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Using Polypropylene Fibers in Concrete to achieve maximum strength

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Abstract- Polypropylene is a thermoplastic polymer utilized as a part of wide assortment of uses including bundling, materials (e.g., ropes, warm clothing and covers). Polymer cement is a piece of gathering of cements that utilizes polymers to supplement bond as a cover. The sorts incorporate polymer-impregnated solid, polymer cement, and Polymer-Portland-bond concrete. The aim of the study was to achieve maximum strength of concrete by using optimum weight of polypropylene fibers. Fiber reinforced concrete is used in a variety of engineering applications because of its satisfactory and outstanding performance in the industry and construction field. Polypropylene fiber in concrete mix design is used for multiple purposes that includes rigid pavement, self-compacting concrete and other applications. 40 cylinders of polypropylene concrete were casted and tested for 7 and 28 days' strength for both compressive and split tensile strength. It was concluded that the significant improvement was observed in ultimate compressive strength after 7 and 28 days. The optimum percentage of Polypropylene fiber was obtained to be 1.5 percent of cement by volume. The addition of small amount of polypropylene improved the mechanical properties of concrete.

Key words: Polypropylene, Concrete, fibers, compressive strength, split tensile strength

Introduction:

Cement is an essential construction material around the world. This material that is so vital for construction industry should be endued with most ideal properties *(Zhang, Zhang et al. 2016)*. The standards on which strengthened cement basic outlines were constructed depend on solid material utilized along with quality of steel. Strand in solid enhances the quality of the solid. Concrete, as typical cement-based composite, is composed of cement as binder, coarse aggregate as framework, fine aggregate and fly ash as filler, as well as water and other agents. However, cracks and fissures usually appear on the surface of concrete when it is subjected to tensile or flexural loading due to its poor toughness, thereby resulting in the failure of concrete *(Lura and Terrasi 2014)*. Polypropylene (PP) is a thermoplastic polymer utilized as a part of a wide assortment of uses including bundling materials (e.g., ropes, warm clothing and covers), stationery, plastic parts and reusable compartments of different sorts, research facility gear, amplifiers, car segments, and polymer banknotes. Therefore, in recent years, chopped synthetic fibers, such as polyethylene (PE) *(Wang, Le et al. 2016)*, polyvinyl alcohol (PVA) *(Sahmaran and Yaman 2007)*, polyethylene terephthalate (PET) *(Foti 2011)* and polypropylene (PP) have been added to concrete as reinforcement to enhance the mechanical and engineering properties of concrete. Mechanical properties of concrete, such as residual strength, tensile splitting strength, and flexural strength after heating may also change by including fibers *(Peng, Yang et al. 2006; Tanyildizi 2009)* Micro- and macro-synthetic fibers deal with micro- and macro-cracks, respectively, and some research has been performed to introduce macro-synthetic fibers as a steel fiber-replacement in shotcrete and other structural applications *(Oh, Park et al. 2005; Oh, Kim et al. 2007; Suji, Natesan et al. 2007)*. Depending on their shape and geometry, the fibers are capable of considerably enhancing the ductility, impact resistance, fracture energy, fire resistance, and durability of concrete *(Oh, Park et al. 2005; Oh, Kim et al. 2007)*. Due to their low modulus of elasticity relative to that of steel fibers as well as their crimped shape, macro-synthetic (macro-polymeric) fibers demonstrate higher deformation at peak load, toughness, post-cracking load carrying capacity, and reduced crack width *(Yang, Min et al. 2012)*. Among various fibers, macro-polymeric and polypropylene fibers as synthetic fibers have been attracting increasing attention of researchers due to their lower cost and weight, resistance against corrosion and acids, excellent toughness, and enhanced shrinkage cracking resistance *(Alhozaimy, Soroushian et al. 1996; Banthia and Gupta 2006).* Various researchers have discussed the mechanism of fiber matrix interaction by using various models to compute the bonding between the fibers and cement matrix. The bonding of fiber and the cement matrix plays a major role in the composite behavior. The fibers can interfere and cause finishing problems. Thirumurgan at el. *(Thirumurugan and Sivakumar 2013)* reported that workability of concrete decreases with increase in polypropylene fibers but it can be overcome by addition of high array water reducing admixtures. To improve workability of concrete, more water is added but this can lead to reduction in compressive strength. The decrease in strength can be due to additional water or due to an increase in entrapped *(Balaguru and Shah 1992)* . Kumar et al carried out experimental investigations on M15, M20 and M25 grade fly ash concrete reinforced with 0%, 0.5%, and 1% polypropylene fibers. It was observed that the compressive strength also increased with the rise up to 1% in fiber content for all the three grades of concrete. Murahari and Rama Mohan Rao *(Murahari and Rao 2013)* tested 500 x 100 x 100 mm specimens under three-point loading in accordance with ASTM C78. The observations showed that the flexural strength increased with content up to 0.3 percent. The specimen was observed to gain more strength at 28 days as compared to 56 days. Presence of polypropylene fibers inhibits intrinsic cracking in concrete. Fibers in the matrix increase cohesion and hence the failure is observed to be ductile and gradual for the fiber reinforced deep beams. Peng Zhang and Li *(Peng, Yang et al. 2006)* used 0.04%, 0.06%, 0.08%, 0.1%, and 0.12% of polypropylene fibers in concrete containing 15% fly ash and 6% silica fume. They tested beam specimens under three-point loading and reported that addition of fibers greatly improves the fracture parameters of concrete composite such as fracture toughness, fracture energy, effective crack length, maximum mid-span deflection, critical crack opening etc. The fibers embedded in concrete affect the stress and strain, enhance the stress redistribution and reduce strain localization.

