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Study on Partial Replacement of Cement with Waste Paper Sludge Ash in Fibre Reinforced Concrete

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Abstract: ***Portland cement is the most important ingredient of concrete and is a versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This work examines the possibility of using waste paper sludge ash to produce a low cost concrete by blending various ratios of cement with paper sludge ash and to reduce disposal and pollution problems due to waste paper sludge ash. The innovative use of waste paper sludge ash in concrete as a supplementary cementitious material was tested as an alternative to fibre reinforced concrete. In this study waste paper sludge ash was partially replaced from 5%, 10%, 15% in cement to get optimum point and from this optimum point addition of glass fibres with different proportions i.e from 0.1%, 0.2%, 0.3%, 0.4% and also steel fibres with different proportions i.e from 0.5%, 1%, 1.5%, 2% are used in concrete for M25 mix and tested for its compressive strength, splitting tensile strength and flexural strength up to 28 days of strength and compared with conventional concrete. Durability tests are also conducted for these mixes with 5% of H2So4 and HCl. Test results indicate that use of waste paper sludge ash in concrete has improved the performance of concrete in strength aspect***

Keywords: Compressive strength, Durability, split tensile strength, Flexural strength, Durability, Waste Paper Sludge Ash, M25Concrete

1. Introduction

In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. Paper mill sludge is a major economic and environmental problem for the paper and board industry. An enormous quantity of waste paper sludge is generated all around the world. In India, 0.7% of total urban waste generated comprises of paper sludge. Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. In functional terms, paper sludge consists of cellulose fibers, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. The material is viscous, sticky and hard to dry and can vary in viscosity and lumpiness. It has an energy content that makes it a useful candidate as an alternative fuel for the manufacture of Portland cement. This research will summarize the behaviour of concrete with the waste paper sludge ash by replacement of cement in the range of 5%,10% and 15% which may help to reduce the disposal problem of sludge and enhance the properties of M25 concrete. As wastepaper sludge ash contains higher percentage of silicon dioxide SiO2, it may provide extra strength to concrete. In addition to these fibres are also added to obtain more strength.

2. Materials and Properties

In this research work various materials like Cement, Fine Aggregate ,Coarse Aggregate, water, glass and steel fibers were used and their properties are examined by taking the help of IS [INDIAN STANDARD] codes.

2.1 Cement

Ordinary Portland cement of 53 Grade was preferred for this study. The physical properties of cement are categorized as per IS 456-2000

Table 1: Properties of cement

S.No	Properties	Value	Permissible limit as per IS: 12269-1987
1	Specific Gravity	3.12	Varies from 3.1 to 3.15
2	Initial Setting time	58min	Should not be less than 30 Min
3	Final Setting time	300 min	Should not be more than 600 Min
4	Fineness test	1% retained	<10%

2.2 Fine Aggregates

Locally available river sand was preferred as fine aggregate for entire experimental work. The physical properties of sand was carried out by taking the help of IS 383-1970 and IS 2386-1963 code books.

Table 2: Properties of fine aggregate

S.No	Properties	Value	Permissible limit as per IS: 383-1970
1	Specific Gravity	2.6	Should be between the limit 2.6-2.7
2	Fineness Modulus	2.73	2-4
3	Grading Zone	Zone II	--

2.3 Coarse Aggregate

Crushed Granite stone of sizes 20mm and 10mm were selected for this work. Taking the reference of IS codes the properties of coarse aggregate have been tested

Table 3: Properties of coarse aggregate

S.No	Properties	Value	Permissible limit as per IS: 2386-1963
1	Specific Gravity	2.64	In between range 2.6-2.8
2	Fineness Modulus	6.48	6.5-8

2.4 Waste Paper sludge ash

This material is collected from Vedadri Paper Mills(India) pvt. Ltd. The chemical properties of waste paper sludge ash are

Table 4: Chemical Composition of Waste Paper Sludge Ash

Property	Value
Silicon Dioxide	59.47%
Calcium Oxide	8.69%
Alumina and Ferric Oxide	10.45%
Magnesium Oxide	3.13%

