Experimental Study on Fibre Reinforced Concrete With Partial Replacement of Cement With Quarry Dust And Metakaolin

B Sanyasi Naidu[1], L Bhanu[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] KITS Divili

Abstract- *Concrete is the widely used construction material in civil engineering field. The demand and cost of cement is increasing day to day, so experts are looking for supplementary materials with the main objective of reducing solid waste disposal and environmental problems, by using waste as supplementary by maintaining the same properties or by enhancing the properties, by using selected materials. Quarry dust (QD) is a waste product produced during the crushing process. It is used in partial replacement of cement in various proportions. This quarry dust which is released directly into environment can cause environmental pollution. To reduce the impact of the quarry dust on environment and human, this waste can be used to produce new products or can be used as admixture in concrete so that the natural resources are used efficiently and hence environmental waste can be reduced. Different types of fibers used to increase tensile strength and reduce cracks in the concrete.The study has been made to evaluate the effect on mechanical and durability properties of* M_{30} *grade concrete made with replacement of cement with Quarry dust, (0%, 10%, 15%, 20%, 25% and 30%) and Metakaolin, (0%, 2.5%, 5.0%, 7.5%, 10.0% and 12.5%) by weight and the addition of Steel fibers and glass fibers in different percentages (0%, 0.5%, 1%, 1.5% and 2%). For each set 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 for cubes.*

Keywords- Quarry dust, solid waste disposal,tensile strength, Metakaolin, Compression test, Flexural test, Sulphate

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world. The main constituent in the conventional concrete is Portland cement. The amount of cement manufacture release approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials Quarry dust is a by-product from the crushing process during quarrying activities. Quarry dust has been used for different activities in the construction industry. The dust produced by quarrying has already been used in the construction industry for projects such as road building, and making materials such as bricks and tiles. The dust has been found to be suitable for these practices, and this makes its transformation into a useful cement mix replacement more likely.

Metakaolin(MK) is a pozzolanic material which is manufactured from selected kaolins, after refinement and calcination under specific conditions. It is a highly efficient pozzolana and reacts rapidly with the excess calcium hydroxide resulting from OPC hydration, via a pozzolanic reaction, to produce calcium silicate hydrates and calcium alumino silicate hydrates. It differs from other supplementary cementitious materials like fly ash, slag or silica fume, in that it is not a by-product of an industrial process; it is manufactured for a specific purpose under controlled conditions. It is produced by heating kaolin, one of the most abundant natural clay minerals, to temperatures of 650-900°C. It is a fine, natural white clay which contains the highest content of silica.

One method to improve the brittle behavior of the concrete is the addition of small fibers in concrete. 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 steel and glass fibers are added to concrete, leads to improvement in cracking and tensile strength.

II. MATERIALS & PROPERTIES

Cement

Ordinary Portland Cement (53 grade) conforming to IS 8112 was used. The different laboratory tests were conducted on cement to determine initial and final setting time, and specific gravity as per IS 4031 and IS 269-1989. The results confirms to the IS recommendations.

Table 1: Properties of cement

S.No	*Properties*	*Value*	*Permissible limit as per IS: 12269-1987*
1	Specific Gravity	3.11	Varies from 3.1 to 3.15
2	Initial setting time	63min	Should not be less than 30 Min
3	Final setting time	321 min	Should not be more than 600
4	Fineness test	1% retained	<10%

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	2.61	Should be between the limit 2.6-2.7
2	Fineness Modulus	2.26	Should be between 2-4
3	Grading Zone	Zone II	---------

Coarse aggregates

Crushed Granite stone of sizes 20mm was 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	2.66	In between range 2.6-2.8
2	Fineness Modulus	7.68	In between range 6.5-8

Water

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

Quarry dust

Quarry dust is collected from local stone crushing units. It was sieved by IS: 90 micron sieve before mixing in concrete.

