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A Study on Strength of Fibre Reinforced Concrete with Palm Oil Fuel Ash as Partial Replacement of Cement

A. Krishna priya[1], V. Kanaka Durga[2]
M.Tech(Structural Engineering)[1], Assistant professor[2]
Department of Civil Engineering
Amrita Sai Institute of Science and Technology, Andhra Pradesh, India

Abstract:
One of the main products required in manufacturing concrete is cement, with the increase in the amount of cement used, heat of hydration increases which will lead to the formation of cracks in concrete accompanied by shrinkage effect. To control this, palm oil fuel ash and agro waste which contains some amount of silica act as a pozzolonic material is being used as cement replacement and its strength is compared with conventional concrete of grade M25. Palm oil fuel ash which is obtained by burning palm fruit and dry leaves of palm oil tree in palm oil mills is also used to control heat of hydration effect on concrete, after pulverizing and making into a fine powder. In this study cement is being replaced with palm oil fuel ash in different percentages (5%, 10%, 15%,20%) to get an optimum point. From this optimum point the Steel fiber in different percentages (0%, 0.5%, 1%, 1.5% and 2%) and glass fiber in different percentages (0%, 0.1%, 0.2%, 0.3%, 0.4%). For each set of fibers, mechanical properties were studied by performing Compression test for Cubes, Flexural test for beams and Split Tensile test for cylinders and durability properties were studied by performing sulphate attack test cubes.

Keywords: Concrete, Palm Oil Fuel Ash, Steel Fibre, Glass fibre, compressive strength, flexural strength and split tensile strength

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption using supplementary materials. Palm oil industry is one of the most important agro industries in India. Besides the production of crude palm oil, a large amount of solid waste is also an output from the palm oil industry. Annually, more than two million tons of solid waste of palm oil residue, such as palm fibre, shells, and empty fruit bunches are produced. Utilization of palm oil fuel ash (POFA) is minimal and unmanageable, while its quantity increases annually and most of the POFA are disposed of as waste in landfills causing environmental and other problems. One method to improve the brittle behaviour of the concrete is the addition of small fibers in concrete with randomly distributed. Such reinforced concrete is called Fibre Reinforced Concrete (FRC). There are different types of fibers that can be used in FRC they are Steel fibers, Glass fibers, Synthetic fibers, Carbon fibres, Nylon fibre. In this study the addition of steel and glass fibers are added to concrete, leads to improvement in cracking and tensile strength

II. MATERIALS AND PROPERTIES:

2.1 Cement:

Cement used in this experiment work is ordinary Portland cement of 53- grade available in the local market. The cement should be fresh and of uniform consistency. The specific gravity of the cement is 3.15. All properties of cement are tested by referring IS 12269 – 1987.

Table .1. Properties of cement

Sl. No.	Property	Value
1	Fineness test	1%
2	Setting time a)initial b)final	63min 321 min
3	Specific gravity	3.11

2.2 Fine Aggregates: Locally available sand conforming to grading zone II which is passing from 4.75 mm sieve and of specific gravity of 2.58 is used.

Table.2. Properties of fine aggregate

Sl. No.	Property	Value
1	Sieve analysis	Zone II
2	Specific gravity	2.58
3	Fineness Modulus	2.26

2.3 Coarse Aggregate: Locally available crushed stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970. Specific gravity of course aggregate is 2.66.

Table.3. Properties of coarse aggregate

Sl. No.	Property	Value
1	Specific gravity	2.66
2	Fineness modulus	7.68

2.4 Water
Fresh potable water free from acid and organic substances was used for mixing and curing concrete.

2.5 Palm Oil Fuel Ash
Solid waste of palm oil residue, such as palm fibre, shells, and empty fruit bunches are produced. Utilization of palm oil fuel ash (POFA) is minimal and unmanageable, while its quantity increases annually and most of the POFA are disposed of as waste in landfills causing environmental and other problems.

