Experimental Behaviour of Beam Column Joint By Using Reactive Powder Concrete

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Abstract— Now a day many inventions comes in civil engineering field like pre-fabricated technology, usage of high strength concrete, different types of composite panels,etc.One of the technologies is reactive powder concrete which contains cement, fine aggregate and sub-cementitious materials like fly ash, silica fume, quartz powder and some additional material based on quality improvement. In our project, initially we casted mortar cubes of sizes 70.6mm $\times$70.6mm $\times$70.6 mm to determine the strength of concrete comparatively with normal concrete for 10 trial mix ratios (cement : fine aggregate : fly ash : silica fume : quartz powder) which have simultaneous reduction amount of sand and increment of sub-cementitious materials. From the test results, we casted beam column joint for maximum grade mix with 1% of steel fiber. The result shows that increment of cementitious matter will enhance good bonding character and consequently reduce permeability and also the steel fiber addition increases the flexural, compressive strength of concrete.

Index Terms— Materials used fly ash, silica fume, quarts powder, beam-column joint.

1 Introduction

The behaviour of beam column joint made up of reactive powder concrete is studied under forward loading. Normal concrete contains cement, fine aggregate and coarse aggregate. In our project, we have used reactive powder concrete which contains cement, fine aggregate, fly ash, silica fume, quartz powder with certain percentage of steel fiber. By the use of these sub-cementitious materials, the voids in concrete are filled and consequently the water permeability is reduced.

1.1General

This chapter explains about the practical progress of the progress in our project such as casting,mixing,curing,testing of mortar cube specimens and beam column joints for conventional concrete mix and reactive powder concrete mix.

1.2 Materials Used In Conventional Concrete

For M_{20} grade of concrete, the materials used are

- Cement
- Fine aggregate
- Coarse aggregate

1.3 Cement

In our project, normal Portland pozzolona cement is used. This act as the binding material between fine aggregate and coarse aggregate together to get target strength with specific curing period.Cement is the binding material used in reactive powder concrete in addition with sub cementitious materials. Selection of type of cement mainly depends on the specific requirements of concrete. It determined the strength and properties of fresh and hardened concrete. Variation in chemical composition and physical properties of cement affects the concrete compressive strength more than variation in any other single material. We have used Portland pozzolona cement.

Table 1
Properties of cement

Physical properties	Values	Permissible range
Specific gravity	3.14	3.10 - 3.15
Normal consistency	31	30 - 35
Initial setting time(min)	37	30 minimum
Final setting time(min)	570	600 maximum

1.4 Fine Aggregate

The particle passing through 4.25 mm sieve is used in mixing of concrete. IN this type of reactive powder concrete the maximum particle size of fine aggregate are balanced by using reactive powder concrete. Fine aggregate used in our project which is taken from sample passing through 4.75 mm in dry condition to avoid bleeding problem due to mixing. It should be properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contaminations.

1.5 Coarse Aggregate

The 20 mm size of coarse aggregate is used in conventional mix of concrete. The crushed stone aggregates were collected from the local query. The maximum size of aggregates were 20 mm. The physical properties of coarse aggregate are Specific gravity 2.77, Water absorption 1.23%, Bulk density 1694.8 Kg/m^3, Fineness modulus 5.96.

1.6 Materials Used In Reactive Powder Concrete

The materials used are

- Cement
- Fine aggregate
- Fly ash

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- Silica fume
- Quartz powder
- Steel fiber

The properties of cement, fine and coarse aggregates are already specified. The characteristics of sub cementitious materials are given as below.

1.7 Fly Ash

Fly ash is one of the sub cementitiousmaterials used as the part of reactive powder concrete. Class F fly ash has little calcium content and a higher silica and iron content and is typically produced by burning bituminous coal. It is comprised mainly of alumino-silicate glassy particles, but also contains crystalline material.

