Study the behavior of Flyash blended Steel Fiber Reinforced Concrete exposed to Corrosive Environment

Priyanka R. Singh[1], Niraj D. Shah[2]
[1] Galgotias University, Greater Noida, India
[2] Parul University, Vadodara, India

Abstract

In this paper, the behavior of flyash blended steel fiber-reinforced concrete exposed to corrosive environments has been investigated. Three test programs were conducted: one dealt with the effect of induced corrosion by Sulphuric acid on the compressive strength, second on the weight and third on the volume of flyash blended steel fiber-reinforced concrete specimens and plain concrete. The process of corrosion occurring in Flyash blended SFRC subjected to corrosive environment was systematically evaluated. The effects of steel fibers on the durability of concrete for M25 grade have been studied by varying percentage of steel fibers and flyash in concrete. Concrete specimens were prepared with steel fibre inclusions at 1%, 1.5% and 2% by weight of cement. Cement was replaced with flyash at 20%, 40%, and 60% of the total cement weight. The corrosion is induced by the immersion of cubes in 5% H_2SO_4 solution. The results concluded that fly ash blended steel fiber reinforced concrete is more resistant when compared with conventional concrete.

Keywords: *SFRC, Sulphuric acid, Chemical attack, Induced Corrosion & Flyash.*

1. Introduction

Most of the steel fiber reinforced concrete research is done just to solve a specific problem, and little information is available concerning the structure performance degradation of flyash blended SFRC. Steel fiber reinforced concrete (SFRC) possesses many excellent dynamic performances which has now attained acknowledgment in numerous engineering applications since it has several advantages. The randomly distributed steel fibers can be utilized to improve the physical properties of reinforced concrete structures due to the resistance from crack initiation to crack propagation. Concrete has some deficiencies such as low tensile strength, low post cracking capacity, and brittleness. Fiber addition in the concrete brings a better control of its cracking and improves its mechanical properties. Various types of fiber can be used. The metal and more particularly, steel fibers are most largely employed. Steel fiber-reinforced concrete (SFRC) is in many ways a well- known construction material, and its use had gradually increased over the last decade. The mechanical properties of SFRC are well described based on the theories of fracture mechanics. SFRC has a high cracking resistance and more progressive post behavior. It is widely used in various types of engineering construction field with its good crack resistance. Studies also indicate that the high volume fly ash with steel fibre incorporated rebar concrete had shown a favorable reduction in the corrosion potential. Concrete being very alkaline in nature, is extremely susceptible to acid attack. The mechanism for this process is very simple. The products of cement hydration are shown below.

$$CS + H = C\text{-}S\text{-}H + CH$$

Calcium Silicate + Water = Calcium Silicate Hydrate + Calcium Hydroxide.

Acid attack is caused by the reaction of an acid and the calcium hydroxide portion of the cement paste which produces a highly soluble calcium salt by product. These soluble calcium salts are easily removed from the cement paste thus weakening the paste's structure as a whole. This basic reaction is shown below.

$$\text{Acid } X + CH = CX + H$$

Acid + Calcium Hydroxide = Calcium Salt + Water

More aggressive acids such as hydrochloric, acetic, nitric, and sulphuric acids produce calcium salts that are very soluble. Less aggressive acids such as phosphoric acids produce calcium salts with a lower solubility. These low soluble salts can act as a partial inhibitor to the overall process by blocking tiny passage in the cement paste through which water flows. This reduces the amount of calcium salts that enter into solution and retard the overall process.

A more aggressive and destructive case of acid attack occurs when concrete is exposed to sulphuric acid.

The calcium salt produced by the reaction of the sulphuric acid and calcium hydroxide is calcium sulphate which in turn causes an increased degradation due to sulphate attack. This process is illustrated below.

$H_2SO_4 + Ca(OH)_2 = Ca(SO)_4 + 2H_2O$

Acid + Calcium Hydroxide = Calcium Sulfate+ Water (calcium sulfate product contributes to sulfate attack)

The dissolution of calcium hydroxide caused by acid attack takes place in two phases. The first phase is the acid reaction with calcium hydroxide in the cement paste. The second phase is the acid reaction with the calcium silicate hydrate. As one would expect the second phase will not begin until all calcium hydroxide is consumed. The dissolution of the calcium silicate hydrate, in the most advanced cases of acid attack, can cause severe structural damage to concrete. Acids attack concrete by dissolving both hydrated and unhydrated cement compounds as well as calcareous aggregate. In most cases, the chemical reaction forms water-soluble calcium compounds, which are then leached away. Siliceous aggregates are resistant to most acids and other chemicals and are sometimes specified to improve the chemical resistance of concrete. Concrete deterioration increases as the pH of the acid decreases from 6.5. In fact, no hydraulic cement concrete, regardless of its composition, will hold up for long if exposed to a solution with a pH of 3 or lower.

