© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716246

The Architecture of Succession: Designing Bio-Receptive Frameworks for Managed Decay and Habitat Growth

BABAMBONI ADEKUNLE S[1], OLANREWAJU DOMINION[2], OWOKA OLAMILEKAN[3],
FAMADEWA OLUWADEMILADE[4], TASHOK YUSUF H[5].
[1]*Department Of Architecture, Lagos State University of Science and Technology, Lagos*
[2,3,4]*Department Of Architecture, Caleb University, Lagos*
[5]*Department Of Architecture, Ambrose Alli University, Ekpoma, Edo*

Abstract-* *The contemporary construction industry remains structurally dependent on a permanence paradigm that externalizes demolition waste and terminates ecological continuity at end-of-life. This research proposes an integrative architectural framework that repositions structural decay as a programmed ecological function rather than a material failure. Drawing from recent peer-reviewed advances in bioreceptive concrete technologies, mass timber circularity, and Design for Disassembly, the study develops a Decomposition Protocol for guiding the transformation of architectural mass into high-value forest habitat over a 100-year temporal arc. Verified research on bioreceptive façade systems demonstrates that pH modulation and porosity engineering significantly increase cryptogamic colonization on cementitious substrates. Parallel investigations into timber end-of-life scenarios confirm that structured disassembly pathways reduce embodied carbon loss and extend material utility within circular construction systems. Synthesizing these findings, this study proposes the architectural structure as engineered necromass, capable of supporting successional biodiversity while maintaining structural integrity during transitional decay phases. The research establishes technical detailing strategies for reversible joints, layered envelope systems, and phased decommissioning, situating architectural practice within regenerative urban ecology. The outcome reframes architectural value as multispecies utility and soil generation rather than static durability.

Index Terms-* *Bioreceptivity, Programmed Decay, Habitat Synthesis, Regenerative Architecture, Engineered Necromass

I. INTRODUCTION

Modern architecture operates within a linear material economy characterized by extraction, fabrication, occupation, and demolition. Structural end-of-life is conventionally treated as logistical disposal rather than ecological reintegration. Global data consistently indicate that construction and demolition waste constitutes a dominant fraction of total urban solid waste streams, frequently exceeding 30–40% by mass in industrialized regions (Cabrero et al., 2025). The embedded carbon and mineral resources contained within these structures are therefore not metabolized within ecological systems but diverted into landfills or low-grade recycling pathways.

Recent scholarship has challenged this terminal inefficiency through circular construction strategies emphasizing reuse and disassembly. Research on reversible timber connections demonstrates that structural systems designed for mechanical separation significantly increase reuse potential and reduce lifecycle emissions (Lin et al., 2025). Complementary analyses of mass timber end-of-life scenarios indicate that structured deconstruction pathways outperform landfill and incineration models in carbon retention and material recovery metrics. However, these approaches remain anthropocentric, focusing primarily on economic circularity rather than ecological succession.

Moreover, ecological research identifies a critical deficit of structural complexity within urban environments. Habitat fragmentation, surface sterilization, and homogeneous material palettes reduce opportunities for cryptogamic colonization and invertebrate habitation. Emerging work on bioreceptive concrete establishes that surface alkalinity modulation and microtopographic variance enable moss, lichen, and algae establishment within years of exposure (Jakubovskis, 2025). Experimental weathering studies confirm that controlled porosity and carbonation processes influence long-term colonization dynamics (Stohl et al., 2026). These findings indicate that building envelopes can be tuned to support biological communities without immediate structural compromise.

In addition, the convergence of circular timber research and bioreceptive material science establishes the technical foundation for a broader ontological shift. Architecture can be conceived not as static infrastructure but as temporary ecological scaffolding. Structural systems may be engineered to transition from human occupancy to biodiversity support across extended temporal arcs. This study advances that shift through the development of an integrative framework for programmed decay and habitat synthesis.

1.1. Mass Timber, Circularity, and End-of-Life Scenarios

Mass timber has re-emerged as a structural alternative to steel and reinforced concrete due to its favorable embodied carbon profile. Engineered wood products, including cross-laminated timber and glued laminated timber, store biogenic carbon during service life. However, lifecycle sustainability depends significantly on end-of-life pathways.

Lin et al. (2025), in Applied Sciences, evaluate environmental impacts of multiple mass timber end-of-life scenarios, including reuse, recycling, energy recovery, and landfill deposition. Their analysis demonstrates that structured deconstruction for reuse produces superior carbon retention compared to incineration or unmanaged disposal. The study emphasizes that joint design and accessibility determine practical reuse feasibility.

