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Earth LEGO at Lake Agege Farm – A Ghanaian innovation for sustainable building

LEGO is synonymous with child's play, quick assembly, and flexible construction. Earth building, generally, is not. That these apparent opposites can be reconciled is the subject of this article which looks at the functionality, design requirements and materiality of a new, innovative adobe brick. The advantages and disadvantages of this novel kind of brick have been explored in practice, along with different material formulas, in the building of a small, functional building on Lake Agege Farm in Ghana.

The brick is produced by a small Ghanaian start-up company. It employs an interlocking principle that facilitates quick and simple bricklaying without typical mortar joints. The profile of the bricks also makes it possible to integrate utilities such as water and electricity concealed within the brick. Made of laterite, the innovative brick is inexpensive, sustainable and offers a modern way of building in a country where concrete palaces seem to sprout out of the ground at every turn, only to disintegrate soon after in the tropical and maritime climate.

At present, however, buildings made of red Ghanaian earth still have the stigma of being backward and primitive, and there are too few good examples of innovative model homes and settlements to persuade people otherwise.

In early 2020, a first international workshop was held to trial the performance of two variants of the brick, both produced not far from the building site, in construction, weather resistance, surface coating and colour design over the next few years.

The original formula for the laterite brick was made with stabilising additives to achieve better weather resistance and edge stability so that they are comparable to good cement blocks. The producer had developed this formula using cement but this had the disadvantage of significantly reducing their recyclability. The case study house built at Agege Farm aims to show that no additives are needed at all, or at least not where surfaces are protected against moisture ingress.

The Institute for Organic Farming and Earthbuilding (IOFE), which is based at and operates from the farm, sees itself as a research facility and educational institution for intercultural exchange on topics related to sustainability. As part of this, it runs workshops on earth building. In the next few years, a house for students and five farmhouses are to be built on the 8-hectare site, as well as the functional building discussed in this paper. Each will be built using different traditional construction methods or adapted to today's technical possibilities.

Technology in earth construction: still stuck in the past?

The availability of earth plaster finishes with mother-of-pearl or herbal or sisal fibre additives testify to a growing awareness in recent years of the design possibilities of earth plasters in domestic living environments. In terms of quality, ease of use and surface finish, they now rival conventional lime-cement or synthetic fibre plasters from the DIY market. They are innovative and also competitively priced. But can the same be said for earth construction, and more specifically for building with adobe bricks? For the most part, they are still the same traditional square block, usually in Normal Format (NF) that they always were, sometimes with additional lightweight aggregates. Do adobe bricks still have to look they did for thousands of years, regardless of whether from the Yemen, Mali, Senegal or India? The answer is no, and one doesn't even need to look to the German market to find an example: a small Ghanaian start-up has demonstrated that it is possible to break new ground in earth construction, and earth masonry construction in particular.

"This is the way we we lay the bricks..."

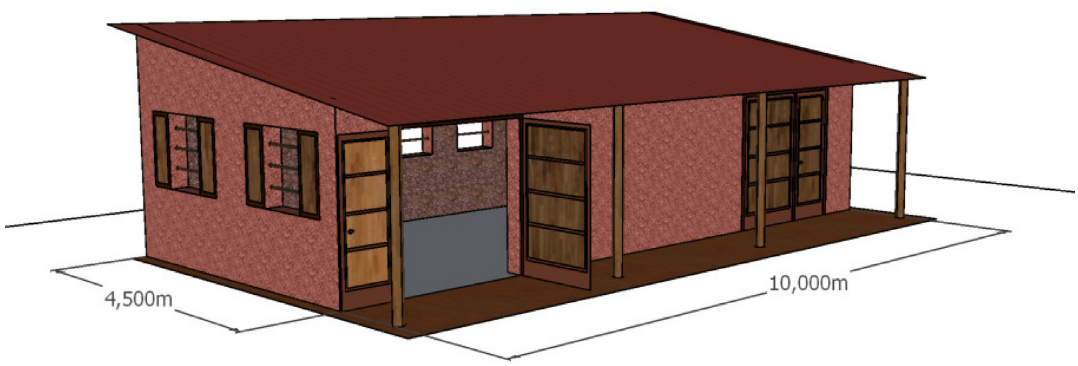
In spring 2020, a cooperation between the Ghanaian laterite brick manufacturer MAGGLO and the Institute for Organic Farming and Earthbuilding (IOFE) gave rise to the development of a new, pure laterite brick with no additives that spins forward the thread of earth architecture in Ghanaian countryside in a new form. MAGGLO has been producing laterite bricks for a number of years using a system of Thai and Indian origin. Its special feature is its interlocking form which can best be described as a LEGO set in large. What makes this novel is its use in a real-world scenario without requiring screws or binders to construct walls and buildings. Employing this simple but ingenious idea, MAGGO developed an unfired brick made of compressed laterite for the Ghanaian market.

