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"STUDY ON INTERNAL CURING OF STEEL FIBER REINFORCED CONCRETE USING SUPER ABSORBENT POLYMER"

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Abstract – *The demand of construction of high strength concrete in the field of civil engineering is growing and it is gathering the interest during last couple of years. The curing of concrete structures in an effective manner is very essential to make sure that concrete structures meet intended performance and durability. Non self curing or external curing may not provide the desired performance of concrete due to extreme low permeability. In order to overcome of such draw back the intention is shifted to advanced technology i.e internal curing or self curing of concrete which can achieve the desired intended performance of High Performance Concrete (HPC). In the method internal curing water is available throughout matrix which will enhance the rate of hydration of cement due to presence of additional internal water which is not part of mixing. The internal curing technology can be achieved by using Super Absorbent Polymer (SAP) where SAP will act like internal water reservoirs and supply water to concrete 'from internal to external' surface. Super Absorbent Polymers (SAP) is a group of polymeric materials that have the ability to absorb and retain a significant amount of liquid from their surroundings within their structures without dissolving. In this study it is experimentally examined about the influence of SAP on the mechanical properties such as compressive strength, split tensile strength, flexural strength, shear strength and impact strength of self curing concrete by varying the SAP's addition ranges from 0.1% to 0.4% by weight of cement with 2% steel fibers by volume of concrete as constant for all mixes and compared with normal conventional cured steel fiber reinforced concrete i.e. water-curing after a period of 28 days.*

Key words: SAP(Super absorbent polymer),Hooked end steel fibers, Compressive strength, Flexural strength, Split tensile strength, Shear strength and Impact strength,Workabilty tests.

1. INTRODUCTION

Concrete plays very vital role as it is principally used material in the field of constructions of civil engineering. Therefore, it grasps attention for improving mechanical properties of concrete. Curing of concrete in proper manner is necessary to achieve high strength and durability with intended performance. The external curing method is used to achieve this which is a conventional curing technique. High performance concrete (HPC) has low water~to~cement (w/c) ratio (i.e below or equal to 0.4%) and it is essential to enhance strength and durability of concrete. It will also lead to self desiccation of concrete due to cement hydration process and it causes change in volume which is called as Autogeneous Shrinkage of concrete. Internal curing (IC) of concrete with help of small properly distributed water reservoirs may be able to solve this problem. Internal curing of concrete is an advanced technique in which additional moisture is provided to concrete structure and which leads to effectual hydration process of cement and hence, results in reduced self-desiccation of concrete. For providing additional moisture in concrete during internal curing agents are introduced.

The various objectives of present study are

1. To produce M30 grade of concrete using super absorbent polymer as an internal curing agent in Self curing technique and to study the characteristics of self curing concrete with addition of steel fibers (i.e 2% by volume of concrete).
2. To preserve water dissipate that occurs during non self curing due to water evaporation from external or outer surface of concrete.
3. To study the effect of internal curing of water at different dosages of SAPs and with constant adding up of 2 %(two percent) of steel fibers by volume fraction on the workability of Self curing Concrete and the workability is measured by various methods namely a) slump Cone test, b) compaction Factor test, c) Vee-Bee consistometer and d) flow table test.
4. The objective is also to promote the rate of hydration of cement using SAP to achieve higher strengths.
5. To study the effect dosage of super absorbent polymer ranges from (0.1% to 0.4%) by

weight/mass of Cement on mechanical properties of concrete i.e compressive strength, Split tensile strength, Flexural strength, shear strength and impact strength.

6. To study the mechanical properties of non-self curing concrete (i.e water curing) and self curing concrete with addition of SAP ranges from 0% to 0.4 % by weight of cement.
7. To analyse the effect of addition of SAP on mechanical properties of internal curing concrete and to find at which optimum dosage value of SAP the strengths are maximum.

2. MATERIALS AND METHODOLOGY

Cement-Ordinary Portland cement of Jyoti 53 Grade was used for casting all the specimens. It was tested as per IS 12269-1987 recommendation. Cement properties are tabulated below.

