International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

AN EXPERIMENTAL INVESTIGATION ON SELF CURING CONCRETE WITH SILICA FUME USING SODIUM POLYACRYLATE AND PEG 6000

T. Amutha[1], R. Pandiarajan[2]

[1]PG Student, (CIVIL - Structural Engineering), [2]Assistant Professor
[1,2]Sri vidya college of Engineering and Technology, Tamilnadu, India-626005

ABSTRACT: *Now a day's construction field facing many problems one of them is a scarcity of water. Proper curing is not practically possible in most of the cases. So, the concept self-curing distributes the extra curing water (uniformly) throughout the entire 3-D concrete microstructure so that it is more readily available to maintain the saturation of the cement paste during hydration and reducing the autogenous shrinkage. The objective of the project is to investigate the strength characteristics of self-curing concrete with silica fume incorporating different chemical curing agents and to eliminate the shrinkage effect. The grade of concrete selected was M30.The self-curing agents used is polyethylene glycol-6000 (0.2%, 0.3% and 0.4%) and SAP (0.2%, 0.3% and 0.4%) relative to cement mass. Partial replacement of cement with silica fumes (5 and 10%) to increase the properties of the concrete. The optimum mix ratio is taken for the casting of the beam and the strength characteristics will be studied and compared with the control mix. The effect of variation in strength parameters, elastic properties and shrinkage i.e., Compressive Strength were studied for a different dosage of self-curing agent and shrinkage reducing agent PEG 6000 to reduce early-age shrinkage and at the same time, maintains the mechanical properties and durability of concrete. Finite element models are generated in ANSYS using Graphical User Interface (GUI). The experimental deflection of the beams was compared with the results obtained analytically using ANSYS.*

Keywords: *Self-curing, Silica fume, SAP, PEG 6000*

1. INTRODUCTION

Concrete is the widely used construction material in the world. Concrete is a very durable material. To make the concrete strong and durable we need to cure the concrete for minimum 10 days, curing is done using the conventional water which is used for the mix. It is found that one third of water is used for the construction field. Now a day there is scarcity of water in all over the world, to minimize the water consumption in construction field, self curing concrete is developed for reducing the autogenous shrinkage.ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water which is not a part of the mixing Water". To minimize the amount of water used for the construction, self curing is adopted. There are many internal curing agent available, such as water paper shred, saw dust, calatropis gigantean milkweed, palak green leaves, super absorbent polymer (SAP), PEG Polyethylene glycol etc., Poly ethylene glycol 6000 is chose as an internal curing agent because of its low cost and easy availability in the market. PEG 6000 is added to the concrete by the percentage of cement added to it. Optimum percentage of PEG 6000 can be found out by trial and error method of addition.

1.1 OBJECTIVES

To investigate mechanical properties of self curing concrete with silica fume using different chemical curing agent. To reduce shrinkage effect and water usage for curing. To compare the flexural strength of RC beam with immersed curing concrete and self curing concrete using various chemical curing agents.

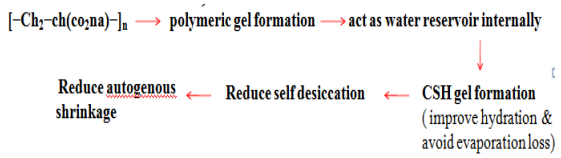
1.2 SELF CURING MECHANISM

Self curing agents Sodium polyacrylate and PEG 6000 plays major role in hydration process.

Reduce evaporation in concrete during hydration.

Self desiccation ⟶ reduction in disjoining pressure and voids formation in conventional concrete due to improper curing. ⟶

Sodium polyacrylate and PEG 6000 high water retention capacity



Self desiccation is reduced while using self curing agent.

No evaporation loss during the hydration process because curing is done by internal agents.

Increase the hydration process C-S-H gel formation and achieve the strength without any autogenous shrinkage.

2. SUMMARY OF LITERATURE REVIEW

Incorporation of silica fume into concrete mixtures enhances all physical properties and mechanical properties compared to conventional concrete.

The benefits of internal curing are numerous which include, increased hydration process and strength development, reduced autogenous shrinkage and cracking, reduced permeability, and increased durability.

Adding polyethylene-glycol by weight of cement reduces evaporation of water from concrete. It increases the water retention capacity of the concrete and reduce the water usage for curing.

