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Article

Community-Led Climate-Responsive Social Infrastructure: Reframing Low-Carbon Construction in the Global South

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Abstract: The construction sector accounts for a substantial share of global greenhouse gas emissions, yet many low-carbon building approaches remain inaccessible in resource-constrained settings because they depend on capital-intensive technologies and formal supply chains. This study examines how community-led construction can contribute to climate-responsive infrastructure through the integration of material reuse, passive environmental design and collective action. Using a qualitative case study of the Ulwazi Educare Centre in Delft, Cape Town, the research draws on 45 semi-structured interviews, field observations, project documents and photographs to explore the environmental, social and institutional dimensions of an alternative construction approach. The findings show that discarded tyres and other locally available materials were reconfigured into durable community infrastructure through participatory construction. Participants consistently associated the building with improved thermal comfort, reduced reliance on mechanical heating and cooling, opportunities for skills development, employment and collective ownership. The study interprets these findings through the lens of post-natural building, an analytical framework that explains how climate-responsive infrastructure can emerge from the interaction of material reuse, passive environmental design, and collective labour in resource-constrained contexts. The study also identifies important constraints to the wider adoption of community-led climate-responsive infrastructure. While participants perceived environmental and social benefits, scaling such approaches depends on organisational capacity, professional expertise and institutional legitimacy. The findings are based on qualitative evidence and do not quantify thermal performance or embodied carbon, highlighting the need for complementary engineering assessments. By integrating environmental, social and institutional dimensions, the study contributes a socio-technical perspective on low-carbon construction and expands debates on climate-responsive infrastructure in the Global South.

Keywords: Low-Carbon Construction, Circular Economy, Passive Design, Community-Led Infrastructure, Climate -Response Architecture, Post-Natural Building.

1. Introduction

The construction sector is a major contributor to global climate change, accounting for approximately 37% of global energy- and process-related carbon dioxide emissions and more than one-third of global energy demand (UNEP, 2022; Cabeza et al., 2022). These emissions arise from both operational energy use and the embodied carbon associated with construction materials such as cement and steel, which remain among the largest industrial sources of greenhouse gas emissions (Habert et al., 2020). International climate assessments, therefore, emphasise the urgent need to reduce both operational and embodied emissions through transformative changes in construction practices (Cabeza et al., 2022; UNEP, 2022).

These challenges are particularly acute in rapidly urbanising regions of the Global South, where infrastructure deficits intersect with climate vulnerability and persistent socio-economic inequality.

Many low-income communities continue to lack safe, affordable and climate-resilient housing, while access to essential services such as education and healthcare remains limited (UN-Habitat, 2026; UNICEF, 2026). Addressing these challenges requires construction approaches that are environmentally sustainable, economically accessible and socially responsive to local contexts (Swilling et al., 2016).

Current debates in sustainable construction have largely focused on energy-efficient technologies, low-carbon materials, and green certification systems (Pomponi & Moncaster, 2017). While these approaches have improved environmental performance, they often depend on capital-intensive technologies, specialised expertise and formal supply chains that remain inaccessible in many resource-constrained settings (Agyeman et al., 2016). Scholars have therefore called for more context-sensitive approaches to climate-responsive construction that recognise informality, material scarcity, and limited institutional capacity, while building on locally available resources, community knowledge, and adaptive construction practices (Malik et al., 2024; Rajendran et al., 2026).

Material reuse, passive environmental design and community-led construction have each emerged as important approaches to sustainable construction. Reusing locally available waste materials can reduce demand for virgin resources while supporting more circular approaches to construction (Geissdoerfer et al., 2017). Recent research further highlights the growing role of recycled and upcycled materials in promoting resource efficiency, sustainable construction and environmental responsibility, while recognising the technical, economic and regulatory challenges that continue to limit their wider adoption (Milad, 2025). Passive environmental design strategies, including building orientation, natural ventilation, and high-thermal-mass wall systems, can improve indoor comfort while reducing reliance on mechanical heating and cooling systems, particularly in warm climates (Santamouris, 2016; Manshour & Lehmann, 2026). Community-led construction has also gained increasing attention for supporting local employment, skills development and collective ownership of infrastructure (Turner, 1976; Hamdi, 2010; Mitlin & Satterthwaite, 2013). More broadly, sustainable building practices are increasingly recognised for their contribution to community well-being, resilience and social inclusion (Ruchit & Charles, 2024). Despite these advances, these themes are frequently examined within separate bodies of literature. Less attention has been paid to how material reuse, passive environmental design, and community participation are negotiated and integrated within a single community-led infrastructure project operating under the institutional, regulatory, and resource constraints common in many low-income settings (Watson, 2009; Mukiga & Venter, 2025; Mukiga, 2026).

This study addresses that gap through a qualitative case study of the Ulwazi Educare Centre in Delft, Cape Town. The project combines earth-filled recycled tyres, passive environmental design principles and community participation in the construction of an early childhood development centre. Rather than evaluating the building's technical performance, the study examines how participants understand the interaction between these practices and how they perceive the institutional conditions that enable or constrain their implementation. In doing so, the study builds on earlier discussions of post-natural building (Apotsos & Venter, 2020) by applying and extending the concept to examine community-led climate-responsive social infrastructure. The paper offers a qualitative perspective on how reused industrial materials, passive environmental design, and collective construction practices are understood, negotiated, and implemented within a resource-constrained community setting, while considering their broader relevance to climate-responsive construction debates.

