Influence Of Grey Water As Mixing Water On Properties And Strength Of Cement

Rajesh T. Peche, Dr. Sanjay S. Jamkar, Dr. Parag A. Sadgir

Ph.D. Scholar, Department of Applied Mechanics, Government College of Engineering, Aurangabad, India
Department of Applied Mechanics, Government College of Engineering, Aurangabad, India
Department of Civil Engineering, Government College of Engineering, Aurangabad, India

ABSTRACT: From the immemorial time water has been the part of all basic human activities. The water we are most concerned with is fluid and fresh and is least available. As economic activities are growing, the demand of water is also growing. At the same time increase in population is lowering per capita availability of fresh water. Exploiting more and more water resources would put more pressure on environment- ecology which has already become fragile. As per all codes of concrete the water used for mixing and curing should possibly be the potable water. Constructional activities play major role in infrastructural development. Water has undisputed important place in civil construction and so far no alternative to water is available.Chemical limits of water for concrete, suggested by different codes of concrete indicate that non potable water can be used as mixing water. Reuse of non-potable water like grey water can reduce the pressure on fresh water resources.On this background, investigations on all possible uses of all types of waste water in construction industry, is the need of the hour. Present study has been conducted to investigate the influences of use of grey water o properties of cement.

Keywords: cement, concrete, grey water, mixing water

1 INTRODUCTION

Water is one of the most important elements in human life and construction. India has more than 17 percent of the world's population, but has only 4% of world's renewable water resources. [1] Constructional activities play a major role in the infrastructural development. Water has an undisputed important place in civil construction and so far no alternative to water is available. Construction industry is among the most water consuming industries. But there is one relief that it does not essentially need fresh or potable water. Chemical limits for water for construction, suggested by different codes indicate that many types of non-potable water can be used for construction [2], [3], [4], [5], [6]. Reuse of non-potable water like grey water for construction can reduce the burden on fresh water resources and the environment. It is clearly mentioned by Duff A. Abrams [7] that "In spite of the wide variation in the origin and type of the water used, and contrary to previously accepted opinion, most of the impure water gave good results in concrete, probably due to the fact that the quantity of harmful impurities present were quite small". Duff A. Abrams(1924), Harold H. Steinour(1960), Joo-HwaTay et al (1987), O. Z. Cebeci et al (1989), Marcia Silva(2010), Mohammad Shekarchi et al (2012), AinulHaezahNoruzman et al (2012), S.O Ojoawo et al (2014), M. Karthikeyan et al (2014),M.Kanitha et al (2014) studied effects of raw and treated domestic waste water as water for mixing concrete. Almost all results of parametric study suggest the feasibility of using treated domestic waste water as mixing and/or curing water. Household wastewater is mainly divided in black water and grey water. Black water consists of the discharges from toilets. Black water contains nitrogen and phosphorous in high concentrations and most of the pathogens, germs and pharmaceutical residues [8].Commonly, grey water should consists discharges from showers, baths, washing machines and hand basins. Some definitions include wastes from kitchen sinks also but there is no consensus.Grey water is relatively low in pollution [9]. Amount of grey water generation estimated by different studies is about 70% of domestic water supply. Considering the amount of domestic water supply and grey water generation in cities, grey water has great potential to cope up with the need of water for construction.

2 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. As cement is the only ingredient of concrete responsible for binding action, study of use of grey water on cement becomes important. This paper presents the study of effects of grey water on the properties of cement.

3 QUALITY REQUIREMENTS OF MIXING WATER

According to IS and all other codes of concrete Potable water is generally considered satisfactory for mixing concrete [2], [3], [4], [5], [6]. The impurities in mixing water harmful to concrete are compiled (Table1) from various codes like ASTM C 1602/C 1602M-04[2], ASTM C94[3], BS EN 1008:2002[4],IS 456[5], AS1379-2007[6]. These are Color, Odor, total solids, Chlorides, Sulphates, Acids, Alkali, phosphates, nitrates, lead, zinc, Oils and fats, Detergents, etc.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 tests specified in 5.4.1.2 and 5.4.1.3. 5.4 of IS-456 .

