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Green Innovations In Concrete Technology: Formulating Ecofriendly Self-Compacting Concrete With Biodegradable Residues

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Abstract
The worldwide construction sector is rising due to the rapidly growing economy. The manufacture of cement requires significant energy, exhausts natural resources, and releases substantial quantities of greenhouse gases. CO2 emissions during cement manufacture are a primary contributor to the degradation of the ozone layer. Furthermore, natural organic wastes such as fly ash, wheat straw ash, and rice husk ash pose environmental hazards due to their emission of poisonous gases, contributing to environmental pollution. Experimental investigations were undertaken to explore eco-friendly, effective, and inexpensive alternatives to cement as a substitutive material. These substitutes may include agricultural and industrial wastes, and their potential benefits can be realized through recycling, renewal, and reutilization procedures. The use of these wastes as substitute materials leads to significant energy conservation and a decrease in cement consumption, hence mitigating CO2 emissions into the environment. The incorporation of these environmental wastes as a substitute for cement in concrete will yield advantages both environmentally and economically. This will advance the development of green concrete. Self-Compacting concrete involved the development of concrete by the partial substitution of cement with fly ash and wheat straw ash. Polycarboxylate superplasticizer was employed to improve the workability of concrete. The percentages of cement replacement were 0%, 5%, 10%, 15%, 17%, and 20%. The workability and compressive strength were assessed at all percentages, and the results were compared to those of standard concrete.
Keywords: *Green concrete, Self-compacting concrete, Workability, Organic waste, Fly ash, Wheat straw ash*

1. INTRODUCTION

Self-Compacting Concrete has revolutionary concrete placement because it does not require any vibrating machine for compaction and flows under its own weight. It was first developed in the 1980s by researchers of Japan, concrete of very high workability that flows under its weight without bleeding and segregation [1-3]. Developments in Japan in earlier times were focused on the elimination of compaction of concrete because, during its compaction, the concrete loses its strength and durability, however, adequate compaction of such concrete required skilled labor. At that time in Japan, the lack of skilled labor in the construction industry was the cause of the reduction of construction work, with subsequent bad effects on concrete durability. There was another problem in the compaction of concrete at high altitudes. To overcome these durability and compaction problems in construction structures independently, there was a need of using self-compacting concrete [4]. The basic idea of using SCC was to eliminate the construction time, to avoid the compaction problems at high altitudes, and also to overcome noise produced during the compaction process [5]. SCC yields early strength and faster use of a structure that is produced with less water-cement ratio. For the improvement of Self-Compacting Concrete to acquire high mobility, it is important to utilize a superplasticizer. Moreover, the addition of a superplasticizer helps to decrease the w/c ratio and also enhances the durability and strength of concrete [6]. SCC can be prepared with low cement by adding such type of materials that have high strength and fineness more than cement [7] [8]. The use of fly ash and wheat straw ash reduces bleeding, permeability, water demand and heat of hydration, it is very beneficial to use FA and WSA in SCC as a mineral. However, strength development is slower; it increases the workability as compared to conventional vibrating concrete [9]. Roughly one ton of CO2 gas, as the fundamental ozone depleting substance, discharges into the climate for each ten tons of cement. Finally, the major benefit of fly ash and wheat straw ash is that replacement of a large amount of cement with fly ash and wheat straw ash helps to reduce emissions of CO2, which makes it greener concrete [10-12]. Multiple additives are nowadays used in the concrete and other material particularly for the evolving greener concrete [13-15].

FA and WSA can serve as substitutes for cement to enhance the characteristics of concrete. The use of FA and WSA is highly beneficial as they are both cost-effective and enhance durability, strength, and workability. The incorporation of FA typically maintains viscosity, reduces the risk of obstruction, and decreases the necessity for a superplasticizer. Utilizing Self-Compacting Concrete expedites construction and diminishes human requirements, hence lowering total costs. It can be effortlessly positioned within intricate formwork and substantial reinforcement. Furthermore, the issues of segregation and bleeding are virtually nonexistent. However, the invention of self-compacting concrete necessitated highly competent and experienced laborers. Self-Compacting Concrete (SCC) comprises the same constituent's aggregates, cement, admixtures, and water as conventional concrete; however, its reduced coarse aggregate content, substantial fine aggregate proportion, specific admixture combination, and low water-to-cement ratio contribute to its self-compacting properties. The ascent of air bubbles to the surface without vibration renders SCC innovative, primarily due to its dense structure, composition ratios, and material properties [16]. Workability, strength, and durability constitute three fundamental characteristics of concrete. The workability is associated with new concrete, while strength and durability pertain to hardened concrete. Conversely, new concrete possesses workability, whereas hardened concrete exhibits strength and durability [17]. The concrete must be capable of permeating the dense rebar configuration without obstruction or segregation. The inadequate placement and lack of effective vibratory compaction render the design of such concrete exceedingly challenging. Self-Compacting Concrete (SCC) represents a novel phase of High-Performance Concrete (HPC) that attains remarkable deformability and uniformity in its fresh stage, occupying all available space around the support, seamlessly flowing around dense reinforcing steel bars while consolidating under its own weight without the need for external vibration [18].

