Mathematical Statistician and Engineering Applications
ISSN: 2094-0343
2326-9865

Investigation on Enhancement in Compressive Strength of Concrete by Reusing Effluent for Casting and Curing

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Article Info
Page Number: 3024-3033
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022
Publication: 19 August 2022

Abstract
The study is associated with the use of effluent for casting and curing of concrete as for both the cases the consumption of potable water is used. At present, the wastewater is treated in a sewage treatment plant (STP) and effluent is released in the nearby stream. For this study, seven different combinations were created for casting and curing of M20 grade concrete using potable water and effluent. The effluent is collected from two STP (Kasarwadi & Akurdi, Pune). The water samples were tested and the feasibility was checked according to Indian standards (IS). The water is used to cast 42 cubes. And those are tested for Compressive strength. The maximum compressive strength was observed for the third combination (PD_2) where the casing was in Portable water(P) and Curing in Effluent (D_2) as 34.79 MPa.The formation of C-S-H gel is more in the PD_2 combination and also percentage weight of CK is 5.46 which leads to higher compressive strength.

Keywords- Effluent water, Concrete, XRD, Microstructure, Reuse of water

1. INTRODUCTION:

Due to the increase in the demand for potable water, it is required to explore the alternate source of water which can be used for casting and curing concrete. The wastewater generated in the cities were treated in Sewage Treatment Plant (STP) and then released in the nearby stream. In this study, the treated water is reused in casting and curing concrete. According to IS 456:2000, for casting and curing of concrete portable water shall be used. If STP treated water (effluent) is used, the price of the water needed for construction can be reduced by up to 68 per cent. When portable water was used for curing, the compressive strength was 18.92 MPa at 7 days and 24.41 MPa when STP treated water was utilised. (Ms. Spoorthy B C et. al,2012). Pimpri Chinchwad Municipal corporation (PCMC) is having 13 STP and the total Effluent generated is 258 MLD. From the treated effluent 3.5 MLD is used for gardening purpose and other is disposed of in the nearby river. Approximately 20MLD water is required for only construction work in the area. So, the detailed study is carried out By creating 7 different combinations using 1. Portable water (P) 2. Treated Effluent from STP-1 (D_1) 3. Treated effluent from STP-2 (D_2) for casting and curing as shown in Table No.4

LITERATURE SURVEY

Report from the corporation and research papers were referred to identify the area of work. Some of the details are summarized below.

The water samples were obtained from three local plants of treatments.(Mohammad Shekarchi et.al,2012) The treated effluents' chemical compositions and physical properties were investigated. The use of treated effluents instead of freshwater for concrete mixing could save a significant amount of freshwater. (Ainul Haezah Noruzman et.al,2012) Concrete samples with w/c ratios of 0.4, 0.5 and 0.6 were cast with collected effluent and also with tap water to facilitate comparison of evaluated properties. Significant improvements in strength and water tightness were particularly recorded in concrete mixes of w/c = 0.5 and 0.6. Several batches of concrete were tested, with 0 per cent, 25%, 50%, 75%, and 100% reclaimed wastewater in the total mixing water required for each batch. The reference or control batch was made of concrete containing 0% recovered wastewater. The average value of the three was taken as the compressive strength for that particular batch. (Devendra Swami,et. al,2015) Between 25 and 100 per cent of the tap water used in concrete was replaced with wastewater. (Joo-Hwa Tay and Woon-Kwong Yip,1987) M 20 & M 40 concrete were prepared using portable and sewage water. M20 concrete was adopted. A total of 12 concrete cubes were cast and cured for 3, 7, and 28 days, respectively. The compressive strength of plain concrete was positively influenced by Physico-chemical characteristics measured in treated wastewater effluents.(K. S. Al-Jabri et. al,2011)Also, To investigate the viability of employing treated effluent for concrete mixing, a compressive strength test and setting time were performed. G 30 & G35 strength concrete was used for the study.(Vijay H,2017). The compressive strength is 10.830% more in the case of concrete cubes prepared by using treated sewage water. (Ooi Soon Lee et. al,2001) The use of treated domestic wastewater for mixing and curing may have resulted in a loss in compressive strength. The presence of bicarbonates content (647mg/l) higher than the allowed limit compared to the allowable limits (400mg/l) could explain the decrease in compressive strength. (Sachin Mane et. al,2019) There was no improvement in tensile and flexural strength by using Secondary Treated Waste Water (STWW). The compressive strength of concrete is increased by mixing STWW at the end of 60 days. (Vinut Kulkarni et.al,2014) Two different combinations 1. Cement(80%)+ Fly ash(20%)+treated wastewater & Cement(80%)+ GGBS(20%)+treated wastewater were used in the mix design.M20 grade of concrete is used.The second combination gives a better result than the first.(Ramkar A.P.& Ansari U.S.,2016) According to the results of the Rapid Chloride Penetration Test, the charge passed in coulombs is less than 4000, indicating that chloride permeability is moderate for potable water and more than 4000 for treated wastewater, indicating that chloride permeability is high. (Mr Asif Rashid Shaikh & Dr. V. M. Inamdar,2016) C-S-H gel formation in the concrete prepared with treated waste water is good, so the strength of the concrete is more.(P. Rama Mohan Rao et.al,2014). To create acceptable performance-based criteria to use the expanding diversity of concrete that will become available, it is necessary to have a thorough understanding of durability and the microstructural mechanisms involved.(Karen L. Scrivener,2009)

