Diplomarbeit

SHAPING DESERT SOIL

DOCUMENTATION, ANALYSIS AND COMPARISON OF DIFFERENT CONSTRUCTION TECHNIQUES BASED ON AN EARTH BUILDING PROJECT IN THE SEMI-DESERT REGION OF AFAR, ETHIOPIA

TECHNISCHE UNIVERSITÄT WIEN

ausgeführt zum Zwecke der Erlangung des akademischen Grades
eines Diplom-Ingenieurs unter der Leitung
von

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CONTENTS

ABSTRACT

In 2015 Katharina Schönher kicked off the Afarkindergarten-project, an earth-building project in Ethiopia, as part of her thesis. The project is dedicated to creating housing space in the city of Logia for students of the Afar pastoral tribe from the rural area. In a semi-desert region, where wood for construction purposes is rare, but at the same time construction systems of permanent housing heavily rely on wood, the project takes its focus on earth construction techniques and is trying to establish a load bearing earth building technique.

This thesis describes and analyses the construction process of three similar sized already erected hostel buildings, which were built in three different construction techniques. The first building was designed by Schönher and mainly executed under her lead as an adobe brick construction. The second hostel is built in rammed earth wall technique and was built mainly under my lead and the third hostel was built by an external contractor and executed in a locally commonly used reinforced concrete frame structure with cement brick infill.

Since newly introduced and unknown construction techniques always are implicating all sorts of unpredictable difficulties and teething troubles compared to already established construction techniques, the goal is to analyse and compare key parameters of the construction process - how the construction processes of the new techniques can be optimized and furthermore, determine which construction technique is suitable for the region, how do people react to the new techniques and what problems can be avoided in advance, going forward?

KURZFASSUNG

Katharina Schönher startete 2015 ein Lehmbauprojekt in Äthiopien, das Afarkindergarten-Projekt. Das Projekt widmet sich der Aufgabe Wohnunterkünfte in der Stadt Logia für Schüler aus ländlichen Regionen vom Volk der Afar, einem nomadischen Hirtenvolk, zu schaffen. In der Halbwüstenregion, wo Holz ohnehin einen sehr seltenen Rohstoff darstellt, gleichzeitig aber die lokale Bauwirtschaft auf holzintensive Bauweisen setzt, will das Projekt den lasttragenden Lehmbau als alternative Bautechnik etablieren.

In dieser Arbeit werden die Bauprozesse der drei bereits fertiggestellten Gebäuden, die in etwa gleich groß sind und in drei verschiedenen Bautechniken ausgeführt wurden, verglichen und analysiert. Das erste Haus wurde von Schönher entworfen und hauptsächlich unter ihrer Aufsicht als Lehmziegelbau ausgeführt, das zweite Haus wurde als Stampflehmbau ausgeführt und vor allem unter meiner Aufsicht ausgeführt und das dritte Gebäude wurde von einem externen lokal ansässigen Bauunternehmer als Zementziegelbau mit Stahlbetonskelett ausgeführt.

Da neu eingeführte, noch nicht bekannte Bautechniken sehr oft im Gegensatz zu schon etablierten Bautechniken verschiedene unvorhersehbare Schwierigkeiten und Anfangsprobleme mit sich bringen, zielt diese Arbeit darauf ab die drei Bauprozesse zu vergleichen und Optimierungspotential der neu ausgetesteten Bautechniken aufzuzeigen - Wie wurde lokal auf die neuen Bausysteme reagiert und wie können zukünftig Probleme im voraus vermieden und Prozesse optimiert werden?

FOREWORD

Being responsible for a construction project in a foreign country is always a difficult task. Implementing new construction techniques in a foreign country comes with great responsibility and unexpected challenges, especially when introducing such technologies to developing countries. Is there really a need for new construction technologies? If so, which construction technique really could benefit the people, their life, their economy and still preserve or sustain the ecology. Would it be affordable? What are the local circumstances? Not only in terms of living environment but also in terms of construction resources. Having a reliable local partner in the region was one important factor in initializing the Afarkindergarten-project.

Another factor was getting to know the people, the country, the culture. Ethiopia is an extremely rich and diverse country. The economy is growing rapidly but climate change and globalisation are impacting people's reliance on livestock. Ethiopians are facing new challenges in this changing environment. The project emerged years ago and before the first construction works started, an immense amount of research work and field trips were done in the area to gather information and get a closer look at people's life in the Afar region. A student course field trip, individual research field trips by Alice Eigner, Emilia Chocia, Katharina Schönher and the general expertise of Valerie Browning and her NGO provided a deep insight on the local living conditions and the problems people are facing.

Planning, choices of materials and execution with local workers are equally important ways to influence the construction business of the Afar region in a positive way. Research and analyses in the context of execution of the project was not only important at the beginning but should be an ongoing effort to evaluate the implementation of the construction technologies.

Until now the project consists of three already finished hostel buildings, a sanitary house with two showers and two toilets, a kitchen building and a rain protected common area outdoors. It's crucial to compare the already erected buildings and the still planned buildings in the future. To analyse the construction process and the product of execution of the finished houses and, therefore be able to learn from the already finished buildings, is the main task this thesis wants to fulfil.be able to learn from the already finished buildings, is the main task this thesis wants to fulfil.

ACKNOWLEDGEMENT

First, I would like to thank everybody who contributed to the realisation of the Afarkindergarten-Project: from the ones who did the ground research work the project could build on, the people initiating the project, the many volunteer workers from Europe who over the course of the project came to Logia to help on the construction site, the financial supporters of the project and to all the people in Ethiopia and especially in Logia who helped to realize the project.

Especially I want to thank my professor Andrea Rieger-Jandl for the great support, advice and guidance over the whole course of my work.

I greatly appreciated Valerie Browing's and her husband Ismael Ali Gardo's welcoming hospitality and unrestricted commitment.

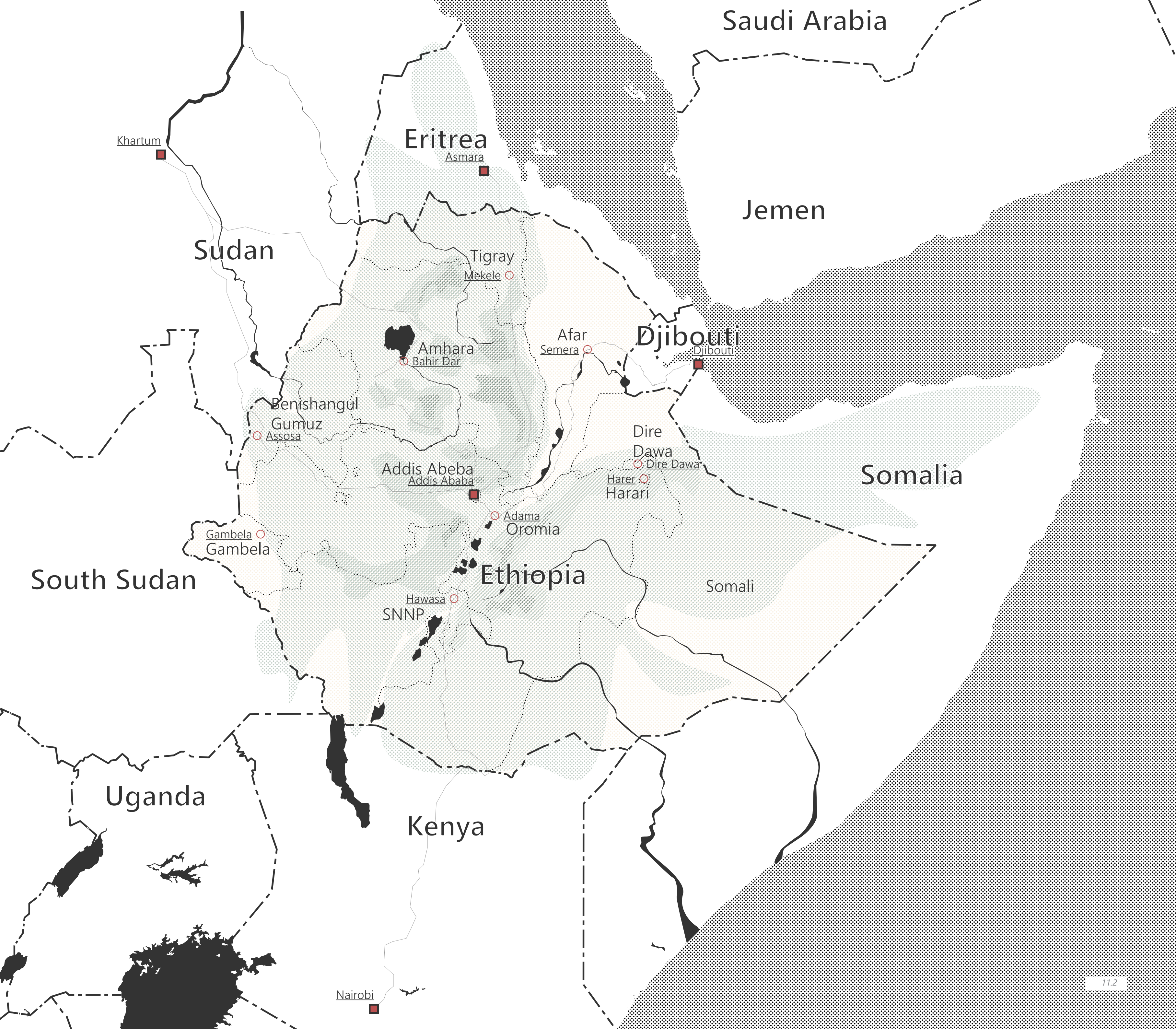
I want to express my gratitude to Katharina Schönher who introduced me to the project. She did so much groundwork on the project on which I could rely on and she was always supportive with countless valuable advice and tips for the work and management of the construction site, the life in Afar and Logia and much more. Her competent, untiring and focused way of leading the construction site inspired me in my work on the construction site. As well as Katharina also, Mark Ortler was supportive and inspiring in his competent, target-oriented and problem-solving work ethic on the construction site. I'm grateful to Denise Kießling who also worked on the project and was a great support for the team and for my finalisation of this thesis.

Over the whole course of this work many friends and family gave me meaningful advice and support of all kind. I'd like to thank all of them and especially Katharina Durak and Stephan Almasy.

I also want to deeply thank my family - my siblings and parents – for their support during my work on the thesis, the realisation of the project and over the whole course of my studies.

And finally I'm deeply grateful to my wife Hemma who supported me in Logia on the construction site and in Austria at this thesis and during my studies and together with my daughter Anna constantly is inspiring and motivating me.

RESEARCH



Saudi Arabia
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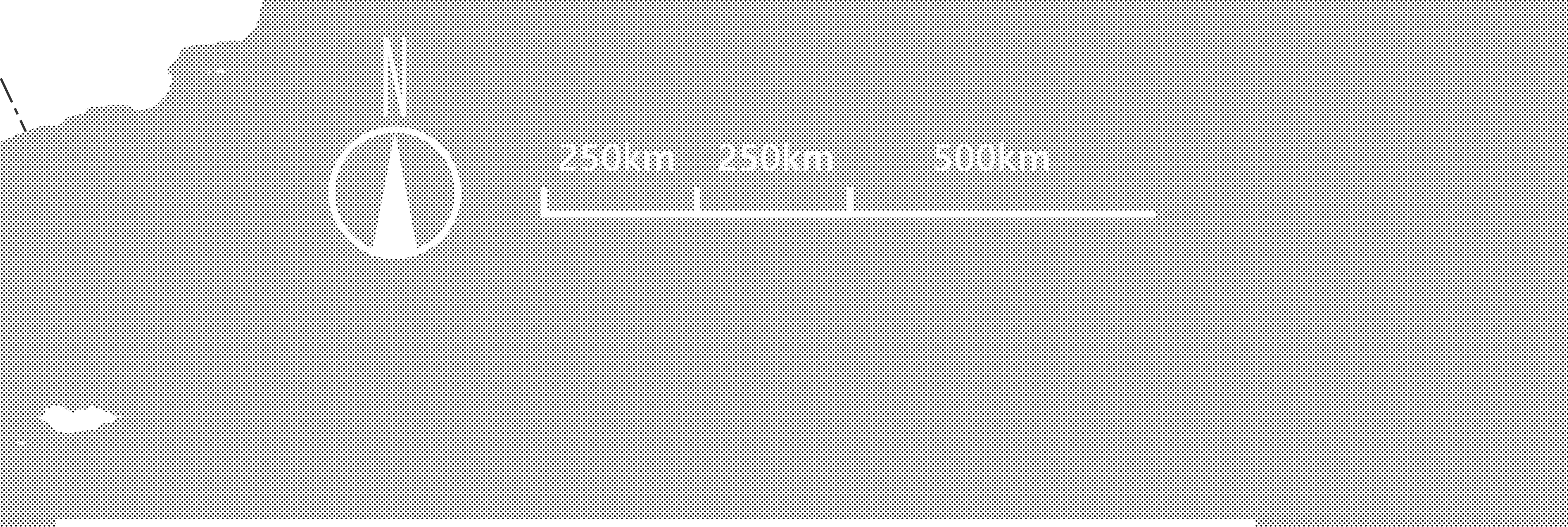


1 PROJECT LOCATION

fig. 11.1 | climate zones of Ethiopia according to Köppen-Geiger - graphic based on data from (Peel 2007)

fig. 11.2 | map of Ethiopia (2017) regional states, urban centres and topography

1.1 Ethiopia

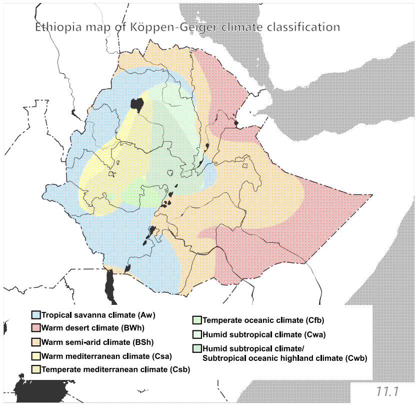
(የኢትዮጵያ ፈደራላዊ ዲሞክራሲያዊ ሪፐብሊክ) Ethiopia is considered to be one of the poorest countries in the world. In the last ten years, from 2006 to 2016, the GDP (PPP) more than doubled from USD 69.4 Billion (2006) to USD 164.7 Billion (2016)(worldbank.org/... Nov. 2017). Even though the economic development is rising rapidly, not all the ethnic groups do benefit the same and general poverty is still very high. The multiethnic east African nation is home of more than 80 different ethnic groups and equality many languages and has a long and rich history going back centuries (CSA and ICS International, 2012). It is one of the oldest continuously independent states in Africa (Briggs, 2009).

Geographical location

Ethiopia is a landlocked nation in the northern hemisphere on the horn of Africa. It´s surrounded by Kenia, Somalia, Djibouti, Eritrea, Sudan and South Sudan. Eritrea and Djibouti are separating the country from the red sea. The southern border of the country is about 380km north of the Equator. The total area of the country covers about 1.1 million square kilometres, which is about the size of central Europe [Swiss, Germany, Austria, Slovenia, Hungary, Slovakia, Czech, and Poland (Brockhaus, 1998)]

Topography and climate

The Ethiopian geography offers a great diversity due to its topography, which features a range from the highest peak of Mount Ras Degen (4550metres above sea level) in the highlands down to the Afar depression (125 meters below sea level). The Ethiopian rift valley is surrounded by the highlands of the Ethiopian and the Somalian plateaus. (CSA and ICS International, 2012; fao.org/[...]/Ethiopia/... 11/2017)
Even though Ethiopia is close to the equator the climate differs a lot, due to the big



11.1

variety in altitude. Temperatures in the country are reaching from a annual mean of 34.5 degrees Celsius in the Danakil Depression, where highs can reach up to 47 degrees Celsius, to minimum temperatures fall below zero in the upper reaches of Mount Ras Degen (4.620metres) in the highlands, where the mean annual temperature is even less than 0 degrees Celsius. The annual temperatures of the vast area,

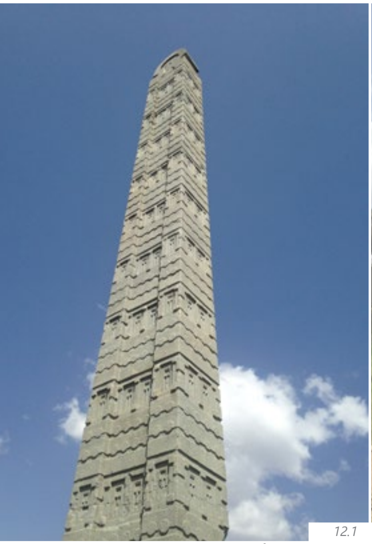


fig. 12.1 | Aksum – first stelae of Aksum where created between the 1st and 4th century AD. The stelae most likely originated from grave stelae. The shown stele is the second largest stele of Aksum with 24.6m. After it was taken by the Italians in 1937 and shipped to Rome, it was returned to Ethiopia in 2004 and (Deix 2013). The ruins of the ancient city of Aksum are listed as UNESCO world heritage since 1980 (whc.unesco.org in Jan. 2018)

fig. 12.2 | Aksum – The largest stele in the Aksum Stelae Park is 33.3m high. It is not clear if the stele already broke, when it was tried to erect or, if, it broke down in the course of time (Deix 2013)

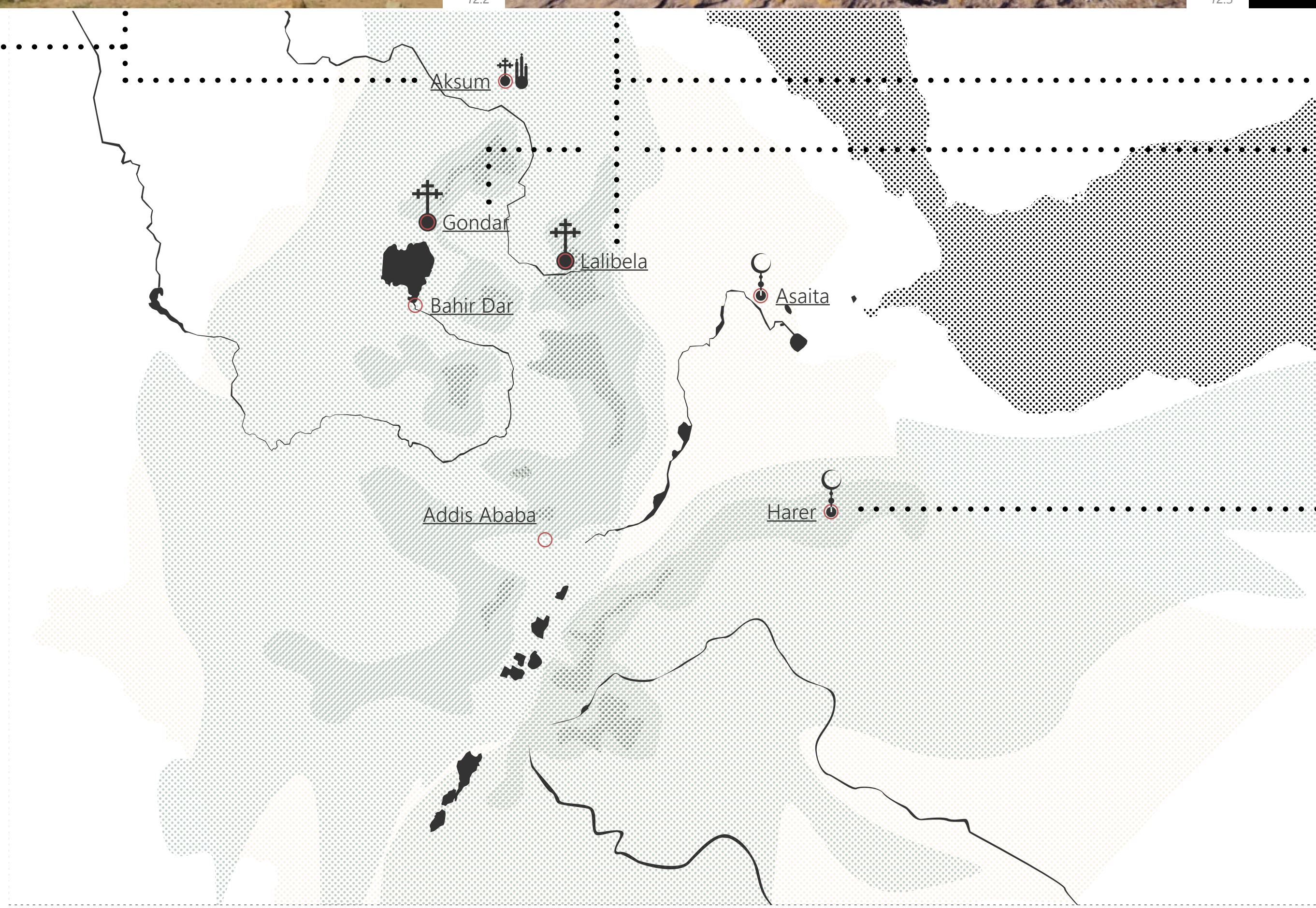
fig. 12.3 | Lalibela - Beta Giyorgis – Church of St. George - view from the ground level. The courtyard is carved down into the solid rock. A religious woman is listening to the early mass

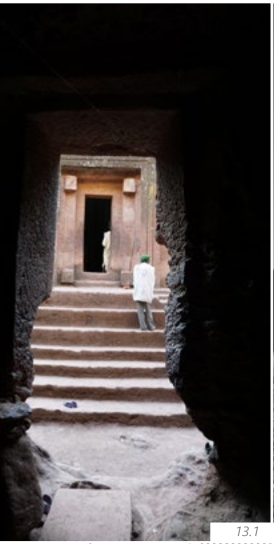
fig. 13.1 | Lalibela - one of the eleven Rock-Hewn Churches - Biete Ghiorgis - showing the so-called monkey-heads architectural features in the corners of the main entrance portal (Deix 2013). The churches are listed as UNESCO world heritage since 1978 (whc.unesco.org in Jan. 2018)

fig. 13.2 | Gondar - Fasil Ghebbi „Royal Enclosure" - a medieval fortress-city founded by Emperor Fasiladas in 1636 - influenced by the Aksumite style and Portuguese missionaries (Deix 2013)

fig. 13.3 | Gondar - Fasilidas' Bath - summer and holyday palace and bath

fig. 13.4 | Harrar - "the walled city" - the walls around the historic, Islamic city were erected between the 13th and the 16th century. The city is listed as UNESCO world heritage since 2006 (whc.unesco.org in Jan. 2018)

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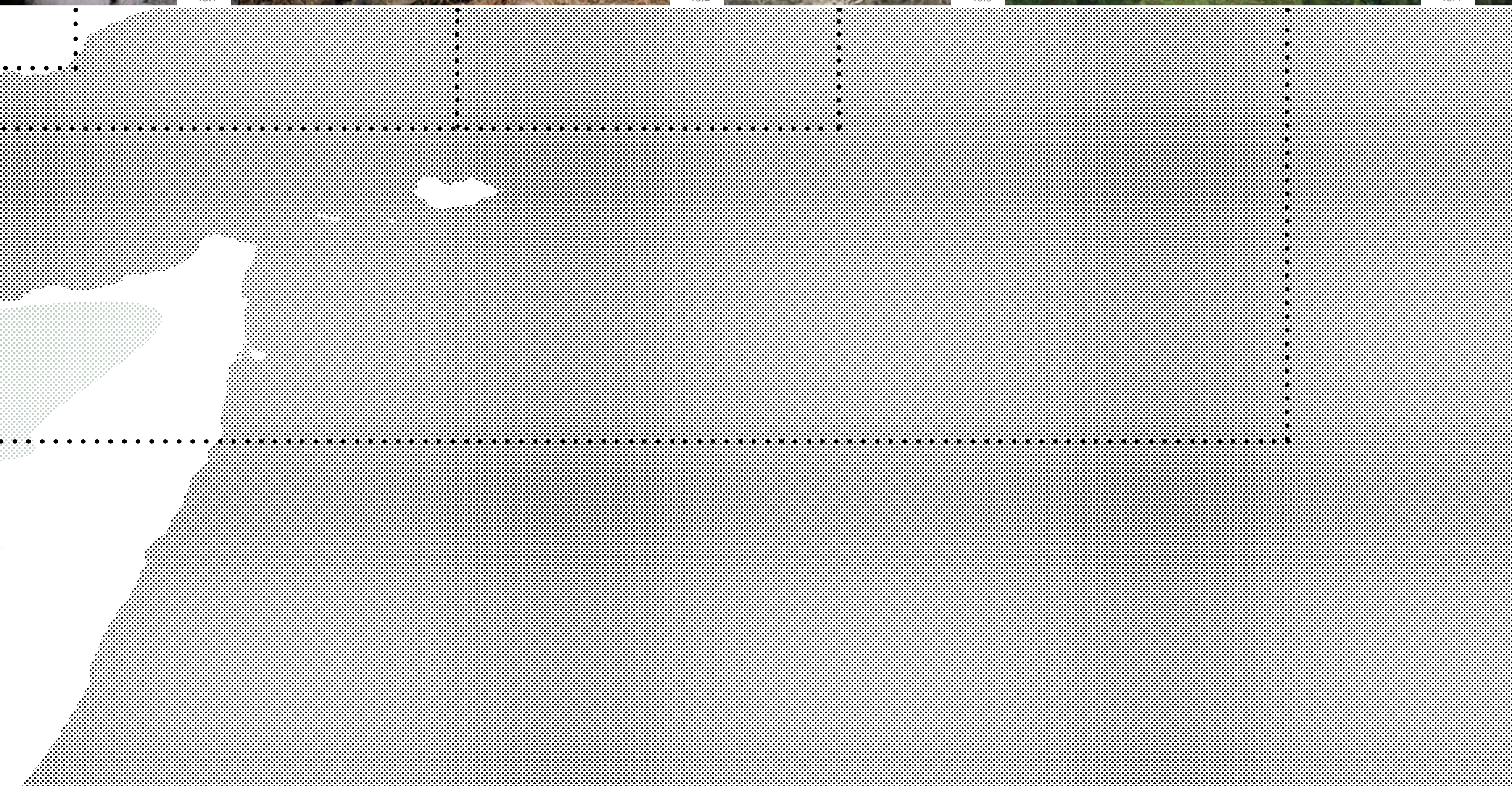

including the plateau and marginal slopes is between 10 and 20 degrees Celsius.
Climatic heterogeneity is a general characteristic of the country. According to Köppen-Geiger three of the five world's main climate groups are represented in Ethiopia - tropical, arid and temperate, which can be subdivided eight different climate classes (fig. 11.1)(Peel, Finlayson, Mcmahon 2007)
Rainfall in Ethiopia is generally correlating with the altitude. The highland above 1500 meters a.s.l. receives substantially more rainfalls than the lowlands. One exception is the western lowland where rainfall is high. Despite the variation in amount and area of the general rainfall, which makes agricultural planning difficult, a substantial proportion of the country gets enough rain for rainfed crop production. (fao.org/[...]/Ethiopia/... 11/2017)
The longest of the three seasons in Ethiopia is the long dry season and lasts from September to March. From March to April there is a short rainy season, the *"belg"* and from June to August there is the long rainy season (britannica.com/places/Ethiopia/... 02/2018)

Historical overview

Situated at the Horn of Africa, the Ethiopian history reaching back through many ancient empires, with the prehistory, even reaching back to the first steps of mankind. Many important palaeontological discoveries were made in Ethiopia. Therefore, Ethiopia is also perceived as one of the cradles of mankind. Humanoid skeleton fragments dating back 4.2 million years, were found in Ethiopia. The Australopithecus, *"Lucy"*, might be the most famous paleontological discovery in Ethiopia. It's the most complete skeleton of an early hominid found yet.
The Name of the country can be derived from the ancient Greek, where it was used for a historical region, which included Abyssinia, Nubia, Sudan, and parts of Libya. (Helfritz, 1972)
Aksum and D'MT are one of the oldest civilizations in the area of today's Ethiopia with D'MT dating back to almost 1000BC. The south Arabic influenced temple in Yeha, which might have been also the capital of D'MT kingdom, is the oldest still standing structure in Ethiopia. Maybe the civilization of D'MT already disappeared before the rise of the Aksum empire or it was unified together with other political groupings on the Tigray plateau under the rulership of Aksum. (Shaw, Sinclair, Andah., Okpoko, Ed., 1995)
The pre-Christian empire of Aksum is estimated to have lasted from the 1st Century BC to the 7th century AD. The Aksumites were trading with India, Arabia, Persia, and Rome. Manni, a Persian writer even considered Aksum to be one of the four major empires of the world. King Ezana established in 340 AD Christianity as the official main religion in Aksum. Which made it the first nation in Africa that embraced Christianity, while some regions of today's Ethiopia also were part of the early development of Islam. As Islam expanded in the area around the Red Sea in the 7th century, the Christian nation became more and more isolated. Since the Aksumites had to draw back on the red sea coast and lost their maritime trade routes, they drew their attention to the north Ethiopian highlands. At that time the country became known as Abyssinia. The center of power shifted from the city of Aksum to regions in the south, where Aksumite cultural, political, and religious influence had been established by then. (Ofcansky, T., Berry, Ed., 1993; Helfritz 1972, Deix 2013)
In about 1137 the Zagwe Dynasty in the province Lasta came to power. The capital city Roha (later known as Lalibela) gained importance. Ethiopian Christianity reached its peak of its physical expression during that period. The construction of the stone carved churches (fig. 12.3, fig. 13.1) in the capital city Adefa is attributed to the reign of King Gebra Maskal Lalibela (1190 – 1225). Therefore, later the city became known as Lalibela. In 1270 an Amhara noble, proclaimed himself king and ended the Zagwe Dynasty. (Ofcansky, T., Berry, Ed., 1993; Helfritz 1972)
After 1270 until the beginning of the 16th century, Abyssinia again gained importance and saw a cultural revival in addition to expansion of the empire. Nevertheless conflicts, starting in the mid-15th to the mid-17th century, because of the Islamic expansion, a far-reaching migration of Oromo and Portuguese missionaries that were called to help against the Islamic invasion but also tried to convert the orthodox to Roman Catholicism, weakened the empire again. In 1636, after the dispute with Roman Catholics was settled, the emperor Fasiladas built his palace in Gondar (fig. 13.2, fig. 13.3) and established the city as the first permanent capital city since the fall of the Zagwe Dynasty. The city became the political as well as cultural centre of Ethiopia during the Gondar period. The Gondar period ended in 1769. In the following century, which was temed by Ethiopians *"the area of princes"*, Ethiopia as a united empire didn't exist anymore. Kings of Gondar had no actual political power anymore and were only figures of representation, while Influential nobles made the decision or even chose their own king.

(Ofcansky, T., Berry, Ed., 1993)
From 1855 to 1888 Emperor Tewodros II and later emperor Yohannis IV and the Shewan prince, Menelik – who ultimately was becoming Emperor himself in 1889 and founded the city Addis Abeba in the 1870ies - were working on the reunion of the different principalities of Ethiopia, whilst the latter was also fighting against the other two leaders. After the death of Yohannis IV, Prince Menelik finally became Emperor Menelik II in 1889. In that year Menelik II signed a contract with Italy, that secured for Italy the territory of modern day Eritrea and in return guaranteed the acceptance of Ethiopia's full sovereignty. When Italy didn't hold up to the agreement, Menelik II successfully defeated Ethiopia against an Italian invasion. For the first time an African country could defeat European invaders. With the enthronement of Menelik, Addis Abeba also became the capital city of Ethiopia. During his rulership, the construction of the Addis-Djibouti-highway started, and electricity, telephone, schools and hospitals were introduced. (Schönher, 2015, Eigner, 2014, Ofcansky, T., Berry, Ed., 1993)
After the death of Emperor Menelik II in 1913, succession struggle kept on for 17 years, until in 1930 the sun of a Ras of Harar, TAfari Mekonnen, was crowned, taking the name Haile Selassie I. TAfari started to modernize Ethiopia in the years before his crowning. Schooling was promoted, ministries were appointed, and a newly created bureaucracy built on the model of European administrative regulations and legal code books. In his early years as emperor schools were further established, a penal code enacted, printing press to establish national wide newspaper was imported, the availability of telephone service and electricity was increased, public health was promoted, and the Bank of Ethiopian was founded. (Ofcansky, T., Berry, Ed., 1993)
In October 1935 Italy under the rulership of Mussolini, again invaded into Tigray region and managed to occupy the entire country until March 1936. The Emperor had left into exile to London, were he led the Ethiopian resistance until British forces defeated the Italians in 1941 and freed the country. After his return to Ethiopia he re-established his absolute sovereignty. Several wars were waged during his rule and at the end of his reign dissatisfaction among the population became increasingly high until he had to step down after a military coup in 1974.
The Derg (Amharic for *"committee or council"*; socialist-inspired Military Coordinating Committee) took over and soon promoted Ethiopian Socialism. The Derg, took a radical approach on land reform. The Land Reform Proclamation of March 1975 nationalized all rural land, abolished tenancy, and put peasants in charge of enforcement. In July 1975, also all urban land, rentable houses, and apartments were nationalized. Even though people were generally in favour of a land reform, the radical approach of the Dreg led to a federating of more and more oppositional groups. Towards the end of the 1980s, several crises, including famine, economic collapse, and military setbacks in Eritrea and Tigray, challenged the Derg. In addition, as democratic reform swept through the communist world, it became evident that Addis Ababa no longer could rely on its allies for support
In May 1991 the EPRDF (Ethiopian People's Revolutionary Democratic Front) entered the parliament and took over governance. The new constitution, that reorganized the country in to nine regional states, *kilil* - Tigray, Afar, Amhara, Oromiya, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples (SNNP), Gambela, and Harari - and two city administrations - Addis Ababa and Dire Dawa, became official when the Party officially was elected in 1995. Dire Dawa was under federal administration until it became a chartered city like Addis Abeba in 2004. The regional states are subdivided in districts, *weredas*, which themselves are divided into subdistricts, *kebeles*. (Deix, 2013; Schönher, 2015; Eigner, 2014; Ofcansky, T., Berry, Ed., 1993; worldstatesmen.org/... 02/2018))

ethnic groups/demographic

Ethiopia has with 4.99 children per woman (CIA, the world factbook, 2017) one of the highest fertility rate and has with annual growth in population of about 2-3%, (Rieger-Jandl, 2013) one of the fastest growing population in the world. The population increased from about only 15 Mio in 1935 (Rieger-Jandl, 2013)) to 42.6Mio in 1984 and 73.8Mio in 2007, with today reaching about 100Mio estimated and according to the U.S. Department of Health and Human Services might reach 228.1 Mio in 2050 (U.S. Department of Health and Human Services, 2016) . Other extremes in demographic statistic is the youth of population. When measured by age the population of Ethiopia is one of the youngest in the world, with less than 3% of the population being older than 65 and a median age of 17.7 years. Also, the urbanization rate is still very low, with only 16% of the population living in urbanized areas. 84% of the population are living on the countryside mainly as self-sufficient peasants. In the highland areas, where minority of the population is living, the rural population relies on small farming, while in the lowland areas the rural population relies on their livestock for their pastoralist lifestyle. The three largest regional states in terms of population are Oromia, Amhara and SNNP (Southern Nations of Nationalities and People) which together hold 80% of Ethiopian population.

