Title: **Reimagining Plastics in the Built Environment: Ecobricks at the Ridge, Cape Town**

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Reimagining Plastics in the Built Environment: Ecobricks at the Ridge, Cape Town

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Tessa Brunette is an architect and building envelope designer, holding the position of associate and office leader, Arup, in Cape Town. She specializes in delivering innovative, integrated design solutions that are grounded on sustainable principles. Her skill set and experience lie in leading the delivery of integrated multidisciplinary engineering on complex projects, often using teams across geographies. She holds degrees from both the University of Cambridge and the University of Cape Town (UCT), and has spoken at a number of conferences in South Africa on the work in which she and Arup are involved. She has also taught part-time at UCT in its Professional Master's program since 2015.

Fiona Carr joined Arup in 2019 as a graduate structural engineer with the buildings team after working as a port and coastal engineering and planning consultant for over three years. She completed her master's degree with a distinction in structural engineering at UCT and further obtained her master's degree with a distinction in structural engineering at Imperial College London. Since joining the buildings team at Arup, Fiona has worked on several projects ranging from office, residential, and mixed used facilities. She is determined to enhance and positively affect the world and local environments through creative, holistic, appropriate, efficient, and sustainable design of engineering solutions.

Anthony Graham-Jolly is a structural engineer in the buildings team at Arup. He has a strong desire to influence responsible development on projects he works on through lean design and carbon-efficient solutions. He was the lead structural engineer for The Ridge, where innovative ecobrick solutions were employed.

Gareth Griffiths is a Cape Town-based post-graduate materials scientist, built environment writer and magazine editor. He has been the technical writer for the V&A Waterfront on the Ridge project referenced in this paper. He is also editor of *To Build* magazine, a South African built-environment industry magazine with a focus on sustainability.

Abstract

The use of ecobricks in 2020 at the Ridge, a commercial development within the V&A Waterfront, Cape Town, a mixed-use, retail, tourist, and harbor precinct, presented a novel way of reducing the project's carbon and energy footprint, while sequestering a ubiquitous and environmentally detrimental waste stream from the open environment. The paper also highlights the positive and beneficial relationship between local communities and developers. The authors highlight the opportunity within the built environment for innovative ways to replace virgin construction materials with otherwise non-recyclable waste materials, including the context in which they are used, the risks, and the benefits. Through use of ecobricks in this project, some 5.5 metric tons of plastic waste were kept out of the ocean.

Keywords: Ecobricks, Construction, Life Cycle

Plastic Waste: Challenging the Urban Environment to Be Creative

Over 300 million metric tons of plastic is produced every year, of which half is used only once and then discarded, then surviving several hundred years on the planet as pollution. Of this, over 8 million metric tons of plastic is dumped into the oceans every year (Jambeck et al. 2015). The downstream damaging effects of such plastic waste significantly outstrip the negative effects of greenhouse gas (GHG) production caused by the manufacture of such plastics in the first place (Hamilton et al. 2019).

The use of ecobricks as void formers in place of conventional, hydrocarbon-based materials at the Ridge (Griffiths 2020, Mouton 2019), a new commercial project at the V&A Waterfront (V&A) in Cape Town, successfully demonstrates how replacing virgin and generally high-carbon-content construction materials with ecobricks can generate both positive environmental and social impacts (see Figure 1). Ecobricks commonly consist of non-recyclable, single-use plastics harvested from waste streams. In the case of the Ridge project, they consisted of the ubiquitous two-liter polyethylene terephthalate (PET) single-use beverage bottles, filled with other single-use plastic packaging waste.

Ecobricks at the Ridge: Demonstrating a "New Normal" Approach

The use of ecobricks at the Ridge building is one of the first such projects in the South African commercial building sector. In recent years the V&A Waterfront has become a leading developer of sustainable buildings in South Africa and has focused intently on removing single-use plastics within its properties.

In doing this, its development team has proactively sought ways to include ecobricks in construction projects as part of the overall solution for dealing with the plastics crisis. They found uses for ecobricks in smaller applications, such as a food garden, where the bricks are used to create raised beds in which vegetables are grown for distribution to displaced urban people. This resource was created and managed in partnership between the developer and a local non-profit, non-governmental organization (NGO) called the Ecobrick Exchange (EBE).

The suggestion to incorporate ecobricks in the Ridge project was put forward at "blue sky" multidisciplinary collaborative workshops during the early design stage for the project. The project's engineers suggested the use of ecobricks as void formers to replace otherwise virgin materials, including lightweight concrete and/or expanded polystyrene (EPS), to form solid spaces within designated areas of the concrete frame structure where there were to be raised floor slabs (see Figure 2).

