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RESEARCH ARTICLE OPEN ACCESS

Experimental Investigation on Self Curing Fibre Reinforced Concrete Using Monofilament and Fibrillated Polypropylene Fibre

M.Ramalakshmi,* S.Ravi Shankar**

*(Structural Engineering, Prist University, Madurai Campus, Thanjavur
Email: ramipwd@gmail.com)

** (Department of Civil Engineering, Prist University, Madurai Campus, Thanjavur)

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Abstract:

Self- curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation this is achieved by polyethylene glycol 400. Then fibrous material which increases its structural integrity here the monofilament and fibrillated polypropylene fibres are used to bridging up the micro cracks and post flexural toughness to the structure which enhances the strength, stiffness, ductility. The compressive strength of monofilament polypropylene fibres can be increased by 8.3% and fibrillated polypropylene fibre can be increased by 12.2% as compared to conventional concrete for optimum percentage 1% of PEG 400. The split tensile strength of monofilament polypropylene fibre can be increased by 23.2% and fibrillated polypropylene fibre can be increased by 28.6% as compared to conventional concrete for optimum percentage 1% of PEG 400.

Keywords — **Polyethylene glycol 400, Monofilament Polypropylene fibre, Fibrillated Polypropylene fibre, self curing fibre reinforced concrete, conventional concrete.**

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I. INTRODUCTION

The process of reducing the evaporation of water from the concrete is the principle behind internal curing or self-curing. Self-curing agents forms hydrogen bonds with water molecules and reduces the evaporation loss. Thus it cures itself and forms self-curing concrete. There are two major methods available for self-curing of concrete. The first method is by using saturated porous light weight concrete aggregate to supply internal source of water, which can replace the water consumed by chemical shrinkage during hydration of cement. The second method is done by using Polyethylene Glycol (PEG) which helps to retain water in concrete by reducing the evaporation of water from the surface. Then fibrous material which increases its structural integrity here the monofilament and fibrillated polypropylene fibres are used to bridging up the micro cracks and post flexural toughness to the structure which enhances the strength, stiffness, ductility.

II. MATERIAL PROPERTIES

TABLE.I
PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATES

S. NO	DESCRIPTION	TEST RESULTS	
		Fine aggregate	Coarse aggregate
1.	Type	M-Sand	Crushed
2.	Specific gravity	2.76	2.86
3.	Total water absorption	1%	0.5%
4.	Moisture content	Nil	Nil
5.	Fineness modulus	2.63	
6.	Grading	Zone-II	
7.	Maximum size		20mm

TABLE.II
PHYSICAL PROPERTIES OF MFPPF AND FPPF

S.NO	PARAMETER	VALUE	
		MFPPF	FPPF
1	Melting point	162°C	165°C
2	Specific gravity	0.91	0.91
3	Length	12 mm	12 mm
4	Colour	white	white
5	Diameter	24 micron	30 micron
6	Alkali and acid resistance	100%	100%
7	Water absorption	Nil	Nil

POLYETHYLENE GLYCOL 400 (PEG 400)

Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula $H(OCH2CH2)_n$ OH, where n is the average number of repeating oxy-ethylene groups typically from 4 to about 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weights. One common feature of PEG appears to be the water-soluble nature.

TABLE.III
PHYSICAL PROPERTIES OF PEC400

S.NO	PARAMETER	VALUE
1	Appearance	Clear liquid
2	Odour	Nil
3	Colour	colourless
4	Molecular weight	400 g / mole
5	pH	5-7
6	Density	1.2 g/cc
7	Specific gravity	1.09

TABLE.IV
MIX PROPOSITIONS

W/C ratio	Cement	Fine aggregates	Coarse aggregates
0.45	1	1.54	2.6

III. DESCRIPTION OF SPECIMEN

The current experimental program includes seven specimens. The proportions of the specimens were namely S1, S2, S3, S4, S5, S6, and S7 were casted.

SLUMP TEST

Slump of the concrete is calculated by varying the % of PEG 400 for various specimens were calculated by using slump cone of top diameter is 100mm, bottom diameter is 200mm and the height of the cone is 300mm. The slump values of the concrete with self-curing additives of PEG 400 were determined through the slump test.

