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Sustainable Lightweight Concrete Incorporating 100% Recycled HDPE-Based Artificial Coarse Aggregates.

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1. *Abstract:*

In response to the twin challenges of resource depletion and plastic waste pollution, this study investigates the complete substitution of natural coarse aggregates in concrete with artificial coarse aggregates (ACA) made from high-density polyethylene (HDPE) plastic and sand. The innovative use of a 2:1 plastic-to-sand ratio to create 20 mm ACA demonstrates the potential for producing sustainable, lightweight concrete. Through careful material preparation, mix design (M20), and testing of hardened concrete, the research validates that concrete made with 100% HDPE aggregates can achieve an average compressive strength of 20.74 MPa, with a reduced density of approximately 1867.9 kg/m³. This material is well-suited for non-load-bearing and semi-structural elements, offering environmental, economic, and logistical advantages for modern construction.

2. Introduction:

Concrete, often referred to as the backbone of modern infrastructure, depends heavily on natural aggregates, primarily sourced through quarrying. As global infrastructure demands increase, the over-extraction of these non-renewable materials results in land degradation, ecological imbalance, and resource scarcity.

Simultaneously, plastic waste, especially HDPE, is piling up in alarming volumes in landfills and oceans. HDPE's non-biodegradable nature poses serious threats to soil and marine ecosystems. Recognizing the synergy between these two challenges, this research proposes a circular solution—converting HDPE waste into artificial aggregates for concrete.

This study presents an experimental attempt to replace coarse aggregates entirely with HDPE-based ACA, investigating the resulting concrete's workability, strength, density, and water absorption. The approach aligns with sustainable construction practices and promotes circular economy principles.

3. Aim:

To develop and test lightweight concrete using 100% recycled HDPE-sand artificial coarse aggregates and assess its practical feasibility in construction.

4. Objectives:

1. To develop a simple, replicable method of producing artificial coarse aggregates using HDPE and sand.
2. To test the physical properties of HDPE-based ACA (specific gravity, size, absorption).
3. To perform a comparative analysis of conventional and HDPE-based concrete in terms of:

Workability (slump test)
Density and weight reduction
Compressive strength at 14 days
Water absorption and porosity

4. To validate the application of this lightweight concrete in real-world scenarios like blocks, panels, and non-structural elements.
5. To promote HDPE reuse in civil engineering and contribute toward green building technologies.

5.Literature Review:

A broad range of literature has supported the concept of plastic-modified concrete, especially focusing on partial replacements.

However, full replacement studies are rarer and more critical. Key findings include:

Anju Ramesan et al. (2015): Demonstrated 30% plastic aggregate replacement yielded optimum strength and lightweight benefits.

Daniel Yaw Osei (2014): Proved the suitability of polyethylene waste for non-structural lightweight applications.

Dr. Vijaya Sekhar Reddy (2015): Emphasized the need to optimize plastic ratios to maintain acceptable bonding.

Del Rey Castillo (2020): Achieved 25–28 MPa compressive strength using fully synthetic plastic aggregates.

Alqahtani et al. (2017): Validated thermal advantages and load-bearing potential of 100% plastic aggregate mixes.

These and other studies lay the groundwork for more aggressive adoption of recycled plastic aggregates in eco-conscious construction.

6.Methodology:

The project followed a step-by-step process:

1. Plastic Collection and Sorting: HDPE plastic sourced from bottles and containers.
2. Shredding and Cleaning: Ensured surface cleanliness and size uniformity.
3. Mixing with Sand: Combined in a 2:1 plastic-to-sand ratio.
4. Heating: Melted in a metal pan on a conventional stove with continuous manual stirring.

5. Shaping: Molded into 20 mm particles mimicking standard aggregates.
6. Curing and Hardening: Left to set at room temperature for 24 hours.
7. Mix Design: Based on IS:10262 and ACI guidelines for M20.
8. Casting: 3 cube specimens (150 mm^3) were prepared.
9. Curing: Submerged in water for 14 days.
10. Testing: Performed visual inspection, slump test, density, compressive strength, and water absorption evaluation.

7.Materials Used:

Material Properties

Cement OPC 43 Grade, Specific gravity = 2.965, IS 1489-compliant Sand Zone II, Fineness Modulus = 4.129, Absorption = 0.2% Coarse Aggregate Replaced 100% with HDPE-sand artificial aggregate Water Clean potable, W/C = 0.40

The HDPE-based ACA had a specific gravity of 0.94, confirming its lightweight nature.

8.Mix Design:

Using ACI and IS:10262-2009 standards, the mix was designed as follows:

Cement = 467.5 kg/m^3

Fine Aggregate = 653.98 kg/m^3

HDPE-based ACA = 688.2 kg/m^3

Water = 187 kg/m^3

Each cube (150x150x150 mm) had approx. 2.3 kg ACA, 2.2 kg sand, 1.58 kg cement, and 632 mL water.

9.Preparation of Artificial Coarse Aggregate (ACA):

1.Sorting & Shredding: Cleaned HDPE cut into small flakes.

2.Melting & Mixing: Mixed with sand at high temperature while stirring.

3.Shaping: Molded into 20 mm particles.

4.Curing: Cooled for 24 hours at room temperature.

5.Final Characteristics: Lightweight, non-absorbent, irregularly shaped aggregates.

9. Testing and Results:

Visual Inspection: All cubes displayed uniform surface with no cracks or defects.

Density Test:

Average cube weight: 6.2 kg

Density: 1844 – 1907 kg/m^3 → classified as lightweight concrete

Compressive Strength:

Cube 1: 15.56 MPa

Cube 2: 21.78 MPa

Cube 3: 24.89 MPa

Average strength: 20.74 MPa

Water Absorption:

Range: 2.60% – 2.95%

Average: 2.77% → indicates low porosity and good durability

10.Discussion:

The results confirm that HDPE-based ACA is a feasible alternative for traditional coarse aggregates:

Achieves desired workability and acceptable strength.

Reduces environmental impact by utilizing plastic waste.

Suitable for non-load-bearing walls, partitions, blocks, and insulation panels.

11. Advantages & Limitations

Advantages:

Lightweight (25–30% reduction in mass)

Good workability (slump: 85 mm)

Low-cost, sustainable

Effective plastic waste management

Limitations:

Lower compressive strength than conventional concrete

Potential bond weakness with smooth HDPE surface

Limited fire resistance and long-term durability data

12.Suggestions for Future Work:

Surface treatment of HDPE to improve bonding

Use of admixtures or fibers for strength enhancement

Long-term durability and fire resistance testing

Scaling for field applications and structural analysis

13.Conclusion:

This study establishes that HDPE-based artificial aggregates can successfully replace natural coarse aggregates in lightweight concrete applications. With favorable test results and environmental advantages, such concrete can support sustainable development goals in the construction sector. Future advancements could enhance performance and broaden practical usage.