Technologies for smart high performance composite bridges for rapid infrastructure in construction management system

M.Jothy Lekshmi

PG Student
Department of Civil
Arunachala College of Engineering for Women
Mail id: jothygeorge5@gmail.com

Abstract- Concrete is the most broadly used material in construction worldwide and Reactive Powder Concrete (RPC, a type of ultra-high performance concrete) is a relatively new member of the concrete family. In this work the critical parameters of RPC mix design are investigated and the mix design is explored through a program of concrete casting and testing. Owing to the enhanced microstructure of RPC, porosity and permeability can be significantly decreased in the concrete matrix. This benefits the durability characteristics of RPC elements resulting in a longer service life with less maintenance costs than conventional concrete. It has been used for high integrity radiation waste material containers because of its low permeability and durability. 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 fiber. Slump test and compressive strength of the specimen will be carried out.

Keywords: **Reactive Powder Concrete Fibre reinforced concrete, dynamic increase factor, Relative Fiber Matrix Stiffness.**

1 INTRODUCTION

1.1 Need of the Project

Concrete is very strong in compression but weak in tension. As a Concrete is a relatively brittle material, when subjected to normal stresses and impact loads. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of fiber, the micro-cracks are arrested. Fibre reinforced concrete (FC) is superior than ordinary concrete in strength, durability and many other aspects. The properties of RPC can be further improved by the addition of a polymer styrene butadiene rubber emulsion to produce polymer modified fibre reinforced concrete.

The flexural and compressive strength were determined based on an experimental study..

1.2 Scope of the Project

There is no standard approach to assessing the impact resistance of concrete. This investigation utilizes relatively well accepted impact equipment to evaluate the mechanical properties of RPC under dynamic loading. The compressive and flexural tensile strengths of plain and fibre reinforced RPC are investigated using a variety of specimens and apparatus. The dynamic increase factor (DIF) is evaluated to indicate the strain rate sensitivity of the compressive and flexural strength.

Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers.

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. Fibre-reinforcement is mainly used in shotcrete, but can also be used in normal concrete. Fibre-reinforced normal concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations etc) either alone or with hand-tied rebars Concrete reinforced with fibres (which are usually , glass or “plastic” fibres) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. Shape, dimension and length of fibre is important. A thin and short fibre, for example short hair-shaped glass fibre, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength

1.3 Effect of Fibres in Concrete

Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, so it cannot replace moment resisting or structural reinforcement. Some fibres reduce the strength of concrete.

Some recent research indicated that using fibres in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibres. The results also pointed out that the micro fibres is better in impact resistance compared with the longer fibres.

1.4 Necessity

- It increases the tensile strength of the concrete.
- It reduces the air voids and water voids the inherent porosity of gel.
- It increases the durability of the concrete.
- Fibres such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons**.**

1.5 Factors Effecting Properties of Fibre Reinforced Concrete

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

1. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorbsion of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as, glass and carbon impart strength and stiffness to the composite.

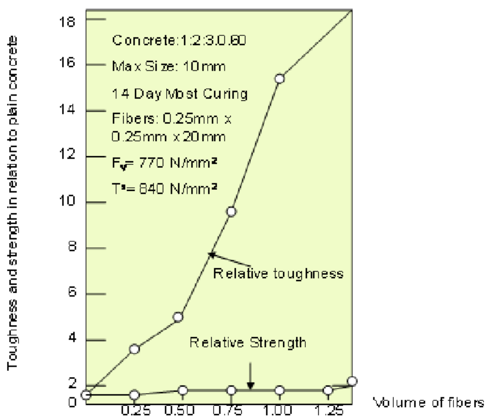


Figure 1.1: Relative Fiber Matrix Stiffness

2. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it. Fig 1.1 and 1.2 show the effect of volume on the toughness and strength. It can see from Fig 1.1 that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

3. Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table 1.1 shows the effect of aspect ratio on strength and toughness.

Table 1.1 Aspect ratio of the fiber

Type of concrete	**Aspect ratio**	**Relative strength**	**Relative toughness**
Plain concrete	0	1	1
With	25	1.5	2.0
Randomly	50	1.6	8.0
Dispersed fibers	75	1.7	10.5
	100	1.5	8.5

4. Orientation of Fibers

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibers are randomly oriented. To see the effect of randomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed.