Figure.1. Pofa

2.5.1 Comparison of Chemical composition of POFA and OPC

Table.4. Comparision of pofa and opc

CHEMICAL COMPOSITIONS	OPC (%)	POFA (%)
Silicon Dioxide (SiO_2)	20.1	55.20
Aluminium Oxide (AL_2O_3)	4.9	4.48
Ferric Oxide (Fe_2O_3)	2.5	5.44
Calcium Oxide (CaO)	65	4.12
Magnesium Oxide (MgO)	3.1	2.25
Sodium Oxide (Na_2O)	0.2	0.1
Potassium Oxide (K_2O)	0.4	2.28
Sulphur Oxide (SO_3)	2.3	2.25
Loss On Ignition (LOI)	2.4	13.86

2.6 Steel Fibre
Fiber 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 steel fiber type used here is hooked end with 30mm fiber length and 0.5mm diameter. The aspect ratio of the fiber is the ratio of its length to its diameter and generally the aspect ratio ranges from 30 to 150 and here the aspect ratio of the steel fiber is 60.

Figure.2. Steel fibres

The following value gives the effects of fibers on concrete.

Table.5. Properties of steel fiber

Properties	Improvement Over Ordinary Concrete
Ductility	5 to 10 times
Impact resistance	100 to 200%
Cracking & flexural strength	80 to 120%
Shear strength	50 to 100%
Bearing strength	50 to 100%
Abrasion resistance	several times

2.7 Glass fibre
It is material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong, and robust material. The glass fiber type used here is A-R glass with 50mm fiber length and 0.1mm diameter. The aspect ratio of the glass fiber is 500.

Figure.3. Glass fibre

Table.6. Properties of glass fibre

er Length	nsity, Cm^3)	nsile ength, Pa	dulus, a	cent ngation
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III. EXPERIMENTAL WORK

Mix design for each set having different combinations are carried out by using IS: 10262 – 2009method. The mix proportion obtained for normal M25 grade concrete is 1:1.32:2.74 with a water-cement ratio of 0.45.

Table.7. Mix proportions

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

The experimental investigation consists of casting and testing of 9 sets along with control mix. Each set comprises of 18 cubes, 3 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. By taking different percentage of POFA, along with steel & Glass fibers 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 fiber and Glass fiber. The concrete was filled in layers and compacted. The specimens were removed after 24 hours and submerged in water for curing. After a curing period of 7 and 28 days specimens were taken out and tested.

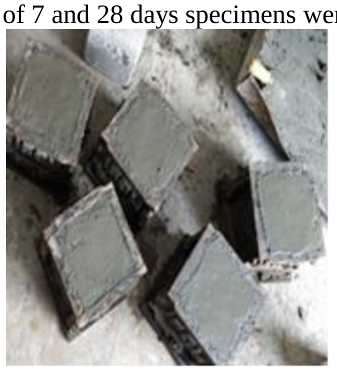


Figure.4. Cubes

IV.TESTS AND RESULTS

A number of tests were carried out to determine the design mix properties of concrete in the laboratory. In the present work, the strength of the hardened concrete is determined. The strength criterion includes measurement of following parameters:

- Compressive Strength on cubes
  Flexural Strength on beams
- Split Tensile Strength on Cylinders

4.1 Compressive strength

Compression test on cubes of size (150 x 150 x 150)mm was performed on compression testing machine. Optimized Results of Trial Mixes are as shown in tables from the results of trial mix.

Figure.5. Cubes for compression testing[1]

Table.8. Compressive strength of trail mix

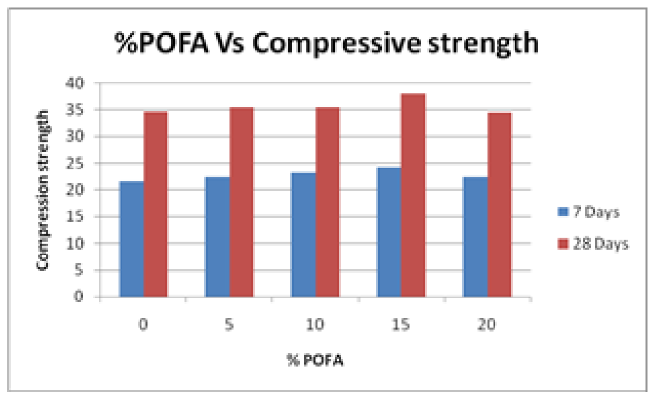
Mix details	Strength in Mpa		
	7 days	14 days	28 days
Conventional	21.6	25.33	34.75

4.1.1 POFA optimum percentages

The mix proportion with partial replacement of OPC with 0%, 5%, 10%, 15%, 20% of POFA are calculated.

