Technium Vol. 4, No. 7 pp.11-21 (2022)
ISSN: 2668-778X
www.techniumscience.com

Synthesis, characterization and mechanical study of polypropylene polymer based reinforced concrete with different admixture

Syed Mahmood Mohiuddin Sarmast[1], Anil Kunte[1] and Aashish S Roy[2]
[1] Department of Civil Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University, Vidyanagari, Jhunjhunu, Rajasthan-333001, India
[2] Department of Chemistry, S.S.Tegoor Degree College, Gubbi Colony – 585104, Karnataka, India

Abstract. We have fabricated two different concrete based on polypropylene fibers with three different percentage admixture and water repellent dosages. The mortar mixtures were proportioned with cement to sand ratio of 1:3 and 1:4. The important FTIR peaks indicates that the presence of polypropylene fibers, and water repellent silicon in concrete mixture. The XRD spectra confirmed that the angle 2θ value with corresponding planes are because of mainly tetrahedrally arranged silicate and octahedrally arrangement of aluminate groups in mixed concrete. The reinforced concretes were cast for the same flow level but different percentages of polypropylene fibers (0, 5, 10 & 15%) dosage. The mechanical study proves that the compressive strength and tensile strength of the concretes increases with increase in polypropylene based concrete mixtures up to 10 wt %. However, it is also noted that the admixture significantly enhances the mechanical strength and decreases the early shrinkage of the concrete.
Key words: Polypropylene, Concrete, Admixture, Tensile strength

Author of corresponding: Aashish S Roy
Email id: aashisroy@gmail.com ; **Phone:** +91-9108809031

1. Introduction

Polymers are one of the popular and common materials in the world and it is reported that the global production increases every year by 0.7 %. Worldwide the plastic production reach to 369 million tones which is largely affected the marine animals and plants on earth [1]. The long-term recital of cement bound materials may be compromised, due to their weakness to cracking, which is unswervingly linked to their low tensile strength. Mechanical loading and environmental circumstances may lead to the improvement of tensile stresses in concrete structural elements [2]. When these exceed the tensile strength of the concrete, cracks will build up. The construction of cracks may compromise the overall mechanical performance of a structure, providing easy access for the entrance of water and other agents which may result in the corrosion of reinforcing steel or weakening of other components [3].

The reinforcement of polymer in concrete is not innovative technique. Nowadays, specification, overall performance, manufacturing and conformity of fibers for concrete are strictly prescribed. Though, in beyond few years new fiber kinds have been examined and their programs in concrete were investigated [4]. The Polypropylene makes one of the promising plastic materials to be used in

the concrete due to the high toughness, good fatigue resistance, integral hinge property and good heat and chemical resistance etc [5]. There are some other properties such as semi rigid and optically translucent made it more viable to prepare composite sheets to coat over concrete slab surface [6, 7]. To curtail the negative effect of cracks, the notion of self-healing concrete, i.e. concrete which is able to repair itself without human intervention, has emerged as a possible solution to enhance the durability of concrete structures [8, 9].

Therefore, the author made an attempt to enhance the mechanical strength and significantly enrichment of self healing crack properties using the Polypropylene fiber in different composite with various admixtures. The prepared concrete motors subjected for structural and mechanical studies.

2. Materials and Methods

2.1 Materials

The entire admixtures used for the concrete structural study were industrial grade. The Polypropylene fibers were purchased from Dolphin Floats Pvt Ltd, India having density of 0.9 kg/m^3 with elongation of 19% and 6 mm in length. The Polycarboxylate Ether superplasticizer with purity 98% and density 1.1 g/ml supplied by Chemipol Pvt Ltd, Kothari Group of Industries, India. The bonding agent Styrene – butadiene rubber which has the strength from 500 – 3,000 PSI and elongation is about 635% and water soluble Silane compounds were procured from Mayfare Biotech Pvt Ltd, Mumbai, India.