1.6 Different Type Of Fibers

1. Fiber Reinforced Concrete

2. Polypropylene Fiber Reinforced (PFR) cement mortar & concrete

3. Glass-Fiber Reinforced Concrete

4. Asbestos Fibers

5. Carbon Fibers

6. Organic Fibers

1. Fiber Reinforced Concrete:-

A no of fiber types are available as reinforcement. Round fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick. Fiber made from mild drawn wire. Conforming to IS:280-1976 with the diameter of wire varying from 0.3 to 0.5mm have been practically used in India.

2 Polypropylene Fiber Reinforced (PFR) cement mortar&concrete.-

Polypropylene is one of the cheapest & abundantly available polymers polypropylene fibers are resistant to most chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees centigrade). So that a working temp.

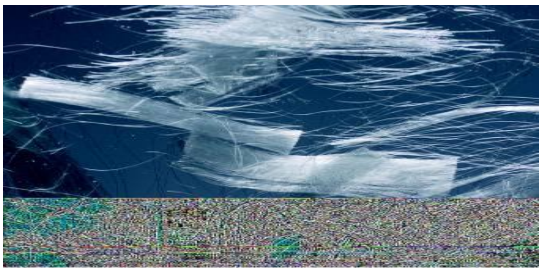


Figure 1.2: Polypropylene fiber reinforced cement-mortar & concrete.

Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix.

3. Glass-Fiber Reinforced Concrete:-

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape.

Figure 1.3: Glass-fiber reinforced concrete

Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm.The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products.

4. Asbestos Fibers:-

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement.

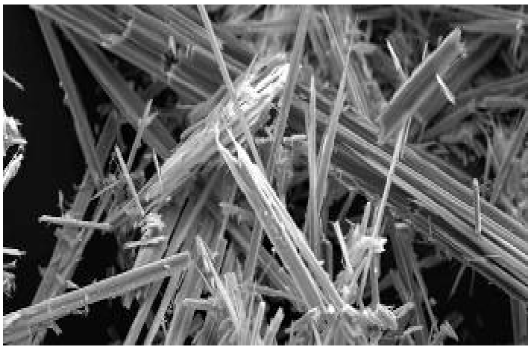


Figure 1.4: Asbestos fiber

Asbestos fibers here thermal mechanical & chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements.

5. Carbon Fibers:-

Carbon fibers from the most recent & probability the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expansive. Their strength & stiffness characteristics have been found to be superior even to those of . But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resign coating.

6. Organic Fibers:-

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a super plasticizer.

2 FIBRE REINFORCED CONCRETE

Fibre Reinforced Concrete are structural materials that are gaining importance quite rapidly due to the increasing demand of superior structural properties. These composites exhibit attractive tensile and compressive strengths, low drying shrinkage, high toughness, high energy absorption and durability. This is due to the tendency of propagating micro-cracks in cementitious matrices to be arrested or deflected by fibres, which is guaranteed by the local bond between fibres and matrix. Studies show that fibre-matrix interfacial bond is provided by a combination of adhesion, friction and mechanical interlocking. Thus fibre reinforced concrete has superior resistance to cracks and crack propagation.

In tension, RPC fails only after the fibre breaks or is pulled out of the cement matrix. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix.

Objectives

- To evaluate the effect of water dosage, silica fume dosage, curing methods, steel fibre addition and technical requirements for reactive powder concrete.
- The key factors of mix design are investigated systematically through a series of experiments to investigate the influence of individual constituent material properties on overall behavior.
- To develop an understanding of the mechanical properties of reactive powder concrete (with fibre and without fibre) under impact loading.

3 MIX DESIGN OF CONCRETE MATERIALS

Aggregates

The coarse aggregate chosen for FRC is typically round in shape, is well graded, and smaller in maximum size than that used for conventional concrete typical conventional concrete could have a maximum aggregate size of 40 mm or more. In general, a rounded aggregate and smaller aggregate particles aid in the flow ability and deformability of the concrete as well as aiding in the prevention of segregation and deformability of the concrete as well as aiding in the prevention of segregation.

All normal concreting sands are suitable for FRC. Both crushed and rounded sands can be used. Siliceous or calcareous sands can be used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for the rheology of the FRC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

Cement

Fly ash

Fly ash (or) pulverized fly ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition varies with type of fuel burnt, load on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve.

Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast-furnace slag is a non metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. The granulated material when further ground to less than 45 micron will have specific surface about 400 to 600m2/kg. the chemical composition of blast furnace slag is similar to that of cement clinker.

Cao 30-45%
Sio2 17-38%
Al2o3 15-25%
Fe2o3 0.5-2.0%
Mgo 4.0-17.0%
Mno2 1.0-5.0%
Glass 85-98%
Specific gravity 2.9

The performance of slag largely depends on the chemical composition. Glass content and fineness of grinding. The quality of slag is governed by IS 12089 of 1987.

