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Micro Structure Analysis of Reactive Powder Concrete

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Abstract:- 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. Present paper deals with microstructure analysis of RPC an optimized composition of RPC with variation of fibre content is studied at regular interval of time The results indicate that steel fiber surface has covered with densely cementations material. The hydrated cement matrix or mortar held on side surface of steel fiber. It was clearly observed that there is a good bond between hydrated cement matrix and steel fiber in interfacial zone of RPC. Microscopic images of RPC confirmed the holding of hydrated cement matrix on side surface of steel fiber in SEM images.SEM micrographs show that, in general, the change in microstructure in the concrete after time was mainly due to the change in the arrangement of the C-H-S compounds. From the SEM micrographs we can observed the various component of RPC also, it development with age and with different curing condition (normal and hot curried). Microstructure of hot water curried sample is much faster than the normal water curried sample.

Keywords:- Reactive powder concrete, SEM, ultra high strength concrete, hot water curing.

I. INTRODUCTION

The scanning electron microscope (SEM) is one of the most versatile instruments available for the examination and analysis of micro structural characteristics of solid objects. The primary reason for the SEM's usefulness is the high resolution that can be obtained when bulk objects are examined. The microscope has been a powerful tool in the study of cement and concrete since the early development of these materials. Le Chattelier (1882) was among the first to apply the microscope to the study of cementitious materials.

This investigations of micro-cracking ranges from macroscopic studies of the behavior of cracked specimens to a microscopic study of the cracks themselves. The presence of micro-cracks was predicted on the basis of macro behavior and verified by microscopic study.

Ultra-High performance cement –bases materials like reactive powder concrete (RPC), are potential candidates. RPCs are constituted of Portland cement, silica fume, quartz sand, steel fibers and super plasticizer. Their rheology is improved by using a super plasticizer. This also results in a water/cement ratio as low as 0.23 the basic principles underlying their development have already been published by Richard and Cheyrezy. They include the elimination of coarse aggregates, optimization of the granular skeleton, and densification of the cementation matrix through a post set heat treatment.

Ultra High performance concrete represents a technological leap ahead for the construction industry. Among already built initials applications, reactive powder concrete (RPC) lies at the forefront. These cementitious materials have originally been developed by e.g. Richard and cheyrezy (1995) but the original formulation has to be adapted to local materials.

II. SPECIFICATION OF MATERIALS

Table 1: Specifications of the materials used for RPC

Sample	Specific Gravity	Particle Size Range
Cement (IS 12269: 1987)	3.15	31 µm – 7.5 µm
Silica fume (ASTM C1240-97B)	2.2	5.3 µm – 1.8 µm
Quartz sand	2.7	5.3 µm – 1.3 µm
Steel fiber - 13mm (ASTM A 820-96)	7.1	Length 13 mm and dia. 0.45 mm
Steel fiber – 25mm (ASTM A 820-96)	7.1	Length 25 mm and dia. 0.4 mm
20mm Aggregate (IS. 383:1970)	2.78	25mm – 10mm
10mm Aggregate (IS. 383:1970)	2.78	12.5mm – 4.75mm
River sand (IS 383: 1970)	2.61	0.6 mm – 0.15 mm

2.1 Selection Parameters

From the above descriptions and the literature survey carried out some basis have been finalized for the selection of different components of RPC. The selection parameters are summarized in the Table 2.

Table 2: Selection parameters for RPC components

Components	Selection Parameters	Function	Particle Size	Types
Sand	Good hardness readily available and low cost	Give strength, Aggregate	150µm– 600 µm	Natural, Crushed
Cement	C3S : 60%; C2S : 22%; C3A : 3.8%; C4AF : 7.4%	Binding material, Production of Primary hydrates	1µm-100 µm	OPC Medium fineness
Quartz Powder	Fineness	Max.reactivity during heat treating	5µm - 25 µm	Crystalline
Silica Fume	Nature and quantity of impurities	Filling the voids, Enhance rheology, Production of secondary hydrates	22m2/g (Fineness)	Procured from the zirconium industry (highly refined)
Steel Fibers	Good aspect ratio	Improve Ductility	L :13-25mm, Dia:0.15-0.5mm	Corrugated
Super-plasticizer	Less retarding characteristic	Reduce water to cement ratios	--	Polyacrylate-based (or) polycarboxylate based

III. COMPOSITION OF REACTIVE POWDER CONCRETE

RPC is composed of very fine powders (cement, sand, quartz powder and silica fume), steel fibers (optional) and super plasticizer. The super plasticizer, used at its optimal dosage, decreases the water to cement ratio (W/C) while improving the workability of the concrete. A very dense matrix is achieved by optimizing the granular packing of the dry fine powders. These Reactive Powder Concretes have compressive strengths ranging from 160 MPa to 800 MPa.

Table 3: Optimzed composition of RPC used in Experimental program (parts by mass)

Materials	**Part by mass of cement**
Cement	1
Sand	1.5
Silica fume or pozzolan	0.32
Powdered quartz sand	0.36
Steel fibers	0.20
Water	0.23
Super plasticizer	0.04

IV. RESULTS AND DISCUSSION

The microstructures of the young and mature pastes of reactive powder concrete can be seen in various figures, in which examples of areas of anhydrous cement (residual cement), calcium hydroxide (CH) and lumps of silica fume (SF) have been identified.

