International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Examining and Testing the Bending and Flow Characteristics of Self-Consolidating Concrete Strengthened with Natural Fibers

Anjani Kumar[1], Mihir Kumar Sharma[2], Pramod Kumar Sahu[3], Amar Nath Kumar[4]

[1] Lecturer, Sandip Foundation's Shri Ram Polytechnic, Sijoul , Madhubani
[2]Lecturer, Sandip Foundation's Shri Ram Polytechnic, Sijoul , Madhubani
[3]Lecturer, Sandip Foundation's Shri Ram Polytechnic, Sijoul , Madhubani
[4]Lecturer, Sandip Foundation's Shri Ram Polytechnic, Sijoul , Madhubani

A B S T R A C T

The growing issue of trained worker shortages in the building sector explains the necessity of self-compacted concrete. One advantage of SCC is that it speeds up the constructing process and permits concrete to gain its strength earlier. The aforementioned article examines the fluidity and flexural characteristics of self-compressing concrete reinforced with fibers from sisal and fiber from abaca in addition to steel. The fibers from steel are blended uniformly with 0.3 % and 0.6 % of sisal or abaca, using three various proportions (0.5%,1%,1.5%). To understand the material's mechanical characteristics, splitting tensile and flexural forces are assessed at the time of life (7th and 28th in days) for different self- compressing concrete samples developed with different fiber types. Additionally, procedures e.g. the Slumping flows, J-ring, and U-box investigations are executed sequentially to comprehend the passage of self- compressing concrete.

Keywords: SCC, Steel Fiber, fluidity, flexural characteristics, sisal, abaca

1. INTRODUCTION

Concrete that is compressing itself due to gravity (SCC) is made instead of the requirement for shaking. "Hajime Okamura" initially proposed the concept of self-compaction concrete in the 1980s in order to guarantee that the concrete receives an appropriate quantity of consolidation and have the right uniformity. Even with significant reinforcing, self-compressing concrete is a exceptional functioning material that allows for flow under itself in its gravity and maintain the required uniformity. In addition to its capacity to resist separation, it has high flowability and can pass through complex structures. The following are some significant characteristics of self-compaction concrete. A few adjustments, such as increasing the granularity and decreasing the water-powder proportion and using the additive, are necessary to obtain these qualities. Increasing the degree of fineness of the content enhances the overall blend in the self-compaction process, which, in turn, affects shrinkage and creep outcomes [1]. A stabilizing agent, also known as a Flow resistance modifying agent (VMA), is used to increase the separation tolerance of SCC [2]. In addition to reducing the likelihood of shrinkage and creep, this also facilitates a decrease in separation. The right proportions must be used in the concrete since uneven placement and compression may occur in bleeding and separation. Here are some more guidelines for researchers. [3] Developing a honeycomb structure to produce a newly designed self-compacting concrete (SCC). In the aforementioned research, we examine how different fiber doses and amounts, in addition to the fibers of steel, affect the mechanical characteristics of SCC [1,3].

2. INGREDIENTS

2.1 Cement and Water

In this study, we use OPC (Ultratech Cement) in the design of mixes for 53 grades of cement. In this mix design, the amount of cement to water is taken as 0.40. The analysis of the cement was conducted to determine its relative density and initial setting time. For 53 OPC Grade of cement, the cement takes 30 min. to set initially [4]

2.2 Coarse-Grained Material and Fine-Grained Material

Sand is utilized as a Fine-grained material with a size range of (0–2) mm, whereas angled material with a size range of (8.00 to16) mm is utilized as an aggregate with a coarse texture.

Fig.1. Fine-grained material **Fig.2. Coarse-grained material**

2.2 Fly Ash

Within the scope of this research fly ash is used as class F category. Silica and alumina is the prime constituent of fly ash. On comparing both Classes F & C of fly ash, minor value of calcium content present in Type F fly ash. Class F fly ash's chemical profile is described below. Mention in List 1.

List 1 chemical profile of Fly Ash (Class F)

Characteristics	**Necessary %**
Silicon Di-Oxide (SiO_2)	58.6
Ferrous Oxide (Fe_2O_3)	3.33
Aluminum Oxide (Al_2O_3)	28.28
Quick Lime (CaO)	2.25
Magnesia (MgO)	0.38
Alkalis (Na_2O+K_2O)	1.85
Sulfur Trioxide $SO_{3,}$ (max^{m}.)	4.35
Water Percentage, (max^{m}.)	2.85
Thermal Loss, (max^{m}.)	4.19

2.3 High-performance plasticizer

ADDAGE PLAST PCE 850 is used as the Chemical additive. For the reason that "sulfonated melamine and naphthalene formaldehyde condensate", which causes particles to repel one another electrostatically, it differs from the traditional additives. It produces concrete with an ideal density, extremely maximum power, and few voids. The dose determines the setting time, which can range between 1 to 4 hours. Mentioned in List 2.

