An Experimental Study on the Influence of Sisal Fiber & Combination of Sisal and Steel Fiber Reinforcement on the Properties of Self Compacting Concrete & Conventional Concrete

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Abstract— **Self compacting concrete (SCC) plays a significant role in construction industry as it reduces labor cost, results in faster construction and provides smooth finishing surface. In the present study, by combining the properties of self compacting concrete and fiber reinforced concrete that delivers high performance in many fronts. Fresh and hardened properties of self compacting concrete were determined through various experiments. Compressive strength and flexural strength are evaluated for the specimen casted with varying percentage of sisal fiber (0%, 0.25%, 0.5%, and 0.75%) and combination of % sisal fiber and 0.25% steel fiber after 7 days and 28 days of curing for M35 mix design. The study gives an insight into the influence of incorporation of sisal fibers and combination of sisal and steel fibers on the fresh and hardened properties of concrete.**

Index Terms— **Self compacting concrete, conventional concrete sisal fiber, combination of sisal and steel fiber, fresh state properties (L- box, U-box, J-ring, Flow table, T500 time, and slump Flow) hardened state properties (compressive strength, and flexural strength test)**

I. INTRODUCTION

Self compacting concrete was first introduced in Japan at 1980s. Self Compacting concrete (SCC) is described as "the most innovative development in concrete construction for several decades". SCC is casting does not require additional inner or outer vibration for the compaction and showing no segregation or bleeding of concrete. It is proved to be beneficial from having ability to flow through restricted areas and heavy reinforcement in structural member requires less labors, environmental friendly, and providing better finishing surface.

SCC consists of same components as conventional concrete which are cement, coarse and fine aggregate and water in addition of chemical and mineral admixtures. Importance must be given for mix proportioning Since SCC often contains a large quantity of powder materials to maintain sufficient yield value and viscosity of the fresh mix, hence reducing bleeding, segregation and settlement. As, the use of a large quantity of cement increases cost and results in greater temperature rise, the use of mineral admixture such as fly ash, blast furnace slag, or limestone filler could increases the slump of the concrete mix without increasing its cost.

SCC has fallowing three main characteristics

- Filling ability: Ability of filling a formwork completely under its own weight.
- Passing ability: Ability to overcome obstacles such as congested reinforcement areas under its own weight without hindrances.
- Segregation resistance: homogeneous composition of concrete during and after the process of transport and placing.

The concrete which have the capicity to resist crack and also improves static and dynamic properties of concrete by addition of small quantity of fibers is known as fiber inforced concrete.

Sisal fiber is abstracted from the plant known as sisal plant which is one of the most widely used natural fiber. It grows in very dry and hot region and can be cultivated very easily without any need of fertillizers and pesticides. This fibers are mostly used for making ropes,twins Since it is highly durable and posess the high strength. Compared to other natural fibers Sisle fibers has more intractions between cement matrix or concrete ingredients

II. OBJECTIVES OF PRESENT STUDY

- To arrive at mix propotion for SCC and conventional concrete (CC) of M35 grade by suitable procedure of mix design and also the same has to be carried out for sisal fiber reinforced self compacting concrete.
- To study the influence of sisal fiber reinforcement,by adding varying proportion of sisal fibers to the fresh and hardened properties of SCC.
- To study the influence of volume fraction of sisal fiber reinforcement on the fresh properties of SCC such as L- box test, U-box test, V-funnel test, slump flow test, J-ring test and T500 slump flow test and hardened properties such as compressive strength test and flexural strength test.

III. METHODOLOGY

Methodology involves preparation of mix design for a typical M35 grade concrete for both SCC and CC. All the materials required for experment are tested according to IS codal provisions. The design mix are casted using pan mixers and tested for fresh and hardened properties of concrete.The casted moulds are kept for curing and are tested for 7 days and 28 days compressive and flexural test.

IV. MATERIALS USED AND ITS PROPERTIES

A. *Cement*

Ultra-tech ordinary Portland cement of 53 grade conforming to IS: 12269:19587 has been used. Testing of physical properties of concrete is important and it is done by carrying out experimental work such as specific gravity, consistency, fineness, initial and final setting time with reference through IS:4031(part-5)1988 is tabulated in table I.

