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Experimental Investigation on Strength and Durability Properties of Steel and Glass Fibres with M30 Grade Concrete using Waste Paper Sludge

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Abstract - *Paper mill sludge is a major economic and environmental problem for the paper an d 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. 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 M_{30} 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 H_2So_4 and HCl. Test results indicate that use of waste paper sludge ash in concrete has improved the performance of concrete in strength aspect.*

Key Words: Compressive strength, Durability, split tensile strength, Flexural strength, Durability, Waste Paper Sludge Ash, M_{30} Concrete

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 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 fibres, 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. In plain concrete structural cracks develop even before loading, due to drying shrinkage or other causes of volume change. The width of these initial cracks is few microns, but their other dimensions may be of higher magnitude.

2. MATERIAL PROPERTIES

Concrete is a composition of three raw materials. Cement, Fine aggregate and Coarse aggregate. These three raw materials play an important role in manufacturing of concrete. By varying the properties and amount of these materials, the properties of concrete will changes.

2.1 Cement:

The cement should be stored under dry conditions and for as short duration as possible. Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the Cement content. The Cement used in this project is Ordinary Portland Cement of 53 grade confirming to IS 12269 – 1987. The specific gravity of the cement is 3.12

Table 1: Physical Properties of Cement

S NO	Property	Results
1	Normal consistency	33%
2	Initial Setting Time Final Setting Time	35minutes 350minutes
3	Fineness of Cement	1%
4	specific gravity	3.12

2.2 Fine Aggregate:

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by

specification. Fine aggregates conforming to grading zone III with particles greater than 2.36 mm and smaller than 150 mm removed are suitable.

Table 2: Physical Properties of Fine aggregate

S NO	Property	Results
1	specific gravity	2.6
2	Fineness modulus	2.75
4	Grading Zone	III

2.3 Coarse Aggregate:

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification. According to size coarse aggregate is described as graded aggregate of its nominal size i.e. 40 mm, 20 mm, 16 mm and 12.5 mm etc. Locally available crushed stones conforming to graded aggregate of nominal size 20 mm and 10mm as per IS: 383 – 1970. Specific gravity of coarse aggregate is 2.65

2.4 Waste paper sludge ash:

Waste Paper Sludge ash is a waste material formed during paper manufacturing process by wooden pulp in a paper mill along with certain ingredients. It imposes a major economic and environmental crisis in Paper and board industry. The recycling and disposal are the main routes for paper sludge which are put on land-spreading as agricultural fertiliser, incineration in Combined Heat Power (CHP) plants in the paper mill, producing paper sludge ash, or disposal to landfill. Specific gravity of WPSA is 2.7

Fig-1: Waste Paper Sludge Ash

2.5 Water:

Water used in the mixing is to be Fresh potable water free from acid and organic substances was used for mixing and curing concrete. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of beams.

2.6 Fibres:

Fibre or fibre is a natural or synthetic substance that is significantly longer than it is wide. Fibres are often used in the manufacture of other materials.

2.6.1 Steel Fibres:

Fibre is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter.

Table 3: Specifications of steel fibres

Fibre Type	Fibre Length	Fibre Diameter	Aspect Ratio
Hooked End	30mm	0.5mm	60

Fig-2: Steel Fibres

2.6.2 Glass Fibres:

It is material made from extremely fine fibres of glass Fibre glass is a lightweight, extremely strong, and robust material. The glass fibre type used here is E glass with 50mm fibre length and 0.1mm diameter. The aspect ratio of the glass fibre is 500.

Fig-3: Glass Fibres

3. EXPERIMENTAL PROGRAMME

The experimental investigation consists of casting and testing of 12 sets along with control mix. Each set comprises of 12 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. By taking different percentage of Waste paper sludge ash, along with steel & Glass fibres individually as a

partial replacement of cement will be replaced accordingly with the different percentages by weight of ash and different percentages by weight of steel fibre and Glass fibre.

Cube specimen dimension is of 15 cm x 15 cm x 15 cm, cylinder specimen dimension is 15 cm x 30 cm and beam specimen is 50 cm x 10 cm x 10 cm.

4. MIX DESIGN

Mix Design is done as per Indian standards .Mix Design is the process of selecting suitable ingredients of concrete and determining their relative quantities for producing concrete of certain minimum properties as strength, durability and consistency etc., as economically as possible. Mix design done for M_{30} grade concrete. The mix design was calculated by using IS: 10262:2009. The mix design obtained is 1:1.36:2.82 with a water/cement ratio of 0.40

5. CASTING OF SPECIMENS

After completing the mix proportioning of materials concreting is done to represent the characteristics. Three types of concrete specimens are prepared in respective moulds in casting procedure. The types of specimens are Cubes, Beams and Cylinders.