COMPRESSIVE STRENGTH

The cubes of size 150x150x150 mm were casted and cured in air. The main aim is to determine the compressive strength of conventional concrete and self curing of fibre reinforced concrete specimens at 7 and 28 days age of test specimens. Then the compression testing machine of 2000KN capacity is used to conduct the test.

SPLIT TENSILE STRENGTH

Cylindrical specimens are casted with dimensions 150 mm diameter and 300 mm height and cured in air. The cylinder is placed in such a way that the load is applied on the circumference area of the cylinder. The cylinder is then subjected to loading and then the strength is calculated by applying load until the cylinder is subjected to failure.

FLEXURAL PERFORMANCE OF RC BEAMS

The concrete beams of suitable size 1700x150x100mm were cast. Two points loading was employed for determination of flexural strength under two point loading at the age of 28 days with simply supported end condition, cantered over bearing blocks adjusted for an effective span of 1500 mm

IV. EXPERIMENTAL INVESTIGATION

SLUMP TEST

The slump test values of different mix proposition of PEG 400 with 1% of monofilament and fibrillated polypropylene fibres.

TABLE.V
SLUMP TEST.

S.No	% Increase of Peg 400	Slump value(mm)
S1(CC)	0	71
Monofilament polypropylene fibre of 1%		
S2	0.5%	77
S3	1%	81
S4	1.5%	86
Fibrillated polypropylene fibre of 1%		
S5	0.5%	73
S6	1%	79
S7	1.5%	82

The addition of PEG 400 increases workability of concrete but at the same time the addition of fibre reduces the workability.

COMPRESSIVE STRENGTH

Compressive strength results obtained for different specimens cast by varying the percentage of polyethylene glycol 400 by 0.5 %, 1.0% and 1.5% for monofilament polypropylene fibre of 1% and fibrillated polypropylene fibre of 1% after that which were cured in air after that it was tested at the 7 days and 28 days respectively.

TABLE.VI
COMPRESSIVE STRENGTH OF CONCRETE

S.NO	% increase of PEG 400	% of MFPPF	% of FPPF	Compressive strength in N/mm2		% increase or decrease in compressive strength
				7days	28days	
1	Conventional concrete			24.6	36.2	-
2	0.5	1	-	25.4	37.1	+ 2.5%
3	0.5	-	1	25.9	37.8	+ 4.5%
4	1.0	1	-	26.8	39.2	+ 8.3%
5	1.0	-	1	27.3	40.6	+12.2%
6	1.5	1	-	26.2	38.1	+ 5.2%
7	1.5	-	1	26.5	38.6	+ 6.6%

The compressive strength of conventional concrete is 36.2 N/mm^2 then which is increased by varying the % of PEG for SCFRC for both monofilament and fibrillated polypropylene fibres. The fibrillated polypropylene fibres show higher strength when compared with monofilament polypropylene fibres. Beyond 1% of adding solution starts to decrease instrength.

SPLIT TENSILE STRENGTH

Split tensile strength results obtained for different specimens cast by varying the percentage of polyethylene glycol 400 by 0.5 %, 1.0% and 1.5% for monofilament polypropylene fibre of 1% and fibrillated polypropylene fibre of 1% after that which were cured in air after that it was tested at the 7 days and 28 days respectively

TABLE.VII
SPLIT TENSILE STRENGTH OF CONCRETE

S.NO	% increase of PEG 400	% of MFPPF	% of FPPF	Split tensile strength in N/mm2		% increase or decrease in Split tensile strength
				7days	28days	
1	Conventional concrete			2.3	2.8	-
2	0.5	1	-	2.5	3.37	+20.3%
3	0.5	-	1	2.72	3.4	+21.5%
4	1.0	1	-	2.78	3.45	+23.2%
5	1.0	-	1	2.9	3.6	+28.6%
6	1.5	1	-	2.6	3.32	+18.5%
7	1.5	-	1	2.8	3.44	+22.9%

The results shows that the split tensile strength of concrete is 2.8 N/mm^2 then which is increased by varying the % of PEG for SCFRC for both monofilament and fibrillated polypropylene fibers. The fibrillated polypropylene fibre shows higher strength when compared with monofilament polypropylene fibres. Beyond 1% of adding solution starts to decrease instrength.

FLEXURAL STRENGTH TEST

Flexural strength results obtained for different specimens cast by varying the percentage of polyethylene glycol 400 by 0.5 %, 1.0% and 1.5% for monofilament polypropylene fibre of 1% and fibrillated polypropylene fibre of 1% after that which were cured in air after that it was tested at the and 28 days respectively.

