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Mechanical and durability properties of fluoropolymer modified cement mortar

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Abstract. The addition of different types of polymers such as SBR, VAE, Acrylic, etc. in concrete and mortar leads to an increase in compressive, tensile and bond strength and decrease in permeability of polymer modified mortar (PMM) and concrete (PMC). The improvement in properties such as bond strength and impermeability makes PMM/PMC suitable for use as repair/retrofitting and water proofing material. In the present study effect of addition of fluoropolymer on the strength and permeability properties of mortar has been studied. In the cement mortar different percentages viz. 10, 20 and 30 percent of fluoropolymer by weight of cement was added. It has been observed that on addition of fluoropolymer in mortar the workability of mortar increases. In the present study all specimens were cast keeping the workability constant, i.e., flow value 105±5 mm, by changing the amount of water content in the mortar suitably. The specimens were cured for two different curing conditions. Firstly, these were cured wet for one day and then cured dry for 27 days. Secondly, specimens were cured wet for 7 days and then cured dry for 21 days. It has been observed that compressive strength and split tensile strength of specimens cured wet for 7 days and then cured dry for 21 days is 7-13 percent and 12-15 percent, respectively, higher than specimens cured one day dry and 27 days wet. The sorptivity of fluoropolymer modified mortar decreases by 88.56% and 91% for curing condtion one and two, respectively. However, It has been observed that on addition of 10 percent fluoropolymer both compressive and tensile strength decreases, but with the increase in percentage addition from 10 to 20 and 30 percent both the strengths starts increasing and becomes equal to that of the control specimen at 30 percent for both the curing conditions. It is further observed that percentage decrease in strength for second curing condition is relatively less as compared to the first curing condition. However, for both the curing conditions chloride ion permeability of polymer modified mortar becomes very low.

Keywords: fluoropolymer modified cement mortar; cement mortar; SBR polymer; acrylic

1. Introduction

Cement concrete and cement mortar are preferred constru[1]ction material for nearly last two centuries, besides their poor tensile strength, higher drying shrinkage and low chemical resistance. To overcome these disadvantages normal cement concrete and cement mortar, a concept of modification by addition of polymers such as latexes, liquid resins, water soluble polymers etc. was introduced around 80 years back (Cresson 1923, Lefebure 1924). The properties of cement concrete/mortar modified by the addition of polymers depend upon organic polymer and cement gel matrix. A lot of research has been carried out in various countries on polymer modified concrete and mortar. On the basis of research carried out in the field, polymer modified cement mortar is available and used for various applications in the construction industry. Due to its properties such as improved toughness, better durability, improved mechanical properties and specifically better bond strength as compared to normal mortar, it can be also be used for repair and rehabilitation of structures. It is established from the previous research that the properties of mortar can be as compared to normal mortar, it can be also be used for repair and rehabilitation of structures. It is established from the previous research that the properties of mortar can be improved by the addition of different type of polymers, but still more research is required to understand the polymer modification mechanism. Various researches have worked on different aspects of polymer mortar and concrete starting from its proper preparation with different materials for studying its properties (Wang *et al.* 2004**,** Wang *et al.* 2008, Aggarwal *et al.* 2007).

Earlier studies on polymer modified mortar (PMM) have already upheld that the mechanical and physical properties of fresh and hardened SBR-modified mortar show considerable improvement with the addition of various percentages of polymers (Andal *et al.* 2008). The properties of acrylate and EVA polymer-modified mortars, when used as repairing material, showed an increase in compressive strength (10 to 20%), tensile strength (30 to 40%) and direct shear bond strength (40 to 50%) (Barluenga and Olivares. 2004). The VAE-modified cement mortar has a compact matrix, wherein the polymer coating cloaks the cement form and fills in the space between cement and sand to enhance the bond strength (Medeiros *et al.* 2009). The cracking resistance and adhesive strength of EVA-modified mortars has been observed to improve at a polymer-cement (p/c) ratio 0.12 (Chen *et al.* 2011).

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The addition of SBR and VAE polymers improves the properties like workability, flexural strength, toughness and impermeability of conventional cement mortar (CCM) (Ali *et al.* 2012, Wang and Wang 2011, Wang *et al.* 2004, Wang *et al.* 2005). Ohama 1995, Sakai and Sugita 1995 have concluded in their studies that the aggregates of PMM are united by interpenetration of monolithic phase and polymer phase. This co-matrix phase results in improved properties of the polymer-modified mortar such as improved adhesion, improved workability, improved durability and strength as compared to ordinary cement mortar. Out of the vast available range of addable polymers, dispersions like SBR, EVA and PAE have been found to perform better than other dissolvable polymers (Afridi *et al.* 1999, Wu *et al.* 2011)

Wang *et al.* (2004) studied the effect of variation of polymer-cement ratio (P/C by weight) on the mechanical and physical properties of styrene–butadiene rubber (SBR) emulsion modified cement mortars keeping water-cement ratio constant (0.4 by weight). It was observed that up to P/C ratio 0.01, the toughness of modified mortars increases with increase in P/C ratio and flexural and mechanical properties depends upon the apparent bulk density. However, when P/C ratio is greater than 0.01, the mechanical properties are more or less independent of the apparent bulk density. Further, it was observed that by adopting a mixed curing (6 days immersed and 21 days dry) as compared to continuous wet curing the mechanical properties of polymer modified mortars improves. The compressive strength of polymer modified mortar, cured continuously wet, increases with increase in P/C ratio from 0.01 to 0.08. It is further observed that in continuous wet curing, due to hydration of cement and polymer film formation, the compressive strength increases with increase in curing period, but the strength of mixed cured specimens always remains greater than wet cured specimens irrespective of P/C ratio. However, in case of mixed curing the compressive strength sharply increases with change in P/C ratio from 0.01 to 0.02, thereafter with an increase in the P/C ratio up to 0.08 the strength increases in the same pattern as for wet cured specimens.

Similarly, flexural strength of polymer modified specimens subjected to the mixed curing regime is always greater than that of control specimens irrespective of P/C ratio and curing period. In case of wet cured specimens the flexural strength slightly increases with increase in P/C ratio from 0.01 to 0.02, then it decreases with further increase in P/C ratio up to 0.07 and thereafter remains constant up to P/C ratio 0.1. As observed in compressive strength, the flexural strength of wet cured polymer modified specimens also increase with increase in curing period.

Golestaneh *et al.* 2010 investigated the effect of addition of different percentages of silica powder (100, 150 and 200%) by varying the amount of percentage resin (10, 15 and 20%) on compressive strength of polymer concrete. From the results it was observed that on addition of silica powder as filler material in the polymer concrete the compressive strength increases many folds. The cast polymer concrete with 200% silica powder (15% fine, 25% medium and 60% coarse silica powder) and 15-20% epoxy resin gives compressive strength 128.9 MPa and flexural strength 22.5 MPa.

