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## Use of pond ash as replacement of Fine sand and SCBA as replacement of cement in Self Compacting concrete

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**Keywords***Pond ash, Sugarcane bagasse ash (SCBA), Self-compacting concrete (SCC), Cement replacement, Fine aggregate replacement, Sustainability.***ABSTRACT**

Environment and economics have been an important concern for the sustainable development of construction materials. Industrial and agricultural by-products into concrete construction seem to be a possible solution. This review discusses the use of pond ash to partially replace fine sand, while SCBA is used to partially replace cement in the production of self-compacting concrete (SCC). The pond ash has been fine enough to impart some improvements in workability and filling ability to SCC while grasping natural sand resources. SCBA, an agro-waste from sugar industries, having pozzolanic properties improves the strength, durability, and microstructural properties when used as a supplementary cementitious material. In addition to encouraging sustainable waste management, the incorporation of these materials in the SCM also helps to mitigate the environmental effects related to the extraction of cement and sand. The review addresses previous research findings, mix design considerations, mechanical properties, durability performance, and areas of research concerning these environmentally friendly SCC mixtures.

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**1. INTRODUCTION:**

Concrete's many benefits, including its low cost, great compressive strength, and wide range of applications, make it the building material most frequently utilized in modern civil engineering [1]. Due to the rapid speed of urbanization, the amount of concrete consumed worldwide has increased significantly. An industry that uses a lot of energy and resources and has a big environmental impact is cement manufacturing [2]. Together with other greenhouse gas emissions, cement manufacturing has emerged as the primary source of CO<sub>2</sub> emissions [3]. Approximately 4 billion tons of CO<sub>2</sub>

are released annually worldwide, 7% of these emissions are attributable to cement production [4]. Therefore, using an eco-friendly SCM in cement can help cut down on greenhouse gas emissions, including CO<sub>2</sub>.

Pond ash as shown in Fig 1, a byproduct of thermal power plants, is being used more and more in SCC to partially replace fine sand [5]. Pond ash's high silica concentration, spherical particles, and pozzolanic feature can enhance SCC's workability and durability [6]. Counteracting segregation and supporting particle packing by replacing fine sand with pond ash are important for self-leveling properties of the SCC, which might otherwise need mechanical vibration [7]. Sustainability benefits are also conferred by pond ash use, because it leads to depletion of natural sand, which in several regions is an issue [8]. Studies have shown that replacing fine sand with pond ash up to a certain limit (usually about 20 to 30%) leads to optimum compressive strength and durability without impairing the fresh-state properties of concrete; adding more than the maximum weakens the

material due to increasing porosity [9]. When used in an optimized manner, pond ash emerges as a due environmental, cost-effective alternative for sustainable production of SCC [10].



Figure 1: Pond Ash

SCBA, a byproduct of the sugar industry's combustion, is used by SCC to partially replace cement (Fig. 2) [11]. This increases the SCC's long-term strength and durability due to SCBA's high silica concentration, fineness, and pozzolanic reactivity [12]. The higher the amount of SCBA, usually up to 10–20% replacement for cement, the better will be the workability of SCC; opposite is the heat of hydration, which reduces, thus making it resistant to chemical attacks [13]. It is good from environmental perspectives since cement reduction itself is one among the highest CO<sub>2</sub> contributors in concrete production. SCBA contributes to microstructural densification, culminating in low permeability and high durability [14]. However, high amount of replacement can cause lower strength at early ages due to slow pozzolanic reactivity. Basically, SCBA creates one eco-friendly alternative in the development of highly performance concrete while also contributing to waste utilization and mitigation of the environmental footprint in concrete technology.



Figure 2: Sugarcane Bagasse Ash

The use of pond ash as a fine sand substitute and SCBA as a partial cement substitute in Self-Compacting Concrete enhances sustainability by using industrial and agricultural waste. This combination improves workability, reduces environmental impact, and maintains or enhances mechanical and durability properties, making SCC eco-friendlier and more cost-effective.

### 1.1 Physical and Chemical Property for pond ash and SCBA

Table 1 shows some important physical test results

of pond ash. Specific gravity is 2.63, meaning its relative density compared to water. Being finer means that more surface area of 2.95 m<sup>2</sup>/kg is available per unit mass that can influence reactivity, workability in concrete mixtures [15]. Pond ash has a light gray shade which can affect the appearance of concrete products. Pond ash particle shapes being mostly rounded and sub-rounded enhances workability and flow properties during concrete application as a substitute material.