Fiber reinforced concrete was successfully used in variety of engineering applications, because of its satisfactory and outstanding performance in the industry and construction field. Most of the research in the last four decades has been done on mechanical behavior of fiber reinforced concrete and fiber to study how fibers perform so well in concrete. Balaguru performed the uniaxial compression test on fiber concrete and observed that the fibers can affect the facet of uniaxial compressive behavior that involves shear stress and tensile strain *(Balaguru and Shah 1992)*. This observation was made based on the increased strain capacity and also from the increased roughness (area under the curve) in the post-crack portion of the stress-strain curve.

The influence of polypropylene fibers has been studied by using different proportions and lengths of fibers to improve the performance of lightweight cement composites. The fibers used in this study had different lengths (6 mm and 12 mm) while the fiber proportions were 0.15% and 0.35% by cement weight in the mixture design. Compared to unreinforced LWC, polypropylene (PP) reinforced Lightweight Cement Composites (LWC) with fiber proportioning 0.35% and 12 mm fiber length, caused 30.1% increase in the flexural strength and 27% increase in the 17-splitting tensile strength. Increased fiber availability in the LWC matrix, in addition to the ability of longer PP fibers to bridge on the micro cracks, is suggested as the reasons for the enhancement in mechanical properties. All reinforced lightweight concrete specimens displayed improvement in their mechanical strength as a result of fibers performance in cement matrix. Among all fiber proportions and lengths, only the PP fiber with 12 mm length and proportion 0.35% performed better in all respects compared to the physical and mechanical properties of reinforced lightweight concrete*(Bagherzadeh, Pakravan et al. 2012).*

This paper concentrates on the impacts of miniaturized scale manufactured polypropylene fiber in enhancing solid quality. The main concern being the provision of ideal amount of polypropylene fiber for enhanced compressive and flexural quality. This paper concentrates on the impacts of miniaturized scale manufactured polypropylene fiber in enhancing solid quality. The main concern being the provision of ideal amount of polypropylene fiber for enhanced compressive and flexural quality.

Methodology:

Materials

The Ordinary Portland Cement ASTM Type l of Grade: 42.5 with 60 % consistency was used. The coarse aggregate which used were passing from 12.70 mm sieve and retained on 9.52 mm sieve. Other properties of coarse aggregates are as presented in table 1.

Table 1: Properties of Coarse Aggregates

Finenes Modolus	Water Absorption	Specific Gravity	Impact Value	Crushing Value
2.56	2 %	2.44	10 %	20.75%

Fine aggregates from different mineralogical sources, but of similar fineness modulus, were used. Natural siliceous sand having rounded and smooth particles were used as reference sand. Crushed sands were selected with different petrographic characteristics but similar grading curves were used. Highly effective concrete additive Pozzolanic Silica Fume is used as supplementary cementitious material. The physical and chemical characteristics of Portland cement is shown in table 2.

