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BEHAVIOUR OF STEEL FIBRE REINFORCED TERNARY BLENDED CONCRETE WHEN EXPOSED TO CHEMICAL ATTACK

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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 durability properties. Even such well designed and prepared cement concrete mixes under controlled conditions also have certain limitations because of which the above properties of concrete are found to be inadequate for special situations and for certain special structures. Hence variety of admixtures such as fly ash , silica fume , stone dust and Alcofine etc. are used with partial replacement of the regular cement concrete.

Hence an attempt cot has been made in the present investigation on partial replacement of cement with Alcofine1203 along with incorporation of different types of steel fibres of two aspect ratios with different percentages of the volume concrete. To attain the 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 cube compressive strength and split tensile strength with variation in different percentages of ALCOFINE 1203 and various percentages of different types of steel fibres have been studied.

The addition of higher fibre content with higher aspect ratio and partial replacement of cement with Alcofine 1203 lead to enchanced compressive strength of ordinary Portland cement mix. Blending of cement with ALCOFINE 1203 lead to workable concrete without super plasticizer.

Under normal condition as, most concrete structures are subjected to a range of chemicals no more severe than that imposed by ambient environmental conditions. However there are important cases where these structures are exposed to chemicals (e.g., sulphuric acid , hydrochloric acid and chemicals).

***Keywords**: Concrete, Ternary Blended Concrete, Fibre Reinforced Concrete, Steel Crimped Fibres,Hooked fibers, Fly ash, Aspect Ratio, Workability,H2So4,HCl,MgSo4 ALCOFINE 1203.*

I. INTRODUCTION

Under normal condition as, most concrete structures are subjected to a range of chemicals no more severe than that imposed by ambient environmental conditions. However there are important cases where these structures are exposed to chemicals (e.g., sulphuric acid , hydrochloric acid and chemicals).

With the advancement of technology and increased field applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for any situations. Added to this, it is necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixture is found to be an important alternative solution.

The use of Pozzolonic materials in cement concrete paved a solution for –

1.Modifying the properties of the concrete.
2.Controlling the concrete production cost.
3.To over come the scarcity of cement and finally
4.The economic advantageous disposal of industrial wastes. The most important pozolanic materials are fly ash, silica fume and Alcofine whose use in cement and concrete is thus likely to be a significant achievement in the development of concrete technology in the coming few decades.

II. TERNARY BLENDED CONCRETE

Ordinary concrete has a single cementitious material i.e. cement. Binary blend of concrete includes cement as the binding material and a pozzolanic material being added. Ternary blended concrete marks the inclusion of two different pozzolanic materials to the concrete with cement acting as the primary binding material.
Admixtures are very fine when compared to cement. In worst case, the admixtures are at least twice as fine as cement. Admixtures are rich in silica content. They not only act as replacement to cement but also enhance the durability of concrete. Durability of concrete is increased by the reduction of Calcium Hydroxide content which causes Sulphate Attack. Fly ash from coal fired power plants isimportant in modern concrete technology. Used in together with Portland cement, they contribute to concrete with selected properties.
In the present investigation Ternary Blended Fibre reinforced concrete has been used. The binary blend of concrete using fly ash has the advantage of producing better workability but there is a late development of

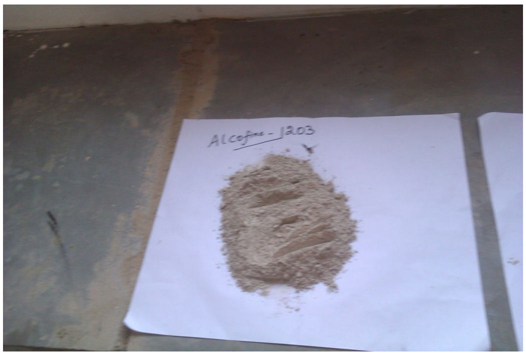
strength. When metakaolin is used in the binary blend of concrete, there is an early gain of strength but the concrete produced is lesser workable. So, when the fly ash and metakaolin are used, the ternary blend of concrete gives better workability as well as there is an early gain in strength.

III. ALCOFINE 1203

ALCCOFINE1203 performs in superior manner than all other mineral admixtures used in concrete within India. Due to its inbuilt CaO content, ALCCOFINE1203 triggers two way reactions during hydration

- Primary reaction of cement hydration.
- Pozzolanic reaction: ALCCOFINE also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel, similar to pozzolans.

