American Journal of Construction and Building Materials
2020; 4(1): 27-32
http://www.sciencepublishinggroup.com/j/ajcbm
doi: 10.11648/j.ajcbm.20200401.15
ISSN: 2640-0022 (Print); ISSN: 2640-0057 (Online)

Compressive Behaviour of Steel Fiber Reinforced Concrete Exposed to Chemical Attack

Kesava Raju Vegesana*, Srinivasa Rao Killamsetty

Department of Civil Engg, Andhra University, Visakhapatnam, India

Email address:
engineersves@gmail.com (K. R. Vegesana), killamsetty@yahoo.com (S. R. Killamsetty)
*Corresponding author

To cite this article:
Kesava Raju Vegesana, Srinivasa Rao Killamsetty. Compressive Behaviour of Steel Fiber Reinforced Concrete Exposed to Chemical Attack. *American Journal of Construction and Building Materials*. Vol. 4, No. 1, 2020, pp. 27-32. doi: 10.11648/j.ajcbm.20200401.15

Received: April 29, 2020; **Accepted**: May 25, 2020; **Published**: June 9, 2020

Abstract: In this modern age, Civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional concrete has become mandatory. It has been found that steel fibers added in specific percentage to concrete improves durability of structure. The present study aims at comparing the durability in terms of weight loss and reduction in compressive strength of controlled concrete (with 0% steel fibers) and steel fiber reinforced concrete (with3% steel fibers), when exposed to acid, Sulphate and chloride attack. The grade of concrete designed for the study is M30. Hookend steel fibers with aspect ratio 50 at 0% and 3% of weight of cement are used. The specimens of 150 × 150 × 150 mm cubes are casted to find the weight loss and compressive strength of concrete. The specimens were demoulded after 24hours from the time of casting and the specimens are kept underwater for a period of 28days after that the specimens are immersed in the 5% concentrated solutions of H_2So_4, $MgSo_4$ and Nacl for a period of 30, 60, 90, 120, 150 and 180days. The experimental studies revealed that the steel fiber reinforced concrete is performed better than that with controlled concrete after exposed to the chemical attack.

Keywords: Steel Fibers, Weight Loss, Compressive Strength, Acid Attack, Sulphate Attack, Chloride Attack

1. Introduction

The concrete containing Portland cement, being highly alkaline, is not resistant to attack by strong acids. The most vulnerable part of the cement hydrate is $Ca(OH)_2$, but C-S-H gel canal so be attacked. Concrete can be attacked by liquids with a pH value below 6.5. The attack is severe only at a pH below 5.5. The attack is very severe at a pH below 4.5. Acid rain which consists mainly of Sulfuric acid and nitric acid and has a pH value between 4 and 4.5 may cause surface weathering of exposed concrete. Acids such as H_2SO_4, nitric acid, hydrochloric acid, acetic acid are very aggressive as their calcium salts are readily soluble and remove from the attack. Sulfuric acid is very damaging to concrete as it combines an acid attack and sulphate attack. HCl has a mild attack and Na_2CO_3 is negligible.

Sea water generally contains 3.5% of salt by weight. The pH of sea water varies between 7.5 to 8.4. Sea water also contains some amount of CO_2. It is commonly observed that deterioration of concrete in sea water is often not characterized by the expansion found in concrete exposed to sulphate action, but takes more in the form of erosion or loss of constituents from the parent mass without exhibiting undue expansion. It is also found that concrete will have lost some part of lime content due to leaching. Concrete exposed to sea water will suffer deterioration due to attack of dissolved chemical s on the products of hydration, there by crystallization of salts within the concrete under the alternate conditions of wetting and drying, frost actions, mechanical attrition and impact by waves and corrosion of reinforcement embedded in it.

Solid salts do not attack concrete but, when present in solution, they can react with hydrated cement paste, particularly common are sulphates of sodium, potassium, magnesium and calcium which occur in soil or in ground water. Sulphates in ground water are usually of natural origin but can also come from fertilizers or from industrial effluents. The main cause of sulphate attack on concrete is due to transport of sulphate ions in various concentrations in water together with cations, the more common of which are calcium, magnesium and sodium.

