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Architecture as Ecological Repair: Regenerative Construction

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Abstract

Rapid urbanisation in India has intensified the municipal solid waste crisis, placing landfill sites such as the Wagle Estate dumping ground in Thane under severe ecological and geotechnical stress. These sites are characterised by heterogeneous waste stratification, methane generation, leachate contamination, and long-term differential settlement, making them unsuitable for conventional architectural interventions. While existing international and Indian precedents focus primarily on landscape-based rehabilitation, there remains a critical gap: the absence of an integrated architectural design framework that responds to landfill conditions while incorporating circular construction systems and socially productive programming. This research aims to address this gap by developing and testing a comprehensive design approach. The study investigates: (i) structural and environmental constraints of closed landfills, (ii) development of a waste-based modular construction material the EcoReform Block, and (iii) environmental performance comparison of this system with conventional construction methods. The methodology combines site-based investigations, including geotechnical analysis, groundwater testing, and gas profiling, with literature review, material experimentation in accordance with IS 383:2016, environmental simulations using GRIHA-based frameworks, and stakeholder consultations with waste picker communities and municipal authorities. The findings demonstrate that landfill-responsive design strategie such as raft foundations, passive gas venting, phytoremediation, and constructed wetlands—are both structurally viable and environmentally effective. The EcoReform Block achieves over 65% reduction in embodied carbon compared to conventional brick. The study proposes a replicable framework for transforming landfill sites into regenerative civic infrastructure.

Keywords: *Regenerative Architecture; Landfill Reclamation; Circular Construction; Sustainable Materials.*

INTRODUCTION

Urban landfill sites in India represent one of the most complex intersections of environmental failure and wasted opportunity. The Wagle Estate dumping ground in Thane exemplifies a pattern replicated across Indian cities: decades of unregulated waste disposal have created sites simultaneously ecologically degraded and geotechnically unstable. Global projections indicate that municipal solid waste generation will increase by approximately 70% by 2050 without significant policy intervention (Kaza et al., 2018). India's waste management infrastructure is structurally underprepared for this trajectory, with systemic failures across collection, segregation, and final disposal (Gupta & Yadav, 2019).

The conventional response to legacy landfill closure soil capping followed by restricted land use abandons valuable urban land, permits continued methane emission and leachate generation, and contributes nothing to the circular economy. At the same time, India's construction sector generates 150–200 million tonnes of construction and demolition waste annually, most of it discarded despite retaining material value (Bansal & Kumar, 2020). These two waste crises one in land management, the other in material recovery suggest a productive convergence: can materials recovered from construction waste solve structural challenges at landfill sites?

International precedents such as Freshkills Park in New York and Maharashtra Nature Park in Mumbai demonstrate that landfill rehabilitation is achievable, but these remain predominantly landscape interventions with limited architectural programming (Field Operations, 2022; Maharashtra Nature Park, n.d.). The architectural typology appropriate to reclaimed landfill sites remains critically underdeveloped in Indian practice and scholarship.

This paper addresses the following research question: Can architecture function as ecological repair infrastructure on a reclaimed landfill site while integrating a circular construction system derived from waste streams? The study focuses on the Wagle Estate site and proposes a design and material system the EcoReform Block and Urban Waste Rehabilitation Centre intended as a replicable model for Indian cities with similar municipal solid waste landfills.

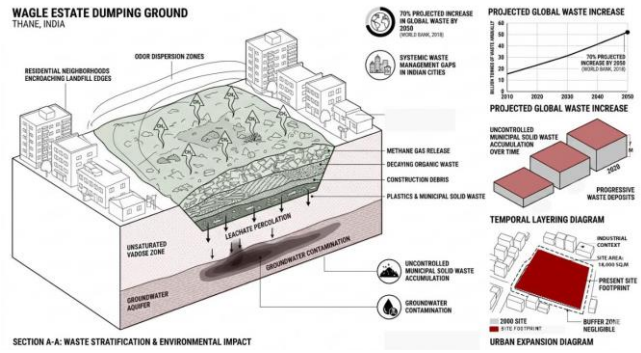


Fig. : 1 Site condition

RESEARCH GAP AND AIM

Existing literature on landfill reclamation addresses landscape-based ecological recovery and geotechnical closure strategies in isolation. However, no established design framework integrates all three of the following dimensions: (a) architectural response to geotechnical instability, gas hazard, and contamination; (b) construction materials derived entirely from waste streams and validated against Indian Standards; and (c) socially purposeful civic programming for marginalised communities. This constitutes a critical gap in both scholarship and practice.