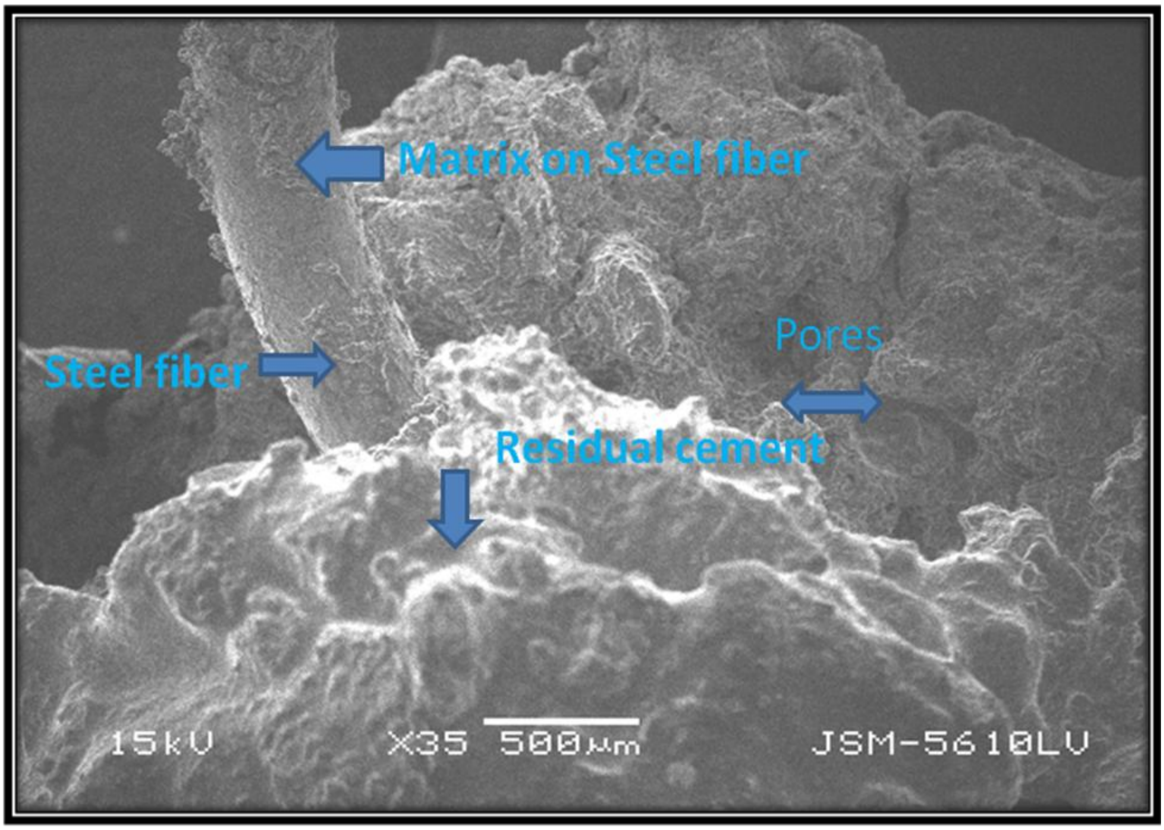

Fig.6.3.1 Microstructure of a RPC (SEM) after 1day

Fig. No: 6.3.1 & 6.3.1/A images of hardened RPC paste at 1day. Typical view of representative fiber/matrix regions of mature Reactive powder concrete sample are shown in high magnification in fig. No: 6.3.1 under controlled laboratory conditions of 21±1^{o}c and relative humidity of 53±5 %, the microstructure is characterized by closely packed hydration products with small signs of micro cracking or macro porosity due to the shrinkage. Micrographs of the interfacial regions of the reactive powder concrete examined at 1, 7, 28 and 180 days for normal curing and compared with hot curried sample for 2days at 90◦c temperatures remaining period normal curried. The 1 day results indicate an increasing amount of the un-hydrated material (residual cement), which can shown as a light bright color and good reactive powder concrete matrix on the surface of steel fiber as shown in fig.No.6.3.1.

Also we can clearly see that there is a good connection in interfacial zone of cement concrete matrix and steel fiber, and this case shows the strongly bonding between steel and concrete. The steel fiber can seen a black color due to opaque. It may be conclude that the wavy face of steel fiber increase the holding of hydrated mortar matrix on the steel fiber surface. Polarizing microscopy technique is easy way for observing the bond characteristics between steel fiber and hydrated cement matrix in RPC without pull out test.

However, this study presents the microstructure of RPC by SEM and polarizing microscopy technique when steel fiber embedded in the hydrated cement matrix. This case also shows that there is a good bond between steel fiber surface and reactive powder concrete or hydrated cement matrix.