Table1: Maximum Permissible Limits of Impurities in Mixing Water and Potable water.

Parameter	unit	Maximum permissible limit of chemicals in mixing water suggested by various codes. [2], [3], [4], [5], [6]	permissible limit for potable water specified by IS10500 [10]
Color	Hazen units	Pale yellow or paler	5-15
Odour	Agreeable	No smell– EN1008	Agreeable
Turbidity	N.T.U.	---	1-5
pH	Nil	≥4 – EN1008, >5 – AS1379, >6- IS456	6.5-8.5
Detergents	---	Any foam should disappeared within 2 minute- EN1008	0.2-1(Anionic detergents as MBAS)
Total Solids	mg/lit.	50,000 - ASTM C94, ≤2000- IS456, ≤1% of total aggregates	2000 (Dissolved solids)
Oil and grease	mg/lit.	< 50 – AS1379, No more than visible traces- EN1008	Below detectable limit (mineral oil)
Chlorides	mg/lit.	≤500- EN1008, ≤500- ASTM C94, ≤500-IS456	250-1000
Nitrates	mg/lit.	≤500- EN1008	45
Sulphate	mg/lit.	≤2000 - EN1008, ≤3000 - ASTM C94, < 500 – AS1379, < 400- IS456	200-400
Total Alkalinity	mg/lit.	<1500- EN1008, ≤600- ASTM C94	200-600
Phosphates	mg/lit.	100– EN1008	---
Lead	mg/lit.	100– EN1008	0.01
Zink	mg/lit.	100– AS1379	5-15

4 EXPERIMENTAL PROGRAM

In this study, the grey water samples (GW) from two different sources were used for mixing. For comparison tap water (TW) was used to prepare control specimens.Standard consistency, initial and final setting times, soundness and compressive strengths of cement were determined by using both TW and GW for mixing.

4.1 Materials

Cement: 53 Grade Ordinary Portland cement confirming to IS12269 [11].

Mixing water: Tap water (TW) confirming to IS10500 and grey water (GW) obtained from residential apartment and boy's hostel building was used in this study. The process for preparing the grey water samples started from collecting the grey water for use after equalization for 24 hours.

Fine aggregates: Standard sand from Ennore, Tamil Nadu specified by IS650 [12] was procured for compressive strength test of cement. .

4.2 Testing Procedures

- Screened and equalized grey water samples were sampled and analyzed for potential pollutants of concrete by procedures given in different parts of IS3025 [13].
- Standard consistency test was performed as per procedures given in IS4031part 4-1988 [14].
- Initial and final setting time tests were carried out as per procedures in IS4031 part 5-1988 [15].
- Soundness test was conducted in accordance with IS4031 part 3-1988 [16] to ascertain the presence of free lime and magnesia by measuring the expansion of cement.
- Compressive strength test was carried out according to IS4031 part 6-1988 [17].

5 Grey Water Screening and Collection

Three barrel screening system was set to screen out floating and suspended materials in grey water. Setup consist of first barrel having two screens, second barrel filled with 20-10mm coarse aggregates and third filled with 10-4.75mm coarse aggregates. Outflow from third barrel was collected in big tank for equalization. Figure 1 showing the setup of primary screening and collection of grey water.

