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# Strength Properties and Potentials of Concrete Produced with Crushed Cow Horns as Fine Aggregate Replacement

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## ABSTRACT

This study investigates the potential of crushed cow horns (CCH) as a partial replacement for fine aggregates in concrete production. Six concrete mixes were prepared with varying replacement levels of sand by CCH (0%, 20%, 40%, 60%, 80%, and 100%). Standard tests were conducted on fresh and hardened concrete, including slump, density, compressive strength, split-tensile strength, and flexural strength. Results show that replacement levels above 60% led to specimen failure under self-weight. At 20% and 40% replacement, compressive strength decreased by 15.74% and 16.86%, respectively, compared to the control. The study concludes that CCH has potential as a lightweight aggregate in concrete production at low replacement levels, contributing to sustainable waste management.

**Keywords:** Concrete, Lightweight aggregates, Crushed cow horns, Fine aggregate replacement, Compressive strength.

## INTRODUCTION

Concrete is the most widely used construction material globally, second only to water. However, its sustainability has been questioned due to the large-scale depletion of natural aggregates (Mehta and Monteiro, 2014). The extraction of sand for fine aggregates has created significant environmental challenges, including riverbed degradation, erosion, and loss of aquatic habitats (Koehnken *et al.*, 2020). Because of this, alternative aggregate sources from agricultural and animal waste materials are gaining increasing research interest as a pathway toward sustainable construction practices (Mangi et al., 2019). Cow horns, which are largely disposed of as abattoir waste, are fibrous, lightweight, and rich in keratin (Sharma and Gupta, 2016). Their disposal, often through open dumping or burning, poses environmental hazards and contributes to pollution. In the search for sustainable construction solutions, researchers are beginning to explore animal by-products such as horns, hooves, feathers, and other keratin-rich wastes as potential partial replacements for natural aggregates in concrete (Tesfaye et al., 2017). Given their composition and availability, cow horns may provide a viable substitute for sand in concrete mixes, particularly in regions where they are abundantly produced as waste. Using cow horns not only reduces environmental waste and promotes circular economy practices but may also lower the demand for natural sand. This study therefore investigates the application of crushed cow horn as a fine aggregate replacement in concrete, with a focus on evaluating its mechanical properties, durability potential, and suitability for sustainable construction.

## LITERATURE REVIEW

Several studies have evaluated the use of alternative aggregates sourced from industrial and agricultural wastes. Adeyanju and Manohar (2011) reported that the inclusion of steel fibers and iron filings significantly influenced the thermal and mechanical properties of concrete. Vasudevan (2016) examined iron sand as a partial replacement material and found that the optimal substitution level for achieving improved strength was around 5%. Similarly, Olutoge (2010) investigated sawdust and palm kernel shells as aggregate replacements and concluded that lightweight concrete could be produced at a reduced cost without completely compromising strength. Malik et al. (2013) demonstrated that waste glass powder can effectively replace up to 30% of sand in concrete mixes, resulting in improved compressive strength. More recently, research on animal by-products such as cow bones and horns has indicated favorable mechanical properties, suggesting potential for their use in sustainable concrete production (Fapohunda et al., 2016; Oloko et al., 2017). Many researchers have explored using agricultural, animal and industrial wastes as partial replacements for natural aggregates or cement in concrete, aiming to reduce cost, save natural resources, or improve sustainability. In general these studies show that some waste materials may be usable up to certain limits without severely compromising strength, though workability, density and durability may be affected.

Oloko, Ogarekpe, Agunwamba, Idagu, Bejor, Eteng, Ndem, & Oloko (2017) studied *burnt and crushed cow bones* (BCCB) used as partial replacement for fine aggregate (sand) in concrete using mix ratios 1:2:4 and 1:1½:3. They replaced fine aggregates with BCCB at 0%, 10%, 20%, 30%, 40% and 50%. Their results showed that water–cement ratio increased as BCCB content increased, and compressive strengths at 28 days ranged from about 16.49 N/mm² to 24.29 N/mm² for mix 1:2:4, and from about 18.71 N/mm² to 29.73 N/mm² for mix 1:1½:3. They observed that replacement up to some moderate level can be feasible. (Oloko et al., 2017)

Another related work is by Fapohunda, Shittu, Aderoju, & Abiodun (2016) who tested *crushed cow bone (CCB)* as partial or full replacement of fine aggregate (sand) by weight in concrete. They replaced sand with CCB in increments of 10% up to 100%. They found that workability goes down (the concrete becomes less workable) as more CCB replaces sand. Also, density and compressive strength decrease with increasing replacement but they observed that **up to about 20% replacement** by weight, the compressive strength was *not significantly different* from control concrete (Fapohunda et al., 2016).

Recent advancements in sustainable construction materials have explored the incorporation of waste-derived and bio-based materials into concrete production to improve environmental performance and reduce dependence on conventional aggregates. Studies involving animal-derived materials, particularly cow bone ash and related derivatives, have demonstrated potential in enhancing certain mechanical and durability properties of concrete. These materials, being organic-based hard tissues, exhibit characteristics such as inherent porosity, variable density, and distinct bonding behavior within the cementitious matrix.

In this context, a novel approach involving the use of cow horn as a constituent material in concrete has been introduced by the authors through a patented development (Agbede ***et al.,*** 2025). The invention, titled **Cow Horns Based Concrete** (Patent No. NG/PT/NC/O/2025/20360), provides a framework for utilizing processed cow horn fibers or particles as a partial replacement for conventional fine aggregates. Unlike bone-based materials, cow horns are primarily composed of keratin, which may influence mechanical interlocking, absorption characteristics, and overall composite behavior differently within the concrete matrix. At the time of this study, there is limited or no documented evidence in peer-reviewed literature specifically addressing the application of crushed cow horn as a fine aggregate replacement in concrete. This highlights the novelty of the present research and underscores the need for experimental validation of its engineering properties. Therefore, this study builds upon the patented concept by providing detailed laboratory investigation and performance evaluation of cow horn-based concrete under varying replacement levels.

Furthermore, insights from studies on other waste materials such as plastic aggregates, rubber particles, and agricultural residues provide a comparative framework for understanding the behavior of unconventional materials in concrete systems. These studies collectively emphasize the importance of material characterization, bonding behavior, and performance trade-offs when integrating non-traditional constituents into cement-based composites.

These two studies with cow bone are relevant because cow horns are also animal hard tissues; though horn and bone differ in composition, they may have similar issues: hardness, organic content, possible porosity, absorption, and effects on bonding. But I did not find at least at the time of this search a published study that uses crushed cow horn specifically as a fine aggregate replacement in concrete in peer-reviewed journal, so this topic might be somewhat novel.

