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Experimental Investigation on the Mechanical Properties of Self Curing Concrete Using Sodium Lignosulphonate and Polyvinyl Alcohol

T. A Sajana Khader¹, T.S Shabana²

P.G. Student, Department of Civil Engineering, Jai Bharath College of Management & Engineering Technology,
Ernakulam , Kerala, India,

Associate Professor, Department of Civil Engineering, Jai Bharath College of Management & Engineering Technology,
Ernakulam, Kerala, India

ABSTRACT: Concrete is a composite material composed primarily of cement, aggregate, admixture and water. Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. As water is becoming a scarce material day by day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. However, good curing is not always practical in many cases. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its performance and durability. The aim of this experimental investigation is to study the strength of concrete using Poly Vinyl Alcohol (PVA) and Sodium Lignosulphonate (SL) as self curing agent. The functions of self curing agent is to reduce the water evaporation from concrete, and hence they increase the water retention capacity of concrete compared to the conventionally cured concrete. In this study, compressive strength, split tensile strength and flexural strength of concrete containing self curing agent is investigated and compared with those of conventionally cured concrete. It is found through this experimental study that concrete cast with PVA and Sodium Lignosulphonate as self curing agent is stronger than conventional curing. M35 grade concrete is considered as reference mix and strength properties of reference mix were determined. Self curing agents PVA (0.24%, 0.48% and 0.96%) and SL (0.5%, 1%, 1.5% and 2%) by weight of cement were added combination to the reference mix and their strength properties were studied and compare with reference mix.

KEYWORDS: Self curing concrete, PVA, SL

I. INTRODUCTION

Concrete is the most widely used building material. It has the distinction of being formed into desired shape most conveniently. It is an artificial material consisting of ingredients such as cement, fine aggregates, coarse aggregates and water. Aggregates are the major ingredients of concrete. Any construction activity requires several materials such as concrete, steel, bricks, stone, glass, clay, mud, wood and so on. For its sustainability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect environment, economize and lead to proper utilization of energy. Curing of concrete structures is important to ensure they meet their performance and intended durability requirements. Internal curing (IC) is a very promising technique that can provide additional moisture in concrete for a more effective hydration of the cement. During hydration of the cement, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and cause cracks to develop at the early-age. This situation can be solved by using the self-curing agents like 'Poly Vinyl Alcohol' and 'Sodium

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Lignosulphonate' they can retain the moisture for a long period of time. The 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 that is not part of the mixing water. Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside itself' through the internal reservoirs created. 'Internal curing' is also referred as 'Self curing'.

Mechanism of Internal Curing

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure, thus reducing the rate of evaporation from the surface.

Significance of Self-curing

When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, significant autogenous deformation and (early-age) cracking may result. Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking

II. LITERATURE REVIEW

B. Ajitha et al (2017), The experimental study is carried out to examine the use of water-soluble and water retains by using polyvinyl alcohol PVA as self-curing agent. In the present work strength characteristics of self-curing concrete is to be better found and compared with conventional concrete of similar mix design. The result which shows that the compressive strength and workability of self curing concrete is found to be more than conventional concrete at certain percentage of Polyvinyl Alcohol added to the concrete mix.

K.Nithya et al (2017), The current study involves the use of shrinkage reducing admixtures in concrete which helps in self-curing and helps in better hydration and hence strength. Polyvinyl alcohol is added in various proportions are 0.03%, 0.06%, 0.12%, 0.24%, 0.48%. It was establish the compressive strength, flexural strength, tensile strength. The maximum compressive strength, flexural strength and tensile strength is establish respectively.

Mohammad Suhail (2017), This paper reports an experimental study carried out to investigate the usage of sodium lingo sulphonate as self curing agent. In this study compressive strength, split tensile strength and modulus of rupture of self-curing concrete with varying percentages (0.5%, 1%, 1.5% and 2%) for 7 and 28 days are analyzed, tested and compared with conventional concrete of similar mix design were studied for M20 grade and M25 grade.

K.Vybhav Reddy et al (2016), The aim to this investigation is to study the strength and durability properties of concrete using water-soluble polyethylene glycol, polyvinyl acetate and polyvinyl alcohol as self-curing agents. In this we study the PEG, polyvinyl acetate and polyvinyl alcohol at different proportions of 0.5%, 1%, 2%, 3% and 4% for M20, M30, M40, M50 and M60 mix grade. Also study the compressive strength and split tensile strength at varying percentages of PEG, polyvinyl acetate, polyvinyl alcohol and compared to nominal concrete.