The glassy material in fly ash is what causes it to be useful as a concrete additive. The glass reacts with calcium hydroxide, which is produced within the concrete during hydration of the Portland cement component, to form additional cementitious material that increases strength and durability. The carbon (unburned coal) in fly ash is usually detrimental because it adsorbs air entraining admixtures from fresh concrete.These admixtures are used to improve the concrete's resistance to freeze-thaw damage.

Another important property of a fly ash is the overall particle size because smaller particles give the fly ash a greater reactivity in concrete compared to larger particles. It has low carbon content and a high proportion of small glassy particles.

Fly ash

1.9 Silica Fume

Micro silica 600 type is used in our project. Silica fume is also known as microsilica, it is a very fine pozzolanic material, composed of amorphous silica produced byelectric arc furnaces as a byproduct of the production of elemental silicon or ferro silicon alloys. Silica fume is an ultrafine material with spherical particles less than 1 μm in diameter, the average being about 0.15 μm. This makes it approximately 100 times smaller than the average cement particle. [1] The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m^3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3

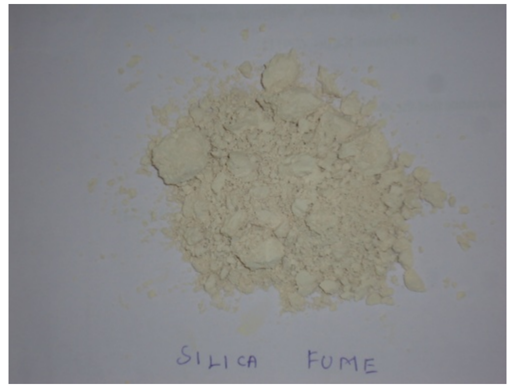
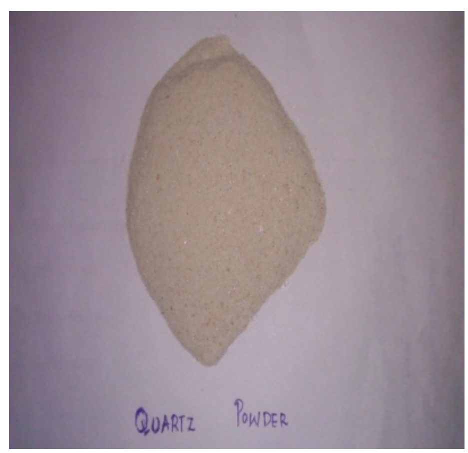


Fig 3.2Micro silica

1.8 Quartz Powder

The quartz powder recovered from normal rocks due to some weathering action as a part in reactive powder concrete. Natural moulding sand contains variable amount of clay, which acts as bond between the sand grains. This sand, therefore, posse strength, plasticity and refractoriness to varying extend depending upon the clay minerals present. When it contains a greater amount of clay, it is blended with river sand, which is relatively clay free so as to get the optimum properties desired in the sand mixture.
Washed grains shall be mostly sub-angular to rounded shape. As far as possible, the sand shall be free from gravel. Natural moulding sand for use in foundries shall be of three main grades, namely, A, B and C with respect to clay content.

Grade	Clay %
A	5 -10
B	10-15
C	15-20



Quartz powder

1.10 Steel Fiber

Due to this kind of fiber mixing, especially the aspect ratio (ratio of length to cross section dimension) is considered to enhance the reactivity and efficiency of fibers with concrete mix.the properties are given as below.

Table 2

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Properties of steel fiber

Properties	Description
Shape	Straight , hook-end, deformed
Diameter	0.5mm
Length	15 mm
Density	7900 kg/m3
Specific Gravity	7.90
Finalised Aspect ratio	30

Steel fiber

2. Testing of Materials

The following test are carried as follows

- Specific gravity test
- Impact test

The **specific gravity** test is done on following materials specially. Those are

- Silica fume
- Quartz powder

The following figure 3.5 show the test setup of those materials as below.