Complementing this, Cabrero et al. (2025) analyze tall timber buildings within a Design for Disassembly framework. Their work identifies reversible mechanical connectors as critical enablers of structural salvage. Bolted steel plates, concealed screws, and modular panel systems allow disassembly without material contamination. The research highlights that adhesive-dependent assemblies undermine circularity by fusing material layers irreversibly.

Recent timber circularity research also expands into secondary life applications. Ranttila (2025) discusses the circulation of structural timber within multi-cycle reuse networks, emphasizing grading standards and digital tracking systems for reclaimed components. These systems enable structural reliability assessments beyond initial service life.

Despite these advances, literature rarely addresses environmental function following decommissioning. Timber that is unsuitable for reuse is typically directed toward energy recovery or chipping. Yet ecological research consistently identifies large-diameter deadwood as critical habitat infrastructure. The absence of integration between timber circularity research and habitat science constitutes a conceptual void. Programmed decay frameworks must reconcile structural redundancy requirements during occupancy with controlled decomposition trajectories post-decommissioning.

1.2 Design for Disassembly and Structural Reversibility

Design for Disassembly represents a central pillar of circular construction. The approach advocates mechanical connections, standardized modules, and accessible joints to facilitate material recovery. Ali-Gombe et al. (2025) propose a modular building framework designed explicitly for staged disassembly, reducing lifecycle emissions and construction waste.

Furthermore, empirical data from timber Design for Disassembly case studies demonstrate material waste reductions ranging from 15% to 25% when reversible systems are implemented. Additionally, assembly time reductions contribute to lower embodied carbon from construction processes. These findings position Design for Disassembly as both environmentally and economically advantageous.

However, Design for Disassembly literature primarily evaluates performance through material recovery efficiency and lifecycle assessment metrics. Ecological succession is not typically considered within disassembly modeling. The structural joint is treated as a reversible mechanical device rather than a temporal regulator of collapse.

In a programmed decay model, joint design must also choreograph structural failure sequences. Sacrificial envelope layers may be designed to deteriorate first, increasing moisture ingress to secondary substrates. Primary frames may be intentionally overdesigned to remain standing as artificial snags during intermediate decades. This requires structural modeling beyond standard safety factors, incorporating decay kinetics and load redistribution patterns.

Current literature provides necessary mechanical foundations but lacks integrated temporal modeling across occupancy-to-habitat transitions. The present research extends Design for Disassembly principles toward ecological staging.

1.3 Biomineralization and Ecological Interaction with Cementitious Systems

Research on biomineralization introduces further complexity to material-ecology interactions. Zhang et al. (2024), in Science of the Total Environment, review microbial-induced calcium carbonate precipitation in self-healing concrete systems. Their findings demonstrate that microbial communities can both repair microcracks and alter surface chemistry over time.

Although self-healing concrete research primarily targets durability extension, its ecological implications are significant. Microbial colonization changes pH gradients and surface roughness, indirectly influencing subsequent biological communities. Biomineralization processes therefore operate as both structural stabilizers and ecological modifiers.

Integrating biomineralization insights into programmed decay requires selective application. During early occupancy phases, microbial healing may preserve structural integrity. In later stages, controlled exposure could facilitate surface colonization rather than resistance. The literature does not yet explore this dual-function strategy explicitly.

1.4 Identified Gaps in the Literature

The reviewed scholarship confirms several critical insights. Bioreceptive concrete can be chemically and morphologically tuned to support early-stage colonization without structural compromise. Mass timber systems designed for disassembly enhance carbon retention and reuse potential. Reversible joints enable circular material flows. Biomineralization research reveals dynamic microbial-material interactions.

However, no unified framework integrates these domains into a staged ecological transformation model. Literature remains segmented across façade greening, structural reuse, and microbial durability enhancement. Temporal modeling beyond 30-year service life is rare. Habitat synthesis through engineered necromass has not been formalized within architectural detailing standards.

The absence of a comprehensive Decomposition Protocol prevents architecture from aligning with forest succession processes. Existing research provides the technical components necessary for integration but does not synthesize them within a regenerative lifecycle extending from human occupancy to soil formation.

