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Blueprints from Plastic: A Novel Taxonomy for Sustainable Building Materials in Nigeria

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Abstract
Nigeria faces a dual challenge of mounting plastic waste and a pressing need for sustainable construction materials. This Paper proposes a systematic classification framework for recycled plastics to support their effective use in the building sector. Drawing on an extensive literature review, material property analyses, and a comparative examination of relevant case studies, the research identifies key recycled plastic types such as PET, HDPE, PVC, and PP, and evaluates their mechanical, thermal, and aesthetic performance. The framework categorizes these materials based on parameters including tensile strength, durability, UV and moisture resistance, and processability, and then maps each category to optimal building components. For example, designating high-durability materials for load-bearing walls, and transparent or color-customizable plastics for windows and partitions. By aligning material properties with specific functional requirements and local environmental conditions, the study demonstrates how tailored selection of recycled plastics can yield cost-effective, energy-efficient, and culturally resonant building designs. This approach not only advances sustainable architecture in Nigeria but also reinforces circular economy principles by transforming waste into valuable assets. The insights presented offer architects, builders, policy-makers, and other industry stakeholders a replicable guide for incorporating recycled plastic materials into innovative design strategies for a greener built environment.

***Keywords*: Plastic, Recycling, Sustainability, Taxonomy.**

1. INTRODUCTION

The rising tide of global plastic waste presents an urgent environmental dilemma and a creative design opportunity. In recent decades, the built environment has emerged as a crucial frontier for addressing sustainability, with architecture at the helm of material innovation. Among the many strategies developed to mitigate the adverse impacts of non-biodegradable waste, the reuse of recycled plastics in construction offers both functional utility and aesthetic versatility, (Iroegbu et al, 2021). Yet, despite growing interest, applications of recycled plastics in architectural design remain fragmented, particularly within the Nigerian context where material scarcity and waste management challenges intersect (Abdulfatah, 2023)

This paper investigates the incorporation of recycled plastics into architectural practices, with an emphasis on both functional and aesthetic dimensions. It responds to the pressing need for a structured understanding of how these materials are sourced, categorized, and applied across a range of building typologies. While past studies have explored eco-design and sustainable construction techniques, few have proposed a coherent taxonomy that captures the dual performance, (physical and visual) of recycled plastics.

Grounded in extensive literature review and validated through case study analysis, this study offers a taxonomy that classifies recycled plastics based on form, use, and spatial integration. The paper not only contributes to sustainable material discourse but also positions this taxonomy within a wider architectural context to support more conscious design decisions.

The structure of the paper is as follows: Section 2 reviews existing literature and global approaches to recycled plastics in design; Section 3 describes the methodology employed for data gathering and taxonomy development; Section 4 presents the findings and discussion on functional and aesthetic applications; and Section 5 concludes with insights and recommendations for design professionals, policymakers, and future researchers.

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2. CONTEXT

As the global demand for sustainable construction intensifies, increasing attention has been directed toward the integration of recycled materials in architecture. Plastics, long regarded as environmental nuisances, are gaining recognition as a versatile resource with potential for structural and aesthetic innovation. However, literature on the architectural application of recycled plastics remains scattered across disciplines, with limited synthesis of their functional performance, aesthetic contributions, and context-specific adaptability (Ahmed and Aly, 2023).

Early research focused predominantly on the environmental implications of plastic reuse, addressing issues such as lifecycle impact, pollution mitigation, and carbon footprint reduction. While these studies highlighted the ecological benefits of recycling plastics, they often lacked detail on how such materials could be structurally or creatively utilized in buildings (Nielsen et al, 2020).

In more recent work, scholars have begun exploring functional applications of recycled plastics in construction, such as plastic bricks, insulation panels, and acoustic tiles, showcasing their affordability, water resistance, and durability. These innovations demonstrate the potential of plastics not just as a filler material but as a key component in resource-efficient construction systems. However, these uses are frequently documented in isolation, without a clear system for evaluating or categorizing them within a coherent framework (Kuttimarks et al, 2025).

On the other hand, literature addressing the aesthetic use of recycled plastics remains relatively sparse. Isolated studies and design case reports illustrate applications in façade treatments, furniture, and modular partitions, often praising their color variety, translucency, or expressive textures. Yet few sources attempt to articulate how these visual qualities can be systematically harnessed or integrated with functional goals.

