Mortarless Compressed Earth Block Dwellings

A Low-Cost Sustainable Design and Fabrication Process

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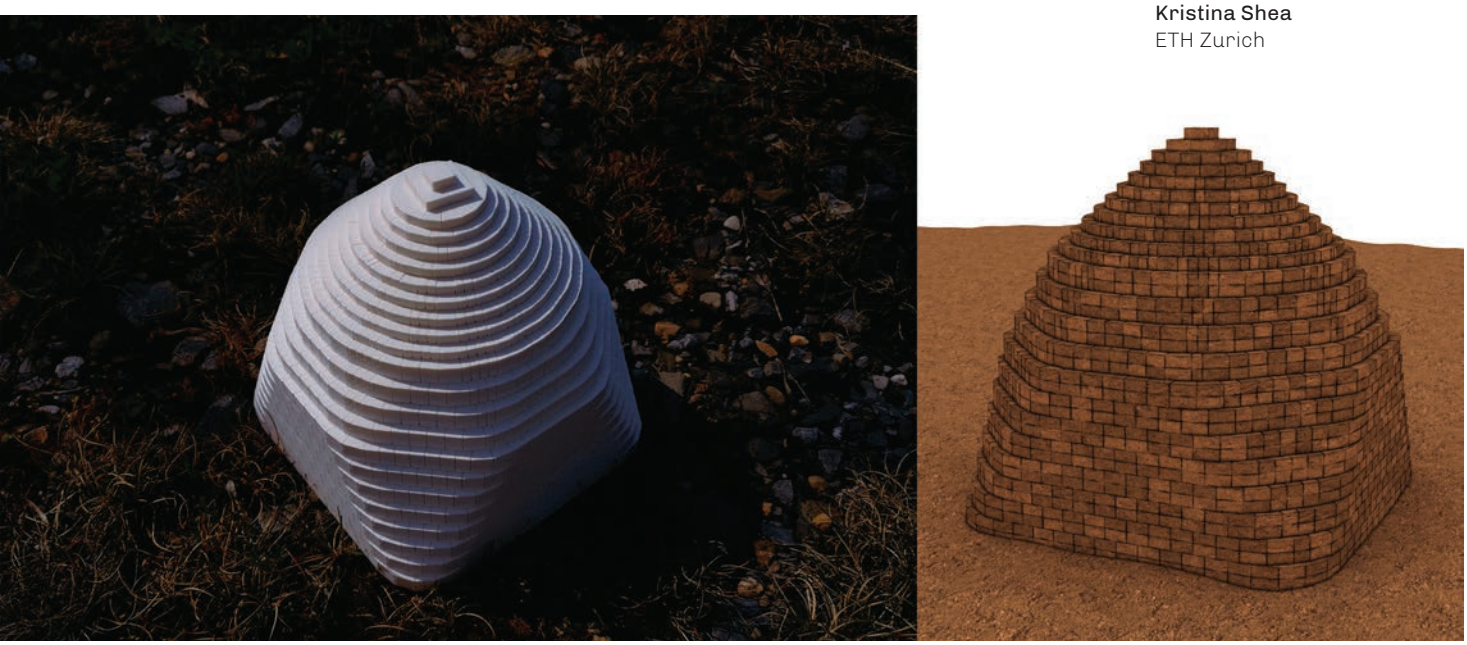


