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Study on Development of M20 and M25 Grades of Self Curing Concrete Using Formaldehyde and Sodium Polyacrylate

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Abstract: Self-curing concrete, a specialized solution, eliminates external curing for optimal performance in construction. It maintains internal moisture, reducing autogenous shrinkage and early-stage cracking. This innovative approach, promoting sustainable practices, is valuable for high-rise buildings and bridges. Self-Curing properties achieved in concrete through the incorporation of Sodium Polyacrylate and Formaldehyde. Extensive testing was conducted on diverse concrete samples to evaluate their properties, encompassing workability, compressive strength, tensile strength, and flexural strength. Sodium polyacrylate which is a super absorbent polymer is added to the concrete mix of M20 & M25 grade of concrete in variations (0%, 0.2%, 0.4%, 0.6%, 0.8%, 1.0%) by weight of cement. Formaldehyde added to concrete mix used as shrinkage reducing agent is added 1% with water. Light weight aggregate like brick chips replaced 10% of coarse aggregate are used because bricks absorb and holds a large amount so water. So pre-saturated brick chips are also used to provide internal curing. Sand is replaced by wood powder by 5%, as it also absorbs water. The compressive strength tests were carried out on M20 and M25 grade concretes with different water-cement ratios (for M20 w/c ratio is 0.50 & for M25 w/c ratio is 0.40), adhering to BIS: 516 – 1959 standards. The results indicated that the addition of sodium polyacrylate by weight of cement up to 0.6% led to optimal compressive strength values, beyond which further additions resulted in a decline in strength. Similarly, the split tensile strength tests for M20 and M25 grade concretes showcased the highest values at 0.6% addition of sodium polyacrylate by weight of cement. Subsequent increases in the additive led to a decrease in split tensile strength. Finally, the flexural strength tests for both M20 and M25 grade concretes yielded their highest values at 0.6% sodium polyacrylate by weight of cement, with diminishing flexural strength observed with higher additive percentages. These findings offer valuable insights into enhancing the self-curing properties of concrete and optimizing its characteristics by utilizing sodium polyacrylate as an additive.
Keywords: Sodium Poly-Acrylate; Formaldehyde; Brick-Chips; Wood Powder; Portland Pozzolana Cement (PPC); Workability; Compressive Strength Test; Split Tensile Strength; Flexural Strength Test.

I. INTRODUCTION

Self-curing is a process in which cement undergoes hydration with the assistance of additional internal water that is distinct from the mixing water. The conventional understanding of concrete curing involves creating conditions that prevent water from evaporating from the surface, essentially curing "from the outside to the inside." On the other hand, internal curing facilitates curing "from the inside to the outside" by utilizing internal reservoirs that have been incorporated into the concrete mixture. These reservoirs are formed with the help of superabsorbent polymers like sodium polyacrylate, saturated wood powder, or lightweight fine aggregates & lightweight coarse aggregate like brick chips. Another term commonly used interchangeably with "Self-Curing" is "Internal-Curing."

II. EXPERIMENTAL MATERIALS

A. *Sodium Polyacrylate (SPA)*

The use of sodium polyacrylate as a super absorbent polymer in concrete holds up its potential of improving a variety of concrete qualities, including concrete strength.

Properties: -

1) Replacing Portland Pozzolana Cement (PPC) with more sustainable alternatives is a crucial step towards reducing the environmental impact of the construction industry. One such alternative is the use of superabsorbent polymers (SAP), specifically sodium polyacrylate (SPA), which has the remarkable ability to absorb and retain large amounts of water, expanding its volume significantly.

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2) In this study, PPC is partially replaced with Sodium Poly-acrylate (SPA) in M20 and M25 concrete mixes at various percentages ranging from 0% to 1% at intervals of 0.2%. The properties of both fresh and hardened concrete are investigated to assess the impact of sodium polyacrylate on concrete performance.

The addition of SPA to the concrete mix leads to several benefits: -

- *Increased Workability:* The presence of SPA in the mix improves the workability of fresh concrete, making it easier to handle and place during construction.
- *Extended Setting Time:* The setting time of concrete is increased as the percentage of SPA is increased. This can be advantageous in certain construction scenarios where longer setting times are required.
- *Water Retention Capacity:* SPA acts as a mini-reservoir, storing significant amounts of water within its structure. During the hydration process, this stored water is gradually released, providing sufficient moisture for cement hydration and promoting proper curing.
- *Environmentally Friendly:* By adding SPA to PPC cement, we are reducing the requirement of water during hydration process results in self-curing. This ultimately reduces the wastage of water and help in saving environment.
- *Improved Concrete Performance:* The presence of SPA can enhance the strength and durability of concrete, especially if proper curing conditions are maintained. While the use of SPA as a cement replacement shows promise in this study, further research and practical application in real-world construction scenarios are essential to fully understand its long-term effects on concrete properties and its potential as a sustainable alternative to PPC. The development and adoption of eco-friendly construction materials and practices are crucial steps towards achieving a more environmentally conscious and sustainable construction industry.

