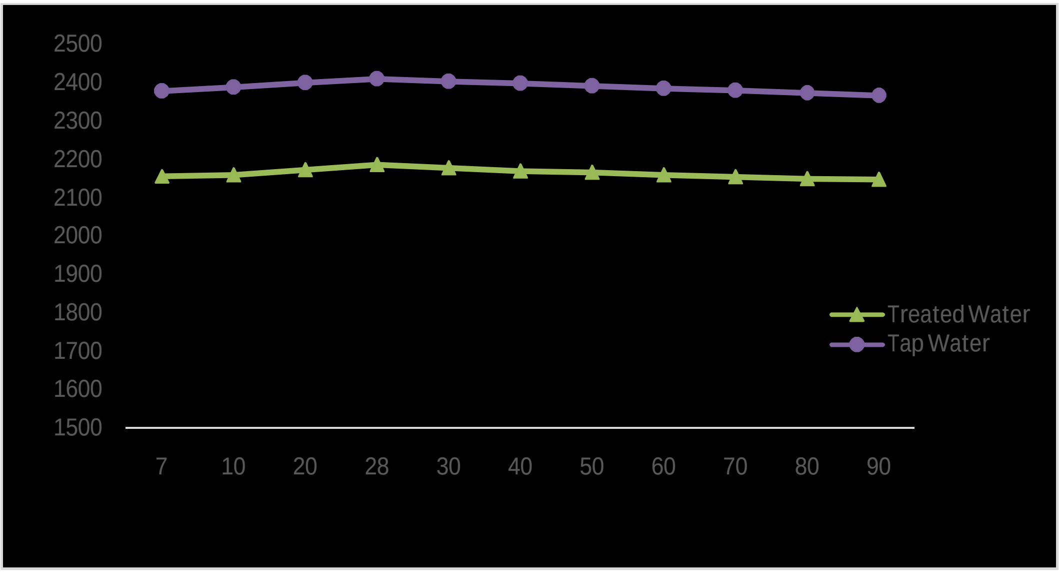

Figure (11): Comparison between density for additive sludge content A10 of Tap water and Treated water

VI. CONCLUSION

Based on the experimental investigations reported , the following conclusions are drawn:

1. Low organic sludge with organic content less than 13% can be used as an additive to concrete mix without causing a marked reduction in compressive strength. 5% dry sludge by cement weight can be added to concrete mix without introducing any change in mix preparation. However, increasing the percentage of added sludge more than 5% decreased the workability of the mix and subsequently caused a reduction in the slump value obtained. In general, the rate of strength developed for all sludge concrete were lower compared to control mix without sludge.
2. 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 made by treated water was 92.7%.
3. 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 and the density of treated water and tap water is less than 10%, so there is no problem in using the treated water as mixing water that lead to solve the lacking of water in Jordan .
4. Regarding the density of sludge concrete with A10 , it is important to mention that the density is decreased when use treated water instead of tap water but doesn't strongly bad effect.

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