Aggarwal *et al.* (2007) studied the effect of addition different percentages of epoxy emulsion on the properties of cement mortar and compared the results with those of the acrylic modified cement mortar. The PMM test specimens were prepared by mixing Portland cement of grade 43 and quartz sand no. 10 in the of ratio 1:3. Polymer content in PMM varied from 0 to 30% by weight of cement. It was observed that on addition of polymers, due to the lesser surface tension of polymer molecules, the flowabilty of PMM increases. The water content in PMM was so adjusted to keep the flow value in the range of 110-120 mm. The results show that PMM prepared using epoxy emulsion offers more resistance to chloride ion and carbon dioxide penetration and improved strength properties as compared to PMM prepared using acrylics.

The performance in terms of strength and permeability of PMM prepared using SBR latex and PAE emulsion is reported as better than that prepared using VAE polymer powder. The oxygen permeability of PMM, determined using parameters developed by Cabrera and Lynslade, is much lower than normal cement mortar and it further decreases with an increase in the curing period. The decrease in permeability of PMM may be attributed due to filling of small pores between cement and sand by smaller particles of polymers and form monolithic film around the cement and aggregate particles (Ramli *et al.* 2012).

Zulkarnain *et al.* (2008) carried out investigation to study the behavior of polymer modified ferrocement in flexure. Ferrocement specimens of size 125×350×30 mm, reinforced with three layers of square welded wire mesh, were cast. The specimens were tested under 1/3rd loading arrangement and their various parameters, such as load v/s deflection, first crack load and maximum load carrying capacity, were monitored. From the test results it is observed that polymer modified ferrocement has a higher first crack load, maximum load, and lower deflections as compared to normal ferrocement specimens. The behavior of polymer modified ferrocement further improves with an increase in the curing period. This improvement in behavior of polymer modified ferrocement may be due to formation of polymer film, which binds the aggregates and cement particle and makes durable matrix.

Fluoropolymers are the polymer materials in which hydrogen atoms in the analogous hydrocarbon polymer structure are partially or fully replaced by fluorine atoms. In case of full replacement the fluoropolymers are termed as perfluoropolymers and in case of partial replacement these are termed as partially fluorinated polymers. Fluoropolymers due to its stable carbon-fluorine covalent bonding, special electronic structure of fluorine atom and the unique intra molecular and inter molecular interactions between the fluorinated polymer segments and the main chains, have higher chemical resistance, weather resistance and low coefficient of friction, surface energy and dielectric constant (Teng *et al.* 2012). Fluoropolymers are currently used in various industries. One of the major application is in the textile industry where it is used as fabric protector and to give water repellent properties to the fabric. In poly fluoroalkyl acrylate PFA-Cy (where *y* is the

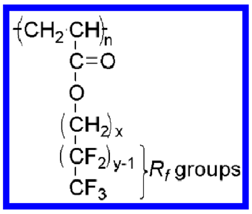

Fig. 1 Chemical Structure of poly (perfluoroalkyl acrylate)s [PFA-Cy, where y is the fluoromethylene number of the Rf Groups] (x=1 for y=1 and 2, x=2 for y=4, 6, 8, and 10) (Honda *et al.* 2005)

Table 1 Properties of Portland Pozzolana cement (PPC)

Sr. No	Characteristics	Values obtained experimentally	Value Specified by IS : 1489-1991 (Part 1)
1	Standard consistency, (percent)	35.5	-
2	Fineness of cement as retained on 90μ Sieve (percent)	2	2-5
3	Specific gravity	2.98	-
4	Soundness of cement (mm) (by Le-Chatelier apparatus)	2	10
5	Initial setting time (minutes)	110	30 (minimum)
6	Final setting time	400	600 (max)
7	Compressive strength (N/mm^2)		
	7 days	23.82	22 (mini)
	28 days	44.24	33 (mini)

fluoromethylene number of the Rf groups) with 'y' grater than or equal to eight has high water repellent property (Honda *et al.* 2005). The Fig. 1 shows the chemical structure of perfluoroalkyl acrylate copolymer.

When fluorolpolymers are added in cement mortar its action with cement is similar to that of acrylic resins and results in bonding between cement and waterproofing particles (Krishnan *et al.* 2013).

In the present paper effect of addition of different percentages of fluoropolymers viz. 0%, 10%, 20%, and 30% and different curing conditions, i.e., 1 day wet 27 days dry and 7 days wet and 21 days dry, on the mechanical and durability properties of mortar has been presented.

2. Experimental program

In the present study an experimental program was planned to investigate the effect of addition of fluoropolymer emulsion and different curing conditions on compressive strength, split tensile strength and permeability of cement mortar. The description of various materials which were used in this study is given below:

2.1 Cement

Portland Pozzolana Cement (PPC) of ACC make conforming to Indian Standard IS:1489-1991 (Part 1), from a single lot and free from lumps was used throughout the course of the investigation. The physical properties of the cement as obtained from various tests conducted in accordance with relevant IS standards are given in Table 1.

Table 2 Physical properties of fine aggregate

Sr. No	Characteristics	Values
1	Type	Natural Sand
2	Specific gravity	2.62
3	Water absorption	1.02 %
4	Moisture content	0.12%
5	Fineness modulus	2.22
6	Grading zone	III

Table 3 Composition/Information on Ingredients of Fluoropolymer Emulsion (AsahiGuard E-series (AG-E400))

Sr. No.	Name	%weight
1	Fluoropolymer	-
2	Emulsifier	-
3	Dipropylene glycol	5.4
4	Acetic acid	> 0.1

Table 4 Physical and chemical properties of fluoropolymer emulsion (AsahiGuard E-series (AG-E400))

Sr. No.	Properties	Value
1	Appearance	Milky white emulsion
2	Odour	Glycol odour
3	ph	Acidity
4	Flash point (method)	> 1000C (Extimate)
5	Specific gravity	1.00-1.10
6	Solid Content	20%
7	Ionic charge	Weakly Cationic
8	Solubility	Easily diluted in water(Dispersible)
9	Solvent Content	Dipropylene glycol 5.4%

2.2 Fine aggregates

Locally available natural riverbed sand, light brown in colour, was used as fine aggregates. Sieve analysis and physical properties of fine aggregate obtained, on testing as per IS: 383-1970, are shown in Table 2.

2.3 Water

Potable water free from any detrimental contaminants was used for casting and curing specimens.

2.4 Fluoropolymer emulsion

In the experimental program**,** the commercially available fluorocarbon based product AsahiGuard E-series (AG-E400), used as water repellant in the fabric industry, the synonym fluoropolymer emulsion was used. Fluoropolymer emulsion was milky white in colour as shown in Fig. 2. The fluoropolymer used is thermoplast elastomer. The

Fig. 2 Fluoropolymer emulsion (AsahiGuard E-series (AG-E400))

composition/information on ingredients, physical and chemical properties (as provided by manufacturer) of AsahiGuard *E*-series (AG-E400) synonym fluoropolymer emulsion is given in the Tables 3-4.