In 2021, researchers examined the effects of WSA as a partial substitute for cement on the mechanical characteristics and workability of concrete. The results indicated that the use of WSA as a partial replacement for Portland cement adversely impacted the slump of concrete mixtures. Chemical admixtures can be incorporated into the concrete to enhance workability as needed. Substituting cement with wheat straw ash up to 10% enhanced the toughened characteristics of SCC. Exceeding 10% replacements results in a reduction of concrete's compressive strength, the increase in strength resulted from filler capacity and its reactivity with calcium hydroxide, yielding more reaction products [19]. In 2016, Thirumal and Harish conducted experiments on Self-Compacting Concrete (SCC) utilizing silica fume (SF) and fly ash (FA) as partial substitutes for cement. The results were ascertained by combining different proportions of FA and SF in concrete. Cement in concrete was substituted with 10-30% fly ash and 30% silica fume or a combination of both, resulting in exceptional compressive strength. A 10% substitution of fly ash resulted in exceptional tensile and flexural strength. The mixture of fly ash and silica fume was employed to achieve the maximum compressive strength of SCC [20]. In 2019, authors partially substituted wheat straw ash for cement in the formulation of self-compacting concrete (SCC). It was determined that the replacement of WSA in concrete enhanced the compressive strength. The concrete exhibited the highest compressive strength with a 10% substitution of wheat straw ash and the lowest compressive strength with a 20% substitution of wheat straw ash. It was observed that a substitution level of up to 10% of WSA filled all gaps in concrete composites, resulting in a denser concrete with enhanced strength [21]. In 2019, a limited number of authors partially substituted wheat straw ash with cement in the formulation of self-compacting concrete (SCC). The experimental study results suggest that wheat straw ash, as a natural agricultural byproduct, can be employed as a substitute for cement due to the silica produced by the chemical activation process. The synthesis of silica from agricultural waste yields environmentally sustainable outcomes with a viable and cost-effective product. WSA and RSA enhanced the tensile and compressive strength of concrete. The optimal replacement of cement with Rice Straw Ash (RSA) and Wheat Straw Ash (WSA) at 28 days strength was seen at 15%. The water penetrability of concrete diminished following the substitution of concrete with WSA. The presence of WSA in higher grades of cement was suggested to enhance the durability of concrete. The workability and slump of WSA

and RSA concrete mixtures were enhanced using a superplasticizer. WSA may be substituted with cement owing to its pozzolanic properties and could enhance the sustainability of construction materials [22]. In 2020, researchers concluded that the incorporation of FA and SF in concrete mixtures yielded cost-effective and environmentally beneficial results while reducing the heat of hydration in concrete. The compressive strength of SCC containing 25% Fly Ash and 0% Silica Fume was 35% inferior to that of the Portland cement control, attributed to the slow pozzolanic reaction and dilution effect of Fly Ash. The maximum compressive strength was achieved with a composition of 25% Portland cement, 65% Fly Ash, and 10% Silica Fume. The integration of silica fume (SF) and fly ash (FA) yielded a favorable outcome on split tensile strength, with a 10% addition of SF enhancing the tensile strength of concrete. The static elastic modulus of cement combining fly ash and silica fume was similarly accessible [23].
The objective of project work is given as:

- To evaluate the mechanical characteristics and workability of SCC with the partial substitution of cement with fly ash.
- To evaluate the mechanical characteristics and workability of self-compacting concrete (SCC) through the partial substitution of cement with wheat straw ash.
- To evaluate the mechanical characteristics and workability of self-compacting concrete (SCC) with the substitution of mixed ashes for concrete.

2. MATERIALS AND METHODS

2.1. Cement

In this study, DG cement was employed as a binding agent. Concrete that self-compacted was made with this cement. It was bought from Choudhary Muneer Traders, located at 28°25'17.67" N and 70°17'44.6" E, Chowk Pathanistan, Rahim Yar Khan, Pakistan. DG cement has a dark gray color. D.G. Khan Cement Company Limited, located in D.G. Khan, Punjab, Pakistan, was the seller. For the concrete mixes, six bags of cement were bought.

2.2. Fine Aggregate

Fine aggregates are those that pass through No. 4 sieves. They could be fragments of crushed stone or natural sand. Because it fills the spaces between aggregates, it is utilized as a filler material in concrete. Additionally, it protects concrete from shrinking and breaking. For this study, harrow sand was acquired from Al-Hafiz Traders in Rahim Yar Khan, Punjab. The color is pale brown. It has granular-sized particles. Harrow sand outperforms local pit sand in terms of results.

2.3. Coarse Aggregate

Aggregates remaining on a 4.75 mm sieve are considered coarse. In addition to being utilized as filler material to give the concrete its homogenous bulk, coarse aggregates gives the concrete strength and body. They are made by crushing naturally occurring stones, and the aggregates' shape determines how strong they are. Choudhary Muneer Traders, located at 28°25'17.67" N and 70°17'44.6" E, Chowk Pathanistan, Rahim Yar Khan, Pakistan, supplied the Sargodha aggregate utilized in this study. It measured between 20 and 25 mm and had an angular form. The coarse aggregate has a dark grey or greenish hue.

2.4. Fly Ash

After burning crushed coal in electric generator power plants, fly ash is produced as a byproduct. It's a finely ground powder. When water is added, the aluminous and siliceous elements in this pozzolan help to structure the concrete. FA is divided into two classes, Class C and Class F, based on physical and chemical characteristics. This research project uses Class F of FA to enhance self-compacting concrete.

The fly ash required for this study was acquired from Bukhari Constructions Block D EME Sector, located at 31°18'08.57" N and 70°04'40.6" E in Lahore, Punjab, Pakistan. Class F FA was utilized in the creation of SCC. Fly ash is dark grey, buff to tan in hue. Fly ash was filtered through No. 200 sieves and used in self-compacting concrete.

2.5. Wheat Straw Ash

WS is an agricultural product that contains a significant amount of SiO. Upon combustion, it produces ash that is rich in SiO, exhibiting pozzolanic properties due to the presence of aluminous and siliceous materials. Wheat straw ash was obtained through the combustion of wheat straw at an uncontrolled temperature. The Wheat Straw Ash utilized in this study was processed through a #200 sieve.

2.6. Superplasticizer

Polycarboxylate superplasticizers serve as additives in the formulation of self-compacting concrete. The following chemical compounds can reduce water requirements by as much as 30%. These are utilized in the concrete at minimal percentages. Superplasticizers additionally delay the curing process of concrete. Their application enhances the workability of concrete while maintaining strength and durability. Additionally, superplasticizers enhance the performance of fresh concrete paste. Alfafast Super 50 is a superplasticizer used for the preparation of self-compacting concrete. The item was acquired from Al-Falah Chemicals, located in the Union Commercial Area on Shahrah-e-Faisal, Karachi, Pakistan, with coordinates 24°52’06.64” N and 67°04’00.66” E. Ten liters of superplasticizer were acquired for the production of concrete.