Result:

Specific gravity of silica fume = 2.4

Specific gravity of quartz powder= 3.9

The **impact test** is carried by using following material combination specially for preparing new type of aggregate as a part of our project for reactive powder concrete. The materials used are

- Silica fume
- Quartz powder
- Cement

The following figure shows aggregates and the test setup of impact test as below.

Aggregates after preparation

The result has given lower impact value comparatively with conventional one.

2.1 Casting of Mortar Cubes

Initially to identify the strength of reactive powder concrete and conventional concrete, the mortar cube test is carried out by using mortar cubes of sizes 70.6 mm × 70.6 mm × 70.6 mm for ten reactive powder trial mix ratios and conventional mix ratio of 1: 3

2.2 Mix ratio of mortar cubes

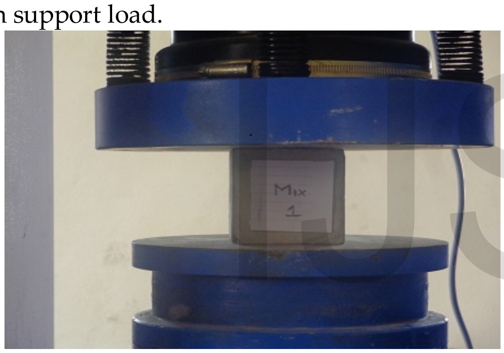
The mix ratios are given in following table no.3.1 and 3.2 respectively.

Table 3
Mix values for reactive powder concrete

Trial no	Mix specification	Ratio values				
		Cement	Fine aggregegate	Fly ash	Silica fume	Quartz powder
1	Mix 1	1	1.5	0.5	0.5	0.5
2	Mix 2	1	1	1	0.5	0.5
3	Mix 3	1	0.5	1	1	0.5
4	Mix 4	1	0.25	1	1	0.75
5	Mix 5	1	0.2	1	1	0.80
6	Mix 6	1	0.15	1	1	0.85
7	Mix 7	1	0.12	1	1	0.88
8	Mix 8	1	0.10	1	1	0.90
9	Mix 9	1	0.081	1	1	0.92
10	Mix 10	1	0.05	1	1	0.95

2.3 Experimental setup

The mortar cubes are inserted in medium of compression test base with support load.



Compressive testing of mortar cube

Table 4
Optimum mixes selected for casting beam column joint

Trial no	Mix specification	Ratio values				
		Cement	Fine aggregegate	Fly ash	Silica fume	Quartz powder
1	Mix 6	1	0.15	1	1	0.85
2	Mix 7	1	0.12	1	1	0.88
3	Mix 8	1	0.10	1	1	0.90

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2.4 Loading application

The forward loading was applied in beam column joint. The load application causes stress on both compressive members and tensile membersalso. These two types of loading is done to check the axial compressive strength and shear strength at beam column joint under conventional mix and reactive powder mix respectively.

3.RESULTS AND DISCUSSIONS

3.1 Results of mortar cube

The loading and corresponding stress values are listed below for all trial mixes for reactive powder concrete and conventional concrete.

Table 5
Test Result For Conventional Mix Concrete

Mix specification	Trial no	Load (kN) 7 days	Average load(kN) 7 days	Compressive stress (N/mm^2) 7 days	Average stress (N/mm^2) 7 days
Mix M_{20}	1	40.31	41.013	8.03	8.160
	2	39.52		7.82	
	3	43.21		8.63	

Table 6
Test results for reactive powder concrete

S.No	Mix id	Ratio					Comp. Load (7days) in kN	Comp. Strength (7days) in N/mm^2
		Cement	FA	Fly ash	Silica fume	Quartz powder		
1	Mix 1	1	1.5	0.5	0.5	0.5	72.10	14.465
2	Mix 2	1	1	1	0.5	0.5	83.80	13.479
3	Mix 3	1	0.5	1	1	0.5	70.23	14.091
4	Mix 4	1	0.25	1	1	0.75	69.76	13.962
5	Mix 5	1	0.2	1	1	0.80	84.77	17.010
6	Mix 6	1	0.15	1	1	0.85	81.03	16.257
7	Mix 7	1	0.12	1	1	0.88	88.37	17.729
8	Mix 8	1	0.10	1	1	0.90	74.65	14.977
9	Mix 9	1	0.08	1	1	0.92	47.25	9.480
10	Mix 1o	1	0.05	1	1	0.95	26.47	7.717

3.2 Graphical representations

The results corresponding to various mixes and various percentages of materials are given as below.