Internationally, several classification systems exist for sustainable materials, primarily organized by origin, composition, or environmental performance. However, these schemes rarely accommodate the dual design (functional and aesthetic) value of recycled plastics. Moreover, they are largely developed in Western or high-income contexts, offering limited relevance to the material realities and climatic conditions of countries like Nigeria, where informal recycling dominates and material access varies widely.

This study responds to these gaps by proposing a design-centered taxonomy for recycled plastics, one that explicitly accounts for both performance and visual impact across architectural elements. It contributes to a growing movement in material innovation that seeks to bridge environmental consciousness with design creativity, particularly in the Global South, where such integration is often both a necessity and a challenge.

3. RESEARCH METHODS

This study employed a mixed qualitative methodology, combining a thematic literature review with case study analysis to develop a taxonomy for the architectural application of recycled plastics. The research unfolded in three phases: data gathering, taxonomy formulation, and validation through contextual analysis.

3.1 Literature Analysis

An extensive review of academic publications, industry reports, material specifications, and architectural case studies formed the basis of the taxonomy. Sources were selected for their relevance to plastic reuse, material performance, and aesthetic innovation in construction. Thematic coding was used to identify recurring patterns in how recycled plastics are classified and applied globally, highlighting gaps in existing frameworks, particularly in the integration of functional and aesthetic attributes.

3.2 Taxonomy Development

Drawing from the coded themes, an initial framework was proposed, organizing recycled plastic applications into categories based on:

- Form (e.g., pelletized, sheeted, modular)
- Functionality (e.g., insulation, cladding, partitioning)
- Aesthetic contribution (e.g., color, transparency, surface finish)
- Spatial integration (interior, exterior, furniture, envelope)

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This taxonomy was refined through iterative comparison with real-world design examples and aligned with architectural language to ensure usability by practitioners.

3.3 Case Study Selection

To evaluate the applicability of the taxonomy, six representative architectural case studies were selected. Selection criteria included:

- Use of recycled plastics as a significant material component
- Availability of documented design intent or performance data
- Regional and typological diversity

Each case was analyzed to map the materials used onto the proposed taxonomy, noting both functional and aesthetic outcomes.

3.4 Validation Approach

The cross comparison of coded literature insights and empirical case results served to validate the taxonomy's utility. By identifying how consistently real-world examples aligned with the proposed categories, the study tested the clarity, flexibility, and comprehensiveness of the classification system.

4. DISCUSSION

4.1 Case study Integration

The taxonomy presented in Section 4.2 was built on insights drawn from eleven architectural projects, six global and five regional, that repurpose recycled plastics in both structural and decorative roles. By examining each project's material choices, processing methods, and design intentions, recurring attributes (plastic type, source, form, function, aesthetics, spatial use) were identified, and became the backbone of the classification system.

Below is a summary of those case studies and how each one contributed to the taxonomy's six key attributes.

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Table 4.1.1 Summary of Recycled-Plastic Case Studies

Case Study	Location	Plastic Type(s)	Application	Functional Role	Aesthetic Role	Taxonomy Insight
The Plastic House	London, UK	PET, PVC, Composites	Cladding, flooring, furnishings	Thermal insulation, weatherproofing	Vivid color variations, texture mimicry	Showed multi-material mixes and interior uses
The Eco Ark	Taipei, Taiwan	PET bottles	Modular façade blocks, structural	Load-bearing shell, daylight modulation	Translucent, repetitive modules	Validated large-scale plastic block construction
Ocean Plastic Waste Pavilion	Dubai, UAE	Ocean-collected PET	Exhibition panels, flooring	Moisture barrier, rapid assembly	Graphic storytelling, mixed-media textures	Highlighted narrative-driven, mixed-source plastics
The Green School	Bali, Indonesia	PET bottles, PC sheets	Wall infill, insulation, roofing	Energy efficiency, buoyant roofing	Educational patterns, visible bottle cores	Illustrated cultural and educational integration
The Plastic Road	The Netherlands	HDPE, PP	Road modules	Durable pavement, low maintenance	Modular grid aesthetic	Demonstrated infrastructure use of recycled plastics
Plastic Bottle Houses	Mexico & USA	PET bottles (sand-filled)	Load-bearing walls, insulation	Thermal mass, structural enclosure	Random brick pattern, playful translucency	Defined "bottle-brick" as a distinct category
The EcoHouse Project	South Africa	PET bottles, HDPE, PP	Affordable housing walls, panels	Cost-effective load-bearing, passive cooling	"Earthen" hues from sorted plastics	Showed local adaptation for low-cost housing
Plastic Road Initiatives	South Africa & Kenya	HDPE, PP	Road modules	Weather-resistant infrastructure	Interlocking module pattern	Confirmed regional viability of structural modules
Waste-to-Construction Projects	Kenya	HDPE, PP, PET	Plastic bricks for housing, parks	Load-bearing infill, acoustic damping	Brick-like textures	Linked brick form to multiple plastic streams
Plastic Bottle Brick Homes	Nigeria	PET bottles	Wall construction	Thermal insulation, structural stability	Patterned façade, visible cores	Validated bottle-brick approach in Nigerian context
Urban Green Spaces & Public Furniture	Ghana	HDPE, PP	Benches, fencing, paving	Moisture-proof seating, durable pavement	Bright colors, smooth curves	Extended taxonomy into furniture and landscape elements