Self curing agents Sodium polyacrylate and PEG 6000 plays major role in hydration process.

Self desiccation ⟶ reduction in disjoining pressure and voids formation in conventional concrete due to improper curing.

Superabsorbent polymers (SAP) have a potential application as internal curing agent for concrete and mortars. Its high capacity to absorb water from fresh mix and release it over time can control autogenous shrinkage in early ages.

3. MATERIAL USED

Cement
Fine Aggregate
Coarse Aggregate
Reinforcement
Silica Fume
Super Absorbent Polymer
Polyethylene Glycol 6000

3.1. MATERIAL PROPERTIES TEST

TESTS FOR CEMENT
- Specific gravity of cement
- Consistency test of cement
- Initial and final setting time

TESTS FOR FINE AGGREGATE
- Specific gravity of fine aggregate
- Sieve analysis of fine aggregate

TEST FOR COARSE AGGREGATE
- Specific gravity of coarse aggregate
- Sieve analysis of coarse aggregate
- Water absorption test for coarse aggregate

4.1 WATER ABSORPTION TEST FOR SAP

To determine the water retaining capacity for SAP. Water absorption test was done and details.

Table:1 Water Absorption for SAP

S NO	Material	Dry weight (gms)	Saturated weight (gms)	Water absorption
1	SAP	25	2755	110 times

4.2 WATER ABSORPTION FOR PEG 6000.

To determine the water retaining capacity for PEG 6000. Water absorption test was done.

Table :2 Water Absorption for PEG 6000

S NO	Material	Dry weight (gms)	Saturated weight (gms)	Water absorption
1	PEG 6000	25	1250	50 times

4.3. XRF ANALYISIS FOR SILICA FUME

X-Ray Fluorescence is a non-destructive analytical technique used to determine the elemental composition of the given sample. XRF result are taken from CECRI karaikudi, shows silica content is more about 90.298 So it is suitable for concrete.

4.4 SEM ANALYISIS FOR SILICA FUME

A scanning electron microscope is information about the surface topography and composition of the samples SEM images for silica fume shows that porous and flaky shape which represents the silica content. Hence it is used for replacement of cement in concrete. Silica fume increases the early strength and pozzolanic reaction.

4.5 SEM ANALYISIS FOR SODIUM POLYARCYLATE

A scanning electron microscope is information about the surface topography and composition of the samples. SEM image for SAP which is agglomerated circle ball like structure that absorb the water about it capacity and act as a internal curing agent.

5. EXPERIMENTAL PROGRAMME

5.1 COMPRESSIVE STRENGTH TEST

The most common of all tests on hardened concrete is the compressive strength test. Compressive strength test on specimen is treated in a standard manner which includes full compaction and curing for a specified period which gave results representing the potential quality of the concrete. The age at which specimen tested is governed by the information required. The standard specimen is tested at prescribed ages, generally 28 days, with additional test often made at 3 to 7 days. The Dimension of cube mould is 150 mm x 150 mm x 150 mm. Compressive strength is done by various percentages of self curing agents and addition of 10% silica fume.

Compressive strength in MPa = Load at failure P / Area of loading A

5.2 SPLIT TENSILE STRENGTH TEST

Split tensile strength is used to determine the tensile strength of the concrete indirectly. It is done using a cylinder specimen of diameter 150mm and height 300mm. The specimen is placed horizontally in the compression testing machine and loaded.

Tensile strength = $2P/\pi DL$

Where P = applied load
D = Diameter of the specimen,
L = Length of the specimen

5.3 FLEXURAL STRENGTH TEST

After the curing period the specimen is taken out from the curing tank and wiped clean. The dimension of the specimen and the weight of the specimens were noted down with accuracy. The beam testing machine should be provided with two rollers 38 mm diameter on which the specimen is placed and the rollers are spaced such that the distance between two rollers should be 333.34 mm. The load is applied through two similar rollers mounted at the third point of the supporting span, i.e., 333.34 mm centre to centre. The load is divided equally between the two-point loading rollers are mounted in such a manner that the load is applied axially and without subjecting to any torsion stresses.