2.7. Samples Preparation

All ingredients were meticulously prepared for the initial basic testing and development of self-compacting concrete in accordance with ASTM, BS, and AASHTO standards. Fine aggregate is processed through sieve No. 4 to eliminate coarse aggregates and other impurities from the sand. Various sieves are utilized for testing different ingredients, including No. 200 (75 µm) for assessing fineness and consistency of cement, as well as determining initial and final setting times. No. 8 (2.36 mm), 10 mm, and 12.5 mm sieves are employed for the aggregate impact value test. The No. 4 (4.75 mm) sieve is used for measuring the bulk density, specific gravity, and relative density of aggregates. Additionally, the No. 8 (2.36 mm) sieve is applied in the crushing value test of aggregates. For specific gravity tests on fly ash and wheat straw ash, the No. 200 (75 µm) sieve is also utilized. A combination of six sieves (No. 4, No. 8, No. 16, No. 30, No. 50, No. 100) is used to determine the fineness modulus of sand. Furthermore, the No. 200 (75 µm) sieve is employed for fineness testing of fly ash and wheat straw ash, as well as for their application in Self-Compacting Concrete (SCC).

2.8. Mix Design

Water cement ratio = 0.44
Water content = 165 kg/m^3
Cement content = 375 kg/m^3
Quantity of coarse aggregate = 1018.422 kg/m^3
Fine aggregate = 721.48 kg/m^3
Ratio of concrete mix design = 1: 1.9: 2.71

3. RESULTS AND DISCUSSION

3.1. Cement Tests

3.1.1. Fineness of Cement (ASTM C184-94e-1)

Weight of sample taken = 100 g Retain weight on #100 sieve = 5 g
Percentage retained on #100 sieve = 5 % Passing percentage = 95 %

Range

According to the **ASTM** standard, the fineness of cement should be greater than 90%.

Discussion

Upon conducting the fineness test for cement, we determined that the fineness of DG cement is 95%. The specifications indicate that cement with a fineness exceeding 90% yields satisfactory results. The cement utilized in this project exhibits a fineness of 95%, indicating its suitability for our application.

3.1.2. Consistency Test (ASTM C187-16)

Weight of cement = 300 g Weight of water added = 94 g
Percentage of water added = 31 % Initial reading = 39 mm Final reading = 5.5 mm

Range

According to ASTM standards, the consistency of cement should be from 4 mm to 6 mm.

Discussion

After performing the consistency test, we found the consistency as 5.5 mm. The results are in range.

3.1.3. Initial and Final Setting Time (ASTM C191-13)

Weight of cement = 300 g
The normal consistency = 31 %
The volume of water added = 94 * 0.85 = 79.9 g
Initial setting time = 57 minutes; Final setting time = 9 hours and 51 minutes

Ranges

According to **ASTM** standard, the initial 5 ± 0.5 mm and final setting time should be 8 to 10 hours.

Conclusion

After performing the initial and final setting time of cement, it was found that the initial setting time as 57 minutes and final setting time as 9 hours and 51 minutes.

3.2. Fine Aggregate Test

3.2.1. Fineness Modulus of sand (ASTM C136-136M-16)

Table 1: Fineness Modulus of Sand

Sieve Size	Weight Retain (g)	Cumulative Weight Retain (g)	Cumulative % age Retain
4.75 mm	53	53	5.29
2.36 mm	88	141	14.08
1.18 mm	144	285	28.47
0.6 mm	154	439	43.856
0.3 mm	184	623	62.237
0.15 mm	341	964	96.304
Total	**964**	**964**	**250.23**

Fineness Modulus (F.M) = 250.23/100 = 2.502

Ranges

According to ASTM standards, the fineness modulus of sand should be from 2 to 4

Conclusion

After performing the fineness modulus test on sand, it was found that the fineness modulus of sand as 2.502.

3.3. Coarse Aggregate Tests

3.3.1. Specific Gravity and Absorption (ASTM C127-15)

Oven dry weight (A) = 3000 g; SSD weight (B) = 3021 g; Apparent weight (C) = 1944 g

A. Specific gravity in SSD condition = B/(B–C) = 3021(3021-1944)

Specific gravity in SSD condition = 2.805

B. Specific gravity in dry basis = A/(B-C) = 3000(3021-1944)

Specific gravity in dry basis = 2.785

C. Apparent specific gravity = A/(A-C) = 3000(3000-1944)

Apparent specific gravity = 2.84

D. Water absorption = (B-A)/A * 100 = (3021-3000)/3000 *100 = 0.6 %

Ranges

Ranges for Specific Gravity = 2.5 to 3 Ranges for Water Absorption = 0.1 to 4

Conclusion

SSD specific gravity = 2.805 (In Range) Water Absorption = 0.6% (In Range)

3.3.2. Aggregate Impact Value Test (ASTM D4254-16)

Weight of sample = 0.738 kg (738 g)

Weight of sample passed by # 8 sieve = 12 g

Aggregate Impact value (AI) = (12/738) *100 = 1.626 %

Conclusion

Aggregate Impact Value (AIV) = 1.626% which means that our aggregate is very strong.

3.3.3. Bulk Density of Aggregate (C29/C29M-17a)

Empty weight of mold = 5.4 kg Volume = 0.010078 m^3

Lose weight (weight of sample + mold) = 19.64 kg

Weight of sample = 19.64 – 5.4 = 14.24 kg

Loose bulk density = 14.24/0.010078 1413.39 kg/m^3

Compacted weight (weight of sample + mold) = 21.23 kg

Weight of sample = 21.23 – 5.4 kg = 15.83 kg

Compacted bulk density = 15.83/0.010078 = 1566.81 kg/m^3

Ranges

According to **ASTM** standard, the bulk density of aggregate should be from 1200 to 1775 kg/m^3

Conclusion

Bulk density test on aggregate was performed and determined 1566.81 kg/m^3 as the answer.

3.3.4. Crushing Value of Aggregate (BS 812-110)

Empty weight of mold = 2970 g

Weight of aggregate + mold = 5526 g

Weight of aggregate = 5526 – 2970 = 2556 g
Weight of aggregate sample passed through #8 sieve = 398 g
Crushing value = (398/2556) * 100 = 15.57 %

Ranges

According to **BS** standard, the crushing value of aggregate should be from 0% to 40%.