2. Literature Review

Nithin dsouza et al (2018) [12] Studied on strength and durability aspects of steel fiber reinforced concrete. For their study M25 grade concrete with hookend type steel fibers dosages of 0.5%, 1% and 1.5% by weight of concrete having an aspect ratio of 60 were used. The specimens are tested for 7 and 28 days age. It is observed that, when compared to conventional concrete the steel fiber reinforced concrete was more resistant to acid attack and sulphate attack, leading to less loss of weight and compressive strength for concrete with addition of steel fibers. Among the different percentages of steel fiber reinforced concrete, the 1.5% steel fiber reinforced by weight of its concrete is more resistant to the acid attack and sulphate attack.

Vamsi Krishna and Srinivasarao (2016) [14] Studied on durability of steel fiber reinforced concrete. The grade of concrete adopted is M30. Fiber dosage of 0.5%, 1% and 1.5% by volume of concrete were used for their study. Hookend steel fibers were randomly dispersed in concrete. The cube specimens were immersed in 3% Sulfuric acid for acuring period of 28 days and 56days. Steel fibers were found to be effective to acid resistance. Percentage loss of weight was increased with increasing in fiber dosage subjected to acid curing. Compressive strength decreased with increase in fiber dosage respectively subjected to acid curing compare to normal concrete. Fiber dosage of 0.5% shows better results.

Basavaraj and Amaresh (2015) [3] studied on durability of steel fiber reinforced concrete. For their study M40 grade concrete with steel fibers of dosage of 0.75%, 0.1% and 1.25% by volume of concrete having an aspect ratio of 54. After 28days of curing, the cube specimens are removed from the curing tank and then the cube specimens will be immersed in 3% H_2SO_4 solution an d the pH 4 is maintained constant throughout the test for a period of 5, 10, 15, 20, 25, 30, 35, 40 and 45days. Steel fiber reinforced concrete is more resistant to acid attack, when compared with conventional concrete. Highest resistance to acid attack is observed incase of 1.25% steel fiber reinforced concrete as indicated by lowest % loss in weight. Water absorption of conventional concrete is found to be higher than the steel fiber reinforced concrete. Conventional concrete has absorbed 0.577% of water where as 1.25% SFRC has absorbed 0.364% of water. Compressive strength of conventional concrete was less than SFRC after the 45days acid attack to cubes. Porosity of SFRC is considerably less than that of conventional concrete. Lowest porosity was observed in case of 1.25% SFRC mix. i.e. Conventional concrete has a porosityof 13.978% where as 1.25% SFRC has porosity of 5.33%.

Velayutham and cheah (2014) [15] studied on the effect of steel fiber on the mechanical strength and durability of steel fiber reinforced high strength concrete subjected to normal and hygrothermal curing. Hygrothermal curing was performed by placing the specimens into a hot water bath for 24 hours after the 7days normal curing at 700°C., which was optimum temperature under the curing condition. The steel fibers were added at volume fractions of 0.5%, 1%, 2% and 3%. Two types of cooling regimes i.e. normal curing and hydrothermal curing are used for investigations. Steel fiber high strength concrete shows an increase in compressive strength and flexural strength with normal water curing compared to hydrothermal curing. Normal strength concrete shows an increase in compressive and flexural strength with hygrotheramal curing. It has been found that steel fiber high strength concrete is not suitable for hygrothermal curing compared to normal strength concrete.

Srinivasarao et al (2012) [13] Studied on durability of steel fiber reinforced Metakaolin blended concrete. The grade concrete adopted is M20. Crimped steel fibers with 60 aspect ratio at 0%, 0.5%, 1% and 1.5% of volume of volume of concrete are used. 150x150x150mm cubes were cast and cured for 28days in water, after then immersed in solution of 5% concentrated H_2SO_4 and HCL solution. The loss of compressive strength and weight loss were observed after 30, 60 and 90days of immersion. Durability studies revealed that 10% replacement of cement with Metakaolin along with crimped steel fibers with 1.5% steel fibers content is more durable when compared to normal concrete after exposure to the HCL and H_2SO_4 solution. The percentage loss of compressive strength and loss of weight are increasing in with the time of exposure to acid attack. The percentage loss of compressive strength and loss of weight in 5% H_2SO_4 solution is higher than 5% HCL solution.