Fig-4: Specimens

6. TESTS AND RESULTS

The well cured specimens in curing tank are tested for Compressive strength, split tensile strength and Flexural Strength. By taking out the specimens from the curing tank, the specimens were exposed to sun light for surface drying. After the drying process, the specimens are processed for testing. The specimens are tested for 7 days, 28 days and 90 days strengths.

- Compressive strength
- Split tensile strength
- Flexural strength

Compressive 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 and 28 days of testing.

Fig-5: Testing Cube in CTM

The mix proportions with partial replacement of OPC with 0%, 5%, 10%and 15% of WPSA are calculated.

Table 4: Compressive strength for different WPSA optimum percentages

S.NO	% of WPSA	Compressive Strength (MPa)	
		7 days	28 days
1	0	25.38	38.5
2	5	26.84	40.11
3	**10**	**28.52**	**41.26**
4	15	27.54	39.89

Table 5: Compressive strength for steel fibre

S.NO	WPSA %	% of Steel Fibre	Compressive strength	
			7days (N/mm^2)	28 days (N/mm^2)
1	0	0	25.38	38.5
2	10	0.5	28.67	41.41
3	**10**	**1**	**30.81**	**43.41**
4	10	1.5	29.16	40.85
5	10	2	27.81	39.01

Table 6: Compressive strength for glass fibre

S.No	WPSA %	% of Glass Fibre	Compressive Strength	
			7 days (N/mm²)	28 days (N/mm²)
1	0	0	25.38	38.5
2	10	0.1	27.12	39.88
3	10	0.2	28.22	41.76
4	**10**	**0.3**	**30.34**	**43.23**
5	10	0.4	28.81	42.11

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 M_{30} grade concrete separately for replacement of slag, glass & steel fiber by cement respectively finally combined percentage of ash & steel fiber mix, slag & glass fiber mix in which maximum strength is obtained was used to get optimized strength.

Table 7: Flexural test for different WPSA optimum percentages

S.NO	WPSA %	Flexural Test	
		7 days (N/mm²)	28 days (N/mm²)
1	0	3.91	4.8
2	5	4.05	5.25
3	**10**	**4.38**	**6.04**
4	15	4.12	5.62

Table 8: Flexural test for steel fibre

S.NO	WPSA %	% of Steel Fibre	Flexural Test	
			7 days (N/mm²)	28 days (N/mm²)
1	0	0	3.91	4.8
2	10	0.5	4.25	5.48
3	**10**	**1**	**4.72**	**6.30**
4	10	1.5	4.35	5.6
5	10	2	4.07	5.20

Table 9: Flexural test for glass fibre

S.NO	WPSA %	% Of Glass fibre	Flexural Test	
			7days (N/mm²)	28days (N/mm²)
1	0	0	3.91	4.8
2	10	0.1	4.05	5.35
3	10	0.2	4.25	5.60
4	**10**	**0.3**	**4.40**	**6.05**
5	10	0.4	4.10	5.80

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 M_{30} grade concrete separately for replacement of slag, glass & steel fiber by cement respectively finally combined percentage of slag & steel fiber mix, slag & glass fiber mix in which maximum strength is obtained was used to get optimized strength.

Table 10: Split Tensile Strength test for different WPSA optimum percentages

S.NO	WPSA %	Split tensile Test	
		7 days (N/mm²)	28 days (N/mm²)
1	0	2.72	3.50
2	5	2.98	3.95
3	**10**	**3.15**	**4.30**
4	15	2.80	4.05

Table 11: Split Tensile test for steel fibre

S.NO	WPSA %	% of Steel Fibre	Split Tensile Test	
			7 days (N/mm²)	28 days (N/mm²)
1	0	0	2.72	3.50
2	10	0.5	3.05	4.25
3	**10**	**1**	**3.25**	**4.85**
4	10	1.5	3.15	4.40
5	10	2	2.92	4.05

Table 12: Split Tensile test for Glass fibre

S.NO	WPSA %	% of glass fibre	Split Tensile Test	
			7days (N/mm²)	28 days (N/mm²)
1	0	0	2.72	3.50

2	10	0.1	2.91	3.95
3	10	0.2	3.15	4.15
4	**10**	**0.3**	**3.56**	**4.50**
5	10	0.4	3.25	4.40

7. DURABILITY STUDIES

The Acid resistance of concrete Hydro Chloric acid (HCL), Sulphuric Acid (H_2SO_4) 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.

