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Grey Water- A Potential Source of Water for Construction

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ABSTRACT: *Grey water is potentially less contaminated waste water. Taking scarcity of water into consideration various global agencies are suggesting reuse of grey water for different purposes. Water is one of the major ingredients of concrete and most used material in constructional practices. The grey water available from domestic sources is being used for gardening purpose. As discharge of grey water within the urban area is huge and as good as 60% of per capita domestic water supply, the possibility of its reuse for construction is investigated. Samples of grey water are collected from various domestic sources and their chemical analysis is carried out. Quality of grey water is compared with requirements of water for construction suggested by various codes. It is observed that the requirements like oil fats, colour, detergent, suspended matter, odour, pH were within prescribed limits. Presence of chemicals like chlorides, sulphates, alkalis, and other harmful contaminations were also within permissible limits. Investigation is further carried out to study the influence of grey water on strength of concrete. Concrete cubes of grades M-20, M-25, M-30, M-35 and M-40 were cast using potable and grey water and tested for compressive strength on 7^{th} day and 28^{th} day. The results of compressive strength of concrete with grey water are found almost same or little less than the concrete with potable water.*

Keywords: *Concrete strength, Grades of Concrete, Grey water, Mixing water, Potable water.*

I. INTRODUCTION

Concrete has been the most widely used construction material due to its mouldability in the fresh state, and durability over a long period. Water and concrete are the two materials most used by mankind: water in the first place and concrete in the second [1]. There is an increasing demand for concrete for infrastructural developments all over the world. Water is one of the major ingredients of concrete when hydraulic cement is used. Each gram of cement of average composition needs about 0.253 g of water for hydration [2]. Water is also needed for imparting workability and also for curing. The requirements to be satisfied by water for the use in concrete are specified in various codes [3,4,5]. Mostly all the codes specify that the potable water [6] can be satisfactorily used for making concrete. It means that construction industry demands huge quantity of potable water which is becoming scarce day by day [7]. India is already on the brink of entering the list of water stressed countries [8]. In India, with around 17% of the world's population, it has only 4% potable water. Rapid economic growth and urbanisation are widening the gap between demand and supply [8, 9]. At present, grey water generated is mostly going as a waste or utilised to a little extent for irrigation purposes.

Household wastewater is mainly divided in black water and grey water. Black water consists of the discharges from toilets and contains nitrogen and phosphorous in high concentrations and most of the pathogens, hormones and pharmaceutical residues [10]. Grey water consists of the discharges from kitchen sinks, showers, baths, washing machines and hand basins. It accounts for up to 75% of the waste water volume produced by households. Grey water is relatively low in pollution [11] and therefore, after appropriate treatment, has great potential for reuse in non-potable water applications such as infiltration, irrigation, toilet flushing, washing and construction [11, 12]. Recently many Countries, States and Organizations are trying to propagate the use of treated grey water for irrigation,

gardening, washing etc. [13,14,15,16]. Considering the quantum of population and construction in India, grey water may become a continuous and potential source of water.

Quality requirements of mixing water

According to IS-456 and SP 23, EN 1008, ASTM C94, AS 1379 Potable water [6]is generally considered satisfactory for mixing concrete [3,4,5]. In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time specified in Indian standards[4]. IS 456 recommends the use of water with minimum pH value as 6. Based on the finding of researchers and codes on concrete, the list of impurities in mixing water and their effect on concrete can be summarized as given in Tables1, 2 and 3.

Table 1: Effects of impurities in mixing water on some properties of concrete [6]

Impurity	Effect on concrete
Oil, fat or detergents	Air entraining possible
Calcium chloride and some other calcium salts	Probability of accelerated setting
Sugar, salt or zinc, lead, and a range of other inorganic and organic materials	Probability of set retardation
Chloride ions	Strong probability of steel corrosion

Table 2: Preliminary requirements of mixing water [6]

Oils and fats	Not more than visible traces.
Detergents	Any foam should disappear within 2 minutes.
Colour	The colour shall be assessed qualitatively as pale yellow or paler
Odour	No smell, except the odour allowed for potable water

Table 3: Mandatory chemical and other limit for concrete mixing water [6]

Chemical	Limit, ppm	Notes
Chloride, Cl^-	500 - 1,000	Prestressed concrete/grout, reinforced concrete
Sulfate, SO_4	3,000	EN 1008 limit. Water with higher salt contents has been used satisfactorily.
Alkalies, as (Na_2O +0.658 K_2O)	1,500	Total sodium and potassium ions, computed as Na_2O eq, from all ingredients is limited to 2.8 kg/m3 of concrete to safeguard potential alkali-aggregate reaction if used with reactive aggregate.
Total solids	50,000	ASTM C9411 optional requirement. See section 5.4.2 for possible use of water with solids exceeding the limit.
Harmful Substances		
Sugars	100	AS 1379 and EN 1008 requirements. In the first instance, qualitative tests may be carried out. If the qualitative tests show a positive results, either the quantity of the substance shall be determined or tests for setting time and compressive strength shall be performed.
Phosphate, P_2O_3	100	
Nitrates, NO_3^-	500	
Lead, Pb_2^+	100	
Zinc, Zn_2^+	100	
pH	>5.0	AS 1379 requirement
Oil and Grease	<50	AS 1379 requirement

II. NEED FOR INVESTIGATION

Taking in to account the scarcity of potable water and steep rise in its demand for developmental works, attempts are being made to examine the usefulness of "Grey Water" for making concrete. This paper presents the study of use of grey water for the production of concrete.

