Corrosion studies of Self Compact Concrete with dilute Hydrochloric Acid in Chemical Industries

Appanna Babu.Gunta

Abstract: ***Corrosion is the deterioration or destruction of material by chemical or electro chemical reaction with its environment. The effect of the effluent dilute Hydrochloric acid on self compact concrete was cured using concrete with water-binder ratio 0.5, of after making there to shape of cubes. Silica fume content was 7.5% by weight of cement & fly ash content 17.5% by weight of cement. High range water reducing agent (HRWRA) was to ensure the better workability. For each mix sample, the effect of the variable parameters like p^H value of the acid & its concentration, time of exposure, were studied. Also the effects of sea water & air on these mixes were studied. In this study the concrete cubes were exposed to hydrochloric acid (HCl) of different concentrations like (25 ppm, 50 ppm, and 100ppm), seawater, open air and pure water. The amount of acid consumed by concrete per unit surface area, variation of concrete strength and weight with time for different concentrations of hydrochloric acid was summarized. The tests revealed that self compacting concrete (SCC) cubes consumed acid, in all concentrations for 90 days, in increasing order with increase in concentration of acid, The rate of consumption of acid is higher initially and then decreases gradually with age. With 25 ppm concentration of hydrochloric acid in contact , the concrete cubes shows a slight gain in weight as well as strength where as, in all remaining concentrations Hydrochloric acid, the weight and the strength followed a decreasing trend with increase in concentration of Hydrochloric acid studied. The consumption of acid on concrete cubes increased with increase in time. The percentage decrease in strength increased with increase in the hydrochloric acid concentration. The use of both silica fume, fly ash resulted in drastic reduction in chloride permeability at all the ages.***

Keywords: Compressive strength, silica fume, durability, fly ash, corrosion, and self compacting concrete.

I. INTRODUCTION

The usage of concrete structures in the modern civilized work has been beyond expectations making them now and then a scare commodity. Under certain climatic/ environmental conditions, they too were found to under go chemical attack leading to, if neglected, catastrophic failures, which are even unwarranted some times. Most of the chemical industries emit out various pollutants, as per norms of the pollution control board. In some industries these limits are not properly followed. While in some cases though the limits are followed even small concentrations of emmittences, some times, affect the strength of concrete due to corrosion. In view of this, there is lot of threat of deterioration due to chemical corrosion [1] to the concrete structures, which are with in premises of industries, And also to the other civil structures in proximity of these industries. Acidic environment is prevalent in fertilizer, tanning industries, smelters etc, the pollutants in the effluent water streams, affect the concrete structures near the effluent drainages and water bodies while the chloride gases [2] pollutants get converted to hydrochloric acid due to photo chemical reaction, rainout, washout and due to reaction with the moisture content.

The present work is envisaged to study the effect of hydrochloric acid on self-compact concrete. Chlorides act on the concrete structures and lead to deterioration [3]. Self-compact concrete is a high performance concrete. It is very useful application in the precast industry because of its requirements for high strength and high flow ability [4]. Self-compact concrete is used to improve the productivity of casting congested sections and to ensure proper filling of restricted areas, such that concrete can improve the homogeneity of high flow able concrete that is necessary to good bond development with reinforcing steel, adequate structural performance and proper durability [5].

In the present work, studies are conducted on the self compacting concrete made with silica fume, OPC, fly ash and admixtures where exposed to different concentrations of hydrochloric acid and open air, sea water and pure water. The amount of acid consumed by concrete per unit surface area with time, strength and weight reduction in concrete and depth of deterioration of concrete for a given amount of acid consumed are studied. These calculations are useful to estimate the life expectancy of the structures and to take necessary steps to protect the concrete by providing additional cover or by applying protective coatings etc.

II. MATERIALS AND METHODS

Cement: Commercially available Ordinary Portland Cement 53 grade used in the study. The cement was tested for a various properties as per IS 4031-1981.Cement was used in present study is 5.247 kg per every nine cubes.

Silica fume**:** Fosroc 10,000 slurry type silica fume was used. 0.4 kg of silica fume was used for every nine cubes.