TABLE I
PHYSICAL PROPERTIES OF CEMENT

Sl. No	Properties	Results
1	Specific gravity	3.15
2	Standard consistency	32
3	Fineness	6%
4	Initial setting time	40 min
5	Final setting time	390 min

B. *Coarse Aggregate*

Coarse aggregate (C.A) are particle that is retained by the 4.75 mm sieve. C.A of 12mm down size is used in concrete mix design. Its physical properties were calculated with reference through IS: 2386 (part III) of 1963 and is tabulated in table II

TABLE II
PHYSICAL PROPERTIES OF COARSE AGGREGATE

Sl. No	Properties	Results
1	Specific gravity	2.64
2	Fineness modulus	3.20
3	Loose density	1373.50 Kg/m^3
4	Water absorption	0.5%

C. *Fine Aggregate*

Fine aggregate are aggregate which passes through 4.75 mm sieve. Self compacting concrete requires fine aggregate which are well graded and having low water absorption. Manufactured-sand confining to grading zone II is used in concrete mix design.

TABLE III
PHYSICAL PROPERTIES OF FINE AGGREGATE

Sl. No	Properties	Results
1	Specific gravity	2.63
2	Fineness modulus	2.32
3	Loose density	1436.50 Kg/m^3
4	Water absorption	2.23%

D. *Mineral Admixture*

Mineral Admixture used in this experiment is class C fly ash which is having a specific gravity of 2.35

E. *Chemical Admixture*

Super plasticizer (SP) place a vital role in SCC as it reduces w/c ratio by 30%, without affecting the workability of concrete. They are also called as reducers. Superplasticizer used in this experiment is Master Glenium SKY 8650. Viscosity modifying agent (VMA) is used to minimize the accumulation of bleeding water, resistance to segregation and to enable balance between fluidity and passing ability.

F. *Sisal Fiber*

Sisal fiber is used as an environment friendly strengthening agent to replace glass fibers as well as asbestos fibers in composite material. Sisal fibers are cut to a length of 35mm having a diameter of 0.2mm.volume of concrete is considered for determining the fiber content to be added for mix. Fiber content of 0.25%, 0.5%, and 0.75% of cementations materials is adopted.

G. *Steel Fiber*

Hook end steel fiber having a length of 35mm and 0.5mm diameter is used in this experiment. Combination of 0.25% of steel and 0.25% of sisal fiber was used to known its combined effect on the compressive as well as flexural strength in conventional and self compacting concrete.

V. MIX DESIGN

Mix design for SCC of grade M35 is carried out as per Nan Su et al and mix design for CC of grade M35 is carried out as per IS: 10262:2019

A. Comparison of Design Mix for CC and SCC

One of the major requirements of SCC is it requires more amount of cementitious material to achieve required flow. Fly ash as a mineral admixture when added in addition to cement can satisfy these criteria without affecting the durability of concrete. Hence and compensative material is added to achieve the mix.

TABLE IV
COMPARISON OF MIX DESIGN RESULT CC AND SCC

Sl. No	Materials	CC in kg/m^3	SCC in Kg/m^3
1.	Cementitious material		
	a. Cement	479	313.644
	b. Fly ash	-	187.23
2.	Aggregates		
	a. Fine aggregate	655.60	916.8
	b. Coarse aggregate	1073.74	661.48
3.	Water content	191.6	195.33
4.	Admixture(SP)	0.5%	1.5%

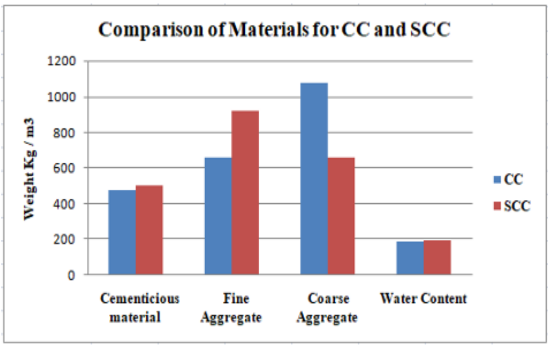

Fig 1: Comparisition of materials of CC and SCC

From fig 1 it is clear that SCC raquires more amount of cementitious material and fine aggregate but less amount of coarse aggegate compared to CC

