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INVESTIGATION OF GREY WATER USE IN CONSTRUCTION: AN ECO-FRIENDLY CIVIL ENGINEERING APPROACH

[1]Rajesh T. Peche, [2]sanjay S, Jamkar

[1]Research Scholar, [2]Former Associate Professor
[1]Department of Applied Mechanics
[1]Government College of Engineering, Chatrapati Sambhajinagar, Maharashtra State, India.

Abstract : : Many countries, including India, have been experiencing a lack of fresh and clean water for years. As concrete is one of the world's most widely produced materials the water demand of construction industry is always huge. The mixing water guidelines promote the use of fresh or potable water for concrete mixing. As a result, it is critical to investigate the viability of using wastewater in concrete production and in constructional activities too. This study investigates the potential use of grey water, in concrete production. Grey water was considered as a potential alternative because of its widespread availability, perennial nature, and low contamination levels. In this investigation, cement and concrete specimens were prepared using grey water from three different sources. The attributes of these cement and concrete specimens were compared to those of cement and concrete specimens created with potable water i.e. municipal tap water. The set time and compressive strengths of cement specimens prepared by grey water are satisfying the criteria of water appropriateness for mixing. Similarly concrete specimens prepared by grey water are either satisfying the criteria or showing marginally better results than tap water specimens. Soaps, detergents, and surfactants in grey water may be responsible for the improved properties of concrete.

Index Terms **- Grey water, mixing water, compressive strength, concrete.**

1. INTRODUCTION

On 23rd December one of the leading news house reported about the use or wastage of 800 million litres water for construction in Latur of Maharashtra State of India [1]. In the next summer consequences immediately arise in the form of heavy drinking water crises in the area. The solution turns into bringing the valuable consignment of fresh drinking water over a distance of 343 km. Till july 2016 nearly 240 million litres water was supplied to Latur and some adjoining areas by train called Jaladoot [2]. Water scarcity in India has been widely reported by various agencies and recently also by Niti Ayog of India [3]. Almost all guidelines for mixing water for concrete indicate the use of fresh or potable water is safe for concrete making and it can be used without prior testing [4,5,6,7]. On this background the Latur incident may be an eye opening about the use of fresh or potable water for construction. But the great researcher Abram Duff in 1924 in his research document "Tests of Impure Waters for Mixing Concrete" [5] give an approach for use of non-potable water for concrete mixing. Reuse of non-potable water can reduce the pressure on fresh water resources. A fraction of domestic waste water called Grey water may be the solution on this.

Grey water is one part of domestic waste water. Household waste water can be broadly divided into two parts one is grey water and second is black water. Black water consists of discharge from toilets and grey water consists of other discharge excluding water form kitchen sink. According to NEERI [9], WHO[10] grey water is considered to be only weakly contaminated by pathogenic organisms and other potentially dangerous substances. Grey water is relatively low in pollution and therefore, after appropriate treatment, has great potential for reuse in non-potable water applications such as infiltration, irrigation, toilet flushing, washing water, etc [11].

Detergents and soap water from bathroom and laundry share the major fraction of contaminants in grey water. Detergents and soaps are the key bases of anionic surfactants found in Grey Water. A. Gross et all [12], L. Hernández Leal [11], Almoayied K. Assayed [13] and many other reported the Anionic surfactants' presence in terms of Methylene Blue-active substances (MBAS) which confirm the presence of detergents in grey water.

As an admixture carboxylic acids are used as water reducer and are often found in soaps and detergents which are integral part of grey water. Effects of water reducers and superplasticizers are almost same i.e. increased flowability with retarded set and reduced water–cement ratio. These effects may lead to improvement in strength of concrete [14,15,16].

NEERI estimated that quantity of grey water is around 75% of household water use [9]. Marsha Wright (1996) [17] claims that about 65% of domestic wastewater is grey water. M. Lamine et al. (2007) [18] and L. Hernández Leal et al. (2010) [11] stated that grey water accounts for up to 75% of the wastewater volume produced by households. Figure of quantity of grey water given by Sara Finley [19] is $2/3^{rd}$ of the total water use. It can be concluded that the amount of grey water produced is almost half of the domestic water supply. Grey water is a huge, perennial and ubiquitous source of water. Therefore considering the huge demand of

water in construction industry and the incidences like Latur [1] the use of grey water for concrete mixing should be investigated. It is deliberated that "the water fit for mixing is fit for curing" [20]

2. ASSESSMENT OF QUALITY OF MIXING WATER

Almost all codes stated that potable water is suitable for making concrete and other construction activities. However, if there are no records or the water is unsafe to drink, its appropriateness can be assessed using the instructions provided in various codes.