Conclusion

The crushing value of our aggregate is 15.57% which is in the range.

3.4. Fly Ash tests

3.4.1. Sieve analysis of fly ash (ASTM C136-136M-16)

Weight of fly ash taken = 100 g

Table 2: Sieve Analysis of Fly Ash

Sieve Size	Weight Retain (g)	Cumulative Weight Retain (g)	Cumulative % age Retain
4.75 mm	0	0	0
2.36 mm	0	0	0
1.18 mm	0	0	0
0.6 mm	0	0	0
0.3 mm	0.5	0.5	0.5
0.15 mm	3	3	3
Total	**7.5**	**3.5**	**3.5**

3.4.2. Fineness of fly ash (ASTM C184-94e-1)

Weight of fly ash taken = 100 g

Table 3: Fineness of Fly Ash

ASTM Designation: C184-94e-1				
Sr. No.	**Weight of Sample taken (W) (g)**	**Weight of sample Retain (R) (g)**	**Percentage Retained (%) on No. 200 sieve**	**Percentage of Fineness (%)**
1	100	5	5	95.16
2	100	4.5	4.5	
3	100	5	5	

Conclusion

After performing the fineness test on fly ash, it was determined that fly ash is 95.16% fine.

3.4.3. Specific Gravity Test (ASTM D854)

Table 4: Specific gravity of Fly Ash

ASTM Designation D854				
Sr. No.	**Weight of Sample (g)**	**Weight of Water + Pycnometer (g)**	**Weight of Water + Pycnometer + Sample (g)**	**Specific Gravity of Fly Ash**
1	200	1460	1572.2	2.23
2	200	1459.5	1576	2.395
3	200.5	1465.5	1582	2.395
Avg.	**200**	**1461.67**	**1576.7**	**2.33**

Conclusion

After performing the specific gravity test on fly ash, it was found that the specific gravity as 2.33.

3.5. Wheat Straw Tests

3.5.1. Sieve analysis of Wheat straw Ash (ASTM C136-136M-16)

Weight of wheat straw ash taken = 100 g

Table 5: Sieve Analysis of WSA

Sieve Size	Weight Retain (g)	Cumulative Weight Retain (g)	Cumulative % age Retain
4.75 mm	0	0	0
2.36 mm	0	0	0
1.18 mm	0	0	0
0.6 mm	0	0	0

0.3 mm	1.5	1.5	1.5
0.15 mm	4	4.5	4.5
Total	**4.5**	**6**	**6**

3.5.2. Fineness of Wheat Straw Ash (ASTM: C184-94e-1)

Weight of Wheat straw ash taken = 100 g

Table 6: Fineness of WSA

ASTM Designation: C184-94e-1				
Sr. No.	**Weight of Sample taken (W) (g)**	**Weight of sample Retained on No.200 (g)**	**Percentage Retained (%) on No. 200 sieve**	**Percentage of Fineness (%)**
1	100	4.5	4.5	95.8
2	100	3	3	
3	100	5	5	

Conclusion

After performing the fineness test on wheat straw ash, it was found that our wheat straw ash has 95.8% finer particles.

3.5.3. Specific gravity of WSA

Weight of WSA taken = 200 g

Table 7: Specific Gravity of WSA

ASTM Designation D854				
Sr. No.	**Weight of Sample (g)**	**Weight of Water + Pycnometer (g)**	**Weight of Water + Pycnometer + Sample (g)**	**Specific Gravity of Wheat Straw Ash**
1	200	1481	1571	1.82
2	200	1480	1572	1.85
3	200.5	1479	1573	1.89
Avg.	**200**	**1480**	**1572**	**1.852**

Conclusion

The specific gravity of wheat straw ash is 1.852.

3.6. Workability of Fresh Concrete

3.6.1. Workability of Self-Compacting Concrete containing Fly Ash

Table 8: Workability of SCC Containing FA

Sr. No.	**Material Name**	**Percentage Replacement**	**Mix Name**	**Workability (mm)**
1	Basic concrete	0 %	A	12.7
2	Fly Ash	5 %	C	161.11
3		10 %	D	169.56
4		15 %	E	177.82
5		17 %	F	185.42
6		20 %	G	190.5

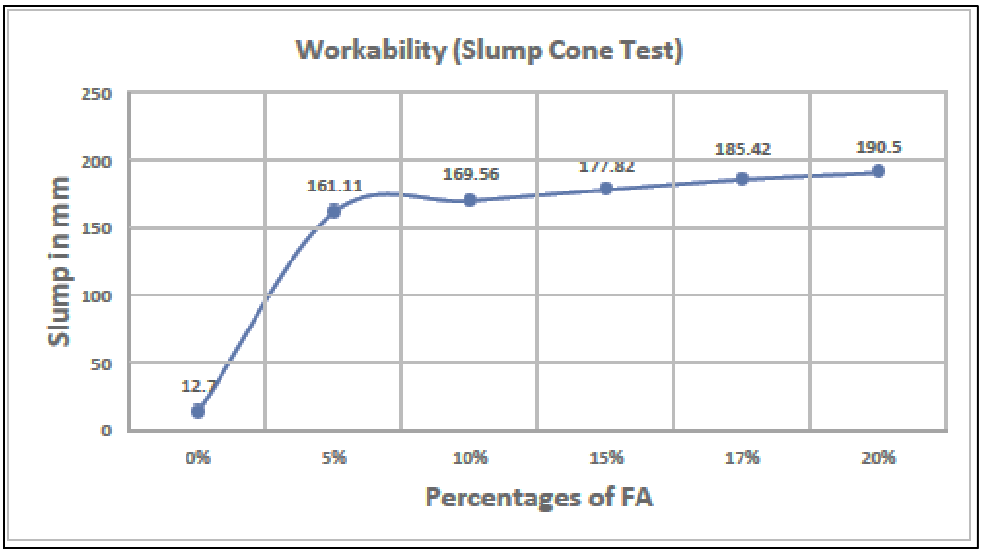

Figure 1: Workability of concrete containing FA

As fly ash is finer than cement, so it is determined that the workability of self- compacting concrete containing fly ash increases by increasing the percentage of replacement of cement with fly ash.