3. Results and discussion

To achieve the objectives of the present study firstly effect of addition of different percentages (viz. 0%, 10%, 20% and 30%) of fluoropolymer on the workability of the mortar was studied by performing flow test on the fresh mortar. It was observed that with the addition of the fluoropolymers the workability of the mortar increases tremendously. This increase in workability may be due to fact that the fluoropolymer particles are smaller than both the cement & sand particles and thus act as ball bearings providing hinge type action and hence increasing the workability and entrained air in fluoropolymer modified mortar. Moreover, fluoropolymer emulsion used in the study has 74.5% water content, this results in an increase in total water content in mortar, hence workability. So, it was decided that in the further course of study the flow value of the mortar will be kept in range of 100±5_mm. To achieve this the water content to be added in the mortar was adjusted for each percentage addition of flouropolymer by trial and error so that flow value remains in the desired range. The water content calculated for different percentage additions of flouoropolymer is shown in Table 5.

In a further study keeping the flow value in the range of 110±5 mm eighteen specimens using cement mortar ratio 1:2 (by weight) were cast for each property to be investigated i.e. compressive strength, split tensile strength, RCPT and sorptivity. Out of theses eighteen specimens for each property nine were cured wet for 1 day and dry for 27 days, whereas other nine specimens were cured wet for 7 days and dry for 21 days. All specimens were tested after 28 days of curing

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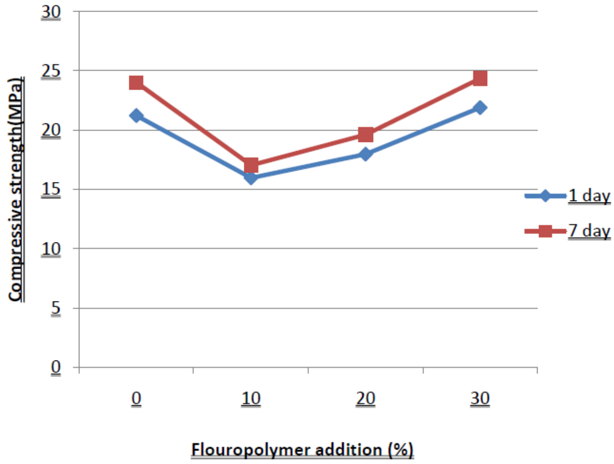

Fig. 3 Comparison between 1 day wet 27 day dry curing and 7 day wet 21 day dry curing conditions for compressive strength tested at 28 days

Table 6 Comparison between 1 day wet 27 days dry curing and 7 days wet 21 days dry curing conditions for compressive strength tested at 28 days

Sr. No.	Specimen	Compressive strength after 28 days (N/mm^2)	
		1 day curing 27 dry	7 days curing 21 dry
1	F-0	21.23	24.02
2	F-10	15.97	17.05
3	F-20	17.97	19.62
4	F-30	21.90	24.35

3.1 Compressive strength

To study the effect on compressive strength, three cubes (size 70.6×70.6×70.6 mm) each for percentage, i.e. 0, 10, 20 and 30 percent of polymer contents (designated as F-0, F-10, F-20, and F-30 respectively) for both curing conditions i.e., 1 day wet 27 days dry & 7 days wet 21 days dry, were cast keeping workability constant as described above. The results of compressive strength (average of three) for the specimens under different curing conditions are shown in Table 6 and and Fig. 3

From the test results it can be observed that specimens cured wet for 7 days and dry cured for 21 days have 7-13 percent higher strength as compared to specimens cured wet for 1 day and dry cured for 27 days. Further, it can be observed that for both the curing conditions compressive strength decreases with the addition of 10 percent fluoropolymer. However, with the increase in percentage addition of fluoropolymer from 10 to 20 and 30 percent the compressive strength increases and it becomes almost equal to that of the control specimen at 30 percent addition.

3.2 Split tensile strength

To study the effect on split tensile strength, three cylinders (size 100 mm dia.×200 mm height) each for

Table 7 Comparison between 1 day curing 27 day dry and 7 day curing 21 day dry curing conditions for split tensile tested at 28 days

Sr. No.	Specimen	Split tensile after 28 days (N/mm^2)	
		1 day curing 27 dry	7 day curing 21 dry
1	F-0	1.38	1.59
2	F-10	1.31	1.47
3	F-20	1.76	1.92
4	F-30	2.06	2.31

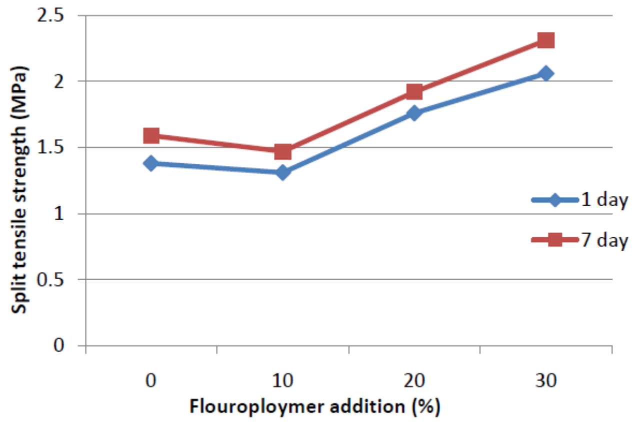

Fig. 4 Comparison between 1 day curing 27 day dry and 7 days curing 21 days dry curing conditions for split tensile tested at 28 days

varying percentage, i.e., 0, 10, 20, 30 percent of polymer contents for both curing conditions, i.e., 1 day wet 27 day dry & 7 day wet 21 day dry, was cast keeping workability constant as described earlier. The results of split tensile strength of the specimens under different curing conditions are shown in Table 7 and Fig. 4.

Results show the similar trend as observed for the compressive strength, i.e., splits tensile strength of all specimens cured under curing condition 2 is higher than that for curing condition 1 by 12-15 percent. The spilt tensile, on line with compressive strength, also decreases on the addition of 10 percent fluoropolymer and thereafter increases with increases in percentage addition of fluoropolymer to 20 and 30 percent. The percentage increase in split tensile strength is of the order of 20-27.5 percent and 45-50 percent on addition of 20 and 30 percent fluoropolymer respectively.

3.3 Durability properties

Durability of fluoropolymer modified cement mortar was evaluated by performing sorptivity and rapid chloride permeability test (RCPT).

