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# Treated wastewater: An alternative for concrete industry

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**ABSTRACT**

Water is important ingredient of widely used construction material concrete. Most of the specifications recommend potable water for concrete, imposes a heavy burden on the cost of production. The present study was an attempt to study the possibility of usage of treated wastewater for concrete preparation, so that the shortage and cost using potable water can be greatly reduced by determining the influence of wastewater on the strength of concrete. Wastewater from a near by wastewater treatment plant were collected and analyzed in terms of their physicochemical properties along with potable water for comparison purposes. The study reveals that the consistency of cement remains same for all types of mixing wastewater. There is an increase in initial setting time with deteriorating quality of mixing wastewater but the final setting time remains same. The compressive strength of concrete of tertiary treated wastewater is close to that of tap water but higher than that of PTWW & STWW. The study indicates that the use of tertiary treated wastewater will be an alternate to save the precious fresh water and also the cost of concrete production may be reduced.



## Introduction

Concrete is the most widely used construction material in the world. It is one of the largest water consuming industries needs approximately 150 liters of water per cu.m. of concrete. (Marcia) Part of mixing water is utilized in the hydration of cement and the balanced water is required for importing workability to concrete. However the quantity and quality of mixing water must be viewed carefully as the strength and durability of concrete depends on the presence of chemicals in mixing water (Patil).

Most of the specifications recommend the use of potable water for making concrete. The present use of potable water for the preparation of concrete imposes a heavy burden on the cost of production, especially at the places where there is high demand for and shortage of supply of portable water for domestic consumption. Hence measures to be taken to conserve portable water as much as possible to prevent the shortage in the future. A practical solution would be the use of treated effluent from the wastewater treatment plants for concrete preparation. The efforts towards wastewater reuse have lately gained worldwide consideration and attention in construction industry, which is second largest industry next to agriculture. Currently, the treated effluent from sewage treatment plants is flowed directly into waterways. With proper water quality control the treated effluent can be considered as a potential water resource for concrete preparation which will economically benefit the construction industry and contribute to sustainable development by conserving portable water. Review of the literature on the use of wastewater for concrete around the world has revealed the use of reclaimed water in concrete, with various levels of success. Naser Alenezi., studied the strength of concrete using tertiary treated wastewater from a wastewater treatment plant with different percentages. The study reveals that the use of tertiary treated wastewater in concrete mixes does not affect its strength. Ooi soon Lee and et.al carried out studies on feasibility of using treated effluent for concrete mixing. The tests have showed that treated effluent increases the compressive strength and setting time when compared with potable water. Ibrahim-Ghusain and et.,al studied the suitability of using, primary treated wastewater, secondary treated wastewater and tertiary treated wastewater for concrete mixing. The study reveals that primary treated wastewater, secondary treated wastewater retard setting time and lower the strength but the tertiary treated wastewater was found to be suitable for mixing concrete with no adverse effects on setting time and strength. Mohamad Terro and et.al investigations on the effect of elevated temperatures on the compressive strength of concrete made with treated wastewater indicates that concrete made with primary treated wastewater, secondary treated wastewater showed lower strengths at ambient temperatures and longer setting time than the concrete made with tap water and tertiary treated wastewater. Marcia Silva e'tal study on the usage of wastewater for concrete suggested that significant differences do not exist between mortar cubes made of portable water versus sewage treatment plant water.

The object of present paper is to study the feasibility of using treated wastewater for concrete preparation as well as determining the influence of wastewater on the strength of concrete to conserve fresh water for sustainable development.

## Methods & Experimental Procedure

Samples of wastewater were collected from a wastewater treatment plant. The physicochemical parameters were analyzed in the laboratory as per standard methods. In addition potable water was analyzed for comparison purposes.

For the preparation of concrete specimens, 43 grade of ordinary Portland cement conforming to IS: 12269-1987(reaffirmed 2007) was used (Table 1).

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Natural River sand which satisfying the required properties conforming to to IS: 2386 (Part-I & part III)-1963 was used (Table2).

The maximum size of the coarse aggregate was limited to 20mm and down size to get the maximum compressive strength.

The mix design was carried out as per IS: 10262-2009. Concrete cubes of $M_{20}$ and $M_{30}$ grades with different types of mixing water were prepared with a water cement ratio of 0.55% and tested for compression strength for 7days and 28days.