Microstructure analysis can be done using X-ray diffraction (XRD), X-ray fluorescence (XRF), and a scanning electron microscope (SEM) with an energy dispersive X-ray analysis system (SEM-EDX). *(Mr. Manjunatha.M, 2017).* After 28 days, the interface has a substantial number of well-crystallised C-S-H (and a small amount of weakly crystalline fibres), as well as CH deposits. The ITZ's porosity increases as the aggregate substitution

extent grows, however the maximum pore size reduces from around 30 m for 0% substitution to 16 m for 100% substitution..*(Dhirajkumar Lal) et. al,2009)* Numerous calcium hydroxide (big white plates) and non-reactant lime particles can be seen in the SEM micrograph. *(L. Evangelist et.al, 2013)* Although a small amount of unhydrated cement may build, the hydration that occurs during the life of the concrete ensures a functional interfacial zone. *(E. Hewayde, M. Nehdi et.al, 2006)* Microstructural data might differ dramatically from image to image, necessitating the use of numerous images to reduce scattering effects..*(M. Etxeberria, E.Vazquez and A. Marı,2006).* To establish acceptable performance-based criteria to employ the expanding diversity of concrete that will become available, it is necessary to fully comprehend the durability and microstructural mechanisms involved. *(David Darwin & Mohamed Nagib Abou-Zeid (2016).*

3. EXPERIMENTAL PROGRAMME

For the proposed work, the material required is Ordinary Portland Cement, Aggregate, portable water and Effluent. Those materials were tested according to the guidelines given by Indian Standard.

The test was carried out by referring to Indian Standard and the results are summarized in table no.1 & 2

Sr. No.	Parameters	Kasarwadi	Akurdi	Standards	IS Code Referred
1.	Initial setting time of cement	35 minutes	30 minutes	>=30 minutes	IS 4031 (part 5&269), IS 5513
2.	Final setting time of cement	180 minutes	200 minutes	<600 minutes	IS 4031 (part 5&269), IS 5513
3.	Soundness test of cement	7 mm	8 mm	<10 mm	IS 4031 (part 3&269), IS 5514
4.	The moisture content of C.A.	0.75%	0.78%	-	IS 2386 (part 3)
5.	The moisture content of F.A.	2.5%	2.39%	-	IS 2386(part III)
6.	Water Absorption of C.A.	1.87%	1.93%	2%	IS 2386 (part 3)
7.	Water Absorption of F.A.	2.76%	2.72%	-	IS 2386(part III)
8.	Specific Gravity of C.A.	2.79	2.77	2.6-2.8	IS 2386 (part 3)
9.	Specific Gravity of F.A.	2.92	3.0	2.5-2.8	IS 2386(part III)
10.	Fineness	5.35		-	IS 383, IS 2386-

	Modulus of Coarse Aggregates			1963
11.	Fineness Modulus of Fine Aggregates	3.15	3.2	IS 383, IS 2386-1963