Flexural strength = PL/BD^2

Where P = ultimate load,
L = Length of the specimen,
B = Breadth of the specimen,
D = depth of the specimen
Length = 1200m mm, Breadth = 100 mm, Depth =150 mm, d = 120 mm a = 333.33 mm. The beam is cast with nos of 10 mm dia bar for main reinforcement and 8 mm dia for vertical stirrups spacing of 140 mm c/c

BEAM SUBJECTED TO TWO POINT LOADING

$y = wa/24EI(3L^2 -4a^2)$

EI = flexural rigidity
L = length of the member
W = load
y = deflection (value obtained from graph)
a = Length/3 value

5.4 DRYING SHRINKAGE TEST

This test method describes the procedure for determining the drying shrinkage or change in length of concrete specimen due to changes in moisture content. A length measuring apparatus incorporating a dial gauge capable of measuring the length accurately to 0.005 mm. The mould size 0f 200 mm x 100 mm x 100 mm. Length comparator measures the initial drying shrinkage of concrete. Drying oven capable of maintaining a temperature of 50 ± 1^0.

TEST PROCEDURE

Cast concrete specimens as per the required dimension and store it in moist air for 3 to 7 days. Drill a shallow depression at the center of each end of the specimen so that it can accommodate a 6.5 mm diameter steel ball. These steel balls are fixed in to this depression by cementing the balls with neat rapid hardening Portland cement. After fixing the steel balls, clean the balls to remove any cement adhering to it and then apply lubricating grease to prevent corrosion. Then the test specimens are kept in moist condition for at least 24 hours in order to allow the cement to harden. After 24 hours, immerse the test specimens in water maintained at a temperature of 24 to 30^0 C until 28 days. (Remember the no of days are counted starting from the day when the specimens are casted). After removing the specimens from water, clean the grease from the balls and immediately measure the length of the specimen to an accuracy of 0.005mm by the length measuring apparatus. Then dry the specimens in oven for at least 44 hours. After 44 hours of drying, remove it from oven and cool it for at least 4 hours in a desiccators. After cooling, again measure the length of the specimen using the length comparator. Record this reading as the '***original wet measurement***'. Repeat the process of oven drying, cooling and measuring until constant length is attained, that is , when the difference between two consecutive length measurement readings is less than 0.01 mm for a 15 cm specimen and proportionately greater for larger specimen. Record the final reading as '***dry measurement***'. After the dry measurement has been taken, measure the length of the specimen adjacent to the balls to the nearest 0.5 mm and record this as the '***dry length***'.

5.5 WATER ABSORPTION TEST

Water absorption test was done affirming to ASTM C_642 97. Initially the mortar specimens were dried absolutely to expel dampness by using Hot air oven for a duration of 24 hours. The samples were taken out from the oven and their initial weights were noted as W_0 (kg). The samples were immersed into water not less than a period of 48 hours. The final weight of the samples W_1 (kg) was recorded after taking out the immersed samples from water. The rate of water absorption is calculated by using the following expression.

Rate of water absorption = $(W_1-W_0)/W_0 \times 100$

6. RESULTS

6.1 COMPRESSIVE STRENGTH TEST RESULTS

While using 5 % of silica fume in self curing concrete doesn't show any increment in concrete's strength were as 10 % silica fume shows an increase in strength of self curing concrete to a level of 0.2% PEG 6000 28 days strength 36.45 N/mm² increases 8.61% of compressive strength.

Table:3 Compressive Strength for 7 and 28days

Material	Percentage		Compressive strength N/mm²	
			7 days	28 days
Conventional concrete with immersed curing	-		**26.18**	**33.56**
Self curing				
Sodium polyacrylate with silica fume	5 % silica fume	0.2	18.85	28.76
		0.3	23.39	32.13
		0.4	23.21	31.52
PEG 6000 with silica fume		0.2	19.21	29.15
		0.3	22.93	30.67
		0.4	23.30	32.07
Sodium polyacrylate with silica fume	**10% silica fume**	0.2	26.23	34.15
		0.3	**27.12**	**34.65**
		0.4	25.62	33.74
PEG 6000 with silica fume		**0.2**	**27.38**	**36.45**
		0.3	25.83	33.94
		0.4	25.87	34.07

6.2 SPLIT TENSILE STRENGTH TEST

While using 5 % of silica fume in self curing concrete it doesn't show any increment in concrete's strength where as 10 % silica fume shows an increase in strength of self curing concrete to a level of 0.2% PEG 6000 28 days' strength 3.415 N/mm ² compare to conventional concrete. While using 5 % of silica fume in self curing concrete doesn't show any increment in concrete's strength where as 10 % silica fume shows an increases of 4.62% in split tensile strength compare to conventional concrete.