M.Srihari et al (2016), In this paper mention that Concrete is most widely used construction material due to its good compressive strength and durability. . In the present study, the effect of admixture, Poly Ethylene Glycol (PEG) & Super Absorbent Polymer (SAP) are studied with proportions of PEG 0.2% and SAP 0-0.4% in M25 grade of concrete. Comparing both types of concrete with conventional concrete the compressive, split tensile and flexural strength are found and optimum percentage of curing agent is determined.

M.Pavan Kumar et al (2016), This paper conducted an experimental study on self curing concrete using liquid paraffin wax This study investigates the role of liquid paraffin wax as a self curing agent and compares this with the effect of different curing regimes simulating traditional methods of curing.

Magda I. Mousa et al (2015), The aim of the Investigated Physical properties of self-curing concrete. In this study the effect of two different curing-agents has been examined in order to compare them for optimizing the performance of concrete. The first used type is the Pre-soaked lightweight aggregate (leca) with different ratios; 0.0%, 10%, 15% and

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20% of volume of sand, and the second type is a chemical agent of polyethylene-glycol (Ch.) with different percentages; 1%, 2% and 3% of weight of cement.

III EXPERIMENTAL WORK CONDUCTED

MATERIALS USED

Cement: In this total project work Ordinary Portland cement of 53 grades was used. Cement act as binding material. The properties of cement is depends upon chemical composition, the process of manufacture & degree of fineness of cement grains.

Fine Aggregate: The fine aggregate used was M sand.

Coarse Aggregate: Locally available aggregate were used. The aggregate is tested as per IS 2386. 20 mm maximum size aggregate was used and retained on 12.5mm IS sieve.

Water: Water used was fresh, colorless, odorless and tasteless, convenient water that was free from cause early-age cracking organic matter of any type.

Table 1 Properties of Cement

Tests	Values	IS Specification
Standard Consistency	36 %	33-35%, IS: 4031 (Part 4) -1988
Initial setting time	35 min	>30 min, IS: 4031 (Part 5) -1988
Final setting time	360 min	<600 min, IS: 4031 (Part 5) -1988
Fineness	9%	< 10%, IS: 4031 (Part I) -1996
Specific gravity	3.14	3 – 3.15, IS 4031 (Part III)- 1988

Table 2 Properties of Fine aggregate.

Tests	Test Results	IS Specification
Sieve analysis (Fineness Modulus)	3.11 zone II	2.1 -3.37, IS: 2386 –Part 1 -1963
Specific Gravity	2.65	2.6 -2.8, IS:2386 –Part 3 -1963
Water Absorption	2.1%	2–4%
Moisture Content	2.5%	Up to 10%

Table 3 Properties of Coarse Aggregate.

Tests	Test Results	IS Specification
Sieve analysis (Fineness Modulus)	6.2	6 -6.9, IS: 2386 –Part 1 -1963
Specific Gravity	2.67	2.5 -2.9, IS:2386 –Part 3 -1963
Water Absorption	0.54%	0.5–1%
Moisture Content	0.24%	-

Polyvinyl Alcohol: Commercially Polyvinyl alcohol is produced from polyvinyl acetate by a continuous process. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of anhydrous sodium methyl ate or aqueous sodium hydroxide.

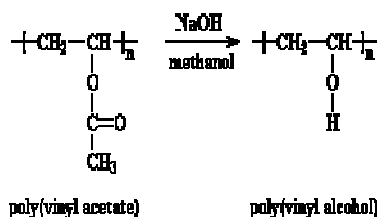


Fig 1 The formation of PVA

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Polyvinyl alcohol is an odorless and tasteless, translucent, white or cream colored granular powder. Polyvinyl alcohol contains two OH groups. It helps to retain water in concrete. It is soluble in water, slightly soluble in ethanol, but in soluble in other Organic solvents. Typically a 5% solution of polyvinyl alcohol exhibits a PH in the range of 5.0 to 6.5. Polyvinyl alcohol has excellent emulsifying and adhesive properties. PVA is fully degradable and dissolves quickly. PVA has a melting point of 230°C and 180-190°C.



Fig 2 Purchased Poly Vinyl Alcohol

Sodium Lignosulphonate: Sodium Lignosulphonate (lignosulfonate) is a water reducer and is mainly used for concrete mixture as water-reducing additive. This chemical has low air content, water reducing rate is high, low dosage, adapt to most kind of cement. Formulated using best constituents, this chemical contain more than 80% of organic matter, is rich in potassium and nitrogen.