The over 80 different ethnic groups vary in size from over 20Mio to only about 100 people. The two biggest ethic groups, Oromo (34million) and Amhara (27million) together do make up nearly 60Mio in population, which is about two thirds of the country's whole population. This two groups, together with Tigrayans, Somali, Afar, Sidama, Gurage and Harari form also the eight broad ethnic groups. (Rieger-Jandl 2013; worldatlas.com/... 07/2017)

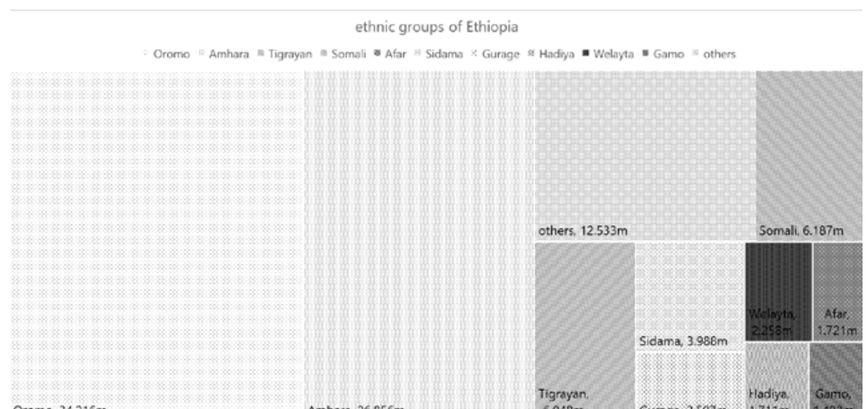

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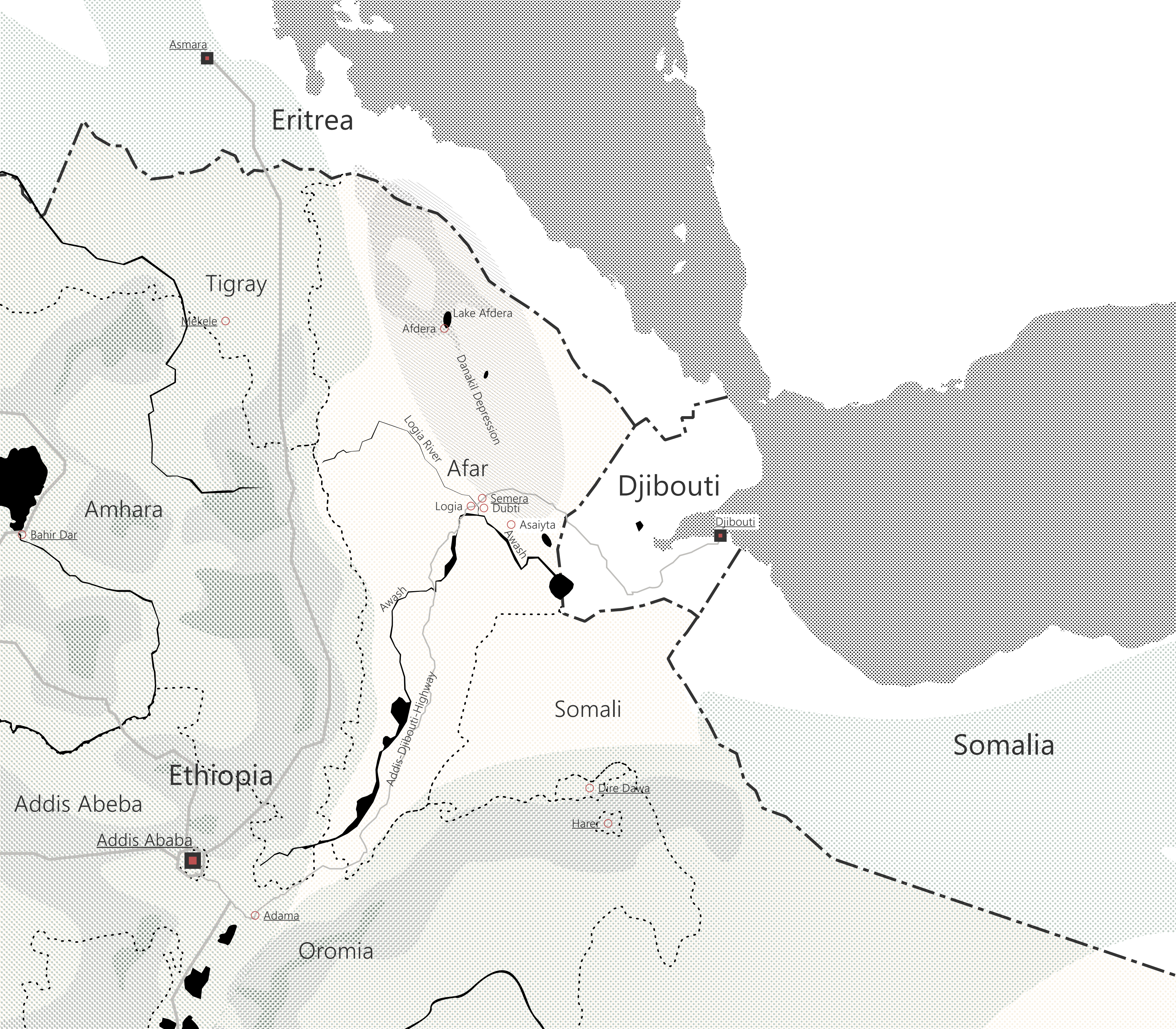
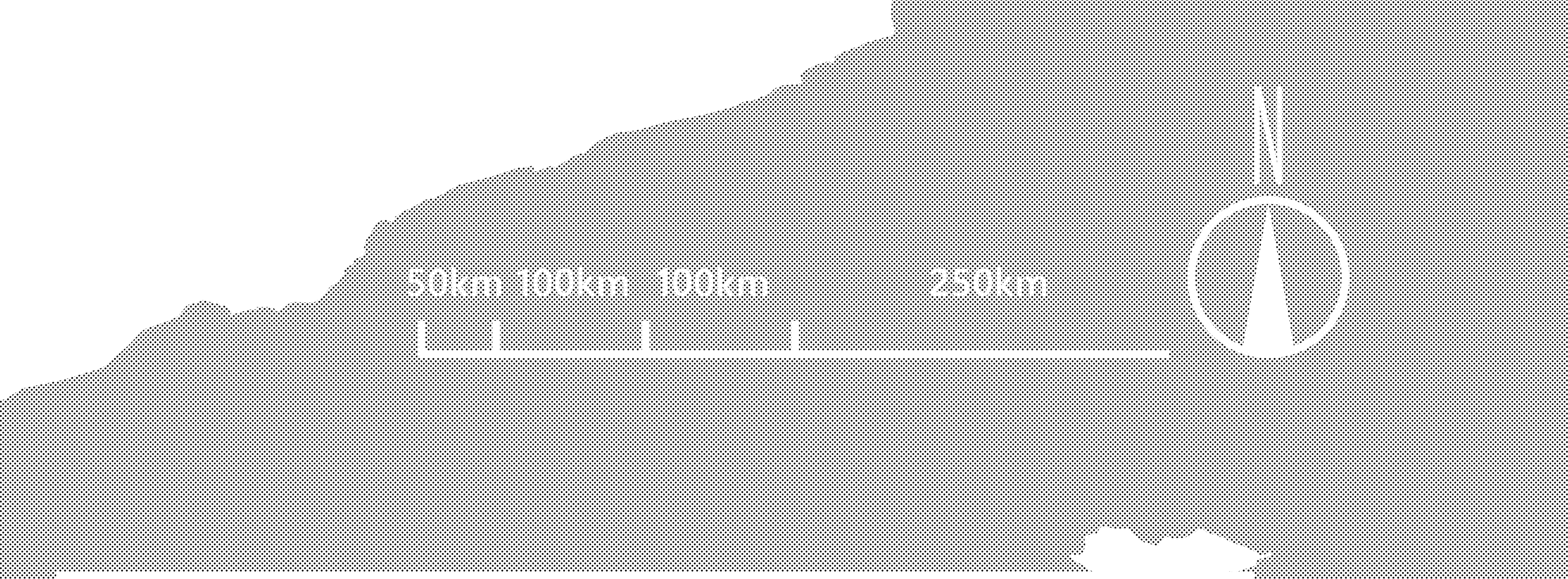
fig. 16.1 | graph generated based on data of the (worldatlas.com Jul. 2017)



Asmara
Eritrea
Tigray
Mekele
Lake Afdera
Afdera
Danakil Depression
Logia River
Afar
Djibouti
Amhara
Semera
Logia
Dubti
Asaiyta
Djibouti
Bahir Dar
Awash
Awash
Addis-Djibouti-Highway
Somali
Somalia
Ethiopia
Dire Dawa
Addis Abeba
Harer
Addis Ababa
Adama
Oromia



1.2 Afar

"A desert landscape formed from sand and volcanic rocks, summer temperatures up to 50°C; no shadow to escape the sun; odd spiky plants that cling to life" – that's how John Little is describing the region on the horn of Africa encompassing northern lowlands of Ethiopia, Djibouti at the entrance of the red sea and Eritrea – the Afar triangle. A region, where it's hard to imagine anyone would like to live. And still it's home to some people, the Afar people, nomads, who wander from waterhole to waterhole while carrying everything they possess on a camel – even their houses. (Little, 2008)

The depressed area of the Afar triangle, is in a unique tectonically location, where three massive rifts meet. 25 million years of high tectonic activities, due to the intersection of the Red Sea-, the East African and the Gulf of Aden Rift, were shaping todays landscape in the Afar triangle - a land depression that is slicing through the Ethiopian plateau and covered by volcanic rocks in large areas. (Chocian, 2017)

According to the Köppen-Geiger climate classification there are five different climates across the whole Afar-triangle, with the clear majority being warm dessert (BWh) and warm semi dessert (BSh) classified areas. Only in the most southern part of the region, where the highlands are beginning, there is a small part classified as temperate climate. (Peel, Finlayson, Mcmahon, 2007) Rainfall in the region differs from 600 mm in the south and west to less than 200 mm in the Dallol Depression, an extreme hot and arid area on the Ethiopian-Eritrean border. Dallol is said to be the hottest region on earth, where people are living, where temperatures are reaching more than 47°C in the summer. The high variation in rainfall from year to year and the high temperatures, that lead to high evapotranspiration, leads to even less surface water, which is hardly needed by the pastoralist people. There are three main seasons. The big rainy season, *karma*, which lasts from July to August/September is followed by a long rainless period, the dry season *giilal*, from Oct./Nov. to Jan./Feb. In the winter month temperatures are cooling down a little bit. Between the two, big seasons, in the spring month March and April the *sugum*, a small rainy season, that mostly lasts only for about two weeks, is accruing. Temperatures are reaching its highest peak right before the *karma* in May and June. (Chocian, 2017)

The Afar Regional National State (ARNS) is one of the nine regional states of Ethiopia. The sate covers about 100.000 km² with about 1.4 Mio inhabitants. 13% living in towns. The vast majority is Afar people (90% Afar)(CSA, 2008)

19 *fig. 19.1* | map of Afar Regional State (2017) urban centres, rivers and topography

19.1

"

Their appearance is striking. Some say the Afar are descended from the Pharaohs. They have ebony skin, the men typically have a broad forehead framed by a hairstyle right off the wall of an Egyptian tomb, which they artfully arrange into myriad corkscrew curls, dressed with butter. They wear a short sarong, sandals their chest is bare and at the waist they curry a large curved knife.

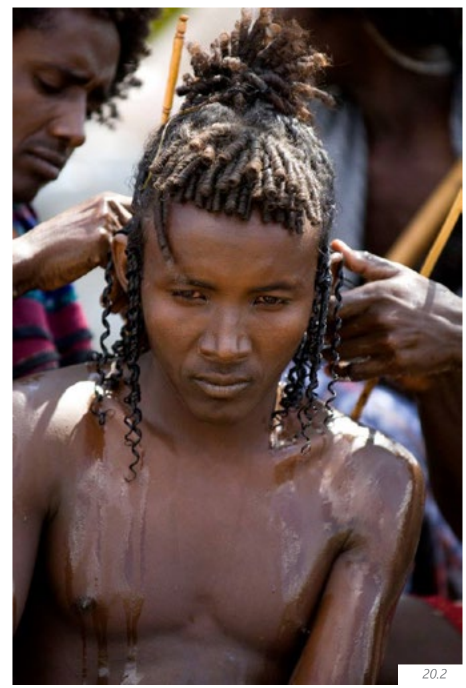
Afar women are tall and slim with the fine features typical for the Horn. They are very often arrestingly beautiful. They wear long, brightly patterned dresses with sometimes a red-and-blue striped T-shirt, or occasionally nothing at all on top. Their long black hair is parted in the middle, sometimes plaited into numerous corn rows and held behind with a twist of cord. They enhance this outfit with necklaces or headbands made of brightly coloured plastic beads.

"

(Little, 2008)

fig. 20.1 | Logia – 2016 - young Afar girl living in the youth hostel in Valerie Brownings' compound

20.1



20.2

fig. 20.2 | Afar countryside - young man getting his hair dressed with butter (apdaethiopia.com Feb. 2018)

21.1

fig. 21.1 | Logia – 2016- main road of Logia that is also the Addis-Djibouti-Highway. The photo was taken from one of the few multistore buildings in Logia, a restaurant and hotel. On the street small bajajes are bustling around in between a train of big trucks und some fairly big off-road cars.

1.3 Logia

The city Logia developed along the Addis-Djibouti-Highway, in the center of the Afar Region, where the Awash river - the biggest and most important river in the Afar Region - is changing direction to the south. It seems that there is no official spelling for the name. It often is spelled differently, even in official documentation form same years the spelling can vary from Logia to Logiya or Logya.
The city is situated in the Administrative Zone 1 and part of the Dubti wereda, which is one of the eight weredas of Zone 1. There is no official date when the city was founded, but it is very likely that the city developed during the construction of the Addis-Djibouti-Highway in the 1960s, even though, there are reports that first permanent settlement might have started already in the 1940s. The oldest mosque in the city was founded in 1960 according to Eigner. The relatively young city is one of the fastest growing cities in the Afar Region. According to the last two official censuses, the population in the city quadrupled between 1994 and 2007 from 3230 to 14038 inhabitants and is still rapidly growing. The last official estimation based on a census was done in 2012, where the city's population was estimated at about 19719 people. Due to the continuous high growth rate of the city, it might already be the largest city in the Afar Region, surpassing Asayita and Dubti. (Eigner, 2014; CSA, 1996; CSA, 2008)
In addition to the generally increasing urbanization rate in the Afar Region, the high growth rate of Logia most probably can be attributed on one hand to its location at the main import and export street of the country, the highway that connects the capital Addis Ababa with the port of Djibouti, where daily thousands of trucks pass the city, which is a big economic factor for the town. Truck drivers often stay in the city over night. Along the highway, which is running right through the center of the city, mostly hotels and bars are facing the main street. On the other hand, the move of the capital city of the Afar Region from Asayita to Semera, the neighbouring city to Logia, also is contributing to the high growth rate of Logia. University, Government, Organizations have been moved to Semera and many People who are living in Logia and working in the offices of Semera are shuttling every day to the only 5-kilometer distant capital. (Eigner, 2014)
Even though in rural areas of the Afar Region nearly 96% of the population are ethnic Afar, in cities the number is much less at about 52% according to the census from 2007. Amhara is the second biggest ethnic group in cities with about 30%. The bigger diversification in population is also impacting the share in religion. While in the rural regions of Afar 98% of population are Islamic, in the cities only 77% are Islamic. According to Eigner there are ten mosques, one Orthodox church and one Protestant church in Logia (state 2012). Two of the mosques and the Orthodox church are fairly big and clearly visible from distance. (Eigner, 2014; CSA, 1996; CSA, 2008)
The main axis of the city is the highway which runs from south-west to north-east. In the north east, the city is bordered by the Logia River which until today prevents the city from growing in the north-east direction along the highway towards Semera. Therefore, the city is primary developing in three directions: along the highway in only one direction to the south-east and perpendicular to the highway in both direction. But in the south-west the city soon will reach another boundary, an irrigation canal that connects the Tendaho Dam with the sugar cane plantations along the Awash river between Dubti and Asayita. The first

raw of house sideways the highway is primary dedicated to commerce. Hotels and restaurants, bars, shops and banks are lined up along the highway. There are also other commercial areas spread over the whole city. Two bigger ones are the *dalalaganda*, the Afar market street, running parallel to the highway in the norther part of the city and the *laganda*, the Amhara market, also running parallel to the highway but on its south side (Hummed Abdu Hummed)[22.1]. There also developed some kind of profession districts in the city. For example, there is a street where nearly all the welder and metal workshops of the city can be found. Another area is dedicated to the wood traders.
The highway is the only bituminized street in the city and for long was the only paved street in the town. In 2016 another street to the new built high school was plastered. Some unpaved roads are heavy trafficked by cars and bajajes and therefore badly affected by road holes which in the dry season often are covered by a thick layer of powdery dust, where missteps should be minded, because the unpredictable depth of the holes and the potentially extremely hot dust. In the rainy period, the holes can quickly transform into rainwater pools that can block passage through streets for days.

note 22.1 | informal interview with Hummed Abdu Hummed about the marketstreets in Logia in March 2017

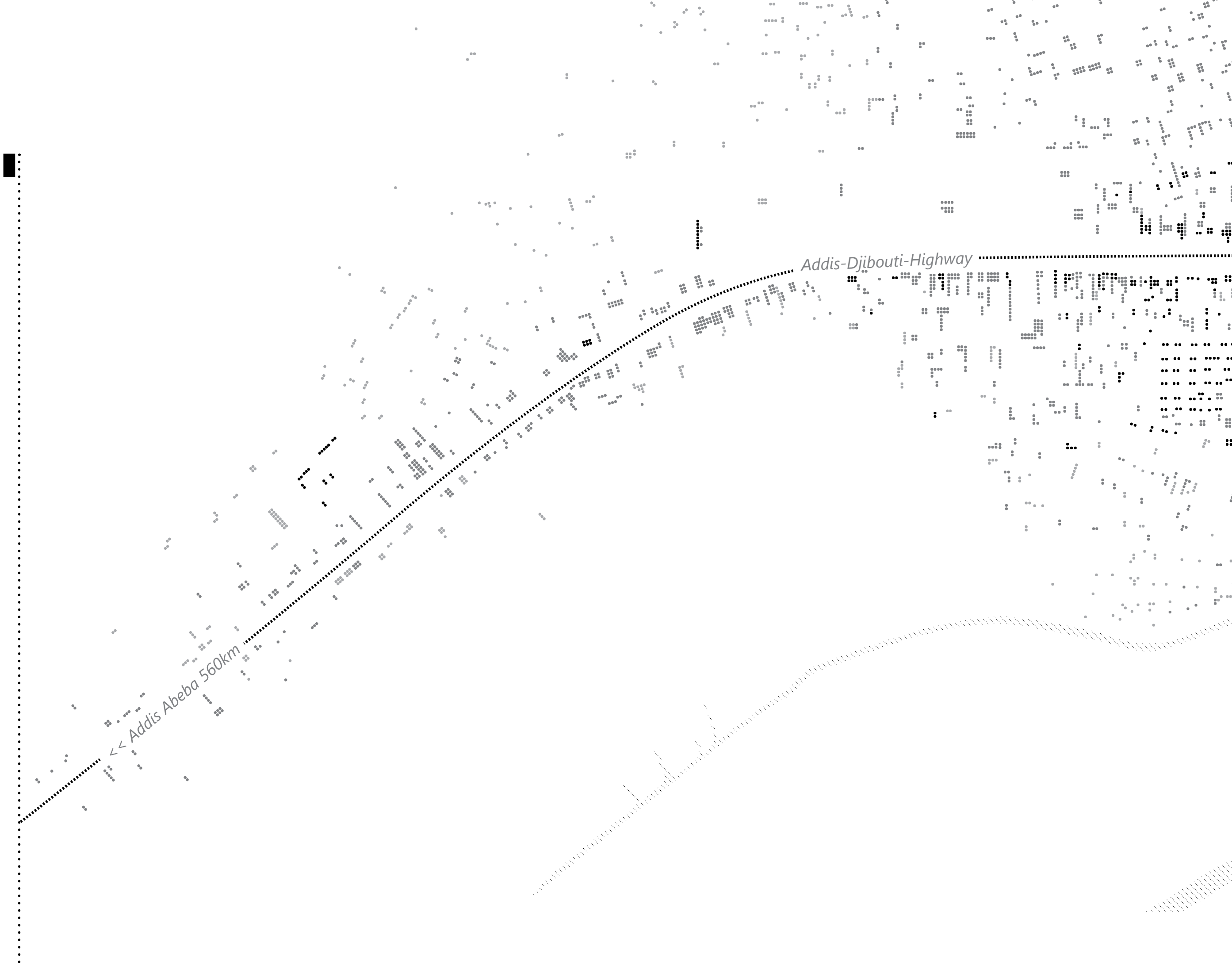


fig. 23.1 | map of Logia

note 23.1 | based on maps from EIGNER, A., (2013). Afar Architecture in Transition – from mobile structures towards permanent settlements. Vienna: Master-thesis Technical University Vienna (p. 34-35) and SCHÖNHER, K., (2015). A house for nomads - Development of earth building technologies for the Afar Region (p. 38-39)

note 23.2 | based on maps data from Google/maps

23.1

1.4 First trip to Logia *(personal experiences)*

After I first encountered with the project in January 2016, when Katharina Schönher and Mark Ortler were presenting the project at the university of technology in Vienna (TU-Wien), I really wanted to learn more about the project and decided to travel to Ethiopia and contribute to the project on-site.
In March 2016 I visited the construction site for one month to participate on the construction of the building. For this month from the 18th of march until the 14th of April I was living in Valerie Browning's house in Logia and was contributing at the construction site.

Staying in Logia for a month gave me a very good first-hand insight with the troubles and circumstances around building constructions in Logia. During my stay a yearlong dry season caused by the El Niño climate phenomena reached its peak and lead to a drought and made it necessary to order a tank wagon and an additional water tank to the site, so that we could continue the construction work. Only one week after the water shortage heavy rainfalls destroyed many bricks and even some parts of the wall. Thanks to a field worker of APDA we also got the chance to see another City in the Afar Region. Jusuf Mohammed a field worker took us with him on an overnight trip to the countryside of Kori and Afdera, where we got to see the Afdera Salt Lake. Another time we made a short trip to the former capital city of the Afar Region Asayita and got to see the weekly market, the old stone build houses and the green oasis along the Awash river.


25.1

fig. 25.1 | Asayita – 2016- outdoor beds on the roof terrace of a Asayitan hotel with view down to the Awash river and the sugar factory and the sugar cane plantation on the distance. Sleeping outside and being able to enjoy a mostly clear and unpolluted starry sky is one of many small benefits of the Afar region.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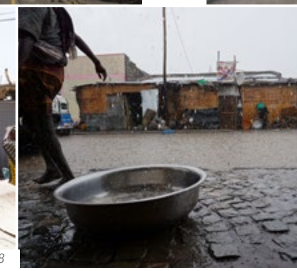

fig. 26.1 | Afdera – salt fields on the lakefront of Lake Afdera

fig. 26.2 | Asayita - palm leaves on the weekly market of Asayita – prepared for the production of "senana" (Afar mats to cover the deboyta)

fig. 26.3 | Asayita - palm leaves on the weekly marked of Asayita – prepared for the production of "senana" (Afar mats to cover the daboyta)

fig. 26.4 | Street to Afdera with salt fields and the Lake Afdera in the background

fig. 26.5 | construction site of the Afarkindergarten-project, when the tank wagon had to be ordered because of the drought

fig. 26.6 | Logia – river bed of the Logia River – picking up clay for construction of ch'qa houses

fig. 26.7 | ch'qa house under construction – soil is mixed with straw and sometimes with dung and used as infill material between a wooden structure of lined up narrow placed poles. The same material is also used as plaster material on the inside and outside. The wooden structure and the first layer of plastering is shown in the photo. Often ch'qa houses in Logia only don't get the final rendering.

fig. 26.8 | weekly market of Asayita – this part of the marked is dedicated to senana (Afar mats)

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After two traumatizing days on my own in the capital Addis Abeba I arrived in Logia.

I'm now in the country since Tuesday and after a really rough start, I now have fully arrived in the Ethiopian daily business. In Addis Abeba my Smartphone was robbed just a few hours after my arrival at 7:00 AM. So, there I was already stressed and tired form the lack of sleep during the night flight. No mobile phone, no SIM, no phone numbers. Back to the Ethio Telkom Shop to purchase a new SIM-card and then in search of a mobile phone shop, that isn't trying to completely rip you off. Which is extremely hard, when you are obviously a foreigner (locally called "firangi") and first time in Ethiopia. Since, when a firangi enters the door of a mobile phone shop there coincidently only are $ 200 plus devices available anymore ;). After some search I found a dump phone that still was hugely overpriced, but I was desperate enough to buy it. After all, I only needed it to communicate with the other people from the Construction team, a smartphone or internet capability was not my priority. I had to organize my trip from addis to Loya and without any phone it just wouldn't have been possible.

I went to bed early and had a pretty bad sleep. There were thousands of mosquitos in my room and even though I knew that there is no danger form malaria in Addis, I slept under my mosquito net and still was bitten quite a few times when I accidently touched the net.

At the next day I took a mini bus to the centre, went to a museum and wanted to step by at the Ethiopian Airlines office at the Hilton hotel, because I knew there is an office. On my way to the office I young man told me that the office at the Hilton hotel is most possibly closed because of the lunch break and he could show me the way to the Ethiopian airlines main office in the city centre. I followed him, and he brought me to the office where I could ask for the next flight to Semera in case my car transportation wouldn't work out. I was very happy that all worked out great and offered him to buy him a coffee. He said okay and showed me the way to one of the most famous coffee places in Ethiopia. He even paid for us both and offered me to show me around a little bit in that area. We went to a restaurant because I wanted to return his hospitality, but again he insisted to pay on his own and we head a great meal together.

After that he tried to lure me in to chew khat-leafs, but I thankfully refused after thinking about about eating uncooked greens in Ethiopia

When we went back to the Ethiopian airlines office he started to tell me about a dictionary he was needed for his studies, and I already knew what's going to happen. He asked me for 1000birr (which was about 45$), which after all is the salary for half the month for most people in Ethiopia and seemed way to high to me. I really didn't like the discussion and he become more and more obtrusive. I went to the office, booked my flight to Logia for the next day and gave him 200birr for the unintended city tour he gave me and just wanted to be left alone. 50m after we divided another duo of two boys started to talk to me...wanted to pay me a tea or coffee. I was glad the flight to Semera was booked and I wouldn't have to wait for the APDA car for an indefinite time

Next day at 8 AM I arrived at Semera and half an hour later I arrived in Logia. Mark and me went to the construction site and I was introduced to the workers.

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(journal - Kraßnitzer M. 27/03/16)


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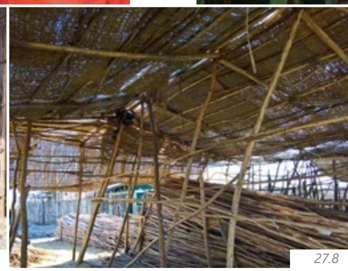
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27.11

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...And now? I already learned a to speak a little bit Amharic and Afar, I move completely independent through the town, go on errands for Mattias und am feeling totally comfortable. I'm working on the construction site and earn every day new blisters on my hands, I get along great with the workers and enjoy it here. It is really laborious but also satisfying. The things Mattias is achieving. I can't even de-scribe how he is liked and admired by the workers. I guess you have to see it on your own. It seems like he seems to be supposed to be here. It's nice to see him like this. I'm even a little bit proud of him.

I already got an Ethiopian Name. All people on the site call me Aisha. By now I even react on this name. Silence and quiet I don't even know anymore. It seems like in the son of rainhard may "irgend ein depp bohrt immer irgendwo" / "there is always a fool around using the drilling machine" It seems like the same here. If there isn't a Child screaming, it might be the muezzin, a cat, a sheep or a goat. I'm fasci-nated by the muezzin. Sometime its beautiful and sometimes, well...it can also be pretty annoying when he starts singing at six AM in the morning and is robbing me by half an hour of my treasures sleep.

I always wear pyjamas here. It's a lightly dress for Women. It has similarities to a fabric bag but its is way more cooling than jeans and shirts. I even ware a headscarf. Most of the time tied up to a chignon. It also is affective against the heat. It doesn't matter what I wear, if I wear local clothing or my regular cloths the attention here is always on me. All people are staring on me. I already got used to it, but sometimes I'm still uncomfortable with it. Now we are at a restaurant waiting for our meal. Yesterday we came here to Semera for the day off. We enjoy the togetherness, have a bathroom only for us and there even is a pool. The most luxury here in the hotel might be, not to have to cross the whole compound yard when going to the toilet...