TABLE.VIII
TEST RESULTS OF BEAMS

Specimen	Ultimate failure load (KN)	Ultimate deflection(mm)		First crack load (KN)	First crack load mid span deflection (mm)
		L/2	L/3		
S1(CC)	33.2	12.86	10.17	10.02	2.20
Monofilament polypropylene fibre of 1%					
S2	38.02	16.72	14.3	10.7	2.42
S3	42.3	18.02	17.8	12.46	2.03
S4	34.4	24.02	22.6	10.25	3.33
Fibrillated polypropylene fibre of 1%					
S5	38.86	16.23	14.86	11.5	2.36
S6	44.8	17.72	16.3	13.8	2.17
S7	33.6	23.35	21.72	9.53	3.62

The above results show that the specimen S6 has higher flexural strength when compared with other specimens. The specimen S3 also has a high strength when compared with conventional concrete but less than S6 and higher than all other specimens.

TABLE .IX
FLEXURAL STRENGTH OF BEAM

S.No	Specimen	Ultimate load (KN)	Flexural Strength (N/mm2)	% increase or decrease in Flexural strength
1	S1 (CC)	33.2	25.08	-
2	S2(MFPPF)	38.02	28.72	+14.5%
3	S3(MFPPF)	42.3	31.9	+27.19%
4	S4(MFPPF)	34.4	26.99	+7.62%
5	S5(FPPF)	38.86	29.36	+17.1%
6	S6(FPPF)	44.8	33.8	+34.76%

7	S7(FPPF)	33.6	25.38	+1.2%

DISPLACEMENT DUCTILITY

TABLE.X
DUCTILITY INDEX

S.No	Beam	First crack load mid span deflection (Δy in mm)	Ultimate load mid span deflection load (Δ u in mm)	Ductility index μ = Δ / u Δy	% increase or decrease in Ductility index	Ductility Ratio
1	S1 (CC)	2.8	12.86	4.5	-	-
2	S2 (MFPPF)	3.20	16.72	5.2	+15.6%	1.2
3	S3 (MFPPF)	3.03	18.02	6.0	+33.3%	1.3
4	S4 (MFPPF)	4.67	24.02	5.1	+13.3%	1.13
5	S5 (FPPF)	3.26	16.23	5.0	+11.1%	1.11
6	S6 (FPPF)	3.10	17.72	5.7	+27%	1.26
7	S7 (FPPF)	4.82	23.35	4.9	+9%	1.1

The ductility index of different specimens among those S3 shows higher ductility index and higher ductility ratio compared to that of other specimens. Then next to S3, the S6 shows higher ductility index and higher ductility ratio. The entire specimen shows higher ductility index to that of conventional concrete S1.

STIFFNESS

TABLE.XI
STIFFNESS AT FIRST CRACK LOAD

S.No	Beam	First crack load (KN)	First crack load mid span deflection (mm)	Stiffness (KN/ mm)
1	S1 (CC)	10.02	2.20	4.5
2	S2(MFPPF)	10.7	2.42	4.45
3	S3(MFPPF)	12.46	2.03	6.1
4	S4(MFPPF)	10.25	3.33	3.1
5	S5(FPPF)	11.5	2.36	4.9
6	S6(FPPF)	13.8	2.17	6.3
7	S7(FPPF)	9.53	3.62	2.6

The stiffness at first crack load here S6 shows higher stiffness in first crack load. Then the S3 shows higher stiffness in first crack load next to that S6 compared to that of S1 then the S7 shows the least stiffness to that of all specimens.

TABLE.XII
STIFFNESS AT ULTIMATE LOAD

S.No	Beam	Ultimate load (KN)	Ultimate load mid span deflection (mm)	Stiffness (KN/ mm)	% increase or decrease stiffness
1	S1 (CC)	33.2	12.86	2.4	-
2	S2(MFPPF)	38.02	16.72	2.31	-3.75%
3	S3(MFPPF)	42.3	18.02	2.47	2.9%
4	S4(MFPPF)	34.4	24.02	1.6	-33%
5	S5(FPPF)	38.86	16.23	2.41	0.4%
6	S6(FPPF)	44.8	17.72	2.53	5.5%
7	S7(FPPF)	33.6	23.35	1.44	-40%

The stiffness at first crack load here S6 shows higher stiffness in ultimate load. Then the S3 shows higher stiffness in ultimate load next to that S6 compared to that of S1 then the S7 shows the least stiffness to that of all specimens.