Table 4 Properties of Sodium Lignosulphonate

Index Items	Standard Value	Test Result
Appearance	Dark brown	Meets the requirement
Lignosulphonate	50% (min)	55
Dry matter	92% (min)	94
Moisture content	7.0% (max)	3.9
PH Value	7-11	8
Inorganic salts (Na_2SO_4)	5.0% (max)	1.9
Total reducing matter	4.0% (max)	4.1
Water insoluble matter	2.5%	1.3



Fig 3 Sodium Lignosulphonate.

This sodium Lignosulphonate is ideal for applying to dam project, building project, thruway project etc. This chemical is as plasticizers in making concrete, where it facilitates concrete to be made with less water while sustaining the ability of the concrete to flow. These are also used at the time of producing cement, where they act as grinding helps in the cement mill and as a raw mix slurry deflocculant.

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MIX DESIGN

Mix design is done according to IS 10262: 2009. Concrete mix of M35 is adopted and based on that the target mean strength is determined. The proportion of the mix is 1:1.664:3.06:41. The different mixes which are used in this study are listed in the following table. During this study the PVA is varying in 0.24 % to 0.96 % of cement which is combined with 0.5 % to 2% of Sodium lignosulphonate. N which is taken as the control mix with zero percentage PVA and zero percentage Sodium Lignosulphonate (SL) and the control specimens are conventionally cured ie water curing.

Table 5 Mix details for 1 m³ of concrete

MATERIAL	QUANTITY (KG/M ³)	PROPORTION
Cement	419.512	1
Fine Aggregate	698.23	1.664
Coarse Aggregate	1286.14	3.06
Water	172	.41

FRESH PROPERTIES OF CONCRETE

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

Table 6: Slump characteristics.

Sl No	Mix	Slump (mm)
1	N	75
2	P _{0.24} SL _{0.5}	76
3	P _{0.24} SL ₁	78
4	P _{0.24} SL _{1.5}	80
5	P _{0.24} SL ₂	82
6	P _{0.48} SL _{0.5}	78
7	P _{0.48} SL ₁	79
8	P _{0.48} SL _{1.5}	81
9	P _{0.48} SL ₂	83
10	P _{0.96} SL _{0.5}	79
11	P _{0.96} SL ₁	81
12	P _{0.96} SL _{1.5}	83
13	P _{0.96} SL ₂	84

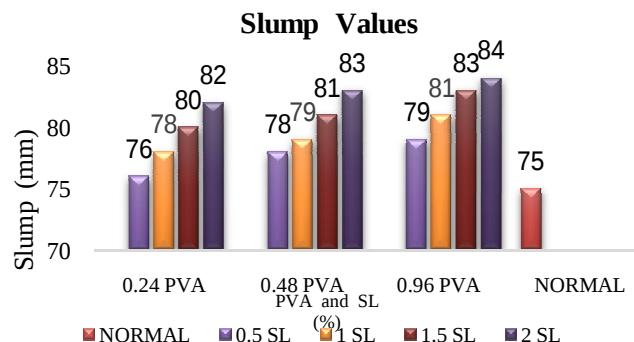


Fig 4 Graph showing the variation of slump values

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The slumps of different mixes were shown in table and fig shows the graphical representation of slump values of concrete. The slump value of self curing concrete is increases with addition of self curing agent. The slump value increased up to 12% as compared with normal concrete.

MECHANICAL PROPERTIES OF CONCRETE

Compressive Strength: Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. The compressive strength tests were done on concrete cube specimens of size 150mm X 150mm X 150mm. The cubes were tested after air curing periods of 7th and 28th days

Split Tensile Strength: The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

Flexural Strength: Flexural strength is one measure of the tensile strength of concrete. It is measure of an unreinforced concrete beam or slab to resist in bending.

The test results of compressive strength split tensile strength and flexural strength are tabulated in table 7. The graph variation are show in fig 5, fig 6 and fig 7.

Table 7 Mechanical properties of Self curing concrete.

