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A laboratory investigation on performance of ultra-high strength concrete by using reactive powder

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***Abstract*— Concrete plays a vital role during the construction. Nowadays, while designing a structure, more important is being given to strength and durability of the concrete. Each structure may need some special properties that have to be satisfied by them for good performance. We know that concrete is good in compression and weak in tension. For increasing in compressive strength, we added that chemical admixtures into the concrete. This concrete has higher strength as compared to that ordinary concrete. The strength and durability of this concrete is depends on it mix proportions. Reactive powder concrete (RPC) is a developing composite material that will allow the concrete industry to optimize material use, generate economic benefits, and build structures that are strong, durable, and sensitive to environment. A comparison of the physical, mechanical, and durability properties of RPC and high performance concrete, (HPC) shows that RPC possess better strength (both compressive and flexural) Compared to HPC. This paper reviews the available literature on RPC, and presents the results of laboratory investigation such as fresh concrete properties, compressive strength, flexural strength, comparing RPC with HPC. Specific benefits and potential applications of RPC have also been described.**

***Index Terms*— Concrete, HPC, RPC, Strength, Durability**

I. INTRODUCTION

HPC is not a simple mixture of cement, water, and aggregates. Quite often, it contains mineral components and chemical admixtures having very specific characteristics, which impart specific properties to the concrete [1-3]. The development of HPC results from the materialization of a new science of concrete, a new science of admixtures and the use of advanced scientific equipment to monitor concrete microstructure [4].

RPC was first developed IN France in the early 1990s and the world's first RPC structure, the Sherbrooke Bridge in Canada, was constructed July 1997 [5-8]. RPC is an ultra-high-strength and high ductility cementations composite with advanced mechanical and physical properties [9-10]. To consists of a special concrete where the microstructure is optimized by precise gradation of all particles in the mix to yield maximum density RPC is emerging technology that lends a new dimension to the term "High Performance Concrete " [11-14]. It has immense potential in construction due to its superior mechanical and durability properties compared to conventional high performance concrete, and could even replace steel in some applications.

II. MATERIALS AND METHODS

A. Composition of RPC

Reactive powder concrete has been developed the have strength from 200 to 800 Mpa with required ductility. it is new technique involved in the civil engineering .Reactive powder concrete in made by replacing the conventional sand and aggregate by ground quartz less than300 micron size, silica fume, synthesized precipitated silica ,steel fibers about 1 Cm in length and 180 micron diameter [15].

RPC is composed of very fine powders (cement, sand, quartz powder, and silica fume), steel fibers (optional) and a super plasticizer. The super plasticizer, used at its optimal dosage, decreases the water binder ratio (w\b) while improving the workability of concrete [16-18]. A very dense matrix is achieved by optimizing the granular packing of the dry fine powders. This compactness gives RPC ultra –high strength and durability .Reactive powder concretes have compressive strength ranging from 200 Mpa to 800Mpa.

Table. 1 Typical composition of reactive powder concrete 800 Mpa

1.	Portland cement – type V	1000 kg/m3
2.	Fine sand (150 – 400 micron)	5001 kg/m3
3.	Silica fume (18 m^2/gm)	390 kg/m3
4.	Precipitated silica (35 m^2/gm)	230 kg/m3
5.	Super plasticizer (polyacrylate)	18 kg/m3
6.	Steel fibers (length 3mm and dia.180µ)	630 kg/m3
7.	Total water	180 kg/m3
8.	Compressive strength (cylinder)	490 – 680 Mpa
9.	Flexural strength	45 – 102 Mpa

B. Principles for developing RPC

Some of the general principles for developing are given below [19],

1. Elimination of coarse aggregates for enhancement of homogeneity.
2. Utilization of the pozzolanic properties of silica fume.
3. Optimization of the granular mixture for the enhancement of compacted density.
4. Optimal usage of super plasticizer to reduce w/b and improve work ability.
5. Application of pressure (before and during setting) to improve compaction.
6. Post-set heat-treatment for the enhancement of the microstructure.
7. Addition to small-sized steel fibres to improve ductility.

C. Properties of RPC

The mixture design of RPC primarily involves the creation of a dense granular skeleton. Optimization of the granular mixture can be achieved by the use of packing models [20].

Table. 2 Properties of RPC

Property of RPC	Description	Recommended value
Reduction in aggregate size	Coarse aggregate are replace by fine sand, with a reduction in the size of the coarse aggregate by a factor of about 50.	Maximum size of fine sand is 600 µm
Enhanced mechanical properties	Improved mechanical properties of the paste by the addition of silica fume	Young's modulus values in 50-75 Gpa range
Reduction in aggregate to matrix ratio	Limitation of sand content	Volume of the paste is at least 20 % voids index of non-compacted sand

D. Laboratory investigations

The materials used for the laboratory study, there is specification and properties have been presented in the table.