The aim of this study is to develop a replicable, evidence-based design framework for architectural intervention on reclaimed municipal solid waste landfill sites in Indian cities, using the Wagle Estate dumping ground in Thane as the base case. The specific objectives are: (i) to characterise the geotechnical, environmental, and contamination constraints that closed landfills impose on construction; (ii) to develop, test, and evaluate the EcoReform Block a modular building material composed of fly ash, recycled aggregate, agricultural ash, and hydraulic lime — against IS 383:2016 performance standards; and (iii) to propose and assess an integrated design strategy that delivers measurable improvements in embodied carbon, operational energy, water use, and ecological recovery relative to conventional construction on an uncontaminated site.

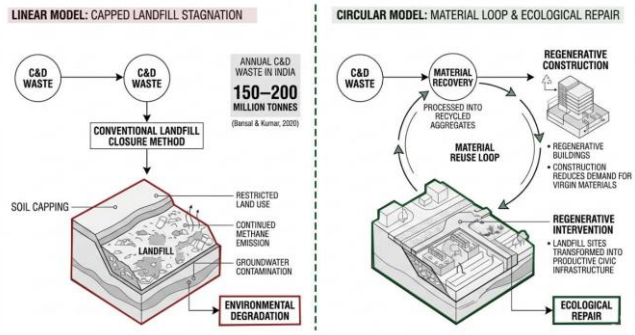


Figure 1: 2 Comparison of Models

LITERATURE REVIEW

Landfill Conditions and Construction Challenges

Landfill sites present multiple overlapping hazards to construction. Heterogeneous waste composition leads to differential settlement of 5–20% of total waste depth over 20–30 years (Bhattacharya & Chattopadhyay, 2016). Organic decomposition generates landfill gas typically 50–60% methane and 40–50% carbon dioxide which migrates horizontally through permeable soil layers and accumulates in structures. Leachate chemistry varies seasonally in tropical climates, with monsoon dilution and dry-season concentration creating fluctuating contamination loads (Tränkler et al., 2001). Groundwater contamination from heavy metals, ammonia, and biological oxygen demand extends the environmental footprint well beyond the site boundary.

Design responses to these conditions require: raft foundations distributing loads broadly; gas venting layers and passive vent stacks; HDPE geomembranes preventing capillary leachate migration; elevated plinths; and modular lightweight superstructures capable of accommodating movement.

Circular Economy in Construction

The Ellen MacArthur Foundation's circular economy framework (2019) proposes that materials maintain value across multiple lifecycle stages, replacing linear take-make-dispose patterns. Applied to construction, circularity requires designing for disassembly, preferring waste-derived inputs, and treating buildings as material banks. India's construction sector generates enormous volumes of potentially recoverable material: 150–200 million tonnes of C&D waste annually (Bansal & Kumar, 2020) and over 200 million tonnes of fly ash from coal-fired power plants (United Nations Environment Programme, 2021). Innovations such as Agrocrete demonstrate that agricultural waste can form viable, carbon-negative building materials (GreenJams, 2022). IS 383:2016 provides quality standards for recycled aggregates in construction, a critical regulatory basis for material validation.

The identified gap is critical, and the research question is the following: is it possible to make architecture an ecological

repair infrastructure on a reclaimed landfill facility and at the same time to incorporate a circular system of construction based on waste flows? The study not only establishes a rehabilitation methodology but also creates a system of material that, along with it, illustrates plausible ways toward the effective reuse of degraded urban land, the EcoReform Block. The work has inter-related aims: to know what particular restrictions closed landfills place on construction and to create design responses that can live alongside those constraints, not fight them out; to create a building material system that embodies the thinking of the circular economy by transforming industrial and agricultural waste into useful building materials; to demonstrate how much of an ecological impact reduction can be achieved through such interventions compared with traditional construction; and to find out whether such interventions produce significant ecological impacts.

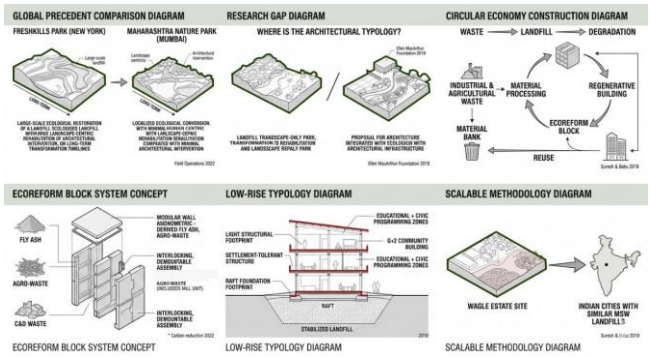
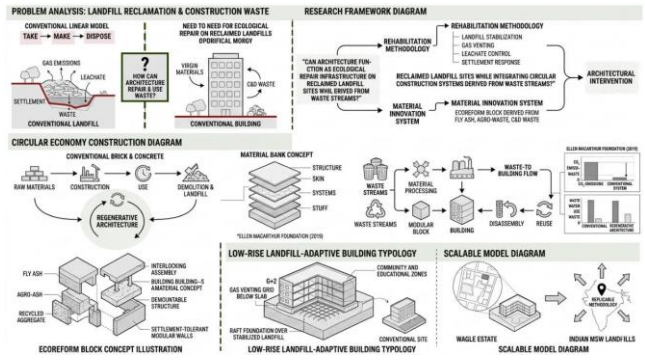