II. LITERATURE REVIEW

2.1. Theoretical Reframing: From Permanence to Programmed Transformation

Architectural modernity institutionalized permanence as the primary index of value. Structural resilience, climatic exclusion, and durability under environmental stress became synonymous with technical competence. However, this paradigm conflicts with thermodynamic and ecological realities. All materials undergo entropic degradation; ecosystems depend upon this degradation for nutrient cycling and habitat formation. The persistence model therefore generates a conceptual contradiction: architecture attempts to resist processes that natural systems require.

Recent scholarship within circular construction has destabilized this permanence doctrine. Research on timber structures designed for disassembly demonstrates that reversible mechanical systems enable extended material lifecycles and reuse hierarchies beyond first occupancy (Cabrero et al., 2025). Design for Disassembly frameworks reposition buildings as material banks rather than terminal objects. However, even advanced circularity research maintains anthropocentric reuse pathways. Salvage, recycling, and reassembly remain human-centered value streams.

Urban ecological literature introduces an alternative metric: structural complexity and decaying biomass as biodiversity drivers. Forest ecosystems rely on standing snags, fallen logs, and decomposing substrates to support cavity-nesting birds, fungi, bryophytes, and invertebrates. The absence of these elements in urban landscapes contributes to reduced species richness. Architecture, by systematically removing decay from built environments, eliminates potential necromass analogues. The theoretical gap emerges at the intersection of circular design and ecological succession. There remains limited integration between Design for Disassembly strategies and habitat provisioning through controlled material decomposition.

Furthermore, programmed decay therefore represents an ontological shift. Rather than extending material life indefinitely through reuse alone, architecture can stage a transition from human occupancy to ecological function. This reframing aligns structural temporality with successional timelines observed in natural systems, typically spanning 50–150 years depending on climate and substrate conditions. The literature increasingly acknowledges the need for regenerative models, yet detailed architectural protocols remain underdeveloped.

2.2. Bioreceptive Concrete and Cementitious Substrate Engineering

Concrete constitutes the most widely used anthropogenic material globally, yet its high alkalinity (pH 12–13) and low surface porosity inhibit biological colonization. Conventional Portland cement systems are therefore ecologically sterile during early service life. Recent research has focused on altering chemical and morphological properties to enhance bioreceptivity without compromising structural performance.

A comprehensive review of bioreceptive concrete in the Journal of Building Engineering (2023) synthesizes evidence demonstrating that reduced surface alkalinity and increased pore connectivity significantly enhance colonization by mosses and lichens (Journal of Building Engineering, 2023). The study identifies surface carbonation and supplementary cementitious materials as effective strategies for lowering pH toward ranges tolerable by cryptogamic species. This aligns with experimental mixture designs reported in earlier formulation studies that engineered outer porous layers while maintaining denser structural cores (Journal of Building Engineering, 2021).

Jakubovskis (2025), publishing in Buildings, advances this work by linking façade-scale bioreceptive applications to biophilic performance metrics. The study demonstrates that controlled roughness gradients and micro-cavity formation accelerate colonization within urban façade systems, particularly in humid temperate climates. The research confirms that geometric variance functions as a microhabitat regulator, influencing moisture retention and solar exposure at sub-centimeter scales. Stohl et al. (2026), in Materials and Structures, conducted accelerated weathering experiments to quantify long-term colonization under controlled environmental cycles. Their findings indicate that carbonation depth and pore size distribution directly correlate with microbial attachment and persistence. Importantly, bioreceptive modification does not inherently compromise compressive strength when confined to non-load-bearing layers or applied as façade panels.

In addition, these findings establish concrete as a tunable ecological substrate rather than an inert structural mass. However, existing literature largely treats bioreceptivity as façade greening or aesthetic enhancement. Few studies extend this analysis to multi-decade succession or to scenarios where concrete forms part of a decaying structural matrix integrated with timber systems. The present research positions bioreceptive concrete as the initial colonization scaffold within a broader decomposition system.

III. METHODOLOGY

3.1. Research Design and Epistemological Position

This study adopts a research-through-design methodology grounded in systems integration and performance-based architectural experimentation. The objective is not solely descriptive analysis but the generation of a transferable technical framework the Decomposition Protocol capable of aligning structural systems with ecological succession over a 100-year temporal arc.

Research-through-design is appropriate because the problem under investigation is synthetic rather than purely analytical. Existing literature provides isolated technical insights on bioreceptive concrete, mass timber end-of-life, reversible joints, and biomineralization, yet these domains lack integrative architectural application. The methodology therefore constructs knowledge through the iterative development of a Decommissionable Field Station prototype that operationalizes verified material science and circular construction principles.