B. Shrinkage Reducing Admixture (FORMALDEHYDE)

When shrinkage-reducing admixtures are introduced during batching, both short- and long-term shrinkage can be greatly reduced. This is realized by addressing the underlying issue that's causing the cement paste's pores and capillaries to shrink as it dries. The specified amount of formaldehyde is added to the water during batching process to reduce shrinkage in concrete.

C. Saturated Light Weight Aggregate

When referring to a set of aggregates with a relative density lower than standard density aggregates (natural sand, gravel, and crushed stone), light weight aggregate is also known as low density aggregate. In M20 and M25 concrete, specified amount of coarse particles are substituted for light weight aggregate (brick-chips).

D. Saturated Wood Powder

A byproduct of furniture and timber manufacturers is wood powder. Also have high water absorption properties which can be used to provide internal water to concrete during the hydration process. A specified amount of fine aggregate is replaced by saturated wood powder. Wood powder is light weight & has the properties to hold water for a long period of time which makes it useful for self-curing.

E. Cement

Portland pozzolana cement (Fly ash based) of Ultratech, conforming to IS: 1489-1, was the cement used in the experimentation.

III. DESIGN MIX

The mix proportion of M20 & M25 grade of concrete by using Sodium Poly-Acrylate & Formaldehyde is given in Table 5 and Table 6 respectively. The design mix of M20 & M25 grade of concrete by using Sodium Poly-Acrylate & Formaldehyde is shown in Table 7 and Table 8 respectively. The Design mix prepared by IS: 10262-2019.

Table 1: Proportion of M20 Grade Concrete by Weight of Cement

M20 Grade			
Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (litre)
306	686.1	1267	153
1	2.24	4.14	0.50

Table 2: Addition/Replacement details w.r.t Control Mix for M20

S. No.	Addition of Sodium Polyacrylate by wt. of cement (%)	Cement (%)	Fine Aggregate		Coarse Aggregate		Water %	Addition of Formaldehyde to Water %
			Natural Sand (%)	Replacement with Wood Powder (%)	Natural Coarse Aggregates (%)	Replacement with LECA (i.e., Brick Chips) %		
1	0	100	100	0	100	0	100	1
2	0.2	100	95	5	90	10	100	1
3	0.4	100	95	5	90	10	100	1
4	0.6	100	95	5	90	10	100	1
5	0.8	100	95	5	90	10	100	1
6	1.0	100	95	5	90	10	100	1

Table 3: Proportion of M25 Grade Concrete by Weight of Cement

M25 Grade			
Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (litre)
382.5	679	1150.04	153
1	1.8	3.01	0.40

Table 4: Addition/Replacement details w.r.t Control Mix for M25

S. No.	Addition of Sodium Polyacrylate by wt. of cement (%)	Cement (%)	Fine Aggregate		Coarse Aggregate		Water %	Addition of Formaldehyde to Water %
			Natural Sand (%)	Replacement with Wood Powder (%)	Natural Coarse Aggregates (%)	Replacement with LECA (i.e., Brick Chips) %		
1	0	100	100	0	100	0	100	1
2	0.2	100	95	5	90	10	100	1
3	0.4	100	95	5	90	10	100	1
4	0.6	100	95	5	90	10	100	1
5	0.8	100	95	5	90	10	100	1
6	1.0	100	95	5	90	10	100	1

A. *Sample Matrix For Various Grades*

Table 5: Data to Represent No. of Samples Corresponding to % Addition from Control Mix for M20 Grade

%Age Addition	No. of Cubes for Compressive Strength Test		No. of Cylinders for Split Tensile Strength Test		No. of Beams for Flexural Strength Test		Grade
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days	
0	5	5	3	3	3	3	M20
0.2	5	5	3	3	3	3	
0.4	5	5	3	3	3	3	
0.6	5	5	3	3	3	3	
0.8	5	5	3	3	3	3	
1.0	5	5	3	3	3	3	
Total	60		36		36		132

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Table 6: Data to Represent No. of Samples Corresponding to % Addition from Control Mix for M25 Grade

