Footprint, Handprint: Pursuing Regenerative Architecture in Rwanda

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Over the past fifteen years, MASS Design Group has developed an approach to design and construction that focuses on minimizing a project's ecological and carbon footprint whilst maximizing its human handprint. We have come to understand that a regenerative project requires a holistic approach to defining both its performance as well as its provenance — that a building's impacts extend well beyond its site boundaries to include where materials are sourced and processed, and the hands through which they pass.

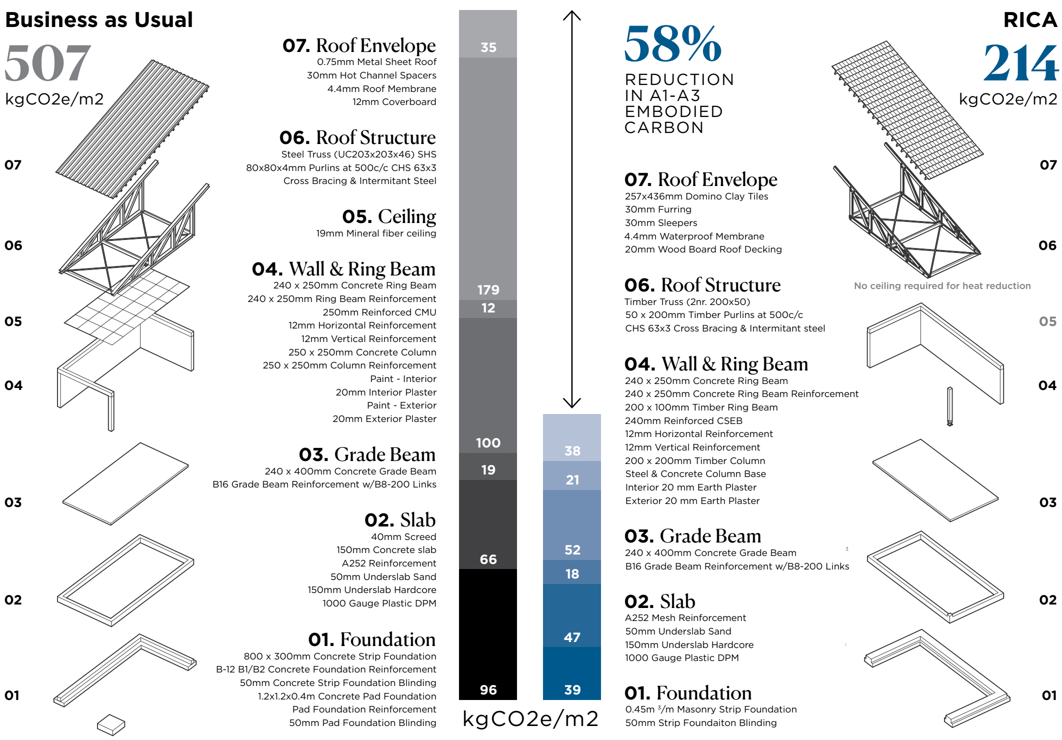
The Rwanda Institute for Conservation Agriculture (RICA) demonstrates how the hyper-local sourcing of materials can dramatically drive down a project's carbon footprint.

Our recognition that a building has both a footprint and a handprint emerged organically. MASS began as a small group of architects working with Partners in Health (PIH) and the Government of Rwanda to design and construct a hospital in a rural, un-electrified, underserved part of the country. Fifteen years ago, Rwanda was investing in its reconstruction from the 1994 genocide. The country focused on its health sector as a core building block and was eager to innovate and create examples for development rather than replicate previous (and often imported) models. Designing and building in such a context required us to leave our assumptions behind and unlearn the systems of global supply we have unconsciously relied on. We had to figure out how to source both materials and labor as regionally as possible in response to the constraints of the project's remote location in a landlocked country with an 18 percent import tax.