The housing situation in Ghana, rural exodus and socio-cultural purpose of the project

The location of the workshop and the site of the construction of the first (experimental) "model house" is a piece of almost unspoiled bushland on the periphery of Baafikrom, a village near Mankessim in the Central Region of Ghana. Here, too, the rural perspective is gradually being dominated by the urban one. Like in post-war Germany, traditional earth construction is regarded as being outdated, insufficiently durable, backward-looking and anything but "en vogue". Concrete, on the other hand, is increasingly popular. Most Ghanaians must wait many years or even decades to lay just the first few courses of their dream house using so-called cement block bricks. Finishing it can take even longer, not least because the price of cement is rising exponentially. And indeed, many cement block houses are unfinished and already dilapidating.

As we know, cement is not an African invention. Just as the import of wheat from America undermined the basis of native crops such as rice and heralded the beginning of an exodus form the countryside, the "good people of the West" have also succeeded in displacing a traditional building technique perfected through thousands of years of trial and error. Cement is also ill-suited to the Ghanaian climate, as anyone who has spent a night without air conditioning in a "cement palace" can tell you. This is where MAGGLO comes into play with its development of an invention from India and Thailand that helps anyone construct a good building for themselves. At the same time, it fosters a meaningful connection between construction and agriculture in one and the same place and thereby contributes to counteracting the shift towards shifting cultivation. This is one of the foremost goals of the IOFE: to assist every wandering farmer to build his own "dream house" brick by brick. Subsistence farmers often travel many kilometres to grow fruit on a previously torched field. But once the local flora and fauna has been destroyed, the earth is laid bare allowing rain to wash out the last nutrients and pollute the rivers.

01 Outline sketch of the functional building that was built as part of the workshop



02 The workshop organised by the Institute for Organic Farming and Earthbuilding took place at Agege Farm in Ghana and was sponsored by the Ghanaian laterite brick producer MAGGLO

Aim of the first workshop on the construction of a model house

The path from A to B, i.e. from subsistence farming to MAGGLO bricks and rural earth architecture is not as straightforward as it may seem. The workshop aimed to trace some of the reasons for this, and to offer a better, more sustainable alternative to the constructions propagated by the likes of Heidelberg Cement and their Ghanaian subsidiaries. The workshop was organised as a joint venture between MAGGLO and IOFE in conjunction with Cape Coast University.

A further goal was to motivate farmers to use the bricks and their simple family-friendly participation-construction method to build innovative, experimental, and also model houses. No one wants to go back to the dark mud hut. But even innovative buildings still need to be safe, and the concern is that traditional earth building cannot provide that. So the third goal of the project was to trial a variant of the MAGGLO brick that does without any stabilising additives in the construction of a single-storey building.

To this end, one could take a descriptive-analytical examination of the building material with the help of laboratory investigations, or alternatively turn to field experiments which, as the name already suggests, is closer to our context in Ghana.

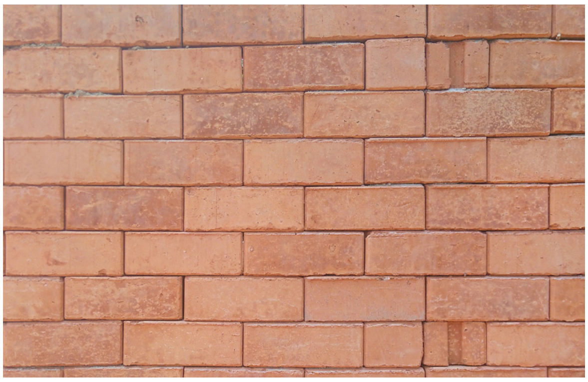
The material of MAGGLO bricks

Whether in the supermarket or in the building supplies store, one often only discovers that a product is not as pure as it seems when one studies the small print. At present, the MAGGLO laterite bricks are actually 85% laterite, 10% quarry dust (a by-product of crushing rock) and about 5% cement. In addition, a liquid hardener of Thai origin is added, the composition of which we were unable to determine prior to our workshop.