3.6.2. Workability of Self-Compacting Concrete containing Wheat Straw Ash

Table 9: Workability of SCC Containing WSA

Sr. No.	Material Name	Percentage Replacement	Mix Name	Workability (mm)
1	Basic concrete	0 %	A	12.7
3	Wheat Straw Ash	5 %	H	169.23
4		10 %	I	183.11
5		15 %	J	176.54
6		17 %	K	167.71
7		20 %	L	149.21

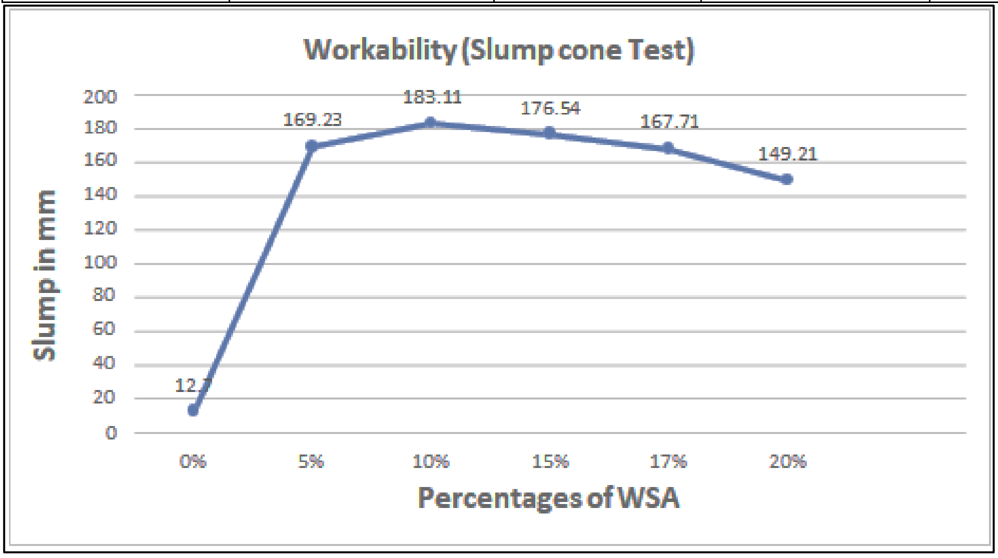

Figure 2: Workability of concrete containing WSA

The findings indicated that the workability of self-compacting concrete improved with a 10% replacement of Wheat Straw Ash, followed by a decline thereafter. Wheat straw ash has the capacity to absorb water due to its silica content. The quantity of silica rises as the percentage of wheat straw ash in concrete is increased. Consequently, the workability of SCC diminishes as the percentage of wheat straw ash increases.

3.6.3. Workability of SCC containing both Fly Ash and Wheat Straw Ash

Table 10: Workability of SCC on Combined Ashes

Sr. No.	Material Name	Percentage Replacement	Mix Name	Workability (mm)
1	Basic concrete	0 %	A	12.7

3	Fly Ash + Wheat Straw Ash	5 %	M	165.16
4		10 %	N	176.33
5		15 %	O	171.8
6		17 %	P	169.91
7		20 %	Q	163.44

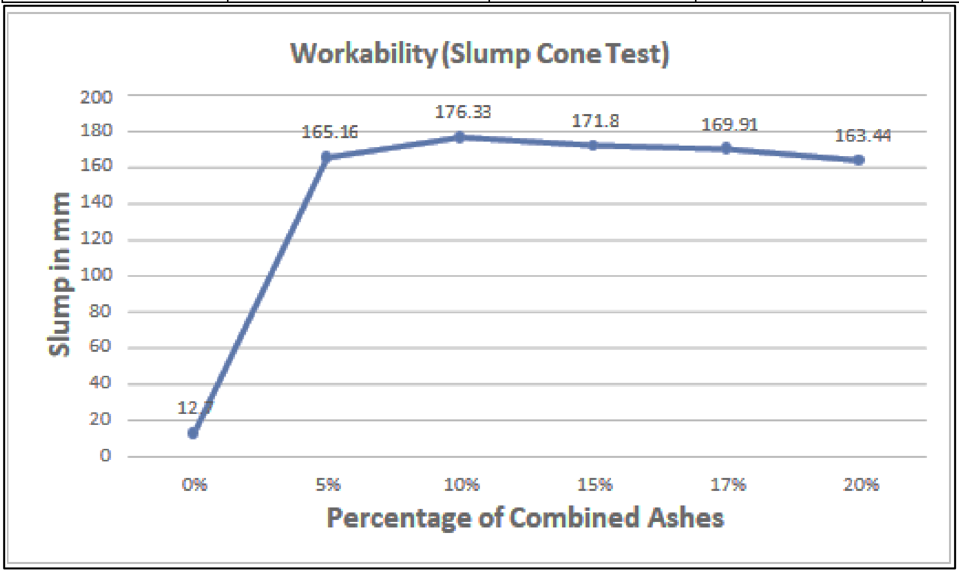

Figure 3: Workability of concrete on combined ashes

The workability of self-compacting concrete enhanced with a 10% replacement, subsequently experiencing a decline. The decrease in workability can be linked to the silica content present in wheat straw ash. The increase in silica content correlates with a higher percentage of wheat straw ash in concrete. As a result, the workability of self-compacting concrete decreases, when the replacement of combined ashes, specifically Fly Ash and Wheat Straw Ash surpass 10%.