This results in denser pore structure and ultimately higher strength gain. This booklet presents results of examination carried out on ALCCOFINE1203 in comparison with Silica Fume in concrete, and the effect it has on workability, water requirement, admixture requirement, strength and durability. Thus, obtained results confirm that properly designed mixes with judicious use of ALCCOFINE 1203 exhibits superior properties than Silica Fume.



IV. CRIMPED STEEL FIBERS

Concrete is the most widely used structural material in the world is prone to cracking for a variety of reasons. These reasons may be attributed to structural, environmental or even economics factors, but most of the cracks are formed due to the inherent weakness of the material of resist tensile forces. When concrete shrinks, and it is restrained, it will crack.

Steel fiber reinforcement offers solution to the problem of cracking by making concrete tougher and more ductile. R&D and filed trails overthree decades have proved that addition to steel fibers to conventional plan or reinforced and pre-stressed concrete member at the time of mixing / production in parts strength, performance and durability of concrete.

V. HOOKED END FIBERS

The length of the steel fiber provides enhancement in both micro-macro cracking performance and post-first-crack performance of concrete.Aspect ratio gives better understanding of bonding potentials. Fibers having aspect ratio greater than 2" usually have balling potential.

The hook-end steel fibers were developed to increase the bond between the fiber and concrete, it being the best configuration needed to fully enhance cracking performance, as well as flexural strength

Table 1.Typical oxide composition of Fly ash

S.No	Characteristics	Percentage (%)
1	Silica, Sio_2	49-67
2	Alumina, Al_2O_3	16-28
3	Iron Oxide, Fe_2O_3	4-10
4	Lime, CaO	0.7-3.6
5	Magnesia, MgO	0.3-2.6

6	Sulphur Trioxide, SO_3	0.1-2.1
7	Loss on ignition	0.4-1.9
8	Surface Area m^2/kg	230-600

Table 2. Properties of crimped steel fibers

S.No.	Property	Value	Remarks
1	Diametr	0.45mm	Properties confirms to ASTM A820 Standard requirement
2	Length	36mm	
3	Aspect ratio	80	
4	Tensile strenth	1100Mpa	
5	Specific gravity	0.78	

Table 3. The hook-end fiber can be used with the following parameters:

Diameter range:	**0.4 mm – 1.05 mm**
Length:	**30, 50, 60 mm (most common)**
Tensile strength (T/S):	**1100 ÷ 1500 N/mm²**

VI. TEST RESULTS AND DISCUSSIONS

The experimental investigation adopted entropy & shack lock method of mix design procedure for designing M50 grade concrete. The mix proportion of opcc are given in table. The ratio of the quantities obtained were Cement: Fine Aggregate: Coarse Aggregate = 1: 0.95: 2.68 with W/C=0.33

Mix Proportion of OPC Concrete of M50 grade

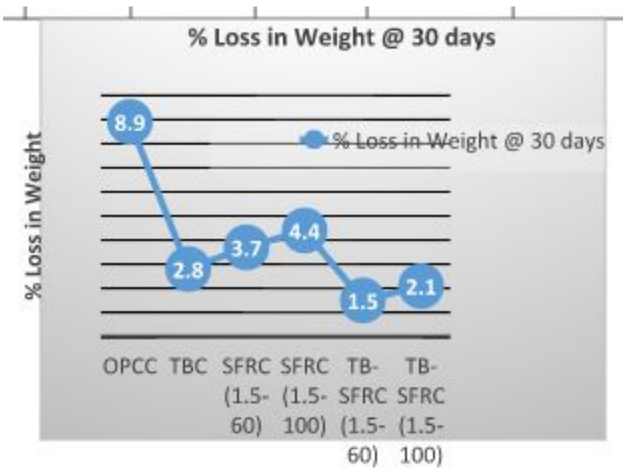
Sl.no	Material (kg/m3)	Quantity of material (kg)
1	Cement	450
2	Alcofine 1203	0
3	Water (liters/m3)	155
4	Fine Aggregate	430
5	Coarse Aggregate	1210
6	Super Plasticizer	1.0% by weight of Cement
7	Water Cement Ratio (W/C)	0.33
8	Workability (C.F)	0.89

The below tables gives the values of loss in weight due to chemical attack in 5%HCl, 5%H2So4 and 5%MgSo4.

Studies on loss of weight of OPCC , TBC , SFRC and TB-SFRC mixes in different solutions.