3.1 Requirements

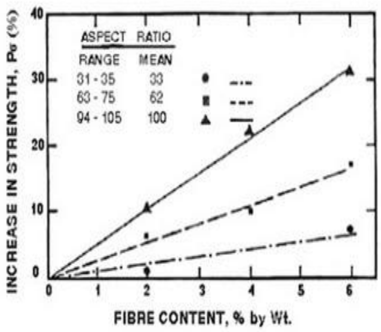
a) Specified minimum strength = 20 N/Sq mm
b) Durability requirement
i) Exposure Moderate
ii) Minimum Cement Content = 300 Kgs/cum
c) Cement (Refer Table No. 5 of IS:45-2000)
i) Make Chetak (Birla)
ii) Type OPC
iii) Grade 43
d)Workability
i) Compacting factor = 0.7
e) Degree of quality control Good

3.2 Test Data For Materials Supplied

a) CEMENT
i) Specific gravity= 3.05
ii) Avg. comp. strength 7 days = 46.5 more than 33.0 OK
28 days = 55.0 more than 43.0 OK
b) COARSE AGGREGATE
i) 20mm Graded
Type Crushed stone aggregate
Specific gravity = 2.68
Water absorption = 1.46
Free (surface) moisture = 0
c)FINE AGGREGATE (Coarse sandi)
Type Natural (Ghaggar)
Specific gravity = 2.6
Water absorption = 0.5
Free (surface) moisture = 1.4
3. TARGET MEAN STRENGTH (TMS)
a) Statistical constant K = 1.65
b) Standard deviation S = 4.6
Thus, TMS = 27.59 N/Sqmm
4. SELECTION OF W/C RATIO
a) As required for TMS = 0.5
b) As required for 'Moderate' Exposure = 0.55Assume
W/c ratio of 0.5
5. DETERMINATION OF WATER & SAND CONTENT
For W/C = 0.6C.F. = 0.8Max. Agg. Size of 20 mma)
Water content = 186 Kg/cumb)
Sand as percentage of total aggregate by absolute volume = 35 %
Thus,Net water content = 180.42 Kg/cum
Net sand percentage = 33 %

3.3 Properties of RPC

Compressive strength
Fibres do little to enhance the static compressive strength of concrete, with increases in strength ranging from essentially nil to perhaps 25%. Even in members which contain conventional reinforcement in addition to the fibres, the fibres have little effect on compressive strength. However, the fibres do substantially increase the post-cracking ductility, or energy absorption of the material.



Tensile strength

Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some instances to perhaps 60%, with many investigations indicating intermediate values, as shown in Fig. 2.1.

Flexural strength

fibres are generally found to have aggregate much greater effect on the flexural strength of RPC than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increase in flexural strength is particularly sensitive, not only to the fibre volume, but also to the aspect ratio of the fibres, with higher aspect ratio leading to larger strength increases. Fig. 2.2 describes the fibre effect in terms of the combined parameter W*l/d*, where *l/d* is the aspect ratio and W is the weight percent of fibres. It should be noted that for W*l/d* > 600, the mix characteristics tended to be quite unsatisfactory. Deformed fibres show the same types of increases at lower volumes, because of their improved bond characteristics.

3.4 Mix Design

- Grade designation : M25
- Type of cement : opc 53 grade conforming to IS 12269,2008
- Maximum nominal size of aggregate : 20mm
- Minimum cement content : 300 kg/m3
- Maximum water-cement ratio : 0.50
- Workability : 100mm (slump)
- Exposure condition : moderate
- Method of concrete placing : hand
- Degree of supervision : good
- Type of aggregate : crushed angular aggregate
- Maximum cement content : 450 kg/m^3

Properties of Concrete Improved by Fibers

- Flexural Strength:

Flexural bending strength can be increased of up to 3 times more compared to conventional concrete.

- Fatigue Resistance: Almost 1.5 times increase in fatigue strength.
- Impact Resistance: Greater resistance to damage in case of a heavy impact.

3.4.1. Initial mix composition

In designing the mix it is most useful to consider the relative proportions of the key components by volume rather than by mass.

- Water / Powder ratio by volume of 0.80 to 1.10
- Total powder content – 160 to 240 liters (400 – 600 Kg) per cubic meter.