VI. EXPERIMENTAL WORK

A. *Fresh properties test on self compacting concrete is carried out by following test*

- Slump Flow Test or T_{500} Slump Flow Test

- V-Funnel Test
- L-box test
- D.U-box test
- J-ring test
- Flow table test

B. *Hardened properties test on self compacting concrete is carried out by following test*

- compressive strength test
- Flexural strength test

Variables to be considered while determining the Fresh properties of SCC are varying percentage of sisal fiber by 0%, 0.25%, 0.5% and 0.75% of total cementitious material with 1.5% of SP dosage. Fly ash, viscosity modifying agent, aggregates and cement are added according to mix design considerations. From the obtained mix cubes and beam were casted and after curing for 7 and 28 days its hardened properties are tested.

VII. RESULTS AND DISCUSSIONS

A. *Fresh and Hardened Properties of Conventional Concrete*

conventional concrete mix desgin was carried out for M_{35} grade concrete and for the same mix sisal fiber reinforcement was added to know influence at its fresh and hardened state

TABLE V
FRESH AND HARDENED PROPERTIES OF CONVENTIONAL CONCRETE WITH AND WITHOUT SISAL FIBERS

Type	Slump in mm	Compressive Strength in N/mm^2	Flexural Strength in N/mm^2
		@28 Days	@28 Days
CC (12mm down coarse aggregate with 0.5% SP)	60	40.1	5.12
FRC (12mm down coarse aggregate with 0.5% SP and 0.5% sisal fibers)	50	40.01	6.3

From table V it is observed that compression and flexural strength of sisal fibers reinforced concrete is higher than compared to that of trial mix without sisal fibers.

B. *Influence of Super Plasticizers on the Fresh Properties of SCC*

To adopt the percentage of SP dosage in mix design, super plasticizer (Master Glenium Sky 8650) is varied from 0.5% to 1.75% and slump flow test is carried out to observe the time required to reach 500mm diameter on slump flow table

TABLE VI
TRIAL MIX SLUMP FLOW RESULT FOR SCC

Date of Casting	SP in %	D1 in mm	D2 in mm	D Average in mm	T500 in Seconds
01/01/2020	0.5	No flow occurred			
01/01/2020	0.75	No flow occurred			
02/01/2020	1.0	510	520	515	7
02/01/2020	1.25	550	580	565	6
04/01/2020	1.5	605	600	600	3
04/01/2020	1.75	Segregation observed not satisfactory			

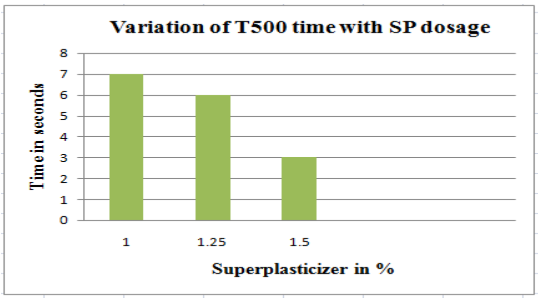

Fig 2: Variation of T500 time with SP dosage

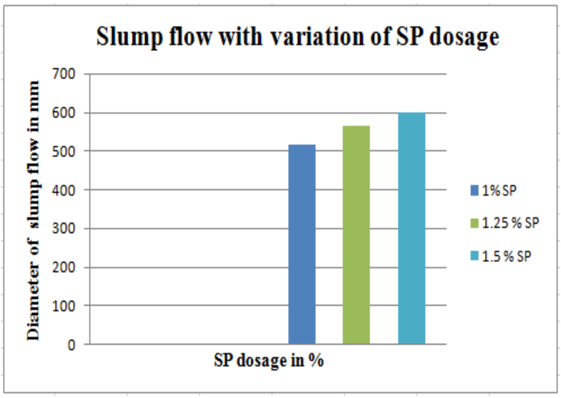

Fig 3: Variation of slump flow with SP dosage

From fig 2 and fig 3 it is clear that as the percentage of SP increases T500 time decreases and flow diameter increases. Sp percentage is adopted in between 1% to 1.5% because below 1% no flow occurs and above 1.75% concrete shows segregation