List 2. Characteristics of ADDAGE PLAST PCE 850.

Characteristics	**Constituent (%)**
Calcium Chloride	< 0.2 %
Relative Density	1.06 at 25°C
Air entrapped	<1
Chloride Matter	< 0.2 %

2.4 Viscosity regulator (VMA)

VMA from ASTRRA CHEMICALS is utilized as an additive to change viscosity. For creating concrete with increased viscosity, it was specifically created. It resists separation and has notable stability. Its shell lasts little more than six months. The VMA's properties include improved flowability, increased viscosity, no influence on the air percentage of the concrete, no influence on the set time, and no influence on the concrete's compression power [5].

2.5 Metal steel with Organic Fibers: Abaca and Sisal

Fibers of steel are utilized in concrete as reinforcing. Additionally, it improves strength during tension and toughness, decreases plastic contraction and breaking, enhances resilience to both thawing and freezing, and lowers service and restoration costs. In addition to iron fibers, abaca and sisal fibers are utilized as reinforcement substances to improve the fluidity and strength properties of concrete. Compared to iron fibers, the fibers are far less expensive. While abaca is derived from the stems of bananas, The Agave sisalana plant is the source of sisal [6].

Fig.3. Sisal Fiber

Fig.4. Abaca Fiber

Fig.5. Steel Fiber

Table 3. Characteristics of Fibers

Characteristics	**Alloyed iron**	**Sisal**	**Abaca**
Stretching capacity (MPa)	450	400-700	400-980
Ultimate Extension %	2.57	2.75	2 - 4
Dia. (mm)	0.6	0.1-0.8	0.1-0.
Ratio proportion	27	N.A	N.A
Density ratio (kg/m^3)	7850	1580	1300
Modulus of elasticity (GPa)	210	9-22	29-32
Moisture level	0.03	6.55	5.6

2.6 Self Compressing Concrete Proportioning

Self Compressing Concrete Proportioning is provided in the list that follows.

Table 4 Composition of High Fiber Reinforced -SCC Blend.

Constituent	**Concrete density (kg/m3)**
Cement (O.P.C)	471
Fly Ash	93
Coarser-grained materials	612
Finer-grained materials	917
Water	205
Additive	4.5

The aforementioned method serves as the foundation for the design Proportioning. We assess the amount of water needed to maximize the mixture's fluidity and solidity. The next stage is determining the precise quantity of fiber that must be included to achieve the required structural integrity. After making slight adjustments to the quantities and incorporating an adequate amount of coarse-grained materials, samples are tested for variation (sensitivity) in structural suitability. Ultimately, the necessary experiments were conducted after the newly prepared SCC was mixed in a blender.

3. EXPERIMENTAL STUDY

The analysis procedures that need to be carried out using different fiber types and concentrations are as follows: The Bending Capacity Test and Splitting Elongation Strength Test determine the flexure qualities of specimens whereas the Cone Flows Trial, U-box Trial, and J-Ring Trial determine their flow characteristics.

Fig.6. Cone Flow Test, J-Ring Test and U Box Test

The blend design relies on strength and durability criteria, tailored for a temperate climate. After the age (Days) of 7 and 28 of curing, the split tensile and bending strengths of the cubes and cylinders were evaluated. The "EFNARC recommendations and Okamura and Ouchi's work on self-compaction concrete" have been consulted in order to determine the proportions of the cement mass, fine-grain components, and coarse-grain substances. [7].

3.1 Cone (Slump) Flow Test

In the absence of obstacles, the flat flow is assessed using the cone flow test. The assessment technique for identifying indicators and the slump serves as the foundation for the test procedure: circular dia. of concrete and time T500 sec (duration between the beginning flow and the 500 mm dia. of concrete flow) provides a measurement of the concrete's fluidity and flowability. To conduct the trial, the inner surface of the mold must first be cleaned using a brush and lubricant. The mold is then placed on a non-porous, flat, horizontal base plate. Pour the prepared concrete mixture into the mold in three equal levels. Use a trowel to smooth the concrete, ensuring any excess coating is removed, without tapping it with a rod. Remove the mold from the concrete as soon as possible, moving it carefully and vertically. The slump height is determined by measuring the variation between the height of a mold and the height of the sample. The findings from the cone flows evaluations for the different blends is: [4].