3.7. Compressive strength results of SCC

The compressive strength test was performed on self-compacting concrete after 3 days, 14 days, and 28 days. Concrete cylinders having dimensions of 4 in x 8 in were prepared, cured, and tested. The results obtained after 3 days, 14 days, and 28 days are given below

3.7.1. Compressive strength of normal (basic) concrete cylinders

Table 11: Compressive Strength of normal concrete

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
A-3	12.88	12.71	13.02	12.87
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
A-14	27.09	27.22	27.47	27.24
	28 Days Strength of Cylinders			
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
A-28	29.51	29.46	29.83	29.6

3.7.2. Compressive strength of normal (Basic) concrete by adding 2.5% superplasticizer

Table: Compressive Strength at 2.5% Superplasticizer

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
B-3	12.92	12.72	13.02	12.89
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)

B-14	27.81	27.99	28.1	27.97
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
B-28	30.34	30.17	30.51	30.34

3.7.3. Compressive strength of SCC containing Fly Ash Compressive strength of concrete at 5% Fly Ash replacement

Table 12: Compressive strength at 5% FA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
C-3	12.98	13.21	13.12	13.1
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
C-14	27.94	28.11	28.24	28.07
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
C-28	30.56	30.91	30.44	30.64

3.7.4. Compressive strength of concrete at 10% Fly Ash replacement

Table 13: Compressive strength at 10% FA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
D-3	12.85	13.35	13.17	13.12
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
D-14	27.98	28.46	28.15	28.2
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
D-28	30.77	31.24	31.11	31.04

3.7.5. Compressive strength of concrete at 15% Fly Ash replacement

Table 14: Compressive strength at 15% FA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
E-3	13.47	13.97	13.53	13.64
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
E-14	28.8	29.81	29.15	29.25
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
E-28	32.24	31.67	32.15	32.02

3.7.6. Compressive strength of concrete at 17% Fly Ash replacement

Table 15: Compressive strength at 17% FA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)

F-3	14.95	15.66	15.27	15.29
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
F-14	30.96	31.54	31.17	31.22
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
F-28	32.8	33.2	33.16	33.05

3.7.7. Compressive strength of concrete at 20% Fly Ash replacement

Table 16: Compressive strength at 20% FA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
G-3	14.31	14.08	14.75	14.38
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
G-14	30.64	29.9	30.27	30.27
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
G-28	32.22	32.11	32.3	32.21

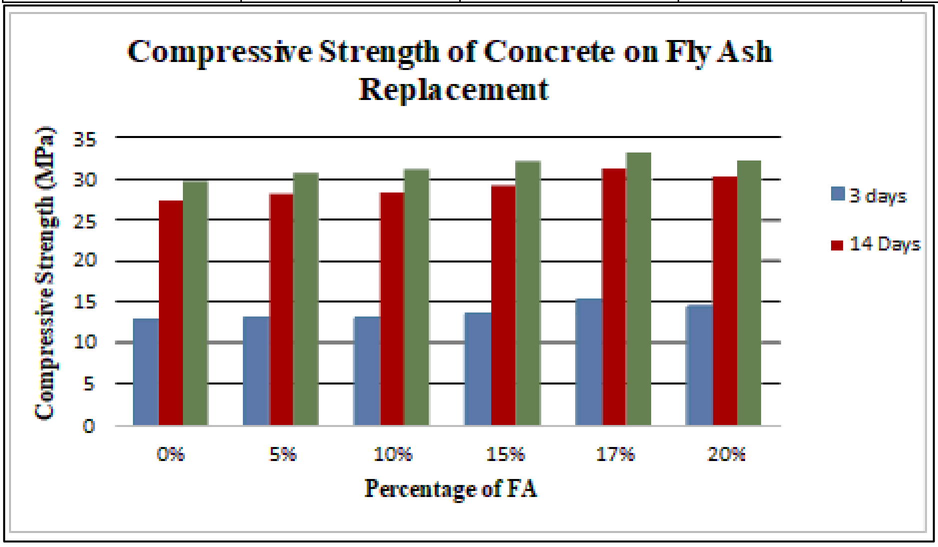

Figure 4: Compressive strength on FA replacement

3.7.8. Compressive strength of SCC containing WSA

Compressive strength of concrete at 5% Wheat Straw Ash replacement

Table 17: Compressive strength at 5% WSA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
H-3	12.89	13.35	13.81	13.35
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
H-14	28.52	28.81	28.32	28.55
28 Days Strength of Cylinders				

Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
H-28	31.54	31.49	31.65	31.56

3.7.9. Compressive strength of concrete at 10% Wheat Straw Ash replacement

Table 18: Compressive strength at 10% WSA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
I-3	15.53	15.24	14.58	15.45
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
I-14	29.91	29.8	29.38	29.7
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
I-28	12/5/2021	33.77	33.84	33.7

3.7.10. Compressive strength of concrete at 15% Wheat Straw Ash replacement

Table 19: Compressive strength at 15% WSA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
J-3	14.11	14.27	14.37	14.25
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
J-14	28.11	28.55	28.06	28.24
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
J-28	32.32	32	32.2	32.17

3.7.11. Compressive strength of concrete at 17% Wheat Straw Ash replacement

Table 20: Compressive strength at 17% WSA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
K-3	13.2	13.47	13.08	13.25
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
K-14	27.31	27.09	27.19	27.2
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
K-28	31.1	30.42	30.15	30.56

3.7.12. Compressive strength of concrete at 20% Wheat Straw Ash replacement

Table 21: Compressive strength at 20% WSA

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
L-3	11.65	12.11	11.72	11.82
14 Days Strength of Cylinders				

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Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
L-14	26.5	26.62	26.43	26.52
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
L-28	28.26	28.81	28.1	28.36

