

Utilisation of Cow Dung Ash and Ceramic Waste in Concrete: A Strength-Based Study

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Abstract. As the demand for river sand increases and its availability decreases, there is an urgent need to identify sustainable alternatives. This study investigates the viability of using cow dung ash (CDA) as a partial replacement for cement and ceramic waste (CW) as a fine aggregate substitute in concrete. The experimental program included incorporating 5% CDA by weight of cement and varying the CW content to 15 %, 30 %, and 45 % by weight of fine aggregate. The physico-mechanical properties were assessed, and the combination of 5 % CDA and 30 % CW produced the best compressive and tensile strength results. Higher CW contents resulted in no significant improvements. The 28-day results confirmed a significant long-term improvement, with mixes containing CDA and ceramic waste achieving 6.9 % to 17.2 % higher compressive strength than the control. Gains in split tensile strength of 8 % to 16 % show how CDA and ceramic waste work together to improve the microstructure of concrete. These improvements demonstrate ceramic waste as an innovative and sustainable partial replacement that offers advantages in terms of strength and durability.

1 Introduction

Rapid urbanization and industrialization in countries such as India result in depletion of natural resources for infrastructure and amenities. Given the depletion of these natural resources for concreting, research is currently being conducted to reduce their consumption. There is a need to save natural resources. Such as aggregate and sand, by using alternative materials that are either reused or discarded as waste. People are looking for alternative materials that can be used as additives or partial substitutes for conventional concrete materials. This can help save natural resources and ensure their availability for future generations. In the building sector, particularly in concrete manufacturing, basic construction

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materials are among the major contributors to environmental issues. Cement, a primary component of concrete, significantly contributes to carbon dioxide emissions due to its production process. Owing to the urgent need for sustainable construction methods, engineers and researchers have been exploring alternative materials to partially replace cement in concrete compositions. To minimize ecological effects while preserving and improving the characteristics of concrete, this study focuses on using cow dung ash (CDA) and ceramic waste (CW) materials as partial replacements for cement and river sand. Ceramic waste can partially enhance concrete quality by shifting out cement and fine aggregates. Advancements in concrete technology have the potential to reduce natural resource consumption. Efforts have shifted towards recovery, resource reuse, and alternative solutions to reduce environmental hazards. In addition to agricultural waste, a variety of industrial by-products have shown partial replacements for fine aggregates in the composition of concrete. When properly incorporated, these resources offer an eco-friendly way to dispose of industrial waste and improve the performance of concrete. In addition to lowering carbon emissions, using these by-products in concrete strength and long-term durability increases.

2 Reviews of Literature

The effect of CDA in cement was investigated, and the results indicated that an increase in CDA content leads to a reduction in workability, bulk density, and compressive strength, while water absorption increases. [1]. CDA used as sand replacement (3-15%) improved electromagnetic shielding effectiveness up to 20 dB at 10 GHz, with conductivity $\sim 10^{-2}$ S/m, but reduced compressive strength beyond 15% replacement [2]. The mortar with ceramic waste powder and fine particles not only increased the compressive and tensile strength but also improved chloride and sulfate resistance and lowered porosity and cracking by better microstructure formation [3]. Conducted a study on the utilization of CDA and fly ash as partial substitutes for cement. This paper shows that CDA and fly ash replace by 10 % and 20 % of the concrete materials. Increasing the replacement percentages of materials decreases the strength and workability of concrete. Studies done by the use of CDA as a substitute for cement. The results indicate that 10 % CDA in concrete performed well in floor and wall applications [4]. In Ziala Village, Bangladesh, biogas plants convert cow dung into renewable energy and nutrient-rich fertilizer, reducing fertilizer costs and firewood use, improving environmental conditions and socioeconomic status, although waste mismanagement persists [5].

Cement mortar specimens containing ceramic waste powder (CWP) in the range of 525% exhibited higher compressive and flexural strengths after heating at 200°C-800°C [6]. Lower porosity and better thermal resistance were found by XRD and SEM investigations, respectively [7]. An in-depth investigation was carried out on concrete incorporating CDA under fresh water exposure conditions. The findings indicated that CDA can contribute to the development of high-performance concrete with enhanced durability and sustainability. The results show low thermal conductivity and lightweight. Micro ceramic powder (3.5 μ m) from ceramic waste replaced cement upto 40% achieving >80 MPa compressive and 10 MPa flexural strength after 180 days, At 20% replacement, 9.6% cost savings and 6.62% energy reduction were observed [8]. Experimental studies demonstrated that the use of crushed glass as aggregate and finely ground glass powder enhances the durability characteristics of concrete. [9].