Table 1: Pond ash physical properties

Properties	Values
Specific Gravity	2.63
Fineness (m <sup>2</sup> /kg)	2.95
Color	Light Gray
Shape	Rounded

The chemical composition of pond ash is shown in Table 2. Main constituents of pond ash are Alumina (Al<sub>2</sub>O<sub>3</sub>), which amounts to 43.56%, and Silica (SiO<sub>2</sub>) at 41.67%, which together form the major portion of the composition that renders its pozzolanic activity when used with cement. Calcium Oxide (CaO) exists in an extremely low percentage, being only 0.73%, giving it minimal cementitious behavior if any. Iron Oxide (Fe<sub>2</sub>O<sub>3</sub>) accounts for 8.27% and Potassium Oxide (K<sub>2</sub>O) constitutes 3.11%, which both have an influence on chemical stability and durability of concrete. Titanium Dioxide (TiO<sub>2</sub>) exists at 1.32%, while Manganese Oxide (MnO) is only present in trace quantities almost negligible to this count of 0.1%. These chemical properties make pond ash a good contributor as a secondary ingredient in concrete production, thus making it sustainable and conserving haltingly natural resources [15].

Table 2: Pond ash chemical properties

Constituents	Value
Al <sub>2</sub> O <sub>3</sub>	43.56
SiO <sub>2</sub>	41.67
CaO	0.73
Fe <sub>2</sub> O <sub>3</sub>	8.27
K <sub>2</sub> O	3.11
TiO <sub>2</sub>	1.32
MnO	0.1

According to Table 3, SCBA's physical characteristics are crucial for its application as an additional ingredient in concrete. Because of its specific gravity, which ranges from 2.1 to 2.6, SCBA is lighter than conventional cement materials. Its fineness typically varies between 300 and 600 m<sup>2</sup>/kg, providing a large surface area that enhances reactivity. SCBAs can be light grey or dark grey in color, depending on the circumstances of combustion. The particle shape is mostly irregular and porous, which contributes to good interlocking and improved bonding in concrete mixtures. These characteristics make SCBA

suitable for sustainable construction applications [16].

**Table 3: Physical Property SCBA**

Sl. No	Property Type	Properties	Typical Values
1	Physical Property	Specific Gravity	2.1 – 2.6
2		Fineness (m <sup>2</sup> /kg)	300 – 600
3		Color	Light Gray to Dark Gray
4		Particle Shape	Irregular / Porous

The chemical properties of SCBA make it an excellent addition to cementitious materials used in the production of concrete, as shown in Table 4 [17]. The primary component  $SiO_2$  makes up 50–60% of its composition and hence plays a vital role in pozzolanic activities.  $Al_2O_3$  occurs in the range of 5–15%, while  $Fe_2O_3$  ranges from 2–10%.  $CaO$  is present in a range of 1–5%, and  $K_2O$  ranges from 2–6%; such components influence the chemical stability of ash [18].  $LOI$  refers to the sum of 5 to 15%, pointing to unburnt carbon content. It is these properties that show the potential of SCBA in achieving better sustainability for concrete [19].

**Table 4: Chemical Property SCBA**

Sl. No	Property Type	Properties	Typical Values
1	Chemical Property	$SiO_2$	50 – 60%
2		$Al_2O_3$	5 – 15%
3		$Fe_2O_3$	2 – 10%
4		$CaO$	1 – 5%
5		$K_2O$	2 – 6%
6		$LOI$	5 – 15%

## 2. Self-Compacting Concrete (SCC)

A unique kind of concrete called SCC fills the form work without vibrating and flows under its own weight. It is primarily used in areas with crowded form work or construction sites and limited access to skilled labor. The capacity of SCC to fill, pass, and segregate are its primary new characteristics. Finer particles should improve the flow properties of concrete, hence in SCC, a 60:40 ratio is typically used, with a higher percentage of fine aggregate and a greater volume of coarse aggregate. Concrete cannot flow if the amount of coarse aggregate rises. For this kind of concrete, super plasticizers must be added to improve flow, and in certain situations, VMA is added to concrete to preserve mix homogeneity. SCC reduces noise pollution and improves worker safety on the job site, making it an environmentally friendly concrete [24].

In 2021 Li *et al.* [20] investigated the SCC with SHPB was used to extensively analyses the impact-