Fly ash: Fly ash used in the experimental work was obtained from NTPC thermal plant Vishakapatnam.Fly ash having mean size 3 mm was used in the investigation and 0.9182 kg of fly ash used in every nine cubes.

Coarse and fine aggregate**:** 13 kg of coarse and fine aggregate was used.

Superplasticiser: Superplasticizar is a modern type of water reducing admixture, much more effective than the other mixtures and 52.47 ml of admixture were used.

Revised Version Manuscript Received on December 24, 2016.

Appanna Babu.Gunta, Department of Chemical Engineering, Dire Dawa Institute of Technology, Dire Dawa University, Dire Dawa – 1362, Ethiopia.

III. EXPERIMENTAL WORK

10×10×10 cm of 63 concrete cubes were cast to study the compressive strength and weights and consumption of acid. These cubes are prepared by every nine sets of cubes from above data.

First set nine cubes were kept in water for 7, 14, 28 days. Second, third and fourth sets are kept in water for 28 days and then exposed to pure water, sea water, atmosphere air for 7, 28 and 90 days. 5^{th}, 6^{th} and 7^{th} set of cubes were kept in water for 28 days and then exposed to hydrochloric acid of 100 ppm, 50 ppm and 25 ppm concentrations in different closed containers respectively for 7,28 and 90 days.

A. Volumetric Analysis Adopted for Replenishing the Acid Consumed

After 28 days of water curing the cubes were exposed to dilute hydrochloric acid of 100 ppm, 50ppm and 25ppm concentrations. The strength of acid was measured at regular interval and the depleted acid was replenished. The strength of hydrochloric acid present in the sample was estimated by volumetric analysis.

IV. RESULTS AND DISCUSSION

The advantage of SCC prompts for regular usage as a structural concrete. The initial increase in cost is expected to give some trade off due to reduction in the number of labor engaged and elimination of vibrators. Further, it is expected to offer better resistance in aggressive environment due to the type of ingredients used. In this context an attempt has been made to study the resistance of SCC to aggressive environment like hydrochloric acid.

From the experimental investigations, the data has been tabulated and graphically represented to show the behavior of SCC with respect to volume of acid consumed, loss of weight and compressive strength of concrete when exposed to conditions such as acid, air, Sea water and water.

The chlorides formation on the surface of the concrete cubes in the form of white fins and a spongy layer of small thickness can be predominantly seen in the case of concrete exposed to 25ppm Hydrochloric Acid. In case of 100 ppm and 50 ppm concentration of Hydrochloric Acid, the dissolving attack being dominant the surface got dissolved fast and hence no fins or spongy layer formation could be seen on the surface.

A. Variation of Consumption of Acid:

The variation of consumption of acid (V) in lt/m^2 of surface area of SCC cubes with age for a maximum age of 90 days was studied. The concrete cubes were first cured in water for 28 days and then immersed in acid solutions of 100 ppm, 50 ppm and 25 ppm concentrations for 90 days. The quantity of acid consumed by the cubes is found to increase with the increase in all concentrations of acid. The rate of consumption of acid is higher initially but it gradually decreases with age. The maximum variation of acid consumed after 28 and 56 days exposure to hydrochloric acid of 100 ppm, 50 ppm and 25 ppm concentrations.

Table II shows the variation of volume of acid consumed in lt/m ^{2} of surface area with age for concrete exposed to hydrochloric acid of 25 ppm concentration. Compacted concrete had less consumption initially and then increased.

Tab II & III shows the variation of volume of acid consumed with age for cubes in Hydrochloric acid solution of 100 ppm and 50 ppm concentrations. Compacted concrete having less consumption initially and then increases more acid at 28 and 56 days.

B. Variation of Compressive Strength:

The variation of compressive strength for concrete cubes where exposed for 90 days to 100 ppm, 50 ppm, 25 ppm concentrations of acid solution, sea water, open air and pure water were studied. The Compressive strengths were found out at the end of 7, 28 and 56 days for all series. For 100 ppm and 50 ppm of acid exposure the compressive strength decreased with increase in dosage of hydrochloric acid. But for 25 ppm of acid exposure the compressive strength was lightly improved, probably due to the further curing of the concrete at very low concentrations, making it as equal as water.