In order to study the setting times, cement paste of ordinary Portland cement was made with different types of mixing water were prepared. The test was carried out in accordance with IS. The procedure involved is the preliminary determination of amount of mixing water required to produce a cement paste of standard consistence. Potable water was also used as a control paste.

**Results and Discussions**

**Analysis of wastewater and tap water**

The results of tap water and wastewater are tabulated in the table 4. From the results, the values the $p^H$ of PTWW, STWW and TTWW and TW varies from 7.20 to 7.32, but the $p^H$ of TW is 8.31. However, $p^H$ of all the wastewater is with the permissible limits as per IS-456:2000. Also the values of suspended solids of PTWW, STWW, TTWW and TW were in the range of 800 mg/l to 100mg/l, which is within the permissible limit as per IS 456:2000. Again the organic impurities of PTWW, STWW, TTWW and TW were in the range of 180 mg/l to 40 mg/l, which is within the permissible limit as per IS 456:2000. Further the sulphate concentration of PTWW, STWW, TTWW and TW ranges from 69 mg/l to 43 mg/l, which is within the permissible limit as per IS 456:2000. Finally, the Chlorides concentration of PTWW, STWW, TTWW and TW varies from 242 mg/l to 56 mg/l, which is within the permissible limit as per IS 456:2000.

**Study of the Effect of wastewater on cement properties**

**Results of standard consistency of cement**

Table 5 summarizes the results of the standard consistency of cement for different types of mixing water used for making the concrete. The standard consistency is 30% for all types of mixing water. From the results obtained the standard consistency for different mixing water is within the permissible limit and the quality of mixing water does not have any adverse effect on the consistency of cement.

**Results of Initial setting time**

The initial setting times of cement for different types of mixing water are given in the table 6. From the results it was observed that initial setting time of PTWW, STWW, TTWW and TW are 90, 85, 70 and 70 min respectively. It is clear from the results that there is an increase in initial setting time for PTWW, STWW but remains same for TTWW and TW. Therefore from the observations it can be deduced that the deteriorating quality of mixing water due to presence of impurities of mixing water has an adverse effect on initial setting time.

**Results of Final setting time**

The final setting time of cement for different types of water used for making the concrete are as listed in the table. 8. From the results obtained it was observed that final setting time of PTWW, STWW, TTWW and TW are found 410 min. Further it can be deduced that the quality of mixing water does not affect the final setting time.

**Studies on Compressive Strength**

**Results of compressive strength of cement motor**

The compressive strength of motor cubes for 3days and 7days are presented table 9. The compressive strength of motor cubes for different types of mixing water ranges for3days varies between 17.35 to 20.85N/mm$^2$and for 7days ranges between 27.63 to 30.91N/mm$^2$. From the results, it was observed that the compressive strength of motor gets decreases with the deterioration of mixing water. Further it can be deduced that the quality of mixing water affect the compressive strength of motor.

**Results of Compressive Strength of cement concrete**

**Results of Compressive Strength $M_{20}$**

The table 10 summaries the compressive strengths of $M_{20}$ grade concrete for 7 days and 28 days with different mixing water. The results of the compressive strength of concrete for 7 days and 28 days are 19.50N/mm$^2$,21.22N/mm$^2$,22.11N/mm$^2$,24.43N/mm$^2$ and 27.98N/mm$^2$,28.86N/mm$^2$,32.07N/mm$^2$,35.13N/mm$^2$ respectively. The results indicate that compressive strength of TTWW is higher than that of PTWW and STWW. The decrease in compressive strength for primary treated wastewater and secondary treated wastewater may due to the presence impurities in the wastewater. The results also indicate closeness between the compressive strength of TTWW and TW.

**Results of Compressive Strength $M_{30}$**

The table 11 summaries the compressive strengths of $M_{30}$ grade concrete for 7 days and 28 days with different mixing water. The compressive strength of concrete for tertiary treated wastewater is higher than that of PTWW & STWW for both for 7 days and 28 days. The decrease in compressive strength for PTWW &STWW may due to the presence impurities in the wastewater. Overall, a higher strength was obtained for the cubes of TTWW than PTWW & STWW. There is closeness exists between the compressive strength of TTWW and TW.