Properties	Results	Permissible limits as per IS 12269-1987
Fineness of cement	7.5%	It should not be more than 11% (i.e >11%)
Normal consistency	34	It should be less than 34 %(i.e <34%)
Specific gravity	3.15	
Setting time of cement		
a) Initial	45 minutes	should not be less than ½ an hour i.e 30 minutes
b) Final	345 minutes	should not more than 10 hours i.e 600 minutes

Table1 properties of cement

Fine Aggregate (FA)-Naturally available river sand as per IS 383-1970 of Zone- II is utilized. Specific gravity of FA is determined as per the method confirming to IS 2386 and results gained comply with the code specifications. The sieve analysis and specific gravity of fine aggregates are listed under Table.

SL.No	IS Sieve Size in mm or micron	Cumulative %age passing of FA	Ranges for Specifications of FA- Zone II (IS:383-1970)
1	4.75 mm	96	90-100
2	2.36mm	90	75-100
3	1.18mm	85	55-90
4	600 µ	54	35-59
5	300 µ	25	8-30
6	150 µ	2	0-10
7	Pan	0	0
Specific gravity : 2.61			

Table 2 sieve analysis and specific gravity of FA

Coarse Aggregate (CA) - Locally available angular crushed aggregates as per IS 383-1970 is used in this experimental work of study. Specific gravity of coarse aggregate is determined using the method confirming to Indian Standard 2386 and results are tabulated in table.

Shape of aggregate	Angular crushed
Specific gravity of aggregate	2.70
Size of aggregates	Passing through 20 mm down size

Table 3 properties of CA

Steel fiber- In present course of work hooked end type of steel fibers of size 1mm diameter and 35mm length giving aspect ratio of 35 were used. The physical properties of steel fibers are mentioned under table.

SL.No.	Parameter	Values
1	Size	1.00 mm (dia)
2	Length	35 mm
3	Aspect ratio	35
4	Tensile strength	1167 Mpa
5	Density	7850 kg/m^3

Table 4 physical properties of steel fiber

Super Absorbent Polymer (SAP)-Usually SAPs are added at rate of 0% to 0.6% by weight of cement. The SAPs materials are covalently cross-linked compounds. SAPs are non-toxic and non-corrosive materials which have capacity of absorption of water up to 250-300 times of its own weight. SAPs are negatively charged carboxylic group and positively charged acrylate compound which attracts water and they, exhibit behaviour of shrinking and swelling when subjected to drying and water respectively. The specific different properties of SAP are tabulated under table.

FORM – dry	Crystalline white powder
FORM – wet	Transparent gel
Particle size <120mesh	<5%
> 80 mesh	>1%
pH value	6-6.5
Density	0.59- 0.65 g/cm^3
Absorption in 0.9% NaCl Solution	≥54g/g

Table 5 properties of super absorbent polymer

Water- The purpose of use of water is for both mixing and curing and it shall be clean and free from the any of the detrimental materials such as acidic compounds, alkaline, salt substances, sugar compounds, organic materials or other substances that may be harmful to concrete structure. Potable water which is used for drinking purpose is in general suitable in mixing and for curing of concrete.

Super plasticizer- Conplast SP430 is a kind of Sulphonated Napthalene Polymers and it is available in the market in the form of liquid bearing brownish color & which is instantly forms dispersion in water. The properties of super plasticizer SP430 are tabulated in table.

Specific gravity	1.220 -to- 1.225 at 300^0 Celsius
Contents of Chloride	Nill to IS: 456-2000
Air Entrainment	addition of 1% of air is entrained

Table 6 properties of super plasticizer

3. MIX DESIGN FOR M30 GRADE OF CONCRETE -Mix Design is a one of the process by means of which suitable ingredients in the concrete are selected and in order to determine their relative quantity with object of producing concrete possessing minimum desirable properties like workability in fresh state minimum desirable strength and durability in hardened state. Mix proportion obtained by after mix design is tabulated below.