Table.9. Compressive strength with pofa

S. No	% POFA	Compressive Strength	
		7 days strength	28 days strength
1	0	21.6	34.75
2	5	22.5	35.45
3	10	23.15	35.56
4	**15**	**24.36**	**38.04**
5	20	22.46	34.51

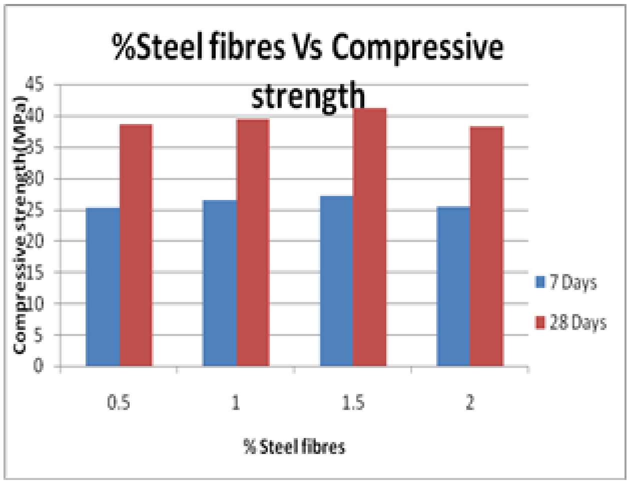


Graph.i. Compressive strength with pofa for 7 and 28days

From the test results, the optimum percentage replacement of POFA was found to be at 15%. It is observed that the properties of can be maintained with POFA as partial replacement of cement at15%.

Table.10. Compressive strength with steel fibre

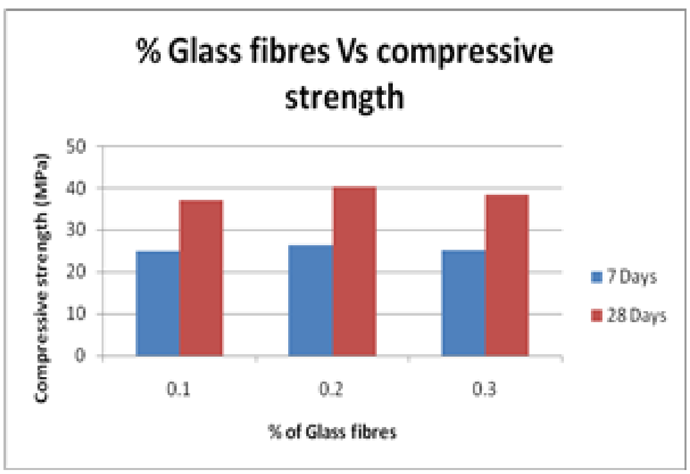
Sl .No	POFA %	% Of Steel fiber	7 days (N/mm^2)	28 days (N/mm^2)
1	15	0	21.6	34.75
2	15	0.5	25.32	38.61
3	15	1	26.41	39.43
4	**15**	**1.5**	**27.3**	**41.13**
5	15	2.0	25.41	38.31



Graph .ii. Compressive strength with pofa and steel fibres for 7 and 28days

Table.11. Compressive strength with pofa and glass fibres

S.No	POFA %	% Of glass fiber	7 days (N/mm^2)	28days (N/mm^2)
1	15	0	21.6	34.75
2	15	0.1	24.88	37.16
3	**15**	**0.2**	**26.24**	**40.23**
4	15	0.3	25.14	38.22
5	15	0.4	24.33	37.74



Graph.iii. Compressive strength with pofa and glass fibres for 7 and 28days

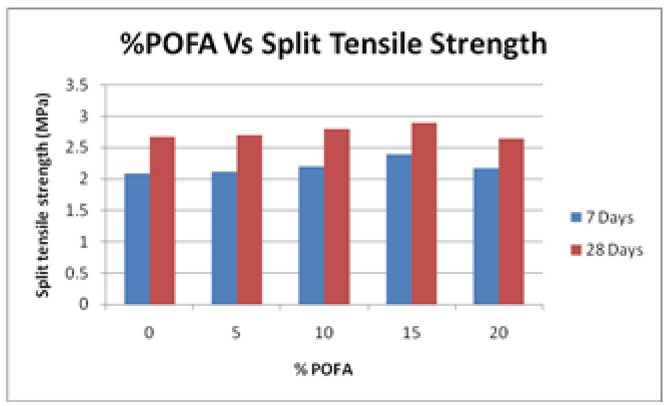
4.2 Split Tensile Test

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 POFA, glass & steel fiber by cement respectively finally combined percentage of POFA & steel fiber mix, POFA & glass fiber mix in which maximum strength is obtained was used to get optimized strength.