Table:4 Split Tensile Strength for 28 days

Material	Percentage	Split tensile strength N/mm²
		28 days
Conventional concrete	**-**	**3.264**
Self curing		
Sodium polyacrylate with silica fume 5%	0.2	2.750
	0.3	2.910
	0.4	3.050
PEG 6000 with silica fume 5%	0.2	2.950
	0.3	3.134
	0.4	3.212
Sodium polyacrylate with silica fume 10%	0.2	3.256
	0.3	3.304
	0.4	3.235
PEG 6000 with silica fume 10%	**0.2**	**3.415**
	0.3	3.334
	0.4	3.243

6.3 FLEXURAL STRENGTH

6.3.1 Conventional RC Beam

RC beam M30 grade concrete have a size of 1200 mm length, 100 mm breadth and 150 mm depth. The immersed curing is done for 28 days.

Table:5 Dial Gauge reading for Conventional Beam

Load (tonne)	Left			Middle Digital dial gauge (mm)	Right		
	Division		Deflec-tion (mm)		Division		Deflec-tion (mm)
	Inner	Outer			Inner	Outer	
0	9	0	0	0	3	0	0

0.5	9	14	0.14	0.12	3	8	0.08
1	9	24	0.24	0.44	3	17	0.17
1.5	9	45	0.45	0.78	3	63	0.63
2	10	12	1.12	0.98	4	18	1.18
2.5	10	35	1.35	1.02	4	27	1.27
3	10	48	1.48	1.23	4	56	1.56
3.5	10	76	1.76	1.42	4	84	1.84
4	10	98	1.98	1.67	4	97	1.97
4.5	11	08	2.08	1.98	5	6	2.06
5	11	38	2.38	2.04	5	32	2.32
5.5	11	59	2.59	2.67	5	68	2.68
6	11	64	2.64	3.01	5	89	2.89
6.5	12	9	3.09	3.45	6	12	3.12
7	12	34	3.34	3.76	6	36	3.36
7.5	13	79	4.79	4.52	6	48	3.48
8	14	06	5.06	4.86	6	79	3.79
8.48	**14**	**12**	**5.12**	**5.34**	**7**	**66**	**4.66**

6.3.2 Self Curing Beam Using 10% Silica Fume and Sodium Polyacrylate

Self curing RC beam M30 grade concrete using sodium polyacrylate 0.3% and silica fume 10% have a size of 1200 mm length, 100 mm breadth and 150 mm depth. Casting of self curing beam and curing under room temperature. The normal room temperature self curing for RC beam is done for 28 days.

Table: 6 Dial Gauge reading for SC RC Beam using Sap

Load (tonne)	Left			Middle Digital dial gauge (mm)	Right		
	Division		Deflec-tion (mm)		Division	Deflec-tion (mm)	
	Inner	Outer			Inner	outer	
0	2	0	0	0	11	0	0
0.5	2	26	0.26	0.24	11	07	0.07
1	2	48	0.48	0.45	11	21	0.21
1.5	2	67	0.67	0.76	12	03	1.03
2	3	12	1.12	0.81	12	34	1.34
2.5	3	68	1.68	1.02	12	71	1.71
3	3	74	1.74	1.45	12	92	1.92
3.5	3	98	1.98	1.98	13	10	2.10
4	4	05	2.05	2.12	13	37	2.37
4.5	4	25	2.25	2.66	13	78	2.78
5	4	88	2.88	2.98	13	94	2.94
5.5	5	6	3.06	3.78	14	22	3.22
6	6	24	4.24	4.78	15	34	4.34
6.5	7	38	5.38	5.76	16	18	5.18
7.21	**8**	**03**	**6.03**	**6.01**	**17**	**42**	**5.42**

