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Effect of using secondary treated wastewater in production and curing of concrete

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Abstract

The water consumption keeps on increasing due to the huge increase in the overall human population. This increasing consumption presents the vital need for providing alternative solutions at which can preserve the increase in water use. Therefore, the reuse of wastewater is considered the best option in order to reduce or provide alternative use of water in multiple applications. One of the common ideas that were developed during the past few years is the use of treated water in concrete mixing and curing instead of using potable water. However, the major concern that was related to this aspect is the possibility of influencing the properties of concrete while using treated wastewater. The aim of this research is to examine the influence of using treated wastewater in the procedure of mixing and curing concrete cubes. Some of the concrete cubes will be mixed using potable water, while others will be mixed using secondary treated wastewater. The reached results in this research demonstrated that the use of treated and mixed wastewater accomplished higher compressive strength than the use of water. The highest compressive strength recorded was 41.63 MPa with anaverage value of 38.4 Mpa, which was designed through the use of treated water in the mixing and curing of concrete cubes. The consistency of concrete has a minimal effect when using the treated wastwater in the concrete mixture.This indicated that treated wastewater could be quite useful in terms of accomplishing required properties and results of compressive strength in the design of concrete mixtures.

1. Introduction

Concrete was rated as the greatest commonly used material all over the universe, the industry of concrete has responsibilities towards society and environment to grant a sustainable development. One of the main sources of air pollution is the process of the concrete production industry. The main factor that gives preference to the use of concrete in construction because of its strength and durability properties [1]. It was stated that in the cement industry, producing a one-ton quantity of cement cause production of one ton of greenhouse gasses and carbon dioxide gas that considered to be one of the reasons for global warming [2]. As a result of enormous quantity of natural material required to produce the required amount of concrete per year, concrete production is not considered environmentally friendly industry also it is considered as obstacle to granting sustainable development, for example, high rate of energy consumption, carbon dioxide production, high usage of water and waste produced due to construction and demolition [3]. As a result of water shortage and a huge increase in population, sustainable development and clean production of concrete which cause no harm to the environment became very important targets. During the years 1959 to 1999, the population of the world has increased to double, the population jumped from 3 to 6 billion capita. It was stated by the Census Bureau in the

United States of America, it is strongly predicted that the population of the world would increase to reach 9 billion capita by 2043, or at least increase to double compared to 1999 [4]. Due to such a huge increase in population, demand on the water will also increase; this will result in the reuse of water (recycling) and water conservation [5].

Water is considered one of the major resources that ensure the quality of life for human beings. It is also considered a vital element that is currently used in several applications and procedures at which defines the basic importance of water. There are several applications in the construction sector, which use potable water in its processes, including the mixing of concrete. Adding water in the concrete mixture is essentially required to ensure the homogeneity of concrete mixture to generate the required compressive strength. However, the consumption of water is still increasing dramatically nowadays to ensure the progress of developments and its use in various applications. Hence, this increase in water consumption became a major issue which presents future difficulties in managing the limitation of water. Therefore, it became quite important to consider alternative solutions to prevent and limit the use of freshwater in various construction projects and concrete mixture. One of those solutions is to take into consideration the use of wastewater in various construction applications at which can provide the same results of PW and at the same time ensure the existence of water for future generations. The use of treated wastewater in concrete mixing and curing will produce a sustainable construction solution without any influence on its mechanical properties [6].

The general aim is to replace freshwater in concrete mixture by secondary TWW to ensure the availability of water and develop sustainable cities. This could be done through establishing an experimental program by defining the required concrete properties and amount of water in order to generate concrete mixture using secondary TWW. Also the research conduct an experimental test on the concrete cube in order to estimate compressive strength, and then compare results between concrete cubes that are mixed using either PW or wastewater, and then using different water in process of curing.