Fig1 and Fig2 show the development of the compressive strength for $M_{20}$ and $M_{30}$ grade cubes at different ages respectively. All the graphs have similar trend, that is, an increase in the compressive strength with an increase of age. It was observed that all types of wastewater gives an increase in early strength for 7days compare to the ultimate strength of 28 days. The tertiary treated wastewater give an increase in compressive strength compare to that of PTWW & STWW for $M_{20}$ and $M_{30}$ grades of concrete for both 7days and 28 days.

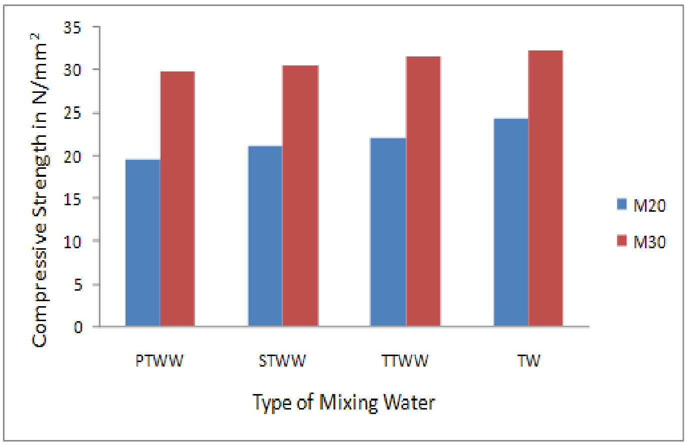


**Fig 1: Compressive Strength of $M_{20}$ and M30 Concrete at 7 days**

**Table:-1 Properties of Cement.**

| SL.NO | Property | Values |
|---|---|---|
| 01 | Specific gravity | 2.87 |
| 02 | Fineness | 1% |
| 03 | Initial Setting Time | 80 minutes |
| 04 | Final Setting Time | 410 minutes |
| 05 | Water for standard consistency | 30% |

**Table:-2 Properties of fine aggregate.**

| SL.NO | Property | Unit | Values |
|---|---|---|---|
| 01 | Specific gravity | - | 2.57 |
| 02 | Dry bulk density | $Kg/m^3$ | 1427 |
| 03 | Water absorption | % | 2.7 |
| 04 | Moisture content | % | 2 |

**Table: - 3 Properties of the coarse aggregate**

| Sl.No | Property | Unit | Results |
|---|---|---|---|
| 01 | Specific gravity | - | 2.65 |
| 02 | Dry bulk density | Kg/m3 | 1564 |
| 03 | Water absorption | % | 0.3 |
| 04 | Moisture content | % | 0.5 |

**Table: 4 Average Characteristic of wastewater and tap water.**

| Sl.No | Parameters | Primary treated wastewater | Secondary treated wastewater | Tertiary treated wastewater | Tap water |
|---|---|---|---|---|---|
| 01 | pH | 7.20 | 7.24 | 7.32 | 8.31 |
| 02 | Suspended solids., mg/l | 800 | 400 | 100 | - |
| 03 | Dissolved solids., mg/l | 772.00 | 768.82 | 770.58 | 460 |
| 04 | Conductivity., µS/cm | 1187.7 | 1182.8 | 1185.5 | 765 |
| 05 | Total Hardness., mg/l | 250 | 250 | 240 | 344 |
| 06 | Alkalinity., mg/l | 216 | 224 | 132 | 270.2 |
| 07 | Chloride., mg/l | 242 | 231.99 | 217 | 56.0 |
| 08 | Sulphate., mg/l | 69 | 47 | 43 | 16 |
| 09 | Dissolved Oxygen., mg/l | Nil | 1.5 | 4.0 | 6.0 |
| 10 | Biochemical Oxygen Demand., mg/l | 180 | 110 | 40 | 3 |
| 11 | Chemical Oxygen Demand., mg/l | 288 | 240 | 124 | 20 |

**Table: - 5 Standard consistency of cement for different types of mixing water.**

| Sl.No | Types of mixing water | Values | Permissible limit |
|---|---|---|---|
| 01 | Primary treated wastewater | 30 % | 30-32% |
| 02 | Secondary treated wastewater | 30 % | |
| 03 | Tertiary treated wastewater | 30 % | |
| 04 | Tap water | 30 % | |