Beyond bones and animal wastes, many studies with other waste materials help provide context. Olutoge, Quadri, & Olafusi (2012) investigated *palm kernel shell ash* (PKSA) as partial replacement of cement in

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concrete. They used PKSA for 10% and 30% replacement of cement in 1:2:4 mix and water-cement ratio of 0.5. They found that although strength of the concretes with PKSA did not exceed that of ordinary Portland cement control, the 10% replacement gave a 28-day compressive strength (~22.8 N/mm²) that was considered satisfactory. Workability and density were also somewhat affected. (Olutoge, Quadri, & Olafusi, 2012)

Other works on sawdust and palm kernel shells as fine and coarse aggregate replacements show significant drops in strength when waste content is large. For example, Usman, Idusuyi, Ojo, & Simon (2012) studied the substitution of sawdust and PKS for fine and coarse aggregate in concrete in Bauchi, Nigeria; they found reductions in compressive strength for all mixes containing sawdust and palm kernel shell, and the higher the substitution, the greater the reduction. (Usman *et al.,* 2012.)

Studies with waste glass are also informative. Gholampour, Ozbakkaloglu, Valizadeh Kiamahalleh, & Gencel (2025) considered concrete in which natural sand was replaced up to 25% by glass sand (GS) while using glass powder (GP) and other supplementary cementitious materials. They found that up to 25% replacement of sand by glass sand gave properties comparable to conventional concrete, with small losses in compressive strength and elastic modulus. (Gholampour et al., 2025) Zebilila, Mustapha, Kikaa, Adu, and Osei (2024) studied replacing sand by waste glass powder (10-30%) and found that at 20-30% replacement of sand, compressive strength of concrete is greater than or close to control concrete. (Zebilila, Mustapha, Kikaa, Adu, & Osei, 2024)

In "Structural Efficiency of Concrete Containing Crushed Bone Aggregates," researchers used crushed bone (again, mostly from animal bones) as fine aggregate replacement. They found that up to 25% replacement by weight gave reasonable compressive strength (~17.10 N/mm² at 28 days) but beyond that strength dropped sharply. (Arid Zone Journal, 2020)

**From all of this, some general patterns emerge:**

- Up to about **20-25% replacement** of fine aggregate with animal bone based materials or similar hard waste tends to be the maximum before strength drops too much.
- Workability generally decreases as the replacement increases (more water may be needed or admixtures).
- Density decreases somewhat with higher waste replacement (because animal waste materials are lighter/porous).
- Strength at early ages can be more affected; at later ages, strength tends to "catch up" somewhat—but often still lag behind the control.
- Compressive strength is most commonly measured. Flexural/tensile strength and durability (absorption, water permeability, etc.) are less frequently reported but important.

Thus, studies with cow bone and crushed bone suggest that replacing natural fine aggregate with bone material up to about 20-25% might be feasible with acceptable strength loss. Given that, one can hypothesize that *crushed cow horn* might behave similarly (or could be better/worse depending on physical / chemical differences: horn has keratin, is less mineral, more organic than bone), so careful testing is needed. Potentials include reduced cost, reduced environmental waste (animal byproducts), lighter concrete, possibly better insulation or acoustic performance (if horn causes porosity), but risks include reduced bond strength, increased water absorption, faster deterioration, or inconsistent material quality.

**Potential for Crushed Cow Horn**

Though direct studies on crushed cow horn are scarce, we can make some reasoned predictions based on the bone/animal-waste literature. Cow horn is rich in keratin and contains less mineral content than bone; it may thus be more porous, more elastic, less stiff, absorb more water, and possibly degrade (biologically or chemically) if not properly treated. If horn is crushed, cleaned, possibly heat treated or chemically stabilized, then used as partial replacement (say 10-20%) of fine aggregate, it might provide acceptable strength with reduced density. The strength properties at such replacement levels might be similar to those found with crushed cow bone (~20–25% replacement) if compaction, curing, and mix design are optimized. But replacing higher percentages will likely reduce compressive strength significantly, increase water absorption, reduce durability and workability.

**Properties of Cow Horn**

Porous materials just as cow horns are characterized by a low density. Although mechanical properties such as stiffness, toughness and strength might not be outstanding compared to bulk materials, the low density allows them to attain high specific mechanical properties. Structural biological materials, such as cancellous bone, dentine, bird beaks and feathers, hooves and horns, can be considered porous materials.

Over the last few years, structural biological materials have attracted increasing attention from materials researchers. For the most part, this interest has focused on bones (Currey JD., 1990; Spatz H-CH et al. 1996; Vashishth D, et al, 1997), teeth (Jameson MW, et al 1993; Marshall GW, et al 2001), mollusk shells and hooves elucidating the relationship between structure, mechanical properties, and their mutual interaction. Meyers and co-workers (Meyers MA, et al 2008; Chen PY, et al 2008) have published review articles on the structure and properties of structural biological materials. Horns grow on animals from the bovidae family, which include cattle, sheep, goats, antelope, oryx and waterbuck, and are tough, resilient and highly resistant to impact. In the case of male bighorn cow, the horns must be strong and durable as they are subjected to extreme loading impacts during the life of the animal and unlike antlers, will not grow back if broken. Cow Horns are not living tissue – there are no nerves and they do not bleed when fractured. On the living animal, horns encase a short bony core composed of cancellous (spongy or trabecular) bone and covered with skin, which projects from the back of the skull. The horn is not integrated to the skull and can pull away if the hide is removed.

There are quite a variety of horn shapes and sizes. Unlike other structural biomaterials (e.g. bone, tusk, teeth, antlers, mollusk shells), horns does not have a mineralized component and is composed primarily of α-keratin.

α-Keratin is a structural, fibrous protein found in wool, hair, nails, mammalian claws, equine and bovine hooves, and horns. In a-keratin glycine and alamine, the smallest amino acids, are found in high concentrations. The keratin molecules are held together by H-bonding and disulfide cross-linked bonds, due to the presence of cysteine. The disulfide bridges produce more rigidity in the structure and contribute to the insolubility of keratin. At the lowest level, two polypeptide chains (Fresa RD, 1986; Fresa RD, 1980), which belong to a family of related proteins, form two-strand coiled-coil molecules approximately 45mm in length and 1mm in diameter. These molecules are helically wound and assemble into microfibrils (called intermediate filaments, IFs), forming 'superhelical' ropes 7nm in diameter (Feughelman M., 1997). The a-helices are mainly parallel tithe long axis of the ropes. Theses Ifs are embedded in a viscoelastic protein matrix. This matrix is composed of two types of proteins – high sulfur proteins, which have more cysteinyl residues, and high glycine-tyrosine proteins, which have high contents of glycyl residues (Fresa RD, 1980).