C. *Fresh Properties of SCC with and without Sisal Fibers with 1.5% SP*

1. *Slump Flow Test*

Following points are observed from results obtained through the graph shown in fig 4 and fig 5

- Slump flow diameter decreases with increase in fiber content from 0 % to 0.5%
- At 0.75% of fiber content slump flow decreases due to resistance of fiber to the flow of matrix.

TABLE VII
VARIATION OF SLUMP FLOW AND TIME WITH AND WITHOUT FIBERS

% of Sisal Fibers	T500 Time in Sec Limitations(2-5 sec)	Slump Flow in mm Limitations (600-800 mm)
0	3	675
0.25	4	660
0.5	5	650
0.75	6	630

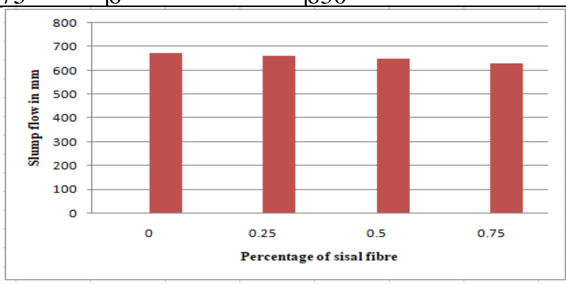

Fig 4: Slump flow test result of sisal fiber reinforced SCC

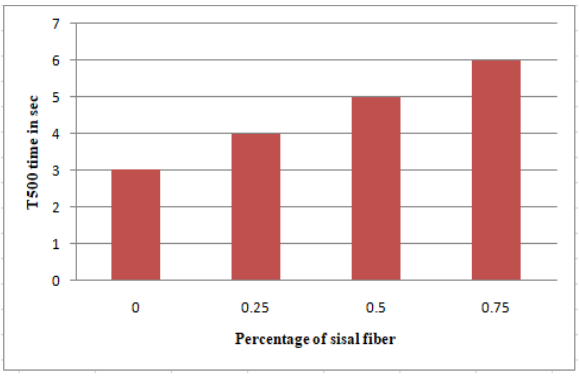

Fig 5: T_{500} test results of sisal fiber reinforced SCC

2. V-Funnel Test

Table VIII shows the results of V-funnel test required for flow of concrete from device outlet was recorded. The results show that by increasing the percentage of sisal fiber from 0.5% to 0.75% shows increase in flow time this is due to resistance to flow by fiber as shown in fig 6

TABLE VIII
VARIATION OF TIME FLOW WITH SISAL FIBER REINFORCED SCC

Sl. No	Percentage of Sisal Fibers in %	V-Funnel Limitations(6-12 sec)
1	0	9
2	0.25	9
3	0.5	10
4	0.75	14

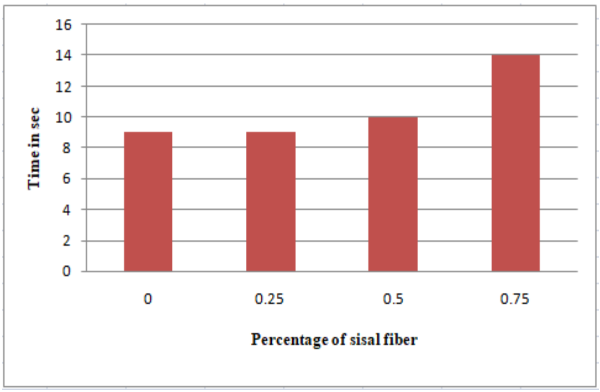

Fig 6: Variation of time flow with sisal fiber reinforced SCC

3. L-Box Test

Table IX shows the variation of J-ring with respect to varying percentage of sisal fiber and graph plotted in figure 7 represent its variation. From the results following observation is made

- In addition to incremental percentage of sisal fibers from0.25% to0.75% flow gradually decreases
- Maximum decreases in flow are absorbed in 0.75% sisal fibers and the blockage increases with increase in fiber content.