 Coarse aggregate content normally 28 to 35 percent by volume of the mix.
 Water cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 liter/m3

4 SPECIMEN PREPARATION AND TEST METHODS

In the test, both silica fume and fly ash remained unchanged. However, the amount of fibers and polymer varied. Firstly, fibers, cement, stone, sand, silica fume and fly ash were added and mixed for about 5 min. Then, water, SBR latex, and superplasticizer were added. The mixture was mixed until a uniform concrete was obtained. Three specimens will be prepared for each mix Batching, mixing and casting operations was carefully done. The Concrete mixture will be prepared by hand mixing on a watertight platform. The coarse Aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. On the watertight platform, the coarse and fine aggregates were mixed thoroughly. The fly ash and Cement will be mixed dry to uniform colour separately.

1. Workability Test:-Workability is carried out by conducting the slump test and compaction factor test. As per I.S. 1199-1959 on ordinary concrete and fiber reinforced concrete.
2. Compressive strength test:-The compressive strength of concrete is one of most important properties of concrete in most structural applications.

For compressive strength test, cube specimens of dimensions 150 x 150 x 150mm were cast for M35 grade of concrete. After curing, these cubes will be tested on Compression Testing machine as per I.S. 516-1959. The failure load was noted. In each category two cubes were tested and their average value is reported. The compressive strength will be calculated as follows,

Compressive strength (MPa) = Failure load / cross sectional area.

3. Flexural strength test:-For flexural strength test beam specimens of dimension 150x150x700 mm were cast. The specimens will be demoulded after 24 hours of casting and were transferred to curing tank wherein they will be allowed to cure for 28 days. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 600 mm divide into three equal parts and rest on Flexural testing machine.

4.1 Slump Test

Slump flow is one of the most commonly used SCC tests at the current time. This test involves the use of slump cone used with conventional concretes as described in ASTM C 143(2002).The main difference between the slump flow test and ASTM C 143 is that the slump flow test measures the “spread” or “flow” of the concrete sample once the cone is lifted rather than the traditional “slump ” (drop in height) of the concrete sample. The T50 test is determined during the slump flow test. It is simply the amount of time the concrete takes to flow to a diameter of 50 centimeters .

Apparatus

1. Mould in the shape of a truncated cone with the internal dimensions 200mm diameter at the base,100mm diameter at the top and height of 300 mm, conforming to EN12350-2
2. Base plate of stiff non - absorbing material, at least 700mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500 mm diameter.
3. Trowel
4. Scoop
5. Ruler
6. Stopwatch

5 RESULT

Fibres are generally found to have aggregate much greater effect on the flexural strength of SFRC than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increases in flexural strength are particularly sensitive, not only to the fibre volume, but also to the aspect ratio of the fibres, with higher aspect ratio leading to larger strength increases.

i The fibres may already be clumped together before they are added to the mix; normal mixing action will not break down these clumps.
ii Fibres may be added too quickly to allow them to disperse in the mixer.
iii Too high a volume of fibres may be added.
iv The mixer itself may be too worn or inefficient to disperse the fibres.
v Introducing the fibres to the mixer before the other concrete ingredients will cause them to clump together.

5.1 Applications Of Rpc

The uses of RPC over the past thirty years have been so varied and so widespread, that it is difficult to categorize them. The most common applications are pavements, tunnel linings, pavements and slabs, shotcrete and now shotcrete also containing silica fume, airport pavements, bridge deck slab repairs, and so on. There has also been some recent experimental work on roller-compacted concrete (RCC) reinforced with fibres.

5.2 Advantages Of Rpc

The main advantage that RPC has over standard concrete is its high compressive strength. It demonstrated RPC with compressive strengths ranging from 200 to 800 MPa, and fracture energies up to 40kJ/m^2. Other advantages include low porosity, improved microstructure and homogeneity, and high flexibility with the addition of fibres. As a result of its superior performance, RPC has found application in the storage of nuclear waste, bridges, roofs, piers, seismic-resistant structures and structures designed to resist impact/blast loading.

6 CONCLUSION

The study on the effect of fibers can still be a promising work as there is always a need to overcome the problem of brittleness of concrete. The following conclusions will be being drawn from the investigation.

1. Density of concrete is more as the percentage of fiber increases.
2. Slump will lose at the higher percentage of fiber & lesser fly ash content.
3. Workability of concrete is improves when fly as percentage increases.
4. The specimen will give good Compressive strength and Flexural strength.
5. The Super-plasticizer is necessary for higher grade to get required slump & workable mix.

In the second phase the concrete cube with variable percentage of fibre reinforcement will be made. Slump test and compressive strength of the specimen will be carried out.

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