Comparison Among Various Mix Trials ForRPC

From this graph, it shows that the loading and compressive stress values are higher in mix 7 comparatively with other mixes.

3.3 Comparison Between Conventional Concrete And Reac-

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tive Powder Concrete

This graph shows the optimum behaviour of reactive powder concrete comparatively with conventional concrete mix of M $_{20}$ grade.

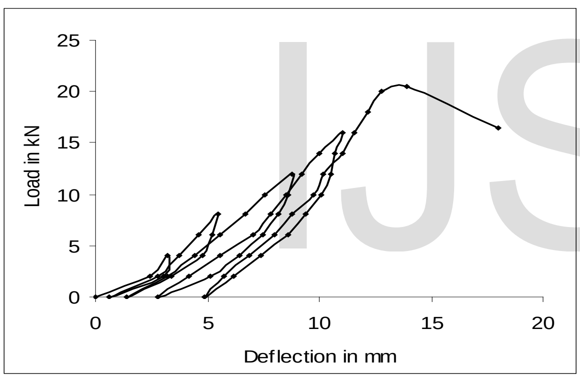
3.4 Cyclic Behaviour Of Beam – Column Joint

Experiments were conducted on beam – column joints under cyclic loading using two different mixes and compared with the conventionally reinforced concrete specimens. The performance was evaluated with respect to strength, ductility and energy absorption characteristics.

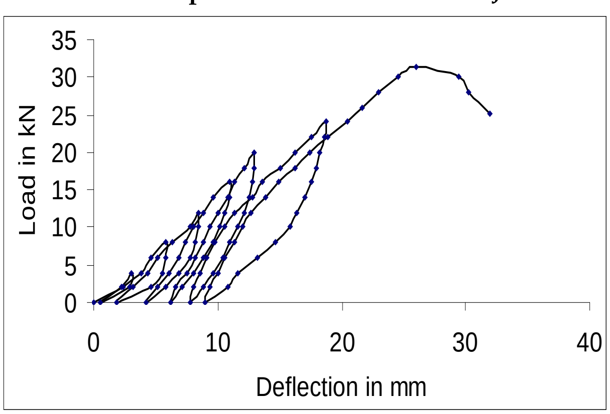
3.5 Load Vs Displacement Curves

Figure show the load-displacement curves of beam-column joint specimens. All the two fibrous joints show better performance when compared with conventional. It is observed that RPC fibre reinforced concrete joints had spindle shaped curves compared to control specimen. Owing to the inherent limitations of the testing arrangement, the load-deflection-curvature could be traced only upto 80% of the post-ultimate loading in the descending portion of the curve.

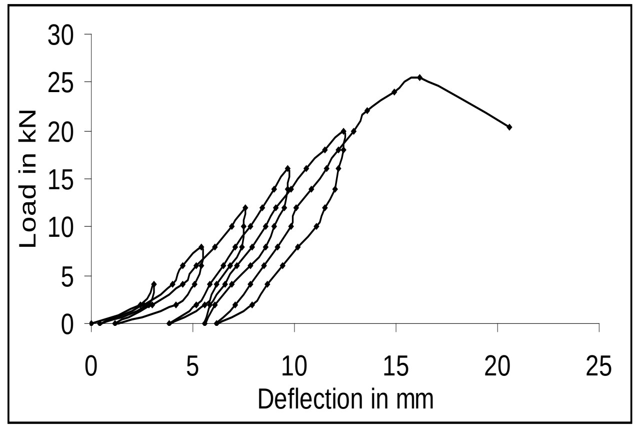
Load – Displacement Curve of Conventional Joint