TABLE IX
VARIATION OF L-BOX RATIO WITH SISAL FIBER REINFORCED SCC

Sl. No	Percentage of Sisal Fiber in %	L-box Limitation (H_2/H_1=(0.8-1))
1	0	0.95
2	0.25	0.81
3	0.5	0.75
4	0.75	0.7

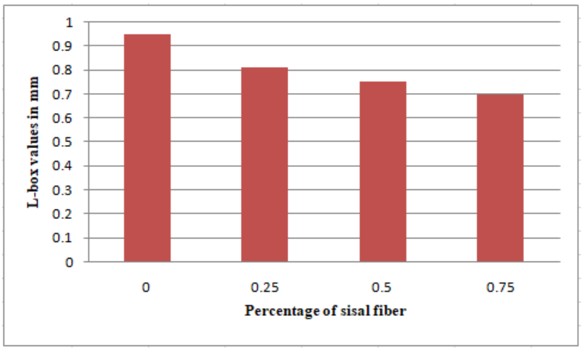

Fig 7: Variation of L-box ratio with sisal fiber reinforced SCC

4. J-Ring Test

Table X shows flow variation of J-ring with respect to varying percentage of sisal fiber and graph plotted in fig 8 represent its variation. From the results following observation is made.

- In addition to incremental percentage of sisal fiber from 0.25% to 0.75% flow gradually decreases.
- Maximum decrease in flow is absorbed in 0.75% sisal fiber and the blockage increases with increasing fiber content.

TABLE X
VARIATION OF J-RING HEIGHT WITH SISAL FIBER REINFORCED SCC

Sl. No	Percentage of Sisal Fiber in %	J-Ring Limitation (0-10 mm)
1	0	4
2	0.25	6
3	0.5	9
4	0.75	12

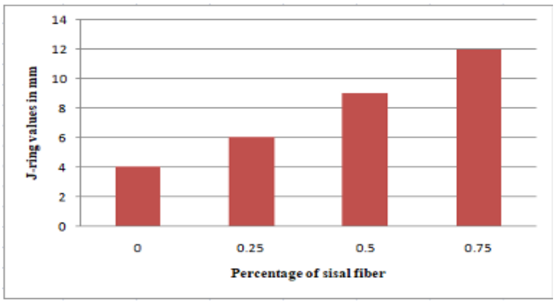

Fig 8: Variation of J-ring height with sisal fiber reinforced SCC

D. Hardened Properties of Conventional Concrete with and without Sisal Fiber

1) Compressive Strength Test Results at 7 days and 28 days

TABLE XI
COMPRESSIVE STRENGTH TEST RESULTS AT 7 DAYS AND 28 DAYS WITH AND WITHOUT SISAL FIBERS

Sl. No	Percentage of Sisal Fiber in %	Compressive Strength in N/mm²	
		@7 Days	@28 Days
1	0	25	44.4
2	0.5	26	45.15

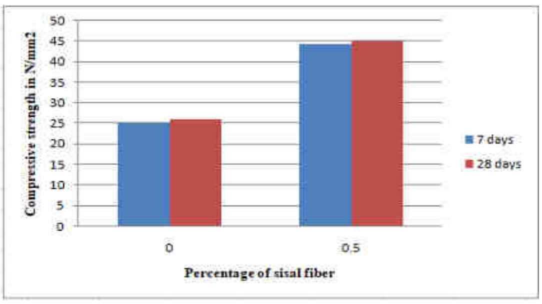

Fig 9: 7 and 28 days compressive strength

The concrete specimen was tested after 7 days and 28 days of curing for compressive strength and the results obtained are tabulated in table XI and figure 9 represent the variation of compressive strength with respect to varying percentage of sisal fibers. Following observation was made based on the results obtained

- Specimen with 0.5% sisal fibers shows slight increase in compressive strength compared to specimen with 0% sisal fiber.