Table. 3 Materials used in the study and their properties

Sl. no	Sample	Specific gravity	Particle size range
1.	Cement, OPC, 53-grade	3.15	31 µm – 7.5 µm
2.	Micro silica	2.2	5.3 µm – 1.8 µm
3.	Quartz powder	2.7	5.3 µm – 1.3 µm

4.	Standard sand, grade-1	2.65	0.6mm – 0.3 mm
5.	Steel fibres (30 mm)	7.1	Length: 30 mm and diameter:0.4 mm
6.	River sand	2.61	2.36 mm – 0.15 mm

E. Mixture design of RPC and HPC

The process of mixture selection of RPC and HPC is given below. Considerable numbers of trial mixtures were prepared to obtain good RPC and HPC mixture proportions.

Table. 4 Mixture proportions of RPC and HPC

Material	**Mixture proportions**	
	RPC – F	HPC – F
Cement	1.00	1.00
Silica fume	0.25	0.12
Quartz powder	0.31	-
Standard sand grade 1	1.09	-
River sand	0.20	-
30 mm steel fibres	0.03	0.023
Admixture (polyacrylate based)		
Water	0.2	0.4

Workability and density were recorded for the fresh concrete mixtures. Some RPC specimens were heat cured by heating in a water bath at 90° C after until the time of testing. Specimens of RPC and HPC were also cured in water at room temperature. The performance of RPC and HPC was monitored over time with respect to the following parameters.

- Fresh concrete properties.
- Compressive strength
- Flexural strength
- Water absorption

III. RESULTS AND DISCUSSION

A. Fresh concrete properties

The workability of RPC mixtures (with and without fibres), measured using the mortar flow table test as r\per ASTMC109, was in the range of 120-140%. On the other hand, the workability of HPC mixtures (with fibres), measured using the slump test as per ASTM C231, was in the range of 120-150mm. The density of fresh RPC and HPC mixture was found to be in the range of 2500-2650 kg/m^3.

B. Hardened concrete properties

Compressive strength

The compressive strength analysis throughout the study shows that RPC has higher compressive strength than HPC, as shown in fig. compressive strength is one of the factors linked with durability of a material.

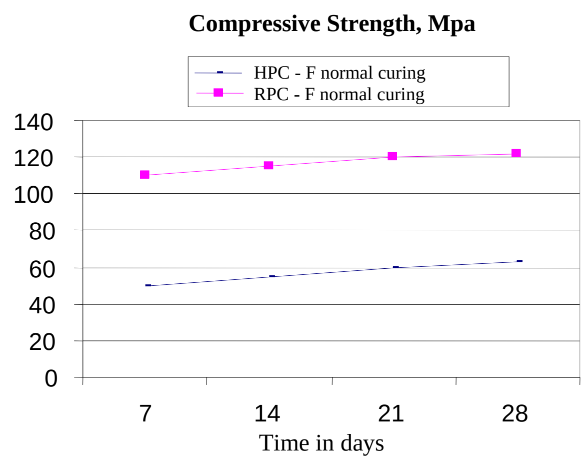


Fig. 1 Compressive strength of RPC and HPC

The maximum compressive strength of RPC obtained from this study is as 198 Mpa, while the maximum strength obtained for HPC is 75 Mpa. The incorporation of fibres and use of heat curing was seen to enhance the compressive strength of RPC by 30 to 50%. The incorporation of fibres did not affect the compressive strength of HPC significantly.

Flexural strength

Plain RPC was found to possess marginally higher flexural strength than HPC. Table clearly explains the variation in flexural strength of RPC and HPC with the addition of steel fibers. Here the increase of flexural strength of RPC with the addition of fibers is higher than that of HPC.

As per literature [21], RPC 200 should have an approximate flexural strength of 18 Mpa. The reason for low flexural strength obtained in the study could be that the fibers used (30mm) were long and their diameter was relatively higher. Fibre reinforced RPC (with appropriate fibres) has the potential to be used in structures without any additional steel reinforcement. This cost reduction in reinforcement can compensate the increase in cost by the elimination of coarse aggregates in RPC to some extent.

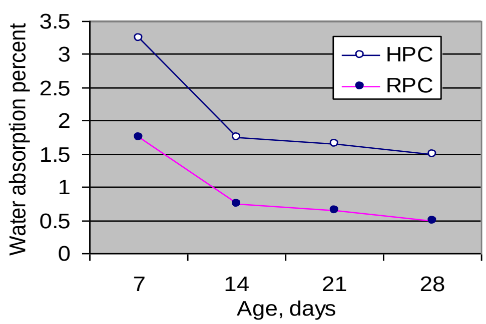
Table. 5 Flexural strength test results

RPC	RPC –F	HPC	HPC – F
NC*	NC*	NC*	NC*
11 Mpa	18 Mpa	8 Mpa	10 Mpa

*NC = Normal curing.

