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Strength Properties of Self-Curing Concrete with Sodium Lignosulphonate

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Abstract
Water is the most important ingredient for any construction activity. Without water, concrete cannot be prepared for its good compaction and cohesiveness. In view of the large quantity requirement of the concrete and massive urbanization need for new technology based innovations which have been increased many folds. This is done by using Self-curing admixtures like Polyethylene glycol, Sodiumlignosulphonate, Polyvinyl alcohol in concrete which help in curing concrete by retaining its moisture content. To achieve proper self-curing, the self-curing admixtures are added in required proportions to maximize the properties of concrete. Sodium Lignosulphonate, a chemical self-curing admixture is used in proportions of 0.25%, 0.5%, 0.75%, 1.0%, 1.5% trials by weight of cement as cement replacement in the grades of M40 and M50 to achieve self-curing concrete. The Mechanical properties of self-curing concrete are compared with that of conventional concrete. It is observed that the workability of concrete increases with an increase in self-curing compound that is sodium lignosulphonate. The compressive strengths for self-curing concrete obtained with 0.25% of sodium lignosulphonate is greater than conventional concrete by 6.07% and 3% for M40 and M50 grades of concrete respectively. The trial of 0.25% sodium lignosulphonate obtained maximum splitting tensile strength as well as flexural strength for both M40 and M50 grades and the values greater than conventional concrete.

Keywords: Self-curing, Sodium lignosulphonate admixture, Conventional concrete, Self-curing concrete, Workability, Mechanical properties of concrete.

1. Introduction

The curing of concrete is the major area that lacks attention and importance in the construction field, especially in India. Proper curing provides the concrete with its desired properties. Appropriate curing of concrete structures is important to fulfill good performance and durability requirements. This is accomplished in traditional curing by external curing. But it is not always possible to cure on some occasions such as water shortage, concreting works are done at greater heights, etc., To overcome such problems self-curing is adapted.

There are several advantages of self-curing that are, heightened hydration process, strength development, increased durability, reduced permeability, reduced autogenous shrinkage, and fissures, etc., some measures must be taken to prevent the loss of water from the surface of the concrete.

Therefore, self-curing can be considered as creating a favorable environment for concrete during the early period for uninterrupted hydration. Self-curing concrete is one among the special concretes which is gaining its importance in recent days, as it avoids errors in curing which were caused by a human along with curing structures which are not accessible, also terrains where curing becomes difficult and in places where the fluoride content badly influences the property of concrete.

The use of self-curing admixtures is very important from the point of view that saving water, a necessity, each cubic meter of concrete requires 3 m3 of water in construction, most of which is used for curing, that amount of water can be saved. 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 to as 'Self-curing.Admixtures that help in retaining the moisture content from evaporating and help in the process of hydration are termed self-curing admixtures. There are natural and chemical admixtures that can be used as self-curing admixtures.

- Natural admixtures
  - Wood powder
  - Light weight aggregates
  - Spinaciapleracea
  - Calatropis gigantean
- Chemical admixtures
  - Poly-Ethylene Glycol (PEG)
  - Poly-Vinyl Alcohol (PVA)
  - Poly-Acryl Amide (PAM)
  - Sodium Lignosulphonate (SL)
  - Poly-Acrylic Acid (PAA)

Among the admixtures mentioned above, studies are done on most of the admixtures and are proved that adding the admixtures in a certain proportion will help in curing concrete internally without much change in the mechanical properties of concrete.

1.1 Advantages of Self-Curing

It is the alternate of construction in desert regions where major scarcity of water is there.

Self-Curing (Internal Curing) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do.

Provides water to keep the Relative Humidity (RH) high, keeping self- desiccation from occurring.Eliminates largely autogenous shrinkage.

Can make up for some of the deficiencies of external curing, both human-related and hydration.

Increases the strength of concrete to some extent.

1.2 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 to shrinkage which may cause early-age cracking

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1.3 Sodium Lignosulphonate Admixture

Sodium Lignosulphonate (lignosulfonate) is a water reducer and is mainly used for concrete mixtures as a water-reducing additive. This chemical has low air content, water reducing rate is high, low dosage, adapt to most kind of cement. Formulated using the best constituents, this chemical contains more than 80% of organic matter, is rich in potassium and nitrogen.Lignosulfonates are obtained from sulfite pulping processes wherein cellulose is extracted from wood in the pulp industry. The so-called sulfite pulping process involves mixing sulfur dioxide (SO2) with an aqueous solution of the base to generate the raw liquor for cooking the wood. In water, the sulfur dioxide forms sulfurous acid (H2SO3), which degrades and eventually sulfonates the lignin by replacing a hydroxyl group with a sulfonate group, allowing it to be solubilized and separated from the cellulose in non- precipitated form. Lignosulfonate is also used as a dispersing agent in materials, such as in the production of brick or tile. Details are given in figure 1and 2.

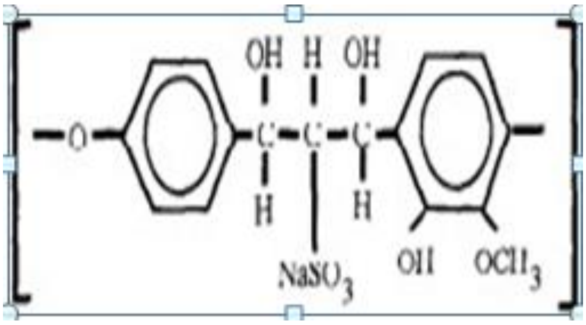


Figure 1. Sodium Lignosulphonate Monomer

This sodium lignosulphonate is ideal for applying to dam projects, building projects, thruway projects, etc. This chemical is also used 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 help in the cement mill and as a raw mix slurry deflocculant.

