Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (41) No. (1) January, 2019

Effect of Using Treated Wastewater in Mixing and Curing of Concrete on its Compressive Strength

H.El-Ghorab[1], M.El-Hossieny[1], M.S.Ibrahim[1] and M.Kohail[2],
1. Department of Public Works, Ain Shams University, Cairo, Egypt.
2. Department of Structural Engineering, Ain Shams University, Cairo, Egypt.

ملخص البحث:
يهدف هذه البحث إلى دراسة تأثير إستخدام مياه الصرف المعالجة في خلط ومعالجة الخرسانة المسلحة، وذلك على قوة تحمل الضغط، لتحديد صلاحية إستخدام هذه الخرسانة. وتمثل تلك النقطة أحد الحلول لمشكلة ندرة مياه الشرب في الكثير من أنحاء العالم مما يستوجب إيجاد مجالات جديدة لإستخدام مياه الصرف المعالجة وتقليل إستخدام مياه الشرب.في هذا البحث سوف يتم مقارنة تحمل الضغط للخرسانة بين عينات من الخرسانة تم خلطها ومعالجتها بثلاثة أنواع من مياه الصرف المعالجة وهم معالجة أولية وثنائية وثلاثية، وبن الخرسانة التي تم خلطها ومعالجتها بمياه صالحة للشرب. ويتم دراسة قوة الضغط لأعمار مختلفة للخرسانة وهم 7 ، 28 ، 90 ، 180 يوم.أوضح البحثأن مقاومة الضغط للخرسانة المخلوطة بمياه الصرف المعالجة تزيد مقاومتها في الأعمار الصغيرة (7 و 28 يوم) كلما قلت نسبة المعالجة، ولكن في الأعمار الكبيرة (90 و 180 يوم) تقل مقاومة الضغط لتلك الخرسانة عن الخرسانة المخلوطة بمياه الشرب بنسب مختلفة حسب درجة معالجة مياه الصرف.

Abstract:

The objective of this paper is to identify the effect of using treated wastewater in mixing ang curing of concrete on its compressive strength to identify the suitability of its usage.The problem is that potable water is considered to be scarce in many of the world's countries and finding applications for treated wastewater reuse is very effective in preserving potable water resources. This study compares the concrete's compressive strength for specimens mixed and cured by three different types of treated wastewater which are primary, secondary and tertiary treated wastewater to that for specimens mixed and cured by potable water,compressive strength was assessed at different concrete ages (7, 28, 90, 180 days)

The results show that As the water treatment level increases, the compressive strength at initial stages (7 and 28 days) decreases, while the compressive strength at late stages (90 and 180 days) increases.

Key Words:Treated Wastewater, concrete, compressive strength.

1. INTRODUCTION

Fresh water scarcity is considered a major problem worldwide, where sources of fresh water are diminishing as a result of pollution or climatic changes. Therefore, most countries with fresh water scarcity seek methods to reduce fresh water consumption on public and industrial scale .Treated wastewater reuse has been a rapidly growing field worldwide as the whole international community is adopting sustainabilty measures in order to insure perserving of fresh water scarce resources, where it is common nowadays to find treated wastewater reuse applications in almost all water consuming fields, such as agriculture, landscaping, industrial applications, ground water replenishing and many other fields.

The main target of the study is to identify the effects of using treated wastewater in the concrete industry on its compressive strength as both mixing and curing water as an alternate to potable water.

This study is aiming to find the variation in compressive strength of concrete mixed and cured using several types of treated wastewater with different levels of treatment (Primary, Secondary, Tertiary).

The experimental part of the study included first the required lab experiments to assess the treated wastewater quality on aspects of its constituents and contaminants, to evaluate the suitability of the water in usage regarding mixing and curing of concrete and study their effect on the concrete. Primary, secondary and tertiary treated wastewater samples were used, and a control sample of potable water.

Also, lab experiments on concrete specimens mixed and cured using diverse types of treated wastewater and potable water took place to assess the discrepancies compressive strength

2. LITERARTURE REVIEW

Water Treatment:

The main objective of wastewater treatment is usually to allow human and industrial effluents to be disposed of without endangering human health or polluting the environment. Also, reuse of treated wastewater can be considered as both disposal and utilization and indeed is an effective form of wastewater disposal given the amount of potable water that has been saved.

The main objective of primary treatment is to remove settleable solids by sedimentation, and floating material (scum) by skimming, which represents approximately (25~40%) of the BOD, (50~70%) of the TSS, and 65% of the oil and grease.