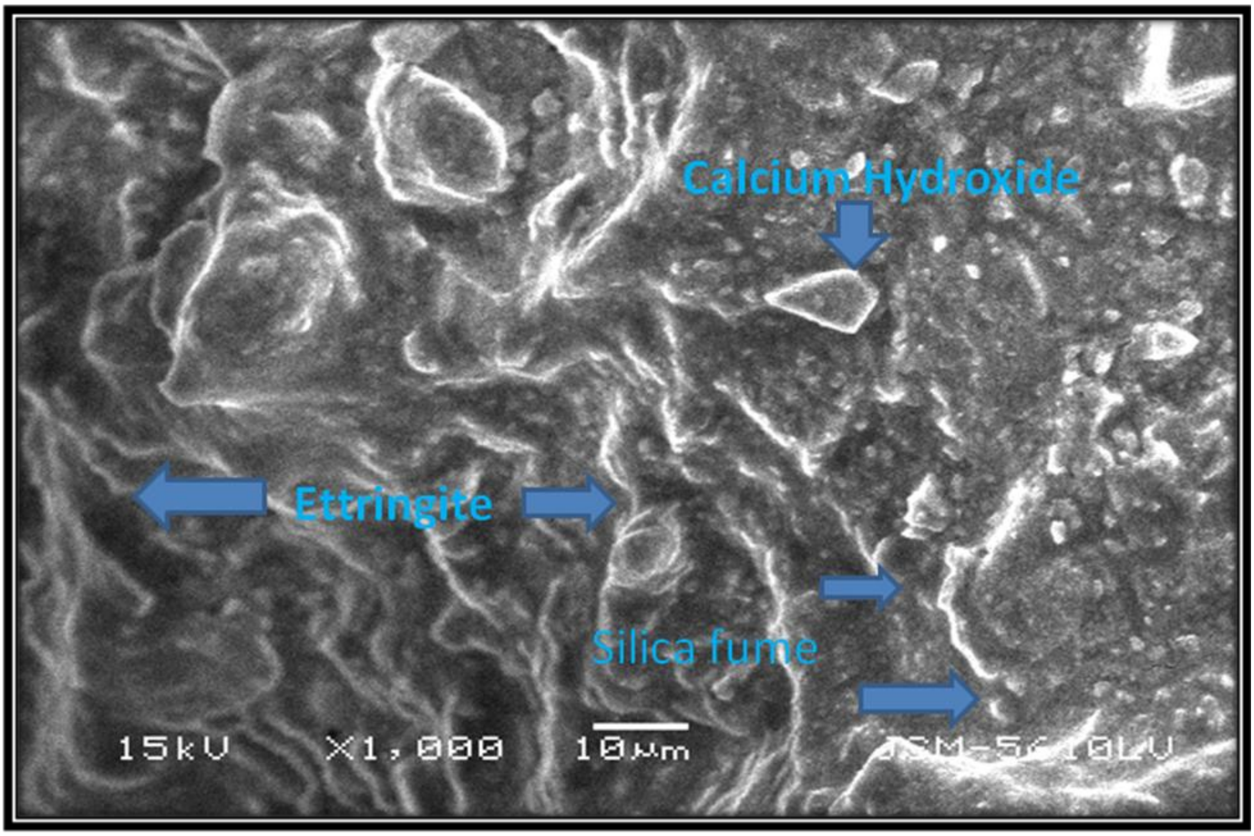

Fig.6.3.2 Microstructure of a RPC (SEM) after 1day

Fig. No: 6.3.2, 6.3.3 &6.3.4 illustrate images of young pastes surface of hardened RPC. In this image one can seen plate of calcium hydroxide is made by its relative brightness, exhibiting a typical hexagonal habit. It can be seen very clearly in bright color in fig.No:6.3.4, and ettringite (sulfate irons react with calcium aluminates), which clearly seen in fig.No:6.3.4 with magnification up to 10µm.

SEM observation of silica fume appears all in form of typical agglomerates of round dark grains with the very small size, which can be seen by the magnification up to 10µm in fig. No: 6.3.2 and 6.3. 3.

The 1 day results indicate an increasing amount of the anhydrous (residual) cement or material is much higher due present of the silica fume to effect on the arrangement of the cement grains and, this is the particle size distribution of the anhydrous cement grains in the interfacial zone during mixing.

