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Experimental Study on Durability of Binary Blended High Strength Steel Fibre Reinforced Concrete Using Alccofine 1203 as Mineral Admixture

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Abstract: *Cement concrete is the most widely used material for various constructions. Properly designed and prepared concrete results in good strength and durable properties. Even such well designed and prepared concrete mixes under controlled conditions also have certain limitations because of which above properties of concrete are found to be inadequate for special situation and for certain special structures. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. To overcome the above ill effects, the advent of newer materials and constructions techniques and in this drive, admixture has taken newer things with various administers has become a necessity. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. As a result, the use of new mineral admixtures has considerably increased within the concrete industry. Hence variety of admixture such as fly ash, silica fume, rise husk ash, GGBS, metakaoline, stone dust and Alccofineetc are used with partial replacement of cement to enhance the properties of regular cement concrete. Research work has been done on the properties of durability of concrete binary blended with ALCCOFINE 1203 without steel fibres. Hence an attempt has been made in this investigation on partial replacement of cement with ALCCOFINE 1203 along with incorporation of crimped steel fibres of two aspect ratios with different percentages of the volume concrete. To attain the setout objectives of the present investigation, M50 grade concrete has been taken as reference concrete. Fresh concrete properties like slump, compaction factor and hardened concrete properties like residual compressive strength and weight loss have been studied. It is found that the Residual Compressive Strength of blended concrete is 4 to 9% greater than the OPCC mix after immersion in HCl, 7 to 10% greater than the OPCC mix after immersion in H2SO4 and 4 to 8% greater than the OPCC mix after the immersion in MgSO4 for duration of 30 to 90 days. The loss in weight of blended concrete is 4 to 7% lesser than the OPCC mix after the immersion in HCl, 6 to 14% lesser than the OPCC mix after the immersion in H2SO4 and 5 to 7% lesser than the OPCC mix after the immersion in MgSO4 for duration of 30 to 90 days.*

I. INTRODUCTION

Many researchers have studied the properties of ordinary Portland cement concrete and fibre reinforced concrete using Fly ash, Silica fume, Metakaoline, Rise husk ash, GGBS, etc., as cement replacement materials. Very few researchers have done work using Alccofine 1203 as cement replacement material. No researchers have made an attempt with addition of steel fibres to binary blended concrete using Alccofine 1203 as mineral admixture. Due to the associated environmental pollution caused in the production of cement to reserve the virgin raw materials used in cement making for future generations and at the same time due to the availability of supplementary cementing materials like Alccofine 1203 which is an engineered material, an attempt has been made to study strength and durability properties of concrete blended with Alccofine 1203 with and without crimped steel fibres. Not much literature is available on durability properties of binary blended concrete using Alccofine 1203. Also no compressive study was done on strength and durability properties of Alccofine 1203 blended concrete using crimped steel fibres.

Hence, considering the gap in existing literature an attempt has been made to study the strength and durability properties of Alccofine blended concrete with and without crimped steel fibres.

The present investigation is an attempt to study the residual compressive strength and percentage weight loss of OPCC, BBC, SFRC and BB-SFRC mixes. The experimental investigation adopted *Erntroy* and *Shack Lock* method of mix design procedure for M50 grade concrete. Cubes of size 100mm*100mm*100mm were casted and cured for 28 days and then immersed in 5% dilution of HCl, H_2SO_4 and $MgSO_4$ for a period of 30, 60 and 90 days and then tested for percentage weight loss and residual compressive strength. The crimped steel fibres of circular cross-sectional were used in this investigation. The sizes (Length/Diameter/Aspect ratio) of the steel fibres are 27mm/ 0.45mm/60 and 45mm/0.45mm/100. The variables used in the investigation are fibre content of 0, 0.5, 1.0 and 1.5% of volume of concrete and aspect ratio of fibres are taken as 60 and 100. Based on carefully conducted experiments on cement concrete by using Alccofine 1203 and crimped steel fibres, yields higher compressive strength and showed more resistance to acid attack.

II. LITERATURE REVIEW

Faisal F Wafa and S.A. Ashour (1992**)** carried out experimental investigations on properties like cube compressive strength, splitting tensile strength and modulus of rupture of concrete by incorporating hooked-end steel fibres with 0% to 1.5% as volume fraction. They concluded that addition of 1.50% by volume of hooked-end fibres resulted in 4.6% increase in compressive strength, 59.8% increase in split tensile strength and 67% increase in modulus of rupture of plain cement concrete. Also they developed equations for predicting the experimental results.

