INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078

(Volume 8, Issue 2 - V8I2-1291)
Available online at: https://www.ijariit.com

Experimental investigation on steel fiber reinforced concrete with partial replacement of fine aggregate by copper slag

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ABSTRACT

In many developing countries, concrete is the most extensively used "manmade" material for construction in all types of civil engineering projects. Concrete is also an environmentally friendly material, which is more important in locations where environmental awareness is expanding. Researchers have been attempting to increase the quality, strength, and durability of materials against adverse exposures for decades. Concrete made of Portland cement is regarded to be a fragile substance. Unreinforced concrete cracks and fails when subjected to tensile pressures. Steel reinforcement has been utilized to solve this problem since the mid-nineteenth century. The reinforcing steel is expected to carry all tensile loads in a composite system. When fibers are added to the concrete mix, the composite system's tensile load capability is increased as well. In reality, research has shown that fiber reinforcing can improve the final strength of concrete. The goal of this study article is to employ solely fibers. On 150x150x150mm cube and 150mmx300mm cylindrical specimens, the experimental investigation consisted of casting and compression testing using a test method that gave the complete compressive strength, split tensile test with and without steel fiber of volume fractions 0,1,and 1.5, percent of 0.75mm diameter of aspect ratio of 80 on ordinary Portland cement concrete and replacing fine aggregate with copper slag of 40% and 60%. Based on the findings, higher crack resistance and improved tensile strength will be discovered. At 7 days, 21 days, and 28 days after curing, the proposed sample will be analyzed. These findings will reveal if the FRC is suitable for proper confinement in structures subjected to high loads such as seismic and impact loads.

***Keywords**: Confinement, Mechanical Properties, Steel Fiber, Transverse Reinforcement.*

1. INTRODUCTION

In tension, concrete is brittle. At around 10 to 15 percent of the ultimate load, microcracks appear in the matrix of a structural element, and at 25 to 30 percent of the ultimate stress, macrocracks appear. As a result, without continuous bar reinforcing components in the tensile zone of supported parts such as beams or slabs, plain concrete members cannot be expected to withstand substantial transverse loads. Continuous reinforcing, on the other hand, cannot stop or reduce the progression of microcracking and macrocracking. The purpose of such reinforcement is to take over the role of a section's tensile zone and assume the tension equilibrium force. The insertion of randomly spaced discontinuous fibre elements should aid in the stopping or spreading of microcracks that are known to form early in the stress history. Although fibres have been used to strengthen brittle materials like concrete since the dawn of time, newly created fibres have been widely used in the last three decades around the world. Steel, glass, polypropylene, and graphite are among the commercially available varieties. Concrete fibre composites are composed up of hydraulic cements, fine and coarse aggregates, pozzolanic cementitious materials, admixtures frequently found in traditional concrete, and a dispersion of discontinuous, small fibres made of steel, glass, organic polymers, or graphite.

1.1 Scope

- To improve structural strength.
- To reduce steel reinforcement requirements.
- To improve ductility and rigidity.
- To improve crack resistance.
- To increase abrasion and freeze thaw resistance.
- To attain high durability.

2. MATERIAL PROPERTIES

2.1 Physical properties of materials

Cement

Table 1: Properties of cement

S.No	Properties	Test Results
1	Specific gravity	3.15
2	Initial Setting Time	38 min
3	Final setting time	560 min
4	Normal consistency	32%

2.2 Coarse Aggregate

Table 2: Properties of Coarse Aggregate

S.No	Properties	Test Results
1	Fineness Modulus of coarse aggregate	7.6
2	Specific gravity	2.71
3	Water Absorption	0.4%
4	Bulk Density Loose Compacted	 1320 kg/m³ 1450 kg/m³

2.3 Fine Aggregate

Table 3: Properties of Fine Aggregate

S.No	Properties	Test Results
1	Fineness Modulus of fine aggregate	2.53
2	Specific gravity	2.6
3	Water Absorption	0.8%

2.4 Steel Fibres

Table 4: Properties of steel fibre

S.No	Properties	Value
1	Aspect ratio (L/d)	80
2	Tensile strength	1300 N/mm^2
3	Wire diameter	0.75 mm
4	Fiber length	60 mm

