EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF REACTIVE POWDER CONCRETE

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Abstract

Reactive Powder Concrete (RPC) is a high strength, new generation concrete, formed from a special combination of constituent materials. The composition of reactive powder concrete includes cement (ordinary Portland cement), fine sand, silica fume, quartz powder, and high tensile steel fibres. Reactive powder concrete is grouped under ultra high performance concrete. This type of concrete has enhanced mechanical and durability properties. This concrete has a very high compressive strength of 200 MPa which can be improved further by introducing steel fibers upto 800MPa. In this project, the fresh density, the compressive strength and the dry density for the reactive powder concrete with varying percentage of fly ash for 5%, 7.5%, 10%, 12.5% and 15% by weight of cement will be done.

Key words: fly ash; high performance concrete;fresh density;dry density; compressive strength

1. Introduction

Reactive Powder Concrete (RPC) is a high strength, new generation concrete, formed from a special combination of constituent materials. The composition of reactive powder concrete includes cement (Ordinary Portland Cement), fine sand, silica fume, quartz powder, and high tensile steel fibres. Reactive powder concrete is grouped under ultra high performance concrete. This type of concrete has enhanced mechanical and durability properties. This concrete has a very high compressive strength of 200 MPa which can be improved further by introducing steel pellets up to 800MPa. This new family of concrete has improved ductile behavior with a flexural strength of 25MPa to 40MPa. These performances are due to the improved microstructure properties and highly discontinuous pore structure. Also, the toughness index of this concrete is high when compared with the ordinary confined concrete.

There is almost no carbonation and chloride ion penetration and near zero sulphate attack. Moreover the resistance to abrasion is near to rock. The net effect is a maximum compactness and highly disconnected pore structure. There is also no shrinkage or creep, which makes the material very suitable for application in prestressed and prefabricated structures. The high strength and easiness to produce using customary industrial tool by casting injection, and extrusion makes it suitable for prefabricated structural applications

Many researchers around the world have developed Reactive Powder Concrete that could be classified, as Ultra High Performance Concrete (UHPC). This technology of producing RPC is covered in one of many patents in the range of UHPC known as “Ductal”. This material has a capacity to take high load, deform and support flexural and tensile load, even after initial cracking. Characterization of materials used in RPC has progressed to such an extent that the use of RPC in full-scale structures is distinctively visible on the horizon. Research and observations to date indicate that RPC has the potential to expand its usage in new forms that have been considered impossible until recently.

In here , a general introduction about high strength reactive powder concrete is done. The properties of such concrete show a substantial improvement over conventional concrete of low or medium strength. High Strength Reactive Powder Concrete is a concrete which has an extremely low water to cement ratio (i.e. less than 0.26), higher binder content, optimum packing density to eliminate capillary pore and provide an extremely dense matrix. It is a high strength material formulated from a special combination of combination of constituent materials which include Portland cement, silica fume, fine aggregate, high-range water reducer and water. The material has the capability to sustain deformation and resists flexural and tensile forces, even after initial cracking.

1.2 Advantages of Reactive Powder concrete

- Reduction in self-weight and a consequent reduction in the foundation cost.
- The ability to withstand large column loads with reasonable sizes of columns.
- Reduction in floor thickness and beam height.
- Elimination of a few footing because of adoption of larger spans.
- Superior durability and long-term performance.
- Lower creep and shrinkage.
- Reduction in member-size,
- Resulting in an increasing in the usable floor space.
- Elimination of coarse aggregate.

1.3 Objectives of Developing Reactive Powder Concrete

- Elimination of coarse aggregate for enhancement of homogeneity.
- Utilization of pozzolanic properties of silica fume.
- Optimal usage of super plasticizer to reduce W/C ratio and at the same time improves compaction.
- Post-set heat treatment for enhancement of the microstructure.
- Addition of small sized steel fibre to improve ductility.

2. Literature review

Arvind M. and Senthil Kumar V. (2015) studied the flexural behavior of high strength reactive powder concrete. The materials used were sand, silica fume, silica powder, steel fibre and water. The fine aggregate used in the range of 1.16 mm sieve. The silica fume was replaced to cement 25% and they were in grey powder form. The crushed quartz powder of size 70µm was used. The steel fibre of length 35mm and dia 0.45 mm were used to increase compressive strength and flexural strength. The steel fibre was added at 1.5% to the total volume of concrete. From this journal, the authors concluded that the compressive strength was 12 N/mm^2. The ultimate load of the beam was 82 kN which was more than 1.5 times of the safe load estimated as 40kN.

D. Agharde and Dr. S. A. Bhalachandra (2016) studied the mechanical properties of reactive powder concrete using fly ash. The ordinary Portland cement grade 53 was used with specific gravity 3.15.The fine sand was used with specific gravity 2.96 (size 150-400 micron). The materials used were silica flour, silica fume, and steel fibre. The acrylic polymer based - Dynamon SX super plasticizer was used. In this study, fly ash was replaced with silica fume. The compressive strength test was conducted. The compressive strength increased to 87Mpa when 20% of fly ash was replaced with silica fume while 100% of fly ash was replaced with silica fume compressive strength was 80Mpa. The flexural strength increased up to 22Mpa.