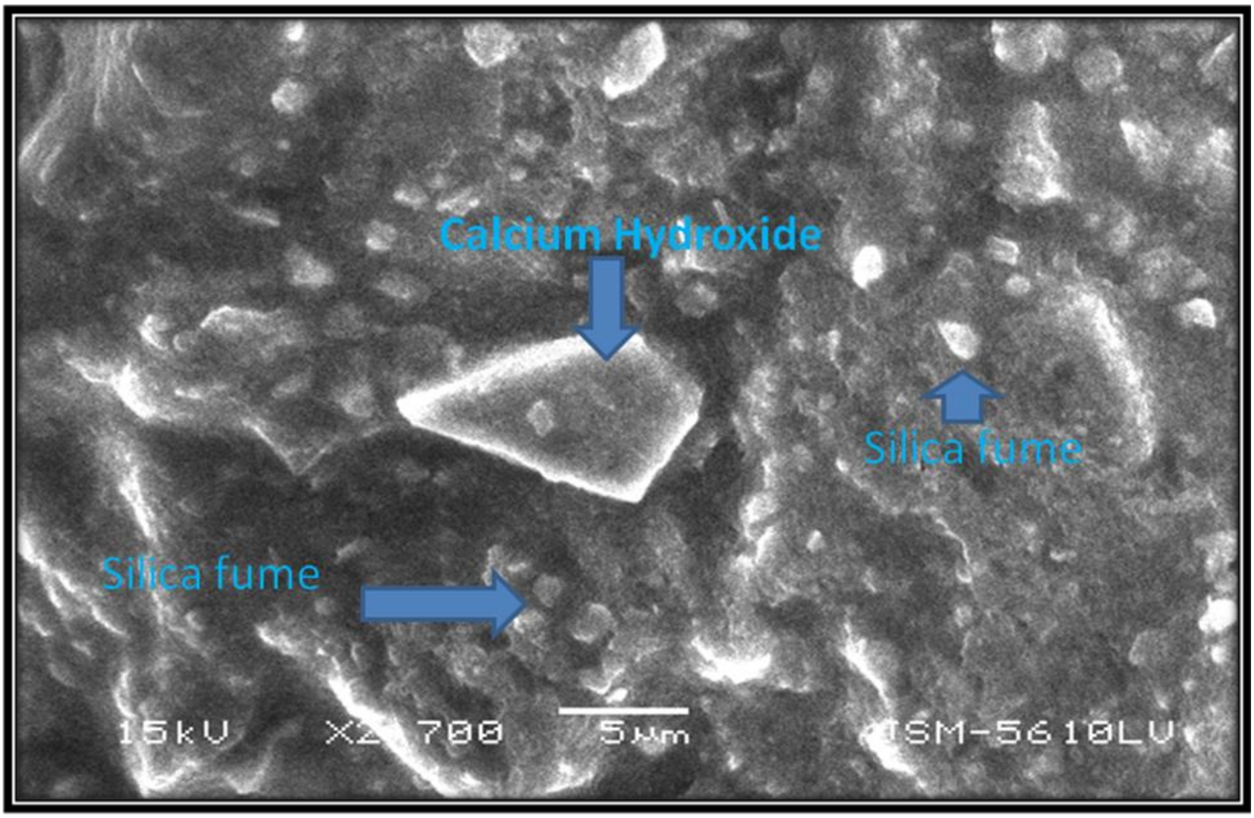

Fig.6.3.3 Microstructure of a RPC (SEM) after 1day

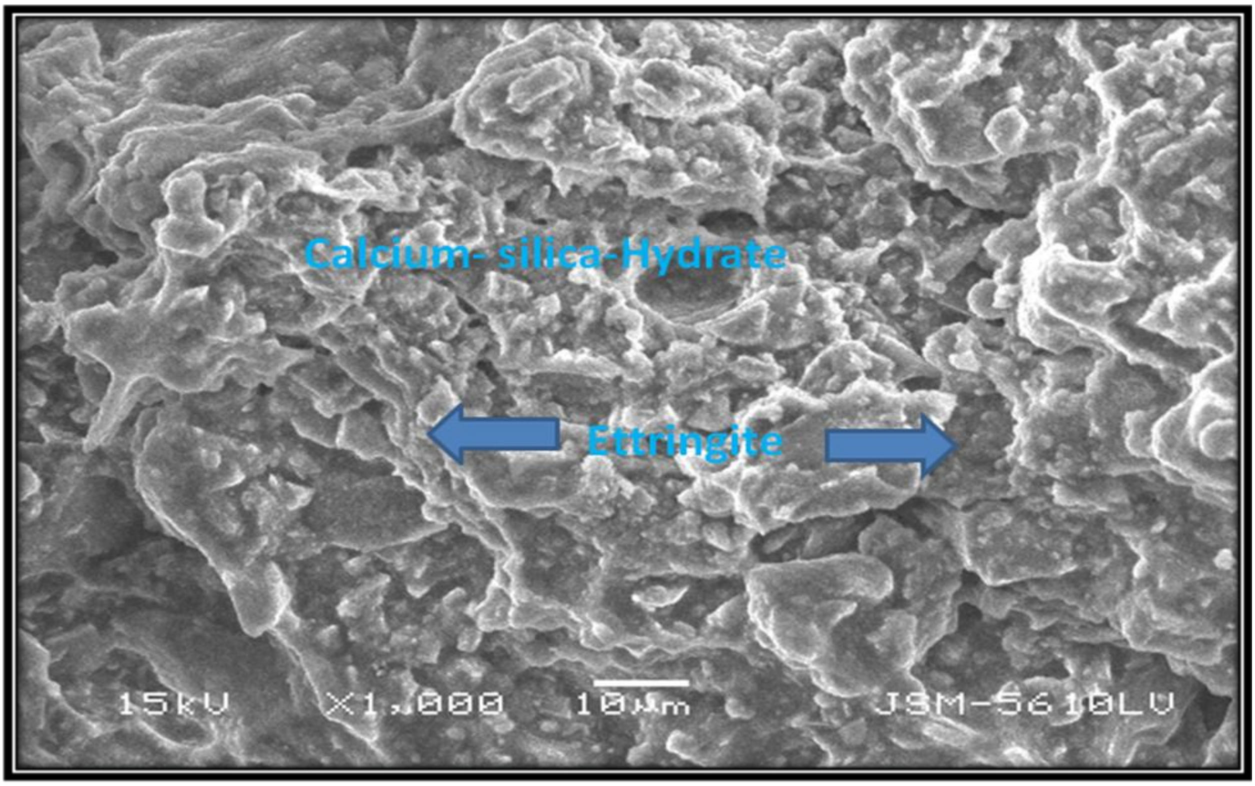

Fig.6.3.4 Microstructure of a RPC (SEM) after 1day

After the 7 days of leaching of a sample extracted from the normal curing water, hydration of reactive powder concrete is illustrates ettringite with its needle-like habit, blocky calcium hydroxide crystal showing their characteristic cleavage parting along the basal plane.

Calcium-silicate-hydrate gel (C-S-H) identified by its short needle-like form and fine bundles and it get shrinkage after 7days, which can be seen in fig. No: 6.3.5. While in fig. No: 6.3.4 Calcium-silicate-hydrate gel (C-S-H) is in expended like a bundle. Also show the pore portion in the RPC in above fig No: 6.3.5&6.3.6. After the 7days normal water curing concrete, there is still remaining the anhydrous cement. Which can be identified by the light color, also identified the silica fume and calcium hydroxide in circular and plate shape in fig No: 6.3.6.