3.3.1 Sorptivity

To determine the sorptivity of mortar, three cylinders (100 mm diameter×200 mm height) each for a varying percentage of polymer contents, i.e., 0, 10, 20, 30 percent for both curing conditions i.e., 1 day wet 27 days dry & 7 days wet 21 days dry, were cast keeping workability

Table 8 Results for Sorptivity test of Fluoropolymer Emulsion modified cement mortar specimens 1 day curing 27 day dry

Sr. No.	Specimen	Dry weight W_1 (gm)	Wet weight W_2 (gm)	$\Delta W = W_2 - W_1$ (gm)	Sorptivity Value (cm/√sec)
1	F-0	806	824	18	0.402
2	F-10	763	772	9	0.210
3	F-20	814	818	4	0.093
4	F-30	803	805	2	0.046

Table 9 Results for sorptivity test of fluoropolymer emulsion modified cement mortar specimens 7day curing 21 day dry

Sr. No.	Specimen	Dry weight (W_1)gm	Wet weight (W_2)gm	$\Delta W = W_2 - W_1$ (gm)	Sorptivity value(cm/√sec)
1	F-0	815	826	11	0.256
2	F-10	780	786	6	0.139
3	F-20	775	778	3	0.070
4	F-30	758	759	1	0.023

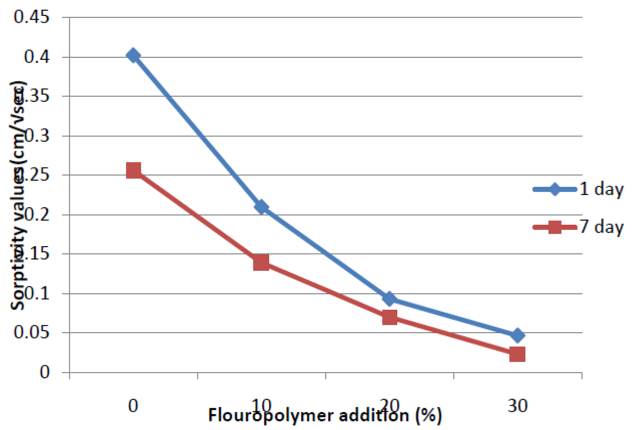

Fig. 5 Results for sorptivity test of fluoropolymer emulsion modified cement mortar specimens 7day curing 21 day dry

constant. The cast cylinders were cut longitudinally and samples of (size 100 mm dia. ×50 mm height) was immersed in water for 30 minutes. The results are shown in Tables 8, 9 and Fig. 5.

From the test results it can be observed that sorptivity value, which indicate the amount of water absorbed in capillary suction, decreases drastically from 0.402 to 0.046 and 0.256 to 0.023 for curing condition one and two respectively, when percentage addition of fluoroplomer has been increased from 0 percent to 30 percent. However, as in the case of strength properties, sorvitivity for the second curing condition is always less than that for curing condition one irrespective of percentage addition of fluoropolymer.

3.3.2 Rapid chloride permeability test

To study the effect on permeability, three cylindrical specimens of size 100 mm×200 mm were cast for each percentage of fluoropolymer contents, i.e., 0, 10, 20, 30 percent for both (1 day wet 27 day dry & 7 day wet 21 day

Table 10 Results for rapid chloride permeability test of fluoropolymer emulsion modified cement mortar specimens 1 day curing 27 day dry & 7 day curing 21 day dry

Sr. No.	Specimen	Total charge passed after 6 hours (Coulombs)	
		1 Day curing 27 day dry	7 Day curing 21 day dry
1	F-0	5678	3348
2	F-10	2383	1459
3	F-20	1127	519
4	F-30	978	429

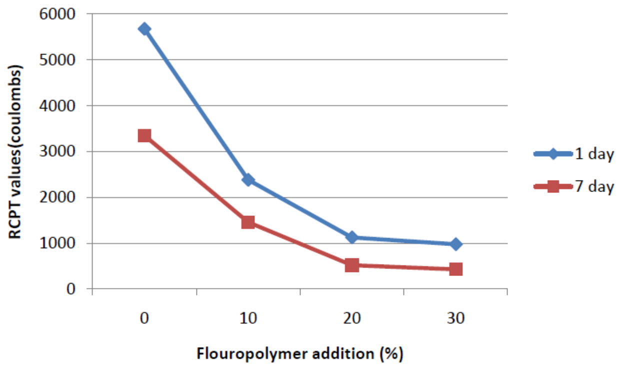

Fig. 6 Results for rapid chloride permeability test (RCPT) of fluoropolymer emulsion modified cement mortar specimens 1 Day curing 27 day dry & 7 day curing 21 day dry

dry) curing conditions, at constant workability. The specimens were tested after 28 days of curing as per ASTM C 1202-97. The rapid chloride permeability test results under different curing conditions are shown in Table 10 and Fig. 6 and it is observed that:-

In control mixture, chloride ion permeability is higher as compared to fluoropolymer modified cement mortar for both 1 day wet & 27 day dry & 7 day wet 21 days dry curing conditions. For all the percentage addition of fluoropolymer chloride ion permeability of mortar decreases and becomes very low (<1000, as per ASTM C 1202-97 criteria) on addition of 30% fluoropolymer for curing condition one and 20% for curing condition two.

4. Discussion of results

The experimental results indicate that with the addition of fluoropolymer in cement mortar, irrespective of type of curing conditions used, firstly both compressive and split tensile strength decreases. However, with the increase in percentage addition of the fluoropolymer both strengths starts increasing. The permeability of the cement mortar on the addition of fluoropolymer decreases drastically irrespective of percentage of polymer added and keeps on decreasing with an increase in percentage addition of fluoropolymers

To understand the changes in the internal structure of the cement mortar on addition of different percentages of fluoropolymer and curing conditions *X*-ray diffraction (XRD) test and scanning electron microscopy (SEM) was carried out. XRD and SEM images obtained are shown in Figs. 7-22 and the appropriate structures are marked over the pictures and their designation as follows:

C: C-S-H GEL
E: ETTRINGITE
V: VOID SPACE
PC: PLATED CRYSTALS (Ca(OH)2)