"

(journal - Kraßnitzer H. 10/02/17)

27

fig. 27.1 | making "buna" on the construction site – roasting, crushing and brewing coffee beans

fig. 27.2 | young boy visiting the construction site of the Afarkindergarten project

fig. 27.3 | Asayita – hotel on the cliff edge facing the Awash River

fig. 27.4 | young boys visiting the construction site of the Afarkindergarten project

fig. 27.5 | Kori wereda – 2016 - on a field trip to the rural areas of Kori after heavy rains in April

fig. 27.6 | Semera – 2016 - first heavy rains in April, that broke the exceptionally long arid period of 2015/16

fig. 27.7 | two workers doing the mud work on a ch'qa house; in the background the wooden structure of ch'qa house; in the foreground steal pillars bearing the porch roof and the natural stone masonry wall of the porch

fig. 27.8 | construction wood shop in Logia

fig. 27.9 | Logia river during the long arid period of 2015/16

fig. 27.10 | small lane in Logia with typical fences to prevent passers-by from seeing into courtyards

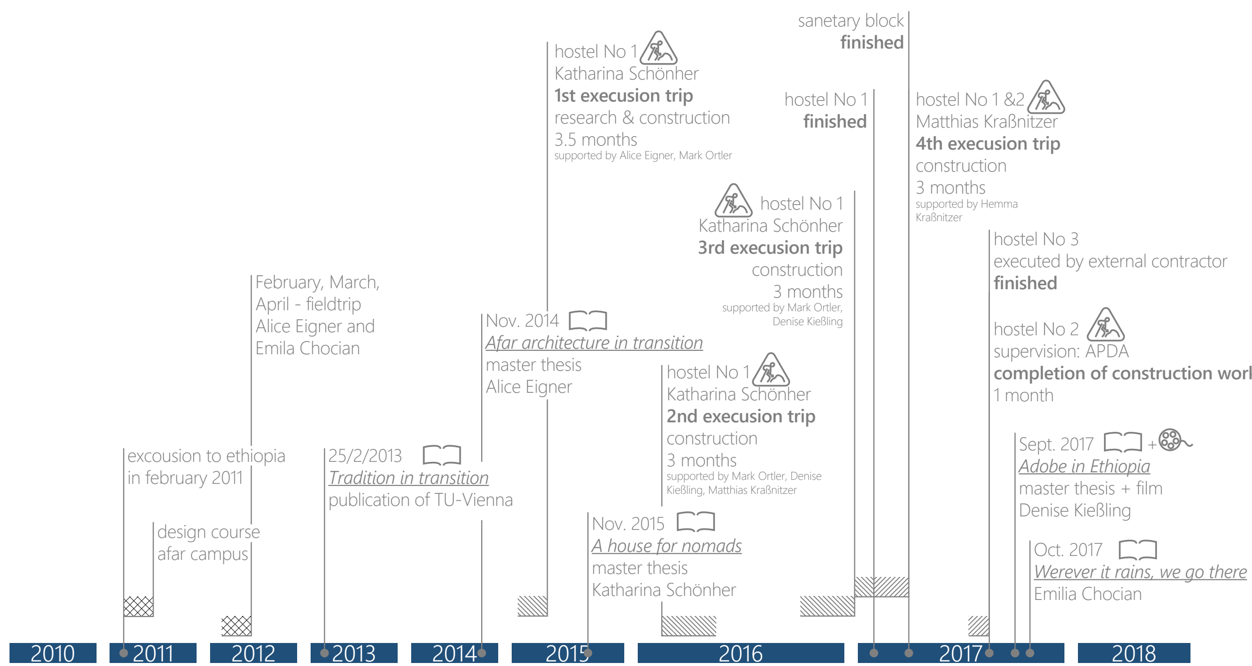
fig. 27.10 | Afdera wereda – small village on the road from Semera to Afdera town. Corrugated steel sheets as only available construction material

2 THE AFARKINDERGARTEN-PROJECT

2.1 Introduction

The project is situated in one of Ethiopians poorest and hardest region to live in, the Afar Region. The main goal of the project is to plan, design and realize a youth hostel compound for students from the nomadic Afar tribe, which are coming from the countryside to the city to continue their education. Since in many regions of the Ethiopian multi-ethnic state people are to fare off the grid and cut off from any infrastructure, access to education is often limited. This does lead to the problematic situation where inhabitants of those regions often are excluded from political, economic and juridical participation and decision-making. Due to rapid economic and environmental changes in the region, like road construction, fast growing cities, construction of dams and large-scale plantations, the grassland of of Afar is shrinking and an increasing number of Afar people is forced to give up the traditional life style and settle down in the city. Breaking with their traditional life style, Afar people are even more dependent on other ethnic groups in Ethiopia. Traditional urban jobs, especially in the trade and the construction business, are not common in Afar culture. Therefore, education is one important way to give the Afar people a better perspective.

fig. 28.1 | timeline of the origination and progress of the Afarkindergarten-project; publications around the project and around the Afar Region in general that emerged parallel to the project (data emerged on the basis of Denise Kießling, 2017)



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29.1

fig. 29.1 | from left: Valarie Browning (founder and head of APDA), Mark Ortler, Katharina Schönher and Matthias Krassnitzer, the core team of the Afarkindergarten-project. (Ahmend on the ladder fixing the façade panel)

2.2 Origination

The Austrian female architect Katharina Schönher started the Afarkindergarten-project in 2014 as part of her master thesis, *"A house for nomads"* and continued her contribution to the project beyond her graduation until today.
On a study trip to Ethiopia in 2011 she met Valerie Browning, the founder, and head of a local NGO in the Afar Region, the Afar Pastoralist Development Association (APDA).
In conjunction with Valerie Browning and APDA, Katharina Schönher started to design student hostel compound, where children from nomadic families from the countryside can live in the city to get access to higher education. Schools on the countryside are rare. APDA is employing teachers that are traveling with the nomadic groups, but only for basic education. APDA is already running student hostels but their demand for accommodation facilities is constantly increasing. Since APDA is further expanding their educational efforts, and gave more and more students from the countryside – especially girls - the chance to extent their education in the city and visit high school, their accommodation facilities became too small. At that time also most of APDA's student hostels were not owned by the organization but rent. Therefore, APDA decided to create its own hostel campus. The new compound should contain hostel accommodation for 50 rural students, but also become an education complex over time. A kitchen, community space, community gardens and accommodation for staff and a guard and a kindergarten were requested.

The final master plan by Katharina Schönher contained the following building:

- 4 hostel buildings with sleeping places for 28 boy and girls in total
- 1 Kindergarten with four groups for 60 children and a playground
- 2 houses for the staff
- 1 sanitary block with two showers and two toilets
- 1 guard house
- 1 kitchen (located in the already on the site existing old bakery)
- 1 rain protected communal outdoor space

2.3 APDA

Valery Browning, an Australian Nurse and development aid worker founded the non-governmental organisation together with her husband, Ismael Ali Gardo in 1993. Ismael Ali Gardo is an Afar himself. The Association was founded after a gathering of Afar tribe elders regarding the problems of the Afar, with the main goal in helping the future development of the Afar and finding solutions. Early working was concentrating on supplying medicine and food to Afar, that were harmed in the conflict between the FRUD (Front for the Restoration of Unity and Democracy) and the Issa-dominated Djiboutian government. Later the organisation concentrated on healthcare and developed concepts for mobile health care that fits the life style of Afar. The community selected someone, who was educated by APDA to be the mobile health worker of the group. After a one year training the worker travels with the community. In 1996 they started to educate *"mobile teachers"*. They started with 21 teachers, today there are more than 231 teachers working for APDA. The concept is based on the same idea as the mobile health workers. Despite their ongoing efforts in health care, the organisation in 1999 started an initiative to educate female extension workers, who are specialized to tell women about decease, hygiene, sanitation, improved birth practices, treat patients and train the TBAs (traditional birth attendants), who are living with the community. APDA's success in their fight against FGM (female genital mutilation) is relying on their extension workers, the education efforts and initial persuading they have to do and their connection to the TBAs. They also constantly try to get the compliance of clan elders and religious leaders to stop FGM.

IN 1997, APDA moved into their first office in Assaita. Since the capital city of the Afar Region changed, and the governmental institutions moved from Assaita to Semera, also APDA moved their headquarter to Logia, the neighbouring town of Semera. APDA also has today a large interest in preserving the environment of the pastoralist Afar, which is strongly compromised by more extreme climate due to climate change and state plants of sugar cane and cotton along the awash river (Little, 2008; apdaethiopia.com/Afar 02/2018)

Today APDA is additionally pursues the following strategies:

Teaching and training the community in drought management

Promoting a stop charcoal production campaign

Construction of rainwater harvesting dams

Re-forestation through the spill – over from such dams and constructing shallow catchments that will keep rain – water for up to 1 month. This is sufficient to rejuvenate dormant natural seeds. APDA also re-seeds pasture land with grass seeds where the seed is depleted through wind storms

Lobbying and negotiating with the government for laws to protect the environment

Is investigating the viability of alternative cooking and construction for towns and villages.

(apdaethiopia.com/Afar 02/2018)

31.1

31.2

fig. 31.1 | Valerie Browning founder of APDA in front of a daboyta talking to young Afar

fig. 31.2 | Valerie Browning looking after a Afar man

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I've been here 25 years in Afar and my strong feeling is that, it would be better for people, and you can never get governments to do this, but people, genuine people, people who really want justice and want to see a better world, to back and to be with people, who are making good changes for themselves, you know. The dramatic stories of how many people were bombed or whatever, will always hit the media, and it's a terrible thing when people die like this – shocking.

But, nevertheless you've got Afar who are living in the hardest – it's described as the hardest place on earth to live, in many respects, because of the heat, because of the lack of water, and because to get a living is extremely hard. Afar are able to make a solution, in a very difficult place, with very little resources and it's a bitty other people in the world aren't with them, you know.

I mean, something is out of balance. We could come into balance, if we listen to the way people like here live. I think, I think it's a great thing about this society.

"

(Valerie Browning - Interview 2015)

31.3

31.4

fig. 31.3 | Afar women getting an injection by Valerie Browning; the women is weaving Afar mat stripes

fig. 31.4 | mobile classrooms pioneered by APDA in the Afar Region; teachers travel with the nomads

"

constructing through the direction, through voluntary people a hostel. A hostel so that people who come from far away can continue their learning. They don't have to stop at our mobile school level, they can go on to the government school level and we hope go to university and be professional people. And not only are we constructing a hostel, but we are learning a way to preserve our forest, through having mud bricks rather than building a house from wood and setting up a mud brick business, so that other areas of Afar, we hope, will do the same and preserve the forest. All in all, it's a very excellent thing, it's very innovative, it's very much what is needed to find solutions for the problems we face here.

"

(Valerie Browning - Interview 2015)

2.4 Basic idea

Apart from the functional needs for the new houses the kindergarten-project has a strong focus on sustainability. Not only the sustainability of the construction and the construction materials, but also of the construction process.

three fundamental and equally important pillars of the project.

One is in having a reliable local Organisation, that truly needs the houses and is capable to further maintain the houses. Especially in foreign aid it is important that building projects will be used and maintained. Working and interacting on a project in foreign developing countries is great reasonability, not only to the donor, but also to the local community.
Another important pillar for the project was to establish the new building technique, by training local worker on the material and educating them about clay building techniques and not only by showing off a new building technique to the community. But also, more importantly to give the regional native ethnic – the Afar - a chance for a professional training in permanent building techniques and therefore become independent from the highlander's contractor business.
Third and equally important was the sustainable building technique. To show locals – not only the Afar, also civil engineers and contactors active in the region - an affordable and sustainable alternative to the wood intensive *ch'qa* house constructions.

32.1

fig. 32.1 | masterplan of the project by Kathatina Schönher

33.1

fig. 33.1 | workers of teh last construction period from 2016/2017

2.5 Workers

The inconstant way of life for many people in Ethiopia made it hard for us to have a stable and constant team of workers. Many People don't have a permanent address and are living with their family or friends, often on the move, staying wherever they can find work. Especially, after the long construction pause it was hard to reunite the team and only in the end of the second construction phase a more stable team started to form. Leading to a mostly unchanged team of workers over the whole period of the last construction phase from October 2016 to completion in Summer 2017. One worker was part of the team over the whole construction period since January 2015, Hummed Abdu Hummed. Another two workers, Ahmed and Ibrahim, joined the team very early in February 2016. While in the beginning of the construction the work and training program was only meant for Afar, over time the approach changed and a healthy mix of Afar, Amhara and other ethnos, of professional and non-professional workers was aimed at.

On one hand, the main intention was to teach Afar people a new construction technique with low financial barrier for starting off new businesses and to therefore to give the Afar community the opportunity to become more independent from traditionally established and mainly Amharic contractors. On the other hand, as the project moved forward it become clear that there also was a need for professional workers to help on the site. This lead to a constantly re-evaluating the ration of different ethnos on the site. And while the mixture of different ethnic groups often led to an intercultural enrichment and exchange of knowledge, it sometimes also caused tensions between the ethnic groups. The mixture of professional and non-professional workers on the site also rose the discussion of salary and how to combine the workshop and training program and the constant need to earn money to support their families (see also chapter Comparison: 1.3 Labour expenses). Workers of the team of last construction period could actually participate in all construction steps of both earth building techniques, from brick production to clay masonry work, clay pestering and timber frame structure to even rammed earth works and material preparation. During that construction period capabilities and talents of each worker become more and more visible.

34.1

fig. 34.1 | Team of workers 2016/17:

(from top left to bottom right)

Mohammed Omer Mohammed joined the team in October 2016. He is an Afar from the rural region of the Afar Region in Ethiopia. He doesn't speak any other language but his mother tongue and had in the beginning also troubles with reading the tape measure.

Bared Osman Mohammed joined the team in mid-November 2016. He is an Afar lives who lives in Logia for several years. Even though he didn't speak English he was fast to understand basic instruction and fast in understanding complex construction tasks. He was highly motivated at the construction site.

Ahmed Argewe Ahmed is an Amharic construction worker who joined the team in early 2016 at an age of 24. His experience in construction work was immediately a great asset to the whole team. He already knew how to work with the level, basic carpentry work and how to work with cement and trowel. Sometimes he brought his 3-year-old son, Kalit, to the construction site. and later also his wife Maserat started to work on the construction site. Ahmed later also was reasonable for the technical supervision. Even though Ahmed didn't speech English very well in the beginning of the construction works he was eager to improve his English skills and always asked how the tools are called in English, but also told us the Amharic name of tools and construction material

Kalit Ahmed Argewe is the son of Ahmend and Maserat he often come with his parents to the site and played with other kids in the neighborhood.

Maserat Zigabu : joined the team in the end of November 2016. She was the first woman working on the construction site, apart from European helpers. Which was also an unusual situation for many workers on the site. Even though in the mainly Orthodox Amhara and Oromia Regions we often saw woman working on construction sites in the mainly Moslem Afar Region it was very unusual. Masarat is originally from Bahir Dar in the Amhara Region and originally also was Orthodox before she converted to the Islam to marry her husband.

Imam Abate Ahmed joined the team in October 2016 but already worked a few days in Mai at the construction site. Like Ahmed he is an Amharic construction worker who had already experience in working with cement, cement plaster, cement mortar, masonry work and basic carpentry work. Ahmed and Imam often also taught others how the tools are used properly.

Idris Husen Hasan together with Abdu Gedefe was contracted to build the tank for the sanitary house. When they finished the house, they become part of the construction team and continued with the sanitary house, but Indris also contributed on the earth building constructions.

Ali Mohammed Ali joined the team in October 2016. He is Afar and spoke Afar and Amharic.

Muktar Mohammed Ahmed joined the team in the end of November 2016. He is from a refugee from Eritrea and therefore very good educated. He speaks Afar, Tigrinya, Amharic, Arabic and English. Similar to Hummed, Muktar would often would interpret for us to the group of workers. Even though he was one of the last workers who joined the team he – also because of his good English skills – could fast catch up with the matter of earth construction techniques and still could catch experiences in adobe bricks production and masonry on the last rows of the adobe house. He is very talented in handling the trowel especially when doing the plaster.

Ali Argewe Ahmed joined the team in mid-November. He only had construction work experiences as a helper.

Abukar Abdalla Ali joined the team in October 2016. He is Afar and living in Logia as an Eritrean refugee since 2016. Like Bared and Muktar he is highly motivated and interested in the earth construction work. He especially was very talented in the rammed earth work. He had an immediate understanding of the right ramming force to apply and how the texture of the earth material needs to be. He later become primary responsible for the earth ramming works. He didn't speak English very well but improved it over time.

Hummed Abdu Hummed is Afar and originally from Eritrea and living in Ethiopia, Logia for about five years as a refugee. He was the first who joined the team in 2015 when the project started. As he was personally known by Valerie Browning she was quick to recommend him as a worker and he helped in the beginning forming a team. As the project moved forward responsibility was laid off to him. He speaks Afar, Amharic, Tigray and also some basic English, which according to him can be attributed to the supposedly good Eritrean education system. He therefore often was chosen to translate for the whole construction site group and helped us in the city when doing errands, helped us negotiating and often was sent by his own to shop for construction material. His involvement in the construction management also led to him taking responsibilities and he was one of the workers who was chosen to be responsible when the construction continued after our return to Europe.

Abdu Gedefe Tasama is a professional mason who joined the team in December 2016. He was mainly responsible for the sanitary house but wasn't involved in the earth construction work.

Ibrahim Mohammed Ali is also an Afar from Eritrea and living in Ethiopia since 2016. He first joined the team in March 2016 and later started an education in finance. He re-joined the team in the end of 2016 and worked on the site for four days a week, while finishing his financing class.

CONSTRUCTION PROCESS

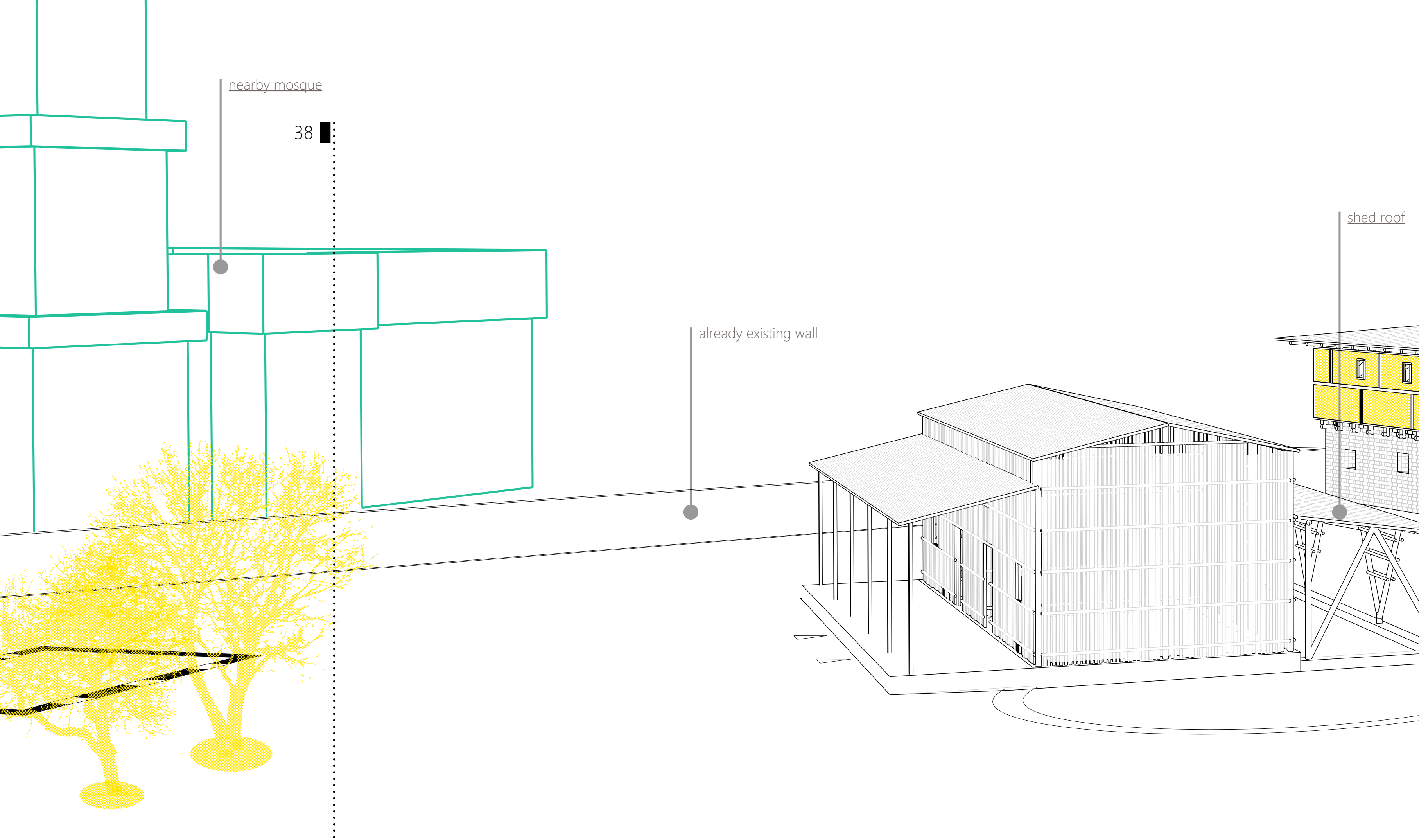
37.1

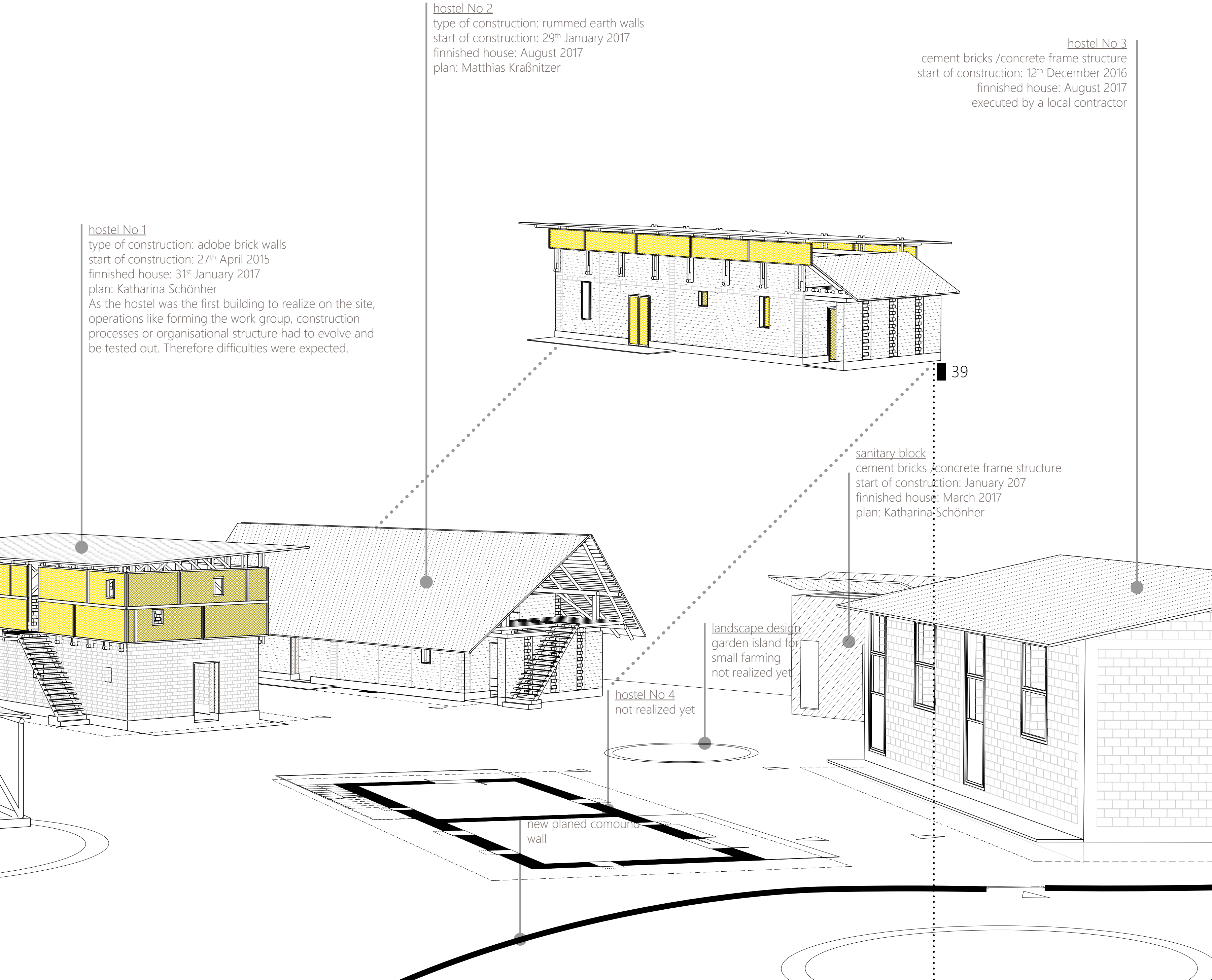
fig. 37.1 | final rendering

1 INTRODUCTION

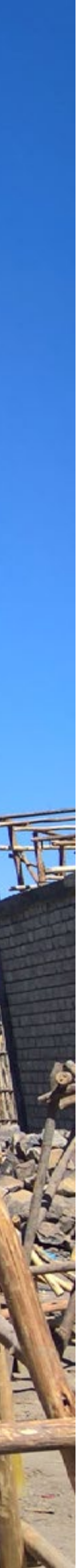
In January 2016 I first encountered the Afarkindergarten-project, when I visited a presentation of the project by Katharina Schönher and Mark Ortler at the TU-Wien. After the presentation I got in contact with Katharina and Mark and decided to visit the construction site in Ethiopia from 15th of March till 15th of April, because I wanted to contribute to the project. During my visit I almost daily worked on the site and got a better understanding of the local cultures, people and environmental impacts and conditions and an overview of the local resources in terms of materials, tools, manpower, know-how and infrastructure. I got to see the actual cultural and technological differences to Europe and I could observe the difficulties and barriers Katharina Schönher had to deal with. I got a sense of where the limits for realization are.

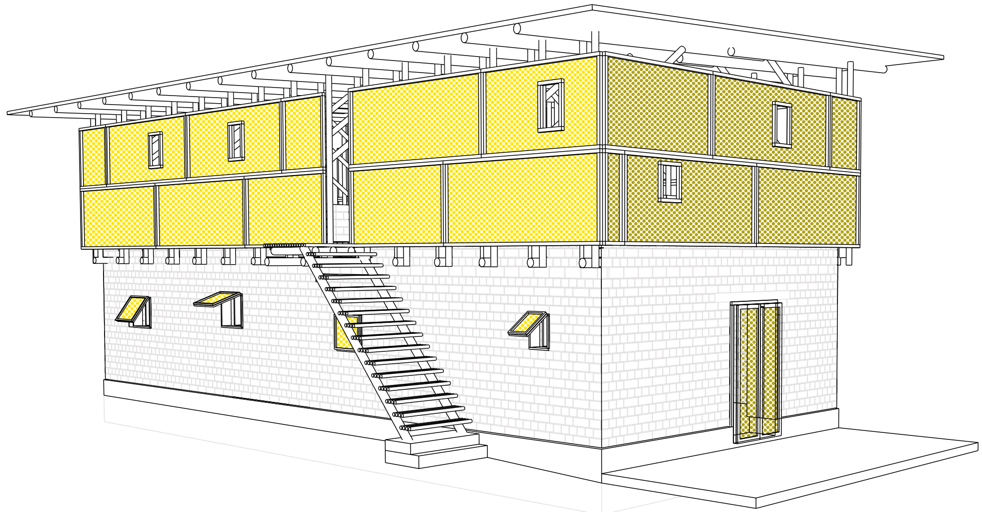
When I joined the project in March 2016 the project was already in the running for about one and a half year. Even though this might sound much, it isn't. A lot of the preparation work, planning and testing had to be done, before the actual construction work could be started in March 2015. Rainy season, Visa, travel expenses for project contributes and infrastructural problems were adding up to the already long construction process.




hostel No 2
type of construction: rummed earth walls
start of construction: 29th January 2017
finnished house: August 2017
plan: Matthias Kraßnitzer
hostel No 3
cement bricks /concrete frame structure
start of construction: 12th December 2016
finnished house: August 2017
executed by a local contractor
hostel No 1
type of construction: adobe brick walls
start of construction: 27th April 2015
finnished house: 31st January 2017
plan: Katharina Schönher
As the hostel was the first building to realize on the site, operations like forming the work group, construction processes or organisational structure had to evolve and be tested out. Therefore difficulties were expected.
39
sanitary block
cement bricks /concrete frame structure
start of construction: January 207
finnished house: March 2017
plan: Katharina Schönher
landscape design
garden island for small farming
not realized yet
hostel No 4
not realized yet
new planed comound wall

40.1





41.1

2 CONSTRUCTION PROCESS - HOUSE 1

From January 2015 to May 2015 Katharina Schönher visited Logia in regard to the Afarkindergarten-porject and started the construction process of the youth hostel complex. This first three-and-a-half-month-long trip, set the stage for further construction work. A lot of basic management, networking, research and material tests had to be done in this stage of the project, including testing the clay material, measuring construction sites, building a shade roof and preparing a storage for the tools and labour organisation.

After the basic preparation work, two months were left for starting the first construction work. Until her departure, excavation was done, the foundation was finished, 2000 Bricks had been produced and the first masonry work had begun. During her absence, the bricks were stored in the storage building and the brickwork was covered with tarpaulin.

After finishing her master thesis, Schönher went back to Logia to continue the construction in February 2016. Heavy storms, sun radiation and free grazing goats destroyed the tarpaulin, which led to rain-damage on the already built wall. Therefore, the courses had to be removed and rebuild. The shed roof for the brick production also had to be renewed, because of damage due to termites and until the 8th May twelve courses were finished. This time the already finished wall parts were covered with corrugated iron sheets. After the rainy season in October, Katharina Schönher could continue with the construction works in Logia. The last five courses were finished and Ring beam, ceiling, brick wall in the upper floor and the timber frame structure for the roof and upper floor room were finished constructed until January 2017. In early January, I took site management responsibilities over from Schönher and we could finish the first hostel building at the end of January 2017. For the first hostel building an irregularly long construction process like this was expected. After all, the site was conceptualized also to educate and train workers but also due the general infrastructure in Ethiopia and especially in the Afar Region. Water supply and planned construction breaks due to rainy seasons were contributing to the relatively long construction phase as well.

42.1

42.2

2.1 Preparing the construction site

The preparing for the project in Logia started in January 2015 when Katharina Schönher first saw the building two possible building sites.

The following months were important for doing research, testing of the clay and to find a team of local workers, which want to learn this new kind of construction method and to prepare the site for the beginning of the construction work. To build a shade roof for the brick production was also one of the first important steps. Because there first were two different possible building sites, the material testing, and construction of shade roofs was done on two sites.

The shade roof on the ultimately chosen construction site was later modified to be twice the size as before. Later, during the rainy season, a corrugated iron layer on the roof was added to protect the produced bricks from rain. In the following year the roof had to be rebuilt because termites had already destroyed big parts of the wood pillars which were paled directly into the ground. When rebuilding the roof, Katharina Schönher made the decision to make the shade roof a permanent part of the compound and therefore to build the new shade roof in more durable way to be protected against wind forced and termites. The V-shape wooden pillars are disconnected from the ground and reinforcing the construction. Additionally, it was important to easily be able to exchange the round timber pillars.

The test-bricks which where created has been tested in the laboratory of the EiABC (Ethiopian Institute of Architecture, Building Construction and City Development) (fig. 42.1) and were able to reach the German Standard, the DIN 18954, which is valued with 3-5 kg/cm² of compressive strength and the highest measured brick even reached 22 kg/cm² of compressive strength (Schönher, 2015).

2.2 Storage

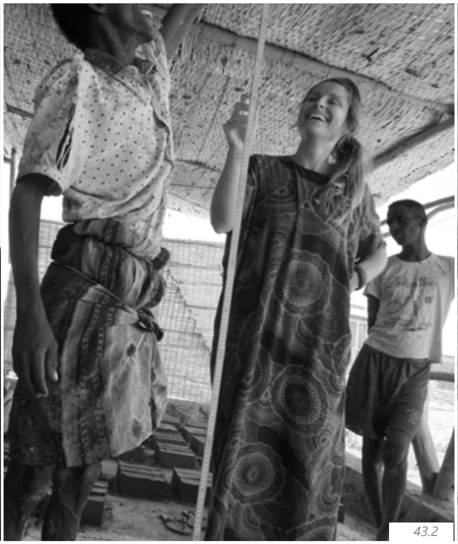
There are already two existing buildings at the construction site. One small room shelter about 3.5m x 4m and a two-room-house which was formerly used as a bakery. Both buildings were constructed in the *ch'qa*-house technique. The old bakery is about 12.50 m long and 5m wide. On the long side front of the building there is also a veranda. During the preparing phase of the construction site one room of the old bakery was reorganized, cleaned up and prepared as the general storage room (fig. 42.5) for the construction site. A new entrance to the storage on the north side, facing the construction site, was installed, a shelf was built, and electric installation were renewed. Shortly after the construction work started, a guard was hired to watch over the construction site all day and night. The guard Abdu Hummed and his wife Majram came to live with their two children in the second room of the old bakery building.

The storage is also important to lock up the construction materials and tools. To have a lockable storage room for stocking the construction materials, wasn´t only convenient, but also important. Unlike most sites in Logia at the Afar-hostel site, construction materials were purchased in advance and workers didn't need to bring their own tools to the site, even though it's very common in that region for workers to bring their own tools for their specific work to the site. As, one main aim for the project was, to train new workers and give people from the Afar tribe, who traditionally don't work on building construction sites, the chance to learn new construction techniques, most workers didn't even possess their own construction tools. So there had to be a stock of tools on the site.

fig. 42.1 | testing the clay bricks at the EiABC in Addis Abeba in Feb. 2015; 25 adobe bricks were brought to Addis Abeba by truck to be tested and tested on the compressive strength

fig. 42.2 | linear shrinkage test: sieved clay, that doesn't contain particles larger than 2mm, is moistened and put into three forms with the dimensions of 220/25/40 mm. The mould can be immediately stripped three of this longish samples should be prepared. tem-plate marks are made on the samples at a distance of 200mm. After the sample is finished dried the distance between the marks can be compared to the original distance of 200mm *(Minke, 2016)*

43.1



43.2

43.3

43.4

43.5

fig. 43.1 | sediment test: clay material is mixed with a lot of water in a glass. When the material settles on the ground, heavy material settles first. The material gets separated in different layer and the composition of the clay can be evaluated. Of course, water-soluble components like salt cannot be determined. The results on the site showed a high clay content mixed with smaller parts of fine sand particles *(Houben/ Guillaud 1986)*

fig. 43.2 | ball dropping test: a ball with 4cm in diameter, from a mixture as dry as possible, but still wet enough to be formed, is dropped from a height of 1.5m on a flat surface. The amount of cracking and deformation indicates the high of bonding forces. This can vary from completely bursting to only small cracks on the surface. As the ball dropping test on the site showed only small cracks and little deformation on the ball, hummed, a worker from the site, wanted to drop the material also from 2m height. Which was quite a challenge to him, due to his physical appearance *(Minke, 2016)*

fig. 43.3 | analysing the originally available site, that finally wasn't chosen because it was situated outside of the town way off from the cities' infrastructure

fig. 43.4 | Hummed, translating to the workers the lectures on clay

fig. 43.5 | interior of the storage on the construction site *fig. 44.1* | Hummed, Alice and Mark breaking the ground for the first hostel by starting excavation

44.1

2.3 Basement excavations and loam extraction

All the main buildings for the education compound were designed to have clay walls as the main loadbearing element. At least for the first floor. The concept of the clay housing compound is to use the excavated clay material as the main building material. The size of each ditch for the foundation is calculated to provide enough raw clay material for the walls of one house.