To reserve future living, multiple water applications must be taken into consideration including water pollution, water quality management, and environmental conditions. Egypt is considered one of the major countries around the world that might suffer from the scarcity of water by the end of 2025 due to the use increase in its population. Nowadays, the basic human life and other living creatures depend mainly on water use in its basic environment. The main source of water in Egypt is considered the Nile River [7]. Around 3 percent of water supplies normally resulted from rainwater and other groundwater that are non-renewable. Nile River contains daily pollutions from various resources such as agricultural activities, chemical fertilizers, and pesticides. In addition, pollutions that are resulted from water can be due to human use, industrial use, or the presence of oil and grease. Water quality deterioration is one of the major negative influences on water availability in different forms. It can decrease the development of water sustainability in Egypt, but it can also play a major role in resulting in infecting diseases that might affect public health [8].

Each use of water requires a certain degree of quality that must be obtained during the procedure of water treatment according to guidelines and standards that are followed in each organization [9]. The increase in the content of dissolved solids causes an increase in the compressive strength of concrete for a certain level followed by a slight decrease in the compressive strength, due to a further increase in the total dissolved solids [10].

The characteristics of the concrete mixture such as concrete strength and durability have affected due to the reuse of treated wastewater instead of freshwater in concrete mixing and curing [11]. Also the reuse of wastewater in concrete higher up the concentration and penetration depth of chloride ion to concrete due to the impurities of wastewater that cause more voids in the concrete mixture [12].

2. Material and Methods

2.1 Wastewater Treatment Plant

The wastewater treatment plant is known by Berka plant which is located nearby El Salam City. The first stage of this wastewater treatment plant began in 1990 where only a limited number of operations were conducted back then. These operations included sieve operation, grit removal, primary sedimentation tank, thickening tank, and pumps. The second stage was conducted in 1995 which involved the adding of the final sedimentation tank, and chlorination tank. The generated water in this treatment plant is used for landscape works and agricultural use. The designed capacity for this plant was assigned to be 600,000 meter cube per day. However, the resulted treated water is less than the required amount as it produces only from 400,000 to 450,000 meter cube per day. The quality of water that is produced follows Law 48 that was established in 1992, in addition to Law 93 that was established in 2001 and updated 2005. Figure 1 indicates the layout of Berka wastewater treatment plant in Egypt and photos of some units. It consists of 8 fine mechanical sieve, 8 grit removal for oil and grease, 12 primary sedimentation tank which had an overall diameter of 45m, 4 aeration tank that had a dimension of 38m*36m, 16 final sedimentation tank which had an overall diameter of 45m, and 2 stations for chlorination including 4 buffering rooms.

Figure 1: Berka wastewater treatment plant (Egypt)

Two different samples were taken from a wastewater treatment plant; each sample had the same properties and characteristics in order to be used twice in preparing the concrete mixture. Table 1 showed the characteristics of wastewater per each day that entered the treatment plant, while Table 2 contains properties and results for the primary sedimentation tank, and the last Table 3 represents the characteristics of secondary TWW and the properties that were resulted in water.

Table 1: Rate of entered wastewater treatment per each day

Entered wastewater m^3/day	462550
Temp in Celsius	18
pH	7.33
Sulfide mg/L	3.3
TSS mg/L	200
TS mg/L	750
COD mg/L	415
Ammonia-Nitrogen mg/L	41

Table 2: Results of wastewater generated from Berka wastewater plant

Temp in celsius	18
pH	7.52
TSS mg/L	15
TS mg/L	330
COD mg/L	63
Sulfide mg/L	0.9
RCL2	1
Ammonia-Nitrogen mg/L	2
D.O. mg/L	4.1
TSS removal %	93
COD removal %	85

Table 3: Biological treatment results from Berka wastewater treatment plant

Elements	First Stage	Second Stage	Third Stage	Fourth Stage
D.O mg/L	2.3	2.5	2.2	2.1
MLSS mg/L	3900	4700	4550	4850
MLVSS mg/L	2700	3280	3190	3300
S V I Ratio	141	85	143	136
F/M Ratio	0.2	0.2	0.2	0.2
MCRT Days	5.8	7.0	6.8	7.3
RAS SS mg/L	96000			48000

2.2 Concrete Mixture Design

The design of concrete cubes will follow the American Concrete Institution Method in order to reach the required properties that can allow the possibility of comparing the results of using secondary wastewater in mixing and curing of concrete cubes. The basic assumptions and characteristics of the concrete mixture using PW or secondary TWW are shown in Table 4.