## CONCLUSION FROM LITERATURE

The literature indicates that animal bone waste (burnt or crushed) can partially substitute fine aggregate in concrete up to about 20-25% by weight, maintaining acceptable strength (especially 28-day compressive strength), though with some loss in workability and density. Using other waste materials (glass, sawdust, PKS, etc.) supports the notion that partial replacement of fine aggregates could be sustainable and economically beneficial, provided the replacement levels are moderate and the waste material is properly processed. Because cow horn is not exactly the same in structure as bone, more specific research is needed before conclusions.

## MATERIALS AND METHODS

The materials and experimental procedures adopted in this study are based on the patented methodology developed by the authors for producing cow horn-based concrete (Agbede, Olutoge, & Agbede, 2025). The patent, **Cow Horns Based Concrete** (NG/PT/NC/O/2025/20360), outlines the processing, preparation, and incorporation of cow horn materials into concrete as a partial replacement for fine aggregates.

Cow horns used in this study were sourced from the Department of Veterinary Medicine, University of Ibadan, and subjected to a series of preparation stages including cleaning, drying, and mechanical shredding to obtain fibrous and particulate forms suitable for concrete mixing. The processed cow horn material was then incorporated into the concrete mix at varying replacement levels (0%, 20%, 40%, and higher proportions where applicable) to evaluate its influence on fresh and hardened concrete properties. The mix design followed standard procedures for conventional concrete, with adjustments made to account for the physical characteristics of the cow horn material, including its lower density and potential water absorption behavior. Concrete specimens were cast using standard moulds and subjected to curing under controlled conditions. Laboratory tests were conducted to determine workability, density, compressive strength, split-tensile strength, and flexural strength.

While the patented method provides the foundational framework for material preparation and application, this study extends the scope by incorporating systematic experimental design, sensitivity analysis, and performance evaluation under varying conditions. This approach ensures that the patented concept is rigorously validated within an engineering and scientific context, thereby bridging the gap between innovation and practical application.

**Materials**

Dangote Portland-Limestone cement (Grade 42.5, CEM II B-L) was used. Sharp river sand with specific gravity 2.65 served as fine aggregate, while crushed granite (10 mm max size) was used as coarse aggregate. The crushed cow horn (CCH) used for this research work was sourced from the Abattoir of the Department of Veterinary Medicine, University of Ibadan. Bones were detached from the horn and then sun dried. The horns were then crushed into small fibers as shown in figures 1, 2 and 3. . The physical and chemical properties of the CCH are shown in Tables 1 and 2 respectively

**Figure 1:** Cow horns sourced from Department of Veterinary Medicine, University of Ibadan

**Figure 2:** Washed Cow horns ready for shreading


**Figure 3:** Cow horn shredded using Meter saw Machine

**Figure 4:** Shredded/Crushed Cow Horn Fibers

**Figure 5:** Moulding CCH cubes using wooden frames

**Figure 6:** Dismantling the mold frame after CCH concrete is hardened

**Figure 7:** Curing CCH lightweight concrete in water

**Figure 8:** Weighing the CCH lightweight Concrete Cubes

**Table 1:** Physical Properties of Cow Horn

| PROPERTIES | TEST RESULTS |
|---|---|
| Poisson’s ratio | 0.38 |
| Color | Ash |
| Water absorption | 0.44%, |
| Dry densities | 1184 kg/m3 |

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**Table 2:** Chemical Composition of Cow Horn

| ELEMENTS | COMPOSITION (%) |
|---|---|
| Sulphur (S) | 10.00 - 81.00 |
| Molybdenum (Mo) | 7.70 - 32.00 |
| Calcium (Ca) | 2.50 - 8.32 |
| Zinc (Zn) | 1.20 - 2.40 |
| Potassium (K) | 0.41 - 1.00 |
| Copper (Cu) | 0.00 - 0.34 |
| Indium (in) | 0.30 - 1.00 |
| Rhenium (Re) | 1.70 - 3.20 |
| Aluminium (Al) | 0.00 - 0.78 |
| Selenium (se) | 0.00 - 2.70 |
| Silion (Si) | 0.00 - 0.33 |

**(Source:** Abdullahi et al, 2007**)**

**Mix Design**

Concrete mix proportion was 1:2:4 (cement:sand:coarse aggregate) with water/cement ratio of 0.6. Replacement of sand with CCH was varied at 0%, 20%, 40%, 60%, 80%, and 100%.

**Test Procedures**

Cubes (100 mm) and cylinders were cast, cured for 28 days, and tested for slump, density, compressive, split-tensile, and flexural strengths.

## RESULTS AND DISCUSSION

**Workability**

Slump values decreased with higher CCH content. 0–40% mixes had zero slump, while 60–100% showed shear slump.

**Density**

At 20% and 40% replacement, densities decreased by 13% and 15% relative to control (2410 kg/m³).

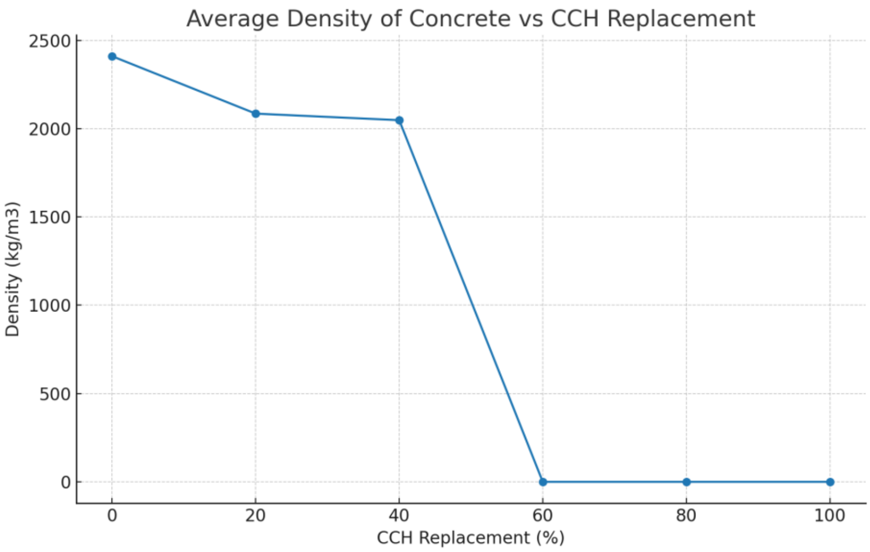


**Figure 9:** Average density of concrete vs. CCH replacement.

**Compressive Strength**

Control: 24.49 N/mm²; 20% CCH: 20.64 N/mm²; 40% CCH: 20.36 N/mm².