%Age Addition	No. of Cubes for Compressive Strength Test		No. of Cylinders for Split Tensile Strength Test		No. of Beams for Flexural Strength Test		Grade
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days	
0	5	5	3	3	3	3	M25
0.2	5	5	3	3	3	3	
0.4	5	5	3	3	3	3	
0.6	5	5	3	3	3	3	
0.8	5	5	3	3	3	3	
1.0	5	5	3	3	3	3	
Total	60		36		36		132

IV. EXPERIMENTAL METHODOLOGY

To determine the qualities of concrete, numerous experiments were run on a range of samples. Workability, concrete's compressive strength, tensile strength, and flexibility strength tests are carried out.

Fig. 1: Specimens of Self Curing Concrete

A. *Workability*

The consistency of reference mix and modified concrete of each mix group are determined using slump test according to IS 1199:1959.

The main objective of the slump test is to assess how easily a concrete mix can be placed, compacted, and finished during construction. It provides crucial information about the concrete's rheological properties, which affect its handling, placement, and overall performance.

Table 7: Slump Value of M20 Grade Concrete

SLUMP VALUE			
S. NO.	%AGE ADDITION	GRADE	SLUMP (mm)
1	0	M20	64
2	0.2		67
3	0.4		68
4	0.6		70
5	0.8		72
6	1.0		75

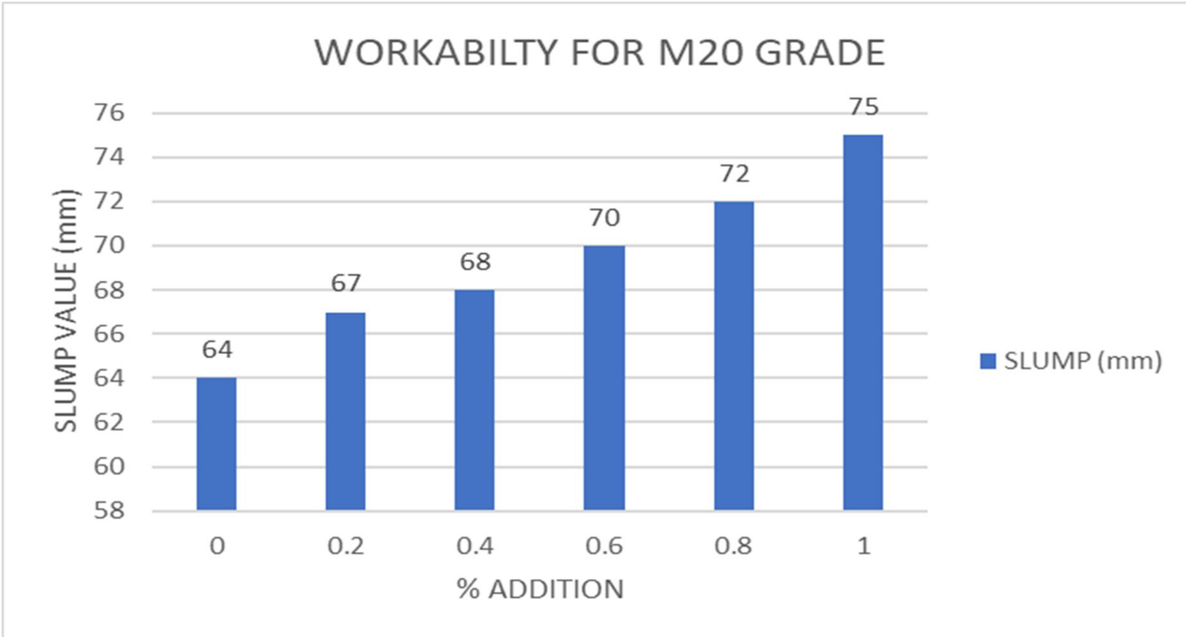
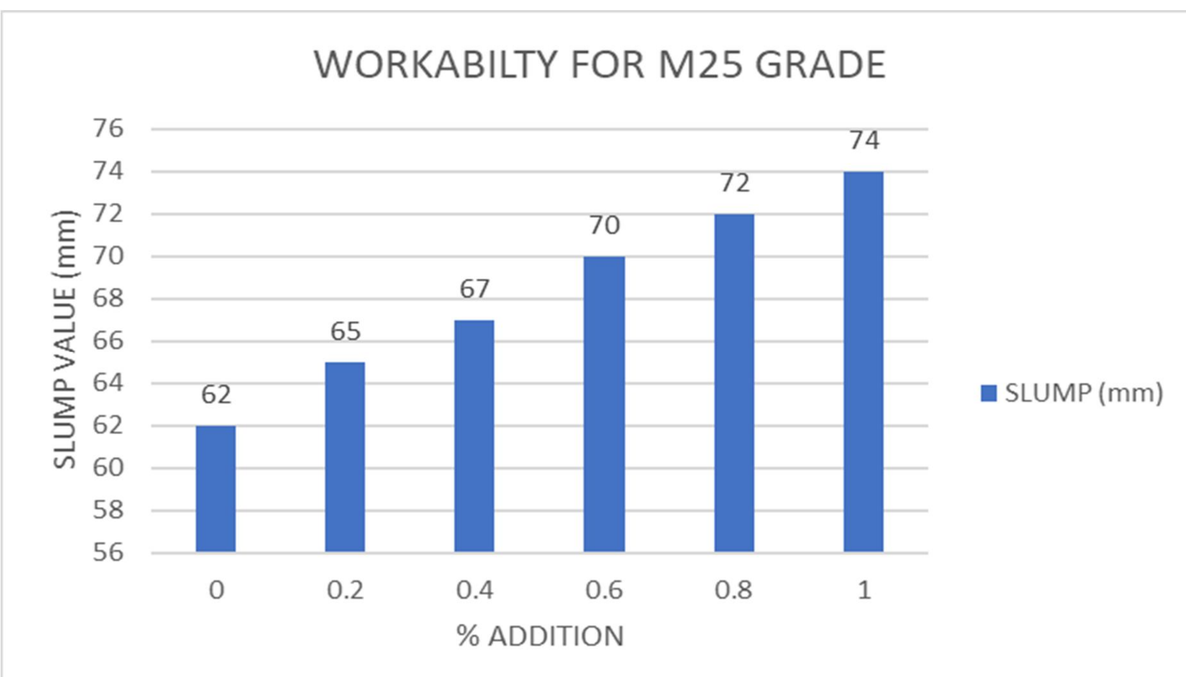