LOAD – DEFLECTION BEHAVIOUR

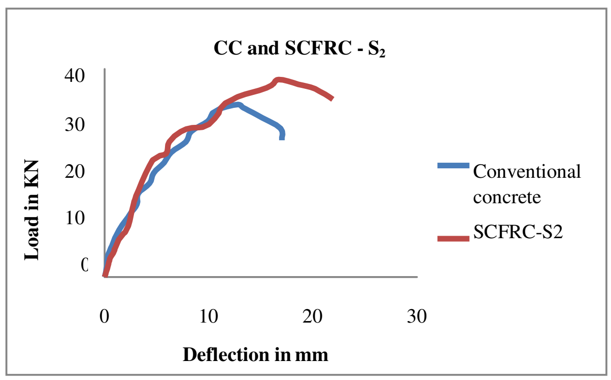

Fig.1. Load Vs Deflection of CC and SCFRC - S2

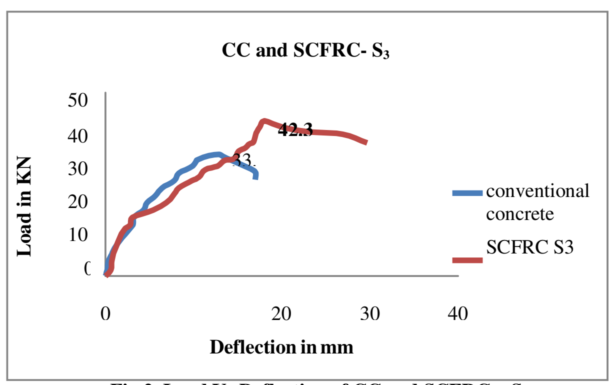

Fig.2. Load Vs Deflection of CC and SCFRC – S3

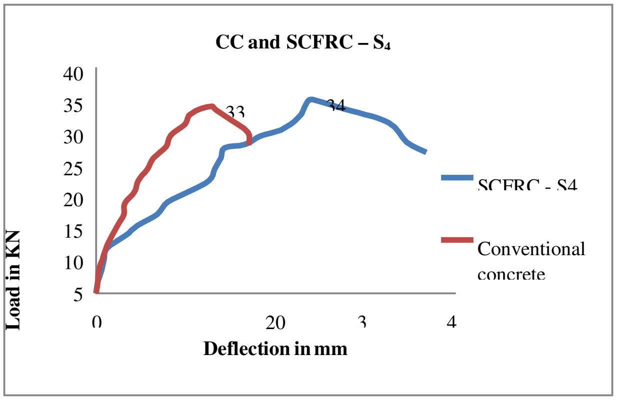

Fig.3. Load Vs Deflection of CC and SCFRC – S4

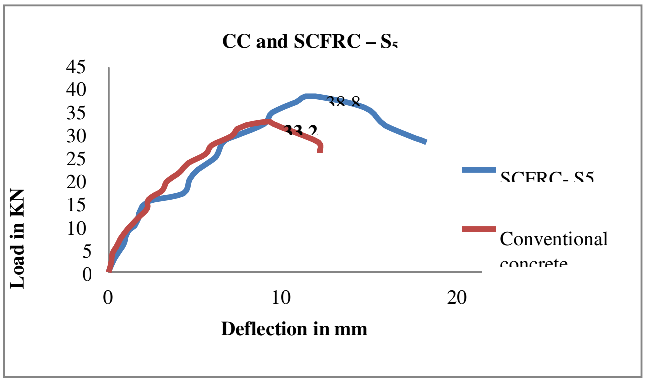

Fig.4. Load Vs Deflection of CC and SCFRC – S5

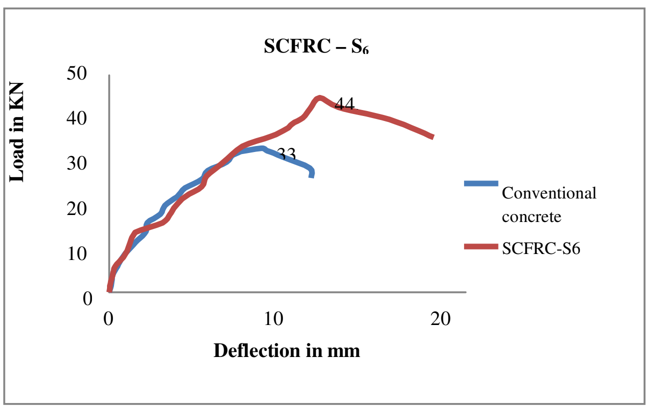

Fig.5. Load Vs Deflection of CC and SCFRC – S6

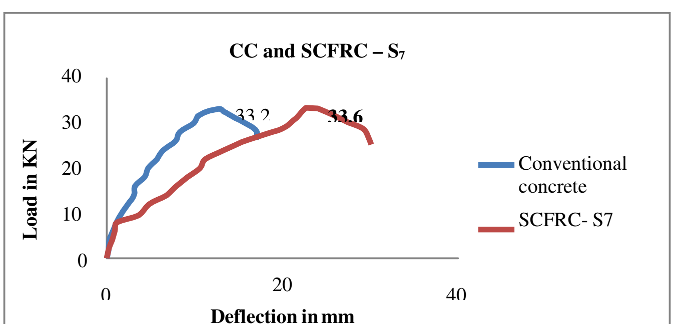

Fig.6. Load Vs Deflection of CC and SCFRC – S7

Comparison of CC and SCFRC of S2, S3, S4, S5, S6 and S7 here the ultimate load for SCFRC S6 is 35% as high as CC with mid span deflection of 17.72mm and also the S6 is higher than all other specimens.

V. CONCLUSIONS FROM THE EXPERIMENTAL INVESTIGATION.

The following conclusions were reached from the experimental part of this investigation

- The use of self curing agent (poly ethylene glycol) in the concrete mix under air curing regime improves the mechanical properties by retaining water.
- The compressive strength of monofilament polypropylene fibres can be increased by 8.3% and fibrillated polypropylene fibre can be increased by 12.2% as compared to conventional concrete for optimum percentage 1% of PEG 400.
- The split tensile strength of monofilament polypropylene fibre can be increased by 23.2% and fibrillated polypropylene fibre can be increased by 28.6% as compared to conventional concrete for optimum percentage 1% of PEG 400.
- The flexural behaviour of self curing concrete of MFPPF and FPPF and conventional concrete were studied. The S6 shows higher flexural strength 44.8 KN with 17.72 mm mid span deflection which shows 35% as high as conventional concrete.
