David Kraler, Christoph Lachberger
Faculty for Architecture and Planning, TU Vienna, Austria

Mondikolok Healthcare Centre – A healthcare facility constructed of wood and earth in South Sudan

The project

The construction of Mondikolok Healthcare Centre in the southern-most part of South Sudan was carried out as part of a diploma thesis for the Faculty for Architecture and Planning at the Technical University Vienna and was commissioned by the Austrian NGO "Osttirol für Jalimo/Mondikolok". Research, planning and construction were completed within three years (from 2012 to 2015).

Early on, the initiator of the project expressed the explicit wish to construct the Healthcare Centre as an earthen building made of local materials. This represents a rather unusual perspective within the context of development cooperation, but offered an ideal starting point for our efforts to work together with the local people in the construction of a building which uses locally available and natural materials, allowing the building to be integrated into the cultural and social setting and, at the same time, to play a leading role in ecological aspects. Here, the process-oriented approach of the project, a mutual transfer of knowledge, and a possible positive impact on the local building culture constitute key factors. In order to fulfill these requirements it became necessary to conduct extensive research on the ground even before the planning process could begin.

Analysis & potentials

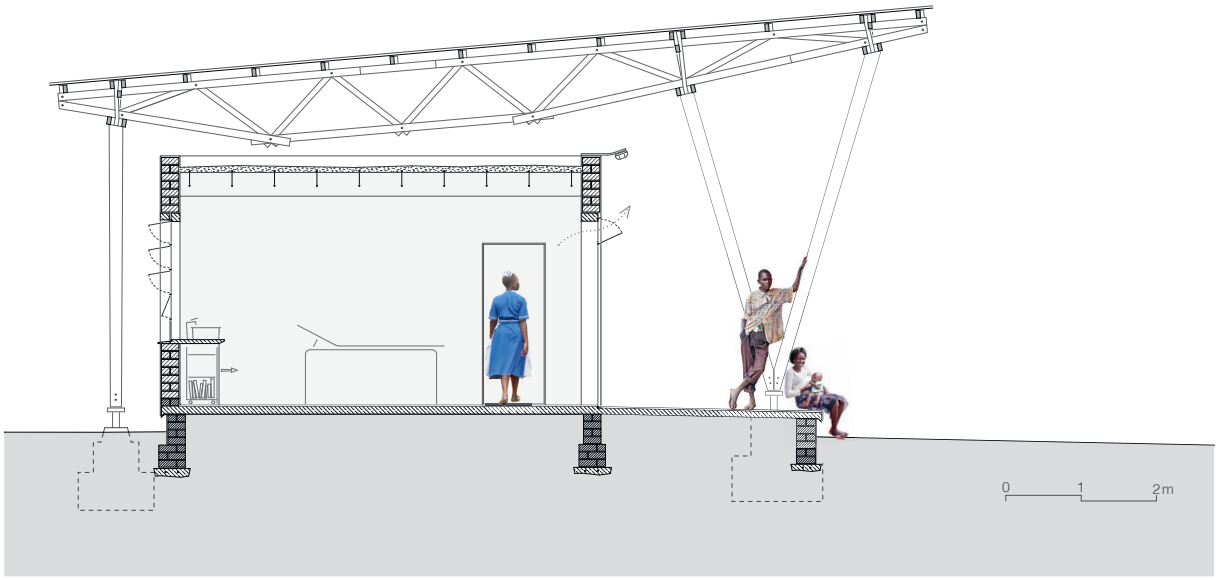
An APD study (= anthropological pre-design study) was conducted to examine local culture, building culture, traditional building techniques, lifestyle, climate conditions as well as the availability of building materials. This formed the basis for the development of key principles for subsequent planning:

The building culture of the Kuku people in the Kajo-Keji region is primarily characterized by a system of scattered paths and individual compounds without fences. Typically, these compounds consist of a number of traditional one-room houses which to this day are constructed by their inhabitants. The design of these mud huts – called *tukuls* – has been developed over generations to fit the local conditions. They are therefore well adapted to the local climate (on average 20 - 40°C, four-month dry season and a rainy season with some heavy rainfall) and can be constructed by the owners themselves using locally available building materials (earth, grass, wood, and bamboo) and a minimum of tools. The knowledge

Typical traditional family *compound*

Foto: Eva Huber

Traditional *tukul* with externally-placed wooden posts



Cross-section of building

of the general population concerning practical work with these building materials is remarkable.

The basic design of the *tukul* – earth walls and a roof structure made of wood and bamboo covered with local reed – is often modified by using different construction methods. Variations can be found in the use of different earth building techniques for the walls as well as a possible detachment of the roof structure for a number of reasons: On the one hand, there is the less permanent technique of covering a woven timber/bamboo lattice with mud which can be constructed year-round and is referred to by the local population as the traditional or older method. The newer adobe building technique, on the other hand, can only be used if the construction of a new *tukul* can wait till the next dry period since adobe blocks cannot be dried during the rainy season. Another variation can be found in the detachment of the roof structure: For the first of the two construction methods, the roof is typically laid onto the posts of the wattle-and-daub structure which have been driven into the ground. For the "modern" adobe technique there might be deviations: here, the roof structure is either placed directly on top of the earthen walls or laid onto individual wooden supports which are driven into the ground.