Table 4: Main properties of Concrete Mixture

Compressive strength= 30 Mpa.
Percentage of defects: 2.5%.
Assumed degree of quality control: Good and Good construction
Slump: (30-80) mm.
Type of aggregate used: crushed dolomite (type 1).
Nominal maximum size of aggregate = 12.5 mm.
Fineness modulus of sand = 2.4.
The specific weight of cement = 3.1.
The specific weight of coarse Aggregate = 2.6.
The specific weight of fine aggregate =2.5.
Entrapped air content (air voids percentage) = 2.5 %.
Weight of water = water content * relative water content = 215*0.92 =197.8 Kg

2.3 Experimental Work

2.3.1 Slump Cone Test

To determine the degree of workability and consistency of the concrete mixture, a slump cone test was applied. the test was done based on ASTM C 143 standards. The steps of the experiment were as follow as in Figure 2: prepare the concrete mixture; fill only one-third of the slump cone with concrete; compact the layer using a rod with 25 strokes; repeat the previous steps for the remaining two-thirds of the slump cone; lift the cone and measure the slump height.

2.3.2 Compressive Strength Test

The compressive strength test is one of the destructive tests of concrete that can identify the ability of concrete material to resist the loads without any cracks or distortion of the material. to run out the test we should first prepare concrete specimens.

The initial step as in Figure 2 is to prepare the various components that will be used in order to generate the required mixture of concrete. Each component was weighed individually in order to determine the overall weight of the mixture by using a weight recorded. Each concrete cube included 1.5 Kg of cement, 2.6 Kg of fine aggregate (sand), 0.7 liter of water, and 2.95 Kg of coarse aggregate. The experiment will involve the use of around 72 concrete cubes.

The first 36 cubes will use PW in curing by dividing them into two parts, the first 18cubes will use PW, while 18 of them will use TWW. The rest 36 cubes will use secondary TWW in curing operations while it will also be divided into 18 cubes mixed with PW, while the rest 18 cubes will use wastewater in its mixture. All 72 cubes will be tested after 7 days, 28 days, and 56 days to measure the results of compressive strength in case of using PW, and compare the results with the secondary TWW.

The mixture of concrete cubes starts by adding cement, fine aggregate, and coarse aggregate into the concrete mixture before starting to mix all these components. Then, water content started to be added into the mixture before keeping them in the machine until reaching the required homogenous between all these components. Then the resulted mixture was poured into concrete cubes, which had an overall area of 15*15*15 cm.

Figure 2: Experimental Work

3. Results and discussion

3.1 Slump Cone Test Results

This test was conducted after completing a mixture of concrete which is mainly applied to estimate the capability of concrete and workability of the mixture to reach required properties and ensure that it will have sufficient capabilities to resist any extensively applied loads. The results reached in the first mixture showed that the slump cone reached around 40 millimeters. On the other hand, the slump cone test for the second mixture accomplished around 80 millimeters. This variation in workability is due to the effect of the presence of suspended solids in TWW [13].

3.2 Compressive Strength

After conducting the required test on specimens poured and cured using PW, the results obtained in the form of compressive strength are shown in Figure 3. The average compressive strength after 7, 28, and 56 days were 26.17, 36.49, and 37.84 Mpa respectively. Figure 4 showed the average compressive strength when using TWW in concrete curing. The average results were 26.59, 32.88, and 36.45 Mpa respectively. The second group of concrete cubes was mixed using TWW. The compressive strength of concrete cubes that cured in PW is shown in Figure 5. The average compressive strength starts with 35.91 Mpa after 7days and ended with an average of 38.39 Mpa after 56 days. Figure 6 showed the compressive strength of concrete cubes mixed and cured using TWW. The average results were 36.78, 38.61, and 39.24 Mpa after 7, 28, and 56 days respectively. In the first period from concrete poring till the 28 days where compressive strength testing for concrete cubes took place, the results show that the compressive strength values using treated wastewater are higher than the value of fresh concrete [10] [14].

