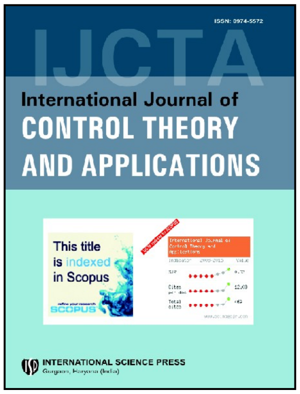

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The Influence of Hyposludge and Polypropylene Fibres on the Mechanical Properties of Self Compacting Concrete

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Abstract: Objective: The main objective of the study is to determine the mechanical parameters of SCC with Ordinary Portland cement and replacing it with different levels of hyposludge and addition of different percentages of Recron 3s fibres.

Method: An investigation on the mechanical properties of M 50 grade Self-Compacting Concrete (SCC) with replacement of cement by hypo sludge, and addition of polypropylene fibres at different percentages. In this study different percentages (2,4,6,8 and 10%) of hypo sludge is replaced in Ordinary Portland Cement and found optimum percentage of hypo sludge as 4.Different percentages (0.2,0.3,0.4 and 0.5% by weight of cement) of Recron 3s polypropylene fibres were added to optimum dosage of hypo sludge (4%) replaced in cement.

Findings: The "compressive strength" "split tensile strength", and "flexural strength" were found on 7, 28 and 56 days. It has been found that usage of Hypo sludge with fibres has beneficial effects on the strength properties of SCC concrete.

Improvements: From this study at 0.3% addition of polypropylene fibres in both cut lengths increases its compressive strength and at 0.4 % increases split tensile strength and 0.3% increases flexural strength of concrete.

Keywords: Hypo sludge; Recron3s polypropylene fibres; "compressive strength"; "split tensile strength"; "flexural strength"; Fibre reinforced concrete.

1. INTRODUCTION

Self-compacting concrete is highly flowable, stable concrete which flows into congested reinforcement without vibration. An International Organization known as EFNARC gives guidelines on the specification and preparation of self-compacting concrete [1]. Hyposludge, an Industrial waste from paper mill is used as cement replacement material in concrete. The concrete is brittle materials with low tensile strength and low shear capacity. However, with the use of fibres, tensile strength increased in brittle materials. American Concrete Institute (ACI) defines Fibre Reinforced Concrete (FRC) made with hydraulic cements, aggregates and discrete reinforcing fibres.

Fibre reinforcement is one of the effective ways to increase the strength properties of SCC [2]. By incorporating polypropylene fibres in SCC increases ductility, load carrying capacity and external post cracking.

N. Dharani, A. Ashwini, G. Pavitha and G. Prince Arulraj prepared M 25 concrete; hyposludge is used as replacement material in cement at 0, 10, 20, 30, 40 and 50%. For each percentage of replacement of cement with hyposludge, Recrons 3s fibres were added at 0.10, 0.21, 0.30 and 0.40%. They conclude 30% replacement of cement by hyposludge is optimum when Recrons 3s fibres are not added and also conclude that 20% replacement of cement by hyposludge is optimum when 0.4% Recrons 3s fibres are added. The addition of Recrons 3s fibres in concrete it is found decrease compressive strength and split tensile strength and increases the flexural strength as fibre content increases [4, 5].

S. Goel, S. P. Singh and S. K. Kaushik [10] studied the flexural exhaustion strength in self-compacting concrete. They compared the flexural exhaustion strength of SCC with normally vibrated concrete (NVC). In their study the materials used for SCC mix, Ordinary Portland Cement [11], class F fly ash, crushed stone aggregates (12.5 mm) and locally available coarse sand. They tested three cubes of size 150×150×150 mm for obtaining its 28 days compressive strength and seven beam specimens of size 100×100×500 mm for static flexural and flexural fatigue tests. They conclude that SCC showed enhanced metrics over its corresponding item NVC.

P. Dinakar, M. Kartik Reddy, Mudit Sharma examine fly ash on self-compacting concrete behaviours with Portland Pozzolana Cement (PPC) substituted with 10 to70% fly ash .They examine the mechanical properties and durability properties of SCC [7]. They observed that fly ash replacement of 30 to 50% would be for progressing SCC while PPC were employed. Hence the optimal fly ash of 30% showed higher compressive potency.