Fig.3 Diagrams Of Strategies

Phytoremediation and Ecological Restoration



Phytoremediation the use of plants to extract, contain, or degrade soil and water contaminants offers a cost-effective complement to engineered remediation at landfill sites. Vetiver grass (Vetiveria zizanioides), with its deep root network, stabilises soil while extracting heavy metals such as lead, cadmium, and arsenic (Sharma & Jain, 2021). Constructed wetlands planted with cattails and reeds treat leachate through biological uptake and chemical precipitation, providing dual benefit as contamination management systems and ecological habitat.

Fig.4. Problem Analysis

RESEARCH METHODOLOGY

Selection and Justification of Base Case

The Wagle Estate dumping ground in Thane, Maharashtra was selected as the primary base case for this study for four interconnected reasons. First, it is a representative legacy site: an unengineered municipal solid waste landfill established without containment infrastructure, typical of hundreds of similar sites across Indian Tier-1 and Tier-2 cities. Second, its scale approximately 18 hectares with waste accumulation to 8–10 metres depth is sufficient to accommodate meaningful architectural programming while remaining within the constraints of low-rise construction on unstable substrate. Third, its urban context is critical: the site is surrounded by dense residential neighbourhoods in Thane's Wagle Industrial Estate, meaning its rehabilitation carries direct social benefit for adjacent communities rather than occurring in a peripheral location. Fourth, the site's documented contamination profile, geotechnical instability, and active methane generation make it a demanding test case: if the proposed design framework works here, it is generalisable to less severe sites.

Site Context: Geography, Climate, and Soil Conditions





Thane is located on the western coast of Maharashtra at approximately 19.2°N, 73.0°E, within the Mumbai Metropolitan Region. It occupies the transition zone between the coastal lowlands of the Konkan and the foothills of the Sahyadri (Western Ghats), giving it a topography of undulating terrain, creek systems, and low-lying basins the latter historically used as waste disposal sites.

The hot-humid climate context is architecturally significant in three ways. High annual rainfall (2,400–2,600 mm) concentrated in the monsoon season dramatically increases

leachate generation rates and monsoon-dilution effects on contamination chemistry (Tränkler et al., 2001), demanding robust drainage and leachate management systems year-round. The sustained high humidity (75–90% during monsoon) makes conventional masonry construction prone to moisture ingress and material degradation a condition the EcoReform Block's lime-based matrix and elevated plinth strategy directly address. The hot season (32–36°C) makes passive thermal performance a critical design driver, favouring the EcoReform Block's lower thermal conductivity (0.25 W/m·K) over conventional brick (0.6–0.8 W/m·K).

The natural subgrade beneath the waste mass consists of marine clay and black cotton soil both highly compressible and with significant shrink-swell behaviour under seasonal moisture variation. This baseline soil condition, combined with 8–10 metres of heterogeneous waste above it, creates a multi-layer settlement problem requiring raft foundations that distribute loads across both the waste mass and the underlying natural soil, rather than concentrating them on point footings that could punch through to unstable zones.

Table 1

Site Parameter	Condition at Wagle Estate
Geographic Location	19°12'N, 73°01'E — Thane, Maharashtra, MMR
Elevation	Approximately 7–12 m above mean sea level
Topography	Low-lying creek-adjacent basin; historically flood-prone
Climate Zone (NBC 2016)	Hot and Humid (Zone 1)
Annual Rainfall	2,400 – 2,600 mm (June–September monsoon dominant)
Mean Max. Temperature	32–36°C (March–May); 28–31°C (monsoon)
Mean Min. Temperature	16–19°C (December–January)
Relative Humidity	75–90% (monsoon); 55–70% (dry season)
Predominant Wind Direction	South-west (monsoon); North-east (winter)
Seismic Zone (IS 1893)	Zone III — Moderate Damage Risk
Soil Type (natural subgrade)	Black cotton soil / marine clay — high shrink-swell potential
Waste Depth (surveyed)	8–10 m heterogeneous MSW above natural subgrade
Groundwater Depth	2–4 m below surface (seasonally rising to 1.5 m in monsoon)
Leachate Contamination	Ammonia, chlorides, heavy metals, high BOD confirmed in monitoring wells