Table 8: Slump Value of M25 Grade Concrete

SLUMP VALUE			
S. NO.	%AGE ADDITION	GRADE	SLUMP (mm)
1	0	M25	62
2	0.2		65
3	0.4		67
4	0.6		70
5	0.8		72
6	1.0		74



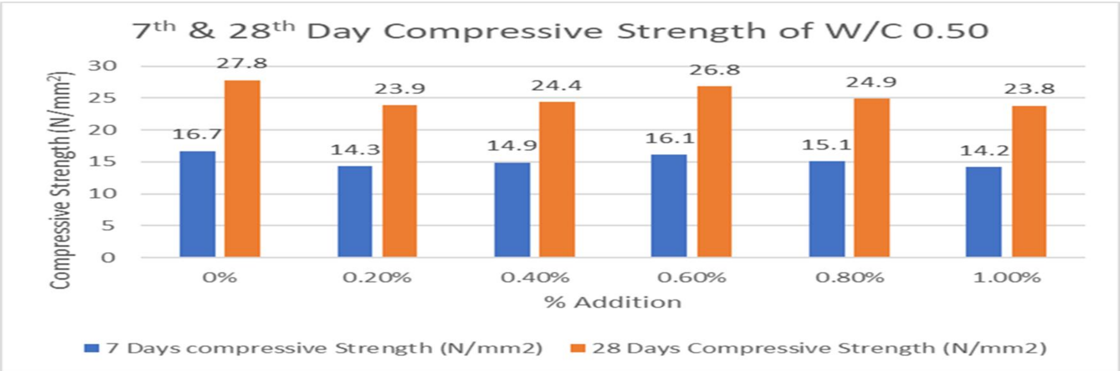
B. Compressive Strength (IS:516 - 1959)

The compressive strength tests were done on M20 grade w/c ratio (0.50) & M25 grade with w/c ratio (0.40) with the help of Compressive testing machine. The code referred for this test was BIS: 516 – 1959.

