Effect of waste steel scrap fibers on mechanical properties of geopolymer concrete

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Abstract : *Ordinary Portland Cement is the primary source of binder used in the production of normal strength concrete. The production of Portland cement releases CO_2 which causes many environmental issues like global warming etc. to overcome this problem an alternative source of binding material fly ash is used to making geopolymer concrete. In this experimental study, we have used two alkaline liquids as binders, sodium hydroxide (12.5 M) and sodium silicate. A mix proportion of geopolymer concrete is design as M30 grade. The different percentage of waste steel scrap fibers are added in the mix at various percentages of 0%, 0.5%, 1%, 1.5% and 2% at 0.5% increment. The strength parameters like compressive strength, split tensile strength, flexural strength were found. And compare the results with mix of 0% percentage of fibres.*

Keywords*: geopolymer, fly ash, waste steel scrap fibers, alkaline activators, ambient curing.*

1.INTRODUCTION

Several research and investigations are in progress to reduce the use of Portland cement in normal strength concrete. Because the use of ordinary Portland cement in the construction industry is the major suppliers of co_2 emission in to the atmosphere which causes some environmental issues.
In 1978, Joseph Davidovits a French material scientist coined the word “geopolymer”. Geopolymer is a “inorganic polymer”. He suggested that an alkaline liquid can be used to react with the silicon (Si) and the aluminium (Al) in a source material by product materials such as fly ash to produce binders. In this experimental study the lathe machined waste steel scrap fibres are used to study the effect of different percentage of fibres on the strength of geopolymer concrete. As it is the waste material hence this is the way by which we can reduce the waste material in the environment. In this study low calcium (ASTM class F) fly ash is preferred as source material than high- calcium (ASTM class c) fly ash. Because the presence of calcium in high amount may interfere with polymerization process and prolonged the strength of geopolymer concrete. And the aim of this study is to find the properties of geopolymer concrete developed under ambient curing.

2.OBJECTIVE OF STUDY

- To evaluate the optimum percentage of fiber.
- To study the effect of waste steel scrap fibers on the properties of geopolymer concrete. Fibers are added with volume fraction of (0.5% to 2%)at an interval of 0.5% by mass of geopolymer concrete.
- To find compressive strength, split tensile strength, flexural strength of geopolymer concrete.

3.MATERIALS

3.1 fly ash

Fly ash is removed from the combustion gases by the dust collection system, either mechanically or by using electrostatic precipitators. The types and relative amounts of incombustible matter present in the coal determine the chemical composition of fly ash.The chemical composition is mainly composed of the oxides of silicon (Sio_2), alumina (Al_2o_3), iron (fe_2o_3), and calcium (cao),whereas magnesium, potassium, sodium, titanium, and sulphur are also present in a traces amount. In the present experimental work, low calcium, fly ash (ASTM CLASS F) were collected from the Electrostatic precipitators of the SARNI THERMAL POWER PLANT IN M.P. (India), was used. It has a specific gravity of 2.15 with a particle size of 5-10µm.

Table 1. The Chemical composition of fly ash

S.no.	Constituents	% of constituents
1.	Sio_2	67.35
2.	Al_2O_3	22.8
3.	Fe_2O_3	5.55
4.	CaO	1.21
5.	MgO	0.07
6.	K_2O	1.29
7.	Na_2O	0.0001
8.	Tio_2	1.38
9.	LOI	3.30

Figure 1. fly ash

3.2 fine aggregate

Fine aggregates are also one of the main ingredients of the geopolymer concrete which helps in bonding between aggregate and fly ash properly. The size of sand is used in work is lower than 4.75mm sieve. IS:383 1963 defined the fine aggregate which will passes through 4.75mm IS sieve and retained over 75µM IS sieve is known as fine aggregate. Locally available river sand which was obtained from river Narmada sand, having a lower size of about 4.75mm was used as a fine aggregate.

Table 2. Physical properties of fine aggregates

S.no.	Properties	Results
1.	Type	Natural
2.	Specific gravity	2.60
3.	Fineness modulus	3.18
4.	Particle size	4.75mm down

Figure 2. fine aggregates

3.3 coarse aggregate

The coarse aggregate is broken crushed stone and it is free from clay , weeds and the organic matters. The size of Coarse aggregate should be as per IS: 383-1970, Crushed angular metal of 20mm size.

Table 3 Physical properties of coarse aggregates

S.no.	Properties	Results
1.	Type	crushed
2.	Specific gravity	2.90
3.	Fineness modulus	7.22
4.	Particle size	20mm

Figure 3. coarse aggregates

3.4 waste steel scrap fibers

Crimped steel fibres from lathe machine collected from local shop R.K. Engineering Works Industrial area Vidisha (M.P) was used for investigation . The long fibres were cut into approximately 15mm length, were used for the study.