related features of steel fibres that were 0.5%, 0.75%, and 1.0%. The findings demonstrate that using steel fibres with a composition of no more than 1.0% successfully produces SCC with excellent workability and markedly increased impact resistance. A number of impact parameters, including elastic modulus, failure modes, peak stress, and peak strain, are strongly impacted by the strain rate and steel fibre composition. In 2024 Yaqin *et al.* [21] examined how adding macro-PP fibres to high-strength concrete affected its mechanical and novel qualities. The study examined three distinct concrete strengths 40, 45, and 50 MPa with fibre contents ranging from 0 to 1.5% v/f. To test the mechanical and fresh qualities, Both ASTM standards and RILEM specifications have been utilised to test the bond of bar reinforcements in concrete. The test results indicate that there is no appreciable change in the new concrete's density, air content, or workability. In 2024 Ashteyat *et al.* [22] presented basalt fiber's impact on SCC's mechanical, rheological, and durability characteristics. For the investigation, five different combinations of self-compacting concrete were created: a control mixture as well as mixtures containing 0.1%, 0.2%, 0.15%, and 0.05% basalt fibres. The impact of basalt fibres on the rheological characteristics of fresh SCC was evaluated using slump flow and V-funnel flow. In 2025 Saud Khan *et al.* [23] presented novel approaches to accurately predict the HFR-SCC's *cs*, *ffs*, and *ts* using a variety of ML algorithms, such as RFR, GEP, ANFIS, XGB, and AdaBoost. Cement, fly ash, temperature, fibre content, and nine other inputs have all been collected from global published literature in order to achieve this goal. In 2023 Montaser *et al.* [25] developed the bond behavior of self-compacted concrete (SCC) and normally vibrated concrete (NVC) is examined, and the disparities are emphasized. Four factors are examined in relation to the reinforcement: (i) kind of concrete (SCC or NVC), (ii) strength of SCC characteristic, (iii) length of lap splice, and (iv) depth of concrete cover. For the investigated beams, it was discovered that extending the splice length enhanced energy absorption and altered the failure mode to one that was more ductile, even in areas with weak bond quality. In 2025 Hussein *et al.* [26] focused on the mechanical, rheological, and durability characteristics of 15 SCC combinations that comprise polypropylene fibres (PP), colloidal nanosilica (CNS), and recycled concrete aggregate (RCA). In addition to substituting coarse natural aggregate (CNA) for 20% of coarse recycled aggregate (CRA), fine natural aggregate (FNA) was used in place of 25%, 50%, 75%, and 100% of fine recycled aggregate (FRA). In 2024 Aadi *et al.* [27] investigate manufacturing of SCC mixes,

wherein CKD is used in different weight percentages 3%, 6%, 9%, 12%, and 15% instead of cement. The toughened mechanical properties of SCC include compressive strength, splitting tensile strength, and flexural strength. Additionally reported and compared to the sole cement-cast

control combination are the fresh state parameters, such as slump flow diameter, T500, V-funnel, and L-box tests. Summary of Recent Studies on Self-Compacting Concrete (SCC) and Related Innovations are discussed in Table 5.

**Table 5: Summary of Recent Studies on Self-Compacting Concrete (SCC) and Related Innovations**

Author (Year)	Material	Focus	Key Variables	Tests	Main Finding
Li <i>et al.</i> , 2021 [20]	CKD as cement substitute	SCC fresh & mechanical properties	CKD content (3–15%)	Slump flow, T500, V-funnel, L-box, compressive, tensile, flexural strength	SCC performance compared to control (100% cement)
Yaqin <i>et al.</i> , 2024 [21]	Macro PP fibers	High strength concrete properties	Fiber content (0–1.5%), concrete strength (40–50 MPa)	ASTM & RILEM tests	Workability ↓, air content ↑, density stable
Ashteyat <i>et al.</i> , 2024 [22]	Basalt fibers	SCC rheological, mechanical, durability	Basalt fiber content (0–0.2%)	Slump flow, V-funnel	Fiber affects fresh SCC rheology
Saud Khan <i>et al.</i> , 2025 [23]	ML models	Predict strength properties	Cement, fly ash, temp, fiber content, etc.	GEP, ANFIS, XGB, AdaBoost, RFR	Reliable prediction of strength
Montaser <i>et al.</i> , 2023 [25]	SCC vs NVC	Bond behavior in poor zones	Concrete type, strength, splice length, cover depth	Energy absorption, failure mode	Longer splice → ductile failure mode
Hussein <i>et al.</i> , 2025 [26]	RCA, CNS, PP fibers	SCC rheology, mechanical, durability	RCA/FRA (25–100%), CRA (20%)	Rheological, mechanical, durability tests	Studied aggregate replacement effects
Aadi <i>et al.</i> , 2024 [27]	CKD as cement substitute	SCC fresh & mechanical properties	CKD content (3–15%)	Slump flow, T500, V-funnel, L-box, strength tests	SCC performance vs. control mix

### 3. Industrial By-products in Concrete

In 2013 Dimas *et al.* [28] investigated the red mud's potential for employing the geopolymerization process to produce inorganic polymeric materials was investigated. The main objective was to produce inorganic polymeric materials that may be used as huge bricks or other artificial structural components. In a very alkaline environment, red mud and an alkali metal silicate solution undergo a chemical reaction as part of the geopolymerization process.