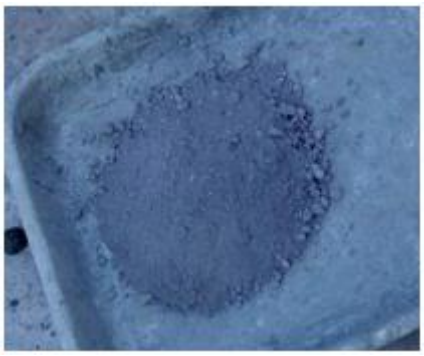


Figure 1: Waste paper sludge ash

2.5 Fibres

2.5.1Steel fibres

- Diameter:- 0.5mm
- Length:- Available in30mm
- Density:- density of steel fibre is 7900kg/m3
- Aspect Ratio:- 60

Figure 2: Hooked steel fibres

2.5.2 Glass fibres

The type glass fibres use are ar- glass type fibres.the properties are given below.The length of glass fibres is 50mm and diameter is 0.1mm.

Table 5: Properties of Glass Fibres

Property	Value
Density, (g/Cm^3)	2.7
Tensile Strength, MPa	1700
Modulus, GPa	72
Percent Elongation	2.3

Figure 3: Glass fibres

3. Concrete Mix Proportion

The mix design for M25 has carried out by following the specifications and limitations of Indian Standard Code (IS 10262-2009). The target meant strength was inspected as 34.5N/mm2.The water to cement ratio is taken as 0.45. The mix proportion for M25 grade concrete is 1:1.34:2.76

Table 6: Results of M25 Mix

Material	Cement	Fine aggregate	Coarse aggregate
Kg/m^3	406.33	659.23	1116.05

4. Tests Done on Concrete for Strength and Durability

A number of tests were conducted on concrete determine the design mix properties of concrete in the laboratory. The strength criterion includes measurement of following parameters**:**

4.1 Compressive Test

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the Compressive strength of 7 days, 28 days testing.

Figure 4: Testing of cubes in compressive testing machine

4.2 Split tensile Test

Split tensile was performed on cylinders 150mm dia. and 300mm height on compression testing machine. The failure load was recorded to find out split tensile strength. After testing the concrete (split tensile strength) for M25 grade

concrete separately for replacement of sludge ash and adding glass & steel fibre by cement respectively finally combined percentage of sludge ash and adding glass & steel fibre in which maximum strength is obtained was used to get optimized strength.

Figure 5: Testing of cylinders in split tensile testing machine

4.3 Flexural Test

Flexural test was performed on beams by placing them on universal find out the flexural strength. After testing the concrete (flexural strength) for M25 grade concrete separately for replacement of sludge ash and adding glass & steel fibre by cement respectively finally combined percentage of sludge ash and adding glass & steel fibre in which maximum strength is obtained was used to get optimized strength.

Figure 6: Testing of Beams in Flexural Testing Machine

4.4 Durability Test

The concrete acid resistance was observed by two types of tests named as Acid attack factor test and Acid durability factor test. The concentrations of acids in water are 5% HCL and 5% H2SO4.concrete can be attacked by liquids with pH value less than 6.5 and attack is severe when pH value is below 5.5. At pH value below 4.5, the attack is very severe. As the attack proceeds, all the cement compounds are broken down and leached away. Here HCL andH2SO4 which are having pH value 3.01 and 2.75 which cause a very severe attack are used to study the durability properties. To check acid resistance of concrete Hydro Chloric acid (HCL), Sulphuric Acid (H2SO4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

Preparation of 5% H2SO4 per Litres of Water:

The volume of acid to mix in water is calculated by the formula C1V 1=C2V2

C1 is the Concentration of H2SO4 = 98% V1 is the Volume required = 20 lit

C2 is the required concentration = 5% V2 is the required volume of acid Volume of H2SO4 (V2) = C2V2/C1

=5×20/98 =1.02 litres

i.e., to prepare 20 lit solutions of H2SO4, volume of acid required is 1.02 litres

Preparation of 5% HCl 20 per Litres of Water:

The aicd volume to be in the water can be obtained from the formula

C1V1=C2V2

Where,

C1 is the Concentration of HCl = 35%

V1 is the Volume required = 20 lit

C2 is the required concentration = 5%

V2 is the required volume of acid

Volume of HCl (V2) = C2V2/C1

=5×20/35

=2.85 liters

i.e., to prepare 20 lit solutions of HCl, volume of acid required is 2.85 liters

Figure 7: Sulphuric acid and HCl

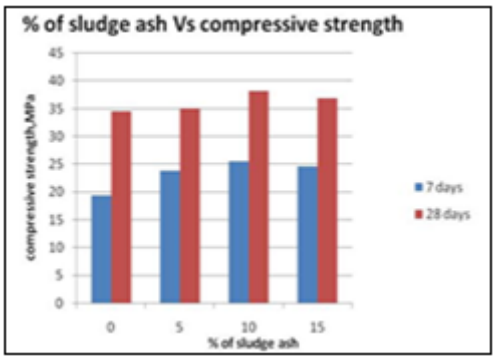
Figure 8: Acid curing

5. Results

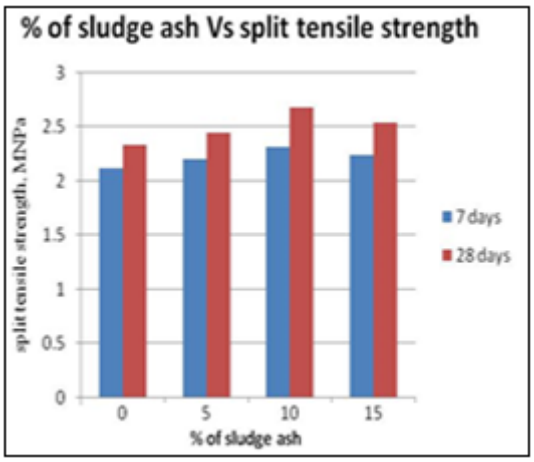
The results for different mix proprtions are as follows:

Table 7: Results Using Sludge Ash in Concrete

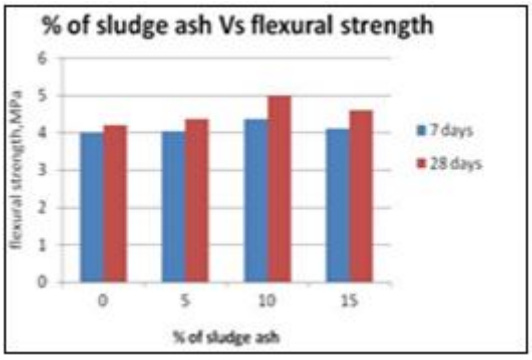
%	Compressive strength		Split tensile strength		Flexural strength	
	7 days	28 days	7 days	28 days	7 days	28 days
0%	19.38	34.5	2.12	2.34	4.01	4.21
5%	23.84	35.11	2.21	2.45	4.05	4.38
10%	**25.52**	**38.26**	**2.32**	**2.68**	**4.38**	**5.01**
15%	24.54	36.89	2.24	2.54	4.12	4.62



Graph 9: Graph for % of sludge ash vs compressive strength [2]



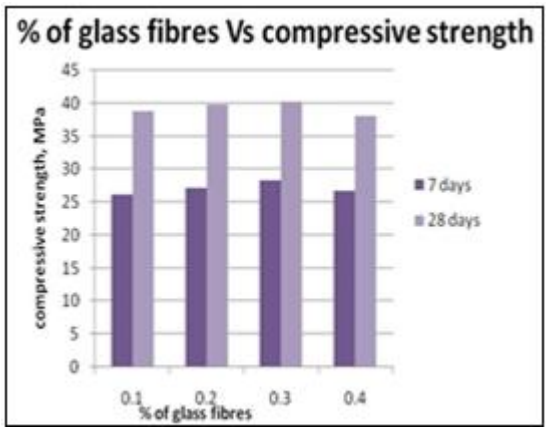
Graph 10: Graph for % of sludge ash vs split tensile strength