Mix	Compressive Strength (N/mm ²)		Split Tensile Strength (N/mm ²)		Flexural Strength (N/mm ²)	
	7 th Day Compressive Strength	28 th Day Compressive Strength	7 th Day Split Tensile Strength	28 th Day Split Tensile Strength	7 th Day Flexural Strength	28 th Day Flexural Strength
N	28.3	40.12	2.68	4.39	3.3	6
P _{0.24} SL _{0.5}	30.82	41.18	2.47	4.75	3.5	6.25
P _{0.24} SL ₁	32.86	43.134	3.31	5.86	4.54	7.01
P _{0.24} SL _{1.5}	28.45	38.83	2.85	5.01	4.09	6.89
P _{0.24} SL ₂	25.63	36.012	2.25	4.38	3.31	6.01
P _{0.48} SL _{0.5}	31	42.45	2.87	5.41	3.73	6.5
P _{0.48} SL ₁	33.5	46.01	3.71	6.62	4.96	7.65
P _{0.48} SL _{1.5}	29.5	41.03	3.12	6.01	4.36	7.2
P _{0.48} SL ₂	27.77	38.12	2.67	5.03	3.4	6.91
P _{0.96} SL _{0.5}	28.86	40.4	2.5	4.45	3.2	6.02
P _{0.96} SL ₁	30.52	41.54	3.22	5.49	4.21	6.35
P _{0.96} SL _{1.5}	28.05	38.21	2.34	4.76	3.82	5.89
P _{0.96} SL ₂	24.42	36.98	2.12	4.52	3.12	5.54

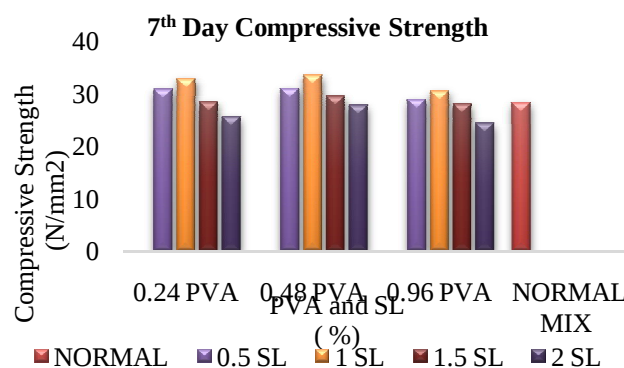


Fig 5 Graph Showing the Variation of Compressive Strength 7th day

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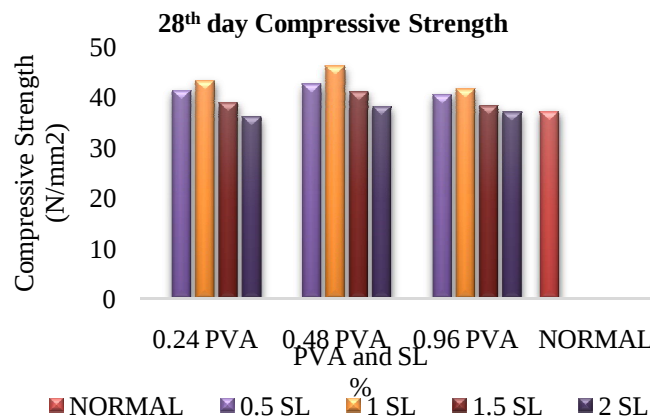


Fig 6 Graph Showing the Variation of Compressive Strength 28th day

From the fig 5 and fig 6 the result it is observed that the compressive strength of air cured concrete increases with Sodium Lignosulphonate up to 1% then it decreases for 1.5% and 2% of Sodium Lignosulphonate with every combination of Poly vinyl alcohol. The mix P_{0.48} SL₁ with 0.48 % Poly Vinyl alcohol and 1% Sodium Lignosulphonate give maximum compressive strength as compared to all other mixes. When compared to normal mix, the self curing concrete is 23.94% higher the compressive strength.

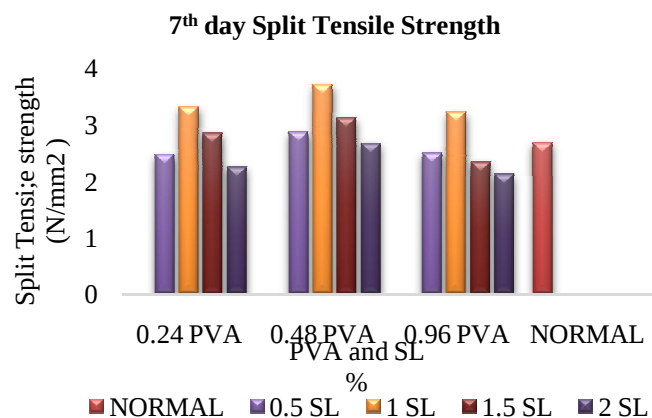


Fig 6 Graph Showing the Variation of Split Tensile Strength 7th day.

