A Study on Properties of RPC With Various Silica Fume And Alccofine Content

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Abstract
Reactive Powder Concrete (RPC) is high strength new generation concrete. It is grouped under ultra high performance concrete. strength ranging from 200 MPa to 800 MPa with flexural strength up to 50 MPa. Although suitable guidelines are not available to produce RPC in India, the present study focuses on developing RPC of compressive strength up to 150 MPa.
Along with the development of RPC, The effects of the variable parameters on the properties of rpc were carefully studied which are the silica fume content (0%, 10%, 15%, 20%, 25%, and 30%), Alccofine content (0%, 10%, 15%, 20%, 25%, and 30%) also studies the effect of the steel fibers on the volume fraction (0%, 1%, 2% and 3%) and find the optimum amount of steel fibre.

Keywords: *Reactive powder concrete, Silica fume, Alccofine, Steel fiber, UHPC, Compressive strength*

INTRODUCTION

Reactive Powder Concrete (RPC) is an ultra high strength and high durable material with advanced mechanical properties. Reactive powder concrete is a concrete without coarse aggregate, but it contains cement, silica fume, silica sand, quartz powder and steel fiber with very low water to binder ratio. The original concept of RPC was first developed, in early 1990, by researchers at Bouygues laboratory in France. The addition of supplementary material, elimination of coarse aggregates, very low water to binder ratio, addition of steel fibers, heat curing and application of pressure before and during setting were the basic concepts on which it was developed.

Compressive strength of RPC ranges from 200 to 800 MPa, flexural strength between 30-50 MPa and Young's modulus up to 50-60 GPa. RPC structural elements having an extremely low porosity and dense matrix which can resist corrosion, chemical attack, impact loading from vehicles and vessels, and sudden kinetic loading due to earthquakes.

Wille et al. [8] carried out an experiment to develop ultra high performance without any heat treatment and pressure application. Some conclusion drawn from research, In cement C3A content should lower than 8 %, which reduce the water content and increase the strength. optimum amount of silica fume was found to be 25 % of the cement by weight. Optimum amount of plasticizer found in range of 1.4 to 2.4 % of weight of cement. Water to binder ratio should be less than 0.2

Lee and Chisholm [10] studied the effect of steel fibers on the mechanical properties of RPC. They observed that the addition of 2% straight steel fibers with aspect ratio of 62 to 65 for the RPC mix improve the tensile strength of composite cementitious materials. They also found that the addition of steel fibers also improves the compressive strength.

As the standard code is not available to design RPC, here an attempt is made to design RPC mix with locally available materials referring literature. The RPC cube specimens were cast and tested to evaluate the compressive strength.

EXPERIMETAL DETAILS

A. Material Specification

a. Cement
OPC 53 grade cement was used throughout this experiment. Its chemical and physical properties confirm to the provision of IS 12269.

b. Silica sand
Silica sand of maximum 600 μm was used. Having yellowish white colour and density of 1580 kg/m^3.

c. Quartz powder

Quartz powder having the fineness of 45 μm was used. It is in a pure white powder form and density is 1460 kg/m^3.

d. Mineral admixture

Silica fume has been used in the RPC mixture for this study. The percentages used were 10%, 15%, 20%, 25%, and 30% as a weight of cement. The chemical composition and physical requirements show that the silica fume conforms to the chemical and physical requirements of ASTM C1240 and IS:15388 specifications.

Alccofine was also used in this study. The percentages used were 10%, 15%, 20%, 25%, and 30% as a weight of cement.

e. Steel fiber

Straight steel fibers used throughout the experimental program. The steel fiber used has diameter 0.5 mm, length 13 mm (aspect ratio = 65), density 7800 kg/m3 and ultimate tensile strength of 2800 MPa.

f. Admixture

Master Glenium SKY 8777 (based on second generation polycarboxylic ether polymers) superplasticizer were used to produce the RPC mixes. It is compatible with all type of cement. A dosage range of 500 ml to 1500ml per 100kg of cementitious material. The admixture comply with the requirement of IS 9103.

B. Mixing Proportion

Material	Proportion
Cement	955 kg/m^3
Silica sand	1051 kg/m^3
Quartz powder	50 kg/m^3
Supplementary material	Varying the Percentage
Steel fiber	2 % by volume of concrete
Water to binder ratio	0.2
Admixture	1200 ml per 100 kg of cementitious material

*Admixture dosage as per BASF manual.