2.2 Preparation of reinforced concrete

A total of 10 mortar road were cast for two different mix ratios and three different percentage polypropylene polymer dosages. The mortar mixtures were proportioned with cement to sand ratio of 1:3 and 1:4. The reinforced concretes were cast for the same flow level but different percentages of polymer (0 (PP0), 5 (PP1), 10 (PP2) & 15 (PP3 wt %) dosage [10, 11]. Three mortar slabs for a mix ratio of 1:3 (Cement: sand) were exposed to direct heat from the sun and, four mortar slabs for each mix ratio of 1:3 and 1:4 (cement: sand) were kept away from direct heat. The shrinkage and cracks were measured using the aid of measuring scale and use of magnifying lens. The data's were recorded for plastic shrinkage at 5 hours and drying shrinkage at 3, 7, and 28 days [12].

2.3 Composition of admixture

Table 1: Chemical composition in concrete

Concrete code	Polypropylene	Silicon	Polycarboxylates
PP0	0	0.5 wt %	1.6 wt %
PP1	5	0.5 wt %	1.6 wt %
PP2	10	0.5 wt %	1.6 wt %
PP3	15	0.5 wt %	1.6 wt %

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3. Characterization technique

The different functional groups and chemical compositions of the films were investigated by using "Thermo-Nicolet 6700 FTIR (Japan) spectrophotometer". The XRD is used to determine the mineralogical composition of the raw material components as well as qualitative and quantitative phase analysis of multiphase mixtures. The occurrences of minerals in clay were identified by comparing 'd' values. The identification of powdered concrete was performed using X'Pert pro X-ray diffractometer with nickel filter. Diffraction data were obtained by exposing the samples to Cu-Ka X-rays, which has a characteristic wavelength of 1.5414 A˚.). The diffractograms were recorded in terms of 2u between 208 and 808 ranges. The two-wave-plate compensator (TWC) technique is introduced for single-point retardation measurements using Birefringence Measurement Systems, Hinds Instruments, India. The resolution of the TWC is shown to be 0.001 nm. TWC enables the measurement of sample retardation with as little as 0.13% errors and thus is more accurate than either the Brace–Köhler or the Sénarmont method. The morphology of the polypropylene polymer based reinforced concrete in the form of powder deposited on glass going to investigated using Philips XL 30 ESEM scanning electron microscope (SEM). The prepared concrete samples have been subjected for mechanical study using Universal Testing machine (UT – 2080) has loading accuracy well within ±1% with 1000 Kgf load capacity system provided by U-CAN DYNATEX INC, Taiwan Central Science Park, Taiwan.

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4. Results and Discussions

4.1 Fourier transform infrared (FTIR) spectrometer

Figure 1 shows that the FTIR spectra of polypropylene fiber doped concrete with different percentages. The important peaks observed at 405.39 cm^{-1} corresponding to Si – O out of plane deformation, 606.72 cm^{-1} due to the Al – O, CO_3 and Si = O rocking and stretching in plan of symmetry, 684.51 cm^{-1} for Si – OH stretching and bending, 841.91 cm^{-1} for C – C stretching, 908.71 cm^{-1} for CH_3 rocking, 1233.58 cm^{-1} for C – H wagging in plane, 1223.26 cm^{-1} for CH_2 symmetrical bending, 1414.03 cm^{-1} due to CH_3 symmetrical bending, 1625.25 cm^{-1} for C – O bending, 2856.09 cm^{-1} for CH_3 asymmetry stretching, 3762.06 cm^{-1} for O – H bending. These important peaks indicates that the presence of polypropylene fibers, water repellent silicon in concrete mixture [13 – 17].