Table 5. Percentage of fiber in the SCC Blend

Specimen ID	**Sisal**	**Abaca**	**Steel**
SCC Blend	-	-	-
Blend 1	0.6	-	0.4
Blend 2	1.1	-	0.4
Blend 3	1.7	-	0.4

Blend 4	0.6	-	0.7
Blend 5	1.1	-	0.7
Blend 6	1.6	-	0.7
Blend 7	-	0.6	0.4
Blend 8	-	1.1	0.4
Blend 9	-	1.6	0.4
Blend 10	-	0.6	0.7
Blend 11	-	1.1	0.7

Table 6. Cone Flow alternative in SCC Blend Quantity

Specimen ID	**Flow Dia (mm)**	**T500 (sec)**
SCC Blend	609	5.9
Blend 1	591	5.9
Blend 2	482	11.1
Blend 3	471	15.9
Blend 4	521	10.2
Blend 5	476	13.1
Blend 6	444	15.9
Blend 7	592	6.5
Blend 8	500	10.55
Blend 9	479	16.1
Blend 10	581	6.2
Blend 11	542	10.7

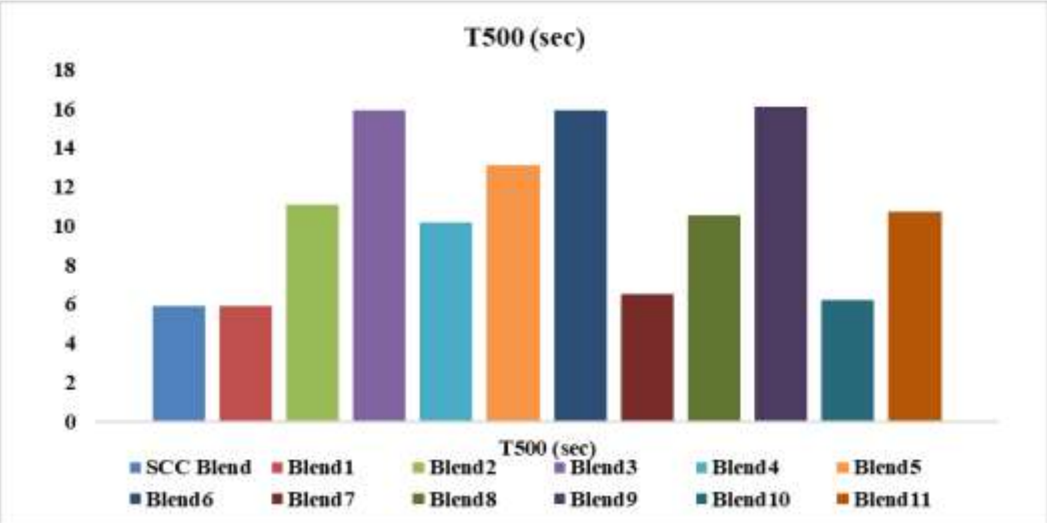

Fig.7. Visual Display of T500 for Different Mixes

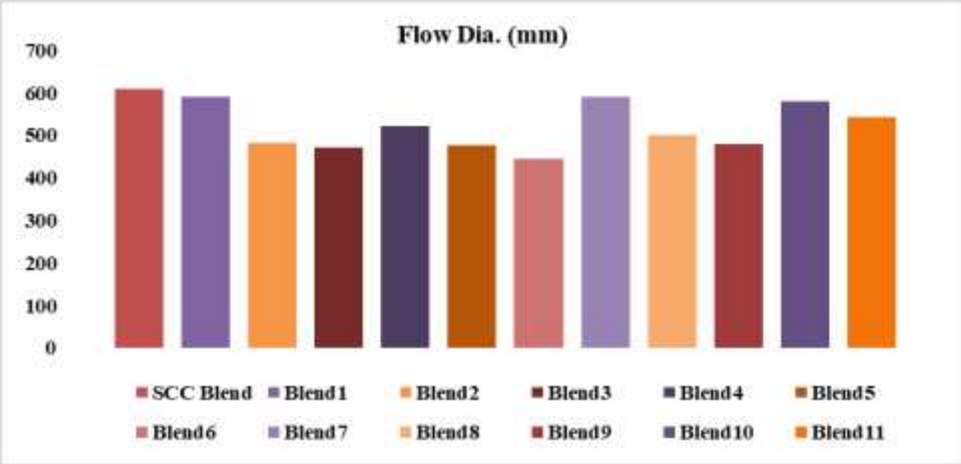

Fig.8. Visual Display of the Flow Dia. of Different Mixtures

It is implied that the fiber percentage may have an impact on the concrete's flowability because the Cone Flow Test findings show variations in the dia. and T500 for different mixtures. In fig 7 and 8, It has been determined that the flowability may be enhanced by a blend that has less sisal, abaca, and steel fibers. The highest flowability features of composite fiber SCC are demonstrated with a recommended amount of 0.6% sisal/abaca and 0.4% steel fibers, which is nearly identical to the standard SCC criterion. Therefore, it may be concluded that hybrid mixes with Vf > 0.9% fail to meet the SCC criteria. In comparison to sisal, abaca fiber works superior with steel.