Table 1 Results obtained for the water samples collected from STP

Sr.No.	**Parameters**	**Kasarwadi**	**Akurdi**	**Standards**	**IS Code Referred IS 3025**
1	Temperature	26.5°C	26.4°C	27 °C	Part 9
2	pH	7.9	7.9	6.5 to 8.5	-
3	Turbidity	7.6 NTU	7.6 NTU	8 NTU	Part 10
4	Total Solids mg/l	345	280	350	Part 9
5	TDS mg/l	265	190	350	Part 16
6	TSS mg/l	80	90	2000	Part 17
7	TVS mg/l	120	195	200	Part 18
8	TFS mg/l	320	320	3000	Part 18
9	Alkalinity mg/l	112	168	20-200	Part 23
10	Chlorides mg/l	74.98	64.98	2000	Part 32

Table 2 Test Result for the Treated effluent from STP

After getting results for the Course aggregate, Cement, fine aggregate, mix design for M20 grade is prepared. The proportion calculated is summarized in table 3.

The proportion for the mix is as under, Table No 3

Material	**Cement**	**Water**	**C.A.**	**F.A.**	**W/C**
Unit	Kg	Kg	Kg	Kg	Kg
	360.426	178.382	1223.635	724.754	0.45

Table 3 Mix proportion used for casting of concrete

For the seven different combinations, 42 cubes were cast and tested for compressive strength. To know the reason for getting more strength X-ray diffraction (XRD) test was carried out at National Chemical Laboratory (NCL), Pune.

The seven combinations created for casting and curing using portable water and the effluent from two STP is as shown in the following Table No.4

Combination Number	Water u for Casting	Water for Curing	Total quantity of Cubes used for Compression Test	
			7 Days	28 Days
1.	P	P	3 Nos.	3 Nos.
2.	P	D_1	3 Nos.	3 Nos.
3.	P	D_2	3 Nos.	3 Nos.
4.	D_1	P	3 Nos.	3 Nos.
5.	D_2	P	3 Nos.	3 Nos.
6.	D_1	D_1	3 Nos.	3 Nos.
7.	D_2	D_2	3 Nos.	3 Nos.
Total Number of Cubes			21	21
Gross Quantity			42	
P = Portable water D_1 = Effluent from Kasarwadi STP D_2 = Effluent from Akurdi STP				

Table No.4 Various combinations used for casting and curing of concrete cube samples.

Results obtained at the age of 7 days and 28 days of concrete for various combinations are summarized in Table No.5

Sr. No	Combination (Set of 3 Cubes)	Average Strength after 7 days in N/mm^2	Average Strength after 28 days in N/mm^2
1	PP-1, PP-2, PP-3	24.10	---
2	PP-4, PP-5, PP-6	---	31.89
3	D_1P-1, D_1P-2, D_1P-3	22.07	---
4	D_1P-4, D_1P-5, D_1P-6	---	32.04
5	PD_1-1, PD_1-2, PD_1-3	23.63	---
6	PD_1-4, PD_1-5, PD_1-6	---	32.68
7	D_1D_1-1, D_1D_1-2, D_1D_1-3	22.90	---
8	D_1D_1-4, D_1D_1-5, D_1D_1-6	---	30.96
9	D_2P-1, D_2P-2, D_2P-3	21.80	---
10	D_2P-4, D_2P-5, D_2P-6	---	31.78
11	PD_2-1, PD_2-2, PD_2-3	25.00	---
12	PD_2-4, PD_2-5, PD_2-6	---	34.79
13	D_2D_2-1, D_2D_2-2, D_2D_2-3	22.89	---
14	D_2D_2-4, D_2D_2-5, D_2D_2-6	---	33.94

Table No. 5 Compressive strength at 7 & 28 Days of concrete.

The compressive strength of those combinations are summarized in table No. 5 and Graphically represented in Fig. No 1 It is observed that according to the guidelines given by Indian standard, the strength is gained by all the combinations of concrete. The highest compressive strength was observed for the combination PD2. In this combination, for the

casting of concrete portable water is used and for Curing effluent water from Akurdi STP was used.