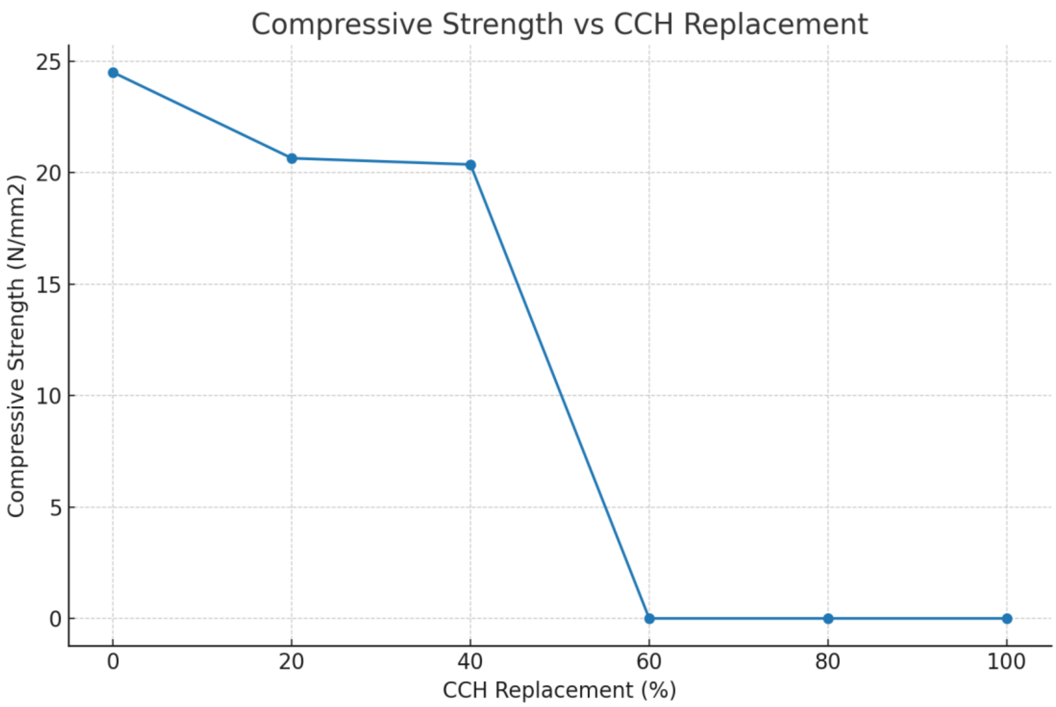


**Figure 10:** Compressive strength vs. CCH replacement.

**Split-Tensile Strength**

Control: 1.76 N/mm²; 20% CCH: 1.51 N/mm²; 40% CCH: 1.49 N/mm².

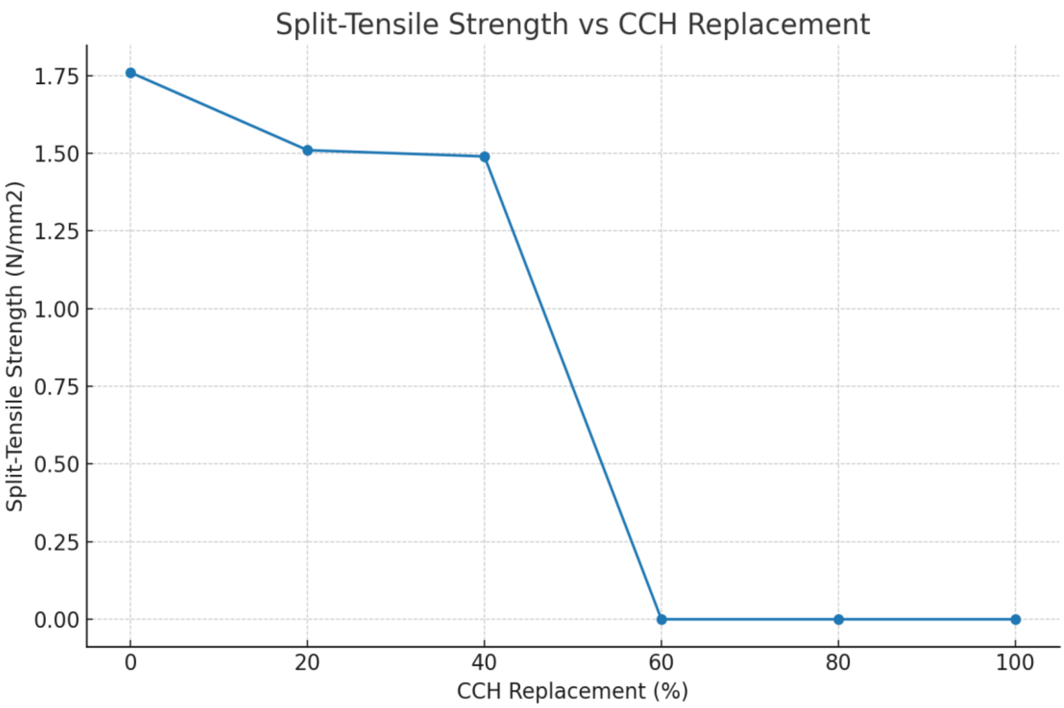


**Figure 11:** Split-tensile strength vs. CCH replacement.

**Flexural Strength**

Control: 3.87 N/mm²; 20% CCH: 3.23 N/mm²; 40% CCH: 3.15 N/mm².