Fig. 2: Testing of Self Curing Concrete

Table 9: Compressive Strength for M20 grade of Concrete

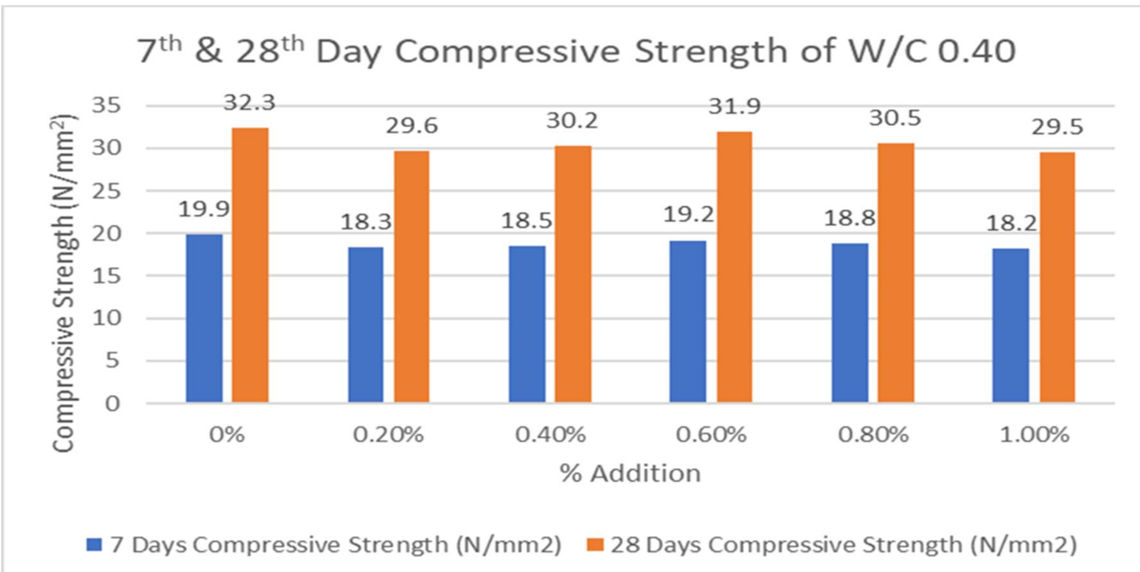
Addition (%)	7 Days compressive Strength (N/mm^2)	28 Days Compressive Strength (N/mm^2)
0%	16.7	27.8
0.2%	14.3	23.9
0.4%	14.9	24.4
0.6%	16.1	26.8
0.8%	15.1	24.9
1.0%	14.2	23.8



From the above table, we can observe that at w/c ratio of 0.50 for M20 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the compressive strength has optimum value 26.8 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the compressive strength starts decreasing.

Table 10: Compressive Strength for M25 grade of Concrete

Addition (%)	7 Days compressive Strength (N/mm^2)	28 Days Compressive Strength (N/mm^2)
0%	19.9	32.3
0.2%	18.3	29.6
0.4%	18.5	30.2
0.6%	19.2	31.9
0.8%	18.8	30.5
1.0%	18.2	29.5

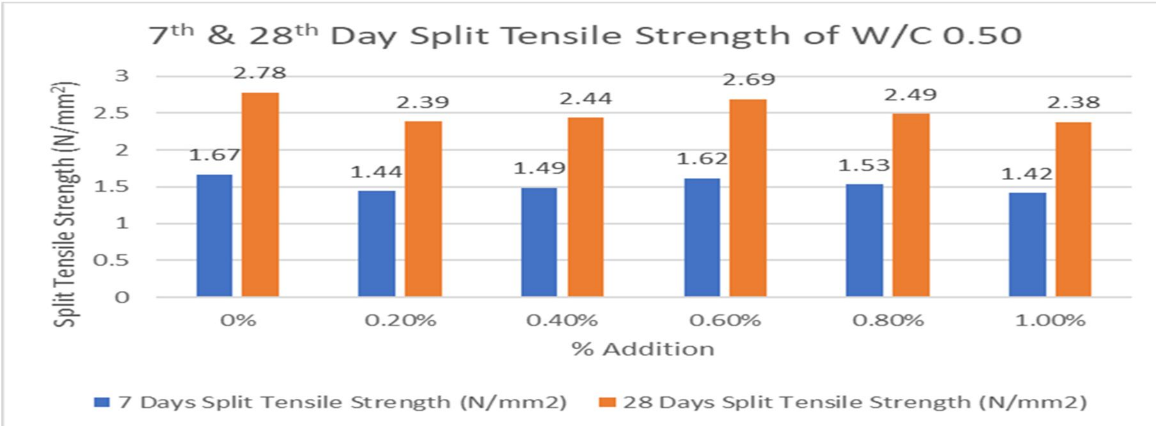


From the above table, we can observe that at w/c ratio of 0.50 for M20 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the compressive strength has optimum value 31.9 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the compressive strength starts decreasing.