The variation of 7, 28 and 90 days compressive strength of concrete cubes curing in water, open air and Sea water was studied. For open air and sea water these strengths showed a slight variation in decreasing order at 7 days and 28 days and then the strength decreases 90 days exposure.

It was also observed, that the strength reduced with increase in exposure time. In all concentrations the percentage reduction of strength was high for 54 days and there after the percentage reduction of strength was marginal.

V. CONCLUSIONS

- 7.5% replacement of cement by silica fume has shown improved strength properties of the self compacting concrete. Therefore in all cases 7.5% replacement was considered. The silica fume thus added accelerates the strength development due to its pozzolinic reaction at an early stage. It also helps in improving the durability of concrete and reducing the deterioration when exposed to hydrochloric acid of different concentration.
- The use of fly ash in the concrete increases flow ability and workability, it further helps in the development of strength at early stages.
- The absolute strength of concrete, increased with time for all acid concentrations up to about 50 days of curing and beyond 50 days the absolute strength values showed gradual fall depending on the concentration of the acid exposed. The percentage decrease in strength increased with increase in the hydrochloric acid concentration.
- Chlorides in the hydrochloric acid are the essential pollutant that deteriorates the concrete strength due to formation of corresponding chlorides chemically**.**

Conflict of Interests

We are declaring that there is no conflict of interest regarding of this paper**.**

REFERENCE

1. Corrosion of metal in concrete, ACI Committee 222, American concrete institute, Farmington Hills, 1989.

2. Saudal-Bahar,Emmanuel, Attiogbe and Hasankamal Investigation of corrosion damage in the rein forced concrete structures in KUWAIT, ACI materials Journal, May-June1998, vol.95, No.3, pp. 226-231
3. Matta, z.g Chlorides and corrosion in the Arabian Gulf environment, Concrete International,, May 1992, Vol 14, No 5, pp 47-48.
4. Hajimc Okamura, Self Compacting high performance concrete, Concrete International, March 1997, pp 56-59.
5. Gjory O.E. and Vessenland Effect of condensed Silica fume on steel corrosion in concrete, ACI Materials Journal, No 6, Vol 27, 1997.
6. Samir Surlaker Self compacting concrete, ICJ Journal, January-March 2002.
7. ACI Committee 2001, Guide to durable concrete, ACI Materials Journal, Sep-Oct 1991.
8. Al – Amoundi, Mohammed Maslehuddin and Mohammed M. Saadi, Effect of magnesium sulphate and sodium sulphate on the durability performance of plain and blended cement, ACI materials Journal, No.1, Vol.92, Jan – Feb 1995, pp15-24.
9. Al. Amondi, Influence of chloride ions on sulphate deterioration in plain and blended cements", ACI Materials Journal, No.167, Vol.46, June 1994.
10. Appa Rao G, Raghu Prasad B.K., Fracture energy and softening behavior of high strength concrete, Cement and concrete Research, Vol 32, pp 247 – 25,2002.
11. Bache H.H, Densified cements, Ultra-Fine Particle Based Materials, Paper presented at 2nd International conference on Superplasticizers in concrete, Ottawa, Canada,1982.
12. Biczock, Concrete corrosion-concrete protection, 8th edition, Academia Kaido Budapest, 1972, pp 545.
13. Lawrence C.D., Sulphate Attack on concrete, Magazine of Concrete Research, No.153, Dec 1991.
14. Celik Ozyildurim, Laboratory Investigation of Low Permeability Concrete Containing Slag and Silica Fume, ACI Materials Journals No.2, Vol.91, March-April,1994.
15. Detwelin, Fap Dhenda and Natala, Use of supplementary cementing materials to Increase the Resistance to Chloride Ion Penetration of Concrete Cured at Elevated Temperatures, ACI Materials Journal, No.2, Vol.91,Jan-Feb 1994.
16. Dieb and Hooton Water permeability measurement of high performance concrete using a high pressure triaxial test, Cement and Concrete Research, No:6, Vol.25, 1995.
17. Shaker .F.A , A.S.El-Deib, and M.M.Reda, Durability of styrene-butadiene latex modified concrete, No.5, Vol.27, 1997, pp 711-720.
18. Zha .F.P , B.I.G. Barr, F.D Lydon, Fracture properties of high strength concrete with varying silica fume content and aggregates, Cement and Concrete Research, Vol 25,1995,pp 543-552.
19. Ferraris. F.Chiara, Brower Lynn, Celikozy ildirim, Daczko Joseph, Workability of Self compacting concrete, PCI International symposium on HPC, Sept 25-27, 2000.
20. Giaccio. G, C.Rocco, R. Zerbino The fracture energy of high strength confutes, Materials Structures, Vol 26, 1993, pp 381-386.
21. G.Vander Wegen, Behaviour of concrete affected by seawater under high pressure, Material and Structures, No.163, Vol.26, November 1993.
22. Glenn Willian Depy, Freeze thaw and acid resistance of polymer impregnated concrete, Durability of Concrete, ACI Special Publication, Vol 47, 1975.
23. Hajimc Okamura, Self Compacting high performance concrete, Concrete International, March 1997, pp 56-59.
24. Hinduy, Drying Shrinkage of Ready – Mixed High Performance Concrete, ACI Materials Journal, No.3, Vol.91, May-June 1999.
25. Huseyin Sarisinem, Mohd.Maslehuddin, Abdulhamid, J. AL-Tayyib and Abdulaziz, I Al-Mana, Permeability and Durability of Plain and blended cement concretes cured in field and laboratory conditions, ACI Materials Journal, No.2,Vol.92, Mar-April-1995.

