Durability Study on OPC and Slag based Cement Reinforced with Steel Fibers under Sulphate Attack

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ABSTRACT:- Concrete are subjected to environmental effect due to their weakness in resisting under acid and alkaline exposure. Usage of ingredients in the concrete provides resistance to environmental exposure and it's mainly by the usage of pozzolanic and mineral admixture. It provides better bonding with concrete by filling the capillary proves and improves in the initial and final hydration process of cement with other ingredients. Steel fibers addition in concrete increases the flexural and tensile strength of concrete irrespective of the orientation. The present study focus on the durability study on strength aspect of ordinary Portland cement and steel slag based cement with and without steel fibers. Mix proportion of M30 grade concrete was used in the study for all mixes. The percentage of steel fibre used is in the range of 0%, 0.5%, 1%, and 1.5% to the volume fraction of the concrete. In the study manufacturing sand was used for all mixes. Concrete without fibre addition had shown better workability compared with steel fibre concrete. Workability of the concrete is affected with the use of steel fibre and it's compensated with the addition of superplasticizers. It is observed that compressive strength increases with increases in the addition of steel fibre in concrete. Flexural strength and tensile strength of the concrete increases and it optimum for 1.5% steel fibre addition in concrete. The ultrasonic pulse velocity test shows higher value for plain concrete without fibre compared with steel fibre reinforced concrete. Steel fibre utilisation in slag based concrete had shown increase in strength of concrete compared to ordinary Portland cement based concrete. Durability study on concrete was executed for both cements with and without fibre under sulphate attack and the respective compressive strength of concrete was also determined.

Keywords: OPC, slag based cement, steel fibre, Msand, Super plasticizer

1.0 INTRODUCTION:

Ahcene. Merid (2015) Durability of concrete is mainly affected by exposure of the concrete to industrial waste and other non organic waste materials. The exposure is non preventable and it can be resisted by using mineral admixture in concrete and also increase in the grade of concrete. The concrete is weaker under pore formation inside the matrix and the exposure to sulphate environmental leads to percolation of sulphate causing expansion of concrete core, spalling of concrete and loss of strength in concrete at later ages.

A.Sumathi (2015) fiber reinforced concrete is combination of concrete matrix with short or long discontinuous fibres and it's added to improve the tensile, ductility and crack arrester under loading. Steel fibers are more efficient, increase the strength of concrete based on the size orientation and surface orientation etc.Utilisation of steel fibres are more predominate in the airports, highways and bridges overlays, sewer pipes and curtain walls due to their crack arresting and ability to withstand high impact force. In high performance concrete steel fibre addition increases the strength as well as durability resistance of concrete compared with nominal concrete. It is observed that fibre reinforced concrete exposed to acid and sulphate environment had observed minimum weight loss compared to plain concrete.

R. Kandasamy (2014) fibre concrete is composite material used to improve the tensile, flexural and energy absorption capacity of the concrete. It also improves the static and dynamic properties of concrete. Manufacturing sand addition improves the compressive strength of concrete compared to river sand. Flexural strength of fibre with Msand shows high strength compared with concrete with fibre and river sand.

Yingwu Zhou 2015 concrete exposed to sulphate environment increase the corrosion rate of steel inside the concrete. Increase in corrosion rate is higher after 60days of sulphate corrosion exposure and it leads to decrease in the compressive strength of the concrete. Sulphate attack under corrosion environment decreases the bonding between steel inside the concrete.

SHUBHAM ROY (2018) fibre reinforced concrete with steel fibre had shown improvement in the strength with respectect to the addition of steel fibre inside the concrete. Msand provides better bonding with cement compared to river sand under well graded condition. The workability of Msand with fibre is less compared to river sand with fibres due to the rough structure and usage of super plasticizer improves the workability of concrete. steel fibre are used to bridge the cracks in the concrete.ad it improves the flexural strength of concrete.

Research significance

The present study shows the important findings on durability study on the compressive strength gain and the resistance of the concrete subjected to sulphate attack. In this study manufacturing sand was a 100% replacement and its impact with waved steel fibre was observed. The effect of sulphate attack on the strength behaviour of concrete under was also determined using sodium sulphate in air temperature.

2.0 EXPERIMENTAL INVESTIGATION

The materials used in the present experimental investigation are as follows.

