MASTER THESIS

ELEMENTARY SCHOOL IN SENEGAL

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DIPLOMARBEIT

Elementary School in Senegal
Grundschule in Senegal

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ABSTRACT

Deutsch

Ziel dieser Arbeit ist es, einen Entwurf für eine Grundschule in Marsassoum, Senegal, zu entwickeln. Die provisorische Struktur der derzeitigen Schule soll durch einen neuen Entwurf ersetzt werden, welcher unter Berücksichtigung und gegebenenfalls Optimierung der vorhandenen vernakulären architektonischen Traditionen einen Dialog zwischen Alt und Neu schaffen soll. Der neue Vorschlag für das Schulgebäude soll auf Grundlage einer Untersuchung der für die Region Senegal charakteristischen kulturellen und traditionellen Bauweisen, der klimatischen Bedingungen und der vor Ort bezogenen Materialien sowie nachhaltiger, kostengünstiger Bautechniken entwickelt werden. All diese Elemente gelten als gleichermaßen wichtig und sollen somit in den Entwurfsprozess einfließen und schließlich umgesetzt werden. Die neu gebaute Struktur der Schule beinhaltet 7 Klassenzimmer, eine Bibliothek, Büros, Latrinen, eine Kantine, einen Obstgarten sowie Flächen im Freien, welche es ermöglichen sollen den Kindern von klein auf die Grundlagen der Landwirtschaft und des Ackerbaus zu vermitteln und sie mit Nahrung und Wissen über die Bedeutung der Ernährung für unser Wohlbefinden zu versorgen.

English

This thesis aims to develop a design for an elementary school in Masassoum, Senegal. The temporary structure of the current school will be replaced with a new design which should represent a dialogue between the old and new, respecting and taking into consideration the vernacular architectural traditions and optimizing those methods if needed. The new proposal for the school building will be developed based on a research about the local cultural and traditional building approaches, climate conditions and locally sourced materials, characteristics for the region of Senegal, and sustainable, low-cost construction techniques. All these elements are considered to be equally important and will therefore be implemented in the design process. The newly built structure of the school will contain 7 classrooms, a library, offices, latrines, a canteen, an orchard and open spaces to teach kids from an early age some basic agriculture and farming, as well as providing them with food and with knowledge about the importance of nutrition for our well-being in general.

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1. INTRODUCTION

When choosing my master's thesis, it was important to me from the start to choose a topic where the task had more potential than the design of just a fictitious building. Since I have always been fascinated by African culture, the competition announced by Archstorming and "Let's Build My School" drew my attention instantly and provided me with an incentive to take a closer look at the place, th region and the country. They were looking for design proposals for a primary school in a small town, called Marsassoum in the Casamance region of Senegal.
Education, on the other hand, has always been an important pillar throughout my life and dedicating my master's thesis to this topic, as well as addressing real problems like lacking educational infrastructure and low literacy rate, was another primary reason and motivation.

Currently in some regions of Senegal, only 50% of school-age children have access to education and if they do, in some cases classrooms are often crammed with up to 80 students per class due to limited number of structures. Despite the fact of being one of the most politically stable countries on the African continent, educational environment is still lacking and many schools recognized by the government of Senegal are often built as fragile temporary structures, which rarely survive the rainy seasons, therefore classes are being cancelled. As a result, many primary shool aged children dropout before reaching secondary education and falling victim to child labour, begging or street selling.

The design process is focussed on finding a holistic architectural response which addresses the current problems and climatic challenges of the site and builds on traditional construction methods, social aspects, sustainability and simple, low-cost techniques. The innovative proposal should act as a sample stimulating discussions and generating new impulses in the development of the educational architecture.

This diploma thesis is divided into three parts: an overall research about the country, a thorough research and analysis, presented in a 10-step workflow and a design proposal as a final outcome, based on the first two stages of the process.

“ Education is the most powerful weapon which you can use to change the world. ”

- Nelson Mandela

2. RESEARCH - SENEGAL

Fig.1: World Map

Fig.2: Administrative map of Senegal

2.1 GENERAL INFORMATION

The Republic of Senegal occupies the westernmost tip of Africa, where the continent extends into the Atlantic Ocean. It forms the transition between the Sahel and the tropical zone. The neighbouring country to the east is Mali. To the north, beyond the Senegal River, is the state of Mauritania. To the south of Senegal are Guinea and Guinea-Bissau. The country of Gambia is an elongated enclave completely enclosed by Senegal, dividing the southern tropical region called Casamance from the rather dry part of Senegal. As a result of being located at an ecological boundary, the country is endowed with a diverse environment, which is how the country's national symbols were chosen: the baobab tree and the lion. Senegal has a national territory spanning 196 712 km² and a population of approximately 16,7 million inhabitants.[1] Administratively Senegal is organized in 14 regions and the capital Dakar is located at the tip of Cape Verde Peninsula on the west coast.

1 http://www.ansd.sn/index.php, 13.02.2021

Fig.3: Map - topography and climate zones

2.2 TOPOGRAPHY

Most of the area of Senegal is a flat plain – a western segment of the broad savanna that extends across the continent at the southern ridge of the Sahara. The character of the landscape dominates by a flat expanse of sparse grasses and woody shrubs, remarkable only for the near-total absence of natural landmarks or major elevation changes. The terrain lies primarily below 100m above sea level and in the hilly southeast only a few ridges exceed 396m. The country reaches its highest level, 581m, at an unnamed point near Nepen Diakha. The Atlantic coast, washed by the Canary Current, is sandy and surf-beaten, whereas the coast south of the Saloum River consists of rias (drowned valleys) and mangroves. There are four rivers on the national territory of Senegal: Sénégal, Saloum, Gambia (Gambie) and Casamance rivers. The only lakes in the area of Senegal are Lake Guier, which is situated 64km east of the city of Saint-Loui, and Lake Retba, known as the Pink Lake which has an unusual yet vivid pink colour.[2]

2 NELSON, Harold D. et al.: Area Handbook for Senegal, Washington, American University (Second Edition), 1974, p.39

Fig.4: Map of Senegal - Amounts of precipitation

2.3 CLIMATE

The overall climate is conditioned by the tropical latitude of the country and outstands with relatively high daytime temperatures throughout the year, a long annual dry season, and a shorter wet season in the entire land. The annual precipitation increases massively from north to the south and the temperatures increasing from coast to interior. A dry northeast trade wind, called "harmattan" occurs during the dry season, roughly from November until April. It sweeps across Sahara before entering Senegal, often bringing with it fine sand that severely restricts visibility. Other prevailing winds are the moist maritime winds that bring the rains. In the southeastern areas of Senegal, the rainy season often starts in May and lasts about 6 months, whereas in the north it decreases to 3 months. Along the cooler coastal zone, temperatures are ranging between 17-27°C, in the northern Sahelian zone the temperature drops from a maximum of 40°C during the day to 14°C during the nights. Moving to the hot and humid south, the average temperature is approximately 30°C throughout the year.[3]

3 https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Change%20Risk%20Profile%20-%20Senegal.pdf, 16.03.2021

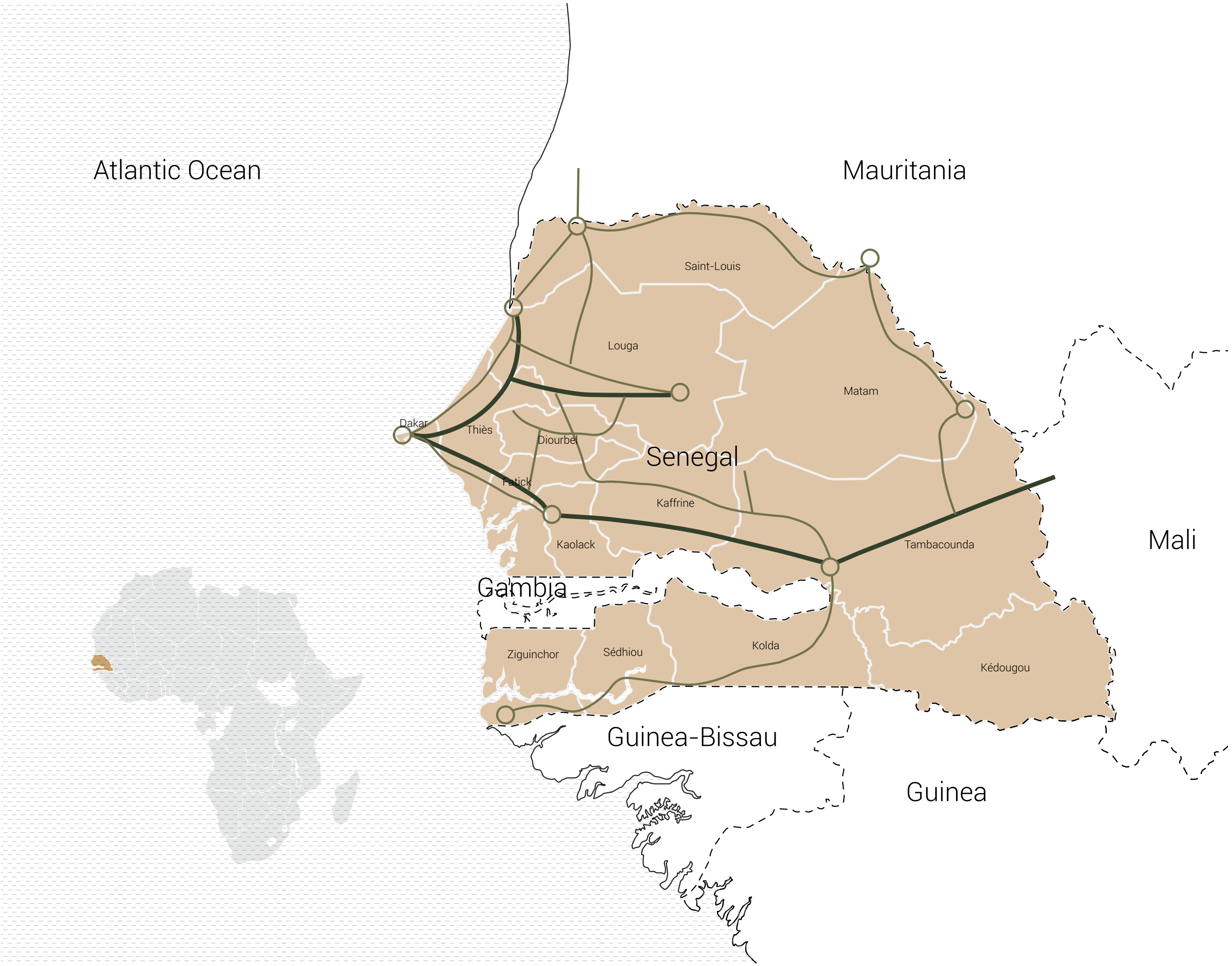


Fig.5: Map of Senegal - Infrastructure

2.4 ECONOMY AND INFRASTRUCTURE

Despite widespread poverty and high unemployment/ underemployment, Senegal's economy is considered one of Africa's most stable (IMF 2010)[4]. Senegal's economy, on the other hand, is susceptible to changes in rainfall and global commodity prices. Agriculture currently serves as the country's primary source of jobs and income, employing approximately 60% of the population. Dakar, being the commercial and administrative hub of former French West Africa due to its excellent natural port, has helped in developing a reasonably efficient transportation network and access to the West African market, which has resulted in the creation of manufacturing capacity around the port area. The economy of Senegal has historically been based on a single cash crop, the peanut. The government, on the other hand, has worked to diversify both cash crops and subsistence agriculture by diversifying into commodities like cotton, garden produce, and sugarcane, as well as supporting non-agricultural sectors. At the turn of the century, the government was effective in making fishing, phosphates, and tourism major sources of foreign exchange, though the state of the transportation and power infrastructure limited the amount of expansion possible. Mineral resources such as gold, coal, and natural gas were also exploited, which helped to diversify the economy. While Senegal's rivers provide a large number of fish, with its almost 700km of coastline, the sea remains the major provider of the catch. The outcome of several years of building up the industry, fishing goods now lead all exports in terms of value.[5]

4 http://www.tizir.co.uk/wp-content/uploads/2012/02/Tizir-Senegal-Brochure..pdf , 08.04.2021

5 https://www.britannica.com/place/Senegal/Economy , 08.04.2021

Fig.6: Roads of Casamance

2.4 ECONOMY AND INFRASTRUCTURE

Though infrastructure deficits have hindered Senegal's economy to some degree, the historical strategic location of the French occupation in Dakar has left a legacy of significant transportation and communication infrastructure in and around the country's capital. The country's transportation network has largely evolved in the western part of the country, roughly bounded by Saint-Louis, Kaolack, and Dakar. Approximately half of Senegal's vast road network is open all year. A line from Saint-Louis to Dakar, with a branch line running from Louga inland to Linguère, and a line from Dakar to the Niger River at Koulikoro, Mali, are part of the rehabilitated and extended rail system. Senegal's three seaports are Kaolack, Ziguinchor, and Dakar. Despite their limited navigability, the rivers, especially the Sénégal, have historically served as important transportation corridors. However, after the completion of rail lines at the end of the 19th century, their importance has declined.[6] Due to the flat gradients of the country, rivers can be navigated from the sea up to hundreds of kilometers inland. This also leads to distinctive connecting roads. For example, one can easily get from Dakar to Ziguinchor by boat. As we know from numerous films and photos, the common connecting roads are dusty red-brown earth tracks. Most often they are in a good condition and their laterite thickness makes them stronger and more durable than asphalt roads.