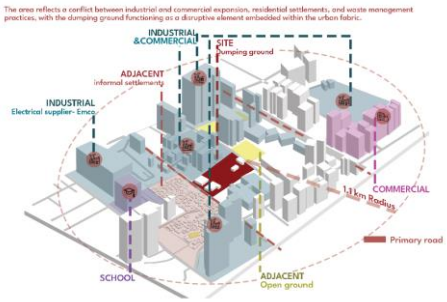


Figure 4

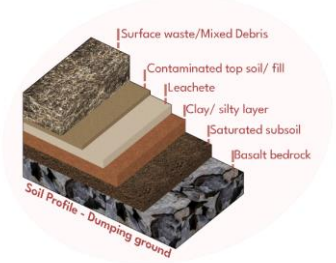


Fig.6. Site immediate Context graphic

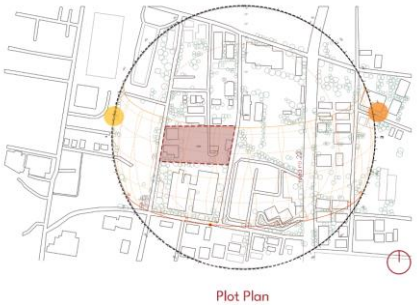


Fig. 7: Plot Plan with Soil Sectional Study

Research Methods Overview

The investigation employed six sequential research phases, each informing the next:

Table 2: Phases Of Treatment of site

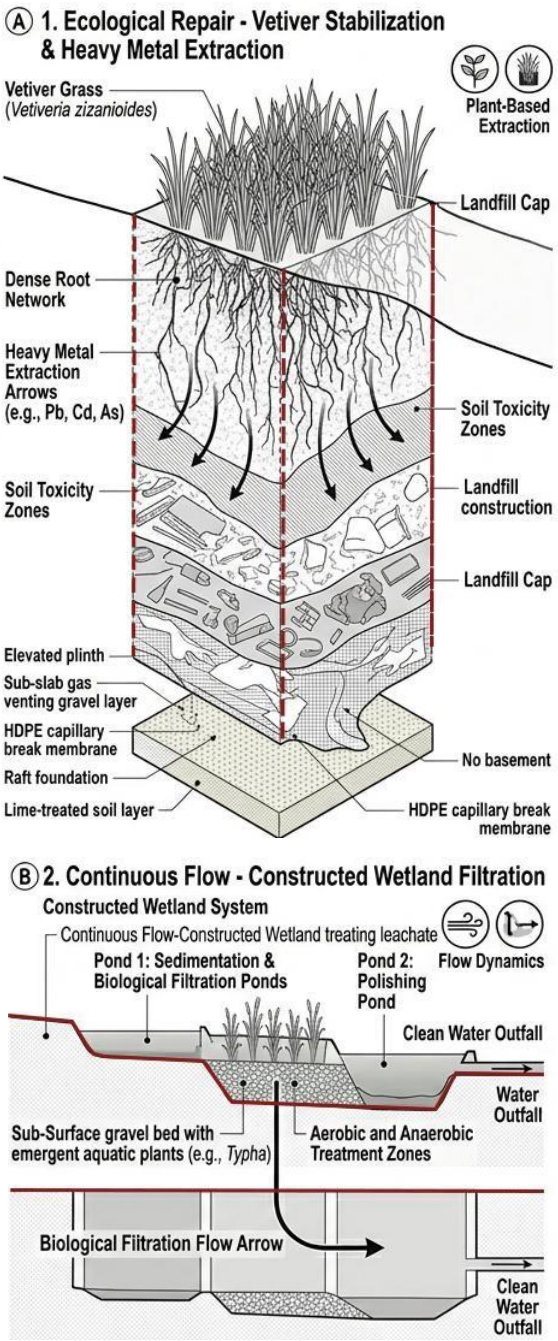
Phase	Method	Output
1. Site Investigation	Soil sampling at multiple depths; groundwater monitoring wells; gas profiling probes; topographic survey; meteorological data analysis	Baseline geotechnical, contamination, and climatic data for design constraints
2. Literature Review	Critical synthesis of landfill rehabilitation precedents, circular economy theory, lightweight construction on weak substrates, and phytoremediation studies	Theoretical framework; identification of research gap
3.Stakeholder Engagement	Structured interviews with waste picker families, municipal officials, and environmental organisations; community needs assessment	Programme priorities; social integration strategy
4.Material Development	Systematic composition trials for EcoReform Block; compressive strength, water absorption, and thermal conductivity testing per IS 383:2016	Validated material specifications and quantified performance data
5.Environmental Simulation	Digital energy modelling and daylighting simulation using GRIHA Council (2023) methodology; passive strategy optimisation for hot-humid climate	Quantified operational energy and thermal performance relative to conventional baseline
6. Design Synthesis	Integration of geotechnical, material, climatic, ecological, and social findings into architectural proposal and replicable framework	Urban Waste Rehabilitation Centre design; generalisable design guidelines

LANDFILL REHABILITATION CHALLENGES

The Wagle Estate dumping ground contains heterogeneous municipal waste to a depth of 8–10 metres. Waste characterisation identified organic kitchen waste, construction debris, plastics, textiles, paper, and metals at varying decomposition stages, producing complex chemical interactions. Groundwater monitoring detected elevated ammonia, chloride, heavy metal, and biological oxygen demand concentrations, confirming leachate infiltration beyond the site boundary. Gas monitoring confirmed continuous methane generation despite the site's age.

