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Experimental Investigation on Hybrid Fibre Reinforced Self Compacting Concrete

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ABSTRACT - This project deals with properties of fresh and hardened self-compacting concrete reinforced with a combination of steel and sisal fibers as Hybrid fiber. Two percentages of sisal fibers (0.5%, 1%) are mixed with a uniform 0.4% and 0.8% of steel fibers. Flow properties, Compressive strength and Split tensile strength are evaluated at 7 days and 28 days for various specimens of self-compacting concrete. The experimental results concluded that the sisal fibers have a good capacity of using it as a reinforcement material along with steel for self-compacting concrete mix. In the flow/passing experimental techniques like the Slump Flow, T500mm Slump Flow, V-Funnel Test, J-Ring Test, L-Box Test and T5min V-Funnel Test, the concrete mix design with a lower fiber content of sisal fibers with steels proves to be beneficial for the workability of concrete. The experimental results was observed that high concentration of steel along with sisal fibers in self compacting concrete improves the compressive strength of 28 days are 29.33, 30.22, 30.67, 31.11, 32 N/mm^2 and split tensile strength of 28 days are 3.74, 3.89, 3.96, 4.03, 4.17 N/mm^2

Keywords: Hybrid fiber, sisal fiber, self-compacting concrete,

I. INTRODUCTION

Over the last decades, Self-Compacting Concrete (SCC) is an essential advancement in concrete technology, since it moves based on its weight without the demand for vibration in narrow areas and complexity of the formwork relative to the conventional concrete. The SCC was proposed for the first time in 1986 by Professor Hajime Okamura, but the first time in 1986 by Professor Ozawa in Japan. Due to its broad applicability, SCC has been investigated in various countries, including the USA, Japan and Canada for its potential in structural engineering and constructions. SCC provides several benefits, such as easy production, high productivity and high structural consistency. The Self Compacting Concrete mixture of fibrous steel exhibits better efficiency in comparison with standard vibrated concrete in fresh and hardened states owing to the inclusion of fibers.

II. MATERIALS AND METHODS

2.1 CEMENT

World production is about four billion tons per year, of which about half is made in China. If the cement industry were a country, it would be the third largest carbon dioxide emitter in the world with up to 2.8 billion tones, surpassed only by China and the United States. The initial calculation reaction in the production of cement is responsible for about 4% of global CO_2 emissions. The overall process is responsible for about 8% of global CO_2 emissions, as the cement kiln in which the reaction occurs is typically fired by coal or petroleum coke due to the luminous flame required to heat the kiln by radiant heat transfer. As a result, the production of cement is a major contributor to climate change. Cement is a finely pulverized material which by itself is not a binder, But develops the binding property as a result of hydration. Scope for Silicon di-Oxide as reinforcement

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TABLE.1 CHEMICAL COMPOSITION OF CEMENT

COMPOUND	REQUIREMENT (%)
Silica (SiO_2)	19
Iron Oxide (Fe_2O_3)	1.5
Alumina (Al_2O_3)	6
Calcium Oxide (CaO)	66
Magnesium Oxide (MgO)	2
SO_3, max	2.5
Moisture Content, max	2
Loss on Ignition, max	3

FIG .1 CEMENT

2.2 FINE AGGREGATE

Fine aggregate is the essential ingredient in concrete that consists of natural sand orcrushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. The concrete or mortar mixture can be made more durable, stronger and cheaper if you made the selection of fine aggregate on basis of grading zone, particle shape and surface texture, abrasion and skid resistance and absorption and surface moisture. Fine aggregates are the structural filler that occupies most of the volume of the concrete mix formulas. Depending on composition, shape, size and other properties of fine aggregate you can have a significant impact on the output.

Fig. 2 Fine Aggregate (Sand)

2.3 **COARSE AGGREGATE**

Coarse aggregates are irregular broken stone or naturally occurring rounded gravel used for making concrete. Materials which are large to be retained on 4.75 mm sieve size are called coarse aggregates, and its maximum size can be up to 63 mm. Coarse aggregates are generally obtained by blasting in stone quarries or by breaking them by hand or by crushers. Machine crushed stones consist of stones of various sizes whereas Hand broken aggregates consist of only single size stones. To produce graded aggregates for high-class concrete, they are again mixed in specific proportions. Coarse aggregates for structural concrete consist of broken stones of hard rock like granite and limestone (angular aggregates) or river gravels (rounded aggregates). For non-structural mass concrete of low strength, broken bricks, foamed slag, clinker, etc., may be also used as coarse aggregates.