3. Experimental Programme

Materials used:

Cement: Portland pozzolana cement (PPC) used in this study conforms to IS1489-1:1991.

Sand: Locally available river bed sand with specific gravity 2.57 Conforming to grading zone II of IS 383:1970 is used.

Water: Potable water is used in the present study.

Coarse aggregate: Coarse aggregate having specific gravity 2.78 is used.

Steel fibres: Hook-endtypewithaspectratio50.

Mix proportion (M30): 1:1.82:3.35 with w/c ratio 0.45 (IS10262:2009).

Solutions: 5% concentrated H_2SO_4, $MgSO_4$ and NaCl solutions.

Casting and curing of specimens:

The specimens of 150 × 150 × 150mm cubes are casted to find compressive strength of concrete and weight loss of concrete. The total numbers of cube specimens casted for testing are 108. The specimens were demoulded after 24hours from the time of casting and the specimens are kept under water for a period of 28days after that the specimens are immersed in solutions for a period of 30, 60, 90, 120, 150 and 180 days respectively

Figure 1. *Casting of cube specimens.*

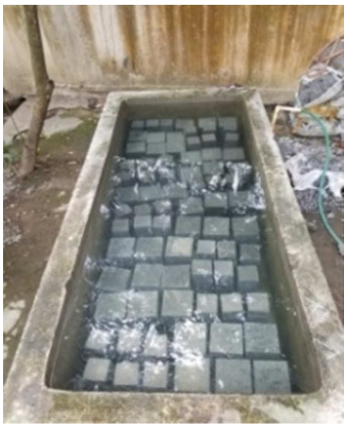

Figure 2. *Cubes under curing.*

Figure 3. *Cubes after chemical attack.*

Testing of specimens:

After completion of specified curing period, the specimens are removed from the curing tanks and tested for weight loss and compressive strength.

Weight loss:

The weight of cubes before immersed in solutions by using an electronic weighing machine and that weight is considered as initial weight in kilograms. After the cubes are removed from the solutions for specified duration, the weight of cube is measured which is considered as the final weight in kilograms. The difference in weights is the loss in weight.

Compressive strength:

The cubes are tested in 2000kN capacity digital compression testing machine after removing the cubes from chemical solutions. The testing is done as per IS: 516-1970. The load is applied till the specimen fails. The maximum load at which the specimen failed is noted. Load divided by the area of cross section of the specimen gives the compressive strength of the specimen. Each sample comprising of 3 cubes were tested and the average value is reported.

Figure 4. *Weight loss test on concrete cube.*

Figure 5. *Compression test on cube.*

4. Test Results and Discussions

Loss of weight of specimens after immersion in 5% H_2SO_4, $MgSO_4$ and NaCl solutions:

Table 1. *Percentage weight loss of controlled concrete and steel fiber reinforced concrete after immersion in 5% concentrated H_2So_4, $MgSo_4$, and NaCl solutions*

S. No	MixID	Solution	% weight loss at different ages					
			30days	60days	90days	120days	150days	180days
1	M30 with 0% SF	H_2So_4	6.76	9.96	12.24	13.76	14.83	16.93
2	M30 with 3% SF		6.44	9.76	13.05	13.44	14.49	16.07
3	M30 with 0% SF	$MgSo_4$	0.23	0.35	0.51	0.62	0.84	0.93
4	M30 with 3% SF		0.12	0.27	0.43	0.59	0.63	0.70
5	M30 with 0% SF	NaCl	0.35	0.39	0.45	0.64	0.71	0.75
6	M30 with 3% SF		0.28	0.35	0.43	0.47	0.67	0.71

