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Enhancing Properties of Concrete Mix Using Different Types of Waste Materials: A Review Paper

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ABSTRACT- The proliferation of civilization, industry, and urbanization, along with population growth, has contributed significantly to the generation of waste materials, and this trend continues to this day. Such waste has far-reaching impacts on both human health and the environment, leading to environmental degradation and rendering it non-environmentally friendly. To address these concerns, many scientists have directed towards the possibility of using waste materials as a substitute for some components of the concrete mixture. Numerous studies have demonstrated the effectiveness of incorporating such materials such as (coal bottom ash (CBA), waste plastic and fibers, wood waste, and soft drink bottle caps) in enhancing concrete's properties, including durability, compressive and tensile strength, water content, slump flow, and suitability for reuse in engineering projects. The use of such materials not only provides an economic solution but also promotes environmental preservation by mitigating environmental problems.

KEYWORDS: Coal bottom ash (CBA), waste plastic and fibers, wood waste, soft drink bottle caps, concrete, durability, compressive and tensile strength, slump flow.

I. INTRODUCTION

Concrete gains potency, endurance, and plasticity, which have made it a preferred construction material. Concrete is one of the most used materials in construction and buildings, due to its strength and durability, in addition to its plasticity and the ability to mold it into various shapes and forms. Also, due to its strength, it is used in the construction of bridges, tunnels, airports, and dams (Kishore et al., 2020). However, producing concrete can be costly at times due to the expensive materials used. Additionally, the production of cement results in substantial carbon dioxide emissions (Ahmad et al., 2021), causing adverse impacts on the environment and climate. Hence, scientists tended to search for ways to reduce the cost and minimize the impact of concrete on the environment while preserving its properties.

Researchers have widely adopted the use of waste materials to enhance concrete properties. Various waste materials, including coal bottom ash, waste plastic, fibers, cassava peel ash, wood ash, and recycled fibers from carpet waste, have demonstrated effective changes in the properties of concrete, such as strength, workability, and specific weight, among others. Moreover, utilizing waste materials has reduced the negative impact of ordinary concrete on the environment, rendering these materials eco-friendlier and more sustainable while preserving the use of concrete in building and construction. For Example. Mixing glass powder into the concrete has resulted in significant strength improvements, surpassing that of normal concrete after 14 and 28 days (Vasudevan et al., 2013). And Malik et al (2013) showed that substituting sand with waste glass powder at varying levels (10%-40%) results in changes in the properties of concrete. Specifically, the compressive strength increased by 15% after 7 days, 25%, and 9.8% after 28 days at 20% and 30% replacement, respectively. Additionally, water absorption was reduced by 5% at 40% replacement, but the splitting tensile strength decreased with the increase in waste glass content. In an experimental study by Prasanna et al (2014), E-waste particles were used as coarse aggregates in concrete with replacements of 5%, 10%, 15%, and 20%. The fineness modulus of coarse aggregate with various E-waste contents was observed as 6.937. Compressive strength tests were conducted at 7, 14, and 28 days, and it was found that the compressive strength of concrete was optimum when coarse aggregate was replaced by 15% with E-waste. Beyond that, the compressive strength decreases. In Alzaed's (2014) study, four different percentages of iron filings (0%, 10%, 20%, and 30%) were added to the concrete mix, and the variation in compression and tensile concrete strengths after 28 days was measured. Results showed that adding 30% iron filings to the mix increased the compressive strength of concrete by 17% while adding 10% iron filings increased the tensile strength by 13%.

This study aims to explore and identify significant waste materials that can be used in concrete to enhance its properties by replacing certain proportions of conventional materials. Several materials, including coal bottom ash (CBA), waste plastic and fibers, wood waste, soft drink bottle caps, beverage tins, steel powder, mild steel lathe waste, recycled concrete paving, crushed ceramic bricks, burnt sewage sludge, pumice, and olive stone, have been proven to improve various properties of concrete, such as compressive strength, density, thermal conductivity coefficients, water penetration depth, tensile splitting strength, slump flow, and more.

II. MATERIALS AND METHODS

A. Coal Bottom Ash (CBA)

Coal bottom ash is formed in coal furnaces of coal-fired power plants (Nasrudin et al., 2022, Singh et al, 2013). It has been utilized to develop and enhance the properties of concrete to promote sustainability and preserve the environment. The incorporation of coal bottom ash has proven to be effective in increasing the strength and durability of concrete while minimizing its impact on the environment (Hasim et al., 2022; Singh et al., 2015). Additionally, the use of coal bottom ash has provided a cost-effective solution in the production of concrete and construction. In a recent study conducted by Hasim et al (2022) replaced fine and coarse aggregates of concrete were replaced with 50%, 60%, 70%, 80%, 90%, and 100% of fine and coarse coal bottom ash (FCBA and CCBA) as shown in Fig.1 and Table.1.

Table 1: The proportions of fine and coarse coal bottom ash (FCBA and CCBA) used in mixing concrete (Hasim et al., 2022)

Mix Ratio of Coal Bottom Ash	**Cement density (Kg/m^3)**	**Sand (Kg/ m^3)**		**Coarse Aggregate in kilogram per meter cube**		**Water Cement Ratio**
		Sand	**Fine Coal Bottom Ash**	**Gravel**	**Coarse Coal Bottom Ash**	
Ordinary Concrete	400	750	0	720	0	
50% (Fine/ Coarse)	400	375	410	360	390	0.5
60% (Fine/ Coarse)	400	300	492	288	468	0.5
70% (Fine/ Coarse)	400	225	574	216	546	0.5
80% (Fine/ Coarse)	400	100	656	144	624	0.5
90% (Fine/ Coarse)	400	75	738	72	702	0.5
100% (Fine/ Coarse)	400	0	820	0	780	0.5