Figure 2. Sodium Lignosulphonate

- **Features:**
  - Better water-solubility
  - Surface activity and dispersion force
  - Antimicrobial and preservative properties
- **Application Areas:**
  - Porcelain
  - Animal feed
  - Petroleum industry
  - Concrete admixture

- Metallurgic engineering
- Pesticides

The sodium lignosulphonate product can be applied as a generally built material and water reducing admixture of series multifunction high-performance water reducing admixture, in the field of concrete additives.

1.4 Mechanism of Self-Curing

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapor 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 vapor pressure, thus reducing the rate of evaporation from the surface.

1.5 Need for Self-Curing Concrete

A concrete structure needs to be cured with water for the hydration process to continue. Proper curing provides the concrete with its desired properties. It is not always possible to cure on some occasions such as water shortage, concreting works are done at greater heights, etc., In such cases, the use of self-curing admixtures in concrete helps to prevent moisture loss from concrete and helps in the process of hydration. Self-curing can be considered as creating a favorable environment for concrete during the early period for uninterrupted hydration. The use of self-curing concrete helps in saving huge amounts of water required for curing.

1.6 Aims and Objectives

To determine the design mix proportions of self-curing concrete, using chemical admixture sodium lignosulphonate, for various trials of 0.25%, 0.50%, 0.75%, 1.00%, and 1.50%, for M40 and M50 grades of self-curing concrete.

To obtain the mechanical properties of self-curing concrete, using chemical admixture sodium lignosulphonate, for M40 and M50 grades of concrete.

1.7 Scope of Present Study

There are various self-curing chemical admixtures available on which studies were done and proved. The sodium lignosulphonate chemical admixture is used in M20 and M35 grades of concrete in the trial proportions of 0.5%, 1.0%, 1.5%, and 2.0% to study the mechanical properties of self-curing concrete. In this study, sodium lignosulphonate is used to design M40 and M50 grades of concrete in trials of 0.25%, 0.50%, 0.75%, 1.00%, 1.50% and to study the mechanical properties of self-curing concrete.

Sodium lignosulphonate is used in powder as the self-curing agent. Superplasticizer, conplast SP430 DIS is used as a water-reducing admixture, the amount of SP430 added is kept constant throughout all trials is constant.

2. Literature Review

IlkerBekirTopcu, OzginAtesin (2016)., [01] In their study of “Effect of high dosage lignosulphonate and naphthalene sulphonate based plasticizer usage on micro concrete properties” have found that in concrete production because plasticizers are used for a small percentage by weight of cement (in the range from 0.3% to 1.5%).Azhagarsamy, Sundaraman (2016)., [02] have studied the strength and durability properties of concrete using water-soluble polyethylene glycol (PEG 400) 0.5% a self- curing agent using M20 grade concrete. The compressive strength at 3, 7, and 28 days have been obtained with normal curing and self-curing condition.Sanjay Kumar R, Suganya Devi K (2016)., [03] deals with self-curing reinforced concrete beams enclosed with steel I section by utilizing Polyethylene glycol (PEG-