Mainly, secondary treatment follows primary treatment and its main purpose is the removal of biodegradable dissolved and colloidal organic matter using mostly aerobic biological treatment processes, which is performed in the presence of oxygen by aerobic microorganisms (mainly bacteria) that consumes the organic matter in the wastewater and produce inorganic end-products (principally CO_2, NH_3, and H_2O)

The purpose of tertiary treatment is providing a final treatment stage after the secondary treatment processes which would raise the effluent quality to the desired level, and increase disinfection effectiveness, through removing suspended, colloidal, dissolved organic and inorganic constituents that remain after conventional secondary treatment **[1]**. Tertiary treatment can be accomplished by a variety of methods such as chemical precipitation, filtration, adsorption, reverse osmosis, ion exchange and extended secondary biological treatment to further stabilize oxygen-demanding substances or remove nutrients.

Treated Wastewater Reuse Applications

Wastewater reuse has numerous benefits. With proper treatment, treated wastewater would meet some needs and purposes, such as toilet flushing water, cooling water, and many other applications. The reuse of treated wastewater is mostly attractive in arid climates under water stress circumstances. Also, some treated wastewater effluents contain useful constituents, such as organic carbon and nutrients such as nitrogen and phosphorous, which could be beneficial for agriculture and landscaping.

When considering treated wastewater reuse in concrete industry, the main concerns on the quality of mixing water are those related to the effect on concrete's workability, strength and durability. The suitability of water can be defined from past service records or tested to assure its performance limits such as setting times and compressive strength. Limits are placed on the impact of mixing water to the total alkalis, chloride and sulfate of all concrete ingredients so as to control the durability of the concrete.

Concrete's Compressive Strength

The compressive strength of the concrete is considered one of the most important properties of the concrete, and the best indicator of its quality and suitability. Also, it is proven that the other properties of the concrete such as tensile and bond strength improve as the compressive strength improves and vice-versa.

Factors Governing Reuse of Treated Wastewater in Concrete Industry

According to ECP-203-2007, if the following criteria are satisfied concerning usage of non-potable water in mixing concrete, such water can be used:

1) The initial setting time of the concrete mixed with the impure water shouldn't exceed the initial setting time of the same mix but mixed with potable water instead by more than 30 minutes, and that the initial setting time shouldn't be less than 45 minutes in any case.
2) The compressive strength at 7 and 28 days of age of mortar specimens mixed with the impure water shouldn't be less than 90% of the compressive strength at same ages of the same mix but mixed with potable water instead.
3) Limited concentrations for some materials such as chlorides, sulfates, total solids, etc.

However, the treated wastewater effluent varies in quality according to type and degree of treatment, and effluent of all types of conventional treatment contains different impurities of different concentrations that may affect the properties of concrete and may also cause damage to its reinforcement directly or indirectly.

3. MATERIAL AND METHODS

The materials used in the study are the constituents of a traditional concrete mix which includes water, cement, coarse aggregate, and fine aggregate.

The treated wastewater included in the study are primary, secondary, and tertiary treated wastewater. The control specimens are to be mixed and cured with potable water. Each concrete specimen is mixed and cured using the same type of water.

Primary and secondary treated wastewater quantities were collected from Gabal El-Asfar Wastewater Treatment Plant located in El-Khanka in the city of Qalyubia in May 2017. Tertiary treated wastewater was obtained by furtherly treating the secondary treated wastewater inside the faculty's laboratory using a slow sand filter.Potable water was collected from a water tap in the material properties and tests lab of the faculty of engineering, Ain Shams University.

All types of treated wastewater along with potable water were chemically analyzed in the central lab of the faculty of Science, Ain Shams University, where all tests were done under the accordance of Standard Methods for the Examination of Water and Wastewater,and the results were as follows:

Table 1: Water Analysis Results

Parameter	PTWW	STTW	TTWW	PW	Notes
pH	7.3	7.4	7.5	7.8	-
Total Dissolved Solids	797.5	846.5	924.5	250	ppm
Total Suspended Solids	65.5	9.5	9	0	ppm
Total Solids	862.7	855.4	932.9	250	ppm
Chemical Oxygen Demand	131.4	51.7	19.9	0	ppm
Chlorides	179	232.4	250.8	90	ppm as Cl^-
Sulfates	147.1	161.3	233	70	**ppm as SO_4^{--}**
Phosphates	6.26	4.88	4.2	0	**ppm as PO_4**
Ammonia	28.4	31	30.3	0	**ppm as NH_3**
Alkalinity	200	224	223	60	**ppm as$CaCO_3$**

The cement used was Tourah Cement 42.5 R which is considered to be a type I ordinary Portland cement. It has a 2-day strength of 25.31 N/mm^2 and 28 days strength of 45.52 N/mm^2.