The paper examines the use of sustainable concrete with 15% cow dung ash replacing cement and 1.5% plastic waste used as an admixture [10]. Experimental results from static load tests on reinforced beams indicated that the use of this concrete enhanced the load capacity, flexural strength, stiffness, and decreased deflection when compared with conventional M20 concrete, thereby showcasing superior

mechanical and environmental performance [11]. Concrete with 10%-20% ceramic waste powder (CWP) has been found to have lower strength. However, a ternary blend (50% cement, 15% CWP, 35% BFS) managed to achieve a 56, day strength and durability that is comparable to the synergistic pozzolanic reactions. Dry cow dung powder effectively removed Cr (III), Cr (VI), and Cr (II) from wastewater following pseudo-second-order kinetics ($R^2 \approx 0.997$), demonstrating eco-friendly heavy metal adsorption potential [12].

The study shows cow dung ash 8-10% and corn stalk ash 7.5% partially replace cement, maintaining strength while improving sustainability overall [13]. Concrete containing 2.6-3.5% CDA, 1% coconut fiber improved compressive and tensile strengths by 55-70% at 28 days, offering economical and eco-friendly benefits [14]. This study investigates whether cow dung-based adsorbents are cost-effective and efficient for removing dyes and heavy metals from water, exhibiting high uptake capacities. Langmuir/Freundlich isotherms and pseudo-second-order kinetics best describe their adsorption behavior [15].

3 Experimental Program

3.1 Materials Used

Ordinary Portland Cement (OPC) of grade 53 was used as a binding material in this study. River sand, as per Zone II, IS 383, was used as the fine aggregate. CDA and CW were used as partial substitutes for cement and river sand. 20 mm size coarse aggregate was used. Fig. 1 presents the Ordinary Portland Cement (OPC) and Cow Dung Ash (CDA) used in this study to illustrate its physical appearance in the concrete mix.



Fig. 1. Physical appearance of OPC and CDA used as a partial replacement of cement.

Cow dung was dried and burned under controlled conditions, then sieved and occasionally ground. Approximately 5 kg of dried cow dung was subjected to uncontrolled burning at a temperature of 600°C to produce 1 kg of CDA. CW must be crushed and sieved to a standard size. Table 1 presents the chemical compositions of OPC and CDA. To determine the fine modulus, a sieve analysis test was conducted, and the grading curve was drawn according to IS 383-1970, as shown in Fig. 2. The graph indicates that CW has a fineness modulus of 2.38, whereas river sand has a fineness modulus of 2.8. CW particles, on the other hand, closely resemble the form of river sand. The fine aggregate and CW are located between the minimum and maximum ranges of Zone II according to the sieve analysis graph. Table 2. Table 2 presents the physical characteristics of the materials used in the investigation. CDA can be produced in rural or agricultural locations with abundant cow dung. The particle size of CDA was 80 µm. This reduces the concrete's heat of hydration, CO₂ emissions, and landfill usage. It is extremely cheap, or even free, particularly in rural regions. It is economical in developing or rural areas, especially for eco-projects or affordable homes.

Table 1. The relation between CDA Composition Analysis and the ASTM OPC standard.

Chemical Composition	Oxide content (%)	
	OPC	CDA
SiO ₂	18.78	79.22
CaO	54.66	3.71
Al ₂ O ₃	2.87	5.62
MgO	3.46	1.88
Fe ₂ O ₃	4.03	2.98
SO ₃	1.13	0.19
L.O.I	4.83	4.25
IR	9.69	1.65