In 2016 Sundeep *et al.* [29] developed the incorporation of additional Pozzolanic elements into geopolymer concrete is the aim of this investigation. Fly ash was substituted with pozzolanic elements, specifically GGBS and RHA, in geopolymer concrete in accordance with goal two. Geopolymer concrete's compressive strength is tested using varying ratios of RHA and GGBS. The results demonstrated that using RHA and GGBS in place of fly ash in geopolymer concrete is not feasible.

In 2019 Paiva *et al.* [30] focused on the creation and processing of geopolymers that use mine tailing, a rough-to-process high-sulfidic mining refuse, as a fine aggregate. An essential first step in comprehending the behavior of geopolymers and their transition from a fresh to a hardened state was

the application of rheology analysis. This solution was used to study the effects of temperature and curing conditions of various formulations, as well as the kind of precursor binder (blast furnace slag or metakaolin) and mine tailing concentration. In 2015 Trochez *et al.* [31] proposed employing a spent fluid catalytic cracking catalyst (SFCC) as a precursor to create geopolymers and determining whether it is feasible. Publications and mechanical and structural characterizations of alkali activated SFCC binders with varying overall (activator + solid precursor) SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> and Na<sub>2</sub>O/SiO<sub>2</sub> molar ratios have been made. The extra silicate species supplied by the activator is responsible for the decreased mechanical strength of geopolymers with higher SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> for all observed Na<sub>2</sub>O/SiO<sub>2</sub> ratios. In 2019 Sisol *et al.* [32] developed the SiO<sub>2</sub>/Na<sub>2</sub>O ratio and the amount of Na<sub>2</sub>O in the activation solution characteristics of alkali-activated materials have been studied in relation to their impacts on the hardened geopolymer strengths from ground GGBFS. Analysis of the compressive and flexural strength test findings has been done using ANOVA. Seven, twenty-eight, and ninety days out, the strengths were examined.

Composition of Chemicals in Different Industrial Table 6 discusses materials and by-products.

Table 6: Chemical Abilities of Different Industrial Materials and By-Products

Raw (%)	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO (%)	SO <sub>3</sub>	LOI	Average	SiO <sub>2</sub> \Al <sub>2</sub> O <sub>3</sub>
Red mud [28]	4143	2061	736	1028	43	892	991	78.32	1.63
Metakaolin [28]	184	4098	5266	142	56	18	ND	95.66	-
Slag (GGBS) [29]	20–160	700–1200	2700–3800	ND	ND	3400–4300	ND	34.2–51.6	2.52–3.42
RHA [29]	26	39	9495	ND	25	54	ND	95.6	-
Slag (BFS) [29]	120	960	3230	220	50	3850	ND	43.1	-
Zinc mine tailing [29]	1923	640	2515	9	23	83	1868	50.78	-
Metakaolin [29]	110	4350	5250	180	30	20	130	97.1	-
Bagasse ash [30]	300	500	6500	ND	ND	900	1700	82	13
SFCC [31]	91	4157	4809	85	22	219	ND	90.79	1.15
GGBS [31]	30	851	4030	ND	ND	3701	ND	86.12	4.7
Bagasse ash [32]	300	500	6500	ND	ND	900	1700	73	13

#### 4. Analysis of PA and SCBA Replacement

In this review method, we discuss SCC and the usage of industrial by-products in concrete, regarding Pond Ash (PA) and SCBA in particular. The review also investigates the effects of SCBA and Pond Ash on the workability, strength, and durability of SCC. The economic and environmental advantages of employing these industrial waste materials in the manufacturing of concrete are examined from a different angle, emphasizing the decrease in raw material consumption, waste disposal issues, and building material costs.

##### 4.1 Pond Ash (PA)

In 2024 Patrisia *et al.* [33] investigated environmentally friendly structural concrete brick compositions that use recycled glass sand that hasn't been cleaned and pond ash. It seeks to present scientific proof of its fire resistance, thermal insulation, and technical performance in accordance with AS/NZS 4455.1:2008 standard. To learn more about the mechanisms underlying the reactions and how their characteristics change over time, pore-structure, chemical, and microstructural investigations are also performed. In 2021 Yimam *et al.* [34] investigated the concrete was poured, the workability of each mix was tested, and the porosity measured between 25- and 50-mm. Seven separate samples containing pond ash in 5% increments, ranging from 0% (control) to 30%, were utilized in the construction of 150 mm by 150 mm by 150 mm concrete cubes. The results showed that when the pond ash concentration increased, the concrete's density and workability declined.