Table 4. Properties of waste steel scrap fibers

S.no.	Properties	Values
1.	Cross section	Deformed, crimped
2.	Length	15mm
3.	Density	7850 kg/m^3
4.	Youngs modulus	2x10^5 N/mm^2
5.	Specific gravity	7.85

Figure 4. waste steel scrap fibers

3.5 Alkaline activators

combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline activators. Sodium-based solutions were preferred because they were cheaper than potassium-based solutions.

A. sodium hydroxide (NAOH)

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. The sodium hydroxide (NAOH) solution was prepared by dissolving the flakes in water. The mass of NAOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar(M). For example: 12.5 M = (12.5X40) = 500 gm of NAOH flakes/lit water.

Table 5. Properties of sodium hydroxide(NAOH)

Parameters	Properties
Chemical formula	NAOH
Molecular weight	40 gms
Specific gravity	2.12

B. sodium silicate (Na_2Sio_3)

Sodium silicate also known as water glass or liquid glass, available in liquid (gel) and solid both form. In this study sodium silicate is used for the making of fiber reinforced geopolymer concrete.

Table 6. Chemical and Physical properties of sodium silicate(Na2SiO3)

Parameters		Properties
Na_2o		15.9%
Sio_2		31.4%
H_2o		52.7%
Specific gravity		1.6
Molar mass		122.06 g/mol

Fig 5. sodium hydroxide

Figure 6. sodium silicate

4.METHODOLOGY

4.1 General

The aim of this research work is to develop fly ash based geopolymer concrete of M-30 grade and study the effects of waste steel scrap fibres on different mechanical properties of geopolymer concrete. In this investigation the cement is replaced by 100% with fly-ash. With concentrated sodium hydroxide solution of molarity 12.5M and keeping the solution to fly ash ratio by mass is 0.40. Waste steel scrap fibers are added in geopolymer concrete with different percentage of 0.5% to 2%. The entire specimen will be cured at an ambient curing. By changing the percentage of steel fibers, different mechanical properties like compressive strength, split tensile strength, flexural strength of geopolymer concrete have tested.
Quantity of materials required per m^3 of geopolymer concrete mix:

Table 7. mix proportion

Materials	**Quantity (kg/m^3)**
Fly ash	405
Fine aggregates	670.92
Coarse aggregates	1273.78
Mass of NAOH	81
Mass of Na_2Sio_3	81
Ratio of alkaline activators (Na_2Sio_3: NAOH)	1:1

4.2 Mix proportion, mixing, casting and curing

Geopolymer Concrete was mixed along with waste steel scrap fibers. Geopolymer Concrete was placed in to the standard mould in layers and compacted satisfactorily. Demoulding was done after 24 hours of casting and the specimens were cured under ambient heat curing at 28 days . After 28 days of ambient curing, the specimens were taken and testing is done.

5. RESULTS AND DISCUSSION

5.1 Compressive strength (IS 516-1959)

Concrete cubes of size 150mmx150mmx150mm were casted for different percentage of waste steel scrap fibres contents from 0% to 2% and 3 cubes were used for each percentage. After 24 hours, the specimens were demoulded and subjected to ambient heat curing. After 28 days of heat curing specimens were taken and tested in compressive strength testing machine.

Compressive strength (N/mm^2) = P/A where, P= Applied load , A= Cross-sectional area of specimen.

Table 8. Compressive strength test results

S. No.	**Waste steel scrap fibers %**	**Compressive strength (N/mm^2) at 28 days**	**% increase in strength**
1.	0%	36.59	-
2.	0.5%	39.03	6.25%
3.	1%	41.69	12.23%
4.	1.5%	44.07	16.97%
5.	2%	37.62	2.73%

Figure 7. testing of cube specimen

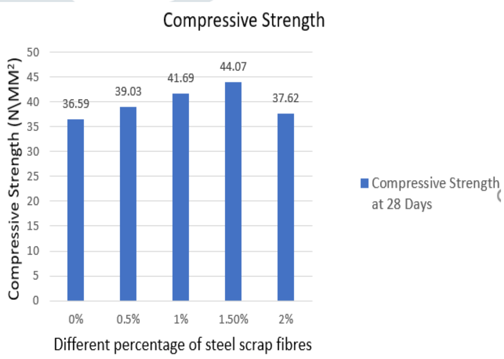

Figure 8.Variation in compressive strength

5.2 Split tensile strength (IS 5816:1999)

For split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were de-moulded after 24 hours of casting and were kept for ambient curing and they were allowed to cure for 28 days. These specimens were tested under compression testing machine. In each category three cylinders were tested and their average value is reported.

Split tensile strength = $2P/\pi DL$ where, P = Applied load, D = Dia. Of cylinder specimen, L = Length of cylinder specimen.