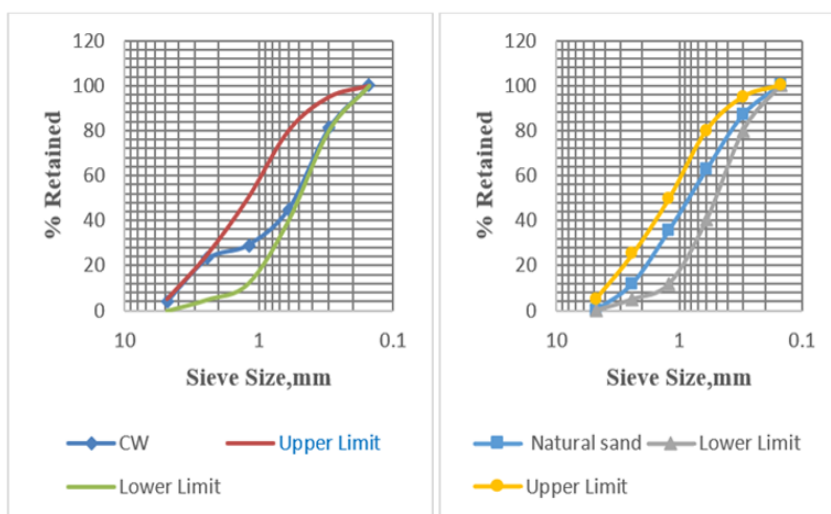


Fig. 2. Grading curve of river sand and CW

Table 2. Physical characteristics of raw materials

S.No.	Materials	Specific gravity	Water absorption (%)	Fineness modulus
1	Cement	2.89	-	-
2	Fine aggregate	2.70	1	2.8
3	Coarse Aggregate	2.64	1.4	-
4	CDA	2.78	-	-
5	CW	2.00	2.13	2.38

CW is widespread in metropolitan areas, especially on building and demolition projects. Waste material is typically free or extremely inexpensive. CW is economical, particularly for green buildings or urban recycling projects.

3.2 Methodology and Mix Proportions

The mix designs were meticulously calculated for M 20 grade as per IS 10262:2009 to identify the optimal replacement levels of cement and fine aggregate that strike a balance between potential material challenges and enhance mechanical properties. The mix ratio of 1:1.5:2.6 was used to cast cubes and cylinders with a W/C ratio of 0.45. The aim of the study was to investigate the effects of substituting 5 % CDA for OPC and adding at a range of 15 %, 30 %, and 45 % CW for river sand. The experimental program involved casting and testing 36 cubes (150 mm× 150 mm× 150 mm) and 36 cylinders (150 mm × 300 mm) to determine the compressive and split tensile strengths of concrete. The pH of potable water was 6.76, which was used in the mix. The concrete mix proportions are shown in Table 3.

Table 3. Mix proportions of concrete with varying ceramic waste and constant CDA

Mix	PERCENTAGE (%)	CEMENT (kg)	FA (kg)	CA (kg)	CERAMIC WASTE (kg)	CDA (kg) (5%)
M1	0	1.44	2.23	3.71	-	-
M2	15	1.368	1.9	3.71	0.33	0.072
M3	30	1.368	1.56	3.71	0.67	0.072
M4	45	1.368	1.23	3.71	1.00	0.072

3.3 Testing on Fresh and Hardened Concrete

This contains some fresh state concrete properties tests such as slump flow, flow table and Vee – Bee consistometer as shown in Fig. 3. Fig. 4 shows the casting, curing, and testing of the specimens.



Fig. 3. Workability test on Concrete

Table 4. Test Results in Fresh Concrete

SI.NO	Basic test	Test value	CW (average)	Standard value
1	Slump cone test	True slump	-	-
2	Flow table test	85 %	75 – 70 %	0 to 150 %
3	Vee-Bee consistometer	10 sec	7 – 10 sec	< 20 sec



Fig. 4. Casting, Curing and Testing of Sample Specimen

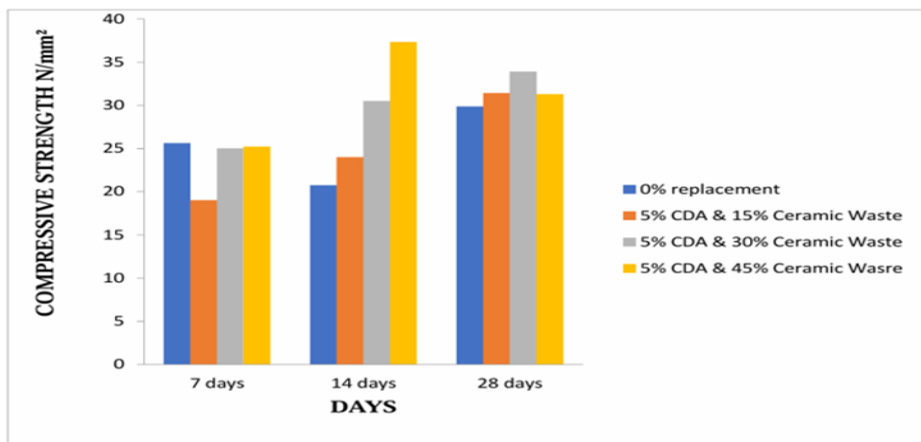


Fig. 5. Compressive Strength at different age

At seven, fourteen, and twenty-eight days of age, the compressive strength test was performed. The 28-day compressive strength for the mix containing 5% CDA and 30% ceramic waste was 32.8 ± 0.9 MPa, where ± 0.9 represents the standard deviation, shown as error bars in the graph. Fig. 5 shows that the compressive strength of CW and 5% CDA

continuously increased gradually up to 30% replacement of CW, after which it gradually decreased.

