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Research Article

Leathercrete-A Sustainable Approach to Fine Aggregate Replacement

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Abstract

Concrete is the most utilized construction material globally, owing to its abundance, durability, extended lifespan, high resilience, and countless applications. Conversely, its extensive usage has considerable environmental implications, including increased carbon emissions and the exhaustion of natural resources. Thus, at the turn of the century, the demand for new building ideologies that incorporate sustainable construction practices—that is, emphasizing sustainable construction while maintaining performance standards—has increased [23]. Worldwide, the increased amount of waste generation from leather industries presents an opportunity to develop a sustainable alternative. This study analyses the feasibility of using leather waste as a partial or complete replacement for fine aggregate in concrete by evaluating its mechanical properties, environmental impact, and economic viability. The findings highlight the potential of leathercrete as an eco-friendly alternative to conventional concrete, reducing waste accumulation and conserving natural resources.

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KEYWORDS: Perceived social support, psychological distress, Mental health Interventions, Emotional Wellbeing

1. INTRODUCTION

The construction industry continuously seeks sustainable practices to reduce reliance on natural resources and minimize waste. Fine aggregates represent a major component in concrete production [1]; however, natural sand is becoming increasingly scarce, and its over-extraction raises environmental concerns. Simultaneously, the leather industries generate significant quantities of waste by-products (Figure 1) that are often disposed of in landfills, causing serious environmental hazards. The tannery industry generates solid leather waste, which comprises keratin waste, leather scraps, fleshings, skin trimming, chrome shavings, buffing dust, and leather trimming [14]. This indicates that the tannery sector produces both liquid and solid waste, in addition to gaseous waste [6]. Using leather waste to create a sustainable alternative – leathercrete - not only alleviates the environmental burden of leather waste but also reduces the exploitation of natural fine aggregates, thereby improving construction sustainability. The key research questions include:

i) Can processed leather waste effectively replace fine aggregate in concrete without compromising structural integrity?
ii) What are the environmental implications of using tannery waste in construction materials?
iii) How does the inclusion of leather waste affect the mechanical properties of concrete?

Figure 1: Pile of leather waste

2. OBJECTIVES

The primary objectives of this research are to:

i) Evaluate Sustainability: Assess the environmental benefits of using leather waste as a fine aggregate replacement.

ii) Determine Optimal Replacement Level: Identify the optimum percentage of leather waste replacement (by volume) that maintains acceptable workability and mechanical properties.

iii) Analyze Mechanical Performance: Investigate the effects of leather waste on compressive, tensile, and flexural strengths at early (7 days) and later (28 days) curing ages.

iv) Examine Durability Aspects: Observe the influence of leather incorporation on concrete density and workability.

v) Provide Practical Guidelines: Offer recommendations for incorporating leather waste in concrete for non-structural applications.

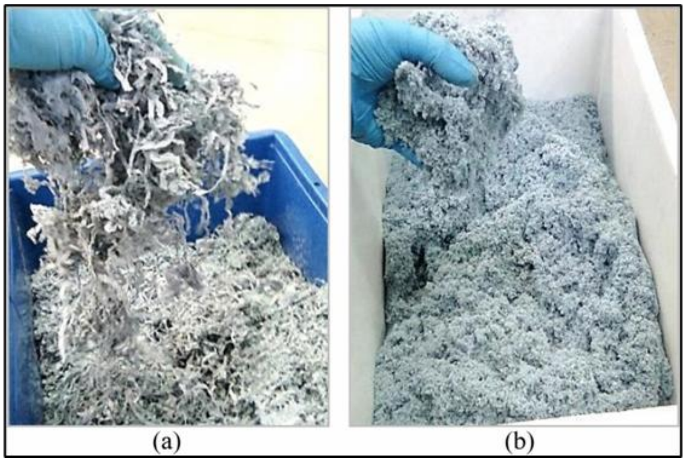
3. LITERATURE REVIEW

Every year, over 6 million tonnes of solid waste are produced worldwide by the leather industry. According to estimates, China and India generate 1.4 million tons and 150,000 tons of leather waste annually, respectively, making them the major contributors to the worldwide leather waste generation. Countries in Asia (apart from China), the Middle East, Europe, South America, and North and Central America are among the other major contributors.

Previous studies have explored various waste materials as fine aggregate replacements, such as fly ash, crushed glass, and rubber. Research on tannery waste applications in construction materials remains limited. The chemical composition of leather, particularly chromium content, raises concerns about leachability and strength performance [9]. This study expands on existing research by addressing these challenges through material processing and mix optimization. Studies have shown that incorporating industrial waste materials into concrete can enhance sustainability, reduce costs, and minimize environmental degradation.