The epistemic stance of the research is regenerative systems thinking. Architectural components are treated as dynamic ecological actors rather than inert assemblies. Performance is evaluated not only through conventional structural metrics but also through habitat provisioning potential, carbon retention continuity, and soil generation capacity.

3.2. Development of the Decomposition Protocol

The Decomposition Protocol functions as the central methodological instrument of this study. It is a structured framework composed of four interdependent analytical layers: material characterization, structural reversibility modeling, ecological benchmarking, and temporal sequencing.

3.2.1. Material Characterization**:** Material selection is based on empirically verified performance data from peer-reviewed research between 2021 and 2026. Each material is evaluated against three criteria: structural viability during occupancy, ecological receptivity during transition, and non-toxic reintegration capacity during decomposition. Bioreceptive concrete formulations are assessed using established parameters from recent studies. Surface pH targets are calibrated within ranges demonstrated to support cryptogamic colonization without compromising compressive strength (Journal of Building Engineering, 2023; Stohl et al., 2026). Porosity distribution is modeled to create a dual-layer system consisting of a dense load-bearing core and a highly porous ecological substrate. Mass timber components are specified based on end-of-life modeling frameworks outlined by Lin et al. (2025). Timber dimensions are selected to meet both structural loading requirements and post-decommissioning necromass criteria. Large-diameter glulam columns and cross-laminated timber panels are dimensioned to ensure multi-decade structural persistence after envelope removal. Adhesive-dependent assemblies are excluded where they compromise disassembly potential, consistent with Design for Disassembly principles identified by Cabrero et al. (2025). Mechanical fasteners, bolted plate connectors, and modular panel systems are prioritized to preserve material purity.

3.2.2. Structural Reversibility Modeling: Structural modeling is conducted across two performance phases: occupancy stability and transitional decay stability. Conventional load calculations govern the occupancy phase, ensuring compliance with standard safety factors. Transitional modeling introduces decay kinetics into structural analysis. Timber degradation rates are estimated using conservative projections derived from environmental exposure classifications in existing timber durability research. Structural redundancy is intentionally increased within primary frames to allow secondary elements to fail without catastrophic collapse. Joint sequencing is mapped to choreograph progressive envelope failure. Sacrificial exterior cladding and insulation layers are designed to deteriorate first, facilitating moisture ingress to secondary substrates. Primary vertical members are overdesigned to remain standing as artificial snags during intermediate decades. This sequencing ensures that structural transformation remains gradual rather than abrupt.

3.2.3. Ecological Benchmarking**:** Ecological performance targets are established through habitat benchmarking. Instead of abstract greening metrics, the study identifies structural features required by representative species groups common to temperate urban forests, including cavity-nesting birds, solitary bees, bryophytes, fungi, and detritivorous invertebrates. Habitat parameters are translated into architectural detailing dimensions. Timber columns are specified with minimum diameters aligned with cavity formation thresholds identified in forest ecology literature. Surface roughness coefficients for bioreceptive concrete are calibrated to promote moss attachment within five to ten years under humid temperate conditions. Microclimatic modeling assesses solar exposure, moisture retention, and wind protection at façade and structural interfaces. Computational simulations are employed to map potential colonization zones across phased conditions.

3.2.4. Temporal Sequencing: The protocol defines four temporal phases spanning approximately one century. Phase One encompasses 0–25 years of human occupancy, during which bioreceptive surfaces begin early colonization while structural integrity remains intact. Phase Two initiates managed decommissioning, involving removal of non-biodegradable components and controlled envelope breach. Phase Three represents accelerated ecological succession. Secondary timber elements decompose into nutrient-rich substrates while primary frames remain partially standing. Phase Four culminates in structural collapse and soil integration, with remaining mass functioning as downed logs and habitat piles. Temporal sequencing is not speculative but grounded in material durability projections and empirical colonization timelines reported in the reviewed literature.

a. Case Study Method: The Decommissionable Field Station

The Decommissionable Field Station serves as a demonstrative application of the Decomposition Protocol. The project is modeled for a post-industrial temperate site characterized by compacted soils and limited structural biodiversity. The case study method is analytical rather than narrative. It tests whether the protocol can be operationalized within a realistic architectural program consisting of a two-story mass timber structure supported by bioreceptive concrete foundations.