6 https://www.britannica.com/place/Senegal/Manufacturing#ref55055 , 08.04.2021

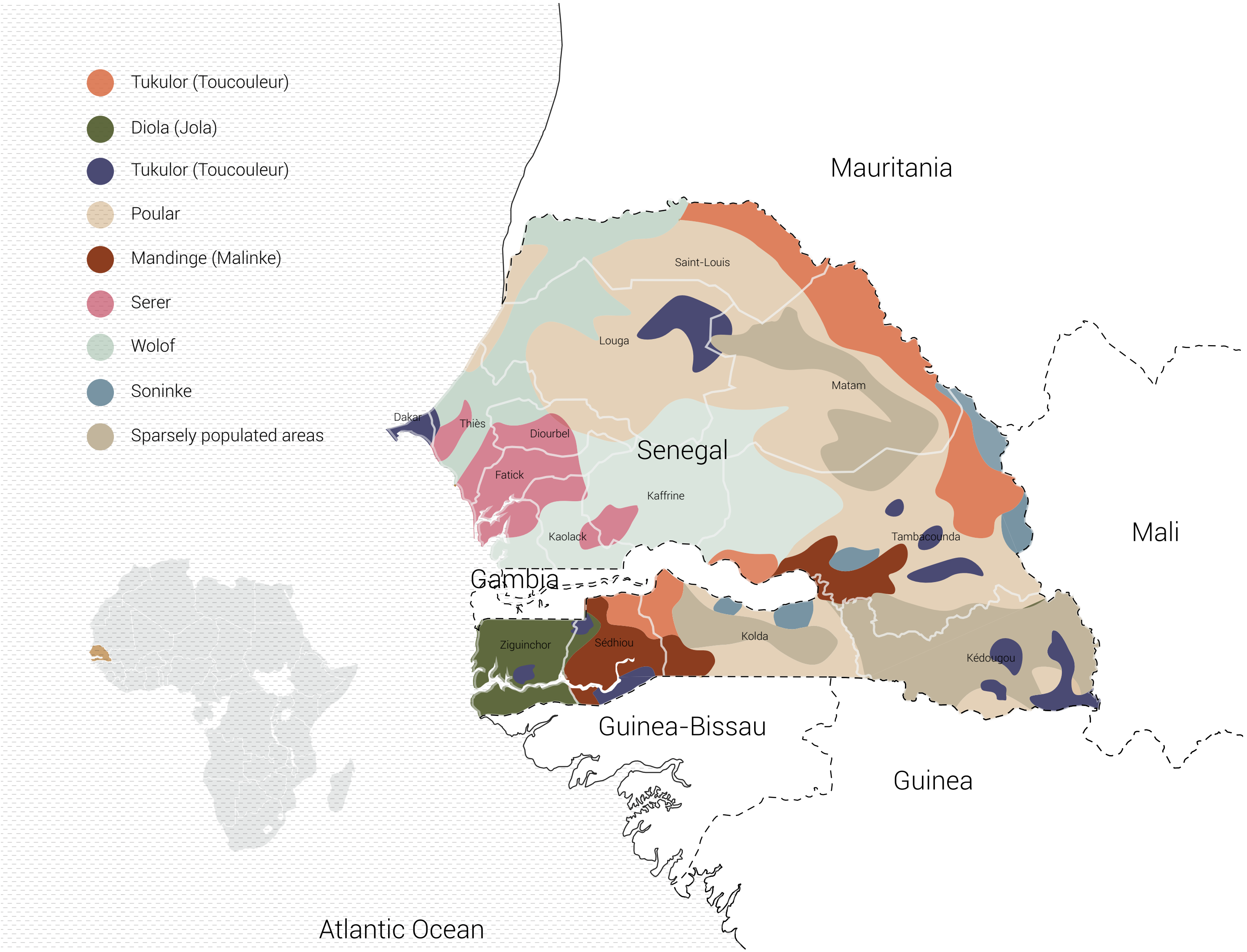


Fig.7: Map of Senegal - Ethnic Composition

2.5 ETHNIC GROUPS

The demographical structure of Senegal could be described as ethnically diverse. In spite of this diversity, there is no significant interethnic conflict, as they are largely associated with many shared customs. However, conflict persists in Casamance region inhabitated by the Diola (Jola).

Wolof
Approximately two-fifths of the population are Wolof. After French, their language is the most widely spoken in the republic. Their dominance is justified also by the fact that they are found in all the reaches of the social, political and economic orders. They are located in the northwestern quarter of the country and dispersed in the urban areas.

Tukulor
The Tukulor account for more than a quarter of the population, defining them as the second biggest ethnic group in the republic. Since the Tukulor have often intermarried with both the Wolof and the Fulani, it can be difficult to distinguish them. Their traditional domain is located around the part of the valley that is being flooded by the Senegal river.

Fig.8: Malinke people

2.5 ETHNIC GROUPS

Serer

The Serer are closely related to the Wolof and make up about 15% of the population. The areas that they are settled in, are the regions south and east of Cap Vert as well as the Saloum Islands. Many of them stick to local cultural traditions and have been slower to embrace modernizing patterns than the Wolof and other ethnic groups.

Diola (Jola) and Malinke (Mandingo)

The Diola and Malinke people make up a small percentage of the population – comprising 4% and 4.2% respectively. The Diolas represent Senegal's most isolated large group. The Homeland of this group is the fertile, well-watered area of the lower Casamance River, whereas Malinke people populate the area east of Diolas in the centre of Casamance region.
Other small groups consist of such peoples as the Soninke, who were the founders of the ancient state of Ghana. They are present near the upper reaches of the Senegal River and in the neighbouring countries as Gambia and Mali.[7]

7 NELSON, Harold D. et al.: Area Handbook for Senegal, Washington, American University (Second Edition), 1974, p.68

Fig.9: Women of the Wolof community

2.6 RELIGIONS AND LANGUAGES

Noticeably dominating among the different religious groups is the group of people identifying themselves as Muslims. Compared to Christianity which is practiced by a growing but still very small population – 4.1%, Islam makes up a vast majority of approximately 95.% of the population. Most of the Christians are Roman Catholics and only a small segment of Protestants. Senegalese Islam is characterized by its organization of various Muslim brotherhoods which are led by spiritual leaders known as “marabouts” and play a key role in political, social and economic levels. Within the larger ethnic groups, only the Serer and the Diola have significant segments still devoted and practicing indigenous religious beliefs and their members belong to small groups populated in Casamance Region and the Bassari in the remote southeast. Overall the country is characterized by its religious tolerance and the freedom of the individual religious choice protected by the Constitution.[8]
The country shows great diversity both linguistically and ethnically. Senegal is home to 39 languages among which French, being the official one, is taught in schools and used in administration.
The most widely spoken indigenous languages in the country are Wolof used by 80% of the Senegalese people and being considered as potential future national language and Manding, being spoken in West Africa by a vast majority.[9]

8 NELSON, Harold D. et al.: Area Handbook for Senegal, Washington, American University (Second Edition), 1974, p.138

9 https://www.britannica.com/place/Senegal/Languages#ref255582, 06.04.2021

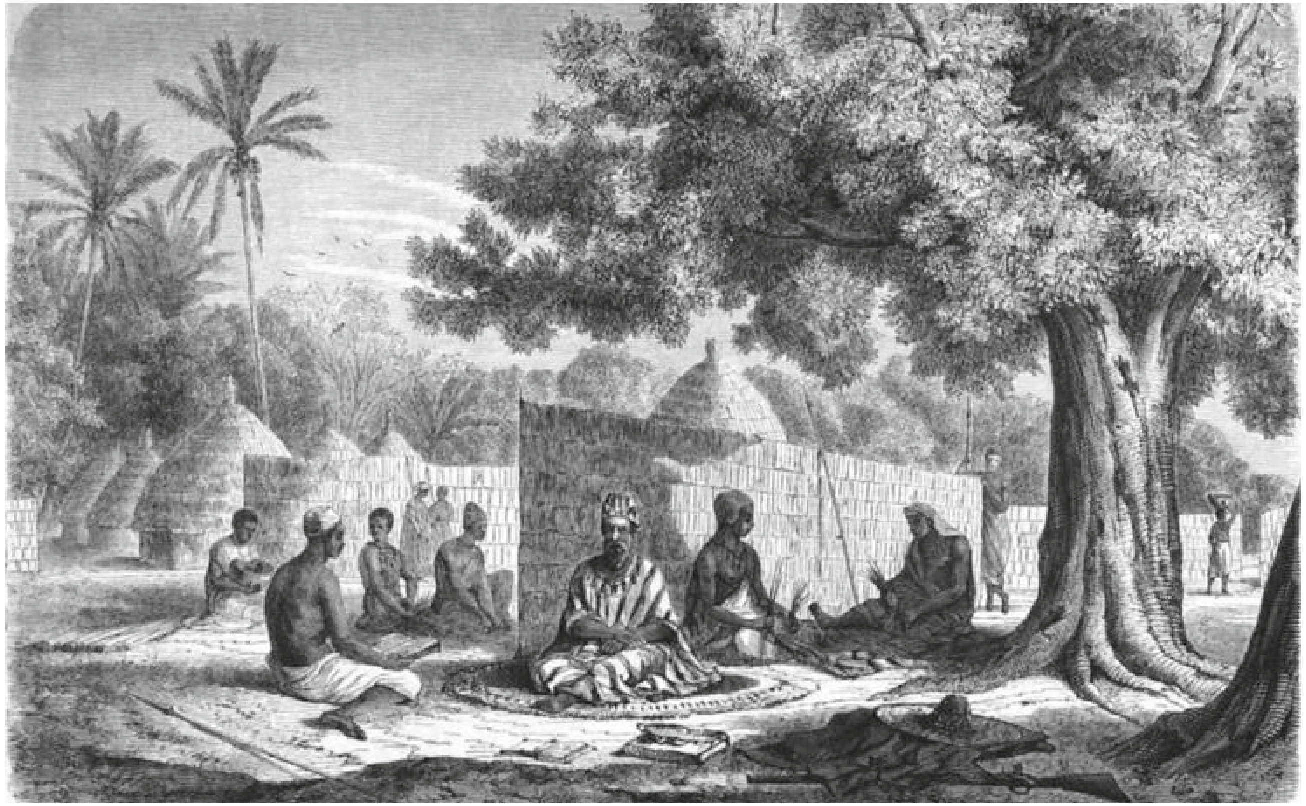


Fig.10: A Wolof chief and residence in mid-19th century CE

2.7 BRIEF HISTORICAL BACKGROUND

The history of Senegal dates back to ancient times and was influenced by several empires who took over. Paleolithic and Neolithic axes and arrows as well as pottery, wall paintings and some metal artifacts have been found in the area of Cap Vert peninsula and in the middle valley of Senegal River. The stone circles, believed to date from the 3rd century BCE to the 16th century CE, were declared as UNESCO World Heritage site in 2006.[10] In the 11th century the territory around lower Senegal River was occupied by the Empire of Ghana. Later the Manding people of Ghana broke away and formed the Mali Empire and all but western parts of present-day Senegal were in its territory. By the end of 14th century internal turbulences reduced the power of the empire and one of the former vassal states – Songhai – in turn expanded and formed an empire of its own. By the beginning of 16th century one third of the region of Senegal was occupied but not for long. After being challenged by northern groups the empire falls apart by the end of the century.[11] The Djolof Empire, which emerged at the same time as the decline of the great empires, occupies an important position. The fusion of different tribes is the beginning of one of the oldest dynasties in Senegal with the predominant colloquial language "Wolof". The area of Senegal that was occupied by the Jolof Empire was running inland from Dakar about 320 km between the basins of the Senegal River and the Gambia River. The formation is believed to have come into existence during the last haslf of the 13th century and lasted until the 16th, when the five states, that the empire was consisting of – Cayor, Baol, Oualo, Sine and Saloum, started fighting with each other.

10 https://www.britannica.com/place/Senegal/History, 16.03.2021

11 NELSON, Harold D. et al.: Area Handbook for Senegal, Washington, American University (Second Edition), 1974, p.12

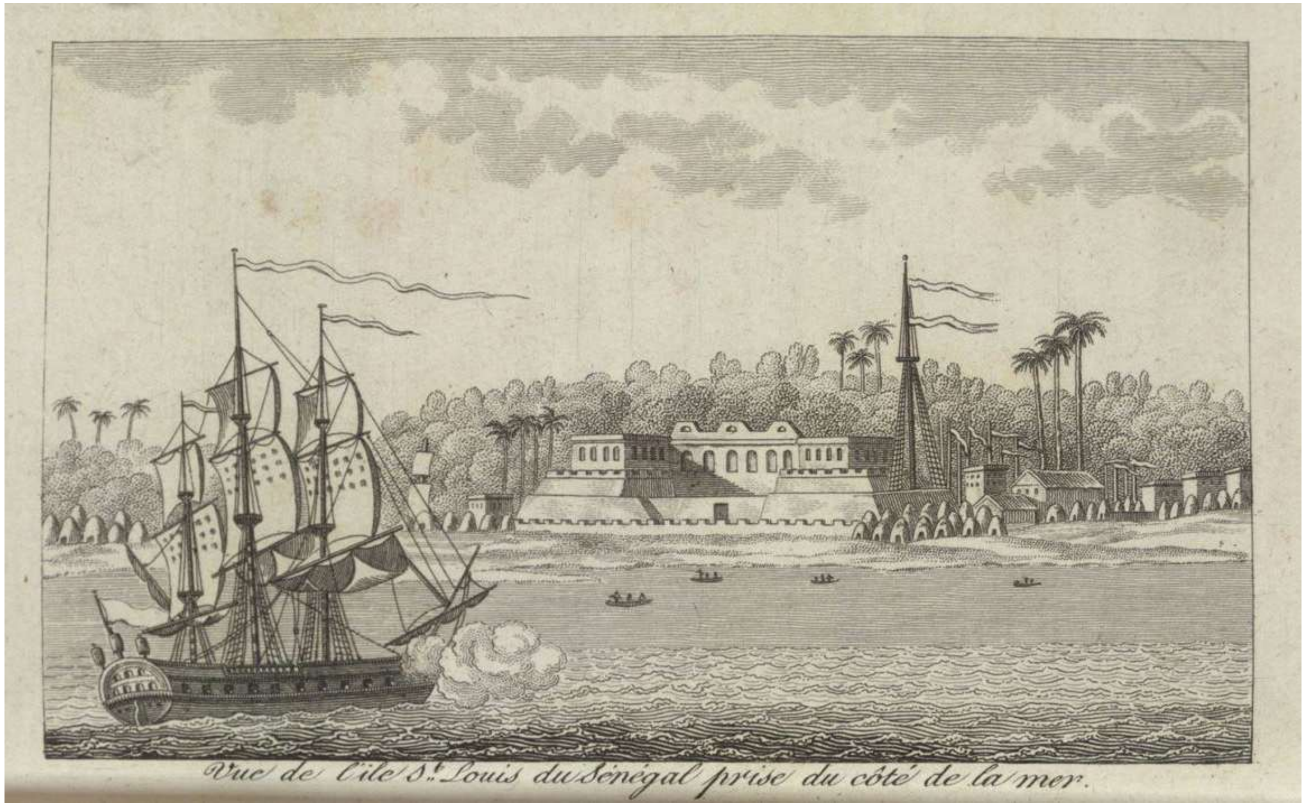


Fig.11: Saint-Louis in 1780

2.7 BRIEF HISTORICAL BACKGROUND

A turning point in the history of Senegal is considered the period from the 15th century onwards, when various European powers, including Portugal, the Netherlands, France, and the United Kingdom, fought for trade in the region. The Portuguese landed first on Cap Vert in 1544. Until the 17th century their powerful influence was superseded by that of the Dutch and then the French. The slave trade that was initiated by the Portuguese carried on and reached its peak during the 18th century. However the first acts of opposition against the imperial forces occurred at the beginning of the 19th century, leading to the abolition of the slave trade in 1807. After two periods of occupation, the British reclaim their property rights to France in exchange for the 'navigable part of the Gambia River. The French advanced inland along the River Senegal alongside the former Portuguese area of Casamance below the Gambia River, which was defined in 1886 in an agreement with Portugal. The French government approved a large program of railway construction between St. Louis and Dakar which was built during the years between 1882 - 1886. Shortly after after completion, Dakar became the most important port in West Africa and the new capital of Senegal. At about the same time the exact state borders between Gambia and Senegal were established and they are still valid today.[12] Senegalese people gradually gained more influence, and in 1914, they elected Blaise Diagne as the first deputy to the French National Assembly in Paris. Demands for the independence of Senegal grew during mid-20th century and on June 19, 1960 the independence was declared and signed 3 days later on June 22, 1960. This event marks the beginning of the end of the French Community in Africa.

