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A STUDY ON THE STRENGTH OF A FIBRE REINFORCED CONCRETE PARTIALLY REPLACED WITH CEMENT BY DUST AND METALKOLIN

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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 M30 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 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: FRC, Metakaolin, Compression test, Flexural test.

1.0 INTRODUCTION:

Cement is likely the most broadly utilized development material as a part of the world. The principle constituent in the traditional 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. The incorporation of supplementary cementitious materials like Quarry Dust (QD) and Metakaolin (MK) improves mainly the mechanical properties of concrete and also reduce the cement consumption. It is one of the strategies to enhance the fragile conduct of the solid is the expansion of little fibers in cement with haphazardly circulated. Such strengthened cement is called Fiber Reinforced Concrete (FRC). There are diverse sorts of fibers that can be utilized as a part of FRC they are Steel fibers, Glass fibers, Synthetic fibers, Carbon fibers, Nylon fibers. In this study the option of steel and glass fibers are added to solid, prompts change in breaking and rigidity. Plain concrete possesses a very less tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are present in the concrete and its poor tensile strength is due to the propagation of such micro cracks. 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.

Quarry Dust:

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.

Advantages of Using Quarry Dust

Use of Quarry Dust in cement and concrete results in

- Increased strength
- Enhanced durability
- High resistance to chloride penetration
- High resistance to sulfate attack
- Improved surface finish
- Enhanced architectural appearance

Metakaolin:

Metakaolin is a manufactured pozzolanic mineral admixture, which significantly enhances many performance characteristics of cement-based mortars, concretes and related products. Metakaolin, a white, amorphous, aluminum-silicate material formed from refined kaolin clay, interacts violently with calcium hydroxide to produce compounds having cementitious value.

Advantages of Using Metakaolin

Use of Metakaolin in cement and concrete results in

- Excellent workability
- Reduced permeability
- Controls alkali-silica reactivity
- Cost beneficial as reduces usage of super plasticizer

Fiber Reinforced Concrete:

The term Fiber Reinforced Concrete (FRC) is defined by ACI committee 544 as a concrete made of fibers hydraulic cements containing fine or coarse aggregates and discontinuous discrete fibers. Inherently concrete is brittle under tensile loading. Mechanical properties of concrete can be improved by reinforcement with randomly oriented short discrete fibers, which prevent and control initiation, propagation and coalescence of cracks.

2.0 LITERATURE REVIEW

A.V.S.Sai Kumar, Krishna Rao B **[1]** studied the effect on mechanical properties of M30 grade concrete made with partial 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%) .Tests for compressive strength, split tensile strength and flexural strength were conducted. Venkata Sairam Kumar N. **[2]** studied the characteristics of M20, M30 and M40 grade concrete with partial replacement of cement with Quarry Dust by replacing cement with 10%, 15%,20%,25%,30%,35% and 40%. Tests for compressive strength and split tensile strength were conducted. Dr. Naeem Ijaz1, Muhammad **[3]** studied the effect on mechanical properties of M15 grade concrete made with partial replacement of cement with Quarry dust (0%, 15%, 25% and 35%). Tests for compressive strength and split tensile strength were conducted. J.M. Khatib, E.M. Negim **[4]** studied the compressive strength, density and ultrasonic pulse velocity of mortar containing high volume of metakaolin (MK) as partial substitution of cement. Up to 50% of MK was used to replace cement in increment of 10. The results indicate that the maximum strength of mortar occurs at around 20% MK. Avinash Gornale, S Ibrahim Quadri **[5]** studied the effect on Compressive, Flexural and Split tensile strength of various grades of Glass fiber reinforced concrete and the mixes were compared with ordinary concrete mixes of M20, M30 and M40 grades of concrete. The workability of concrete decreases with the addition of Glass Fibers. Mr. Nikhil A. **[6]** The study focuses on the compressive strength performance of the blended concrete containing different percentage of slag and steel fiber as a partial replacement of OPC. The cement in concrete is replaced accordingly with the percentage of 10 %, 20%, 30%, and 40% by weight of slag and 0.5%, 1%, 1.5%, 2% by weight of steel fiber. Concrete cubes are tested at the age of 3, 7, and 28 days of curing. Sumathi and K**.** **[7]** the study was conducted to evaluate the mechanical characteristics of the High Strength steel Fiber Reinforced Concrete. The concrete mix design was done for M40 grade concrete. However, the specimens have been tested for different water cement ratio and it is arrived from the slump test. Milind, V. Mohod **[8]** By adjusting the percentage of fibres in concrete, it has been determined how fibres affect the strength of concrete for the M 30 grade. By cement volume, fibre contents were adjusted by 0.25%, 0.50%, 0.75%, 1%, 1.5%, and 2%. In order to test the compressive strength, cubes measuring 150 mm x 150 mm x 150 mm and beams measuring 500 mm x 100 mm x 100 mm were cast. Before being crushed, each specimen was cured for 3, 7, and 28 days.