Kaushik S.K., et.al (2003) carried out experimental investigations on the mechanical properties of reinforced concrete by adding 1.0% volume fraction of 25mm and 50mm long crimped type flat steel fibres. It was observed that short fibres acts as crack arrestors and enhances the strength, where as long fibres contributed to over ductility. They concluded that best performance was observed with mixed aspect ratio of fibres.

Dinakar p., Babu K.G. and Manu Santhanam et al. (2008)conducted an experimental study on the durability properties of self compacting concretes (SCCs) with high volume replacements of fly ash. Eight fly ash self compacting concretes of various strength grades were designed at desired fly ash percentages of 0, 10, 30, 50, 70 and 85% in comparison with five different mixtures of normal vibrated concretes (NCs) at equivalent strength grades. The durability properties were studied through the measurement of permeable voids, water absorption, acid attack and chloride permeation. The results indicated that the SCCs showed higher permeable voids and water absorption than the vibrated normal concretes of the same strength grades. However, in acid attack and chloride diffusion studies the high volume fly ash SCCs had significantly lower weight loss and chloride ion diffusion.

Deval Soni, Suhasini Kulkarni, Vilin Parekh, et al. (2013)conducted experimental study on High-Performance Concrete with mixing of Alccofine and Fly ash. They evaluated the performance of high strength concretes containing supplementary cementitious materials. Prepared the strength of concrete of grade M80 with locally available ingredients and then studied the effects of different proportions of Alccofine and Fly ash content in the mix. The Alccofine and fly ash are added by weight of cement as a replacement. The concrete specimens were tested at different age level for mechanical properties of concrete, namely, Cube Compressive Strength and Flexural Strength.

III. DESIGN METHODOLOGY

MIX DESIGN

Mix design is defined as process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economic as possible. The first object is to make the concrete at the most economical.

Mix design of M50 grade concrete

In the present study high strength concrete of M50 grade. The investigation has adopted *Erntroy* and *Shack Lock* method of mix design. Using this method the mix proportions obtained is Fine aggregate: Coarse aggregate: Cement is 1:0.95:2.68 with Water Cement Ratio: 0.33

Table 1 The ratio of mix proportions of OPC concrete of M50 grade

Cement in kg	Fine Aggregate in kg	Coarse Aggregate in kg
450	430	1210
1	0.95	2.68

Table 2 Mix proportions of OPC Concrete of M50 grade

S.No.	Material (kg/m^3)	Quantity of material (kg)
1.	Cement	450
2.	Alccofine 1203	0
3.	Water (Lit/m^3)	155
4.	Fine aggregate	430
5.	Coarse aggregate	1210
6.	Super plasticizer (SP430)	1.0% by weight of cement
7.	Water Cement Ratio (W/C)	0.33
8.	Workability	0.890

Compressive strength of concrete

Table 3 Compressive Strength of OPCC, BBC and BB-SFRC Mixes

S.No.	Type of Mix	Fibre Content (%)	Aspect Ratio (AR)	Compressive Strength (MPa)	% increase in Compressive strength of BBC, SFRC &BB-SFRC Mixes w.r.t OPCC
1.	OPCC	0	0	58.20	-
2.	BBC	0	0	68.50	17.70
3.	SFRC (0.5-60)	0.50	60	60.40	3.80
4.	SFRC (1.0-60)	1.0	60	61.46	5.60
5.	SFRC (1.5-60)	1.50	60	62.80	7.90
6.	SFRC (2.0-60)	2.0	60	60.76	4.40
7.	SFRC (0.5-100)	0.50	100	61.05	4.90
8.	SFRC (1.0-100)	1.0	100	62.91	8.10
9.	SFRC (1.5-100)	1.50	100	64.20	10.30
10.	SFRC (2.0-100)	2.0	100	61.80	6.20
11.	BB-SFRC (1.5-60)	1.50	60	69.40	19.20
12.	BB-SFRC (1.5-100)	1.50	100	70.90	21.80