Figure.6. Cylinders for split tensile testing [2]

Table.12. Split tensile strength with pofa

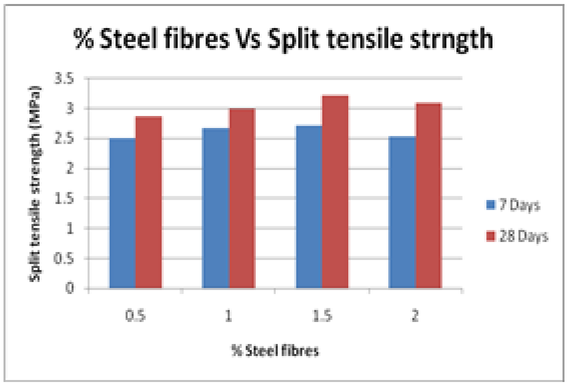
S.No	POFA %	7 days (N/mm^2)	28 days (N/mm^2)
1	0	1.95	2.54
2	5	2.11	2.7
3	10	2.2	2.8
4	**15**	**2.4**	**2.9**
5	20	2.17	2.65



Graph.iv. Split tensile strength with pofa for 7 and 28days

Table.13. Split tensile strength with pofa and steel fibres

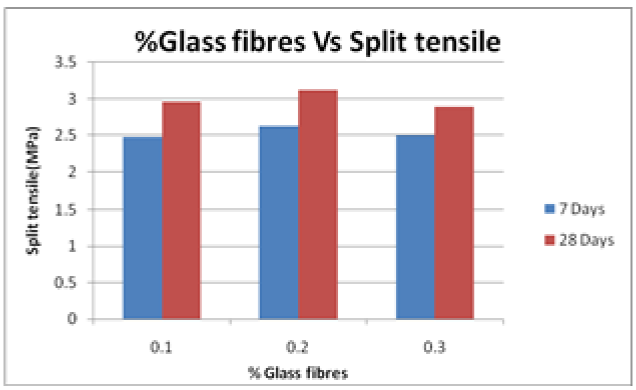
S.No	POFA %	% Of Steel fiber	7 days (N/mm^2)	28 days (N/mm^2)
1	15	0	1.95	2.54
2	15	0.5	2.51	2.87
3	15	1.0	2.67	2.99
4	**15**	**1.5**	**2.73**	**3.22**
5	15	2.0	2.54	3.09



Graph.v. Split tensile strength with pofa and steel fibres for 7 and 28days

Table.14. Split tensile strength with pofa and glass fibres

S. No	POFA %	% Of Glass fiber	7 days (N/mm^2)	28days (N/mm^2)
1	15	0	1.95	2.54
2	15	0.1	2.48	2.96
3	**15**	**0.2**	**2.63**	**3.12**
4	15	0.3	2.5	2.89
5	15	0.4	2.34	2.79



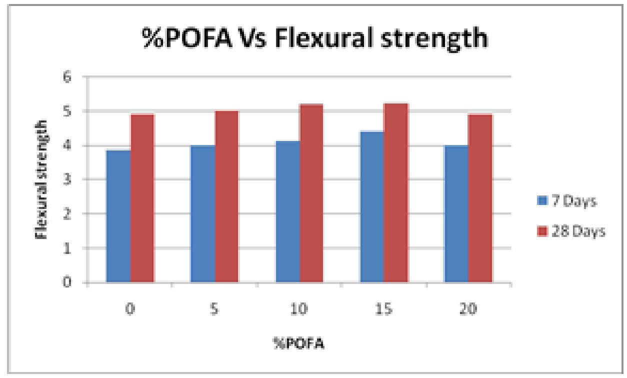
Graph.vi. Split tensile strength with pofa and glass fibres for 7 and 28days

4.3 Flexural test

Flexural test was performed on beams of (500×100×100)mm size by placing them on universal find out the flexural strength. After testing the concrete (flexural strength) for M25 grade concrete separately for replacement of POFA, 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 .15. Flexural strength with pofa