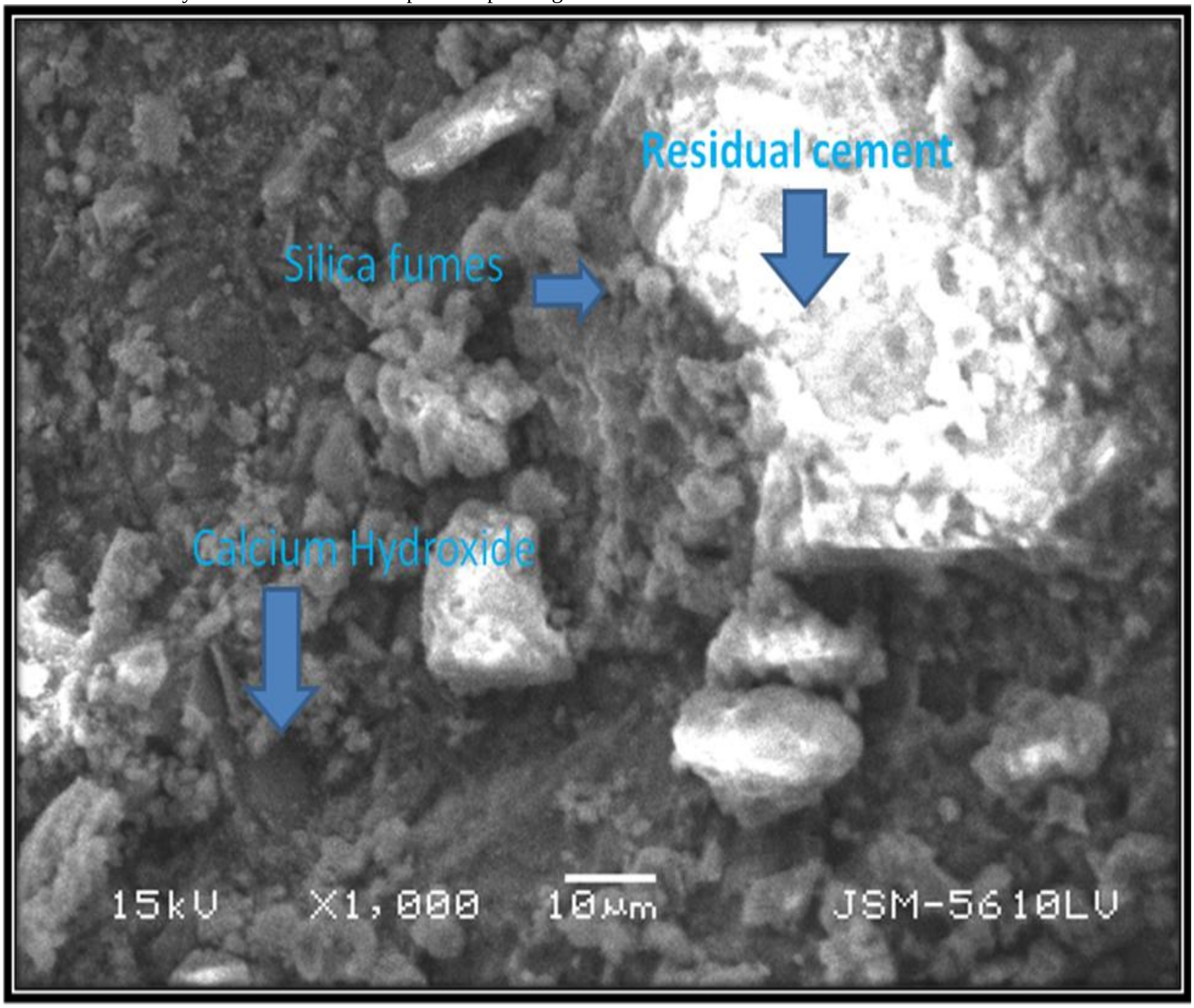

Fig.6.3.6 Microstructure of a RPCN (SEM) after 7day

This can be seen by the magnification equal to 1000.while in hot curried water sample anhydrous (residual cement) was less as compare with 1&7days result of normal curried water sample as shown in fig.No:6.3.7&6.3.10,it indicate that the process of hydration was faster in hot water curried than normal water curried samples. As hardened cement paste (RPC) matures, filling of the voids spaces eliminates the well-formed crystals shown in the fig.No:6.3.7 with the resulting microstructure appearing nondescript. Cement appears bright followed by calcium hydroxide; C-S-H and void appear dark in fig.No:6.3.7, 6.3.8.

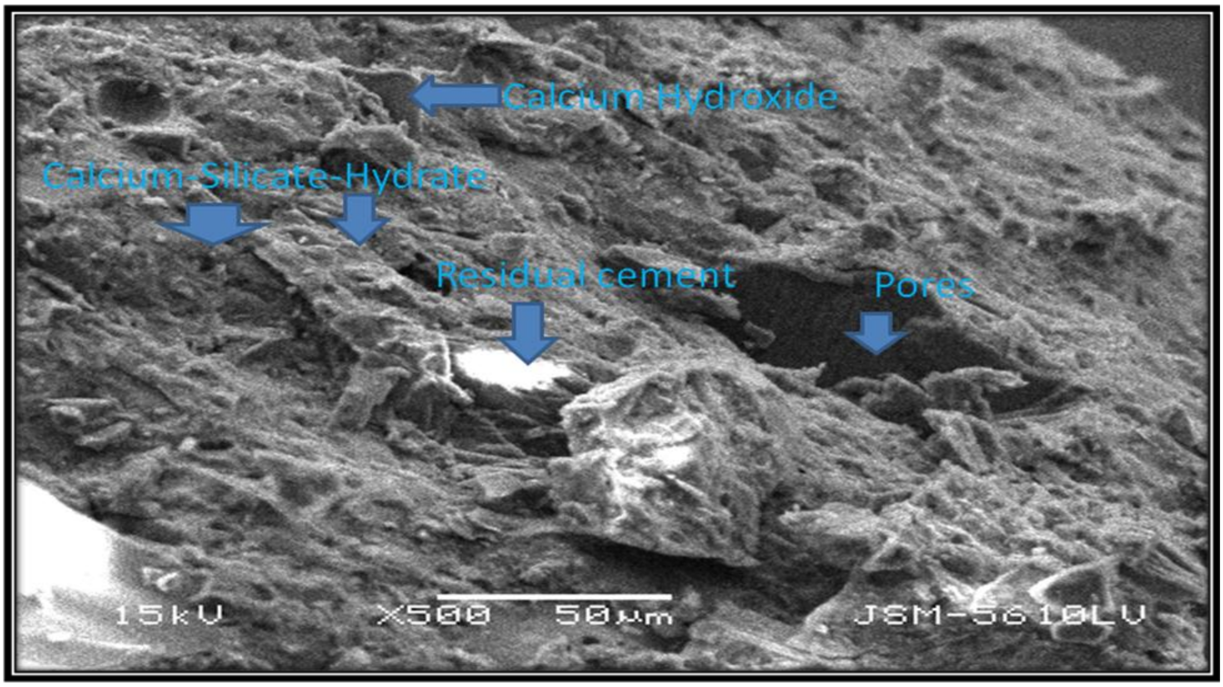

Fig.6.3.7 Microstructure of a RPCH (SEM) after 7day

In the concrete containing silica fume very few discrete areas of calcium hydroxide could be identified at either age, also indicating a change in the formation of calcium hydroxide (CH) with regard to the 1 day sample.

Calcium-silicate-hydrate gel(C-S-H) fine bond in normal water curried after 7days sample in fig No: 6.3.5, while partly in hot water curried as shown in fig.No:6.3.6 &6.3.7.