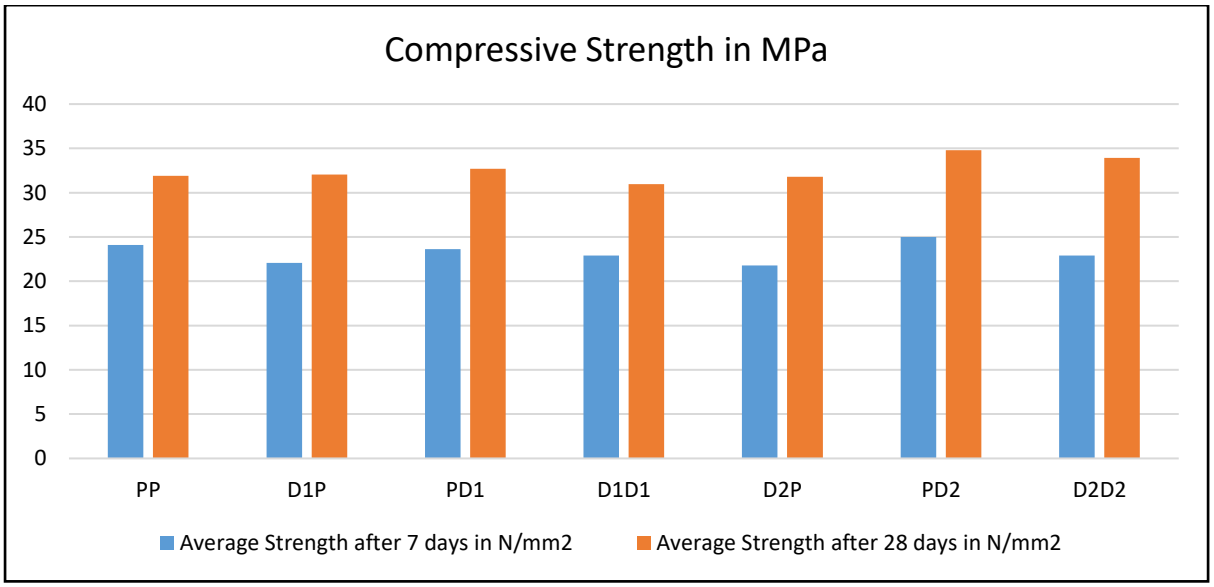

Fig No 1. Compressive strength of concrete at the age of 7 & 28 days,

To analyse the reason for getting maximum compressive strength for the PD_2 combination, microscopic analysis was carried out using the X-ray diffraction (XRD) Method at the National Chemical Laboratory (NCL, Pune). Three combinations PD_2, D_2D_2 & D_2P was selected for microanalysis as the compressive strength for D_2P is 31.78MPa, increases to 34.79 MPa for PD2 and again lower for D_2D_2 as 33.94 MPa.

The XRD elemental analysis for the three combinations, PD_2, D_2D_2 & D_2P was summarized in table No.6

XRD Elemental analysis of cement concrete for three proportions:

Weight %	**C K**	**OK**	**Na K**	**Al K**	**Si K**	**P K**	**Pb M**	**Cd L**	**Ca K**	**Fe K**	**Hg L**
D_2P	2.76	43.35	0.45	1.71	8.27	0.5	0.12	0.03	32.59	2.51	0
PD_2	5.46	47.52	2.06	2.28	9.05	0.6	0.1	0	24.52	1.32	0
D_2D_2	3.57	45.19	0.95	6.74	0	0.51	0.05	0.05	34.14	1.68	7.1

