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Application and properties of Fiber Reinforced Concrete

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Abstract - *The main aim of the project is to understand the full operation of a ready-mix- concrete (RMC) plant, learn about the development and application of the concrete made up of fiber (FRC).The initial part of the work is to gain knowledge about the different parts of RMC plant in detail. The second part of the work deals with the raw materials used in the production of FRC. Lab tests on FRC analysis of FRC was done in Raipur RMC plant. The next part of the study deals with the understanding of properties of fiber reinforced concrete, its advantages over normal concrete and its role in sustainable development and environment protection.*

Key Words: Fiber Reinforced Concrete, Aspect Ratio, Fiber, Flexural Strength, compressive strength, Ready Mix Concrete

1. INTRODUCTION

As we know concrete is very much weak in tension and strong in compression [4]. In olden days hair of horse was using as a reinforcement in the mortar and some of them are using straw as a reinforced material in the mud bricks. Now a days with the introduction of fibers in plain or reinforced concrete gives better solution for reinforcement in the concrete. The development of fiber-reinforced concrete (FRC) helps to achieve sustainable development. Now a days FRC is widely used because of its effectiveness and durability. It is much stable, tough and resistant as compared to plain concrete and hence problem of cracks are minimized by using FRC. A concrete mix with fiber can provide environmental and economic benefits. Fiber reinforced concrete enhances the compressive strength, flexural strength and also increases durability and concrete finishing. It also decreases permeability, workability and bleeding in concrete. This report shows the significance of fiber reinforced concrete and its viability in Raipur RMC plant. The study area of the project comes under the central zone of India, Chhattisgarh, Raipur. In Raipur, the project is done at ULTRATECH RMC Division, Sherikheri (Raipur). The average atmospheric temperature is 30 centigrade. The site is far away from the city,to prevent pollution of the city. FRC is very old technique and it was invented in the year 1849 by Mr.Joseph Monier. Main scope of the work is to know the working and components of RMC plant, lab testing and properties of ingredient of concrete, concrete mix proportioning and properties of fiber reinforced concrete.

Fig -1: ULTRATECH RMC Division Raipur

1.1 Operation and description of the plant

Working of the plant is shown in the figure 2. In this figure all the component of RMC plant such as control system, cement silo, aggregate batching system, screw conveyor, measurement system etc. is shown to understand its operation and working principle. Description of the plant is shown in figure 3 with the help of flow chart.