The detachment of the roof structure is done for several reasons. For example, it allows for the erection of weather protection for the building site independent of the earthen walls. Another probable reason can be found in the constructive approach to termite control: The insects, which are common to the Kajo-Keji region, cause damage to the grass roofs which, in turn, leads to rapid erosion of the earthen walls below. All local species live underground and are unable to fly. Therefore, the wooden poles which are driven into the ground remain major weak points of the *tukul*. Compared to the surrounding earthen walls, however, potential contact points are reduced to a manageable number of single points. These can be better monitored, and damaged wooden sections can be replaced with relative ease.

As a result of the severe termite problem, as well as the modern image of a Western building culture and the desired Western lifestyle associated with it, a growing trend to build with permanent materials can currently be noticed: Not only larger buildings are now being constructed using fired bricks, reinforced concrete, Hydraform blocks, steel and corrugated metal, but increasingly also private residencies as so-called *permanent houses*. The consequences range from an unbearable indoor climate, ecological problems, the loss of local knowledge and identification with one's own building culture to socio-economic problems: Small farmers who have been used to collecting building materials from the bush or near their property often completely overextend themselves financially by buying imported, industrially manufactured materials. The Hydraform blocks,

Assembling the roof structure

which are used by missionaries on site, do not really present a viable alternative due to their high content of cement and the associated disadvantages.

As a consequence, during the research phase the essential question arose of how to develop a contemporary building technique which meets modern requirements without renouncing or overly romanticizing existing know-how, lifestyle and building traditions. Therefore, in addition to studying the social, cultural and building cultural aspects of the local society, we made it a major focus of our first research trip to actively and physically engage with the building materials of earth and wood which were available on location. For example, our participation in the local production of earth blocks not only provided an opportunity for us to actively understand the material but contributed greatly to the building of mutual trust with the local population. Through this we obtained a clear picture of the extent of the locals' actual knowledge of working with earth and, at the same time, were able to introduce them to our idea of executing the project together with their help using local techniques.

The possibility of using local materials and traditional knowledge for our project became more and more realistic: A smart combination of traditional building techniques and innovation was to be used to construct a building made of earth and wood which is larger and more durable than a *tukul*. What appeared to be a logical and reasonable approach to us Europeans seemed just as unthinkable to the rural population of Kajo-Keji. After all, according to local understanding, the building process of a traditional *tukul* differs greatly from that of a *permanent house*:

Mason Ogwal laying earth blocks

Foreman Matata sourcing suitable soil

Foto: Eva Huber

Pre-fabrication of the ceiling elements

Application of daub onto the ceiling elements

While a *tukul* is built by the owners themselves, a *permanent house* is always constructed by hired builders. This separation is so widely accepted that the possibility of blending both processes is simply not considered in local ways of thinking. It was not until actual construction commenced that the majority of people involved could see for themselves that this approach would not only result in a high-quality building but, in addition, everybody involved could benefit by gaining knowledge and skills.

The use of the traditional local adobe technique which was essential for this approach was rejected by the Austrian project initiator for a long time: Here, the idea of building with earth was closely linked to the aesthetics of rammed earth construction, and it required lengthy efforts to convince them of this alternative. Although extensive field studies on location and various expert opinions could prove that the execution of the project using the rammed earth technique was not adequate and reasonable, the project initiator only agreed to the use of adobe with personal reservations.

Building system & termite control

In order to best take advantage of the potentials found on location (in particular with respect to building materials and knowledge in the field of earth building) the extreme termite problem needed to be sufficiently dealt with. A building system was developed which did not have to rely on the application of insecticides or an excessive use of steel and cement to combat termites, and which was consequently based on a constructive strategy for termite control:

The wooden roof structure was strictly separated from the solid earthen structure beneath – similar to certain traditional *tukuls*. In order to truly reduce the contact points between the wooden structure and the ground to an absolute minimum, two or four round timber posts are combined on one base. Finally, the design of Termite Shields at these critical points forms a barrier which prevents a hidden infestation in the structure's interior. Possible attacks on the surface – which are always linked to the insects' "structures" – remain visible and can therefore be easily removed.

While an infestation of aggressive termites in timber construction can actually lead to the failure of the entire structure, termite attacks in earth buildings are primarily a cosmetic problem. In order to prevent this – as well as for reasons of hygiene – the solid earthen structure was built on a slab of reinforced concrete with anti-crack reinforcement and termite shields along the edges. However, due to the large contact surfaces in solid construction, the risk of termite attacks cannot be ruled out entirely. Therefore, load-bearing timber or bamboo parts directly connected to the earthen walls had to be avoided. Instead, reinforced concrete lintels, steel windows and door frames as well as a specially designed composite ceiling of earth and steel were installed. For the development of this component – and for the construction of the solid earthen structure in general – we were able to rely on the vast collective knowledge on site for working with the local building material earth.