12 http://www.columbia.edu/~msj42/Senegambia.htm, 16.03.2021

Fig.12: Map of Senegal - Casamance Region highlighted

2.8 CASAMANCE CONFLICT

The origins of this conflict go back a long way to when what is now Senegal was partly the territory of the Mandinga Empire of Mali. Towards the end of this empire, Mandinga clans developed in southern Senegal, Guinea and Guinea-Bissau. Another empire, the Djolof Empire, developed in the 16th century on the Senegal River and is the beginning of the oldest dynasty in Senegal. The "Wolof" population group that emerged from this dynasty now makes up the majority of Senegal's population and is opposed in Casamance to the Mandinga, who have lost their empire. In addition, Casamance had a different affiliation at the time of colonial rule. While the rest of Senegal was French territory from the 17th century onwards, Casamance, which was also geographically separated by the Gambia River, belonged to Portugal until 1886, when it was handed over to France. The conflict has been smouldering since 1982, when protesters gathered in Ziguinchor after the MFDC (Mouvement des forces démocratiques de Casamance) removed the Senegalese flag from public buildings, calling for the Casamance region's independence. The conflict breaks out between 1992 and 2001, killing hundreds of civilians in just a few weeks. In 2007 another breakout of violence results in thousands of refugees. The condition has improved after negotiations between the Senegalese government and the rebels, but the war and the MFDC's efforts are still ongoing.[13]

13 https://fas.org/irp/world/para/mfdc.htm , 14.05.2021

3. COMPETITION BRIEFING

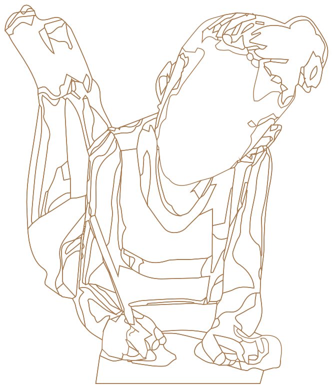


Fig.13: Cover of the competition's briefing

3.1 ABOUT THE COMPETITION

Archstorming is a company founded by two young architects and a lawyer on February 2017. The aim of the company is not only to expose architectural ideas and get solutions to many urbanistic problems but also to respond social demands and try to make a better world. The objective is to expose a minimum of three and a maximum of five architecture competitions per year, so that the interested people have the opportunity to show their ideas on a very visual and syntactic way, being as much resolutive, innovative and respectful with the matter as they can.

LBMS (Let's Build My School) is a UK registered charity, which was founded in 2016 and consists of a group of architects who believe that educaton is a universal right. Therefore their mission is building schools in remote villages across the world, yet their priority are the underpriviliged areas of Senegal, Africa.[14]

In collaboration with LBMS, Archstorming is calling for proposals to design an elementary school "Sambou Toura Drame" in Marsassoum, Senegal.

14 https://www.letsbuildmyschool.org/, 20.02.2021

Fig.14: Primary school pupils in Senegal

3.2 CONTEXT: SENEGAL

Let's Build My School commenced their activities in Senegal (where two of the charity's founders are from) in regions where only 50% of school-age children have access to education and where classrooms are often crammed with up to 80 students per class due to the limited number of structures. Senegal is ranked 164th out of 189 countries in the most recent UN Human Development Index report. Despite being one of the most politically and economically stable countries on the African continent, the country has a low literacy rate of about 43% and low enrolment rates in primary and secondary schools; 38% of primary school cohorts dropout before reaching secondary education. As a result, many children in Senegal fall victim to child labour, begging or street selling; it is estimated that around 100 000 Senegalese children roam the streets, begging for money and food.
According to SOS Children's village, an organisation working in Senegal since 1976, although the situation is improving in the country, the challenge now is to enable girls to remain in school once they are enrolled (thousands are still being forced into domestic labour as soon as they are old enough to work). The fallout of the education crisis on society includes economic distress, violence and crime, civic disengagement and struggling communities.
In consequence of the issues stated, LBMS decided to focus on the educational aspect and build schools in severy lacking areas to give a chance to every child for a better future and participate in the economical development of their country.[15]

15 https://www.archstorming.com/uploads/9/5/7/7/95776966/lbms_-briefing-en.pdf, 20.02.2021

Fig.15: Site pictures of the current school

3.3 THE PLOT

The plot extends to approximately 1170m². It has a rectangular shape. The longest side measures 37m while the shorter - 25m. The plot is completely flat, there is no slope to be considered.
The main entrance is located at the west side. It can stay where it is currently or it can be relocated to the south if necessary.
There is a big moraceae tree in the middle of the plot that has to be kept. It provides shadow to the kids and they spend a lot of time under it. It has an approximate height of 6.5m and the tree crown's diameter is around 16m.
The plot has the following constructions currently:

- **Classrooms:** There are two temporary buildings that function as classroom; their dimensions are 17.5m x 6.5m and are built with woven bamboo walls and zinc roof. These structures will be demolished.

- **Brick building:** It is located at the South-West corner of the plot and has two different rooms and measures 4.4m x 8.4m. It is built with cement walls and metal roof and used as a small library and director's office.

- **Latrine module:** Located at the South-East corner, it contains two latrines. This module will be replaced with a new one and relocating it is also allowed.

- **Well:** There is a well at the North-West part of the plot which could be demolished considering the fact that almost no water is coming out of it.

- **Electric pole:** There is an electrric pole in the South-West corner of the plot that has to be kept outside the school. [16]

16 https://www.archstorming.com/uploads/9/5/7/7/95776966/lbms_-briefing-en.pdf, 20.02.2021

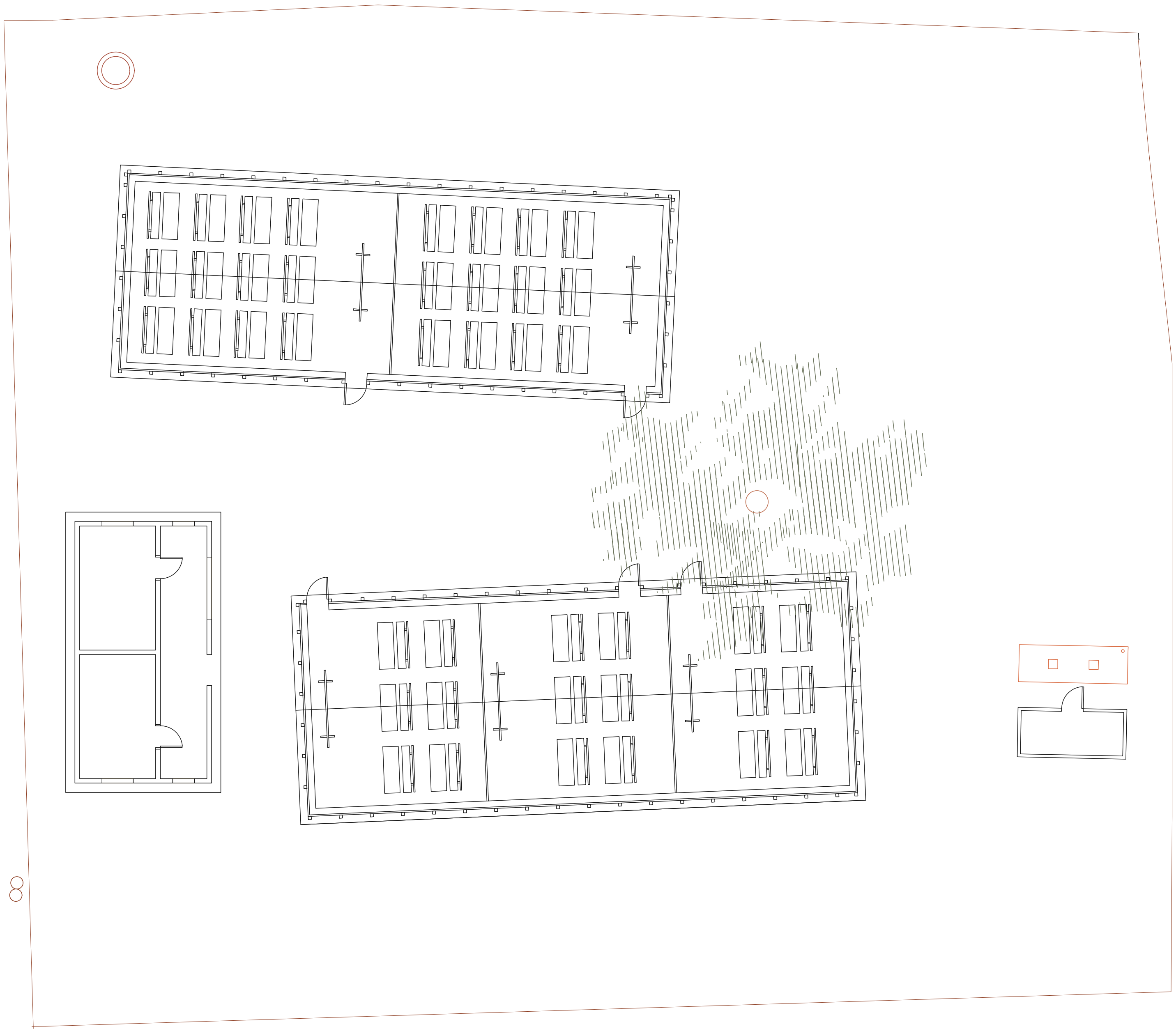


Fig.16: Plan of the current school building, 1:200

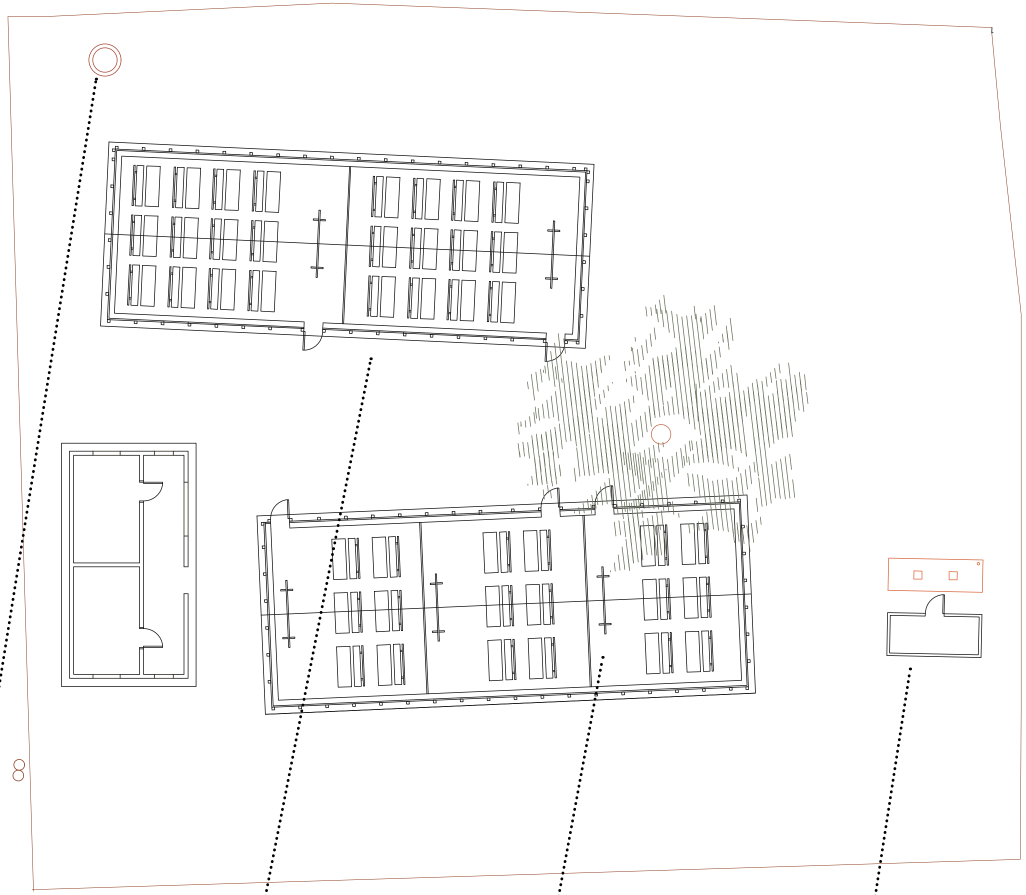


Fig.17: Well at NW plot

Fig.18: Exterior of a classroom

Fig.19: Interior of a classroom

Fig.20: Latrine module

3.4 THE PROJECT PROGRAM

- **Classrooms:** The school needs 7 classrooms. The size of each classroom must be 63 m², since this is a general requirement of the Government of Senegal. The number of classrooms is fixed and can't be modified in the proposal.

- **Library:** The students are currently using one of the rooms of the block building as a library, but the space is too small so a larger one should be taken into consideration in the design. No constraints about the size of the new library.

- **Offices:** Two small offices are needed - one for the director and another that will be used by the teachers during class breaks or meetings.

- **Latrines:** The current latrine module can be demolished and relocated where desired. The school needs 3 cubicles: 1 for boys, 1 for girls, 1 for adults.

- **Canteen:** If there's enough space in the design, it is recommended to include a small kitchen and a dining room but since the area of the plot is very limited this space is not compulsory.

- **Orchard and Corral:** Considering that parents do not have enough money to pay the canteen for their children, a great option would be to include an orchard so the school can be self sufficient and grow its own vegetables, as well as raise chickens.