Anjan Kumar M. U. et al., (2017) underwent the study on reactive powder concrete properties with cement replacement using waste material. The performance of reactive powder concrete without quartz powder and replacement of cement with fly ash and GGBS was studied. The materials used were cement, silica fume, fly ash, GGBS, sand, steel fibre, and super plasticizer. The sand of size below 2.36 mm size was used. The steel fibre of diameter 0.2mm and 10mm length was used. The cement was replaced with fly ash at 5%, 10%, 15% in the mixes. The RPC with 5% replacement gave highest compressive strength of 128 MPa. The RPC with 15% replacement of cement by fly ash and GGBS gave flexural strength of 28.525 Mpa.

3. Scope and objective

The objective is to study the compressive strength of reactive powder concrete cubes by replacing cement with fly ash at 0%, 5%, 7.5%, 10%, 12.5% and 15%.

4. Experimental programme

The experimental programme was designed to find the optimum dosage of fly ash and the characteristics of concrete such as fresh density, dry density and compressive strength. The details of number of specimens and size of specimens are shown in Table1 ***Table 1 :*** *Specimen description for cubes*

specimen	size	mix a	mix b	MIX C	MIX D	MIX E	MIX F
CUBE	100mm x100mm x100mm	12	12	12	12	12	12

4.materials used

4.1.1 Cement

Ordinary Portland Cement (OPC) – The cement used during the experiment is Ordinary Portland Cement of Grade 53 conforming to IS 12269:1987.

4.1.2 Fine Aggregate

Fine aggregate used for RPC should be properly sieved to give minimum void ratio and free from deleterious materials like clay, silt and chloride contamination etc., Here, it is used in the range of 1.16mm sieve.

4.1.3 Water

It should be clean from all the organic impurities as well as other dust particles. It should not be saline in nature.

4.1.4 Silica fume

It is in grey powder form micro silica which contains latently reactive silicon dioxide and no chloride or other potentially corrosive substances. It has 94.3% of silicon dioxide.

Figure 1: *Sample of silica fume*

4.1.5 Silica sand

The crushed quartz/silica sand used in the experiment is in a form of white powdered quartz flour. The particle size range is 70µm. Quartz sand acts as effective filler material at normal water curing. The content of silicon dioxide is 99.9% and it has some trace of ferrous oxide and aluminium oxide.

***Figure 2:** Sample of silica sand*

4.1.6 Steel fibres

The fibre used here is a hooked end steel fibre with an aspect ratio of 77 which has a length of 35 mm and a diameter of 0.45 mm. Mostly steel fibres are used in UHSC to improve both the compressive and tensile strength because no other fiber will give the required high strength to the concrete.

4.7 fly ash

Fly ash is a coal combustion product that is composed of the particulates that are driven out of coal-fired boilers together with flue gases. It is produced by the burning of powdered coal.

***Figure 3:** Sample of fly ash*

4.2. Casting programme

Casting of the specimens were done as per IS:10086-1982, preparation of materials, weighing of materials and casting of cubes. The mixing, compacting and curing of concrete are done according to IS 516: 1959. The plain samples of cubes were cured for 28 days in water pond and the specimens with fly ash were cured for 28 days at room temperature by placing them in shade. The reactive powder concrete is designed and the material required per cubic meter of concrete is shown in Table 2.

***Table 2:**quantity calculation*

Mixes	Cement (kg)	Sand (kg)	Silica fume (kg)	Fly ash (kg)	Quartz sand (kg)	Steel fiber (kg)	Super plasticizer (ml)	Water (ml)
Mix A	3.18	3.89	0.24	-	2.17	0.05	34	1711
Mix B	2.98	3.89	0.24	0.20	2.17	0.05	34	1711
Mix C	2.88	3.89	0.24	0.30	2.17	0.05	34	1711
Mix D	2.78	3.89	0.24	0.40	2.17	0.05	34	1711
Mix E	2.68	3.89	0.24	0.50	2.17	0.05	34	1711
Mix F	2.58	3.89	0.24	0.60	2.17	0.05	34	1711

4.3. Testing

4.3.1 Fresh density test

A fresh concrete is filled in a 1 litre capacity container and kept in weighing machine. By slightly tapping at the sided of the container, compaction is done. Excess concrete is struck off and the container is wiped off. The weight thus obtained gives the fresh density of concrete.

4.3.2 Dry Density Test

A specimen after demoulding must be cured for 28 days in water. This cured specimen is wiped off clean and kept in oven for drying at 110 degree celsius for not less than 24 hours. The dry density of sample is calculated by

$$\text{Dry density} = \frac{\text{Dry mass of the specimen}}{\text{Volume of the specimen}}$$

4.3.3 Compressive Strength

The compressive strength test for cubes was conducted in compression testing machine as per IS 516 : 1964. The cubes were tested in compressive testing machine at the rate of 140 kg/cm^2/min. and the ultimate loads were recorded.