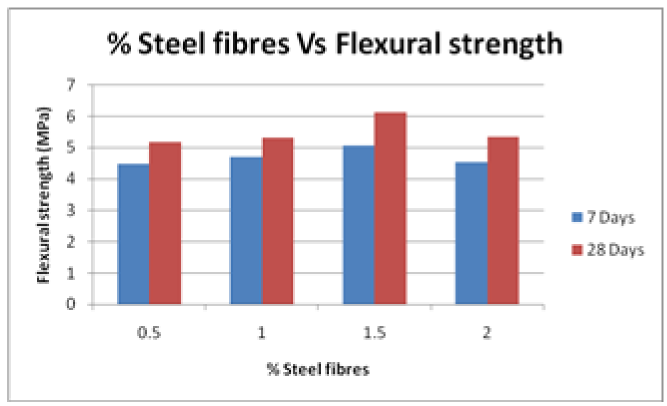
S.No	POFA %	7 days (N/mm^2)	28 days (N/mm^2)
1	0	3.97	4.95
2	5	4.01	5.02
3	10	4.12	5.21
4	**15**	**4.42**	**5.23**
5	20	4.01	4.93



Graph.vii. Flexure strength with pofa for 7 and 28days

Table.16. Flexural strength for steel fiber

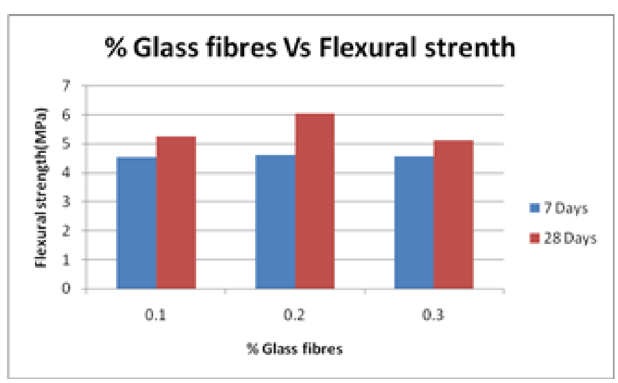
S.NO	POFA %	% OF STEEL FIBER	7 days (N/mm^2)	28 days (N/mm^2)
1	15	0	3.97	4.95
2	15	0.5	4.49	5.18
3	15	1	4.69	5.31
4	**15**	**1.5**	**5.08**	**6.14**
5	15	2	4.54	5.34



Graph.viii. Flexural strength with pofa for 7 and 28days

Table.17. Flexural strength for glass fibres

S. No	*POFA %*	*% Of Glass*	*7 days (N/mm*	*28days (N/mm*
1	15	0	3.97	4.95
2	15	0.1	4.54	5.26
3	**15**	**0.2**	**4.63**	**6.05**
4	15	0.3	4.56	5.12
5	15	0.4	4.35	5.06



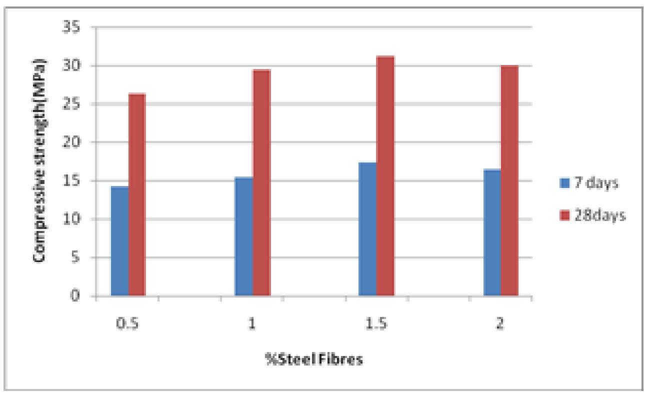
Graph.ix. Flexural strength with pofa for 7 and 28days

V.DURABILITY

Durability studies of compressive strength of concrete effected with 5% of HCl and H_2SO_4 acid is studied at 15% replacement of POFA along with different percentage of steel and glass fibers.

Table.18. Compressive strength of steel fiber reinforced pofa concrete after h_2so_4 acid curing

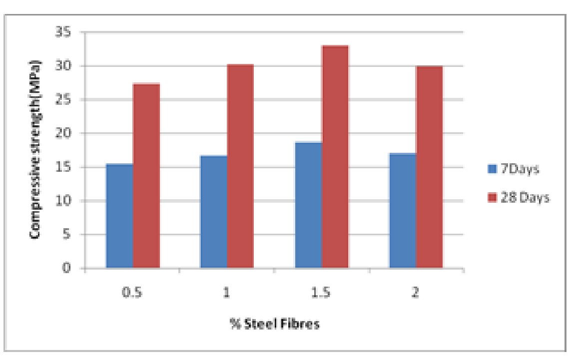
S.NO	% of POFA	% of steel fiber	Compressive strength(N/mm^2)	
			7days(5%H_2SO_4)	28days(5% H_2SO_4)
1	15	0.5	14.23	26.34
2	15	1.0	15.41	29.47
3	**15**	**1.5**	**17.33**	**31.24**
4	15	2.0	16.45	29.98