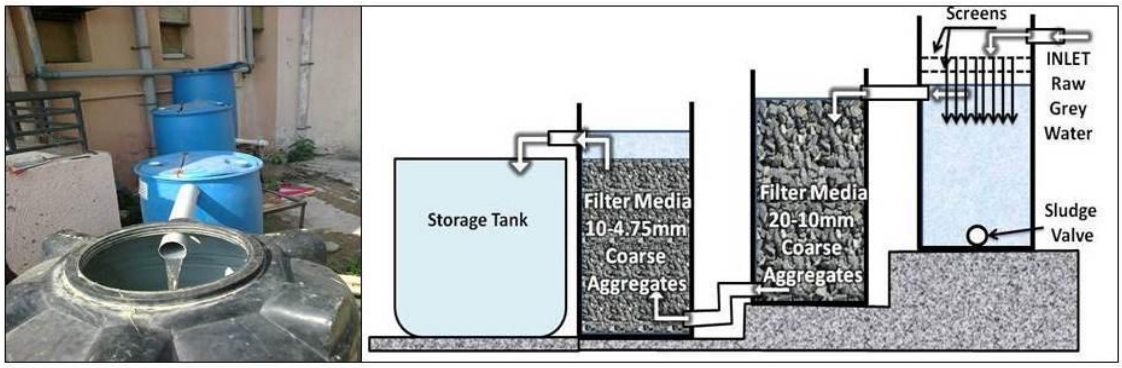

Figure1. *Setup of Grey Water Screening and Collection*

6 TEST RESULTS AND DISCUSSION

6.1 Chemical Analysis of Grey Water

Test methods given in different parts of IS3025 "methods of sampling and test (physical and chemical) for water and waste water" were adopted for sampling and testing for different chemicals. As per EN 1008:2002 E the colour shall be assessed qualitatively as pale yellow or paler. The samples of grey water (GW1, GW2) used for mixing were light milky in colour which is within the permissible limit. According to EN-1008 No smell, except the odour allowed for potable water and a slight smell of cement and where blastfurnace slag is present in the water, a slight smell of hydrogen sulphide. Practically no smell of both the grey water samples was noticed. B.O.D. of the grey water samples, GW1 and GW2, used for concrete mixing were found to be 18 and 56, whereas C.O.D. values were 29 and 153mg/lit respectively. The C.O.D. to B.O.D ratios are 1.61 and 2.73. The COD/BOD ratio is a good indicator of greywater biodegradability. A COD/BOD ratio below 2–2.5 indicates easily degradable wastewater. While greywater is generally considered easily biodegradable. [18] The total coliform concentration in the samples GW1 and GW2 of grey water used for concrete mixing was found to be 10MPN/100ml & 6.1 MPN/100ml whereas fecal Coliform concentration found to be 3.7MPN/100ml & 1.8MPN/100ml respectively. According to A.M. Neville [19]Concrete are generally resistant to microbiological attacks because its high pH does not encourage such actions. The amount of almost all chemicals in both grey water samples, GW1 and GW2, are found to be under the permissible limits set by all codes of concrete and mixing water. This indicates that grey water can be used as mixing water for concrete. Test results of the chemical properties of grey water are presented in Table 2.

Table 2: 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 → / Parameters ↓	Unit	GW1 / Boy's hostel GEC	GW2 / Govt. Qtrs. Appt. Bldg.	TW	Maximum permissible limit of chemicals in mixing water suggested by codes of concrete. [2], [3], [4], [5], [6], [20]
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 disappear 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 Not more than visible traces-EN1008
5	Chlorides (as Cl)	mg/lit.	26	34	24	≤500- EN1008, ≤500- ASTM C94 ≤500-IS456
6	Nitrates (as NO2)	mg/lit.	0.071	1.85	0	≤500- EN1008
7	Sulphate (as SO4)	mg/lit.	1.4	2.8	0	≤2000 - EN1008 ≤3000 - ASTM C94 < 500 – AS1379 < 400- IS456

8	Alkalinity (as calcium carbonate)	mg/lit.	104	100	71	<1500- EN1008 ≤600- ASTM C94
9	Phosphates (as PO4)	mg/lit.	0.21	0.17	---	100– EN1008
10	Lead (as Pb)	mg/lit.	0.9	1.2	0	100– EN1008
11	Zink (as Zn)	mg/lit.	0.06	0.08	0	100– AS1379

6.2 Standard Consistency Test

Standard consistency of Cement paste is defined as percentage of water by weight of cement paste, which produces a consistency, which permits a Vicat plunger G of 10 mm diameter to penetrate up to 33 mm to 35 mm of the Vicat mould. Gauging time shall be counted from the time of adding the water to the dry cement until commencing to fill the mould [14]. Results of standard consistency test of cement used in the study are shown in Table 3. Results show that the amount of water required for Standard Consistency of cement is almost same in case of both TW and GW samples. In this case no significant difference in behaviour of TW and both samples of GW were noticed.