Loss in Weigth of OPCC,TBC,SFRC & TB-SFRC Mixes After Immersion in H2SO4 (5% dilution)

Sl .NO	Type of Mix	Weigth Before Immersion @ 30 days (gms)	Weigth After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Weigth After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Weigth After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	2630	2396	8.9	2272	13.6	2040	21.4
2	TBC	2550	2478	2.8	2425	4.9	2340	8.2
3	SFRC (1.5-60)	2770	2667	3.7	2570	7.2	2451	11.5
4	SFRC (1.5-100)	2790	2660	4.4	2519	9.7	2402	13.9
5	TB-SFRC(1.5-60)	2715	2675	1.5	2598	4.3	2549	6.1
6	TB-SFRC (1.5-100)	2750	2692	2.1	2596	5.6	2555	7.2



Loss of weight of specimens after immersionin 5% H2SO4 solution in 30 day

Loss of weight of specimens after immersion in 5% H2SO4 solution in 60 days

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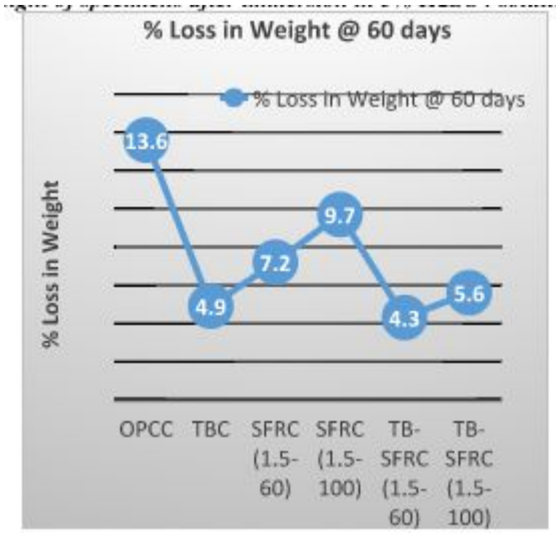
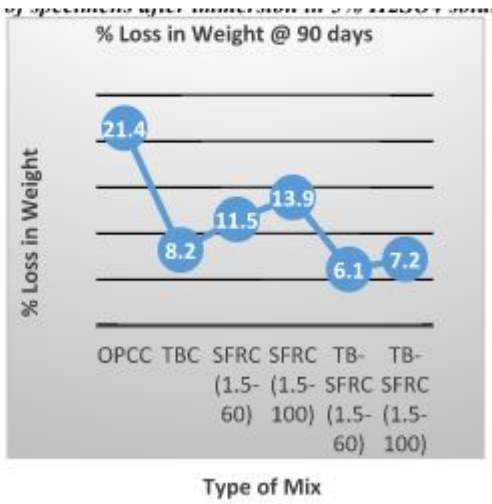
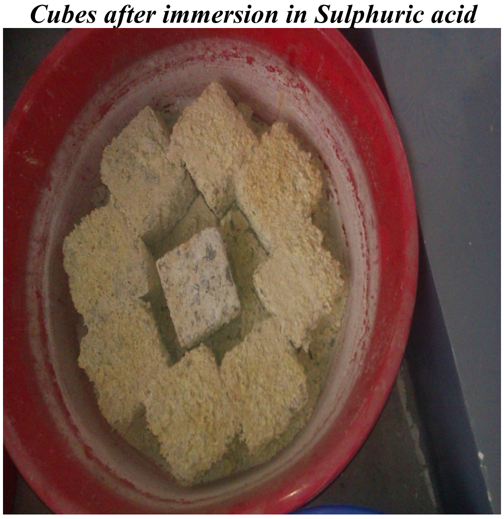


Loss of weight of specimens after immersion in 5% H2SO4 solution in 90 days



Cubes after immersion in Sulphuric acid



- The percentage loss of OPCC mix after immersion in 5% H2SO4 solution. These values vary from o to 8.90% for 30 days , 0 to13.60% for 60 days and 0 t0 22.40% for 90 days respectively.
- The percentage loss of TBC mix after immersion in 5% H2SO4 solution. These values vary from 0 to 2.80% for 30 days , 0 to 4.90% for 60 days and 0 to 8.20% for 90 days respectively.