3.2 J-Ring Test

It measures the concrete's fluidity and its ability to flow through reinforcement and obstacle-filled areas. For this purpose, the Test of Cone flow is conducted in conjunction with the aid of the j-ring. in the field, the test serves as a quality-control measure. together with the J-Ring, the cone shaped equipment is positioned in the middle of the fluidity table and is poured with concrete. After that, the concrete is let go to permit it to begin flowing. Measurements are taken using a measuring tape or ruler to find the dia. of the circular spread shaped by the concrete, and a stopwatch to record the T500 flow time. The primary advantage of the trial is its ability to measure; for the T500, a stopwatch serves the purpose to record the concrete flowing time, and a scale is used to measure the circular dia. of the concrete forms as it flows. The test's primary advantage is that it takes into consideration the blockage by taking into account the the J-Ring that the concrete is flowable through. This causes a variation in the altitude of the concrete as it travels through the empty spaces and, ultimately, the flow ceases. The J-ring trial for flowability results for the different combinations are:

List 7. J-Ring Fluidity alteration in SCC blend percentage

Specimen ID	**Flow Dia. (mm)**	**T_{500} (sec)**
SCC Blend	369	8.0
Blend 1	361	8.4
Blend 2	334	11
Blend 3	332	17
Blend 4	351	10
Blend 5	323	14.5
Blend 6	319	15
Blend 7	363	7.9
Blend 8	341	13
Blend 9	331	17
Blend 10	348	7
Blend 11	309	10.5