The assessment of water appropriateness for mixing is defined by several codes of combining water and concrete, as shown in Table 1.

Table 1: Strength and set time criteria given by various codes.

Parameter	IS 456 [20]	EN 1008 [21]	ASTM C1602 [22]	AS 1379 [23]
Setting time	Initial ≥ 30min and final ≤ 10 hrs	Initial ≥ 1 hr and final ≤ 12 h with both ± 25% from control.	From 1:00 early to 1:30 later than control	Initial 60 min early to 90 min ahead than control.
Compressive strength	min 90 % of control at 28 days	minimum 90% control at 7& 28 days	min 90 % of control at 7 days	min 90 % of control at 7& 28 days

Duff Abrams [8] stated that the test for setting time is not an appropriate guide to assess the fitness of water for concrete making.

3. EXPERIMENTAL PROGRAMS

The experimental program consists of the determination of Initial and final setting time test of cement, compressive strength test of cement and concrete as per relevant standards. Reference specimens are casted and cured by using municipal tap water for mixing. Similarly the specimens for comparison are casted and cured by using three grey water samples collected from different locations. After experimentation the findings are analyzed and discussed.

3.1 MATERIALS USED

1. Cement: OPC 43 Grade confirming to IS:8114
2. Fine aggregates: For cement specimens: Standard sand, confirming to Zone II as per IS:383
For concrete specimens: River sand, confirming to IS:650
3. Coarse Aggregate: Graded 20 mm NMSA aggregate confirming to Zone II as per IS:383
4. Mixing Water: A) Tap Water: Confirming to IS:10500, for preparation of reference specimens
B) Grey water: Mixing water under study, Screened grey water from residential buildings and Boys hostel
5. Curing water: A) Tap Water: Confirming to IS:10500, for of reference specimens
B) Grey water: Mixing water under study, Screened grey water from residential buildings and Boys hostel
6. Admixture: Fosroc Conplast SP 430 Confirming to IS: 9103

The designations of specimen prepared for tests are given in Table 2

Table 2: Designations of Grey water samples, cement specimens and concrete specimens

Type of mixing water	Designations of Specimen		
	Water	Cement	Concrete
Tap Water from Municipal council supply	TW	TWC	TWCC
Grey water from Government Engineering College Boy's Hostel	GW1	GWC 1	GWCC 1
Grey water from Government employees residential apartment	GW2	GWC 2	GWCC 2
Grey water from Private residential apartment	GW3	GWC 3	GWCC 3

The study is intended to use untreated grey water for concrete making. Therefore, samples of grey water are collected after screening in order to remove floating and suspended matter. The photos of grey water collection system is shown in Fig 1, It consists of three 200 lits barrels connected to each other. The first barrel is provided with two screens to remove floating materials. The screened water is passed through from top of a second barrel containing 20 to 10mm coarse aggregates. Then the water is flown upward through the third barrel containing 10 to 4.75mm coarse aggregates and coarse sand for more screening and subsequently collected in a bigger tank for equalization. Sludge valves are supplied for the recurring backwashing in each barrel.

Fig. 1: Photos of grey water collection system

3.2 MIX PROPORTIONING OF CONCRETE

Concrete having compressive strength covering the variety of ordinary to high strength as per IS 456-200017 is considered for the study. Accordingly, water cement (w/c ratio) is varied from 0.35, 0.45 and 0.55. OPC 43 grade cement, coarse aggregate of nominal maximum size of 20 mm, river sand confirming to zone three as per IS 383, water and super plasticizer is used. Basic water content 180 kg/m3, 25% water reduction and 0.5% super plasticizer are the constant parameters adopted. As per IS 10262-200915, for each w/c ratio portion of fine and coarse aggregate are calculated.

4. RESULTS AND DISCUSSION

As per IS:4031 Part-4 the standard consistency tests and as per IS:4031 Part-5 the setting time tests of OPC 43 Grade cement were carried and results are shown in Table 3.

Table 3: Comparison of results of standard consistency of cement mixed with grey water and tap water

Specimen	Cement type	Quantity of cement gms	Water required, ml Avg.	Standard Consistency % Avg.
TWC	43 Gr. OPC	400	123.33	30.83
GWC1		400	116.66	29.17
GWC2		400	121.66	30.42
GWC3		400	118.33	29.58

All three grey water samples show marginal lesser standard consistency than tap water. Indicate improved flowability of cement paste when mixed with grey water.

The setting time tests of the cement specimens mixed by using all three samples of grey water are carried out as per the IS: 4031part 5. The results are then compared with specimens prepared by tap water. Results are tabulated in Table 4.