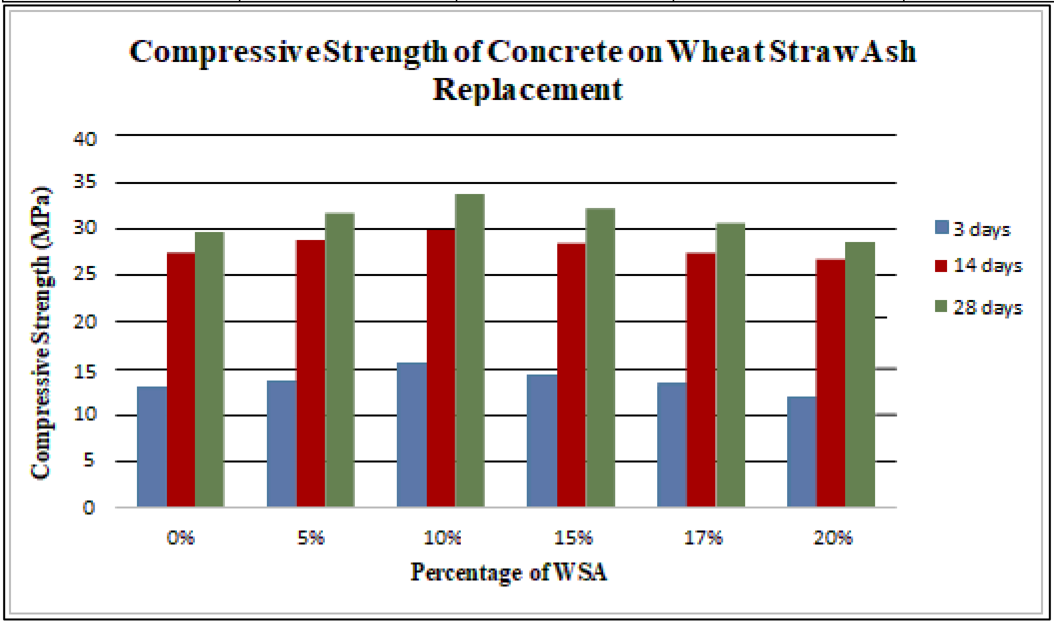

Figure 5: Compressive strength on WSA replacement

3.7.13. Compressive strength of SCC by utilizing combined ashes

3.7.13.1. Compressive strength of concrete at 5% replacement of cement with combined ashes

Table 22: Compressive strength at 5% Combined ashes

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
M-3	13.34	13.71	13.56	13.53
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
M-14	28.61	28.81	28.02	28.48
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
M-28	30.8	30.65	30.03	30.25

3.7.13.2. Compressive strength of concrete at 10% replacement of cement with combined ashes

Table 23: Compressive strength at 10% combined ashes

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
N-3	14.6	14.43	14.21	14.23

14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
N-14	29.62	29.29	29.77	29.56
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
N-28	31.95	31.29	31.13	31.46

3.7.14.3. Compressive strength of concrete at 15% replacement of cement with combined ashes

Table 24: Compressive strength at 15% combined ashes

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
O-3	15.99	15.84	15.51	15.78
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
O-14	30.11	30.81	30.53	30.48
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
O-28	32.8	32.78	32.89	32.58

3.7.15.4. Compressive strength of concrete at 17% replacement of cement with combined ashes

Table 25: Compressive strength at 17% combined ashes

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
P-3	14.14	14.2	14.35	14.17
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
P-14	29.55	29.17	29	29.24
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
P-28	31.81	30.99	31.15	31.31

3.7.15.5. Compressive strength of concrete at 20% replacement of cement with combined ashes

Table 26: Compressive strength at 20% combined ashes

3 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
Q-3	13.57	13.13	13.81	13.5
14 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
Q-14	28.6	28.15	28.51	28.42
28 Days Strength of Cylinders				
Sample Name	Test 1 (MPa)	Test 2 (MPa)	Test 3 (MPa)	Average Strength (MPa)
Q-28	29.88	29.14	29.02	29.35