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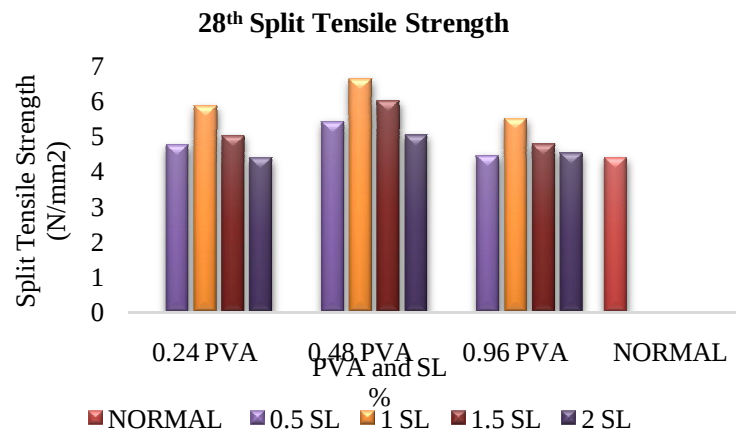


Fig 7 Graph Showing the Variation of Split Tensile Strength 28th day.

From the result it is observed that the Split tensile strength of air cured concrete is increases with Sodium Lignosulphonate up to 1% then it is decreases for 1.5% and 2% of Sodium Lignosulphonate with every combination of Poly vinyl alcohol. The mix P_{0.48} SL₁ with 0.48 % Poly Vinyl alcohol and 1% Sodium Lignosulphonate give maximum Split tensile strength ascompared to all other mixes. When compared to normal mix, the self curing concrete is 50.7% higher the Split tensile strength

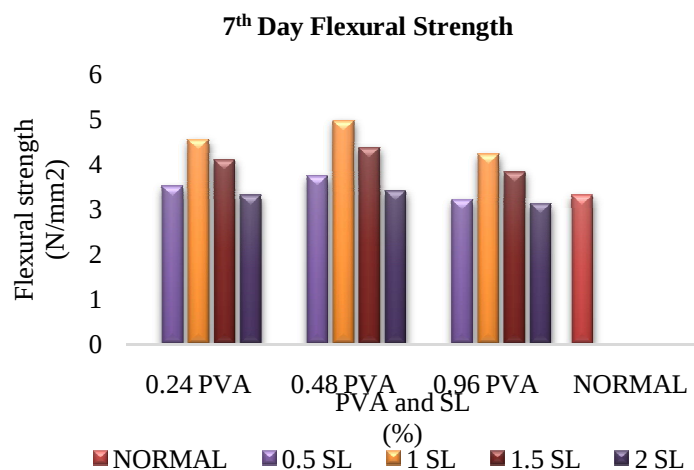


Fig 8Graph Showing the Variation of Flexural Strength 7th day.

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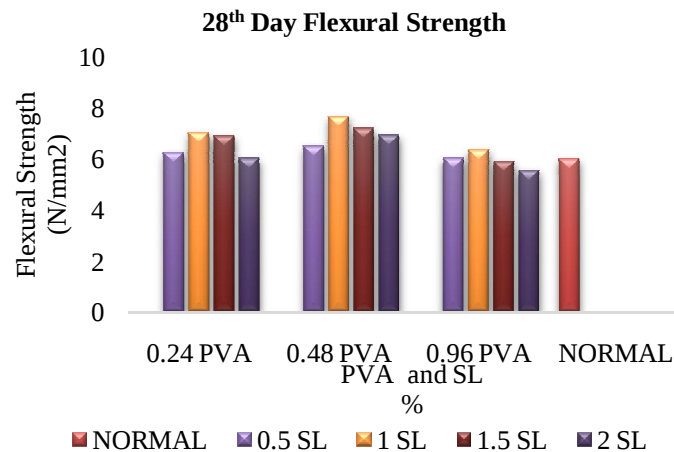


Fig 9 Graph Showing the Variation of Flexural Strength 28th day.

As same as the above results of compressive strength and split tensile strength. The flexural strength is also increased by the addition of self curing agents. The mix $P_{0.48} SL_1$ with 0.48 % Poly Vinyl alcohol and 1% Sodium Lignosulphonate give maximum flexural strength as compared to all other mixes. When compared to normal mix, the self curing concrete is 27.5% higher the flexural strength.