400) as an internal curing agent, and comparisons have been made between basic curing concrete beams.R. Malathy (2017)., [04] conducted experimental work on the new and hardened properties of organic self-curing concrete with 30% fly ash as part of a cement substitute. G. Thrinath, P. Sundara Kumar (2017)., [05] conducted work on internal curing concrete by Polyethylene Glycol (PEG) as cement replacement would investigate the compressive and bending qualities of the M30 grade concrete. Cement is partially replaced by PEG-400 as 0.5 %, 1 %, 1.5 % and 2 % by weight of cement.DaudMohamad, WaniMohdSapuan (2017)., [06] this paper exhibits the impact of using baby diapers polymer as an internal curing admixture in self-curing concrete. In this process, baby diaper powder was used in different proportions (1%, 2%, 3 %, 5 % and 10 %) of cement weight.HasanSahanArel a, ErtugAydin (2017)., [07] the effects of various metal-cation containing lignosulfonate-based plasticizers on the properties of concrete mixtures produced using cement with various Ca(SO4)2H2O, tricalcium aluminate, and tetra calcium alumino ferrite contents were investigated. NageshT.Suryawanshi, Sunil B.Thakare (2018)., [08] this study used the combination of metakaolin as mineral admixture, poly-vinyl alcohol (PVA), and polyacrylic acid (PAA) as chemical admixtures, for self-curing concrete. The experiment was conducted on high-strength concrete and a target mean strength of61.51 N/mm2 fixed by various trail mixes. In the study, cement is replaced with metakaolin at differing proportions between 5% and 15%, and the optimum value was found at 5% and up to 7.5% strength equals to control mix.M. V. Jagannadha Kumar, K. JagannadhaRao, B. Dean Kumar, V. Srinivasa Reddy (2018)., [09] this study aims to discover an ideal mix proportion of self-curing concrete for different grades M20, M40, and M60 by supplementing polyethylene glycol (PEG-400) as an internal curing agent.K V S Gopala Krishna Sastry, PutturuManoj Kumar (2018)., [10] this study focuses on the impact of self-curing agents such as Poly-Ethylene Glycol (PEG), Poly Vinyl Alcohol (PVA), and Super Absorbent Polymer (SAP) on the concrete mix of M25 grade (reference mix). T. A SajanaKhader, T.S Shabana (2018)., [11] investigated the mechanical properties of self-curing concrete by adding Sodium Lignosulphonate (SL) and Polyvinyl alcohol (PVA) as self-curing agents. M35 grade concrete is used at a rate of PVA 0.24%, 0.48%, 0.96% and SL 0.5%, 1%, 1.5%, 2% by weight of cement. PVA and SL can retain moisture for a long period.S. El-Dieband, T. A. El-Maaddawy, (2018)., [12] experimented on assessment of reinforcement corrosion protection of self-curing concrete by utilizing water-soluble polymers like polyethylene glycol (PEG) and polyacrylamide (PAM). Vaisakh G, M S Ravi Kumar, P Siva Bala (2018)., [13] the primary goal of this research was to examine the various properties of M50 grade self-curing concrete by using polyethylene glycol (PEG-400) as the internal curing agent.Ahmad Mustafa Sabaoon, Navinderdeep Singh (2019)., [14] the primary purpose of this study was to examine the mechanical properties of self-curing concrete by incorporating natural and chemical compounds as self-curing agents, such as wood powder and polyethylene glycol 400 (PEG-400).Zaheer Ahmed, Harshith H J, Dr. Mushtaq Ahmed Bhavikatti, Akshatha B A (2019)., [15] analyzed the mechanical properties of self-curing concrete with the application of light expanded clay aggregate (LECA) as a natural mixture. In this study, coarse aggregates are replaced by light expanded clay aggregates up to 20% for M30 grade concrete.CvkChaitanya, Priya Prasad, D. Neeraja, A. Ravitheja (2019)., [16] this study is being carried out to report on the use of pre-saturated lightweight aggregates (LECA) has been well established to counteract self-desiccation and autogenous shrinkage. Mohammad Balapour A, Weijin Zhao (2020)., [17] the essential objective of this assessment was to assess the likely utilization of a novel lightweight

total (LWA), spherical permeable responsive aggregate (SPoRA), delivered from squandering coal bottom debris, for self-curing of concrete.

3. Experimental Programme

3.1 Materials Used

OPC 53 grade cement conforming to code IS: 12269-1987 having a specific gravity of the cement is 3.15 is used with appearance in grey powder form. The cement is purchased from a nearby retailer. The cost of cement is Rs.350/- per bag. Where each bag contains 50 kgs of cement. Cement is purchased just before it is used. Cement when exposed to moist conditions, forms lumps, to avoid this cement bags were stacked and stored in dry condition. The properties of cement are tabulated below.

Table1:Properties ofCement

Property	Value	ISSpecification
Specificgravity	3.15	3-3.15,IS4031(PartIII)-1988
Fineness	9%	<10%,IS4031(PartI)-1996
StandardConsistency	33%	33-35%, IS4031(Part4)– 1988
InitialSettingtime	35 minutes	>30min,IS4031(Part5)-1988
FinalSettingtime	420 minutes	<600min,IS4031(Part5)-1988

3.2 CoarseAggregates

Coarse aggregates that are crushed granite, of size 20 mm or below that has been wellgraded of typical particle shape angular were used as the coarse aggregates for thepresentinvestigation. Samples are presented in figures 3 and 4.

Thefollowingtestswereperformedoncoarseaggregate

- Sieveanalysis
- Specificgravity
- Waterabsorption

Figure 3. (a) Coarse Aggregate, (b) Sieving the Coarse Aggregate, (c) Fine Aggregate

Property	Value
Specific Gravity	2.74
Fineness Modulus	6.72
Water Absorption	0.5

Table 2: Coarse Aggregate Properties

3.3 FineAggregates

For this study, locally available river sand that is well within IS 383 – 1970 is used.Sand is sieved using a 4.75mm standard sieve and is tested for its properties it shouldbe free from materials like clay, silt content and chloride contamination, etc. The sandwascleanedandscreenedatthelaboratorytoremoveal-lotherdeleteriousmaterialsandested as per the procedure given in IS: 2386 – 1963 presented in figure.3 (c).

Thefollowingtestswereperformedonfineaggregate

- Gradingofsand
- Specificgravity
- Waterabsorption

Generally, the sand having a fineness modulus of more than 3.2 is not used for making good concrete. Fineness modulus can also be used to combine two types of aggregate to get the desirable grading. Fineness modulus limits for various zones of sand according to IS 383-1970. From the sieve analysis shown in the table below the fine aggregate is graded as Zone II grading tabulated below.

Table 3: Fine Aggregate Properties

Property	**Value**
SpecificGravity	2.65
Fineness	2.464
WaterAbsorption	1.48

3.4 Sodium Lignosulphonate

Concrete water reducing agent, sodium lignosulfonate is a kind of powder low air- entraining retarding water-reducing agent. It belongs to an anionic surface-active substance, has an adsorption and dispersion effect on cement, and can improve various physical properties of concrete.