The bearing surface of machine was wiped off clean and the surface of the specimen was cleaned. The specimen was placed in machine in such a manner, load was applied to opposite sides of the cubes such that casted side of specimen was not top and bottom. The axis of the specimen was carefully aligned at the centre of loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. Maximum load applied on specimen was recorded.

The objective of this investigation is achieved by conducting the following tasks:

i. Fresh density of cubes was evaluated.
ii. Dry density of cubes was evaluated.
iii. The compressive strength of cubes at 28 days was evaluated.

5. Results and discussion

The results obtained from various tests such as fresh density, compressive strength and dry density were discussed and compared with conventional concrete.

Table 3: *Test results for the fresh density*

MIX	FRESH DENSITY Kg/m³
MIX A	4006
MIX B	4317
MIX C	4594
MIX D	4681
MIX E	4732
MIX F	4769

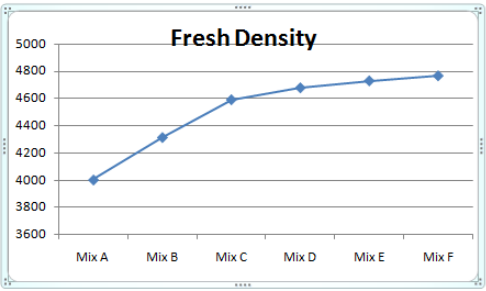

Figure 4: *Variation of fresh density*

Table 4: *Test results for the dry density*

MIX	DRY DENSITY kg/m³
MIX A	6009
MIX B	6475
MIX C	6521
MIX D	6726
MIX E	6825
MIX F	6933

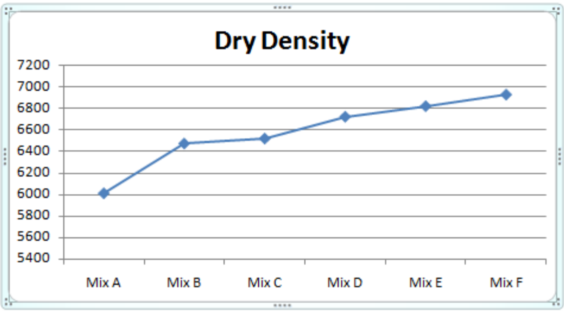

Figure 5 : *Variation of dry density*

Table 5: *Test results for the compressive strength*

MIX	AVERAGE COMPRESSIVE STRENGTH IN 7 DAYS (Mpa)	AVERAGE COMPRESSIVE STRENGTH IN 28 DAYS (Mpa)
MIX A	107.14	123
MIX B	111.08	127.5
MIX C	115.9	135.6
MIX D	117.5	147.28
MIX E	118.7	152.57
MIX F	120.8	155.38

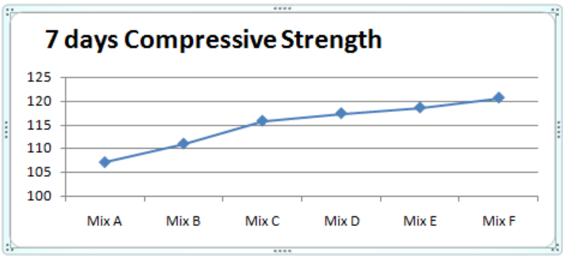

Figure 6 : *Variation of 7 average days compressive strength*

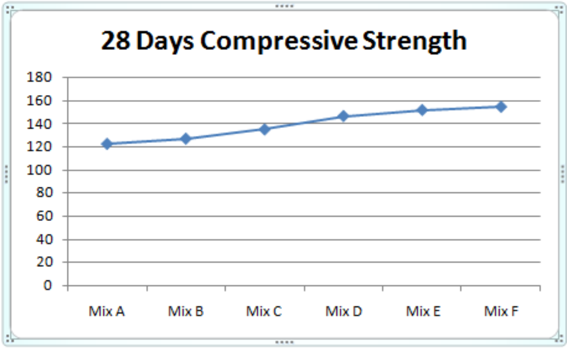

Figure 7 : *Variation of 28 average days compressive strength*

6. Conclusion

- The fresh density increased with increase in percentage of fly ash.
- The dry density increased with increase in percentage of fly ash.
- The compressive strength values at 7 days and 28 days were increased with increase in percentage of fly ash.
- Hence, it was observed that the addition of fly ash has no impact in the fresh density, dry density and compressive strength of reactive powder concrete.
- Further expansion of this project work in phase II, regarding flexural behavior of reinforced concrete beams for reactive powder concrete with varying percentage of fly ash for 5%, 7.5%, 10%, 12.5%, and15%, by weight of cement will be done.

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