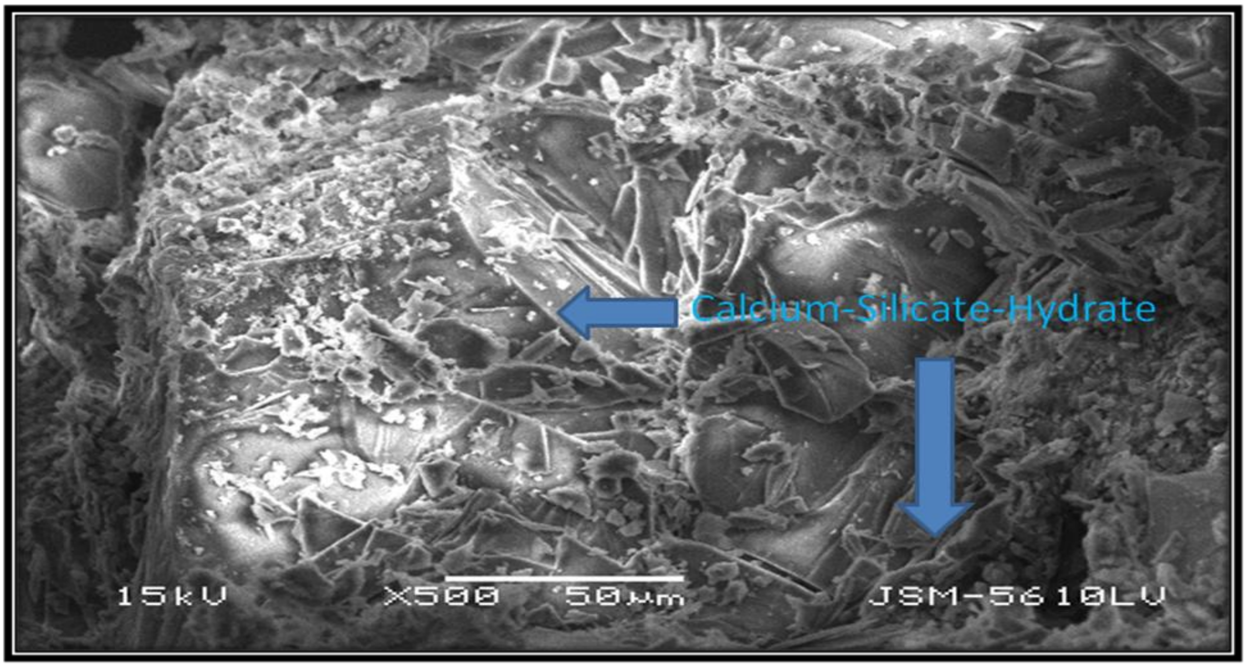

Fig.6.3.9 Microstructure of a RPCH (SEM) after 7day

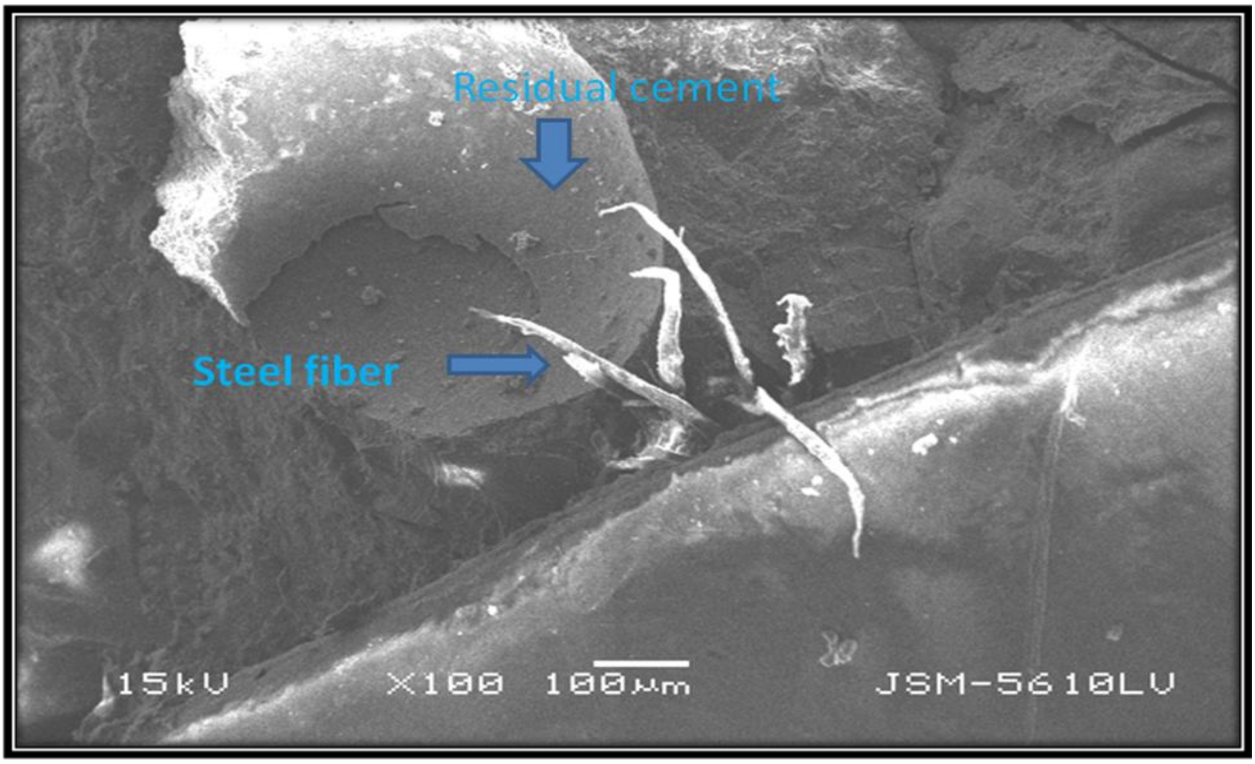

Fig.6.3.10 Microstructure of a RPCH (SEM) after 7day

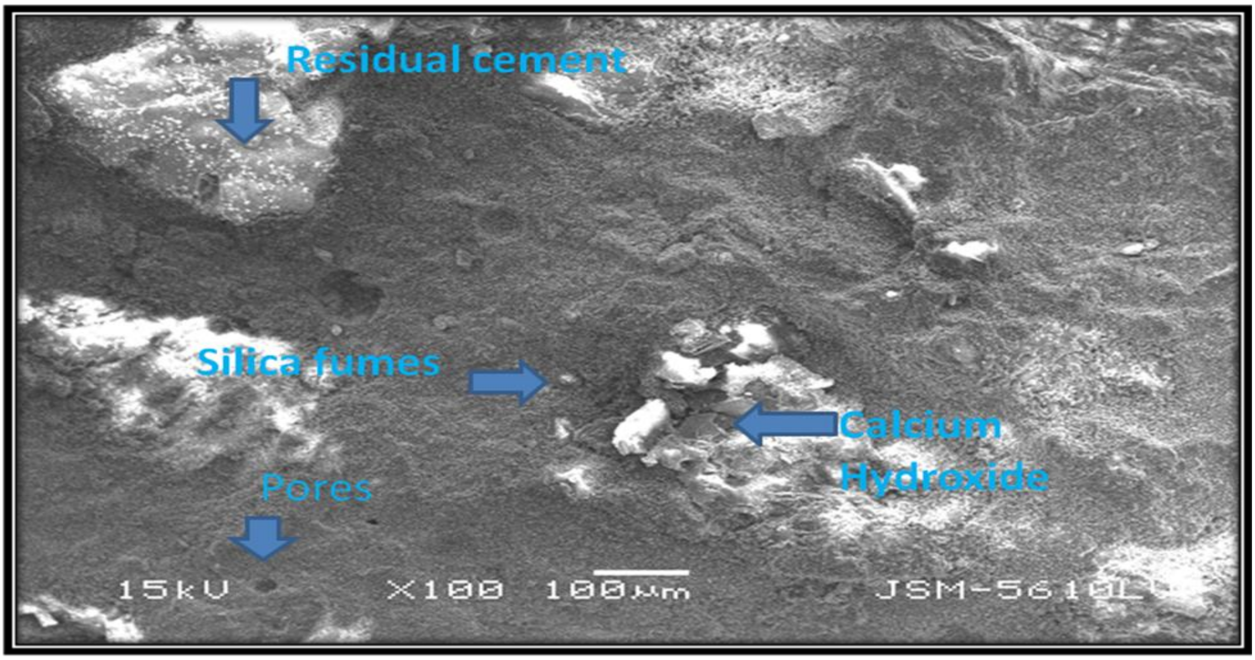

Fig.6.3.11 Microstructure of a RPCN (SEM) after 28day

After 28days anhydrous cement was much more in normal water curried then the hot water curried as shown in fig No:6.3.11, 6.3.12 and 6.3.13, also development of C-S-H much more amount in hot water curried for 7days , the same observation is there in normal water curried at 28days and 7days, which was compared at 10µm having magnification 1000.