2.1 Cement

Ordinary Portland cement of 53 grade and high strength slag based having 28 days compressive strength of 53.2 MPa and 54MPa satisfying the requirements of IS: 12269–1987 was in the present study. The specific gravity of cement was found to be 3.15 for both cement.

2.2 Fine Aggregates

Manufacturing sand obtained from locally available source passing through 4.75mm IS sieve, conforming to grading zone-II of IS: 383-1978 was used with fineness modulus of 2.59 and specific gravity of 2.77.

2.3 Coarse Aggregate

Machine crushed well graded angular blue granite stone with 20 mm size, conforming to IS: 383-1978 was used. The specific gravity and fineness modulus was found to be 2.78 and 6.7 respectively.

2.4 Waved steel fibre

Waved steel fibre was used in the present study. It has high elastic modulus and tensile strength. The aspect ratio of the fibre is 80 (60/0.75) and snapshot of the fibre is shown in figure 1. The steel fibres are free from rust.

Figure 1. Waved steel fibre

2.6 Chemical Admixture

High range water reducer Conplast SP430 super-plasticizer was used in the study to reduce the water content for the concrete with specific gravity of 1.18.

2.8 Mix Design

Mix design for M30 grade concrete was used in the study with a target mean strength of 38.5 MPa. The water cement ratio was kept constant as 0.45 for all mixes. In the study the proportion of steel fibre was in the range of 0, 0.5%, 1% and 1.5% for OPC cement based and slag based concrete. The detailed proportions of all mixes were presented in **Table 1**.

Table 1 Mix Design Proportion for Different Mixes

Mix ID	Cement (OPC)	Cement (Slag cement)	Msand	Coarse Aggregate	Steel fiber	Water	Superplasticizer
	(kg/m^3)				%	(Litre/m^3)	(kg/m^3)
MF0	380		711	1283	0	160	1.9
MF1	380		711	1283	0.5	160	1.9
MF2	380		711	1283	1	160	1.9
MF3	380		711	1283	1.5	160	1.9
MFS0		380	711	1283	0	160	1.9
MFS1		380	711	1283	0.5	160	1.9
MFS2		380	711	1283	1	160	1.9
MFS3		380	711	1283	1.5	160	1.9

2.9 Casting and curing of specimen

Concrete ingredients were mixed in dry condition first in a pan type concrete mixer of capacity 40 Kg for a period of 3 minutes, and then water is added slowly with super plasticizer 1% to improve workability for various mixture proportions. Steel fibres were added later and mixed thoroughly in the pan mixer for 2 minutes and casted in steel cube moulds of standard size 150 X 150 X 150 mm and compacted on a table vibrator. The surface finishing was done to obtain a uniform smooth surface.

2.10 Compressive strength

Compressive strength of different mixes were carried out using cube specimen of standard size 150 x 150 x 150mm in a digital compression testing machine of 2000KN .The cube specimen were kept in air temperature for a period of 10 hours from wet curing before testing. The details of the compression test is shown in Figure 2

Figure 2 Compression test setup

2.11 Flexural and Split tensile strength:

Flexural strength and split tensile strength of concrete was carried using prism of 500 x 100 x 100mmm and cylinder specimen of 150mm x 300mm respectively. The flexural strength of the beam specimen with and without fibre are carried out using third point loading under universal testing machine of 100ton capacity. The spilt tensile was carried out in digital compression testing machine.

2.10 Sulphate Attack:

Resistance of the concrete subjected to sulphate attack was performed using cube specimen immersed in the water diluted with 5% sodium sulphate salt for a period of 90 days. The specimens are kept in a water tub and the diluted is replaced for after every 15 days. The specimens are immersed in sulphate solution for a period of 28, 56 and 90 days before testing. Compressive strength of the cube specimen subjected to acid attack is evaluated using 1000kN compression testing machine.

3.0 EXPERIMENTAL TEST RESULTS AND DISCUSSION

Test results are presented graphically and in tabular forms and have been discussed under various categories.

3.1 Properties of fresh concrete:

Fibre reinforced concrete at fresh state shows decreases in the workability with increase in the dosage of fibre in the concrete. Slag based concrete had shown decrease in the workability compared with ordinary Portland cement concrete. The workability of 75- 100m slump was maintained for all mixes and achieved with the help of super plasticizer.