The following research questions guide the study:

1. How do participants understand the interaction between material reuse, passive environmental design and community-led construction in shaping climate-responsive social infrastructure at the Ulwazi Educare Centre?

2. How do participants perceive the institutional conditions that enable or constrain the wider application of these practices?

2. Literature

2.1. Beyond Technocentric Paradigms: Rethinking Low-Carbon Construction

The built environment has become a central focus of climate change mitigation because of its substantial contribution to global greenhouse gas emissions. Construction activities generate both operational emissions associated with building use and embodied emissions arising from the extraction, manufacture and transportation of construction materials. The production of conventional construction materials such as cement and steel remains among the largest industrial sources of greenhouse gas emissions (Habert et al., 2020; IEA, 2023; UNEP, 2022). Consequently, efforts to decarbonise the built environment have increasingly prioritised material innovation, energy-efficient technologies and green building certification systems (Pomponi & Moncaster, 2017).

These approaches have made important contributions to improving environmental performance. However, their implementation often depends on capital-intensive technologies, specialised expertise and formal supply chains that are not equally accessible across different socio-economic contexts (Agyeman et al., 2016; Swilling et al., 2016). Recent work on global decarbonisation similarly argues that achieving low-carbon transitions requires greater attention to the social, institutional and infrastructural conditions that shape the adoption of sustainable construction practices (Riffat et al., 2026). Climate-responsive construction, therefore, requires more than technological innovation alone. It also depends on the capacity of communities and institutions to adapt solutions to local environmental, economic and social conditions.

This shift has led to growing recognition of community-based and informal construction practices as important sources of environmental innovation. Ryan (2011) argues that traditional construction practices challenge the assumption that sustainability depends primarily on advanced technologies. Similarly, Malik et al. (2024) demonstrate how informal construction practices in Malawi respond creatively to material scarcity, limited financial resources and local environmental conditions. In the South African context, Mukiga (2026) shows how tyre-based construction extends regenerative design principles by combining material reuse with community participation to address environmental and social challenges simultaneously. Together, these studies suggest that climate-responsive construction can emerge through locally embedded practices that integrate environmental objectives with community knowledge and collective action.

Rather than positioning technology and community knowledge as competing approaches, emerging scholarship increasingly views sustainable construction as a socio-technical process shaped by the interaction of materials, design, institutions and social practices (Scott, 2007; Apotsos & Venter, 2020). This perspective recognises that technological innovations are embedded within broader social, political and institutional contexts that influence how they are adopted, adapted and scaled. Building on this understanding, the concept of post-natural building provides a useful analytical lens for examining how reused industrial materials, passive environmental design and community participation interact within community-led climate-responsive infrastructure. It shifts attention from individual technologies to the relationships among material innovation, collective action, and the institutional conditions that shape their wider adoption.

2.2. Circularity in Practice: Material Reuse Between Formal and Informal Systems

The circular economy has emerged as an important framework for reducing waste, extending material life cycles and limiting resource extraction through strategies such as recovery, reuse and recycling (Geissdoerfer et al., 2017; Adams et al., 2017). Within the construction sector, these principles have encouraged adaptive reuse, material recovery and design for disassembly as alternatives to linear patterns of production and consumption. However, circular economy frameworks have largely evolved around formal industrial systems and commercial supply chains. Consequently, they often pay less attention to the everyday reuse practices that characterise informal and resource-constrained communities (Scott, 2007; Mukiga & Venter, 2025).

Research on vernacular and community-based construction demonstrates that locally available and repurposed materials can reduce demand for virgin resources while supporting construction practices that respond to local environmental and socio-economic conditions (Oliver, 2006; Bronner, 2006). Similarly, Agyenim et al. (2026) show that circular waste management systems can generate environmental and economic benefits when embedded in local practices and supported by community participation. Together, these studies suggest that circularity extends beyond industrial recycling systems to include locally embedded forms of material reuse shaped by available resources, practical knowledge and community action.

Tyre-based construction provides one example of this broader understanding of circularity. Paschich and Hendricks (1995) documented the use of discarded tyres as structural building elements, while subsequent engineering research has evaluated their structural and thermal performance (Saikat et al., 2019; Xu et al., 2022). More recent work in South Africa has shown how earth-filled tyre walls can combine material reuse with regenerative design principles and community participation (Mukiga, 2026). These studies illustrate the potential of waste materials to be reimagined as construction resources within community-led projects rather than being treated solely as environmental liabilities.

At the same time, the use of recycled tyres in construction continues to generate important technical and regulatory questions. Concerns have been raised regarding fire safety, long-term durability, potential toxicity and end-of-life management (Mohajerani et al., 2021). While studies and user experiences often report positive perceptions of structural performance and indoor comfort, wider acceptance depends on continued technical evaluation, appropriate regulatory oversight, and context-specific evidence (Mukiga & Venter, 2025). These considerations highlight the importance of examining not only the environmental potential of reused materials but also the social, institutional and technical conditions that influence their acceptance and wider application.