Coarse sand was used as the fine aggregate for concrete. Chemical and physical analysis were done to assess the properties of the sand.

Table 2: Fine Aggregate Sieve Analysis Results

IS Sieve Size	Percent Passing
4.75 mm	97.30%
2.36 mm	91.20%
1.18 mm	76.90%
600 microns	30.50%
300 microns	6.10%
150 microns	0.40%

Table 3: Fine Aggregate Chemical and Physical Analysis Results

Parameter	Result
Volumetric Weight	1.58 ton/m^2
Specific Gravity	2.653
Fine Materials Weight %	1.60 %
Chlorides Weight %	0.0177 %
Sulfur Trioxide Weight %	0.2551 %

Crushed stone was used as the coarse aggregate for concrete. Chemicalandphysicalanalysiswere done to assess the properties of the sand.

Table 4: Coarse Aggregate Sieve Analysis Results

IS Sieve Size	Percent Passing
37.5 mm	100 %
31.5 mm	100 %
28 mm	100 %
20 mm	100 %
10 mm	54.18 %
5 mm	1.13 %

Table 5: Coarse Aggregate Chemical and Physical Analysis Results

Parameter	Result
Volumetric Weight	1.549 ton/m^2
Specific Gravity	2.71
Water Absorption	1.00 %
Los Angeles Abrasion Test	19.70 %
Fine Materials Weight %	1.20 %
Chlorides Weight %	0.03599 %
Sulfur Trioxide Weight %	0.3611 %

4. RESULTS AND DISCUSSION

Compressive strength of concrete is assessed by applying axial compressive load to the concrete cylindrical specimens at a specified rate until failure occurs, and then the compressive strength of the specimen is obtained by dividing the maximum load reached during the test by the cross-sectional area of the specimen. This procedure is done as specified in ASTM's standard test method for compressive strength of cylindrical concrete specimens, designation: C39/C39M

Table 6: Compressive Strength for Concrete in N/mm²

Age of Concrete	PTWW	STWW	TTWW	PW
7 days	26.40	25.94	24.29	21.69
28 days	28.53	28.06	27.12	26.41
90 days	29.95	32.30	31.36	33.01
180 days	30.89	32.77	33.01	35.84

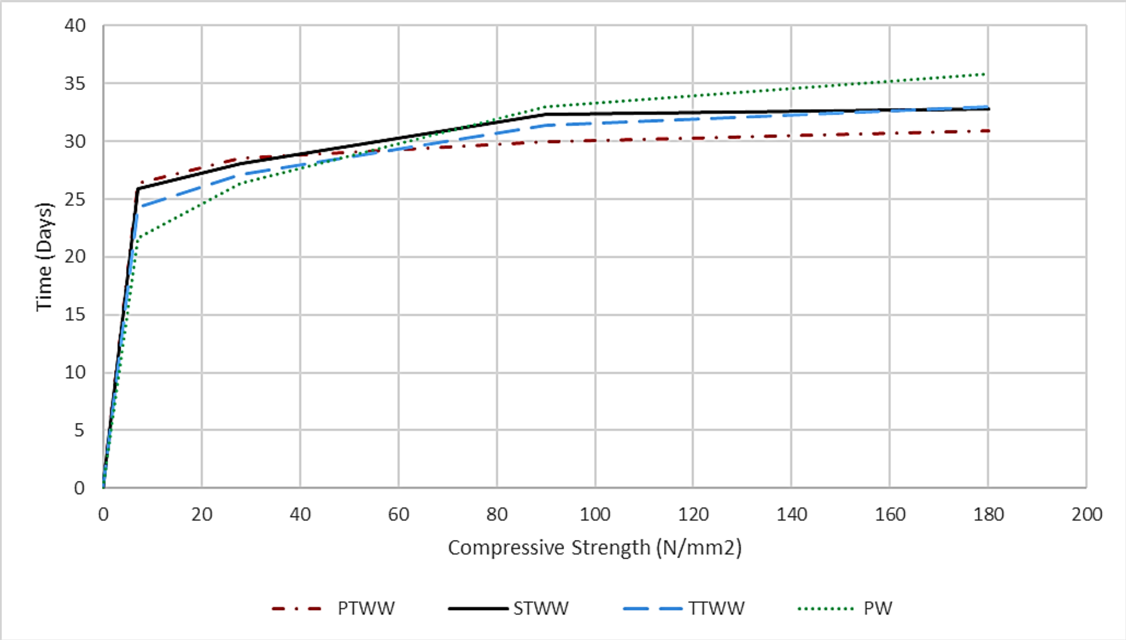

Figure 1: Comparison Between Compressive Strength Against Time for Different Mixing Water Types