Table No 6 The XRD elemental analysis for the three combination

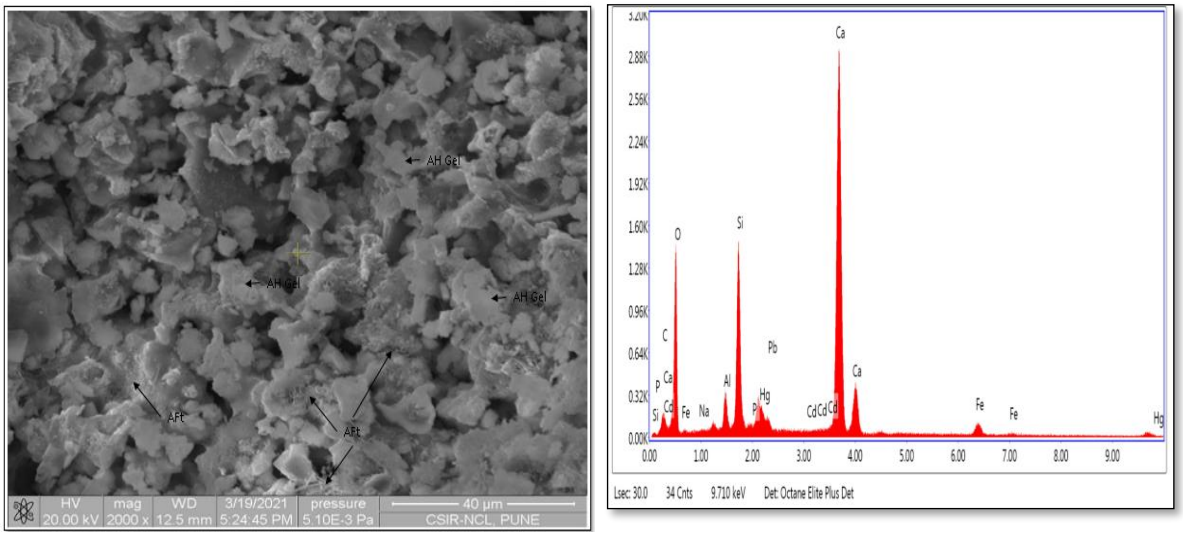

Fig No 2 XRD Spectrum for D_2P sample

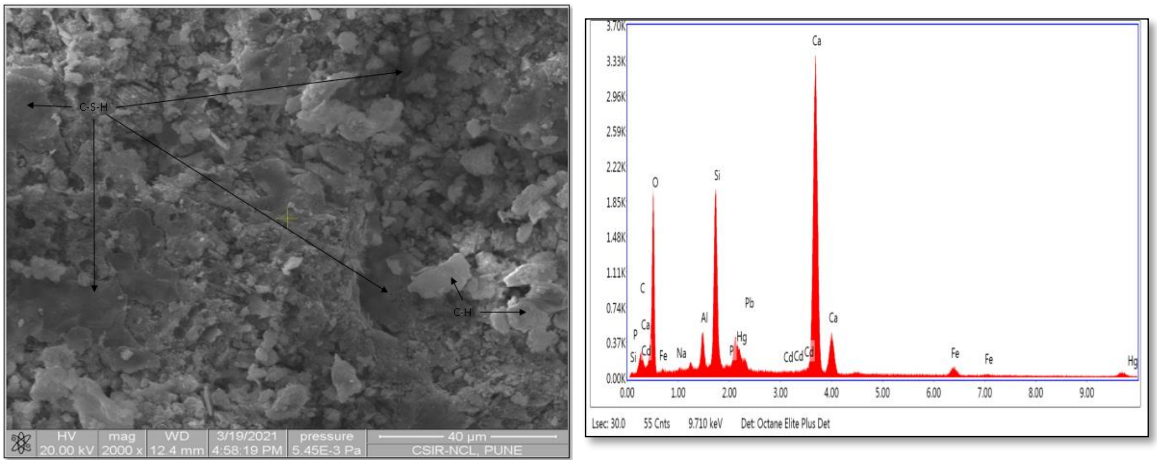

Fig No 3 XRD Spectrum for PD_2 sample

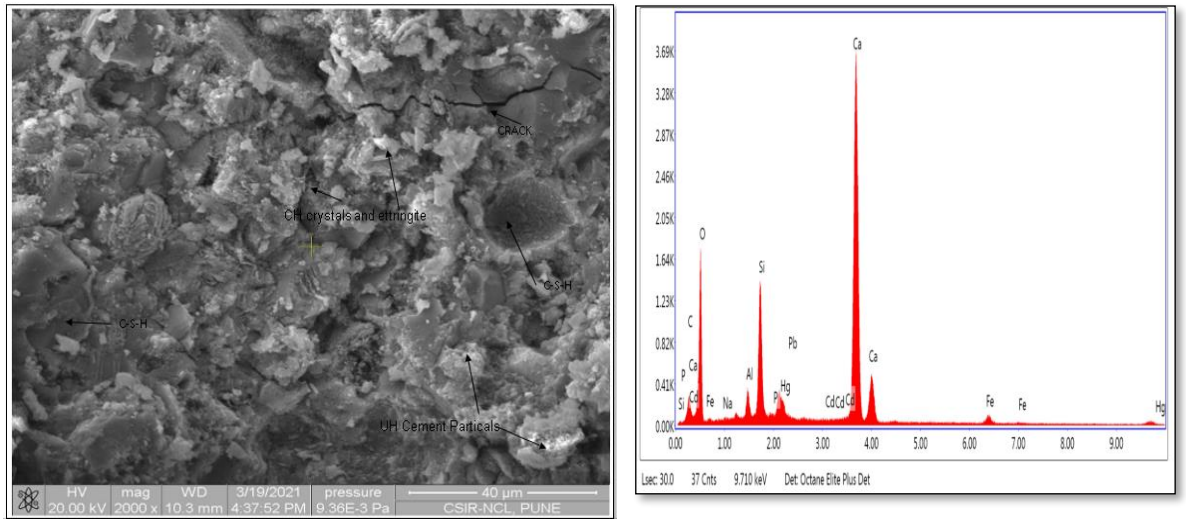

Fig No.4 XRD Spectrum for D_2D_2 sample

The four principal minerals as C3S, C2S, C3A & C4AF react with each other and form a complex structure. The calcium silicate reacts to give calcium hydroxide and calcium silicate hydrate and give Aft & AFm.

It is clearly observed from Fig No.2 that the formation of Aft (Aft denotes the phases related to ettringite-calcium aluminium trisulfate with F indicating the possible substitution of iron for aluminium in the structure) and AH Gel (Aluminium Hydroxide) is more. The hydration process was not completely occurred for this combination and results in lower strength. Whereas for the combination PD2, the C-S-H gel (Calcium Silicate hydrate) is completely formed and the uniform dark grey colour patches which cover most of the area can be observed in the microstructure.

UH (Unhydrated particles) and CH (Calcium Hydroxide) are the brightest particles in the microstructure. The C-S-H gel forms dense material and can also be observed in the D_2D_2 combination.(refer Fig No 3& 4)

The percentage weight for calcium observed as maximum 5.46% in the PD_2 & lowest as 2.76% for D_2P.

Weight %	**C K**
PD_2	5.46
D_2D_2	3.57
D_2P	2.76

Table No 7 The percentage weight for calcium observed for three combinations in micro analysis.

CONCLUSION

From above research work it is concluded that,

1. The effluent received from the STP located at Kasarwadi and Akurdi, Pune can be reused for casting and curing purpose.
2. The compressive strength for PD_2 is maximum and the same can be used on the construction site. Here all other combinations also satisfy the strength criteria given in the Indian standard.
3. The analysis report of microstructure of concrete shows that Cyanogen chloride (CK) is maximum for the PD_2 combination.
4. The C-S-H gel formation is highest in the PD_2 combination and leads to higher compressive strength.

REFERANCES

1. Ainul Haezah Noruzman, Bala Mohammad, Mohammad Ismail, Zaiton Abdul-Majid (2012), “Characteristics of treated effluent and their potential applications for producing concrete”, Journal of Environmental Management,27-32.
2. David Darwin And Mohamed Nagib Abou-Zeid (2016),"*Application of automated image analysis to the study of cement paste microstructure*”, Materials Research Society

symposia proceedings.