These “original formula” bricks are extremely robust and weather resistant. In our own experiments, three years of German rain, frost and sun has had little visual impact on the bricks.

The use of such additives provides a level of ‘built-in’ product safety that is still often lacking in countries such as Ghana. The architectural language of modern earth construction has not yet made its way into Ghanaian universities and the use of simple protective construction measures such as good foundations and wide, projecting eaves is still not common knowledge among bricklayers. Safety through the use of additives is, therefore, a plausible option. But it is not sustainable. As a result, with the input of IOFE, a formulation was developed for making laterite bricks using only the most important and ecological sustainable ingredients: the “red earth”, or laterite.

More recently (in October 2020) tests have shown that the hardener used in the original formula bricks is *Duraplast 400*. This gives added impetus to our exploration of a PURE laterite alternative.

03+04 Unfired, compressed bricks made of red laterite earth with smooth surfaces

Form and design of the MAGGLO bricks

The high compression force of the MAGGLO brick press – 2000 lb or 907 kg – makes it possible to provide consistently performant bricks with reliably accurate dimensions. Measuring 12.5×25×10 (H)cm and with a weight of 5.3 kg, they are small enough to be transported by hand. The special profile lintel blocks weigh only 4.5 kg. The high compaction of the press means the outer surfaces of the stones are extremely smooth. Despite their technical appearance, even unrendered buildings made of laterite bricks blend harmoniously into the Ghanaian landscape due to their red laterite colour. If the homeowner wishes to render the exterior for optical reasons, the surfaces need roughening or a plaster base to provide a sufficient key for plaster adhesion.

The functionality of MAGGLO blocks

The interlocking principle is a product of two round approx. 1 cm high protrusions on the top surface that match corresponding depressions in the underside of the bricks, creating a good, stable connection. A special feature of the MAGGLO bricks are two round holes at the centre of these protrusions that run vertically through the entire brick. They can be used to route electrical cables and water pipes concealed within the walls. A third rectangular hole in the centre of the brick and two cut-outs at each end of the brick are designed for adding poured grouting, made of a liquid laterite mix, as means of providing necessary vertical stabilisation for the walls.

Stacking requires expertise!

The workshop: Detecting initial problems and optimising the bricks

The aim of the first LEGO workshop was to construct a simple functional building to test the arrangement and strengths and weaknesses of the interlocking technology as well as its feasibility for 'family-build' construction scenarios. In addition, stabilised and unstabilised (PURE) bricks were to be employed and compared within the same building.

05-07 The special feature of MAGGLO bricks are their interlocking forms that can be assembled without mortar



08 To stop the liquid grouting escaping through the vertical joints between blocks, especially when halved manually on site, the gaps must be closed with a thick laterite mortar (see arrows)

We were looking to find answers to the following questions:

- Production of the bricks: have all construction details been considered? For example, do half-brick sizes need to be specially fabricated, requiring additional production and storage facilities and with it time and costs, or can whole bricks be halved manually on site?
- Distribution of tasks: Which details require considered execution by a master builder (dimensional tolerances of the bricks, horizontal and vertical compensation in the masonry bonding), and which work can be carried out by unskilled persons, e.g. family members and friends?
- What comes before and after bricklaying, i.e. what preparatory measures are needed prior to erecting the walls, and what must they be able to sustain after construction (foundation and roof)?
- How important is the orientation of the bricks, i.e. top and bottom? How is that defined? Are there advantages or disadvantages in laying bricks upside down?
- After how many brick courses must vertical grouting take place to be effective?
- Are there obvious differences in the construction/handling of the original and PURE formula bricks?
- Is it possible to do completely without cement when laying bricks over larger openings? Can vertical and lintel grouting made of a more liquid PURE mixture provide sufficient stability in single-storey buildings?

Findings and outlook

Findings: Brick forms

1. The producer suggests bedding the bottom course of bricks in cement to compensate for irregularities in the foundation and the brick undersides. If one wishes to avoid cement completely, another brick shape with a flat underside is necessary so that the first brick course can lie as flat as possible on the foundation or damp-proofing layer. Slicing flat the base of the bricks (as in our case) can only be a makeshift solution.
2. Pre-manufactured half-bricks for corners, wall connections and all window jambs are necessary for professional and efficient construction. While it is relatively easy to halve whole bricks with a bush knife, it results in further work in a subsequent step: the vertical joints between sliced half-bricks and the neighbouring whole bricks need to be sealed with a laterite mortar mix to prevent the liquid grouting from escaping and running down the outside of the wall.