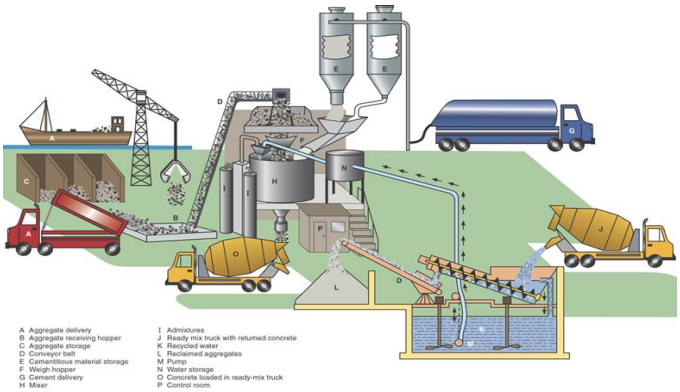

Fig -2: RMC Plant working of different components

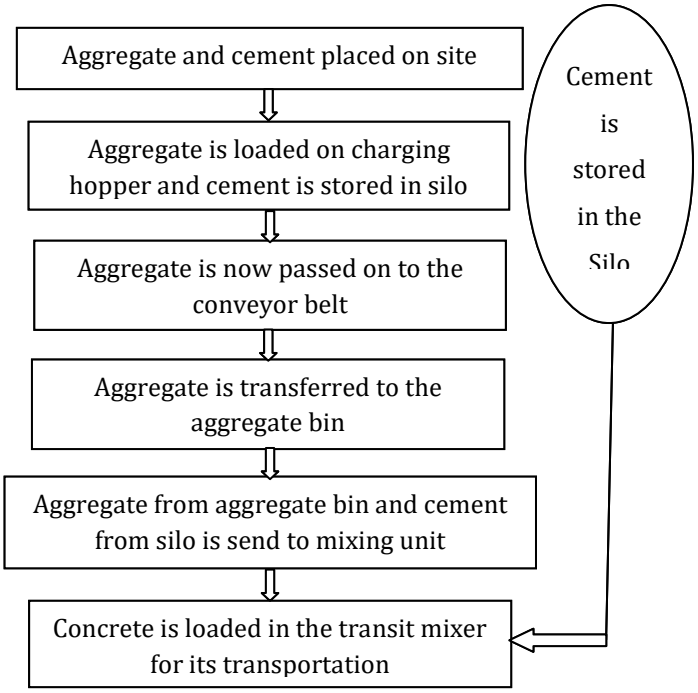

Fig -3: Flow chart of description of RMC Plant

1.2 Main ingredients of Fiber Reinforced Concrete

Main ingredients used to manufacture fiber reinforced concrete are aggregate, sand, cement, admixture, water and fiber.

Aggregate: Aggregates give shape to the concrete and reduces shrinkage. The nominal aggregate size used in this work is 20 mm and 10 mm.

Sand: The locally available natural sand is used in this project. Specific gravity of sand used is 2.63 and it conforms IS 650 specifications [6].

Cement: Cement used in this work is OPC 43 grade confirming IS: 8112 [7].

Water: The water which is going to be used for the mix should be dirt free/clean and also of good quality. The pH value of the water used is in between 6 to 8 as per IS 456:2000 [5].

A**dmixtures:** Among several Admixtures accelerating agents may be used just to minimize the influence of the glucose retardant.

Fibres: A fibre is a small sized reinforcing material produced from materials like plastic, glass, carbon etc in various shapes and size [1]. Because natural fibers are naturally available materials, so there aspect ratio is not proper because they are not uniform in diameter and length. Polypropylene Fibers in the form of plain and twisted shape is generally used. They are hydrophobic, so do not absorb water and hence there will be no effect on water to be mixed in concrete.

A convenient parameter describing the aspect ratio of the fiber by (L/D), which means the fiber length divided by an equivalent fiber diameter. The length of fibers may vary from 1 to 2 in. (25 to 500 mm). Typical aspect ratio ranges from 30 to 150 for length of 6 to 75mm.

1.2.1 Methods of mixing

Mixing of FRC can be done using different methods [2]. Generally two types of methods of mixing of fibers used which are wet and dry mixing. In case of wet mixing, low volume of fiber fraction is used. In both the methods mix should be uniform and homogenous so that there will be no any segregation of the fibers during mixing. With the increase in aspect ratio, volume and quantity of fiber, and size as well as quantity of aggregate will increase segregation and hence there will be decrease in workability of concrete. To cover the whole surface area of the fibers with paste, water cement ratio 0.4-0.6, and minimum quantity of cement 400 kg/m^3 are required [3]. As Compare to conventional concrete, FRC generally required higher cement, fine aggregate, and smaller size coarse aggregate.

2. TEST ON INGREDIENT OF CONCRETE

2.1 Test on aggregate

Aggregate Impact Value: The test is done on coarse aggregate and determined the impact value as per IS 2386 part IV [10].

Aggregate impact = $(W_1 - W_2)/W_1 * 100$

Where
W_1 – wt. of aggregate passing 12.5 mm sieve
W_2 – wt. of aggregate retained after impact on 2.36 mm sieve.

Flakiness index and elongation index: This test is used to find out whether the aggregate is too much flaky or elongated. As per strength and bonding flakiness and elongation index of the aggregate should be less. Flakiness index and elongation index of coarse aggregate was determined as per IS 2386 part 1 [8].

Moisture content: Moisture content of an aggregate was find out with the help of air oven.
Take a wet sample and weigh it and name it as W_1.
Take the weight of dry sample and name it W_2.
Moisture content = $(W_1 - W_2)/ W_1 * 100$

Density using cylindrical metal mould: It is used to find out bulk density as well as loose density of aggregate.

Specific gravity: Pycnometer is used to find the specific gravity of aggregate as per IS 2386 part III [9].