From the images it can be observed that cement mortar

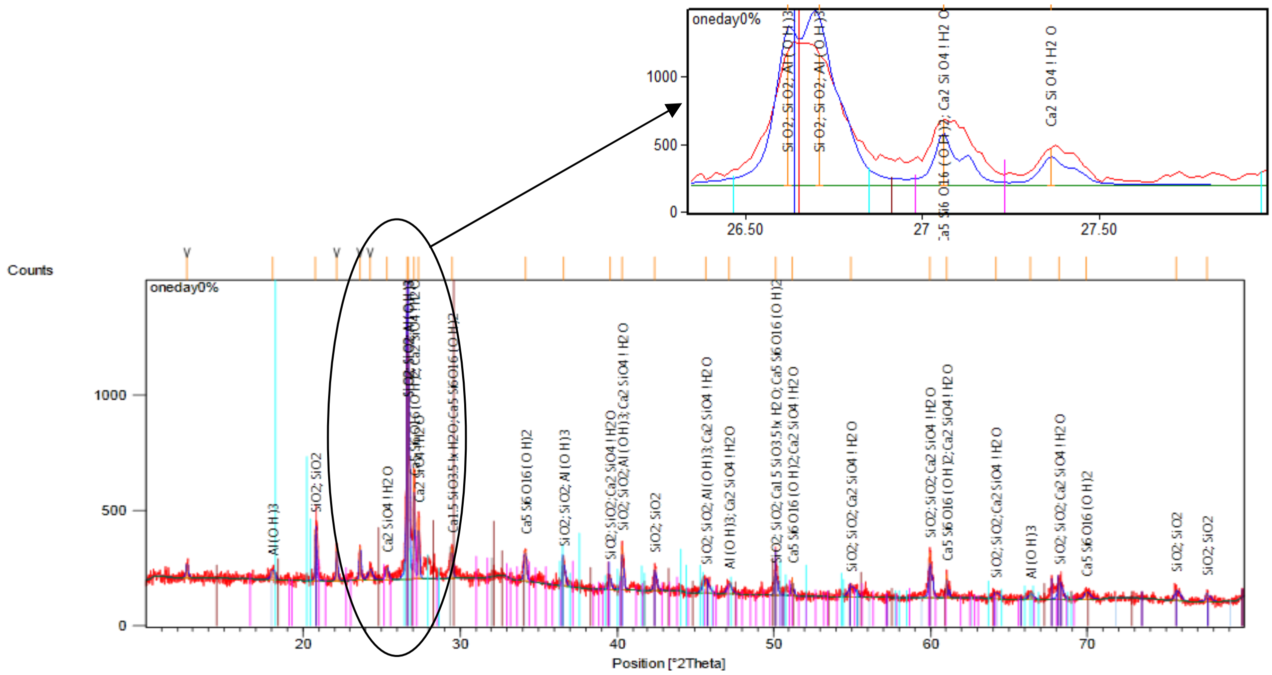

Fig. 7 (a) XRD image of 1 day wet 27 day dry and zero percent flouropolymer specimen, (b) XRD image of 1 day wet 27 day dry and zero percent flouropolymer specimen – maginified view

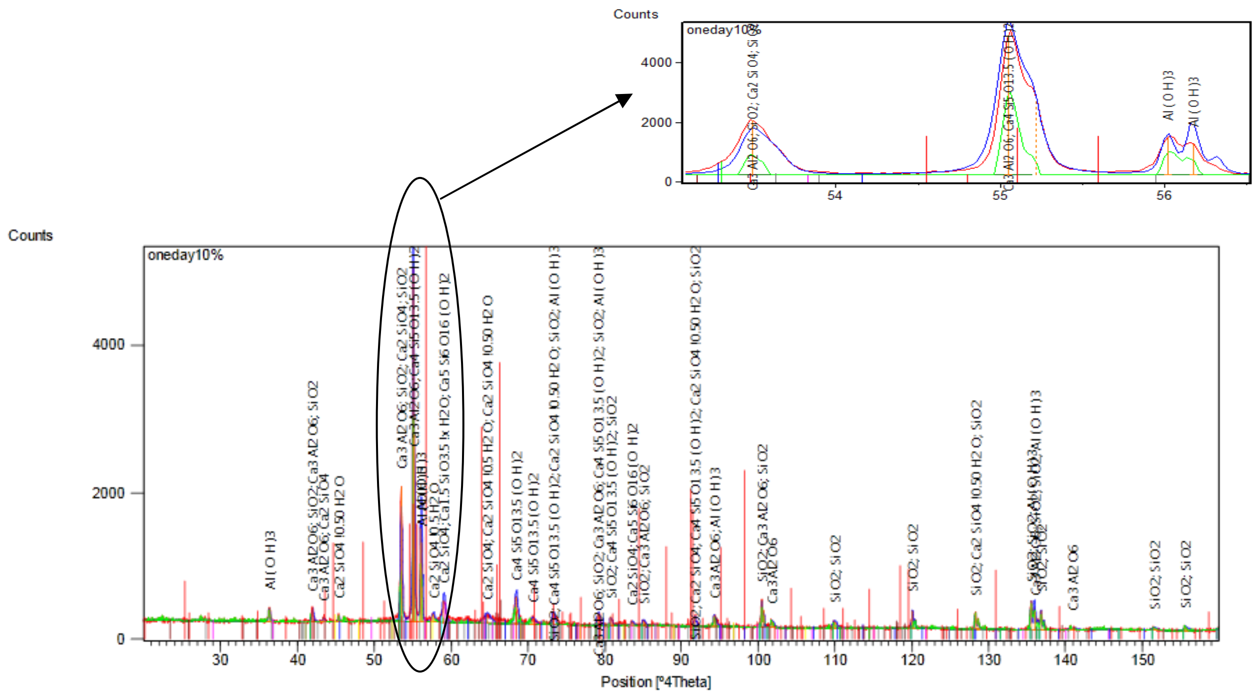

Fig. 8 (a) XRD image of 1 day wet 27 day dry and 10 percent polymer specimen, (b) XRD image of 1 day wet 27 day dry and 10 percent polymer specimen – magnified view

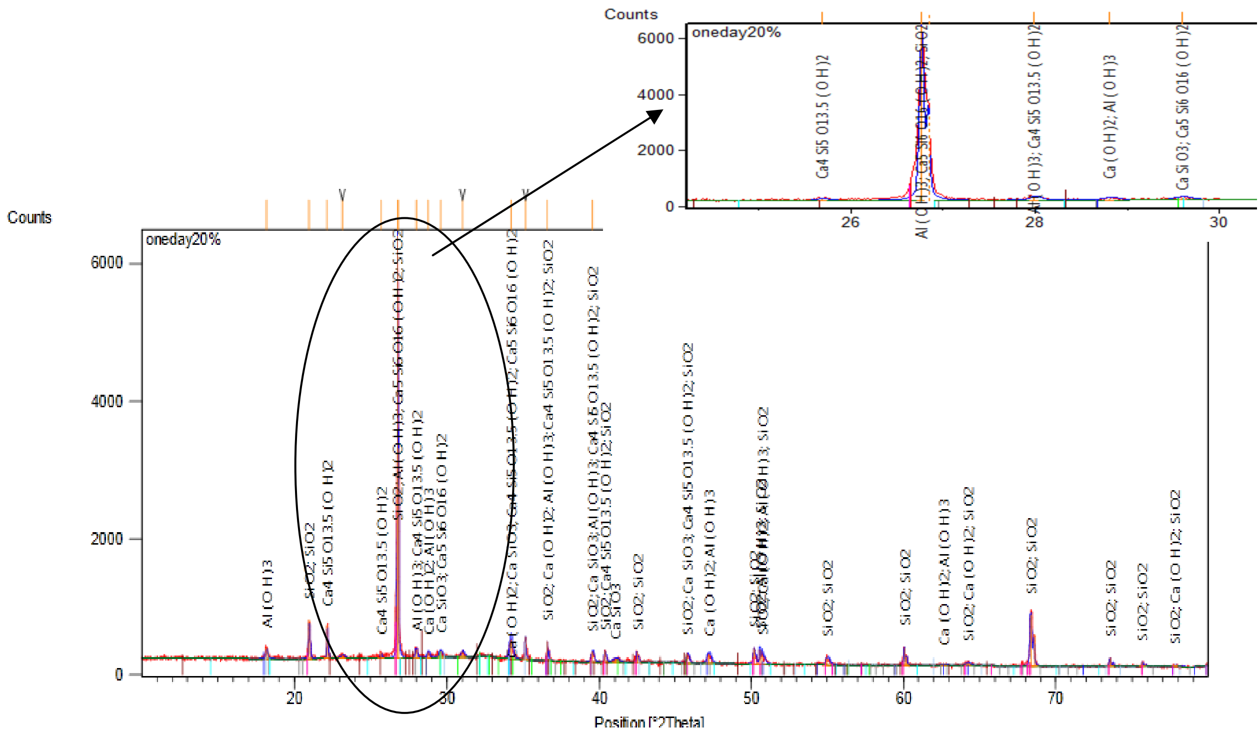

Fig. 9 (a) XRD image of 1 day wet 27 day dry and 20 percent flouropolymer specimen, (b) XRD image of 1 day wet 27 day dry and 20 percent flouropolymer specimen