Load – Displacement Curve of RPC1 Joint



Load – Displacement Curve of RPC2Joint

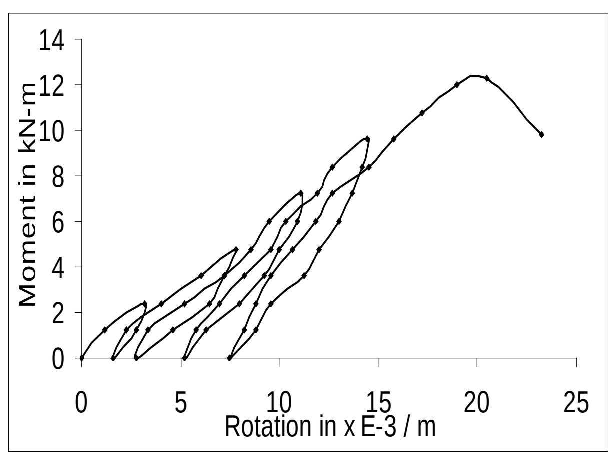


The ultimate point in both the curves is noted and the corresponding load, deflection and rotation values are shown in Table. RPC1mix increase the ultimate load carrying capacity of conventional joint by 53%. RPC2 mix gives strength enhancement of 34% over conventional joint. The pattern of crack propagation in the joint itself shows the strength enhancement. For instance, more number of minor cracks of smaller width was formed because of the bridging action of fibres which leads to more strength than conventional.

3.6 Moment Vs Curvature Curves

It has been found that ultimate curvatures of fibrous specimens also increased more than conventional ones by about 1.90 and 1.72 times for RPC1 and RPC2 fibres respectively. The curvature (strain to depth ratio) of the beams was calculated from the strain readings measured at 15 mm below the extreme compression fibre and 15 mm above the extreme tension fibre. The curvature values also increased in fibrous joints like deflections.

Moment - Curvature Curve of Conventional Concrete



Moment - Curvature Curve of RPC1 Concrete

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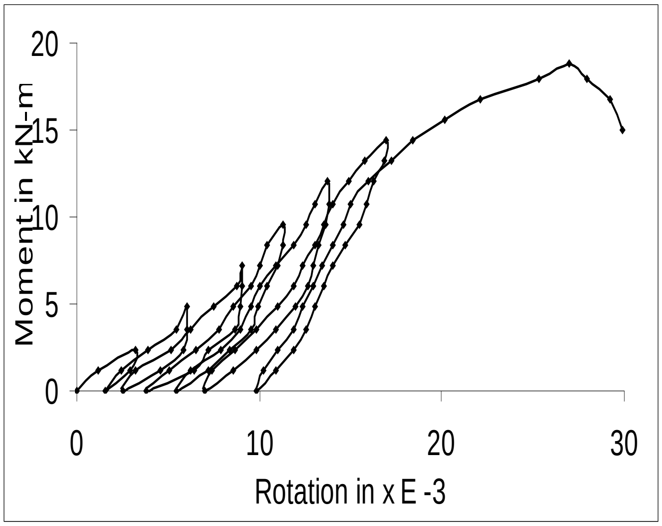
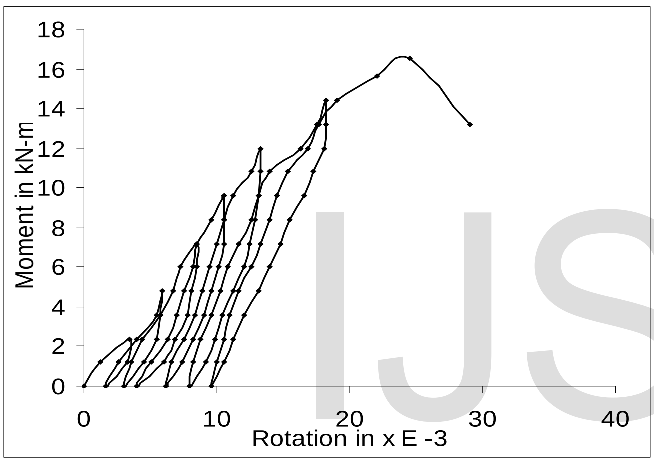