PIH tasked us to look at every decision as an opportunity to create a positive impact in the communities we were privileged to serve. That mandate pushed us to look at the project's immediate context as the *terroir* of design decision making, a lesson that has since become our philosophy. In place of a product catalog of materials and suppliers, we instead relied on a close reading of the region's material vernacular and the wisdom of local builders and craftspeople. Butaro Hospital's innovation is a result of its constraints and context: wards designed to function in the absence of electricity; walls built from the stones surfacing in surrounding fields; stones shaped and laid by the hands of Butaro's incredible masons.

A few years later, the African Wildlife Foundation invited us to design and build a primary school for the community of Ilima. Ilima is located in the center of the Democratic Republic of the Congo (DRC) — a geographic and logistic reality that made getting materials to the project site expensive, time consuming, and difficult. All imported materials and tools would spend a few weeks traveling up river from Kinshasa to Mompono; from there, they would be transported along a road no wider than your shoulders — at points on the back of a dirt bike — for the better part of four hours in each direction. Drawing on the lessons learned from PIH and Butaro, we focused our attention on Ilima; specifically, who is there,

Figure 1. **Carbon Axon Diagram comparing the embodied carbon in a conventional building with the Rwanda Institute for Conservation Agriculture.**



how do they build, what do they build with, and what materials are available in abundance? Our team spent weeks on the ground interviewing local craftspeople, collecting material samples, and working with the community to establish a site for the school.

On return to Kigali we sent the materials — primarily soils and wood samples — to a lab to help determine their suitability for structural and finish applications. We discovered that the soils harvested from multiple termite mounds surrounding the site provided an ideal mix for a robust, sun-dried block that could form the exterior walls of the school. An endemic hardwood (African Padauk) shares traits with cedar, enabling it to withstand rain and rot, and it could be cleaved and shaped with a froe to provide a durable, easily replaceable roofing system. Ilima Primary School is ultimately a result of local knowledge and lab testing, the alchemy of our commitment to seeking innovation grounded in the specifics of a place and its people.

Ilima Primary School was also our first attempt to thoroughly audit the socio-economic and environmental impacts of the projects. Our role as architect, engineer, construction manager, and procurement officer provided a detailed accounting of both costs and quantities. Sourcing 99 percent of the building's weight from within a ten-kilometer radius allowed 74 percent of the project's construction budget to make its way into the immediate communities. Harvesting stone, soils, and woods from the immediate context meant that 83 percent of the budget was put in the hands of project labor, with only 17 percent required to purchase tools, fasteners, and limited amounts of cement for the foundations.

Ilima was also our introduction into quantifying the upfront impacts of construction. We worked with researchers at Massachusetts Institute of Technology (MIT) to explore the embodied carbon of our projects for the first time. The results shocked us. The building's carbon footprint (15 kg CO_2e/m^2) was twenty-eight times lower than the global average for schools due entirely to the reliance on locally sourced stone, earth and wood. This small school, built of locally abundant and readily renewable materials in the middle of DRC, provided us our first glimpse of the potential for a regenerative, climate-positive architecture.

Soon thereafter, we were presented with an opportunity to push the limits of a design process that focused on minimizing the carbon footprint whilst maximizing its human handprint. In 2016, Howard G. Buffett Foundation invited us to help them envision, design, and build from the ground up a university focused on educating the next generation of agricultural innovators. Howard's investment in agricultural


An aerial view of the Rwanda Institute for Conservation Agriculture, or RICA.

education reflects his deep belief in small-scale farming as a fundamental component of addressing long-term food security and peace worldwide. The conception of the Rwanda Institute for Conservation Agriculture (RICA) is thus grounded in an education of small-farm realities: providing the conditions for its students and researchers to scale innovations that leverage human capital and creativity as the primary means of increasing agricultural yield and economic value.

We proposed a "One Health" approach — a holistic design method that seeks to balance and optimize the health of people, animals, and ecosystems. One Health is rooted in the understanding that the health of one community is inextricably linked with those around it, and that all systems

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flourish through an exchange of ideas, energy, and matter. To begin understanding these exchanges, our first step once again required investing in an extended immersion of the site and the surrounding communities of people, plants, and animals. Conducting workshops with local communities to assess material and labor practices also cultivated

a deeper understanding of the area's unique social, ecological, and agricultural history.