DURABILITY PROPERTIES

Durability of concrete is its ability to perform satisfactory in the exposure condition to which it is subjected over an intended period of time with minimum maintenance. The environment in which the concrete is exposed plays an important role in the durability. The tests conducted to determine the durability characteristics are

Water Absorption: One of the most important properties of good quality concrete is low permeability, especially one freezing and thawing. A concrete with low permeability will resist entering of water and is not as capable to freezing and thawing.

Table 8 Water Absorption of Self Curing Concrete

Mix	Percentage of Water Absorbed	
	7 th Days	28 th Days
$P_{0.24} SL_{0.5}$	0.11	0.34
$P_{0.24} SL_1$	0.109	0.326
$P_{0.24} SL_{1.5}$	0.105	0.314
$P_{0.24} SL_2$	0.1	0.303
$P_{0.48} SL_{0.5}$	0.09	0.28
$P_{0.48} SL_1$	0.081	0.276
$P_{0.48} SL_{1.5}$	0.072	0.253
$P_{0.48} SL_2$	0.064	0.245
$P_{0.96} SL_{0.5}$	0.042	0.232
$P_{0.96} SL_1$	0.041	0.229
$P_{0.96} SL_{1.5}$	0.039	0.226
$P_{0.96} SL_2$	0.037	0.221

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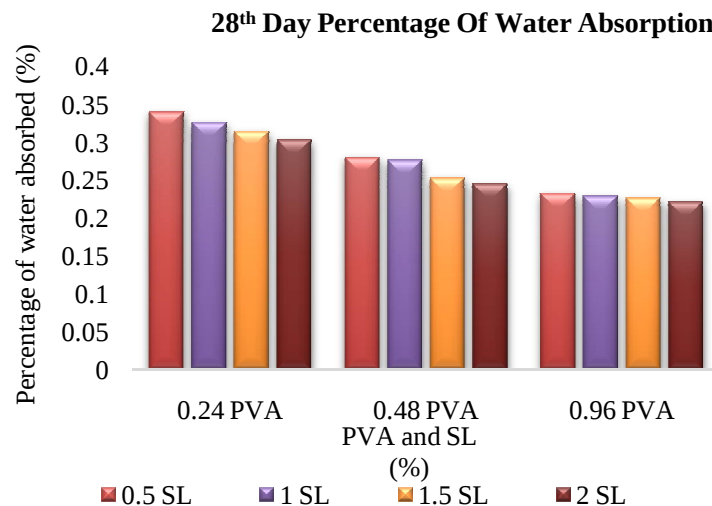


Fig 10 Graph Showing the Variation of Water Absorption of 28th day

From the result we concluded that the water absorption of the self curing concrete is decreases with the addition of the combination (PVA and SL) of self curing agent. One of the main reason for this is ,they are water reducing agents.

Acid Resistance of Self Curing Concrete: Cube size of 100x100x100 were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% of diluted H_2SO_4 is used. The cubes were to be immersed in acid solution for a period of 28 days. The concentration is to be maintained throughout this period. After 28 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack was determined. The degree of attack was evaluated by measuring the expansion of concrete cubes, compressive strength and weight losses of the specimens. The results are shown in table 9 and graph variations are shown in fig 11 and fig 12.

The weight loss is calculated as,

$$\text{Percentage of weight loss} = \frac{(W_1 - W_2)}{W_1} * 100$$

Chloride Resistance of Self Curing Concrete: The chloride resistance of concrete was studied through chemical attack by immersing concrete blocks in 5% of NaCl solution. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. The mass of specimens ere measured and the mass losses were determined. Also loss in strength is determined. The results are shown in table 9 and graph variations are shown in fig 13 and fig 14.

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Table 9 Acid Resistance and Chloride Resistance of Self Curing Concrete