The size of each space can vary depending on the proposal. Having exterior spaces where the kids can play and run is also important and necessary.[17]

17 https://www.archstorming.com/uploads/9/5/7/7/95776966/lbms_-briefing-en.pdf, 20.02.2021

4. DESIGN WORKFLOW

> “ There are lots of resources given by nature for free. All we need is our sensitivity to see them and our creativity to use them. ”
>
> - Anna Heringer

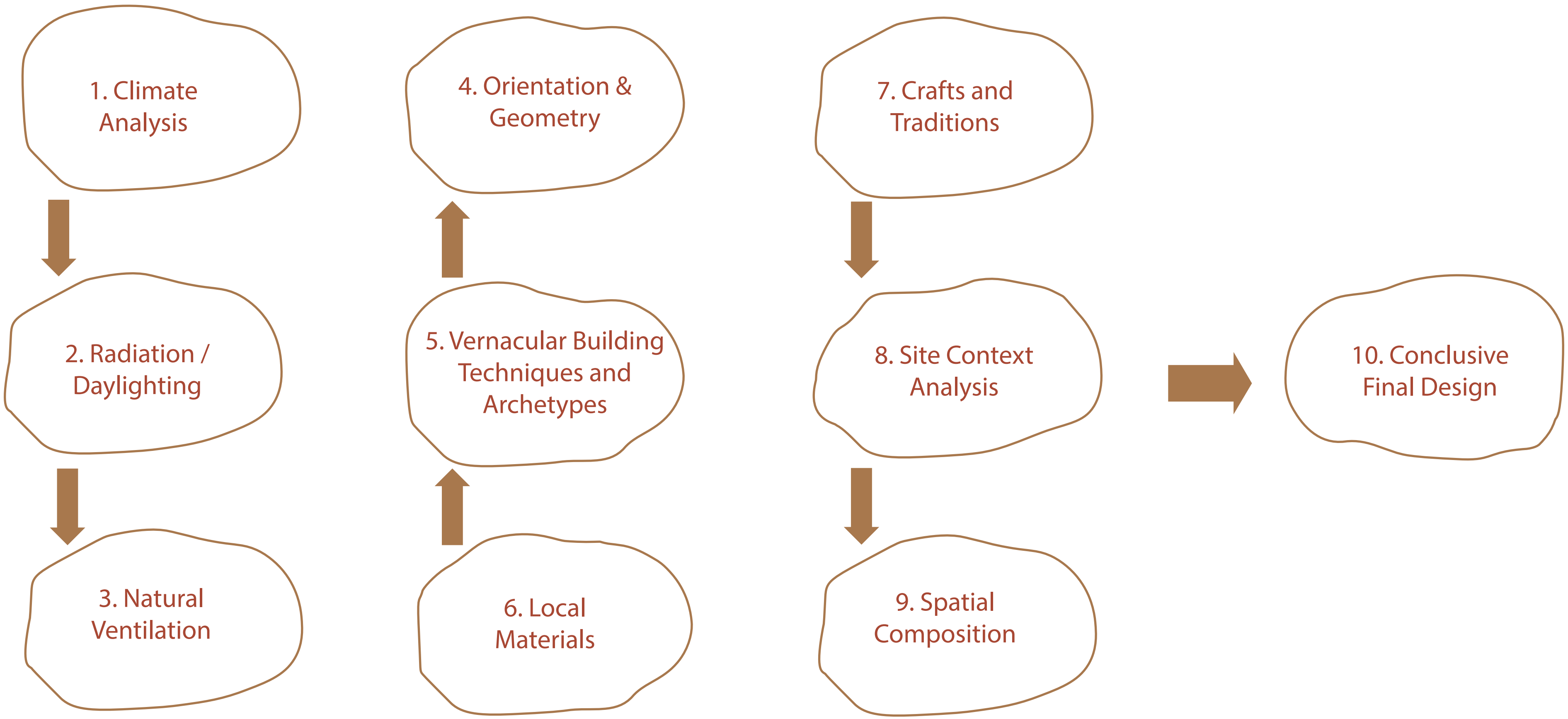


Fig.21: Workflow in 10 Stages

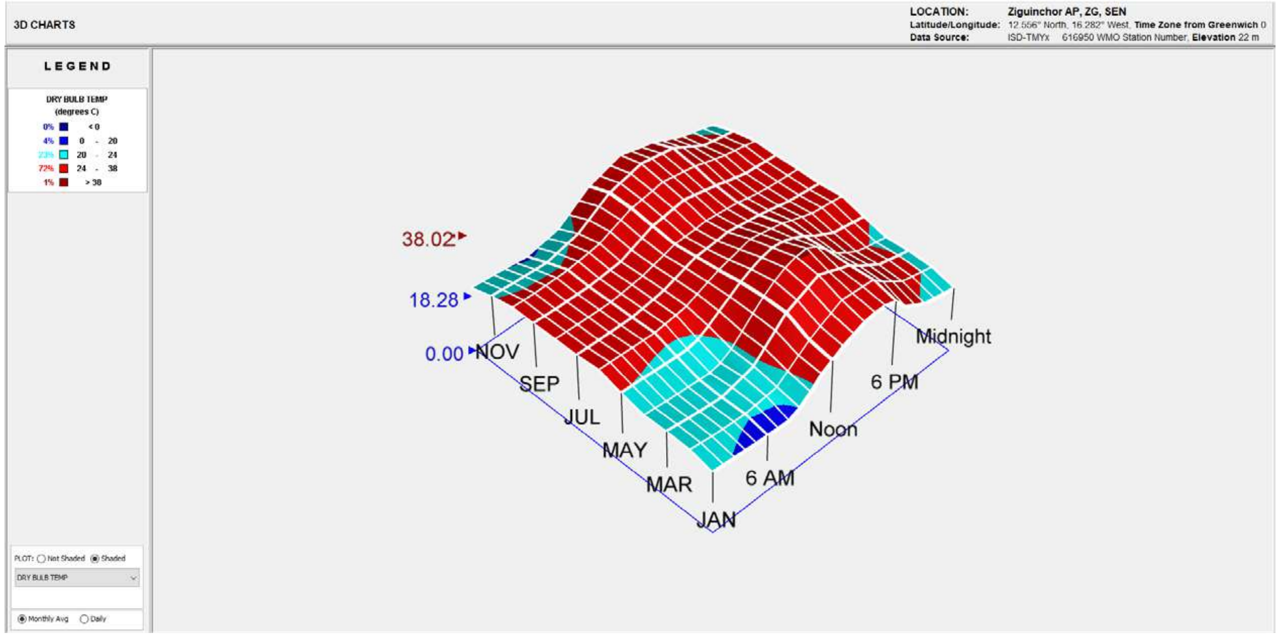


Fig.22: Dry bulb temperature chart - along the bottom are shown the months and along the side - the hours of the day

4.1 CLIMATE ANALYSIS

Climate is one of the biggest constraints when it comes to designing a responsive building to the local context. This depends first and foremost on understanding the local conditions, hence first doing a detailed accurate analysis. Thermal comfort is traditionally spoken about only in terms of temperature. Those vague but widely held perceptions are only a small part of a much greater group of factors that work together to drive the universal physical phenomena – the human body's heat balance.[18] A software called "Climate Consultant" has been developed by the UCLA (University of California, Los Angeles) and released for an intended target group, consisting of architects, engineers and students from these fields.[19] It reads the local climate data for all 8760 hours per year in EPW (Energy Plus Weather) format files which are available for over a thousand stations from across the world and provides suggestions for passive design strategies that could be used as the first steps of the workflow. So for any chosen location – Ziguinchor in this case as the next biggest town to Marsassoum, the software will suggest building design strategies appropriate to the unique characteristics of that climate. The goal is to facilitate the way towards a more energy-efficient and more sustainable building, uniquely designed for its particular spot on our planet and reaching a high level of sophistication – both aesthetically and functionally.

18 https://www.fmlink.com/articles/thermal-comfort-a-key-to-occupant-satisfaction-and-productivity/, 20.03.2021

19 http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php, 20.03.2021

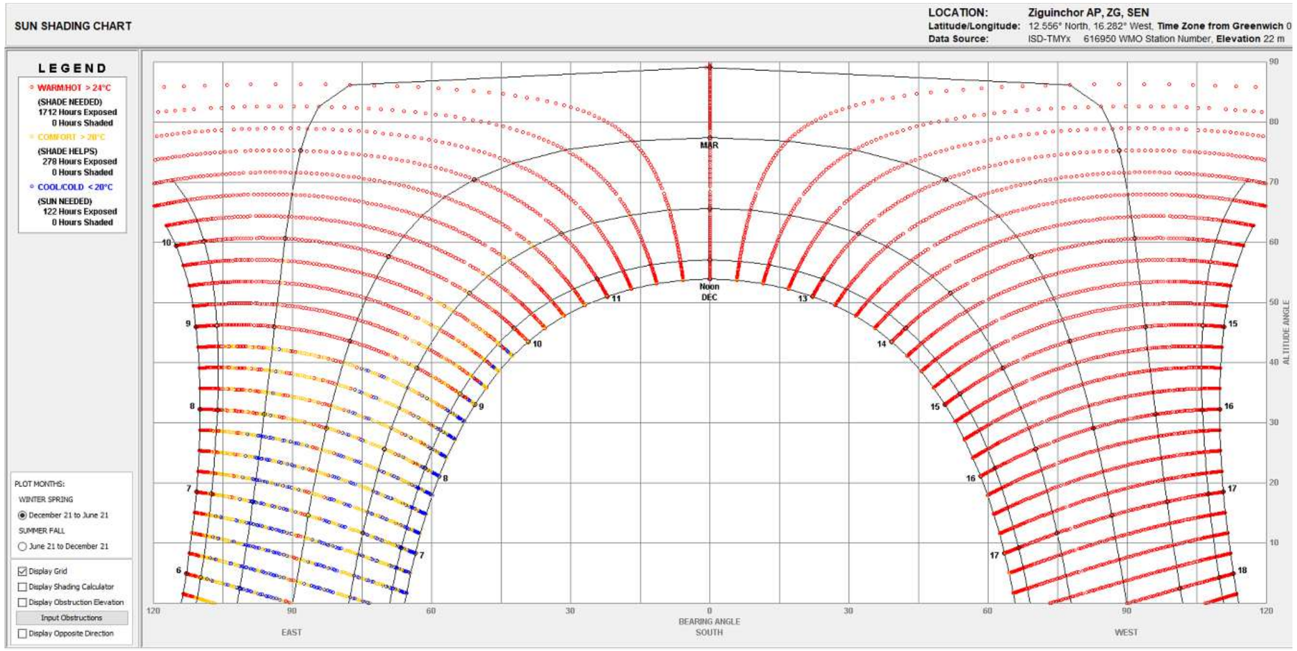


Fig.23: Sun shading chart

4.2 RADIATION & DAYLIGHTING ANALYSIS

The sun shading chart shows the sun's bearing angle (along the bottom) and altitude (vertically) for every 15 minutes of the year in colored dots. The yellow dots indicate comfort conditions when the dry bulb temperature is within the comfort zone as defined on the "criteria" field. Red dots indicate overheat conditions when the dry bulb temperature is above the comfort range. Blue dots stand for underheat conditions when the temperature is below the bottom of the comfort zone. Therefore the window openings should be fully shaded wherever there are red and blue dots. As seen on the chart, the prevailing colour is red, hence shading is one of the major factors, taken into account during the design process. After studying various shading strategies, a conclusion was made to implement a large
roof overhang in the design as a main shading device and to avoid big openings on the south, west and east facades, to prevent solar radiation from falling on building surfaces and penetrating into the spaces.

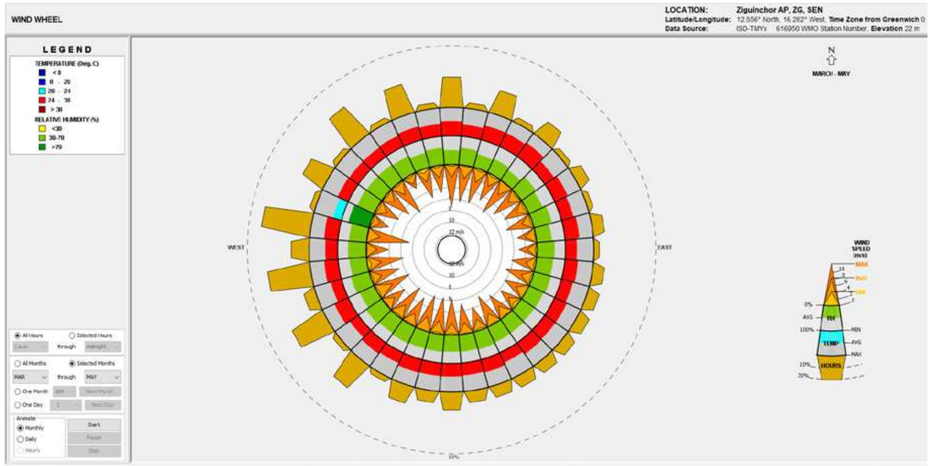


Fig.24: Wind wheel showing

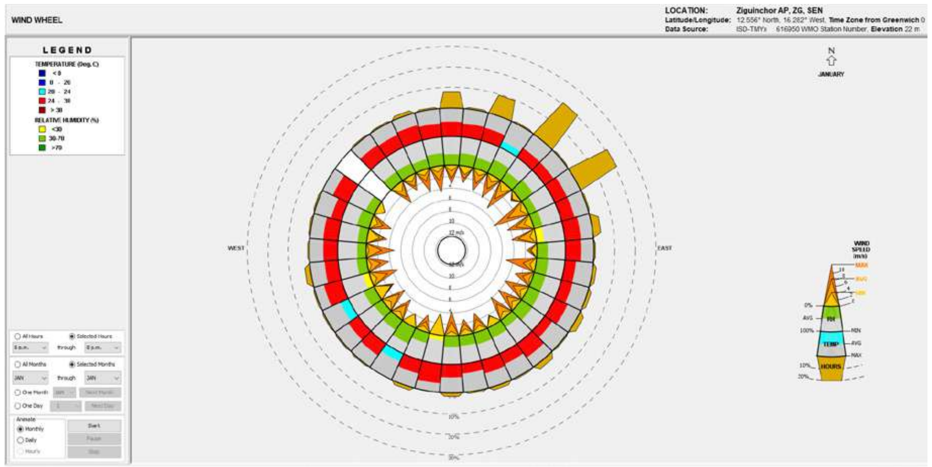


Fig.25: Wind wheel

4.3 NATURAL VENTILATION

A starting point for the analysis of the parameter “natural ventilation” is the wind velocity and wind direction charts. Wind orientations according to the inlet openings are first priority, while locational and dimensional relationships between the inlet and outlet openings – second.
The speed of the wind in Ziguinchor, respectively in Marssasoum, is on average 1.8 m/s. The prevailing wind for much of the year is from the northeast and from the west. Based on the results of this data and after studying different wind-driven cross-ventilation techniques inside single rooms, a conclusion was made to implement staggered openings on opposite walls to achieve a comfortable indoor air velocity in the classrooms of the school building. On one hand, cross ventilation at opposite sides can achieve 3 times average air velocity (indoor) than one-sided ventilation for the same space and wind conditions, and on the other hand, staggered openings in combination with deeper rooms can create longer air flow paths, hence making these techniques suitable for a site like Marsassoum with average wind speed pattern. The best case of the staggered openings in accordance to vertical level is attained when the inlet is at lower level and the outlet of the opposite wall - at the upper.[20] When these strategies are applied, combined with high thermal mass, the building can retain comfortable interior temperature throughout the day, while natural ventilation would make possible night flushing through the openings of the facade to cool down the thermal mass.