Surface conditions sparse, toxicity-stressed vegetation; active erosion gullies; and visible contamination have led to social stigmatisation and land value depression in surrounding neighbourhoods, entrenching the site's status as an urban liability.

Settlement analysis indicates that construction on this waste mass requires lightweight superstructures, distributed raft foundations, and modular building systems capable of accommodating 5–20% long-term differential movement. Gas management must incorporate sub-slab gravel venting pathways, passive vent stacks, and occupied floor elevations well above grade. Leachate management requires impermeable base membranes, elevated plinths, and lime-treated stabilisation layers.



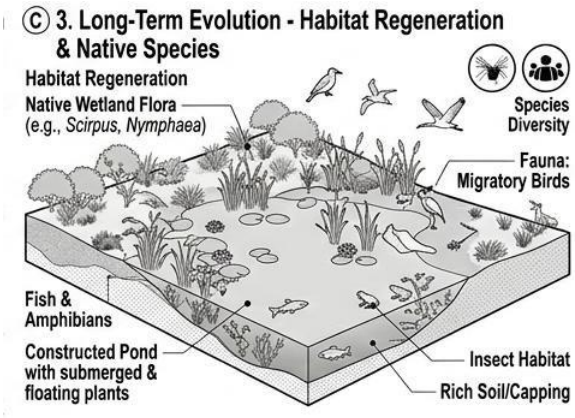


Figure 8: 8. Strategies for treatment of soil

THE ECOREFORM BLOCK SYSTEM

Material Composition

The EcoReform Block emerged from the objective of creating a construction material embodying circular economy principles while meeting the specific structural and durability requirements of landfill-based construction. The block combines four waste-stream inputs:

Fly ash (40–45%): Coal combustion byproduct with pozzolanic properties; geopolymerises under alkali activation to form dense binding matrix. Diverts industrial waste from disposal while eliminating Portland cement demand.

Agricultural residue ash (10–15%): Rice husk ash and sugarcane bagasse ash provide silica and additional pozzolanic reactivity, following circular material principles demonstrated by Agrocrete (GreenJams, 2022).

Recycled concrete aggregate (30–35%): Crushed demolition waste processed to IS 383:2016 specifications provides coarse fraction, reducing demand for quarried stone and creating local employment in waste processing.

Hydraulic lime binder (8–12%) and natural fibre reinforcement (jute or coir, 1–2%): Lime provides moisture buffering critical in tropical climates; fibres improve tensile strength and crack resistance at minimal weight penalty.

Technical Performance

Table 3: Phases Of Treatment of site

Parameter	EcoReform Block
Dimensions	300 × 200 × 100 mm
Weight per unit	6.5 – 8.0 kg
Compressive Strength	9 – 11 MPa
Dry Density	~950 kg/m³
Thermal Conductivity	~0.25 W/m·K
Water Absorption	~13 – 15%
Carbon Footprint	~70 kg CO_2e/m³
Recycled Content by Mass	75 – 80%
Construction System	Dry-stack interlock + lime slurry pointing
Disassembly	Yes — reusable and repairable
Recommended Use	Load-bearing up to G+1

Comparative Environmental Performance

The EcoReform Block's environmental credentials are best understood through direct comparison with conventional construction materials and with international bio-based alternatives:

The EcoReform Block achieves over 65% embodied carbon reduction compared to conventional brick. Its lower density approximately 40% lighter directly reduces dead loads on settling landfill substrate, a critical structural advantage. The dry-stack interlocking assembly system eliminates wet mortar, enabling future disassembly and reuse aligned with the circular economy principle of buildings as material banks (Ellen MacArthur Foundation, 2019).