Of course, testing the clay material on the site was necessary before making the final decision to use the excavation material on site to fabricate the bricks. As mentioned prior, test results were very positive. During the time we stayed in Logia, we recognized that all over the city of Logia the ground material is very similar, and it is very likely that on most building sites in the city, the scooped material from the foundation ditch could be used as the main building material.

Even though the commonly used *ch'qa*-building-technique is a very clay intensive construction technique, the clay, which is used only as an infill material is mostly brought from the river bed. It was a big surprise for most local craftsmen and engineers that it is possible to use the clay material from the building site for the construction.

One hostel building with a floor area of twelve on five metre, does provide about 40m³ of usable excavation material. The top thin layer of about 5-10 cm is mixed with sand, silt and other materials, like organic material and is separated from the construction material.

The excavation for the foundation was first measured and marked with bow-tout lines (fig. 45.1). The excavation was done by hand, which is the usual and most common way in that region. After all, big excavation machinery is very rare in that area and even on way bigger construction sites the excavation work is done by hand. Two people use together one spade to loosen the ground, before the material can be scooped out. The diggings for the foundation of the hostel has been done by three workers in about three to four work days.

2.4 Foundation

A professional mason was contracted to build the foundation for the hostel. The executed stripe footing was built in natural stone masonry work, a commonly used founding method in Logia. Big Stones are hewn to fit in a kind of stretcher bond, forming a double row of stones. The gap, which occasionally occurs in the centre of the foundation wall is filled up with small stones and cement mortar (fig. 45.2). (Schönher, 2015)

The stones were brought to the site by trucks from the semi-desert region in the surrounding of Logia. Three rows of natural stones were laid for the stripe footing be-

45.1

45.2

fig. 45.1 | finished excavation hole – mid-March 2015

fig. 45.2 | start of masonry work – fragments from the hewn stones of the outside rows and smaller stones are filled in the middle

45.3

neath the walls (fig. 45.3). The ground area of the rooms was laid out with hewn stones with about 25 cm in diameter and gravel, small stones and sand was filled on top of it and later in the construction process the rammed earth floor of the rooms was applied on the layer of sand and gravel.

fig. 45.3 | finished foundation for the first hostel – three courses of hewn naturel stone masonry – the reinforcement irons are already concreted in the foundation *fig. 46.1* | preparing the raw material for bricks production – on the left: preparing a new pile of the composition and mixing it dry first – in the background: an already finished prepared pile with a hollow on top to fill it with water and let it soak for two days – on the right: mixing the already soaked material again and add water to get the right texture for production

46.1

2.5 Preparing the material

The raw materials - the excavated clay and the sand from the riverbed - needs to be further treated to be usable for the earth building process. The sand needs to be screened to be usable for thinning the raw clay material. Furthermore, the composition of clay and the screened sand needs to be mixed properly and soak in water for 24 to 48 hours.

Sieving

If the raw clay material from the excavation contains too much impurity through large sized grain, the raw material should be sieved (Minke, 2016). Too large stones in the mixture can weaken the bonding forces and might cause the brick to crack (Kießling, 2017). Fortunately, the quality of the raw clay soil was very good and crushing or sieving the raw clay was not necessary. The small stones that occasionally found a way into the final mixture, were easily removed during the last phase of mixing the material with the hands before throwing it into the mould. Still the Sand that was added to thinning the clay had to be sieved.
In Logia, there are two different types of sand available. A very fine sand from the Logia river bed, which is most of the year dry and a more gravely sand from the awash river bed in Mille. For the bricks, mostly the Logia river sand was used, because it was more consistent in its grain-size distribution. The sand was sieved in two steps. Therefore, two screens with different sized meshes were build. The finer screen allowed a sieve fraction of up to 2mm (fig. 46.2).

Thinning

To reduce shrinkage and prevent the bricks from cracking during the drying process, the raw clay material had to be mixed with Sand. Finding the right mixture is very important. If you add to much sand ,the binding forces can be harmed because there is not enough clay, but on the other hand sand is important to reducing the shrinkage and improve the compressive strength (Minke, 2016). Different sample bricks with different mixing rations were produced. The samples with the mixture of 3:2 (clay to sand) gave the best results. After several production batches the mixture finally was fine-tuned at nine wheelbarrows of clay to 5.5 wheelbarrows of sand, where the least cracks during the drying occurred. Small heaps of the material were prepared (fig. 46.1). Preparing and mixing had to be done by hand. Mixing the dry clay and sand first in a pile proved to be the most effective and least exhausting way to mix the material.
After mixing the pile of the dry material properly, a pothole is formed at the tip of the pile and water is added and the dry material in continuously blend with the water (fig. 47.1). When all the material is wet, a pothole is formed again on the tip of the heap and water is added again. Then the heap is covered with plastic tarpaulin and the material is let to soak for at least two days. Before using the material for the brick production, it must be mixed again.

47.1

2.6 Bricks production

There is a variety of different adobe production techniques. Either the material is thrown into a mould or it is pressed into a mould by manually operated presses or by *"fully automatic block-making presses"* (Minke, 2016). Even though throwing the material into the mould is the oldest and most primitive technique, it still has advantages over newer loam-block production processes. The throwing technique for manual adobe production can be a lot more economical in low-wage countries and especially for small sites and manually producing on the site is way more flexible. At first, moulds for three blocks were used at the site. The semiliquid material must be thrown into the mould with great force. This is necessary to get better compaction and higher strength of the dry brick (fig. 47.2). In the beginning three people worked on one mould. As the workers got more experienced only two people could work on one mould and later the three-brick mould were exchanged with a six-brick mould, which increased production time a lot. About 300 bricks /worker/ day could be reached at peak.

The moulds were constructed by a joiner in Austria. The used material was plywood form high-quality concrete pouring plates. This material is coated in phenol formaldehyde resins, so the water can't soak in and the mould can be removed easier. It isn't possible to get this material in Logia and reproducing the moulds in Logia was very difficult. The skills of local joiners are not on bar with those in Austria, high-tech machinery is not available, and the material selection is very limited. The lifespan of local produced moulds was drastically lower than from those produced in Austria. After the material got thrown into the mould, the spill over material is removed, the top surface is straightened and

47.2

47.3

fig. 47.1 | fadding water to the pre-mixed dry material and mixing it with water again – as clay expand and form a water protective layer when water is added, the material must be turned over several times to really make sure the whole material is moistened

fig. 47.2 | Mark screening the sand for the bricks production

fig. 47.3 | brick production process – placing the mould – forcefully throwing in the material in about two or three throws – remove the material with a metal trowel - removing the mould by slowly lifting it up (see fig. 48.1)

fig. 48.1 | brick production process – removing the mould right after pulling the overspill material off and straightening the top surface

48.1

fig. 48.2 | the ready-to-use material was carried with wheelbarrows or tanks to the production surface and mixed with hands

48.2

fig. 48.3 | predrying of bricks under the shed roof

48.3

smoothed, and the mould is slowly taken off. Then the mould will be washed before using it again for the next bricks. To make the mould easier to remove from the casted block, a small amount of vegetable-oil was added to the water which was used for washing. When it was noticed that many bricks were cracking during the drying process at the exact same spot, a very thin layer of sand was dusted on the concrete production surface before the mould was placed to prevent the drying material from bounding with the concrete surface and therefore the shrinkage process of the brick couldn't be influenced. The green adobe blocks are left untouched on the production surface under the shade roof for 24 to 48 hours to pre-dry and then put outside to dry under the direct sunlight. To safe space after about three days the bricks are stapled. It still takes about two weeks for the brick to dry fully through. Therefore, it's important to leaf air gaps between bricks, when stapling, so the bricks can continue drying.


49.1


49.2


49.6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49.5

Difficulties that appeared during the brick production

The workers haven't worked with the material before and had to learn what is important when producing the bricks. How to test the material. How long the material must soak. How to find the right mixture. How to throw the material into the mould.
The first educating period took about one week. But it wasn´t easy to find a reliable team of workers, who were willing to work under given circumstances. After all, for the first few moth the building project was an education program were the workers weren't payed. We convinced the financial responsible management that the workers also should get payed.
Construction pauses due to the big raining season led to a changing team of workers. So new workers, who were not on the site the season before or workers who were hired after the project had started, had to be instructed during the ongoing production process. Fortunately, the workers quickly also started to teach each other the production process.

Rain

Even though the construction work was paused during the big rainy season, there are several smaller rainy seasons during the year. The small rainy seasons are only two to five days of rain spread out over 2-3 weeks and therefore very hard to predict. During that period, drying the bricks under the open sky was very risky but still necessary and covering the bricks during the night with plastic tarpaulin was not always possible, especially when the work on the wall already was started. Then the tarpaulin was needed to cover the wall and bricks only could be covered with mats from woven bamboo stripes. When the rain was too heavy, the mats couldn't protect the brick or when severe storms uncovered the brick, up to 300 finished bricks were destroyed during the night. The broken bricks could be reused but crushing the bricks to make them usable again was additionally work (fig. 49.5).

Water supply

During the first working season there was no water-pipe at the site, so the water had to be brought to the site by donkey cart. Every morning the water tanks on the site had to be refilled with the water from the donkey carts. Later a waterpipe was installed on the site. As it is common in many cities of the Afar region, running water on the water pipe isn't always available during the whole day. Sometimes water is only available for a short period of time during the morning and evening hours. Therefore, a water tank to store water on site was needed, which had to be refilled every evening.
Because of a very dry year in 2015, where the big rainy season was totally absence, in spring 2016 the water supply in the whole Afar Region went very low. The construction work had to be stoped, until a water truck was arranged to bring water to the site (fig. 49.2).

fig. 49.1 | temporary rivers are emerging on the construction site during heavy rains. This was already known and taking into consideration when designing the master plan. These watercourses during the rainy seasons can be found all over Logia, because the high clay content in the soil is slowing down seepage into the ground

fig. 49.2 | a tank wagon had to be ordered during a dry season

fig. 49.3 | damages due to rain – even though the wall was cover with plastic tarpaulin, wrapping the corners was difficult, because of the reinforcement irons. Heavy rain could leak to the wall and cause damage – later a corrugated iron sheet with drilled holes for the reinforcement irons were prepared on the corners

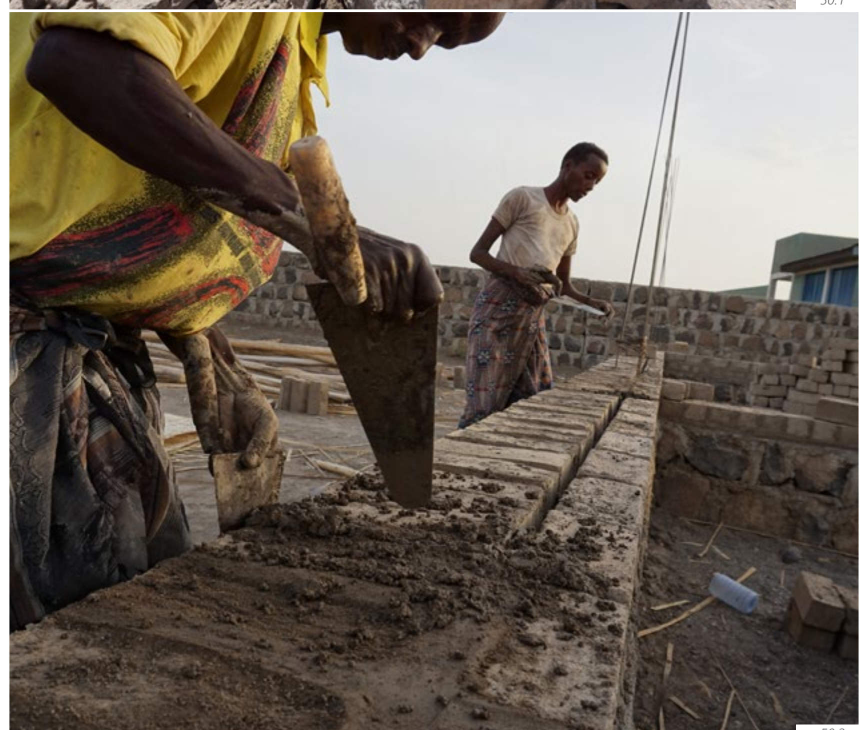
fig. 49.4 | bricks were stored in the open. The stack of bricks also had to be covered daily. If strong wind moved the tarpaulin or the overlap was to small, rain water could flow in grooves under the tarpaulin and cause damage to the pile of bricks

fig. 49.5 | not expected rain could cause damage on the bricks drying in the open

fig. 49.6 | heavy rain during the day – usually in the spring rainy season the rain came overnight – but sometimes it also started to rain during the workday – when the rain started during the day, it only lasted for about half an hour and work could be continued shortly after *fig. 50.1* | making sample part of the wall to try out the composition of the mortar – when too many cracks appeared, it was a sign for a too high clay content and sand was added

fig. 50.2 | properly filling the joints is very important with clay brick masonry. In contrary cement mortar masonry, the strength of clay mortar heavily relies on properly filled joints to hold the brick in place from all sides

50.1



50.2

51.1

51.2

fig. 51.1 | explaining the brickwork system to the workers

fig. 51.2 | laying the bricks

2.7 Masonry work – wall construction

The Brickwork of the hostel is reinforced in the corners of each room, with reinforcement rods, which were anchored in the foundation. An English bond with one and a half bricks thickness was used for the walls. The rods are running in the gaps of the horizontal joints. This system would also allow to reinforce the whole wall, but because of economic reasons and structural analysis it was decided that the reinforcement of corners and joints of the wall is adequate. There was also the idea to reinforce the wall with bamboo sticks but due to a lack of availability of bamboo or similar materials, the commonly used iron bars were chosen.
After testing the mortar and teaching the local workers how the brickwork system works, the first walls could be started.
Between foundation and ring beam there are 17 brick courses. Reinforced concrete lintel beams for the doors and windows were preproduced on the ground and lifted in place later.

2.7.1 Testing the mortar

Different mixing ratios where tried on masonry sample pieces (fig. 50.1). With the two most promising mixtures a small testing part were masoned. The final mixture we decided on were 4:1 (sand to clay). The mixture showed nearly no shrinking cracks in contrast to precious mixtures we tested.
Like mixing the brick material, mixing the mortar was done by hand in piles. The big portion of sand in the mortar made the mixture faster to dry so it was even more important to cover up the finished piles with tarpaulin.

2.7.2 The brickwork

Even the more experienced workers on the site were not familiar with the English bond brickwork, which contains stretchers and headers in each course. The general dimensions of the hostel are synchronised with the size of one brick (24.5 x 11.5 x 9.5 cm) and executing the floor plan accurate is strongly depending on how well those bricks are adjusted in each row so that the gaps are continuously similar in size. To show the workers the brick laying system, the whole group had to recreate the wall segment together, as we showed them first. Every brick needs to cover the gab of the underlaying course (fig. 51.1).
Quite a lot of workers had problems with understanding the brickwork system, which is fairly complex to begin with, and were challenged by learning the new pattern. Over the course of the construction works we got the impression that most Ethiopian workers and even more workers from the nomadic Afar tribe had an overall different understanding of patterns, than most of us European workers. This could be due to cultural and educational differences. More experienced workers started the wall with us together. After we prepared the cornerstone the workers prepared one course on one side of the wall by laying the bricks on the wall but not gluing them. When the row looked good and the gabs were all in the right place and in appropriate size, the team started to glue the bricks with mortar. Less experienced workers started with filling the horizontal gabs to get some sense for the brickwork system and how to work with clay mortar.

fig. 52.1 | interion plaster – undercoat, with a pattern imprint for a better connection to the final rendering

fig. 52.2 | the Afar bed, olloyta, used as substructure for the ceiling

fig. 52.3 | upper floor – timber frame structure with the olloyta as substructure for the ceiling and one worker preparing the bamboo mat as the anti-crumbling layer

2.8 Ring beam

The reinforcement in the corners and joints of the wall were joined with the ring beam on top of the first-floor walls. Ring beam, corner reinforcement and foundation together are forming the frame which holds the corners together and is protecting the building against horizontal forces and movement in case of earthquakes. The reinforced concrete ring beam was realised with adobe bricks as permanent formwork, instead of using cost-intensive wooden planks for the shuttering. The same principal also was used on the rammed earth hostel.

52.1

52.2

52.3

2.9 Ceiling

Lightweight straw loam on a round timber sub-construction is forming the ceiling. The primary load bearing structure of the ceiling is formed by the adobe walls and a twin beam, which is running in the middle of the two rooms on the centre axis of the house. Round timber beams with 10 cm diameter are sitting on top of the primary structure in distance of 30cm to each other. The *olloyta*, a traditional Afar slatted frame is mounted as a supporting structure on top of the load bearing timber beam structure (fig. 52.3). The frame is made from split palm tree sticks, which are tied together with thin tapes of animal skin. In between the slatted frame and the lightweight straw loam, mats of woven bamboo stripes are used as an anti-crumbling layer. Before finishing the ceiling with the earth layer, the round timber construction for the upper floor was erected, the roof prepared the 30cm high outer wall piece in the upper floor was finished (fig. 53.3) while also the first layer of plaster was applied (fig. 52.1).

The flooring for the upper and lower floor was done during the applying of the plaster on the walls.

2.10 Round timber construction

Every third beam of the ceiling is running through the wall to the outside of the building, where the round timber twin pillars of the light weight framework structure are sitting on the beams of the ceiling and connected on the outside of the building with pin joints.

This kind of interlocked timber framework is not common in Ethiopia and might be the first of its kind in Logia. A combination of V-shaped pillars, beams and bracings are forming the frames and holding the structure. The twin posts are forming the clamp for the connection to the main beams of the wooden structure. On top the twin posts are connected to the beams of the primary roof structure and at the bottom to the beams of the ceiling with bolts (fig. 53.1). For most connections, thread rod were used as the bold and due to the limited supply of thread rods, for some connections reinforcing bars had to be used.

façade panels

The façade panels for the upper floor are made from square timber frames with an infill of Afar mats, the *senana*, a woven palm leaf mat. The mats are traditionally used to cover Afar mobile houses. Afar Women are waving the mats from palm tree leaves.

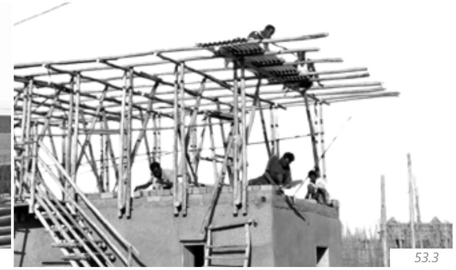
The women make 10cm wide stripes, sometimes even on the go and later connect the stripes together to one mat of about 1 m x 2 m. When the mats are fumigated regularly they become waterproof and do make the rain protection layer for the Afar houses.

The mat must be compressed with high power between the inside and outside timber frames, so that the edges of the mats are held in place even against strong wind forces. The façade panels were preproduced on the ground and then fixed with screws onto the timber frame (fig. 53.5, fig. 53.6).

Also, for the window shutters and doors in the ground floor the Afar mats – *senana* – were used. The mats, which are originally used as the covering layer of the

53.1

53.2



53.3

53.4

fig. 53.1 | first frame for the upper floor timber frame structure. The beams of the roof are connected in the middle

fig. 53.2 | mounting the olloyta on the beam structure of the ceiling

fig. 53.3 | during finishing the timber frame structure and preparing the roof the wall for the upper floor was finished

fig. 53.4 | construction of the roof – roof structure covered with corrugated iron sheets

fig. 53.5 | mounting the first façade panel of the upper floor room – the senana is fixed in a square timber frame

fig. 53.6 | fixing the façade panels on the timber frame construction with screws

53.5

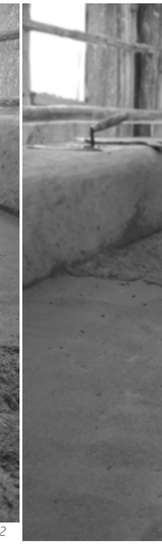
53.6

fig. 54.1 | the upstairs common space with mud flooring – due to a construction problem in the centre, the flooring had to be opened again

fig. 54.2 | applying the final layer of the flooring

54.1

54.2



daboyta[54.1], were clamped as fill in material in timber frames.

2.11 Roof

For the roof covering we chose corrugated iron. It's the most common roofing material in urban regions in Ethiopia and the Afar Region. (CSA, 2008)

There is high supply in many different qualities in urban areas. The sheet metal is easy and fast to mount on the wooden roof construction, but it is more expensive than most other roof materials and doesn't offer any proper thermal isolation on its own, which can be problematic. Especially in hot climate like in the Afar Region, the material can lead to heat accumulation under the roof.

The *"corro-corre"* - how the corrugated iron was called by locals[54.2] - was nailed onto the roof structure with special nails in about one day.

To prevent the upper floor room from overheating, the façade panels aren't reaching all the way up to the roof, but leafing a gap on top, where the air can flow through. Beneath the roof construction, there additionally, a suspended ceiling made of timber framed bamboo mat panels were mounted for better thermal isolation against heat (fig. 57.1).

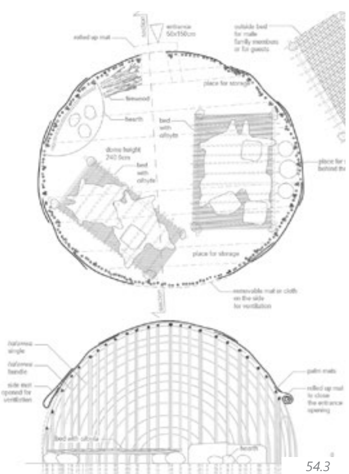
There are still plans to do the roof of one of the compound buildings in an alternative roofing system. To use the palm tree leaves or the already woven palm tree leaf mats would be one possibility. These cheaper and less recourse intensive building materials would also offer better thermal isolation. For the current hostel buildings, the remaining construction time and other resources were too tight for an experimental roofing system, which would require to build different prototypes and do a lot of additional testing.

2.12 Flooring

The flooring material for the upper and lower floor was decided to also be earth. The flooring was applied in several layers and treated differently on the upper and the lower floor.

On the lower floor, one thick layer of a light weight straw loam was applied and compressed with ramming tools. Two thinner layers were applied on top of the first layer with a more clay rich mixture and a little bit of oil added to reduce shrinking cracks. The last layer was compacted and smoothened with a stone and oil during drying, to get a stronger surface.

On the upper floor, more layers were necessary due to the elastic beams of the timber construction. There are slight vibrations when walking on the ceiling and the earth floor must be resistant to this vibration. The subflooring is similar to the lower floor, with a straw loam layer of seven to ten centimetre and compressed earth layer on top. Ramming the earth floor was not possible, due to the resilience of the ceiling. A thin sand layer was added in between the first-floor layer and the second, to disconnect the two layers. This layer was done with a loam morter mixture, very similar to the plaster. The layer for the finishing was divided by palm tree sticks to reduce shrinking cracks (fig. 54.2, fig. 55.1, fig. 55.3, fig. 55.8). The clay material of the last two layers was not rammed but compressed and smoothened by rubbing the surface with great pressure with a stone (fig. 55.4). To increase the durability of the finishing layer, according to Minke, double-boiled linseed oil can be added to the clay mixture or other oil coating or casein glue. But those materials were not available in the Afar Region and we decided to rub the last layer with a regional available oil from vegetables, to increase the water resistance a little bit. (Minke, 2016)



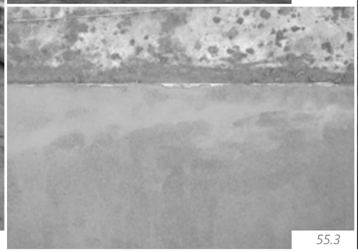
54.3

note 54.1 | the traditional mobile housing of Afar people. A dome shaped construction is formed by sticking bendwood members on both their ends into the ground and connecting the inididual sticks with ropes on their intersection points. The hemispheric dome structure is coverd with multiple layers of *senanas*. (Chocian, 2017)

note 54.2 | informal interview with Ahmed Argewe Ahmed in March 2017


55.1


55.2


55.3


55.4


55.5

fig. 55.1 | applying the final layer of the flooring – the mortar mixture is first applied and smoothened with a trowel

fig. 55.2 | applying the final layer of the flooring – finishing the final lane

fig. 55.3 | flooring - clay mixture of the final layer not yet smoothened with a stone

fig. 55.4 | applying the final layer of the flooring – a team of two workers started on each short end of the room and met in the middle. One worker was applying the material with the trowel, the other was compressing the predried material with a stone

fig. 55.5 | last but one layer of the upstairs flooring – because of many cracks it was decided to do another layer in a different way on top of this one


55.6


55.7


55.8

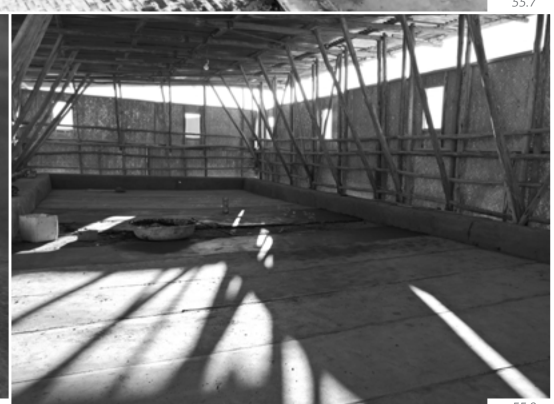

55.9

fig. 55.6 | flooring of the rooms downstairs

fig. 55.7 | first layer of the flooring on the upper floor – straw was added to the material of the first two layers. The bamboo mats used as anti-crumbling layer can be seen

fig. 55.8 | olloyta sticks – splatted sticks from palm leaves – are used to separate the floor area in lanes and therefore reduce the shrinking cracks. After predrying the surface was treated with a stone

fig. 55.9 | upstairs common space shortly before the flooring was finished *fig. 56.1* | first to kids playing in the already finished upper floor common space


56.1


57.1

fig. 57.1 | Finished common space of the first hostel building


58.1


58.2


58.3

fig. 58.1 | final finishing of the exterior final rendering

fig. 58.2 | applying the final rendering on the outside

fig. 58.3 | finishing of the first door – senana is wrapped in mash wire to protect it from animals and fixed inside a square timber frame

2.13 Plaster

Two layers of plaster were applied on the adobe brick walls. The first layer on the brick wall was done inside and outside in the same way. For reinforcement, straw was added to the plaster material. The loam mortar for the plastering was mixed with 5 parts of sand, 1 part of clay and about 1 part of straw. The plaster was mixed manually in like the brick material. The straw was cut in smaller bits before added to the mixture. For a better connection between the first and the second layer of Plaster, a tool with a pattern of only half driven in nails was prepared and used to press notches into the wet surface of the first layer.
The mixture for the second layer - the finishing coat on the interior - was just the same as for the first layer, but without the additive of straw. For the exterior, the mixture and treatment of the final rendering needed some more experimenting. Different techniques and compositions have been tried out on the wall of the existing storage house. Additives like cement and oil were tried out. Cement does improve resistance against rain and other extreme weather conditions of the surface, but the layer won't connect to the first layer very well in long term and would come off very easily after a few years. Additionally, it would destroy many of the other benefits of the clay wall.
If people can afford to have a final rendering on their houses, cement plastering is the applicatory standard in the region, even on clay houses like the ch'qa house, where you can see how easy the cement plaster drops down in large pieces.
It was decided to focus on the technique of compressing the last layer of plaster first with a towel and secondly by rubbing the predried plaster with a stone and oil (fig. 58.1, fig. 58.2). The oil that was rubbed into the plaster should make it more water resistance.

2.14 Finishing work

In the last three weeks of the construction ,a lot of small finishing work was done. The doors and windows were prepared and mounted, parts of the final layer of the plaster were renewed, shade roofs were erected in front of the two entrances (fig. 59.3) and the flooring of the veranda was finished with a thin cement coating. The interior roof construction was covered behind a suspended ceiling (fig. 59.1), but also esthetical reasons and lamps were build (fig. 59.2). The area in front of the stairway was gravelled and bordered with sand filled plastic bottles.


59.1


59.2


59.3

fig. 59.1 | suspended ceiling – panels of framed bamboo mats

fig. 59.2 | suspended ceiling – lamp and panels made from bamboo mats

fig. 59.3 | porch with shadow roof

"

During the first few weeks the construction site felt extremely slow. I was constantly switching from one worker to another and had next to no time to think through, sketch and plan details, like the door, the shedroofs or on the sanitary block. Then there was a feeling of being tested by the workers. They didn't know me very well and wanted to see my skills. Testing how fast they would have to work, how exactly they would have to work, what are my quality demands.

In addition to that we started the fine plastering and I know that I'm not really a talent when it comes to working with a trowel. I mean I know how it works in theory, but I'm just very lousy in the execution. I started the wall together with Ahemend and my part obviously was a complete mess. Well, that made it a bit harder to complain about their own messy work.

But i know what I was aiming for. So, I grabbed the ones that are most talented in handling the trowel and told them how to execute, what's important and where to be careful; what's the right amount of moist; how long it must predry before rubbing the surface with the stone etc.

And since they had to do some parts of the wall again because of sloppy work, they understood that I was serious about my demands.

At least in the handling of other tools like the drilling machine, angel grinder, ramming tools...I could impress them and over time I truly got the impression that they respected me and honestly acknowledged my authority.

Now we are shortly before finishing the first hostel building. Maseret is applying a last layer of compressed earth flooring on the upper floor, because the previous layer didn't meet our requirements, with too many cracks appearing and was sanding quite a bit. Ali is responsible to build and install the hoops that keep the windows open. Ibrahim and Baret finally finish mounting the façade panels, while they destroyed nearly all of our bits. The rest of the team is working on the foundation for the 2nd hostel.

I actually wanted to also work on the planning for the 2nd hostel and refine my ideas and make sketches, but there never seems to be time for it. I go to bed mostly at 9:00 because I'm exhausted from the work, during the lunch break there mostly is other organising work to do and then there are the days where in the evening the kinds from the compound enter my room and either want to play or draw, or one of the hostel girls wants me to help her with her English or math homework...

Overall, I'm very fine. Today I was invited at Ahemed and Maserat's house for lunch. It was delicious. Actually, I wanted to finish the first house on Tuesday or Wednesday, but it probably will still take until Monday. I'm looking forward to the 31st because my wife will come to Logia for a month.