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

Table 4: Properties of Sodium Lignosulphonate

Properties	**StandardValues**
Specificgravity	1.25
Appearance	YellowBrownPowderform
Lignosulfonate	55%(min)
Drymatter	95%(min)
Water-insoluble	1.5%(max)
WaterReducingcapacity	8%min
Sulphate	2%-5%
Moisture	7%max
Calciumandmagnesiumcontent	0.3-1.5%
PackSize	25kg Bag
Purity	98%
pHValue	7.0-11.0

Storage and Handling: This can be easily stored in original closed and undamagedcontainers, in a dry place. The temperature for storage varies from 5°C and 30°C.Keeping away from moisture is always advised. While handling this chemical, aptpersonal protective equipment should always be worn, to stay safe and secure. Anycontactwith skin or eyesshould beavoided, powder is presented in figure2.

3.5 Superplasticizers

Superplastizer(SP's), also known as high range water reducers, are additives used in making high strength concrete. Plasticizers are chemical compounds that enable the production of concrete with approximately 15% less water content. Superplasticizers allow a reduction in water content by 30% or more. These additives are employed at the level of a few weight percent.

Figure 4.Conplast SP 430 DIS

The admixture used is FOSROC companyConplast SP 430 DIS. The superplasticizer used in the mix is 1% by weight of cement. The water content is reduced by adding 1% of the superplasticizer is 23% of water. The amount of superplasticizer used is kept constant throughout all the trials including the conventional concrete. The specifications of Conplast SP 430 are given by the company preseted in figure.4.

Health and Safety instructions: Conplast SP430 DIS is non-toxic. Any splashes on the skin should be washed immediately with water. Splashes on the eyes should be washed immediately with water and medical advice should be sought.

Table 5: Properties of SP 430 DIS

Property	Value
Specific gravity	1.2
Chloride content	Nil (As per BS 5075 part I)
Air entrainment	As per IS 9103

3.6 Water

Potable water confirming the requirements of IS 456-2000 Specifications was used. It should not contain any harmful chemicals. It is used for both mixing as well as curing the concrete. In this study, only conventional concrete is water cured.

3.7 Concrete Mix Design

3.7.1 Compressive Strength Test

Concrete is very strong in compression. It is said that the total compression will be taken by the concrete while any RCC structure is designed. The compression test is the most important strength test for concrete. Desired graded and air-dried samples of aggregates for each batch of concrete shall be taken. The cement samples shall be thoroughly mixed dry either by hand or in a suitable mixer on arrival at the laboratory to ensure that the material has the greatest possible blending and uniformity in it.

The compressive strength of concrete is the strength of hardened concrete measured by the compression test. The compression strength of concrete is a measure of the concrete's ability to resist loads that tend to compress it. It is measured by crushing cube concrete specimens in a compression testing machine.

Table 6: Details of self-curing M40 grade proportions (kg/m^3)

Trial	Self-curingadmixture	Quantity ofcement	Quantityof Coarse Aggregate	Quantity of Fine Aggregate	Quantity ofWater	Super-plasticizer
M40-0	0.00	412	1256.18	659.95	148	4.12
M40-1	1.03	410.97	1256.18	659.95	148	4.12
M40-2	2.06	409.94	1256.18	659.95	148	4.12
M40-3	3.09	408.91	1256.18	659.95	148	4.12
M40-4	4.12	407.88	1256.18	659.95	148	4.12
M40-5	6.18	405.82	1256.18	659.95	148	4.12

Table7:Detailsofself-curingM50gradeproportions(kg/m^3)

Trial	Self-curingadmixture	Quanti-tyofce-ment	Quanti-tyof CoarseAggregate	Quantity of Fine-Aggregate	Quantity ofWater	Super plasticizer
M50-0	0.00	435	1250.54	645.54	148	4.35
M50-1	1.09	433.91	1250.54	645.54	148	4.35
M50-2	2.18	432.82	1250.54	645.54	148	4.35
M50-3	3.27	431.73	1250.54	645.54	148	4.35
M50-4	4.36	430.65	1250.54	645.54	148	4.35
M50-5	6.53	428.47	1250.54	645.54	148	4.35

4. RESULTS:

The slump value obtained for both M40 and M50 grades of concrete

Table8:Slump valueforM40grade trials

Trials	Sodium Lignosulphonate Percentage(%)	Slump (mm)
M40-0	0.00	74
M40-1	0.25	76
M40-2	0.50	77
M40-3	0.75	77
M40-4	1.00	78
M40-5	1.50	79

Table9:Slump valueforM50grade trials

Trials	SodiumLignosulphonate Percentage (%)	Slump (mm)
M50-0	0.00	76
M50-1	0.25	78
M50-2	0.50	79
M50-3	0.75	80

M50-4	1.00	82
M50-5	1.50	82

The value of slump increases slightly for both the grades of M40 and M50 with theincrease in Sodium lignosulphonate, self-curing admixture. This is maybe due to theSL also being a water-reducing admixture of about 8% and is used as a self-curingadmixture.

4.1 CompressiveStrength TestResults

Thefollowing aretheresultsobtained during thestudy

4.2 GradeofConcrete:M40

The compressive strength obtained for both the trials of conventional concrete after 7days and 28 days are tabulated below. The mix proportion of trial A, which obtainedmaximum compressive strength after 28 days is used for the design of self-curingconcretetrials.