Figure 1: (a) Fine coal bottom ash FCBA; (b) Coarse coal bottom ash CCBA (Hasim et al., 2022)

The results showed an effect on the workability of concrete due to a decrease in the slump value of 110 mm, 98 mm, 95 mm, 90 mm, 80 mm, 75 mm, and 68 mm with increasing FCBA and CCBA content. The compressive strength reached 38.28 MPa at 50% FCBA/CCBA, and with increasing FCBA/CCBA content, the porosity of the concrete increased, and lead to a reduction in compressive strength to 30.2 MPa at 100% FCBA/CCBA. Additionally, the tensile test reached a maximum value of 3.01 MPa at 50% FCBA/CCBA, after which it started decreasing, reaching 2.11 MPa at 100% FCBA/CCBA. Thus, the optimal proportion of FCBA/CCBA to enhance the properties of concrete was found to be 50%. Therefore, the utilization of fine and coarse coal bottom ash can be an economic, environmental, and sustainable solution in concrete, with the potential to be used in construction.

According to Ghazali et al (2020), when sand was replaced with varying percentages of CBA (10%, 20%, 30%, 40%, and 50%) as presented in Table 2, it led to a reduction in slump values, with the lowest value of 40 mm observed at 50% CBA, as shown in Table 3. The study found that the compressive strength value at 10% CBA and after 7 days was 27.3 MPa. At 28 days, the highest compressive strength of 39.7 MPa was recorded with 0% CBA. After 56 days, the highest compressive strength was observed with 10% CBA, which was 58.3 MPa. The trend was similar for tensile strength, as illustrated in Table 3.

Table 2: Ingredients and Mixing Ratios (Ghazali et al., 2020).

	Series						
	M-1	**M-2**	**M-3**	**M-4**	**M-5**	**M-6**	**Total**
Replacement Level (%)	**0**	**10**	**20**	**30**	**40**	**50**	**-**
Cement density (kg/m^3)	13.52	13.52	13.52	13.52	13.52	13.52	**81.12**
Water quantity (kg/m^3)	7.44	7.44	7.44	7.44	7.44	7.44	**44.64**
Bottom ash density (kg/m^3)	0	3.19	6.38	9.57	12.76	15.95	**47.85**
Sand (Fine aggregate) (kg/m^3)	31.89	28.70	25.51	22.32	19.13	15.94	**143.49**
Coarse aggregate density (kg/m^3)	28.23	28.23	28.23	28.23	28.23	28.23	**169.38**

Table 3: Displays the Test Results of Replacing Sand with CBA Content over a period of 7, 28, and 56 days

Test		**Replacement Level (CBA) (%)**					
		0%	**10%**	**20%**	**30%**	**40%**	**50%**
Compressive Strength Values (MPa)	**At 7 days**	26.7	27.3	23.9	23	22.5	19.8
	At 28 days	39.7	37.1	34.3	30.7	29.3	28.6
	At 56 days	50.7	58.3	48.2	46.9	40.5	38.2
Tensile stress (MPa)	**At 7 days**	2.25	2.3	2.27	2.1	1.96	1.78
	At 28 days	2.78	2.41	2.3	2.27	2.17	1.78
	At 56 days	2.9	3.24	2.6	2.51	2.3	2
Slump Values (mm)		-	58	53	48	45	40

The study by Siddique et al (2012) showed that using (10 %, 20%, and 30%) of bottom ash led to decreasing in the water-powder ratio. The highest value of compressive strength and split tensile strength was at (15% -20%) of fly ash and 0% of bottom ash, and all values improved with (28-365) days of curring age. The study recommended the possibility of reducing the cost of concrete by replacing sand with less expensive materials, in addition to preserving the environment. Hamzah et al (2015) replaced sand (fine aggregates) with varying percentages of coal bottom ash (CBA) ranging from 0% to 30%. The study estimated the workability and properties of the fresh concrete mixture using different tests as shown in Table 4. The findings indicated a decrease in slump flow value from 715 mm to 550 mm at 30% CBA, thus affecting the workability of concrete and a reduction in the viscosity and segregation resistance of the fresh concrete with increasing CBA content. This reduction was attributed to CBA's water absorption ability. The study found that the best passing ability was achieved at 10%-20% of CBA, while the ideal percentage for producing the best concrete was 15% of coal bottom ash.

Table 4: Displays Fresh Concrete Test Results for CBA Replacement (Hamzah et al., 2015)

CBA Ratio (%)	Workability (mm)	T500 (s)	L-box test (h2/h1)	Degree of Segregation (%)
0%	715	2.59	0.92	9.49
10%	705	2.84	0.89	8.17
15%	700	3.72	0.84	6.71
20%	615	4.00	0.79	5.30
25%	560	4.52	0.75	4.88
30%	550	4.57	0.65	5.00

Lim et al. (2020) discovered that using coarse and fine coal bottom ash as an alternative to gravel and sand has acceptable characteristics in concrete, with the possibility of being effective in producing concrete. The results showed that at 100% replacement, the slump value was 90mm for coal and 140mm for concrete, thus leading to a reduction in workability. And due to the low density of coal bottom ash, the density of concrete was 1850 kg/m3 at 100% replacement, but for concrete was 2350 kg/m3. The compressive strength was 37.28 MPa at 100% replacement, this value is slightly higher than normal concrete which has a value of 36.28 MPa. The study suggests that coal waste can be a viable alternative to conventional aggregates in concrete manufacturing, without compromising its compressive strength or density.