This study builds on these debates by examining how material reuse is understood and negotiated within a community-led construction project. Rather than treating circularity solely as a technical or industrial process, it explores how reused materials interact with passive environmental design, collective labour and local knowledge to shape climate-responsive social infrastructure. Viewed through the lens of post-natural building, circularity becomes both a material practice and a social process embedded in the realities of community action and institutional engagement.

2.3. Passive Design Revisited: Climate-Responsive Strategies in Marginalised Contexts

Reducing operational energy demand remains a central objective of climate-responsive construction. Passive environmental design strategies, including building orientation, thermal mass, insulation and natural ventilation, improve indoor environmental performance while reducing dependence on mechanical heating and cooling systems (Givoni, 1998; Szokolay, 2012). These approaches are particularly relevant in resource-constrained settings, where access to affordable and reliable energy remains uneven and where rising temperatures are increasing the demand for cooling (Santamouris, 2016; Cabeza et al., 2022; UNEP, 2022; Manshour & Lehmann, 2026).

Research increasingly demonstrates that passive design is most effective when it responds to local climatic conditions rather than relying on universal design solutions. This requires careful consideration of materials, building orientation, ventilation and patterns of use within specific environmental and socio-economic contexts. In South Africa, Mukiga (2026) illustrates how earth-filled tyre construction combines passive environmental design with community-led construction to reduce reliance on mechanical cooling while responding to local climatic conditions. Such examples suggest that passive environmental design is not simply a technical intervention but rather part of a broader approach to climate-responsive construction embedded in local practices and available resources.

Despite these advantages, passive environmental design continues to occupy a relatively marginal position within mainstream construction. Contemporary building practices often prioritise construction speed, standardisation and short-term economic considerations, while passive strategies are often treated as supplementary rather than fundamental design principles (de Dear & Brager, 2002; Mukiga & Venter, 2025). This limits opportunities to integrate locally appropriate design approaches into conventional construction systems, particularly in low-income communities where climate resilience is most needed.

Emerging scholarship, therefore, argues that the effectiveness of passive environmental design cannot be understood solely in terms of technical performance. Rather, it depends on the interaction between building materials, construction practices, climatic conditions and how buildings are used and experienced over time (Riffat et al., 2025). Viewed through the lens of post-natural building, passive environmental design becomes more than a set of architectural techniques. It represents a relational process in which environmental performance emerges through the interaction of design, material choices and lived experience within specific social and ecological contexts.

2.4. Community-Led Infrastructure: Participation, Equity, and Resilience

Community-led construction is increasingly recognised as an alternative to conventional top-down models of infrastructure delivery. Rather than positioning communities as passive recipients of development, participatory approaches recognise local people as active contributors to planning, design and construction processes (Turner, 1976; Hamdi, 2010). Research has shown that these approaches can generate employment, strengthen local skills, foster collective ownership and produce infrastructure that is more responsive to community priorities (Mitlin & Satterthwaite, 2013). Such outcomes are particularly important in underserved urban contexts, where formal infrastructure provision often fails to respond adequately to local needs (UN-Habitat, 2022).

Community participation also contributes to climate-responsive construction by embedding environmental innovation within local knowledge and collective action. In South Africa, Mukiga (2026) demonstrates how tyre-based construction integrates material reuse, regenerative design and community participation within the development of an early childhood development centre. The study illustrates that construction can function not only as the production of physical infrastructure but also as a process of building social relationships, strengthening local capabilities and fostering community resilience.

Despite these benefits, translating community-led innovation into wider practice remains challenging. Participatory construction often requires engagement with formal planning systems, professional expertise, and regulatory approval, which may not readily align with community-led approaches (Watson, 2009; Venter et al., 2019). Experiences from Latin America demonstrate how planning systems and housing regulations can constrain locally driven innovation (Fernandes, 2011; Connolly & Wigle, 2017; Lombard, 2014), while research in South Asia similarly highlights the difficulties of integrating community-led upgrading initiatives within formal governance structures (Salauddin & Piracha, 2024). These studies suggest that the long-term success of community-led construction depends not only on local participation but also on the capacity to navigate technical, organisational and institutional processes.

Recent research on global decarbonisation similarly argues that climate transitions require social participation alongside technological innovation (Riffat et al., 2026). Viewed through the lens of post-natural building, community participation becomes more than a mechanism for project delivery. It is the process through which material reuse, passive environmental design and collective action are translated into climate-responsive social infrastructure. At the same time, participation highlights that the wider adoption of such approaches depends on organisational capacity, professional expertise and institutional legitimacy that enable community innovation to move beyond individual projects towards broader transformative practice.