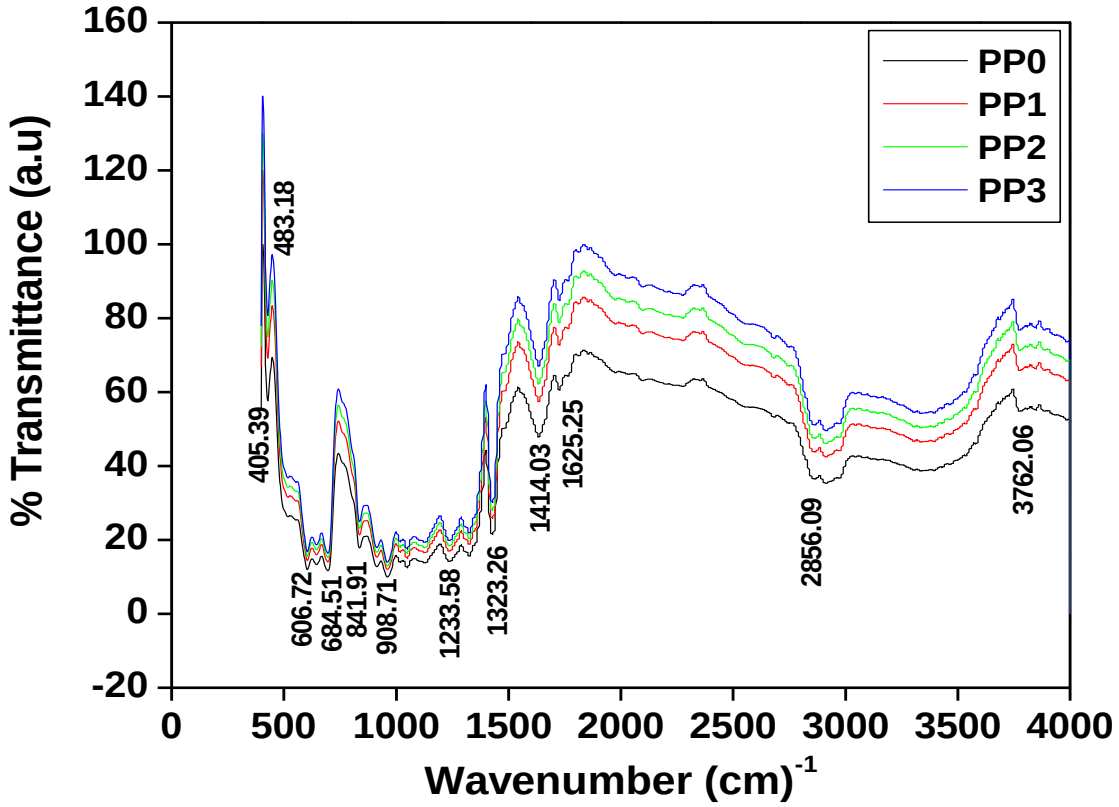

Figure 1 shows that the FTIR spectra of polypropylene fiber doped concrete with different percentages.

4.2 X-ray's diffraction studies

Figure 2 shows the XRD spectra of the concrete with mixture of various weight percentages of admixtures and PP2 (10 wt %) mixed concrete with mixture of various weight percentages of admixtures. It is observed that the angle 2θ value at 18.64Å, 25.13 Å, 30.6 Å, 35.18 Å, 44.5 Å, 48.26 Å, 53.73 Å, 56.42 Å and 62.56 Å corresponds to (111), (112), (220), (311), (222), (400), (411), (422), (511) and (440) are because of mainly tetrahedrally arranged silicate and octahedrally arrangement of aluminate groups in mixed concrete [18].