6.3 Setting Time Test

Initial setting time of cement is defined as the period elapsed between the time when the water is added to the cement and the time at which the needle of circular cross section of having area equal to 1 mm square (needle C of the Vicat apparatus) fails to pierce the test block to a depth of 5 ± 0.5 mm from bottom of mould. Whereas, final setting time of cement is defined as the period elapsed between the time when the water is added to the cement and the time at which the needle of 1 mm square with 5 mm diameter attachment (needle with an annular attachment F), makes an impression on the test block, while the attachment fails to make an impression on the test block [15]. Results of initial and final setting time test of cement used in the study are presented in the Table-4. With respect to tap water, grey water mixes indicate slight increase in both initial and final setting time of cement. The increased values are also within the prescribed values given in IS 12269-1987.

6.4 Soundness test

The cement is said to be sound when the percentage of free lime and magnesia is within specified limits. Soundness test was conducted in accordance with IS4031 part 3-1988[16] to ascertain the presence of free lime and magnesia by measuring the expansion of cement. Results of soundness test are as given in table-5. For 53 grade cement, maximum expansion should not be of 10 mm when tested by the Le-Chateliermethod [11]. Grey water mixed cement pastes show expansions almost same to that of the tap water cement paste. Both soundness test results are well within the prescribed limit given in IS 12269-1987.

6.5 Compressive strength test

Compressive strength of cement indicates the compressive strength of cement mortar cubes of 1:3 proportion, using standard sand as specified by IS: 650 as fine aggregates, tested under compression. Different grades of cement indicate their compressive strength at the end of 28 days tested under compression [17]. Table shows the test results of the compressive strength of reference mix and cement mixed with grey water as a replacement of tap water. It was found that grey water tends to increase the compressive strength of cement. Results shows that the compressive strength of cement mixed with Grey water is higher than that of tap water mixed cement. After analysis of grey water samples and different basic tests on cement, it can be concluded that grey water can be used as mixing water.

Table 3: Results of standard consistency test of cement

Samples	cement	No. of samples	Water required for Standard Consistency, ml			Standard Consistency %	Relative standard consistency%
			min	max	Avg.	Average	
TW	Ultratek 53 Gr. OPC	3	125	135	130	32.5	100
GW-1		3	125	135	128.33	32.08	98.70
GW-2		3	120	135	126.66	31.66	97.41

Table 4: Results of setting time of cement by using tap water and grey water samples used for mixing

Sample	Cement (confirming to IS 12269)	No. of samples	Initial set time (IST) Min.			Relative IST %	Final set time(FST) Min.			Relative FST %
			min	max	Avg.		min	max	Avg.	
TW	Ultratec 53 Gr. OPC	6	45	50	46.66	100	170	180	175	100
GW-1		06	45	50	48.33	103.57	170	180	176.66	100.97
GW-2		06	55	40	49.166	105.37	170	190	180	105.88

Table 5: Results of soundnesstest of cement

Sample	cement	No. of samples	Soundness/expansion of cement, mm.			Relative soundness %
			min	max	Avg.	
TW	Ultratech 53 Gr. OPC	6	1	2	1.41	100
GW-1		6	1	1.5	1.33	94.32
GW-2		6	1	2	1.5	106.38

Table 3: Results of compressive strength test of cement

Sample	cement	No. of samples	28th day Compressive strength of cement			Relative strength at 28th day %
			min	max	Avg.	
TW	Ultratek 53 Gr. OPC	6	57.2	62	59.1	100
GW-1		6	57.6	61.4	59.43	100.55
GW-2		6	57.4	64.2	60.2	101.86

7 CONCLUSIONS

Based on the results of the study the following conclusions can be drawn out.