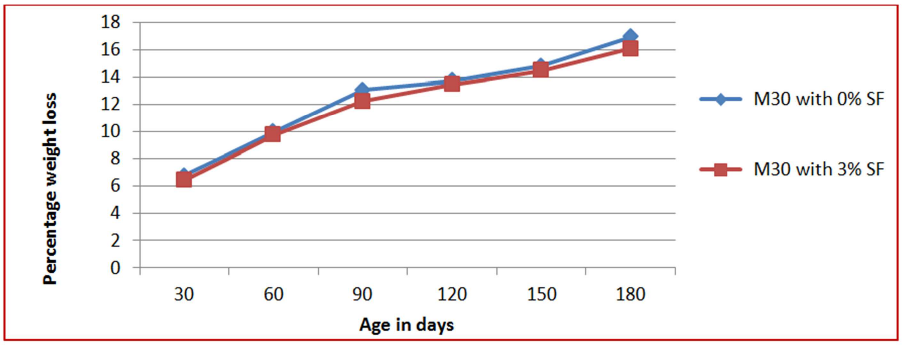

Figure 6. *Variation of weight loss with age for controlled concrete and steel fiber reinforced concrete after immersion in 5% H_2So_4 solution.*

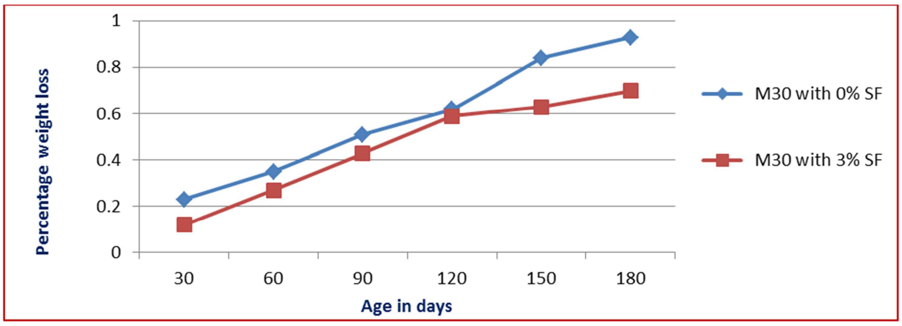

Figure 7. *Variation of weight loss with age for controlled concrete and steel fiber reinforced concrete after immersion in 5% $MgSo_4$ solution.*

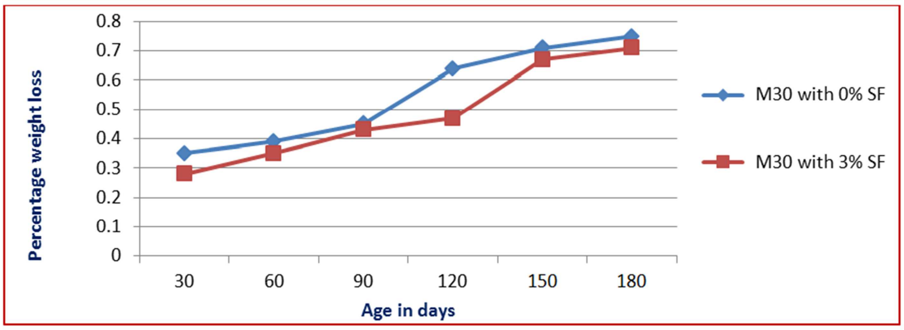

Figure 8. *Variation of weight loss with age for controlled concrete and steel fiber reinforced concrete after immersion in 5%NaCl solution.*

Loss of compressive strength of specimens after immersion in 5% H_2SO_4, $MgSO_4$ and NaCl solutions:

Table 2 gives the percentage loss of weight of steel fiber reinforced concrete and controlled concrete after being immersed in various acidic solutions like H_2SO_4, $MgSO_4$ and NaCl. The compressive strength of steel fiber reinforced concrete (with 3% fibers) is 15.3% more when compared with controlled concrete (with 0% fibers), when the specimens are immersed in H_2SO_4 solution. The compressive strength of steel fiber reinforced concrete (with 3% fibers) is 3.65% more when compared with controlled concrete (with 0% fibers), when the specimens are immersed in $MgSO_4$ solution. The compressive strength of steel fiber reinforced concrete (with 3% fibers) is 13.86% more when compared with controlled concrete (with 0% fibers), when the specimens are immersed in NaCl solution.