Table 9. Compressive strength of M40 conventional concrete (MPa)

Specimen	7 days strength	28 daysstrength	7 days strength	28 days strength
1	33.0	50.67	32.4	48.2
2	37.0	52.44	34.5	46.7
3	40.0	43.55	36.1	44.9
Average	36.67	48.88	34.33	46.6

Table 10. Compressive strength of self curing M40 grade (MPa)

Trials	Sodi-umLigno-sul-phonate	7 days	Avg. 7 days	28 days	Avg.28days
M40-1	0.25%	34.0	37.13	52.44	51.85
		36.4		49.78	
		41.0		53.33	
M40-2	0.50%	42.0	38.67	51.56	49.92
		36.0		44.44	
		38.0		53.78	
M40-3	0.75%	12.4	11.5	27.56	21.48
		11.5		20.89	
		10.6		16.00	
M40-4	1.00%	6.6	6.6	21.33	18.07
		6.1		17.78	
		7.1		15.11	
M40-5	1.50%	4.1	6.9	17.33	17.9
		9.8		19.11	
		6.8		17.26	

The trial M40-1 which is 0.25% of Sodium Lignosulphonate gives the maximum compressive strength. The trials M40-1 and M40-2 i.e., both 0.25% and 0.50% of sodium lignosulphonate chemical admixture, got compressive strength values greater than the conventional concrete. The relation is plotted between compressive strength obtained in MPa and various trials of concrete of M40 grade after both 7 days and 28 days. The 7-day compressive strength is maximum for M40-2 i.e., 0.5% of Sodium lignosulphonate chemical admixture.

Figure 6. Compressive strength after 7 days and 28 days for trials of M40 grade Self-curing concrete.

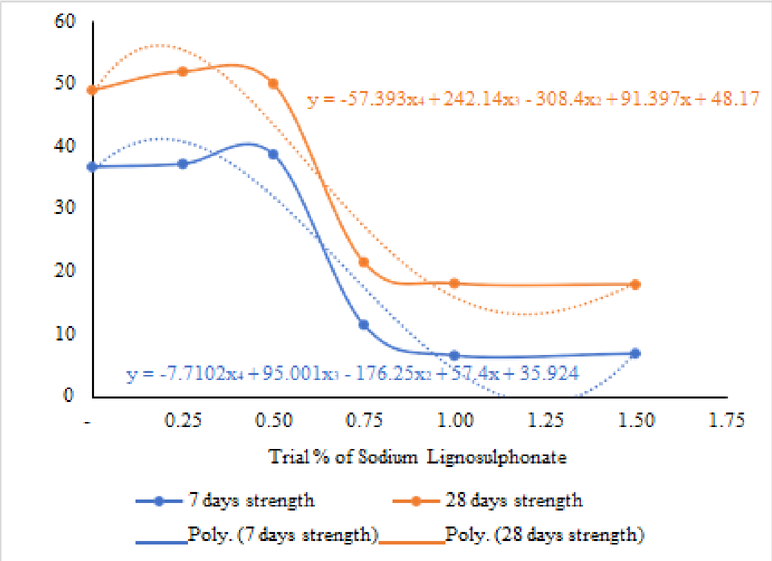
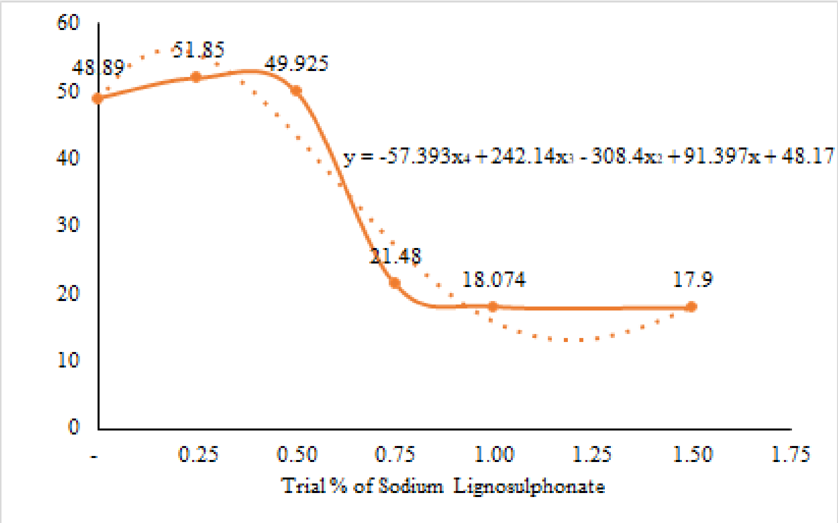
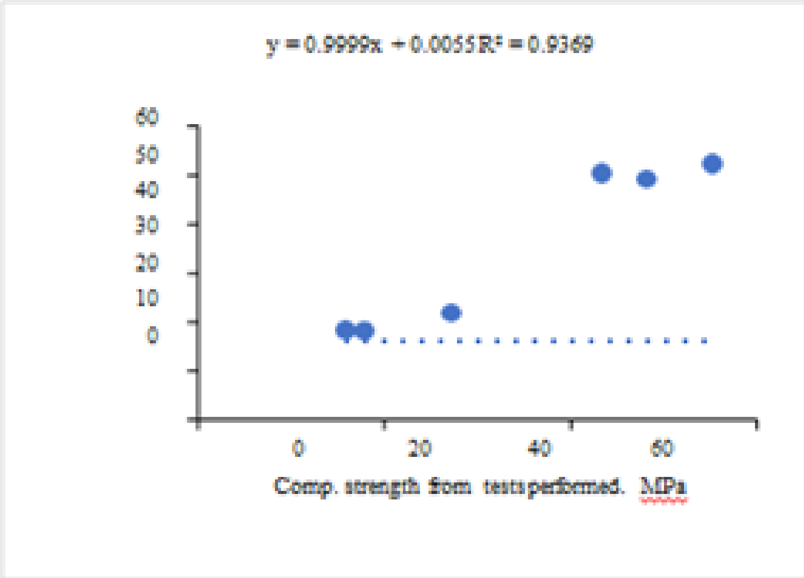


Figure 7.Compressive strength of various trials of M40 grade Self-curing concrete.