2.5. Toward Integrated Socio-Technical Transitions: Defining Post-Natural Building

Existing approaches to sustainable construction offer important but often complementary perspectives. Eco-vernacular traditions emphasise the value of locally available natural materials and culturally embedded building practices (Oliver, 2006). Adaptive reuse focuses on extending the life of existing buildings while conserving the value of embodied materials through their continued use and transformation (Bullen & Love, 2011; Pomponi & Moncaster, 2017), while regenerative design seeks to create mutually beneficial relationships between the built environment and the ecological and social systems in which it is embedded (Mang & Reed, 2012). More recent decarbonisation research has concentrated on reducing embodied carbon through innovations in construction materials, including supplementary cementitious materials, LC^3, geopolymers, recycled aggregates and carbon capture technologies (Rafi et al., 2025). Collectively, these perspectives have advanced the understanding of sustainable construction by addressing different dimensions of environmental performance.

The preceding sections of this review suggest that climate-responsive construction cannot be understood through any single perspective alone. Rather, it emerges through the interaction of socio-technical processes, locally embedded circular practices, passive environmental design and community participation. These dimensions highlight that sustainable construction is shaped not only by material and technological innovation but also by the social, institutional and environmental contexts within which construction takes place.

Building on the work of Apotsos & Venter (2020), this study adopts post-natural building as an analytical lens to examine these interactions. Rather than representing a new theory of sustainable construction, post-natural building offers a way to understand how reused industrial materials, passive environmental design, and collective action are integrated into community-led infrastructure projects. It directs attention to the relationships among material choices, environmental performance, community participation, and the institutional conditions that influence how climate-responsive innovations are developed, implemented, and sustained.

Viewed in this way, post-natural building offers an integrative perspective on community-led, climate-responsive infrastructure. It recognises that sustainability is not achieved through technological innovation alone, nor solely through material reuse or ecological design. Instead, it emerges through the interaction of material reuse, passive environmental design and collective action under conditions of institutional constraint. This perspective provides the conceptual foundation for examining how participants at the Ulwazi Educare Centre understand and experience climate-responsive construction within a resource-constrained community setting.

3. Materials and Methods

3.1. Research Design

This study adopted a qualitative case study design to examine how community-led construction practices contribute to climate-responsive infrastructure through material reuse, passive environmental design and collective action. A qualitative case study is appropriate for investigating contemporary socio-technical processes within their real-world context, where the boundaries between the phenomenon and its setting are closely interconnected (Yin, 2018). Rather than seeking statistical generalisation, case studies generate context-dependent knowledge and analytical insights that contribute to broader theoretical understanding (Flyvbjerg, 2006).

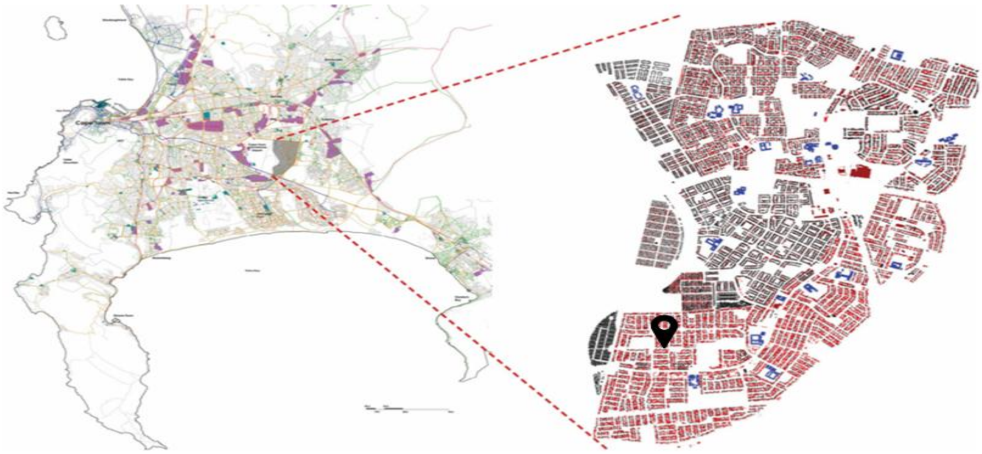
The Ulwazi Educare Centre in Delft, Cape Town, was selected as an illustrative case because it demonstrates an alternative approach to construction that integrates reused materials, passive environmental design and community participation. Examining this case provides an opportunity to understand how these dimensions interact in practice and how community-led climate-responsive infrastructure is negotiated within a resource-constrained urban context.

3.2. Case Selection and Context

The Ulwazi Educare Centre was purposively selected because it exemplifies the study's focus on community-led climate-responsive infrastructure. The project integrates reused materials, passive environmental design and community participation within the construction of an early childhood development centre. As such, it provides an appropriate case for examining how these dimensions interact in practice within a resource-constrained urban context.

The centre is located in Delft, a low-income township in Cape Town characterised by socio-economic vulnerability, infrastructural inequality and environmental pressures (Cirolia & Scheba, 2019). These conditions make the project a valuable example of how community-led construction can respond to local social and environmental challenges while exploring alternative approaches to low-carbon development. The location of the Ulwazi Educare Centre in Delft is shown in Figure 1. The completed Ulwazi Educare Centre is shown in Figures 2 and 3, illustrating its interior and exterior spaces.

Figure 1. Location of the Ulwazi Educare Centre in Delft, Cape Town.