Table 4: Comparison of results of setting time of cement mixed with grey water and tap water

Specimen	Cement type	Initial setting time Avg. minutes	Final setting time Avg. minutes
TWC	43 Gr. OPC	140	356.67
GWC1		143.33	343.33
GWC2		126.67	346.67
GWC3		133.33	340

All setting time results are satisfying the set time criteria expressed by different codes of mixing water as given in the Table 1.

The compressive strength tests of the cement specimens casted and cured by using all three samples of grey water are carried out as per the IS: 4031part 6. The 7^{th} and 28^{th} day compressive strength results are then compared with specimens casted and cured by tap water. The results of compressive strength tests are tabulated in table 5.

Table 5: Comparison of results of compressive strength of cement specimens casted and cured with grey and tap water

Specimen	Cement	7th day Compressive strength of cement, MPa, Avg.	Relative strength %	28th day Compressive strength of cement, MPa, Avg.	Relative strength %
TWC	43 Gr. OPC	34.18	100.00	44.24	100.00
GWC1		34.35	100.50	43.92	99.28
GWC2		33.51	98.04	45.01	101.74
GWC3		33.62	98.36	44.64	100.90

One out of three results of grey water cement specimens show marginally better 7th day compressive strength, whereas Two out of three results of grey water cement show marginally better 28th day compressive strength. All other three are showing marginally lesser compressive strength but are satisfying the compressive strength criteria shown in Table 1. The relative strengths of cement specimens casted and cured by using all three samples of grey water are shown in Fig 2. For comparison the strength of reference specimen i.e. specimen casted and cured by tap water is considered as 100%.

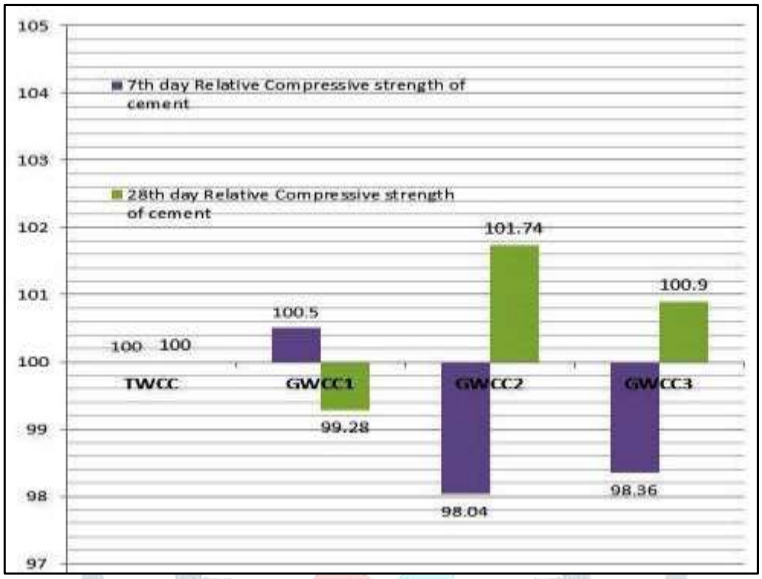

Fig. 2: Relative strengths of grey water and tap water cement specimens

The compressive strength tests of the concrete specimens casted and cured by using all three samples of grey water are carried ou. The 7th and 28th day compressive strength results are then compared with specimens casted and cured by tap water. The results of compressive strength tests are tabulated in Table 6.

Table 6 Comparison of compressive strength of grey and tap water concrete

W/C ratio	Age of concrete	Compressive strength (average of three)				Relative Compressive strength in %			
		TWCC	GWCC1	GWCC2	GWCC3	TWCC	GWCC1	GWCC2	GWCC3
0.35	7 days	38.09	39.11	36.56	38.35	100.00	102.68	95.98	100.68
0.45		30.44	31.28	27.12	27.62	100.00	102.76	89.09	90.74
0.55		20.21	24.04	20.94	22.35	100.00	118.95	103.61	110.59
0.35	28 days	44.47	46.72	44.57	43.08	100.00	105.06	100.22	96.87
0.45		38.38	37.55	40.43	43.22	100.00	97.84	105.34	112.61
0.55		30.49	32.82	31.77	34.13	100.00	107.64	104.20	111.94

Six out of nine results of grey water concrete specimens show marginally better 7th day compressive strength. Similar results are observed i.e. again six out of nine results of grey water concrete are better than tap water concrete.

Three each from 7th and 28th day tests are showing lesser compressive strength but except one all other are satisfying the compressive strength criteria shown in table 1. The relative strengths of concrete specimens casted and cured by using all three samples of grey water are shown in Fig 3. For comparison the strength of reference specimen i.e. specimen casted and cured by tap water is considered as 100%.