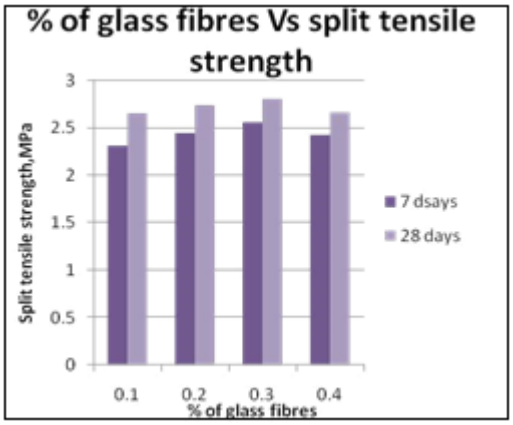
Graph 11: Graph for % of sludge ash vs flexural strength

Table 8: Results by Adding Glass Fibres in Sludge Ash Concrete

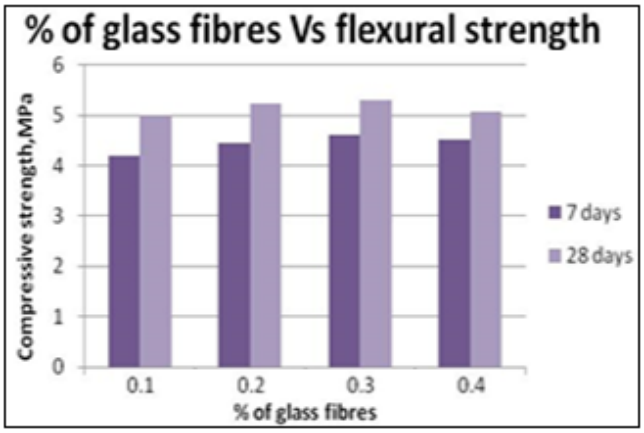
%	Compressive strength		Split tensile strength		Flexural strength	
	7 days	28 days	7 days	28 days	7 days	28 days
0.1%	26.12	38.88	2.31	2.66	4.18	4.99
0.2%	27.22	39.76	2.45	2.74	4.43	5.21
0.3%	**28.34**	**40.23**	**2.56**	**2.81**	**4.6**	**5.29**
0.4%	26.81	38.11	2.43	2.67	4.51	5.06



Graph 12: Graph for % of glass fibres vs compressive strength



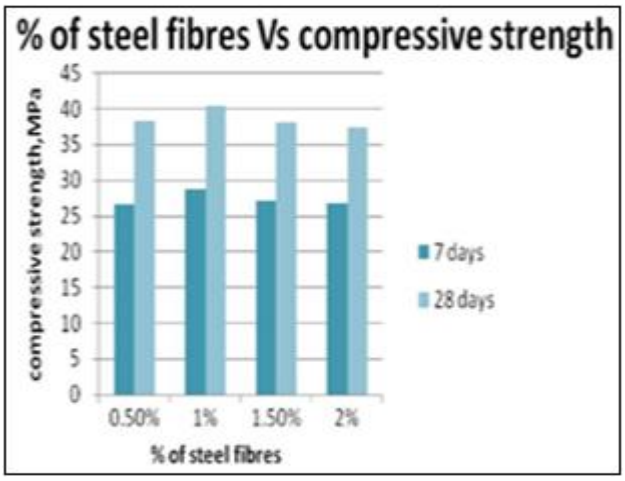
Graph 13: Graph for % of glass fibres vs split tensile strength



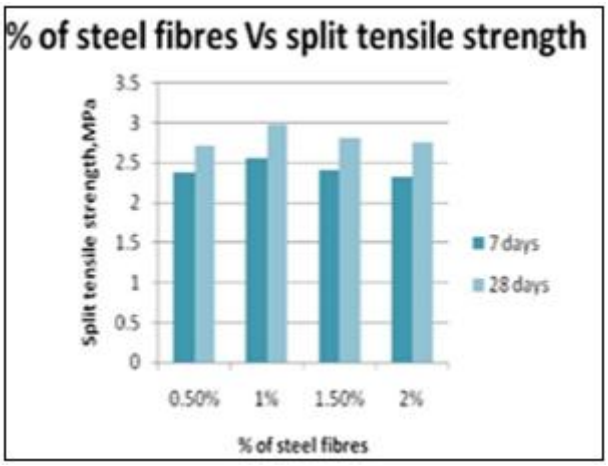
Graph 14: Graph for % of glass fibres vs flexural strength