Moment - Curvature Curve of RPC2 Concrete



3.7 Ductility and Energy Dissipation Parameters

It is desirable to define response indices so as to describe the beam-column joint behaviour quantitatively. In seismic design, the inelastic deformation is generally quantified using ductility parameters. This includes displacement ductility, curvature ductility and energy absorption capacity at system as well as section levels. The cumulative energy absorption and ductility parameters are given in Table. Generally, displacement ductility factor is the ratio of ultimate to yield deflection. Curvature ductility factor was obtained using the relation (Ganesan 2000):

Curvature Ductility Factor = Φ_u / Φ_y

where Φ_u - Curvature at peak load

Φ_y - Curvature at yield = $f_y / E_s(d - x)$

where d - Effective depth

f_y - Yield strength of reinforcement

x - neutral axis depth

E_s - Modulus of elasticity of steel

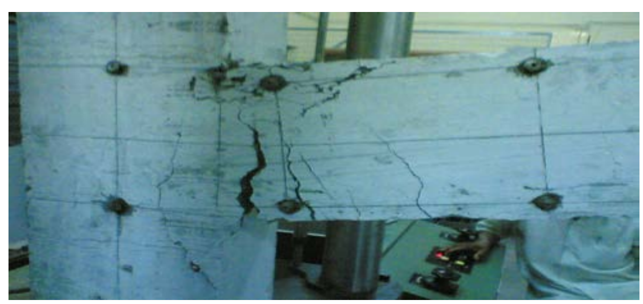
The ductility parameters show significant improvement in the fibrous joints as compared to the controlled joint. Among the specimens, RPC1possesses an improvement in both displacement as well as curvature ductility of conventional joint by 67% and 65%. Similarly RPC2 gives 40% and 54% enhancement improvement in displacement and curvature ductility respectively. As far as the energy absorption capacity is concerned, RPC1 and RPC2 increase the energy absorption capacity by 200%, 130% at system level and 175%, 148% in section level respectively.

Table 7
Results of Beam – Column Joint Test

Type of Specimen	Ultimate Load in kN	Ultimate Deflection in mm	Ultimate Curvature in x 10^{-3} / m
C	20.5	13.9	20.49
RPC1	31.4	26	27.2
RPC2	25.5	16.2	22

Table 8
Ductility Parameters of Beam – Column Joint Test

Type of Specimen	Displacement Ductility Factor	Curvature Ductility Factor	Cumulative Energy Absorption Through Displacement in kN-m	Cumulative Energy Absorption Through Curvature in kN-m
C	1.58	1.35	217	200
RPC1	2.65	2.24	774	548
RPC2	1.80	1.71	355	376



Failure Pattern of RPC 1 Joint

REFERENCES

[1] SerdarAydin, Halityazici, and HusseinIgniter, “Effect of aggregate type on mechanical properties of reactive powder concrete”, ACI Material Journal, Vol.107, Oct, (2010).

[2] HalitYazici, SerdarAydin, and Anil S.Karabulut’ “Mechanical properties of reactive powder concrete containing mineral admixtures under different curing regimes”, Construction and Building Materials, Vol.23, pp.1223-1231, (2009).

[3] Chin-Tsung Liu, Jong-Shin Huang, “Fire performance of highly flow able reactive powder concrete”, Construction and Building Materials, Vol.23, pp.2072-2079, (2009).