2) Flexural Strength Test Results at 7 days and 28 days

TABLE XII
FLEXURAL STRENGTH TEST RESULTS AT 7 AND 28 DAYS WITH AND WITHOUT SISAL FIBER

Sl. No	Percentage of Sisal Fiber in %	Flexural Strength in N/mm²	
		@7 Days	@28 Days
1	0	2.96	3.91
2	0.5	3.1	4.28

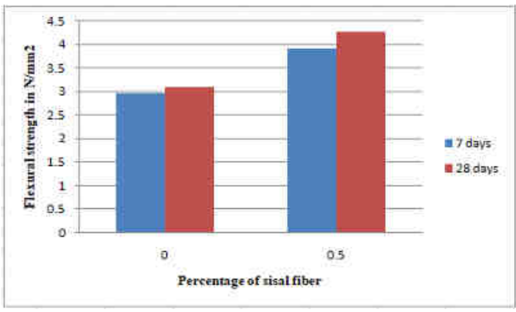

Fig 10: 7 and 28 days flexural strength

The concrete specimen was tested after 7 and 28 days of curing for flexural strength test and the result obtained are tabulated in table XII. Figure 10 represents the variation of flexural strength with respect to varying percentage of sisal fiber. Following observation is made based on the result obtained.

- Specimen with 0.5% sisal fibers shows a slight increase in flexural strength compared to the specimen with 0% sisal fibers.

E. Hardened Properties of Self Compacting Concrete with and without Sisal Fiber

1) Compressive Strength Test Results at 7 Days and 28 Days

TABLE XIII
COMPRESSIVE STRENGTH TEST RESULTS AT 7 DAYS AND 28 DAYS WITH AND WITHOUT SISAL FIBER

Sl. No	Percentage of Sisal Fiber in %	Compressive Strength in N/mm²	
		@7 Days	@28 Days
1	0	22.33	35.2
2	0.25	25.39	36.75
3	0.5	27.1	39.59
4	0.75	30.54	41.31

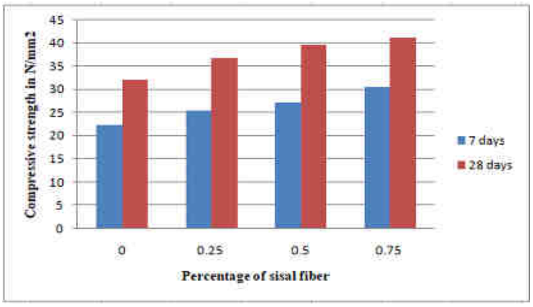

Fig 11: 7 and 28 days compressive strength

The concrete specimen were casted and then cured for 7 and 28 days before testing. The results of compressive strength are tabulated in table XIII. Figure 11 represents the variation of compressive strength with respect to varying percentage of sisal fibers. Following observation was made based on the result obtained.

- At 0.75% of sisal fiber it is observed that the compressive strength of specimen is gradually increased.
- Across the age of curing from 7 and 28 days the compressive strength was increased in the range of 7% to 10% which is the corresponding to respective fiber.

2) Flexural Strength Test Results at 7 days and 28 days

TABLE XIV
FLEXURAL STRENGTH TEST RESULTS AT 7 DAYS AND 28 DAYS WITH AND WITHOUT SISAL FIBER

Sl. No	Percentage of Sisal Fiber in %	Flexural Strength in N/mm²	
		@7 Days	@28 Days
1	0	4.13	5.43
2	0.25	4.31	5.95
3	0.5	4.83	6.63
4	0.75	5.13	6.69

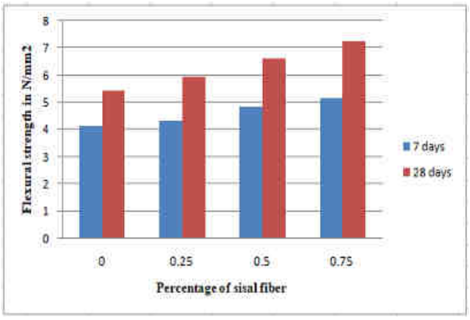

Fig 12: 7 and 28 days flexural strength

The concrete specimen were casted and then cured for 7 and 28 days before testing. The results of flexural strength are tabulated in table XIV. Figure 12 represents the variation of flexural strength with respect to varying strength percentage of sisal fibers. Following observation was made based on the results obtained.