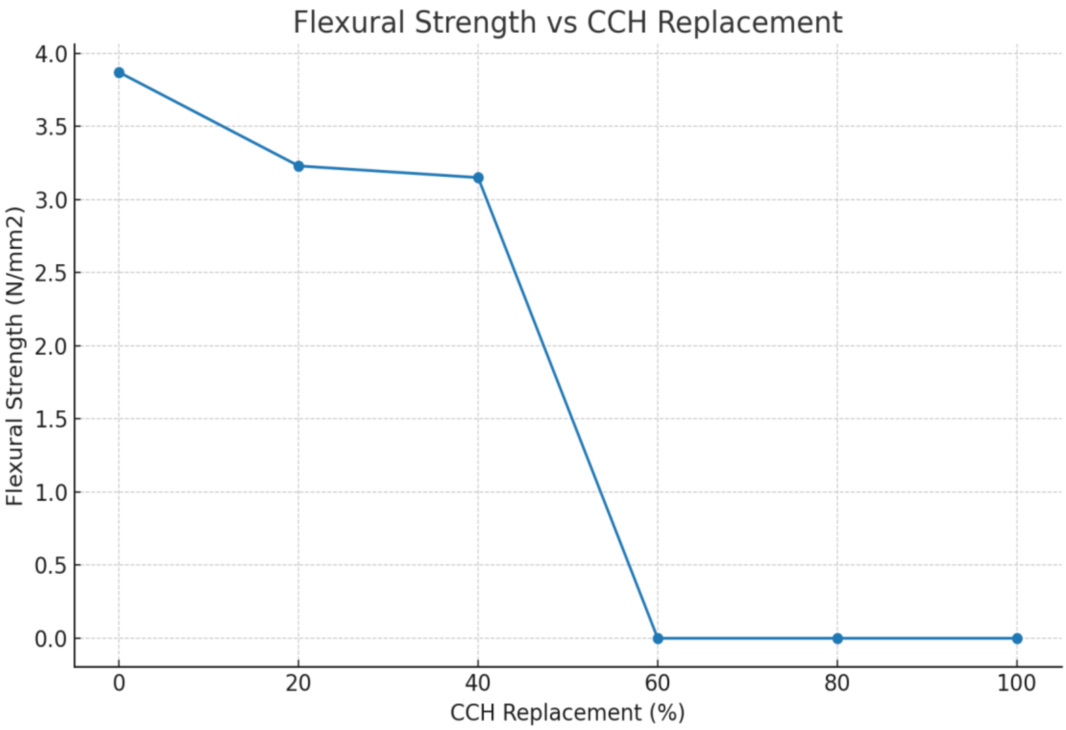


**Figure 12:** Flexural strength vs. CCH replacement.

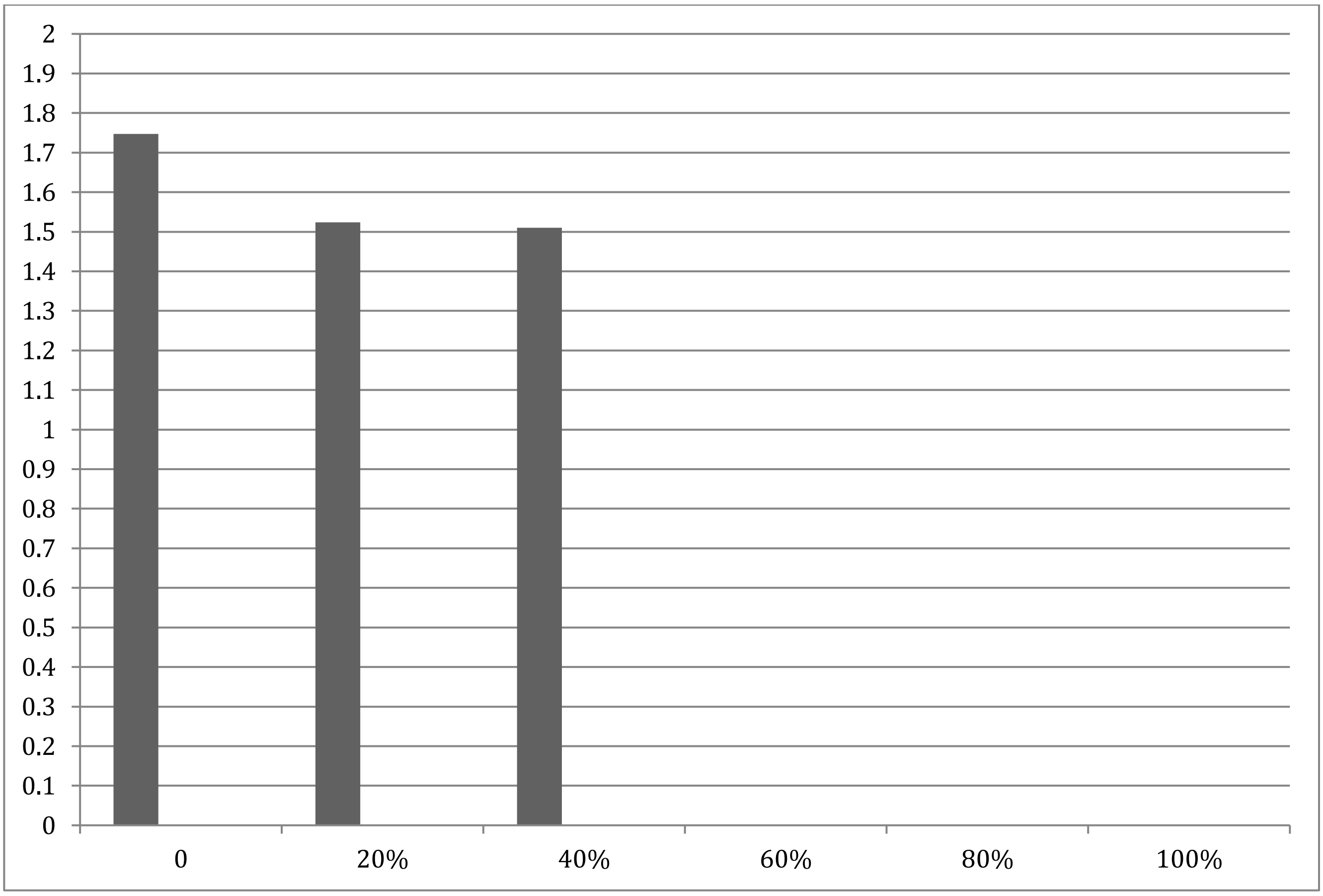


**Figure 13:** Chart showing the