N. Dharani, G. Prince Arulraj and J.Goutham [6] found the mechanical properties of concrete in which Hyposlude and copper slag were as substitution materials for cement and fine cumulative respectively. The replacement of hyposludge in cement is 10, 20, and 30% and better cumulative substitution with copper slag 30, 40, and 50%. They conclude that 10 % replacement of cement by hyposludge yields higher compressive strength and also conclude the optimum percentage of copper slag in fine aggregate is 50%. Optimum of 10% cement substitution with hyposludge and 50% replacement of fine aggregate with copper slag showed increase in flexural strength compared to conventional concrete.

2. METHODOLOGY

(A) Materials used

Cement: Ordinary Portland Cement (OPC) 53 [3] class was employed for M 50 grade concrete conforming to IS: 12269-1987 to cast the specimens. Cement specific gravity is 3.14.

Fine Aggregate: The SCC mixes were prepared by using the clean dry river sand as fine aggregate conformed to IS: 383-1970. Sand specific gravity is 2.65.

Coarse Aggregate: Coarse aggregate of pulverized granite stone conforming to IS: 383-1970 with grain size of max 12.5 mm was employed. Coarse aggregate specific gravity is 2.74.

Water: In general, fresh potable water free from organic matter and oil, is employed in combining the concrete and curing.

Hyposludge: Hyposludge is the primary solid waste material from the paper industry [9]. The presence of silica, magnesium and calcium in hyposludge makes it similar to that of cement, and hence, there is a possibility to replace cement with hyposludge. The hyposludge can minimize the demand for cement and reduce the cost of construction. The chemical properties of hyposludge are given in Table 1.

Table 1
Chemical properties of hyposludge

Constituents	*Percentage (%)*
CaO	49
SiO_2	5.5
Al_2O_3	2
MgO	1.6
Na_2O	1.6
K_2O	1.6

Superplasticiser (SP): In order to improve the workability of SCC, BASF Master Glenium Sky 8777 polycarboxylic ether based superplasticizer was used.

Viscosity Modifying Agent (VMA): In order to control segregation and bleeding from the fresh SCC, BASF Master Matrix 2 (formerly known as Glenium Stream 2) is used as VMA.

Fibre: The polypropylene fibres were used. This fibre was obtained from Reliance Industries Limited and it is named as Recron 3s. The physical and chemical properties of fibres are shown in Table 2.

Table 2
Physical and chemical properties of polypropylene fibres

Product type	*CTP-2012, CTP-2424 Polypropylene*
Cross-section	Triangular
Cut Length	6 mm,12 mm
Diameter	30-35μ
Tensile Strength	4000-6000 kg/cm^2
Melting Point	>250°C
Dispersion	Excellent
Acid Resistance	Excellent

(B) Mixture proportions, mixing process and fresh concrete properties

Mix design followed with the guidelines specific in European Federation offered to special construction chemicals and concrete systems [1]. The design SCC mix 50 MPa was obtained by number of trails with varying quantities of constituent material. The details of designed mix is given in Table 3.For study concerned first identified optimum percentage of utilization of hypo sludge as biased substitution of cement in SCC and add various percentage of Recron 3s fibres. The self-compacting concrete cube specimens were cast with 2, 4, 6, 8 and 10% replacement of cement with hypo sludge as shown in Table 5. Out of above percentages 4% of cement substitution through hypo sludge gives maximum compressive strength and identified as optimum. For this Optimum SCC mix 0.2, 0.3, 0.4 and 0.5% of Recron 3s polypropylene fibres were affixed. The aforementioned mixes are prepared after the 8 trial process. Such mixes can be made possible only by using the appropriate ingredients in proper proportions.

