ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

Mechanical Properties of Concrete Mixed and Cured with Treated Domestic Waste Water

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***Abstract:*— The concrete industry is consuming approximately one billion tonnes of mixing water annually. In addition, large quantities of fresh water are also used for washing the aggregates and curing of concrete which is unaccounted for. The current trend all over the world is to utilize the treated and untreated industrial by-products as a raw material in concrete. This practice not only helps in reuse of the waste material but also creates a cleaner and greener environment. It is very much understandable at this point of time that a variety of supplementary materials and industrial by-products have been successfully incorporated as raw material substitutes, additives, and admixtures in cement and concrete.However, a limited research is being reported for the replacement of water used for mixing and curing.It is reported that approximately, 150 litres of water is required per cubic metre of concrete mixture, without considering other applications of water at the concrete industry. It is to be noted that water is a critical environmental issue and fresh water supplies are becoming limited worldwide. Similar to natural materials like limestone and aggregates, even potable water is becoming scarce.India is facing serious water crisis even for drinking water. The reason are increased population, urbanisation, industrialisation or be it inadequate amount of rain.**

Considering this above scenario into consideration, authors have presented an idea about possible utilization of treated domestic waste water in the concrete and the detail of the investigation will be presented in this paper. The effect of compressive strength of the concrete when treated domestic waste water is used as both mixing and curing waterwill be reported. Concrete cubes will be cast with both treated waste water and laboratory water and later cured with both treated domestic waste water and laboratory water. Compressive strength test would be carried out on the cubes for 3, 7, 28 and 90days and the findings are reported.

***Index Terms* :-- Concrete, treated waste water, curing, compressive strength.**

I. INTRODUCTION

Due to growing agriculture, urban and industrial needs, water table in every continent are falling, which is adversely affecting the drinking water resources and are becoming scare. The most widely used construction material is concrete, commonly made by mixing Portland cement with sand, crushed rock and water. Normal concrete contains about 80 percent aggregate, 12 percent cement and 8 percent mixing water by mass approximately[1]. Water is one of the essential components in the concrete.In today's world, the use of natural resources for the production of aggregates and cement productionhas increased extensively, leading to the depletion of natural resources and hence affecting the sustainable development. In order to reduce the extensive utilization of natural resources, researchers have come up with various alternatives like fly ash, ground granulated blast furnace slag, manufactured sand, recycled aggregates, artificial aggregates and etc., as an alternative for cement and aggregates.On the other hand, the scarcity of water is fast becoming a critical environmental issue worldwide. Concrete industry is consuming annually 1 billion tons of mixing water in the world [2]. With that large quantity of fresh water is used for curing of concrete. The concrete industry has therefore serious impact on the environment with regard to consumption of water. Therefore there is a need to study for alternative to fresh water for mixing and curing of the concrete.

Water is used for domestic and industrial purposes from surface water bodies and underground water sources all over the world[3]. In last few decades, there has been a tremendous increase in both domestic wastewater and industrial wastewater generation due to rapid growth of population and accelerated pace of industrialization. Almost 80% of the water used for domestic purpose comes out as wastewater[4].Year by year, the production of domestic wastewater will goes on increasing making it very difficult to dispose off. World is going to face a huge problem to deal with reduced fresh water availability and increased wastewater generation due to increased population and industrialization.

There is an increasing trend of considering water reuse as an essential component of water resources

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management and sustainable development, not only in dry and water deficient areas, but in water abundant regions as well[5]. Although, it is known that water suitable for drinking should be used for mixing and curing concrete as per the standards[6].As long as the treated wastewater is under the permissible limits as prescribed by the IS code [14-15], it can be utilised as a replacement for potable water in the concrete production.Impurities in water used for mixing concrete, when excessive, may affect not only the concrete strength but also setting time and other mechanical properties. Water with up to 100 ppm of sulphur trioxide or 50 ppm of chlorine being not objectionable for preparation of concrete [8]. Therefore, certain limits may be set on chlorides, sulphates, alkalis, fluorides, nitrates and solids in mixing water or appropriate tests can be performed to determine the effects of these impurities on various properties.

II. EXPERIMENTAL DETAILS

A. Materials and their characterization

Treated domestic wastewater used in this study was obtained from Sewage treatment plant, NITK campus, Surathkal, Karnataka, India. Ordinary Portland Cement (OPC) 53 grade corresponding to ASTM Type-I cement with a specific gravity of 3.11 was used in concrete mixtures. Crushed granite gravel with a size of 12.5 mm and 20 mm down size were used as coarse aggregate with a specific gravity of 2.72. The natural siliceous river sand having a specific gravity of 2.65 was used as a fine aggregate. The physical and chemical compositions of, cement and aggregates are mentioned in Table 1 and Table 2, respectively.