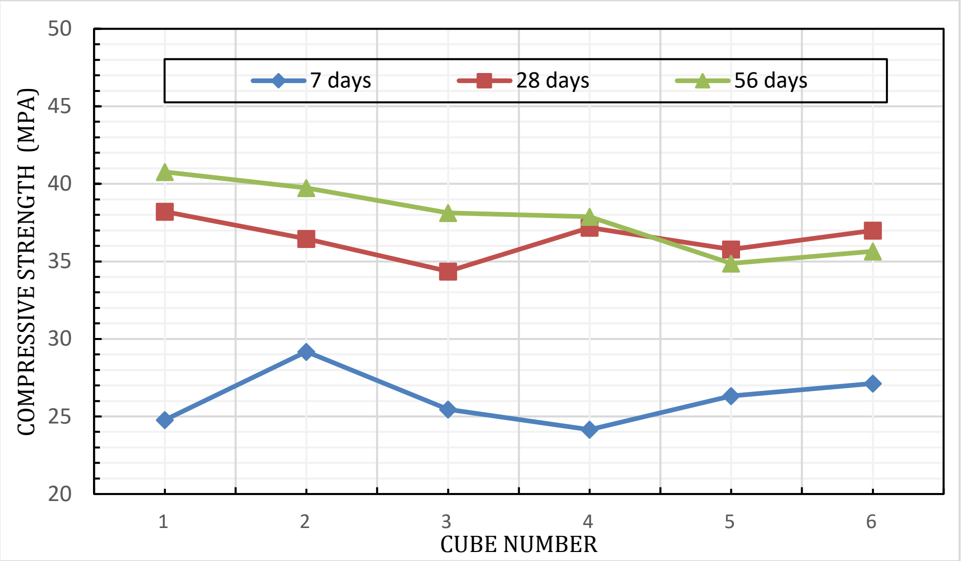

Figure 3: Compressive strength of concrete using potable water in Mixing and curing

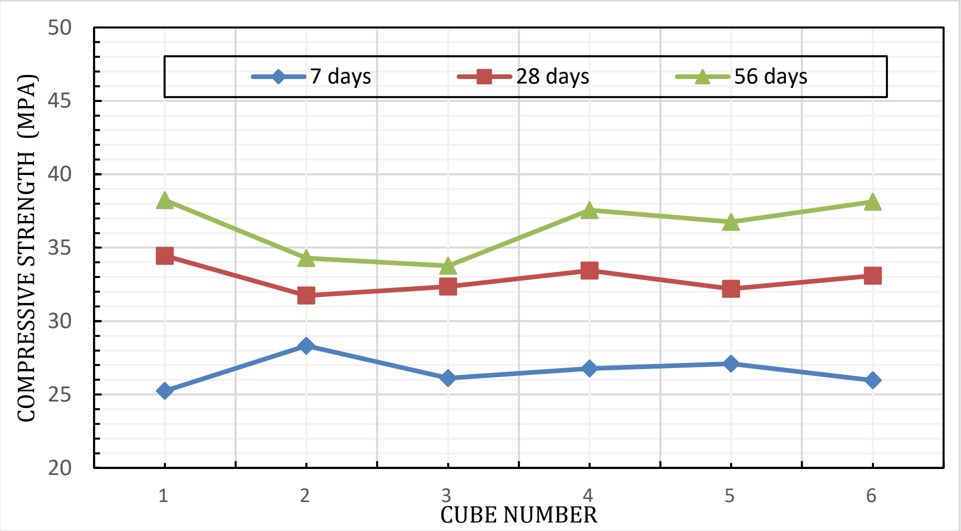

Figure 4: Compressive strength of concrete using potable water in mixing and treated wastewater in curing