1 Single-story CEB Dwellings

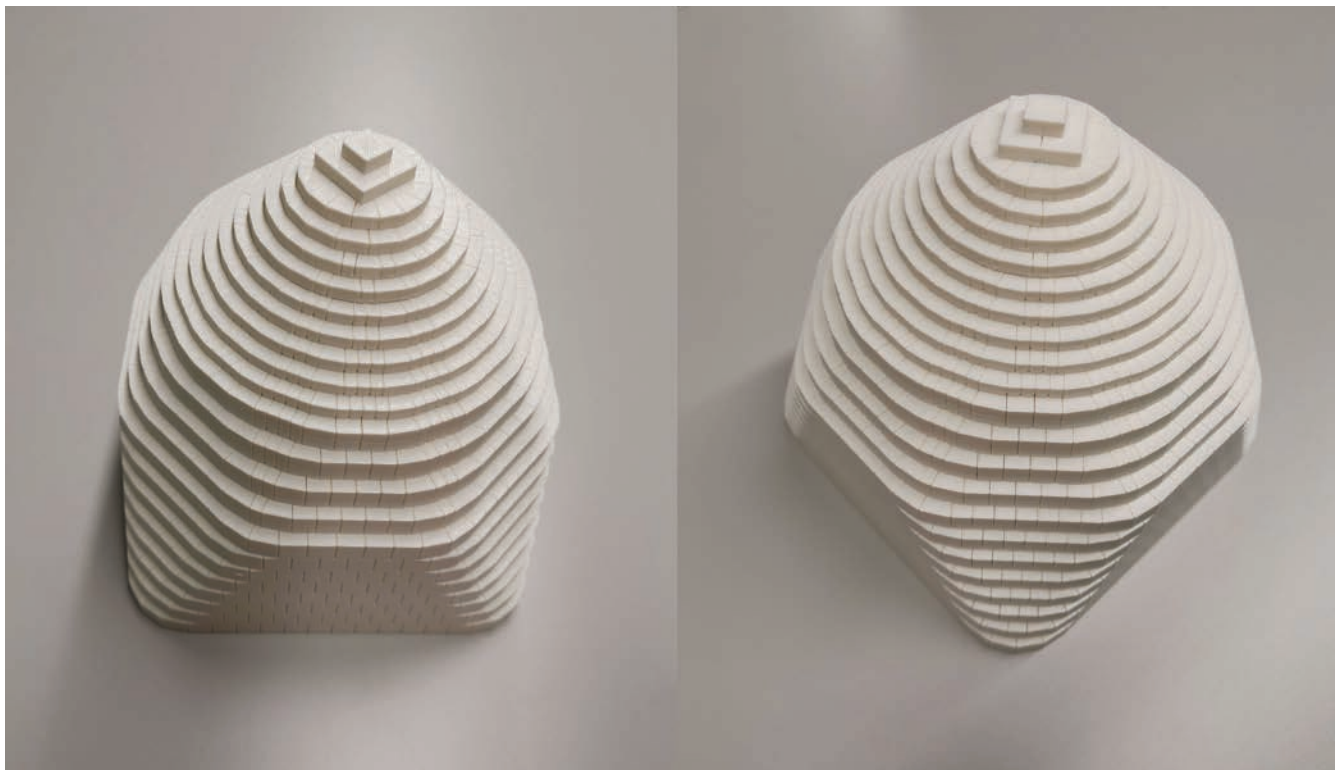
This project develops a template design and an adaptive fabrication process for sustainable Compressed Earth Block (CEB) dwellings for low-income countries. Most existing projects (Wilton et al. 2019; WASP 2021) on sustainable dwellings involve high-tech equipment or skilled workers on-site. This project integrates digital technologies into the design and fabrication processes to reduce these requirements and make the design compatible with conventional construction methods that are actively adopted in low-income countries using minimum infrastructure, skilled labor, and investment.

The template design is a single-story CEB dwelling (Figures 1, 2, 3) consisting of a small number of interlocking brick types (Figure 4). The transitioning geometry, as shown in Figure 5, is optimized for structural efficiency as well as a practical architectural floorplan. The dwelling can either be built as a single-room house or form a multi-room house and complexes according to needs (Figure 6).

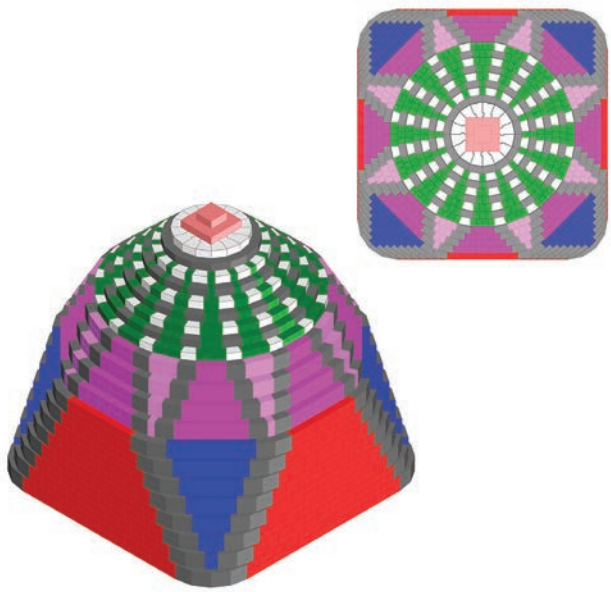
To enable a mortarless and stable assembly during construction, interlocking features, including left-right interlocking and top-bottom interlocking, are embedded into the brick design (Figure 4). The interlocking nature of the bricks acts as a guide to locate and orientate the bricks so that specialist construction knowledge and training are not required,