[4] A.Zenati, M.Lanez, and M.N.Oudjit, “Influence of cementitious additions on rheological and mechanical properties of reactive powder concretes”, Physics Procedia, Vol.2, pp.1255-1261, (2009).

[5] AN Ming-zhe, YI Quan-xin, “Size effect on compressive strength of reactive powder concrete”, journal of China University of Mining & Technology, Vol.18, pp.0279-0282, Mar, (2008).

[6] LIU Juanhong, WANG Lin, “Durability and microstructure of reactive powder concrete”, Vol.24, No.3, (2008).

[7] Allan C.L.Wong, Tony Macken, and Nadarajah-Gowripalan, “Simultaneous measurement of shrinkage and temperature of reactive powder concrete at early-age using fiber Bragg grating sensors”, Cement and Concrete Composites, Vol.29, pp.490-497, (2007).

[8] Zhang Yunsheng, Sun Wei, and Liu Sifeng, “Preparation of C200 green reactive powder concrete and its static-dynamic behaviors”, Cement and Concrete Composites, Vol.30, pp.831-838, (2008).

[9] A.Cwirzen, V.Penttala, and C.Vornanen, “Reactive powder based concretes: Mechanical properties, durability and hybrid use with OPC”, Cement and Concrete Research, Vol.38, pp.1217-1226, (2008).

[10] JU Yang,JIAYuDan, and CHEN Jian, “Mesomechanism of steel fiber reinforcement and toughening of reactive powder concrete”, Sci China Ser E-Tech Sci, Vol.50, No.6,pp.815-832, Dec, (2007).

[11] Ming-Gin Lee, Chui-Te Chiu, “A Preliminary study of reactive powder concrete as a new repair material”, Construction and Building Materials, Vol.21, pp.182-189, (2007).

[12] Nigel G.Shrive and EhabShaheen, “Reactive powder concrete anchorage for post tensioning with carbon fiber reinforced polymer tendons”, ACI Materials Journal, Vol.103, No.6, Dec, (2006).

[13] Ehabshaheen and Nigel G.shrive, “Optimization of mechanical properties and durability of reactive powder concrete”, ACI Material Journal, Vol.103, No.6, pp.444-451, Dec, (2006).

[14] Yin-Wen Chan, Shu-Hsien Chu, “Effect of silica fume on steel fiber bond characteristics in reactive powder concrete”, Cement & Concrete Research, Vol.34, pp.1167-1172, Dec, (2004).

[15] AbouzarSadrekarimi, “Development of light weight reactive powder concrete”, Journal of Advanced Concrete Tech, Vol.2, No.3, pp.409-417, Oct, (2004).

[16] A.S.Dili& Manu Santhanam, “Investigations on RPC: A developing ultra high-strength technology”, Indian Concrete Journal, pp.33-38, Apr, (2004).

[17] O.Bayard, O.Ple, “Fracture mechanics of reactive powder concrete: material modeling and experimental investigations”, Engineering Fracture Mechanics, Vol.70, pp.839-851, (2003).

[18] Mohamed Lachemi, Eric Dallaire, and Jerome Dugat, “Mechanical properties and Durability of two industrial reactive powder concrete”, ACI Material Journal, Vol.94, No.4, Aug, (1997).

[19] C.Andrade, M.A.Sanjuan, “Experimental study of durability of reactive powder concretes”, Journal of Material in Civil Engineering, Vol.8, No.1, Feb, (1996).

[20] Marcel Cheyrezy, Samuel Philippot, and Pedro Nieto, “Investigation of hydration and pozzolanic reaction in reactive powder concrete using Si NMR”, Cement and Concrete Research, Vol.26, No.1, pp.93-100, (1996).

[21] Pierre Richard, Marcel Cheyrezy, “Composition of reactive powder concrete, Cement and Concrete Research, Vol.25, No.7, pp.1501-1511, (1995).