Table 2. *Compressive strength of SFRC and standard concrete after immersion in 5% concentrated H_2So_4, $MgSo_4$ and NaCl.*

S. No	MixID	Solution	Compressive strength (N/mm^2) at different ages in days					
			30	60	90	120	150	180
1	M30 with 0% SF	H_2So_4	17.44	14.05	9.74	9.64	9.43	9.16
2	M30 with 3% SF		22.25	15.08	12.78	10.31	10.29	10.05
3	M30 with 0% SF	$MgSo_4$	39.48	37.61	36.1	33.74	32.16	31.25
4	M30 with 3% SF		40.84	38.11	37.48	34.73	34.11	32.61
5	M30 with 0% SF	NaCl	34.80	34.77	32.24	30.14	28.11	24.56
6	M30 with 3% SF		38.56	37.83	36.1	33.89	32.52	30.67

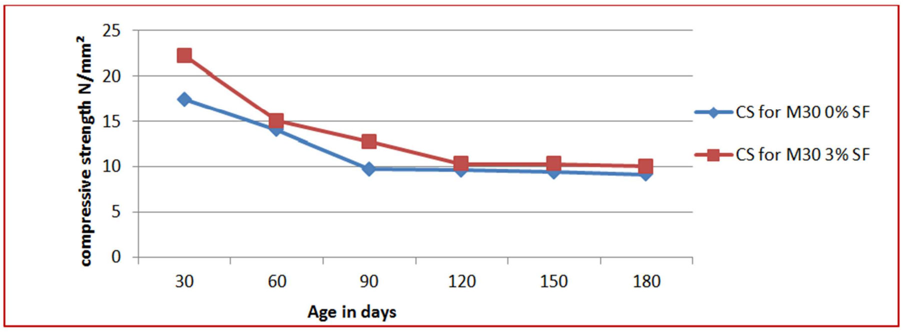

Figure 9. *Variation of compressive strength with age for controlled concrete and steel fiber reinforced concrete after immersion in 5% concentrated H_2So_4 solution.*

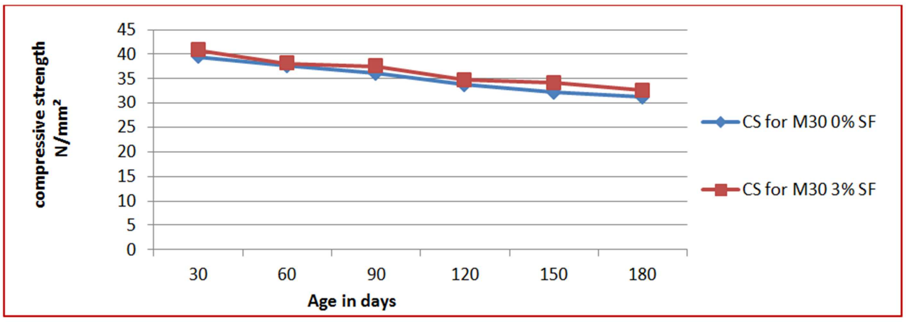

Figure 10. *Variation of compressive strength with age for controlled concrete and steel fiber reinforced concrete after immersion in 5% concentrated $MgS0_4$ solution.*