"

(travel journal - Kraßnitzer M. 27/01/17)


60.1

fig. 60.1 | two Afar construction workers in front of the finished hostel


60.2

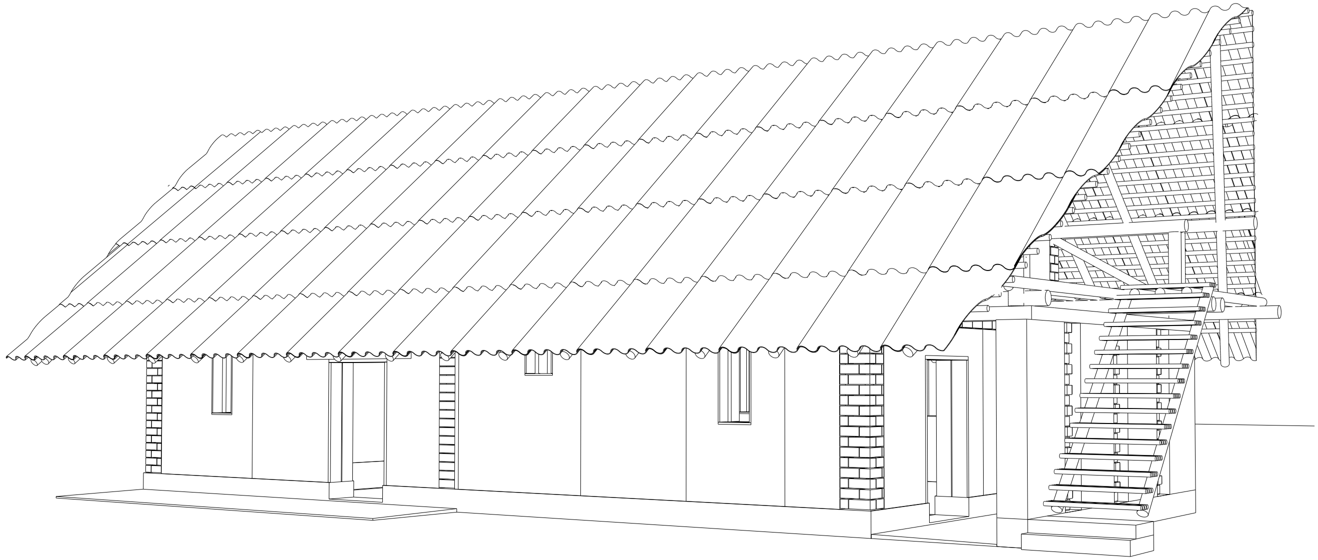
fig. 60.2 | first resident of the new hostel building

61.1

fig. 61.1 | upstairs room already in use

63.1

fig. 63.1 | finished hostel buildings with the first residents

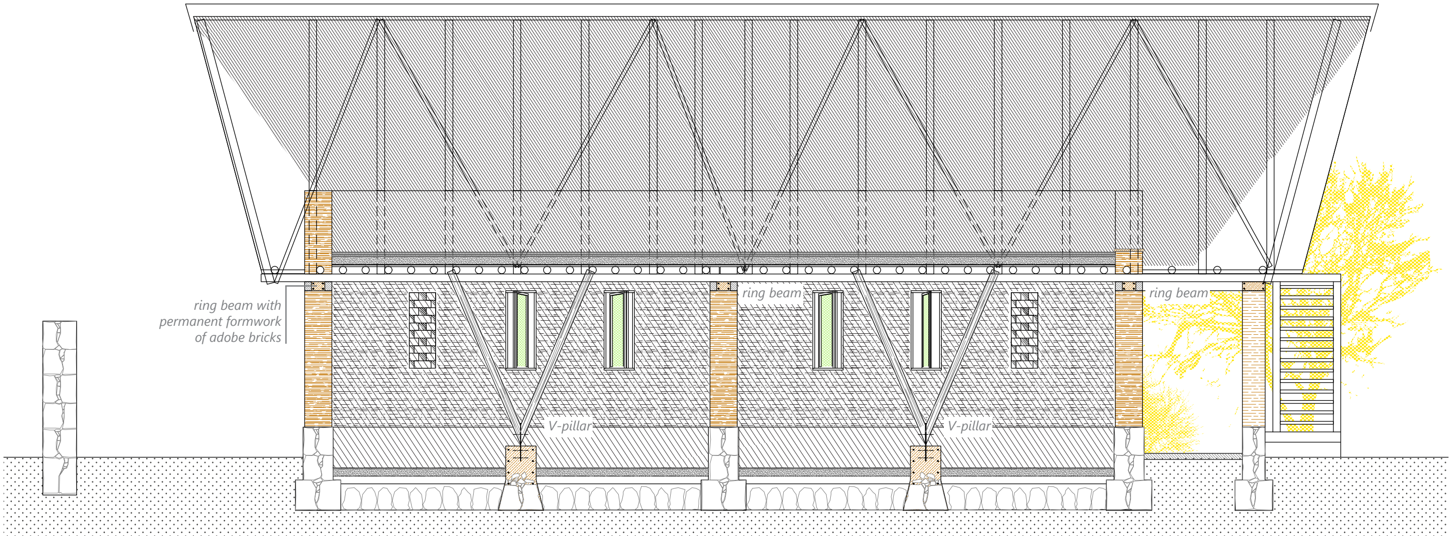


3 CONSTRUCTION PROCESS - HOUSE 2

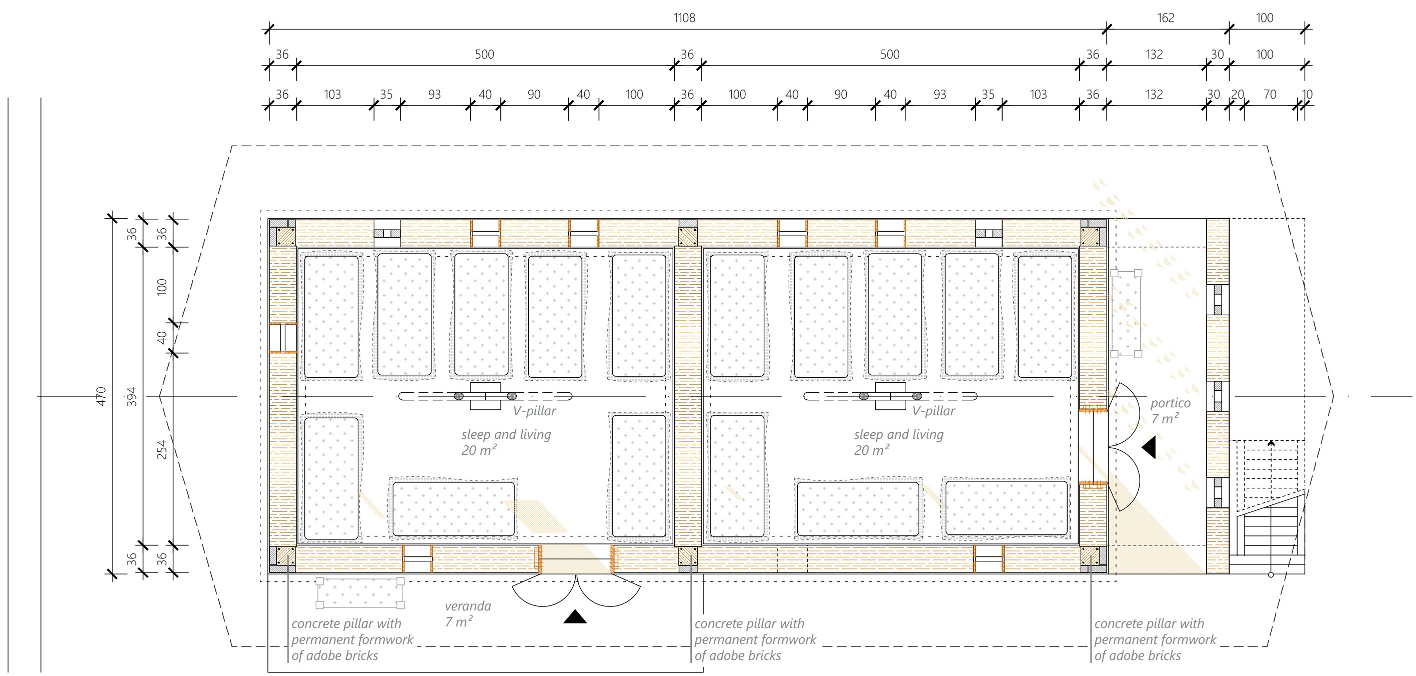
In the first weeks after my arrival in 2017, we started building the foundation for the second house, while finishing the construction work on the first house. The foundation for the second building is executed like the one of the first building in natural stone masonry. Since on the first hoste a modicum in subsidence appeared, the foundation for the second hostel was modified to be broader in the lowermost stone course.
After a briefly planning phase during the construction of the foundation and the complementation of the first hostel, the rammed earth wall construction of the second hostel was started in early February 2017 and the ground floor walls, including ring beam and pillars were finished eight weeks later.

3.1 Design process and principal decisions

The decision to use a different construction system for the second hostel building came actually very late during the construction phase. There was the general idea to build some of the hostel buildings in different types of construction, but when I arrived in Logia in January 2017, the general plan was to build the second hostel in the same system as the first one. The 3rd hostel was outsourced to a regional contractor and already started in a completely different construction technique.
Because the foundation was already in the works when I made the final decision to use the rammed earth construction technique, I already was restricted by the dimensions of the foundation.
The conceptual planning phase already began after my first field trip, in March 2016, when I started to look out for alternative systems for construction. During my construction work in 2016 at the site, I was able to get a better understanding of the regional general conditions.
Because the first and the second hostel should be easy to compare, the general structure and dimensions were set to be about the same at both hostels. As mentioned prior, the construction of the foundation was already in the works, when the final decision to build the load bearing structure in a rammed earth wall system was made. The floor plan is the same as for the first hostel. Also, as for the first hostel, there is a ground floor level with two rooms for sleeping and an upper floor level with a room for studying which straddles the two rooms beneath. Besides the construction system of the walls, the roof was changed, the windows and facade were changed and an Arcade in front of the east entrance was designed to form a small open vestibule and porch on the upper floor, where the stairs arrive. Most of the planning phase was done during the actual construction phase. While the foundation was finished, I was finishing the construction plans on-site.

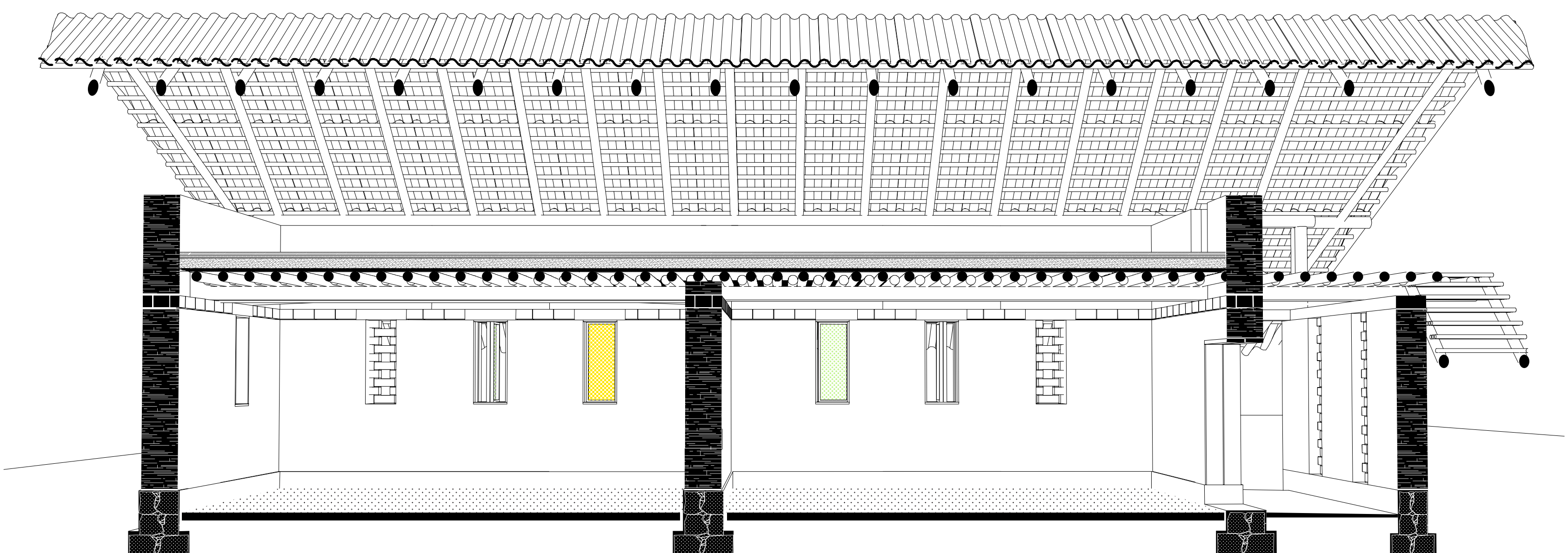


section M 1:100



floor plan (ground floor) M 1:100

north elevation M 1:100



67.1

fig. 67.1 | 3d-section through the originally planned rammed earth house

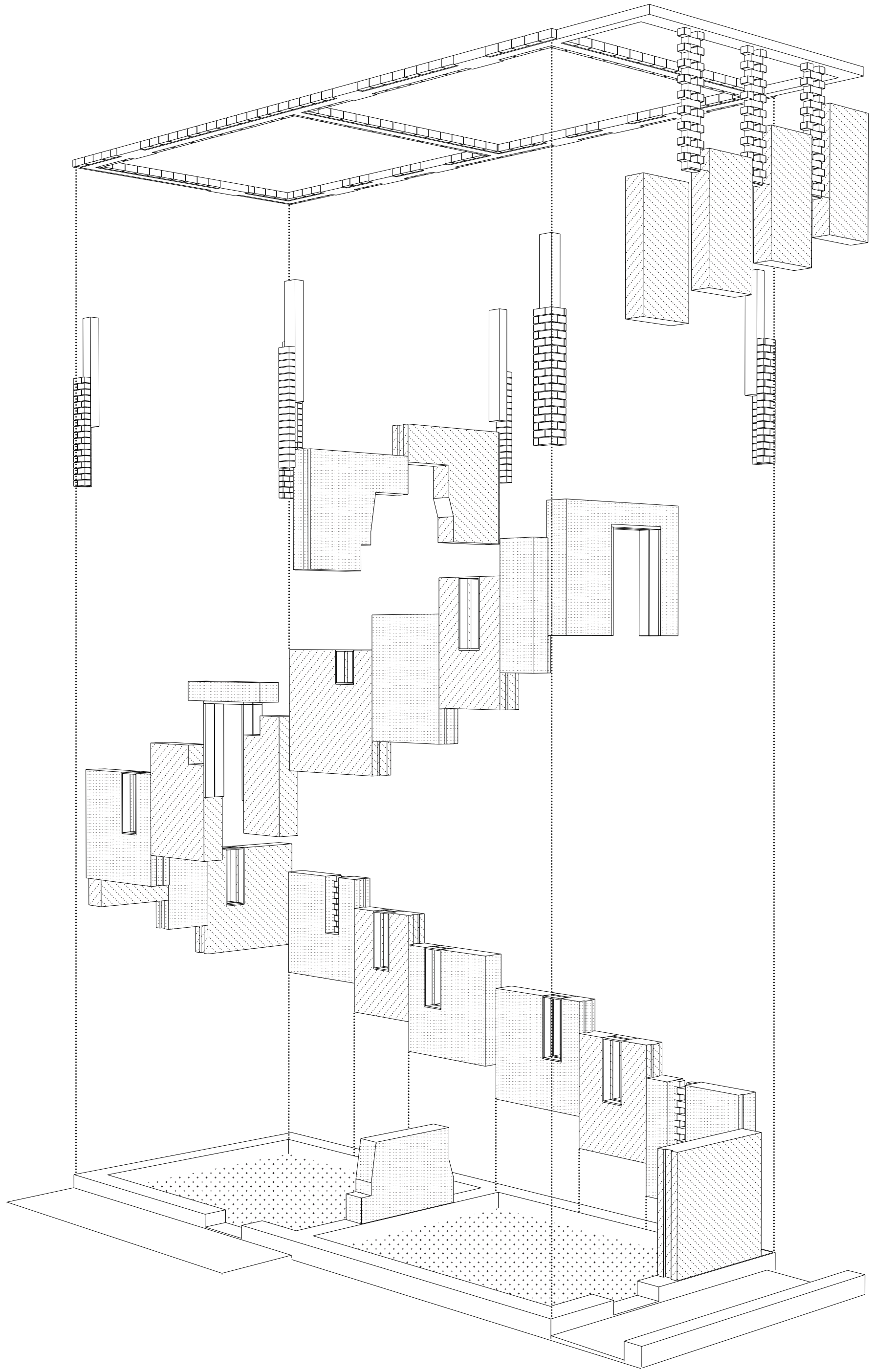
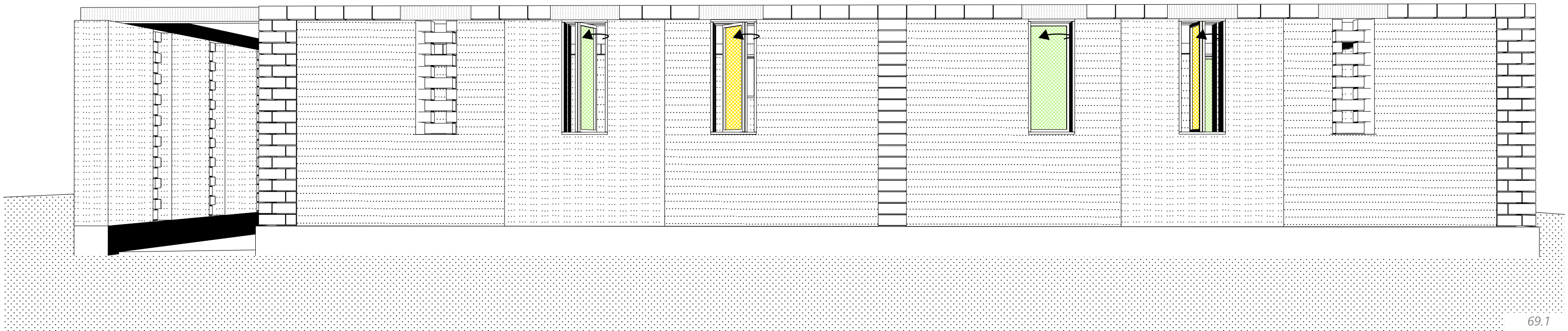


fig. 68.1 | diagram of the construction of the rammed earth wall

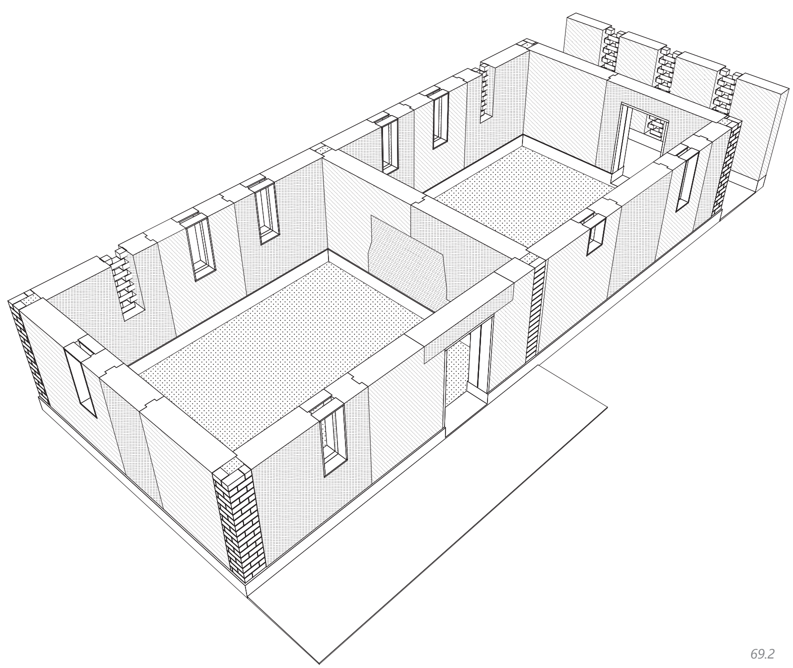
68.1



69.1

Rammed earth walls

For the rammed earth technique, I chose a formwork system developed at the Building Research Laboratory (BRL) at the university of Kassel. Because this System is very efficient in terms of wood usage for the formwork, while also avoiding horizontal shrinking cracks it is very suitable for the project environment. One-story-heigh rammed earth wall segments with up to 2,4m in widths and 1,8m in hight, should be erected in one day. (Minke, 2016)
The final design lead to 25 wall segments for the ground floor wall (fig. 69.2). With an average construction time of 1,3 to 1,5 days for one wall segment it leads to a calculated construction time of about 35 days (fig. 68.1) (real time house 2: about 40 days).



69.2

fig. 69.1 | north elevation of the rammed earth elements

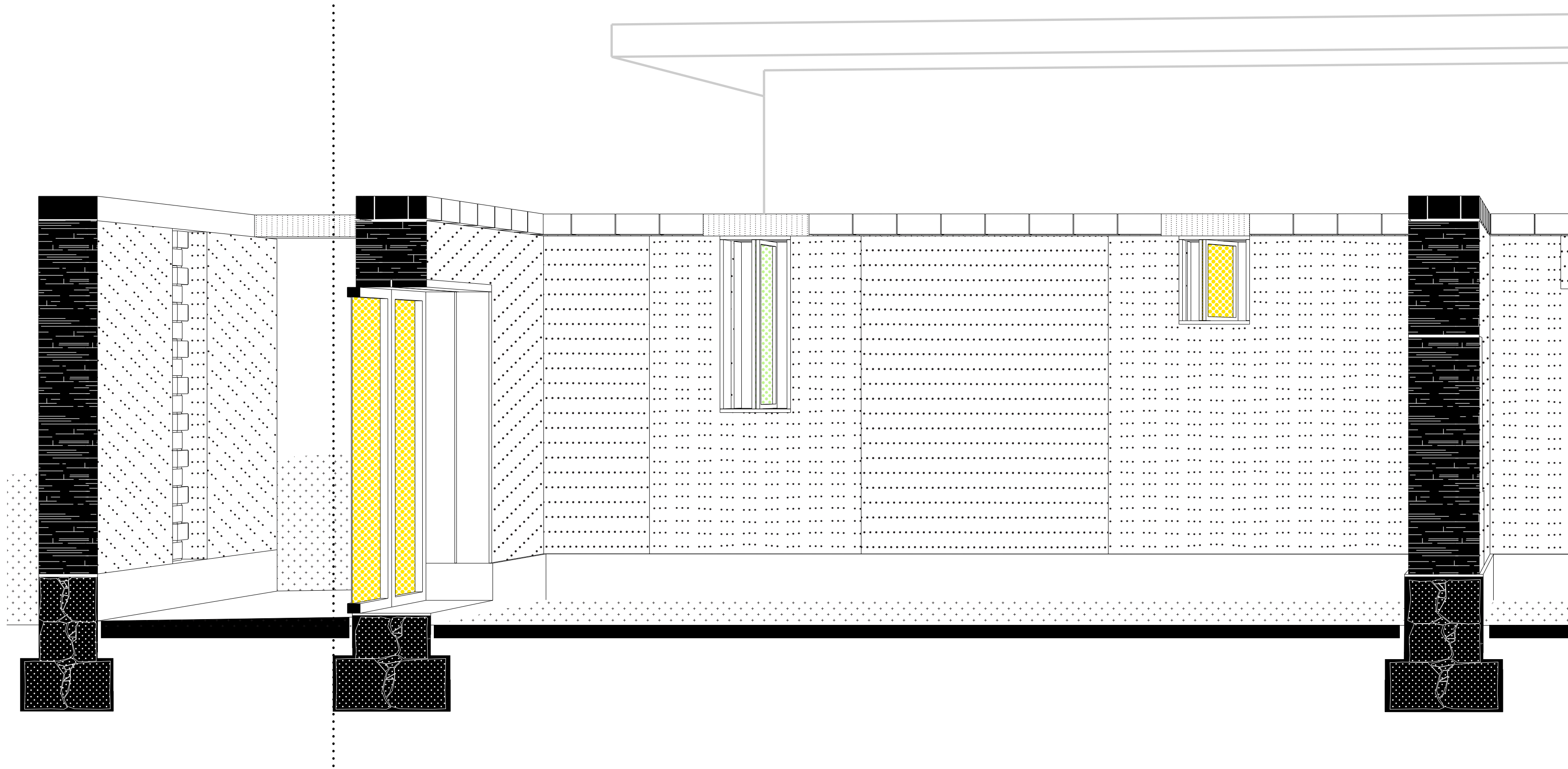
fig. 69.2 | 3d-sketch of all rammed earth panels with windows, and corner reinforcement

Corner and joints

Since the Afar triangle is a highly seismic active area, taking earthquake resistance into consideration was highly important. Therefore, the corners and joints of walls were reinforced with iron. The reinforcement iron at the first hostel was integrated into the brickwork. In the corner the pattern of the brickwork was designed in a way, that the vertical reinforcement iron could run inside the joints of the brickwork. But due to minor bends in the reinforcement iron and small displacement in the brickwork layout, in practice it became very difficult to fit the bricks around the reinforcement irons and let to small delays in the masonry workflow. To integrate the reinforcement irons into the wall more easily, for the second hostel it was decided to strengthen the corners and joints of the wall with reinforced concrete pillars. The rammed earth panels were erected first to let a gap open at the corners (fig: 69.1). The narrow side of the wall segments created the inside corner for the concrete pillar, bricks were used to create the permanent shuttering on the outside corner of the pillar.

Windows and doors

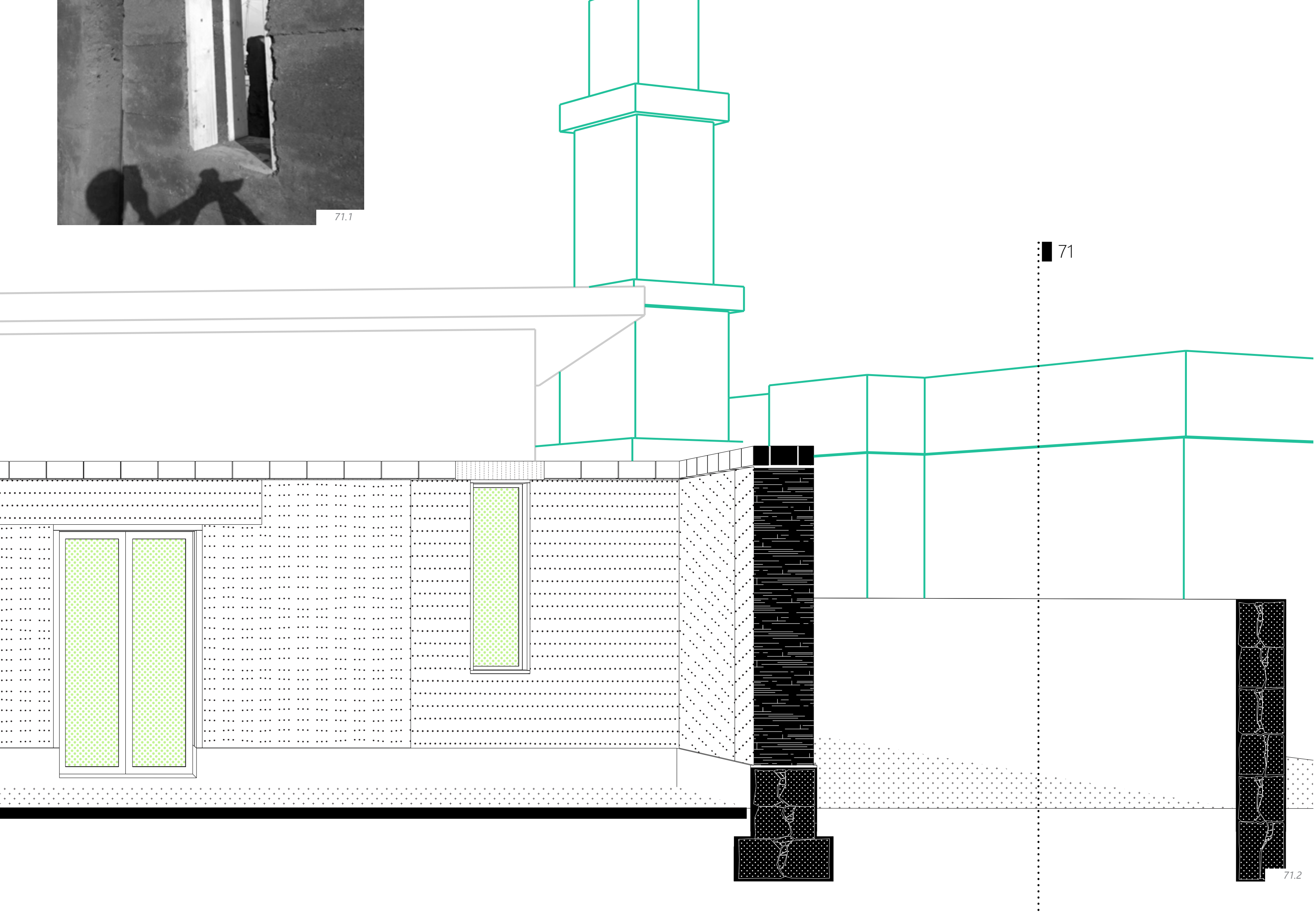
In comparison to the first house, several changes were made to the windows in the second house. The proportions of the window openings were changed to be narrower but mostly higher and while the windows are starting from different heights ,they always reach up to the ring beam so that the ring beam can act as its lintel. nstead of having a reinforced concrete lintel above the door, the rammed earth above the door is reinforced with iron and palm tree sticks and acts as the lintel. The shuttering boards for windows and doors were designed to remain in place and act as window and door frames. Shade panels and doors are executed as timber frame constructions with an infill of senana and are connected to the wooden frames of the openings.



71.1

fig. 71.1 | window frame acting as permanent form-work for the rammed earth wall

fig. 71.2 | longitude section through the rammed earth elements of the hostel – showing foundation rammed earth panels and ring beam



71.2

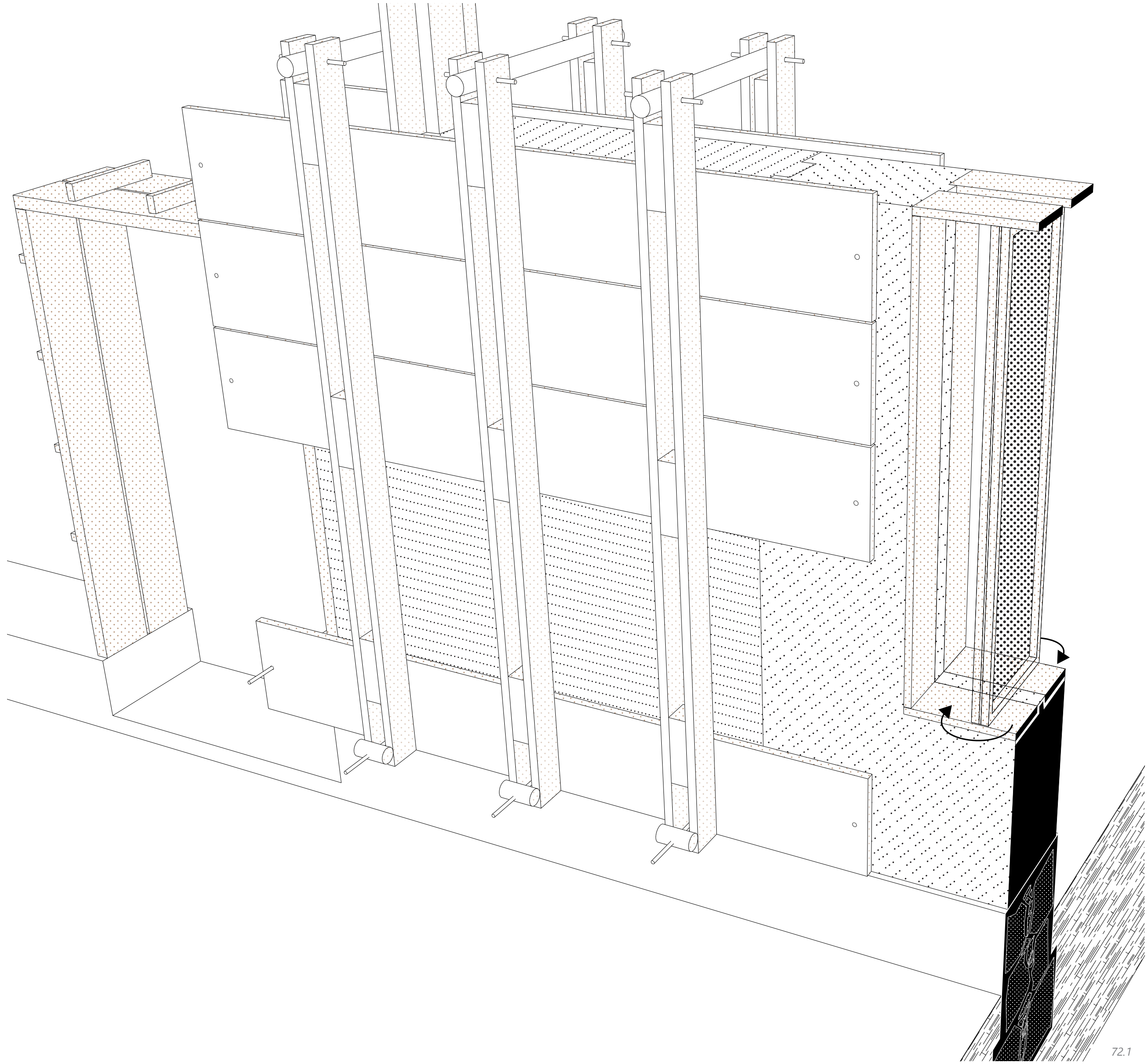


fig. 72.1 | 3d-drawing of the formwork system – showing how to use window- and door frames as permanent shuttering and how to install the formwork – three frames are used to hold the shuttering boards together

Roof and upper floor

A living area was planned upstairs in the attic of the double pitched roof. This type of roof was chosen to also be able to use it for alternative roofing systems with palm tree leaves and plastic bottles or other alternatives to the commonly used corrugated iron.
The external staircase were planned to run along the east side of the house right in front of the colonnade wall, which closes the veranda and to arrive on the veranda of the upper floor.
The ceiling and flooring of the upper floor was planned to be the same as on the first house. Round wood timber beams were used as the subconstruction with the Afar slatted frame on top and a bamboo mat as the anti-crumbling layer.
After I left the building site in April 2017 ,the construction process was overseen by the organisation APDA and because it was important to finish the house as soon as possible, the upper floor living space was canceled and a monopitch roof was reacted 1 m above the ceiling.

