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## Comparative Study on Reactive Powder Concrete with High Strength Concrete

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**ABSTRACT:** Reactive powder concrete is a new cementitious material. The composition of reactive powder concrete is port land cement, very low water-to cement ratio, a high dosage of super plasticizer and the presence of very fine crushed quartz and silica fume. Reactive powder concrete is coarse aggregate free which differs from that of the ordinary concrete. Coarse aggregate in normal concrete is completely replaced by fine quartz sand. The RPC displays excellent granular compactness and its low water content helps reduce porosity. The durability of reactive powder concrete (RPC) and high strength concrete (HSC) has been defined by measuring the water absorption, corrosion and the weight loss of concrete after acid attack and sulphate attack. Concrete is designed from reactive powder concrete and high strength concrete is experimentally conducted and compared. The results shows that the compressive strength, flexural strength and young's modulus for concrete are found to be higher than that of high strength concrete using the same water cement ratio. The durability properties of RPC are better than that of HSC.

**KEY WORDS:** Compressive strength, durability properties, flexural strength, high strength concrete, Reactive powder concrete

### I. INTRODUCTION

The concept of RPC was first developed by P.Richard and M.Cheyrezy.RPC was first produced in the early 1990s by researchers at Bouges' laboratory in france. The world's first RPC structure ,thesherbooke bridge in canada, was constructed in July 1997.The mechanical properties are obtained by decreasing the water/cementitious ratio and often using super plasticizers and silica fume.RPC is a family of concretes obtained by using four major principles:

- Improvement of the material homogeneity by removing all coarse aggregates
- Increase of the compactness by granular optimization and compaction
- Possible improvement of the microstructure by heat treatment
- Achievement of material ductility by the addition of steel fibres

RPC possesses many outstanding properties, they also have certain weakness; for example:

1. Cement content as high as 800-1000 kg/m<sup>3</sup> not only effects the production costs, but also has negative effects on the heat of hydration, causing shrinkage problems; and
2. RPC is generally costly and cannot replace the conventional concrete in most applications where the conventional mixes can economically meet the performance criteria.

RPC has not received much attention in Hong Kong, probably owing to the complicated production process and its unknown and unconfirmed properties when made using local materials. In fact, RPC has been used in the construction of two public highway bridges (Cavill and Chirgwin, 2004; Hajar et al., 2003), numerous pedestrian bridges (Behloul et

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al., 2004; Buitelaar, 2004 Semioli, 2001). Apart from the applications of RPC in constructing bridges, it can be used as a reliable container for radioactive waste from disused nuclear plants because of the

excellent strength and durability (Colleparidi et al., 2003). RPC is also application to building materials as it provides better fire resistance than HPC and ordinary concrete (Liu and Huang, 2009). Research and observations to date indicate that RPC has the potential to expand the use of concrete into new forms that have heretofore been impossible (Greybeal, 2006). Although the production costs of RPC are generally higher than for ordinary concrete, some economic advantages still exist in RPC applications. It is possible to eliminate the use of steel bar reinforcement by incorporating short steel fibers. Moreover, the thickness of concrete elements can be reduced due to ultra-high mechanical performance of RPC, which results in materials and cost savings (Yazici et al., 2009).

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 possesses better strength (both compressive and flexural) and lower permeability compared to HPC. This paper reviews the available literature on RPC, and also presents the results of laboratory investigations comparing RPC with HPC. Specific benefits and potential applications of RPC have also been described.

## II. MATERIALS AND MIX PROPORTIONING

### I. Cement

Portland cement gets its strength from chemical reactions between the cement and water. The process is known as hydration. This is complex process that is best understood by first the composition of cement. For using cement in important and major works it is incumbent on the part of the user to test the cement to confirm the requirements of the Indian standard specifications with respect to its physical and chemical properties. In our project we used ordinary Portland cement 53 grade conforming to IS 8112:1989.

### II. Silicafume

Silicafume is a waste material that is generated during the manufacture of silicon or silicon-ferrous. Silicafume is less than 0.5  $\mu\text{m}$  in size. The entire experimental study was performed using 940-U-type silicafume from the Elkem company in Istanbul-Turkey.

### III. Quartz sand

It is in a form of yellowish-white high purity silica sand. The particles sizes used ranges from 150-600  $\mu\text{m}$ .