B. Waste Plastic And Fibers

Noori and Numan (2020) used waste plastic and fibers in reinforced concrete as Table 5 shown. The results showed that symbols W, WP, WG, and WGP had compressive values of (22.2, 20.3, 24.3, and 22.6) MPa, respectively. The addition of polypropylene fibers to the concrete mix caused a shift in the failure pattern from punching to flexural in all specimens, as observed in the ultimate load, crack pattern, and deflection results discussed for each specimen in Table 6. These findings suggest that incorporating waste plastic and polypropylene fibers in concrete production can enhance the strength and durability of reinforced concrete buildings. Additionally, the observed shift in failure pattern may present an opportunity to optimize the use of these materials in structural designs.

Table 5: Mix proportion (Noori and Numan., 2020)

	Symbol			
	W	**W-P**	**W-G**	**W-G-P**
Cement Content (kg/m^3)	450	450	450	450
Sand (kg/m^3)	910	910	730	730
Plastic Aggregate (kg/m^3)	273	273	210	210
Gravel (kg/m^3)	0	0	450	450
Water (kg/m^3)	139.5	139.5	139.5	139.5
Water Cement Ratio	0.31	0.31	0.31	0.31
PPF %	0	0.6	0	0.6
Sp.%	1.5	1.5	1.5	1.5
Density (kg/m^3)	1870	1865	1993	1963

Table 6: Deflection Characteristics at and Ultimate Loads (Noori and Numan. 2020)

Slabs Type	**Symbol**			
	W	**WP**	**WG**	**WGP**
Initial cracking load (kN)	7.5	8	8	9
Percent increase in Pcr compared to (W)	-	6.7	6.7	20
Maximum load capacity (kN)	19	21	22	25.5
Percent increase in Pcr compared to (W)	-	10.5	15.8	34.2

Max Deflection at Ultimate Load (mm)	5.6	6.3	7.1	8.3
Percent increase in Pcr compared to (W)	-	12.5	26.8	48.21
Density (kg per cubic meter)	1870	1865	1993	1983
Type of failure	Punching	Punching + Flexural	Punching	Flexural

C. Cassava Peel Ash and Wood Ash

Wood ash is a solid residue that remains after burning wood or sawdust in the air. It is composed of carbonates and metal oxides, particularly calcium and potassium, which are present in the woody tissues of plants. When added to concrete, wood ash can improve its porosity and strength. In recent years, there has been growing interest in using cassava as a pozzolanic material in concrete production, as it possesses natural pozzolanic properties. By replacing cement with cassava, concrete can be made more sustainable and environmentally friendly. The reuse of Cassava Peel ash in concrete production can also help mitigate environmental pollution and reduce ecological problems. Overall, the combination of wood ash and cassava in concrete production shows great promise for creating a more sustainable and eco-friendly building material.

In Table 7. Tobi et al (2022) used different ratios of cassava peel ash (CPA) and wood ash (WA) replacing ordinary Portland cement (OPC) to study the compressive strength of concrete. Results showed at 0% and 25% replacement compressive strength ranged between (27.11- 15.93) N/mm², as Table 8, Shows, replacement of 5%, 10%, and 15% of OPC with CPA or WA was suitable for plain concrete, while replacement of 20% or 25% was not useful in structural concrete. Additionally, the study found that higher amounts of pozzolanic materials in cement led to lower strength, but using CPA and WA in concrete production can help reduce environmental pollution.

Table 7: Mix design calculation (Tobi et al., 2022)

Percentage Replacement%	Coarse Agg(kg)	Fine Agg(kg)	Cassava Ash(kg)	Wood Ash(kg)	Cement(kg)
0%	54.88	26.54	0	0	13.72
10%	54.88	26.54	0.68	0.68	12.35
15%	54.88	26.54	1.03	1.03	11.66
20%	54.88	26.54	1.37	1.37	10.98
25%	54.88	26.54	1.72	1.72	1029

Table 8: Compressive Test Result (Tobi et al., 2022)

	Age	Cube No.	Cube weight in kilograms	ρ Of Cube (kg/m3)	(Load) KN	Values of Compressive Strength in (N/mm²)	Average Compressive Strength in (N/mm²)
Compressive Test Result for 0% Replacement	**7**	**A**	8	2370.37	410	18.22	
		B	9	2666.67	433	19.24	19.1
		C	8.6	2548.15	450	20	
	14	**A**	8.3	2459.26	560	24.89	
		B	8.6	2548.14	580	25.78	25.19
		C	8.3	2459.26	560	24.89	
	21	**A**	8.8	2607.41	540	24	
		B	9.0	2666.67	480	21.33	23.70
		C	8.7	2577.78	580	25.78	
	28	**A**	8.2	2429.63	600	26.67	
		B	8.4	2488.89	580	25.78	27.11
		C	8.5	2518.52	650	28.89	
Compressive Test Result for 5%	**Age**	**Cube No.**	**Cube weight in kilograms**	**ρ Of Cube (kg/m3)**	**Load (KN)**	**Values of Compressive Strength in**	**Average Compressive Strength in**