Formula used,

Specific gravity = $(W_2 - W_1)/ ((W_4 - W_1)-(W_3-W_2))$

Where,
W_1- wt. of pycnometer
W_2- wt. of (pycnometer + dry aggregate)
W_3- wt. of (pycnometer + aggregate + water)
W_4- wt. of (pycnometer + water)

Table -1: Various test result on concrete ingredient

Sl No.	Test	Value
1	Aggregate Impact Value (%)	11
2	Flakiness index of 10 mm aggregate (%)	42
	Flakiness index of 20 mm aggregate (%)	24
3	Elongation index of 10 mm aggregate (%)	13
	Elongation index of 20 mm aggregate (%)	16
4	Moisture Content of aggregate (%)	4
5	Bulk density of natural sand (kg/L)	1.63
	Bulk density of 20 mm aggregate (kg/L)	1.54
	Bulk density of 10 mm aggregate (kg/L)	1.55
6	Loose density of natural sand (kg/L)	1.59
	Loose density of 20 mm aggregate (kg/L)	1.46
	Loose density of 10 mm aggregate (kg/L)	1.42
7	Specific gravity of natural sand	2.63
	Specific gravity of 20 mm aggregate	2.71
	Specific gravity of 10 mm aggregate	2.74
8	Standard consistency of cement (%)	29.5
9	Initial setting time of cement (minutes)	175
	Final setting time of cement (minutes)	280
10	Fineness of cement (%)	6

2.2 Test on cement

Vicat apparatus is used to find the standard consistency as per IS 4031 part IV [12], initial setting and final setting time as per IS 4031 part V [13] of cement. Standard consistency is expressed as the amount of water in % by weight of the dry cement.

Fineness of cement: Purpose of this test is to find the fineness % of cement. This is done as per IS 4031 part I [11] which is also called the dry sieve analysis.

2.3 Particle size distribution of sand

Particle size distribution of fine aggregate was done by sieve analysis as per IS 2386 part1. Sieve analysis of soil is shown in Table 2.

Table -2: Sieve analysis of fine grained soil

IS Sieve	Weight retained	% weight retained	Cumulative % weight retained	% Finer	Limits IS383 ZONE-I
4.75	40	2.166	2.166	97.85	90-100
2.36	210	11.375	13.54	86.47	75-100
1.18	585	31.69	45.23	54.78	55-90
600	335	18.14	63.371	36.63	35-59
300	620	33.58	96.951	3.05	8-30
150	50	2.70	99.65	0.35	0-10
75	5	0.27	99.921	0.08	
PAN	1	0.054	99.975	0.03	

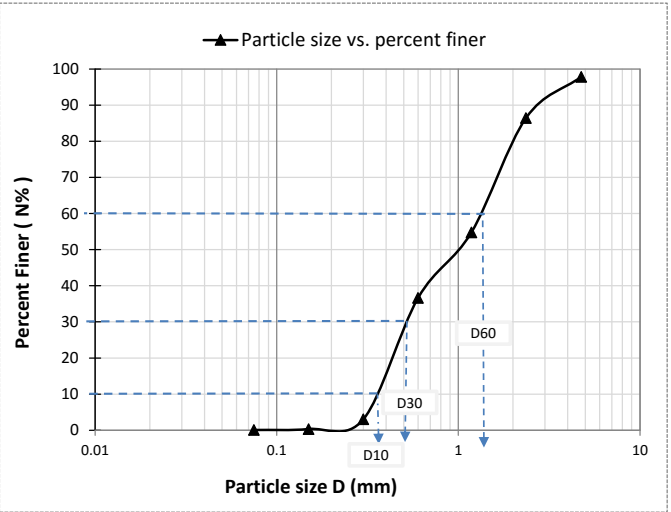

Chart -1: Particle size distribution of fine grained soil

Particle size distribution of fine grained soil is shown in chat 1. From the chart it was found that 60% of sand particle are finer than 1.5 mm, 30% are finer than 0.5 mm and 10% are finer than 0.35 mm.

3. CONCRETE MIX PROPORTIONING

The mix proportion is selected in such a way that workability of fresh concrete should be good/satisfactory and when concrete is hardened, it should have the required amount of strength and durability.