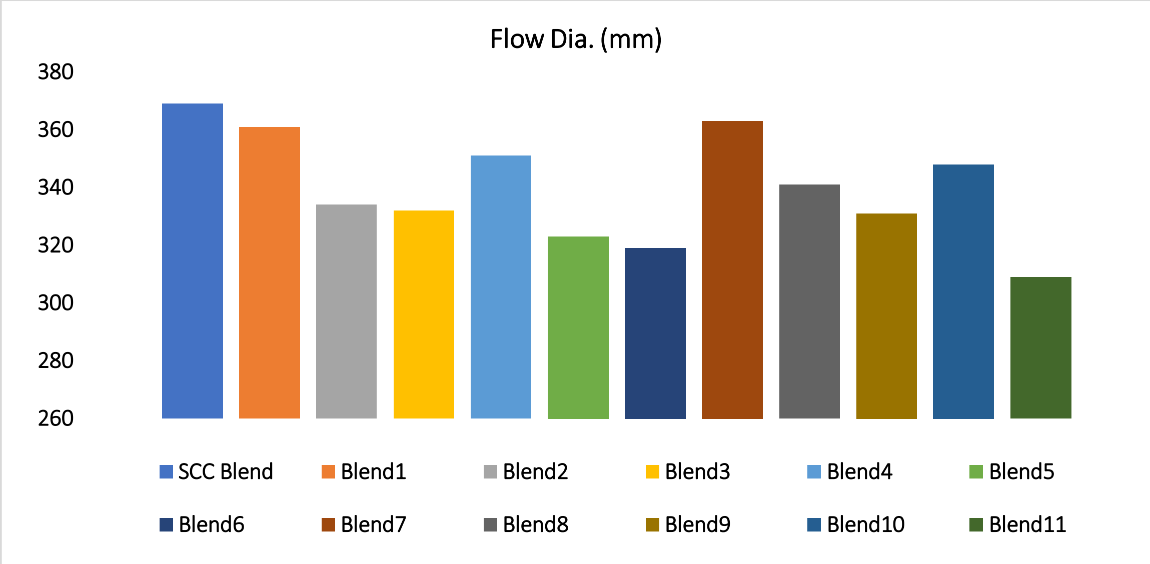

Fig.9. Flow diameter chart for different mixes

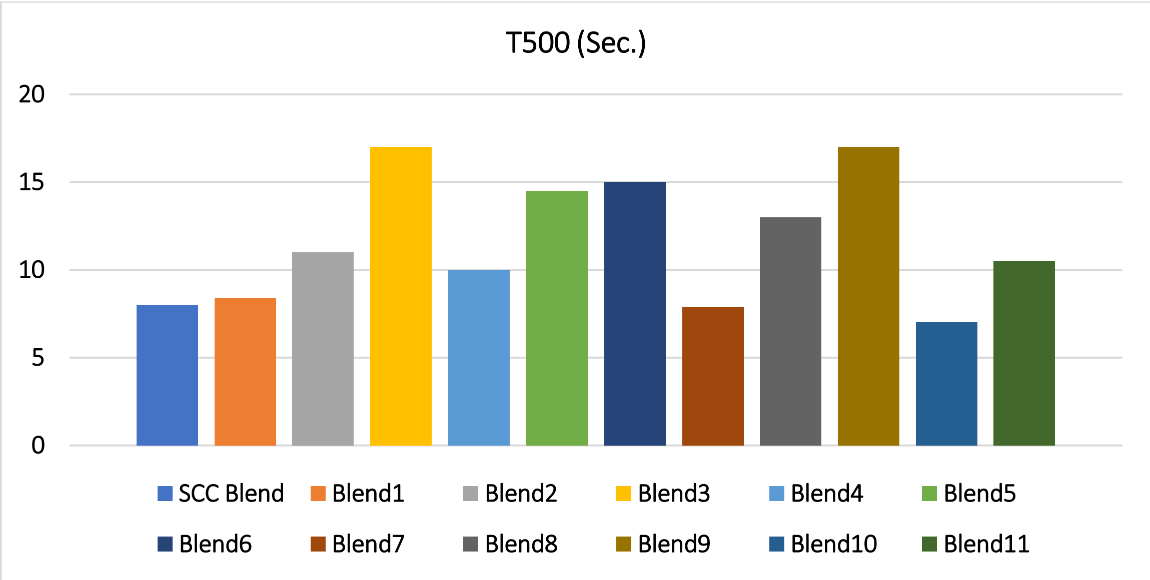

Fig.10. T_{500} chart for different mixes

Comparing the J-ring trial to Cone Flow, identical outcomes were found; however, the inclusion of reinforcement steel rods in the J-ring, which impedes flows and raises the Resistance to flow of the concrete, has caused a decline in the readings of all mixtures.