Replacement						**(N/mm^2)**	**(N/mm^2)**
	7	**A**	8	2370.37	350	15.50	16.72
		B	8.3	2459.26	450	20.00	
		C	8.1	2400	330	14.67	
	14	**A**	8	2370.37	454	20.17	21.02
		B	7.9	2340.74	400	17.78	
		C	8.1	2400	565	25.10	
	21	**A**	8.1	2400	560	24.87	20.88
		B	8.2	2429.62	450	20.00	
		C	8.3	2459.26	400	17.78	
	28	**A**	8.2	2429.62	570	25.33	
		B	8.0	2370.37	550	24.44	24.44
		C	8.6	2548.15	530	23.56	
Compressive Test Result for 10% Replacement	**Age**	**Cube No.**	**Cube weight in kilograms**	**ρ Of Cube (kg/m3)**	**Load (KN)**	**Values of Compressive Strength in (N/mm^2)**	**Average Compressive Strength in (N/mm^2)**
	7	**A**	8.2	2429.62	375	16.67	
		B	8.0	2370.37	355	15.78	15.56
		C	8.1	2400.00	320	14.22	
	14	**A**	8.4	2488.89	550	24.44	21.63
		B	8.0	2370.37	500	22.22	
		C	8.1	2400.00	410	18.22	
	21	**A**	8.2	2429.62	555	24.67	20.00
		B	8.5	2518.52	550	24.44	
		C	8.1	2400.00	450	20.00	
	28	**A**	8.2	2429.62	550	24.44	
		B	8.3	2459.26	500	22.22	23.25
		C	8.2	2429.62	520	23.1	
Compressive Test Result for 15% Replacement	**Age**	**Cube No.**	**Cube weight in kilograms**	**ρ Of Cube (kg/m3)**	**Load (KN)**	**Values of Compressive Strength in (N/mm^2)**	**Average Compressive Strength in (N/mm^2)**
	7	**A**	8.2	2429.62	375	16.67	
		B	8.0	2370.37	355	15.78	15.56
		C	8.1	2400.00	320	14.22	
	14	**A**	8.4	2488.89	550	24.44	21.63
		B	8.0	2370.37	500	22.22	
		C	8.1	2400.00	410	18.22	
	21	**A**	8.2	2429.62	555	24.67	20.00
		B	8.5	2518.52	550	24.44	
		C	8.1	2400.00	450	20.00	
	28	**A**	8.2	2429.62	550	24.44	
		B	8.3	2459.26	500	22.22	23.25
		C	8.2	2429.62	520	23.1	
Compressive Test Result for 20% Replacement	**Age**	**Cube No.**	**Cube weight in kilograms)**	**ρ Of Cube (kg/m3)**	**Load (KN)**	**Values of Compressive Strength in (N/mm^2)**	**Average Compressive Strength in (N/mm^2)**
	7	**A**	7.9	2340.74	300	13.33	
		B	7.8	2311.11	390	17.33	14.81
		C	8.0	2370.37	310	13.78	
	14	**A**	8.1	2400.00	350	15.56	

		B	8.2	2429.63	410	18.22	16.45
		C	8.0	2370.37	350	15.56	
		A	8.2	2429.63	380	16.89	
	21	**B**	7.9	2340.74	360	16.00	16.74
		C	7.8	2311.11	390	17.33	
		A	8.1	2400.00	400	17.78	
	28	**B**	8.0	2370.74	410	18.22	18.52
		C	8.5	2518.52	440	19.56	
	Age	**Cube No.**	**Cube weight in kilograms**	**ρ Of Cube (kg/m3)**	**Load (KN)**	**Values of Compressive Strength in (N/mm^2)**	**Average Compressive Strength in (N/mm^2)**
		A	7.5	2222.22	290	12.89	
	7	**B**	7.6	2251.85	300	13.33	13.33
		C	7.9	2340.79	310	13.78	
Compressive Test Result for 25% Replacement		**A**	8.0	2370.74	310	13.78	
	14	**B**	7.9	2340.79	320	14.22	13.78
		C	8.1	2400.00	300	13.33	
		A	8.1	2400.00	330	14.67	
	21	**B**	8.2	2429.63	340	15.11	15.04
		C	8.1	2400.00	345	15.33	
		A	8.0	2370.74	350	15.56	
	28	**B**	8.1	2400.00	360	16.00	15.93
		C	8.2	2429.63	365	16.22	

D. Recycled Fibers from Carpet Waste

The annual accumulation of carpet waste in landfills presents a plentiful supply of valuable resources that can be transformed into diverse beneficial products (Gardner., 1995; Wang., 1998). In 1994, Wang and colleagues conducted a research study focused on reinforcing concrete with fibers derived from waste carpet materials. The experimental concrete mix was composed of 1.00 cement, 0.44 water, 1.71 sand, 2.63 crushed rock, and an optimal amount of carpet fibers without the addition of any chemical admixtures. The results of the laboratory tests conducted were presented and analyzed in Table 9.

Table 9: Test Results for Concrete Reinforced with Carpet Waste Fiber (Wang. 1997)

		Mix Ratio							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dosage Density (kg/m^3)		A	0.89	1.34	1.79	5.95	8.93	11.90	17.85
Approximately Vf (%)		0.15	0.07	0.11	0.14	0.47	0.70	0.93	1.40
Slump Flow Values(mm)		178	229	184	191	70	51	48	0
Compressive Strength	**MPa**	22.8	20.0	24.3	25.6	27.6	23.7	23.1	17.4
	COV^b	0.11	0.12	0.13	0.08	0.07	0.02	0.14	0.20
Flexural Strength	**MPa**	3.74	3.64	4.20	4.06	3.79	4.11	3.77	3.73
	COV^b	0.09	0.07	0.07	0.08	0.07	0.08	0.07	0.10
Toughness	**I_5**	3.22	3.64	4.20	2.96	2.71	2.95	3.06	3.29
	I_{10}	4.69	3.07	2.98	4.06	3.64	4.17	4.41	5.17
	I_{20}	6.33	4.21	4.01	5.03	4.76	5.77	6.41	7.91

D. Wood Waste

In the 19th century, the utilization of wood waste in concrete was already evident, attributed to its lightweight and economic benefits. At present, developed nations have the chance to integrate wood waste into concrete construction, considering its potential in minimizing environmental impact. Fig 3 presents a study conducted by Abed et al (2019), which aimed to explore the potential of wood waste as a partial replacement for cement in different proportions. The investigation used two types of wood waste as a substitute for cement and sand, as illustrated in Fig 2, and varying volumes of 10%, 15%, 20%, 25%, and 30% of wood were used, as indicated in Table 10. The results of the study, presented in Table 11, demonstrated that the substitution of 20% of cement and sand with sawdust waste yielded commendable structural concrete blocks. Meanwhile, a replacement ratio of 25% and 30% produced lightweight concrete blocks with satisfactory compressive strength. The study identified an optimal replacement ratio of around 20% across all three clusters, offering a practical and eco-friendly solution for building design at a reduced cost.