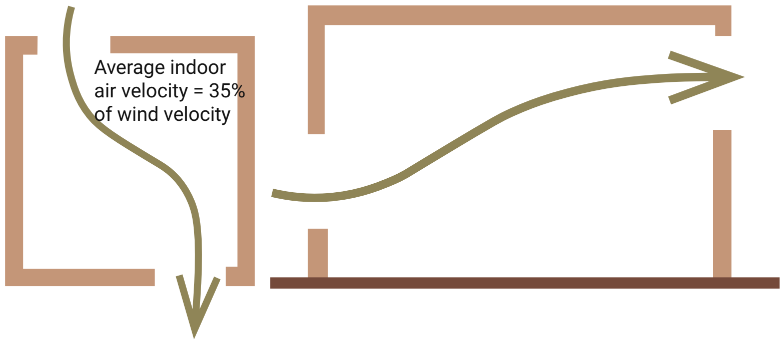


Fig.26: Staggered openings: left - in horizontal level, right - in vertical level

20 Elwan M., “A review on wind-driven cross-ventilation techniques inside single rooms” in: “International Journal of Scientific and Engineering Research (IJSER)”, Egypt, 2018

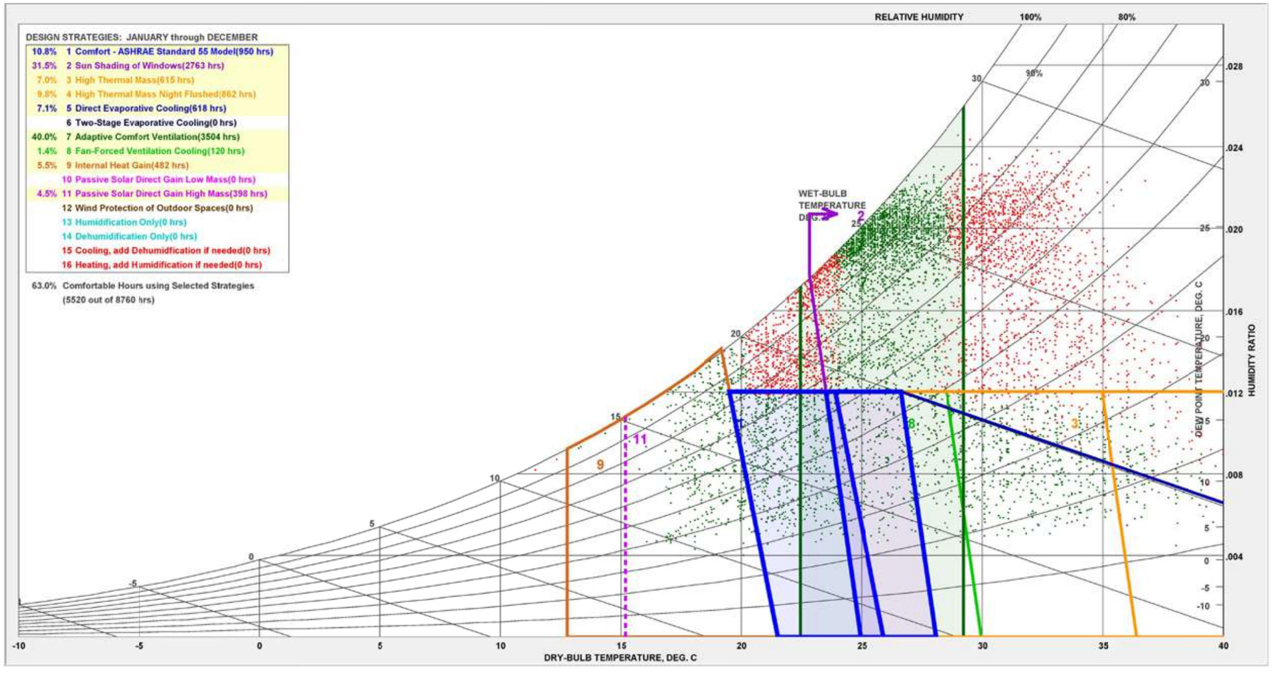


Fig.27: Each hour of the year represented as a red dot on the psychometric chart

4.4 ORIENTATION & GEOMETRY

In naturally ventilated spaces where occupants can open/close windows and the temperatures are relatively high all year round, their thermal response depends in part on the outdoor climate and may have a wider comfort range than in buildings with centralized HVAC systems. This model assumes occupants adapt their clothing to thermal conditions, and are sedentary (1-1.3 met).[21] Therefore no mechanical cooling system is to be considered in the design project, since it is located in an area of the country where the temperatures are relatively high all year round. The psychometric chart is an example of how three different attributes can be displayed concurrently to show the range of comfort and discomfort perceived by the occupants of the building. Each of 13 different design strategies is represented as different coloured zones on the chart.[22]

21 Bhattacharya Y., Milne M., "Psychometric chart tutorial: A tool for understanding human thermal comfort conditions", UCLA, Los Angeles 2007

22 Milne M., Ligget R., Al-Shaali R., "Climate Consultant 3.0: A tool for visualizing building energy implications of climates", UCLA, Los Angeles, 2007

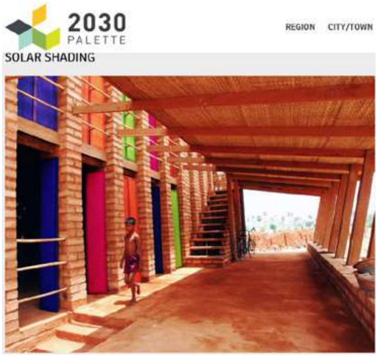


Fig.28: Sra Pou Vocational School in Oudong, Cambodia

Fig.29: Building of the British High Commision in Sri Lanka

Fig.30: Malawi School, Malawi

4.4 ORIENTATION & GEOMETRY

As a last step the software offers design guidelines based on the specific location and climatic conditions, which are meant to facilitate the first design steps and act as necessary pillars for the creation of the concept. In addition to that, the software offers built examples that relate to the given local environmental conditions linking the user to an online platform called "2030 Palette".[23]

- Good natural ventilation can eliminate AC, if windows are well shaded and oriented to prevailing breezes

- To capture natural ventilation, wind direction can be changed up to 45 degrees towards the building by exterior wingwalls and planting

- Long narrow building floorplan can help maximize cross ventilation

- To facilitate cross-ventilation, it is recommended to locate door and window openings on opposite sides of building with larger openings facing up-wind if possible

- On hot days ceiling fans or indoor air motion can make it seem cooler by at least 2.8°C

- Use open-plan interiors to promote natural cross ventilation or use louvred/screened doors and windows

- Shade to prevent overheating and open to breezes

- Provide enough north facing openings to balance daylighting (5% of floor area)

- Low pitched roofs with wide overhangs work well in this climate

- Minimize or eliminate west facing openings to reduce summer and fall afternoon heat gain

- Window overhangs or operable sunshades can eliminate the need for air conditioning

- Use light coloured building materials and cool roofs (with high emissivity) to minimize conducted heat gain

23 http://www.2030palette.org/

4.5 LOCAL BUILDING TRADITIONS

Diola Houses

Diola people are one of Africa's finest architects. They demonstrate it with their ancient multi-storey huts, magnificent earthen castles, and impluvium huts that are only rivaled by the impluvium huts of Papua New Guinea in Eastern Indonesia. The traditional Diola habitat and the Casamance habitat in general therefore consist of earthen walls and unlike other typical Senegalese habitats, it contains multiple rooms (on average five) - a common room that can be considered as a living room, bedrooms and a wide terrace surrounding the entire house. Rice granaries are present in all typical Diola structures, usually located above the bedrooms of the head of the family. Hence, the Diola has always put a priority on their well-being at home.

Fig.31: Diola House

However, the regional uniqueness of Casamance can also be found at the level of the roof and its layout. It is used for the storage of cereals (in particular rice) and the frame is designed to both allow the best air circulation in the home while protecting the stocks from the rain. Tiny strips of mangrove wood arranged in crosses across the large frame on the ceiling act as a protecting layer from the dust between the attic reserves and the living room. In order to have the structure resistant to rot and insects, a rot-resistant palm wood is being used, however, due to overexploitation, this material has unfortunately become scarce. Diola people have always valued aesthetics and the beauty of their homes. The earthen pillars decorated with various patterns such as those of Alliance Française in Ziguinchor (image on the right) are an illustration of this tendency. Shapes, colours and decorations are all pretexts for embellishing their homes and making them unique this way.[24]

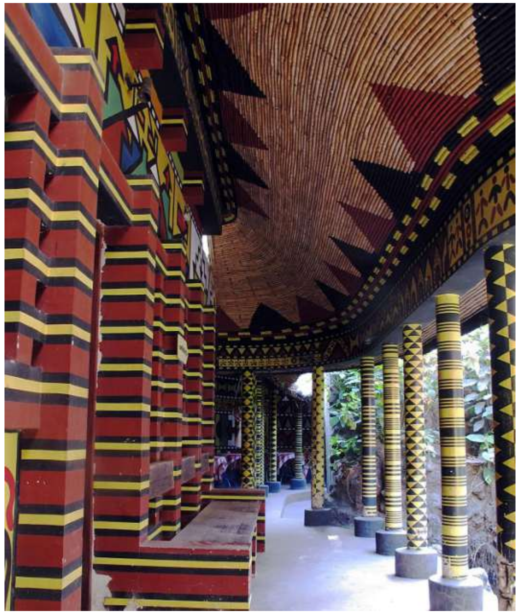


Fig.32: Impluvium house - another type of housing typical for Diola people

24 https://www.planete-senegal.com/senegal/habitat_basse_casamance.php , 11.04.2021

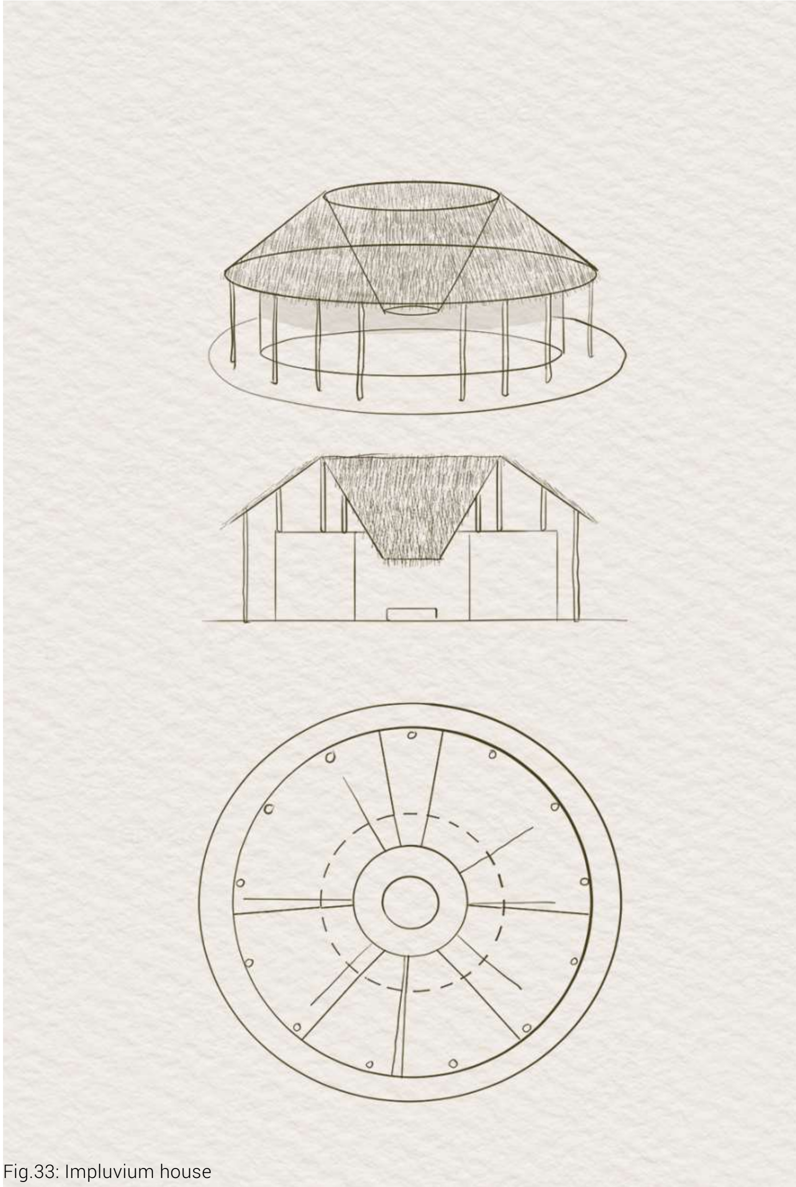


Fig.33: Impluvium house

4.5 LOCAL BUILDING TRADITIONS

Impluvium Houses

An impluvium hut is a form of Senegalese housing found in the Diola region of Casamance and they are considered as another version of the Diola structures. These impressive mud buildings with thatched roofs can be found all over Casamance (sometimes made of tin). If an addition to the house is necessary due to an increase in the family, another impluvium is added, which leads to cluster-like structures. These habitats are circular in shape, unlike the rest of the Diola huts, and their rooms are arranged around this patio which is protected by a double roof that collects rainwater during the rainy season. It also provides a light tunnel that leads to the building's heart. The origin of the impluvium huts seems to be different from what is commonly assumed. The area, populated by the Diola people, has long been an area of constant battles between enemy villages and Mandingo invaders, and it has remained so until recently. The impluvium was needed in order for them to be able to protect their homes against attacks and to maintain a siege. It was built to provide an indoor courtyard safe from spiers, winter downpours, and the scorching sun, rather than just a rain receptacle in an area where there is no lack of water when it rains. This central area under the impluvium is still multifunctional today, serving as a kitchen, a safe play area for children, an enclosure for small domestic animals (poultry, etc.), a place to rest and discuss.