Five trial mixes of OPC Concrete of M50 grade were conducted with five different weights of cement content, fine aggregate and coarse aggregate keeping the water cement ratio constant. These mixes are kept for curing for a period of 7 and 28 days. The compressive strength simultaneously increases for every trial. In the fifth trial the compressive strength decrease from 63Mpa to 58Mpa after curing for 28 days and hence the fifth trial is considered as the optimum

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Table 4 Trial Mixes of OPC Concrete of M50 grade

S.No.	Mix ID	Water Cement Ratio	Cement Content (kg/m^3)	Water (lit/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Super plasticizer 1% of cement	Workability (Compaction Factor)	Compressive strength of OPCC (MPa)	
									7 days	28 days
1.	Trial 1	0.33	500	165	475	1340	5.0	0.81	47.50	74.80
2.	Trial 2	0.33	480	158.50	461	1286	4.80	0.83	48.60	70.30
3.	Trial 3	0.33	470	155	446	1260	4.70	0.86	39.24	66.50
4.	Trial 4	0.33	460	151.8	437	1233	4.60	0.87	42.10	63.80
5.	Trial 5	0.33	450	148.50	428	1206	4.50	0.89	37.50	58.20

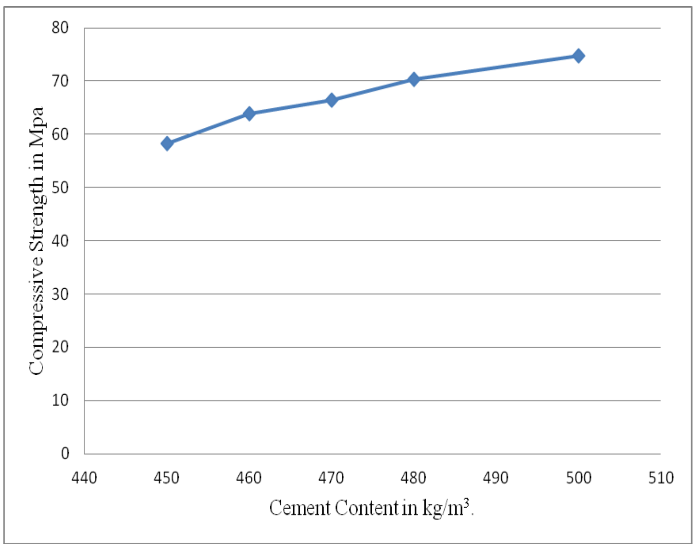
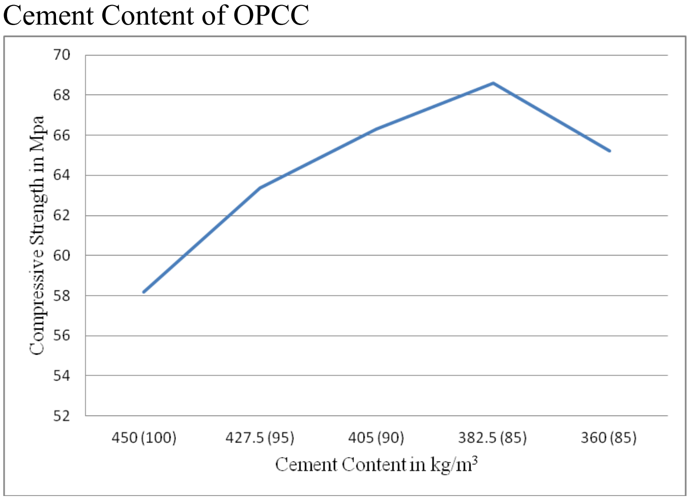


Fig.1 Variation of Compressive Strength with respect to Cement Content of OPCC



Trial Mix Proportions and Compressive Strength of Binary Blended Mixes

Five trail mixes were conducted with M50 grade concrete with partial replacement of cement with different percentages of Alccofine 1203 i.e., 5%, 10%, 15% and 20% and then evaluating the compressive strength.