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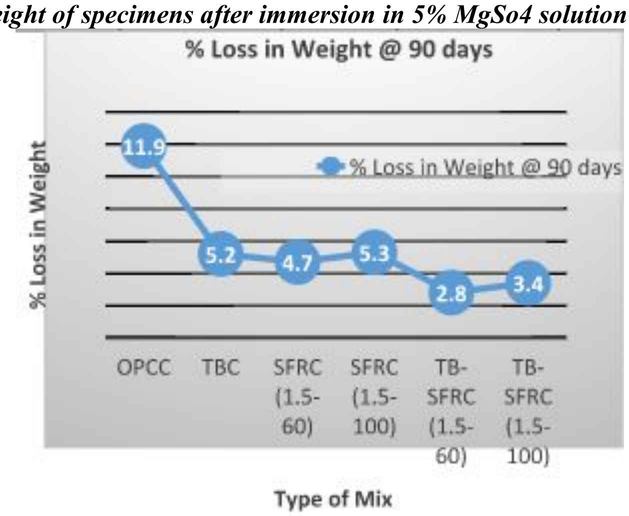
- The percentage loss of SFRC (1.5-60) mix after immersion in 5% H2SO4 solution. These values vary from 0 to 3.70% for 30 days , 0 to 7.20% for 60 days and 0 to 11.50% for 90 days respectively.
- he percentage loss of SFRC (1.5-100) mix after immersion in 5% H2SO4 solution. These values vary from 0 to 4.40% for 30 days , 0 to 9.70% for 60 days and 0 to 13.90% for 90 days respectively.
- The percentage loss of TB-SFRC (1.5-60) mix after immersion in 5% H2SO4 solution. These values vary from 0 to 1.50% for 30 days , 0 to 4.30% for 60 days and 0 to 6.10% for 90 days respectively.
- The percentage loss of TB-SFRC (1.5-100) mix after immersion in 5% H2SO4 solution. These values vary from 0 to 2.10% for 30 days , 0 to 5.60% for 60 days and 0 to 7.20% for 90 days respectively.

- **Similarly for MgSo4**

Loss of weight of specimens after immersion in 5% MgSo4 solution for 90 days



Loss in Weigth of OPCC,TBC,SFRC & TB-SFRC Mixes After Immersion in mgso4 (5% dilution)

Sl. NO	Type of Mix	Weigth Before Immersion @ 30 days (gms)	Weigth After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Weigth After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Weigth After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	2680	2490	7.1	2431	9.3	2360	11.9
2	TBC	2620	2570	1.9	2515	4	2483	5.2
3	SFRC (1.5-60)	2765	2690	2.7	2671	3.4	2635	4.7
4	SFRC (1.5-100)	2750	2645	3.8	2626	4.5	2604	5.3
5	TB-SFRC(1.5-60)	2710	2677	1.2	2653	2.1	2630	2.8
6	TB-SFRC (1.5-100)	2780	2730	1.8	2708	2.6	2685	3.4

The percentage weight loss of TBC , SFRC , TB-SFRC mixes is decreasing due to the partial replacement of cement with 15% Alcofine and 20% fly ash and due to addition of steel fibres to TBC when compared to SFRC mixeswithout mineral admixtures.

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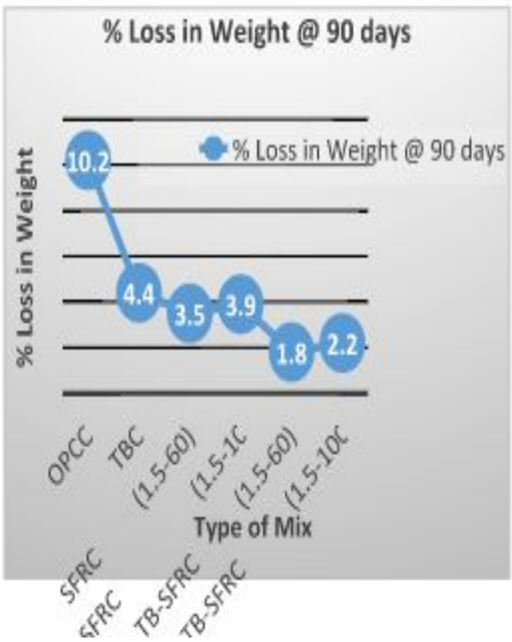
- **Similarly for HCL**

Loss in Weight of OPCC,TBC,SFRC & TB-SFRC Mixes After Immersion in HCL (5% dilution)