C. Split Tensile Strength test (M20 Grade of Concrete)

Table 11: Split Tensile Strength for M20 grade of Concrete

Addition (%)	7 Days Split Tensile Strength (N/mm^2)	28 Days Split Tensile Strength (N/mm^2)
0%	1.67	2.78
0.2%	1.44	2.39
0.4%	1.49	2.44
0.6%	1.62	2.69
0.8%	1.53	2.49
1.0%	1.42	2.38

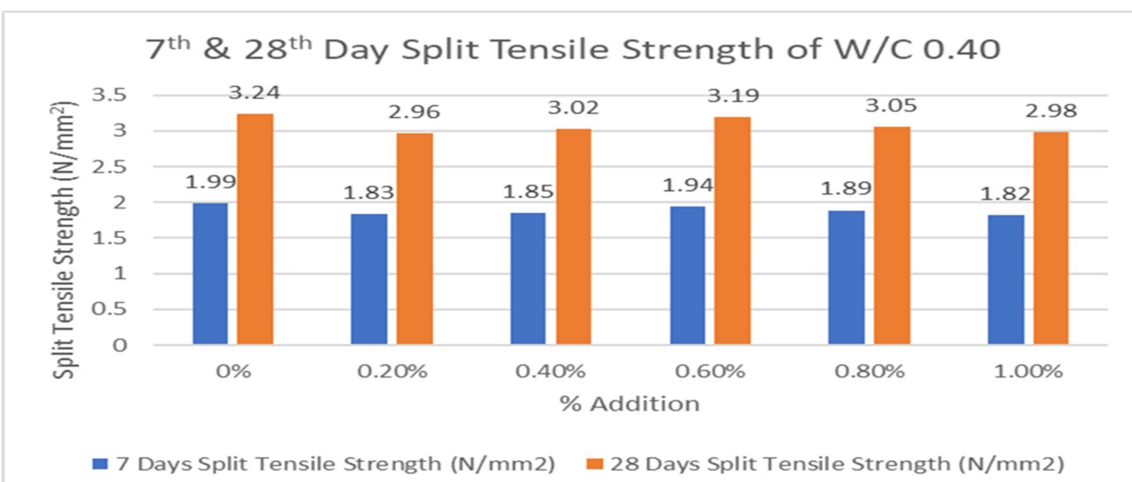


From the above table, we can observe that at w/c ratio of 0.50 for M20 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the split tensile strength has optimum value 2.69 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the split tensile strength starts decreasing.

D. Split Tensile Strength test (M25 Grade of Concrete)

Table 12: Split Tensile Strength for M25 Grade of Concrete

Addition (%)	7 Days Split Tensile Strength (N/mm^2)	28 Days Split Tensile Strength (N/mm^2)
0%	1.99	3.24
0.2%	1.83	2.96
0.4%	1.85	3.02
0.6%	1.94	3.19
0.8%	1.89	3.05
1.0%	1.82	2.98



From the above table, we can observe that at w/c ratio of 0.40 for M25 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the split tensile strength has optimum value 3.19 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the split tensile strength starts decreasing.

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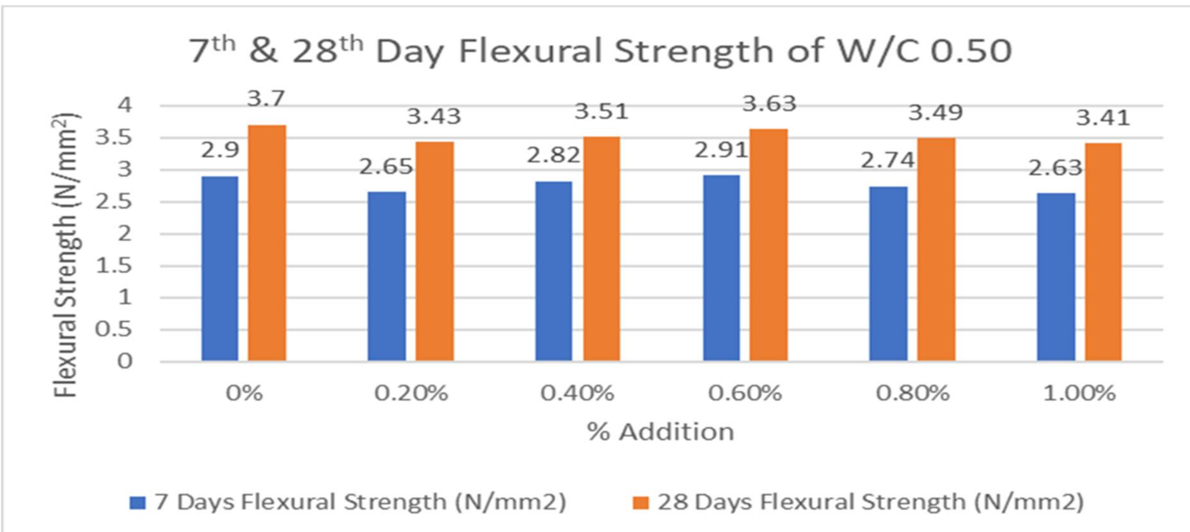
E. Flexural Strength test (M20 Grade of Concrete)