3.2 Compressive Strength of Concrete

Compressive strength of different mix proportions was obtained and its observed that slag based cement with fibre concrete had show better strength compared to ordinary cement fibre concrete. The slag based fibre concrete with 1.5% volume fraction of concrete had shown higher compared to OPC cement fibre concrete. The steel fibre addition had shown increase in compressive strength with increase in the percentage of steel fibre addition. High compressive strength of 44MPa is observed for 1.5% steel fibre addition in slag based concrete. The details are shown in Table 1 and in figure 3

Table 1 Compressive strength for different mixes

Mix ID	Cement (OPC)	Cement (Slag cement)	steel fiber	Compressive strength (Mpa)		
				3 day	7 day	28 day
	(kg/m³)		%	Mpa	Mpa	Mpa
MF0	380		0	17.97	27.65	39.50
MF1	380		0.5	18.29	28.14	40.20
MF2	380		1	18.66	28.70	41.00
MF3	380		1.5	19.02	29.26	41.80
MFS0		380	0	18.43	28.35	40.50
MFS1		380	0.5	18.88	29.05	41.50
MFS2		380	1	19.20	29.54	42.20
MFS3		380	1.5	20.11	30.94	44.20

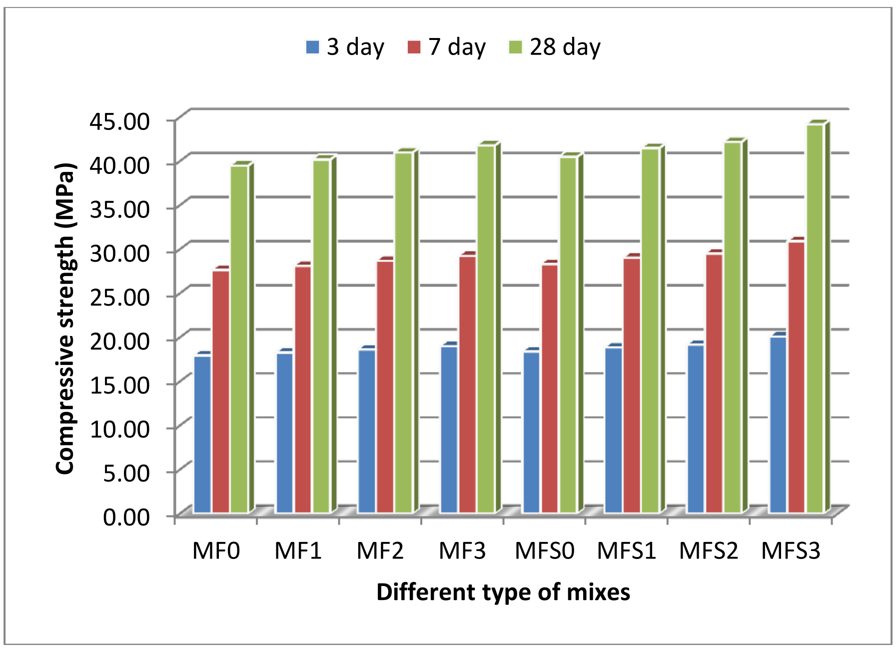

Figure 3 Compressive strength for different mixes

3.4 Flexural and split tensile strength

Flexural strength of fibre concrete had shown increase in strength with addition of fibre in the concrete. Optimum percentage for the study is obtained at 1.5% for both OPC and slag based cement concrete. Addition of MSand in concrete also improves the flexural strength of concrete.

The steel fibre in concrete improves the deflection of the beam before failure and it allows the beam to take load beyond the yield limit. Fibres act as crack arresters in concrete. Split tensile strength of the concrete increases with increase in the percentage of fibres in both concrete and 1.5% addition shows the optimum percentage of steel fibre in concrete. The details are shown in table 2 and figure 4 and 5

Table 2 Flexural and Split tensile strength of concrete

Mix ID	Cement (OPC)	Cement (Slag cement)	steel fiber	Split tensile strength		Flexural strength	
				7day	28 day	7 day	28 day
	(kg/m³)		%	Mpa	Mpa	Mpa	Mpa
MF0	380		0	1.35	1.94	3.10	4.3
MF1	380		0.5	1.58	2.26	3.25	4.52
MF2	380		1	1.72	2.45	3.53	4.9
MF3	380		1.5	1.86	2.65	3.82	5.3
MFS0		380	0	1.45	2.07	3.31	4.6
MFS1		380	0.5	1.82	2.60	3.74	5.2
MFS2		380	1	1.96	2.80	4.03	5.6
MFS3		380	1.5	2.14	3.05	4.39	6.1