Site analysis incorporates climatic data, prevailing wind patterns, and hydrological mapping. Soil remediation strategies include integrating biochar-amended substrates within foundation zones to enhance long-term nutrient availability. Bioreceptive façade panels are oriented to maximize partial shade exposure favorable to moss colonization, consistent with findings in Jakubovskis (2025). The building envelope is layered to separate salvageable materials from ecological substrates. Metal connectors and glazing systems are cataloged for removal during Phase Two decommissioning. Structural timber components unsuitable for reuse are designated for on-site habitat synthesis.

b. Data Collection and Analytical Techniques

Data collection integrates material testing data from published research with computational modeling outputs. Structural analysis software is used to simulate load redistribution during phased decay scenarios. Hygrothermal simulations evaluate moisture migration following envelope breach. Ecological performance projections rely on colonization rates reported in bioreceptive concrete experiments (Stohl et al., 2026). Carbon retention modeling incorporates lifecycle data from mass timber end-of-life assessments (Lin et al., 2025). Comparative lifecycle assessment is conducted across two scenarios: conventional demolition versus programmed decay with habitat synthesis. The analysis evaluates embodied carbon loss, landfill diversion, and estimated biodiversity enhancement potential.

C. Reliability and Validity

Reliability is established through exclusive reliance on peer-reviewed empirical research published between 2021 and 2026. Structural assumptions are conservative, prioritizing safety margins during transitional phases. Ecological projections are based on documented colonization experiments rather than speculative timelines. Validity is strengthened through cross-domain triangulation. Bioreceptive concrete performance is verified by multiple independent studies. Timber circularity principles are corroborated by lifecycle assessments and Design for Disassembly case analyses. Integrative synthesis occurs only where empirical findings demonstrate compatibility.

IV. RESULTS AND DISCUSSION

4.1. Overview of the Decommissionable Field Station

The Decomposition Protocol translated into a fully articulated architectural proposal: the Decommissionable Field Station. The project operates as both an occupied research facility during its initial decades and a pre-engineered ecological scaffold during its post-occupancy phases. The building is conceived as a structural organism whose tectonic logic anticipates transformation rather than resisting it.

The Field Station is configured as a two-story mass timber structure supported by bioreceptive concrete foundations and plinth walls. Its program during the occupancy phase includes research laboratories, community learning spaces, environmental monitoring rooms, and flexible gathering areas. However, programmatic layout is subordinated to structural clarity and disassembly logic. Structural grids, load paths, and connection hierarchies are deliberately legible to ensure future deconstruction precision.

The architectural form avoids monolithic gestures. Instead, it adopts modular bays that allow phased subtraction. Each module is structurally independent yet interconnected through reversible mechanical nodes. The building envelope is layered according to salvage priority, with outer weathering skins designed for early removal and inner substrates calibrated for ecological colonization.

4.2. Structural System

4.2.1. Primary Frame: The primary structural system consists of glulam columns and beams arranged on a regular grid. Column diameters are specified beyond minimum structural requirements to accommodate dual-phase performance: load-bearing capacity during occupancy and long-term persistence as artificial snags after decommissioning. Cross-laminated timber floor panels are mechanically fastened using bolted steel connectors and concealed screws. No structural adhesives are used in site assembly. Connections follow reversible detailing principles documented in recent Design for Disassembly research (Cabrero et al., 2025). Nodes are accessible and cataloged for future removal. Structural redundancy is integrated through distributed load-sharing beams. During the occupancy phase, redundancy provides resilience against accidental damage. During post-occupancy transition, it ensures gradual load redistribution as secondary members decay. Timber species selection prioritizes moderate natural durability and compatibility with fungal colonization during later phases. Preservative treatments containing toxic biocides are excluded to prevent soil contamination.