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Fig. 2 COARSE AGGREGATE

COMPOUND	REQUIREMENT (%)
Silica (SiO_2)	58.5
Iron Oxide (Fe_2O_3)	3.32
Alumina (Al_2O_3)	28.2
Calcium Oxide (CaO)	2.21
Magnesium Oxide (MgO)	0.36
Alkalies (Na_2O+K_2O)	1.84
SO_3, max	4.3
Moisture Content, max	2.8
Loss on Ignition, max	4.17

TABLE 2 CHEMICAL COMPOSITION OF FLY ASH (CLASS F)

2.4 SUPER PLASTICIZER

It is also known as high range water reducers, are additives used in making high strength concrete. Super plasticizers allow reduction in water content by 20% or more. These additives are employed at the level of a few weight percent. Plasticizers and super plasticizers retard the curing of concrete. Super plasticizers are used where well-dispersed particle suspension is required to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio without negatively affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. They greatly improve the performance of the hardening fresh paste. The strength of concrete increases when the water to cement ratio decreases.

III. MATERIALS PROPERTIES

3.1 PROPERTIES OF CEMENT

S.No	Property Test		Obtained Values
1	Type of Cement		PPC
2	Grade of Cement		43
3	Specific Gravity		2.88
4	Setting Time	Initial (min)	30
		Final (min)	600

TABLE.2 PROPERTIES OF CEMENT

3.2PROPERTIES OF FINE AGGREGATE (SAND)

S.No	Property Test	Obtained Values
1	Particle Size (mm)	<4.75
2	Specific Gravity	2.65

3	Fineness Modulus (%)	2.7

TABLE .3PROPERTIES OF FINE AGGREGATE (SAND)

3.3PROPERTIES OF COARSE AGGREGATE

S.No	Property Test	Obtained Values
1	Size of Aggregate (mm)	20
2	Specific Gravity	2.74
3	Water Absorption (%)	0.5

TABLE.4PROPERTIES OF COARSE AGGREGATE

3.4PROPERTIES OF FLY ASH (CLASS F)

S.No	Property Test	Obtained Values
1	Colour	Dark Gray
2	Particle Size (mm)	10µ to 100µ
3	Specific Gravity	2.2

TABLE.6 PROPERTIES OF FLY ASH(CLASS F)

3.5PROPERTIES OF SUPER PLASTICIZER

S.No	PROPERTY	OBTAINED VALUES
1	Type	Polycarboxylate Ether
2	Specific Gravity	1.08
3	Colour	Deep Brown Coloured liquid
4	Chloride content	<0.02
5	Solubility	Readily soluble in water

TABLE.7 PROPERTIES OF SUPERPLASTICIZER

3,6PROPERTIES OF STEEL AND SISAL FIBRES

S.No	PROPERTIES	STEEL	SISAL
1	Diameter (mm)	0.75	0.2-0.6
2	Length (mm)	60	60
3	Density (g/cm^3)	7.85	1.58
4	Aspect Ratio	80	N.A

TABLE.8 PROPERTIES OF STEEL AND SISAL FIBRES

IV. TEST ON FRESH FRC

4.1 FILLING ABILITY TEST

- Slump Flow Test
- T500mm Slump Flow Test
- V-Funnel Test

T500mm Slump Flow Test
V-Funnel Test

4.2 SLUMP FLOW TEST

The slump flow test is used assess the horizontal free flow of self-compacting concrete in the absence of obstructions. The test method is based on the test method for determining the slump.

EQUIPMENTS REQUIRED:
Slump Cone, Base plate, Trowel, Measuring Tape

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PROCEDURE:

- About 6 liters of concrete is needed for this test.
- Place the base plate on level ground.
- Keep the slump cone centrally on the base plate.
- Fill the cone with the scoop.
- Do not tamp.
- Simply strike off the concrete level with the trowel.
- Remove the surplus concrete lying on-base place.
- Raise the cone vertically and allow the concrete to flow freely.
- Measure the final diameter of the concrete in two perpendicular directions and calculate the average of the two diameters.
- This is the slump flow in mm.
- Note that there is no water or cement paste or mortar without coarse aggregate is seen at the edge of the spread concrete.