3. MIX DESIGN

3.1 Stipulation for Proportion

- Grade designation = M25
- Type of cement = Ordinary Portland Cement 53 grade
- Max nominal size of the aggregate = 20mm
- Min Cement content = 300 kg/cum
- Max W/C ratio = 0.5
- Exposure condition = Moderate
- Type of aggregate = Crushed angular
- Aspect Ratio= l/d= 80

3.2 Test Data

Cement-Portland Cement 53 grade
Specific Gravity of cement = 3.15
Specific Gravity of coarse aggregates =2.7
specific Gravity of fine aggregate = 2.6
Sand confirming to zone-III

3.3 Mix Calculation

Volume of concrete = $1m^3$

Volume of cement = Mass of cement /Specific Gravity x1/1000

= 394/3.15x1/1000=0.146 cu.m

Volume of water = Mass of water /Specific Gravity x1/1000

= 197/1x1/1000=0.197 cu.m

Volume of aggregates = a-(b+c) = 1-(0.146+197) = 0.657 cu.m

Mass of coarse aggregate = *d* x Volume of coarse aggregate x Specific

gravity of coarse aggregate x 1000

= 0.657 x 0.64 x 2.7 x 1000= 1135.3 Kg

Mass of fine aggregate = *d* x Volume of fine aggregate x

specific gravity of fine aggregatex1000

= 0.657 x 0.36 x 2.6 x 1000= 615 Kg

Mix proportion = **1 :1.56 :2.88**

Table 5: Materials Required

Steel Fiber Content by Volume (%)	Cement Content (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Copper slag (Kg)		Steel Fiber (Kg)
				40%	60%	
0%	4.78	7.47	13.78	0	0	0
0.1%	4.78	4.48	13.78	2.9	-	0.957
1%	4.78	2.9	13.78	-	4.482	0.957
1.5%	4.78	7.47	13.78	2.9	-	1.430
1.5%	4.78	7.47	13.78	-	4.482	1.430

4. EXPERIMENTAL INVESTIGATION

4.1 Test on Fresh concrete

Slump test

Slump test is carried out to determine the workability of freshly prepared concrete. This test is carried out in a cone of top diameter 10 cm and bottom diameter 20 cm and height 30 cm. The slump cone is filled with the freshly prepared concrete in three layers.

Table 6: Slump Test Results

% of Fibre	Slump value
0%	100 mm
0.75%	49 mm
1.50%	100 mm
2.50%	44 mm
3.50%	50 mm

4.2 Test on Hardened Concrete

In order to determine the mechanical properties (such as Compressive, Tensile and Flexural strength) of concrete 45 cube, 45 cylinder and 45 prism specimens were casted. The size of specimens are

- Cube = 150mmx150mmx150mm

- Cylinder= 150mmx300mm
- Prism = 100mmx100mmx500mm

For each varying percentage of steel fibre, the test conducted consist of 9 cube, 9 cylinder and 9 prism specimens respectively.

5. RESULTS

5.1 Compressive strength test

Table 7: Test Result For Compressive Strength Test

% Fiber	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
0%	17	25.7	31.80
1%	18.804	29.5	36.9
1%	20.12	31.9	39.35
1.5%	19.57	27.6	34.56
1.5%	18.45	26.6	33.21

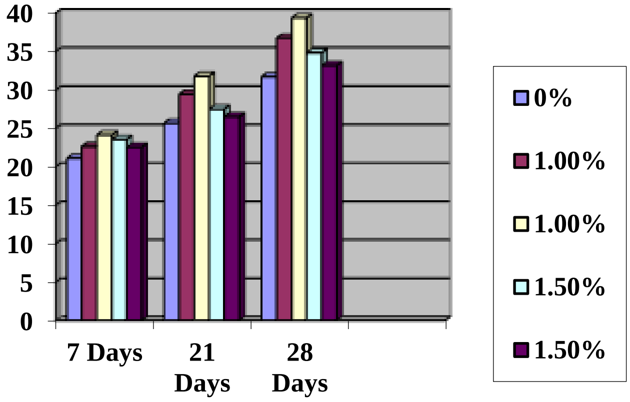

Fig. 1 Compressive strength test results

5.2 Split-Tensile strength test

Table 8: Test Result For Split-Tensile Strength Test

% Fiber	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
0%	3.24	3.54	4.35
1%	3.35	3.61	4.5
1%	3.87	3.98	4.73
1.5%	4.25	4.56	5.16
1.5%	4.42	3.57	4.42