- At 0.75% of sisal fibers it is observed that flexural strength of the specimen is gradually increased.
- The percentage increase in flexural strength is 33.14% with respect to plane SCC.

F. Harden Properties of Conventional Concrete with and without Combination of Sisal and Steel Fiber

1) Compressive Strength Test Results at 7 Days and Days

TABLE XV

COMPRESSIVE STRENGTH TEST RESULTS AT 7 DAYS AND 28 DAYS WITH AND WITHOUT COMBINATION OF SISAL AND STEEL FIBER

Sl. No	**Percentage of Sisal and Steel Fiber in %**	**Compressive Strength in N/mm²**	
		@7 Days	**@28 Days**
1	0	24	44.4
2	0.25% sisal and 0.25% steel	32	49.6

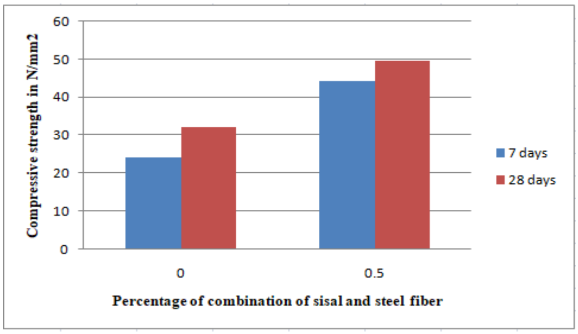

Fig 13: 7 and 28 days compressive strength

The concrete specimen were casted and then cured for 7 and 28 days before testing. The results of compressive strength are tabulated in table XV. Figure 13 represents the variation of compressive strength with respect to with and without combination of sisal and steel fiber. Following observation was made based on the result obtained.

- Compressive strength of specimen with combination of 0.25% sisal and 0.25% steel fiber shows gradually increase in compressive strength compared to specimen with 0% sisal fiber

2) Flexural Strength Test Results at 7 and 28 days

TABLE XVI

FLEXURAL STRENGTH TEST RESULTS AT 7 AND 28 DAYS WITH AND WITHOUT COMBINATION OF SISAL AND STEEL FIBER

Sl. No	Percentage of Sisal and Steel Fiber in %	Flexural Strength in N/mm²	
		@ 7 Days	@ 28 Days
1	0	2.96	3.91
2	0.25% sisal and 0.25% steel	3.23	4.42

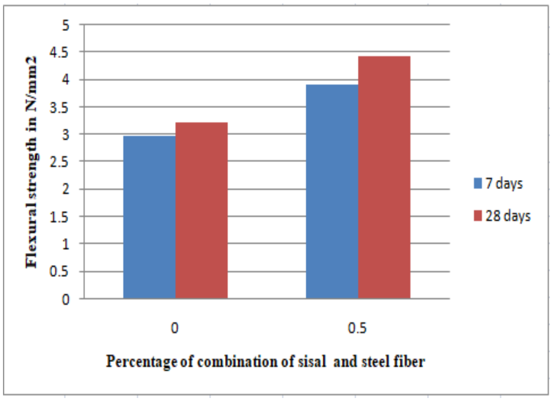

Fig 14: 7 ad 28 days flexural strength

The concrete specimen were casted and then cured for 7 and 28 days before testing. The results of flexural strength are tabulated in table XVI. Figure 14 represents the variation of flexural strength with respect to with and without combination of sisal and steel fiber. Following observation was made based on the results obtained.

- Flexural strength of specimen with combination of 0.25% sisal and 0.25% steel fiber shows gradual increase in flexural strength compared to specimen with 0% sisal fiber.