Water (in kg)	Cement (in kg)	FA (in kg)	CA (in kg)	Super plasticizer (in kg)
157.72	394.3	671.81	1235.52	3.15
0.40	(1)	(1.70)	(3.13)	(0.8% of cement)

Table 7 Mix proportion

4. RESULTS AND DISCUSSIONS

4.1 Workability test results

Slump test results

Table 8 mentioned below, represents the test results of slump for addition of different percentages of super absorbent polymer ranges from 0.1% to 0.4% by weight of cement.

% Addition of super absorbent polymer	Slump (mm)
water curing	27
self curing (0.1% SAP)	38
self curing (0.2% SAP)	53
self curing (0.3% SAP)	72
self curing (0.4% SAP)	60

Table 8 slump test results for addition of SAP

Compaction factor test results

Table 9 mentioned below, represents the test results of compaction factor for addition of different percentages of super absorbent polymer ranges from 0.1% to 0.4% by weight of cement.

% Addition of super absorbent polymer	Compaction factor
water curing	0.78
self curing (0.1% SAP)	0.82
self curing (0.2% SAP)	0.85
self curing (0.3% SAP)	0.89
self curing (0.4% SAP)	0.86

Table 9 slump test results for addition of SAP

Vee-Bee Consistometer test results

Table 10 mentioned below, represents the test results for Vee-Bee consistometer for addition of different percentages of super absorbent polymer ranges from 0.1% to 0.4% by weight of cement.

% Addition of super absorbent polymer	Vee-Bee time (sec)
water curing	38
self curing (0.1% SAP)	36
self curing (0.2% SAP)	33
self curing (0.3% SAP)	30
self curing (0.4% SAP)	32

Table 10 Vee-Bee test results for addition of SAP

Flow table test results

Table 11 mentioned below, represents the test results of Flow table for addition of various percentages of super absorbent polymer ranges from 0.1% to 0.4% by weight of cement.

% Addition of super absorbent polymer	Flow test (%)
water curing	24
self curing (0.1% SAP)	31.6
self curing (0.2% SAP)	38
self curing (0.3% SAP)	47
self curing (0.4% SAP)	41