Examination room with light-colored earth plaster

Construction

The construction of the wooden structure, however, could only draw marginally on local knowledge. This can be explained by the relatively complex structure – which is ultimately based on the constructive approach for termite control – as well as a lack of local knowledge in building larger wooden structures. Although, during the construction phase, we were able to work well together with carpenters from Uganda, the majority of technical input during the construction of both roof structures had to rely on European contributions.

For the earthen structures, on the other hand, our hopes resulting from earlier research were completely met. Already when it came to sourcing suitable soil for block production, the local workers and neighbors' knowledge of the location and materials was invaluable: suitable soil was quickly found 200 meters from the building site. Manual production of the 40,000 traditionally made earth blocks, carried out directly in the clay pit and without the use of additional aggregates, proved to be of astonishingly high quality from a technical perspective. Our assistance was only required with organizational matters, such as providing the necessary water as well as the transport and weather-protected storage of the comparatively large number of blocks.

By contrast, laying the unfired blocks initially posed a challenge to the masons who had been trained in Uganda: even though they knew how to work with unfired clay through the construction of their own *tukuls*, in their professional training they only learned how to lay fired bricks using cement mortars with bedding joints of a minimum thickness of 2.5 cm. The problem was that when constructing walls using manually produced blocks the joints need to compensate for considerably larger inconsistencies and cement mortar is seen as a strong material which should not be used sparingly. All attempts at reducing the thickness of the bedding joints to an acceptable number for earthen construction without questioning the integrity of the few trained specialists on the building site proved to be an unforeseen challenge which required a particularly high degree of sensitivity in dealing with this foreign culture.

The development of the earth/steel composite ceiling which, for the most part, was done using the prototype at a scale of 1:1, allowed for the design of a new building component, free from established routines. The starting point for the design was the necessity of a room enclosure on the one hand, and the risk of overheating the interior with the use of a

Application of the traditional exterior plaster

The completed building

corrugated metal roof on the other. Apart from grass roofs, there are no appropriate ceiling structures in traditional *tukuls*, and the problem of overheating receives no or only insufficient consideration, even in the construction of the *permanent houses* in the region. This made a new design necessary.

Due the termite risk, the goal was to develop a solid earthen ceiling which was not connected to any organic material. It was also not possible to construct the ceiling as an earth block vault because of the limited skills of the workers. By designing the ceiling structure on location at a scale of 1:1 and under real world conditions it was ensured that the ceiling could be constructed using only locally available building materials: With a minimum of materials, common reinforced steel was used to produce curved trusses which were connected to welded wire mesh and fine-mesh expanded metal lath. Similar to the traditional earth building technique still in use today – waddle and daub – the steel structure was then covered with two coats of thrown earth and the bottom of the ceiling was subsequently plastered.

When choosing the technique and suitable material for the exterior and interior plaster we worked even more closely with the locals: The exterior plaster was applied using the traditional technique which is usually carried out by women. Together with the Ugandan foreman the women chose a suitable soil. Approx. 400 m from the building site, a dark gray, relatively lean soil was found which was mixed with "muna" (the left-over mash after the distillation of cassava/manioc roots). After several material tests, approx. 4% linseed oil was added to the exterior plaster. Using a traditional technique, groups of women applied four plaster coasts. With the help of flat rocks the surface was additionally compacted.

On the interior, the first layer of the base plaster coat was applied by masons in order to achieve precise leveling. The finish plaster was once again applied by the women, using traditional techniques, this time in very light shades and without any muna or linseed oil stabilization. The high quality of these surfaces already became apparent during construction: Even local visitors to the building site could hardly believe that the high-quality surfaces they were seeing were produced using traditional earth plaster.

Conclusion

Although the construction of the wood structure required more European input than initially intended, the earth construction allowed for close cooperation with local residents. In addition to constructing a technically sound and aesthetically appealing building, the construction phase in particular accomplished its goal of facilitating a mutual transfer

of knowledge. In addition, the future maintenance of the building appears to be secured in the long term due to the involvement of women from the immediate neighborhood in the initial plastering of the building. When talking to the locals after completion of the building, it also became apparent that the high quality of the finished earthen surfaces as well as the comfortable indoor climate have been able to contribute to an improved image of earth as a traditional building material in the Kajo-Keji region.

Weather-protected waiting area with roof overhang

Publication

A detailed documentation of the entire building process of the Healthcare Center Mondikolok is available as a book:

David Kraler & Christoph Lachberger *Mondikolok 1:1 – Bau einer Gesundheitseinrichtung im Südsudan*, ISBN 978-3-900265-30-4. IVA-Institut für vergleichende Architekturforschung, Vienna

All photos by the authors unless otherwise noted.