Sl.NO	Type of Mix	Weight Before Immersion @ 30 days (gms)	Weight After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Weigth After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Weigth After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	2650	2500	5.6	2443	7.8	2379	10.2
2	TBC	2592	2558	1.3	2512	3.1	2478	4.4
3	SFRC (1.5-60)	2744	2694	1.8	2678	2.4	2648	3.5
4	SFRC (1.5-100)	2772	2697	2.7	2683	3.2	2664	3.9
5	TB-SFRC (1.5-60)	2690	2669	0.76	2652	1.4	2641	1.8
6	TB-SFRC (1.5-100)	2720	2690	1.1	2674	1.7	2660	2.2

Loss of weight of specimens after immersion in 5% HCL solution for 90 days



The percentage weight loss of OPCC, TBC, SFRC and TB-SFRC mixes increases after immersing in 5% HCL solution corresponding to the time of exposure

The below tables gives the values of loss in compressive strength due to chemical attack in 5%HCl and 5%H2So4 and 5%MgSo4.

Studies on loss of compressive strength of OPCC , TBC , SFRC and TB-SFRC mixes in different solutions.

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Loss of compressive strength of specimens after immersion in 5% HCL solution.

Loss of compressive strength of specimens after immersion in 5% HCL solution for 90 days

Sl.NO	Type of Mix	Compressive Strength Before Immersion @ 30 days (gms)	Compressive Strength After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Compressive Strength After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Compressive Strength After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	58.2	53.66	7.8	51.68	11.2	49.58	14.8
2	TBC	68.5	66.17	3.4	65.83	3.9	64.3	6.1
3	SFRC (1.5-60)	62.8	61.1	2.7	66.03	3.6	58.2	7.3
4	SFRC (1.5-100)	64.2	61.95	3.5	61.18	4.7	58.74	8.5
5	TB-SFRC (1.5-60)	69.4	68.3	1.6	67.38	2.9	66.06	4.8
6	TB-SFRC (1.5-100)	70.9	69.34	2.2	68.2	3.8	66.93	5.6

The percentage loss of compressive strength of OPCC , TBC , SFRC and TB-SFRC mixes is increasing after immersion in 5% HCL solution corresponding to the time of exposure.

Loss in Compressive Strength of OPCC,TBC,SFRC & TB-SFRC Mixes After Immersion in H2SO4 (5% dilution)

Sl.NO	Type of Mix	Compressive Strength Before Immersion @ 30 days (gms)	Compressive Strength After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Compressive Strength After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Compressive Strength After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	58.2	48.36	16.9	43.38	20.3	44.76	23.1
2	TBC	68.5	61.99	9.5	60	12.4	59.18	13.6
3	SFRC (1.5-60)	62.8	57.2	8.9	54.26	13.6	53.32	15.1
4	SFRC (1.5-100)	64.2	57.52	10.4	54.69	14.8	52.84	17.7
5	TB-SFRC (1.5-60)	69.4	65.38	5.8	63.92	7.9	63.1	9.2
6	TB-SFRC (1.5-100)	70.9	65.86	7.1	64.6	8.9	63.4	10.6

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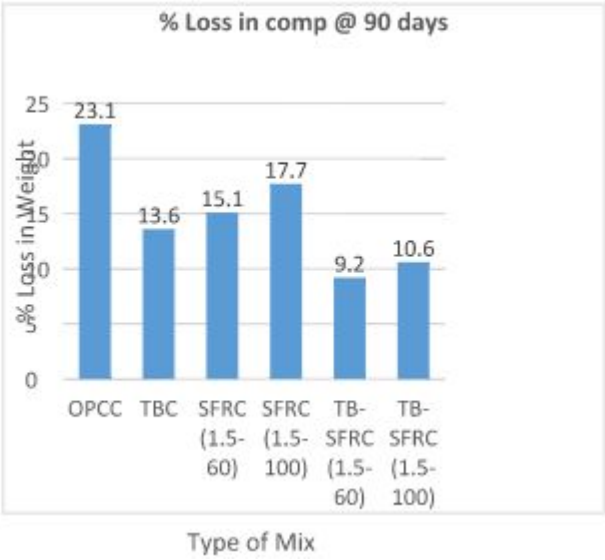
Loss of compressive strength of specimens after immersion in 5% H2So4 solution for 90 days



The percentage loss of compressive strength of OPCC , TBC , SFRC and TB-SFRC mixes is increasing after immersion in 5% H2So4 solution corresponding to the time of exposure.