Table I. Amount of 100 PPM HCL Consumed by Cement Concrete.

S. No	AGE (DAYS)	Volume of HCL Added (ml)	Cumilative Volume of HCL Added (ml)	Volume V(lit/m^2)
1	1	1.67	1.69	0.2463
2	6	2.58	3.27	0.4851
3	12	1.3	7.37	0.8372
4	18	1.3	9.97	1.0855
5	24	1.4	12.57	1.3261
6	30	1.4	17.07	1.9569
7	36	1.4	19.87	2.2548
8	42	1.2	21.07	2.2544
9	48	1.2	23.47	3.7675
10	54	1.2	24.37	4.1314
11	60	0.9	25.17	4.4842
12	66	0.8	26.77	7.2388
13	72	0.8	29.27	7.7347
14	80	0.5	29.87	16.890
15	86	0.5	29.87	17.800
16	90	0.3	30.07	18.240

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Table II. The Amount of 50 PP_M HCL Consumed Cement Concrete Cubes.

S. No	Age (Days)	Volume of HCL Added (ml)	Cumilative Volume of HCL Added (ml)	Volume V(lit/m^2)
1	1	0.845	0.845	0.00242
2	6	0.845	2.44	0.0819
3	12	0.75	3.14	0.1369
4	18	0.70	3.82	0.4156
5	24	0.68	4.5	0.5344
6	30	0.68	5.05	0.8118
7	36	0.55	5.58	0.9479
8	42	0.53	6.61	1.074
9	48	0.50	6.62	1.7577
10	54	0.50	7.12	1.9037
11	60	0.5	7.52	3.0638
12	66	0.4	7.92	3.2611
13	72	0.4	8.12	7.066
14	80	0.2	8.32	7.4055
15	86	0.2	8.42	7.5694
16	90	0.1	8.56	7.8745