Source: Adapted from Cirolia & Scheba (2019).

Figure 2. Interior view of the completed Educare Centre.

Source: Author's fieldwork 2023-2024

Figure 3. Exterior view of the completed Ulwazi Educare Centre.

Source: Author's fieldwork 2023-2024

The completed facility illustrates the integration of reused materials, passive environmental design and collective labour in the construction process.

3.3. Data Collection

Data were collected through semi-structured interviews, field observations, project documents, photographs and reflective field notes. The researcher volunteered at the Ulwazi Educare Centre between 2022 and 2024, which provided prolonged engagement with the project and a deeper understanding of its construction processes, community dynamics and organisational context. This volunteer role was separate from the formal research. Participant recruitment and interviews commenced only after ethical approval had been granted on 31 October 2023.

A purposive sampling strategy was used to recruit participants with direct knowledge of the project. A total of 45 participants were interviewed between November 2023 and January 2024. Interviews were paused during December because many participants had travelled for the Christmas holidays and resumed in January 2024. Participants comprised practitioners (8) from the Natural Building Collective, including architects, engineers and project coordinators; builders (12); community members (15), including parents, volunteers and residents; and collaborators (10) from partner organisations and NGOs.

Semi-structured interviews were selected because they provide sufficient flexibility to explore participants' experiences while maintaining a consistent focus across interviews (Kvale & Brinkmann, 2009; Creswell & Poth, 2018). Interviews explored participants' experiences of material reuse, construction practices, passive environmental design, costs, community participation and institutional challenges. Interviews lasted between 30 minutes and one hour, were audio-recorded with participants' consent and transcribed verbatim. Where participants preferred to speak isiXhosa, a translator assisted during the interviews and the transcripts were translated into English for analysis.

Field observations, reflective field notes, project documents and photographs were used to contextualise and corroborate participants' accounts. Triangulating these multiple sources of evidence enhanced the credibility and depth of the findings (Patton, 2015).

3.4. Data Analysis

The data were analysed using reflexive thematic analysis to identify and interpret patterns across participants' accounts (Braun & Clarke, 2006, 2021; Braun et al., 2024). An inductive approach was adopted, allowing themes to emerge from the interview data, field observations, reflective field notes, project documents and photographs rather than being predetermined.

Interview transcripts were read repeatedly to become familiar with the data before coding was undertaken in ATLAS. ti 22. Initial codes were generated and refined iteratively through constant comparison across the different data sources. Related codes were then organised into broader categories and developed into themes that addressed the study's research aim, consistent with the principles of reflexive thematic analysis (Braun & Clarke, 2021; Braun et al., 2024). Throughout the analysis, evidence from interviews, observations and documentary sources was compared to strengthen the credibility and interpretation of the findings.

3.5. Ethical Considerations

Ethical approval for the study was granted by the General/Human Research Ethics Committee (GHREC) of the University of the Free State (Clearance No. UFS-HSD2023/1478) on 31 October 2023. Although the researcher had volunteered at the Ulwazi Educare Centre before the study commenced, this role was independent of the formal research. Participant recruitment, informed consent, and semi-structured interviews commenced only after ethical approval was obtained.

All participants provided written informed consent before participating in the study. Participation was voluntary, and participants were informed of their right to withdraw at any stage without consequence. Confidentiality and anonymity were maintained throughout the research, and all data were securely stored and used solely for academic purposes (Creswell & Poth, 2018).

3.6. Limitations

As a qualitative case study, the findings are not intended to be statistically generalisable. Rather, they provide analytical insights into community-led climate-responsive infrastructure that may inform broader discussions of socio-technical transitions in low-carbon construction (Yin, 2018; Flyvbjerg, 2006).

The study did not include quantitative measurements of embodied carbon or thermal performance. Consequently, findings on indoor thermal comfort and energy performance are presented as participants' reported experiences, supported by field observations, rather than by independently verified engineering measurements. These findings should therefore be interpreted as experiential evidence that complements, rather than replaces, quantitative assessments of tyre-based construction reported elsewhere (Mukiga & Venter, 2025).

4. Results

The Ulwazi Educare project represents a distinct model of low-carbon, climate-responsive construction, emerging through the integration of material reuse, passive design, and community-led building processes. These elements function as an interconnected socio-technical system, producing environmental, economic, and social outcomes simultaneously. Five key themes are identified: (1) material reconfiguration and circularity, (2) passive thermal performance and energy reduction, (3) cost and value redefinition, (4) community participation and socio-economic benefits, and (5) institutional constraints and scalability tensions.

4.1. Material Reconfiguration and Circularity

A central finding of this study is that participants did not regard discarded tyres as waste but as valuable construction resources. Across participant groups, material reuse was described as a practical response to environmental waste while providing an affordable alternative to conventional building materials.

Practitioners consistently challenged conventional understandings of waste. One practitioner explained:

"I have never really thought of it as 'waste'… I see these as good building materials."

Community members similarly described how their perceptions changed through involvement in the construction process. Initial scepticism was gradually replaced by appreciation of the building's value. As one participant reflected:

"I was like, why are these people bringing this rubbish here… then when I saw this is useful, they use it to build our school… now look at the building, it is standing."