containing zero percent fluoropolymer has uniformly distributed C-S-H gel. The quantitative analysis of XRD images shows 28 percent and 31 percent C-S-H gel in cement mortar containing zero percent fluoropolymer for curing condition 1 and 2 respectively. On addition, of 10, 20 and 30 percent fluoropolymer in cement mortar this percentage first decreases to 23 and 25 percent, then again starts increasing and reaches to 25, 29 and 29, 31 percent respectively. The SEM results show that with the addition of 10 percent floropolymer in the mortar the percentage of C-S-H gel reduces and needle like structures, i.e., Ettringite starts forming, which is a weak structure, hence leads to

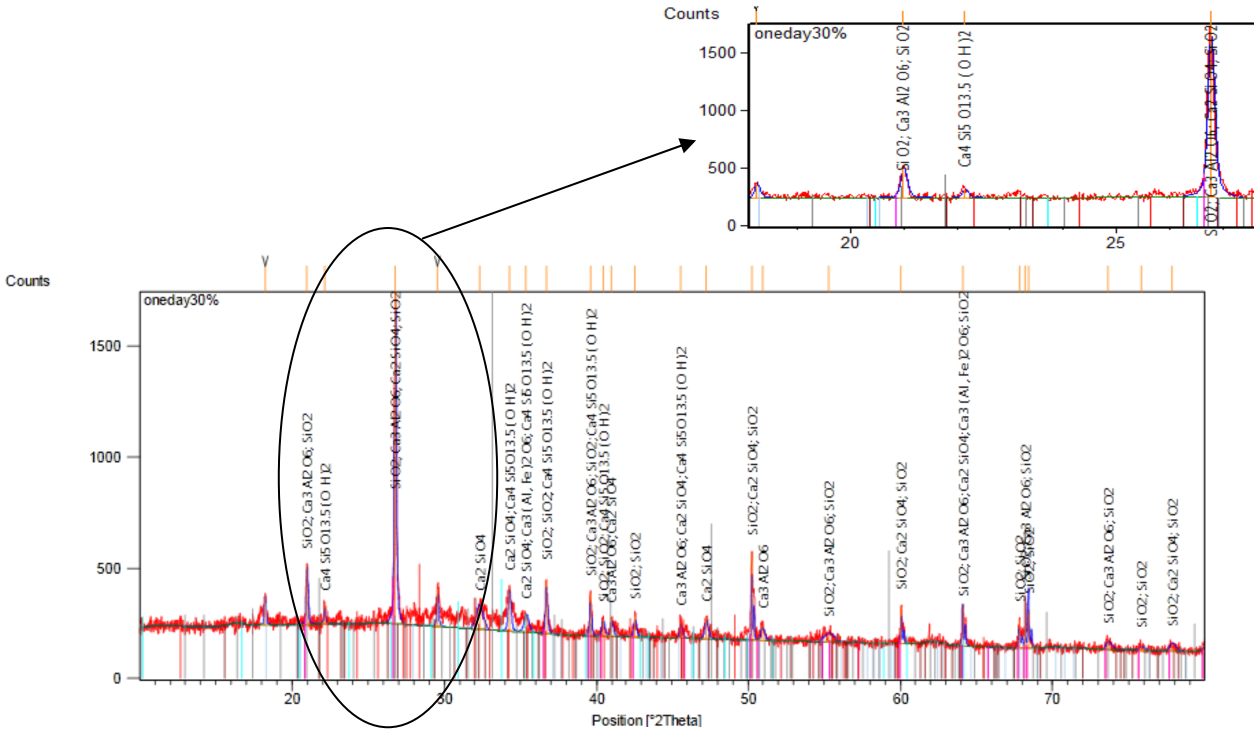

Fig. 10 (a) XRD image of 1 day wet 27 day dry and 30 percent flouropolymer specimen, (b) XRD image of 1 day wet 27 day dry and 30 percent flouropolymer specimen-magnified view

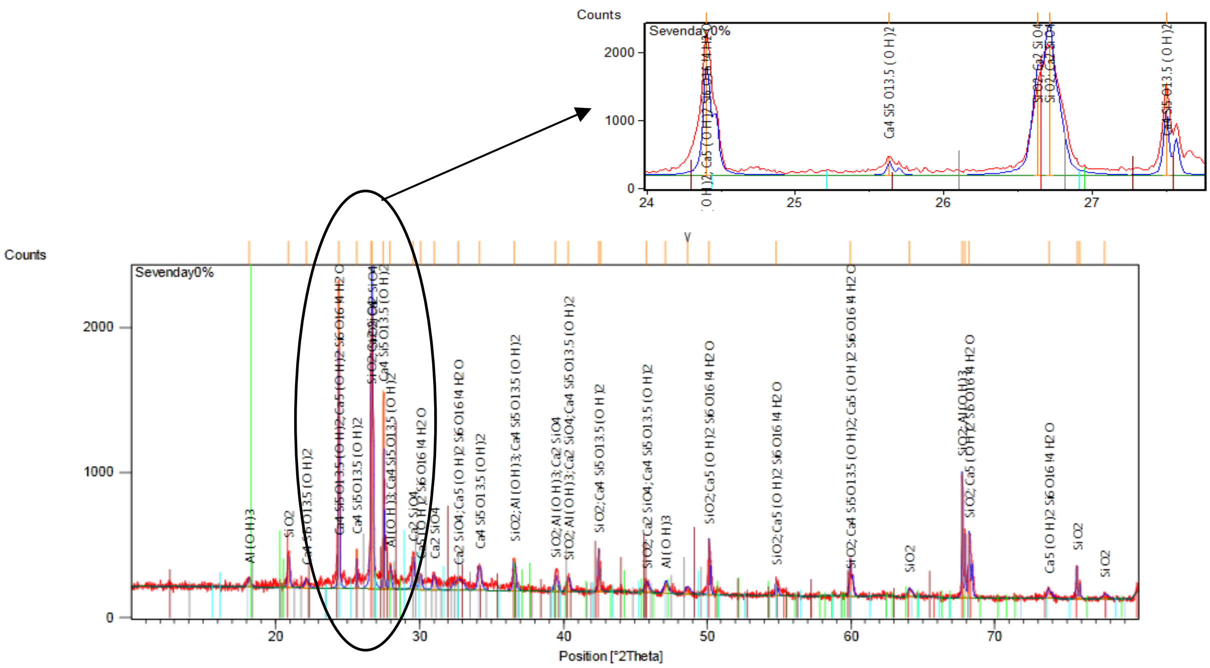

Fig. 11 (a) XRD image of 7 day wet 21 day dry and zero percent flouropolymer specimen (b) XRD image of 7 day wet 21 day dry and zero percent flouropolymer specimen-magnified view

decrease in compressive and split tensile strength. But with the increase in percentage addition of fluoropolymer from 10 to 20 and 30 percent the C-S-H gel percentage again starts increasing and that of Ettringite percentage reduces, hence with an increase in percentage addition of fluoropolymer the compressive and split tensile strength increases.