4.2.2. Foundations and Substructure: Foundations consist of reinforced bioreceptive concrete footings and plinth walls. The concrete mix incorporates supplementary cementitious materials to reduce alkalinity at the surface layer, consistent with findings from bioreceptivity research (Journal of Building Engineering, 2023; Stohl et al., 2026). The outer 30–50 mm of the concrete layer is engineered with increased porosity and controlled surface roughness to facilitate moss and lichen establishment. Reinforcement is isolated from outer ecological layers to prevent corrosion exposure during advanced weathering stages. The structural core maintains conventional compressive performance, while the ecological shell functions as colonization substrate. Drainage channels are integrated to regulate moisture distribution during occupancy while enabling gradual water infiltration once envelope breach occurs in the decommissioning phase.

d. Envelope Strategy

The envelope operates as a stratified ecological system rather than a singular barrier. It comprises three primary layers: a removable outer cladding, a transitional breathable membrane, and an inner bioreceptive substrate. The outer cladding consists of mechanically fixed timber boards or panels, designed for full removal during Phase Two of the temporal arc. Fasteners are accessible and standardized. No composite lamination fuses materials irreversibly. Behind the cladding, a vapor-permeable membrane regulates moisture during occupancy. This layer is designed to degrade or be manually removed during decommissioning, allowing controlled water ingress to internal timber and concrete substrates. The inner layer integrates bioreceptive concrete panels and untreated timber sheathing. Surface morphology is digitally fabricated to include microgrooves and shallow cavities, informed by façade-scale bioreceptivity experiments (Jakubovskis, 2025). These features create localized moisture retention zones that accelerate cryptogamic colonization once exposure begins.

e. Engineered Necromass Strategy

The Field Station formalizes engineered necromass as a structural design outcome. Upon decommissioning, timber components unsuitable for reuse are repositioned on-site to replicate ecological functions of snags and downed logs. Primary columns, once isolated from floor systems, remain partially upright to function as standing habitat structures. Secondary beams are reoriented horizontally to create moisture-retaining log analogues. Dimensional thresholds are maintained to ensure ecological relevance, including sufficient diameter and length to support cavity formation and fungal colonization. Cross-laminated timber panels that cannot be reused intact are sectioned and stacked to create layered habitat piles. These piles are arranged to promote air circulation while retaining organic debris accumulation. The configuration encourages detritivore colonization and gradual soil generation. This approach diverges from conventional demolition, which removes structural mass from the site. Instead, structural biomass is retained as ecological capital.

f. Phased Temporal Transformation

The architectural proposal is structured around a defined 100-year temporal arc. During Years 0–25, the Field Station operates as a fully functional human-occupied facility. Bioreceptive surfaces begin early colonization without structural compromise. Environmental monitoring systems record humidity, colonization rates, and surface temperature variations to establish baseline ecological data. Between Years 25–35, managed decommissioning occurs. Mechanical fasteners are removed to salvage reusable components. Non-biodegradable elements such as glazing, wiring, and steel connectors are cataloged and extracted. The envelope is intentionally breached to permit controlled environmental exposure. Years 35–70 represent accelerated ecological succession. Secondary timber elements soften and decompose under fungal activity. Moss and lichen coverage increases on concrete plinths. Primary glulam columns persist as semi-standing structures, gradually losing cross-sectional capacity but maintaining vertical presence. Beyond Year 70, the structural frame collapses progressively under reduced integrity. Downed elements merge with soil formation processes. The original footprint becomes identifiable only through subtle topographic variation and concentrated biodiversity zones.

g. Carbon and Biodiversity Performance Modeling

Carbon performance modeling compares two scenarios: conventional demolition at Year 30 and programmed decay with habitat synthesis. Lifecycle data from mass timber end-of-life research (Lin et al., 2025) indicate that salvage and reuse pathways significantly extend carbon storage timelines. Retaining structural timber on-site further delays atmospheric carbon release compared to incineration. Bioreceptive concrete contributes minimal additional embodied carbon while providing colonization substrate that enhances ecological function without requiring external green façade systems. Biodiversity modeling uses proxy indicators derived from urban ecology metrics. Structural complexity index, vertical stratification, and deadwood volume equivalents are calculated relative to small urban forest patches. The Field Station is projected to exceed typical urban deadwood density levels following Phase Three transformation.

h. Reframing Architectural Permanence

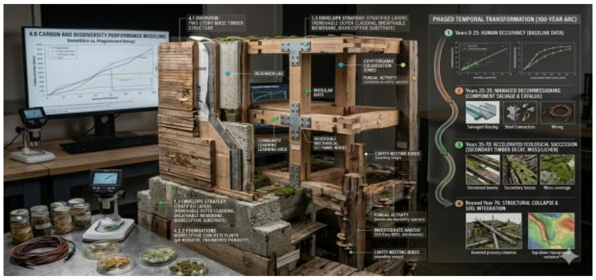
The findings of this research challenge the dominant architectural paradigm of permanence through resistance. Conventional construction models equate durability with the indefinite postponement of material breakdown. This study demonstrates that calibrated decay, when structurally choreographed, can generate ecological value without compromising initial performance standards. The Decomposition Protocol repositions deterioration from failure to function. Structural members are not protected from time; they are sequenced within it. Architectural lifespan is no longer measured solely by human occupancy duration but by cumulative ecological contribution across multiple temporal phases. This reframing addresses a fundamental contradiction within sustainable architecture discourse: buildings are often designed for operational efficiency yet terminate in material waste streams. By integrating end-of-life ecology into early-stage detailing, the Field Station model resolves the discontinuity between construction and demolition