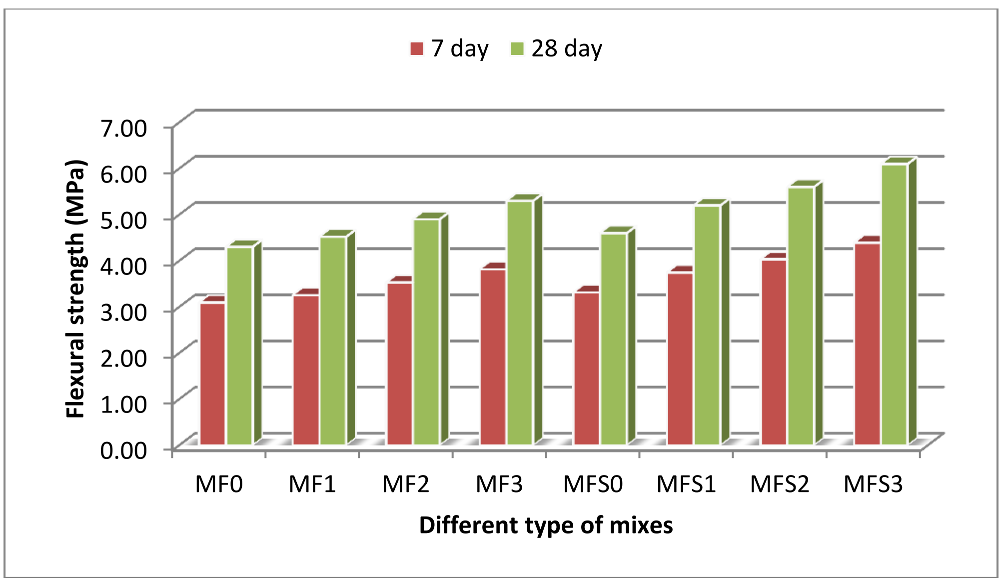

Figure 4 Flexural strength for different mixes

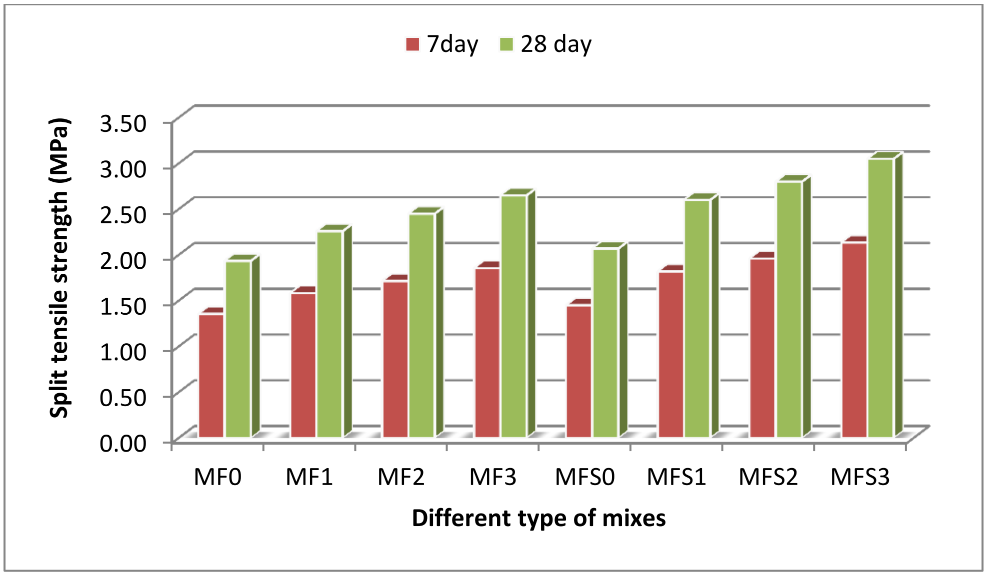

Figure 5 Split tensile strength for different mixes

3.5 Residual compressive strength.

Residual compressive strength is cube specimen test under compression after immersed in the sulphate solution. Sulphate attack on concrete was carried ot for 28 days, 56 days and 90 day immersion in sulphate solution using cube specimen. The cube specimen show surface layer porosity for OPC based fibre concrete compared with slag based fibre concrete. The compressive strength after sulphate attack was observed for all mix proportion for the testing ages. It is observed that slag based concrete shows better resistance and it regain the maximum strength after subjected to sulphate exposure. High residual compressive strength if noted for 1.5% percentage of steel fibre in slag. Based concrete compared with OPC cement concrete. The details are shown in table 3 and the percentage of strength loss is shown in figure 6.