Table 11 slump test results for addition of SAP

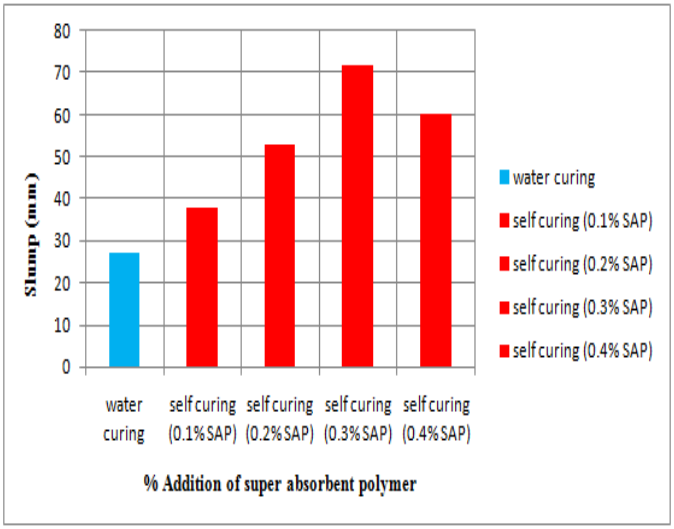

Fig 1 Variation of slump values

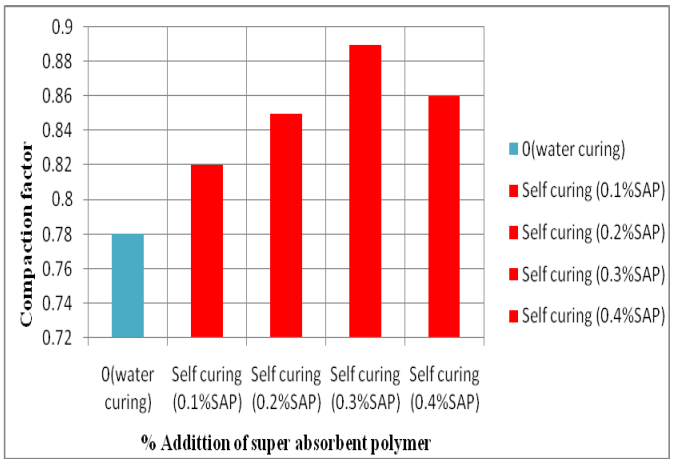

Fig 2 Variation of compaction factor values

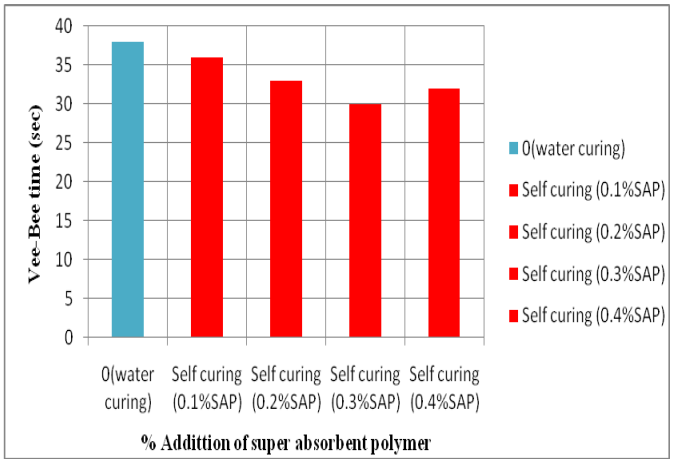

Fig 3 Variation of Vee-Bee test values

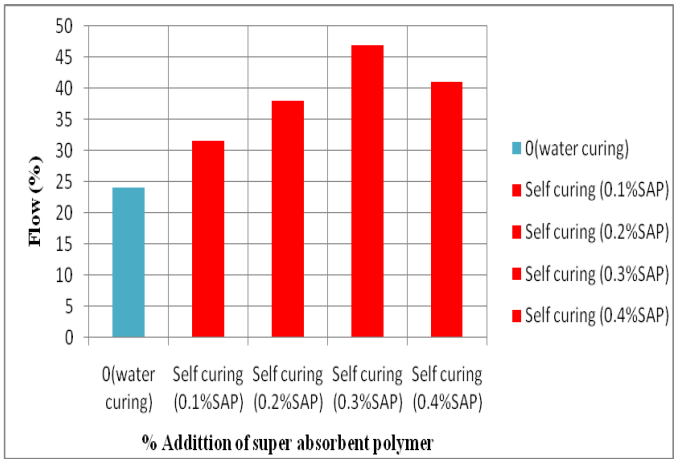

Fig 4 Variation of flow test values

4.2 Strength test results

Compressive strength test results

Table 12 mentioned below, represents the compressive strength values for addition of different percentage of super absorbent polymer from 0.1% to 0.4 % by weight of cement.

% Addition of super absorbent polymer	Compressive strength (N/mm2)
water curing	34.81
self curing (0.1% SAP)	31.04
self curing (0.2% SAP)	36.59
self curing (0.3% SAP)	38.44
self curing (0.4% SAP)	35.33

Table 12 compressive test results for addition of SAP

Split tensile strength test results

Table 13 mentioned below, represents the values of split tensile for addition of different percentage of super absorbent polymer from 0.1%age to 0.4%age by mass of cement.

% Addition of super absorbent polymer	Split tensile strength(N/mm²)
water curing	3.98
self curing (0.1% SAP)	3.04
self curing (0.2% SAP)	4.39
self curing (0.3% SAP)	4.97
self curing (0.4% SAP)	4.1

Table 13 split tensile test results for addition of SAP

Flexural strength test results

Table 14 mentioned below, represents the values of flexural strength for addition of various percentage of super absorbent polymer from 0.1%age to 0.4%age by mass of cement.

% Addition of super absorbent polymer	flexural strength(N/mm²)
water curing	5.33
self curing (0.1% SAP)	4.6
self curing (0.2% SAP)	5.8
self curing (0.3% SAP)	6.47
self curing (0.4% SAP)	5.27

Table 14 flexural strength test results for addition of SAP

Shear strength test results

Table 15 mentioned below, represents the values of shear strength for addition of various percentages of super absorbent polymers from 0.1%age to 0.4%age by mass of cement.