Figure 2: Wood waste: a) Sawdust Waste (SW), b) Wood Waste Aggregate (WWA) (Abed et al. 2019).

Table 10: Mix proportion (Abed et al. 2019)

Group	Mix	(Cement) Kg/ m^3	(Sand) Kg/ m^3	(Gravel) Kg/ m^3	(Water) Kg/ m^3	(Sawdust) Kg/ m^3	(Wood Waste Aggregate) Kg/ m^3
Control	**M1-0**	463	562	1154	176	-	-
1	**M2-10**	416.7	562	1154	176	19.52	-
	M3-15	393.55	562	1154	176	29.28	-
	M4-20	370.4	562	1154	176	39.05	-
	M5-25	347.25	562	1154	176	48.81	-
	M6-30	324.1	562	1154	176	58.57	-
2	**M2-10**	463	504.9	1154	176	28.26	-
	M3-15	463	476.8	1154	176	42.39	-
	M4-20	463	448.8	1154	176	56.52	-
	M5-25	463	420.7	1154	176	70.66	-
	M6-30	463	392.7	1154	176	84.79	-
3	**M2-10**	463	562	1038.6	176	-	55.79
	M3-15	463	562	980.9	176	-	83.69
	M4-20	463	562	923.2	176	-	111.59
	M5-25	463	562	965.5	176	-	139.49
	M6-30	463	562	807.8	176	-	167.39

Table 11: Test Results (Abed et al. 2019)

Test Type		**Replacement (%)**					
		0%	10%	15%	20%	25%	30%
Oven-Dry Density (kg/m^3)	**A set (1)**	2432	2300	2133	2024	1837	1733
	A set (2)	2432	2320	2176	2101	1922	1778
	A set (3)	2432	2300	2157	2024	1887	1758
Slump Values (mm)	**A set (1)**	-	55	40	33	23	17
	A set (2)	-	60	45	39	23	20
	A set (3)	-	70	61	52	33	25
Coefficient of Thermal Conductivity (W/mK)	**A set (1)**	-	1.276	1.067	0.984	0.766	0.646
	A set (2)	-	1.287	1.12	1.016	0.805	0673
	A set (3)	-	1.255	1.081	0.954	0.761	0.656
Compressive Strength Values (MPa)	**A set (1)**	-	27.5	24.56	18.78	14.45	10.21
	A set (2)	-	22.56	19.81	15.33	11.78	7.88
	A set (3)	-	24.87	21.56	17.2	9.32	6.78

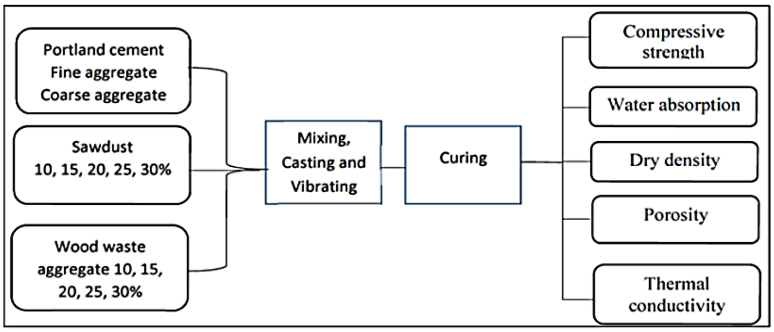

Figure 3: Experimental Work Program (Abed et al. 2019)

In their 2017 study, Gil et al examined the effects of incorporating different amounts of wood sawdust waste (WSW) into mortar reinforced with varying curing times of 7, 30, and 90 days. They added 0%, 0.5%, 1%, and 3% of WSW to the mortar mixture, and results showed 0.5% of WSW gave the highest value of compressive strength, then it went downhill. Despite this, the researchers noted that WSW has a favorable influence on the post-fracture characteristics of mortars, leading to improved ductility.

E. Straw Ash, Micro silica

Pandey and Kumar (2019) used 5%, 10%, 15%, 20%, 25%, and 30% of rice straw ash (RSA) and 2.5%, 5%, 7.5%, and 10% of micro silica (MS) to improve the properties of cement paste. The results, presented in Table 13, showed that using 5% of RSA and 7.5% of MS as replacements in cement resulted in the highest pozzolanic reaction, and a blend of 10% of RSA and 7.5% MS was the most economical. Blending rice straw ash with cement paste up to 30% led to improvements in the initial and final setting times. The study also demonstrated the possibility of using an admixture (cement with RSA and MS) in concrete that requires high strength and durability. However, further research is needed to confirm these properties and to determine the appropriate conditions to achieve them.

Table 12: Mix Proportions of Cementitious Materials (Pandey and Kumar .2019)

	Mix																
Mix Proportion (by weight)	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R 100**	**M 100**	**M1**	**M2**	**M3**	**M4**	**R1 M2**	**R1 M3**	**R2 M2**	**R2 M3**
OPC	100	95	90	85	80	75	70	-	-	97.5	95	92.5	90	90	87.5	85	82.5
RSA	-	5	10	15	20	25	30	100	-	-	-	-	-	5	5	10	10
MS	-	-	-	-	-	-	-	-	100	2.5	5	7.5	10	5	7.5	5	7.5
HRWR Dosage (% by weight.)	-	0.4	0.6	0.75	0.95	1.20	1.35	-	-	0.3	0.35	0.45	0.56	0.85	1.05	1.20	1.45

Table 13: Normal Consistency, Initial & Final Setting timesof Pastes (Pandey and Kumar. 2019).