PRODUCTION NOTES

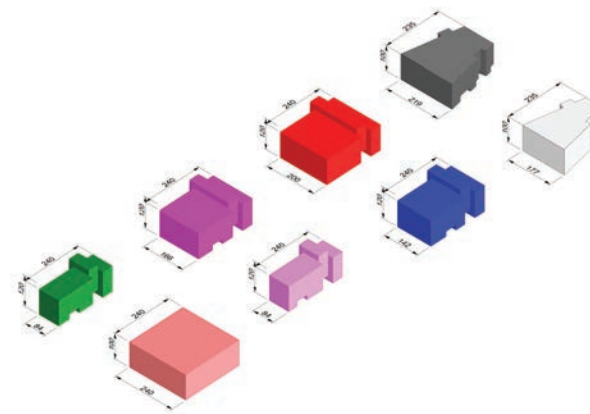
Status: In progress
Location: ETH Zurich
Date: 2021



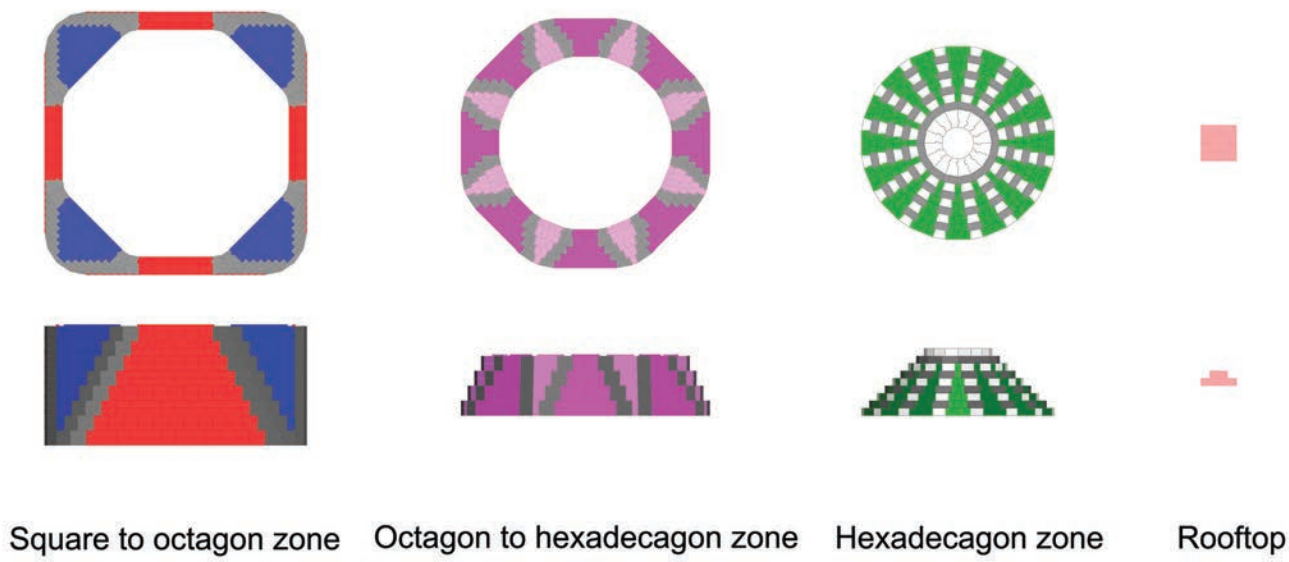
2 A 3D-printed dwelling model



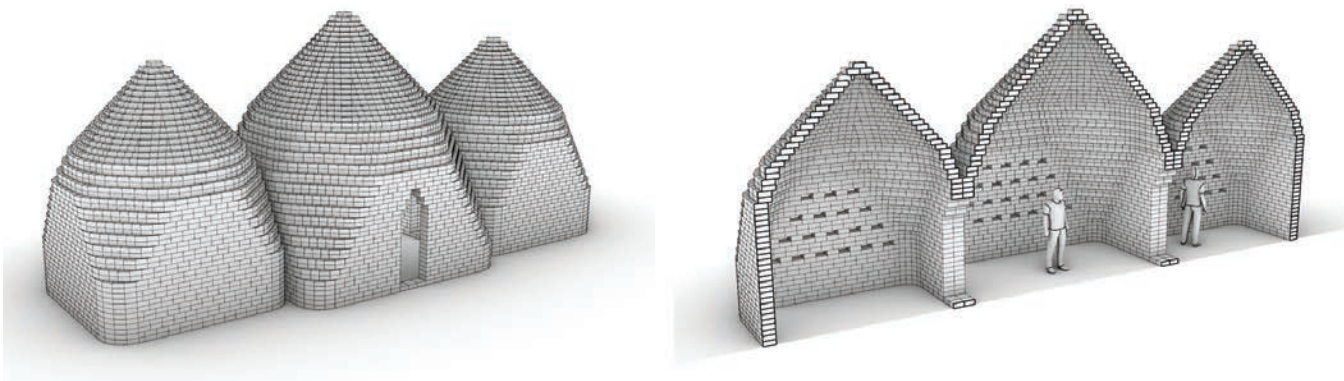
3 A CEB dwelling consisting of eight interlocking brick types