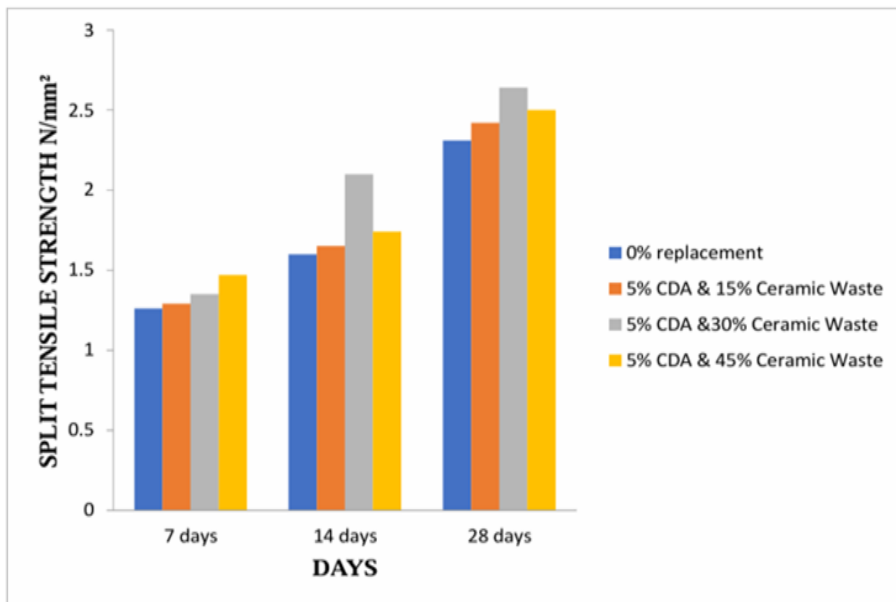


Fig. 6. Split Tensile Strength on Concrete Cylinder

28-day split tensile strength for 5% CDA and 30% ceramic waste was 2.65 ± 0.04 MPa, where the error bar represents the standard deviation of the test results. At seven, fourteen, and 28 days of age, the split tensile strength tests were performed, and showed that the strength of CW and 5 % CDA is continuously increased up to 30% replacement of CW and then gradually decreased, as can be deduced in Fig. 6.

4 Results and Discussion

The consistency characteristics of the mix containing 5 % of CDA and varying percentages of CW showed improvement in the workability of concrete. This is attributed to the fineness and porosity of CDA. The results from the flow table test illustrated that the addition of CDA and CW enhanced the flow characteristics and thereby improved the workability. The incorporation of 5 % cow dung ash shows improvement in the compressive strength, and this was also observed. In general, the use of CDA instead of cement helps in reducing CO₂ emissions from cement manufacturing and greatly protects the environment by lowering greenhouse gas emissions and promoting sustainability. At 30 % replacement level of CW, optimum strength was achieved and reported. This study offers an alternate recycling option for cow dung and CW and provides a viable, sustainable, and eco-friendly cementitious material for the creation of green composites.

5 Conclusion

The test results indicated that the CW varies percentage (15 %, 30 %, and 45 %) and the CDA constant percentage (5%) can be substituted for river sand and cement in concrete. In general, the ultimate load-carrying capability of concrete increased with CW and CDA replacement

compared to ordinary concrete. When the percentage of CW increases further, there is a decreasing trend in the strength. This investigation validated the potential combination of CDA and CW as a partial substitute for cement and river sand. However, further studies could help detect the most effective combinations of CDA with other cementitious materials that can achieve improved mechanical properties and sustainable solutions in the construction industry. The findings show that incorporating CDA and CW into concrete not only improves mechanical performance but also promotes sustainable construction by reducing cement consumption, minimizing river sand exploitation, and mitigating environmental impacts through effective waste utilization.

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