This initiative was also included as one of the innovation credits within the South African Green Building Council's Green Star submission for the overall project, which was subsequently awarded a 6-star SA Green Star Design rating.

From Imagination to Reality

Taking this idea from a blue-sky thought to reality required substantial technical interrogation, specifically related to the reliability of the ecobrick's structural strength, which is largely a product of its density. As the ecobricks are not created in a controlled environment, their structural characteristics are inherently variable. In addition, as a fairly novel composite element, there is little published test data that can be incorporated into structural calculations. Using the ecobricks as a void former was an untested and unknown solution, which made it difficult to quantify when compared with conventional/known solutions.

These challenges were overcome by placing the ecobricks in such a way that they do not bear any structural load. Ideally, for ecobricks to be used structurally, a plastic density that equates to 700 grams per 2-liter bottle is suggested. Moreover, the structural reliability of this weight varies greatly depending on the type of plastics used as fill. Ensuring that the ecobricks were not structurally integral allowed for a lower density, and subsequently weight of plastic, to be used. Instead of measuring the weight, each bottle was thus checked by hand for rough compressibility. The contractor team, led by

Figure 1. The Ridge – a new 6-Star SA Green Star design-rated eco-building at the V&A Waterfront in Cape Town. © Gareth Griffiths

Figure 2. Ecobricks as void formers being filled with concrete in non-load-bearing areas of the floor at the Ridge where no services are required.

Goals Achieved:

Using ecobricks at the V&A, the project team has achieved the following:

- Saved embodied energy from the otherwise production of virgin material to create conventional void formers, as typified by expanded polystyrene (EPS) or lightweight concrete.
- Divert waste from landfills, including that portion which could potentially be discarded or distributed by wind to either clog drainage systems or end up as pollution in the natural world.
- Create community awareness on consumption habits and environmental protection awareness, as well as an income opportunity, through an alternative use of discarded single-use plastic.
- Encourage corporate sector/public cooperation towards joint goals.

South African construction company GVK Siya Zama, set up an ecobrick "filling and control station" (see Figure 3), where designated operatives undertook quality control and "topped up" each individual ecobrick as necessary to the desired compressibility, before they were suitable for use in the building works.

Determining the optimal positioning of the bricks within the void went through various iterations before the design and construction team settled on placing them vertically within the 450-millimeter raised floor area, consisting of a 300-millimeter void with a 100-millimeter concrete slab, over screed and finishes. In this configuration, ecobricks purely fill a void, as the surrounding concrete provides overall support (see Figure 4). A reference-193 (1.93 kg/m^2) steel mesh was placed on top of the ecobricks to hold them in position, preventing them from moving when concrete was poured (see Figure 5), and to control and limit surface cracking.

Sourcing: Community Engagement and Supply

Ecobricks used at the Ridge were taken primarily from two different sources:

1. Community engagement activities, lead and organized by the EBE: Communities were incentivized by way of the developer making a set monetary donation per ecobrick towards an NGO-run preschool in a Cape Town informal settlement. The communities would then make ecobricks using plastic pollution sourced from their surrounding environment and urban habitat, which was dropped off at and then collected from designated locations. Other environmentally-motivated communities from the city's formal residential areas were also involved in the provision of a portion of the ecobricks (see Figure 6).

2. On-site manufacturing, using non-recyclable plastic waste from the building activities, together with top-up supply from the V&A's waste recycling plant nearby as necessary. In addition,

Figure 3. Ecobrick quality control and filling station at the Ridge.