Table III. The Amount of 25 PPm HCL Consumed on Cement Concrete Cube

S. No	Age (Days)	Volume of HCL Added (ml)	Cumilative Volume of HCL Added (ml)	Volume V(lit/m^2)
1	1	0.4425	0.4425	0.0026
2	6	0.4425	0.865	0.0304
3	12	0.42	1.285	0.0692
4	18	0.40	1.685	0.1015
5	24	0.40	2.085	0.1328
6	30	0.40	2.485	0.2034
7	36	0.39	2.875	0.2404
8	42	0.37	3.245	0.2754
9	48	0.35	3.595	0.4122
10	54	0.35	4.275	0.4552
11	60	0.35	4.595	0.4964
12	66	0.33	4.905	0.8037
13	72	0.32	5.205	0.86
14	80	0.30	5.405	1.9769
15	86	0.2	5.62	2.0242
16	90	0.1	5.77	2.125

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Table IV. Strength of Concrete Cubes (10× 10 × 10) cm Cured in 100 PPm HCL.

S. No	Age (Days)	Range of Concrete Strength (Kg/cm^2)	Average Strength of Concrete (Kg/cm^2)	Average Strength of concrete Water (Kg/cm^2)	Difference in Strength (Kg/cm^2)	Percentage Decrease in Streangth Compared To Water
1	7	350 - 400	393	486	93.3	19.17
2	28	450-489	487	516.6	35.6	6.8912
3	54	432-456	456	566.6	90.4	16.714
4	90	432-478	466.6	576.6	110	19.077

Table V. Strength of Concrete Cubes (10× 10× 10)cm Cured in 50 PPm HCL.

S. No	Age (Days)	Range of Concrete Strength (Kg/cm^2)	Average Strength of Concrete (Kg/cm^2)	Average strength of concrete Water (Kg/cm^2)	Difference In Strength (Kg/cm^2)	Percentage Decrease in Streangth Compared To Water
1	7	450-480	476.6	486	10	2.055
2	28	460-473	473.3	516.6	43.3	8.8348
3	54	480-490	500	566.6	56.6	10.58
4	90	493.4-510.0	510.0	576.6	66.6	11.57

Table VI. Strength of Concrete Cubes (10× 10× 10) cm Cured in 25ppm HCL.

S. No	Age (Days)	Range of Concrete Strength (Kg/cm^2)	Average Strength of Concrete (Kg/cm^2)	Average strength of concrete Water (Kg/cm^2)	Difference in Strength (Kg/cm^2)	Percentage Decrease in Streangth Compared To Water
1	7	430-450	456.6	486	29.9	6.1444
2	28	460-482	481.6	516.6	35	6.77
3	54	470-480	480	566.6	76.5	12.51
4	90	495-495	490	576.6	86.6	15.81

Table VII. Strength of Concrete Cubes (10× 10× 10) cm Cured in Sea Water.

S. No	Age (Days)	Range of Concrete Strength (Kg/cm^2)	Average Strength of Concrete (Kg/cm^2)	Average Strength of Concrete Water (Kg/cm^2)	Difference in Strength (Kg/cm^2)	Percentage Decrease in Streangth Compared To Water
1	7	400-403	403	486	83.6	17.19
2	28	456-471.6	471.6	516.6	45	8.71
3	54	498-498	498	566.6	58.3	9.75
4	90	493.4-508.3	508.3	576.6	68.3	11.845

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Table VIII. Strength of Concrete Cubes (10× 10 × 10) cm Cured in Open Air

S. No	Age (Days)	Range of Concrete Strength (Kg/cm^2)	Average Strength of Concrete (Kg/cm^2)	Average strength of concrete Water (Kg/cm^2)	Difference In Strength (Kg/cm^2)	Percentage Decrease In Streangth Compared To Water
1	7	350-376.7	486.6	486	109.9	22.58
2	28	450-510	516.6	516.6	5.7	1.1036
3	54	495-512	524	566.6	46.3	8.45
4	90	495-520.5	576.6	576.6	56.1	9.725