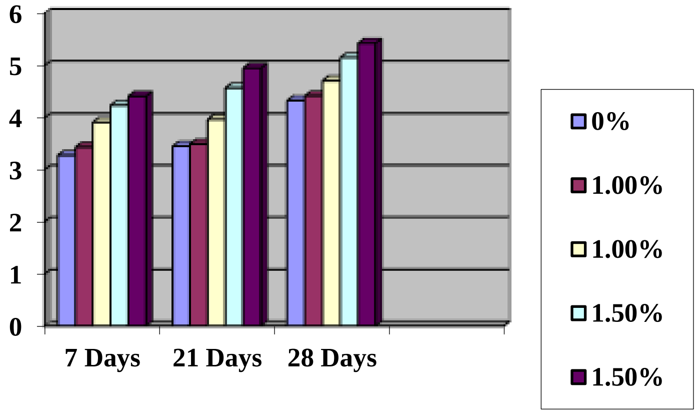

Fig. 2 Split-Tensile strength test results

5.3 Flexural strength test

Table 9: Test Result For Flexural Strength Test

% Fiber	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
0%	5.85	6.21	7.21
1%	6.10	6.72	7.51
1%	6.59	7.12	7.89
1.5%	6.81	7.19	8.1
1.5%	7.7	6.34	7.42

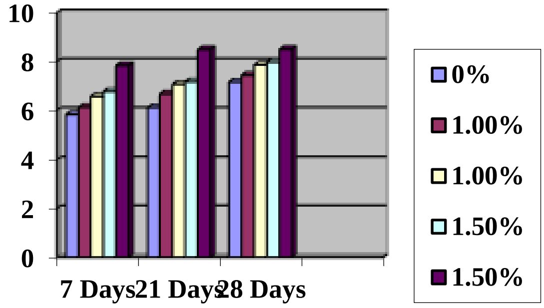

Fig. 3 Flexural strength test results

6. COMPARISON

The mechanical properties of the concrete (Compressive strength, Split-Tensile strength, Flexural strength) varies by increasing the fibre content in the concrete.

The compressive strength of the concrete attain its maximum strength of 39.38 **N/mm^2** at 1.5% fibre addition and decreases at 3.5% of fibre.

By increasing the fibre content, the split-tensile strength increases.

By increasing the fibre content, the flexural strength increases.

Table 10: Comparison Of Percentage Increase In Compressive Strength

PCC N/mm^2	% of fibre	Increase in %
4.33 at 0%	1%	2.07%
	1%	8.77%
	1.5%	18.93%
	1.5%	25.40%

Table 11:Comparison Of Percentage Increase In Split-Tensile Strength

PCC N/mm^2	% of fibre	Increase in %
7.17 at 0%	1%	3.90%
	1%	9.76%
	1.5%	11.29%
	1.5%	18.54%

Table 13: Comparison Of Percentage Increase In Flexural Strength

PCC N/mm^2	% of fibre	Increase in %
31.70 at 0%	1%	15.86%
	1%	24.22%
	1.5%	9.8%
	1.5%	4.5%

7. CONCLUSION

The addition of steel fibre and carbon fibre increases the compressive strength by 24.22% with 1.5% of fibre addition and than decreases by increase of fibre percentage. The split tensile strength test results shows that, the tensile strength of the concrete increases by increasing the fibre addition. The results of the flexural strength test, shows that the increased addition of fibre content enhances the flexural strength of concrete. Increased addition of fibre leads to poor workability and segregation. Fiber concrete has the ability to sustain continuous load and deformations without shattering in to pieces.

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