After comparing the values of pollutants concentrations in the used mixing water types, and that specified by both ECP-203 and ASTM C1602 as maximum values for reinforced concrete mixing purposes, it was found that all water types are acceptable to be used in concrete mixing and curing.

As for ECP-203 requirements for compressive strength, the values for compressive of concrete mixed and cured by all three types of treated wastewater are acceptable as they exceed 90% of that of potable water at age of 28 days.

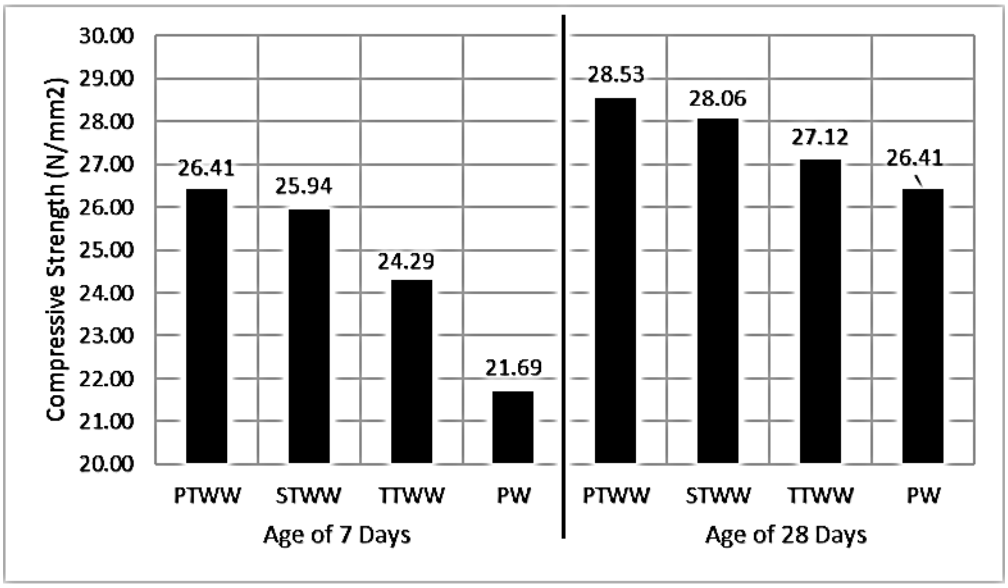

Figure 2: Comparison Between Compressive Strength at Early Age

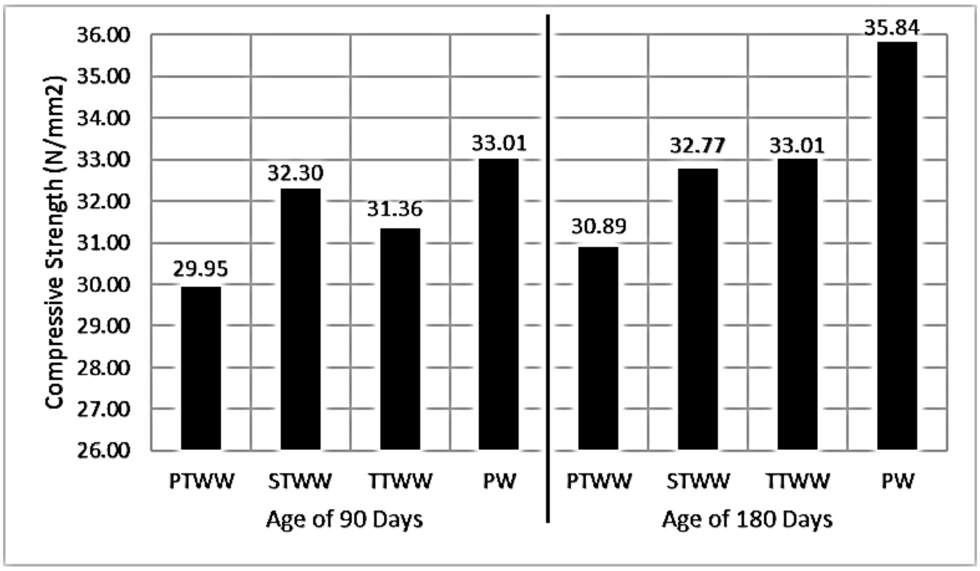

Figure 3: Comparison Between Compressive Strength at Late Age

As the treatment level increases (PTWW<STWW<TTWW<PW), the compressive strength at initial stages (7 and 28 days) decreases, while the compressive strength at late stages (90 and 180 days) increases.