Table 9: Results by Adding Steel Fibres in Sludge Ash Concrete

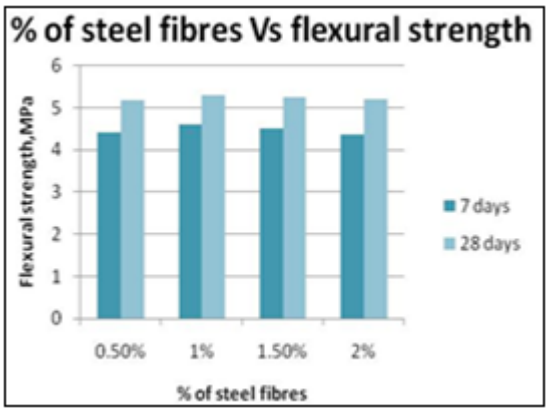
%	Compressive strength		Split tensile strength		Flexural strength	
	7 days	28 days	7 days	28 days	7 days	28 days
0.5%	26.67	38.41	2.38	2.71	4.41	5.18
1%	**28.81**	**40.41**	**2.56**	**2.98**	**4.62**	**5.31**
1.5%	27.16	38.12	2.41	2.82	4.51	5.26
2%	26.81	37.41	2.32	2.76	4.37	5.21



Graph 15: Graph for % of steel fibres vs compressive strength



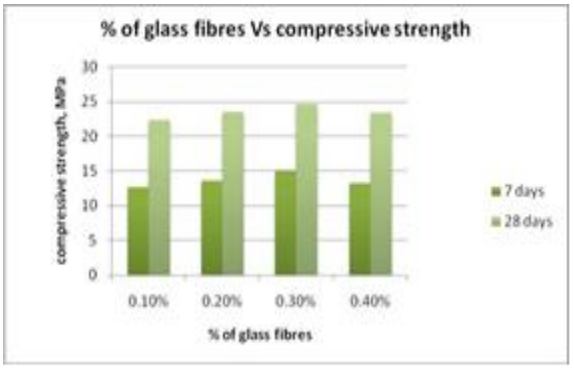
Graph 16: Graph for % of steel fibres vs split tensile strength



Graph 17: Graph for % of Steel Fibres Vs Flexural Strength

Table10: Durability Results by Adding Glass Fibres in Sludge Ash Concrete

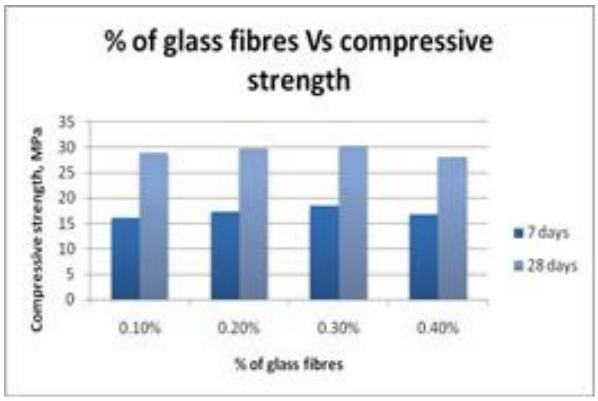
Glass fibers	Curing under 0.5% H_2So_4 % weight loss after 28 days	Compressive strength(N/mm^2) 7days(5% H_2So_4)	Compressive strength(N/mm^2) 28days(5% H_2So_4)
0.1%	4.16	12.66	22.35
0.2%	5.59	13.58	23.44
0.3%	6.34	14.99	24.68
0.4%	6.35	13.24	23.33