- Considering huge and perennial availability, grey water has a potential to fight against scarcity of water.
- The types of grey water used, met the standards of mixing water as mentioned in various codes.
- Grey water should be disinfected before use to avoid health risks to people at work.
- Compared with tap water lesser amount of grey water is required to achieve Standard Consistency of cement.
- Soundness of Grey water mixed cement paste is almost same to the tap water cement paste.
- Grey water reduces the initial and final setting time but that reduction is marginal and still within the prescribed limits.
- Cement mixed with Grey water has more compressive strength than the cement mixed with tap water.
- Increase in compressive strength may be due to the presence of higher soaps, detergents and surfactants in grey water.

REFERENCES

[1] Ministry of Water Resources, Govt. of India, “India Water Week 2012”, VigyanBhavan, Delhi, 8-12 April, 2012.

[2] American Society for Testing and Materials, “ASTM C 1602/C 1602M-04: Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete”, 2004.

[3] American Society for Testing and Materials, “ASTM C94-05, Standard specification for ready-mixed concrete”, 2005.

[4] British standard, “BS EN 1008, Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete”, 2002.

[5] Bureau of Indian Standards, “IS456, Plain andReinforced Concrete Code of Practice”, Fourth Revision July 2000.

[6] Australian Standard,” AS 1379, Specification and supply of concrete”, 2007.

[7] Abrams, Duff A., “Tests of Impure Waters for Mixing Concrete”,Bulletin 12, Structural Materials Research Laboratory, Lewis Institute, Chicago, http://www.portcement.org/pdf_files/LS012.pdf, 1924.

[8] Hernández Leal, “Characterization and anaerobic biodegradability of grey water”, Desalination, Elsevier, 270, 2011, 111–115.

[9] Glenda Emmerson, “Every drop is precious: Greywater as an alternative water Source”, Queensland Parliamentary Library, Publications and resources section, Brisbane, July 1998.

[10] Bureau of Indian Standards, “IS 10500, Draft Indian Standard, Drinking Water – Specification”, Second Revision, 2009.

[11] Bureau of Indian Standards, “IS 12269 Indian Standard, Ordinary Portland Cement, 53 Grade — Specification", 2013.

[12] Bureau of Indian Standards, “IS 650, Indian Standard, Standard Sand for Testing Cement specification", 1991.

[13] Bureau of Indian Standards, “IS: 3025, Indian Standard Methods of Sampling and Test (Physical and Chemical) for Water and Waste Water”, -1986.

[14] Bureau of Indian Standards, “IS : 4031 (Part 4), Indian Standard Methods of Physical Tests for Hydraulic Cement, Determination Of Consistency Of Standard Cement Paste", 1988

[15] Bureau of Indian Standards, “IS: 4031 (Part 5), Indian Standard Methods of Physical Tests for Hydraulic Cement Part 5 Determination of Initial and Final Setting Times", 1988.

[16] Bureau of Indian Standards, “IS: 4031 (Part 3), Indian Standard Methods of. Physical Tests for Hydraulic Cement Part 3 Determination of Soundness", 1988.

[17] Bureau of Indian Standards, “IS: 4031 (Part 6), Indian Standard Methods of Physical Tests for Hydraulic Cement Part 6 Determination of Compressive Strength of Hydraulic Cement other than Masonry Cement", 1988.

[18] Antoine Morel, et al, “Greywater Management in Low and Middle-Income Countries”, Sandec: Department of Water and Sanitation in Developing Countries, September 2006.

[19] A.M. Neville “Properties of Concrete”, Fourth Edition, Pearson Education, 2005.

[20] Use of Recycled Water in Concrete Production, Cement Concrete & Aggregates Australia, August 2007.