Participants also emphasised the importance of locally available materials. Rather than viewing discarded tyres as an environmental burden, they described them as an accessible resource that could be transformed into durable infrastructure. As another participant explained:

"These tyres are lying around… we turn that old tyre into a new building."

These accounts demonstrate that participants understood material reuse not simply as recycling but as the practical transformation of locally available resources into community infrastructure. The availability of discarded tyres as a locally accessible construction resource is illustrated in Figure 4. In doing so, they associated tyre reuse with reduced material waste, lower dependence on newly manufactured building materials and greater environmental responsibility.

Figure 4. Discarded tyres beneath Philip Kgosana Drive in Cape Town, highlighting the accumulation of waste tyres within the urban environment.

Source: Author's fieldwork 2023-2024

This illustrates the availability of discarded tyres that the researcher identified as a locally accessible construction resource. This account demonstrates how materials commonly regarded as waste are reinterpreted as valuable inputs for community-led construction.

4.2. Passive Thermal Performance and Energy Reduction

Participants consistently described the Ulwazi Educare Centre as maintaining comfortable indoor temperatures year-round. Across interviews, they attributed this to the thick tyre walls and the building's passive design, reporting that the indoor environment remained cooler during hot weather and warmer during colder periods without relying on mechanical heating or cooling systems.

One practitioner explained:

"These tyre walls absorb heat during the day and release it slowly… inside the building it stays cool when it is hot outside and warmer during winter."

Community members made similar observations when comparing the Educare Centre with nearby conventional buildings. As one participant noted:

"When you walk inside, you immediately feel the difference… it does not get too hot even on very warm days."

Participants consistently described these thermal characteristics as improving comfort for both children and educators during the building's daily use. Their accounts suggest that passive environmental design was regarded as one of the project's most valued features. The passive design of the tyre walls is illustrated in Figure 5.

Figure 5. Passive design of the tyre walls illustrates the use of compacted tyre construction to support thermal mass.

Source: Author's fieldwork 2023-2024

This figure illustrates the passive design of tyre walls, where compaction and orientation enabled thermal regulation. These accounts highlight how thermal performance was understood through everyday experience rather than measured data. No quantitative records of temperature or energy use were collected, and claims remain experiential.

4.3. Cost and Value Redefinition

Participants consistently challenged the assumption that sustainable construction is necessarily more expensive than conventional building methods. While they acknowledged that tyre construction required considerable labour, they described the overall project as offering good value for its cost, durability and long-term benefits.

One practitioner explained:

"We did Ulwazi with less money, not more."

Participants also emphasised that value extended beyond financial cost. They associated the building with durability, aesthetic appeal and improved indoor comfort. As another practitioner explained:

"You cannot replicate what we built with conventional methods… You cannot make it that nice, strong, durable, or beautiful, and we could still do it for less."

Community members similarly linked affordability to broader household priorities. One participant reflected:

"If they use tyres they will use less money… so they can buy more important things."

These accounts indicate that participants understood value as extending beyond construction costs alone. Rather than focusing solely on financial expenditure, they associated value with durability, environmental responsibility, comfort and the potential to redirect limited household resources towards other essential needs.

4.4. Community Participation and Socio-Economic Benefits

Community participation was a defining feature of the Ulwazi Educare project. Participants described the construction process as creating opportunities for learning, skills development, employment and collective engagement. Rather than contributing labour alone, community members became active participants in constructing the facility.

One participant explained:

"We had to put our hands on the deck and contribute labour… as we also earn some money."

Participants consistently highlighted the importance of learning through practical involvement. A collaborator described how construction became a process of skills development:

"We train them on site… at the end of the day, they would actually have been part of the project."

This involvement also fostered a strong sense of ownership and pride. As another participant reflected:

"Everyone… will have something to say that I was here when this was built."

Beyond the construction process itself, participants associated the project with employment opportunities, income generation and creativity. One participant explained:

"It opened job opportunities… people get to work and get paid."

Another highlighted how the project encouraged new ways of thinking about construction:

"You can create something out of anything… creativity is on another level."

Examples of community participation and creativity during construction are shown in Figures 6 and 7.

Figure 6. Community volunteers mixing cob for wall construction.

Source: Author's fieldwork 2023-2024

Figure 7. Community members participating in the roofing of the Ulwazi Educare Centre.

Source: Author's fieldwork 2023-2024

This illustrates the active involvement of community members throughout the construction process. Participants described these activities as opportunities to acquire practical skills, generate income and contribute directly to the development of the Educare Centre.

These accounts demonstrate that participants viewed construction as extending beyond the delivery of physical infrastructure. They associated the building process with skills development, employment, collective ownership and increased confidence in their ability to contribute to future community projects.

4.5. Institutional Constraints and Scalability Tensions

Participants consistently described challenges in implementing community-led construction within existing regulatory and institutional systems. While they regarded the Ulwazi Educare Centre as a successful project, they explained that obtaining approvals and implementing alternative building methods required considerable time, technical expertise and organisational support.

One practitioner explained:

"The system does not know how to deal with something like this… it does not fit into existing regulations."