Table 9. split tensile strength test results

S. No.	Waste steel scrap fibers %	Split tensile strength (N/mm^2) at 28 days	% increase in strength
1.	0%	2.92	-
2.	0.5%	3.25	10.15%
3.	1%	3.46	15.60%
4.	1.5%	3.53	17.28%
5.	2%	3.39	13.86%

Figure 9. Testing of cylinder specimen

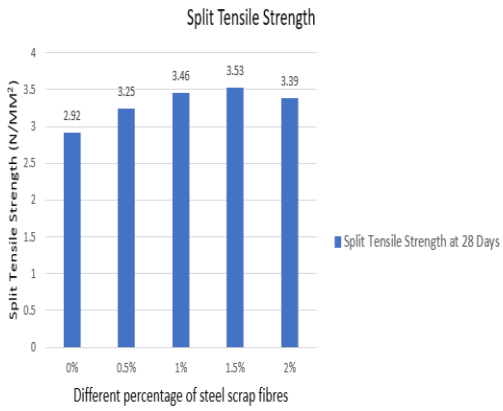

Figure 10. Variation in split tensile strength

5.3 Flexural strength (IS 516:1959)

For flexural strength test beam specimens of dimension 150x150x700 mm were cast. The specimens were de-moulded after 24 hours of casting and were kept for ambient curing and they were allowed to cure for 28 day. These flexural strength specimens were tested under three point loading as per I.S. 516-1959**.**

Flexural strength = Pl/bd^2 where P = Applied load, L = Length of beam specimen, b= Width of specimen, d= Depth of specimen

Table 10 Flexural strength test results

S. No.	Waste steel scrap fibers %	Flexural strength (N/mm^2) at 28 days	% increase in strength
1.	0%	5.18	-
2.	0.5%	5.70	9.12%
3.	1%	6.22	16.72%
4.	1.5%	6.74	23.14%
5.	2%	5.39	3.89%

Figure 11. Testing of beam specimen

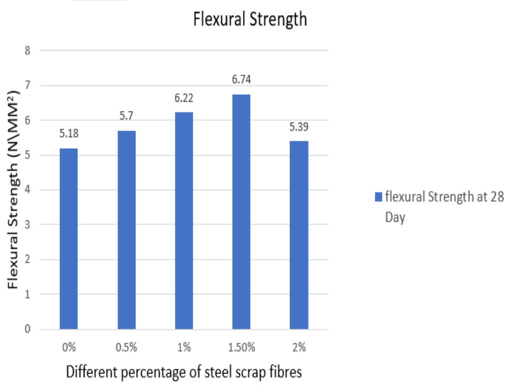

Figure 12. Variation in flexural strength

5.4 Slump test for workability

Slump cone test was performed to determine the workability of geopolymer concrete using standard sizes of slump cone apparatus as per IS: 1199 – 1959.

Table 11 Slump test results for steel scrap fibers

S. No.	Waste steel scrap fibers %	Slump(mm)
1.	0%	80
2.	0.5%	70
3.	1%	65
4.	1.5%	60
5.	2%	60

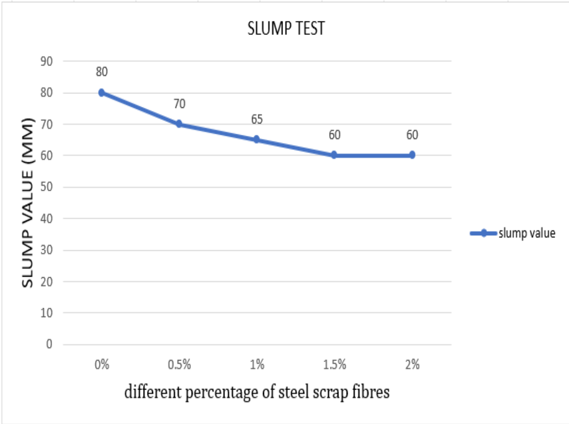

Figure 13. variation in slump value

6. CONCLUSION

1.The maximum compressive, split tensile and flexural strength of geopolymer concrete is obtained at 1.5% addition of steel scrap fiber.
2. It can be concluded that steel scrap fiber act as a crack arrestors and prevent sudden failure of structures.
3. It can be concluded that addition of steel scrap fiber at an optimum content(1.5%) to the geopolymer concrete can increase compressive strength by 16.97% , split tensile strength by 17.28%, and flexural strength by 23.14%.
4. Workability of GPC reduces with increase in percentage of waste steel scrap fibers.
5. It can also improve the toughness (Indicating excellent energy absorbing capacity), impact resistance, fatigue strength, cracking and deflection, modulus of elasticity etc.

7. ACKNOWLEDGMENT

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