Figure 1: Quarry dust

Chemical composition of Quarry dust

Table 4: Chemical Composition of Quarry dust

Chemical Constituent	Quarry dust
SiO_2	62.48
Al_2O_3	18.72
Fe_2O_3	6.54
CaO	4.83
MgO	2.56
Na_2O	NIL
K_2O	0.18
TiO2	1.21
Loss of ignition	0.48

Physical properties of Quarry dust

Table 5: Physical Properties of Quarry dust

Physical Properties	*Value*
Specific Gravity	2.56
Bulk density(Kg/m^3)	1760
Moisture content	Nil

Metakaolin

The mineral admixture Metakaolin was obtained from Astro chemicals Company, Chennai. The chemical formula of Metakaolin is Al_2O_3 $2SiO_2$ H_2O.

Figure 2: Metakaolin

Physical properties of Metakaolin

Table 6: Physical properties of Metakaolin

S No	Physical Properties	Value
1	Specific gravity	2.6
2	Color	White
3	Particle shape	Spherical

Chemical Properties of Metakaolin

Table 7: Chemical composition of Metakaolin

Chemical Constituent	Metakaolin
SiO_2	62.62
Al_2O_3	28.63
Fe_2O_3	1.07
CaO	0.15
MgO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOSS OF IGNITION	2.00

Steel fiber

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.

Figure 3:Steel fiber

Properties of steel fiber

Table 8: Properties of steel fiber

S No	Parameters	Values	Permissible limits
1	Diameter	0.5 mm	0.15 mm-2 mm
2	Length	30 mm	7 mm – 75 mm
3	Aspect ratio	60	20-100
4	Density	7900 kg/cum	---

Glass fiber

It is material made from extremely fine fibers of glass. The glass fiber type used here is A-Rglass**.**

Figure 4: Glass fiber

Properties of glass fiber

Table 9: Properties of glass fiber

S.No	Parameters	Values
1	Diameter	0.1 mm
2	Length	50mm
3	Aspect Ratio	500
4	Tensile strength	1700 MPa
5	Density	2700 kg/cum

III. EXPERIMENTAL WORK

In present study M_{30} grade concrete was designed as per IS: 10262-2009. The weight ratio of mix proportion is 1: 1.7:2.9 keeping water cement ratio 0.45.

Table 10: Mix proportion

S No	Materials	Values
1	Cement	388.8kg/cum
2	Fine aggregate	694.3kg/cum
3	Coarse aggregate	1154.4kg/cum.
4	Water	175litre

Cubes, cylinder sand beams conforming to IS: 516-1964 are casted. After 24 hours the moulds were demoulded and subjected to water curing. Before testing the cubes were air dried for 1 day. Crushing loads, split tensile strength, flexural strength were noted and average of 3 specimens was determined at 7days and 28days.

Figure 3(a): showing cubes compacted with concrete

Figure 3(b): showing cubes in curing

Tests

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

Compression test

Compression test on cubes of size (150 x 150 x 150) mm was performed on compression testing machine.

Figure 4(a): testing of cubes in compressive testing machine

Split TensileTest

Split tensile was performed on cylinders of 150mm dia and 300mm height on compression testing machine. The failure load was recorded to find out split tensile strength.

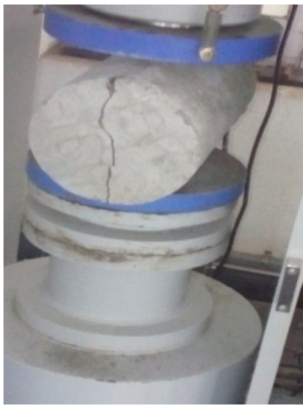


Figure 4(b): Testing of cylinders in compressive testing machine

Flexural Strength Test

In this modulus of rupture is calculated by testing specimens in the universal testing machine. In this line of fracture is the main important property in formulating the modulus of rupture.

The modulus of rupture is denoted by "fcr".

The "f" value is mainly based on the shortest distance of line fracture .