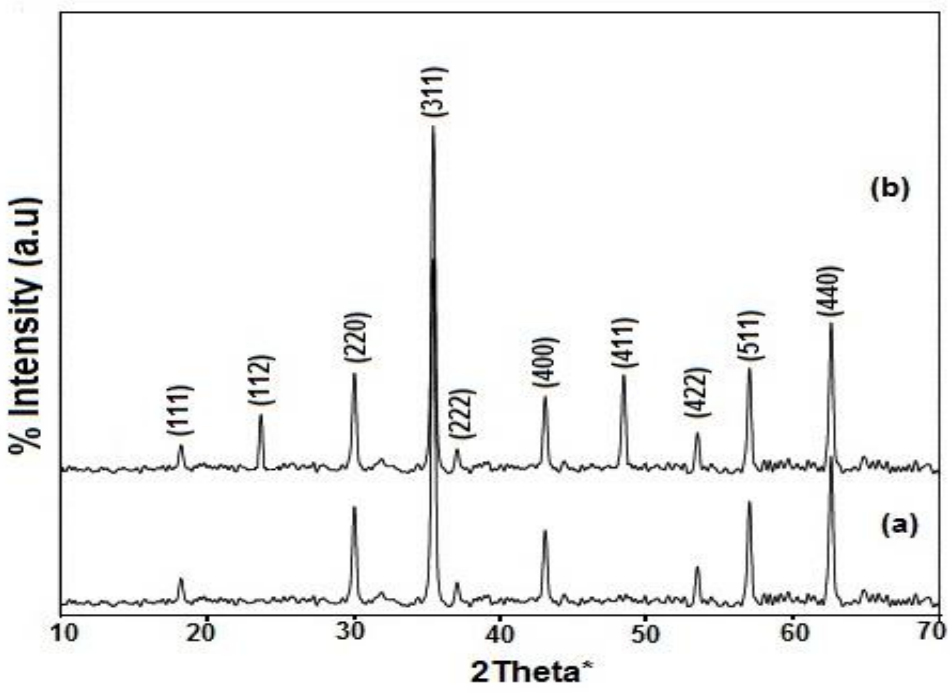

Figure 2 shows the XRD spectra of the concrete with mixture of various weight percentages of admixtures and PP2 (10 wt %) mixed concrete

4.3 Scanning electronic microscopy

Figure 3 shows that the SEM image of concrete with mixture of various weight percentages of admixtures and PP-2 (10 wt %) mixed concrete with mixture of various weight percentages of admixtures. It is observed that the admixture significantly affect the boundary of the clay and cement concrete materials [19]. The image (a) indicates that the clay do not homogeneously mixed with concrete may be due to the indifference surface interaction with the cement materials. However, the presence of polypropylene fiber with silicon in the concrete influence the formation of proper mixing without any aggregate as shown in figure (b) [20].

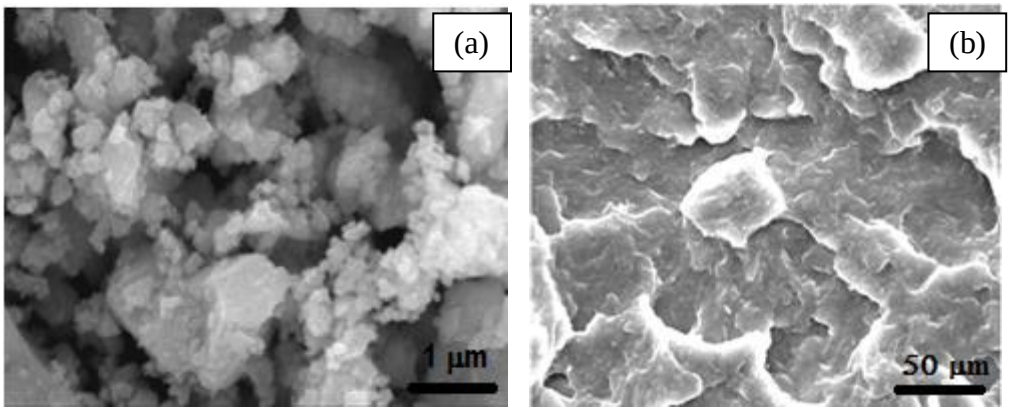

Figure 3 shows that the SEM image of (a) pure concrete without admixture and (b) Concrete with mixture of PP-2 (10 wt %) polypropylene

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4.4 Early shrinkage study

The test is in conformity with the International standard ASTM-C-426 for early shrinking. The equipment for the early shrinkage stages by measuring either decrease in the length or volume of a material resulting from change in moisture content or chemical composition. The height of the blocks is 30 cm and the diameter of the top and bottom of the cone is 10 cm and 20 cm, respectively as shown in digital image (a – d).