Participants also identified construction time and project costs as important challenges. A collaborator noted:

"The challenge… is the time that it takes to construct and the budget… compared to conventional style."

Questions of replication and wider adoption emerged across participant groups. Rather than viewing the approach as easily transferable, participants emphasised that successful implementation depended on access to skilled professionals, organisational capacity and sustained collaboration. As one participant remarked:

"You cannot replicate what we built with conventional methods."

These accounts indicate that participants regarded the wider adoption of community-led construction as dependent not only on innovative building techniques but also on the capacity to navigate regulatory requirements, mobilise technical expertise and sustain collaborative partnerships.

5. Discussion

5.1. Post-natural building: Integrating material reuse, passive design and collective action

The findings demonstrate that the climate-responsive performance of the Ulwazi Educare Centre emerged from the interaction among material reuse, passive environmental design, and collective action, rather than from any single construction technique. Participants consistently described discarded tyres as valuable building resources and experienced improved indoor comfort through passive design. They viewed the construction process as creating opportunities for skills development, employment and collective ownership. Together, these findings indicate that environmental and social outcomes were mutually reinforcing rather than separate dimensions of the project.

This interpretation extends prevailing approaches to sustainable construction. Eco-vernacular traditions emphasise the cultural continuity of natural materials (Oliver, 2006), adaptive reuse focuses on extending the life of existing buildings and materials (Bullen & Love, 2011), while regenerative design seeks to restore ecological systems (Mang & Reed, 2012). Although each of these perspectives makes an important contribution, they tend to emphasise particular dimensions of sustainability. The Ulwazi case suggests that climate-responsive infrastructure can also emerge through the pragmatic integration of reused industrial materials, passive environmental design and community participation within resource-constrained settings.

These findings also reinforce socio-technical perspectives that view sustainability transitions as emerging from interactions among materials, technologies, institutions, and social practices (Scott, 2007; Apotsos & Venter, 2020). Rather than treating community participation as an additional social benefit, the findings indicate that collective labour was integral to the production of the infrastructure itself. Similarly, material reuse and passive environmental design were not independent interventions but interdependent components of the wider construction process.

This study, therefore, proposes post-natural building as an analytical lens for understanding community-led climate-responsive infrastructure in contexts of resource constraint. Rather than privileging material purity, technological sophistication or ecological restoration alone, post-natural building highlights how sustainability can emerge through the integration of reused materials, passive environmental design and collective action. In doing so, it broadens current understandings of low-carbon construction by positioning grassroots innovation as a socio-technical process shaped by environmental, social and institutional interactions.

5.2. Environmental performance: Potential and caution

Participants consistently described the Ulwazi Educare Centre as providing a comfortable indoor environment throughout the year. They associated the thick tyre walls and passive design features with cooler indoor conditions in summer and warmer conditions in winter. They also perceived a reduced reliance on mechanical heating and cooling. These findings indicate that users experienced the building as climate-responsive and energy-efficient in their everyday use of the facility.

These experiences should, however, be interpreted within the scope of the present study. The findings are based on participants' accounts and field observations rather than direct measurements of indoor temperature, energy consumption or embodied carbon. Consequently, the study does not claim to quantify thermal performance or carbon reductions. Instead, it demonstrates how passive environmental performance is experienced, understood and valued by those who design, construct and occupy the building.

Mukiga and Venter (2025) and Mukiga (2026) similarly report positive user perceptions of thermal comfort in tyre-based buildings, including perceptions of reduced reliance on mechanical cooling. Together, these studies suggest that passive environmental design may form an important component of community-led, climate-responsive infrastructure, while also highlighting the need for complementary engineering evidence.

The findings also highlight important practical considerations for the wider adoption of tyre-based construction. Although participants perceived tyres as durable and resilient building materials, questions regarding fire safety, long-term durability, potential toxicity, and end-of-life management remain important considerations for future research and policy development (Mohajerani et al., 2021). Addressing these issues through thermal monitoring, fire-resistance testing, life-cycle assessment, and embodied-carbon analysis would strengthen the evidence base for post-natural building and support its broader acceptance within sustainable construction practice. However, recent fire testing commissioned by the Natural Building Collective demonstrated that a load-bearing rammed-earth tyre wall achieved high fire resistance under standard test conditions, providing evidence that fire safety concerns can be addressed through appropriate design and construction (Natural Building Collective, 2026).

5.3. Institutional legitimacy and scalability

The findings indicate that the wider adoption of community-led climate-responsive infrastructure depends on more than the technical feasibility of alternative construction methods. Participants consistently identified regulatory approval processes, access to professional expertise and the organisational demands of community-led construction as major challenges. These findings suggest that scalability is shaped not only by environmental performance but also by the capacity to navigate institutional systems.

This interpretation extends previous research on grassroots innovation and informal construction. Watson (2009) and Venter et al. (2019) highlight how conventional planning and upgrading approaches can privilege formal, technical and standardised systems over locally adaptive and community-based practices. Similar patterns have been documented across the Global South, where regulatory systems often struggle to accommodate community-led innovation (Fernandes, 2011; Connolly & Wigle, 2017; Lombard, 2014; Salauddin & Piracha, 2024). The Ulwazi case supports these observations but also demonstrates that institutional barriers extend beyond regulation alone. Successful implementation depended on sustained collaboration between community members, architects, engineers, non-governmental organisations and local authorities.