Findings: Work process

1. The preparatory (strip) foundation with damp proofing must be carried out accurately and as



09–11 Uneven brick courses must be corrected using sand, especially at the base of the wall as irregularities affect the subsequent brick courses. Irregularities in vertical perpendicularity can be corrected with the help of a rubber mallet.

level as possible, as irregularities make themselves apparent by the second or third course at the latest. A degree of compensation can be achieved by adding a sand bedding. Ripples in the brick coursing have a cumulative effect the higher one builds, resulting in reduced cohesion and stability when the interlocking is not fully effective. While the stacking technique is very simple, it requires accuracy in its execution as there is no masonry to balance out inaccuracies in execution. One must check the masonry regularly for perpendicularity, especially at corners and openings, as even the smallest horizontal deviations affect subsequent courses.

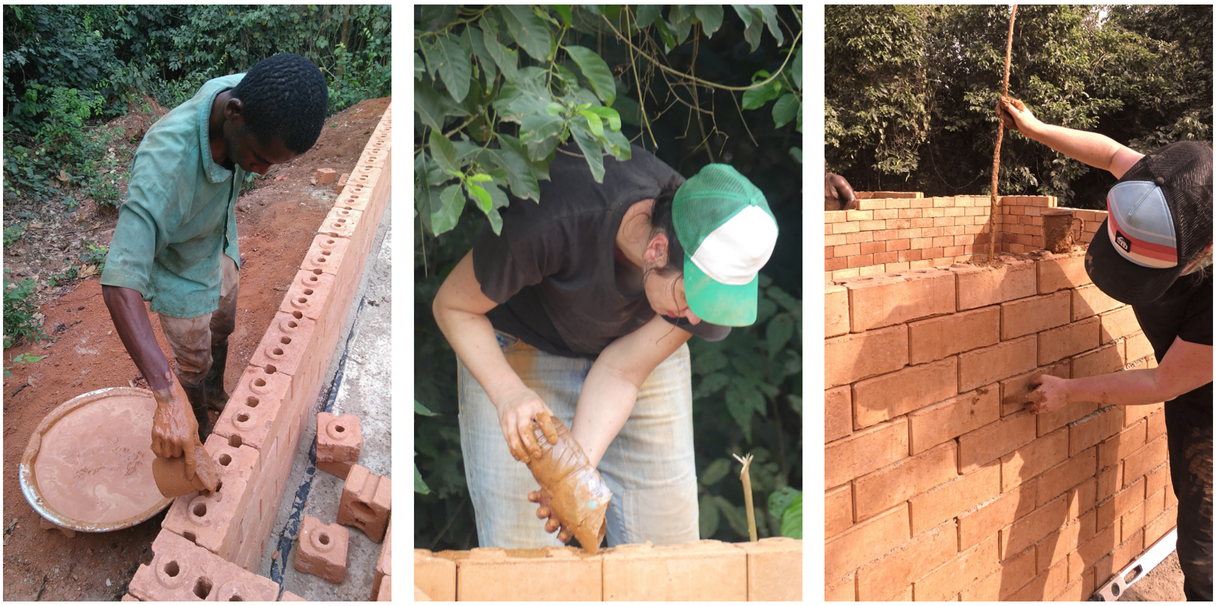
2. At the same time, irregularities in vertical perpendicularity can be corrected easily using a rubber mallet. As long as the building is only stacked and the grouting has not hardened, the walls are surprisingly easy to bring back into shape. This advantage is also a disadvantage. During construction, unloaded, ungrouted walls are relatively unstable and care must be taken not to bash or lean against walls, especially in a family-build situation where children may be on site.

MAGGLO specifies that vertical grouting is done with a liquid mixture of the original formula used to make the actual bricks. The suggested interval is half a storey (windowless wall height) which approximates to every 12 brick courses. However, it quickly became obvious that the mixture does not penetrate deeper than about 6 courses. We opted therefore to pour in grouting after every 4 courses at the latest.

To demonstrate that cement is not needed in the grouting mix either, two alternative unstabilised mixtures were tested.