Figure (2) illustrates the concrete's compressive strength at early ages (7 and 28 days) and it shows that strength of concrete mixed with treated wastewater exceeds the strength of control concrete specimens mixed with potable water, and thus accepted by ECP-203.

Figure (3) illustrates the concrete's compressive strength at late ages (90 and 180 days) and it shows that strength of concrete mixed and cured with treated wastewater drops below the strength of control concrete specimens mixed and cured with potable water.

5. CONCLUSIONS

This study included the effect of applying treated wastewater in reinforced concrete mixing and curing on its compressive strength, through studying the compressive strength of specimens mixed and cured with treated wastewater and comparing the results to control specimens mixed and cured with potable water. Treated wastewater included in the study were primary, secondary and tertiary treated wastewater.

From the results obtained from the water quality lab experiments and the concrete properties lab experiments, and comparing results regarding compressive strength, the following conclusions could be illustrated:

1. Compressive strength of concrete mixed and cured using primary treated wastewater shows high misleading values at age of 28 days, reaching 108% of control samples, as this percentage drops to reach 86% of control samples at age of 180 days.

2. Compressive strength of concrete mixed and cured using secondary treated wastewater shows mildly close results to that of control samples, with 106% at age of 28 days, dropping to 91% at age of 180 days.

3. Compressive strengthof concrete mixed and cured using tertiary treated wastewater shows close results to that of control samples, reaching 103% at age of 28 days, and 92% at age of 180 days.

4. Concrete mixed and cured by all types of treated wastewater must be tested before use for various properties, as properties and contaminants types and percentages of treated wastewater varies from one wastewater treatment plant to another and varies through different times of the year.

5. Strength of concrete mixed and cured by all types of treated wastewater must be assessed in late ages as it has misleading high strength in its early ages, and then strength gain rate decreases, reaching relatively lower strength in late ages when compared with concrete mixed and cured by potable water.

REFERENCES

Metcalf and Eddy, Inc., "Wastewater Engineering, Treatment, Disposal and Reuse", Fourth Edition McGraw-Hill, Inc., New York, N.Y., (2004).

ACI, “Building Code Requirements for Structural Concrete ACI-318-11”, ACI, U.S., (2011)

Permanent Committee of ECP, “Egyptian Code of Practice for Reinforced Concrete Design and Execution ECP-203-2007”, ECP, Egypt, (2007)

Cement Concrete & Aggregates Australia, “Use of Recycled Water in Concrete Production”, Cement Concrete & Aggregates Australia, Australia, (2007).

Department of Environmental Protection, “Reuse of Treated Wastewater Guidance Manual”, Department of Environmental Protection, U.S., (2011)

Steven H. Kosmatka, Beatrix Kerkhoff, and William C. Panarese “Design and Control of Concrete Mixtures”, 14th Edition, PCA, U.S., (2003).

ASTM, “Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete C1602”, ASTM Int’l, U.S., (2011).

Thavamalar A/P Muniandy, “Reusing of Treated Waste Water in Concrete Production”, Faculty of Civil Engineering, UniversitiTeknologi Malaysia, (2009).

A.M.Neville, “Properties Of Concrete”, 5th Edition, Pearson, England, (2011).

APHA, “Standard Methods for the Examination of Water and Wastewater”, APHA, U.S., (1999).

ASTM, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens C39M”, ASTM Int’l, U.S., (2014).

Ibrahim Al Ghusain and Mohammad J.Terro, “Use of Treated Wastewater for Concrete Mixing in Kuwait”, Kuwait J. Sci. Eng. 30, Kuwait, (2003).

ASTM, “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory C 192/C 192M”, ASTM Int’l, U.S., (2006).

ASTM, “Standard Specification for Molds for Forming Concrete Test Cylinders Vertically C470/C470M”, ASTM Int’l, U.S., (2009).