average split-tensile strength of concrete cylinders at the 7th day curing

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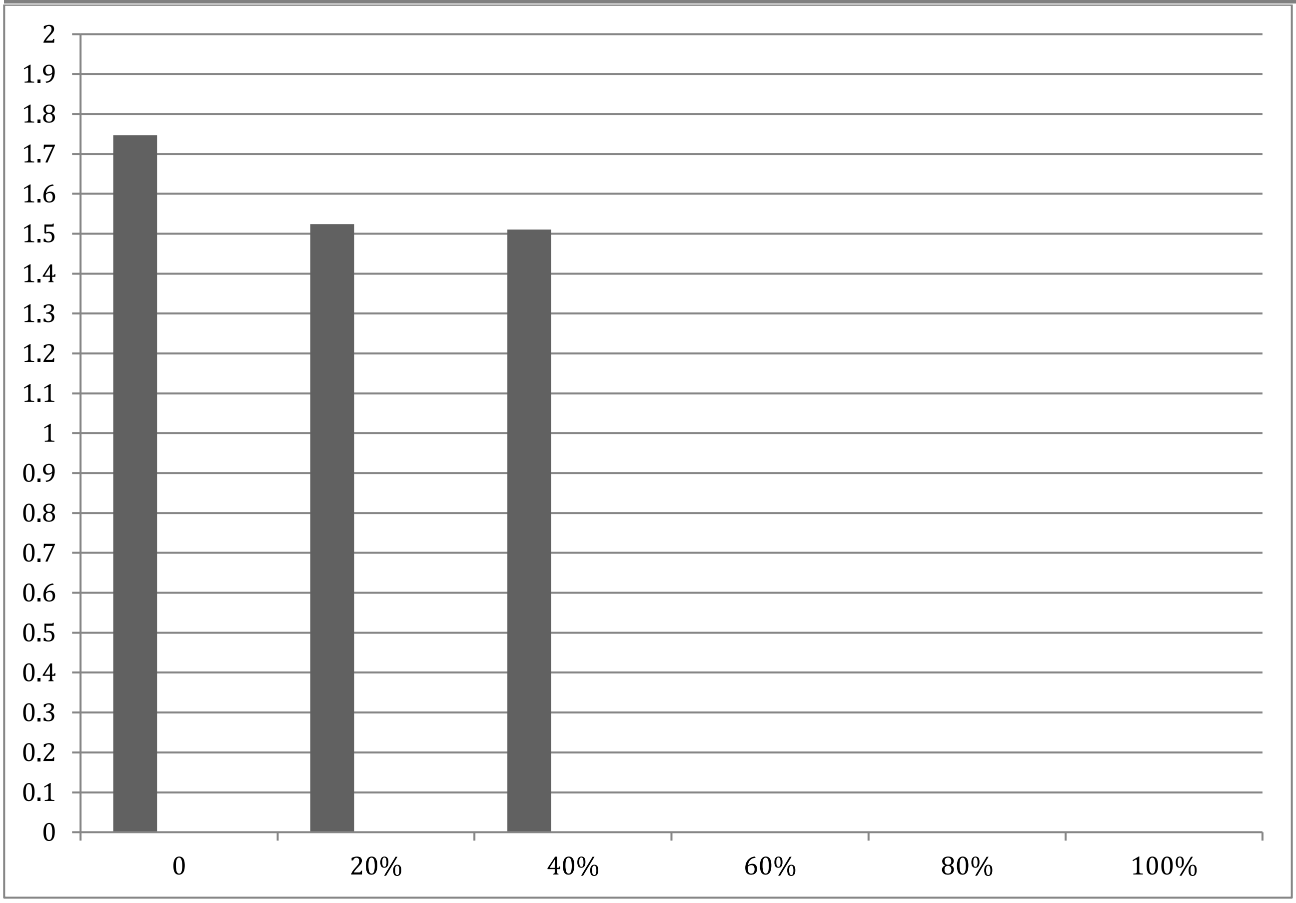