The trendline plotted was a polynomial equation of 4th order which is y = -57.393x4 + 242.14x3 - 308.4x2 + 91.397x + 48.17

Figure 8. R2 graph for M40 grade



The values of compressive strength obtained through the equation and the actual values obtained are tabulated below. The Pearson R2 coefficient value obtained when comparing the values of the equation with that of the tested values is 0.9369. Solving the equation for the max value it is found that max compressive strength is obtained at 0.187% and the value is 56 MPa.

Table 11. Results obtained through testing and Equation for M40 Grade

Trial % of Sodi-umLignosulphonate	Compressivestrengthfor M40trials(MPa)	
	Ob-tainedfromTests	Ob-tainedfromEquation
0.00	48.89	48.17
0.25	51.85	55.30
0.50	49.92	43.44
0.75	21.48	27.23
1.00	18.074	15.91
1.50	17.9	18.03

The compressive strength obtained for both the trials of conventional concrete after 7 days and 28 days is done based on IS 516 and the values obtained are tabulated below.

Table 12. Compressive strength of M50 conventional concrete (MPa)

Specimen	Trial Mix-A		Trial Mix-B	
	7 days strength	28 daysstrength	7 days strength	28 days strength
1	34.50	60.89	36.10	56.70
2	44.80	57.78	34.80	55.30

3	40.00	58.67	38.30	58.40
Average	39.77	59.11	36.40	56.80

Table 13. Compressive strength of self curing M50 grade (MPa)

Trials	SodiumLig-nosul-phonate	7 days	Avg. 7 days	28 days	Avg.28days
M50-1	0.25%	40.2	41.20	62.67	60.89
		40.8		60.44	
		42.6		59.56	
M50-2	0.50%	40.1	40.60	63.11	57.18
		40.5		57.78	
		41.2		50.67	
M50-3	0.75%	31.3	32.4	56.44	45.18
		32.4		42.67	
		33.5		36.44	
M50-4	1.00%	15.3	15.7	26.22	24.88
		16.1		23.56	
		15.7		24.89	
M50-5	1.50%	14.2	13.9	23.11	19.25
		13.6		17.78	
		13.9		16.89	

Figure 9.Compressive strength after 7 days and 28 days for trials of M50 grade Self-curing concrete.

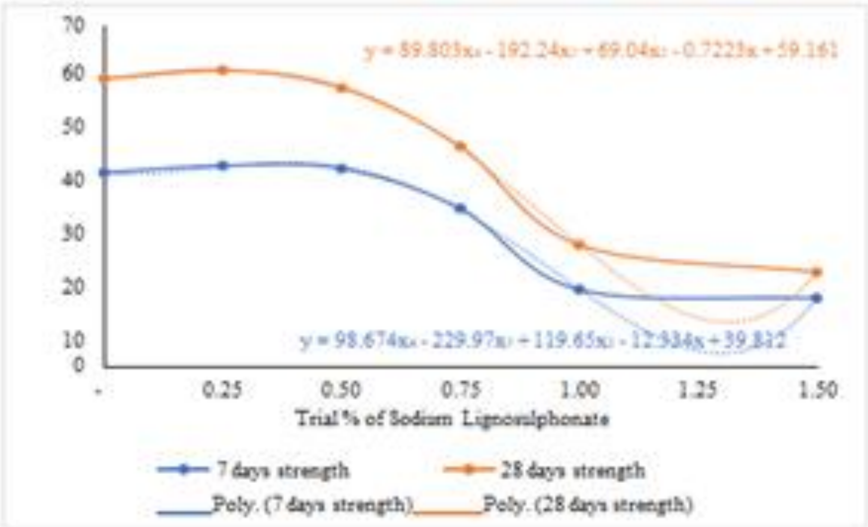
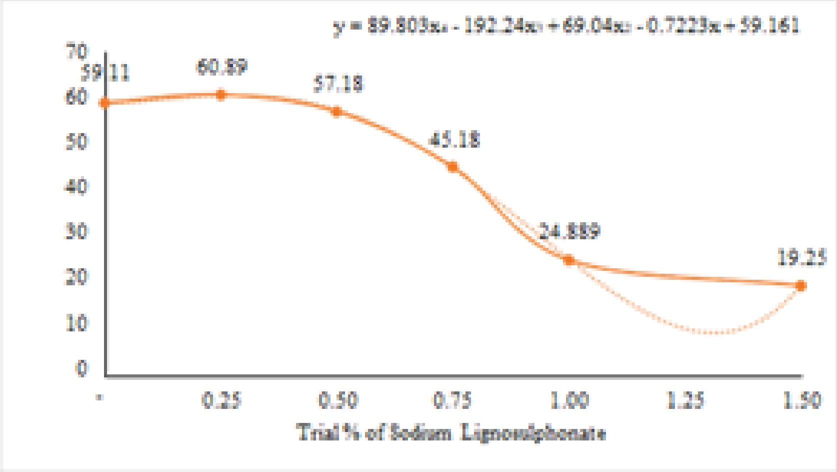