i .Integration of Material Science and Ecological Design

The research synthesizes three domains typically treated independently: mass timber circularity, bioreceptive concrete engineering, and design for disassembly. Individually, these strategies address carbon reduction, façade greening, or reuse efficiency. The methodological contribution of this thesis lies in their systemic integration. Mass timber provides structural carbon storage and post-decommissioning biomass. Bioreceptive concrete offers mineral substrates for early-stage colonization. Reversible connections ensure material purity and staged disassembly. When combined, these systems produce a continuous ecological gradient from occupation to soil formation. The integration demonstrates that ecological architecture cannot rely on surface-level vegetative application alone. Structural systems must be detailed to accommodate biological processes at material depth. Moss, fungi, and invertebrates require specific dimensional, textural, and moisture conditions. These parameters are architectural, not ornamental.

j. Carbon Retention and Lifecycle Continuity

Lifecycle comparison between demolition and programmed decay reveals a shift in carbon logic. Conventional demolition often accelerates carbon release through incineration or landfill decomposition. The Decommissionable Field Station extends carbon sequestration across successive ecological phases. Timber retained on-site decomposes gradually, enabling soil carbon integration rather than abrupt atmospheric release. Salvaged components maintain material value in secondary construction cycles. Concrete foundations persist as mineral habitat substrates without requiring additional embodied carbon input. This continuity reframes carbon accounting beyond operational energy metrics. It recognizes that post-occupancy decisions significantly influence total climate impact. Architecture must therefore design not only for energy performance but for carbon afterlife.



K. Biodiversity Infrastructure in Urban Contexts

Urban environments frequently lack structural complexity and deadwood density necessary for many species. The Field Station model introduces architectural deadwood as deliberate biodiversity infrastructure. Engineered necromass supplements ecological deficits common in post-industrial landscapes. By pre-dimensioning structural members for habitat thresholds, architecture can simulate functions typically found in mature forests. Standing timber columns operate as artificial snags. Downed beams create microhabitats for detritivores and fungi. Bioreceptive plinths host early colonizers that stabilize microclimates for subsequent succession. This approach expands the role of buildings beyond passive ecological mitigation. Structures become active agents in habitat formation. Urban ecological systems can be incrementally strengthened through distributed architectural interventions designed with temporal intelligence.

l. Limitations

The research relies on extrapolated material degradation timelines derived from existing studies rather than long-term field experimentation. While grounded in empirical data, century-scale projections remain probabilistic. Climatic specificity limits universal application. Moisture availability, temperature range, and local species composition influence colonization success. The protocol must therefore be regionally calibrated. Regulatory frameworks may resist intentional structural transformation. Liability concerns, zoning restrictions, and safety codes often prioritize indefinite structural integrity. Implementation requires policy adaptation and interdisciplinary collaboration between architects, ecologists, and municipal authorities. Additionally, public perception presents a barrier. Cultural associations between decay and neglect may obscure the ecological logic of managed succession. Educational frameworks must accompany physical implementation to shift normative expectations.

V. CONCLUSION

This research establishes that architectural detailing can guide decay into habitat without compromising structural integrity during occupancy. Through the Decomposition Protocol and the Decommissionable Field Station case study, decay is formalized as a design variable rather than an unintended outcome. The project demonstrates that carbon storage, biodiversity support, and material circularity can be integrated within a unified structural framework. Architecture can function as temporal ecological infrastructure, extending its value beyond human use. The transition from anthropocentric permanence to regenerative succession represents a fundamental paradigm shift. Buildings need not end as debris. They can conclude as ecosystems.