Table 13: Flexural Strength for M20 grade of Concrete

Addition (%)	7 Days Flexural Strength (N/mm^2)	28 Days Flexural Strength (N/mm^2)
0%	2.9	3.7
0.2%	2.65	3.43
0.4%	2.82	3.51
0.6%	2.91	3.63
0.8%	2.74	3.49
1.0%	2.63	3.41

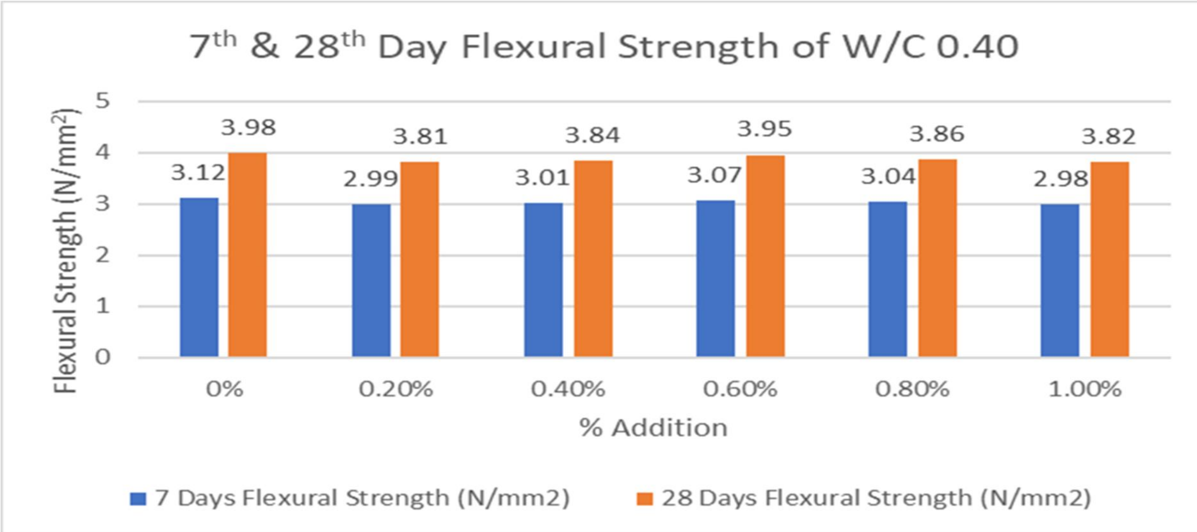


From the above table, we can observe that at w/c ratio of 0.50 for M20 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the split tensile strength has optimum value 3.63 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the flexural strength starts decreasing.

F. Flexural Strength Test (M25 Grade of Concrete)

Table 14: Flexural Strength for M25 grade of Concrete

Addition %	7 Days Flexural Strength (N/mm^2)	28 Days Flexural Strength (N/mm^2)
0%	3.12	3.98
0.2%	2.99	3.81
0.4%	3.01	3.84
0.6%	3.07	3.95
0.8%	3.04	3.86
1.0%	2.98	3.82



From the above table, we can observe that at w/c ratio of 0.40 for M25 grade of concrete, with increase of addition on sodium polyacrylate by weight of cement from 0 to 1%, the split tensile strength has optimum value 3.95 MPA at 0.6% addition of sodium polyacrylate by weight of cement. After 0.6%, further increase in percentage addition of sodium polyacrylate, the flexural strength starts decreasing.