Table 3
Final mix proportions of self-compacting concrete

Cement (kg/m^3)	*F.A (kg/m^3)*	*C.A (kg/m^3)*	*Water (Lit/m^3)*	*W/C Ratio*	*S.P %*	*VMA %*
695.0	985.0	909.0	224.4	0.32	2.0	0.3

The ingredients were thoroughly mixed in the laboratory tilting type mixer in a dry state for about 3 minutes then water was included and blended about 3 minutes. The required quantity of super plasticizer was finally affixed and blended until a monolithic accumulation was obtained. The gain of set time strengthen can be controlled using admixtures and proportioning. Workability tests like slump flow, J-ring, V-funnel and L-box were conducted in conformity with EFNARC guidelines for mixes to ascertain the workability properties of SCC2 shown in Table 4. The mix was then poured into moulds coated with mould releasing agents. The mix was not compacted in the moulds and they were kept in the laboratory environment for about 18 hours until de-moulding sets in. These samples de-moulded and immersed in the potable water for the duration of 7, 28 and 56 days.

Table 4
Workability test results for SCC

Test Method	*Property*	*Unit*	*Value*	*Recommended Values as per EFNARC Guidelines*
Slump flow by Abrams cone	Filling ability	mm	675	650-800 mm
T_{50} Slump flow	Filling ability	sec	3.30	2-5 sec
J-Ring	Passing ability	mm	8.00	0-10 mm
V-Funnel	Filling ability	sec	10.40	8-12 sec
L-Box	Passing ability	h_2/h_1	0.827	0.8-1.0
L-Box T_{20}	Passing ability	sec	3.05	-
L-Box T_{40}	Passing ability	sec	5.40	-

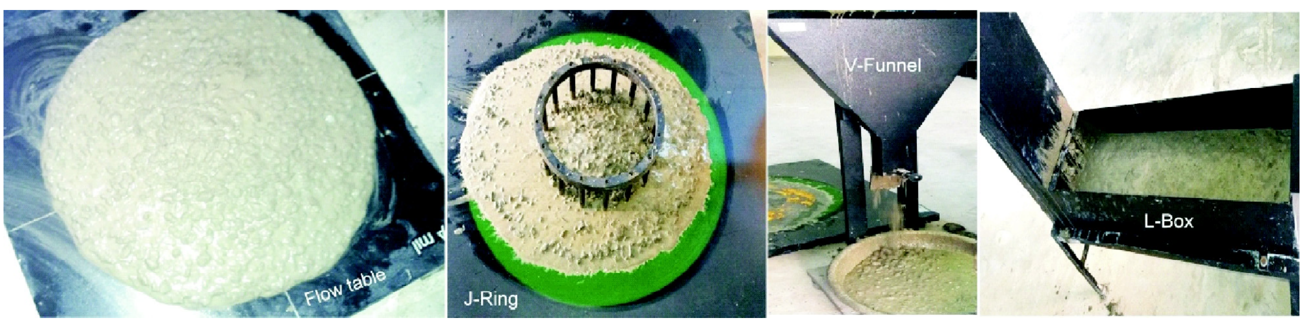

Figure 1: Workability Tests(Flow table, J-ring, V-funnel and L-Box)

Concrete mixes are designated as SCC0 (0% replacement), SCC1, SCC2, SCC3, SCC4 and SCC5 (2%, 4%, 6%, 8% and 10% of hyposludge respectively), FRSCC1, FRSCC2, FRSCC3, FRSCC4, FRSCC5, FRSCC6, FRSCC7, and FRSCC8 (0.2%, 0.3%, 0.4% and 0.5% of Polypropylene fibres of 6 mm and 12 mm cut length respectively).

(C) Test Programme

Determination of Hardened State Properties of SCC

Hardened state properties of these concrete samples were experimented in a compression analysis machine of 2000 kN power. The specimen in the form of a cube 150 ×150 ×150 mm and a cylinder is measuring 150 mm dia×300 mm height and prisms measuring 100 ×100 ×500 mm were taken for testing the "compressive strength", "split tensile strength" and "flexural strength" correspondingly. In this study 111 cube specimens (9 cubes for

SCC0 as conventional mix at 7,28, and 56 days, 36 cubes for SCC1 to SCC5 mixes at 7 and 28 days curing and 72 cubes for FRSCC1 to FRSCC8 mix), were tested for compressive strength [8]. Similarly 81 cylinder specimens and 81 prisms were tested for split tensile strength and flexure strength respectively. The results was obtained in Table 5 and Table 6 taken as an average of three specimens.