% Addition of super absorbent polymer	Shear strength(N/mm²)
water curing	8.43
self curing (0.1% SAP)	7.13
self curing (0.2% SAP)	9.44
self curing (0.3% SAP)	10.28
self curing (0.4% SAP)	8.24

Table 15 shear strength test results for addition of SAP

Impact strength test results

Table 16 mentioned below, represents the values of impact strength for initial crack and final failure for addition of different percentages of super absorbent polymer from 0.1% to 0.4 % by weight of cement.

% Addition of super absorbent polymer	Impact strength for initial crack(N-m)	Impact strength for final failure(N-m)
water curing	899.07	961.31
self curing (0.1% SAP)	615.52	670.85
self curing (0.2% SAP)	968.23	1023.56
self curing (0.3% SAP)	1203.37	1237.95
self curing (0.4% SAP)	975.15	1030.47

Table 16 impact strength test results for addition of SAP

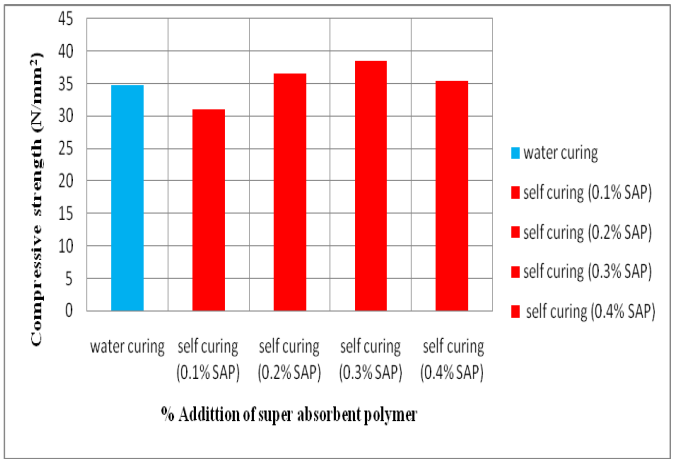

Fig 5 Variation of compressive strength

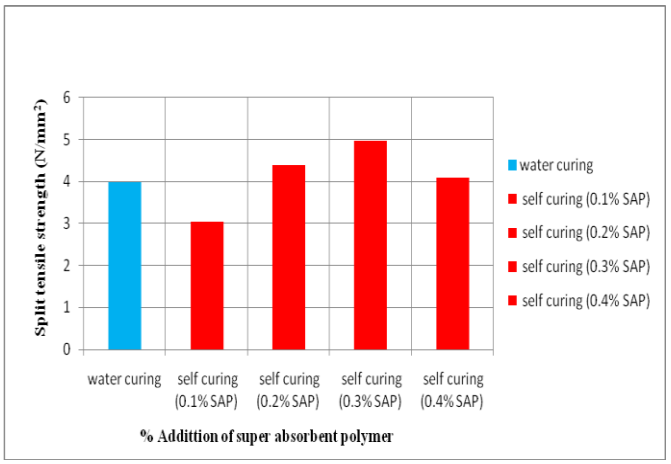

Fig 6 Variation of split tensile strength

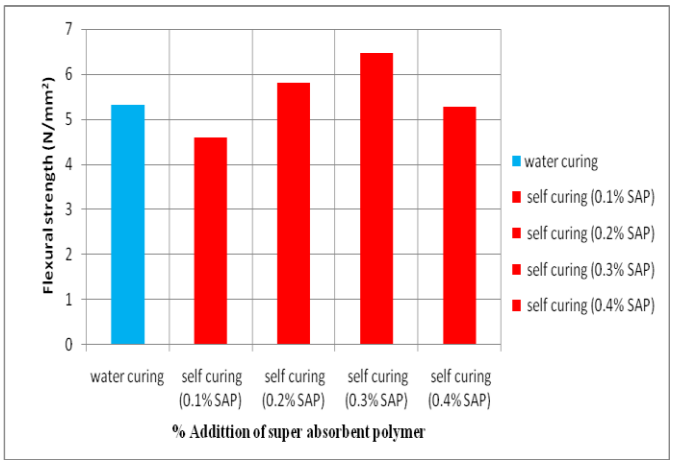

Fig 7 Variation of flexural strength

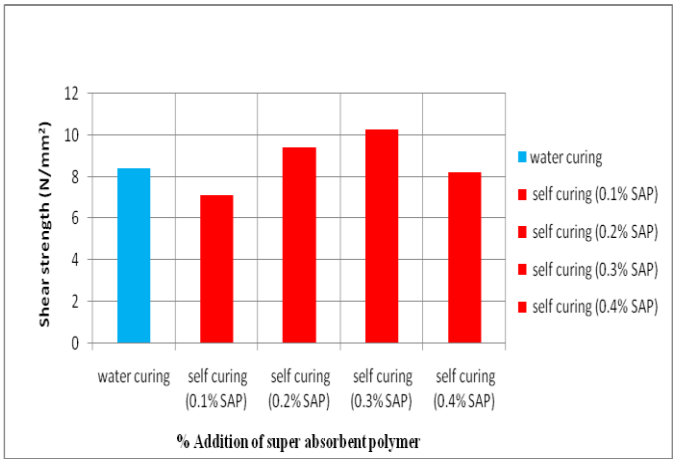

Fig 8 Variation of shear strength

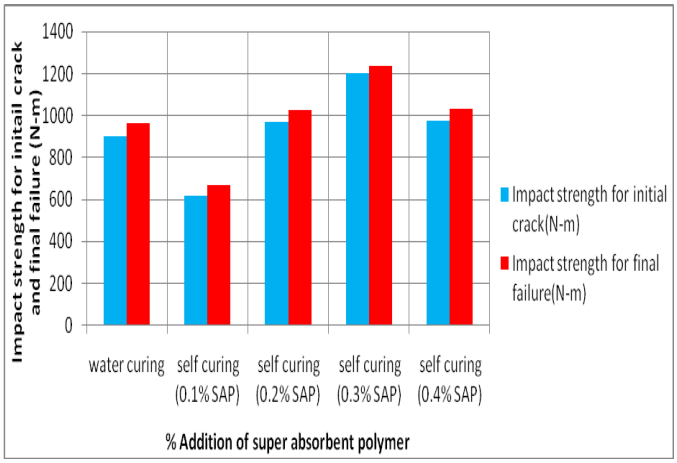

Fig 9 Variation of impact strength for initial crack and final failure

5. OBSERVATIONS AND DISCUSSIONS

An experimental work study was performed on steel fiber Reinforced concrete using super absorbent polymer as an internal curing agent and accordingly following points of observation were made