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III. EXPERIMENTAL PROGRAMME

Chemical analysis of grey water, obtained from hostel building and residential apartment is carried out to verify the concentrations of harmful chemicals. Concrete mixes are proportioned using IS 10262-2009 in order to obtain nearly M20, M25, M30, M35 and M40 grade of concrete. Setting times and compressive strength of each mix is investigated. Dose and type of superplasticiser is maintained constant for all the mixes. The properties of the materials used in the experimental work are given in Table 4.

Table 4 : Properties of Ingredients of Concrete

Cement	OPC 53 GR. Ultratech	Compressive strength: 54 MPa, Initial Setting Time: 121 min, Final Setting Time: 434 min, Specific Gravity: 3.15
Fine Aggregates	Local Sand	Specific Gravity: 2.49, Fineness Modulus : 2.52, confirming to Zone-III grading as per IS 383-1970 Water Absorption: 0. 62% , Moisture content: Nil
Coarse Aggregates	20mm ,Locally available basalt	Specific Gravity: 2.79, Grading confirming to IS 383-1970 Water Absorption: 1.1%, Bulk Dry Density: 1599.67
Superplasticizer	Fosroc Chemicals, CONPLAST SP430	Confirming to IS-9103
Mixing water	Grey water Tap water	Boys hostel, residential apartments Confirming to IS-10500

A set up as shown in Fig. 1 is installed for the collection of grey water samples from boys hostel of Government College of Engineering, Chandrapur and also from residential apartments of State Government employees. Initially samples were passed through green net screens to screen the floating and suspended materials. The water is then allowed to pass through well graded coarse aggregates for further filtration. Sludge valve is provided in the tank for the periodic backwashing.

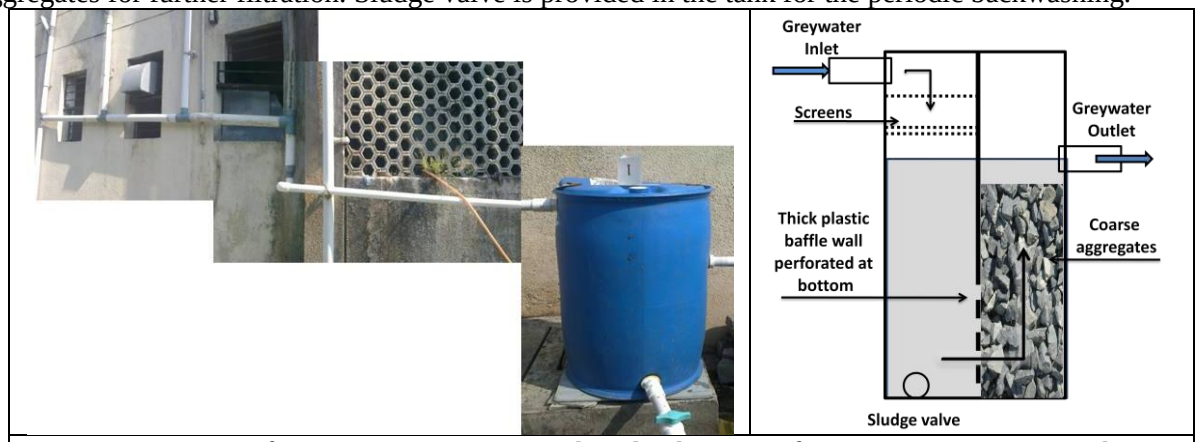

Fig. 1: Set up of Grey water screening tank and Schematic of Grey water screening tank

IV. RESULTS AND DISCUSSIONS

Results of Grey water analysis: The results of chemical analysis of grey water samples are presented in Table 5. It includes presence of objectionable and harmful chemicals and fecal and total coliforms. A comparison of properties of grey water and tap water with reference to codal provisions of mixing water for concrete is shown in Table 5. All tests for the analysis of chemicals and microbiological presence were performed as per IS 3025.

Table 5: Test results of Chemical of Tap Water and Grey Water, used for concrete mixing, and comparison with Provisions for mixing water.