At 7, 14, and 28 days of curing, the compressive strength of pond ash concrete containing 5% and 10% rose by around 0.13%, 3.74%, 2.46%, and 0.04%, 1.14%, and 0.70 percent, respectively, in contrast to the control concrete. In 2025 Fernando *et al.* [35] examined employing crushed waste glass in place of natural sand and pond ash as an extra cementitious component in mortar, emphasizing the

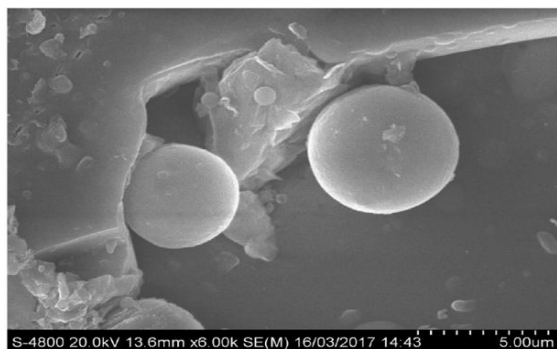
reduction of compressive strength and alkali-silica reaction (ASR) tests. Fly ash, which is well known for its ability to regulate ASR, is getting harder to find as coal-fired power output declines; thus, pond ash has to be looked at as a possible replacement. Pond ash must be carefully studied before being used directly in lieu of fly ash, though, because it is stored in repositories for a long period.

In 2019 Lal *et al.* [36] focused on features of mortar, including as workability, setting time, compressive strength, flexural strength, and bulk densities achieved by adding pond ash. XRD, XRF, and SEM using a SEM-EDX were used to examine the physical properties of mortar that contained pond ash in order to study microstructure analysis and connect these physical attributes with the mechanical properties of cement mortar. In 2010 Jakka *et al.* [37] improved the experimental inquiry focusses about the additional geotechnical features of pond ash samples that were taken at the inflow and outflow points of two Indian ash ponds. utilizing loose and compacted specimens of pond ash samples at various confining pressures, strength characteristics have been examined utilizing consolidated drained (CD) and undrained (CU) triaxial tests with pore water pressure measurements. In 2024 Patel *et al.* [38] developed Concrete compositions were inventively modified to substitute pond ash and foundry sand for conventional concrete as fine aggregates. Concrete of grades M-20 and M-40 has been made with pond ash (20%) in place of fine aggregate, as well as foundry sand (0%, 10%, 20%, 30%, 40%, and 50% by weight). In terms of workability and strength, several concrete mixes have been created, evaluated, and contrasted with traditional concrete. The mechanical properties have been evaluated during 7, 14, and 28 days of testing. Research papers on the use of pond ash in mortar and concrete are summarized in Table 7. The bulk density and compressive strength test results are shown in Table 8. Figure 3 displays images of a scanning electron microscope. Figure 4 compares

fine sand with pond ash.

**Table 7: Summary of Research Studies on the Use of Pond Ash in Concrete and Mortar Applications**

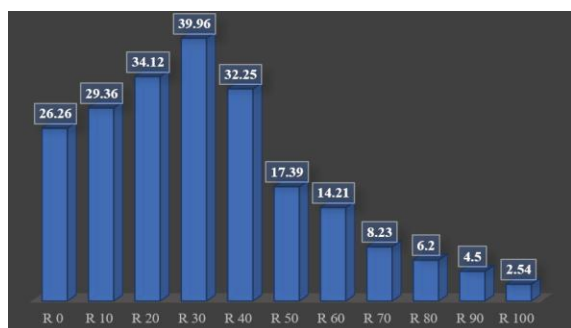
Author (Year)	Material	Objective	Key Tests Performed
Patrisia <i>et al.</i> , 2024 [33]	In structural concrete bricks, combine pond ash with unwashed recycled glass sand.	Study engineering performance, thermal insulation, fire resistance, microstructure, chemical & pore structure analysis.	AS/NZS 4455.1:2008 compliance, thermal insulation test, fire resistance test, SEM, XRF, pore structure analyses
Yimam <i>et al.</i> , 2021 [34]	Pond ash as partial cement replacement (0% to 30%)	Evaluate workability, density, and compressive strength with increasing pond ash content	Workability (slump test), Density measurement, Compressive strength (7, 14, and 28 days).
Fernando <i>et al.</i> , 2025 [35]	Crushed waste glass as sand replacement + pond ash as supplementary cementitious material	Mitigate Alkali-Silica Reaction (ASR) and assess compressive strength	Compressive strength test, ASR evaluation
Lal <i>et al.</i> , 2019 [36]	Pond ash in mortar mix	Examine the characteristics and microstructure of mortar.	Compressive strength, Flexural strength, Workability, Setting time, Bulk density, XRD, XRF, SEM-EDX
Jakka <i>et al.</i> , 2010 [37]	Pond ash geotechnical characterization	Study strength and geotechnical behavior of pond ash	Consolidated Drained (CD) & Consolidated Undrained (CU) triaxial tests, Pore water pressure measurements.