Graph.x. Compressive strength of steel fiber reinforced pofa concrete after h_2so_4 acid curing

Table.19. Compressive strength for m25 grade concrete after hcl acid curing

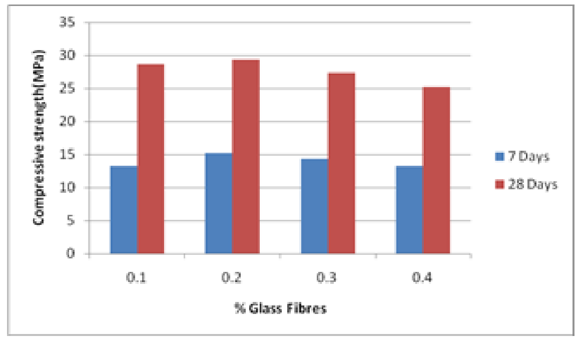
S.NO	% of POFA	% of steel fiber	Compressive strength(N/mm^2)	
			7days(5%HCL)	28days(5%HCL)
1	15	0.5	15.43	27.38
2	15	1.0	16.68	30.21
3	**15**	**1.5**	**18.62**	**32.95**
4	15	2.0	17.01	29.92



Graph.xxi. Compressive strength for m25 grade concrete after hcl acid curing after 7days and 28days

Table.20. Compressive strength for m25 grade concrete after h_2so_4 acid curing

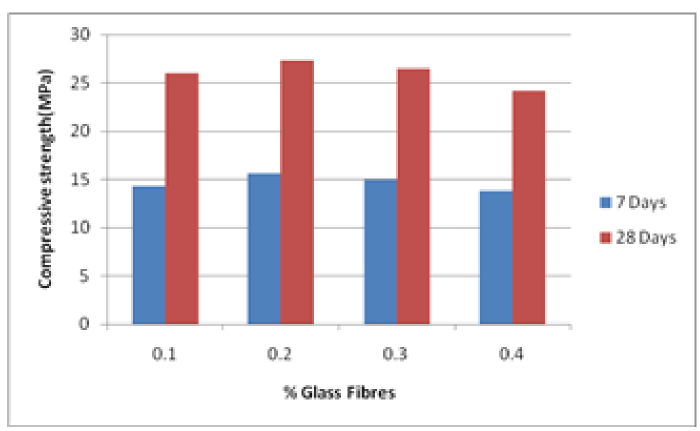
S.NO	% of POFA	% of glass fiber	Compressive strength(N/mm^2)	
			7days(5%H_2SO_4)	28days(5%H_2SO_4)
1	15	0.1	13.25	28.68
2	**15**	**0.2**	**15.23**	**29.34**
3	15	0.3	14.31	27.32
4	15	0.4	13.24	25.21



Graph.xii. Compressive strength for glass fibre reinforced pofa concrete after h2so4 acid curing

Table.21. Compressive strength for m25 grade concrete after hcl acid curing

S.NO	% of POFA	% of glass fiber	Compressive strength(N/mm^2)	
			7days(5%HCl)	28days(5%HCl)
1	15	0.1	14.25	26.01
2	**15**	**0.2**	**15.63**	**27.32**
3	**15**	0.3	14.92	26.45
4	15	0.4	13.85	24.15



Graph.xiii. Compressive strength for glass fibre reinforced pofa concrete after hcl acid curing at 7 days and 28 days.

VI. CONCLUSIONS

- The optimum quantity for partial replacement of cement by Palm oil Fuel Ash is obtains at 15%.
- The concrete mixture with 15% POFA and 1.5% steel fiber has the highest compressive strength, flexural strength and split tensile strength performance at all ages.
- The concrete mixture with 15% POFA and 0.2% glass fiber has the highest compressive strength, flexural strength and split tensile strength performance at all ages.
- The effect of acid on concrete increases with the increase of percentage of POFA.
- The results show that steel fiber is more effective than glass fiber.
- Palm Oil Fuel Ash, glass fiber and steel fiber can be used in concrete as a suitable replacement of cement to make the concrete stronger in compression and tension, to make concrete more economical.

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