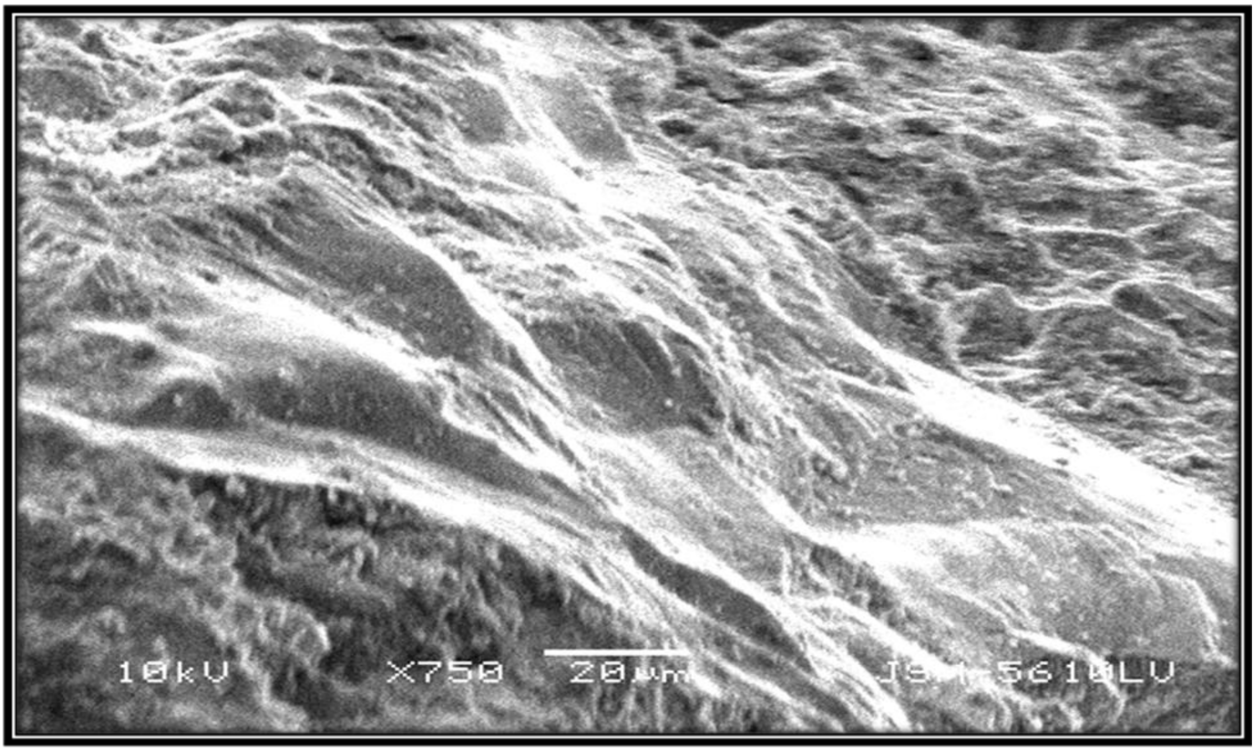

Fig.6.3.15 Microstructure of a RPCN (SEM) after 180 day

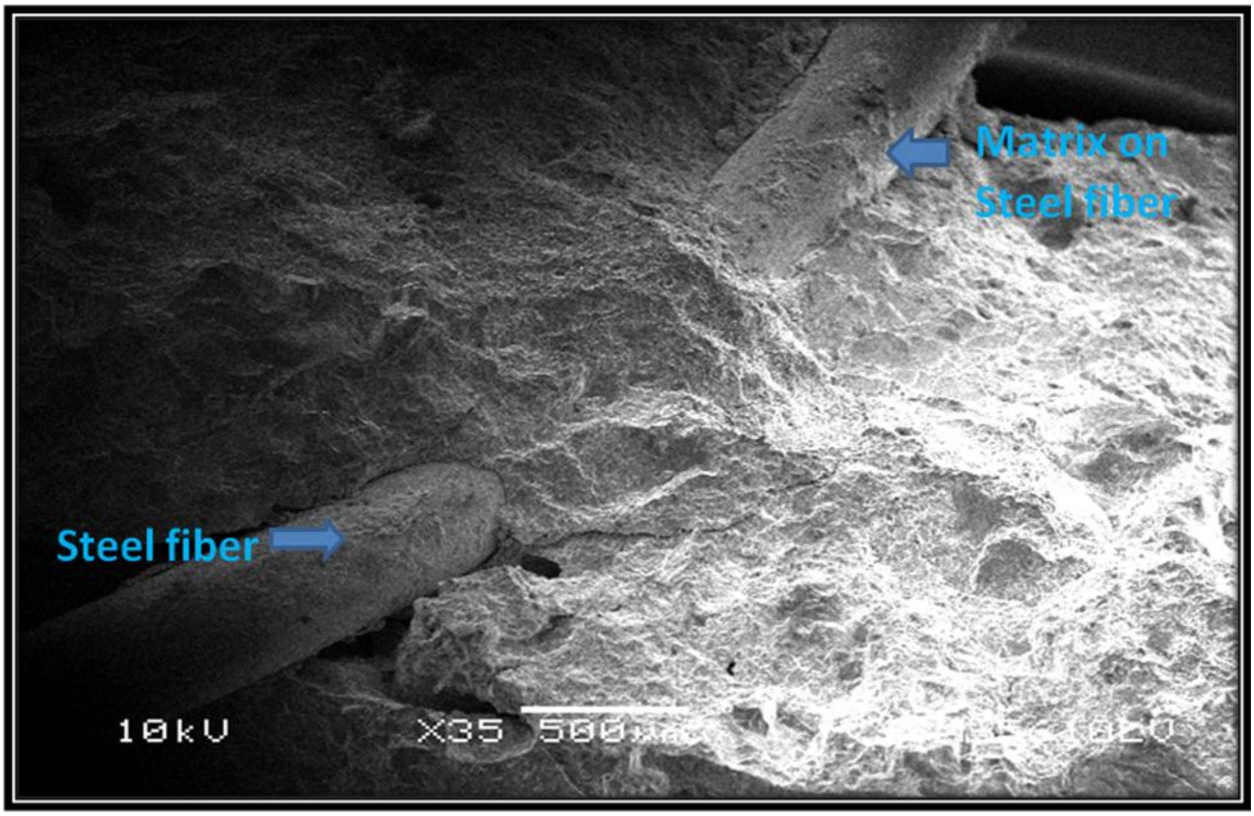

Fig.6.3.16 Microstructure of a RPCN (SEM) after 180 day

V. CONCLUSIONS

- The scanning electron microscopy image analysis result in the present study indicate that a major influence of silica fume in concrete is associated with the densification of the microstructure at the transition zone, resulting in a much lower porosity.
- When the microstructure of the RPC was investigated by using SEM, it reveals that steel fiber surface has covered with densely cementations material. The hydrated cement matrix or mortar held on side surface of steel fiber.
- It was clearly observed that there is a good bond between hydrated cement matrix and steel fiber in interfacial zone of RPC.
- Microscopic images of RPC confirmed the holding of hydrated cement matrix on side surface of steel fiber in SEM images.
- SEM micrographs show that, in general, the change in microstructure in the concrete after time was mainly due to the change in the arrangement of the C-H-S compounds.
- From the SEM micrographs we can observed the various component of RPC also, it development with age and with different curing condition (normal and hot curried). Microstructure of hot water curried sample is much faster than the normal water curried sample.

REFERENCE

[1]. Cheyrezy.M , Maret.V, Frouin.L(1995) " *microstructure analysis for RPC* " cement concrete research ,vol.25 no.7pp.1491-1500,