V. CONCLUSION

1) The strength of concrete increased linearly with the increase in addition of sodium poly-acrylate up to 0.6% by weight of cement. On further addition of sodium poly-acrylate the strength starts to decrease.
2) Workability of concrete increases gradually with the addition sodium poly-acrylate due to their large capacity to store water inside it.
3) Self-Curing Concrete shows nearly same strength when compared to the conventional concrete in results that had been drawn from testing.
4) Self-curing concrete is indeed a valuable alternative in regions where water scarcity is a significant concern. Traditional concrete curing methods often involve a substantial amount of water, which can be impractical and environmentally unsustainable in arid or water-scarce areas. Self-curing concrete offers a solution to this problem by reducing the need for external curing and relying on internal mechanisms to maintain adequate moisture levels for proper hydration of the cement.
5) The optimum dosage of sodium poly-acrylate for maximum strength (compressive strength, tensile strength and flexural strength) was found to be 0.6% for the M20 & M25 (with 10% brick-chips replacing coarse aggregate, 5% wood powder replacing fine aggregate, 1% formaldehyde addition to water and 0.6% sodium poly-acrylate added by weight of cement).

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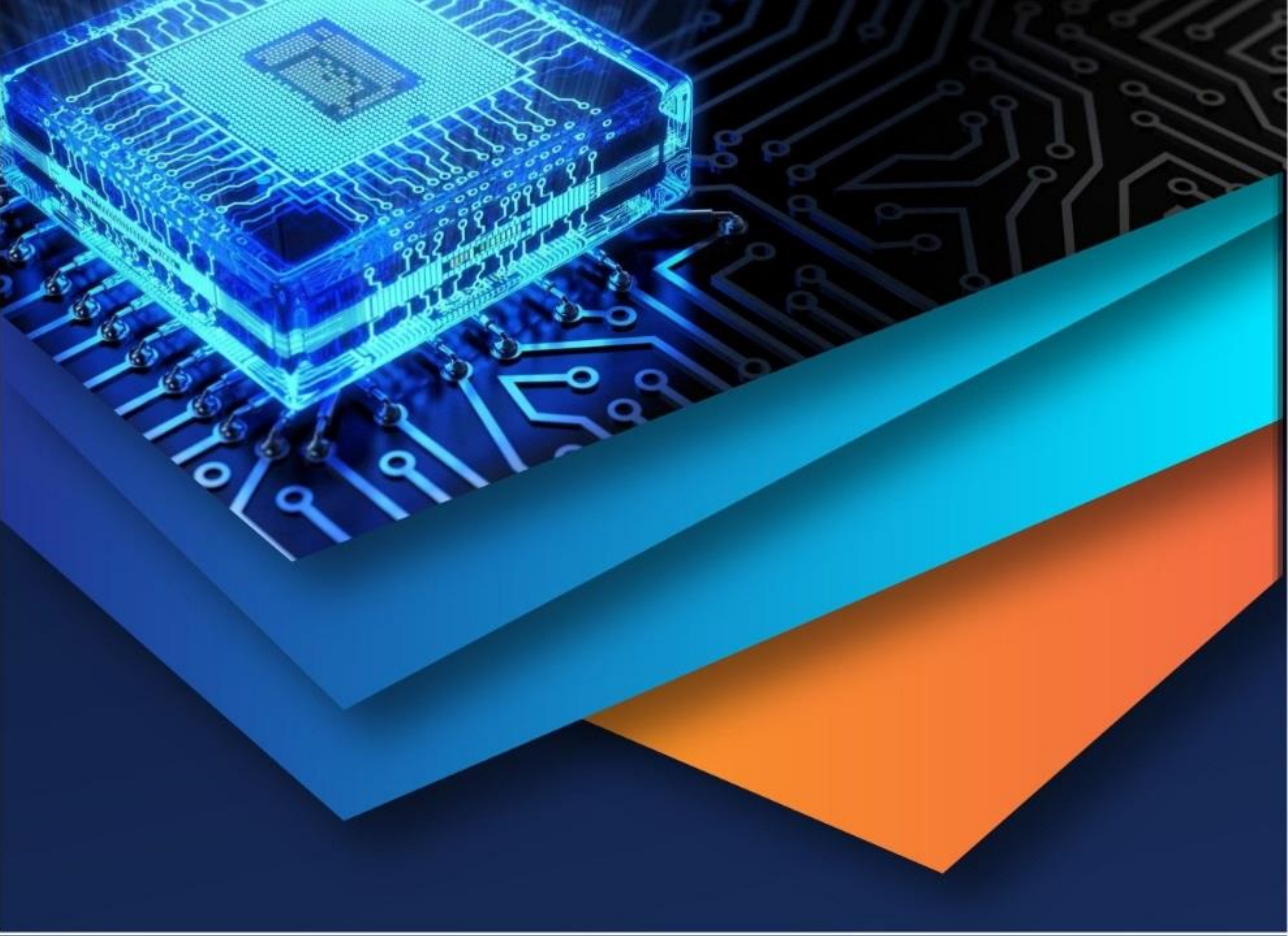

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