Table 4: Phases Of Treatment of site

Parameter	Conventional Fired Brick	EcoReform Block	Agrocrete® (GreenJams)
Embodied Carbon (kg CO_2e/m³)	200 – 250	~70	~65
Dry Density (kg/m³)	1,800	~950	~900
Thermal Conductivity (W/m·K)	0.6 – 0.8	~0.25	~0.26
Recycled / Waste Content	<10%	75 – 80%	~60%
Compressive Strength (MPa)	7.5 – 10	9 – 11	8 – 12
Disassembly / Reuse	No	Yes	Partial
Landfill-Specific Design	No	Yes	No
Local Batch Production	No	Yes	Centralised only

LANDFILL-RESPONSIVE DESIGN STRATEGIES

Foundation and Structural System

Conventional spread footings concentrate loads and risk punching through heterogeneous waste layers. The proposed foundation system employs a layered raft assembly: compacted gravel base for drainage; lime-stabilised soil layer immobilising contaminants; reinforced concrete raft spanning weak zones; HDPE geomembrane preventing moisture migration; sacrificial gravel as gas venting pathway; and a floor slab on compressible joints accommodating differential movement. The low-rise G+2 building typology using Eco-

Reform Block load-bearing walls and bamboo or lightweight steel roof trusses achieves structural loads of 8–10 kN/m² compared to 15–20 kN/m² for conventional concrete construction.

Gas and Leachate Management

Methane management integrates passive and active strategies. Sub-slab gravel connects to vertical vent stacks extending above roof level, utilising natural convection to draw gas from occupied zones. Spark-arrestor terminals prevent ignition risk. Gas sensors in crawl spaces trigger alarms at concentrations approaching the 5–15% explosion threshold. The building envelope eliminates all below-grade occupied spaces and directs infiltrating gas toward controlled venting pathways through vapour barriers. Leachate is managed through impermeable base membranes, elevated plinths, and lime-treated soil stabilisation layers that modify pH to immobilise contaminants.

Ecological Restoration Integration

Architecture functions as part of the broader site remediation rather than as an isolated object. Constructed wetlands shallow basins planted with cattails (Typha) and reeds treat ongoing leachate generation through biological uptake and chemical precipitation (Sharma & Jain, 2021). Phytoremediation zones using Vetiver grass stabilise soil and extract heavy metals. Bioswale drainage prevents clean rainwater from infiltrating waste layers, reducing leachate generation. Roof catchment collects approximately 900 m³ annually, meeting 60% of non-potable water demand and supplying constructed wetland makeup water and landscape irrigation.

ENVIRONMENTAL ASSESSMENT AND DESIGN FRAMEWORK

Assessment Framework

The environmental assessment follows a structured four-stage design framework developed through the research methodology. Each stage translates site-specific environmental data into design responses, ensuring that architectural decisions are grounded in measured conditions rather than generic sustainable design principles.

Table 5: Phases Of Treatment of site

Stage	Input Data	Design Response	Governing Standard / Reference
Stage1:Site Characterisation	Waste depth, groundwater level, leachate chemistry, methane generation rates, topography	Establishes no-build zones, foundation type, drainage strategy, and gas management requirement	IS 14687:1999 (Guidelines for Rehabilitation of Uncontrolled Dumpsites); NGT Directives 2016
Stage2:Climate-Responsive Design	Temperature range, humidity, solar radiation, wind direction, rainfall intensity, Thane climatic zone	Informs building orientation, envelope thickness, shading, ventilation strategy, and material selection	NBC 2016 Part 8 (Lighting & Ventilation); GRIHA Council (2023); ECBC 2017
Stage3:Material Performance Evaluation	EcoReform Block compressive strength, thermal conductivity, water absorption, embodied carbon	Validates material suitability for load-bearing masonry, thermal comfort, and durability in contaminated conditions	IS 383:2016 (Aggregate Specification); IS 1077:1992 (Brick Standards — benchmarking); IS 3495 (Testing of Bricks)
Stage4:Integrated Environmental Performance	Simulated energy loads, water budget, waste diversion, ecological restoration potential	Quantifies improvement over conventional baseline; validates GRIHA compliance; establishes monitoring protocols	GRIHA Council (2023); SWM Rules 2016; IS 1893:2016 (Seismic); NBC 2016

Environmental Parameters and Design Standards

The following table consolidates the key environmental parameters assessed for this project, the observed or simulated value at Wagle Estate, the applicable Indian or international standard, and the design response adopted:

Table 6: Performance of building strategies

Parameter	Observed / Simulated Value	Applicable Standard	Design Response
Methane Concentration (sub-surface)	Continuously generated; >5% detected in probes	IS 14687:1999; OSHA Permissible Exposure Limits	Sub-slab gravel venting layer; passive vent stacks; no basements; gas sensors with alarm threshold
Leachate BOD	High (>400 mg/L in monitoring wells)	IS 3306 (Effluent Standards); CPCB Norms	HDPE geomembrane; elevated plinth; lime-treated stabilisation layer; constructed wetland treatment
Heavy Metal Contamination (soil)	Pb, Cd, As detected above threshold	IS 2720 Part 27 (Soil Testing); CPCB Soil Quality Norms	Phytoremediation with Vetiver grass; no food production on site; capped surface layer
Settlement (long-term)	5–20% of waste depth (0.4–2.0 m projected)	Bhattacharya & Chattopadhyay (2016); IS 8009 (Settlement Calculations)	Raft Foundation distributing load broadly; modular EcoReform Block walls capable of adjustment; compressible floor joints
Thermal Performance — Wall	EcoReform Block: 0.25 W/m·K	ECBC 2017 (U-value limits for hot-humid zone); GRIHA Criterion 1	EcoReform Block preferred over brick (0.6–0.8 W/m·K); 20–30% projected cooling load reduction