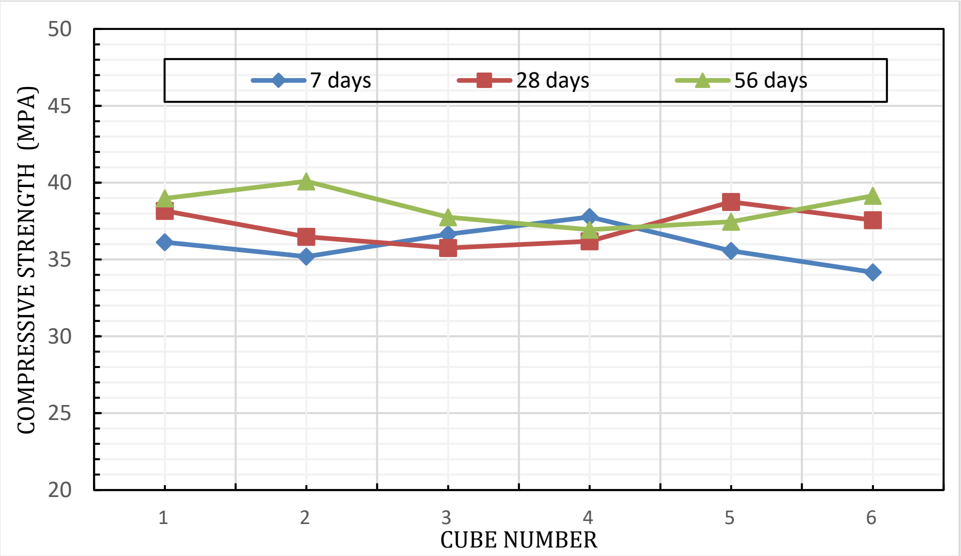

Figure 5: Compressive strength of concrete using treated wastewater in mixing and potable water in curing

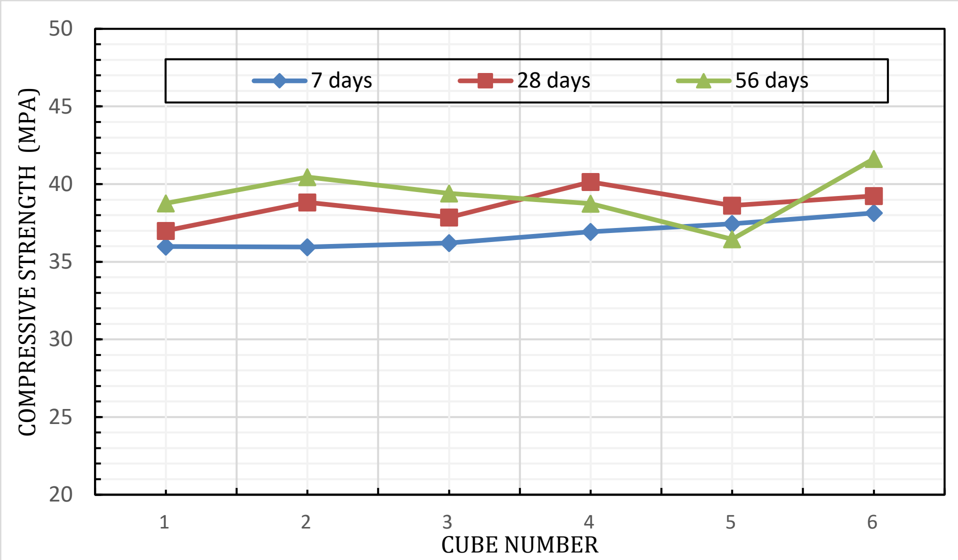

Figure 6: Compressive strength of concrete using treated wastewater in Mixing and curing

The rate of increase in compressive strength after 56 days were reduced compared with the compressive strength values of the concrete cubes using PW [15]. This observation may refer to the increase of the concertation of dissolved solids than a certain range [16].(Al-Ghusain and Terro, 2003) investigated the properties of a concrete mixture that involved the use of different types of wastewater [17]. (Ansari & Ramakar, 2016) specified to examine the influence of using treated wastewater in concrete mixture and its effect on concrete strength [18]. In this resrarch, the compressive strength results shown in Figure 7 were formed in terms of a comparison between reached compressive strength at different conditions to clarify the basic outcome and estimate the most suitable consideration that should be taken into account during the application of using TWW in mixing and curing of concrete cubes.