Fig.34: Impluvium houses forming cluster-like structures

Fig.35: Water-catchment basin of an impluvium house

Fig.36: Interior of an impluvium house

4.5 LOCAL BUILDING TRADITIONS

Impluvium Houses

The interior basin is fitted with an evacuation that allows it to drain its overflow into the outside as if to prove that the impluvium's practical motivation was not only water storage.The catchment basin is lowered, paved with blocks or surrounded by a knee-high mud wall, as in the case of Casa a Impluvium in Casamance. When necessary, clay pots are mounted as catch basins under the roof's overhanging palm cover. Great care is taken to ensure proper ventilation so that the food reserves in the roof do not go mouldy. If an addition is needed when the family grows, another impluvium is added, resulting in cluster-like structures. These crown houses with a central impluvium are now only present in a few specimens, despite being common on the north bank of the Casamance in the past. The agrarian society that gave rise to the unique earthen architecture still retains a wealth of cultural practices and material goods that are remarkably preserved and thus worthy of inclusion in the heritage.[25] In Casamance there are still traditional houses that are occupied by families, traditional houses that have been converted into lodges, and newly constructed impluvium huts that also serve as lodges. The impluvium hut of the Alliance Franco-arts Senegalaise's center in Ziguinchor is a magnificent example of both an impluvium courtyard and decoration patterns typical for the Diola people.

25 http://whc.unesco.org/fr/listesindicatives/2076/ , 11.04.2021

Fig.37: Peulhs house

Fig.38: Peulhs house (Nomads)

4.5 LOCAL BUILDING TRADITIONS

Peulhs' and Peulh's Nomads Houses

The Peulhs are found across Senegal, from north to south, and their traditional dwellings vary greatly depending on the location and the climate. Mostly, the Peulhs are farmers. Their homes in Senegal's southeast were designed to accommodate animals at night and on rainy days. These huts are circular and have only one wide room with a diameter of up to 6 meters. Because of its scale, it is possible to have rich interior fittings. The thatched roof reaches the field, and a closed exterior corridor provides protection for poultry or sheep at night. This type of hut can be found throughout Guinean Fouta Djalon region, the Fouladou region (Kolda region), eastern Senegal (Tambacounda-Kédougou region), and to a lesser extent in Boundou (Malian border). In the rural areas of Ferlo and the Senegal River valley, the Peulhs and Toucouleurs are mostly herders.

The harsh desert climate of northern Senegal has forced a nomadic lifestyle on many of the village families. As a result, a significant portion of the dwellings is logically more ephemeral. Due to a lack of wood and other plants, as well as less lateritic soil than the rest of the world, these light dwellings are made of straw, reeds, and acacia branches, which rarely withstand termites for long period of time. A covered but well-ventilated terrace allows relaxation and good sleep during the hottest hours of the day.[26]

26 https://www.planete-senegal.com/senegal/habitat_traditionnel_senegal.php , 11.04.2021


Fig.39: Peulhs house


Fig.40: Peulhs house (Nomads)

4.5 LOCAL BUILDING TRADITIONS

Bambara Houses

The Bambara hut is a typical African dwelling: circular, small, and with a thatched roof, it can be constructed in less than 48 hours by one person. They're common in eastern Senegal, and their lack of windows makes them ideal for hot weather. They usually have a front entrance door and a back door that leads to the sanitary facilities or an open-air kitchen. The lateritic cob bricks are strong enough to last for many years without any maintenance. Due to the intensity of the rainy season in this Senegalese mainland region, the thatched roof must be replaced or repaired every three to four years.

Bassari Houses

The Bassaris live in tiny, round huts. Their roof is made up of layers of short, compact, and tidy thatch twigs. The walls are often made of mud bricks with a protective coating applied to them. Some villages in eastern Senegal's mountainous region, where the Bassaris live, have chosen a completely different construction material: the rough block of stone. Marble, which is abundant in the Ibelis area, is also sometimes used. This construction process, which is unique in Senegal and extremely rare in Africa, turns Bassari houses into true masterpieces with excellent temperature control.[27]

27 https://www.planete-senegal.com/senegal/habitat_traditionnel_senegal.php , 11.04.2021

Fig.41: Serer House

Fig.42: Petite Cote House

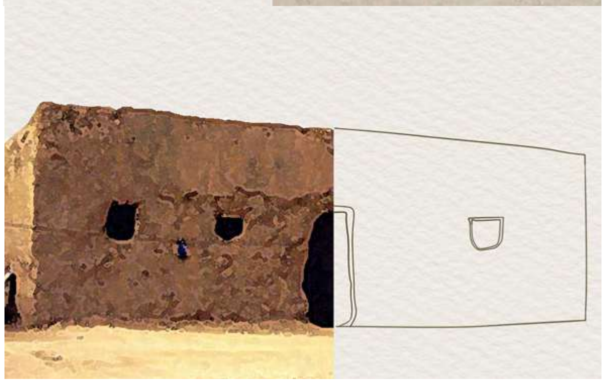


Fig.43: Senegal Valley House

4.5 LOCAL BUILDING TRADITIONS

Serer Houses

Serer huts are characteristic for their square forms and earthen walls. But because of their unique space and limited size, these huts are unsuitable for housing an entire family, unlike Diola huts. The farther north one goes, the more one sees that these homes are clustered around the few remaining water sources. In the area close to Sine-Saloum, roofs roof thatching is usually made of palm leaves, which are more popular than straw, due to their availability in the region. These rural dwellings are similar to the Wolof dwellings in Central Senegal.

Petite Cote Houses

Tiny solid houses form the most comfortable dwellings in the village in the most important villages of the Petite Côte in Casamance. Cement mixed with seashells is commonly used for the walls. The roof is usually made of zinc, but on older ones it is covered in tiles. The dwellings in the suburbs of towns (Ziguinchor, Kaolack, Tambacounda, etc.) are “mutant” huts, which have mud walls similar to traditional huts but are filled with a layer of cement plaster to solidify the huts.

Senegal Valley Houses

Rains are exceptionally scarce in the far north of the country: about 20 rainy days a year, spread out over two and a half months. The only real field crops are grown along the Senegal River’s banks. Hence, the only truly important villages are cloncentrated along its banks. The large mud buildings with several spaces, flat roofs without cover, and the small windows of these dwellings are ideal for this area with verz little rain and temperatures that can be hot during the day (> 40 °C) and cold at night (10 °C).[28]

28 https://www.planete-senegal.com/senegal/habitat_traditionnel_senegal.php , 11.04.2021

4.6 LOCAL MATERIALS

Fig.44: Main material choice

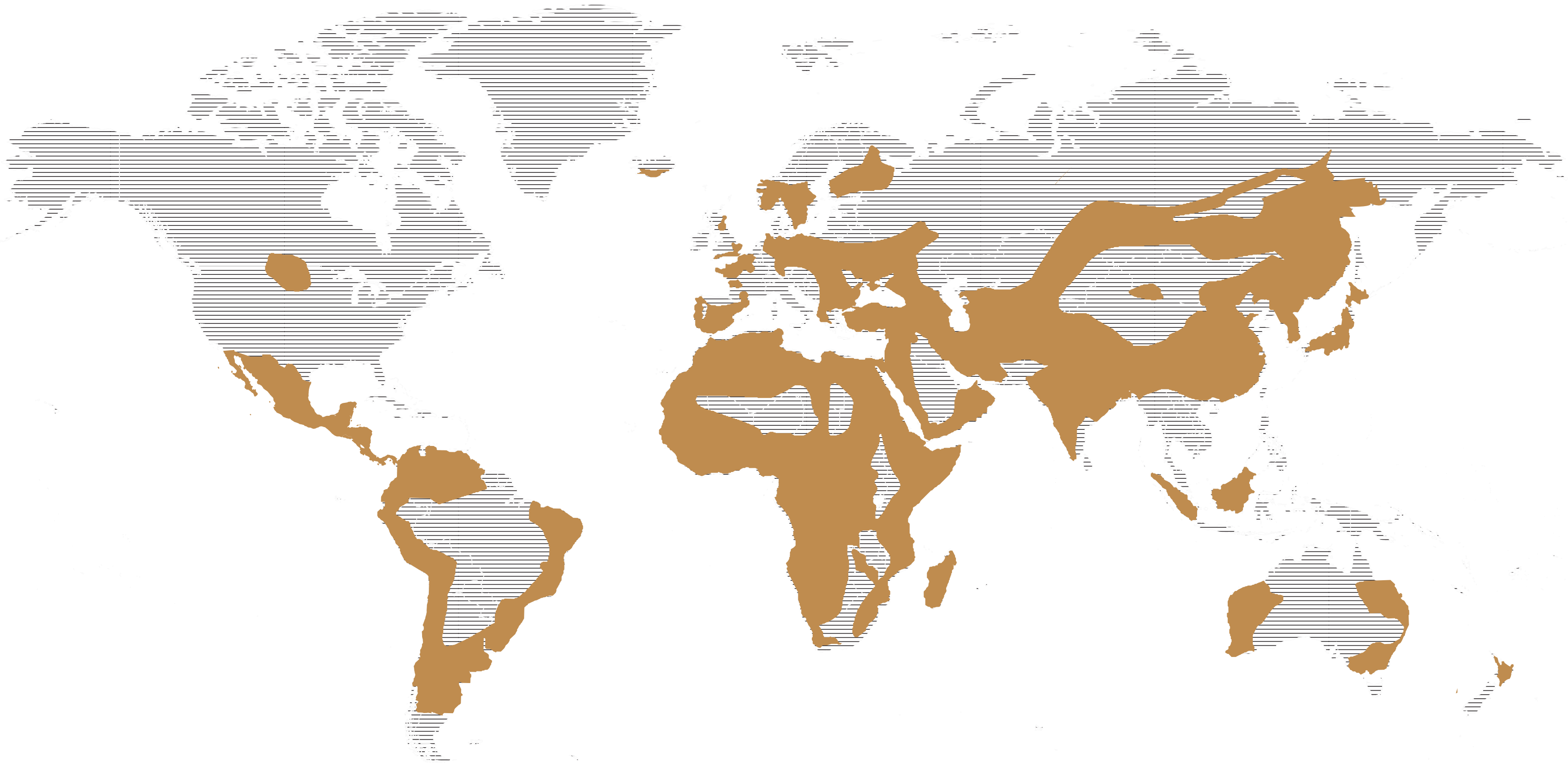


Fig.45: Earth construction distribution across the globe

Fig.46: Laterite soils

4.6.1 EARTH AS A BUILDING MATERIAL

Building with earth

Earth has always been the most common building material in nearly all hot, arid, and temperate climates. Still today, one-third of the world's population lives in earthen houses; in developing nations, it's even higher. For over 9000 years, earth building techniques have been known and some mud brick (adobe) houses dating from 8000 to 6000 BC have been discovered and recorded in Russian Turkestan. All ancient cultures used earth as a building material, not just for homes but also for religious, cultural, and defensive structures. An impressive and well-known example is The Great Wall of China, which was originally constructed entirely of rammed earth and only later covered with stones and bricks. Another examples dating back to early civilizations are the Sun Pyramid in Teotihuacan, Mexico, consisting of a core of approx. 2 million tons of rammed earth, and the bazaar quarter of Sirdjan in Persia, which is covered by domes and vaults, built without formwork or support during construction. Being known for thousands of years to ancient civilizations all over the world, the history of earth as a building material has produced countless constructions, building methods and manufacturing techniques that vary from region to region. Climatic conditions play an important role in the spread of earthen buildings: its excellent heat-insulating, temperature- and moisture-storing properties offer advantages in both hot and cold climates.[29]

29 Minke G., Building with Earth, Design and Technology of a Sustainable Architecture, Birkäuser, Berlin, 2006, p.12

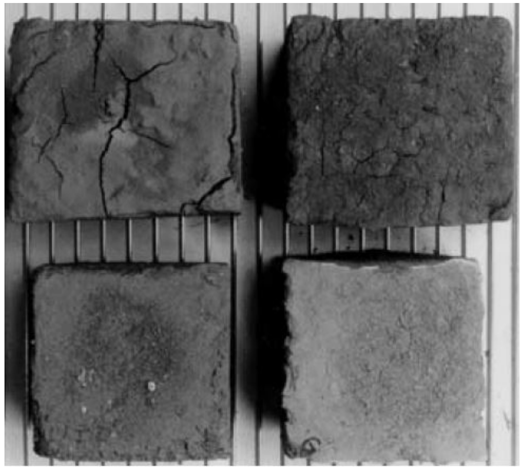


Fig.47: Swelling and shrinkage test

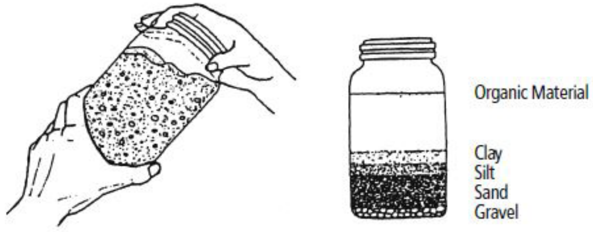


Fig.48: Sedimentation test

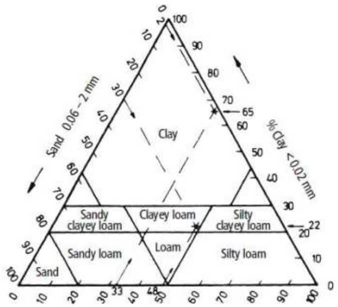


Fig.49: Graphical description of loam's particle composition

4.6.1 EARTH AS A BUILDING MATERIAL

As a building material earth is commonly referred to as loam and by that scientific name it is meant a mixture of clay, silt, sand, and occasionally larger aggregates as gravel or stones.

Disadvantages

1. Loam is not a standardised building material

There is no “standard composition” and so the composition must be determined before processing. The amount and types of clay, silt, sand, and aggregates in the loam can vary depending on the location where it was dug out. As a result, its characteristics can vary from one location to the next, as may the preparation of the correct mix for a particular application. Only after determining the specific composition of the loam invloved, can its properties be estimated and reacted to if necessary by introducing additives.

2. Loam mixtures shrink when drying

In order to be able to process clay, water must be added. It activates the binding properties and helps to bring the building material into the right shape and position - workability. If this water evaporates, the volume is reduced and so-called “shrinkage cracks” occur. The linear shrinkage ratio for wet mixtures is 3-12% and with rammed earth between 0.4% and 2%. However, shrinkage can be significantly reduced by various tricks such as optimising the grain composition or reducing the clay content.

3. Loam is not water-resistant

Loam, particularly when wet, needs to be protected from rain and frost. Roof overhangs, damp-proof courses, and suitable surface coatings for instance could protect earth walls.