Table 5 Trial Mix Proportions and Compressive Strength of Binary Blended Mixes

S. No	Type of Mix	Cement Content (kg) (Cement%)	Alccofine 1203 (kg/m^3) (Alccofine%)	Water (l/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Workability (C.F)	Compressive Strength (MPa) 28 days
1.	Normal	450 (100)	0	148.50	430	1210	0.89	58.20
2.	AL-05 %	427.5 (95)	22.50 (05)	148.50	430	1210	0.916	63.38
3.	AL-10 %	405 (90)	45.0 (10)	148.50	430	1210	0.924	66.30
4.	AL-15 %	382.5 (85)	67.5 (15)	148.50	430	1210	0.940	68.60
5.	AL-20 %	360 (85)	90.0 (20)	148.50	430	1210	0.86	65.20

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Table 6 Workability of OPCC, BBC & BB-SFRC in terms of Slump and Compaction Factor

S.No.	Type of Mix	Slump (mm)	Compaction Factor
1.	OPCC	85	0.910
2.	BBC	120	0.976
3.	SFRC (0.5-60)	70	0.870
4.	SFRC (1.0-60)	60	0.830
5.	SFRC (1.5-60)	40	0.80
6.	SFRC (0.5-100)	65	0.860
7.	SFRC (1.0-100)	50	0.80
8.	SFRC (1.5-100)	30	0.76
9.	BB-SFRC (0.5-60)	80	0.90
10.	BB-SFRC (1.0-60)	65	0.87
11.	BB-SFRC (1.5-60)	55	0.82
12.	BB-SFRC (0.5-100)	70	0.86
13.	BB-SFRC (1.0-100)	50	0.80
14.	BB-SFRC (1.5-100)	40	0.72

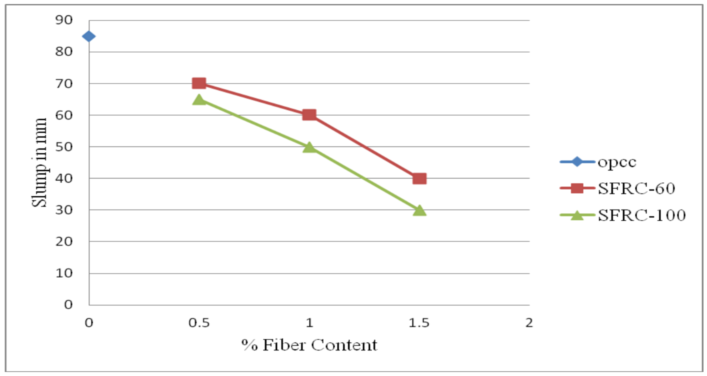

Fig.3 Variation of Slump with respect to % Fibre Content

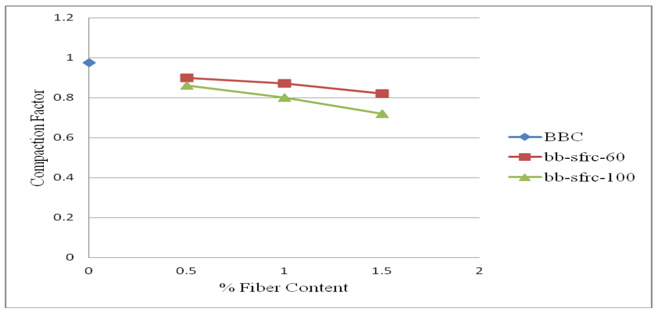

Fig.4 Variation of Compaction Factor with respect to % Fibre Content.

Table 7 Loss in Compressive strength of OPCC, SFRC & BB-SFRC mixes after immersion in HCl (5% dilution)

S.No.	Mix ID	C.S before immersion at 30 days (MPa)	C.S after immersion at 30 days (MPa)	% Loss in C.S after immersion at 30 days	C.S after immersion at 60 days (MPa)	% Loss in C.S after immersion at 60 days	C.S after immersion at 90 days (MPa)	% Loss in C.S after immersion at 90 days
1.	OPCC	58.20	53.66	7.80	51.68	11.20	49.58	14.80
2.	BBC	68.50	66.17	3.40	65.83	3.90	64.30	6.10
3.	SFRC (1.5-60)	62.80	61.10	2.70	66.03	3.60	58.20	7.30
4.	SFRC (1.5-100)	64.20	61.95	3.50	61.18	4.70	58.74	8.50
5.	BB-SFRC (1.5-60)	69.40	68.30	1.60	67.38	2.90	66.06	4.80
6.	BB-SFRC (1.5-100)	70.90	69.34	2.20	68.20	3.80	66.93	5.60