Table 5 sulphate attack on different mixes

Mix ID	Cement (OPC)	Cement (Slag cement)	steel fiber	Compressive strength (Mpa) & loss in strength (%)						
				Normal curing	sulphate attack (28days)	Loss in strength (28days)	sulphate attack (56day)	Loss in strength (56day)	sulphate attack (90days)	Loss in strength (90day)
	(kg/m³)		%	Mpa	Mpa	(%)	Mpa	(%)	Mpa	(%)
MF0	380		0	39.50	38.25	3.16	37.2	5.82	36.5	7.59
MF1	380		0.5	40.20	39.80	1.00	38.8	3.48	37.6	6.47
MF2	380		1	41.00	40.50	1.22	40.1	2.20	38.5	6.10
MF3	380		1.5	41.80	41.50	0.72	40.9	2.15	39.2	6.22
MFS0		380	0	40.50	39.80	1.73	39	3.70	38.1	5.93
MFS1		380	0.5	41.50	41.20	0.72	40.5	2.41	39.4	5.06
MFS2		380	1	42.20	41.85	0.83	41	2.84	40.1	4.98
MFS3		380	1.5	44.20	44.00	0.45	43.2	2.26	42.1	4.75

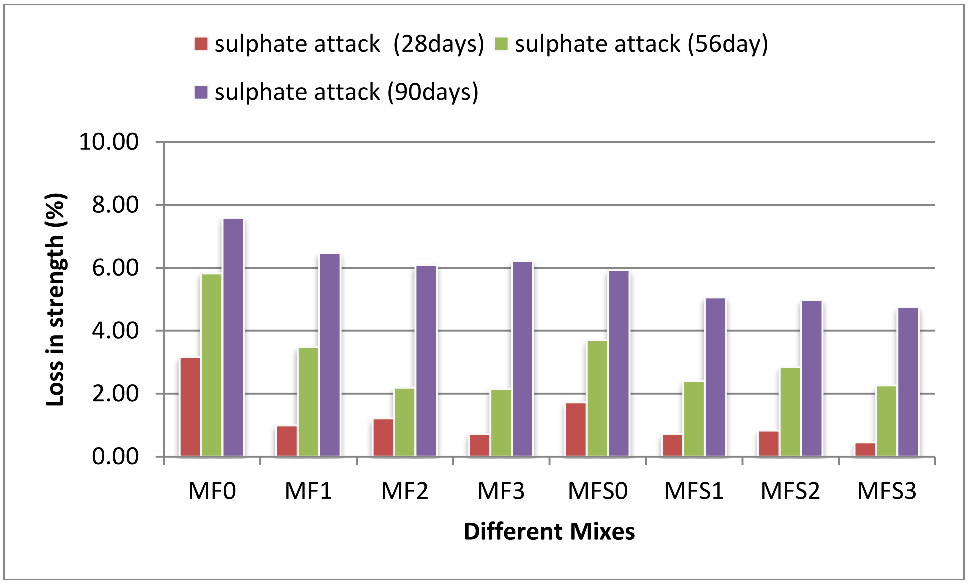

Figure Loss of compressive strength for different mixes

4. Conclusions

Based on the experimental investigation the following conclusions are drawn from the test results.

Compressive strength of slag based cement fibre concrete had shown increase in strength compared to OPC based cement fibre concrete.

Workability of fibre concrete is lower compared with concrete without fibre.

Flexural and split tensile strength shows increase in strength with steel fibre addition.

Slag based fibre concrete with 1.5% steel fibre addition had shown high strength compared with OPC based fibre concrete.

Msand in concrete improves the strength of the concrete for all mixes.

Concrete under sulphate attack had shown less loss in strength for slag based cement fibre concrete compared with OPC cement based fibre concrete.

Steel fibre in concrete had shown high resistance to sulphate attack under residual compressive strength for 1.5% steel fibre addition.

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