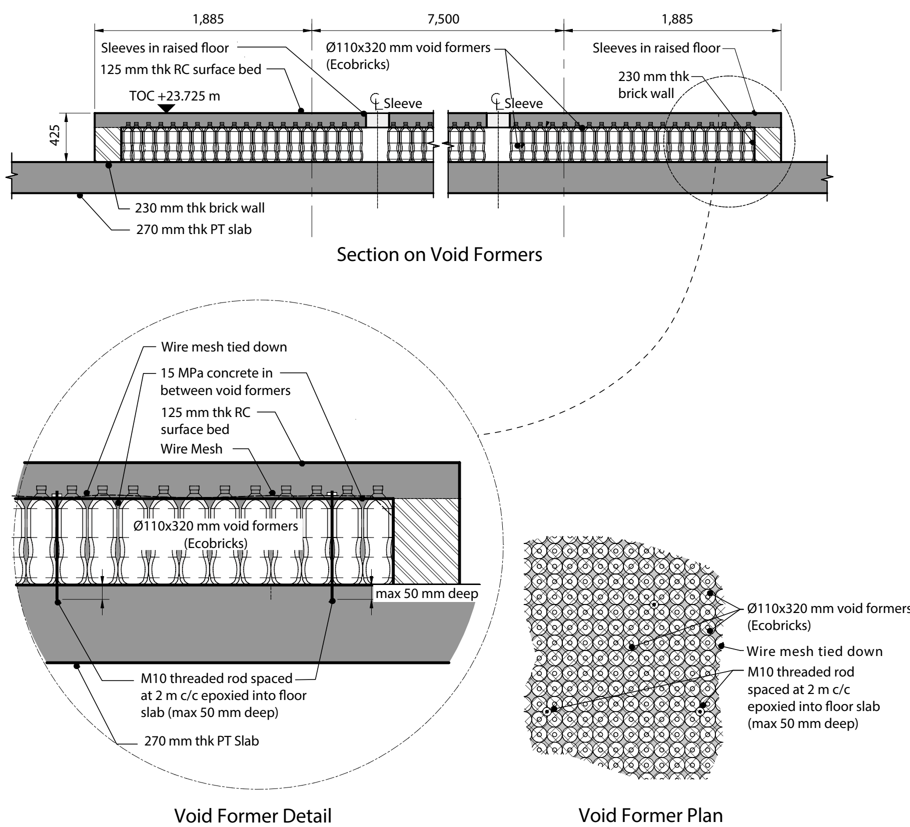

Figure 4. Placement of the ecobricks was determined after numerous iterations. The bricks form voids that would normally be occupied by EPS or lightweight concrete. © Arup

quality control was performed on-site by the contractor.

Community involvement was critical to the success of this initiative. Sourcing the ecobricks from specific communities in Cape Town, where the environmental plastic pollution is pronounced, ensured an immediate and direct impact in reducing single-use plastic waste entering these environments. As the ecobricks were predominantly sourced from schools, this initiative not only increased community awareness of the plastic pollution problem, but also educated the children about environmentally positive behaviors that can protect their future environment. This method of sourcing the ecobricks provided a solution that is tangible, easily achieved and maintained.

Measuring the Benefits

From spot checks done on-site, the bottles averaged 400 grams in weight. Designated areas within the building's concrete floor slab encapsulated 14,000 ecobricks into 41 cubic meters, locking a total of 5.5 metric tons of non-recyclable, single-use plastic into the building fabric for its service life.

The total quantity of material displaced by 2-liter bottles is therefore 28 cubic meters, out of the 41-cubic-meter void, assuming a 2-liter volume for each PET bottle. The remainder is 25-megapascal mass concrete. Traditionally this entire void would have been filled with expanded polystyrene (EPS) or lightweight concrete. Utilizing the Inventory of Carbon and Energy (ICE) methodology (Hammond et al. 2008) ecobrick substitution for conventionally used materials at the Ridge has yielded a net reduction of embodied energy of 20,000 megajoules, compared to using 67 metric tons of lightweight concrete, or 38,000 megajoules, compared with EPS.

These benefits were calculated in line with the life-cycle analysis (LCA) model (Hammond et al. 2008) and employed the "recycled content" approach. This assumes a

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Figure 5. In this configuration, ecobricks purely fill a void, as the surrounding concrete provides overall support. A reference-193 (1.93 kg/m2) steel mesh was placed on top of the ecobricks to hold them in position, preventing them from moving when concrete was poured, and to control and limit surface cracking.

Figure 6. Rosemary Hope, community eco-warrior and parent at the Eros School for special-needs learners near Cape Town was personally involved in the collection and filling of hundreds of ecobricks.

Figure 7. A detail view of a filled ecobrick.

Figure 8. The Delft Early Childhood Development Centre, Cape Town, an ecobrick project facilitated by the Ecobrick Exchange. © Ian Dommisse

negligible energy and carbon contribution to the project by the ecobricks, associated with transportation of the ecobricks from source to site, as transferred from the end-of-life boundary of single-use plastic. Likewise, the assumption is made that all handling, packing, cleaning, and transportation considerations are balanced out by those borne by either the EPS or concrete options.