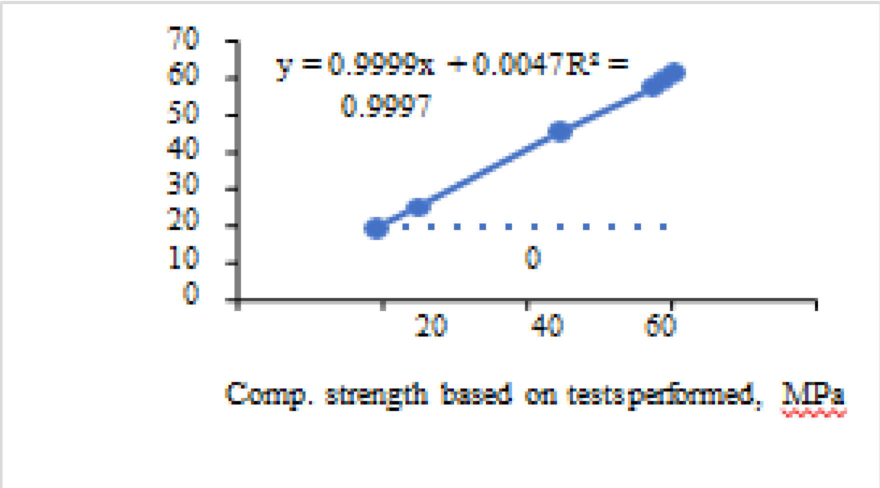
Figure 10.Compressive strength of various trials of M50 grade Self-curing concrete.



The mix proportion of trial C, which obtained maximum compressive strength after 28 days is used for the design of self-curing concrete trials. The specimens of self-curing concrete of M50 grade are not cured using a curing tank like the conventional concrete specimen.

The bar graph shows the compressive strength for M50 grade self-curing concrete. The trial M50-1 whichis 0.25% of Sodium Lignosulphonate gives the maximum compressive strength. Trial M50-1 is the only trial that got compressive strength values greater than the conventional concrete. The 7 days compressive strength and 28 days compressive strength followed a similar pattern.

Figure 11. R2 graph for M50 grade



The trendline plotted was a polynomial equation of 4th order which is y = 89.803x4 - 192.24x3 + 69.04x2 - 0.7223x + 59.161

The values of compressive strength obtained through the equation and the actual values obtained are tabulated below. The Pearson R2 coefficient value obtained when comparing the values of the equation with that of the tested values is 0.9997.

Table 14. Results obtained through testing and Equation for M50 Grade

Trial % of SodiumLigno-sulphonate	Compressivestrengthfor M50trials(MPa)	
	Ob-tainedfromTests	Ob-tainedfromEqua-tion
0.00	59.11	59.16
0.25	60.89	60.64
0.50	57.18	57.64
0.75	45.18	44.77
1.00	24.889	25.04
1.50	19.25	19.24

Solving the equation obtained from the graph to obtain the maximum value, we get the maximum compressive strength is obtained at the dosage of 0.286% which gave 60.71MPa.

4.3 Splitting Tensile Strength Results

The cylinder specimens are tested after 28 days for their splitting tensile strength. The values of Splitting tensile strength for the M40 grade are tabulated below.

The trial M40-1 i.e., 0.25% of sodium lignosulphonate obtained the highest value of splitting tensile strength of 2.78MPa. The value is more than theconventional concrete by 2.96%. All other trials have obtained even lesser values of splitting tensile strength. The value of splitting tensile strength is reduced with an increase in sodium lignosulphonate percentage.The cylinder specimens are tested after 28 days for their splitting tensile strength. The values of splitting tensile strength for the M50 grade are tabulated in Table 4.10. The values are calculated using the formula in IS 5816 also mentioned in chapter III.From the experimental results for the obtained splitting tensile strength in MPa of the conventional concrete along with trial proportions of self-curing concrete. The trial M40-1 i.e., 0.25% of sodium lignosulphonate obtained the highest value of splitting tensile strength of 2.80 MPa and is greater than that of conventional concrete splitting tensile strength of 2.78 MPa by 0.72%. All other trials have obtained even lesser values of splitting tensile strength. The value of splitting tensile strength is reduced with an increase in sodium lignosulphonate percentage.

4.4 Flexural Strength Results

Flexural strengths obtained are of conventional concrete along with trial proportions of self-curing concrete. The trial M40-1 i.e., 0.25% of sodium lignosulphonate gives the highest value of flexural strength 5.85 MPa and is greater than that of conventional concrete value 5.73 MPa by 2.1%. All other trials have obtained even lesser values of flexural strength. The value of flexural strength decreased with an increase in the percentage of sodium lignosulphonate.

The trial M50-1 i.e., 0.25% of sodium lignosulphonate gives the highest value of flexural strength and is greater than that of conventional concrete by 0.3%. All other trials have obtained even lesser values of flexural strength.

5 DISCUSSIONS

5.1 General

In this study, the superplasticizer used is Conplast SP430 DIS. The dosage of superplasticizer used is 1% and is constant throughout all the trials of M40 and M50 conventional and self-curing concrete. The superplasticizer added is well within the IS 10262-2019 standards of typical dosage 0.5% to 1.5%. The specimens in which self- curing admixture is added took a long time to set compared to the conventional mix. This is maybe due to the ability of sodium lignosulphonate to retain moisture. The specimens of conventional concrete are cured using normal curing tank. The specimens of self-curing concrete specimens no water is used to cure them. They are kept in the lab open to atmosphere.