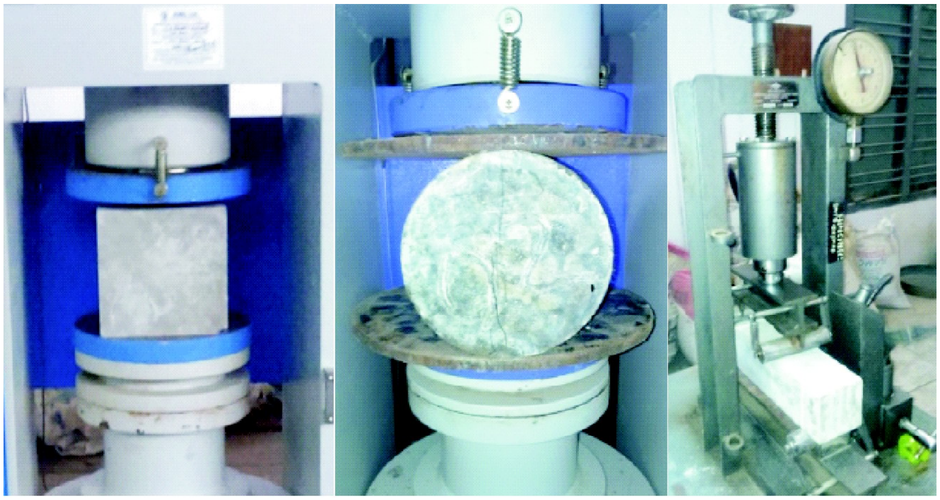

Figure 2: Compression testing, Split Tensile and Flexural Testing

3. RESULTS AND DISCUSSION

(A) Results of Compressive strength

The Compressive strength test results of SCC mix(SCC1 to SCC5) with partial replacement of cement by hyposludge for M 50 grade are tabulated in Table 5 at age of 7 and 28 days. The mixes SCC1 and SCC2 satisfied the target mean strength 58.25 MPa at 28 days. Maximum compressive strength 61.48 MPa (SCC2 mix) obtained at 4 % replacement of hyposludge in cement. The Optimum percentage of Hyposludge was significantly found at 4% replacement of cement. The compressive strength of polypropylene fibre reinforced self-compacting concrete of both cut lengths (FRSCC1 to FRSCC8) tested at 7, 28, and 56 days shown in Table 6.It was observed that the percentage of polypropylene fibres increases the compressive strength decreases. The maximum compressive strength 50.07, 61.48 and 68.59MPa was obtained at 7, 28 and 56 days respectively in FRSCC2 mix for 6 mm cut length with addition of 0.3 % of polypropylene fibres. Similarly the maximum compressive strength 49.48, 64.89 and 69.04MPa was obtained at 7, 28 and 56 days respectively in FRSCC6 mix for 12 mm cut length with addition of 0.3 % of polypropylene fibres.

Table 5
Compressive strength results of hyposludge

S.No	*Mix Details*	*Hyposludge Percentage*	*Compressive Strength N/mm²*	
			7 Days	*28 Days*
1	SCC0	0	42.36	58.67
2	SCC1	2	43.11	59.26
3	SCC2	4	46.96	61.48
4	SCC3	6	42.81	57.33
5	SCC4	8	40.29	56.44
6	SCC5	10	39.70	55.85

(B) Results of "split tensile strength" and "flexural strength"