Mix	Acid Resistance				Chloride Resistance			
	Percentage of Loss in Weight		Percentage of Loss in Strength		Percentage of Loss in Weight		Percentage of Loss in Strength	
	7 th Days	28 th Days	7 th Days	28 th Days	7 th Days	28 th Days	7 th Days	28 th Days
P _{0.24} SL _{0.5}	0.09	2.05	0.81	8.5	0.059	1.24	0.69	6.25
P _{0.24} SL ₁	0.088	2.02	0.78	8.23	0.054	1.22	0.671	6.2
P _{0.24} SL _{1.5}	0.086	1.99	0.75	8.11	0.051	1.215	0.664	6.13
P _{0.24} SL ₂	0.0859	1.98	0.74	7.98	0.042	1.21	0.65	6.12
P _{0.48} SL _{0.5}	0.089	2.02	0.79	7.87	0.05	1.22	0.68	6.21
P _{0.48} SL ₁	0.087	1.976	0.76	7.65	0.044	1.213	0.667	6.16
P _{0.48} SL _{1.5}	0.086	1.976	0.758	7.645	0.041	1.20	0.65	6.05
P _{0.48} SL ₂	0.085	1.965	0.732	7.5	0.039	1.19	0.646	5.94
P _{0.96} SL _{0.5}	0.087	1.99	0.75	7.84	0.045	1.2	0.66	6.04
P _{0.96} SL ₁	0.085	1.96	0.748	7.64	0.041	1.19	0.65	5.87
P _{0.96} SL _{1.5}	0.0845	1.95	0.72	7.42	0.038	1.16	0.641	5.74
P _{0.96} SL ₂	0.084	1.93	0.712	7.1	0.035	1.14	0.637	5.71

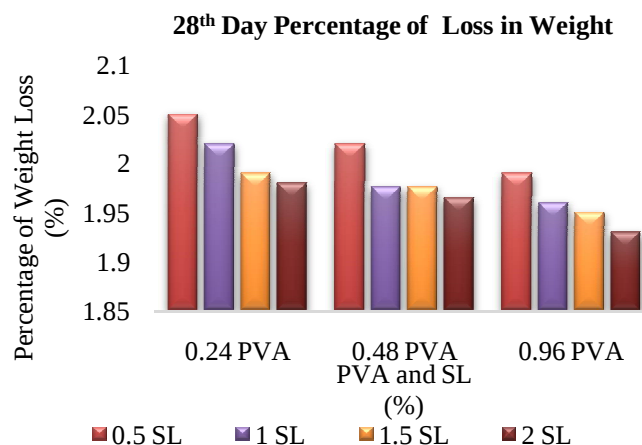


Fig 11 Graph Showing the Variation of Acid Resistance Percentage of Loss in Weight of 28th day.

The acid resistance test of self curing concrete gives the better results. The percentage of loss in weight decreases with addition of self curing agent. The minimum percentage of loss in weight is 1.92% in Acid resistance test. The self curing concrete is better resistance in the durability.

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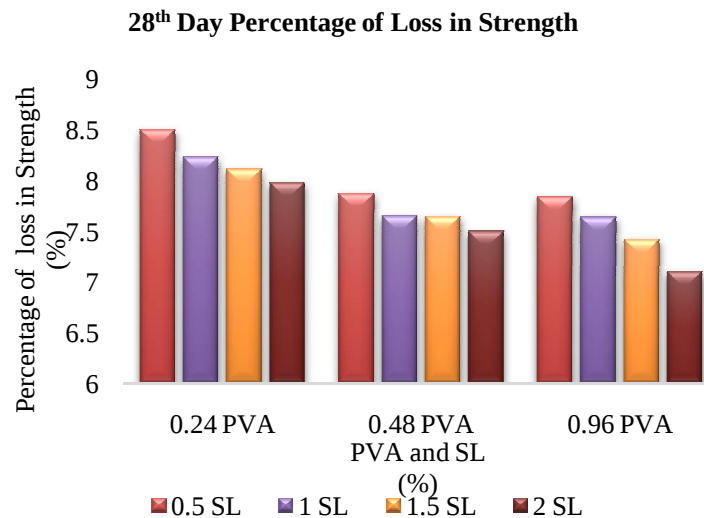


Fig 12 Graph Showing the Variation of Acid Resistance Percentage of Loss in Strength of 28th day.

The acid resistance test of self curing concrete gives the better results. The percentage of loss in strength decreases with addition of self curing agent. The minimum percentage of loss in strength is 7.1% in Acid resistance test. The strength loss in the self curing concrete is less when the addition of the self curing agents. From the above result we can conclude that the self curing concrete is better in acid resistance.