3.0 Material Methods

The experimental investigation consists of casting and testing of 19 sets along with control mix. Each set comprises of 12 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. The cement will be replaced accordingly with the different percentages by weight of slag and different percentages by weight of steel fibers and Glass fibers. 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. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and beams are removed from the curing tank carefully.

The material characteristics that are used in this study given in brief are as follows:

- Ordinary Portland cement 53 grade (KCP cement) with specific gravity of 3.11
- Locally available river sand with specific gravity of 2.61 and confirming to
- zone-2 of IS:383
- Coarse aggregate with specific gravity of 2.66
- Quarry Dust with specific gravity of 2.56
- Metakaolin with specific gravity of 2.6

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.

Cement:

The definition of cement is a bonding substance with cohesive and adhesive qualities that enables it to bind various building elements and create a compacted assembly. One of the most popular varieties of Portland cement is ordinary or normal Portland cement.

Figure 1: Cement

Specific Gravity of Fine Aggregate

Weight of empty Pycnometer W1 =425 gm.
Weight of empty Pycnometer +fine dry aggregate W2 = 757 gm.
Weight of empty Pycnometer + fine dry aggregate + water W3 =1375 gm
Weight of empty Pycnometer + water W4 =1170gm.
Specific gravity of water Gw = 1.0
Specific Gravity of fine aggregate = (W2 – W1) / [(W2 – W1) – (W3 – W4)]
Specific Gravity of Fine Aggregate = 2.61

Specific Gravity of Metakaolin

Weight of empty flask W1 = 15 gm.
Weight of empty flask + cement W2 =84 gm.
Weight of empty flask + cement +kerosene W3 = 95 gm.
Weight of empty flask + kerosene W4 =40 gm.
Specific gravity of kerosene Gk =0.78
Specific Gravity of Metakaolin = (W2 – W1) / [(W2 – W1) – (W3 – W4)]
Specific Gravity of Metakaolin = 2.6

Fineness Modulus of Fine Aggregate and Coarse Aggregate

The Fineness modulus (FM) is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100. The sieve sizes are 150µ, 300µ, 600µ, 1.18 mm, 2.36 mm, 4.75 mm, 9.5 mm, 19.0 mm, 38.1 mm and larger increasing in the ratio of
2:1. The same value of fineness modulus may therefore be obtained from several different particle size distributions

Water

Fresh potable water free from acid and organic substances was used for mixing and curing concrete. Salt water is not to be used

Table 1: Physical Properties of Materials

Physical Properties of Materials	Results
Normal Consistency of Cement	32%
Setting Times of cement Initial Final	 63 minutes 321 minutes
Specific Gravity of cement	3.11
Fineness of cement	1%
Specific Gravity of aggregates of Coarse aggregates Fine aggregates QD MK	 2.66 2.61 2.56 2.6
Fineness Modulus of Fine Aggregate Fineness Modulus of Coarse Aggregate	2.26 7.68

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 aspect ratio of the fiber is the ratio of its length to its diameter.

Table 2: Specifications of steel fibers

Fibre type	Fibre length	Fibre diameter	Aspect ratio
Hooked end	30 mm	0.5 mm	60

Glass Fiber

It is material made from extremely fine fibers of glass Fiber glass is a lightweight, extremely strong, and robust material. The glass fiber type used here is AR glass with 50mm fiber length and 0.1mm diameter. The aspect ratio of the glass fiber is 500.Glass fiber reinforced concrete, also known as GFRC.

Table 3: Specifications of glass fiber

Fiber Type	Fiber length	Fiber diameter	Aspect Ratio
AR glass	50 mm	0.1mm	500

MIX DESIGN

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 M30 grade concrete.

Mix Design – M30: The steps involved in the design of concrete mix as per IS: 10262-2009, IS: 456-
2000.

M30 Concrete Mix Design		
As per IS 10262-2009 & MORT&H		
1	**Stipulations for Proportioning**	
1	Grade Designation	M30
2	Type of Cement	OPC 53 grade
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content (MORT&H 1700-3 A)	320 kg/m^3
5	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
6	Workability (MORT&H 1700-4)	25-50 mm (Slump)
7	Exposure Condition	Severe
8	Degree of Supervision	Good

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.

Figure 2: Mixing of Concrete

Preparation of Concrete Moulds:

Metal moulds, preferably steel or cast iron, strong enough to prevent distortion is required. Specimen without damage and are so maintained that, when it is collected, the dimensions and internal faces are required to be accurate.

Figure 3: Arrangement of moulds

Casting of Beams

For each trail 6 beam specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the beam specimen are of 500mm x 100mm x 100mm.

Figure 4: Specimens casted

Curing

The test specimens are stored in a place free from vibration in moist air of at least 90%relative humidity and at a temperature of 27°C ± 2°Cfor 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds. Unless required for testing within 24 hours, they are immediately submerged in clean fresh water or saturated lime solution and are kept there until they are taken out just prior to test. The water or solution in which the specimens are submerged, are removed every seven days and are maintained at a temperature of 27°C ± 2°C. the specimens are not to be allowed to become dry at any time until they have been tested.