Graph 18: Graph for % of glass fibres vs compressive strength

Table 11: Durability Results by Adding Glass Fibres in Sludge Ash Concrete

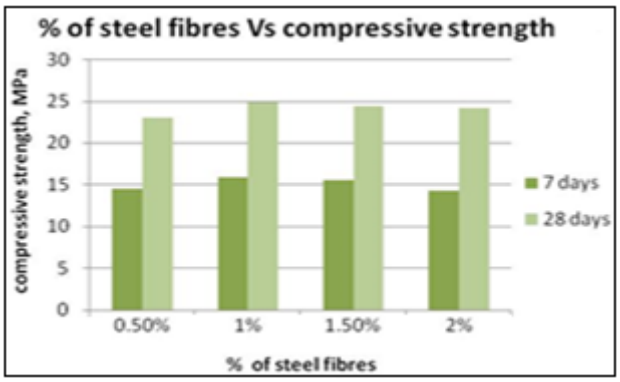
Glass fibers	Curing under 0.5% HCl % weight loss after 28 days	Compressive strength(N/mm^2) 7days(5% HCl)	Compressive strength (N/mm^2) 28days(5% HCl)
0.5%	2.3	16.12	28.88
1%	2.46	17.22	29.76
1.5%	2.66	18.44	30.23
2%	2.69	16.81	28.11



Graph 19: Graph for % of glass fibres vs compressive strength

Table 12: Durability Results by Adding Steel Fibres in Sludge Ash Concrete

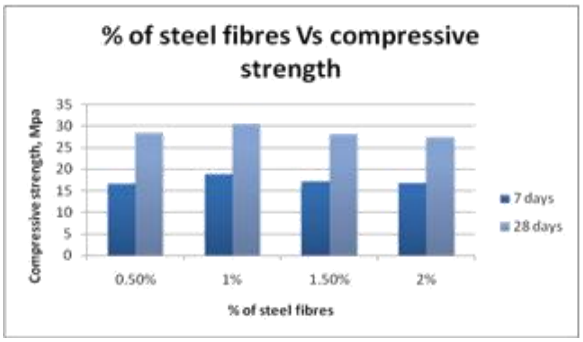
Steel fibers	Curing under 0.5% H_2So_4 % weight loss after 28 days	Compressive strength(N/mm^2) 7days(5% H_2So_4)	Compressive strength(N/mm^2) 28days(5% H_2So_4)
0.5%	4.46	14.44	23.04
1%	5.66	15.85	24.81
1.5%	6.41	15.5	24.54
2%	7.11	14.21	24.11



Graph 20: Graph for % of steel fibres vs compressive strength

Table 13: Durability Results by Adding Steel Fibres in Sludge Ash Concrete

Steel fibers	Curing under 0.5% HCl % weight loss after 28 days	Compressive strength(N/mm^2) 7days(5% HCl)	Compressive strength(N/mm^2) 28days(5% HCl)
0.5%	2.33	16.67	28.41
1%	2.41	18.81	30.41
1.5%	2.58	17.16	28.12
2%	2.63	16.81	27.41



Graph 21: Graph for % of steel fibres vs compressive strength

6. Conclusions

- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and compressive strength obtained is 38.26MPa and increase in strength is 9.827% than conventional concrete.
- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and split tensile strength obtained is 2.68MPa and increase in strength is 12.688% than conventional concrete.
- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and flexural strength obtained is 5.01MPa and
- Increase in strength is 15.96% than conventional concrete.
- By adding glass fibres, the optimum is obtained at 0.3% and the value obtained is 40.23MPa for compressive strength and increase in strength is 14.24% than conventional concrete..
- By adding glass fibres, the optimum is obtained at 0.3% and the value obtained is 2.81MPa for split tensile strength and increase in strength is 16.72% than conventional concrete.
- By adding glass fibres, the optimum is obtained at 0.3% and the value obtained is 5.29MPa for flexural strength and increase in strength is 19.19% than conventional concrete.
- By adding steel fibres, the optimum is obtained at 1% and the value obtained is 40.41MPa for split tensile strength and increase in strength is 14.62% than conventional concrete.
- By adding steel fibres, the optimum is obtained at 1% and the value obtained is 2.98MPa for split tensile strength and increase in strength is 21.47% than conventional concrete..
- By adding steel fibres, the optimum is obtained at 1% and the value obtained is 5.31MPa for flexural strength and increase in strength is 20.71% than conventional concrete.
- In durability the weight loss is higher in H2SO4 than HCl.
- Glass fibres shown better results than steel fibres in durability results

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