CALCULATIONS:

Flow Diameter = (dm+dr)/2

TABULATIONS:

SCC MIX	LARGEST DIAMETER (dm)	DIAMETER PERPENDICULAR TO LARGEST DIAMETER (dr)	FLOW DIAMETER(mm)
Mix0	607	605	606
Mix1	577	579	578
Mix2	560	556	558
Mix3	523	527	525
Mix4	509	513	511

TABLE.8 SLUMP FLOW VARIATION IN SCC MIX PROPORTIONS

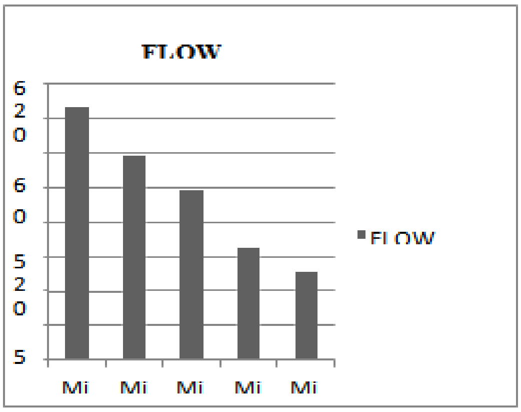

Fig.3SLUMP FLOW VARIATION IN SCC MIX PROPORTIONS

4.3T$_{500mm}$ SLUMP FLOW TEST

When the slump cone is lifted, start the stopwatch and find the time taken for the concrete to reach a 500 mm mark. This time is called T500mm time. This is an indication of the rate of spread of concrete. A lower time indicates greater flow ability.

EQUIPMENTS REQUIRED:
Slump Cone, Base plate, Trowel, Stopwatch

PROCEDURE:

- The procedure for this test is same as for slump flow test. When the slump cone is lifted, start the stopwatch and find the time taken for the concrete to reach a 500 mm mark.
- This time is called T500mm time.
- This is an indication of the rate of spread of concrete.
- A lower time indicates greater flow ability

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TABULATIONS:

SCC MIX	T500mm (Sec)
Mix0	5.52
Mix1	6.48
Mix2	7.93
Mix3	9.39
Mix4	10.87

TABLE.9 T500mm SLUMP FLOW VARIATION IN SCC MIXPROPORTIONS

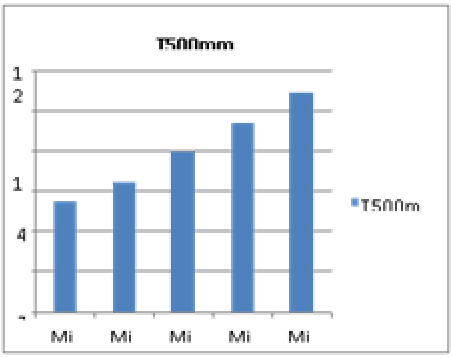

Fig.4 T500mm SLUMP FLOW VARIATION IN SCC MIXPROPORTIONS

4.4V-FUNNEL TEST

V-funnel test on self compacting concrete is used to measure the flow ability. But the flow ability of concrete is affected by its other properties as well which may affect the flow ability of the concrete during testing. 0 2 4 6 8 10 12 Mix0 Mix1 Mix2 Mix3 Mix4 T500mm (Sec) T500mm (Sec) 26

EQUIPMENTS REQUIRED:
V-Funnel, Bucket, Trowel, Stopwatch

PROCEDURE:

- About 12 liters of concrete is needed for the test.
- Set the V-funnel on firm ground.
- Moisten inside of the funnel
- Keep the trap door open to remove any surplus water.
- Close the trap door and place a bucket underneath.
- Fill the apparatus completely with concrete.
- Compaction or tamping is done.
- Strike off the concrete level.
- Open within 10 seconds the trap door and record the time taken for the concrete to flow down.
- Record the time for emptying.
- This can be judged when the light is seen when viewed from the top.
- The whole test is to be performed within 5 min.