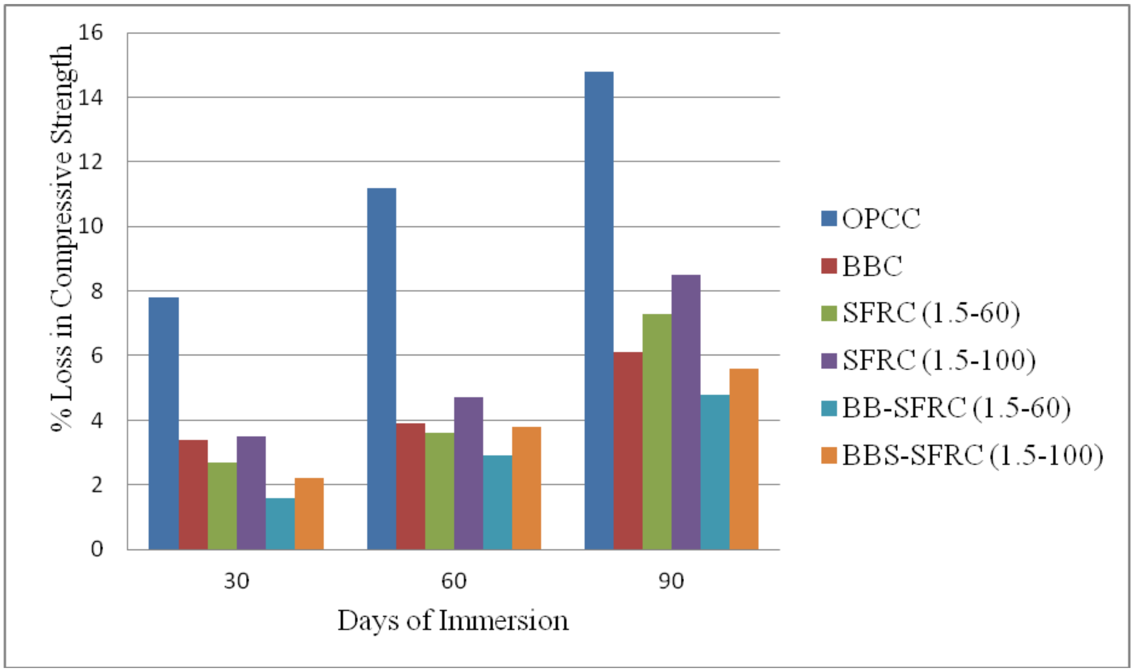

Fig.5 Percentage Loss in Compressive Strength of all Mixes when immersed in5% HCl for different number of days

Table 8 Loss in Compressive strength of OPCC, SFRC & BB-SFRC mixes after immersion in H_2SO_4 (5% dilution)

S.No.	Mix ID	C.S before immersion at 30 days (MPa)	C.S after immersion at 30 days (MPa)	% Loss in C.S after immersion at 30 days	C.S after immersion at 60 days (MPa)	% Loss in C.S after immersion at 60 days	C.S after immersion at 90 days (MPa)	% Loss in C.S after immersion at 90 days
1.	OPCC	58.20	48.36	16.90	46.38	20.30	44.76	23.10
2.	BBC	68.50	61.99	9.50	60.00	12.24	59.18	13.60
3.	SFRC (1.5-60)	62.80	57.20	8.90	54.26	13.60	53.32	15.10
4.	SFRC (1.5-100)	64.20	57.52	10.40	54.69	14.80	52.84	17.70
5.	BB-SFRC (1.5-60)	69.40	65.38	5.80	63.92	7.90	63.10	9.20
6.	BB-SFRC (1.5-100)	70.90	65.86	7.10	64.60	8.90	63.40	10.60