The loss in compressive strength in TBC , TB-SFRC mixes is decreasing due to the partial replacement of cement with in 15% Alccofine and 20% fly ash , addition of steel fibres of 1.5% of volume of concrete to TBC mixes. This may be due to the reduced permeability and better pore reinforcement of mineral admixtures.

The strength loss in 5% H2So4 is higher than in 5% HCL solution.

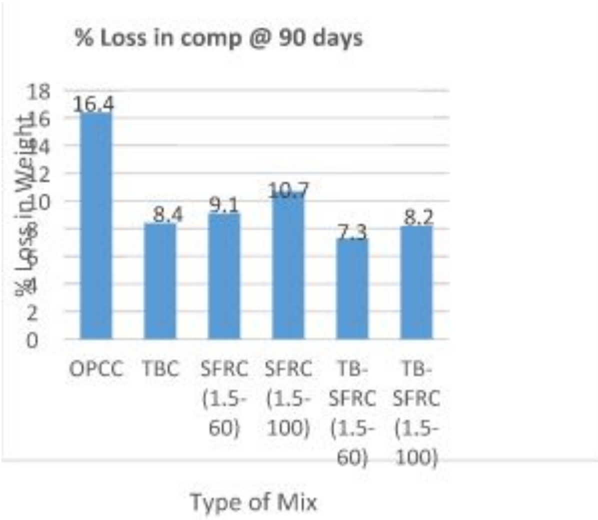
The strength loss is increasing with the age of exposure from 30 to 90 days in 5% HCL and 5% H2So4. Sulphuric acid involves the dissolution and leaching of dissolved constituents of hardened cement from the concrete leading to loss in its compressive strength. Deterioration of concrete may involve the removal of material from the surface by a dissolution mechanism which leads to deterioration of concrete. But the partial replacement of cement with Alccofine , , , fly ash and addition of steel fibres has increased the resistance of OPC concrete to chemical attack.

Loss of compressive strength of specimens after immersion in 5% MgSo4 solution.

Loss in Compressive Strength of OPCC,TBC,SFRC & TB-SFRC Mixes After Immersion in MgS04 (5% dilution)

Sl. N O	Type of Mix	Compressive Strength Before Immersion @ 30 days (gms)	Compressive Strength After Immersion @ 30 days (gms)	% Loss in Weight @ 30 days	Compressive Strength After Immersion @ 60 days (gms)	% Loss in Weight @ 60 days	Compressive Strength After Immersion @ 90 days (gms)	% Loss in Weight @ 90 days
1	OPCC	58.2	53.02	8.9	50.52	13.6	48.65	16.4
2	TBC	68.5	64.94	5.2	63.84	6.8	62.74	8.4
3	SFRC (1.5-60)	62.8	60.22	4.1	57.84	7.9	57.08	9.1
4	SFRC (1.5-100)	64.2	60.54	5.7	58.68	8.6	57.33	10.7
5	TB-SFRC (1.5-60)	69.4	67.73	2.4	66.48	4.2	64.36	7.3
6	TB-SFRC (1.5-100)	70.9	68.27	3.7	67.7	6.1	65.08	8.2

Loss of compressive strength of specimens after immersion in 5% MgSo4 solution for 90 days



VII. CONCLUSIONS

- 15% cement replacement with Alcofine gave optimum strength and workability for ternary blended concrete. Hence ternary blended concrete consisted of 85%OPC and 15%Alcofine.
- The workability of SFRC mixes is decreasing with fibre addition of 0.50% to 1.5% but the mixes were workable after addition of super plasticizer at the rate of 1.0% of weight of ternary material.
- The percentage increase in compressive strength of SFRC with addition of 0.50 to 1.50% of steel fibers 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 fibers with higher aspect ratio is found to vary from 12 % to 21.80% when compared with OPCC mix.
- The percentage loss in compressive strength in 5% H2SO4 solution is higher thanS with other two solutions.
- The percentage loss in weight due to acid attack is increasing with the time of exposure in 5% Hcl , 5% mgso4 and 5%H2SO4 solution.
- The percentage loss in weight is higher when immersed in 5% H2SO4 solution than in other two solutions.
- The TBC showed more resistance to acid attack.
- The present study revealed that 15% replacement of cement with Alcofine is more durable when compared to normal concrete after exposure to acid attack.
- The percentage loss in compressive strength is increasing with the time of exposure from 30 to 90 days in 5% Hcl,5%mgso4 and 5% H2SO4 solution.

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