Fig.5 V-FUNNEL TESTING

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TABULATIONS:

SCC MIX	V-FUNNEL FLOW TIME (tv) (Sec)
Mix0	7.65
Mix1	8.02
Mix2	9.18
Mix3	10.49
Mix4	11.77

TABLE.10 V-FUNNEL FLOW VARIATION IN SCC MIX PROPORTIONS

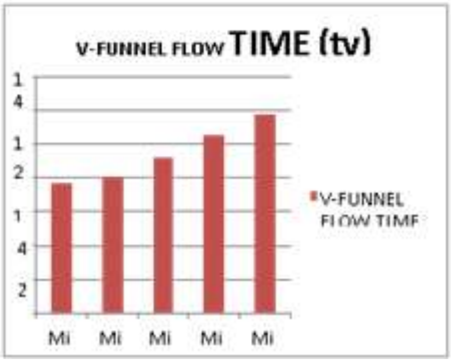

Fig.4 V-FUNNEL FLOW VARIATION IN SCC MIX PROPORTIONS

PASSING ABILITY TEST

➢ J-Ring Test
➢ L-Box Test

4.51 J-RING TEST

• J-ring test denotes the passing ability of the concrete.
• The equipment consists of a rectangular section of 30 mm x 25 mm open steel ring drilled vertically with holes to accept threaded sections of reinforcing bars 10 mm diameter 100 mm in length.
• The bars and sections can be placed at different distances apart to simulate the congestion of reinforcement at the site.
• Generally, these sections are placed 3 x maximum size of aggregate.
• The diameter of the ring formed by vertical sections is 300 mm and height 100mm EQUIPMENTS REQUIRED: Slump Cone, Base plate, J-Ring, Trowel, and Measuring Tape

PROCEDURE:

• About 6 liters of concrete is needed for the test.
• Moisten the inside of the slump cone and base plate.
• Place the J-Ring centrally on the base plate and the slump cone centrally inside the J-ring.
• Fill the slump cone with a scoop.
• Do not tamp. Simply strike off the concrete level with a trowel.
• Remove all surplus concrete.
• Raise the cone vertically and allow the concrete to flow out through the J-ring.
• Measure the final diameter in two perpendicular directions.
• Calculate the average diameter.
• Measure the difference in height between the concrete just inside J-Ring bars and just outside the J Ring bars.
• Calculate the average of the difference in height at four locations in mm.
• Note any border of mortar or cement paste without coarse aggregate at the edge of the concrete
• The acceptable difference in height between inside and outside should be between 0 and 10 mm.

Fig.5 J-RING TESTING

CALCULATIONS:

1. J-Ring flow spread (SJ) = (dm+dr)/2
2. J-Ring Blocking Step (BJ) = [(Δhx1+ Δhx2+ Δhy1+ Δhy2) –Δh0] /4

TABULATIONS:

SCC MIX	LARGEST DIAMETER (dm)	DIAMETER PERPENDICULAR TO LARGEST DIAMETER (dr)	J-RING FLOW SPREAD (SJ) (mm)
Mix0	584	580	582
Mix1	568	566	565
Mix2	530	532	531
Mix3	509	503	506
Mix4	478	482	480

TABLE.11J-RING FLOW SPREAD VARIATION IN SCC MIX PROPORTIONS

SCC MIX	Δh0	Δhx1	Δhx2	Δhy1	Δhy1	J-RING BLOCKING STEP (BJ) (mm)
Mix0	127	131	133	133	129	4.5
Mix1	128	132	133	134	131	4.5
Mix2	130	135	138	136	134	5.75
Mix3	132	140	138	139	136	6.25
Mix4	133	139	142	139	141	7.25