Water absorption

A common trend of decrees in the water absorption with age is seen here both for RPC and HPC. The percentage of water absorption of RPC, however, is very low compared to that of the HPC. The quality of RPC is one among the desired properties of nuclear waste containment materials [22].



Water absorption of RPC and HPC

Fig. 2 Water absorption of RPC and HPC

IV. CONCLUSION

A laboratory investigation comparing RPC and HPC led to the following conclusions.

- A maximum compressive strength of 198 Mpa was obtained. This is in the RPC 200 range (175 Mpa – 225 Mpa).
- The maximum flexural strength of RPC obtained was 18 Mpa, lower than the values quoted in literature (40 Mpa) [23]. A possible reason for this could be the higher length and diameter of fibres used in this study.
- A comparison of the measurements of the physical, mechanical and durability properties of RPC and HPC shows that RPC better strength (both compressive and flexural) and lower permeability compared to HPC.

REFERENCES

[1] Matte V, Moranville M. Durability of reactive powder composites: influence of silica fume on the leaching properties of very low water/ binder pastes. Cement and Concrete Composites 1999;21:1–9.

[2] Richard P, Cheyrez M. Composition of reactive powder concretes. Cement and Concrete Research 1995; 25(7):1501–11.

[3] Long G, Wang X, Xie Y. Very high-performance concrete with ultrafine powders. Cement and Concrete Research 2002; 32:601–5.

[4] Aitcin PC. The durability characteristics of high performance concrete: a review. Cement and Concrete Composites 2003; 25:409–20

[5] Kro¨nlo¨f A. Effect of very fine aggregate on concrete strength. Materials and Structures 1994; 27:185–94.

[6] Neville AM. Properties of concrete. New York: Longman; 1995.

[7] Aldea CM, Young F, Wang K, Shah SP. Effects of curing conditions on properties of concrete using slag replacement. Cement Concrete Research 2000; 30:465–72.

[8] Shi C, Hu S. Cementitious properties of ladle slag fines under autoclave curing conditions. Cement Concrete Research 2003; 33:1851–6.

[9] Mindess S, Young JF, Darwin D. Concrete. New Jersey: Pearson education; 2002.

[10] Talebinejad I, Bassam SA, Iranmanesh A, Shekarchizadeh M. Optimizing mix proportions of normal weight reactive powder concrete with strengths of 200–350MPa, ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 133–41.

[11] Korpa A, Trettin R. The use of synthetic colloidal silica dispersions for making HPC and UHPC systems, preliminary comparison results between colloidal silica dispersions and silica fumes (SF), ultra high performance concrete (UHPC). International symposium on ultra-high

performance concrete; September 13–15, 2004. p. 155–64.
[12] Ma J, Orgass M, Dehn F, Schmidt D, Tue NV. Comparative investigations on ultra-high performance concrete with and without coarse aggregates. Ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 205–12.
[13] Rougeau P, Borys B. Ultra high performance concrete with ultrafine particles other than silica fume, ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 213–25.
[14] Jooss M, Reinhardt HW. Permeability and diffusivity of concrete as function of temperature. Cement and Concrete Research 2002; 32:1497–504.
[15] Maeder U, Gambos IL, Chaignon J, Lombard JP. Ceracem, a new high performance concrete: characterisations and applications, ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 59–68.
[16] Fehling E, Bunje K, Leutbecher T. Design relevant properties of hardened ultra-high performance concrete, ultra-high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 327–38.
[17] Droll K. Influence of additions on ultra-high performance concretes—grain size optimization, ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 285–301.
[18] Teichmann T, Schmidt M. Influence of the packing density of fine particles on structure, strength and durability of UHPC, ultra high performance concrete (UHPC). International symposium on ultra-high performance concrete; September 13–15, 2004. p. 313–23.
[19] Bayard O, Ple O. Fracture mechanics of reactive powder concrete: material modeling and experimental investigations. Engineering Fracture Mechanics 2003;70:839–51
[20] Bentz DP, Haecker CJ. An argument for using coarse cements in high-performance concretes. Cement and Concrete Research 1999; 29:615–8.
[21] Bonneau O, Vernet C, Moranville M, Aitcin PC. Characterization of the granular packing and percolation threshold of reactive powder concrete. Cement and Concrete Research 2000; 30:1861–7.
[22] Feylessoufi A, Tenoudji CF, Morin V, Richard P. Early ages shrinkage mechanisms of ultra-high-performance cementbased materials. Cement and Concrete Composites 2001; 31:1573–9.
[23] Morin V, Tenoudji FC, Feylessoufi A, Richard P. Evolution of the capillary network in a reactive powder concrete during hydration process. Cement and Concrete Research 2002; 32:1907–14.