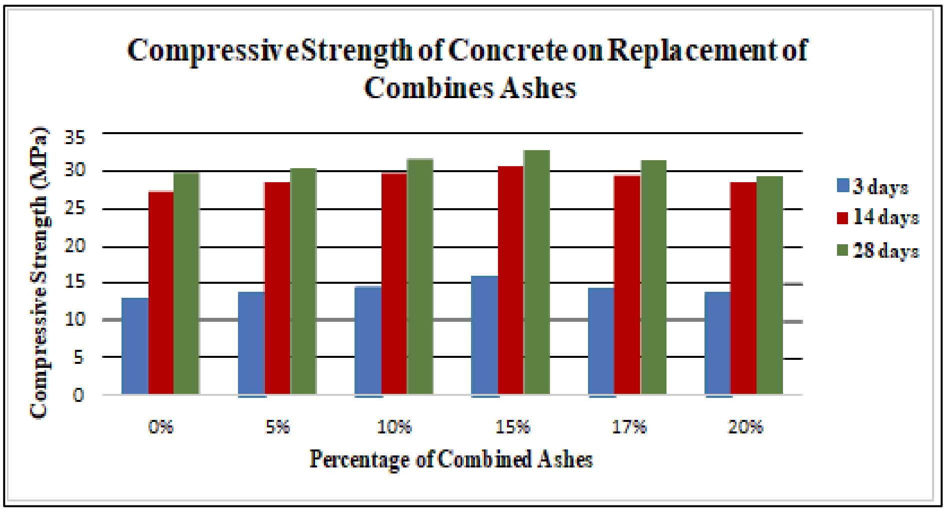

Figure 6: Compressive strength on replacement of combined ashes

3.7.16. 3 Days Compressive Strength of SCC

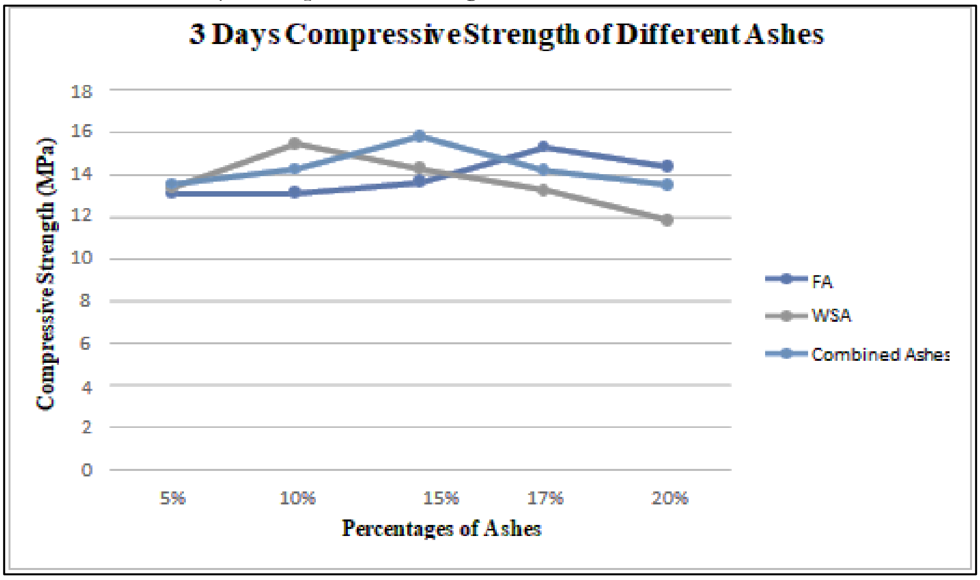

Figure 7: 3 days compressive strength comparison

3.7.17. 14 Days Compressive Strength of SCC

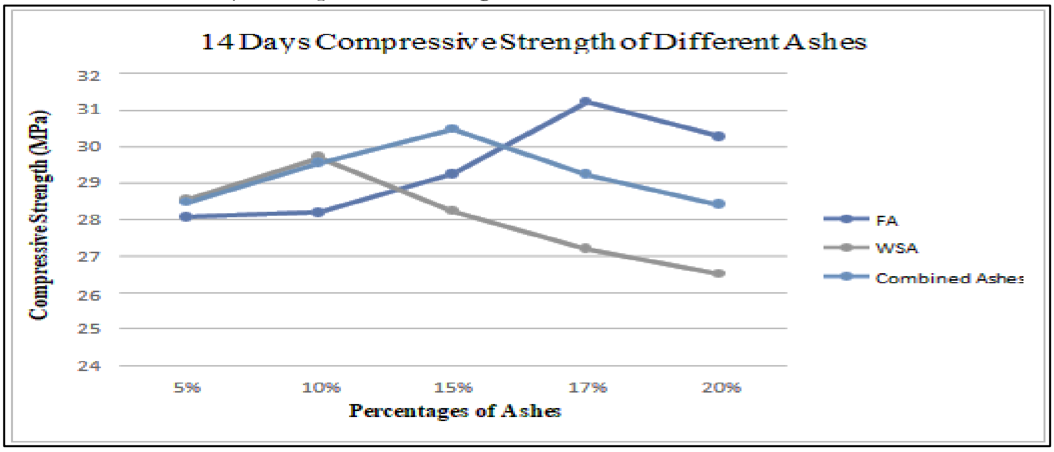

Figure 8: 14 days compressive strength comparison

3.7.18. 28 Days Compressive Strength of SCC

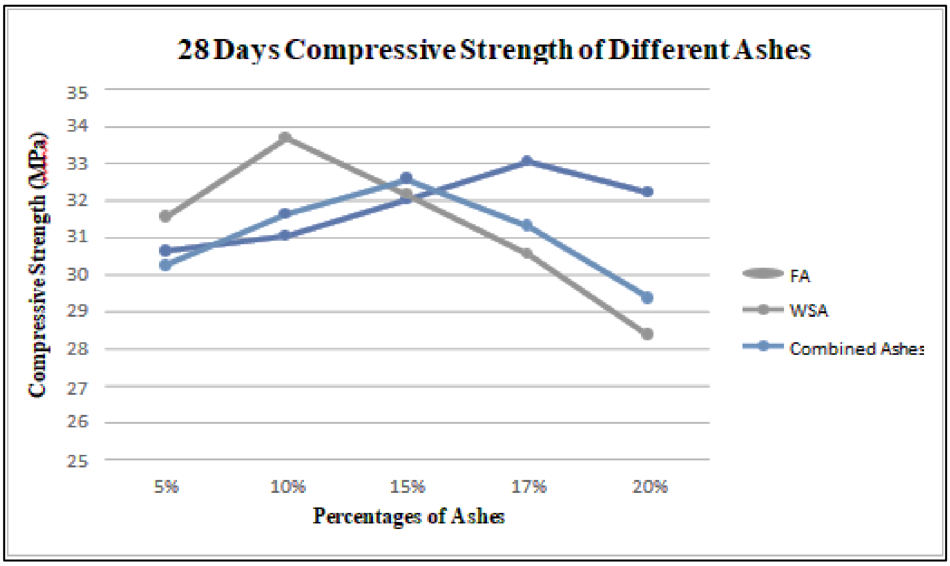

Figure 9: 28 days compressive strength comparison

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusion

Fly ash and wheat straw ash are organic by-products that can be utilized as partial replacements for cement in the formulation of Self-Compacting Concrete (SCC) through the incorporation of superplasticizer. In this study, we developed SCC through the fractional substitution of cement with natural organic wastes and determined that these materials can be utilized in concrete to a certain degree. Cement was partially replaced with fly ash and wheat straw ash at various percentages, including 5%, 10%, 15%, 17%, and 20%. Cement was incrementally replaced by both ashes at varying percentages of 5%, 10%, 15%, 17%, and 20%. Various experiments were conducted on both fresh and hardened concrete. A workability test was conducted on fresh concrete across all percentages, revealing a maximum workability of 190.5 mm at a 20% replacement of fly ash, 183.11 mm at a 10% replacement of wheat straw ash, and 176.33 mm at a 10% replacement of combined ashes. It was observed that as the percentage of wheat straw ash increased, the workability of the concrete decreased. A compressive strength test was conducted on concrete at all percentages after 3 days, 14 days, and 28 days. Our analysis revealed that the maximum compressive strength achieved with 17% fly ash replacement was 15.29 MPa after 3 days, 31.22 MPa after 14 days, and 33.05 MPa after 28 days. At a 10% replacement of wheat straw ash, the compressive strength of concrete was recorded at 15.45 MPa after 3 days, 29.70 MPa after 14 days, and 33.7 MPa after 28 days. In contrast, with a 15% replacement of combined ashes with cement, the concrete achieved strengths of 15.78 MPa after 3 days, 30.48 MPa after 14 days, and 32.58 MPa after 28 days.

4.2. Recommendations

The results indicate that natural organic wastes, including fly ash and wheat straw ash, may be effectively utilized in concrete applications. The development of SCC (Self-Compacting Concrete) can be enhanced through the use of a superplasticizer, as it significantly improves the workability of the concrete. The use of ashes in concrete as a replacement for cement presents a significant opportunity for environmental benefit, given the hazardous nature of these ashes.

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