TABLE.12 J-RING BLOCKING STEP VARIATION IN SCC MIX PROPORTIONS

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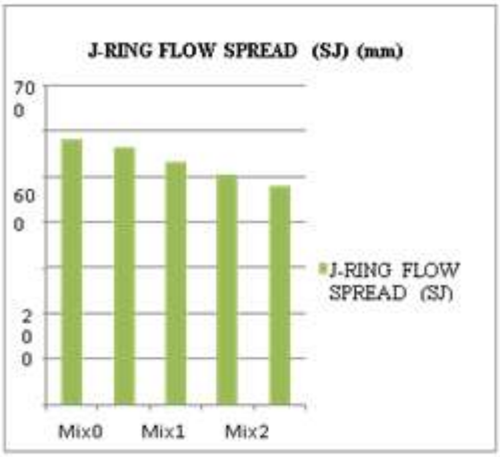

Fig.6J-RING FLOW SPREAD VARIATION IN SCC MIX PROPORTIONS

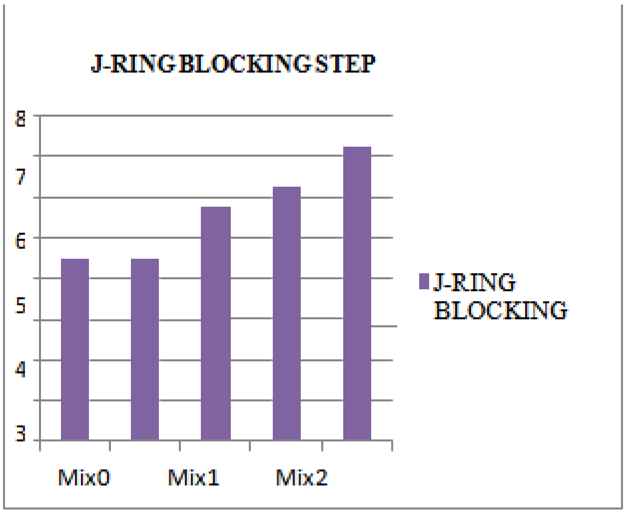

Fig.7 J-RING BLOCKING STEP VARIATION IN SCC MIX PROPORTIONS

4.6 L-BOX TEST

Test measures the filling and passing abilities of SCC. The apparatus consists of a rectangular section L-shaped box. The extent to which concrete flows down the horizontal portion of box depends on yield stress of the concrete. The stability, i.e., resistance to segregation can be visually assessed.

EQUIPMENTS REQUIRED:

L-box, Measuring scale.

PROCEDURE:

- About 14 liter of concrete is needed to perform the test, sampled normally.
- Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it.
- Moisten the inside surfaces of the apparatus, remove any surplus water.
- Fill the vertical section of the apparatus with the concrete sample. Leave it to stand for 1 minute.
- Lift the sliding gate and allow the concrete to flow out into the horizontal section.
- Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400 mm marks.
- When the concrete stops flowing, the distances “H1” and “H2” are measured.
- Calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes.

Fig.8 L-BOX TESTING

CALCULATIONS:
The Blocking Ratio (H2/H1) = _______

SCC MIX	THE DEPTH OF CONCRETE BEFIND THE GATE AFTER FLOW (H1)	THE DEPTH OF CONCRETE AT THE END OF HORIZONTAL BOX AFTER FLOW (H2)	BLOCKING RATIO (H2/H1)
Mix0	100	80	0.8
Mix1	103	76	0.75
Mix2	104	75	0.72
Mix3	106	73	0.69
Mix4	108	70	0.65

TABLE.13 L-BOX BLOCKING RATIO VARIATION IN SCC MIX PROPORTIONS

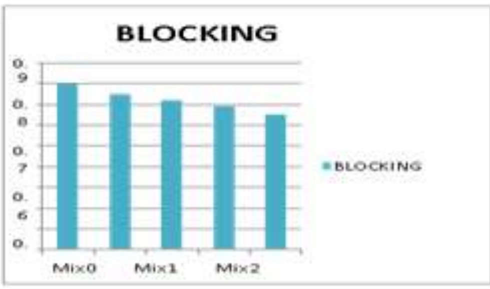

Fig.9 L-BOX BLOCKING RATIO VARIATION IN SCC MIX PROPORTIONS

4.7SEGREGATION RESISTANCE TEST:
- T5min V-FUNNEL TEST

4.8 T5min V-FUNNEL TEST

T5min V-Funnel Test is the one of the segregation test.