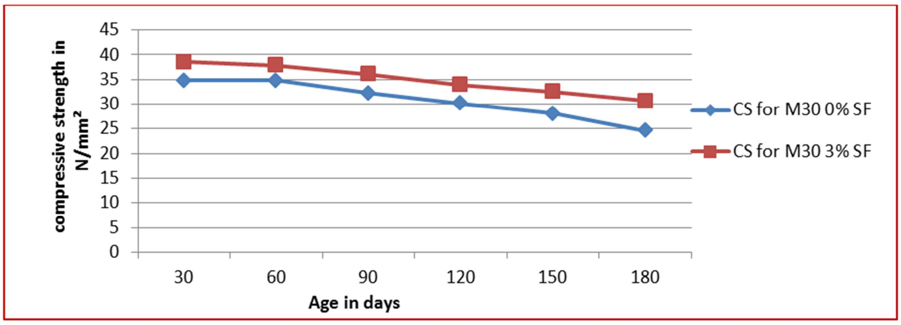

Figure 11. *Variation of compressive strength with age for controlled concrete and steel fiber reinforced concrete after immersion in 5% concentrated NaCl solution.*

5. Conclusions

1. The percentage weight loss in 5% H_2SO_4 solution is higher than 5% $MgSO_4$ solution and 5% NaCl solution in both controlled concrete and steel fiber reinforced concrete.
2. The percentage weight loss is increasing in with time of exposure to acid attack, sulphate attack and chloride attack in both controlled concrete and steel fiber reinforced concrete.
3. The percentage weight loss is less in steel fibre reinforced concrete when compared with controlled concrete in all the three solutions of H_2SO_4, $MgSO_4$ and NaCl.
4. The loss of compressive strength in 5% H_2SO_4 solution is higher than 5% $MgSO_4$ solution and 5% NaCl solution in both controlled concrete and steel fiber reinforced concrete
5. The loss of compressive strength is increasing in with time of exposure to acid attack, sulphate attack and chloride attack in both controlled concrete and steel fiber reinforced concrete
6. The values of compressive strength of steel fibre reinforced concrete were on higher side when compared with controlled concrete in all the three solutions of H_2SO_4, $MgSO_4$ and NaCl
7. Durability studies revealed that the steel fiber reinforced concrete with 3% steel fibers is more durable when compared to controlled concrete with 0% steel fibers after exposed to the H_2SO_4, $MgSO_4$ and NaCl solutions.

References

[1] A. M. Neville, Text Book "Properties of Concrete", Pearson Publishers.

[2] A. R. Santha Kumar, Text Book “Concrete Technology”, Oxford University Press.

[3] Basavaraj and Amaresh,” A study on durability of steel fiber reinforced concrete”, International journal for scientific research and development, volume3, issue6, 2015, pp. 395-401.

[4] IS 456-2000, Plain and Reinforced Concrete Code of Practice, Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002.

[5] IS1489-1991, Portland Pozzolana Cement - Specification, Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002.

[6] IS 10262-2009, Concrete Mix proportioning –Guidelines, Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002.

[7] IS 516-1959, Method of Tests for Strength of Concrete, Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002.

[8] IS 2386 (1963), “Methods of Test for Aggregate for Concrete”, Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002.

[9] Kumar Mehta. P, Paulo J. M. Monteiro, “Concrete micro structure, properties and materials”, Tata McGraw Hill Education Pvt. Ltd.

[10] M. L. Gambhir, Text Book “Concrete Technology”, Tata McGraw Hill Education Pvt. Ltd.

[11] M. S. Shetty, Text Book “Concrete Technology”, S. Chand Publishers.

[12] Nithindsouza, Nayana N Patil, H. M. Rajasekhar Swamy, “strength and durability aspects of steel fiber reinforced concrete”, International journal of civil engineering and technology, volume9, issue7, 2018, pp. 948-957.

[13] P. Srinivasarao, Sravana and Seshadri sekhar. “Durability studies on steel fiber reinforced metakaolin blended concrete”, AKGEC international journal of technology”, volume3, issue1, pp. 38-43.

[14] Vamsi Krishna and Srinivasa rao,” Durability studies on steel fiber reinforced concrete’’, International research journal of engineering and technology”, volume3, issue8, aug 2016, pp. 2119-2023.

[15] Velayutham and Cheah, “The effect of steel fiber on the mechanical strength and durability of steel fiber reinforced high strength concrete subjected to normal and hygrothermal curing’, published by EDP sciences, 2014.