If 110mm < a < 133mm, $f_{cr} = \frac{3PL}{bd^2}$

If a > 133mm, $f_{cr} = \frac{PL}{bd^2}$

If a < 110mm, the test shall be discarded.

Figure 4(c): testing of beams in flexural testing machine

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% H_2SO_4.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 andH_2SO_4 which are having pH value 3.01 and 2.75 which cause a very severe attack are used to study the durability properties.

Figure 4(d): SULPHURIC ACID AND HCl

Figure 4(e): ACID CURING

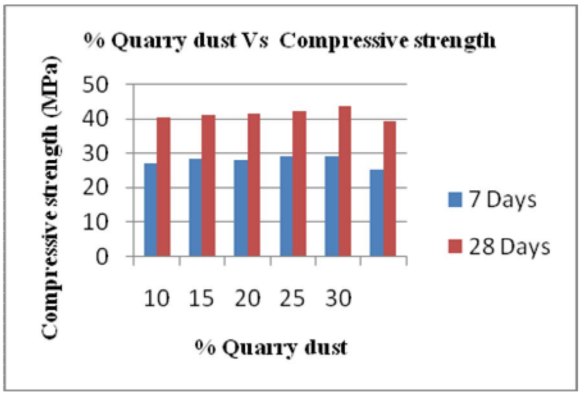
IV. RESULTS

Table 11: Compressive strength of trail mix

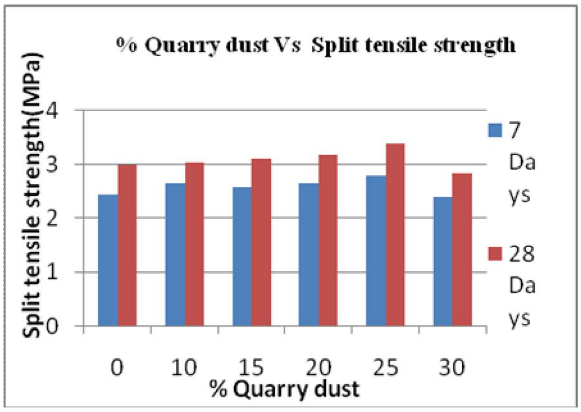
Mix details	Strength in Mpa		
	7 days	14 days	28 days
Conventional	26.7 N/mm^2	30.88 N/mm^2	40.33 N/mm^2

Table 12: Optimum Value of Quarry dust

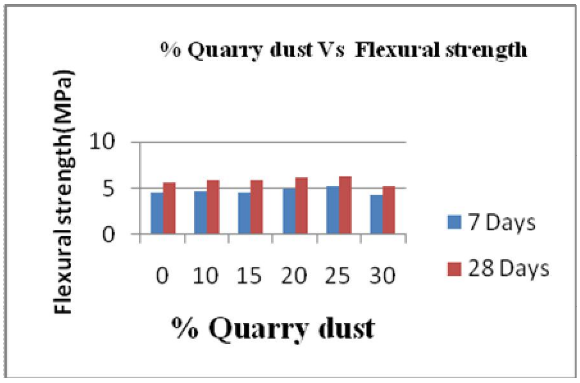
Percentage of quarry dust	Compressive strength, MPa		Split tensile strength		Flexural strength, MPa	
	7 days	28 days	7 days	28 days	7 days	28 days
0	26.7	40.33	2.45	2.99	4.55	5.66
10	28.23	40.82	2.66	3.04	4.63	5.89
15	27.72	41.45	2.59	3.11	4.54	5.92
20	28.81	42.07	2.65	3.19	4.93	6.07
25	**29.12**	**43.45**	**2.80**	**3.4**	**5.21**	**6.25**
30	25.12	39.26	2.4	2.84	4.31	5.26