### IV. Crushed Quartz

It is in a form of white powdered quartz flour. The particles sizes used ranges from 10-45  $\mu\text{m}$ .

### V. Silica fume

Silica fume is a waste material that is generated during the manufacture of silicon or silicon-ferrous. Silica fume is less than 0.5  $\mu\text{m}$  in size. The entire experimental study was performed using 940-U-type silica fume from the Elkem company in Istanbul-Turkey.

### VI. Super plasticizer

The Polycarboxylate based super plasticizer used. The properties of super plasticizer are shown in Table 1.

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Table 1 Properties of Super Plasticizer

Type of sp	Sikamentvi screte- 1250NT
Basis	Polycarboxylic polyether type polymer
Appearance	Yellowish brown liquid
Density	1.08 kg/l
PH value	7
Recommended dosage	1.0-2.5% by weight of cementitious materials

Table 2 Mix proportions

Type of concrete mix	RPC	HSC
Water/binder	0.24	0.24
Cement:kg/m <sup>3</sup>	761	761
Silicafume:kg/ m <sup>3</sup>	247	247
Coarseaggregate:kg/ m <sup>3</sup>	-	732
River sand :kg/ m <sup>3</sup>	-	314
Quartz sand:kg/ m <sup>3</sup>	1090	-
Crushedquartz:kg/ m <sup>3</sup>	226	-
water:kg/ m <sup>3</sup>	244	244
Super plasticizer:kg/ m <sup>3</sup>	15	15

## Mixing sequences

The conventional mixing method is based on BS 1881: part 125 (BSI, 1986). The following sequence in mixing RPC is based on previous studies, as well as the current authors' own trial-and-error approaches

- Dry mixing powders (including cement, quartzsand, crushed quartz and silica fume) for about 3 min with a low speed of about 140 r/min
- Addition of half volume of water containing half amount of superplasticizer
- Mixing for about 3 min with a high speed of about 285 r/min
- Addition of the remaining water and superplasticizer
- Mixing for about 10 min with a high speed of about 285 r/min.

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The entire mixing process takes about 15 min. The RPC mix is compacted using a vibrating table and hand tamping using a square tamping rod.

## Specimen preparation and testing

In this paper 100x100x100mm samples are used for testing compressive strength, acid attack, sulphate attack, water absorption. 100x100x500 mm samples are used for testing of flexure strength. 100mm diameter and 300 mm long cylinder was used for elasticity for concrete. 100 diameter and 50 mm long slices were used for testing rapid chloride penetration.

## III. TEST RESULTS AND DISCUSSIONS

### Compressive strength test

Compressive strength test were carried out on 100X100X100 mm specimen for that 3 cubes were prepared for each mix. Specimen shall be tested after 7 and 28 days respectively. The results of compressive strength results are shown in Table 3.

Table 3 Compressive Strength Results

Mix	Compressive strength N/mm <sup>2</sup>	
	7 Days	28 Days
RPC	54.0	79.2
	56.8	77.7
	57.0	81.2
	Average 55.9	Average 79.37
HSC	41.5	71.3
	42.8	72.8
	43.2	71.9
	Average 42.5	Average 72.00

### Flexural strength

A flexural strength of concrete in beam specimen is load to failure under two point loading. Flexural strength carried by the specimen sizes 100 mm x 100 mm X 500 mm long for three beams were prepared for each mix. Specimen shall be tested after 28 days respectively. The results of flexural strength were shown in Table 4

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Table 4 Flexural Strength For RPC And HSC

Mix Designation	Flexural strength N/mm <sup>2</sup>	
	7 Days	28 Days
RPC	6.0	6.8
	6.4	7.0
	6.5	7.2
	Average 6.3	Average 7.0
HSC	5.4	5.6
	5.2	5.7
	5.4	5.5
	Average 5.4	Average 5.6

### Elastic modulus of concrete

The 100 mm diameter and 150 mm height cylindrical specimen was used to test the modulus of elasticity of concrete. The test results were shown in table 5.