2. Experimental Program

The experimental investigation was focused on the effect of various steel fiber dosages and flyash to resist the chemical attack. It includes the effect of replacement of cement by fly ash and subsequent addition of steel fibers to chemical attack on hardened steel fiber fly ash concrete.

The corrosion test of Flyash blended Steel Fibre reinforced concrete is determined by rebound hammer. Corrosion test has been performed for acidic solution (sulphuric acid) on cube specimens at 1, 7, 14, 21 and 28 days.

3. Test Results

The concrete mix design was done for concrete of grade M25,whose compressive strength(C/S) at the end of 28 days was 33.27 N/mm^2.Table given below shows the effect of sulphuric acid on the Compressive strength, weight and volume of Control and Flyash blended SFRC at 20% & 30% replacement of cement by flyash.

Table1: C/S of Control with induced corrosion by Sulphuric acid at 20% replacement of cement with Flyash in N/mm^2

No. of Days	Control Mix	20% Fly ash Used		
		1% Steel fibre	1.50% Steel fibre	2% Steel fibre
0	**33.27**	**36.97**	**35.86**	**36.81**
7	31.24	32.68	31.81	30.42
14	27.82	31.47	29.72	29.75
28	25.78	28.86	26.34	26.58

Table 2: C/S of Control with induced corrosion by Sulphuric acid at 30% replacement of cement with Flyash in N/mm^2

No. of Days	Control Mix	30% Fly ash Used		
		1% Steel fibre	1.50% Steel fibre	2% Steel fibre
0	**33.27**	**35.24**	**35.45**	**32.79**
7	31.24	32.89	32.15	31.12
14	27.82	31.21	29.93	29.83
28	25.78	28.95	27.12	26.78

Table 3: Compressive Strength of Control with induced corrosion by Sulphuric acid

No. of Days	Initial C/S (N/mm^2)	Change in C/S Cubes after curing (N/mm^2)	Loss in C/S (N/mm^2)	% Loss in C/S
1	33.27	32.81	0.46	1.38
7	33.27	31.24	2.03	6.10
14	33.27	27.82	5.45	16.38
21	33.27	26.81	6.46	19.42
28	33.27	25.78	7.49	22.51

Table 4: Difference in C/S of SFRC (FA30% +SF1%) with induced corrosion by Sulphuric acid

Difference in Compressive Strength				
No. of Days	Initial C/S (N/mm^2)	C/S of Cubes after curing(N/mm^2)	Loss of C/S(N/mm^2)	% Loss in C/S
1	35.24	35.04	0.2	0.57
7	35.24	32.89	2.35	6.67
14	35.24	31.21	4.03	11.44
21	35.24	29.58	5.66	16.06
28	35.24	28.95	6.29	17.85

Table 5: Difference in C/S of SFRC (FA20% +SF1%) with induced corrosion by Sulphuric acid

No. of Days	Initial C/S (N/mm^2)	C/S of Cubes after curing (N/mm^2)	Loss in C/S (N/mm^2)	% Loss in C/S
1	36.97	36.94	0.03	0.08
7	36.97	32.68	4.29	11.60
14	36.97	31.47	5.5	14.88
21	36.97	30.58	6.39	17.28
28	36.97	28.86	8.11	21.94

Table 6: Loss of weight of Control with induced corrosion by Sulphuric acid

No. of days	Weight(kg)	Dimensions(mm)
1	2.450	100*100*100
7	2.450	99*98*98
17	2.290	99*98*97
21	2.210	98*97*97
28	2.160	97*96*96

Table 7: Loss of weight of Control with induced corrosion by Sulphuric acid

Difference in Weight				
No. of Days	Initial Weight (kg)	Weight after curing	Loss in weight(kg)	% Loss in Weight
1	2.5	2.45	0.05	2.0
7	2.5	2.35	0.145	5.8
14	2.5	2.29	0.21	8.4
21	2.5	2.21	0.29	11.6
28	2.5	2.16	0.34	13.6