Graph 1: Compressive strength of Quarry dust



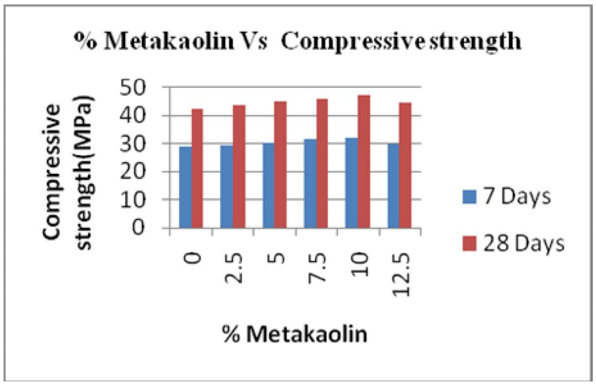
Graph 2: Split tensile strength of Quarry dust



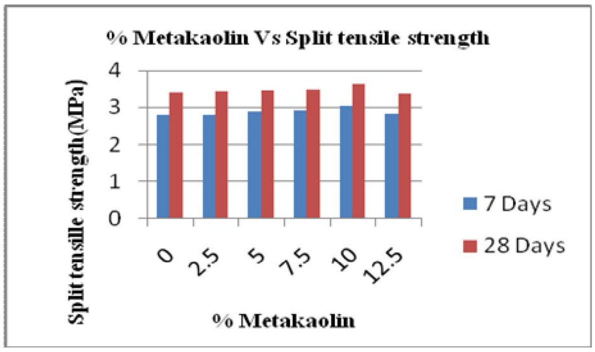
Graph 3: Flexural Strength of Quarry dust

Table 13: Optimum Value of 25% Quarry dust and Metakaolin

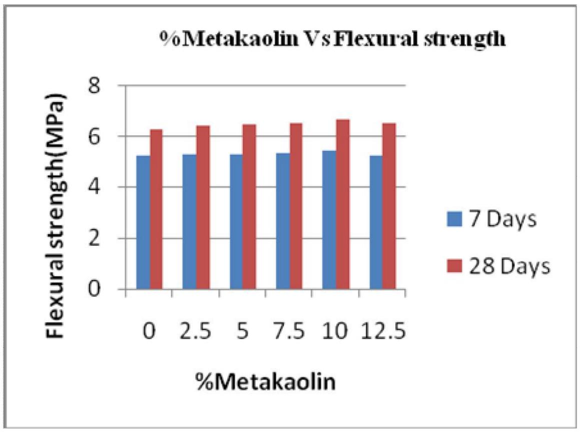
25%QD and percentage of Metakaolin	Compressive strength,MPa		Split tensile strength,MPa		Flexural strength,MPa	
	7 days	28 days	7 days	28 days	7 days	28 days
0	29.12	42.52	2.8	3.4	5.21	6.25
2.5	29.52	43.64	2.81	3.43	5.26	6.38
5	30.22	45.28	2.88	3.47	5.28	6.44
7.5	31.81	46.02	2.91	3.49	5.31	6.48
10	**32.12**	**47.45**	**3.05**	**3.65**	**5.41**	**6.64**
12.5	29.72	44.66	2.82	3.38	5.24	6.49



Graph 4: Compressive strength of Metakaolin



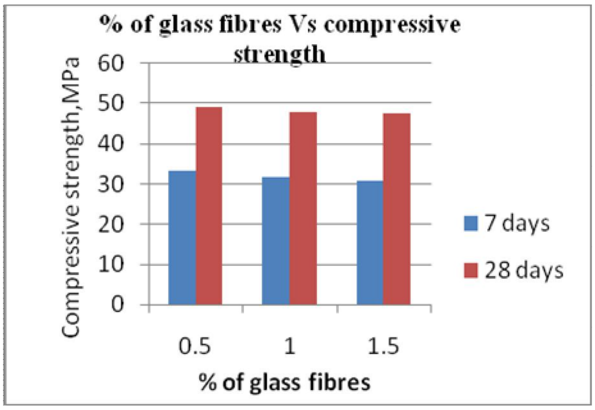
Graph 5: Split tensile strength of Metakaolin