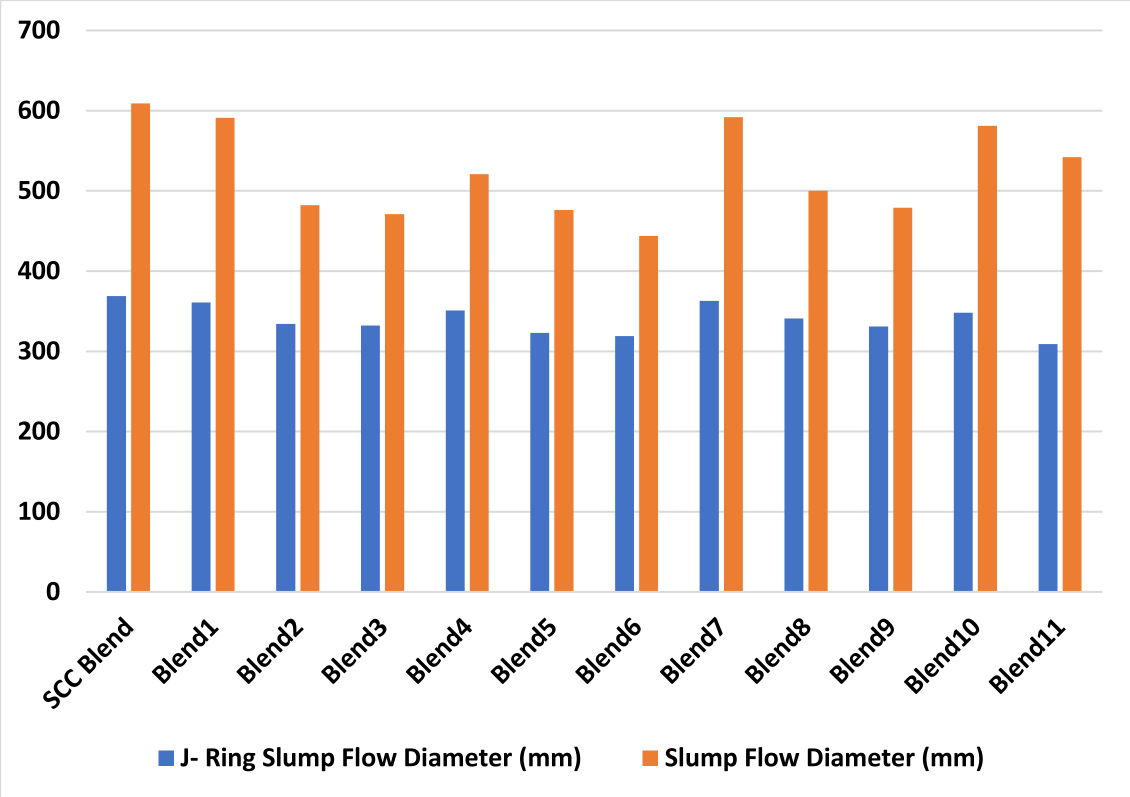

Fig.11. Contrast between the J-ring dia. and cone flow

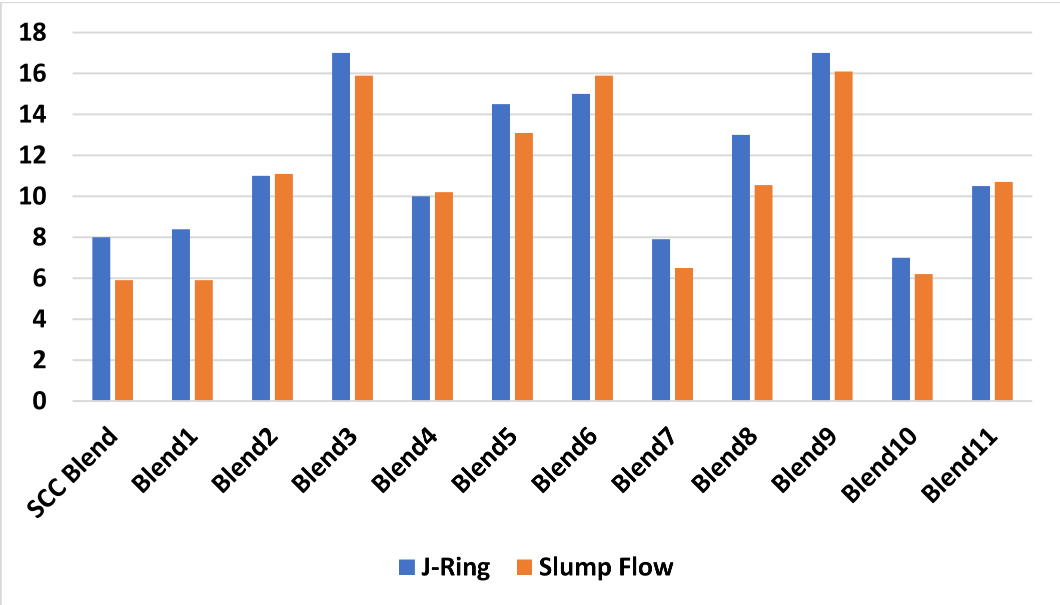

Diagram 12. Contrast between the T_{500} of J-ring and Cone Flows

In Diagram 11 and 12, Both the Diameter and T500 parameters are considered when comparing the data for Cone Flow and J-Ring tests. Because it takes into account every aspect of flowing ability, the J-ring test is a superior In-situ test for determining the flowability of concrete and provides greater control over quality, according to the outcomes.

3.3 U-Box Test

The evaluation determines how easily concrete can be placed. To separate the two sections of the vessel, a small aperture at the lower center of the apparatus contains a rolling gate. Concrete flows through reinforcing bars beneath this gate. The right and left parts of the section have a modification in height. If the concrete flows like water, it will settle flat when at rest i.e. "h_1-h_2 = 0". Thus, when the closest value of this trial is "h1 - h2 = 0", the concrete exhibits optimal flowability and passing ability. The h1/h2 ratio variations for the mixtures used are shown in the following list.

List 8.U-Box Test Flows changes of Unique SCC Blends

Specimen ID	**h_1 (mm)**	**h_2 (mm)**	**h_2 /h_1**	**Explanations**
S.C.C. Blend	321	321	1.000	Best
Blend 1	321	311	0.969	Best
Blend 2	321	252	0.785	Good
Blend 3	321	122	0.380	Obstructive
Blend 4	321	279	0.869	Good
Blend 5	321	169	0.526	Obstructive
Blend 6	321	131	0.408	Obstructive
Blend 7	321	316	0.984	Best
Blend 8	321	267	0.832	Good
Blend 9	321	128	0.399	Obstructive
Blend 10	321	295	0.919	Best
Blend 11	321	243	0.757	Good

The ratio of h_2/h_1 in the U-Box test is the key sign for assessing the flowability of concrete. List 8 shows that for a fiber dosages of V_f<0.8% a amalgam blend is a viable SCC mixture. This blend deviates the least from the standard SCC properties and aligns most closely with the recommended values. The obstructive capacity and flow blockage of the concrete mix increase with the fiber dosage. In this case, the Abaca fibers outperform the Sisal fibers in the flowability test because the blocking tendencies of the Abaca fibers are less pronounced as the fiber dosage increases. For flexural strength testing, all rectangular beams measuring (100 × 100 × 500) mm are cast, while for split tensile capacity testing, cylinders measuring (150 × 300) mm are cast

3.4 Bending Strength Test

Bending ability, defined as the stress level At the threshold where a material yields during a bending test, is a material-specific property. The transverse bending test, commonly performed using a three-point bending procedure, comprises bending a sample with a round or Rectangular cross-section until it cracks or yields. This test is the most frequently used method for the purpose mentioned above