Table 5 Modulus Of Elasticity For RPC And HSC

S.No	Mix Designation	Modulus of elasticity N/mm <sup>2</sup>
1	RPC	41280
2	HSC	39351

### Durability tests

#### Saturated Water Absorption:

Saturated water absorption (SWA) tests were carried out on 100mm cube specimen at the age of 28 curing as per ASTM C 642. The specimens were weighed before drying. The drying was carried out in a hot air oven at a temperature of 105°C. The dried specimens were cooled at room temperature and immersed in water. The specimens were taken out at regular interval of time, surface dried using a clean cloth and weighed. This process was continued till the weights became constant. The difference between the measured water saturated mass and oven dried mass expressed as % of oven dry mass gives the SWA. The water absorption was calculated as % of water absorbed =  $(W_s - W_d) \times 100 / W_d$  Where,  $W_s$  = weight of specimen at fully saturated condition  $W_d$  = weight of oven dry specimen. The results of water absorption were shown in Table 6.

Table 6 Results Of Saturated Water Absorption

Mix	Wet weight (kg)	Dry weight (kg)	Water Absorption (%)
RPC	2.526	2.427	3.91
HSC	2.538	2.456	3.23

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## Acid resistance

The acid resistance tests were carried out on 100 x 100 x 100 mm size cube specimens at the age of 28 days curing. The cube specimens were weighed. Then 5% HCL is mixed per liter of ordinary water. Cube specimens are immersed in completely in the acid solution for 28 days continuously. Then the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Next the weight and the compressive strengths of the specimens were found out

and the average percentage of loss of weight and compressive strengths were calculated. The results of acid resistance shown in Table 7

Table 7 Test Results For Acid Resistance

Mix	% of weight loss	Average	% of strength loss	Average
RPC	1.2	1.0	4.9	5.02
	0.9		5.1	
	0.92		5.08	
HSC	2.03	2.08	9.4	9.45
	2.2		8.4	
	2.02		10.6	

## Sulphate Resistance:

The sulphate resistance tests were carried out on 100 x 100 x 100 mm size cube specimens at the age of 28 days curing. The cube specimens were weighed. Then 5% Na<sub>2</sub>SO<sub>4</sub> is mixed per litre of ordinary water. Cube specimens are immersed in completely in the acid solution for 28 days continuously. Then the specimens were taken out from the sulphate water and the surfaces of the cubes were cleaned. Next the weight and the compressive strengths of the specimens were found out and the average percentage of loss of weight and compressive strengths were calculated. The results of sulphate resistance were shown in Table 8.

Table 8 Test Results For Acid Resistance

Mix	% of weight loss	Average	% of strength loss	Average
RPC	0.62	0.523	1.02	1.07
	0.51		1.04	
	0.44		1.15	
HSC	0.87	0.803	1.8	1.67
	0.84		1.5	
	0.70		1.7	

## Half-cell potential test

The corrosion rate is measured by canin corrosion meter. 100 x 100 x100 mm size cube and 100 mm diameter with 200 mm long cylindrical specimens are used. Depending upon the corrosion rate reactive powder concrete was better than high strength concrete. The tests results were shown in table 9.

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Table 9 Results for Half Cell Potential Test

Specimen	Potential (mv) range		Corrosion range	
	RPC	HSC	RPC	HSC
Cube 1	-110	-218	Very low	Moderate
Cube 2	-74	-315	Very low	Moderate
Cube 3	-59	-309	Very low	Moderate
Cylinder 1	-95	-234	Very low	Moderate
Cylinder 2	-115	-224	Very low	Moderate
Cylinder 3	-89	-230	Very low	Moderate

## Rapid Chloride Penetration Test

The test method of monitoring the amount of electrical current passed through 50 mm thick slices of 100 mm nominal diameter cores or cylinders during 6 hours at 30 mins interval. A potential difference of 60 V dc is maintained across the ends of the specimen, one which is immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The total charge passed in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration. The left hand side of the test cell is filled with a 3% NaCl. Then right hand side of the test cell is filled with a 0.3N NaoH solution. The tests results were shown in table 10.

Table 10 Results for Rapid Chloride Penetration Test

S.No	Mix	Coulombs	Chloride penetration
1.	RPC	1168	Low
2.	HSC	1300.5	Low

## IV. CONCLUSION

The following conclusions could be drawn from the present investigation

- 1) The compressive strength of the reactive powder concrete is  $79.8 \text{ Nmm}^2$  and the compressive strength of high performance concrete is  $72 \text{ Nmm}^2$ . The compressive strength of RPC is 10% higher than HSC.
- 2) The flexural strength of the reactive powder concrete is  $79.8 \text{ Nmm}^2$  and the flexural strength of high performance concrete is  $72 \text{ Nmm}^2$ . The flexural strength of RPC is 10% higher than HSC.
- 3) The modulus of elasticity of RPC and HSC are  $41280 \text{ N/mm}^2$  and  $39351 \text{ N/mm}^2$  respectively.
- 4) It is observed that in water absorption of RPC and HSC are 1.75% and 2.5%. The water absorption of RPC is 0.8% lower than HSC.
- 5) The weight loss in HSC after acid attack is 1.08% greater than RPC and the compressive strength of HSC after acid attack is 4.43% greater than RPC.