While on the other hand, the embodied carbon count (as CO_2e) is marginally higher (at 1,600 kg CO_2e) using the ecobrick-plus-concrete filler combination instead of EPS blocks, the key outcome is the removal of approximately 5.5 metric tons of single-use plastic waste.

According to the World Wildlife Fund (WWF) Living Planet report (Grooten & Almond 2018), plastic use is between 30 and 50 kilograms per person per year in South Africa. At the average of 40 kilograms per person per year, the void formers represent 110 South African citizens' annual use of plastic. Put another way, the project has diverted the equivalent of 110 people's annual consumption of single-use plastic from landfill and oceans.

Plastics and Ecobricks as Building Materials

Ecobricks are discarded two-liter beverage bottles that are filled to a specified density with single-use, generally non-recyclable, plastic (see Figure 7). The polyethylene terephthalate (PET) used to create these two-liter bottles is an extremely tough plastic that does not significantly oxidize in the sun. PET bottles take over 450 years to biodegrade, and are recyclable only through a costly chemical de-polymerization process, or by mechanically shredding into pellets for reincorporation into other PET products such as clothing, bedding, and industrial textiles (Webb et al. 2013). These are energy-intensive processes, whose economic viability is linked to the price of virgin material, and ultimately oil prices.

The single-use plastic filler inside these bottles is also a significant cause of global concern as a large proportion of it ends up as "mismanaged" plastic waste that does not enter a landfill. Instead, this mismanaged waste is distributed into the environment as plastic pollution, contributing towards the estimated 7 percent of annual total plastic waste that enters the ocean—a burgeoning crisis (Jambeck et al. 2015).

Ecobricking offers a first-stage solution to alleviating this problem. If adopted on a significant scale, the practice may sequester a significant load of the plastic waste until a biodegradation solution can be established on a viable commercial scale. Once commercial viability is achieved, the possibilities extend considerably.

Currently shown to reduce the amount of virgin materials used on a project, ecobricks advocate themselves as a void former where EPS or lightweight concrete might ordinarily have been used within slabs, walls, or rooftops. This material saving may be especially felt in tall buildings, where concrete is used in large quantities. Encasing ecobricks in concrete reduces the fire risk.

SUDS and Civil Works

Further applications for ecobricks may exist in the urban environment, surrounding tall building spaces, where they are encased within the ground, naturally protected against fire. Potential applications may be within sustainable urban drainage systems (SUDS) where ecobricks are used to stabilize river/canal walls or increase porosity within drainage paths.

Private Sector and Community Engagement

Ecobricks act as a bridge between communities and private development companies, which often exist in isolation from each other. Local communities could benefit from environmental awareness and cleaner outdoor (litter-free) spaces. Likewise, private sector companies can provide monetary incentives for finished ecobricks that they can effectively use in construction, contributing to zero-carbon buildings in the industry, and eliminating plastic waste from the natural environment (see Figure 8). Of further benefit, a collaborative approach between the community, NGOs such as the EBE, and private-sector companies highlights the importance and benefits of working together to achieve a shared vision in shaping a better world.

Conclusion

Considering that an estimated 32 percent of plastic escapes the collection system, ecobricks can form part of the global transition towards a circular economy for plastic, instead of it becoming waste or pollution. This especially applies to the single-use, small-size plastic waste with a high dispersion rate and low residual value, such are used to fill and create ecobricks.

Further research relating to the effect ecobricks have on a building's energy and comfort performance is required, as well as development of techniques to encapsulate (thus ensuring fire protection) and building with the bricks so that they are left undamaged at the end of their service life in one application, to be readily repurposed for another in the future.

Using ecobricks at the Ridge was an important tool in facilitating a win-win with participating communities, and an important step forward in the built environment in advocating the innovative use of recycled materials, advancing the goal of transitioning to zero-carbon buildings. This decision also complemented the V&A's vision as a developer to set new global design and construction benchmarks for sustainability in the built environment.

The developer set a brief to create a next-generation sustainable commercial office building that aligns with the property owner's vision to become carbon-neutral by 2030. In turn, the design team determined to create a low-energy building contributing towards accelerating the transition to net-zero carbon in South Africa. In line with this, all opportunities to holistically reduce the building's impact were interrogated. The immediate present benefit to the environment, however, was the aforementioned removal of approximately 5.5 metric tons of single-use plastic waste from the environment. This is a true gain. ■

> "The project has removed approximately 5.5 metric tons of single-use plastic waste, diverting the equivalent of 110 people's annual consumption of single-use plastic from landfill and oceans."

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