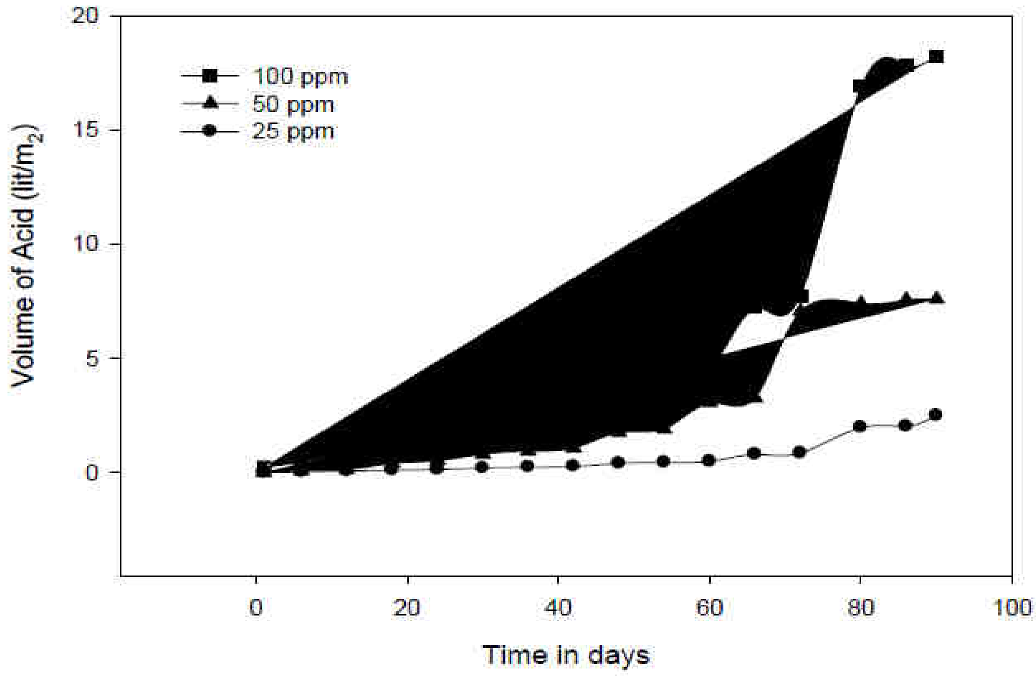

Fig 1: Comparison of Various Concentrations of Acid to Study the Acid Consumption with Time