RESULTS AND DISCUSSIONS

The study has been made to evaluate the effect on mechanical and durability properties of M30 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%). The detailed tabulations and graphs are presented as follows. A number of tests were carried out to determine the design mix properties of concrete in the laboratory. The strength criterion includes measurement of following parameters:

- Compressive Strength
- Flexural Strength
- Split Tensile Strength

Compression Test

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing 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.

Figure 5: Testing cubes in compressive testing machine

Table 4: Compressive strength for different Quarry dust percentages

Percentage of quarry dust	**Compressive strength**	
	7 days	**28 days**
0	26.7	40.33
10	28.23	40.82
15	27.72	41.45
20	28.81	42.07
25	**29.12**	**43.45**
30	25.12	39.26

Table 5: Compressive strength for glass fiber

% of glass fibers	**Compressive strength**	
	7 days	**28 days**
0.5	**33.27**	**49.27**
1	31.69	47.82
1.5	30.87	47.48

Table 6: Compressive strength for steel fiber

% of steel fibers	**Compressive strength**	
	7 days	**28 days**
0.5	**32.64**	**47.46**
1	**33.81**	**48.74**
1.5	**34.68**	**52.68**
2	**33.41**	**48.71**

From the above graph, it is observed that the compressive strength value is higher for the mix 25% QD+10% MK with 1.5% steel fibers compared with other mixes.

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 M25 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 7: Flexural strength of Quarry Dust

Percentage of quarry dust	**Flexural strength, MPa**	
	7 days	**28 days**
0	4.55	5.66
10	4.63	5.89
15	4.54	5.92
20	4.93	6.07
25	**5.21**	**6.25**
30	4.31	5.26

Table 8: Flexural strength for Metakaolin

25% Per centage percentage of Metakaolin	Flexural strength	
	7 days	28 days
0	5.21	6.25
2.5	5.26	6.38
5	5.28	6.44
7.5	5.31	6.48
10	**5.41**	**6.64**
12.5	5.24	6.49

Table 9: Flexural test for glass fiber

% of glass fibers	Flexural strength	
	7 days	28 days
0.5	**5.05**	**6.82**
1	5.44	6.68
1.5	5.26	6.65

From the above graph, it is observed that the flexural strength value is higher for the mix 25% QD with 10% MK, compared with other mixes.

Table 10: Compressive strength of steel fibre reinforced concrete of M30 grade concrete after H2SO4 acid curing

S.NO	% of Steel fiber	Compressive strength(N/mm^2)		
		7days(5%H2SO4)	28days(5%H2SO4)	60days(5%H2SO4)
1	0	22.21	36.12	35.55
2	0.5	23.12	37.24	36.25
3	1.0	24.81	38.12	37.12
4	1.5	26.52	40.92	38.99
5	2.0	24.12	38.34	36.95

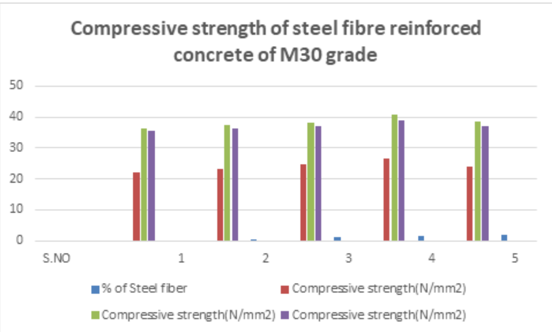
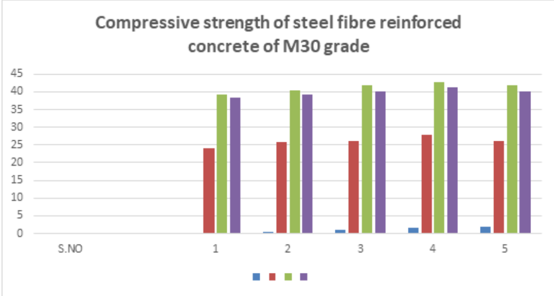


Figure 6: Compressive strength of steel fibre reinforced concrete of M30 grade

Table: Compressive strength of steel fibre reinforced concrete of M30 grade concrete after HCL acid curing

S.NO	% ofsteel fiber	Compressive strength(N/mm^2)		
		7days(5%HCL)	28 days(5%HCL)	60 days (5%HCL)
1	0	24.11	39.25	38.24
2	0.5	25.91	40.32	39.25
3	1.0	26.12	41.81	39.97
4	1.5	27.92	42.72	41.23
5	2.0	25.99	41.99	40.12



Graph 7: Compressive strength of steel fibre reinforced concrete of M30 grade

CONCLUSIONS

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

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 Glass 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.

- In durability the strength loss is higher in H_2SO_4 than HCL

Scope For Future Work:

- Non-destructive tests can also be useful for on-site testing
- Combination of Quarry dust with different other admixture can be carried out.
- Combination of Metakaolin with different other admixture can be carried out.
- 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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