These findings therefore suggest that institutional legitimacy is produced through collaboration rather than technical compliance alone. While the Natural Building Collective successfully navigated regulatory approval by working with qualified professionals and public authorities, participants recognised that such organisational and technical capacity is unlikely to be available to many community-led initiatives. Consequently, the wider adoption of post-natural building depends not only on innovative construction techniques but also on the ability to mobilise financial resources, professional expertise and long-term institutional partnerships.

This study, therefore, extends debates on socio-technical transitions by showing that community-led climate-responsive infrastructure is constrained as much by institutional and organisational capacity as by technical innovation. Expanding the use of post-natural building will require regulatory frameworks that maintain appropriate safety standards while creating greater opportunities for alternative construction practices to be assessed, recognised and supported.

5.4. Construction as social infrastructure

The findings demonstrate that the Ulwazi Educare project functioned as more than a construction initiative. Participants consistently described the building process as creating opportunities for skills development, employment, creativity and collective ownership. Rather than viewing labour-intensive construction as an inefficiency, they understood it as a means of strengthening individual capabilities and community resilience. In this sense, the social value of the project emerged not only from the completed building but also from the process through which it was constructed.

This interpretation extends earlier work on participatory development and community-led infrastructure.Turner (1976) argued that housing should be understood as a process rather than simply a product, while Hamdi (2010) similarly emphasised the role of participation in strengthening community agency. The present findings support these perspectives by showing that collective labour generated practical skills, employment opportunities and a stronger sense of ownership among participants. They also align with Mitlin and Satterthwaite (2013), who argue that community-led initiatives strengthen social capital through collaboration and shared responsibility.

The Ulwazi case further demonstrates that community participation was not an additional benefit accompanying construction but a central mechanism through which climate-responsive infrastructure was produced. Material reuse, passive environmental design and collective labour operated as interconnected components of the same socio-technical process. This finding broadens conventional understandings of sustainable construction by suggesting that environmental performance and community development should be understood as mutually reinforcing rather than competing objectives.

Taken together, the findings suggest that post-natural building expands current sustainability debates by integrating environmental, social and institutional dimensions within a single analytical framework. Community-led climate-responsive infrastructure emerges not only through innovative materials or passive environmental design, but through the collective capacity to mobilise knowledge, labour and institutional partnerships. This perspective positions grassroots innovation as an important pathway for advancing more inclusive and context-responsive transitions towards low-carbon construction in the Global South.

6. Conclusion

This study demonstrates that community-led climate-responsive infrastructure can emerge through the integration of material reuse, passive environmental design and collective action. Drawing on the case of the Ulwazi Educare Centre in Delft, Cape Town, the findings show that discarded industrial materials can be transformed into durable community infrastructure while simultaneously creating opportunities for skills development, employment and collective ownership. Rather than viewing these outcomes as separate, the study demonstrates that environmental performance and community development were mutually reinforcing within the construction process.

The study contributes to sustainability debates by proposing post-natural building as an analytical lens for understanding community-led climate-responsive infrastructure in resource-constrained settings. Rather than privileging material purity, technological innovation, or ecological restoration alone, post-natural building highlights how sustainability can emerge through the interaction among reused materials, passive environmental design, and collective labour. In doing so, the study extends discussions of low-carbon construction by showing that transitions are shaped not only by technological innovation but also by social participation, organisational capacity and institutional legitimacy.

The findings should be interpreted within the scope of the study. Thermal comfort and environmental performance were explored through participants' experiences and field observations rather than quantitative measurements of indoor temperature, embodied carbon or energy use. While these qualitative findings provide valuable insight into how climate-responsive infrastructure is experienced and valued, complementary engineering assessments remain necessary to evaluate thermal performance, fire safety, life-cycle impacts and long-term durability.

The study also demonstrates that the wider adoption of community-led climate-responsive infrastructure depends on more than the technical feasibility of alternative construction methods. Scaling such approaches requires organisational capacity, professional expertise and institutional frameworks that support innovation while maintaining appropriate safety standards. Future research should therefore combine qualitative and engineering approaches across diverse contexts to examine how community-led construction can contribute to more equitable, climate-responsive and low-carbon transitions in the Global South.

Data Availability

The qualitative data underlying this study include interview transcripts that may contain identifiable information. To safeguard participant confidentiality and comply with ethical requirements, these transcripts are not publicly available. Access may be granted upon reasonable request, subject to approval by the relevant ethics committee and adherence to confidentiality agreements.

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Author contribution

A.K. Mukiga: Conceptualisation, Methodology, Investigation, Formal Analysis, Writing-Original Draft Preparation, Writing-Review & Editing.

Informed consent

All participants provided written informed consent before participation. The study’s purpose, confidentiality safeguards, and voluntary nature of involvement were explained in detail before consent was obtained.

Competing interests

The author declares no competing interests.

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