Table 1: Chemical analysis of cement

Content (%)	Chemical analysis of Cement
SiO_2	20.5
Al_2O_3	4
Fe_2O_3	4.02
K_2O	0.8
CaO	64
TiO_2	-
SO_3	1.8
MgO	1.2
Na_2O	-

Table 2: Physical tests on cement and aggregate

Physical Tests	Cement	Sand	Coarse Aggregates
IST (mins)	42		
FST (mins)	362		
Specific Gravity (g/cm^3)	3.11	2.62	2.72
Fineness Modulus	-	2.5	3.9
Zone of Aggregate	-	Z-2	-
Bulk Density (kg/m^3)	-	1700	-

A. Treated domestic wastewater characterization

Domestic wastewater before being used in the construction industry needs to be treated for various solids, inorganic and organic matters which may harm the concrete. Domestic wastewater goes through primary, secondary and tertiary treatment in sewage treatment plant. Small particles like grit, floatable solids and solids that settle by gravity are removed by screens and gravity sedimentation, which is the primary treatment of the domestic wastewater. In the secondary treatment, organic matter present in the domestic wastewater is removed with the help of aeration tank. After the secondary treatment, suspended solids and organic matter are substantially reduced. Nitrogen, phosphorous if present is removed in the tertiary treatment.

The pH value, total dissolved solids (TDS), suspended solids and other characteristics of treated domestic wastewater and laboratory water were determined by standard methods as prescribed in IS 10500: 2012 (Standard method for the examination of water). To check the consistency of the treatment plant, samples were collected for consecutive 4 days at the same time and were tested for various parameters, which are mentioned in table 3. All the samples have pH range of between 6 and 6.3 (Table 3). From the literatureand Indian standard specification [14], it is foundthat pH value range between 6.0 and 8.0 has no significant effect on the compressive strength of concrete[7-9]. According to IS 456:2000 [10], the permissible limit of TDS is 2000 ppm (part per million). From Table 3, it is clearly shown that all water samples tested have their TDS within the acceptable limit.

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Table 3: Treated domestic waste water analysis in mg/l or ppm

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	IS 456 - 2000
pH	6.16	6.13	6.22	6.18	5.5-9
bod	34.56	27.65	29.50	22.04	30
cod	64	43.2	51	41.6	50-250
total solids	1169.7	1429.1	1040.8	1396.3	<3000
total suspended solids	69.7	39.1	40.80	36.30	100-600
total dissolved solids	1100	1390	1000	1360	500-2000
alkalinity	38	30	27	32	<200
hardness	99	92	96.50	101	300-600
nitrate	3.38	3.72	3.66	2.97	<45
sulphate	27.28	22.38	24.01	44.22	<200
chlorides	96.99	95.49	92.49	103.99	<250
fluorides	0.392	0.393	0.381	0.423	<1

C. *Mix proportion and curing periods*

The concrete mix was designed according to IS: 10262-2009 specifications to have desired compressive strength of 30 MPa with w/c ratio 0.45. The details of the concrete mix proportions are given in Table 4. The addition of plasticizers is avoided in the concrete mix design, only to investigate the effect of treated domestic wastewater on the strength development of concrete. In the present study both treated domestic wastewater and laboratory water were used for mixing as well as curing of the concrete. In the process of mixing, fine aggregate and coarse aggregates were first added according to the proportion and mixed for 1 minute. After that cement was added along with half of water and mixed for 2 minutes. The remaining water was then added and mixing is continued for another 3 minutes. Each batch of freshly mixed concrete was then cast into cubes of size 150×150×150 mm for checking compressive strength of the concrete. Four different mixes with each mix comprising of 12 cubes were cast. The following four combinations of concrete mixes were prepared and designated as follows (table 5):

1) Laboratory tap water casting with Laboratory tap water curing - Mix M1.
2) Laboratory tap water casting and treated domestic wastewater curing - Mix M2.
3) Treated domestic wastewater casting and laboratory tap water curing - Mix M3.
4) *Treated domestic wastewater casting and treated domestic wastewater curing - Mix M4.*

The curing method adopted in this research work was submerging the whole concrete samples in the curing water. Curing periods were 3, 7, 28 and 90 days of laboratory water and treated domestic wastewater water curing. Tests on hardened concrete were carried out according to the specifications given in IS: 516-1959.