- The ductility index and ductility ratio shows that the monofilament and fibrillated polypropylene fibres are increased to that of conventional concrete. The ductility index can be increased by 15.6%**,** 33.3%, and 13.3%, for MFPPF of SCFRC among those 1 % of PEG 400 shows higher value of 33.3% to that of conventional concrete. Then the ductility index can be increased by 11.1%, 27%, and 9% for fibrillated can be among those 1% of PEG 400 shows higher value of 27 % to that of conventional concrete. The ductility improvement with addition of monofilament polypropylene fibre shows that 6.3% as higher as compared to that with the addition of fibrillated polypropylene fibre. Then the ductility ratio for MFPPF is higher than the FPPF

- In FPPF, the stiffness can be increased by 5.6% to that of conventional concrete for 1% of PEG 400. Then the addition of 1.5% of PEG 400 shows very less stiffness as compared to that of conventional concrete. In MFPPF, the stiffness can only improved by 3.0% to that of conventional concrete for 1% of PEG 400. Here the usage of FPPF shows higher stiffness as that of MFPPF of SCFRC.
- The self curing fibre reinforced concrete shows better performance when compared with conventional concrete. The overall strength is increased up to 1% of PEG addition and the strength is found to decrease when the proportion of PEG is increased beyond 1% therefore 1% is optimized.
- Though the optimum percentage of PEG 400 is same for both fibres, the fibres FPPF shows higher stiffness, energy absorption when compared with MFPPF due to its better anchorage properties. At the same time displacement ductility and energy ductility is higher for MFPPF compared to that of FPPF.
- The use of self curing concrete reduces the quantity of usage of water for curing hence such concrete can be used in drought region where there is more problem of water. Self curing concrete reduces the cost of curing of water as for $1m^3$ of conventional concrete were required $3m^3$ of water.

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