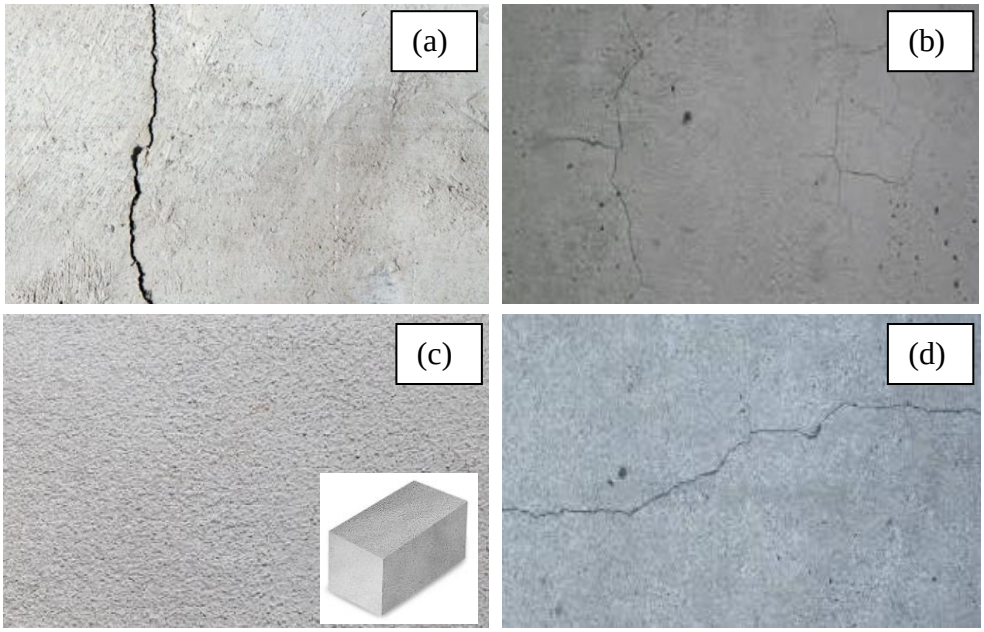

Figure 4 shows the early crack on block surface of (a) pure concrete without admixture (b) 5 wt % of polypropylene (c) 10 wt % of polypropylene and (d) 15 wt % of polypropylene with required weight percentages of admixture in concrete.

Table 2: Shrinkage times up to 21 days for all the polypropylene fibers composition

Time in days / Samples shrinkages in mm	**0 wt %**	**5 wt %**	**10 wt %**	**15 wt %**
3 days	0	0	0	0
7 days	0.14	0.031	0	0.041
15 days	0.25	0.043	0.013	0.083
21 days	0.68	0.048	0.013	0.094

5. Mechanical study

Figure 5 shows that the variation of compressive strength against different weight percentages of polypropylene. It is observed that the compressive strength of the concrete increases with increase in polypropylene weight percentages up 10 wt % for required quantity of admixture added to it. The compressive strength of the concrete enhanced may be due to the capillary contraction and reduce the

porosity of the concrete. It is also important to note that the above 10 wt % of the polypropylene increases the slump loss and causes cracks over the concrete surface. The addition of admixture and water repellent in concrete outcome synergetic effects on compactness and reduction of porosity results increase in compressive strength [21].