Table 13: Summary of brief details for durability study

Acids used	HCL, H_2SO_4
Concentrations for trails	5% in water
Number of days of testing	7 days, 28 and 60 days

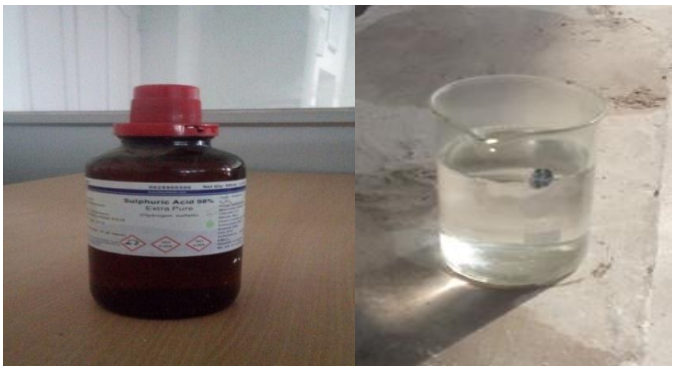


Figure 6: (a) Sulphuric acid (b) Beaker with H_2SO_4

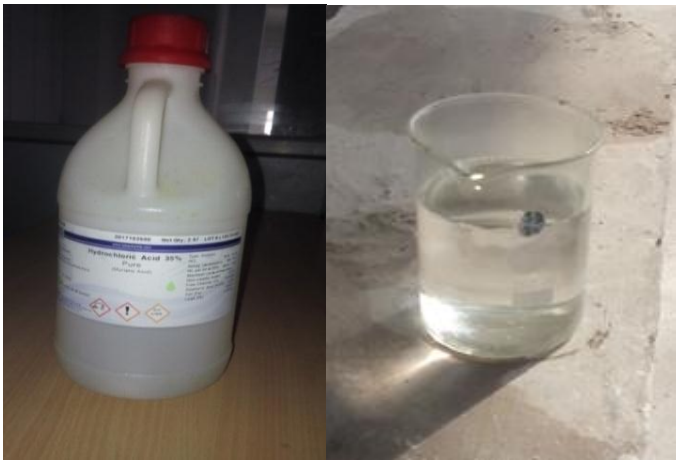
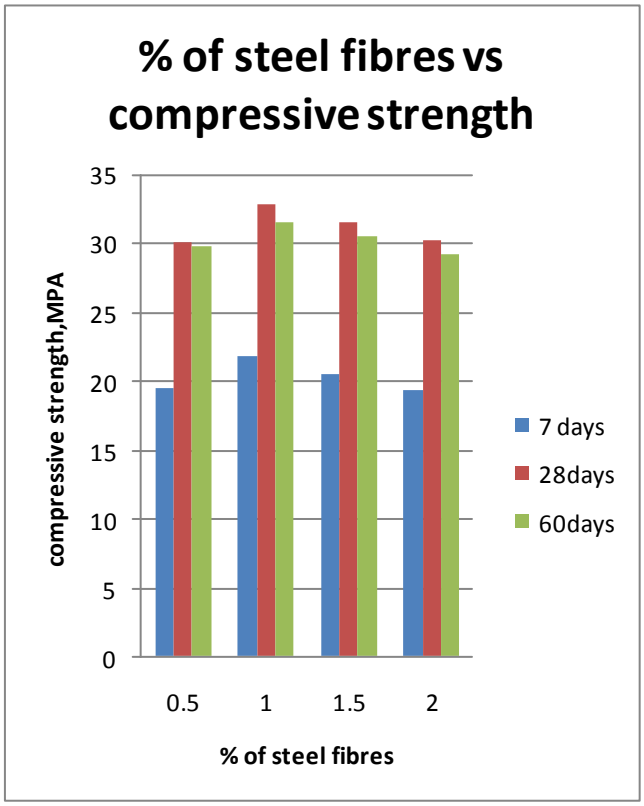
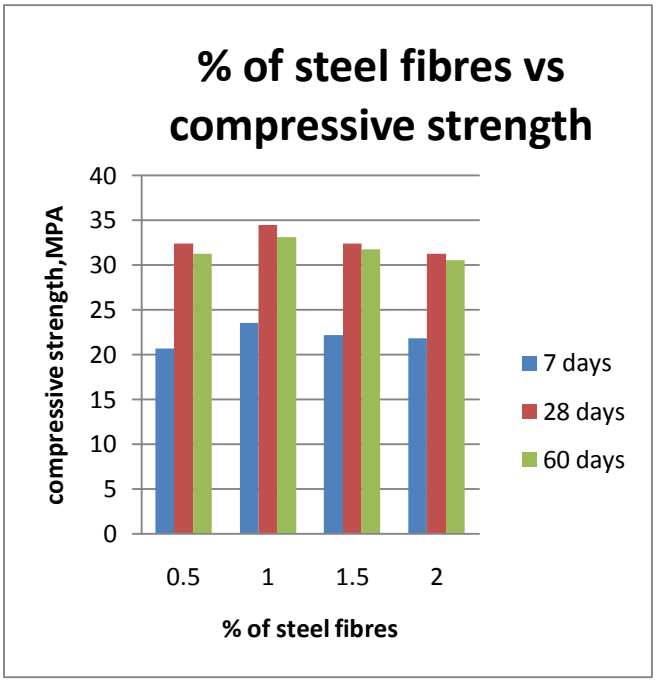