6.3.3 Self Curing RC Beam using 10% Silica fume and PEG 6000

Self curing RC beam M30 grade concrete using polyethylene glycol 6000 0.2% and silica fume 10% have a size of 1200 mm length, 100 mm breadth and 150 mm depth. The normal room temperature self curing is done for 28 days and test results are taken. Ultimate load carrying capacity of self curing beam using (PEG 6000 0.2% and 10 % SF) increase 7.78% compare to conventional beam. After the self curing period the specimen is taken out from the curing tank and wiped clean. The dimension of the specimen and the weight of the specimens were noted down with accuracy. The beam testing machine should be provided with two rollers 38 mm diameter on which the specimen is placed and the rollers are spaced such that the distance between two rollers should be 333.34 mm. The load is applies through two similar rollers mounted at the third point of the supporting span, i.e., 333.34 mm centre to centre. The load is divided equally between the two point loading rollers are mounted in such a manner that the load is applied axially and without subjecting to any torsion stresses. The result comparison for conventional and self curing beam.

Table:7 Dial Gauge reading for SC RC Beam using PEG 6000

Load (ton)	Left			Middle Digital dial gauge (mm)	Right		
	Division		(mm)		Division		(mm)
	Inner	Outer			Inner	outer	

0	16	0	0	0	4	0	0
0.5	16	12	0.12	0.04	4	05	0.05
1	16	21	0.21	0.13	4	29	0.29
1.5	16	42	0.42	0.24	4	35	0.35
2	16	57	0.57	0.48	4	47	0.47
2.5	17	19	1.19	0.76	4	82	0.82
3	17	38	1.38	1.03	4	91	0.91
3.5	17	49	1.49	1.25	5	3	1.03
4	17	56	1.56	1.44	5	17	1.17
4.5	17	78	1.78	1.56	5	32	1.32
5	18	03	2.03	1.98	5	57	1.57
5.5	18	38	2.38	2.48	5	84	1.84
6	18	79	2.79	2.97	6	13	2.13
6.5	19	14	3.14	3.62	6	76	2.76
7	19	32	3.32	3.98	6	84	2.84
7.5	19	58	3.58	4.34	7	27	4.27
8	19	67	3.67	4.81	7	48	4.48
8.5	20	92	4.92	5.16	8	24	5.24
9.14	**21**	**42**	**5.42**	**5.76**	**8**	**48**	**5.48**

Table:8 Result Comparison for Conventional and SC beam

Beam Specimen	Initial Crack Load (Tone)	Ultimate Load (Tone)	Maximum Deflection (mm)	Ultimate Moment (kN m)	Flexural Strength N/mm^2	Flexural rigidity
Conventional Beam	4.5	8.48	5.34	28.26	44.36	$4.96x10^{11}$
Self Curing Beam SPA	3.5	6.84	3.56	22.76	35.77	$3.79x10^{11}$
PEG 6000	**5**	**9.14**	**5.76**	**30.46**	**47.8**	$6.9x10^{11}$

6.4 DRYING SHRINKAGE TEST RESULTS

The initial drying shrinkage or drying shrinkage is calculated as the difference between the ***original wet measurement*** and the ***dry measurement*** expressed as a percentage of ***dry length***. According to IS 6441 part 2 shrinkage limits should be 0.007%.

Initial drying shrinkage = [(original wet measurement – dry measurement)/Original length] *100

Table:9 Drying shrinkage reading

SAMPLE		Least count : 0.01mm Length of the specimen in 200 mm								
	R-10	R-9	R-8	R-7	R-6	R-5	R-4	R-3	R-2	R-1
Conventional	0.13288	0.13288	0.13326	0.13326	0.13320	0.13319	0.13316	0.13314	0.13314	0.13310
Self curing concrete										
PEG 6000 (0.2 % & 10 % SF)	0.12133	0.12133	0.12110	0.12009	0.12009	0.12009	0.12007	0.12006	0.12006	0.12006
SPA (0.2 % & 10 % SF)	0.13320	0.13320	0.13318	0.13317	0.13314	0.13313	0.13311	0.13310	0.13306	0.13303

Table:10 Drying shrinkage result

Sample	Least count : 0.01mm Length of the specimen in 200 mm		
	Length of the member	**Shrinkage Value**	**Initial drying shrinkage**
Conventional concrete	19.986 cm	0.01328 cm	0.0009 %
Self curing concrete			
PEG6000 (0.2% & 10% SF)	**19.987cm**	**0.01213 cm**	**0.00035 %**
SPA (0.2% & 10% SF)	19.9868 cm	0.01320 cm	0.00085%

6.5 WATER ABSORPTION TEST RESULTS

The rate of water absorption is calculated by using the following expression. The water absorption results show that sodium polyacrylate with 0.2% and SF with 10% has less water absorption compared to conventional and PEG 6000. According to ASTM C 642 – 97 water absorption percentages should be within in 5%.