We discovered that the 1,200-hectare site that had functioned as a Ministry of Agriculture testing site was previously a national park, one of only two in Rwanda's savannah region. Working with Rwanda's foremost ecologist, we undertook a detailed ecological survey that identified a series of threatened endemic plant and bird species in the largest remaining intact savannah woodland in southern Rwanda. The plan for the campus builds around existing biodiversity and seeks to heal the landscape by stitching together habitats and agricultural spaces.

The large site also provided the grounds for achieving a climate-positive project. Our team of architects and engineers worked to reduce the upfront embodied impacts of the project to 40 percent of a business-as-usual case by harvesting much of the project's materials from the site itself and by reducing the use of carbon-intensive materials like cement and steel as much as possible. To reduce operational emissions, we worked with Transsolar and Arup to optimize RICA for daylighting, natural ventilation, and water efficiency to reduce demands, thus reducing the size of the solar farm and water treatment facilities that support the off-grid campus. This results in a dramatically reduced life cycle carbon footprint — one that can be offset on-site through twenty years of afforestation and silviculture — which will result in Africa's first climate-positive campus.

Can architecture be regenerative? To become so we need to understand our reciprocal relationship with nature: to take only what is given and what we need; to acknowledge that we have damaged the earth and that it needs healing. Is RICA regenerative? In some ways it heals. Using local knowledge, forty hectares of previously degraded farmland are being restored to savannah woodland, and through carbon sequestration in the forest, at least the climate change impacts of this project will be compensated for by 2040. Materials are inherently emissive, but we can reduce our footprint through intimate knowledge of the places we work, and we can maximize our handprint when we co-create with the people who live there.

ASSESSING HANDPRINTS AND FOOTPRINTS AT RICA

Over four years, we were able to engage over 800 people to build and fit-out the RICA campus, 90 percent of whom live in the surrounding Bugasera district. The project developed a supply chain of materials and finishes that were harvested, sourced, processed, and crafted locally. Ninety-six percent of the materials were sourced within Rwanda, which is slightly smaller than the state of Massachusetts. Of these materials, we chose to present the handprint and footprint of the stone, earth, and wood used in the project.

STONE

So much of a contemporary building's impact is buried underground, out of sight and out of mind, in the form of reinforced concrete foundations — the building's footprint in every respect. Traditional stone mortared foundations are a time-tested, local alternative. At RICA, the quartzite stone was quarried from within ten miles of the site. Each stone was individually placed in an interlocking pattern and caringly mortared by hand. A reinforced concrete grade beam ties the foundation together and resolves bending forces resulting from seismic activity. This foundation solution reduces embodied carbon by 60 percent compared to fully reinforced concrete solutions.

EARTH

The feasibility of earth as a building material is demonstrated by the thousands through Rwanda's vernacular housing. However, construction at the scale of a project like RICA required a rigorous approach to address durability and strength. During conceptual design, our in-house geotechnical and structural engineers dug pits across the site to identify the ideal soil mix for compressed stabilized earth blocks (CSEBs) and rammed earth. Drawing on our knowledge of the land and support from ecologists, we dug in the least ecologically sensitive areas to minimize impact. Through this early phased-testing approach, we optimized the soil mix by adding 4.5 percent Portland cement and 2.5 percent pozzolana (volcanic ash). These amendments significantly improved the durability and compressive strength of the blocks and allowed construction to continue during the rainy season without temporary shelters.

Approximately 2.5 million handmade CSEBs were made on the project site, accounting for 25 percent of total building material. The CSEB walls reduce embodied carbon by 50 percent compared to the more regionally typical concrete block walls. In addition to the invisible climate change benefits, the structure's thermal mass and hygrothermal properties help create a noticeably more pleasant indoor environment during hot, stormy savannah days.

EARTH (cont.)