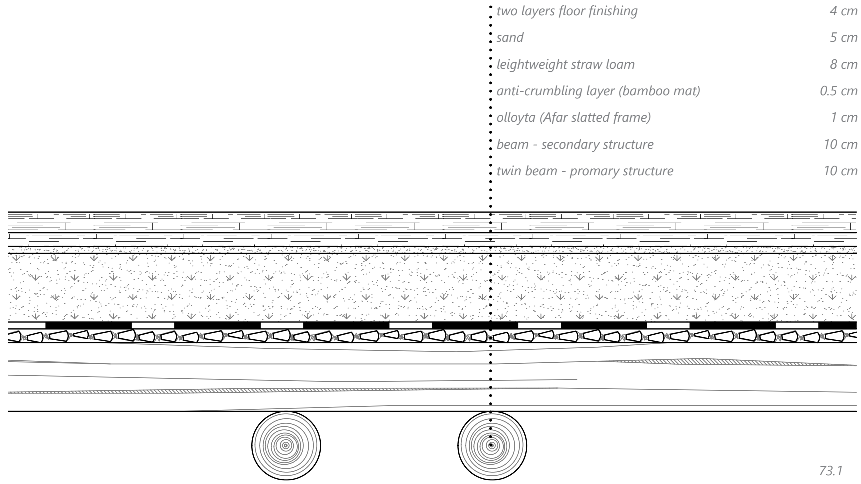
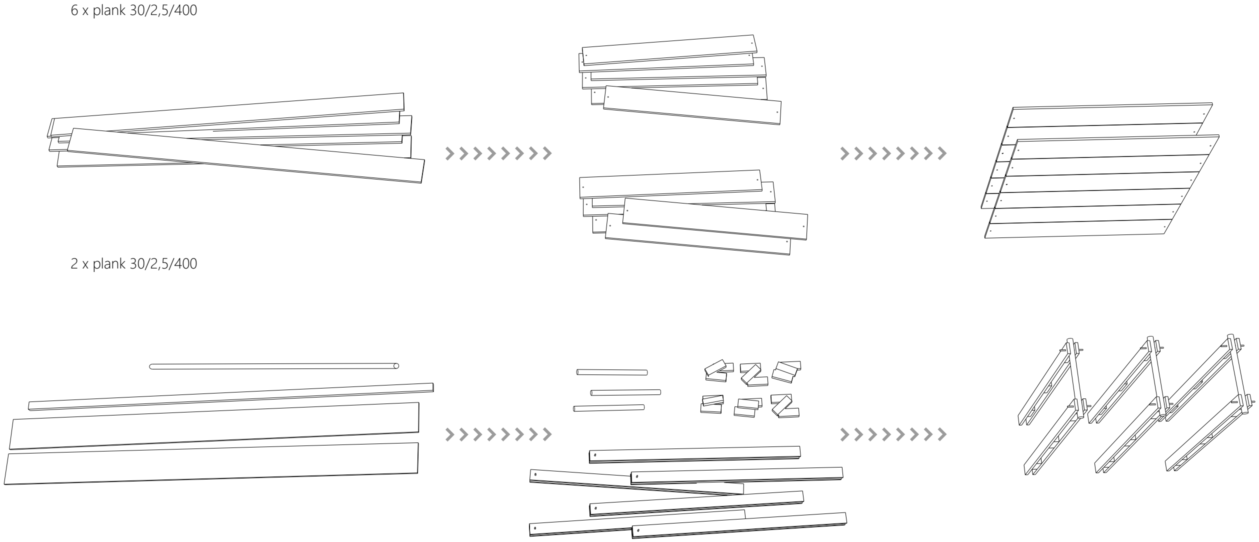


fig. 73.1 | detail of the ceiling structure – with the same layers as in the adobe house

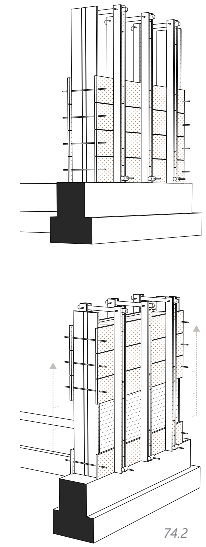
3.2 The formwork system

The selection of different sawn timber is very limited in Logia. Limiting factors, like available demotions, cost of material and the effort of reducing the cutoff to as little as possible, led to building a formwork with 2 metre long shuttering boards. Therefore, rammed earth wall panels were designed to be only about 1,5 m – 1,8 m long. A squared timber was vertically inlaid in the middle a narrow side of the shuttering, to create a vertical groove for a tongue and groove connection in the joints of the wall panels and improve lateral stability.
Six boards of timber with 400/30/2,5 cm were enough to erect all wall panels. Additionally, the spacer frames were built on the site from two timber pieces 400/20/2,5cm. Timber wood in relatively expensive in Ethiopia, therefore it was very important to us to use as little wood for the formwork as possible and to keep the wearout rate low. All the timber needed for the formwork is amounting to a little under EUR 100 / ETB 3400.

fig. 73.2 | rammed earth wall with the shuttering installed at element no. 15



74.1



74.2

fig. 74.1 | diagram of the needs timber for shuttering boards and frames

fig. 74.2 | "sliding formwork" - 3D-skeatch of the move of shuttering boars

fig. 74.3 | fist time installation of the formwork

74.3

3.3 Creating the tools

While finishing the foundation, we started to build the tools to erect the rammed earth wall segments. The wood boards for the formwork had to be brought by donkey cart. It took two people two days to prepare all the tools needed to react the wall.

Ramming tools, formwork and buckets were prepared on site. The timber was ordered at the building supplies store and some boards had to be cut first longitudinal in the cut shop, before brought to the site. The thread for closing the shuttering on the bottom were prepared in a welding shop. The only affordable timber available was very thin and led to problems with the shuttering going forward. Because the timber boards were very thin, the material did bend very easy. It took a lot of practicing to ram the earth in adequate strength and to find the right distance between the formwork frames to prevent the formwork boards from bend too much.

75.1

75.2

fig. 75.1 | additional build tools – ramming tool: handles concreted in metal cans were prepared in several different sizes; to tighten the shuttering thread rods were welded to reinforcement iron

fig. 75.2 | ramming tool inside the shuttering – the tongue and groove system of the wall panels can be seen as well

3.3.1 Building the formwork

Three frames, six shuttering boards and one closing board for the narrow sides were prepared for first testing. The frame is spaced on the top and on the bottom. The top spacer is above the top level of the finished wall part and was permanently fixed to the vertical members. It was not variable and had to be built to fit the thickness of the wall. The top spacer was set at 41cm for the finished wall with the thickness of 36 cm, since the thickness of the boards had to be taken into consideration as well. The frame was opened and closed with adjustable spacers at the bottom. Two thread bars were welded on the endings of a reinforcement iron with 10 mm in diameter (fig. 75.1) and small timber pieces were used as stop bar between the frame and the nuts. The bottom spacer is laid inside an empty conduit for an easy removal when dismantling.

For the shuttering boards, four 30/2,5/400 cm timber boards were cut in half, so that on each side of the wall segment, four shuttering boards with a length of two metre were available. The shuttering boards can be moved from the lower part to the upper part of the wall segment, when the first half of the wall is finished rammed (fig. 74.2).

Since there were problems with moving the shuttering boards in the beginning, first also the boards which were meant for a second formwork system were also used to cover the whole wall segment in formwork.

3.3.2 Building the ramming tools

The ramming tools were built on site in the cheapest and simplest way as possible. Round timber sticks were used for the handle. Different sizes of bottles and cans were mounted to a wooden stick and filled with concrete (fig. 75.1, fig. 75.2). Over time it came clear that plastic bottles weren't durable enough and only metal cans in two different sizes were used. The bigger ramming tool was built with a 2,5l metal can and had about 6kg in heft. The smaller one was built with the 0,75l metal can and about 2kg in heft. The ramming tools could be used with the can-side down or the wooden-stick-side down. The pointier ending of the tool was used to ram the earth along the edges and in the corners, while the flat-based can side of the tool was used for ramming the centre pieces of the wall.

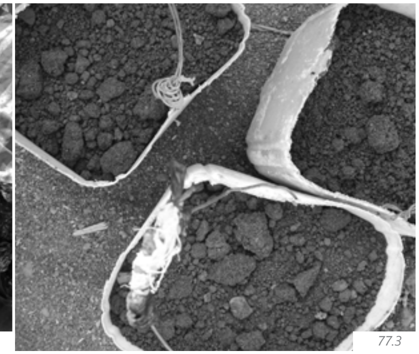
Also, to mix the different layers better together, first every layer was rammed broadly with the pointy side and secondly rammed with the flat-based side.

TRAIL WALL

76.1

77.1

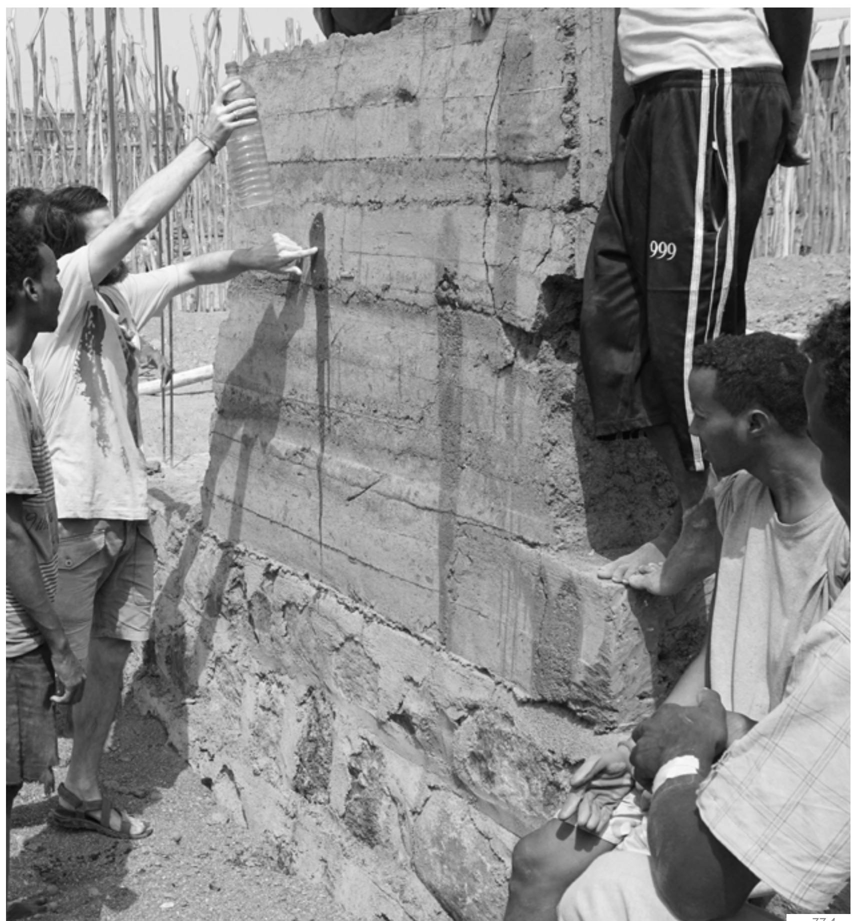
77.2



77.3

3.4 Testing different material mixtures

To find the right composition of the earth, a testing wall with layers of different earth mixtures was build. The material was mixed like the material for the brick in small piles. When preparing the material, it is important that the clay gets enough water to never dry out and is able to soak, but when using the material, it must not be too wet. The material only should be earth-moist. In a hot and dry area like Logia, its challenging to have the material constantly slightly moist without letting it dry out completely. Keeping the balance is not easy and requires constantly covering the material under plastic trampoline. At the site in Logia, it took us a few days to get a feeling for the right moistnes in the earth material and how to keep it constantly at the same level. Sometimes even leaving the piles uncovered for several minutes during picking up the material to fill in the scuttering, would be enough to dry the material and make it unusable.
Three different compositions of the clay-sand-gravel-mixture were prepared to built a trail wall piece (fig. 76.1, fig. 77.4). The final mixture was composed of 25% clay, 50% sieved sand and 25% gravel and river



77.4

fig. 76.1 | the first trail wall with different layers of different compositions

fig. 77.1 | preparing the material for the rammed earth wall – the material should be "earth-moist" and therefore must be much dryer than for mortar or brick production

fig. 77.2 | a portion of the clay was solved in water to have a thin pasty texter and then mixed with small stones in a wheelbarrow to have the stones coated with the clay paste and later added to material

fig. 77.3 | the clay material in the bucket – for one row five buckets were filled into the formwork before the layer was rammed

fig. 77.4 | explaining to workers how a rammed earth wall acts on rain water


78.1


78.2

fig. 78.1 | cracks appeared as a result of too small overlap, when moving the shuttering boards

fig. 78.2 | The cracks and the fact that the wall was slightly leaning, lead to the decision to remove the wall part and rebuilt

rock with stones up to a diameter of 3 cm.

3.5 Teething troubles

When in February 2017 the first trail wall was erected, the best mixture was already visible after just a day of predrying. The workers saw the rammed earth technique for the first time and could collect their first experiences on the first wall piece.

– When enough material with the chosen composition was prepared and the formwork was set up, the first two workers could start on the first actual wall part. When the shuttering was filled and rammed to about 50cm in hight, the spacer frames was opened, and the shuttering boards were moved up so that filling in and ramming the material could continue. Unfortunately, a combination of several small irregularities led to small cracks which grew bigger and bigger right below the shuttering boards on the already finished wall. Three main mistakes led to the appearance of this cracks (fig. 78.1):

- The overlap between the moved shuttering boards and the already finished rammed earth wall was too little.
- The prepared and filled in earth material was too moist and the rammed wall couldn't dry fast enough.
- And the applied ramming force was too high.

At the end of the day when striping the formwork, we could see how the wall was compromised and concluded to brake down the wall right away, as the material was still soft and easy to remove (fig. 78.2, fig. 79.1).

– Because of the unintended throwback, the workers became very skeptical and were insisting to use all available shuttering boards and leave those in place until the whole wall segment was finished. The filled in earth was still a little too wet but in the evening, when dismantling the finished 1,8m high wall penal, but the surface looked very good with no visible cracks or what so ever.

After removing the shuttering boards you could already see that the earth was too moist and shortly after dismantling, small waterdrops started to appear on the surface. The drops seem to have formed from a thin moist-film covering the whole surface of the wall. It became obvious that the earth still was too moist and the wall couldn't dry during the day, since it was covered in the shuttering for the whole day. Because of the heat and the strong ramming work it even seemed that a lot of the water was transpired to the surface of the wall, where it was blocked from evaporate by the wooden boards of the shuttering. After a few minutes the wall started to lean on one side and on some spots earth material started to trickle down. The wall seemed to fold itself and then collapsed entirely (fig. 79.2).

79.1

79.2

79.3

//

The project is pretty good on track....more or less. We already started with the rammed earth wall (therefore I couldn't pick up Hemma from Addis). Sometimes I am a little tired form the constantly explaining something and my quality standard came quite a bit down. I actually never before have built a rammed earth wall on my own and therefore the first wall part did actually surprise me, but also frighten me. The wall is really becoming very strong over time – it really feels like concrete – but the ramming also generates a very high pressure on the shuttering.

The locally available wood is very soft and thin. The actually good wood is extremely expensive and would increase the construction costs substantially. The fist tail wall looks actually quite good but was kind of slow to erect. It was mainly done to find the right mixture.

The actual first wall was a disaster. The sliding formwork system made us some problems. Removing the shuttering boards to early on the bottom, led to cracks on the surface of the wall. since the wall also was leaning I decided to tear down the wall.

... After the failure of the first wall part the works don't want to remove the bottom boards, they are afraid, that the cracks will appear again (even though I explained the reason for the appearance of the cracks) and therefore they use the boards of the second shuttering to continue. I accept. Its straight, after all. When dismantling, the wall actually looks good; The surface is nice (even though there were small drops of water forming on the surface of the wall, which seemed strange), the wall is straight, I told them to change the mixture intermediate, since it looked like they were standing in sludge, when I looked into the shuttering (funny enough nobody else seems to have recognised it). So they changed to a more dry mixture. The wall was already standing for about 10 minutes, dismantled and without support, when on the bottom the earth started to trickle down, and a few moments later it started to lean more and more on one side. Then – woosh – and the whole wall collapsed. The material clearly was to wet, and additionally couldn't dry a bit during the whole day, because the wall was mantled into the shuttering.

When I went to bed in the evening the first nightmares started about the wall. I woke up at 1 or 2 AM, was sweaty and shaking. It was hot – cold – hot; I couldn't sleep anymore and then pain in all my limbs started. Limbs, joints, head, eyes all was on pain and I was extremely thirsty, but we hadn't bought water in the evening. I wasn't able to sleep, and the thirst was maddening. In the morning Valerie came to look after me. She was calming. Before noon I finally could get some sleep. I get a flour soup which seems to make my sweat glands as leaky as Ethiopian water pipes. Hemma went to the site to look after the workers. I gave her instruction for the workers and she is occasionally sending me photos of the building process or calling me, if there are questions. In the evening they seem to finally have erected the first segment of the rammed earth wall. I was really impressed when I came to the site the next day and could look at the on my own. I still felt very bad and couldn't do much physical work, but only overview the site...

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(travel journal - Kraßnitzer M. 27/01/17)

fig. 79.1 | the flawed wall part was removed. As it turned out it wasn't that easy to remove the already erected wall

fig. 79.2 | on a second attempted of the same wall part the wall collapsed after removing the formwork due to a too wet material mixture

fig. 79.3 | the third attempt of the first wall part finally was acceptable

3.6 Wall construction

After initial troubles with the rammed earth panels, the work continued faster and as the workers became more and more experienced with the material, the process became faster and more accurate. Since in the beginning workers still were insecure and were afraid that, when we would move the shuttering boards from the bottom to the top during the erection of the wall, cracks could appear, we first continued to leaf all shuttering boards in place until the wall part was finished, but we did untighten the nuts of the spacer bar during the lunch break, so that air could flow between the shuttering boards and the finished wall and the wall could dry a little bit. After the break the frames were tightened again to continue the ramming work. After accomplishing some wall segments, the team was able to go back to the principle of the slipform and we could use the shuttering boards for two formworks, to work simultaneously on two parts. Due to inaccurate working, sloppy ramming, rain damage or damage during dismantling, some parts of the wall had to be removed and re-erected.

Rain damage

Even though rammed earth walls are resistant to water from the side, the wall can be harmed rapidly when it is exposed to water from the top. During the construction phase it's important that the wall isn't exposed to rain. During the dry season from October to March, rain is very rare in the danakil depression. To protect the walls from rain, we covered the finished wall parts with a thin layer of concrete on the top. Because otherwise we would have needed a lot of plastic tarpaulin and would need to cover and uncover the wall every day.
After we finished the fifth wall segment in about mid-February, there was one very heavy rain day. When we came to the site the next day it was clear, that the concrete cover wasn't enough to protect the new walls, or at least a small overhang would have been necessary. The rain water that accumulated on top of the wall ran down bundled and washed out the top edges of the wall right under the cement covering (fig. 82.1). Some of the damage surely was due to a general unusually heavy rain for that region. After the rain damage we decided to always cover the wall in the evening and uncover the wall in the morning with plastic tarpaulin.

Additional base course

As the construction work continued, it became clear that the foundation, which is built in natural stone masonry occasionally, led to problems with the frames of the formwork system. The uneven surface of the natural stone sometimes juts out a bit, so that the frames for the formwork couldn't be closed properly and sometimes weren't vertically straight. To solve the problem, I built a small fixed formwork, which works like a mould for rammed earth wall segments with only a height of 30 cm. The mould could be placed on the wall with the frames not touching the side of the foundation (fig. 83.3). One course of a 30cm high rammed earth wall was built with the specialized formwork, before the formwork for the one story rammed earth panels could be used as intended again.

Work in progress

After the initial problems and a learning phase, workers became more experienced, more skilled and faster. The workers not only had to learn how to work with the earth material, how much force to use when ramming and what is the right amount of moist in the earth, but also how to adjust the formwork, how to make sure that it is straight and won't move and how to prepare the formwork for the openings. During the construction process, it became clear which workers are interested, committed and talented in which tasks. The enhanced work routine led to a reduction of labour input from about 65 h/m³ in the first week to about 24 h/m³ later on.

Improvements

During the construction of the colonnade the improvement in working speed and the standard of execution became very visible.

81.1

fig. 81.1 | two workers, Abukkar and Muktar, finishing one of the last wall segments

82.1

fig. 82.1 | rain damages on the wall – the rammed earth wall was covered with a thin layer of concrete, which could protect the wall from drastic rain damage, but the rain still did some damage to the wall – later the wall was additionally covered with tarpaulin

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...In the week before we went to Addis there was a heavy rain which worried us. Since there is a small rainy season from end of February, we started to prepare the site for rain in the days before. Three days before the rain we started to bring the 6000 bricks under the shed roof and a day before the rain I told Ali to cover the rammed earth wall parts with a 2-3 cm thin layer of concrete, but we did not yet cover the wall parts with tarpaulin. When we went home in the evening the sky looked clear, there weren't any signs for rain.

In the middle of the night, at two o'clock a crazy heavy thunderstorm started. At three o'clock there was already 10cm high water pool in front of our room door. At about four o'clock I my hopes that any of our walls on the site would sill be standing, were finally gone. It was bucketing down the whole night. In the morning, when the rain was fading for a short period, I took my raincoat and went to the site. The streets were empty. Nobody is leaving the house in Logia, when it's raining. Only 5% of Bajej were in service. There is sludge everywhere and may Streets transform into sea lanes or even into a river.

After all the wall made a surprisingly good impression on me. We covered the wall in tarpaulin and stayed the rest of the time at home.

The next day we started to remove and repair the damaged wall parts.

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(travel journal - Kraßnitzer M. 25/02/17)

83.1

83.2

fig. 83.1 | some parts of the wall had to be removed and re-erected – this particular part because of quality issues; the material was not rammed well enough and might also have been just a little too dry

fig. 83.2 | the earth material was also rammed into the joints of the wall segments – a ball of earth was formed and pressed by hand on the joint and then beaten with a timber piece into the gap

83.3

fig. 83.3 | a 30cm-high wall raw had to be prepared, because on some places the uneven surface of the foundation's natural stone masonry caused troubles when tightening the frames of the formwork

84.1

fig. 84.3 | the tongue and groove connection of the rammed earth wall segments – a square timber was inlaid on the inside of the formwork's narrow side surface

85.1

85.2

85.3

85.4

85.5

85.6

fig. 85.1 | a 30cm-high course of rammed earth segments was built, to have a straight surface to mount the formwork for the high elements on

fig. 85.2 | ramming work of one of the last wall segments

fig. 85.3 | the house two weeks before finishing the ground floor walls

fig. 85.4 | wall segment in detail

fig. 85.5 | laying the bricks for the permanent shuttering of the ring beam

fig. 85.6 | a worker repairing a small wall segment *fig. 86.1* | the reinforcement cage of the pillars with the brickwork as permanent shuttering

fig. 86.2 | Corner reinforcement at the middle wall in the joint where three rammed earth walls meet

86.1

86.2

3.7 Ring beam and pillars

Before finishing the last wall parts, three workers already started to mason the permanent formwork for the pillars in the corners (fig. 86.1, fig. 86.2). The vertical reinforcement irons already were in place, since these were anchored to the foundation, but hoops were added to connect the iron bars every 15 cm to form a reinforcement cage. The formwork of clay bricks was filled with concrete. The ring beam was done in the same technique as the ring beam from the first hostel. Clay bricks were used as dead shuttering. In between the two rows of lateral masoned bricks, the reinforcement bars were connected to form a cage. Because in contrast to the first hostel, the ring beam also acts as the lintel for the windows, above the windows wooden shuttering was used, so that in the area above the window the whole width of the wall was covered by reinforced concrete (fig. 87.2). There also were additional reinforcement irons added, at this spot. While preparing the shuttering and reinforcement for the ring beam took nearly a week, the actual filling with concrete was done in half a day.

Three days after I left, the team also could finish the ring beam that connected the colonnade in front of the entrance with the house.

87.1

87.2

fig. 87.1 | Brickwork in the corners – used as a permanent formwork to concrete the corner reinforced

fig. 87.2 | concreting the ring beam – above the windows the ring beam is acting as the lintel and the beam is more reinforced and widened to the width of the whole wall

fig. 87.3 | The ground floor walls, with corner reinforcement and rein beam finished concerted – the concrete of the ring beam was watered two times a day

87.3


88.1


88.2


88.3

fig. 88.3 | concreting the ring beam that is connecting the colonnade with the rest of the house – received via chat-app on 05/04/2017

fig. 88.3 | Round timber beams for the wall – received via chat-app on 05/04/2017

fig. 88.3 | concreting the ring beam that is connecting the colonnade with the rest of the house – the shuttering boards from the rammed earth walls could be used here – received via chat-app on 05/04/2017

3.8 Finishing the hostel

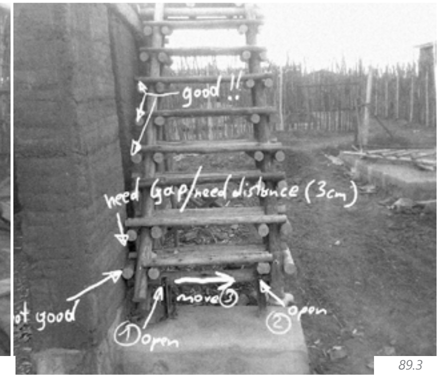
When my stay at Logia came to an end it became clearer, that we wouldn't finish the house until my departure. Because of the problems with the floor and the plaster of the first house and the inconsistent quality of the rammed earth walls on this house, we were a little behind the schedule. In the last week of my stay, I was preparing plans and discussing with the team and a selected lead worker the upcoming steps of construction. I step by step handed over responsibilities to the workers. Different workers were responsible for the working processes they were specialised on. And I installed two lead workers that had the overview over the independent groups. One was technically more advanced and overlooked the construction work and one was more skilled in organizing and had the responsibility of interacting with the APDA office and coordination of the team.

After I left, the workers were on their own and it was important that they would know what to do and how to finish the house as soon as possible, because the big rainy season usually starts in June. Back in Austria it was difficult to communicate with the workers. I could occasionally call them via VoIP services like WhatsApp or imo but since there still was the state of emergency declared for Ethiopia, most social media and internet services were either temporary or even permanent blocked by the government, it was even harder to communicate. Phone calls most of the time dropped fast after being connected and images didn't always go through. Additional difficulties came with the language barrier, where it became clear, that it is actually a lot more difficult to talk to a person with mediocre English skills on a phone than it is talking to him/her in person. Finally after a week I though got the first images of the finished ring beam and the timber beams sub-construction of the ceiling (fig. 88.1, fig. 88.2, fig. 88.3). A few days later I received images of the finished stairs and already started rammed earth wall on the upper floor (fig. 89.1, fig. 89.1). Two weeks later there were troubles with the funding and therefore the workers had problems to receive their salary and some workers left the team. Only a few days later the construction again seemed to have ended. APDA had to acquire new funding or reorganize their finances and restructure the management for the construction.

At the beginning of August, the construction work continued under the observation of a civil engineer from APDA. Due to the time shortage and the technically challenge of the construction, the construction team and APDA built a monopitch roof directly on the waist-height rammed earth wall of the upper floor and scratch the upper floor. The roof, windows and doors were finished until the end of August.


89.1


89.2



89.3


89.4

fig. 89.1 | Rammed earth walls above first floors ceiling – received via chat-app 14/04/2017

fig. 89.2 | wash-bowl in front of the sanitary house – the tank beneath is collecting the grey-water. On the toilets greywater outlets are installed to use the greywater for flushing purposes – received via a chat-app on 20/04/2017

fig. 89.3 | The stairs to the second floor was already constructed before it was decided to put a roof on the house as quick as possible and resign on the attic common room – the workers sent me a photo of the stairs via a chat-app on 20/04/2017 and I commented on the construction and returned the photo

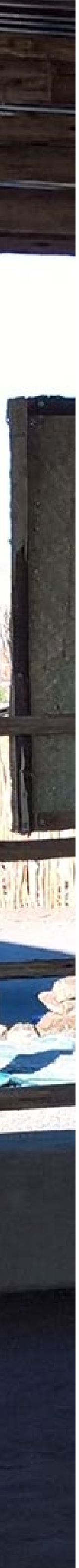
fig. 89.4 | construction site a few days before my depature in 2017

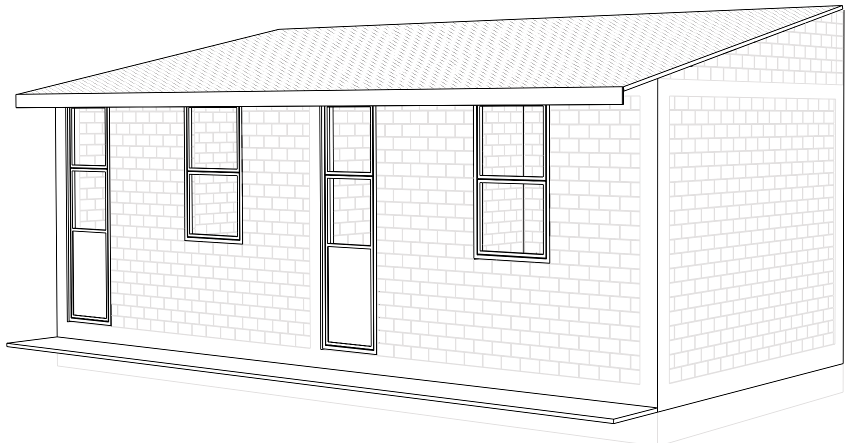
fig. 90.3 | on 27th of Okt. 2017 we finally could see the finished hostels on photos we got sent by APDA – the north side of the rammed earth hostel

90.1

91.1

fig. 91.3 | Finished hostel – south side – Originally only the lower zone of the rammed earth wall (about 50cm above foundation) was planned to be plastered, but eventually the whole hostel was coated with a cement plastering on the exterior. This is by all means not necessary on a rammed earth house, but might be connected to some small rain-damage that occurred on the clay plaster of the adobe house and might have caused distrust to the locally unknown construction techniques





4 CONSTRUCTION PROCESS - HOUSE 3

In April 2017, after heavy rains that led to heavy rain damage on the adobe walls and already produced adobe houses, it was decided to also start a hostel building in a regional common building technique. The choice was made not only to make future comparison between the different building techniques easier, but also to have more secure and predictable construction site conditions with a method that has already proven itself, since the owner felt uncertain over the throwback and was concerned for further development of the construction site. The construction of this hostel was executed by an external regional contractor. The house resembles the classic building structure of higher standard buildings in Ethiopian towns, with the main construction materials being reinforced concrete and cement bricks.

The construction of the third hostel building was started in December 2016 and finished in summer 2017. The floorplan of the building is kept the same as with the first two houses. Even though the hostel was the second one to be started and the second one to be finished, it is considered the third hostel or hostel No 3. Not only because of the master plan, but also because of its lesser importance for the kindergarten project due to its building technique.

The hostel building follows the standard higher-value construction principles in Ethiopia. A one-story building with a reinforced concrete frame structure, which is formed by cast-in-place pillars and ring beam. Cement bricks are used for the infill and corrugated iron for the roof. Each room is having one window and one door, facing the veranda on the frontside of the house. From the ring beam in 3.5 m high the mono-pitch roof is rising. The unusual high of the rooms should prevent the rooms from overheating. The main difference between most concrete buildings in Logia and the hostel building, are the cement brick, which contain more clay soil than usual cement bricks. The bricks were produced with a manually operated press in Logia and were also called *"cement enhanced clay-bricks"* by the contractor.

COMPARISON

95.1

fig. 95.3 | the three hostel buildings in March 2017- on the right the adobe brick house (already finished), in the foreground the rammed earth house (still under construction), in the background the cement brick house (also still under construction)

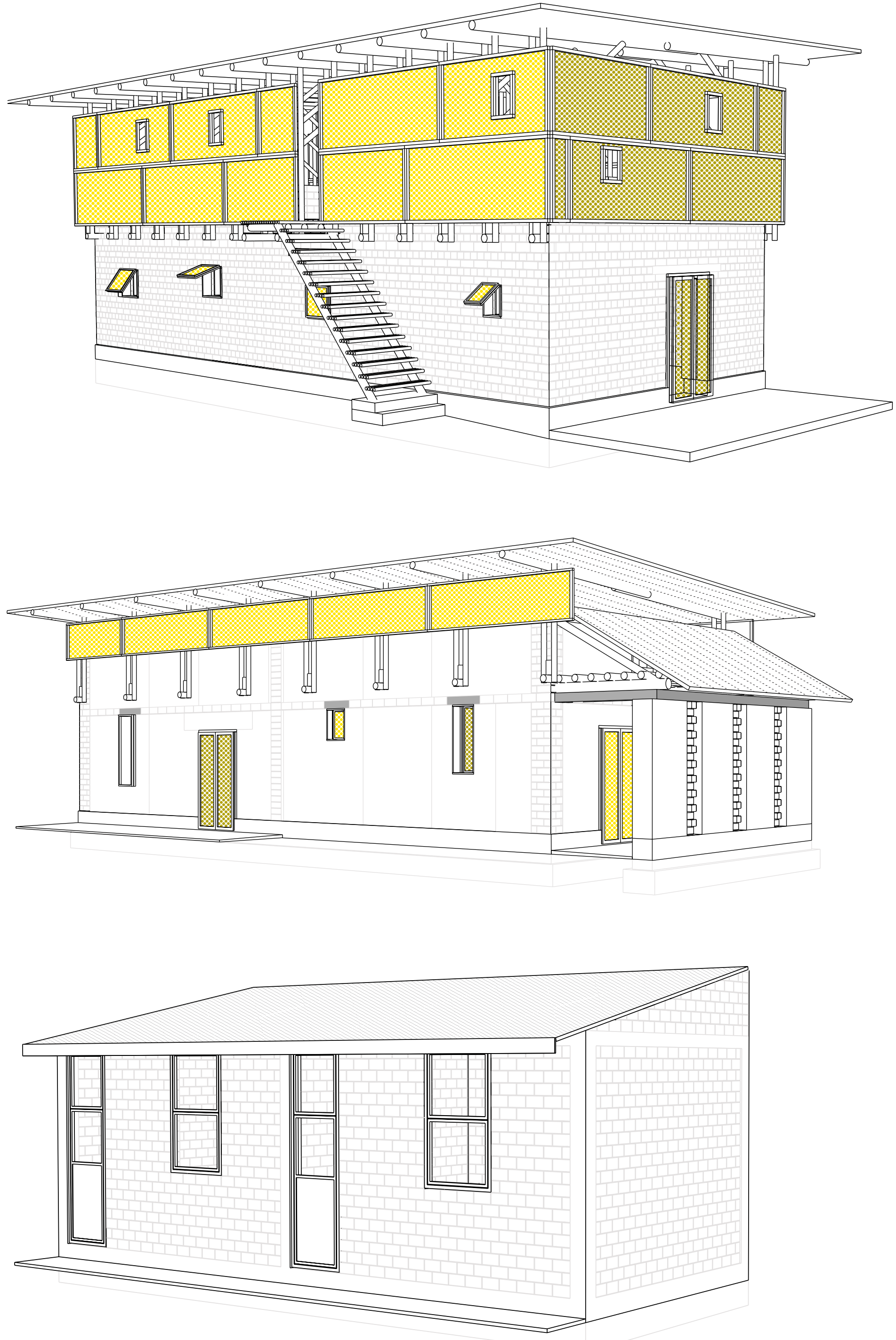


fig. 96.1 | Sketch of the three different hostel building structures – Hostel No 1 built with adobe blocks (on top), Hostel No 2 built in rammed earth wall technique (middle), Hostel No 3 built with cement bricks and concrete frame structure

1 COMPARISON OF THE HOSTEL BUILDINGS

The three already finished hostel buildings of the Afar kindergarten project are different in terms of structure, building technique and materials but very similar in terms of size. Therefore, I want to draw some comparisons between the tree buildings and look at the different advantages and disadvantages of the certain construction processes. To get a sense which process under which circumstances and conditions will be the most beneficial for the people and the region of Logia I was linking several architectural qualities of the different buildings.