G. Harden Properties of Self Compacting Concrete with and without Combination of Sisal and Steel fiber

1) Compressive Strength Test Results at 7 and 28 days

TABLE XVII

COMPRESSIVE STRENGTH TEST RESULTS AT 7 AND 28 DAYS WITH AND WITHOUT SISAL AND STEEL FIBER

Sl. No	**Percentage of Sisal and Steel Fiber**	**Compressive Strength in N/mm²**	
		@ 7 Days	**@ 28 Days**
1	0	22.33	35.31
2	0.25% sisal and 0.25% steel	26.32	36.86

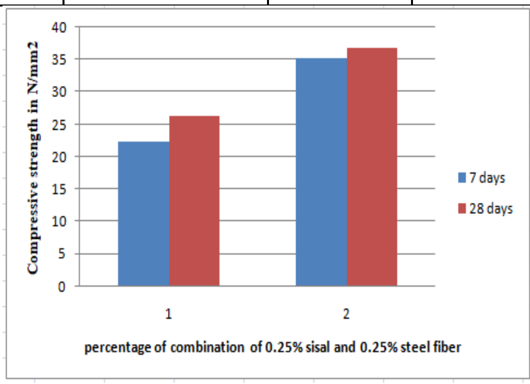

Fig 15: 7 and 28 days compressive strength

2) Flexural Strength Test Results at 7 and 28 days

TABLE XVIII
FLEXURAL STRENGTH TEST RESULTS AT 7 AND 28 DAYS WITH AND WITHOUT SISAL AND STEEL FIBER

Sl. No	Percentage of Sisal and Steel Fiber in %	Flexural Strength in N/mm^2	
		@ 7 Days	@28 Days
1	0	4.13	5.43
2	0.25% sisal and 0.25% steel	4.43	5.57

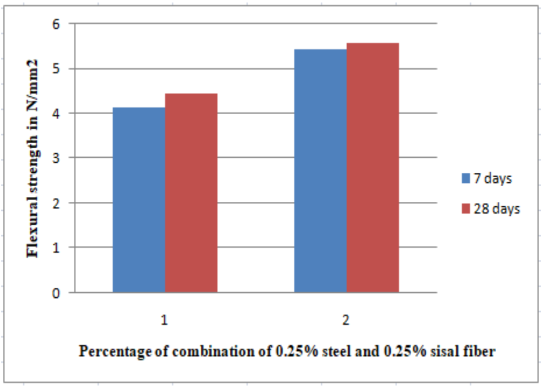

Fig 16: 7 and 28 days flexural strength

CONCLUSION

- To arrive at initial mix design for conventional concrete and self compacting concrete, mix design method described IS 10262.2019 for conventional concrete and NA Su et al a method suggested by euro code for self compacting concrete is accurate and convenient. Final mix design is obtained from trials and error method.
- Self compacting concrete requires more amounts of fines in the mix to achieve flow ability which is obtained by addition of fly ash (mineral admixture) this is evident from comparison of mix designs. SCC also has many benefits like better finished surface, environmental friendly, faster construction.
- From experimental study acceptable flow characteristics for SCC where achieved with dosage of super-plasterers
- between 1% and 1.5% it is also observed that below 1% of SP there is no flow and above 1.5% of segregation occurs.
- With increase in dosage of SP slump flow increases and T500 time decreases also SP dosage addition gives higher workability.
- To study the properties of SP slump flow test, L-box , U- box, J-ring, flow table experiments were carried out. From the test results it is observed that by increasing the percentage of sisal fibers T500 time increases and slump flow decreases also passing, filling and flow ability of SCC decreases.
- From this experimental study, addition of 0.25% of sisal fibers enhances the fresh properties of SCC by reducing bleeding add segregation where as further increase in percentage of sisal fibers decreases workability of SCC.
- From test result of hardened properties of concrete it is observed that compressive strength and flexural strength of specimen increases gradually upto 0.75% of sisal fibers.
- Compressive strength and flexural strength is increased by 29% and 33.14% respectively after addition of 0.75% sisal fiber for M35 mix design.

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