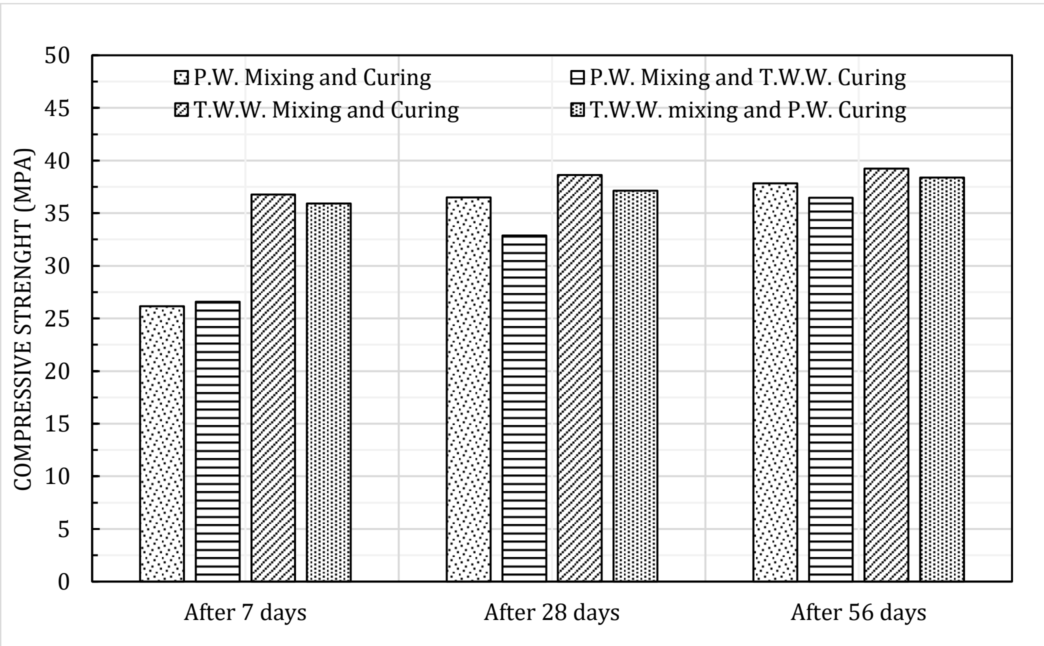

Figure 7: Comparison between Concrete mixing and curing

Conclusion

Quality of water known as one of the major factors that should be taken into account when dealing with any treatment procedure. Such quality is required in most common drinking water for human beings or in the case of using treated water in various applications in the daily life of human beings. The following conclusions have been raised from this research

1. The results of this experiment showed that there is a basic increase in overall compressive strength during the 7 and 28 days from mixing in case of using TWW in the concrete mixture. However, in the case of reaching 3 months after the concrete mixture, the compressive strength reaches its highest compressive strength from using wastewater rather than using PW.
2. Also, The results showed that compressive strength for cubes that were cured using TWW was higher than the ones used PW. The 28 days compressive strength was higher by 3.8 percent than the ones cured using PW.
3. Using TWW in concrete mixture reached the maximum compressive strength value faster than the PW concrete especially in the first 28 days from mixing concrete.

The basic idea for indicating a certain quality for water is related to the result of pollution from either the environment or human use. The major problem of wastewater is that it includes a huge amount of pollution that has a huge influence on the properties of water. Wastewater treatment plant includes multiple processes starting from screen to eliminate solid particles, then the following process is known as a sedimentation tank which aims to remove small particles. The following stages involve the removal of other contaminants that are included in wastewater.

The research was succeeded to perform the possibility of using secondary TWW in concrete mixing and curing. The compressive strength of concrete using TWW is acceptable when compared to the concrete mixture using PW. Concrete durability was acceptable but should be considered as an important factor in future research to ensure the effect of replacing PW by TWW in concrete mixing and curing. Using tertiary TWW can provide better concrete mixture compared by our research mixture using secondary TWW.

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