EQUIPMENTS REQUIRED:
V-Funnel, Bucket, Trowel, Stopwatch

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PROCEDURE:

- Do not clean or moisten the inside surface of the funnel.
- Close the trap door and refill the V-funnel immediately after measuring the flow time.
- Place the bucket underneath.
- Fill the apparatus completely with concrete without tamping or tapping.
- Strike off the concrete level with the top by trowel.
- Open the trap door after 5 minutes after the second fill of the funnel and allow the concrete to flow.
- Calculate the time taken for complete discharge.
- It is called the flow time at T5min.
- For V-funnel test the flow time should be between 8 and 12 seconds.
- For V-funnel flow time at T5min. + 3 seconds is allowed.

TABULATIONS:

SCC MIX	T5min V-FUNNEL FLOW TIME (tv) (Sec)
Mix0	13.14
Mix1	15.98
Mix2	17.03
Mix3	19.19
Mix4	20.81

TABLE.14 T5min V-FUNNEL FLOW VARIATION IN SCC MIX PROPORTIONS

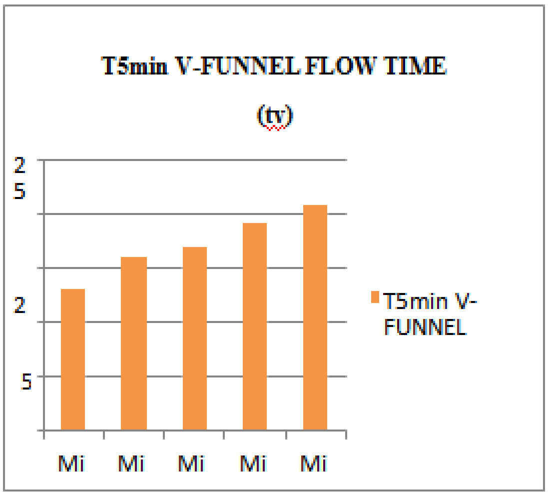

Fig.9 T5min V-FUNNEL FLOW VARIATION IN SCC MIX PROPORTIONS

V. TEST ON HARDENED FRC

5.1COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of material or structure to resist or withstand under compressive. The Compressive strength of a material is determined by the ability of the material to resist failure in the form cracks and fissure. In this test, the push force applied on the both faces of concrete specimen and the maximum compressive that concrete bears without failure is noted. Concrete testing helps us to majorly focus on the Compressive strength of concrete because it helps us to quantify the ability of concrete to resists Compressive stresses among structures where-as other stresses such as axial stresses and tensile stresses are catered by reinforcement and other means.

EQUIPMENTS REQUIRED:
Compression Testing Machine (CTM)
MATERIALS REQUIRED:
Concrete Cube (150mm x 150mm x 150mm).

PROCEDURE:

- Place the prepared concrete mix in the steel cube mould for casting.
- Once it sets, After 24 hours remove the concrete cube from the mould.
- Keep the test specimens submerged underwater for stipulated time.
- The specimen must be kept in water for 7 or 14 or 28 days and for every 7 days the water is changed. Curing of concrete cubes

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• Ensure that concrete specimen must be well dried before placing it on the CTM.

• Weight of samples is noted in order to proceed with testing and it must not be less than 8.1Kg. • Testing specimens are placed in the space between bearing surfaces. 37

• Care must be taken to prevent the existence of any loose material or grit on the metal plates of machine or specimen block. Compression Testing Machine used for finding Compressive Strength of Concrete.

• The concrete cubes are placed on bearing plate and aligned properly with the center of thrust in the testing machine plates.

• The loading must be applied axially on specimen without any shock and increased at the rate of 140kg/sq cm/min. till the specimen collapse.

• Due to the constant application of load, the specimen starts cracking at a point and final breakdown of the specimen must be noted.