	Mix																
Test	**R0**	**R 1**	**R 2**	**R 3**	**R 4**	**R 5**	**R 6**	**R 100**	**M 100**	**M1**	**M 2**	**M3**	**M 4**	**R1 M2**	**R1 M3**	**R2 M2**	**R2 M3**
Consistency (%)	100	95	90	85	80	75	70	-	-	97.5	95	92.5	90	90	87.5	85	82.5
Initial Setting Time (min)	-	5	10	15	20	25	30	100	-	-	-	-	-	5	5	10	10
Final Setting Time (min)	-	-	-	-	-	-	-	-	100	2.5	5	7.5	10	5	7.5	5	7.5

F. Soft Drink Bottle Caps, Beverage Tins, Steel Powder, and mild steel lathe waste

Murali et al (2012) investigated the use of soft drink bottle caps (SDBC), beverage tins (BT), steel powder (SP), and mild steel lathe (MSL) waste, in fiber-reinforced concrete (FFC). As presented in Table 14, by adding SP to FFC, the compressive strength reached its highest value and showed a 41.25% increase compared to conventional concrete and increased the split tensile strength by 40.87% compared to regular concrete. Soft drink bottle caps waste (SDBC) yielded the most favorable outcomes for flexural strength, exhibiting a notable 25.88% enhancement in contrast to regular concrete.

Table 14|: Displays the results of the compressive strength test, split tensile strength test, and flexural strength test (Murali et al, 2012)

Test Number	Notation	Compressive Strength Values (N/mm^2)	Split Tensile Strength Values (N/mm^2)	Flexural Strength (Values)N/mm^2
1	C (conventional)	28	2.72	3.4
2	W1 (SDBC)	33.33	3.42	4.28
3	W2 (BT)	31.11	3.44	3.73
4	W3 (SP)	39.55	3.83	4.2
5	W4 (MSL)	34	3.43	3.84

H. Steel Slag (SS)

Steel slag has proven its effectiveness as an effective alternative to concrete and pavement and protects it from environmental damage (Gencel et al., 2021). The slag is composed of silicon, ferric, calcium, aluminum, and magnesium oxides, as well as elite, larnite, brownmillerite, and ferrite (Martins et al., 2021). Nonetheless, the slag's hydraulic properties, while present, are significantly lower compared to those of Portland cement (Nasrudin et al., 2022). Steel slag (SS) can be used as a substitute for fine or coarse aggregate in concrete without significantly affecting the properties of the concrete. The tabular data presented in Table 15 serves to demonstrate the improvement in some concrete properties because of using steel slag (SS) as a replacement for coarse aggregate in concrete. The results showed an improvement in the strength and durability of the mix, as well as improved resistance to environmental degradation. These findings are indicative of the potential benefits of utilizing steel slag as a sustainable and effective alternative to traditional concrete constituents and offer important insights into the ongoing efforts to develop more efficient and eco-friendly construction practices.

Table 15: Mechanical properties of steel slag concrete (Nasrudin et al, 2022)

	References			
	(Saxena et al 2018)	**(Guo et al 2018)**	**(Baalamurugan et al 2021)**	**(Pang et al 2015)**
Aims	Searching the impact of using (15%-75) of steel slags (SS), as an alternative for coarse aggregate on concrete properties	Studying the influence of replacement sand by steel slag (SS) on compressive strength.	Replacing coarse aggregate with furnace steel slag for induction furnace and studying the effect on its properties	Developing the strength of concrete through mixing seel slag (SS)as an alternative to aggregates
Results	The results showed an increase in compressive strength, specifically by the addition of 50% steel slag, after 28 days. And the same for elasticity modulus, and flexural strength	improvement in static and dynamic compressive strength by adding 20% of steel slag	Using 100% of fine aggregate and 40% coarse aggregate of furnace steel slag , the outcomes showed increasing in the values of compressive strength, density, and radiation protection qualities	Increasing by 20% in compressive strength after 28 days

I. Ceramic waste

The use of ceramic waste in concrete has become an increasingly popular approach in recent years, owing to its potential to enhance the characteristics of concrete. While simultaneously addressing concerns related to sustainability and waste reduction. By incorporating ceramic waste into concrete mixes, it is possible to achieve significant improvements in compressive strength, flexural strength, and other key performance indicators, all while reducing the environmental impact of construction activities. Moreover, the use of ceramic waste can help to mitigate the depletion of natural resources such as sand and gravel, which are commonly used as concrete aggregates (Kou et al 2011; Marinković et al 2016). As such, the incorporation of ceramic waste represents a promising avenue for the development of more sustainable and resilient construction practices in the years to come. Table 16 provides evidence that the use of ceramic waste as a substitute for traditional concrete aggregates is likely to result in a reduction in workability, as evidenced by a decrease in the slump value of the concrete. The slump in value tends to increase as the water-cement ratio is raised, regardless of the percentage of ceramic waste used as an aggregate replacement.

Table 16: The workability of ceramic waste as an aggregate replacement (Nasrudin et al, 2022)

	References		
	(Awoyera et al 2018)	**(Daniyal et al 2015)**	**(Rashid et al 2017)**
Aims	This study's goal is to investigate the effect of using varying percentages ranging from 0% to 100% of the fine ceramic aggregate (FCA) and 0% to 75% of the coarse ceramic aggregate (CCA) on slump flow values.	Using (10%-50%) of ceramic waste as an alternative to coarse concrete aggregate in concrete	Utilization of ceramic waste aggregate as a replacement for natural aggregates to sustainable concrete development.
Results	Slump value reached 40 mm at 100% of (CCA), so low workability	The results indicated that because of the high-water absorption and the angular shape of the ceramic waste and its quantity, it led to a decrease in the workability and thus a decrease in the slump values.	As the amount of ceramic waste content was increased, an observed lowering in the workability of concrete.