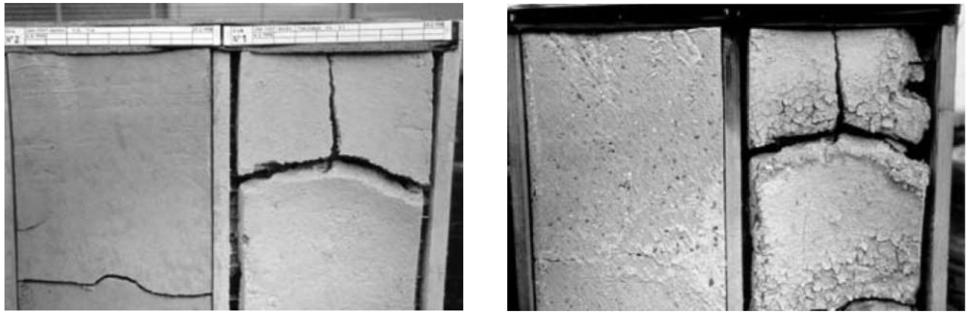


Fig.50: Loam samples before (left) and after (right) being exposed to weather for three years

4.6.1 EARTH AS A BUILDING MATERIAL

Advantages

1. Loam balances air humidity

Due to its ability to absorb moisture and release it again when needed, it regulates the humidity of the room air. An experiment conducted by the Research Laboratory for Experimental Building at the University of Kassel showed that an unfired clay brick absorbs about 30 times as much moisture as a fired brick when the relative humidity of the room air is increased from 50% to 80%.

2. Loam stores heat

In addition, clay stores heat through its mass. The high storage mass results in a time-delayed indoor climate inside the building. Once heated, the masonry remains warm for a while until it cools down.

3. Loam saves energy and reduces environmental pollution

Another advantage of using clay is that it requires less energy than other building materials - both for preparation and for processing. To be precise, only about 1% compared to the energy required for the production of bricks or reinforced concrete.

4. Loam is always reusable

Unlike industrially produced building materials such as concrete, clay is neither hazardous waste nor a burden on the environment. It is earth and can therefore be reused immediately after crushing and adding water.[30]
5. Loam saves material and transportation costs
On most building sites, clay is in the ground during excavation, or at least not far away. This means that there are no costs for transporting the excavated material and no costs for transporting building materials to the construction site.

30 Minke G., Building with Earth, Design and Technology of a Sustainable Architecture, Birkäuser, Berlin, 2006, p.14

Fig.51: Mud wheel designed by the Building Research Laboratory (BRL) at the University of Kassel, Germany

4.6.1 EARTH AS A BUILDING MATERIAL

6. Loam is ideal for do-it yourself construction

Earth construction techniques may normally be carried out by non-professionals if the building is supervised by an experienced person. They are perfect for do-it-yourself construction because the processes are labor-intensive and require only inexpensive tools and machines.

7. Loam preserves timber and other organic materials

Due to the low equilibrium moisture content of 0.4% to 6% by weight and its capillarity, organic materials such as wood are kept dry, provided they are enclosed in clay. Fungal or insect infestation is thus prevented. Preservation takes place.

8. Loam absorbs pollutants

Earth walls are often said to help clean polluted indoor air, but this has yet to be scientifically confirmed. It is true that toxins dissolved in water can be absorbed by earth walls. For example, a demonstration plant in Ruhleben, Berlin, eliminates phosphates from 600m3 of sewage daily using clayey soil. The clay minerals bind the phosphates, which are then extracted from the sewage. The benefit of this process is that the phosphates are converted into calcium phosphate for reuse as fertilizer and no foreign substances remain in the water. Last but not least, radiation from mobile phone networks, radio link systems, GPS and other radiation does not get far with clay due to its shielding effect. Clay does this much better than other building materials and a 24 cm thick clay brick vault absorbs 99.999% of the radiation.[31]

31 Minke G., Building with Earth, Design and Technology of a Sustainable Architecture, Birkäuser, Berlin, 2006, p.14

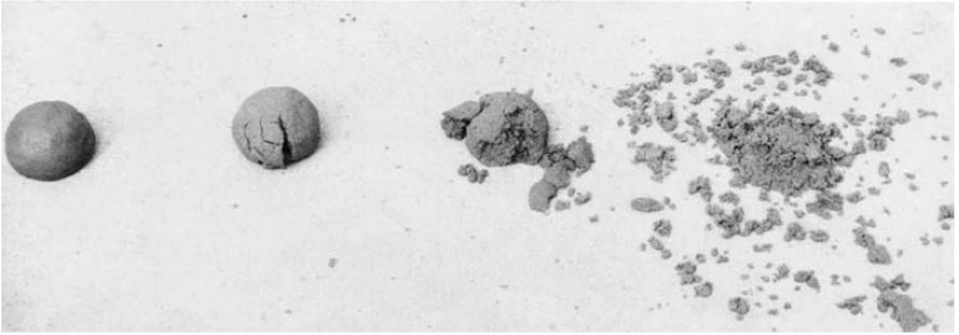


Fig.53: Loam balls after dropping test

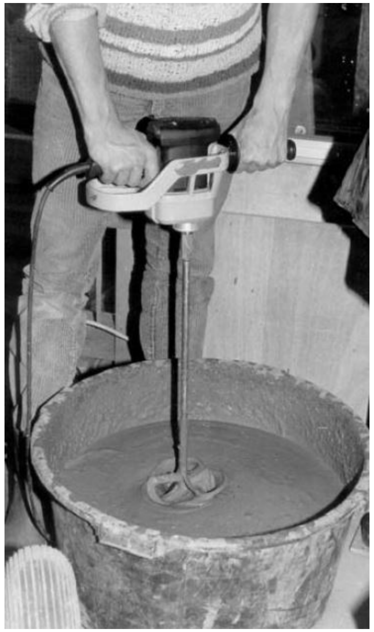


Fig.52: Electric hand mixer

4.6.1 EARTH AS A BUILDING MATERIAL

Preparing of loam

As already mentioned, in many cases there is clay directly on site, or it is even part of the excavation. After determining its composition, usually by an expert look, it is usually a matter of preparing the right loam mixture. For this, a specialist is recommended who can assess how the clay can best be brought to the required quality and which equipment or techniques are necessary for this. However, some methods will be explained below to give a rough overview of what needs to be done and when.

In the case of dry clods of clay, a simple way is to “marinate” them. To do this, place the lumps of clay in a tub and cover with water. within 2 to 4 days, the soft mass can be worked on. A widespread and old method in our latitudes, but not helpful in southern countries, is “wintering out”. Spread the clay over a surface up to a thickness of 40 cm and leave it to lie over the winter. The frost splits the particles and thus crushes the lumps.

Further processing can now be done either manually or mechanically. In African countries, tamping or mixing is often still done with hoes, feet or animals. Mechanical crushing, for example with a tractor or a tiller, is of course easier. However, various other special devices are better suited for crushing and offer the advantage of adding the desired additives. One more effective example is the forced mixer, and in comparison to the conventional concrete mixer, in which the mix is rotated by the drum, the blades or rollers rotate in this case.[32]

32 Minke G., Building with Earth, Design and Technology of a Sustainable Architecture, Birkäuser, Berlin, 2006, p.37

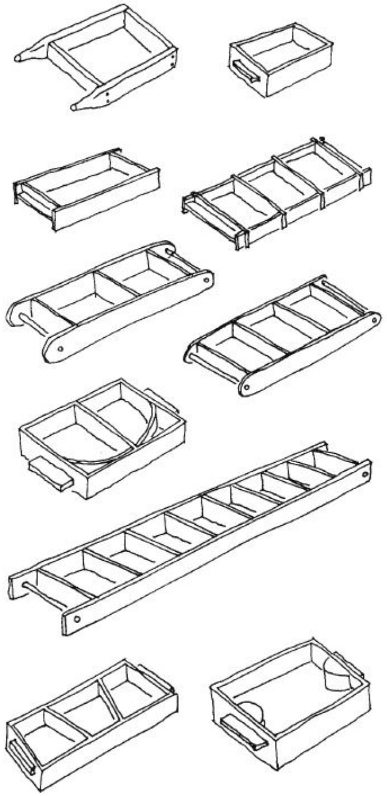


Fig.54: Moulds for adobes

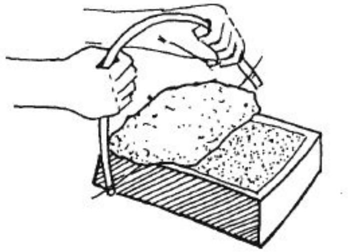


Fig.56: The surface is smoothed by hand or timber piece, trowel or wire

Fig.55: Making adobes in Ecuador

4.6.1 EARTH AS A BUILDING MATERIAL

Production of eathen blocks - Adobe

Clay block construction describes a building technique using unfired clay blocks. They are laid in clay mortar or lime mortar. Clay stones from 8000-6000 B.C. are proof for this ancient building method in dry-hot, subtropical to temperate zones of the earth.
Basically, three types can be distinguished today.

Large-format blocks weigh about 26 kg and they are produced under cover and close to the wall to facilitate their transportation. The second type is called green bricks. They consist of clayey soil with light aggregates such as straw, saw, dust etc., and are much lighter in weight. They are manufactured industrially and are available in various dimensions, used mainly for exterior walls in cool or cold climates due to their thermal insulation effect. Third type are traditional wet loam techniques where no mortar is needed and „plastic loam is bound simply ny ramming, beating, pressing or throwing.“[33] Given the fact that this method is the simplest, since no tools are required, it is still being the most widespread building technique in the developing countries.

33 Minke G., Building with Earth, Design and Technology of a Sustainable Architecture, Birkäuser, Berlin, 2006, p.73

Fig.57: Keur Sambel forest in the region of Sine Saloum, Senegal

4.6.2 BUILDING WITH BAMBOO

Deforestation in Senegal

Historically, Senegal has used the proceeds from groundnut exports to fund food imports, especially cereals such as rice and wheat. However, since the 1970s, falling global prices for groundnuts and related products, poor weather conditions, domestic and international economic shocks, as well as the advent of substitutes, have significantly reduced Senegal's groundnut export earning ability. Despite this, Senegal continues to be one of the world's leading groundnut exporters. Senegal's economy is reliant on this crop, which is consuming a growing share (more than half) of the country's cultivated land in an ecological zone subject to recurring drought cycles. Senegal's major environmental problems include deforestation, overgrazing, soil degradation, and desertification, which are exacerbated in part by the country's rapid growth and continued reliance on peanut cultivation. The state encouraged farmers to cut down trees in order to increase groundnut crop areas in the 1960s, resulting in a vicious cycle of deforestation, soil erosion, flooding, and frequent drought that has wreaked havoc on regional agriculture. The vast majority of people in the Sahel and Sahelo-Sudan region depend on agriculture for their livelihoods, but their ability to sustain themselves is becoming increasingly precarious due to soil erosion and desertification.[34] Another reason is charcoal being used as primary source of energy around the world - be it for cooking, keeping the house warm or industrial fuel. The process of harvesting wood and making charcoal has created a livelihood for thousands of people around the globe. In order to counteract the further shrinkage of Senegal's forests, it is urgently necessary to find alternative building options.[35]

34 https://wrm.org.uy/articles-from-the-wrm-bulletin/section2/senegal-deforestation-by-expansion-of-groundnut-monoculture/

35 https://www.nitidae.org/en/actions/keur-sambel-lutte-contre-la-deforestation-et-developpement-rural-dans-la-foret-de-keur-sambel-au-senegal

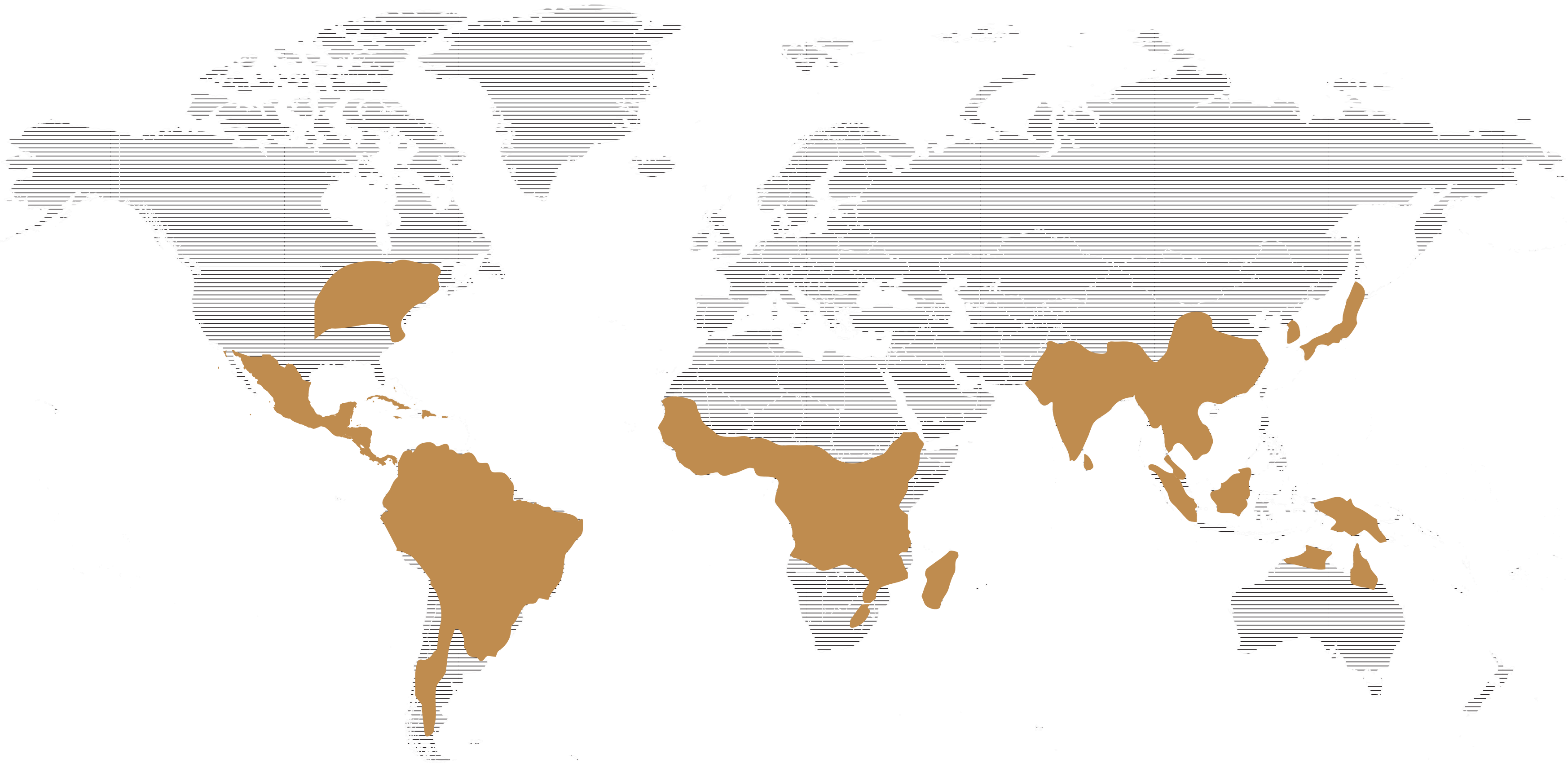


Fig.58: Worldwide distribution of bamboo

Fig.59: Bamboo as a plant

4.6.2 BUILDING WITH BAMBOO

Bamboo as a plant

The word „bamboo“ was first introduced in 1753 by Carl von Linné and describes a very versatile material with more than 2000 different applications, such as ecology, health, household, industry and architecture. Bamboo is a natural, very fast growing building material – some species with 1m overnight, and has a long tradition in many tropical countries in South America, Africa and East Asia, where it is being used due to its abundant occurrence, its good workability and, above all, because of its excellent material properties. Although bamboo has been largely displaced by modern construction, there are many efforts to revive building with bamboo. [36]