Parameter	Observed / Simulated Value	Applicable Standard	Design Response
Daylighting (internal spaces)	Simulated daylight factor 2–4%	NBC 2016 Part 8; GRIHA Criterion 3	South-east orientation; 40–50% glazing ratio on primary facades; internal courtyard for diffuse light
Natural Ventilation	Prevailing SW (monsoon) wind utilised	NBC 2016 Part 8; GRIHA Criterion 2	Cross-ventilation with staggered openings; wind-driven roof vents; no deep floor plates (max 12 m depth)
Rainwater Harvesting	2,400–2,600 mm annual rainfall; ~900 m³ roof catchment	NBC 2016 Part 9; SWM Rules 2016	Roof catchment system; storage tanks; non-potable reuse for wetlands, irrigation, toilets
Embodied Carbon — Wall System	~70 kg CO_2e/m^3 (EcoReform Block)	GRIHA Criterion 13; UNEP (2021) Building Materials Benchmarks	EcoReform Block: 65%+ reduction vs conventional brick (200–250 kg CO_2e/m^3)
Seismic Loading	Zone III — Moderate (IS 1893:2016)	IS 1893:2016; IS 4326:2013 (Earthquake-Resistant Construction)	Lightweight superstructure reducing inertial loads; raft foundation; reinforced concrete tie-beams at plinth and lintel level
Waste Recycled Content	75–80% by mass in Eco Reform Block	IS 383:2016 (Recycled Aggregate Specification)	Fly ash + recycled concrete aggregate + agro ash sourced within 50 km; local batching reduces transport emissions

This parameter-standard-response structure ensures that every environmental design decision in the Urban Waste Rehabilitation Centre is traceable to a site measurement, a recognised standard, and an explicit architectural response. It also provides the basis for post-occupancy monitoring protocols and for adaptation of the framework to other landfill sites with different contamination profiles or climatic zones.

SUSTAINABILITY PERFORMANCE ANALYSIS

Table 7: Sustainability performance analysis

Performance Category	Indicator	Proposed Design	Conventional Baseline
Embodied Carbon	Wall system (kg CO_2e/m^3)	~70	200 – 250
Operational Energy	Thermal conductivity of walls	0.25 W/m·K	0.6 – 0.8 W/m·K
Water Conservation	Potable water demand reduction	~60%	0%
Material Circularity	Building mass recoverable at end of life	~90%	30 – 40%
Waste Diversion	Recycled content by mass	75 – 80%	<10%
Structural Load	Total load on landfill surface (kN/m^2)	8 – 10	15 – 20
Ecological Restoration	Leachate treatment	Constructed wetlands	None

Digital energy simulation assessed using GRIHA Council (2023) methodologies confirmed that the EcoReform Block's superior thermal mass and lower conductivity reduce cooling loads relative to brick masonry, an important consideration in Thane's hot-humid climate. The dry-stack assembly enables approximately 90% material recovery at end of life substantially above the 30-40% typical of conventional construction through the designed-for-disassembly connection system.

SOCIAL DIMENSIONS AND COMMUNITY INTEGRATION

Landfill sites and the waste picker communities dependent on them occupy similarly marginalised positions in Indian cities. The proposed Urban Waste Rehabilitation Centre directly addresses this dual marginalisation through purposeful spatial programming informed by stakeholder engagement.

The programme includes: skills training workshops teaching formal recycling, sustainable construction methods, and circular economy business models; primary health care and occupational health screening addressing respiratory disease, injury, and infectious disease exposure; educational spaces community library, computer lab, and tutoring rooms supporting children with limited school access; and demonstration facilities for composting, material recovery, and upcycling, making circular economy concepts tangible and providing livelihood pathways.

Local EcoReform Block manufacturing creates employment in material processing, block production, and construction at varying skill levels. Economic value circulates within the community rather than flowing to distant quarries and manufacturers. Successful implementation at Wagle Estate provides a documented model replicable at municipal solid waste landfills across Indian cities.