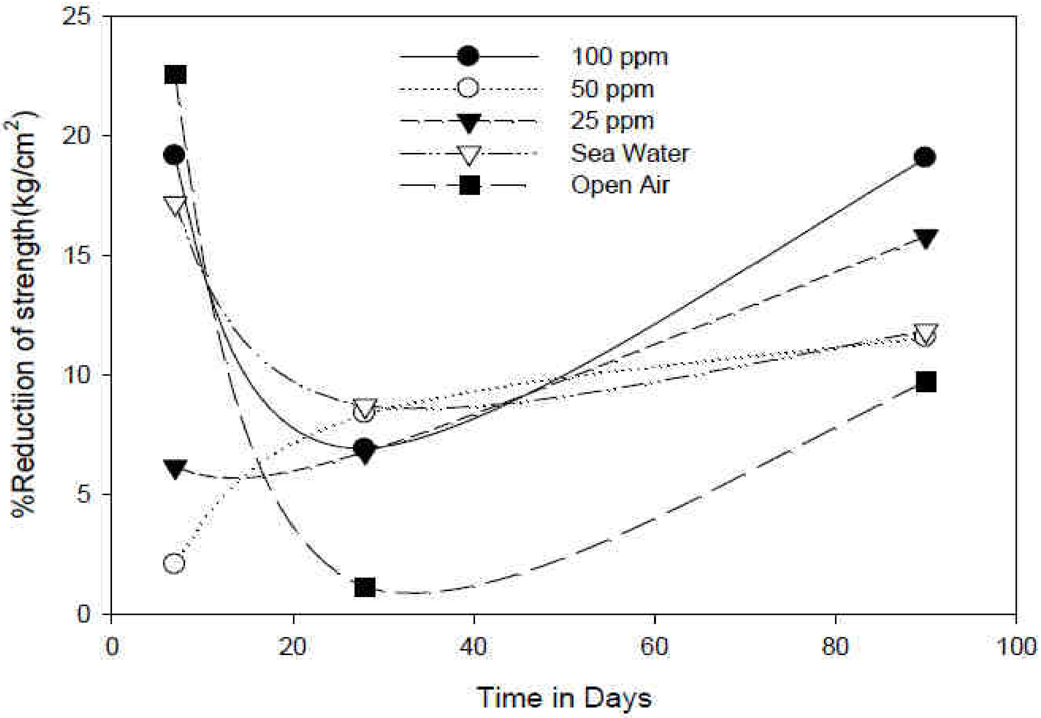

Fig 2: To study the % decrease in strength with time

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

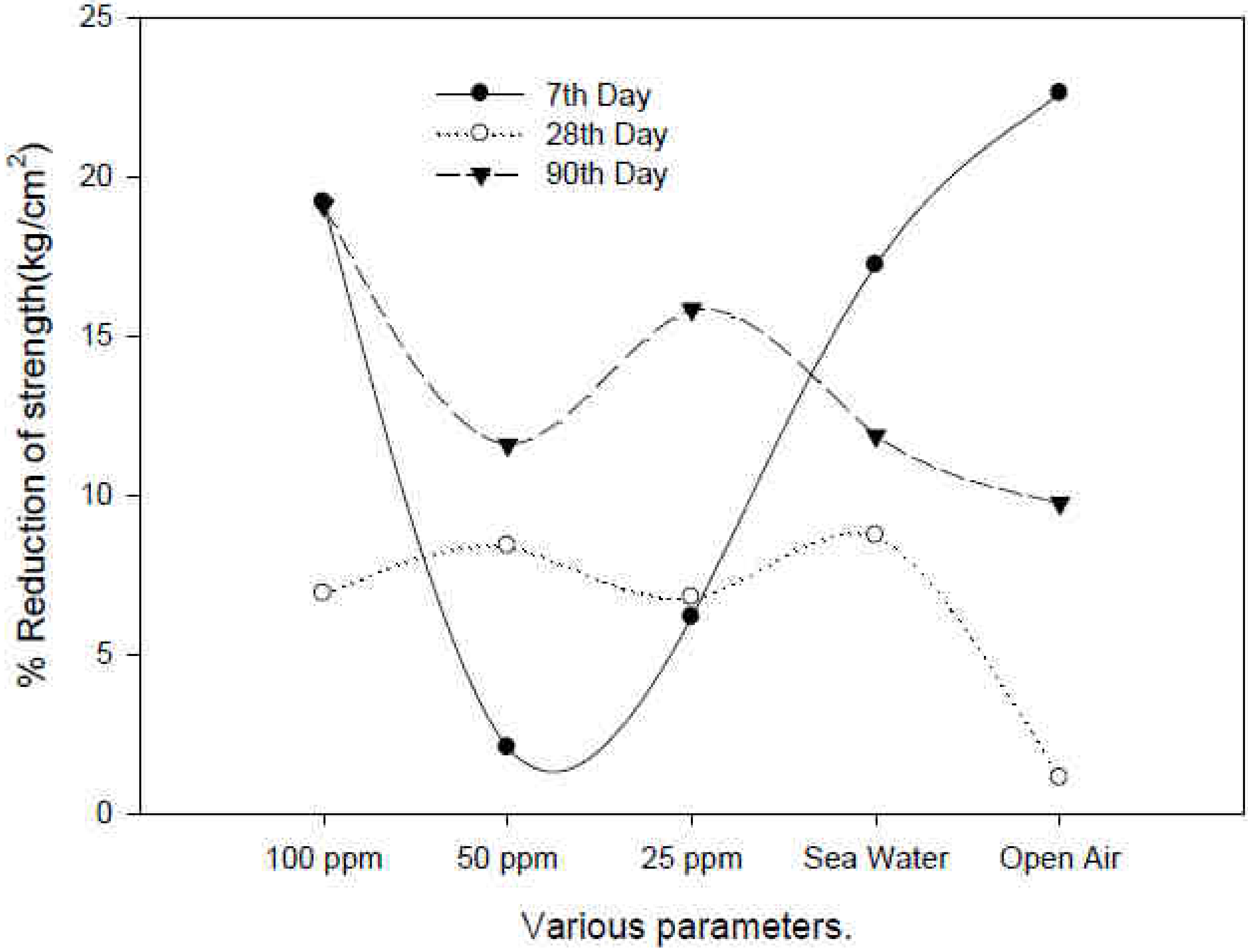