**Figure 14:** Bar Chart showing the split-tensile Strength of Concrete Cylinders at the 14th day of curing

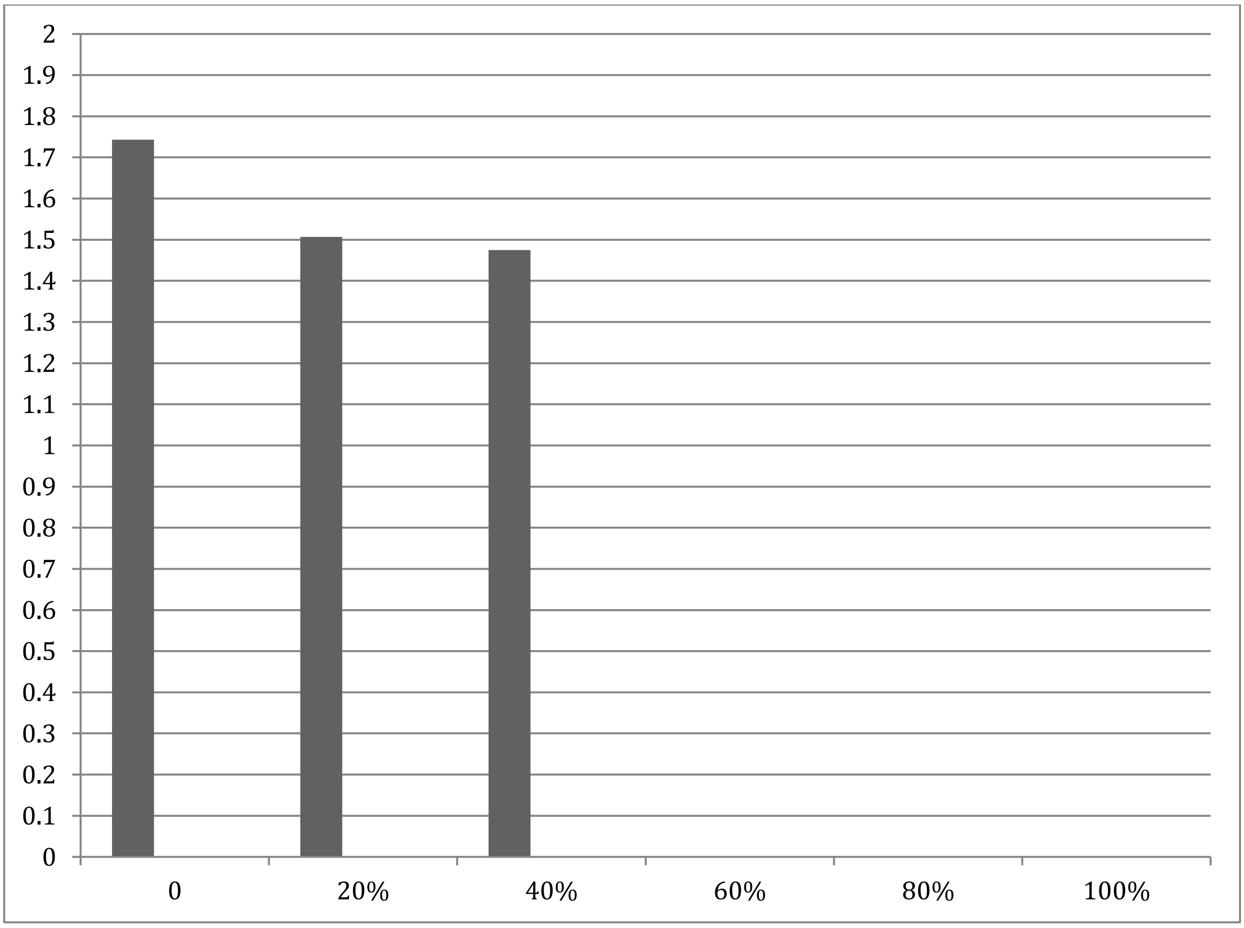


**Figure 15:** Bar Chart showing the split-tensile Strength of Concrete Cylinders at the 21st day of curing

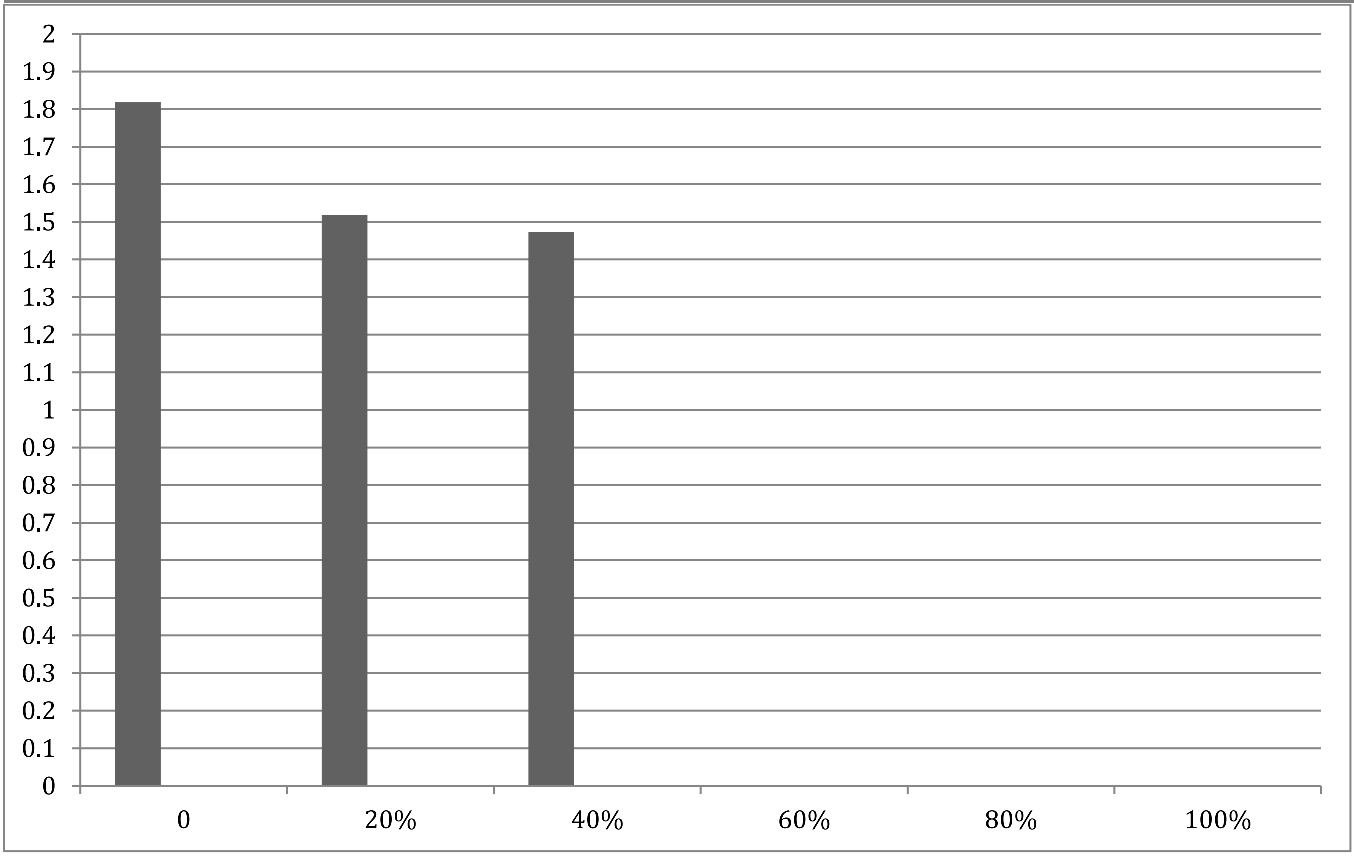


**Figure 16:** Bar Chart showing the Split-tensile Strength of Concrete Cylinders at 28th day of curing

The results obtained from the experimental investigation of Cow Horns Concrete (CCH) are presented and discussed with respect to workability, density, and strength characteristics, as illustrated in Figures 9 to 16.

The workability of the concrete mixes was observed to decrease with increasing CCH replacement. Mixes containing 0-40% CCH exhibited zero slump, indicating very low workability, while higher replacement levels (60–100%) showed shear slump behavior, suggesting reduced cohesion and consistency of the mix. In terms of density, a noticeable reduction was recorded with the inclusion of CCH. As shown in Figure 9, the densities at 20% and 40% replacement levels decreased by approximately 13% and 15%, respectively, when compared to the control mix density of 2410 kg/m³. This reduction confirms the potential of CCH as a lightweight concrete material. The compressive strength results, presented in Figure 10, indicate that the control mix achieved a strength of 24.49 N/mm², while the 20% and 40% CCH mixes recorded values of 20.64 N/mm² and 20.36 N/mm², respectively. Although there is a reduction in strength with increasing CCH content, the values remain within acceptable structural limits for certain applications.

Similarly, the split-tensile strength results shown in Figure 11 reveal a gradual decrease with increasing CCH content. The control mix recorded 1.76 N/mm², while 20% and 40% replacements yielded 1.51 N/mm² and 1.49 N/mm², respectively. The trend indicates a slight compromise in tensile performance due to the introduction of CCH fibers. The flexural strength behavior, as illustrated in Figure 12, follows a similar pattern. The control mix achieved 3.87 N/mm², while the 20% and 40% CCH mixes recorded 3.23 N/mm² and 3.15 N/mm², respectively, indicating a moderate reduction in bending resistance.

Further analysis of strength development over curing periods is presented in Figures 13 to 16, which show the variation of split-tensile strength at 7, 14, 21, and 28 days, respectively. The results demonstrate a progressive increase in strength with curing age across all mixes, with the 28-day results (Figure 16) showing the highest values, consistent with typical concrete behavior. These figures collectively highlight the time-dependent strength gain and confirm that, despite reduced absolute values, CCH concrete maintains a consistent strength development pattern. Overall, the results indicate that while the incorporation of cow horn fibers reduces workability and slightly decreases mechanical strengths, it significantly lowers density and offers potential for lightweight concrete applications with acceptable performance characteristics.