The split tensile test is simple and reliable method of measuring the tensile strength of concrete. The compression testing machine was used to find the tensile strength of concrete by cylindrical specimens. Cylindrical specimens are tested at 7, 28 and 56 days and tensile strength results are presented in Table 6. Each value in Table 6 represents the average value of three cylindrical specimens. The split tensile strength of polypropylene fibre reinforced self-compacting concrete of both cut lengths (FRSCC1 to FRSCC8) tested at 7,28 and 56 days shown in Table 6. It was observed that the percentage of polypropylene fibres increases the tensile strength of concrete increases at all ages. The maximum split tensile strength 3.62, 4.94 and 5.46MPa was obtained at 7, 28 and 56 days respectively in FRSCC3 mix for 6 mm cut length with addition of 0.4% of polypropylene fibres. Similarly the maximum split tensile strength 3.72 ,5.46 and 5.50MPa was obtained at 7, 28 and 56 days respectively in FRSCC7 mix for 12 mm cut length with addition of 0.4 % of polypropylene fibres. The flexural strength test carried out in flexural testing machine by two point loading method. The flexural strength of concrete was obtained by using prism specimens. The results tested at 7,28 and 56 days are presented in Table 6. Flexural strength of all FRSCC mixes increased with increase in age; the flexural strength of polypropylene fibre reinforced self-compacting concrete of both cut lengths (FRSCC1 to FRSCC8) tested at 7,28 and 56 days shown in Table 6. It was observed flexural strength increases with increase in percentage of polypropylene fibres upto 0.3. Beyond 0.3% fibre content the flexural strength decreased. The variation in the "Compressive strength", "Split Tensile strength" and "Flexural strength" test are represented graphically in figure 3, 4 and 5 respectively.