Table 4: Mix design details of concrete

Mix proportion	Quantity in kg/m^3
Cement	413
Fine aggregates	782
Coarse aggregates	1051
Water	186

Table 5: Designationof mixes

Mixing water / Curing water	Laboratory tap water	Treated domestic wastewater
Laboratory tap water	Mix M1	Mix M3
Treated domestic wastewater	Mix M2	Mix M4

III. RESULTS AND DISCUSSIONS

The compressive strengths of concrete cast with laboratory water and treated domestic wastewater and cured with both laboratory water and treated domestic wastewater at various curing ages are presented in table 6. Concrete cubes in Mix M1 which is cast and cured with laboratory water acts as a controlled concrete and helps in the comparison studies with other 3 mixes.It is observed from the Figure 1 that the mix M1 showed a consistent increase in the compressive strength for all the curing ages when compared to other three mixes. The early concrete ages i.e. 3-days and 7-days strength of other three mixes showed a marginal reduction of 2-6 % compared to Mix M1. But in case of 28-days and 90-days, there was a reduction of 6-11% in strength compared to Mix M1. In general there was a slight reduction of strength of all concrete cubes cast with treated domestic wastewater with the increase in the curing age.

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Table 6: Compressive strength at 3 days, 7 days, 28 days and 90 days

Curing ages	Mix M1	Mix M2	Mix M3	Mix M4
3 days	27	25.32	24.67	26.36
7 days	33.18	32.14	31.50	32.66
28 days	46.44	41.22	42.33	43.67
90 days	53.32	47.77	49.50	49.87

When comparing with Mix M1 and Mix M4 which constitute 100% laboratory water and 100% treated domestic wastewater respectively as mixing and curing water, showed negligible reduction in strength during early age i.e., 3-days and 7-days. As the curing age passed, the concrete samples of Mix M4 showed a reduction up to 6% when compared with Mix M1.The reduction in strength in Mix M2, M3 and M4 is mainly due to reduced pH value of treated domestic wastewater when compared to laboratory water.The Mix M4 favoured to be better mix over Mix M2 and Mix M3 when comparing it with Mix M1. Thus Mix M4 with 100% replacement of laboratory water with treated domestic wastewater as both mixing and curing water showed positive and agreeable results. However, the long term performance and durability of concrete made from treated domestic wastewater have not been ascertained. Also the effects of biological constituents, turbidity and presence of E-coli may not be insignificant on compressive strength of concrete especially on long term. These are potential grounds for further studies to provide adequate information on the suitability of treated domestic wastewater for concreting.

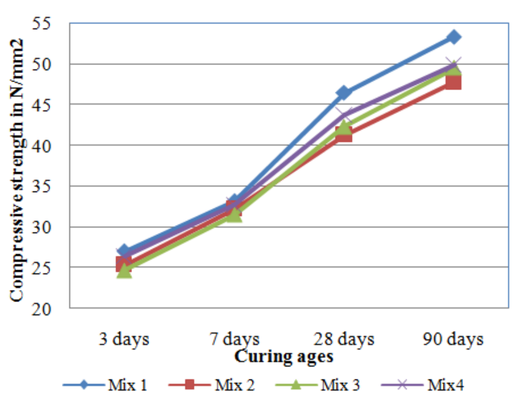

Figure 1: Compressive strength of four different mixes at various curing ages.

IV. CONCLUSIONS

This research was carried out to investigate the effect of Treated domestic wastewater on the mechanical properties of the concrete especially compressive strength, when mixed and cured with treated domestic wastewater. The study analysed the quality of the treated domestic wastewater. Later tests were conducted on the concrete samples made with four different combinations of mix. Main attention was focused on the Mix M4 which was cast with 100% replacement of laboratory water with treated domestic wastewater as both mixing and curing water. Based on the results of this experimental study it can be concluded that, the pH value, total dissolved solids (TDS) and biological oxygen demand (BOD) are the main properties of a treated domestic wastewater that needs to be checked prior to the utilisation in the construction field. The use of treated domestic wastewater had no adverse effect on the slump and density of the concrete. The use of treated domestic wastewater had no noticeable side effects on the strength of the concrete which showed a negligible reduction. In general, the Mix M2, M3, M4 concrete showed a lower strength by 6-11% for ages 28-days and 90-days. However, at early concrete ages of 3-days and 7-days showed almost similar strength to that of controlled concrete (Mix M1). The main reason for reduction of strength is because of decrease of pH value and presence of organic matter in the treated domestic wastewater. Treated domestic wastewater might also be used for curing with no adverse effect on the concrete.

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