CALCULATIONS:

1. Compressive Strength Test = Maximum Load / C/S Area.
2. C/S Area = 150 x 150 = 22500 mm2.

TABULATIONS:

SCC MIX	MAXIMUM LOAD (kN)		COMPRESSIVE STRENGTH (N/mm^2)	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS
Mix0	410	660	18.22	29.33
Mix1	420	680	18.67	30.22
Mix2	440	690	19.56	30.67
Mix3	470	700	20.89	31.11
Mix4	480	720	21.33	32

TABLE.15 COMPRESSIVE STRENGTH ON VARIOUS MIXPROPORTIONS OF SCC

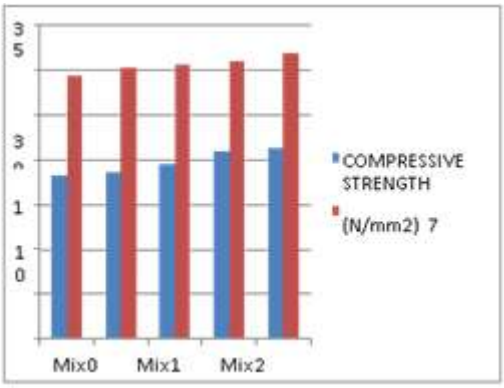

TABLE.10 COMPRESSIVE STRENGTH ON VARIOUS MIXPROPORTIONS OF SCC

5.2SPLIT TENSILE STRENGTH TEST:

The tensile strength of concrete is one of the basic and importance properties. Split tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete Thus it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The test is conducted on the 7, 28 days and its observation are listed below.

PROCEDURE:

• The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers

. • Two bearings strips of nominal (1/8 in i.e. 3.175 mm) thick plywood, free of imperfections, approximately (25 mm) wide, and of length equal to or slightly longer than that of the specimen should be provided for each specimen.

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• The bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine or between the specimen and the supplemental bars or plates.
• Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and cantered over the plywood strip.
• Place a second plywood strip lengthwise on the cylinder, cantered on the lines marked on the ends of the cylinder. Apply the load continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen.
• Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and appearance of fracture

CALCULATIONS:
Split Tensile Strength Test = $2P\ \pi D$
Where,
P – Maximum Load D – Diameter of specimen
L – Length of specimen

TABULATIONS:

SCC MIX	MAXIMUM LOAD (kN)		SPLIT TENSILE STRENGTH (N/mm^2)	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS
Mix0	320	530	2.26	3.74
Mix1	330	550	2.33	3.89
Mix2	350	560	2.48	3.96
Mix3	370	570	2.62	4.03
Mix4	390	590	2.76	4.17

TABLE.16 SPLIT TENSILE STRENGTH ON VARIOUS MIX PROPORTIONS OF SCC

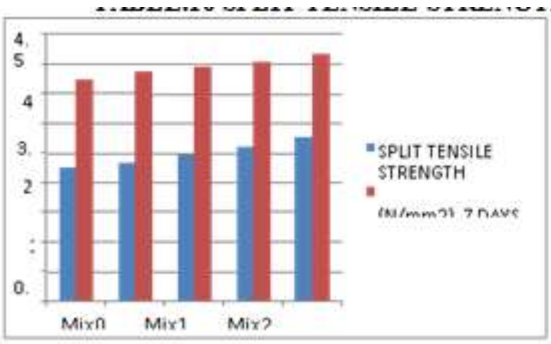

Fig.12 SPLIT TENSILE STRENGTH ON VARIOUS MIX PROPORTIONS OF SCC

VI. RESULTS AND DISCUSSIONS:

The experimental results concluded that the sisal fibers have a good capacity of using it as a reinforcement material along with steel for self-compacting concrete mix. In the flow/passing experimental techniques like the Slump Flow, T500mm Slump Flow, V-Funnel Test, J-Ring Test, L-Box Test and T5min V-Funnel Test, the concrete mix design with a lower fiber content of sisal fibers with steels proves to be beneficial for the workability of concrete. According to the results, it was observed that high concentration of steel along with sisal fibers in self compacting concrete improves the compressive strength of 28 days are 29.33, 30.22, 30.67, 31.11, 32 N/mm2 and split tensile strength of 28 days are 3.74, 3.89, 3.96, 4.03, 4.17 N/mm2 .

VII. CONCLUSION:

The experimental results concluded that the sisal fibers have a good capacity of using it as a reinforcement material along with steel for self-compacting concrete mix. In the flow/passing experimental techniques like the Slump Flow, T500mm Slump Flow, V-Funnel Test, J-Ring Test, L-Box Test and T5min, the concrete mix design with a lower fiber content of sisal fibers with steels proves to be beneficial for the workability of concrete.

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