Fig.13. Bending Capacity Machine

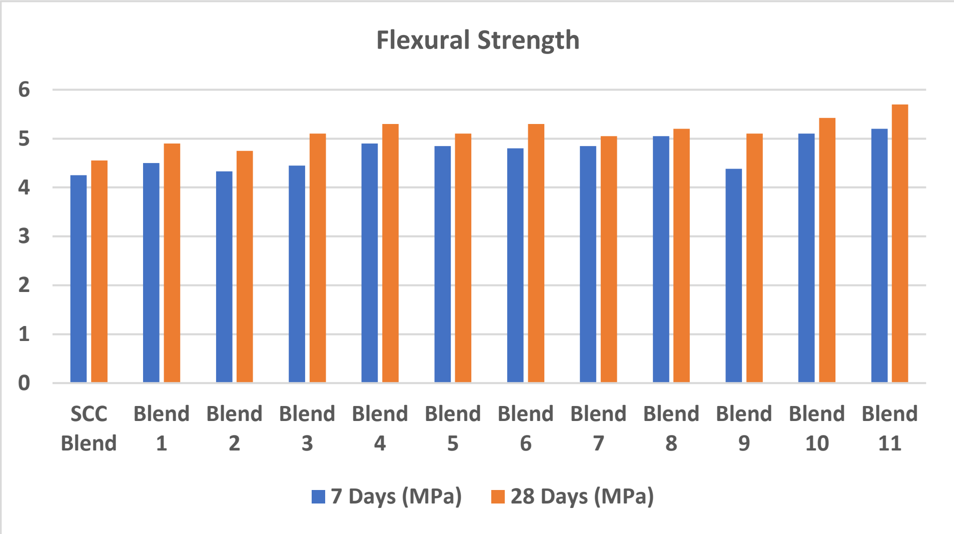

Fig.14. Bending resistance of concrete with different fiber doses (sisal/abaca)

The variation in bending capacity across different blends is presented in the following tables.

Table 9**.** Organization of Bending Capacity of various Blends

Specimen Code	**Bending Capacity**	
	Age (Days) 7 MPa	**Age (Days) 28 MPa**
S.C.C. Blend	4.25	4.55
Blend 1	4.5	4.9
Blend 2	4.33	4.75
Blend 3	4.45	5.1
Blend 4	4.9	5.3
Blend 5	4.85	5.1
Blend 6	4.8	5.3
Blend 7	4.85	5.05
Blend 8	5.05	5.2
Blend 9	4.38	5.1
Blend 10	5.1	5.42
Blend 11	5.2	5.7

The strength in the bending capacity test is influenced by variations in the fiber dosage. As shown in Figure 14 and Table 9, Abaca fibers exhibit significantly higher bending strength than Sisal, with strength increasing as the fiber dosage increases. While sisal fibers range from 4.25 to 4.80 MPa at 7 days and 4.55 to 5.30 MPa at 28 days, abaca fibers have strengths ranging from 4.85 to 5.20 MPa at 7 days and 5.07 to 5.70 MPa at 28 days. The outcomes also show that bending strength increases as the steel dosage is raised from 0.35% to 0.68%. This makes it a strong strengthening substance because of the qualities of steel and abaca fibers.

3.5 Split Tensile Strength Test

When a tubular sample is used for the tensile strength test, it is compressed along its dia. and subjected to a full-length load until rupture occurs.

Fig.15. Compression test equipment for evaluating split tensile capacity

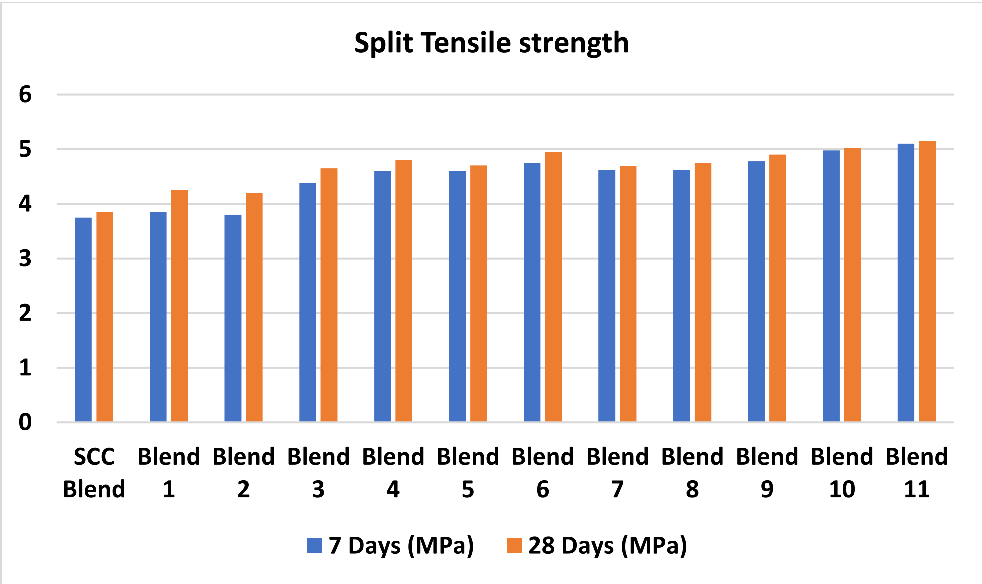

Fig. 16. Split(Divided) Extension Capacity of Concrete with Fiber Dosage

The variance in Split(Divided) Extension capacity in various blends is seen in the following table:

List 10. Organization of Split Tensile Power of numerous Blends

Specimen ID	**Split Tensile Capacity**	
	Age (Days) 7 MPa	**Age (Days) 28 MPa**
SCC Blend	3.75	3.85
Blend 1	3.85	4.25
Blend 2	3.8	4.2
Blend 3	4.38	4.65
Blend 4	4.6	4.8
Blend 5	4.6	4.7
Blend 6	4.75	4.95
Blend 7	4.62	4.69
Blend 8	4.62	4.75
Blend 9	4.78	4.9
Blend 10	4.98	5.02
Blend 11	5.1	5.15

The dose of fibers used for reinforcing affects the capacity in the Splitting resistance. As the fiber dose rises, Figure 16 shows that the "split tensile power" rises, i.e., the ductile characteristics rises. In contrast, sisal fibers have strengths ranging from 3.75 to 4.75 MPa at 7 days and 3.85 to 4.95 MPa at 28 days, while abaca fibers have strengths varying from 4.62 to 5.10 MPa at 7 days and 4.69 to 5.15 MPa at 28 days. This suggests that abaca fiber surpasses sisal fibers in terms of tensile properties. The addition of steel fibers is also vital for enhancing strength properties, and the data shows that the concrete's blend design improved with higher amounts of Metallic and Bio-based fibers (sisal and abaca). Therefore, an optimal blend design would involve a balanced combination of abaca and metalic fibers, with 0.62% metal powder and 1.55% abaca fibers.

4. CONCLUSION

According to the research Conclusions, Plant fibers may be used effectively as reinforcing in concrete mixes in addition to steel.The design of concrete mixes with a minimal fiber amount of Steel and sisal/abaca fiber composites is helpful for concrete flowability in flowing/passing ability testing methods such as the Cone Flow, J-Ring, and U-Box test. Although both natural fibers are effective at providing the quality and mobility, abaca fibers outperform sisal due to their the fiber content, which forms microfibers with a high tensile strength, as well as the inclusion of organic compounds called lignin and pectin that aid in binding the mixture of concrete without separation. Therefore, an adequate fiber amount is ideal, whereas a high fiber level may make it less workable. The primary advantage of using abaca fibers is that they provide the concrete blend a lot of strength.The findings showed that the concrete's tensile and flexural properties were enhanced by a high proportion of steel and abaca fibers.In addition to being readily available, abaca fiber is environmentally beneficial and has a more lucrative utilize compared to other synthetic or created by human’s reinforcement. Future green construction techniques can make advantage of these fiber reinforcement.

References

[1] Durability of Self-Compacting Concrete. (2013). Self-Compacting Concrete,141-213

[2] As’Ad, S., Gunawan, P., & Alaydrus, M. S. (2011). Fresh State Behavior of Self Compacting Concrete Containing Waste Material Fibres. Procedia Engineering,14, 797-804.

[3] Murthy.n, K. (2012). Mix Design Procedure for Self-Compacting Concrete. IOSR Journal of Engineering,02(09), 33-41.

[4] Rahul Roy and Pratyush Kumar, 2017. Study and Experiment Analysis of The Feasibility of Partial Replacement of Industrial Waste Glass Powder as Cement in Self Compacting Concrete. International Journal of Civil Engineering & Technology (IJCIET) - Scopus Indexed.Volume:8,Issue:6,Pages:1-9.

[5] Effect of w /cm and High-Range Water-Reducing Admixture on Formwork Pressure and Thixotropy of Self- Consolidating Concrete. (2006). ACI Materials Journal,103(3).

[6] Bledzki, A. K., Mamun, A. A., & Faruk, O. (2007). Abaca fibre reinforced PP composites and comparison with jute and flax fibre PP composites. Express Polymer Letters,1(11), 755-762.

[7] Specifications and Guidelines For Self-Compacting Concrete-EFNARC-February 2002.

[8] Sharma, M. K., & Bajaj, R. (2023). Experimental Study of Self-Consolidating Concrete in Partial Replacement of OPC with Mineral Additives and Industrial Waste. *International Journal of Research Publication and Reviews*, *4*(7), 1002–1009. https://doi.org/10.55248/gengpi.4.723.48580