**Limitations and Recommendations for Future Research**

While the experimental design adopted in this study is robust covering a wide range of replacement levels (0–100%) and incorporating standard tests on workability, density, compressive, split-tensile, and flexural strengths it is important to acknowledge certain limitations that may influence the broader applicability of the findings. The results clearly demonstrate that moderate replacement levels (20–40%) can produce lightweight concrete with acceptable mechanical performance, thereby supporting sustainable construction practices and circular economy principles through the utilization of animal-based waste materials. However, the study does not address key durability-related aspects such as long-term performance, resistance to environmental exposure, permeability, shrinkage, and chemical resistance (e.g., sulphate attack, carbonation, and chloride ingress). These factors are critical in determining the suitability of Cow Horn Concrete (CCH) for structural or aggressive service environments. Future studies should incorporate durability testing and long-term monitoring to validate the material's performance under real-world conditions.

In addition, variability in the physical and chemical properties of cow horn particles such as particle size distribution, porosity, and keratin composition was not extensively analyzed. Such variability may significantly affect bonding characteristics, water absorption, and overall consistency of the concrete matrix. A more detailed material characterization, including microstructural analysis (e.g., SEM, XRD), is recommended to better understand these influences.

Furthermore, while the study establishes the feasibility of CCH as a lightweight material, it does not provide comparative evaluation against other conventional or alternative lightweight aggregates such as expanded clay, pumice, recycled plastic, or rubber. Incorporating such comparisons would strengthen the positioning of CCH within the broader class of sustainable construction materials. For optimization purposes, future research should also investigate lower replacement levels (below 20%), which may offer a more favorable balance between mechanical strength and weight reduction. Additionally, incorporating life-cycle assessment (LCA) and environmental impact analysis would provide quantitative evidence of the sustainability benefits associated with the use of cow horn materials in concrete production.

Overall, despite these limitations, the study provides a strong foundational framework for the development of cow horn-based concrete and demonstrates its potential as an innovative and sustainable construction material. The findings are therefore considered valid, with the recommendation that further investigations be conducted to address the identified gaps and enhance practical applicability.

# CONCLUSION

Crushed cow horns can be utilized as partial replacement for fine aggregates. While replacement levels above 60% result in structural failure, 20-40% produces lightweight concrete with reduced strength. Future studies should evaluate durability and chemical resistance at ≤15% replacement levels. The findings from this study show that crushed cow horn (CCH) can be used as a partial replacement for fine aggregate in concrete production, but only within limited ranges. At high replacement levels above 60%, the resulting mixes became structurally weak, showing signs of failure both in strength and stability. However, at moderate levels of 20-40%, the concrete produced was lightweight, though with reduced mechanical performance when compared to conventional concrete. This suggests that while cow horn may not entirely replace sand in structural concrete, it holds promise for lightweight concrete applications, particularly in non-load-bearing or partition elements where reduced density is desirable.

In terms of workability, slump tests revealed a noticeable reduction as the proportion of crushed cow horn increased. Mixes containing 0-40% CCH registered zero slump, indicating very stiff mixes, while those with 60-100% replacement displayed shear slump, reflecting poor workability and lack of cohesion. This reduction in slump is most likely due to the fibrous and irregular nature of horn particles, which hinder proper compaction and water distribution.

The density results further highlight this trend. Replacements of 20% and 40% reduced the density of concrete by about 13% and 15% respectively, compared to the control density of 2410 kg/m³. This confirms the lightweight potential of CCH concrete, since the material itself is less dense than natural sand. While such reduction in density is advantageous for lightweight construction, it may compromise strength if not carefully controlled.

Strength properties followed the same declining pattern with increased horn content. Compressive strength dropped from 24.49 N/mm² in the control mix to 20.64 N/mm² at 20% replacement and 20.36 N/mm² at 40% replacement. Although reduced, these values still fall within the range of acceptable strengths for certain classes of concrete used in non-structural applications. Split-tensile strength also decreased, moving from 1.76 N/mm² in the control to 1.51 N/mm² and 1.49 N/mm² at 20% and 40% replacement respectively. Flexural strength followed the same pattern, dropping from 3.87 N/mm² in the control mix to 3.23 N/mm² and 3.15 N/mm² at 20% and 40% replacements. These results emphasize that while crushed cow horn weakens the structural properties of concrete, small replacements still retain considerable strength.

Overall, the study concludes that crushed cow horn can serve as a partial fine aggregate replacement in concrete at moderate levels. The benefits include reduction of environmental waste, production of lightweight concrete, and conservation of natural sand resources. However, strength reductions limit its use in load-bearing structures. Future research should therefore focus on optimizing processing methods, using admixtures to improve workability, and evaluating long-term durability and chemical resistance, especially at lower replacement levels of 15% or below. Such efforts will help determine whether crushed cow horn can transition from experimental use to sustainable practical application in concrete technology.

The results obtained from these laboratory tests provide the needed information from which the following conclusions can be drawn:

1. The use of CCH for partial replacement of fine aggregate at 60% - 100% replacement would lead to shear failure of the concrete cubes under self-weights.
2. The use of CCH for partial replacement of fine aggregate at 20% and 40% replacement decreased the compressive strength of the concrete mix compared to the control mix by 15.74% and16.86%.
3. The use of CCH for partial replacement of fine aggregate at 20% and 40% replacement decreased the split-tensile strength of the concrete mix compared to the control mix by 14.00 % and 15.65 %.
4. The use of CCH for partial replacement of fine aggregate at 20% and 40% replacement decreased the flexural strength of the concrete mix compared to the control mix by 16.61% and 18.65%.
5. After crushing, CCH was found to be a fibrous material and not a grain like the fine aggregates.
6. The use of CCH in concrete production would lead to the improved light weight concrete because of the lesser density of the specimen cubes compared to the density of the control mix.

## RECOMMENDATIONS

Based on the results derived from this research, the following recommendations should be noted:

1. Further investigations can be carried out to evaluate the compressive strength property of concrete produced with CCH as a partial replacement of fine aggregates at percentages lesser than 15%.
2. Further investigations can be carried out to evaluate the thermal and chemical properties of concrete produced with CCH as a partial replacement of fine aggregates at percentages lesser than 15%.
3. Further research can also be done with the use of different concrete mix ratios.

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