The decrease in permeability of fluoropolymer modified mortar may be attributed due to filling of small pores between cement and sand by smaller particles of polymers and form monolithic film around the cement and aggregate particles This further results in reduction in micro cracks

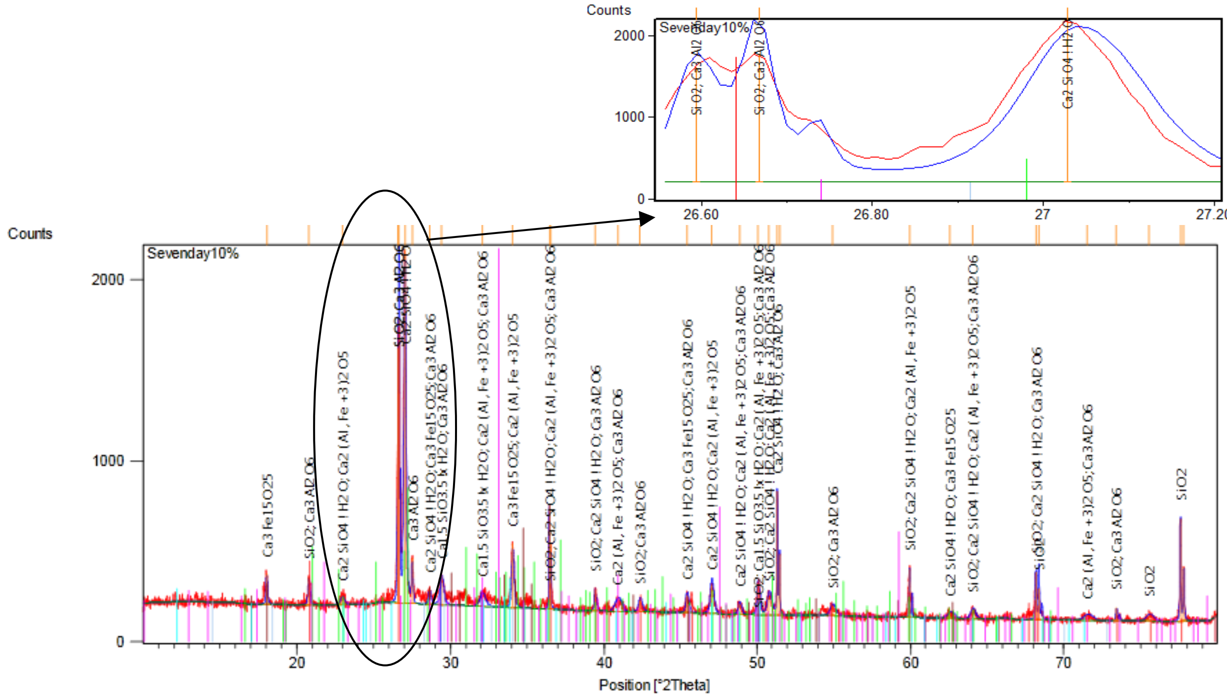

Fig. 12 (a) XRD image of 7 day wet 21 day dry and 10 percent flouropolymer specimen, (b) XRD image of 7 day wet 21 day dry and 10 percent flouropolymer specimen-magnified image

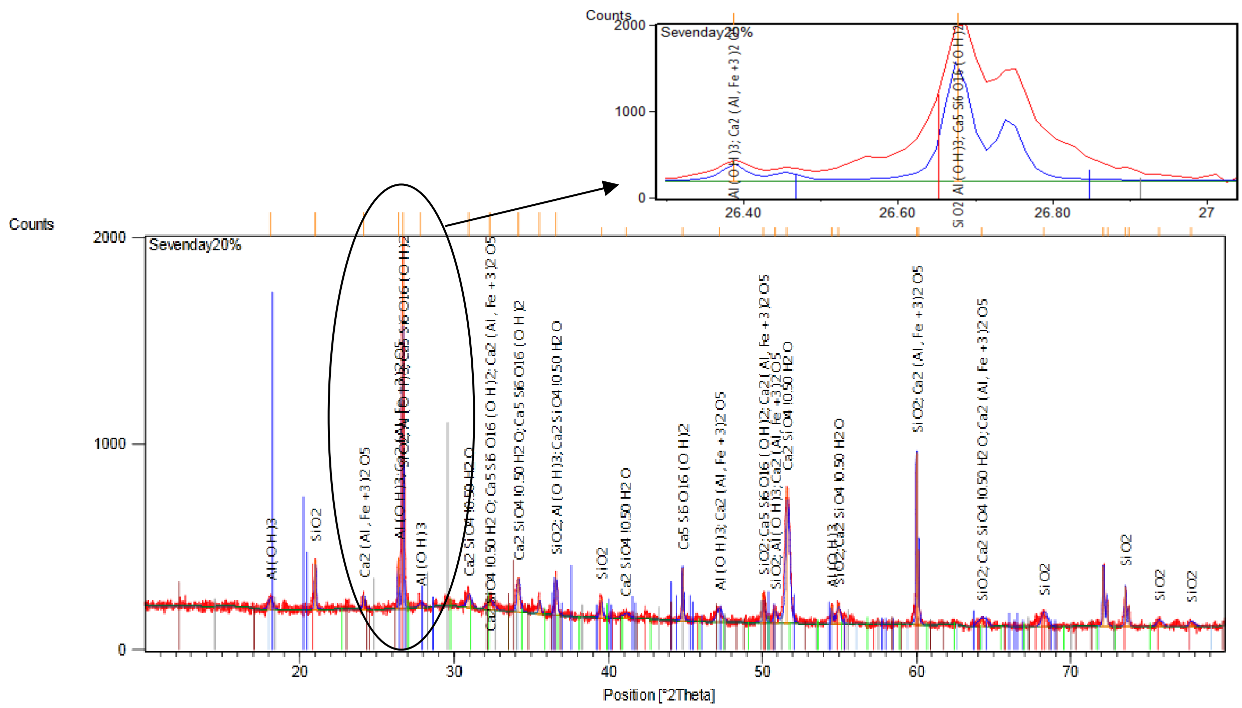

Fig. 13 (a) XRD image of 7 day wet 21 day dry and 20 percent flouropolymer specimen, (b) XRD image of 7 day wet 21 day dry and 20 percent flouropolymer specimen-magnified view

and hence increase in impermeability of mortar.