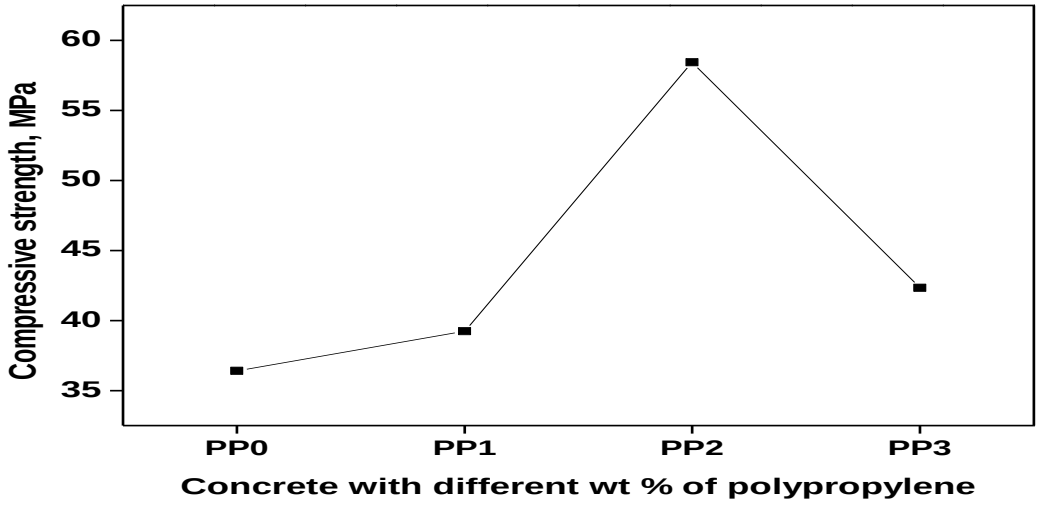

Figure 5 shows that the variation of compressive strength against different weight percentages of polypropylene.

Figure 6 shows the tensile strength of the concrete block with different weight percentages of polypropylene. It is found that the tensile strength of the polypropylene loaded concrete increases with increase in polypropylene for 10 wt %. In flexure tensile test, equal loads are applied at the distance of one – third from both of the beam supports. The loading on the block is increased such that the rate of increase in stress in the bottom lies within the range of 0.02 MPa. It is observed that the concrete has ability to resist the elongation due to tension stress and therefore the concrete has weak in tension whereas strong in compression strength [22]. Another reason to increase the tensile strength is due to the presence of polycarboxylate ether as super plasticizer and silicon oil as water repellent compound which helps in the reduction of capillary size and increase the compactness of the concrete results higher tensile strength [23].

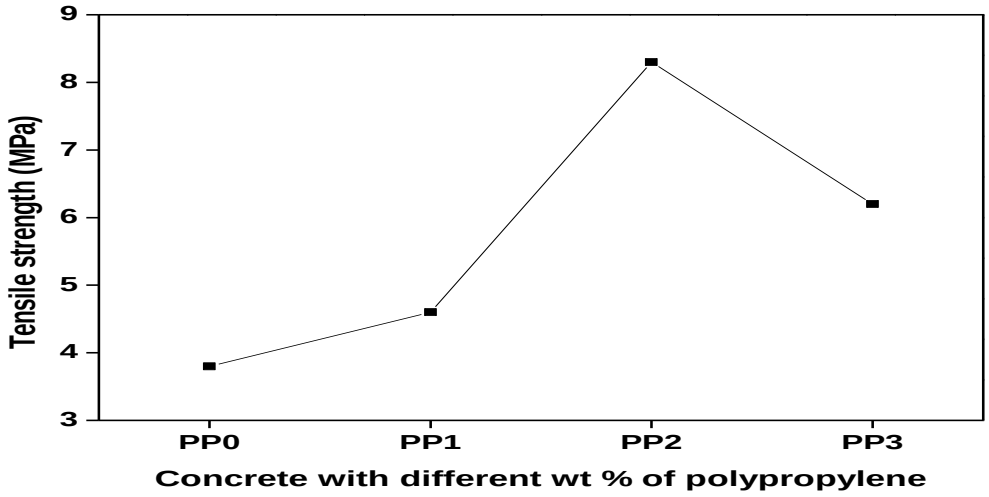

Figure 6 shows the tensile strength of the concrete block with different weight percentages of polypropylene.