- Preparation and other additional site expenditure
- Construction time
- Labour expenses
- Construction cost
- Living quality
- Impact on the ecologic and economic situation of Afar people

As there were different challenges and conditions for each house direct comparison will be difficult.

1.1 Preparation and other additional expenditures

Since the site of the Afarkindergarten-project was not only a construction site but also a program to train workers with new building technologies, more preparation works as usually had to be done.
Setting up the storage, electrifying the storage, setting up a shade roof, preparing the building raw material and preparing the water supply for the site, were the main preparational works on the site in Logia.

Storage

As mentioned prior, construction workers in Ethiopia usually do take their own tools to the construction site, but as there were a lot of non-professionals workers on the site, the tools had to be provided by the site management and stored on site. Especially at smaller constructions sites, there usually are no on-site storage units set up. Since hostel No 3 was erected by a local contractor, a self-contained storage unit wouldn't have been necessary. The employees of the contractor were professional workers and had their own tools with them. Nevertheless, the professional workers took advantage of the already prepared on-site storage as well.
After all, having an electrified storage unit on the site isn't a necessity for any of the three different types of construction, but was necessary due to the factor of working with non-professional workers. Therefore, after establishing a team with well trained professional workers, the necessity for an on-site storage is less relevant, also for the earth building techniques.

Setting up a shade roof

For the adobe house it was necessary to build a shade roof (fig. 98.1; see also chapter construction process: 2.1 Preparing the construction site). Not only for the brick production to pre-dry the wet bricks in the shade, but also to protect stored bricks from rain damage.
For the construction of the cement brick house, a shed roof is not necessary, but it still was a welcome luxury for the workers to have a shade-giving roof when preparing construction materials or having a short break.
The construction of the rammed earth walls house also wasn't dependent on the shed roof, but on the other hand it surely also was welcome for doing the preparation work of certain building materials.
There can be additional expenditures when setting up an extra shade roof for the prick production. On the other hand, because of the hot climate many houses in Logia do have a portico or another kind of rain-protected outdoor area nearby, which could be considered to be erected before starting with the construction of the building. Therefore, any per-erected portico can be used as a production area for the bricks.

Preparing the building raw material

The on-site soil, which is used as the main building material for the construction of the two clay houses, has to be excavated, prepared and mixed to be useable as building raw material. Sand must be sieved, *fig. 98.3* | shed roof and production surface for the brick production process – the roof is constructed as outdoor common space with a permanent purpose

98.1

"

...Katharina and Mark had their flight back to Austria on the 9th of January, the overlapping time period [of our stay] was very short and we had to take care that all the management parts were passed on to me properly.

The following week was quite intensive. I had to break into in the project again and take over the responsibilities step by step. [....] So, I arrived at Logia on Thursday and was the whole day on the site. On Friday, like always, we had "freeday" – (officially on Ethiopia Saturday and Sunday are weekend, but since there are only Moslem working at the site – the Afar Region is mainly Muslim – we choose on the site the Friday to be the day off)

Therefore, on Friday we went to the office (APDA office) and had to finish the paper work from the prior week...submit the bills, calculating the expenses, receiving the money for salary or building materials... for a better understanding of who is responsible for what, I got to know the assigned APDA employees in person...stock issue, finance, where to summit the bills...

Since the next days were the last for Katharina and Mark in Logia and on the site, I tried to get to know the new workers as fast as possible. I only knew two workers from my research trip to Logia in the prior year. The other 10 where new to me and Katharina gave my great tips the different capabilities and what kind of nature they are....and to have some background information about the workers was turned out to be very helpful.

Starting with Monday the 09/01/17 I was on my own at the site. The flooring had to be finalized and the façade panels had to be mounted.

And there I realized that it fast can become busy, being responsible on your own and the opening hours of the office (08:00 – 12:00, 16:00 – 18:00) didn't make it less stressful. When I needed to do something at the office, I always first had to go to the site, tell people what to do, look how the work from the day before turned out, if any cracks appeared, how the material did dry...So when I didn't go to the site before going to the office, there was the risk that some workers didn't know what to do for two or three hours, even though some were competent enough to find them self's something to work on.

Therefore, after visiting the site I had to drive back through the whole city to the office and hope that the office worker I would need is in the office already.

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(journal - Kraßnitzer M. 27/01/17)

fig. 99.1 | faecal sludge tank next to the sanitary building

fig. 99.2 | cement bricks and concrete frame structure of the sanitary building with the already finished concrete ceiling

fig. 99.3 | cement plaster layer of the water tank for the compound on top of the sanitary building

fig. 99.4 | carpentry work of the water tank roof

fig. 99.5 | finished sanitary house

fig. 99.6 | sanitary house shortly before finishing

mixed with the clay and soaked in water.
The on-site preparation of the main construction material of the house is the one main difference in the preparation works of the earth building techniques and the frame structure with the infill of prefabricated cement bricks. The brick production and its preparation were a main part of the construction of the adobe house. To decrease the additional expenditures in erecting a adobe house, the bricks could be pre-fabricated in dedicated production facilities, which would also make an on-site shed roof redundant or at least less important.
For the rammed earth construction, testing the clay composition and mixing the material is necessary.

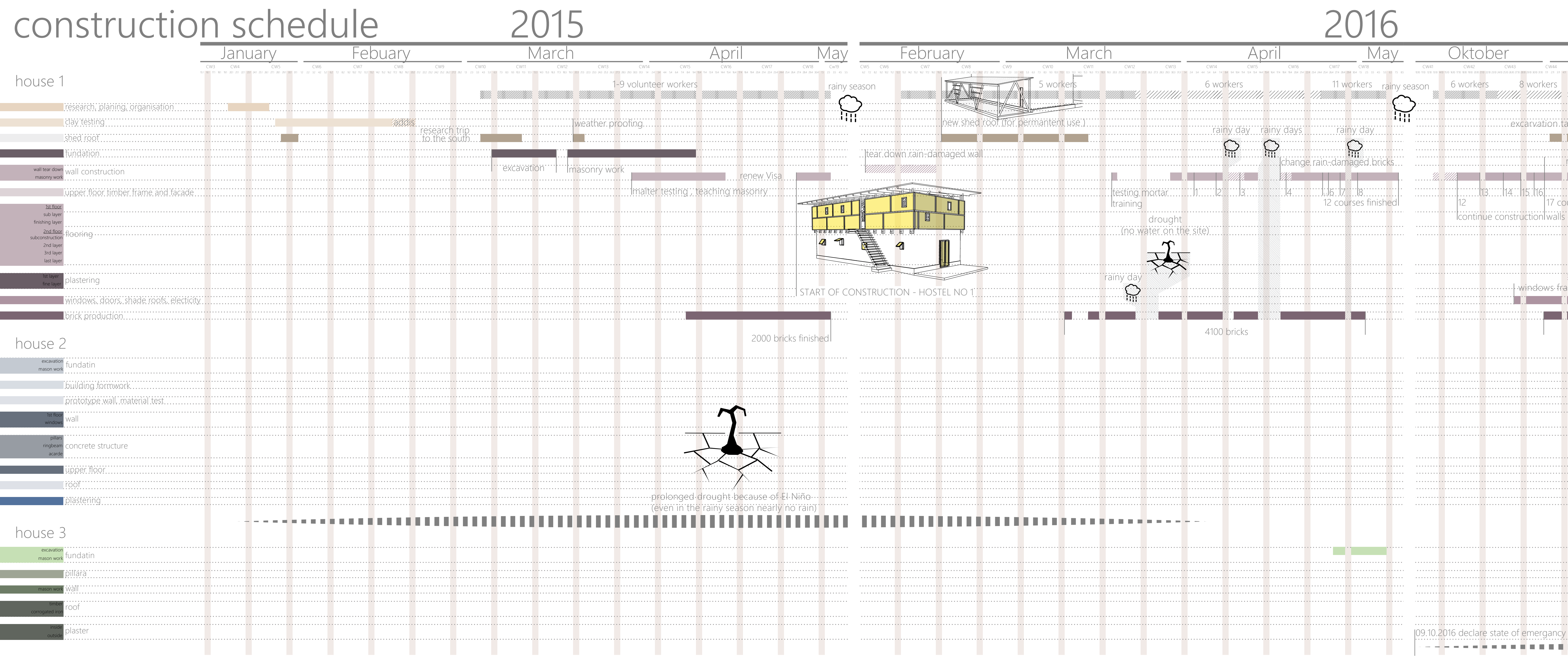
Preparing the water supply

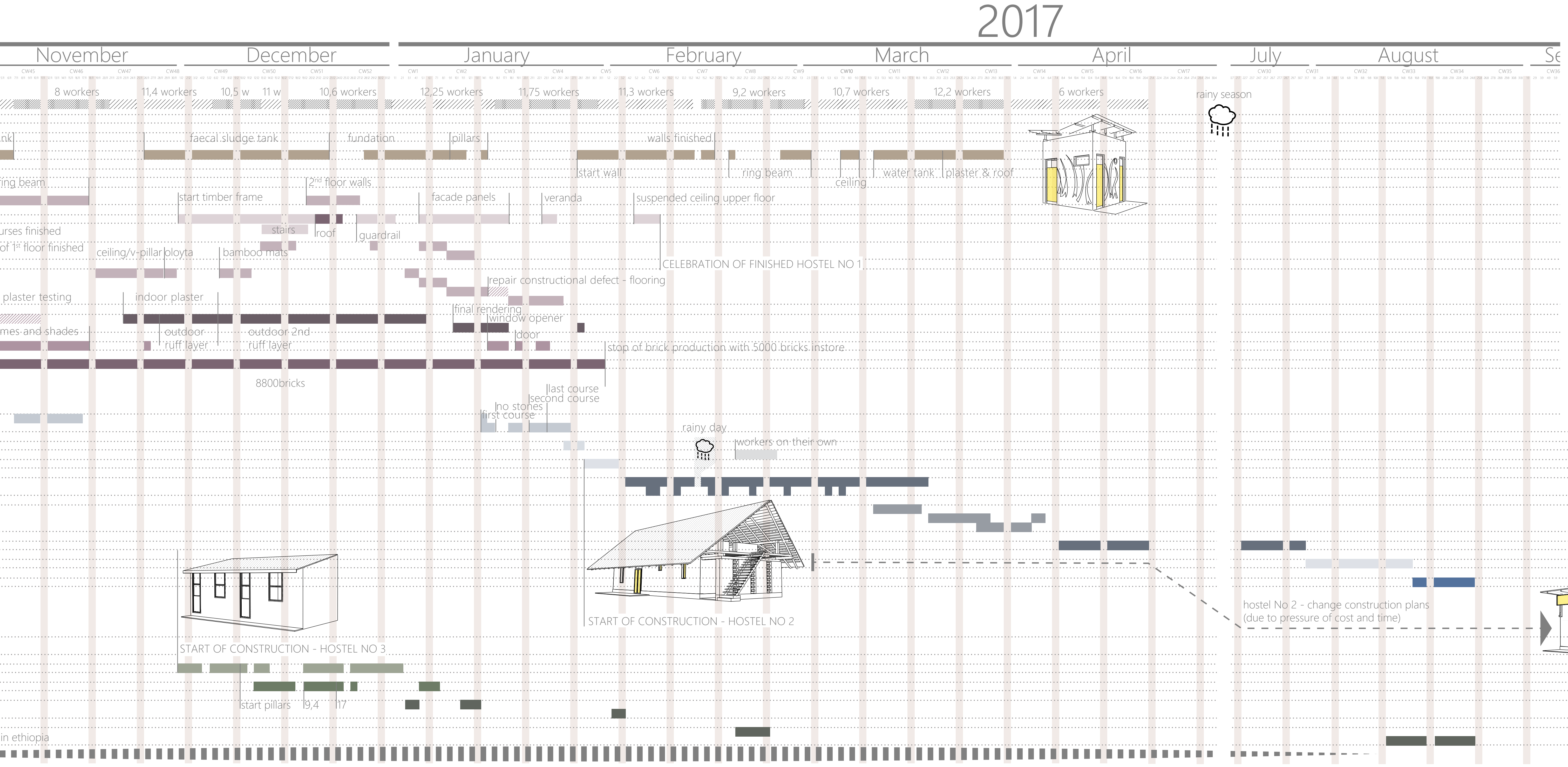
Having a water supply on the site is equally important for each of this construction processes. Since the public water supply is less reliable and, in many cases, there is no direct waterpipe connected to the site, it is important to have a water tank on the construction site, either only for backup or even as primary water supply that has to be refilled every day. As for the kindergarten-project we didn't have any direct water supply to the construction site in the beginning and had to transport the water in tanks on donkey carts every day to refill the onsite water tank. Later an agreement with the nearby mosque was reached, to pay them for a connection to their own water pipe, until we got connected through our own water pipe to the public water supply.

The sanitary house

From December 2016 to March 2017 also the sanitary house (fig 99.1 - fig. 99.6) for the whole complex erected. The small building, that houses two toilets and two shower rooms, with a water tanker on top, also fell under our responsibility and was erected by the two of the professional workers from our team. The faecal sludge tank was built in two weeks in natural stone masonry with a reinforced concrete ceiling that covers it. The building is designed to feature the same reinforced concrete frame structure as hostel No 3. A ring beam on the bottom, four pillars and a ring beam on the top form the basic structure. The wall infill is concrete bricks. The water proximity and the function of the house made the choice, not to use earth building techniques, clear.

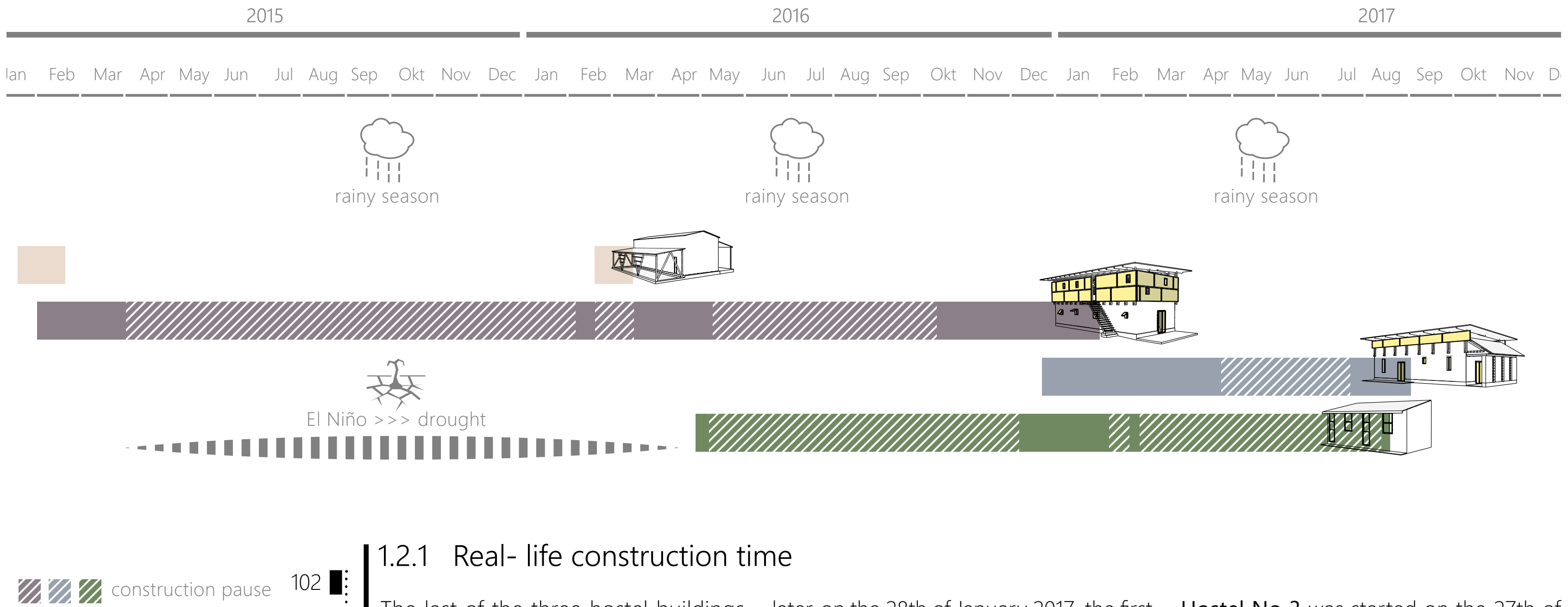
CONSTRUCTION SCHEDULE


construction schedule
2015
2016
January
Febuary
March
April
May
February
March
April
May
Oktober
house 1
1-9 volunteer workers
rainy season
5 workers
6 workers
11 workers
rainy season
6 workers
8 workers
research, planing, organisation
clay testing
addis
research trip to the south
weather proofing
new shed roof (for permantent use)
rainy day
rainy days
rainy day
excavation
shed roof
fundation
excavation
masonry work
tear down rain-damaged wall
change rain-damaged bricks
wall tear down
masonry work
wall construction
renew Visa
malter testing , teaching masonry
testing mortar training
12 courses finished
12
continue construction walls
upper floor timber frame and facade
1st floor
sub layer
finishing layer
2nd floor
subconstruction
2nd layer
3rd layer
last layer
flooring
drought (no water on the site)
1st layer
fine layer
plastering
rainy day
START OF CONSTRUCTION - HOSTEL NO 1
windows, doors, shade roofs, electicity
windows fra
brick production
2000 bricks finished
4100 bricks
house 2
excavation
mason work
fundatin
building formwork
prototype wall, material test
1st floor
windows
wall
pillars
ringbeam
acarde
concrete structure
upper floor
roof
plastering
prolonged drought because of El Niño (even in the rainy season nearly no rain)
house 3
excavation
mason work
fundatin
pillara
mason work
wall
timber
corrogated iron
roof
inside
outside
plaster
09.10.2016 declare state of emergancy



1.2 Time of construction

For a proper comparison between the construction times of the three distinct construction processes and a better understanding of the time periods, a comparison of the real-life construction time (time from construction start to the finished house), the actual construction time (time were construction work took place), and an idealized construction time (idealized time, with an already well-established and -trained team and no rain damage) must be drawn.
While the real-life construction time shows the time period the particular houses were under construction, the actual construction time excludes the big pauses in construction work that were planned because of the rainy seasons or other reasons.
An approximately idealized construction time can show how long it would take to build the houses with an already well-established and well-trained team and exclude any unexpected construction pausing due to unexpected obstacles, broken supply chain.



1.2.1 Real- life construction time

The last of the three hostel buildings was completed nearly two and a half years after the ground-breaking for the first house (fig. 102.1). 31 months after the first testing were done, the first children could move in.
Hostel No 1 was started on the 6th of March 2015 and set the starting point for the whole complex. 23 month (694 days) later, on the 28th of January 2017, the first hostel was finished, after some sloppy parts of the final rendering were redone.
Hostel No 2 was started on the 14th of January 2017 and finished in the end of August 2017, after a redesign had to be done, due to resource and time management. The building was under construction for 7.5 months (226 days).
Hostel No 3 was started on the 27th of April 2016 and was finished 15.5 month (463 days) later, in August 2017. Even though this hostel was built from regional standard materials and not weather dependant, there were several construction breaks.

1.2.2 Actual construction time

While the hostel buildings were up to 23 months under construction, the actual construction time differs from that time span a lot. Even though a lot of the planning work has been done before starting the construction, there also had to be done a lot of planning during the construction period.
Planed construction breaks, because of visa restrictions, rainy seasons or personal time management reasons of the construction management team are excluded from this time calculation. After all the construction management team of the earth building houses had to do the work in conjunction with their regular academic studies and/or Job.

Testing and preparing period

Before starting the construction process the construction site needed to be chosen and preparation und testing of the material for the brick production had to be done. This included finding a team of workers for the construction process, preparing the manufacturing space for the brick production, making the first bricks in different compositions of sand and clay and a trip to Addis to test the compressive strength of the adobe in the laboratory of the Ethiopian institute of Architecture, Building Construction and City Development (EiABC).

Construction period hostel No 1

The hostel was for 96 weeks under construction, of which the construction works were on hold for 64 weeks. For the first hostel construction break were particularly long, because in 2015 Schönher finished her master thesis and APDA had to prioritize finance and labour resources due to a drought crisis in 2015 and 2016.
Excavation and foundation took five weeks to finish. In the first construction phase in 2015 two brick courses were finished in six days. Which had to be removed when the construction continued in February 2016, due to rain damage. In this period the base work for the whole complex was laid. But this early construction phase also

was particularly often interrupted due to unforeseeable circumstances, especially, when you, for the first time, shoulder, on your own, the whole construction management in a country like Ethiopia. Beside the lecturing and training, parts to prepare and educate the team of workers, there were interruptions, due to a 12-day waiting period for a visa in Addis, a 9-day-wait for a car transportation, six days of driving between Addis and Logia and seven days because of illness.

In the second construction phase from the beginning of February to the beginning of May 2016. 12 courses were finished in six weeks. The shed roof was retracted and since it was decided to build it for permanent use as common space, a stone foundation was built as well. Foundation, timber construction, roofing and flooring took three and a half weeks to finish. Several rainy days and a drought, that led to the absence of running water on the site. During the final construction phase the last five courses of the ground floor could be finished in two weeks. Three more weeks were required for the ring beam, the ceiling and the upper floor wall. So overall 14 weeks were used for the adobe masonry work of the house. Parallel to the masonry work of the ground floor, the window and door frames were prepared and build in. Plastering took eight weeks. While simultaneously the timber frame of the upper floor was erected, the roof and the stairs were built, and the flooring was done. In the last week the finishing layer of the flooring was done, some spots of the finishing layer of the plaster were renewed and small finishing work like building lamps, shed roofs on the verandas and a suspended ceiling in the upper floor room, were done. The last construction phase was not interrupted by rain or rain-damage of any kind, which would make this timeframe way more suitable for the construction of an earth building house. It would be ideal to start the construction work in October after the rainy season *karma*, or, if necessary, because of a bigger house, prepare the foundation and maybe brick production before the rainy season and start with the masonry in October.

Concluding the first house, the actual construction work of the essential work steps, without any interruptions, were:

| 5 weeks (32 days) for the foundation and excavation,

| 11.5 weeks (69 days) for masonry, ceiling and ring beam,

| 8 weeks (59 days) for plastering, carpentry and flooring and

| 1 week (6days) for finishing work.

This sums up to 25.5 weeks (153 days) of true construction time, excluding the big construction breaks.

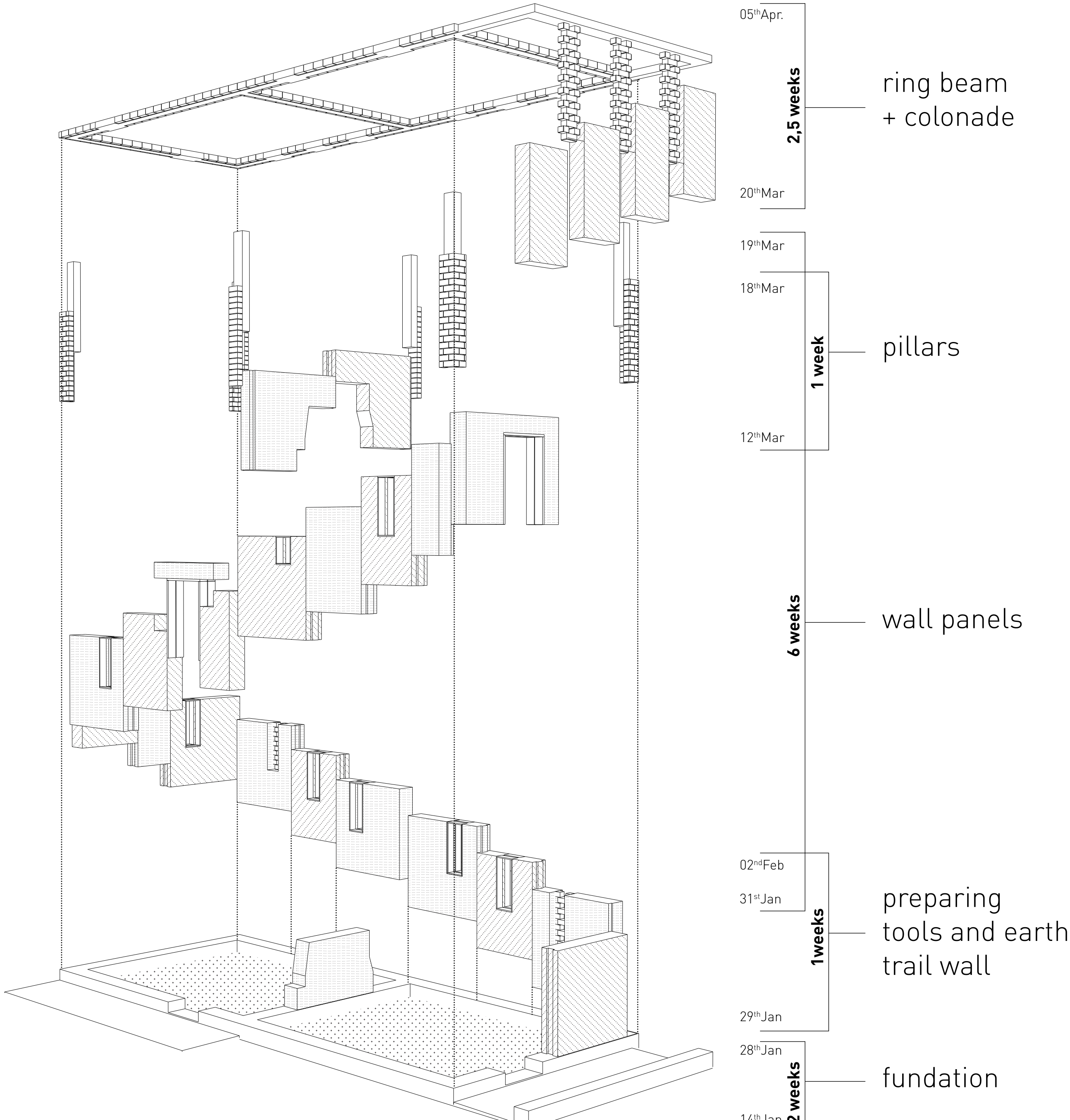


fig. 104.1 | diagram of the construction process of the rammed earth wall

104.1

Construction period hostel No 2

By the time the construction of the hostel No 2 started, the construction site already was established, and a lot of preparation and organisation work already was done. So, it was much easier to start the construction process. The separation of responsibilities between APDA and the site management team, the relationship with construction material suppliers, the storage and the team of workers were already established. Water supply was accomplished as well. The quality of the local available clay was already tested and approved. A large part of the preparation process was already done.
The construction of the foundation started on the 14th of January 2017 during the finishing work of the first hostel and was finished at the end of August 2017.
The local mason, who already built the faecal tank for the sanitary house as a lead worker with three other workers from the team, built the foundation, during the other worker finished the construction of hostel No 1. After two weeks the last of the three courses were finished. Due to a lack of supply of stones, the masonry of the foundation had to stop for two days, where the mason continued working on the sanitary house. Building the framework took two days. One week after finishing the foundation, the first prototype wall was finished and testing of material was done well enough to start construction.
The construction of the ground floor walls was in the following six weeks. Several small interruptions occurred due to rain, rain damage, flaws, and required repair work.
The pillars and ring beam were started during in the last week of wall construction and finished two weeks after the walls were completed. The beams for the ceiling and the V-pillar in the rooms were done in three days. During the construction phase of the upper floor earth walls. The decision was made to cancel the upper floor for now and finish the roofing as soon as possible. The Roofing was finished in mid-August 2017 after some interruptions due to rain.

Concluding the second house, the actual construction work of the essential work steps, without any interruptions, were:

- 2 weeks (12 days) for the foundation,
- 1 week (6 days) for testing and preparing the formwork,
- 6 weeks (36 days) for the rammed earth work and pillars,
- 2.5 weeks (15 days) for ring beam and
- 7weeks (42 days) finishing, ceiling, 2nd floor wall, roof and plastering

This sums up to 18.5 weeks (111 days) of actual construction time, excluding construction breaks.

Construction period hostel No 3

In April 2017, the foundation for the hostel building was finished after the first 2 weeks of being under construction. When construction of the first hostel was paused due to the rainy season, the Construction of this hostel was also stopped and only restarted in the end of November 2017. Ring beam and pillars were done in four and a half weeks and brick masonry was done nearly simultaneously in three and a half weeks and finished on the 7th of January. The roof was finished one week later. In between the several layers of inside and outside construction breaks appear. Three and a half weeks were needed for the last finishing like plastering, doors and windows.

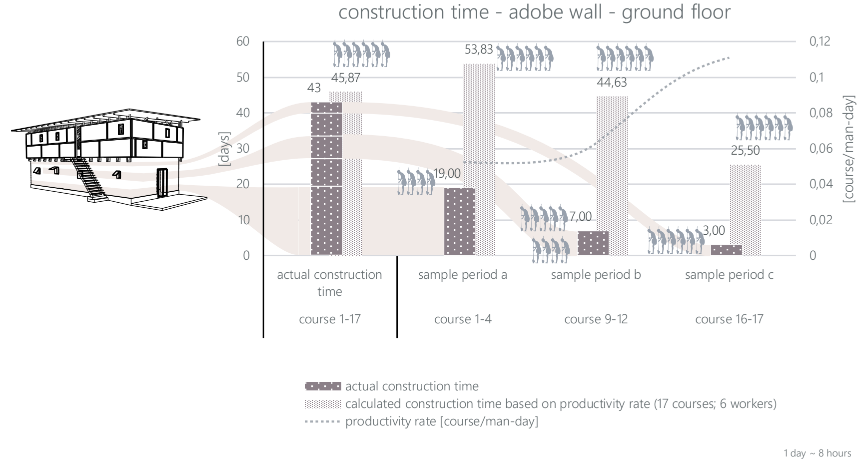
Concluding the third house, the actual construction work of the essential work steps, without any interruptions, were:

- 2 weeks (12 days) for the foundation
- 6 weeks (36 days) for concrete frame and masonry and
- 3.5 weeks (21 days) for finishing work

Therefore, the actual construction time is 11.5 weeks (69 days).

In the end of August, the whole complex was ready for students to move in. Three hostels, a sheltered common space, space for a kitchen in the old bakery building and sanitary house were finished.

fig. 106.1 | diagram based on calculations of efficiency of masonry work of the adobe house



Sample period a - course 1-4:

4 [courses] / 19 [days] / 4 [workers] = 0.05 [courses / man-day]

Sample period b - course 9-12:

4 [courses] / 7 [days] / 9 [workers] = 0.06 [courses / man-day]

Sample period c - course 1-4:

2 [courses] / 3 [days] / 6 [workers] = 0.11 [courses / man-day]

106.1

1.2.3 Ideal construction time

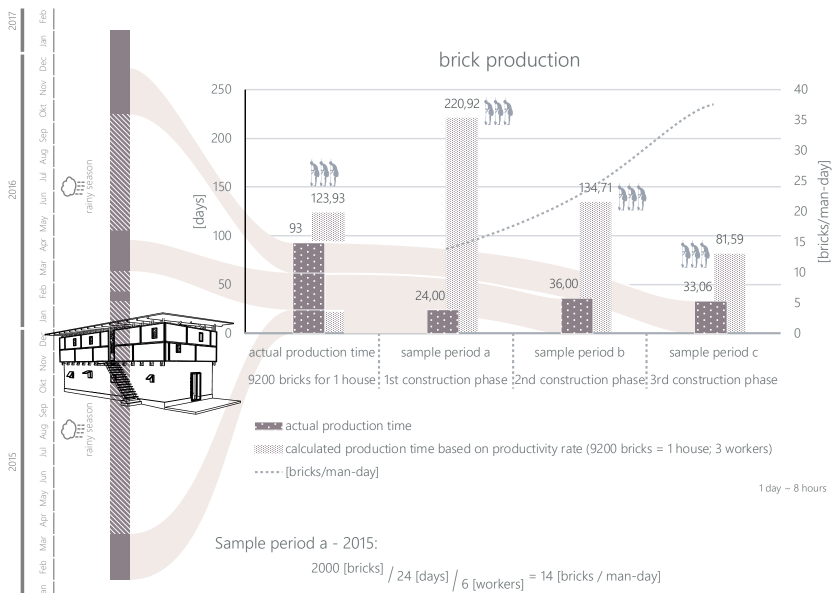
For calculating the ideal construction time, the phases where the workers were already good skilled and operating well together was taken and interpolated on the respective building processes. The foundation will not be included, since it is nearly the same on all three houses.