C. Mixing and Consolidating

a. Mixing

The mortar mixture machine was used to mix the ingredients. Dry ingredients were mixed first with low speed (about 140 rpm) until a homogeneous mixture was reached (based on color and visual appearance). Carbon fibers were also added to the dry mixture. Then Fifty percent of the mixing water and high-range water-reducing admixture were added. Five minutes later, the remaining high-range water-reducing admixture and mixing water were added and mixed with high speed (about 280 rpm). The total mixing time was between 10 and 15 minutes. Mortar mixture machine is shown in figure 1.

b. Workability test

Flow table was used to check the workability of concrete. The circular table having the diameter 25 cm with conical mold having height 5 cm, top diameter 7 cm and base diameter 10 cm.

Mold was firmly held and filled in two equal layers, then lifting the mold and the table was jolted 15 times. The average diameter of the spread was noted.

The spread of concrete after jolting the table shown in figure 2.

Fig. 1: Mortar Mixture Machine

Fig. 2: Flow Table

c. Molding and Placing

70 x70 mm cube mold was used in this study as shown in figure 3. Its placed on a vibrating table, and the RPC added in the mold. The RPC was very thick and viscous, so Consolidation was accelerated by the vibration.

Fig. 3: Cube Mold

d. Curing

The specimens were cured at the normal temperature for 28 days.

Fig. 4: Compressive Testing Machine

e. Testing

Three cube specimens were cast and tested with each RPC mix proportion to evaluate compressive strength at 7 and 28 days. All tests were carried out using compression testing machine as shown in figure 4.

RESULTS AND DISCUSSION

It is important to find the optimum amount of various materials for the best performance of RPC. Hence, the effects of several parameters on compressive strength were investigated which include different percentage of silica fume and alccofine and steel fiber. As there is no standard guidelines for the mix design of RPC, literature was referred. The silica fume and alccofine content was varied from 10 to 30 percent by weight of cement to find the optimum percentage of them in the production of RPC. To study the influence of steel fiber, its percentage was varied from 1 to 3 percent by volume of concrete.

A. Effect of steel Fiber on RPC

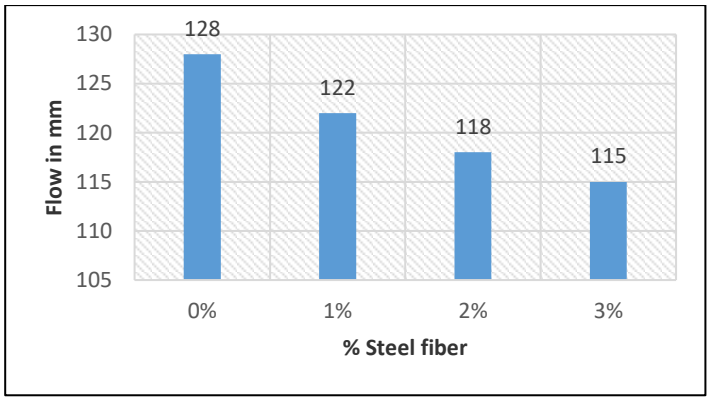

Fig. 5: Flow Table Result

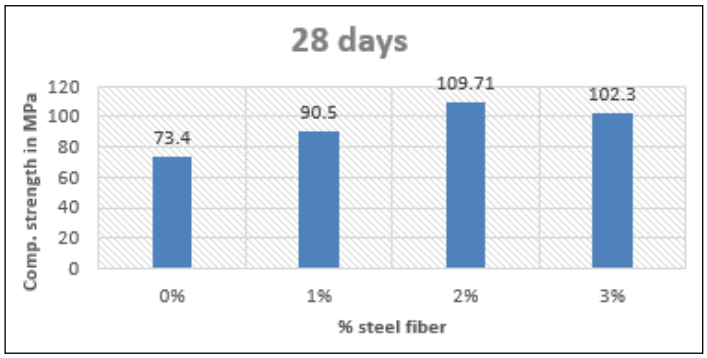

Fig. 6 : 28 days Compressive Strength Result

The effect of varying percentage of steel fiber on the Workability of RPC mix is demonstrated in Fig. 5. It is observed that the workability decreases as the fiber dosage increases. Increase the fiber content will increase the surface area, more water and concrete mixture will required to coat the surface of fibers and get the workable mixture. while the maximum compressive strength was observed at 2% of steel fiber by volume of concrete.