1. It is observed that the workability tests conducted using slump cone, compaction factor, and flow table, the test result values increase as the percentage addition of super absorbent polymer increases from 0.1% to 0.3% by weight of cement in the Steel Fiber Reinforced Concrete And for addition of Super Absorbent Polymer beyond 0.3% by weight of cement workability test values decrease. Thus the highest workability is obtained at an optimum dosage 0.3% of Super Absorbent Polymer. This is due to the reason that adding up of 0.3% by mass of cement of Super Absorbent Polymer may result in uniform distribution of all the particles in concrete mix and addition of higher percentage of Super Absorbent Polymer i.e more than optimum dosage may result into non-uniform distribution hence, segregation in the concrete.
2. Vice-versa in vee-bee consistometer test time goes on decreasing as the percentage addition of super absorbent polymer increases from 0.1% to 0.3% by weight of cement in the Steel Fiber Reinforced Concrete Further addition of Super Absorbent Polymer beyond 0.3% by mass of cement (more than optimum value of SAP) leads to increase in time due to fact of uneven distribution of SAP particles in concrete.
3. As per experimental study, it is found that the compressive strength value for 0.1% addition of Super Absorbent Polymer in Steel Fiber Reinforced Concrete is lesser compare to water cured Steel Fiber Reinforced Concrete. This is due to fact that the dosage of 0.1% of Super Absorbent Polymer is less effective in self curing of Steel Fiber Reinforced Concrete thus it shifts attention to increase the percentage addition of Super Absorbent Polymer in the steel fiber reinforced concrete.
4. It is further observed that at 0.2% & 0.3% addition of Super Absorbent Polymer by weight of cement shows increase in the compressive strength of Steel Fiber Reinforced Concrete & at 0.4% addition of Super Absorbent Polymer by weight of cement shows gradually decrease in compressive strength of Steel Fiber Reinforced Concrete Thus, the value of compressive strength is higher at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement. This is due to fact that, the additional internal water may be available throughout the matrix in self curing of steel fiber reinforced concrete at dosage of 0.2% and 0.3% of Super Absorbent Polymer which will result in increase in rate of hydration of cement.
5. It is noted that, the compressive strength at 0.1% addition of Super Absorbent Polymer in steel fiber reinforced concrete is decreased by 10.83% after 28 days in comparison with water cured steel fiber reinforced concrete. And also noted that, the compressive strength for 0.2%, 0.3% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 5.11%, 10.43% and 1.49% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete.
6. It is observed that the split tensile strength value for 0.1% addition of Super Absorbent Polymer in Steel Fiber Reinforced Concrete is lesser compare to water cured Steel Fiber Reinforced Concrete. This is due to fact that the dosage of 0.1% of Super Absorbent Polymer is less effective in self curing of Steel Fiber Reinforced Concrete.
7. It is further observed that at 0.2% & 0.3% addition of Super Absorbent Polymer by weight of cement

shows increase in the split tensile strength of Steel Fiber Reinforced Concrete & at 0.4% addition of Super Absorbent Polymer by weight of cement shows gradually decrease in split tensile strength of steel fiber reinforced concrete. Thus, the value of split tensile strength is higher at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement. This is due to fact that, the additional internal water may be available throughout the matrix in self curing of steel fiber reinforced concrete at dosage of 0.2% and 0.3% of Super Absorbent Polymer which will result in increase in rate of hydration of cement.