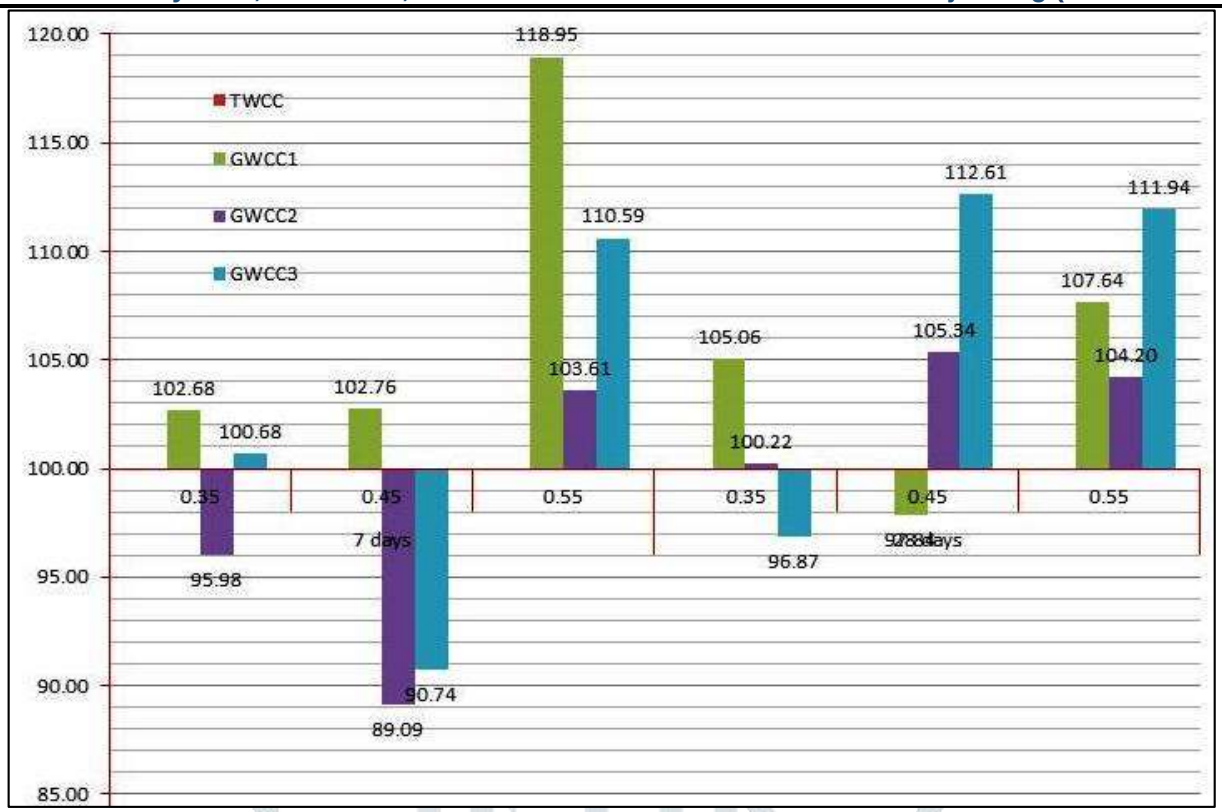

Fig. 3: Relative strengths of grey water and tap water concrete specimens

As per above results, to achieve standard consistency slight less quantity of grey water is seems to be needed than tap water. While in case of both initial and final setting time, marginal decrease has been found. Compressive strength of grey water based concrete is found better than tap water concrete. Almost all results are satisfying the criteria given in table 1. Results are indicative enough to conclude that grey water can be used as mixing water of concrete. It is clearly stated by many researchers that the presence of chemicals harmful to concrete is very low in grey water. Therefore no significant negative variance in results of tap water and grey water mixes has been observed. Specimens mixed by grey water show slight enhancement in properties. It might be due to presence soaps and detergents in grey water used for mixing [14,15,16].

5. Conclusions

Based on the exhaustive literature survey and the results of the experimental work following conclusions can be drawn.

- Grey water is a huge, perennial and omnipresent source of waste water mainly available in urban area.
- Grey water is low contaminated waste water than other waste waters.
- Integral part of contaminations of grey water is soaps, detergents and surfactants.
- Experimental results of standard consistency, initial and final setting time and compressive strength of cement and concrete specimens casted and cured with grey water satisfy the criteria of mixing water given by various codes.
- There are no significant negative variations found in the results of compressive strength of cement and concrete specimens of grey water.
- Presence of soaps, detergents and surfactants in grey water may be responsible for its utility in making concrete.

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