Hostel No 1

Masonry work of the first four courses only could accomplish a productivity rate of 0.05 course/man day, while the courses from 8 to 12 already increased the productivity to 0.06 course/man-day and the last two courses (16 and 17) could reach a productivity rate of 0.11 course/man-day. Comparing the calculated construction time of the most efficient work period (course 16 and 17), based on 17 courses and 6 workers - 25.5 days - to the actual construction time, recalculated based on 6 workers, 46 days, shows a time-saving of 20.5 days, which is nearly 45% less construction time (fig. 106.1). Changing the complex corners reinforcement system to reinforced concrete pillars, would reduce the construction time of the walls even more (about 5-10% estimated).

The comparison between the three brick production periods during the three construction phases of the hostel, does show how efficiency has been increased. Practice, training and coordination of the work flow could improve the productivity rate, but also changing the mould from a 3-brick-mould to a 6-brick-mould, in the last construction phase, could increase efficiency. In the first construction phase 2000 bricks were produced, in 24 days, which leads to a brick per man-day rate of 14. During the second phase of 31 days another 4100 bricks were produced. The brick/man-day rate in that period was 23. In the last construction phase 8800 bricks were produced in 78 days, which lead to an average of 38 bricks per man-day. With the efficiency rate, that was accomplished during the last construction phase three workers would produce the 9200 bricks necessary for the hostel building in 81.6 days, while the actual production time, when estimated with constantly three workers would only reach 123.9 days (fig 107.1). That shows a decrease in production time of about 34%. The construction site shows a general increase in work efficiency during the respective earth construction works of about 30%. Beside the masonry and the brick production, also the clay plastering work and flooring did increase efficiency at about 20%-30%.

fig. 107.1 | diagram based on calculation of efficiency of work of brick production



Sample period a - 2015:

2000 [bricks] / 24 [days] / 6 [workers] = 14 [bricks / man-day]

Sample period b - spring 2016:

4100 [bricks] / 31 [days] / 6 [workers] = 23 [bricks / man-day]

Sample period c - autumn 2016:

3730 [bricks] / 33 [days] / 3 [workers] = 38 [bricks / man-day]

107.1

Due to the improvements in productivity an idealized construction time summed by:

| 1 week (6 days) for the foundation

| 4.25 weeks (25,5 days) (fig. 106.1) masonry;

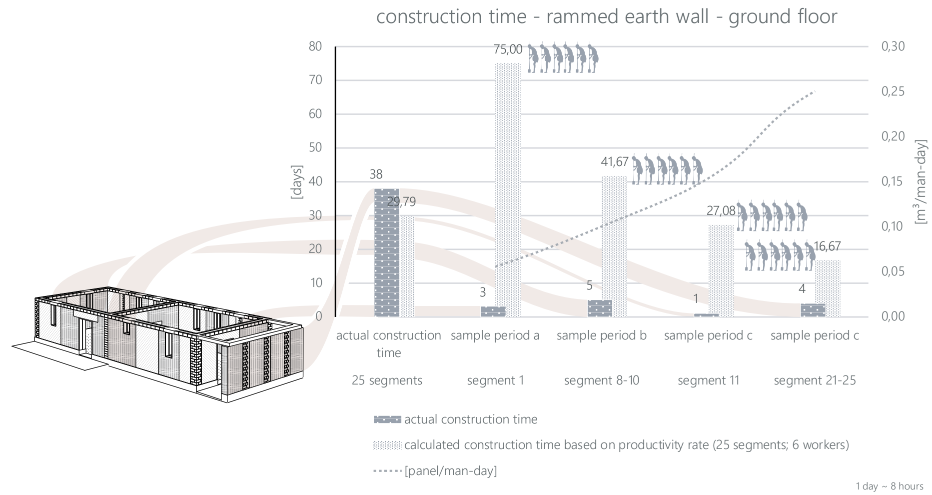
| 6.5weeks (39 days) plastering, carpentry and flooring,

| 1 week (6 days) finishing work

of 12.75 weeks (76.5 days) can be estimated.

This estimation does not include the fluctuation in labour force, but only should reveal the difference between the actual the construction works with an already established and well-trained team and an untrained unprofessional team of construction workers who needs to be trainted in the first place.
Compared to the actual construction time of 25.5 weeks this 12.75 weeks of ideal construction time is and improvement of 50%. When comparing the ideal construction time of the different buildings the additional upper floor room, which adds to the over all construction time, must be considered. The idealized construction time per living space square metre would be 1.04 days, when including the upstairs room.

fig. 108.1 | diagram based on calculations of efficiency of work of the rammed earth walls



Sample period a - segment 1:

1 [segment] / 3 [days] / 6 [workers] = 0.06 [segment / man-day]

Sample period b - segment 8-10:

3 [segment] / 5 [days] / 6 [workers] = 0.10 [segment / man-day]

Sample period c - segemnt 11:

1 [segment] / 1.3 [days] / 5 [workers] = 0.15 [segment / man-day]

Sample period c - segemnt 11:

4 [segment] / 4 [days] / 4 [workers] = 0.25 [segment / man-day]

108.1

Hostel No 2

On the 2nd hostel building a strong increase in productivity can also be seen. The efficiency rate went from 0.06 wall panels per man-day for the first segment to 0.25 wall panels per man-day. The estimated construction time for the ground floor walls is 17 days (fig. 108.1) and therefore 13 days (-43%) lower than the calculated actual construction time would have been with six workers.

Since in the end, the upper floor wall wouldn't have been needed, because of the changed plans, the wall can be excluded from the calculation. Also, the testing period can be reduced by about 50%.

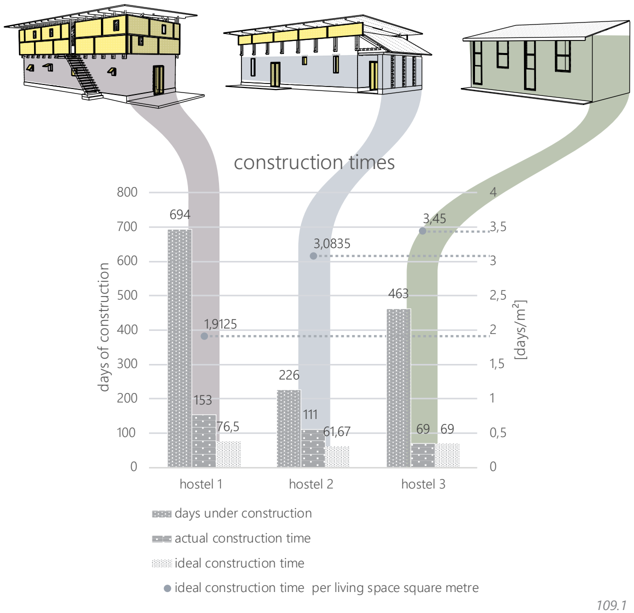
The sum of reductions:

- 1 week (6 days) for the foundation
- 0.5 weeks (3 days) -testing
- 2.77 weeks (16.67 days) (fig. 108.1) - wall segments
- 2 weeks (12 days) - ring beam
- 4 weeks (24 days) - plastering

leads to a calculated ideal construction time of about 10.3 weeks (61.67 days).

Hostel No 3

The idealized construction time of the 3rd hostel equals the actual construction time. Because the third hostel already was built by professional workers and no additional training for the workers was necessary. The house was erected in 69 days by two professional workers.



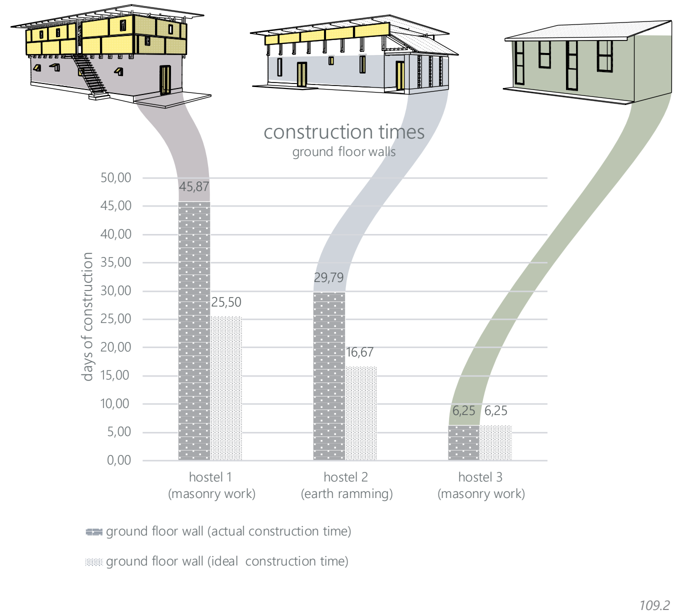


fig. 109.1 | construction times of the three construction techniques in comparison

fig. 109.2 | construction times of the groundfloor walls in comparison

1.2.4 The three different main construction methods in comparison

Even though the three houses are fairly similar in floor plan sizes and structure, a comparison is still hard to draw, because additionally, to the inequality of work force professionality and the additional floor of one hostel, the three houses do also hold up to different levels of architectural ambitions. From the choice of materials to the degree of custom designed construction details and general execution standard ,there were differences, especially between the earth construction buildings and the contractor erected building.

For more detailed and comparable data, a comparison between only the main constructional element, the load bearing ground floor walls, was made. It seems to be the way to generate the most meaningful data for the local construction businesses, that will first and foremost look at cost and construction time, when choosing the main construction system.

The productivity rate is used to have comparable numbers. Since the workers and on the earth construction houses constantly improved their own productivity. The actual construction time was recalculated with an average productivity rate of all the different construction phases, so that a comparison with a 6-workers construction time can be drawn.

With the productivity rate constantly improving, for the adobe house and the rammed earth wall house about 45% each, the productivity rate of the cement brick house still couldn't be reached. The walls of the cement brick house including the pillars were erected by two to three professional workers in 15 days, which led to construction time of 6.25days for six workers and is still 10 days less than the rammed earth wall house.

The masonry work for the adobe house is about four times as time intensive as the masonry of the cement brick house. This is due to some different factors of which some can be optimized to reach lower construction times. For one the corner reinforcement in the adobe house is imbedded in the joint of the brickwork. To simplify the corners the reinforcement could be executed in the same was as on the rammed earth house, where the reinforcement was concreted after the walls were finished, or even like the cement brick house in concreting first the pillars and executing the masonry as infill in between the pillars. Secondly, the clay masonry is by its nature more work intensive. It's important to cram the joints with mortar properly which is more time intensive than working with cement-based mortar. With this point there is also not really a big opportunity to optimize the construction time, apart from a regular optimisation due to work routine. Third, the brick size and brickwork does require way more bricks than the brickwork of the cement bricks. While the single-raw brickwork of hostel No 3 only needed 2200 brick for the nearly three-metre-high walls the brickwork of hostel No 1 required 9200 bricks for its 1.8-metre-high ground floor walls.

1.3 Labour expenses

| Salary cost in Ethiopia:

It's difficult to set standard mean workforce expenses for Ethiopia. Construction workers nearly always are independent freelancers.

Sometimes they unite in small independent teams and sign together a contract for work and labour for a specific part of the construction. For example, for the sludge tank of the sanitary house two professional workers were contracted for ETB 13 260, - (about € 552.50). This can lead to higher productivity rate, because workers decide on their own how many men they need and, the longer the construction process lasts the less becomes the wage rate. But this model is also baring a lot more risk for the workers.

On bigger construction sites contractors often only offer daily jobs, which are divided in different skill level and wage groups. Unskilled workers that are only hired for hewing stones or screening sand do earn about 70-80ETB/day with more skilled workers earning up to 400ETB/day (informal interview with Hummed Abdu Hummed in March 2015).

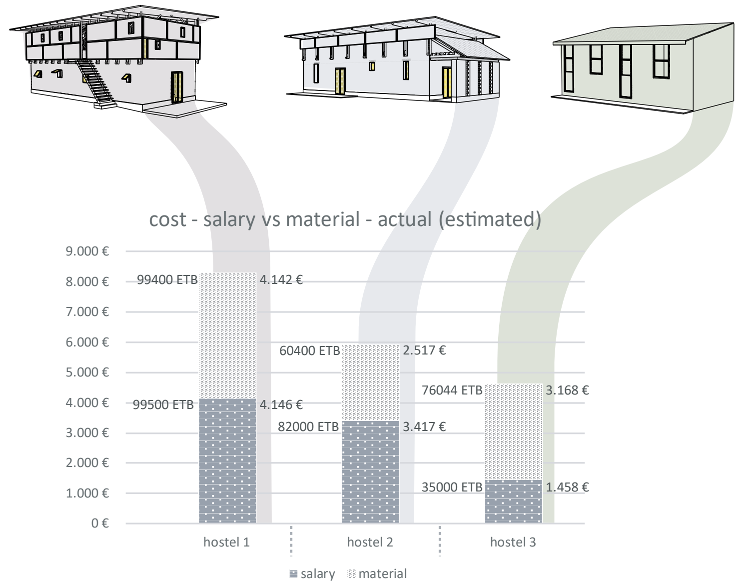
On our construction site in the beginning the workers weren't payed at all, the construction site was only seen as a training course. In the beginning, many workers were only working only temporary on the site - for two or three days a week – and on another site for the rest of the week, to earn the money to sustain their living. Later it was decided to pay the workers a basic salary, because on one hand there were also a lot of work steps on helpers level - highly demanding in terms of physical exertion, but less demanding in terms of construction skills - and on the other hand, it is generally difficult in countries like Ethiopia, with such high unemployment rates, where people are constantly looking for money to earn to support their families, to find people who work for free. When more professional workers joined the team a new discussion on salary arose and it was decided to have three different wage categories. For the cost estimation a median wage rate of 115 ETB was chosen. This is set fairly high, because our intension was to train a team in which every worker is skilled in each step of the construction process.

When going forward and establishing a business, thoughts should be given on the different construction steps and if or how it is possible to hand over certain construction steps to lower skilled and therefore cheaper labour.

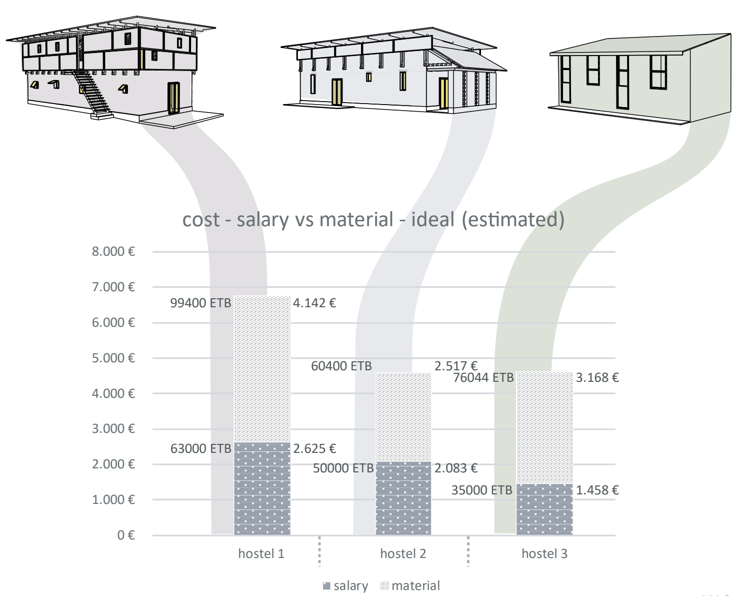
Because of the different contracts in appointments on the construction sites it is not possible to draw a direct comparison in labour expenses, but estimations of the construction cost and construction times show that labour expenses are generally higher on the earth construction hostels. Comparing the salary portion of the actual construction cost shows, that the adobe brick house has 180% higher expenses for salary as the cement brick house and the rammed earth house has 135% higher expenses for salary as the cement brick house. Nevertheless, when comparing the estimated ideal construction costs, which were calculated with higher efficiency rates due to a higher profession level, the work expenses of the adobe house decreases to 80% more than of the cement brick house and the expenses of the rammed earth house decrease to only 45% more than of the cement brick house.

fig. 111.1 | actual construction costs of the buildings - share between salary and material

fig. 111.2 | ideal construction costs of the buildings - share between salary and material



111.1



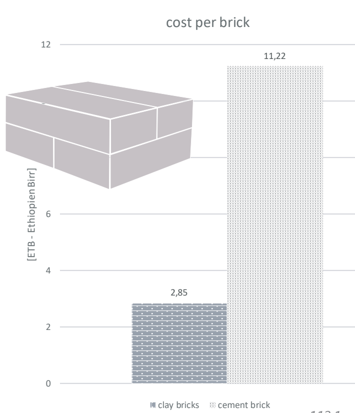
111.2

1.4 Construction cost

A direct and meaningful comparison of costs between the three houses is difficult, because on one hand there are huge fluctuations in construction time, productivity, salary, on the two earth construction buildings and between the three houses the degree of quality in execution also differs a lot. On the other hand, also the additional timber construction of the second floor and the prepared ceiling for the earth construction building do add up to the cost of this houses. Additionally, some of the costs of the cement brick house were not accessible in the timeframe until this work was finished. Both two earth building constructions were planned with additional second floor and executed with a load bearing ceiling and therefore the cost for more material would account into the construction cost of the whole building. There are also many variables that will influence the construction price. There is a general currency fluctuation that affects inflation *(Schönher 2015)*. Even over the course of the construction period of the hostel buildings the inflation was noticeable. From April 2017, the in Logia until April 2018 the exchange rate changed from 1€ = 24ETB to 1€ = 34ETB. Additionally, to the hardly predictable Inflation rate the prices in Ethiopia and even more in economically weaker regions like the Afar Region prices often also regionally can fluctuate depending on *"availability, tradesman, negotiations, seasons and bulk purchases of large enterprises" (Schönher 2015)*.

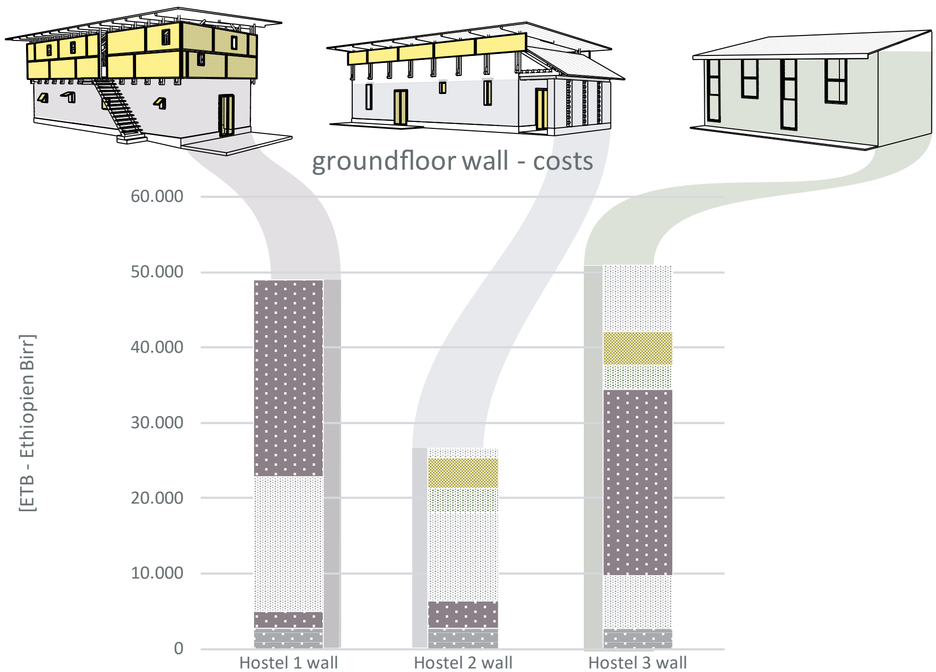
Two different calculations of the construction costs of the three different houses were done, but these calculations must be seen only as ruff estimations, because some parameter had to be estimated and others extracted from the calculation as good as possible. One estimation shows the actual construction costs of the buildings with the extraction of the cost for the sanitary house, restoration of the old bakery and the construction of the shade roofs. The other estimation is using the ideal construction times that were depicted on previous pages and in chart fig. 106.1 - 109.2, for calculation. The cost for tools like wheelbarrows, drilling machine, saws, shovels and more was extracted as well. The calculation was made with the local Ethiopian Birr prices and converted into Euro with the exchange rate from April 2017 (1€ = 24ETB). The cost of construction for the adobe construction is estimated at about 8.300€ (200.000ETB) with about 50% in salary cost and 50% accounted to materials. The cost of the seconds building, the rammed earth building, does add up in this estimation to about 6.000€ (142.000ETB) with nearly 60% accounted to salary and the rest to the materials. 4600€ (111.000ETB) account for the cement bricks construction. The estimation for the cement hostel was the most difficult to make, because the salary of the workers is not known and also the amount of cement used was only estimated. The expenses of the cement hostel also could be a little bit higher, because the missing parameter were estimated on the lower end. In the second estimation where the salary of the earth building houses is lower because a higher level of productivity is assumed, the rammed earth hostel is similar in price to the cement brick house with 4.600€ each hostel. The adobe bricks hostel shows to cost 6.800€ (162.400ETB), including the second floor.

For a more meaningful comparison of the different building systems and to compare the cost of the construction method only the most significant and cost influential construction element, the ground floor walls are calculated to give a more detailed view. Foundation and ring beam are executed similar on all three houses – only the third, cement brick house uses more cement and wood instead of a dead brick shuttering - and therefore excluded. For the comparison of the construction systems again, the idealized construction times were used. The chart in fig. 113.1 clearly shows how bricks and work are the most significant cost factors for the load berating ground floor wall. The estimated cost of the bricks also consists to two-thirds of salary expenses. The estimated price of the adobe bricks includes the raw material, sand, and the workforce expenses during production. The clay was not taken in into account because it can be taken for free from the construction site. Dividing the total cost of the clay bricks for the whole house (26 184ETB) with the count of bricks that are needed for the wall (9200) shows that the cost for one clay brick is 2.85ETB which is about one fourth of the cost of one cement brick, (fig. 112.1). Due to the calculation the adobe wall already is less costly than the cement brick wall but reducing the number of required clay bricks, by fine-tuning the size of bricks and adjusting the brickwork system, could reduce the total cost of clay bricks below the cost of cement bricks. Because of the relatively low salary expenses and no additional high matter of expanses the rammed earth wall is nearly 50% less cost intensive than the cement brick wall.



112.1

fig. 113.1 | cost listing of the groundfloor walls



	Hostel 1 wall	Hostel 2 wall	Hostel 3 wall
cement		1.265	8.855
shuttering		4.012	4.416
gravel		3.300	3.300
bricks	26.184		24.684
salary	17.850	11.669	6.900
sand	2.200	3.600	
reinforcement cage	2.789	2.789	2.789

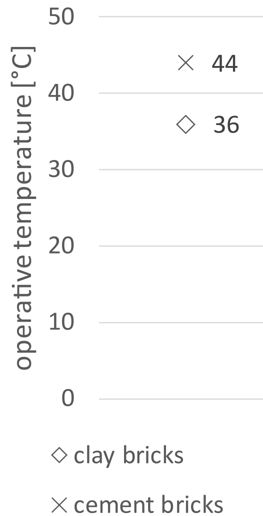
113.1

fig. 114.1 | window size and window shade of the adobe hostel in relation to the width of the wall

fig. 114.2 | temperatures measured in the adobe hostel and an cement brick house in Logia

fig. 114.3 | window openings of the cement brick house in relation to the wall dimensions

114.1



114.2

114.3

1.5 Living Quality

Comparing comfort and living quality of the three houses right now only can be done by personal experience. Measurement of humidity and temperature has been done in the adobe house sporadically and couldn't be done in the other two houses at all, because these houses were still under construction when I left.

But, never the less a vague comparison between the adobe brick house and another cement brick house, which is similar in size and in its basic fabric as the cement brick house on the site, can be drawn. In the end of march, temperatures outside already were reaching 46 degrees Celsius. Around lunch time the temperatures in the cement brick house also reached 44 degrees Celsius, while at the same time temperatures in the adobe brick house were measured at around 36°C. Which shows a fairly big difference in indoor air temperature between the two construction types.

On the site, while we were working on the rammed earth house, local people often came by to look at the already finished adobe construction. When showing them around, they always were surprised by the inside temperatures and couldn't believe how comparatively cool it was inside. They also were delighted by the materials used in the interior. While locals were very sceptical against the clay plaster on the outside (and probably also for that same reason did apply a thin layer of cement plaster on the outside after when we all were back in Austria) the locals really seemed to like the clay plaster on the interior wall surfaces. Also, the use of *senana* (Afar mats) and the *olloyta* (slatted frame) was appreciated by local people, especially by Afar people. The thermal lag due to the massy clay wall could clearly be experienced. The delay in heat transfer and seemed to be around 6-8 hours, because before going into lunchbreak the cool effect of the night-time cool temperatures reaching the internal surface of the wall and cooling down the inside air. This makes natural ventilation also is important as well. When all windows were closed during the whole night, the air temperature inside was unexpectedly high. With partly opened windows during the night, heaving the night-time air cooling down the interior, the difference became clear.


115.1

fig. 115.1 | overproduced bricks of the adobe hostel building

1.6 Impact on the ecologic and economic situation of Afar

Often Afar are forced to give up their traditional pastoral lifestyle due to ecological circumstances. Mostly it's due to the loss of their livestock or restrained range of movement due to land grabbing by commercial purpose (Chocian 2017). Even small changes to the global climate are making a great impact in sensitive areas like the Afar Region. In addition to the global climate change and the rapid growth of the Ethiopian population, the construction of large dams – apart from the largest dam project in Africa the Grand Ethiopian Renaissance Dam Ethiopia is investing in many dam projects - the deforestation will affect the future development of the Afar triangle and will most probably also have a big impact on the Afar people. Finding cheap, less recourse, energy and wood intensive construction techniques to preserve forest, might be more important for Afar people than ever. Their subsistence is relying strongly on the sensitive environment of the afar triangle.

While all three construction techniques are less wood intensive as the ch´qa technique. The cement brick house is a lot more energy intensive than the other two houses. A comparison of the used materials for the ground-floor walls only shows that the content of non-renewable primary energy for the cement brick house is more than ten times higher than form the rammed earth wall. While the materials for the cement brick house burn 8387kWh the rammed earth materials only use 620kWh of non-renewable energy, and the adobe house only comes at 22kWh of non-renewable energy.

Beside the aspect of preserving the living environment of Afar to impact their economic situation there is also the aspect of giving, especially Afar that live in urban areas, the opportunity to become involved in modern branches of economy like the construction business, which is currently highly dominated by settlers from the highlands. With the construction of the two earth building houses several Afar were trained in two different clay building techniques, thought what's important when working with clay hand how to treat the material with the different building techniques

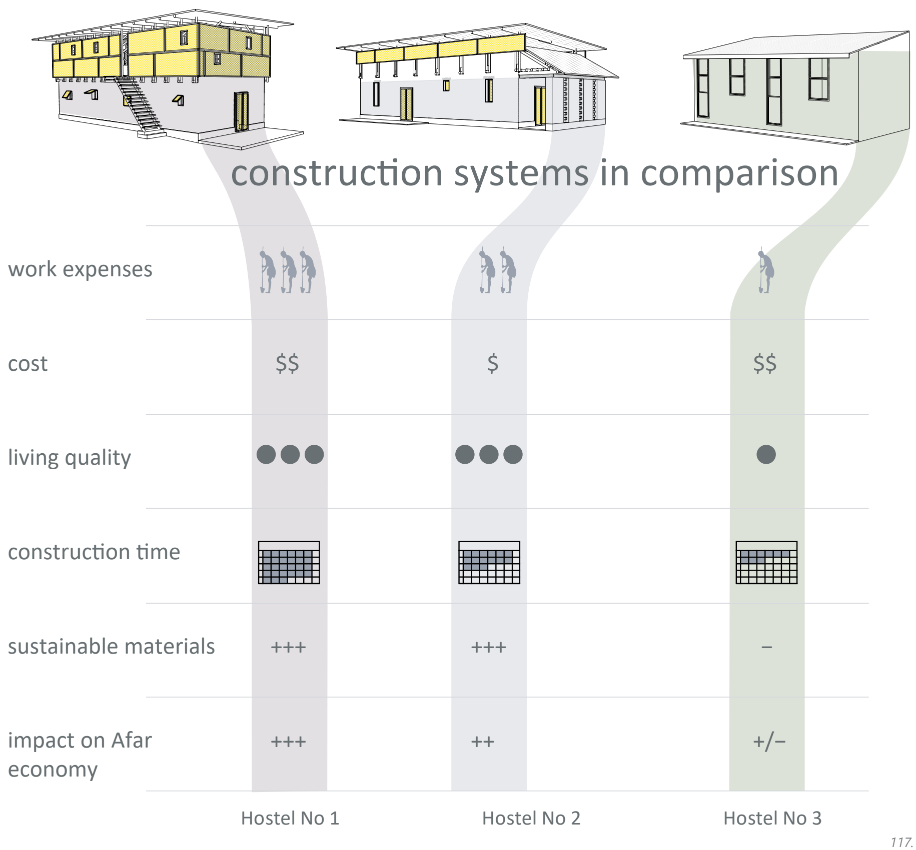
2 CONCLUSION AND FUTURE PERSPECTIVES

Each of the three construction systems does come with its own strength. While the rammed earth wall house due to the combination of relatively low labour expenses and very low material cost comes out as the cheapest construction system, the cement brick construction is by far the fastest and least labour-intensive system and the clay brick house is showing a big protentional for setting up future inexpensive brick production businesses and general opportunities for Afar people to get into the construction business.

Earth vs. Cement

Over the whole course of the construction process the potential for clay as a new cheap construction material that is additionally ecologically sustainable and can be used over and over again became clear. From discovering how universally available and easy to process clay is, to the first material tests, from the discovering of the good quality of the clay material, to the reactions of the local people to the finished house and the interest in the construction process, we were gradually encouraged in our choice for the construction material.
Reservations of local people regarding the construction material were strong. The material was neither seen as very desirable and state-of-the-art nor as a high quality. Over the whole progress of the construction works the increase of involvement and interest of locals in the construction became more and more visible. After the first year under construction students from polytechnic colleges and universities visited more often because word got spread and interest on the construction site grew. Many people couldn't believe that the same material which is used for those low quality *ch'qa* mud-houses is also used for the bricks and the rammed earth wall and that there is absolutely no cement added to the mixture. Furthermore, the workers started to engage increasingly with the material. They developed a certain pride about the material and their knowledge about it. Over time they become more confident in using it.
Finally, a constant improvement in productivity, an optimisation of the process and a gradually increased skill level of the workers were clearly noticeable.
Still, there were setbacks and problems that can be seen as opportunities to learn from. Dealing with construction damage due to rain being the main one. Construction periods that did partly interfere with rainy season, clearly weren't ideal. Of course, we already knew how critical the weather is when using clay as a main construction material. Therefore, a construction pause during the great rainy season *karma* was scheduled upfront. Still, several hundred bricks, parts of the rammed earth wall and several rows of brickwork were damaged by rain. It made clear, that also the small rainy season with only a few rainy days can be quite a challenge when working with clay in a country where temporary rain cover is difficult to accomplish and expensive. Erecting the roof up front on pillars can be one solution to the problem. Another one can be to plan the stages of construction in advance so that the main walls are being erected in the dry season *giilal* between October and February. Even though as mentioned before workers and locals in general were impressed by the new technique and building structure, breaking the mindset of cement being the superior construction material wasn't easy and to some regards it though lasted. When the construction team finished the three houses on their own in summer 2017 they again used cement plaster on the final layer - even though we explicitly told them why cement plaster is not suitable for clay constructions because of its vapor diffusion specifications. In the end the cement plaster might not do harm to the construction because of the generally low humidity in the Afar Region. Therefore, moist inside the walls shouldn't appear but it shows how deep the mindset is sitting.
After all, the construction project shows that clay is equally suitable as a construction material as cement. The material requires more expenses in labour but therefore the costs for the construction material itself are much lower. The effortless reachability and low energy consumption in processing gives it a major ecological advantage.

fig. 117.1 | comparison of the three construction processes



Adobe bricks vs. rammed earth wall

Comparing the two earth building techniques shows that each method comes with their own strong points. The rammed earth construction clearly can score with short construction times and low preparation work. The material is easier and faster to mix and the particularly used shuttering system is fast to build and easy to set up. But complexity and cost would increase fast when changing the shuttering system. The construction system is entirely new to the local people and therefore adjusting the system might be harder. In comparison working with bricks is an already established construction system. Different brickwork systems are already known and professional masons already have a good understanding of the work process. They know what they have to take care of when working with bricks. Also, the bricks can be preproduced.

So, both systems have their particular strengths but constructing with bricks might be better suited to the economic situation of Afar People, since the construction method additionally allows to build up a business for brick production.

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FIGURES