4 Eight brick types and their designs



5 Zones of the CEB dwelling

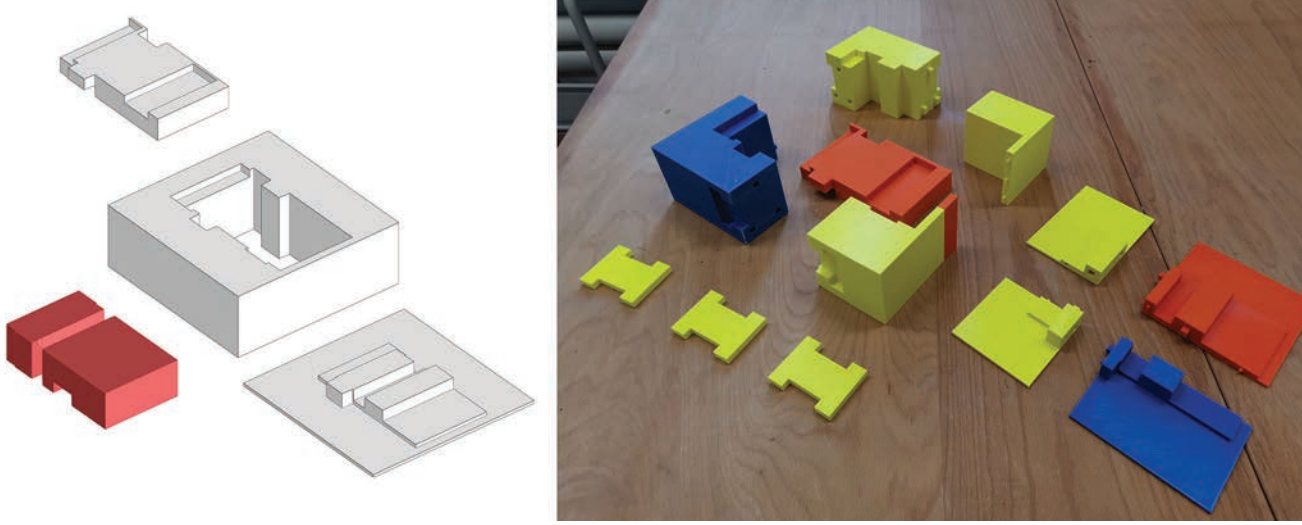


6 Dwelling units can be used in a flexible layout by interconnecting them to form multi-room houses

7 The compressed earth block (CEB) press with the default steel mold

enabling access for low-skilled and first-time builders. However, this interlocking brick design, together with the overall geometry design of the structure, makes it challenging to fit the bricks into the target geometry without any gaps or overlaps. This problem is solved by rigorously computing the trigonometric relationship and developing a parametric design tool that generates feasible designs, including block geometry and layout.

As shown in Figure 4, the brick dimensions, yielded from the aforementioned computational design, are not standardized. Thus, this project proposes a fabrication process for customized interlocking bricks that applies to most of the CEB press machines existing on the market. The press this project started with is the Auram 3000 manual CEB press, with the default steel mold Plain 240 (Figure 7). However, the proposed method can adapt to presses with or without replaceable steel mold/chamber by 3D-printing a set of



8 Example of a brick mold model and its 3D-printed copy

9

9 The earth material is loaded into the 3D-printed mold before closing the lid of the press

10 An assembled section (a corner of the square to octagon zone) of the structure

10

embedded molds for the customized brick geometries (Figure 8), such that it refrains from any modifications to the original steel chamber/mold.

The brick fabrication process is similar to the conventional CEB process except that a 3D-printed mold is put into the steel chamber. Then the raw earth material is loaded into the 3D-printed mold (Figure 9) and compressed. After demoulding, the earth brick is placed on a rack for drying. To complete the sustainable approach, linseed oil is used for waterproofing and no further additives (e.g. cement or lime) are used, which allows for infinitely reusing the bricks or recycling the raw earth material. Figure 10 shows an assembled section of the structure.

By not modifying the press itself, this method drastically expands the application to almost any CEB press, especially low-cost presses in developing countries without replaceable chambers. Compared to other existing projects that use customized steel molds, the proposed method requires less equipment and lead time for mold making. Moreover, the 3D-printed molds are lightweight, portable, and economical. All the digital processes, i.e. computational design, 3D printing, and structural analysis, can be conducted offsite, which significantly reduces the requirements on the construction site, e.g. no need for skilled personnel, high-tech and high-cost machines, and electricity. The next step is to build a full-size demonstration dwelling in the correct climatic and social context.

ACKNOWLEDGMENTS

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IMAGE CREDITS

All the drawings and images are by the authors.

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