B. Effect of Silica Fume and Alccofine on RPC

Workability Results

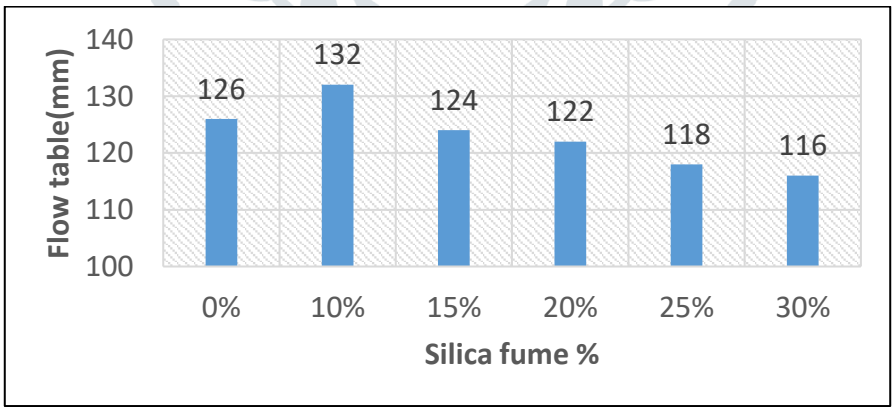

Fig. 7 : Flow Table Result v/s silica fume percentage

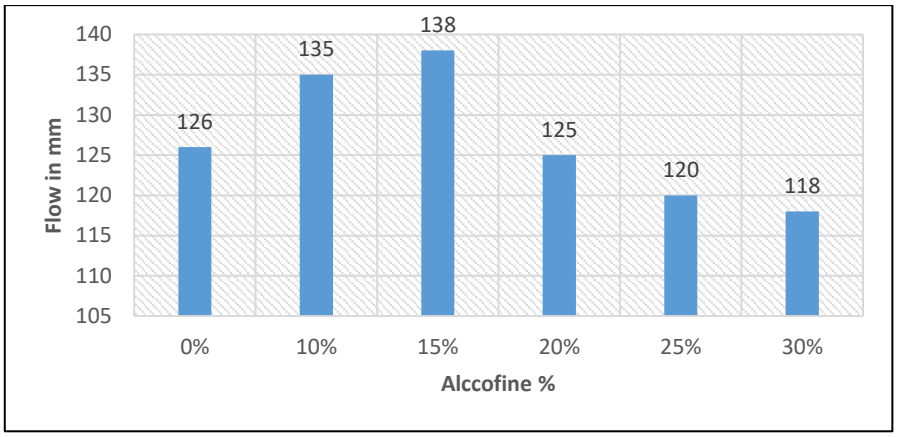

Fig. 8 : Flow Table Result v/s Alccofine percentage

Figure 7 and 8 demonstrated workability tests for different percentage of silica fume and alccofine. It is observed that Workability increase up to 10% of silica fume by weight of concrete, it decreases as the dosage increases because increase in micro content. It is a very fine materials, need much more amount of water to break the flocculation forces developed between particles. So as the amount of silica fume increases it requires more water to get the concrete workable.

Alccofine also shows the same behaviour. Initially upto 15% by weight of alccofine, workability increases. Its get decreases as the increase in micro content.
From graph It is observed that alccofine gives the good workability than the silica fume. Workability increase upto 5% while using alccofine than the silica fume.

Strength Results

From figure 9, it is observed that increasing the silica fume content from upto 25% effectively increases the compressive strength of concrete. However, increasing the silica fume content above the 25 % decreases the compressive strength. Silica fume works in two levels, the physical and pozzolanic reaction. The reaction of Portland cement with water produces many compounds; including calcium silicate hydrates (C-S-H) and calcium hydroxide (CH). When silica fume is added to fresh concrete, it chemically reacts with the calcium hydroxide to produce additional C-S-H which improve the bond between the cement and the surface of the aggregate, more ever the silica fume particle can also fill the voids in the concrete.
However, when silica fume percent increased significantly, the strength decreases, because the silica fume can react to a certain level, after that the silica fume did not participate in the hydration reaction of the concrete and remain inert in concrete.