**Fig 3: SEM for Pond ash [36]**

**Table 8: Compressive Strength and Bulk Density testing [36]**

SR Value	Compressive Strength	Bulk Density (Kg/m <sup>3</sup> × 100)
SR 0	26	23.34
SR 10	29.36	23.23
SR 20	34.12	22.9
SR 30	39.96	21.7
SR 40	32.25	21



**Figure 4: Fine sand vs Pond ash**

**4.2 Sugarcane Bagasse Ash (SCBA)**

In 2022 Wagh & Waghe [39] developed and compare the strength and freshness characteristics of SCC produced with SCBA in 0, 10, 15, and 20%

cement substitution. The new characteristics of SCC remain within the EFNARC range; however, they are significantly reduced if the percentage of SCBA rises as a result of partial cement replacement. Utilising it in SCC has been found to enhance its strength characteristics. In 2020 Anjos *et al.* [40] determined implications of SCBA in mortar production. During this experiment, both fresh and hardened mortars has been taken into account. Features of the fresh type have been determined to be viscosity, flowability, and filling ability; in contrast, the properties of hardened mortars have been investigated using water absorption through capillarity, flexural strength, compressive strength, bond strength, and dynamic modulus of elasticity. According to the findings, SCBA enhanced mortars' mechanical, rheological, and physical qualities, especially when used up to 25% in lieu of Portland cement. Higher levels of the replacement trend, however, resulted in worse mortar performance. In 2022 Gupta *et al.* [41] investigated the substituting cement in SCC with SCBA to prepare the samples in percentages 5, 10, 15, 20, and 25. The control specimen was used to compare the outcomes of these samples. Compressive strength, split tensile strength, U-box, L-box, J-ring, V-funnel, and workability tests (Slump flow, T50cm time) has been performed to assess the fresh and hardened characteristics. Energy-dispersive spectroscopy (EDS), XRD, XRF, and the microstructural examination of the combinations has also been done using field emission scanning electron microscopy. Table 9 shows that the Chemical Oxide Composition and Specific Gravity of Materials.

Table 9: Chemical Oxide Composition

Materials	Oxides															
	[42]	[43]	[44]	[45]	[46]	[47]	[48]	[49]	[50]	[51]	[52]	[53]	[54]	[55]	[56]	[57]
$SiO_2$	0.55	0.55	0.7	0.78	0.76	0.53	0.7	0.56	0.7	0.56	0.65	0.71	0.76	0.65	0.76	0.76
$Al_2O_3$	0.05	0.04	0.03	0.09	0.03	0.07	0.05	0.1	0	0.03	0.06	0.11	0.02	0.05	0.02	0.02
$Fe_2O_3$	0.04	0	0.01	0.04	0.1	0.03	0.05	0.08	0.07	0.04	0.03	0.04	0.02	0.01	0.02	0.02
$CaO$	0.11	0.05	0.02	0.02	0.02	0.03	0.06	0.09	0.02	0.15	0.11	0.07	0.07	0.04	0.07	0.06
$MgO$	0.01	0.05	0.07	0.02	0.03	0.03	0.08	—	—	0.04	0.02	0.02	0.02	—	—	0.02

#### 4.2.1 Study of Silica ( $SiO_2$ ) Content in Sugarcane Bagasse Ash (SCBA)

The silica ( $SiO_2$ ) content in SCBA showed noticeable variation across different studies. A content of 0.55  $SiO_2$  was reported by [42] and [43], while [44] recorded 0.70  $SiO_2$  and [45] reported 0.78  $SiO_2$ . Similarly, [46] documented 0.76  $SiO_2$ , whereas [47] observed a relatively lower content of 0.53  $SiO_2$ . Consistent values of 0.70  $SiO_2$  has been also reported in [48] and [50], while [49] and [51] noted 0.56  $SiO_2$ . A moderate content of 0.65  $SiO_2$  was found by [52] and [55], whereas [53] presented a slightly higher value of 0.71  $SiO_2$ . Furthermore, [54], [56], and [57] each reported 0.76  $SiO_2$ . The graph analysis is shown in Fig 5.