Mixture A	4 : 3 laterite : river sand (vol. prop.)
Mixture B	3 : 1 : 1 laterite : river sand : wood ash (vol. proportion)

12+13 Experimenting with the recipe of the grouting mixture for pouring into the vertical holes of the laterite bricks

14-16 The square holes in the bricks are filled with liquid laterite grouting. Ensuring that it can flow right down into the wall, freeing blockages where necessary, is important to ensure the stability of the wall.

Tests on site showed that mixture A is more suitable. It also quickly became apparent that the liquid mixture is generally too coarse to flow easily through several brick courses, due to the coarse particles of the laterite. The grouting is poured from above and the penetration depth into the underlying courses can and must be checked by visual inspection since small cracks form between the bricks even in optimal construction execution. A first makeshift solution was to help the mixture run down by poking with thin rods, but it quickly becomes laborious. Two preparatory measures proved more effective: the first was to inspect the bricks before laying to ensure the holes are not obstructed by production/storage crumbs and residues; the second to sift the laterite material to remove coarser particles so that the grouting mixture is more homogenous and free flowing.

Findings: Material properties based on actual use and initial laboratory analysis

Another goal of our project was to demonstrate that the PURE laterite bricks produced especially for the project by MAGGLO are just as stable and suitable for use in single-storey construction as the original stabilised bricks. The first test was the construction of the experimental model building on Lake Agege Farm.

In addition, we undertook comparative compressive strength tests at the Kompetenzzentrum BauMV at Wismar University of Applied Sciences (KBauMV). In the first preliminary test, three MAGGLO bricks produced with different mixtures in Ghana were examined.

Brick 1	Original (Laterite, quarry dust, cement, hardener, water)
Brick 2	Laterite, quarry dust, water
Brick 3	PURE (laterite, water)

The tests showed that quarry dust does not improve the properties markedly. If anything, the resulting bricks are more brittle and exhibit less good edge integrity. The PURE laterite bricks, which have no additives, only water, were therefore used for the production process, which also simplifies production on small farm building sites in Ghana.

The first test was carried out with existing test specimens imported from Ghana, but the quantity of bricks was not sufficient to produce reliable results (as per the DIN testing specifications). In addition, the dimensions of the laterite bricks were unfavourable with respect to both items of material testing equipment. A second test series is therefore being planned using PURE laterite specimens produced in Germany that resemble those produced in Ghana.

Table 1 Comparative compressive strength tests

Test specimen	Height cm	Breaking load kN	Compressive strength N/mm^2
Brick 1-a	9.5	206.0	7.15
Brick 1-b	9.5	114.0	3.96
Brick 2-a	9.5	30.0	~ 1.0
Brick 2-b	9.5	28.8	~ 1.0
Brick 3-a	11	29.0	1.0
Brick 3-b	11	43.0	1.49

The first comparative compressive strength tests confirmed that additional additives are not necessary and that PURE laterite bricks could be used for a first experimental single-storey building on Agege Farm.

17+18 Compressive strength testing at the Kompetenzzentrum Bau MV (Wismar University of Applied Sciences)

A further objective of the project is also to improve the sustainability of brick production and thus to produce bricks on site using a mobile press. This would make house building even more climate-neutral, not least because laterite can be found almost everywhere in Ghana, either directly on site or in the immediate vicinity.

Findings: Social aspects

The interlocking stacking principle and the use of laterite makes it possible for virtually anyone, and particular those with few means, to building a single storey structure. The family can help in almost all phases of the construction, reducing construction labour costs. The main requisites are a suitably proficient builder to oversee and direct construction works and the loan of a brick press. Within the space of a week, 3-4 unskilled helpers can stack the MAGGLO bricks together to produce a 3-room building of of approx. 45 m^2.

The 'building recipe' is as follows:

- 1 master builder, trained in interlocking stacking technique, brick production and in important architectural details (e.g. foundation and roof), incl. own tools
- 3-4 helpers, unskilled, ideally family and friends
- 1 professional interlocking-brick press with 2000 lbs compression force, incl. generator, rented for 1 week
- 1 tipper truck load of laterite (32 m^3)
- 1 small lorry load of sand (for the grouting mixture
- 1 grandma for food and childcare
- Water
- 2 weeks construction time

19–22 The whole family can help: whether in transporting the bricks to the site, mixing the grouting mixture, transporting water, feeding the workers, etc. All this helps minimise the construction costs.

23 Africa meets Europe: Knowledge transfer, exchanging ideas, gaining insight. Some members of the construction team in front of the stacked walls of the first experimental laterite LEGO building

24 The building shortly before topping out

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