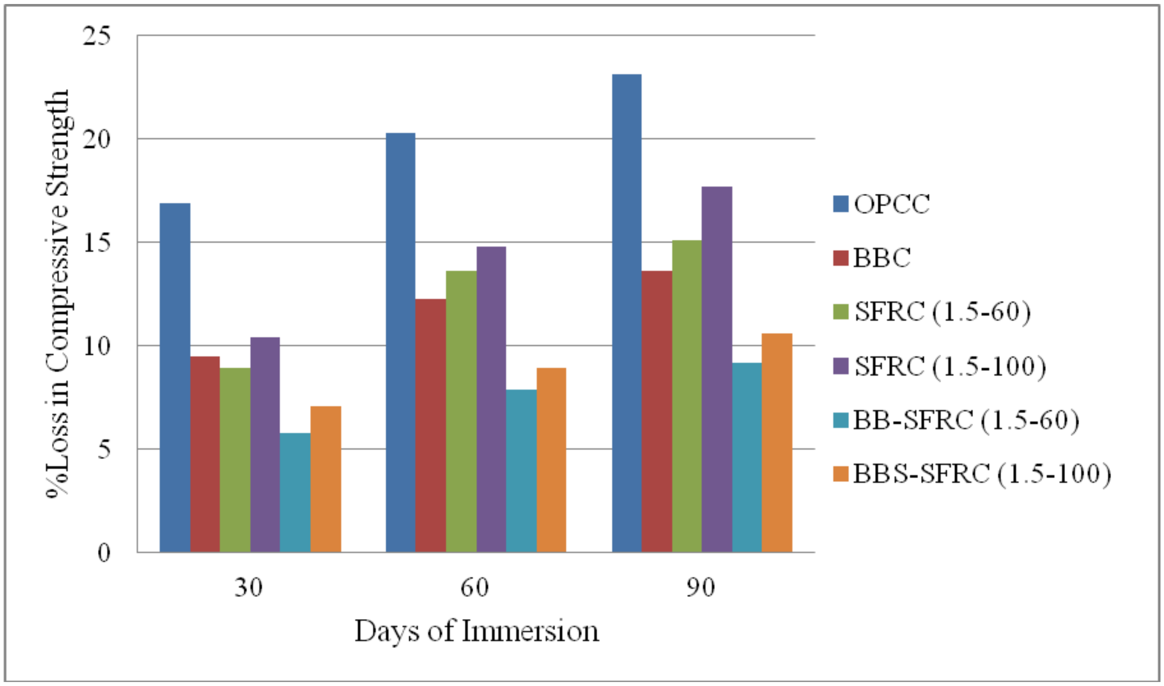

Fig.6 Percentage Loss in Compressive Strength of all Mixes when immersed in 5% H2SO4 for different number of days

Table 9 Loss in Compressive strength of OPCC, SFRC & BB-SFRC mixes after immersion in $MgSO_4$ (5% dilution)

S.No.	Mix ID	C.S before immersion at 30 days (MPa)	C.S after immersion at 30 days (MPa)	% Loss in C.S after immersion at 30 days	C.S after immersion at 60 days (MPa)	% Loss in C.S after immersion at 60 days	C.S after immersion at 90 days (MPa)	% Loss in C.S after immersion at 90 days
1.	OPCC	58.20	53.02	8.90	50.52	13.60	48.65	16.40
2.	BBC	68.50	64.94	5.20	63.84	6.80	62.74	8.40
3.	SFRC (1.5-60)	62.80	60.22	4.10	57.84	7.90	57.08	9.10
4.	SFRC (1.5-100)	64.20	60.54	5.70	58.68	8.60	57.33	10.70
5.	BB-SFRC (1.5-60)	69.40	67.73	2.40	66.48	4.20	64.36	7.30
6.	BB-SFRC (1.5-100)	70.90	68.27	3.70	66.70	6.10	65.08	8.20