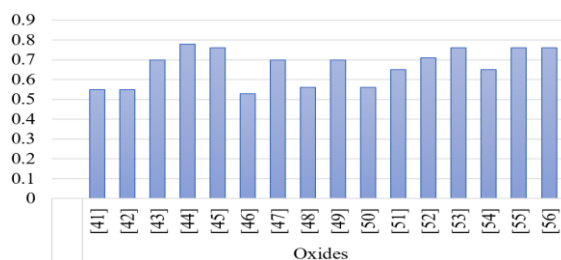


Figure 5:  $SiO_2$  Content in SCBA finding in Exiting works

#### 4.2.2 Study of Alumina ( $Al_2O_3$ ) Content in Sugarcane Bagasse Ash (SCBA)

The alumina ( $Al_2O_3$ ) content in Sugarcane Bagasse Ash (SCBA) showed considerable variation among different studies. A content of 0.05  $Al_2O_3$  was reported by [42], while [43] recorded 0.04 and [44] reported 0.03. Similarly, [45] documented a higher value of 0.09, whereas [46] again showed a lower value of 0.03. The study in [47] observed 0.07  $Al_2O_3$ , and both [48] and [55] reported 0.05. A slightly higher value of 0.10 was noted in [49], while [50] reported no presence of  $Al_2O_3$ . Further, [51] documented 0.03, [52] observed 0.06, and [53] showed the highest value of 0.11. Lower values have been also reported, such as 0.02 in [54], [56], and [57]. The findings indicated that the  $Al_2O_3$  proportion in SCBA generally ranged from 0.00 to 0.11, reflecting wide variability depending on the study. Fig 6 shows the graph analysis of  $Al_2O_3$  Content in SCBA.

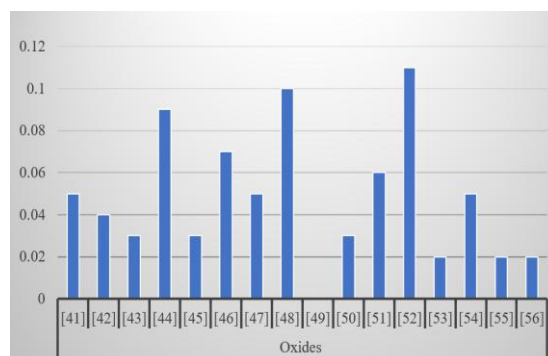


Figure 6:  $Al_2O_3$  Content in SCBA finding in Exiting works

#### 4.2.3 Study of Iron Oxide ( $Fe_2O_3$ ) Content in Sugarcane Bagasse Ash (SCBA)

The iron oxide ( $Fe_2O_3$ ) content in Sugarcane Bagasse Ash (SCBA) was very inconsistent across different studies. [42] said that there is 0.04  $Fe_2O_3$ , [44] recorded 0.01. Another report gave a value of 0.04 by [45] while 0.10 was reported by [46]. A value of 0.03 was given by [47], and [48] gave 0.05. Then, from a different opinion, values of 0.08 from [49], 0.07 from [50], 0.04 from [51], and 0.03 from [52] has been given, whereas [53], [54], [55], [56], and [57] recorded  $Fe_2O_3$  contents of 0.04, 0.02, 0.01, 0.02, and 0.02, respectively. The reported values suggested that  $Fe_2O_3$  content in SCBA from all studies can be taken in the range of 0.00-0.10, showing moderate variation. Fig 7 shows that  $Fe_2O_3$  Content in SCBA.

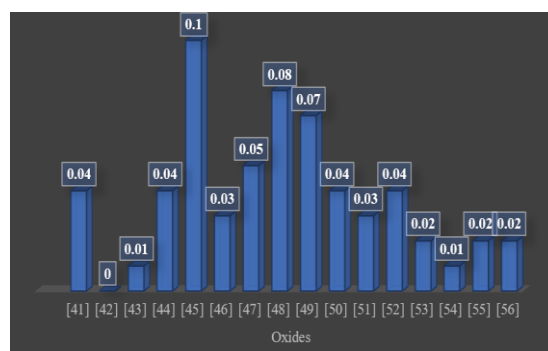
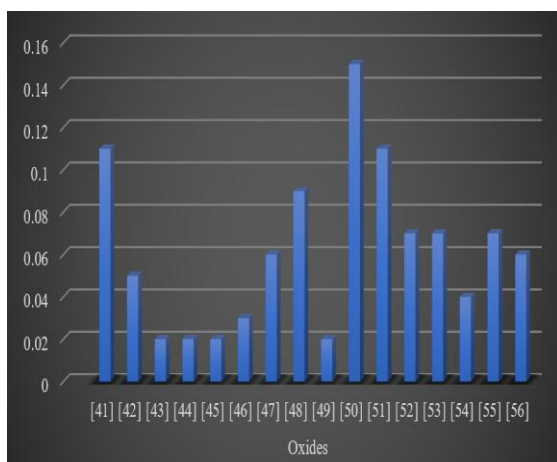


Figure 7:  $Fe_2O_3$  Content in SCBA finding in Exiting works

#### 4.2.4 Study of Calcium Oxide $CaO$ Content in Sugarcane Bagasse Ash (SCBA)

The calcium oxide content in Sugarcane Bagasse Ash was variable among different studies in the literature. One study recorded the amount as 0.11

[42], while 0.05 was recorded in an independent analysis [43]. In contrast, [44] had found only 0.02. Other authors recorded 0.02, [45] and [46], while [47] found 0.03. The study in [48] reported 0.06, and [49] reported 0.09. Then, a lower CaO content of 0.02 was noted by [50], while the highest, that is, 0.15, was found in [51]. Then we enter into the range: 0.11 by [52], 0.07 by [53], and 0.07 by [54]. At 0.04, [55] was a little lower, but at 0.07 and 0.06, [56] and [57], respectively, marked the upper bound of the range. Hence, the findings are interpreted as indicating that the values of CaO content in SCBA are mostly observed in the range of 0.02-0.15, signifying their marked divergence from one another in the various studies reported.