3. Devendra Swami, Kaustav Sarkar and Bishwajit Bhattacharjee (2015), "*Use of treated domestic effluent as mixing water for concrete: Effect on strength and water penetration at 28 days*",Indian Concrete Journal, 1-9.
4. Dhirajkumar Lal , Aniruddha Chatterjee, Arunkumar Dwivedi (2009),"*Investigation of properties of cement mortar incorporating pond ash – An environmental sustainable Material*", Construction and Building Materials (209), 20-31.
5. E. Hewayde, M. Nehdi, E. Allouche and G. Nakhla (2006), "*Effect of geopolymer cement on microstructure,compressive strength and sulphuric acid resistance of concrete*", Magazine of Concrete Research, 58, No. 5, 321–331.
6. Joo-Hwa Tay and Woon-Kwong Yip(1987),"*Use of reclaimed wastewater for concrete mixing*",J. Environ. Eng..113:1156-1161.
7. K. S. Al-Jabri, A. H. Al-Saidy, R. Taha, A. J. Al-Kemyani (2011), "*Effect of using wastewater on the properties of high strength concrete*",Procedia Engineering, 370-376.
8. Karen L. Scrivener (2009),"*Importance of microstructural understanding for durable and sustainable concrete*", Concrete Repair, Rehabilitation and Retrofitting II, Taylor & Francis Group, London,13-20.
9. L. Evangelist, M. Guedes, A. C. Ferro and J. de Brito (2013), "*Microstructure of concrete prepared with construction recycled aggregates*",Microsc. Microanal. 19 (Suppl 4), © Microscopy Society of America 2013,147-148.
10. M. Etxeberria, E.Va´zquez and A. Marı (2006),"*Microstructure analysis of hardened recycled aggregate concrete*", Magazine of Concrete Research, 58, No. 10, 683–690.
11. Mohammad Shekarchi, Mahdi Yazdian & Naser Merhrdadi (2012), "*Use of biologically treated domestic waste water in concrete*",Kuwait J. sci. Eng.39 (2B), 97-112.
12. Mr. Asif Rashid Shaikh,Dr. V. M. Inamdar (2016),"*Study of Utilization of Waste Water in Concrete*"IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),Volume 13(4),105-108.
13. Mr. Manjunatha.M (2017),"*An Experimental Study on Reuse of Treated Waste Water in Concrete – A Sustainable Approach*",International Journal of Latest Engineering Research and Applications (IJLERA), Volume – 02(7),124-132.
14. Ms.Spoorthy B. C., Ms.Bhavana P. V., Ms.Sanjana N. N., Ms.Suchitra S. S. (2012), "*Determination of harden properties of concrete using STP treated water and untreated wash water*", Adichuchanagiri Institute of Technology, Chikkmagaluru.
15. Ooi Soon Lee, Mohd Razman Salim,, Mohammad Ismail, &Md. Imtiaj Ali (2001)," *Reusing treated effluent in concrete technology*", Jurnal Teknologi, 34(F),1-10.
16. P. Rama Mohan Rao, S. M. K. Moinuddina And P. Jagadeesh (2014),"*Effect of treated waste water on the properties of hardened concrete*",Int. J. Chem. Sci.: 12(1), 155-162.
17. Ramkar A.P., Ansari U.S.(2016),"*Effect of Treated Waste Water on Strength of Concrete*",IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),Volume 13(6), 41-45.
18. Vinut Kulkarni, Suresh G Patil, Shivasharanappa(2014),"*Study on compressive strength of concrete by using treated domestic waste water as mixing and curing of concrete*", Volume: 03(12),152-156.

19. Vijay H (2017), "*Reusing Treated Effluents for Making Concrete*", International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS),Volume VI(I),21-29
20. Sachin Mane, Shaikh Faizal, Gyan Prakash, Shamli Bhandarkar, Vikki Kumar (2019),"*Use of Sewage Treated Water in Concrete*",International Journal of Research in Engineering, Science and Management, Volume-2(6), 210-213.

IS CODE REFFERED

1. IS 456 (2000) : Plain and Reinforced Concrete – Code of Practice [CED 2 : Cement and Concrete]
2. IS 3025 (Part 1) [1987, Reaffirmed 2003]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 1 : Sampling
3. IS 3025 (Part 9) [1984, Reaffirmed 2012]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 9 : Temperature
4. IS 3025 (Part 10) [1984, Reaffirmed 2012] : Method of Sampling and Test (Physical and Chemical) for Water and Wastewater, Part 10 : Turbidity
5. IS 3025 (Part 15) [1984, Reaffirmed 2009]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 15 : Total Residue (Total Solids – Dissolved and Suspended)
6. IS 3025 (Part 16) [1984, Reaffirmed 2006]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 16 : Filterable Residue (Total Dissolved Solids)
7. IS 3025 (Part 17) [1984, Reaffirmed 2012]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 17 : Non-Filterable Residue (Total Suspended Solids)
8. IS 3025 (Part 18) [1984, Reaffirmed 2012]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 18 : Volatile and Fixed Residue (Total, Filterable and Non-Filterable)
9. IS 3025 (Part 22) [1986, Reaffirmed 2009] : Method of Sampling and Test (Physical and Chemical) for Water and Wastewater, Part 22 : Acidity
10. IS 3025 (Part 23) [1986, Reaffirmed 2003]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 23 : Alkalinity
11. IS 3025 (Part 24) [1986, Reaffirmed 2009]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 24 : Sulphates
12. IS 3025 (Part 32) [1988, Reaffirmed 2009]: Methods of sampling and test (physical and chemical) for water and wastewater, Part 32 : Chloride