Observation:

1. Target strength $\mathbf{F_t}$ for mix proportioning
   $\mathbf{F_t = f_{ck} + t*s}$ = 40 + 1.65*5 = 48MPa

2. Minimum cement content = 360 kg/m^3 as per IS 456(200)
   Total cementitious material = 1.2 * 360
   = 432 kg/m^3
   But as we are using fly ash to make HVFAC we need higher value.
   Hence cementatious material required = 1.25*360
   = 450 kg/m^3

3. Considering maximum water-cement ratio = 0.35

4. As W/C = 0.35 (assumed) and cement content= 450 kg/m^3.
   Hence quantity of water required = 0.35*450 = 157.5 kg/ m^3.
   But in HVFA concrete we use minimum 40% fly ash. Hence we select minimum cementations content as 570 kg/ m^3. Hence minimum water required = 199.5 kg

5. On the usage of admixtures in concrete water content reduces. For HVFA concrete there is a reduction of 15% water.
   Actual water reduced = 199.5-29.925= 169.575.
   This is approximately 170 kg.
   Hence new water to cementatious ratio = 170/570
   = 0.30.

6. Some of the specific values used from the code for different raw material of concrete:
   Specific gravity of cement = 3.15
   Specific gravity of pulverized fuel ash = 2.26
   Specific gravity of natural sand (zone 3) = 2.63
   Specific gravity of 20 mm aggregate = 2.78
   Specific gravity of 10 mm aggregate = 2.79

Information necessary for accurate calculations:

1. Water absorption:
   For 10mm aggregate = 0.95
   For 20mm aggregate = 0.85
   For natural sand = 2.35

2. Gradation of fine and coarse aggregate

Table -3: Grading of coarse and fine sand

IS sieve designation	Percentage passing	
	40 mm aggregate	20 mm aggregate
80 mm	100	-
40 mm	95 to 100	-
20 mm	45 to 75	95 to 100
4.75 mm	25 to 45	30 to 50
600 micron	8 to 30	10 to 35
150 micron	0 to 6	0 to 6

Volume of cement = (360/3.15)*1/1000 = 0.11 m^3

Volume of PFA= (250/ 2.26)* 1/1000 = 0.11 m^3
Volume of admixture = 1 % of volume of (cement + PFA)
= 0.00022 m^3

Volume of water= (170)* 1/1000= 0.170 m^3

Volume of total aggregate=1-(a+b+c+d) = 0.609 m^3

Weight of 10 mm aggregate= 0.70*2.78*0.25*1000
= 486.5 kg

Weight of 20 mm aggregate= 0.70*2.79*0.35*1000
= 683.5 kg

Weight of sand= 0.70*2.63*0.4*1000=736.4 kg

3.1 Tests performed on cubes and beams of concrete

For the determination of Workability of the concrete slump cone test is performed in which the maximum size of an aggregate should not be larger than 38mm.

The slump formed in this case is a true slump and the slump value is 150 mm.

3.2 Test on Fiber Reinforced Concrete

For determining the effect of fibre in FRC following tests were performed:

3.2.1 Compression test of concrete cube (Target Strenght 43.5 MPa)

Considered three concrete cubes of dimension 150 x 150 x 150 mm for both the test without fiber and with fiber. Find out the value of compression test in both the cases.

Table -4: Compression test result of concrete cube

Cube	Without Fiber	With Fiber
Cube 1st	42.90 MPa	46.50 MPa
Cube 2nd	44.00 MPa	45.90 MPa
Cube 3rd	43.50 MPa	46.70 MPa
Average value	-	46.37 MPa

3.2.2 Flexural Strength test of concrete beam (Target Strenght 4.35 MPa)

Considered three beam of dimension 450 x 150 mm for both the test without fiber and with fiber. Find out the value of flexural strength in both the cases.

Table -5: Flexural Strength test result of beam

Beam	Without Fiber	With Fiber
Beam 1st	4.55 MPa	4.85 MPa
Beam 2nd	4.75 MPa	5.00 MPa
Beam 3rd	4.45 MPa	4.75 MPa
Average value	-	4.86 MPa

4. CONCLUSIONS

In this study laboratory test was carried out on concrete ingredient and fiber reinforced concrete. Based on the experimental results various conclusions achieved are-

1. To improve the properties of the conventional concrete we have used Polypropylene fiber in the concrete mix.
2. Appropriate dosage of fiber improves its flexural strength. It was also observed that fiber improves the ductility since they bind together in the concrete matrix.
3. Due to heat of hydration, cracks formed in the concrete. With the use of fiber in the fresh concrete micro cracks developed in it did not let them propagate in to the deep and hence concrete performance improved.
4. Such micro cracks makes the concrete stronger as cracks propagation up to a certain depth say 1.0mm.
5. These micro cracks are not harmful for the hardened concrete because these are developing only on the fiber surface.

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