4.2 Taxonomy

The table below presents a taxonomy that classifies recycled plastics according to six key attributes: Plastic Type, Common Sources, Forms After Processing, Functions, Aesthetic Contribution, and Spatial Application. This structure is intended to guide architects and designers in selecting recycled plastics based on both performance and visual potential.

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Table 4.2.1 Showing taxonomy of recycled plastics in architecture

Plastic Type	Common Sources	Forms After Processing	Functions	Aesthetic Contribution	Spatial Application
PET (Polyethylene Terephthalate)	Water/soda bottles, food containers	Sheets, fibers, tiles	Acoustic panels, insulation	Translucency, light diffusion	Ceilings, partitions, skylights
HDPE (High-Density Polyethylene)	Detergent bottles, milk jugs	Bricks, lumber, panels	Load-bearing blocks, flooring	Matte texture, color variation	Walls, flooring, outdoor decking
LDPE (Low-Density Polyethylene)	Plastic bags, film wraps	Compressed sheets, membranes	Moisture barriers, roofing	Smooth finish, flexibility	Roof linings, waterproof layers
PP (Polypropylene)	Bottle caps, food tubs	Molded panels, tiles	Furniture, joinery, cladding	Bold colors, high gloss	Furniture, interior cladding
PS (Polystyrene)	Disposable cutlery, foam packaging	Foam boards, insulation blocks	Thermal insulation, lightweight panels	Neutral tones, soft texture	Wall cavities, ceilings, partitions
Mixed/Composite Plastics	Municipal waste, unsorted recyclables	Modular blocks, hybrid panels	Structural infill, temporary shelters	Random patterns, rugged texture	Loadbearing walls, façades

This taxonomy emphasizes design usability by linking material properties to architectural outcomes. It also reflects the realities of material sourcing in Nigeria, where informal recycling streams often yield mixed or hybrid plastic forms.

5. CONCLUSIONS AND RECOMMENDATIONS

This study explored the architectural potential of recycled plastics through the development and application of a design-centric taxonomy that addresses both functional and aesthetic dimensions. By organizing materials along six key attributes, plastic type, source, form, function, visual character, and spatial use, the taxonomy offers a flexible tool that bridges material performance with creative intent. The accompanying case studies validated its practical relevance across varied contexts, showcasing recycled plastics as more than substitutes they are enablers of expressive, sustainable design.

While the results affirm the viability of plastic reuse in architecture, they also expose challenges: limited formalization of recycling systems and public skepticism. Still, the emergence of adaptive, low-cost solutions using these materials suggests strong potential for localized innovation and environmental impact.

Key Contributions:

- Provided a structured, designer-friendly classification of recycled plastics
- Demonstrated the duality of recycled plastics in function and form
- Grounded the taxonomy in real-world architectural projects with regional relevance

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RECOMMENDATIONS:

1. For Architects & Designers: Adopt the taxonomy during early design phases to evaluate recycled plastic options based on both performance and aesthetic goals. Prioritize context-specific materials that align with climate, availability, and cultural acceptance.
2. For Educators & Researchers: Incorporate design-focused material taxonomies into sustainability curricula and explore their adaptation across new typologies, such as infrastructure or adaptive reuse.
3. For Policymakers & Industry: Develop material certification standards and public awareness campaigns to elevate the perception of recycled plastics beyond mere "waste solutions."
4. For Future Research: Extend this taxonomy by integrating quantitative performance data, exploring life-cycle assessments, and testing its application in parametric or digital fabrication workflows.

By reframing recycled plastics as creative, credible building resources, this paper contributes not only a classification system but also a mindset shift. Within the urgency of environmental change lies an opportunity to reshape architecture from the ground up, colorfully, resilient, and responsibly.

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