**Table: - 7 Initial setting time**

| Sl.No | Types of mixing water | Values | Permissible limit |
|---|---|---|---|
| 01 | Primary treated wastewater | 90min | Not less than 30 min |
| 02 | Secondary treated wastewater | 85min | |
| 03 | Tertiary treated wastewater | 70min | |
| 04 | Tap water | 70min | |

**Table: - 8 Final setting time**

| Sl.No | Types of mixing water | Values | Permissible limit |
|---|---|---|---|
| 01 | Primary treated wastewater | 410min | Not greater than 600min |
| 02 | Secondary treated wastewater | 410min | |
| 03 | Tertiary treated wastewater | 410min | |
| 04 | Tap water | 410min | |

**Table 9: Results of compressive strength of cement motor**

| Sl.No | Types of mixing water | Average Compressive Strength(3days) in $N/mm^2$ | Average Compressive Strength(7days) in $N/mm^2$ |
|---|---|---|---|
| 01 | Primary treated wastewater | 17.35 | 27.63 |
| 02 | Secondary treated wastewater | 17.75 | 28.66 |
| 03 | Tertiary treated wastewater | 19.28 | 28.77 |
| 04 | Tap water | 20.85 | 30.91 |

**Table 10: Results of compressive strength of cement concrete**

| Sl.No | Types of mixing water | Average Compressive Strength (7days) in N/mm$^2$ | Average Compressive Strength (28days) in N/mm$^2$ |
|---|---|---|---|
| 01 | Primary treated wastewater | 19.50 | 27.98 |
| 02 | Secondary treated wastewater | 21.22 | 28.86 |
| 03 | Tertiary treated wastewater | 22.11 | 32.07 |
| 04 | Tap water | 24.43 | 35.13 |

**Table 11: Results of compressive strength of cement concrete**

| Sl.No | Types of mixing water | Average Compressive Strength(7days) in N/mm$^2$ | Average Compressive Strength(28days) in N/mm$^2$ |
|---|---|---|---|
| 01 | Primary treated wastewater | 29.84 | 38.56 |
| 02 | Secondary treated wastewater | 30.49 | 40.97 |
| 03 | Tertiary treated wastewater | 31.54 | 43.09 |
| 04 | Tap water | 32.28 | 43.76 |

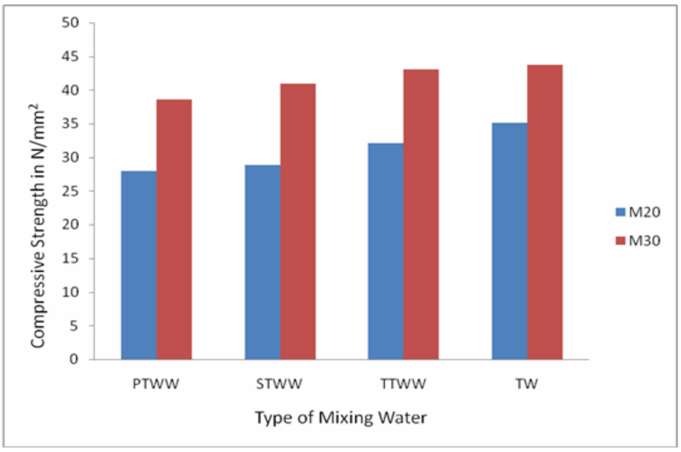


**Fig 2: Compressive Strength of $M_{20}$ and $M_{30}$ Concrete at 28 days**

## Conclusions

The results of wastewater analysis showed that the water quality parameters like pH, suspended solids, organic impurities, sulphate of the mixing waters are with the permissible limits as per IS-456:2000. The consistency of cement was not affected by quality of mixing wastewater. However, the initial setting time of the cement increase with deteriorating water quality of mixing wastewater but does not affect the final setting time. Higher compressive strength of concrete was achieved for $M_{20}$ and $M_{30}$ grade with TTWW compare to that PTWW & STWW. The results of compressive strength of concrete of tertiary treated wastewater are close to that of tap water indicates that the tertiary treated wastewater could be used for concrete particularly at places where there is a scarcity for fresh water. The reuse of treated wastewater for concrete is an alternate not only save the precious fresh water but also provide an opportunity to reduce the cost of concrete production.

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