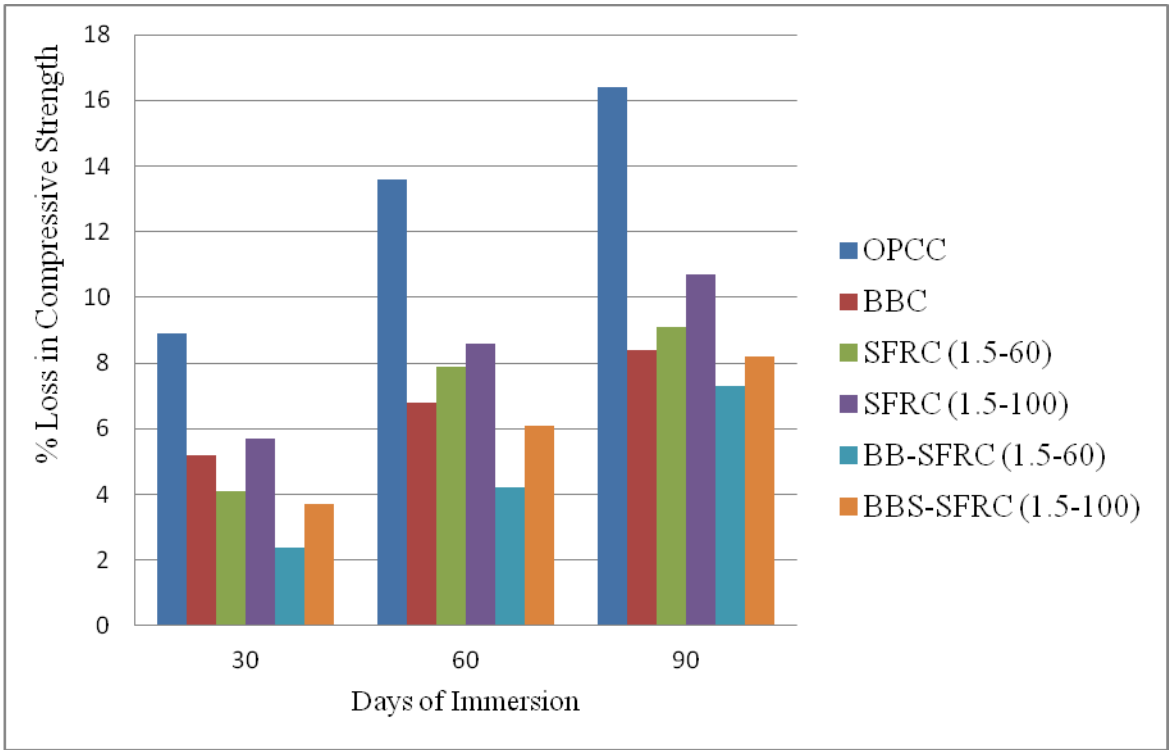

Fig.7 Percentage Loss in Compressive Strength of all Mixes when immersed in 5% $MgSO_4$ for different number of days

IV. CONCLUSION

The following conclusions are drawn from the various experimental results reported in the project.

- 15% cement replacement with ***Alccofine***gave optimum strength and workability for Binary Blended Concrete. Hence Binary Blended Concrete consisted of 85% OPC and 15% of Alccofine.
- The workability of SFRC mixes is decreasing with fibre addition of 0.5% to 1.50%, but the mixes were workable after addition of super plasticizer at the rate of 1.0% of weight of binding material.
- The workability of SFRC mixes is improved with the partial replacement of cement with Alccofine.
- The compressive strength of BBC mix is 17% greater than the compressive strength of OPCC mix.
- The compressive strength of OPCC and SFRC mixes is increasing with the 15% replacement of cement with Alccofine and Steel fibres of higher content and of higher aspect ratio. The reason may be due to the high Pozzolanic reaction of the Alccofine and presence of crimped steel fibre in the OPCC mix.
- The percentage increase in compressive strength of SFRC with an addition of 0.50% to 1.50% of steel fibres with higher aspect ratio is found to vary from 3.80% to 10.30% when compared with OPCC mix.
- The percentage increase in compressive strength of BB-SFRC mixes with an addition of 0.50% to 1.50% of crimped steel fibres with higher aspect ratio is found to vary from 19.20% to 21.80% when compared with OPCC mix.
- The percentage loss in compressive strength of OPCC, SFRC mixes is decreasing with age of exposure to acid due to the presence of Alccofine and Steel fibres.
- The percentage loss in compressive strength in 5% H_2SO_4 is higher than with other two solutions.
- The percentage loss in compressive strength is increasing with the time of exposure from 30 to 90 days in 5% HCl, 5% H_2SO_4 and 5% $MgSO_4$ solution.
- The percentage loss in weight of OPCC and SFRC mixes is decreasing with the age of exposure due to the presence of Alccofine and crimped steel fibres.

- The percentage loss in weight due to acid attack is increasing with the time of exposure in 5% HCl, 5% H_2SO_4 and 5% $MgSO_4$ solution.
- The percentage loss in weight is higher when immersed in 5% H_2SO_4 solution than in other two solutions.
- The BBC showed more resistance to acid attack.
- The present study revealed that 15% replacement of cement with Alccofine is more durable when compared to normal concrete after exposure to acid attack.

Scope for the Future Study

As this investigation deals with the partial replacement of cement only with one admixture i.e., ALCCOFINE 1203 (Binary Blending) incorporating crimped steel fibres of higher aspect ratio, further investigations can be carried on strength and durability studies of ternary or quaternary blended concrete.

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