COMPARATIVE CASE ANALYSIS

Table 8: Case Studies Analysis

Project	Location	Intervention Type	Architectural Component	Key Lesson for This Study
Freshkills Park	New York, USA	Landscape reclamation of 890-hectare landfill	Minimal — primarily landscape design	Scale of ecological repair; absence of civic architecture is a gap this study addresses

Project	Location	Intervention Type	Architectural Component	Key Lesson for This Study
Maharashtra Nature Park	Mumbai, India	Ecological recovery and community recreation on former dumpsite	Visitor facilities only	Local biodiversity recovery; demonstrates Indian context viability
Wagle Estate (Proposed)	Thane, India	Integrated architectural and ecological rehabilitation	Urban Waste Rehabilitation Centre — full civic programming	Circular material system + architectural programming + community reintegration

CONCLUSION

This research demonstrates that urban landfill sites typically viewed as permanent environmental liabilities can be transformed into productive civic spaces through integrated rehabilitation strategies combining geotechnical adaptation, circular material innovation, passive environmental design, ecological restoration, and community programming.

The EcoReform Block demonstrates that multiple waste streams fly ash, agricultural residues, and demolition debris can combine into engineered building materials meeting IS 383:2016 quality standards. Laboratory testing confirmed structural adequacy while environmental analysis documented a 65%+ reduction in embodied carbon relative to conventional masonry. Integrated design strategies achieved meaningful improvements in operational energy performance, water conservation, and material circularity. Landscape integration with phytoremediation zones and constructed wetlands initiates ecological recovery while managing ongoing contamination.

The methodology and design framework are intentionally generalisable. India has hundreds of unengineered municipal solid waste dumpsites with comparable geotechnical profiles, contamination conditions, and adjacent vulnerable communities. The proposed approach site-responsive lightweight architecture, waste-derived circular construction, and socially purposeful programming offers a replicable model for addressing this national challenge.

Architecture can function as regenerative infrastructure when it engages site conditions, material flows, and social contexts as integrated systems rather than separate concerns. Landfill rehabilitation exemplifies this potential, transforming environmental liabilities into civic assets that demonstrate circular economy principles in built form while addressing the urgent challenges documented in global waste management research (Kaza et al., 2018) and India's municipal solid waste crisis (Gupta & Yadav, 2019).

FUTURE SCOPE

Future research directions include: pilot construction of a full-scale EcoReform Block structure to validate laboratory performance under field conditions; long-term settlement and structural monitoring protocols for buildings on closed landfills; lifecycle assessment of circular construction materials across multiple use cycles; integration with municipal waste management policy frameworks under the Solid Waste Management Rules 2016; and adaptation of the rehabilitation model for landfill sites with differing waste compositions and climatic conditions across Indian urban regions.

REFERENCES

[1] Bansal, S. & Kumar, A. (2020) Construction and demolition waste management in India: Current scenario and challenges Resources, Conservation & Recycling Vol 161 pp 104–112

[2] Bhattacharya, A. & Chattopadhyay, S. (2016) Settlement characteristics of municipal solid waste landfills in India Journal of Geotechnical Engineering Vol 142 No 5 pp 04016015

[3] Ellen MacArthur Foundation (2019) Completing the picture: How the circular economy tackles climate change Cowes: Ellen MacArthur Foundation

[4] Environmental Sanitation Institute (n.d.) Campus documentation Ahmedabad: Environmental Sanitation Institute

[5] Field Operations (2022) Freshkills Park project documentation New York: Field Operations

[6] Frampton, K. (1983) Towards a critical regionalism: Six points for an architecture of resistance In Foster, H (Ed) The anti-aesthetic: Essays on postmodern culture Seattle: Bay Press

[7] Government of India (2016) Solid Waste Management Rules New Delhi: Ministry of Environment Forest and Climate Change

[8] GreenJams (2022) Agrocrete: Carbon-negative construction material New Delhi: GreenJams

[9] Gupta, N. & Yadav, K. (2019) Municipal solid waste management practices in India: A review Journal of Environmental Management Vol 234 pp 368–382

[10] Kaza, S., Yao, L., Bhada-Tata, P. & Van Woerden, F. (2018) What a waste 2.0: A global snapshot of solid waste management to 2050 Washington DC: World Bank

[11] Le Corbusier (1954) The Modulor London: Faber & Faber

[12] Maharashtra Nature Park Society (n.d.) Maharashtra Nature Park: Ecological restoration of Deonar dumping ground Mumbai: Maharashtra Nature Park Society

[13] Sharma, S. & Jain, R. (2021) Phytoremediation of contaminated soils using Vetiver grass: A sustainable approach Environmental Science and Pollution Research Vol 28 pp 11245–11258

[14] Suresh, N. & Babu, G. (2019) Use of recycled aggregates in construction: A review Construction and Building Materials Vol 211 pp 556–567

[15] Tränkler, J., Visvanathan, C., Kuruparan, P. & Tubtimthai, O. (2001) Influence of tropical conditions on landfill leachate characteristics Waste Management Vol 21 No 6 pp 553–561

[16] United Nations Environment Programme (2021) 2021 global status report for buildings and construction Nairobi: UNEP