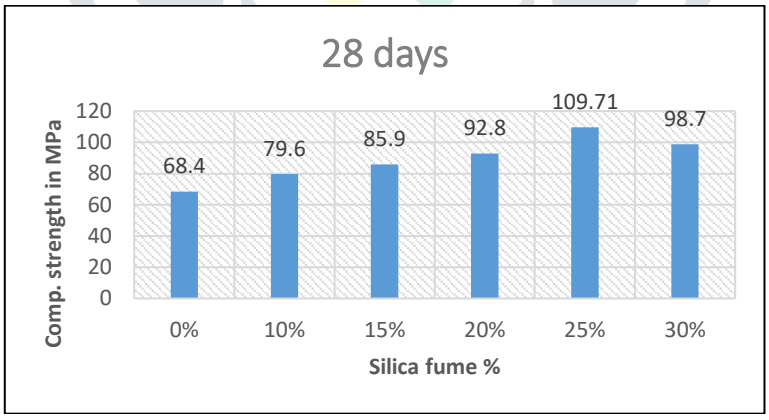

Fig. 9 : 28 days Compressive Strength Result

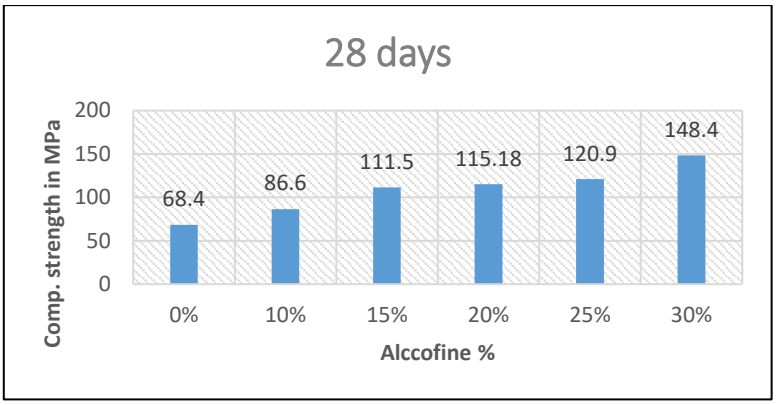

Fig. 10 : 28 days Compressive Strength Result

From figure 10, It is observed that increasing the alccofine content, effectively increases the compressive strength of concrete. Due to inbuilt CaO content in Alccofine it gives a two way reaction during hydration. Primary reaction of cement hydration and pozzolanic reaction, which produce more C-H-S gel. It ultimately increase the strength of the concrete.
From graph it is observed that alccofine gives better result than the silica fume. Strength increases upto 25 to 30% compare to silica fume.
Maximum compressive strength 148.4 MPa achieved at 30% alccofine by weight of cement.

CONCLUSION

From the experimental results presented in this study, the following conclusions can be drawn:

- The maximum compressive strength of 148.4 MPa was achieved after 28 days at normal water curing.
- Increases in steel fibers content will reduce the workability of concrete. Because increase in surface area of steel fibers which required more water and concrete to coat the surface of steel fiber and get the workable concrete.
- As the steel fiber increases, the compressive strength increases also. It will increases upto 2% of steel fiber content after it will decreases. Optimum amount of steel fiber was obtained 2% by volume of the concrete from above study.
- Workability increases upto 10% of silica fume content by weight of cement and in alccofine it increase upto 15% of alccofine content by weight of cement. Workability decreases because of increases in micro content.
- Alccofine gives better workability than the silica fume. Workability increases upto 5% while using the alccofine and compare it to silica fume.
- Increase in the silica fume content will increase in strength. However, increasing the silica fume content above the 25 % decreases the compressive strength. silica fume can react to a certain level, after that the silica fume did not participate in the hydration reaction of the concrete and remain inert in concrete. So strength was decreases as the content increases beyond the 25% by weight of cement.
- Alccofine gives the maximum strength of 148.4 Mpa at 30% by weight of cement.
- Alccofine gives better result than the silica fume. Strength increases upto 25 to 30% compare to silica fume.

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