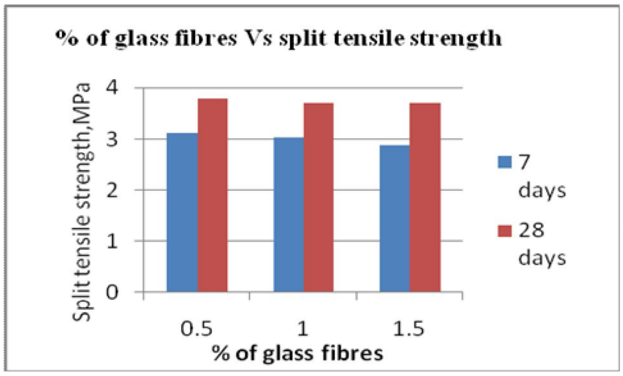
Graph 6: Flexural Strength of Metakaolin

Table 14: Strength values of glass fiber specimens

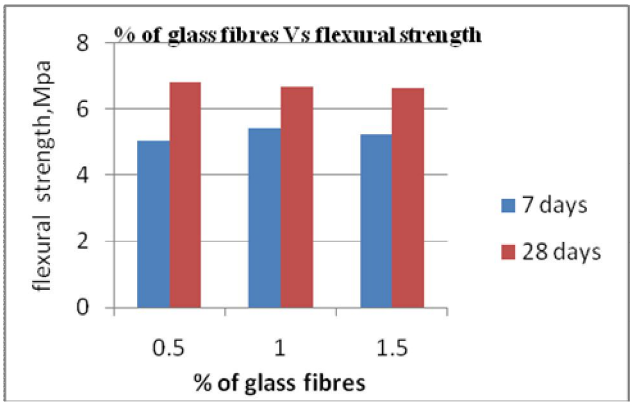
% of glass fibers	Compressive strength,MPa		Split tensile strength,MPa		Flexural strength,MPa	
	7 days	28 days	7 days	28 days	7 days	28 days
0.5	**33.27**	**49.27**	**3.12**	**3.78**	**5.05**	**6.82**
1	31.69	47.82	3.03	3.70	5.44	6.68
1.5	30.87	47.48	2.87	3.69	5.26	6.65



Graph 7: Compressive strength of Glass fibers



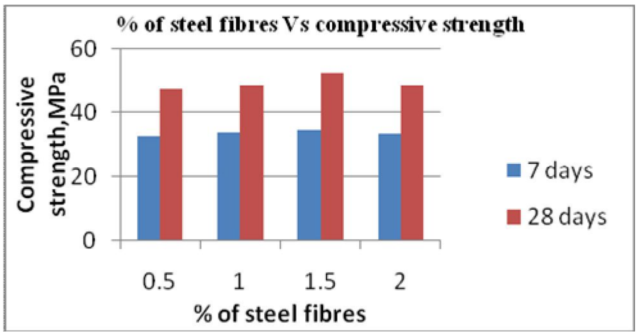
Graph 8: Split tensile strength of Glass fibers



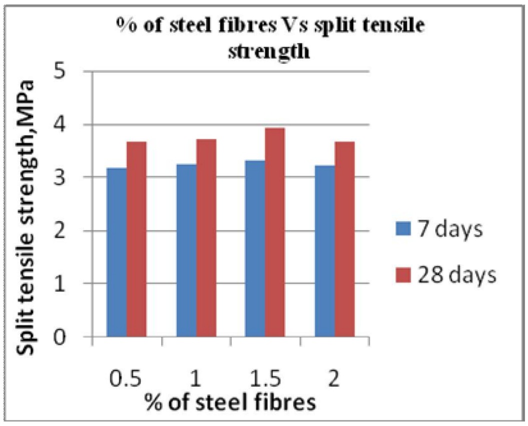
Graph 9: flexural strength of glass fibers