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- 6) The weight loss in HSC after sulphate attack is 0.3% greater than RPC and the compressive strength of HSC after sulphate attack is 0.6% greater than RPC.
- 7) The chloride penetration rating is 1411 coulombs in HSC and 1128 coulombs in RPC.

### REFERENCES

- [1] **Brandt.A.M, J.Olek, M.AGlinicki and C.K.Y.Leung(2012)** Reactive powder concrete-change in compressive strength and modulus of elasticity at high temperature, *Brittle Matrix Composites*, 10, 35-143.
- [2] **Chi-ming Tam and Vivian Wing-Yan Tam(2012)** Micro structural behavior of reactive powder concrete, *Magazine of Concrete Research*, 64, 259-267.
- [3] **Dili A.S and Manu Santhanam (2004)** Investigations on reactive powder concrete: A developing ultra high-strength technology, *The Indian concrete Journal*, 33-38.
- [4] **Dugat.J, N.Roux, G.Bernier(1996)** Mechanical properties of reactive powder concrete, *Journal of Materials And Structural/Materiaux et Constructions*, 29, 233-240.
- [5] **HalitYazici, Engindeniz, BulentBaradan(2013)** The effect of autoclave pressure, temperature and duration time on mechanical properties of reactive Powder Concrete, *Construction And Building Materials*, 42, 53-63.
- [6] **Mehmet Canbaz(2014)**The effect of high temperature on reactive powder concrete, *Construction and Building Materials*, 70, 508-513.
- [7] **Na-Huyun Yi, Jang-Ho Jay Kim, Tong-Seok Han, Yun-Gu Cho, Jang Hw a Lee (2012)** Blast-resistant characteristics of ultra-high strength concrete and reactive powder concrete, *Construction And Building Materials*, 28, 694-707.
- [8] **Roux.N, C.Andrade and M.A.Sanjuan(1996)** Experimental study of durability of reactive powder concretes, *Journal of Materials In Civil Engineering*, 8, 1-6.
- [9] **SerdarAydin and BulentBaradan (2013)** Engineering properties of reactive powder concrete without Portland cement, *ACI Materials Journal*, 619-627.
- [10] **SerdarAydin andBulentBaradan (2012)** High temperature resistance of alkali-activated slag and Portland cement-based reactive powder concrete, *ACI Materials Journal*, 463-470.
- [11] **Seder Aydin, HalitYazici, MertYucelYardimci and HuseyinYigiter(2010)** Effect of aggregate type on mechanical properties of reactive powder concrete, *ACI Materials Journal*, 441-449.
- [12] **Tam.C.M and Vivian W.Y.Tam and K.M.Ng(2012)** Assessing drying shrinkage and water permeability of reactive powder concrete, *Construction And Building Materials*, 26, 79-89.
- [13] **Tao ji, Cai-Yhhen and Yi-Zhuang(2012)** Evaluation method for cracking resistant behavior of reactive powder concrete, *Construction And Building Materials*, 28, 45-49.
- [14] **Tam C.M, V.M.Y.Tam and K.M Ng (2010)** Optimal conditions for producing reactive powder concrete, *Magazine Of Concrete Research*,62, 701-716.
- [15] **Tam.C.M, K.M.Ng and V.W.Y.Tam (2010)** Studying the production process and mechanical properties of reactive powder concrete: a Hong Kong study, *Magazine Of Concrete Research*, 62, 647-654.
- [16] **Wenzhongzheng, BaifuLuo and Ying Wang (2013)** Compressive and tensile properties of reactive powder concrete with steel fibers at elevated temperatures, *Construction and Building Materials*, 41, 844-851.
- [17] **Yin-Wen Chan and Shu-Hsien Chu(2004)** Effect of silica fume on steel fiber bond characteristics in reactive powder concrete, *Cement and Concrete Research*, 34,1167-1172.