In a recent study, Rasoo et al (2022) used different proportions of black tea waste (BTW) which were (2.5%,5%, and 7.5%) instead of using cement. And (5%, 10%, 15%, and 20%) of waste brick powder (WBP) and ceramic tiles powder (CTP) as an effective alternative to fine aggregate. The largest strength improvement at 28 days was observed for samples with M3 (15% brick powder and ceramic tiles + 7.5% black tea), which showed a 22.56% increase. The ideal replacement percentage was also M3. The modified mortar mixtures showed high flexural strength (approximately 51.41% improvement) compared to control samples for 28 days. Additionally, incorporating brick powder, ceramic tiles powder, and black tea waste reduced the absorption ratio and density, improving the water insulation of the cement mortar mixture. In their 2021 study, Soomro et al. replaced cement and coarse aggregate with 10% waste marble powder (M.P) and 10%, 20%, and 30% coarse aggregates, respectively. They conducted a slump test Fig.4 and measured the compressive strength. The results indicated that the slump value decreased from 60mm to 50mm, 40mm, and 30mm when using 10% (M.P) + 10% (C.T), 10% (M.P) + 20% (C.T), and 10% (M.P) + 30% (C.T), respectively. Moreover, the compressive strength decreased as indicated in Table 17.

Figure 4: Conducted a slump test (Soomro et al. 2021)

Table 17: Results of Average Compressive Strength Test (Soomro et al 2021)

Specimen Code	Mix Type	Values of Compressive Strength (M Pa)	Values of Compressive Strength (MPa)
		At 7 Days	At 28 Days
C_1	Control mix	18.83	22
C_2	10% (M.P) +10%(C.T)	17.72	21
C_3	10% (M.P) +20%(C.T)	16.91	19
C_4	10% (M.P) +30%(C.T)	17.63	20

J. Glass powder

Waste Glass powder is a waste product that has proven to be highly effective in improving concrete strength, durability, and many other properties, while also contributing to sustainability efforts through waste reduction. Glass powder can be used as a partial substitute for cement or aggregate, increasing compressive and flexural strength, as well as resistance to corrosion, alkali-silica reaction, and sulfate attack (Taha et al, 2017, Hossain et al, 2013, and Xu et al, 2018). However, the incorporation of glass powder in concrete can have an impact on workability and setting time, and careful consideration of mix design is crucial to achieving optimal performance. The incorporation of glass powder in concrete has garnered significant attention in recent years as a potential means of change and development in cement and concrete features such as workability, strength, and durability, while also promoting sustainable practices by reducing waste. Table 18 sheds light on the impact of using glass powder as a substitute for cement or aggregate in concrete and its effect on the workability and thermal stability of the resulting material.

Table 18: The results of glass powder as a material replacement in cement (Nasrudin et al, 2022)

	Reference		
	(Afshinnia et al 2016)	**(Dong et al 2021)**	**(Pan et al 2017)**
Results	The use of glass powder as a substitute for aggregates in concrete reduces the slump values, resulting in low workability. On the other hand, using glass powder as a substitute for cement leads to an increase in slump values, resulting in high workability.	Results showed that the thermal stability of concrete produced with waste glass was better than that of natural concrete.	Due to the low thermal conductivity of glass powder, the results showed that heat transfer was slower in concrete containing 20% glass powder compared to natural concrete. This indicates that glass powder takes a longer time to reach the target temperature.

K. Recycled Concrete Paving, Crushed Ceramic Bricks, and Burnt Sewage Sludge

In their study, Łukowski et al (2022) used recycled aggregates as a replacement to investigate the properties of cement concrete. As Table 19 shows, they used 25% and 50% of recycled concrete paving (RCP), crushed ceramic bricks (CCB), and burnt sewage sludges (BSS) as replacements for sand (fine aggregate). Table 20 shows the results of different tests. Tests have proven the possibility of using (RCP, CCB, and BSS) as effective substitutes in concrete for aggregates. On the other hand, it is possible to increase the strength and hardness of concrete and reduce the depth of water permeation.

Table 19: The compositions of concrete mixes (Łukowski et al. 2022)

Concrete Designation	Cement	Water	Sand 0/2mm	Crushed Concrete	Crushed Bricks	Sewage Sludge	Gravel 2/8 mm	Gravel 8/16 mm	SP
	(kg/m^3)								
CR0	320	176	580	0	0	0	708	560	4.8
CC25	320	176	448	98	0	0	708	560	4.8
CC50	320	176	299	196	0	0	708	560	4.8
CB25	320	176	448	0	63	0	708	560	4.8
CB50	320	176	299	0	126	0	708	560	4.8
CSS25	320	176	448	0	0	36	708	560	4.8
CSS50	320	176	299	0	0	72	708	560	4.8

Table 20: Test results (Łukowski et al. 2022)

Test Type		Component						
		CR0	CC25	CC50	CB25	CB50	CSS25	CSS50
Compressive Strength (MPa)	After 7 Days	43.7 ± 1.3	37.4 ± 1.4	36.5 ± 2.1	39.1 ± 1.6	42.1 ± 1.3	36.2 ± 1.6	33.8 ± 1.8
	After 28 Days	49.9 ± 1.8	45.3 ± 2.3	44.4 ± 1.9	46.6 ± 1.4	51.7 ± 1.8	44.9 ± 2.6	43.4 ± 2.8
Slump Flow (mm)		200	140	120	150	135	110	90
Tensile Splitting Strength After 28 Days (MPa)		3.3	3.2	2.8	3.4	3.8	3.2	2.7
Water Penetration Depth (mm)		36	39	41	38	40	46	52
Thermal Conductivity Coefficients (W/Mk)		2.3	2.06	1.87	2.18	1.89	2.08	1.90
Volumetric Specific (10^6 J/M^3.K)		1.94	1.89	1.70	1.92	1.72	1.87	1.77
Thermal Diffusivity ($10^{-6} M^2/S$)		1.19	1.10	1.10	1.14	1.11	1.12	1.08