**Figure 8:** CaO Content in SCBA finding in Existing works

## 5. DISCUSSION:

By allowing for the use of superplasticizers, a higher proportion of fine aggregate, a very high powder content, and frequently the assistance of VMA, SCC represents a technological advancement in concrete because without vibrating, it flows and condense under its weight. [20]. Hence, it is quite convenient to place the concrete in heavily reinforced sections or in sites with very limited access and manual labor, plus will less pollution by noise and may improve safety of the site, thus contributing to environmental sustainability [20]. Performance and uniformity would be hampered by a lack of knowledge and, as a result, design of SCC's fresh state properties, such as filling and passing capabilities and segregation resistance. In furtherance of this, recent studies have imparted extended application of SCC through various fibre and material modifications. For example, [20] demonstrated that at high strain rates, fibre levels of up to 1.0% by volume greatly improve an SCC's resistance to impacts, whereas strain rate and fibre content have a substantial impact on failure modes, peak stress, peak strain, and elastic modulus. In the same manner, [21] studied the effect of adding macro-polypropylene (PP) fibres to high-strength SCC (40-50 MPa),

reporting that an increase in fibre content (0-1.5% v/f) causes a slight decrease in fresh density, an increase in air content, and a decrease in workability. [22] reported that basalt fibre-modified SCC with small fibre dosages (0.05%–0.2%) influence its rheological characteristics (slump flow and V-funnel) as well as mechanical and durability properties. On sustainable and durable concrete, Hussein et al. [26] studied SCC containing polypropylene fibres, colloidal nanosilica, and recycled aggregates, showing that alternative combinations can give rise to acceptable strength and durability, though fresh properties tend to be sensitive to the levels of recycled aggregate replacement. [27] deals with cement replacement by CKD in SCC, with gradual workability loss noticed as the content of CKD increased, although mechanical properties at moderate levels of substitution proved either comparable or superior. In essence, the studies point toward fibre type, geometry, stiffness, and dosage as parameters that heavily impact SCC performance and that, therefore, present both advantages and disadvantages in their use. Generally, an optimum fibre content exists, above which problems related to workability appear, together with fibre grouping and segregation [21][22]. Fly ash, nanosilica, and CKD are examples of SCMs that have a lot of promise for increased sustainability and long-term durability, but the reality remains that they decrease the fresh state's flowability and homogeneity, which present pressure on mixing design and quality control [26][27].

## 6. Research gap:

In recent years, although there have been swift advancements in the different aspects of development and application of SCC using a variety of fibres and supplementary cementitious materials, certain essential research gaps persist hindering its optimum performance and adoption. In particular, while individual durability aspects (for example, resistance to chemical attack or high temperatures) have been studied, fibre-reinforced SCC has not been comprehensively evaluated for long-term durability under combinations of environmental stresses such as freeze-thaw cycles, chemical exposure, and sustained cyclic loading, especially with the consideration of real-world climatic conditions [20][21][22]. Most durability tests are limited to short observations lasting 28 to 90 days, with very few extending to one year or beyond [20][26]. In SCC, hybrid fibre systems which incorporate several fibre types including steel, basalt, and polypropylene to take advantage of complementing mechanical properties are also not well-established or well-studied. Most of the existing studies are single-fibre systems; however, it still remains unclear whether combining hybrid fibres yields synergistic or antagonistic effects

concerning fresh flowability, segregation resistance, and post-crack behavior [21][22][26].

## 7. CONCLUSION:

The analysis concludes that using SCBA as an additional cementitious material in place of SCC and partially replacing fine sand with pond ash are strategies for a workable and sustainable solution in contemporary building. With pond ash, enhancement in workability and filling ability occurs, with an added reduction in the demand for natural sand. SCBA in its pozzolanic nature, promotes strength, durability, and microstructural properties. As a result, these two materials not only improve SCC's performance but also address major environmental issues by reducing the need for cement and preventing the uncontrolled exploitation of natural sand, which lowers carbon emissions and conserves natural resources. In addition to improving waste management, the use of these industrial and agricultural by-products gives abandoned goods more economic worth. While previous studies highlight promising outcomes, further investigations are necessary to optimize mix proportions, evaluate long-term durability, and standardize guidelines for large-scale applications. Pond ash and SCBA present a viable pathway toward eco-efficient, cost-effective, and sustainable construction practices.

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