[2]. Cohen, M. D., (1990)"A look at silica fume and its actions in portland cement concrete," The Indian Concrete Journal, Vol. 64, pp. 429 - 437.

[3]. Dias, WPS, *et al,* (1990). "Mechanical proprieties of hardened cement paste exposed to temperature up to 700°C (1292°F), ACI Mater T, 87(2): 60- 165.

[4]. Dili A. S. and Manu Santhanam. (2004) *"Investigation On Reactive Powder Concrete: A Developing Ultra High-Strength Technology"* Indian Concrete Journal.

[5]. Djaknoun S., Ahmed Benyahia .A. Ouedraogo E.(2008) **"***Porosity and permeability of Mortars Exposed to elevated Temperatures"* Journal of Applied Sciences Research, 4(3): 231-240,

[6]. Ehab shaheen and Nigel g. Shrive (2006) *"Optimization Of Mechanical Properties And Durability Of Reactive Powder Concrete"* ACI Structural Journal, vol. 103[6], Nov-Dec 2006.

[7]. Hui.Li, Hui-gang.Xiao, Jie.Yuan, (2004) "Microstructure of cement mortar with nano-Particles", Composites: part B 185-189.

[8]. Neville, A.M., (1995) "Properties of concrete", Pitman, London, 4ème edition, ISBN0-582-23070-5.

[9]. Paul.E. stutzman "*scanning electron microscopy concrete petrography*" national institute of standards and technology 100 bureau drive, stop 8621, Gaithersburg, Maryland 20899-8621.

[10]. Phan, L.T, (1996). "Fire performance of high strength concrete» A report of the state of the art, Maryland: Building and fire Research laboratory, National institute of standards and technology.

[11]. Pierre Richard, Marcel Cheyrezy (1995) "*Composition Of Reactive Powder Concretes".* Cement and Concrete Research, Vol. 25. no. 7, 1501-1511.