Table 2: Chemical Composition of Portland Cement

Constituent	wt. (%)
SiO_2	19.92
Fe_2O_3	2.09
Al_2O_3	6.54
CaO	64.70
Na_2O	0.28
K_2O	0.84
MgO	1.84
SO_3	2.61
LOI	0.73
C_3S	55.90
C_2S	19.00
C_3A	7.50
C_3AF	9.80

Table 3: Properties of polypropylene fibers

Diameter (D) mm	Length (l) mm	Aspect Ratio (l/D)	Tensile strength MPa	Specific gravity
0.0445	6.20	139.33	308	1.33

Mix Proportion

During the investigations, only cement was replaced by PP fibers keeping other mix design variables, like water–binder ratios, quality of ingredients, mix proportions, including the aggregate–binder and coarse–fine aggregate ratios, dosage of SP, mixing procedures, curing conditions and testing procedures, constant.

The mix proportion is adopted as mentioned in table 4. The experimental program included six sets of concrete mixes, prepared by partial replacement of cement by equal weight of PP fibers. The dosages of fibers were 0% (control mix), 0.5%, 1.5%, 2.5%, 3.5% and 4.5% of the total cementitious materials.

To cope with the workability issues super plasticizers (SP) were used whose dosage was also kept constant for all mixes because of the reason that if the dosage of SP is varied with the fibers replacement percentage, then the variations in the concrete strength will occur not only due to variations in the fiber contents but also due to change in the dosage of SP. The mixing procedure and time were kept constant for all the concrete mixes.

Table 4: Mixes Compositions

PPF (%)	PPF (gm)	SP (ml)	Water (ml)	Wt. of Cement (Kg)	Wt. of Sand (Kg)	Wt. of C A (Kg)	Total Wt. (Kg)	No. Cylinders
0	0	0	8600	17.2	34.3	68.6	128.8	8
0.5	86	170	8600	17.2	34.3	68.6	128.8	8
1.5	258	170	8600	17.2	34.3	68.6	128.8	8
2.5	430	170	8600	17.2	34.3	68.6	128.8	8
3.5	602	170	8600	17.2	34.3	68.6	128.8	8
4.5	775	170	8600	17.2	34.3	68.6	128.8	8

Casting of Concrete Specimens

Cubical concrete specimens, 6” x 6” x 6”, were prepared to determine compressive strength and Cylindrical concrete specimen with 6” diameter and 12” high was made for split tensile strength. The concrete constituents were mixed in a revolving drum type mixer for approximately three to six minutes to obtain uniform consistency. Additional mixing time of about two minutes was provided for the PP fibers cement concrete mixtures to ensure homogeneity. After mixing, the cubical moulds were filled in two layers and fully consolidated on a vibrating table to remove any entrapped air.

Results and Discussions:

Both the compressive and tensile strength of concrete was checked by casting a total of 48 cylinders. A detail of the cylinders casted is shown in the table 5.

Table 5: Detail of Cylinders

Sr. No.	PP (%) fibers	Compressive strength		Tensile strength		Cylinders
		7 days	28 days	7 days	28 days	
1.	0.5	2	2	2	2	8
2.	1.5	2	2	2	2	8
3.	2.5	2	2	2	2	8
4.	3.5	2	2	2	2	8
5.	4.5	2	2	2	2	8
6.	0	2	2	2	2	8
7.	Total					48

40 cylinders of different percentages of polypropylene fibers were casted, cured and tested after 7 and 28 days. 10 cylinders tested after 7 days while other 10 were tested after 28 days for compressive strength. Similarly, 10 cylinders after 7 days and the remaining 10 were tested after 28 days for tensile strength. The strength which they achieve using mix design (1:2:4) are given in the table below.

Table 5: Compressive and Split Tensile Strength of Concrete Cylinders

Sr. No.	P.P fibers (%)	W/c ratio	Compressive Strength (psi)		Split Tensile Strength (psi)	
			7 days	28 days	7 days	28 days
1	0%	0.50	2400	4000	1290	1450
2	0%	0.50	2500	3900	1160	1450
3	0.5%	0.50	2550	4150	1200	1590
4	0.5%	0.50	2700	4300	1300	1550
5	1.5%	0.50	3000	4500	1350	1660
6	1.5%	0.50	2900	4700	1390	1750
7	2.5%	0.50	1890	2700	780	960
8	2.5%	0.50	1700	2900	790	950
9	3.5%	0.50	1670	2600	720	930
10	3.5%	0.50	1590	2600	760	910
11	4.5%	0.50	1195	2200	700	890
12	4.5%	0.50	1275	2050	760	900

Figure 1 illustrates the compressive strength of Polypropylene fibers concrete achieved after 7days. The graph concludes that the strength of polypropylene fiber concrete increase firstly from 0% to 1.5% of propylene fibers. But after 1.5% it was observed that the strength decreases which depicts that 1.5 percent is the optimum value of PP fibers in concrete yielding highest value among all. This value is obtained by averaging the values of the two cylinders which yields 2950 psi.