Fig 3: To study the % decrease in strength with time

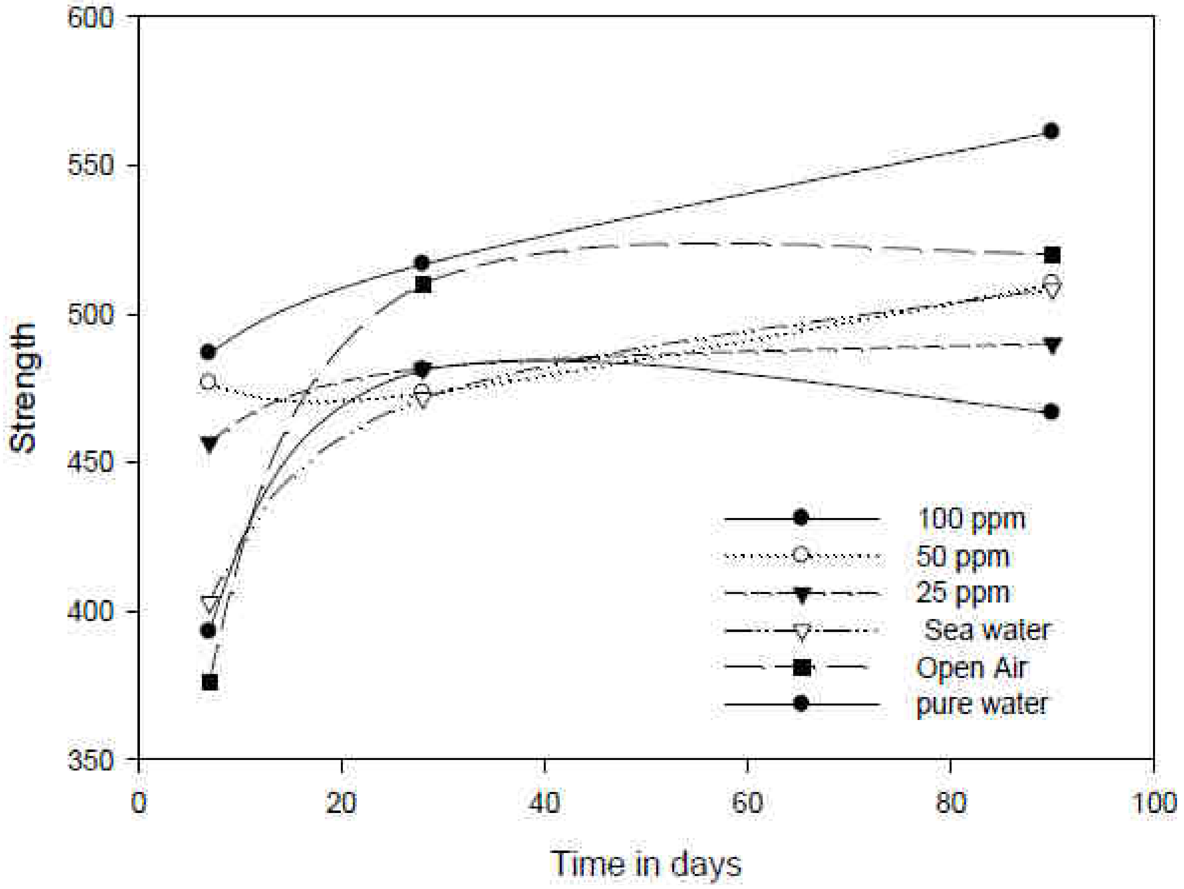

Figure4: To study the strength VS time for various concentrations

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.