There is an increase of voids and concrete is seen porous with the increase in the percentage of sodium lignosulphonate in the study made by IlkerBekirTopcu, OzginAtesin on “Effect of high dosage lignosulphonate and naphthalene sulphonate based plasticizer usage on micro concrete properties”. This might be the reason due to which the obtained values of compressive strengths, splitting tensile strengths, and flexural strengths were decreasing with increase in the percentage of sodium lignosulphonate for both the M40 and M50 grades of self-curing concrete.

5.2 Workability

The workability of concrete increased slightly with the increase in Sodium Lignosulphonate for both the grades of M40 and M50 for the constant water-cement ratio. The value of slump for M40 grade concrete trials increased from 74 mm to 79 mm and for M50 grade trials from 76 mm to 82 mm with increase in percentage of sodium lignosulphonate from 0.0% to 1.5%. The water-cement ratio of 0.36 and 0.34 is obtained for M40 and M50 grade concrete respectively. The mix is designed for the estimated slump of 75mm.

5.3 Compressive Strength

The conventional concrete trails which obtained maximum compressive strength are Mix A and Mix C for both M40 and M50 grades concrete and the mix proportions of respective grades are used in the design of self-curing concrete. The trial with 0.25% of Sodium Lignosulphonate resulted in good compressive strength for both M40 and M50 grades.

The trials of M40-1 and M40-2 i.e., 0.25% and 0.50% of sodium lignosulphonate obtained better compressive strength results than the conventional concrete. The maximum value is obtained at 0.25%. Equation of 4th order polynomial was formed based on the graph plotted for both the M40 and M50 grades obtained compressive strength values. For M40 grade concrete, the Pearson R2 co-efficient value obtained when comparing the values of the equation with that of the tested values is 0.9369. Solving the equation for the maximum value it is found that max compressive strength is obtained at 0.187% and the value is 56 MPa.

The trials of M50-1 i.e., 0.25% of sodium lignosulphonate obtained maximum compressive strength results of all the trials and is greater than the conventional concrete. For M50 grade concrete, the Pearson R2 co-efficient value obtained when comparing the values of the equation with that of the tested values is 0.9997. we get the maximum compressive strength at the dosage of 0.286% which gave 60.71MPa. The 28 days compressive strength obtained for the self-curing concrete for both the grades of M40 and M50 showed a similar pattern.

5.4 Splitting Tensile Strength

The Splitting tensile strength of self-curing concrete is slightly greater than conventional concrete for M50 grade of concrete. For both grades, the maximum splitting tensile strength values are achieved for the trials M40-1 and M50-1 i.e., at 0.25% of sodium lignosulphonate. With the increase in the amount of sodium lignosulphonate, the splitting tensile strength was reduced for both grades of concrete. i.e., the value of splitting tensile strength decreased from trials M40-1 to M40-5 and also for the trials M50-1 to M50-5.

5.5 Flexural Strength

The flexural strength of self-curing concrete of trial M40-1 and M50-1 is greater than that of conventional concrete for the grades of M40 and M50 respectively. The maximum flexural strength values are obtained for both the grades at 0.25% of sodium lignosulphonate, self-curing chemical admixture. With the increase in the amount of sodium lignosulphonate chemical admixture, the flexural strength decreased for both grades of concrete. i.e., the value of flexural strength decreased from trials M40-1 to M40-5 and also for the trials M50-1 to M50-5. All test results are presented in Tables 1-15.

6 CONCLUSIONS

1. The workability of Concrete increased for both M40 grade concrete and M50 grade concrete trials with the increase in the amount of sodium lignosulphonate.
2. Compressive strength of M40-1 and M40-2 i.e., 0.25% and 0.5% of Sodium Lignosulphonate attained higher than the conventional concrete by 6.07% and 2.12% respectively
3. Based on the equation derived from the graph of obtained values, the maximum compressive strength is obtained at 0.187% of sodium lignosulphonate and the value is 56 MPa. The Pearson R2 co-efficient value obtained is 0.9369.
4. Compressive strength of M50-1 i.e., 0.25% of Sodium lignosulphonate obtained higher than the conventional concrete by 2.92%.
5. Based on the equation derived from the graph of obtained values, the maximum compressive strength is obtained at 0.286% of sodium lignosulphonate which obtains compressive strength of 60.71MPa. the Pearson R2 co-efficient value obtained is 0.9997.
6. The splitting tensile strength for M40 grade self-curing concrete is achieved at 0.25% of sodium lignosulphonate which is 2.96% greater than conventional concrete, whereas the value decreased with an increase in the amount of chemical admixture.
7. The splitting tensile strength for M50 grade self-curing concrete is attained at 0.25% of Sodium Lignosulphonate, the value decreased with an increase in chemical admixture. The value is greater than conventional concrete by 0.72%.
8. The flexural strength for M40 grade self-curing concrete is maximum for the M40-1 trial i.e., 0.25% of sodium lignosulphonate, and the obtained value is greater than conventional concrete by 2.1%.
9. The flexural strength for M50 grade self-curing concrete is maximum for the M50-1 trial i.e., 0.25% of sodium lignosulphonate. The value is slightly greater than conventional concrete i.e., by 0.3%.
10. It can be concluded that with the increase in the sodium lignosulphonate chemical admixture in concrete, all the mechanical properties of concrete are decreased.

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