5. Conclusions

On the basis of the present study, following conclusions can be drawn:-

- The addition of fluoropolymer emulsion in cement mortar improves the workability of mortar.
- On addition, of 10 percent fluoropolymer emulsion in cement mortar firstly, both compressive strength and split tensile strength decreases as compared to control mix due to a formation needle like structure, i.e., Ettringite but with further increase in percentage

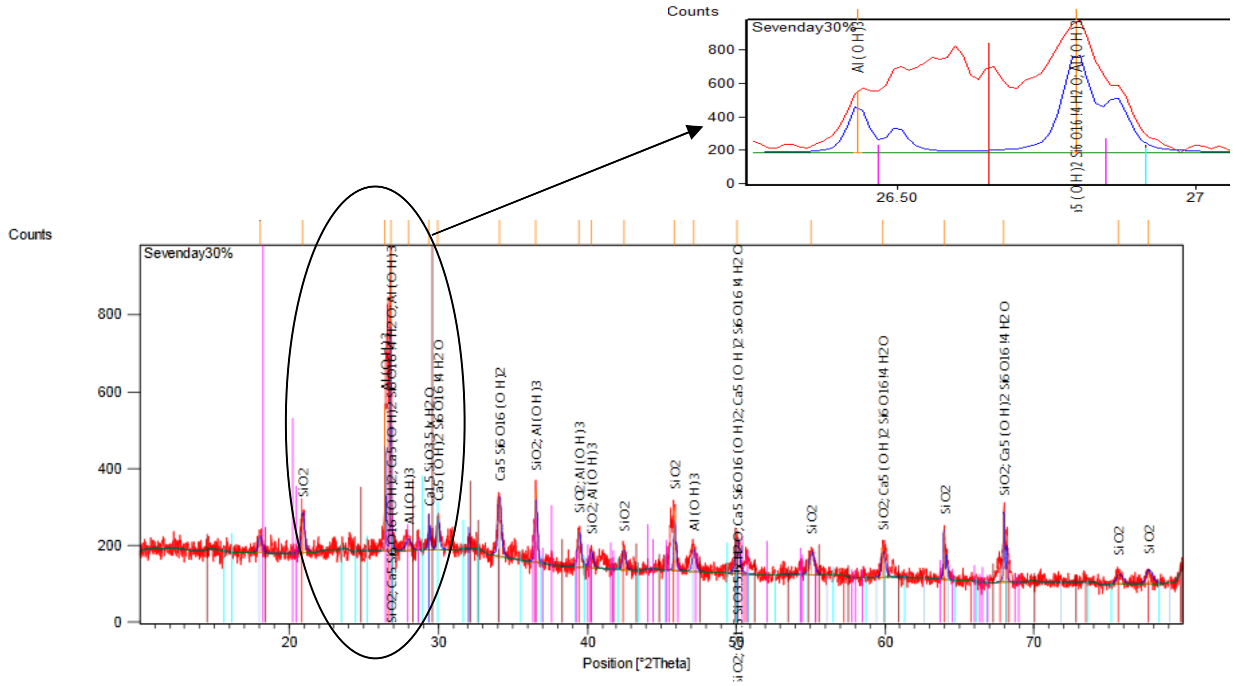

Fig. 14 (a) XRD image of 7 day wet 21 day dry and 30 percent flouropolymer specimen, (b) XRD image of 7 day wet 21 day dry and 30 percent flouropolymer specimen-magnified view

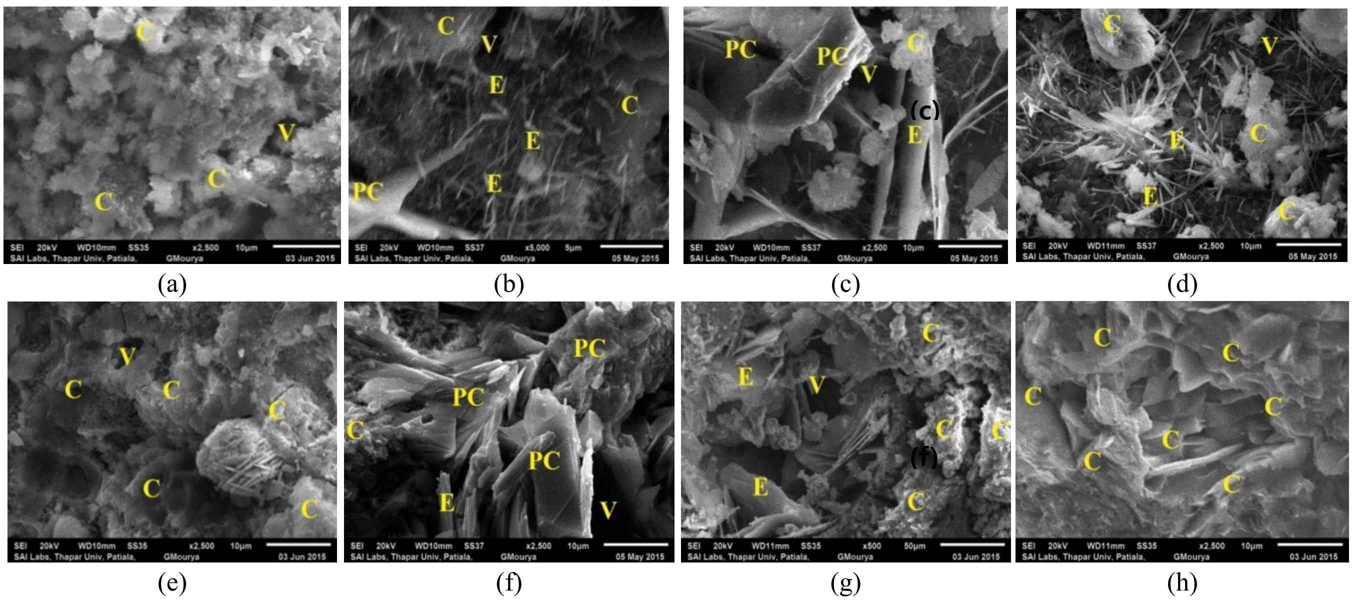

Fig. 15(a) SEM image of 1 day wet 27 day dry and zero percent flouropolymer, (b) SEM image of 1 day wet 27 day dry and 10 percent flouropolymer specimen, (c) SEM image of 1 day wet 27 day dry and 20 percent flouropolymer specimen, (d) SEM image of 1 day wet 27 day dry and 30 percent flouropolymer specimen, (e) SEM image of 7 day wet 21 day dry and zero percent flouropolymer specimen, (f) SEM image of 7 day wet 21 day dry and 10 percent flouropolymer specimen, (g) SEM image of 7 day wet 21 day dry and 20 percent flouropolymer specimen, (h) SEM image of 7 day wet 21 day dry and 30 percent flouropolymer specimen

addition of a fluoropolymer amount of Etteingite starts decreasing which leads to increase in the strength properties of mortar.

• The durability properties, i.e., sorptivity and chloride permeability decreases drastically with the addition of fluoropolymer emulsion in the cement mortar as fluoropolymer particles fill the voids in cement mortar and leading to a dense formation.

• Curing of fluoropolymer modified cement mortar for 7 days wet and 21 days dry as compared to 1 day wet and 27 days dry, shows an improvement in the strength properties and decrease in the permeability of the mortar due to better hydration and formation of more dense structure.

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