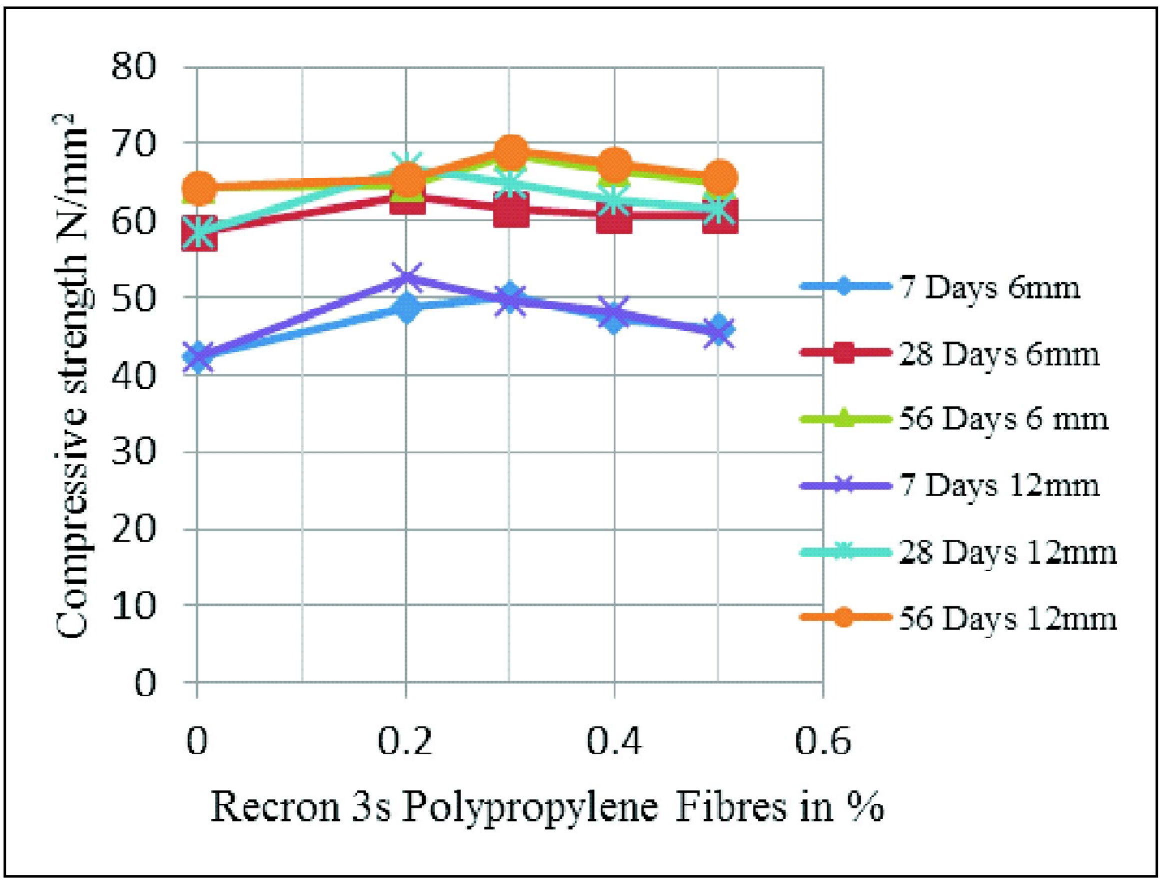

Figure 3: Compressive Strength values of 6 mm and 12 mm Polypropylene fibres

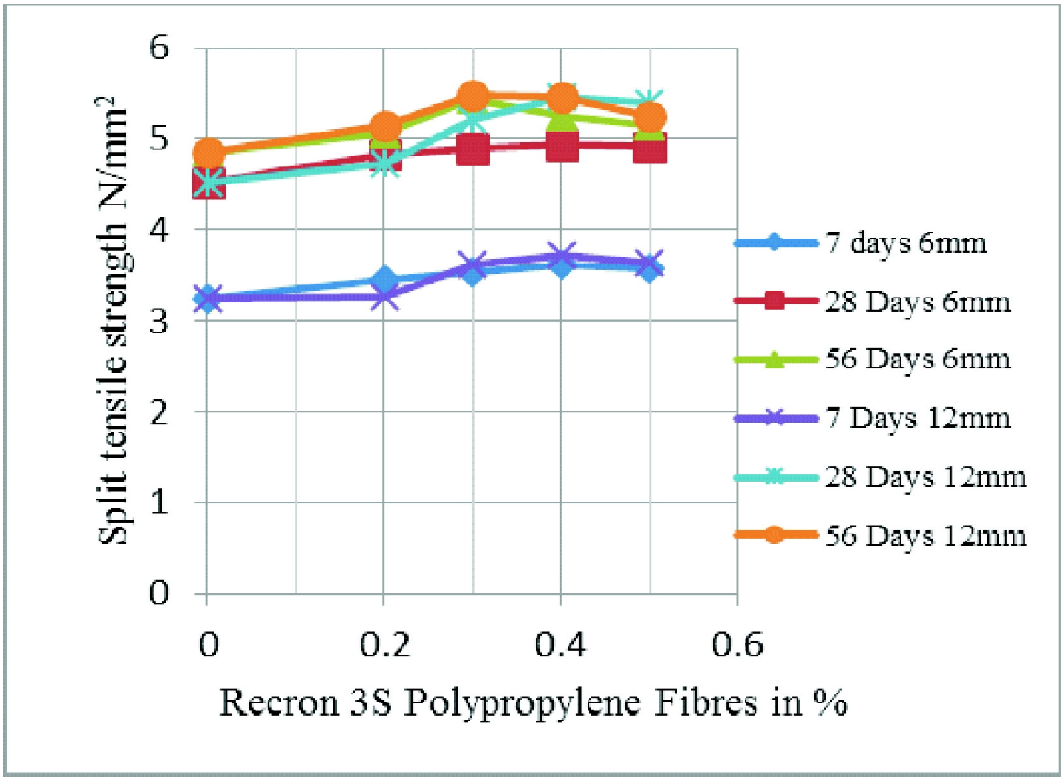

Figure 4: Split Tensile Strength values of 6 mm and 12 mm Polypropylene fibres

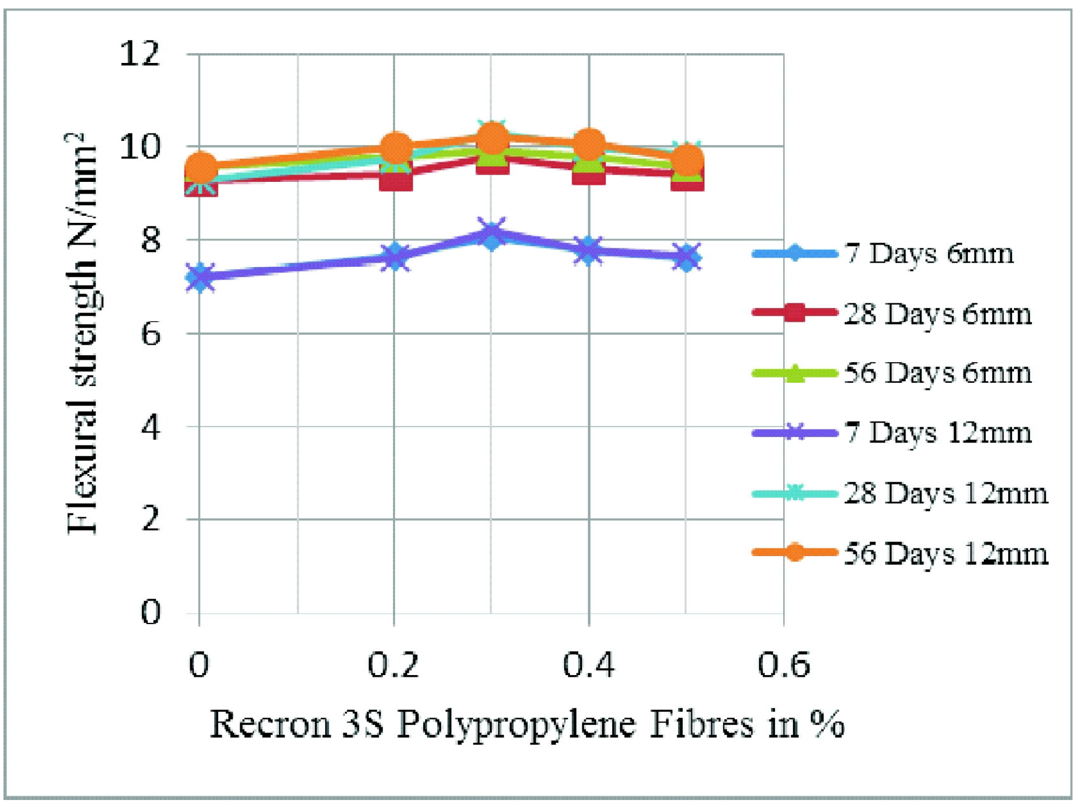

Figure 5: Flexural Strength values of 6 mm and 12 mm Polypropylene fibres

Table 6
Compressive, split tensile and flexural strength results

S.No	*Mix details*	*Fibres Length mm*	*Fibres %*	*Compressive Strength N/mm²*			*Split Tensile Strength N/mm²*			*Flexural Strength N/mm²*		
				7 Days	*28 Days*	*56Days*	*7 Days*	*28 Days*	*56Days*	*7 Days*	*28 Days*	*56Days*
1	SCC0	-	-	42.36	58.67	64.30	3.24	4.52	4.85	7.19	9.30	9.60
2	FRSCC1	6	0.2	48.89	63.26	64.74	3.45	4.83	5.06	7.67	9.40	9.80
3	FRSCC2	6	0.3	50.07	61.48	68.59	3.54	4.89	5.43	8.07	9.80	9.93
4	FRSCC3	6	0.4	47.26	60.88	66.67	3.62	4.94	5.46	7.80	9.53	9.80
5	FRSCC4	6	0.5	45.93	60.74	64.88	3.57	4.91	5.15	7.60	9.40	9.60
6	FRSCC5	12	0.2	52.59	66.96	65.48	3.27	4.71	5.14	7.60	9.75	10.0
7	FRSCC6	12	0.3	49.48	64.89	69.04	3.62	5.21	5.49	8.20	10.27	10.20
8	FRSCC7	12	0.4	48.15	62.67	67.56	3.72	5.46	5.50	7.80	10.0	10.07
9	FRSCC8	12	0.5	45.48	61.63	65.77	3.65	5.39	5.45	7.67	9.83	9.73

4. CONCLUSIONS

The subsequent conclusions are arrived through the above examination:

1. The bleeding and segregation were controlled by dispersion of polypropylene fibres in the concrete mixtures.
2. Optimum percentage of Hyposludge was significantly found at 4% replacement of cement.
3. The maximum compressive Strength of FRSCC occurs at 0.3% polypropylene fibres for both cut lengths in all ages. (FRSCC2 and FRSCC6)
4. The polypropylene fibres accumulation in SCC increases the split tensile strength at all ages in both cut lengths, and maximum split tensile strength occurs at 0.4% polypropylene fibres for both cut lengths in all ages. (FRSCC3 and FRSCC7)
5. The maximum flexural strength of FRSCC was at 0.3% polypropylene fibres for both cut lengths at all ages. The addition of fibres in SCC leads to reduction of crack formation.

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