Mitigating the environmental damage caused by the leather industry requires efficient management of leather waste (Figure 2). By realizing the significance of managing leather waste and the various approaches available for doing so, we may strive towards a more ecologically conscious and sustainable leather sector. It is challenging to establish efficient waste management procedures due to the different economic issues associated with leather waste management. These issues include high expenses, the absence of monetary incentives for processing, disposal, and recycling, and very little market demand for used leather items.

Figure 2: Stabilization of wet leather waste



2.2 Potential Benefits of Leathercrete

i. **Waste Reduction:** Utilizing leather waste reduces the amount of waste going to landfills and minimizes the environmental impact of leather production.
ii. **Cost Savings:** Using leather waste can potentially reduce the cost of concrete production by replacing some natural aggregates.
iii. **Sustainable Practices:** Incorporating leather waste promotes sustainable construction practices and aligns with circular economy principles.

Figure 3: Sustainable development goals

4. METHODOLOGY

Materials used

Cement: Ordinary Portland cement of grade 53.

Fine Aggregate: River sand with a maximum particle size of 4.75 mm.

Coarse Aggregate: 20 mm coarse aggregates.

Leather waste: Post-tanning leather waste processed into fine dust (passing a 2.36 mm sieve) after appropriate cleaning and drying.

Water: Potable water.

Design mix

A standard mix for M25 grade concrete was adopted with a water-cement ratio (w/c) of 0.45. Natural fine aggregate was replaced with processed leather waste at four levels: 0% (control), 10%, 20%, and 30% (by volume).

Table 1: Mix Proportions (per m³ of Concrete)

Mix	Cement (kg)	Water (kg)	CA (kg)	FA (kg)	Leather Waste (%)	Effective FA (kg)
C0	400	180	1050	700	0	700
C10	400	180	1050	630	10	630+70
C20	400	180	1050	560	20	560+140
C30	400	180	1050	490	30	490+210

Specimen: preparation and curing

i) Mixing: Dry mixing of cement, fine aggregate, leather dust, and coarse aggregate for 3 minutes. Water was added and mixed for an additional 5 minutes.

ii) Casting: Concrete was cast into standard cubes (150 mm×150 mm×150 mm) (Figure 4).

iii) Curing: Specimens were covered and cured in water at 23 ± 2 °C for 28 days, with intermediate tests performed at 7 days.

Figure 4: Concrete Mold

Figure 5: Concrete mix poured into the mold

Figure 6: Drying a concrete cube

4.1 Experimental Tests and Observations

The various tests performed on concrete cube specimens include [1,4,5,9].

i) Workability and slump test
ii) Compressive strength test

4.1.1 Workability and Density

Table 1: Slump and density

Mix	Slump (mm)	Fresh Unit Weight (kg/m^3)
C0	75	2400
C10	70	2350
C20	65	2300
C30	60	2250

Observation: The incorporation of leather waste slightly reduced workability and fresh density, likely due to the lower specific gravity and angular shape of leather particles (Figure 8).