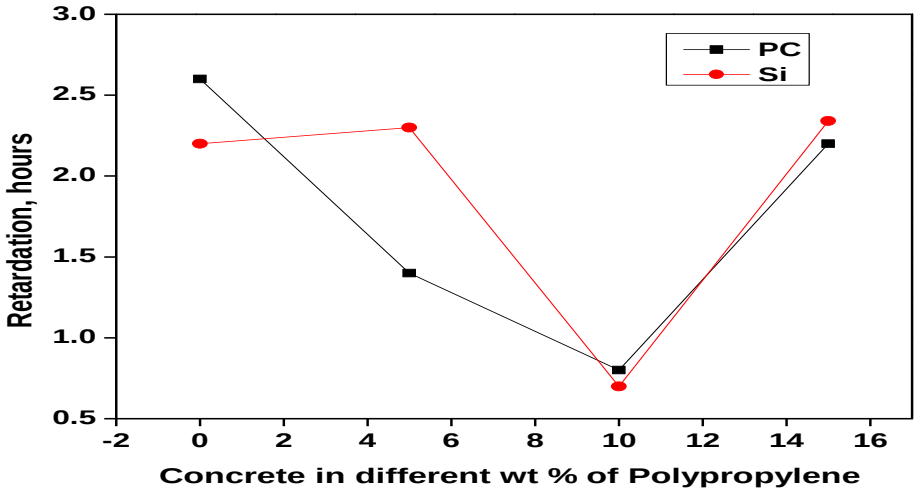

Figure 7 shows the variation of retardation of polypropylene based concrete with different ratio of admixture and water repellent agent.

Figure 7 shows the variation of retardation of polypropylene based concrete with different ratio of admixture and water repellent agent. It is observed that the retardation of the concrete decreases with increase in polypropylene weight percentages up to 10 wt %. The differences in the water demand affected the hydration products and strength development in these systems. Regarding the microstructure studies, it was revealed that C-S-H and C-A-S-H gels prevail in high calcium and silicon systems, whereas in silicon- and aluminum rich systems (N,C)-A-S-H and C-A-S-H gels predominated. However, the early stage compressive strengths indicated a very promising performance from the application point of view [24].

6. Conclusion

The two different concrete based on polypropylene fibers have been prepared with three different percentage admixture and water repellent dosages. The mortar mixtures were proportioned with cement to sand ratio of 1:3 and 1:4. The reinforced concretes were cast for the same flow level but different percentages of polypropylene fibers (0, 5, 10 & 15%) dosage. The mechanical study proves that the compressive strength and tensile strength of the concretes increases with increase in polypropylene based concrete mixtures up to 10 wt %. However, it is also noted that the admixture significantly enhances the mechanical strength and decreases the early shrinkage of the concrete. The important FTIR peaks indicates that the presence of polypropylene fibers, and water repellent silicon in concrete mixture. It is confirmed that the angle 2θ value with corresponding planes are because of mainly tetrahedrally arranged silicate and octahedrally arrangement of aluminate groups in mixed concrete. The surface morphology study confirms that the presence of polypropylene fiber with silicon in the concrete influence the formation of proper mixing without any aggregate. The compressive strength of the concrete increases with increase in polypropylene weight percentages up 10 wt % for required quantity of admixture added to it and concrete strength enhanced due to the capillary contraction and reduces the porosity of the concrete. The differences in the water demand affected the hydration products and strength development in these systems. Regarding the microstructure studies, it was revealed that C-S-H and C-A-S-H gels prevail in high calcium and silicon systems, whereas in silicon- and aluminum rich systems (N,C)-A-S-H and C-A-S-H gels predominated.

Availability of data and material: Data underlying the results presented in this paper are not publicly available at the time of publication, which may be obtained from the authors upon reasonable request.

Competing interests: This is to inform you that author and co-authors do not have any financial or non-financial and even direct or indirect conflict of interest.

Funding: No funding from any agency

Author's information (including Author's position):
Syed Mahmood Mohiuddin Sarmast, Research Scholar, Department of Civil Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University, Vidyanagari, Jhunjhunu, Rajasthan-333001, India
Dr.Anil Kunte, Professor, Department of Civil Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University, Vidyanagari, Jhunjhunu, Rajasthan-333001, India
Aashis S Roy, Professor, Department of Chemistry, S.S.Tegoor Degree College, Gubbi Colony – 585104, Karnataka, India

Authors' contributions
Syed Mahmood Mohiuddin Sarmast has fabricated the hybrid concrete and written the manuscript
Dr.Anil Kunte has constructed the manuscript and analysis the results
Dr.Aashis S Roy has helped in characterization of the hybrid concrete

7. Reference

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Submitted: 07.04.2022
Revised: 15.07.2022
Accepted: 03.08.2022