Figure 7: (a) HCl acid (b) Beaker with HCl

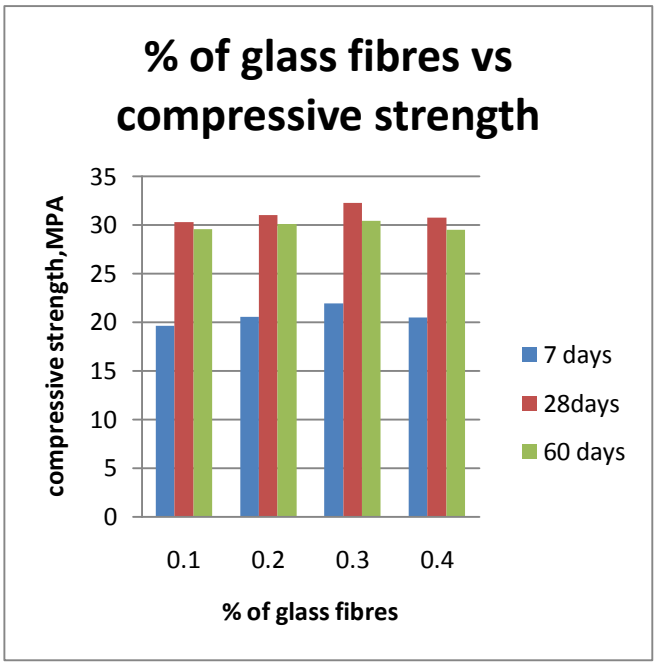
Durability studies of compressive strength of concrete effected with 5% of HCl and H_2SO_4 acid is studied at 10% replacement of WPSA along with different percentages of steel and glass fibres.



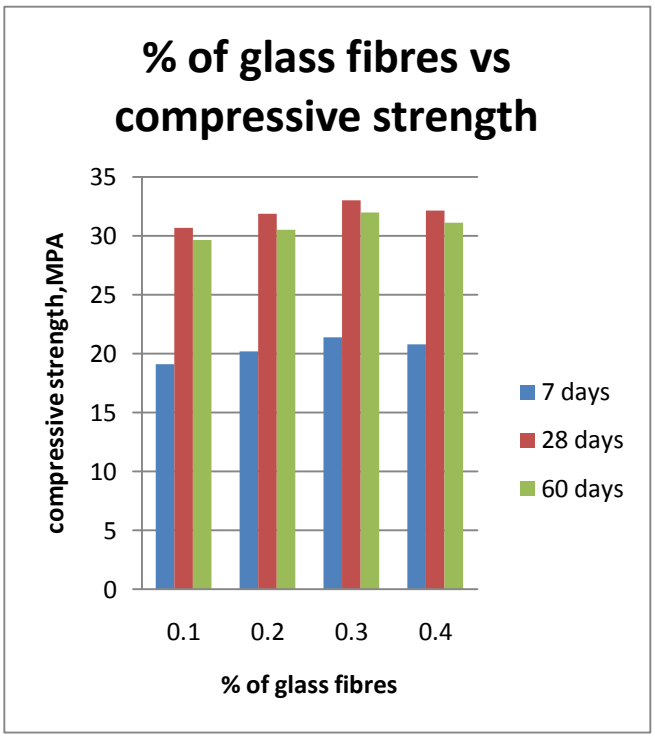
Graph 1: Compressive Strength of5% H_2SO_4 cured WPSA cubes after 7, 28 & 60 days



Graph 2: Compressive Strength of 5% HCl cured steel fibre cubes after 7, 28 & 60 days



Graph 3: Compressive Strength of 5% H_2SO_4 cured glass fibre cubes after 7, 28 & 60 days



Graph 4: Compressive Strength for HCL cured glass fibre cubes after 7, 28 & 60 days

8. CONCLUSIONS

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn:

- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and increase in compressive strength.
- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and increase in split tensile strength.
- By replacing waste paper sludge ash to the concrete, the optimum is obtained at 10% and increase in flexural strength.
- By adding glass fibres, the optimum is obtained at 0.3% and the increase in compressive strength, split tensile strength and flexural strength.
- By adding steel fibres, the optimum is obtained at 1% and the increase in compressive strength, split tensile strength and flexural strength.
- Glass fibres shown better results than steel fibres in durability results.

SCOPE FOR FUTURE WORK

1. Non-destructive tests can also be useful for on-site testing
2. Combination of GGBS with different other admixture can be carried out.
3. Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement etc. need investigation.

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