L. Banana And Palm Leaf Sheath Fibers

The use of natural fibers such as banana and palm leaf sheath fibers in concrete has gained increasing attention in recent years as an environmentally sustainable alternative to traditional reinforcing materials. Several studies have investigated the mechanical properties and durability of concrete reinforced with these fibers. A study by Mehta et al (2018) investigated the effect of banana fiber on the compressive strength and splitting tensile strength of concrete. The results showed that the addition of banana fibers up to 1% by weight of cement significantly improved the compressive and splitting tensile strength of the concrete. A study by El-Tawil et al (2019) examined the durability of concrete reinforced with palm leaf sheath fibers. The researchers found that the addition of these fibers improved the resistance of concrete to chloride ion penetration and increased its durability in harsh environmental conditions. Ganesan et al (2017) investigated the microstructure and mechanical properties of banana fiber-reinforced concrete. The researchers found that the addition of banana fibers improved the microstructure of the concrete and enhanced its mechanical properties. Saad et al (2022) found that adding 1-3% of banana and palm leaf sheath fibers to concrete did not improve its compressive strength significantly. However, the tensile strength of high-strength concrete increased significantly with the addition of 2% PLSF. PLSF was found to be more effective than BF in enhancing the mechanical properties of HSC, and both fibers improved the brittle behavior of HSC. The study suggests the potential use of natural fibers, particularly PLSF, as reinforcement agents in concrete.

M. Pumice And Olive Stone

Fine aggregate (sand) was substituted with 5%, 10%, and 15% of Pumice & olive stone in concrete analysis. The results indicated that the compressive strength of mortar cement was increased by 7% to 28% when using olive and pumice stones treated with superplasticizer, which is comparable to standard values. The water absorption of mortar cement was slightly reduced when using treated olive and pumice stones. The density was significantly decreased when using untreated olive and pumice stones. Furthermore, the thermal conductivity was reduced by 22% to 54% at ratios of 10% and 30%, respectively, when using untreated olive and pumice stones (Abdulkarem et al., 2020).

II. CONCLUSION

Based on the discussed research, the significance of utilizing waste materials in concrete and construction works can be observed. These materials have demonstrated their importance in engineering and their role in environmental preservation. The following points summarize the most significant findings

- Slump values were decreased by replacing sand with CBA. After Seven days and at 10% CBA, and after twenty-eight at 0% CBA observed the highest compressive strength, and at 10% CBA after 56 days, tensile strength followed a similar trend. Using (25-35) % of fly ash and 20% of bottom ash led to an enhancement in the strength of the concrete. And replacement sand with 15% of CBA improved the sustainability of SCC. CBA can replace traditional aggregates in concrete production without compromising strength, although concrete density decreases.
- Using plastic and polypropylene fiber waste as a substitute in concrete components leads to positive outcomes in the properties of concrete such as compressibility, and durability. Polypropylene fibers

possess the capacity to modify the fracture behavior of a structural element by transmuting its failure mode from a punching-dominant mechanism to a flexural-dominated mechanism, which enhances the use of this waste in construction.

- Cassava peel ash and wood ash as a substitute for ordinary Portland cement can help reduce environmental pollution, but high percentages of replacement may not be suitable for structural concrete.
- Recycled fibers which came from carpet waste are a promising approach to waste management and sustainability. Wang showed the feasibility of adding carpet fibers as reinforcement in concrete mixtures.
- Replacing 20% of the cement and fine aggregate with wood waste resulted in the production of structural concrete blocks, whereas 25% and 30% replacement produced lightweight blocks with satisfactory strength.
- Using varying proportions of RSA and MS in cement paste resulted in a cementitious material with increased setting times and the potential for high compressive strength. Further research is needed to investigate its durability.
- Fiber-reinforced concrete incorporating steel powder waste, (SDBC) waste, (BT), and (MSL) waste showed improved mechanical properties compared to conventional concrete. Steel powder waste had the highest compressive and split tensile strength, while soft drink bottle caps waste showed the best results for flexural strength.
- The composition of slag includes various oxides and minerals, but its hydraulic properties are lower than Portland cement. However, using steel slag as an aggregate replacement in concrete showed marked improvements in mechanical performance and durability. These findings indicate the potential of steel slag as a sustainable alternative to traditional concrete materials.
- Evidence suggests that incorporating ceramic waste in concrete as a substitute for traditional aggregates can lead to a reduction in workability, indicated by a decrease in the slump value of the concrete. However, the use of ceramic waste offers the potential to improve the mechanical properties of concrete and reduce environmental impact.
- Glass powder has proven effective in improving the characteristics of concrete and contributes to sustainability efforts. It can substitute cement or aggregate to enhance resistance to corrosion, alkali-silica reaction, and sulfate attack. However, it may affect workability and setting time.
- The incorporation of recycled materials such as CCB and BSS as a partial substitute for sand shows promise for sustainable construction practices, but further research is needed to optimize their use.
- Sand content was substituted with Pumice & olive stone at varying percentages. The addition of superplasticizer-treated stones led to a 7% to 28% upsurge in compressive potency, concomitant with a decrease in water absorption. So, using untreated stones resulted in reduced density and decreased thermal conductivity by up to 54% at a 30% ratio.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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