Table 15: Strength values of the steel fiber specimens

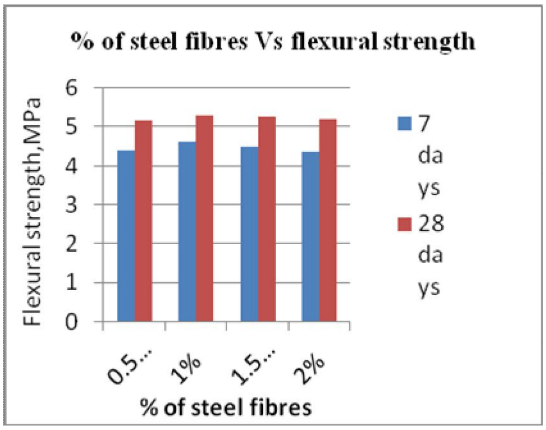
% of steel fibers	*Compressive strength,MPa*		*Split tensile strength,MPa*		*Flexural strength,MPa*	
	7 days	*28 days*	*7 days*	*28 days*	*7 days*	*28 days*
0.5	32.64	47.46	3.17	3.67	6.65	7.24
1	33.81	48.74	3.23	3.72	7.1	7.63
1.5	**34.68**	**52.68**	**3.31**	**3.91**	**7.23**	**7.8**
2	33.41	48.71	3.22	3.66	6.28	6.69



Graph 10: Compressive strength of steel fiber



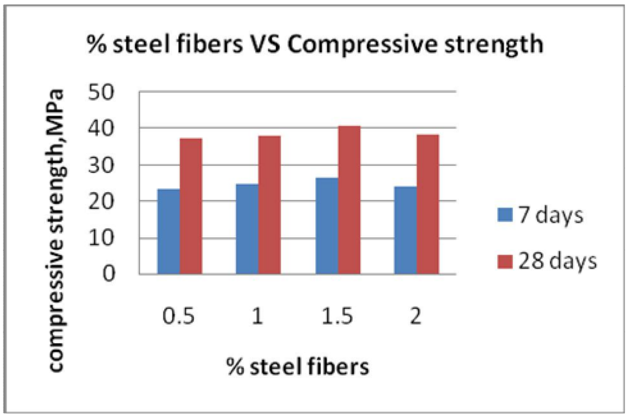
Graph 11: Split tensile strength of Steel fibers



Graph 12: Flexural strength of steel fibers

Table 16: Compressive strength of steel fiber reinforced concrete after H_2SO_4 acid curing

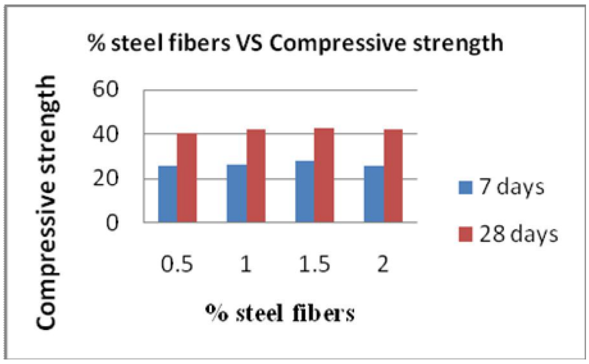
S.NO	*% of steel fiber*	*Compressive strength(N/mm²)*	
		7days(5%H_2SO_4)	*28days(5%H_2SO_4)*
1	0.5	23.12	37.24
2	1.0	24.81	38.12
3	1.5	26.52	40.92
4	2.0	24.12	38.34



Graph 13: Compressive strength for Steel fibre reinforced concrete after H_2SO_4 acid curing at 7 days and 28 days.