Earth, in this context, is a hyper-local material. In five minutes, one can walk from the extraction pit to the canopy under which 60 workers manually press blocks, to the storage shed where thousands of blocks gain their strength, and finally, to the buildings where they are laid. We hypothesize that local material production leads to greater efficiency, reduced waste, and less harm, because witnessing production processes — mining, tree felling, and toxic manufacturing, which often leaches chemicals into the water or fills the sky and our noses with smoke — creates an emotional response and visceral connection to materials.

RICA demonstrates that earth buildings can be built beautifully, safely, and with minimal environmental impact at an industrial scale. Following the project, MASS supported the Government of Rwanda in the development of a standard and guidelines to improve the quality of the two million adobe homes forecasted to be constructed in coming decades.

WOOD

The design of this campus coincided with the first FSC forest management certification in Rwanda. With the idea that architecture is built for and by the place, we worked with the materials that were available through this regional mill, which does not ordinarily produce wood for construction. We built the structural grid with Patula Pine; however, the significant variation in dimensions, quality and volume of wood we received from the mill led us to supplement the supply from other forests. Unfortunately, there were no other regional FSC-certified forests that could meet our needs, which led to the challenging decision to work with a Tanzanian forest that was then seeking FSC certification. After investigating their forestry management practices in person, we determined it was better to support a fledgling sustainable forestry industry than to rely on imported steel members.

Mechanical grading is not currently performed at local mills, so our structural engineers trained personnel to visually grade the wood by assessing knot area ratios and locations. Additionally, we performed supplemental laboratory testing which demonstrated some members performed well below the weakest structural grade that would be assumed in the United Kingdom. When the wood arrived on site, our engineers performed a second visual grading and sorted members so that the strongest ones were used in the most highly utilized locations.

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We would like to acknowledge the enormous team of engineers, architects, and builders who have and continue to work tirelessly to make this highly impactful project a reality. Thank you to our partners Arup, Transsolar, Atelier 10, and the collective that is MASS. And finally, thank you to our project partners; Partners in Health, The African Wildlife Foundation, and the Howard G. Buffett Foundation.

Kelly Alvarez Doran OAA MRAIC is a father, architect, educator, and environmental activist. As Senior Director of Performance and Provenance at MASS Design Group, Kelly supports Principals and Designers to embed environmental objectives into all MASS projects, as well as leading climate-focused research and the training of our entire team. Previously, Kelly led MASS's' Kigali office overseeing the growth of the practice from a team of eight to eighty over five years. He led the design and implementation of several of MASS's projects across East Africa, notably the award-winning Munini District Hospital and Rwanda Ministry of Health's Typical Hospital Plans; Nyarugenge District Hospital, headquarters for One Acre Fund and Andela in Kenya; and the Rwanda Institute for Conservation Agriculture. Kelly holds professorships at The Bartlett and the University of Toronto, where his Ha/f Research Studio focuses on the whole life carbon of the built environment. The outcomes of this research have informed the ongoing development of embodied carbon policies for the City of Toronto and surrounding municipalities.

James Kitchin CEng MICE has a background in structural and civil engineering and deep expertise in designing with healthy, natural, and non-conventional materials. He has written several articles on the subject, and has led research and policy change around building materials and embodied carbon. James strives to minimise the footprint of the built environment through intimate knowledge of place and process, and to maximize the maker's handprint through collaboration. As co-lead of the Performance & Provenance department at MASS, he is committed to imagining, advocating and implementing regenerative practices.

MASS DESIGN GROUP

MASS Design Group was founded on the understanding that architecture's influence reaches beyond individual buildings. Our mission is to research, build, and advocate for architecture that promotes justice and human dignity. MASS (Model of Architecture Serving Society) believes that architecture has a critical role to play in supporting communities to confront history, shape new narratives, collectively heal and project new possibilities for the future. We are a team of over 200 architects, landscape architects, engineers, builders, furniture designers, makers, writers, filmmakers, and researchers representing twenty countries across the globe. We believe in expanding access to design that is purposeful, healing, and hopeful.