Sr.No.	Sample Type → / Sampling locations → / Tests ↓	Unit	Grey Water - 1 / Boy's hostel GEC	Grey Water - 2 / Govt. Qtrs. Appt. Bldg.	Tap Water	Maximum permissible limit of chemicals in mixing water suggested by codes of concrete. [4,5,6]
1	2	3	4	5	6	7
2	pH	Nil	7.9	7.8	6.9	≥4 – EN1008 >5 – AS1379 >6- IS456
2	Detergents	---	foam disappeared within 1 min.		---	Any foam should disappeared within 2 minute- EN1008
3	Total Solids	mg/lit.	170	166	89	50,000 - ASTM C94 ≤2000- IS456 ≤1% of total aggregates
4	Oil and grease	mg/lit.	Little visible traces only		---	< 50 – AS1379 No more than visible traces-EN1008
5	Chlorides (as Cl)	mg/lit.	26	34	24	≤500- EN1008, ≤500- ASTM C94 ≤500-IS456
6	Nitrates (as No_2)	mg/lit.	0.071	1.85	0	≤500- EN1008
7	Sulphate	mg/lit.	1.4	2.8	0	≤2000 - EN1008 ≤3000 - ASTM C94 < 500 – AS1379 < 400- IS456
8	Alkalinity	mg/lit.	104	100	71	<1500- EN1008 ≤600- ASTM C94
9	Phosphates	mg/lit.	0.21	0.17	---	100– EN1008
10	Lead	mg/lit.	0.9	1.2	0	100– EN1008
11	Zink	mg/lit.	0.06	0.08	0	100– AS1379

Other Parameters: Colour of both the samples of grey water was light or pale milky and turbidity between 12 to 14 NTU. Range of BOD_5 found in samples of grey water is 18 to 45 mg/l and the values of COD ranges from 29 to 71 mg/l. Total coliforms found are from 6.1 to 10 and fecal coliforms are from 1.8 to 3.7 MPN.

Results of chemical of Grey Water samples show that the presence of chemicals harmful to concrete are within the standard permissible limits mentioned in various codes [4,5,6]. But due to presence of fecal coliforms in grey water it should be disinfected before use.

Results of Setting time: Setting time tests as per IS: 4031 were carried out, on cement, using six samples each of potable water and grey water from above mentioned sources. The test results are presented in Table 6.

Table 6: Results of Initial and final setting time of cement using both potable and grey water.

Sample	No. of samples	Initial setting time in Minutes				Final setting time in Minutes			
		min	max	Avg.	Difference	min	max	Avg.	Difference
1	2	3	4	5	6	7	8	9	10
Potable water	06	115	125	121	Reference	420	440	434	Reference
GW-1	06	95	100	98.3	- 19%	400	410	406.6	- 6.29%

				3				6	
GW-2	06	100	110	104	- 14.4%	400	420	410	- 5.5%

The results indicate that there is a reduction in initial and final setting time. This may be due to greater values of COD of grey water samples than tap water. However the setting time values comply with the requirements of IS 12216 i.e. initial setting time should not be less than 30 minutes and final setting time not more than 600 minutes.

Set time test results of cement by using both grey samples and potable water for mixing are shown in Table 6. Results show decrease in both initial and final set time but are well within limits as prescribed by IS 456.

Results of Compressive strength: Concrete cubes casted in 15cm cube molds were used to study the effect of grey water on concrete strength. The M-20, M-25, M-30, M-35 and M-40 grade mixes were cast. Trial batches of concrete were casted by batching each mix with potable water for adjustments and adoptions to have appropriate target mean strength. These concretes were used as the reference or control batch. Cubes were cured using respective water used for mixing. Cubes were tested on 7^{th} and 28^{th} day for compressive strengths. For each test, three specimens were tested, and the average value of the three was taken as the compressive strength. All concrete cubes were compacted by using a vibrating table. The cubes were tested on the specified dates using a 2000KN compression testing machine. The test blocks have been prepared and tested in accordance with the requirements of IS 516. The test results are presented in Table 7.

Table 7: Comparison of compressive strengths for potable water and grey water concrete.

Grade of concrete	7 Days Compressive strength of Concrete with					28 Days Compressive strength of Concrete				
	Type of mixing and curing water			%Difference in Comp. Strength with		Type of mixing and curing water			% Difference in Comp. Strength with	
	Tap Water	GW 1	GW 2	GW 1	GW 2	Tap Water	GW 1	GW 2	GW 1	GW 2
1	2	3	4	5	6	7	8	9	10	11
M-20	21.4	22.9	22.45	7.01	4.91	27.1	29.6	29.4	9.23	8.49
M-25	25.3	28.1	26.33	11.1	4.07	33.3	34.4	33.69	3.3	1.17
M-30	28.7	30.3	29.4	5.57	2.44	37.8	39.9	40.26	5.56	6.51
M-35	31.5	35.4	33	12.4	4.76	40.8	42.1	41.5	3.19	1.72
M-40	36.3	39.6	37.6	9.09	3.58	48.6	51.2	49.6	5.35	2.06

As per IS 456 the average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average of strength of three similar concrete cubes prepared with distilled or tap water. The compressive strengths of concrete prepared by grey water and potable water mixing are shown in table7. The results show, increase in compressive strengths, when prepared with grey water. On 7^{th} day, the strength was found to be 2.44 to 12.4% and on 28^{th} day it was 1.17 to 9.23%, a general increase was observed.

V. CONCLUSIONS

The types of grey water used in this study met the standard specification mentioned in various codes but should be disinfected before use.

Grey water reduces the initial and final setting time but that reduction is marginal and still within the prescribed limits.

Increase in compressive strength has been observed when grey water was used. It may be due to higher alkalinity than potable water.

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