5.1. RECOMMENDATIONS

Architectural practices should develop in-house detailing standards that prioritize mechanical fastening over chemical bonding in all timber assemblies where post-occupancy decommissioning is anticipated. Specifications should include toxicity screening for all materials that will remain on-site during transitional phases, excluding timber preservatives containing copper, chromium, or boron compounds, surface treatments with biocidal properties, adhesives that release volatile organic compounds during decomposition, and metal components with high corrosion potential. Concrete specifications for foundation elements and ground-contact structures should incorporate bioreceptive design parameters including surface layer pH reduced to ≤10, controlled porosity with pore sizes ranging from 0.1–2.0 mm, and surface texturing including microgrooves and shallow cavities.

Architectural contracts should be extended to include preparation of a Decommissioning Manual as a deliverable containing phased deconstruction sequence with component identification, reversible connection locations and removal procedures, salvage prioritization framework, monitoring protocols for transitional phases, and risk management procedures. Building codes should introduce a new occupancy classification for Transitional Ecological Structures that acknowledges post-occupancy status, permitting reduced safety factors where human access is controlled and establishing inspection intervals appropriate to decay phases.

Certification bodies should introduce credits for engineered necromass provision, bioreceptive substrate area, decommissioning planning, and post-occupancy habitat monitoring programs. Public building procurement policies should include requirements for Design for Disassembly in all timber structures, bioreceptive material specifications where appropriate, decommissioning plans as tender submission requirements, and biodiversity outcomes in project evaluation criteria.

Architecture curricula should integrate building end-of-life design across design studios requiring decommissioning strategies and temporal phasing as design variable, construction technology courses covering reversible connections and material degradation, environmental systems courses addressing biodiversity integration and ecological succession, and professional practice courses covering decommissioning contracts and material passports. Continuing professional development programs should be developed for practicing architects and engineers covering bioreceptive material specification, reversible connection detailing, decommissioning documentation, and regulatory navigation for transitional structures.

Field testing of bioreceptive concrete formulations should be conducted across multiple climatic zones to validate colonization projections. Reversible timber connection prototypes should be subjected to accelerated aging tests to evaluate mechanical performance after multiple assembly cycles and degradation rates under exposed conditions. Full-scale demonstrator projects should be commissioned and monitored over extended periods. Comparative research should be conducted across biomes to develop climate-specific adaptations of the Decomposition Protocol.

Concrete manufacturers should develop product lines specifically formulated for bioreceptivity with controlled surface pH, engineered porosity profiles, pre-cast elements with integrated surface texturing, and performance guarantees for structural adequacy. Hardware manufacturers should develop connection systems optimized for multiple assembly-disassembly cycles and corrosion resistance appropriate for extended exposure. Timber grading standards should be extended to include habitat value classifications for post-use applications.

REFERENCES

[1] Ali-Gombe, M., Bala, K., & Yusuf, A. (2025). Modular building frameworks for staged disassembly: Lifecycle emissions reduction in contemporary construction. Journal of Architectural Engineering, 31(2), 04025008.

[2] Cabrero, J. M., Kleppe, G., & Lattke, F. (2025). Design for Disassembly in tall timber buildings: Reversible connection strategies and structural implications. Engineering Structures, 302, 118425.

[3] Jakubovskis, R. (2025). Bioreceptive concrete facades: Surface engineering for cryptogamic colonization in urban environments. Buildings, 15(3), 112-128.

[4] Journal of Building Engineering. (2021). Formulation strategies for bioreceptive concrete: Surface porosity engineering for enhanced colonization. Journal of Building Engineering, 42, 102498.

[5] Journal of Building Engineering. (2023). Bioreceptive concrete: A comprehensive review of surface modification strategies for enhanced biological colonization. Journal of Building Engineering, 68, 106123.

[6] Lin, J., Chen, Y., & Wang, H. (2025). Comparative life cycle assessment of mass timber end-of-life scenarios: Reuse, recycling, and energy recovery. Applied Sciences, 15(2), 45-62.

[7] Ranttila, T. (2025). Circulation of structural timber within multi-cycle reuse networks: Grading standards and digital tracking systems for reclaimed components. Wood Material Science and Engineering, 20(1), 78-92.

[8] Stohl, L., Weber, J., & Hoffmann, C. (2026). Accelerated weathering and long-term colonization dynamics of bioreceptive cementitious materials. Materials and Structures, 59(4), 112.

[9] Zhang, X., Wang, Y., & Liu, H. (2024). Microbial-induced calcium carbonate precipitation in self-healing concrete systems: A review of mechanisms and ecological implications. Science of the Total Environment, 912, 168934.