Rate of water absorption = $(W_1 – W_0)/W_0 \times 100$ %

Table: 11 Water absorption test

Sample	Percentage		Heating Weight of concrete cube (kg)		Absorption	
			Before	After	After immersion	Water absorption(%)
Conventional concrete	-		8.45	8.38	8.67	3.46
Self curing concrete						
Sodium polyacrylate with silica fume	5 %SF	0.2	8.265	8.13	8.445	3.823
		0.3	8.382	8.21	8.51	3.603
		0.4	8.214	8.09	8.39	3.708
PEG 6000 with silica fume		0.2	8.42	8.24	8.62	4.6
		0.3	8.365	8.14	8.48	4.176
		0.4	8.295	8.09	8.34	3.065
Sodium polyacrylate with silica fume	10%SF	0.2	8.432	8.28	8.55	3.26
		0.3	**8.494**	**8.37**	**8.61**	**2.86**
		0.4	8.34	8.15	8.456	3.703
PEG 6000 with silica fume		0.2	8.48	8.32	8.62	3.605
		0.3	8.335	8.13	8.41	3.44
		0.4	8.367	8.16	8.47	3.79

7. CONCLUSION

By using self curing agent PEG 6000, water usage for curing can be reduced which decreases the evaporation loss and contribute hydration process. XRF result are taken for silica fume in CECRI karaikudi, shows silica content is more about 90.298 So it is suitable for cement replacement. Ultimate load carrying capacity of self curing beam using (PEG 6000 0.2% and 10 % SF) increases to 7.78% compare to conventional beam Also increases the compressive strength and split tensile strength increases to 8.61% & 4.62% respectively compared to conventional concrete. Internal curing agent SAP and PEG 6000 has 50 to 110 times water retention capacity from its own weight, its dosage escalate the degree of hydration process. Drying shrinkage for shrinkage reducing agent PEG 6000 has 0.00035% less shrinkage percentage compared to conventional concrete and self curing using sodium polyacrylate. Water absorption for sodium polyacrylate 0.3% with 10 % silica fume self curing concrete is 2.86%. Water scarcity crisis can be overcome in future by introducing and implementing the PEG 6000 with concrete which will reduce the additional cost for water in scarcity area by using self curing agent. It diminishes the crack formation and act as a water reservoir for concrete by adding 10% of silica fume which increases pozzolanic reaction. The finishing surface for conventional and self curing beam is almost same; there is smooth surface without any autogenous cracking.

8. REFERENCES

1. ACI (American Concrete Institute) (2008) ACI 308R-01: “Guide to curing concrete. American Concrete Institute”, Farmington Hills”, MI, USA.
2. ASTM (2008) ASTM C642-97: “Standard test method for density, absorption and voids in hardened concrete”. ASTM International, West Conshohocken, PA, USA.
3. Bentz DP, Lura P and Roberts JW (2005) “Mixture proportioning for internal curing”. Concrete International 27(2): 35–40.
4. Dhir RK, Hewlett PC and Dyer TD (1996) “The influence of microstructure on the physical properties of self-curing concrete”. ACI Materials Journal 93(5): 1–7
5. 196-ICC Internal curing of concrete – “International Union of Laboratories and Experts in Construction Materials”, Systems and Structures.
6. IS 456:2000 – “Indian Standard Code of Practice for Plain and Reinforced Concrete”.
7. IS12269 (1987) - "Indian standard for specification for 53 grade OPC", reaffirmed january 1999.
8. IS 10262:2009 – “Concrete mix proportioning”-guidelines.
9. IS 2386:part 3:1963 -"Methods of test for aggregate for concrete".
10. IS 383:1970 - "Specification from fine and coarse aggregate from natural source for concrete".