Table 17: Compressive strength of steel fiber reinforced concrete after HCl acid curing

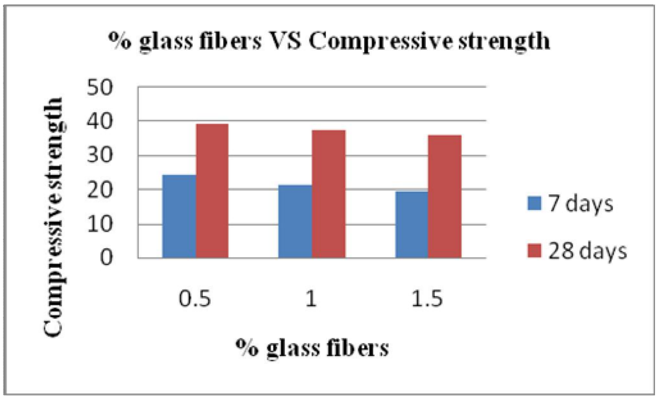
S.NO	% of steel fiber	Compressive strength(N/mm^2)	
		7days(5%HCL)	28days(5%HCL)
1	0.5	25.91	40.32
2	1.0	26.12	41.81
3	1.5	27.92	42.72
4	2.0	25.99	41.99



Graph 14: Compressive strength for Steel fibre reinforced concrete after HCL acid curing at 7 days and 28 days.

Table 18: Compressive strength of glass fiber reinforced concrete after H_2SO_4 acid curing

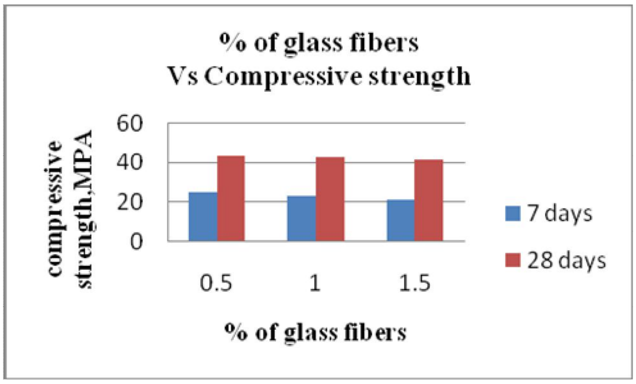
S.NO	% of glass fiber	Compressive strength(N/mm^2)	
		7 days(5%H_2SO_4)	28days(5%H_2SO_4)
1	0.5	24.27	39.23
2	1	21.29	37.52
3	1.5	19.63	36.12



Graph 15: Compressive strength for Glass fibre reinforced concrete after H_2SO_4 acid curing at 7 days and 28 days.

Table 19: Compressive strength of glass fiber reinforced concrete after HCl acid curing

S.NO	% of glass fiber	Compressive strength(N/mm^2)	
		7 days(5%HCl)	28days(5%HCl)
1	0.5	25.21	43.52
2	1	23.12	42.65
3	1.5	21.35	41.98



Graph 16: Compressive strength for Glass fibre reinforced concrete after HCL acid curing at 7 days and 28 days.

V. CONCLUSIONS

- By the comparison of nominal mix, the percentage increase in Compressive Strength, Split tensile strength and flexural strength for Partial replacement of cement with Quarry Dust are 7.18%, 12.05% and 9.44%.
- By the comparison of nominal mix, the percentage increase in Compressive Strength, Split tensile strength and flexural strength for Partial replacement of cement with Metakaolin are 15.06%, 18.8% and 14.75%.
- By the comparison of nominal mix, the percentage increase in Compressive Strength, Split tensile strength

and flexural strength for extension of glass fibers are 18.14%, 20.66% and 17.00%.

- By the comparison of nominal mix, the percentage increase in Compressive Strength, Split tensile strength and flexural strength for extension of Steel fibers are 23.44%, 23.52% and 27.45%.
- The optimum quantity for partial replacement of cement by Quarry Dust is obtained at 25%.
- By making the 25 % of Quarry Dust constant, the optimum quantity for partial replacement of cement by Metakaolin is obtained at 10%.
- The optimum quantity for extension of Glasss fibers is obtained at 0.5%.
- The optimum quantity for extension of Steel fibers is obtained at 1.5%.
- The Durability result shows that steel fiber is more effective than glass fiber.

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