8. It is noted that, the split tensile strength at 0.1% addition of Super Absorbent Polymer in steel fiber reinforced concrete is decreased by 23.62% after 28 days in comparison with water cured steel fiber reinforced concrete. And also noted that, the split tensile strength for 0.2%, 0.3% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 10.30%, 24.87% and 3.02% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete.
9. It is practically noted that the flexural strength value for 0.1% addition of Super Absorbent Polymer in Steel. Fiber .Reinforced .Concrete is lesser compare to water cured Steel. Fiber Reinforced Concrete this is due to fact that the dosage of 0.1% of Super Absorbent Polymer is less effective in self curing of Steel Fiber Reinforced Concrete.
10. It is further observed that at 0.2% & 0.3% addition of Super Absorbent Polymer by weight of cement shows raise in the flexural strength of Steel Fiber Reinforced Concrete & at 0.4% addition of Super Absorbent Polymer by weight of cement shows gradually decrease in flexural strength of Steel. Fiber Reinforced Concrete. Thus, the value of flexural strength is higher at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement. This is due to fact that, the additional internal water may be available throughout the matrix in self curing of steel fiber reinforced concrete at dosage of 0.2% and 0.3% of Super Absorbent Polymer which will result in increase in rate of hydration of cement.
11. It is noted that, the flexural strength at 0.1% addition of Super Absorbent Polymer in steel fiber reinforced concrete is decreased by 13.70% after 28 days in comparison with water cured steel fiber reinforced concrete. And also noted that, the flexural strength for 0.2%, 0.3% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 8.82%, 21.39% and 3.75% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete.
12. It is observed that the shear strength value for 0.1% addition of Super Absorbent Polymer in steel fiber reinforced concrete is lesser compare to water cured Steel Fiber Reinforced Concrete. This is due to fact that the dosage of 0.1% of Super Absorbent Polymer is less effective in self curing of Steel Fiber Reinforced Concrete.
13. It is further observed that at 0.2% & 0.3% addition of Super Absorbent Polymer by weight of cement shows increase in the shear strength of Steel Fiber Reinforced Concrete & at 0.4% addition of Super Absorbent Polymer by weight of cement shows gradually decrease in shear strength of Steel Fiber Reinforced Concrete. Thus, the value of shear strength is higher at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement. This is due to fact that, the additional internal water may be available throughout the matrix in self curing of steel fiber reinforced concrete at dosage of 0.2% and 0.3% of Super Absorbent Polymer which will result in increase in rate of hydration of cement.
14. It is noted that, the shear strength at 0.1% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is decreased by 13.70% and 2.25% respectively after 28 days in comparison with water cured steel fiber reinforced concrete. And also noted that, the shear strength for 0.2% and 0.3% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 9.85%% and 23.01% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete.
15. It is observed that the impact strengths of initial crack and final failure for 0.1% addition of Super Absorbent Polymer in Steel Fiber Reinforced Concrete is lesser compare to water cured Steel Fiber Reinforced Concrete. This is due to fact that the dosage of 0.1% of Super Absorbent Polymer is less effective in self curing of Steel. Fiber .Reinforced .Concrete.
16. It is further observed that initial crack and final failure at 0.2% & 0.3% addition of Super Absorbent Polymer by weight of cement shows increase in the impact strength of Steel Fiber Reinforced Concrete & at 0.4% addition of Super Absorbent Polymer by weight of cement shows gradually decrease in impact strength of Steel Fiber Reinforced Concrete. Thus, the value of impact strength is higher at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement. This is due to fact that, the additional internal water may be available throughout the matrix in self curing of Steel Fiber Reinforced Concrete at dosage of 0.2% and 0.3% of Super Absorbent Polymer which will result in increase in rate of hydration of cement.
17. It is noted that, the impact strength of initial crack and final failure at 0.1% addition of Super Absorbent Polymer in steel fiber reinforced concrete is decreased by 31.54% and 30.22% respectively after 28 days in comparison with water cured steel fiber

reinforced concrete. And also noted that, the impact strength of initial crack for 0.2%, 0.3% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 7.69%, 33.85% and 8.46% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete and final failure for 0.2%, 0.3% and 0.4% addition of Super Absorbent Polymer in steel fiber reinforced concrete is increased by 6.48%, 28.78% and 7.19% respectively after a period of 28 days compare to water cured steel fiber reinforced concrete.

6. CONCLUSIONS

An experimental work study was carried on "steel fiber reinforced concrete using Super Absorbent Polymer" and based on observations of investigations; the conclusions are drawn as under

1. The workability of Steel Fiber Reinforced Concrete is higher at an optimum dosage of 0.3% of Super Absorbent Polymer.
2. The compressive strength of Steel Fiber Reinforced Concrete has increased with increase in various percentage dosages of addition of Super Absorbent Polymer. The compressive strength of Steel Fiber Reinforced Concrete is maximum at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement.
3. The split tensile strength of Steel Fiber Reinforced Concrete has increased with increase in various percentage dosages of addition of Super Absorbent Polymer. The split tensile strength of Steel Fiber Reinforced Concrete is maximum at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement.
4. The flexural strength of Steel Fiber Reinforced Concrete has increased with increase in various percentage dosages of addition of Super Absorbent Polymer. The flexural strength of Steel Fiber Reinforced Concrete is maximum at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement.
5. The shear strength of Steel Fiber Reinforced Concrete has increased with increase in various percentage dosages of addition of Super Absorbent Polymer. The shear strength of Steel Fiber Reinforced Concrete is maximum at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement.
6. The impact strength of Steel Fiber Reinforced Concrete has increased with increase in various percentage dosages of addition of Super Absorbent Polymer. The impact strength of Steel Fiber Reinforced Concrete is maximum at an optimum dosage of 0.3% of Super Absorbent Polymer by weight of cement.
7.

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