Figure 8: Graphical representation of slump and density

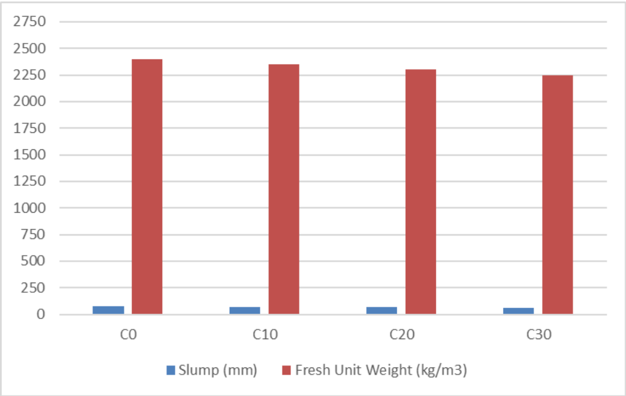


Figure 7: Concrete cube after curing

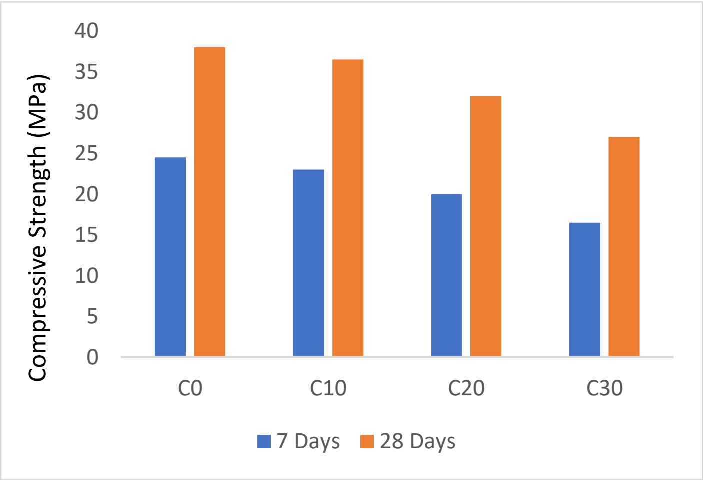
4.1.2 Compressive Strength

Table 2: Compressive Strength

Mix	Compressive Strength (7 days, MPa)	Compressive Strength (28 days, MPa)
C0	24.5	38.0
C10	23.0	36.5
C20	20.0	32.0
C30	16.5	27.0

Observation: Up to 10% replacement, the reduction in compressive strength is minimal (<5% decrease). However, at 20% and 30% replacement, compressive strength declines by approximately 15% and 29%, respectively, compared to the control (Figure 9).

Figure 9: Graphical representation of compressive strength



5. RESULTS AND DISCUSSION

1) Optimum Replacement: Leather waste replacement of 10-20% yields leathercrete with acceptable mechanical properties for non-structural applications.

2) Workability: Leathercrete exhibited improved workability due to the smooth texture of leather particles. Adjustments (minor water or admixture modifications) may be required for higher leather replacement levels.

3) Strength Reduction: Although mechanical properties decrease with higher replacement ratios, the material becomes lighter, which can be advantageous for certain applications.

4) Durability: The addition of leather waste improved water resistance but exhibited moderate sulfate resistance. The results suggest that tannery waste enhances concrete's resistance to moisture absorption, reducing permeability.

5) Thermal and Acoustic Properties: The inclusion of leather waste contributed to better thermal insulation and sound absorption, making leathercrete a suitable material for energy-efficient buildings.

6) Environmental Impact: Chromium leachability was within acceptable limits, making leathercrete a viable and safe material for construction. The life cycle assessment (LCA) of leathercrete indicated a significant reduction in carbon emissions compared to traditional concrete.

7) Economic Analysis: The use of leather waste reduces material costs and landfill disposal expenses, making leathercrete an economically feasible alternative. Large-scale adoption could lead to sustainable industry practices and cost-effective urban development.

8) Sustainability: Using leather waste diverts industrial by-products from landfills and reduces the consumption of natural sand.

Applications

Waste leather can be used in concrete as an alternative to natural aggregates, especially for road construction and self-compacting concrete. Concrete made from leather waste may have more effective thermal insulation and a lower density, but it might also possess more porosity and less compressive strength, based on research. Some specific applications of leathercrete are as follows:

- Self-Compacting Concrete: Leather waste, especially waste sole leather, can be incorporated into self-compacting concrete as a partial replacement for coarse aggregates.
- Sidewalk Concrete: Concrete incorporating leather tannery waste, like "wet blue," has been studied and found to be suitable for sidewalk applications, meeting Brazilian standards.
- Thermal Insulation: Leather waste, including buffing dust and shavings, can be used to enhance the thermal insulation properties of building materials.
- Acoustic Applications: While less common, some studies have explored the use of leather waste in sound panels.
- Composites: Leather waste can be used as a filler and reinforcing material in composites, potentially offering versatile industrial applications.

6. CONCLUSION

By incorporating industrial waste into building, lowering reliance on virgin raw materials, and advancing the ideas of the circular economy, the study promotes global sustainability [15]. The findings suggest that the standard of concrete blocks made from leather waste is on par with regular concrete blocks and that it is a more feasible and promising sand substitute material [13]. Leathercrete not only reduces the dependence on natural sand but also significantly reduces construction costs. Up to 10-20% replacement, the concrete maintains acceptable compressive, splitting tensile, and flexural strengths while offering environmental benefits through waste recycling [10]. The fibrous composition of leather improves the flexural strength of concrete. Water absorption is reduced, thereby enhancing concrete durability. Chromium leachability remains within safe environmental limits. The use of tannery waste mitigates landfill accumulation. Thermal and acoustic improvements make leathercrete suitable for green building applications and sustainable urban development. Although further research is required to optimize mix designs and assess real-world applications, leathercrete is recommended for lightweight, non-load-bearing applications such as partition walls, pavements, and decorative elements.

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