Table 8: Loss of volume of Control with induced corrosion by Sulphuric acid

Difference in Volume				
No. of Days	Original Volume (mm^3)	Volume after Curing (mm^3)	Difference in Volume (mm^3)	% Change in Volume
1	$1x10^6$	941192	58808	5.88
7		941094	58906	5.89
14		941094	58906	6.09
21		922082	77918	7.79
28		893952	106048	10.6

Table 9: Effect of Sulphuric acid on Weight and Dimensions of SFRC (30% FA+1% SF)

No. of days	Weight(kg)	Dimensions(mm)
1	2.450	100*100*100
7	2.360	99*99*99
14	2.290	99*98*98
21	2.250	99*98*97
28	2.210	98*97*97

Table 10: Loss of weight of SFRC (30% FA+1% SF) with induced corrosion by Sulphuric acid

Difference in Weight				
No. of Days	Initial weight (kg)	Weight after curing(kg)	Loss in weight(kg)	% Loss of weight
1	2.5	2.45	0.05	2.00
7	2.5	2.355	0.145	5.8
14	2.5	2.29	0.21	8.4
21	2.5	2.25	0.25	10
28	2.5	2.21	0.29	11.6

Table 11: Loss of Volume of SFRC (30% FA+1% SF) with induced corrosion by Sulphuric acid

Difference in Volume				
Days	Original Volume (mm^3)	Volume after Curing (mm^3)	Loss of Volume (mm^3)	% Loss of Volume
1	$1x10^6$	990000	10000	1
7		970299	29701	2.97
14		950796	49204	4.92
21		931588	68412	6.84
28		922082	77918	7.79

Conclusions

From results, it is clear that there is decline in the compressive strength of concrete after 28 days of induced corrosion with sulphuric acid. It is also observed that there is considerable reduction in the weight, volume and compressive strength of the control. There is a reduction of 22.51% in the compressive strength of control whereas there is only 17.85% decline in SFRC (FA30% +SF1%) and on the contrary 19.23% in SFRC (FA20% + SF1%) when induced with Sulphuric acid .The loss in weight of control is 13.60% for control where as for SFRC it is 10.6%. The loss in volume of control is 11.6 % and in SFRC it is only 7.79 %.Thus, from the results it is evident that Flyash blended SFRC is more resistant to induced corrosion with Sulphuric acid as compared to conventional concrete.

References

[1]Guoping Jiang, ―Study on mechanical properties of steel reinforced high strength concrete subjected to impact loading‖, Earthquake Engineering Research Test Centre of Guangzhou University, Guangzhou 510405, China, 2011.

[2] A.M. Shende, Comparative Study on Steel Fiber Reinforced cum Control Concrete, University of France, France, 2011.

[3] Mohammed Alias Yusof, Normal Strength Steel Fiber Reinforced Concrete Subjected to Explosive Loading, International Journal of Sustainable Construction Engineering & Technology Vol. 1, No 2,2010.

[4] Ali Ellouze, Experimental study of steel fibre concrete slab Part I: behavior under u.d.l, International Journal of concrete structure and materials, vol. 4, no. 2, pp 113-118, 2010.

[5] Cengiz Duran Atiş ,Properties of steel fiber reinforced fly ash concrete, Erciyes University, Engineering Faculty, Department of Civil Engineering, Kayseri, Turkey,2007.

[6] Dr. N. Ganesan & Dr. P.V.Indira, Behaviour of steel fibre reinforced high performance concrete members under flexure, Behaviour of steel fibre reinforced high performance concrete members under flexure May 2007, Vol. 88, pp 20-23, 2007.

[7] R.D Neves& J. C.O Fernandes de Almedia, Compressive behavior of steel fibre reinforced concrete, Structural concrete, 2005, Vol. No. 1, pp 1-9, 2005.

[8] Jean-Louis Granju, Corrosion of steel fibre reinforced concrete from the cracks, Laboratoire Matériaux et Durabilité des Constructions, INSA-UPS, 135 Avenue de Rangueil, 31077 Toulouse Cedex 4, France. 2004.

[9] P.S. Song & S. Hwang, Mechanical properties of high strength steel fibre reinforced concrete, Construction and building material 18,2004, pp 669-673, 2004.

[10] JanuszPotrzebowski, The splitting test applied to steel fibre reinforced concrete , Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, wi tokrzyska 2 , Poland, 2003.