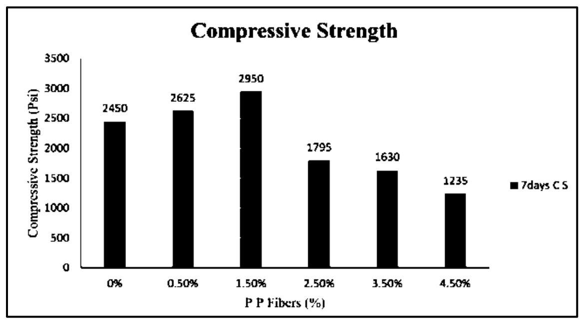

Figure 1: Compressive strength after 7 days curing

Figure 2 demonstrates the compressive strength of polypropylene fiber concrete after 28 days. Similar trend was observed for 28 days strength as depicted by 7 days strength graph. It is concluded that 1.5% is optimum percentage for polypropylene fiber resulting in maximum value of 4600 psi.

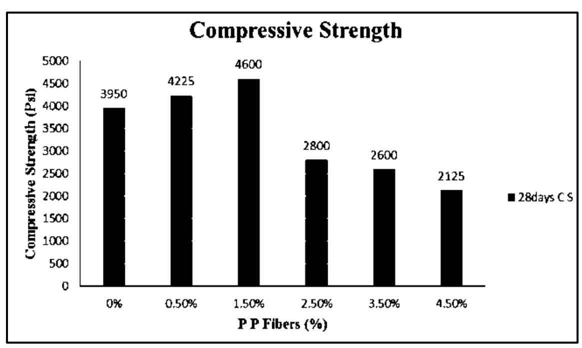

Figure 2: Compressive strength after 28 days curing

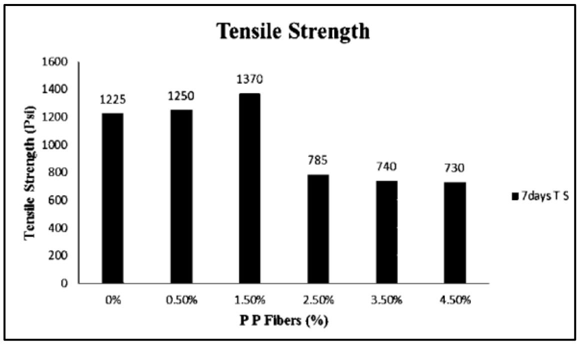

Figure 3: Tensile strength after 7 days curing

Figure 3 shows a similar trend depicting 1.5 percent to be the optimum percentage yielding a value of 1370 psi.

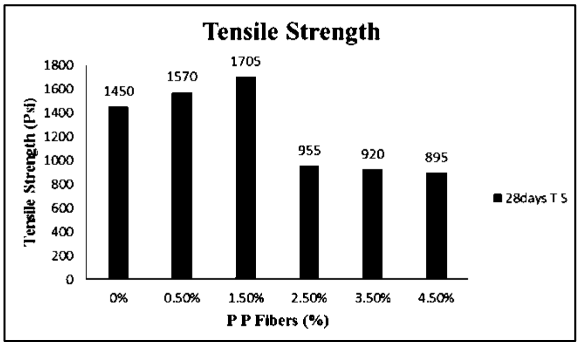

Figure 4: Tensile strength after 28 days curing

Figure 4 depicts the effect of PP fibers on split tensile strength after 28 days. The maximum value obtained for 1.5 percent PP fiber was 1705 psi.

Conclusion:

The use of polypropylene fibers has increased in recent years due to the property of the fibers to eliminate some defects in concrete. The addition of PP fibers to concrete improve its mechanical properties. The high tensile strength as a result of fibers can improve the capacity of the concrete and can control the volume changes with time. From the study it is concluded that inclusion of PP fibers increased the compressive strength by 20% and 16 % after 7 days and 28 days respectively as compared to controlled samples, whereas, 11% and 17% increment was observed in split tensile strength after 7 days and 28 days respectively. The optimum percentage of PP fibers was obtained both in compressive split tensile strength as 1.5% of cement contents. But after 1.5% the decrease is gradual.

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