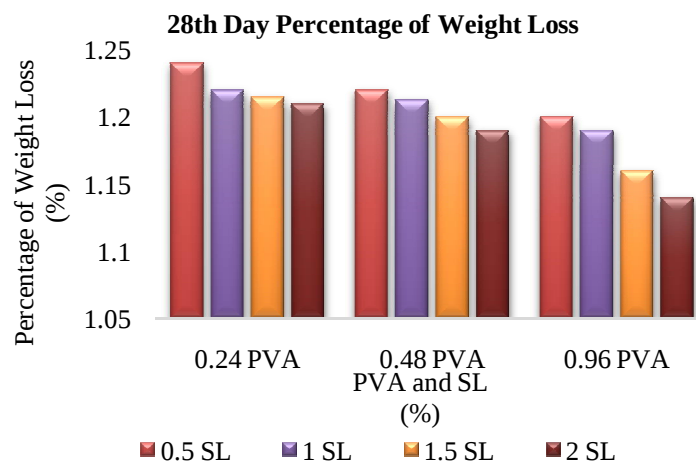


Fig 13 Graph Showing the Variation of Chloride Resistance Percentage of Loss in Weight of 28th day.

The chloride resistance test of self curing concrete gives the better results. The percentage of loss in weight decreases with addition of self curing agent. The minimum percentage of loss in weight is 1.14% in chloride resistance test. The loss weight is less or lower means good quality concrete. The self curing concrete is better resistance in the durability.

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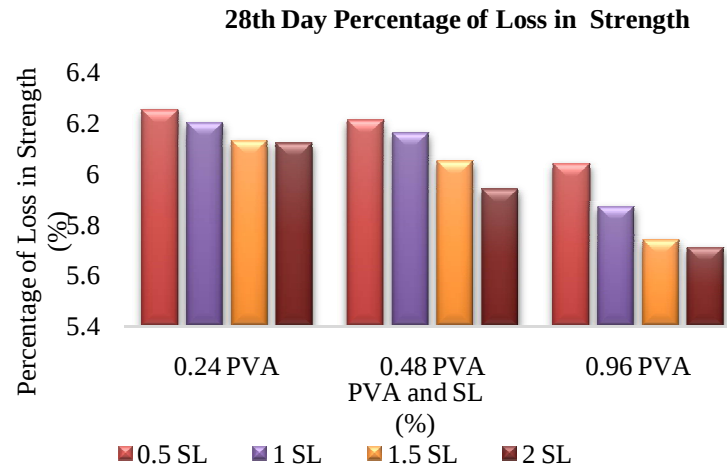


Fig 13 Graph Showing the Variation of Chloride Resistance Percentage of Loss in Strength of 28th day.

The minimum percentage of loss in strength is 5.71%, from this we conclude that addition of self curing agent increases the better result in durability. The loss in strength is decreases with increasing the addition of agents. So self curing concrete is better in durability properties.

IV. CONCLUSION

During this project work the effects self curing agents like Poly Vinyl Alcohol (PVA) and Sodium Lignosulphonate (SL) on the mechanical properties and durability properties of concrete were studied. M-35 mix is used and it is designed according to IS 10262: 2009. The concrete specimens such as cubes (150x150x150 and 100x100x100) cylinders and beams are to be casted and tested for finding the strength of concrete for various percentage replacement of cement with PVA and SL. Based on the investigation following conclusions is drawn.

- From the experimental work, it can be concluded that, concrete with combination of self curing agents PVA and SL attained strength higher than the normal curing concrete
- The slump value of self curing concrete is increases wit addition of self curing agent.
- The mix $P_{0.48} S_1$ with 0.48 % Poly Vinyl alcohol and 1% Sodium Lignosulphonate give maximum compressive strength ascompared to all other mixes. When compared to normal mix, the self curing concrete is 23.94% higher the compressive strength.
- For every combination of PVA (0.24%,0.48%,0.96%) maximum strength is obtained with 1% of SL.
- The split tensile strength is increased by 50.7% for 0.48 % PVA and 1% SL.
- The flexural strength of air cured mixes is increased the value of 27.5% as compared to conventional concrete.
- The percentage of water absorption of the self curing concrete is decreases with the addition of the combination (PVA and SL) of self curing agent. One of the main reason for this is, they are water reducing agents.
- The minimum percentage of water absorption is obtained in the $P_{0.96} S_{L2}$ mix.
- The acid resistance test of self curing concrete gives the better results. Both the percentage of loss in weight and percentage of loss in strength decreases with addition of self curing agent
- The minimum percentage of loss in weight is 1.92% and minimum percentage of loss in strength is 7.1% in Acid resistance test.
- The chloride resistance test of self curing concrete gives the better results. Both the percentage of loss in weight and percentage of loss in strength decreases with addition of self curing agent

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- The minimum percentage of loss in weight is 1.14% and minimum percentage of loss in strength is 5.71% in Chloride resistance test.

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