36 Minke G., Building with Bamboo, Design and Technology of a Sustainable Architecture, Second and Revised Edition, Birkhäuser, Switzerland, 2016, p.9

Fig.60: Sectional cut (legthwise) of bamboo cane with roots

4.6.2 BUILDING WITH BAMBOO

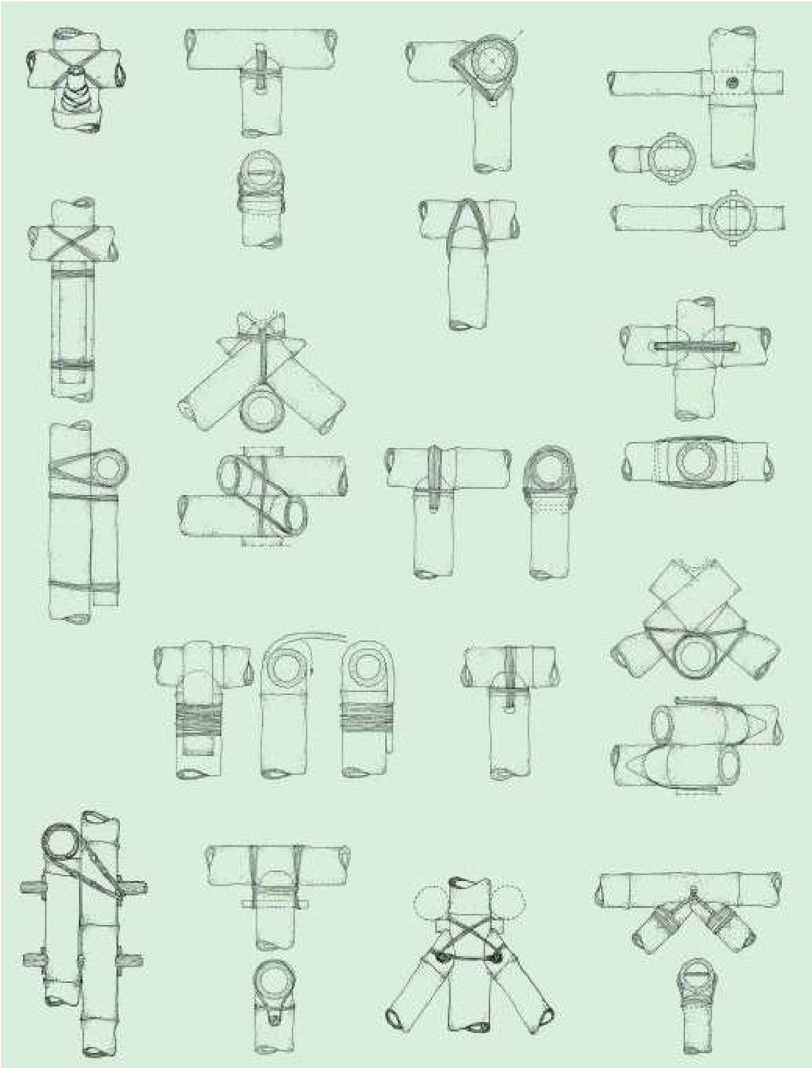
The plant and its cellular structure

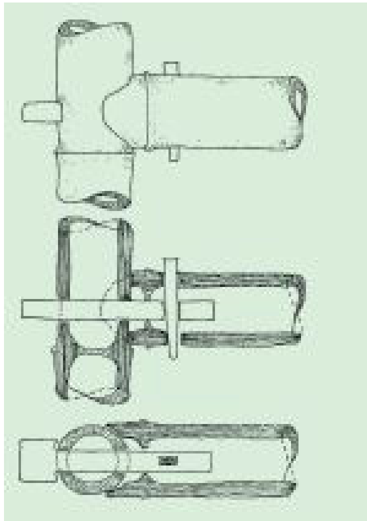
All of the nodes and internodes of the adult culm are compressed in the heart (sprout) of bamboo, with only the internodes extending during development, beginning with the lower ones. Plants in the first generation have a smaller diameter, and as generations pass, they thicken a little more each time. It takes four to six years for a tree to lignify (become woody); after that time, its vascular bundles close and dry out, allowing it to be used for building. During the growth state, the humidity content can be up to 80% in the first part of the stalk, and once the stalk is hard, it lowers to approximately 20%.[37]

Cutting, Drying, Treatment and Storage

Cutting is advised to be made during the dry season and in particular in the waning phase of the moon and in the early hours of the mornings before sunrise, since field observations have shown that during these times the stems have the lowest level of humidity. The most common method of curing is placing them vertically onto a stone and in the sun for at least four weeks so that they dry through evaporation and only then the branches and leaves are cut and the culm is left to dry further in a covered, well-ventilated space. Other methods of drying include microwave drying, heat curing (using live coals at a distance sufficient to avoid burning them with the flames), earth curing (canes being laid in a slurry of clayey earth) and smoke curing (canes bein placed in an enclosed oven). Each of these methods require different drying times. Yet, smoke curing seems to be the most efficient and fast method of all mentioned above. To clean lichens from the surface of bamboo, steel wool or hydrowash with a steam of high-pressure water is being used. The latter is not only more effective but also an inexpensive and healthy option. For surface protection coatings with lime are being used and acts as insecticide and fungicide against fungus, lichens and insects.

37 Minke G., Building with Bamboo, Design and Technology of a Sustainable Architecture, Second and Revised Edition, Birkhäuser, Switzerland, 2016, p.16





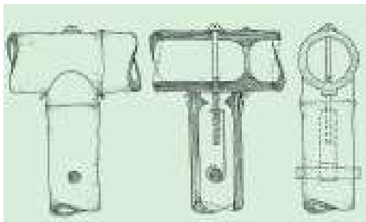


Fig.61: Bamboo connections

4.6.2 BUILDING WITH BAMBOO

Joinery

In general, thinner bamboo canes have better material properties than thicker ones. this is due to the fact that the proportion of tensile outer skin is lower in thicker pipes. It should also be noted that it is not possible to obtain absolute material properties for bamboo, as is the case with wood, because each bamboo cane differs in moisture content, thickness, length and diameter. Traditional joinery example for connecting bamboo pieces is friction tight-rope lashing, using natural materials like coconut fibre, rattan or rafia fibres. Other possibilities are wedge, inner plug and plugin/bolt connections, which can be further strengthened by introducing lashing techniques. Nowadays, as an alternative to natural fibres, galvanised wire is also being commonly used. More sophisticated solutions of joinery represent the interlocking connections which involve a centered steelbox element with multiple bamboo members joined.[38] However, since this work deals with a town in a remote area of Senegal, the main focus is on simple construction methods.

38 Rottke, E., Bamboo Connections. Construction with Bamboo, Aachen, 2009, https://bambus.rwth-aachen.de/de/PDF-Files/Bambus%20Verbindungen.pdf

Fig.62: Senegal river delta

Fig.63: Typha before it has been dried

4.6.3 CREATING OPPORTUNITIES - TYPHA REED

Typha reed and its potentials

In West Africa, Typha is a plague for the rivers. In Senegal and Mauritania, this hazardous and invasive reed is multiplying at an unprecedented pace (especially after the construction of mass dams in the late 1980s). Locals consider it as a real burden and some farmers, upset by the sight of typha in their fields, cut it down, burned it, and even constructed walls to keep it at away, but their efforts have failed. Since it has proven nearly impossible to eradicate this weed, an extensive research into strategies for typha's long-term use have been conducted. Results showing on one hand that it can be used as a bulding material with insulating properties, and on the other hand, it can be used as a fuel raw material for energy production. The Typha Fuel Construction West Africa (TyCCAO) programme therefore aims to "contribute to the energy transition and the fight against climate change by developing the use of renewable fuels and energy efficiency in buildings through the massification and dissemination of products made from typha."[39]

Typha is most often combined with soil to create lightweight soil blocks. The CRAterre association is in charge of producing building materials made from soil and plant fiber from the Typha Australis plant. Typha panels inspired by traditional mats or Terre-Typha panels are a sustainable alternative to the nowadays commonly used metal sheet roofs in Senegal. The sheet metal purchased from China at low prices is often of poor quality and should be replaced every 5 years or so. Contrary to that, houses built with a thatched roof made of typha that is 35 cm thick offer a lifetime of at least 40 years, providing excellent thermal insulation.

Weaving and Indigo Dying

39 https://www.construction21.org/france/articles/h/senegal-dakar-lancement-officiel-du-programme-tyccao.html , 10.04.2021

4.7 CRAFTS AND TRADITIONS

Fig.64: Colourful artisan-made baskets woven by rural Senegalese women

Fig.65: Indigo dye patterns

Fig.66: Wolof weavers

4.7 THE ARTISAN SIDE OF SENEGAL

Women from the Wolof ethnic community in West Africa specialize in a style of basket weaving that has been passed down through the generations in Senegal, and they learned the techniques from their mothers and precedents. The baskets were traditionally made by binding njodax, a thick local grass, with thin palm frond strips. Now they are made out of a more modern material: recycled plastic. Plastic is easier to work with, which means less discomfort for the weavers when they bring their baskets to life.

Another craft that has a long tradition in Senegal are African indigo textiles, with their dark, rich hues and ethereal, geometric motifs. Similar to weaving, this craft is also exercised mainly by Senegalese women and involves dipping fabrics in indigo dye and applying different patterns into the textile. Depending on the fabric's origin area and the maker's imagination, there are a range of color and motif variations among which some of the most familiar ones are "rice grains," "fish bones," and "stairs". To apply the pattern into the cloth, the fabric maker uses undyed cotton and pulls the thread tightly to cinch the yarn. After that, it's dipped in Indigo dye. The dye doesn't reach the section of the fabric contained in the stitches, so it stays white or turns a lighter shade of blue. The darker the hue of blue, the longer the fabric is in contact with the dye. After allowing the fabric to dry, the stitches are cut open one by one by hand, and the pattern revealed.[40]

40 http://obatala.co.uk/blog/textiles/an-indigo-colored-dream-searching-for-blue-gold-at-mufem-in-dakar/ , 13.04.2021

4.8 SITE CONTEXT ANALYSIS

4.8.1 PROJECT AREA AND LOCAL CONTEXT

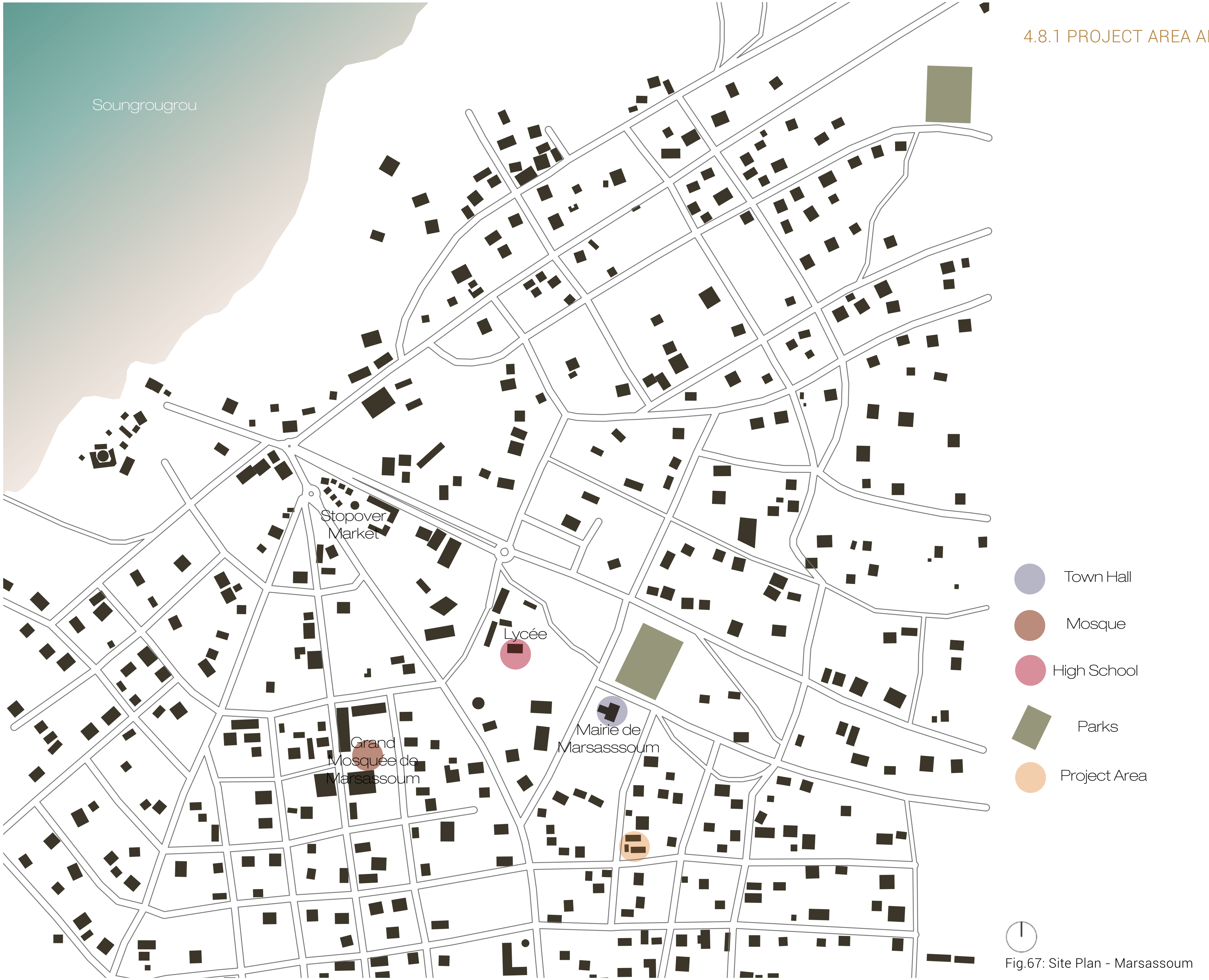


Fig.67: Site Plan - Marsassoum

4.8.2 CURRENT SITUATION

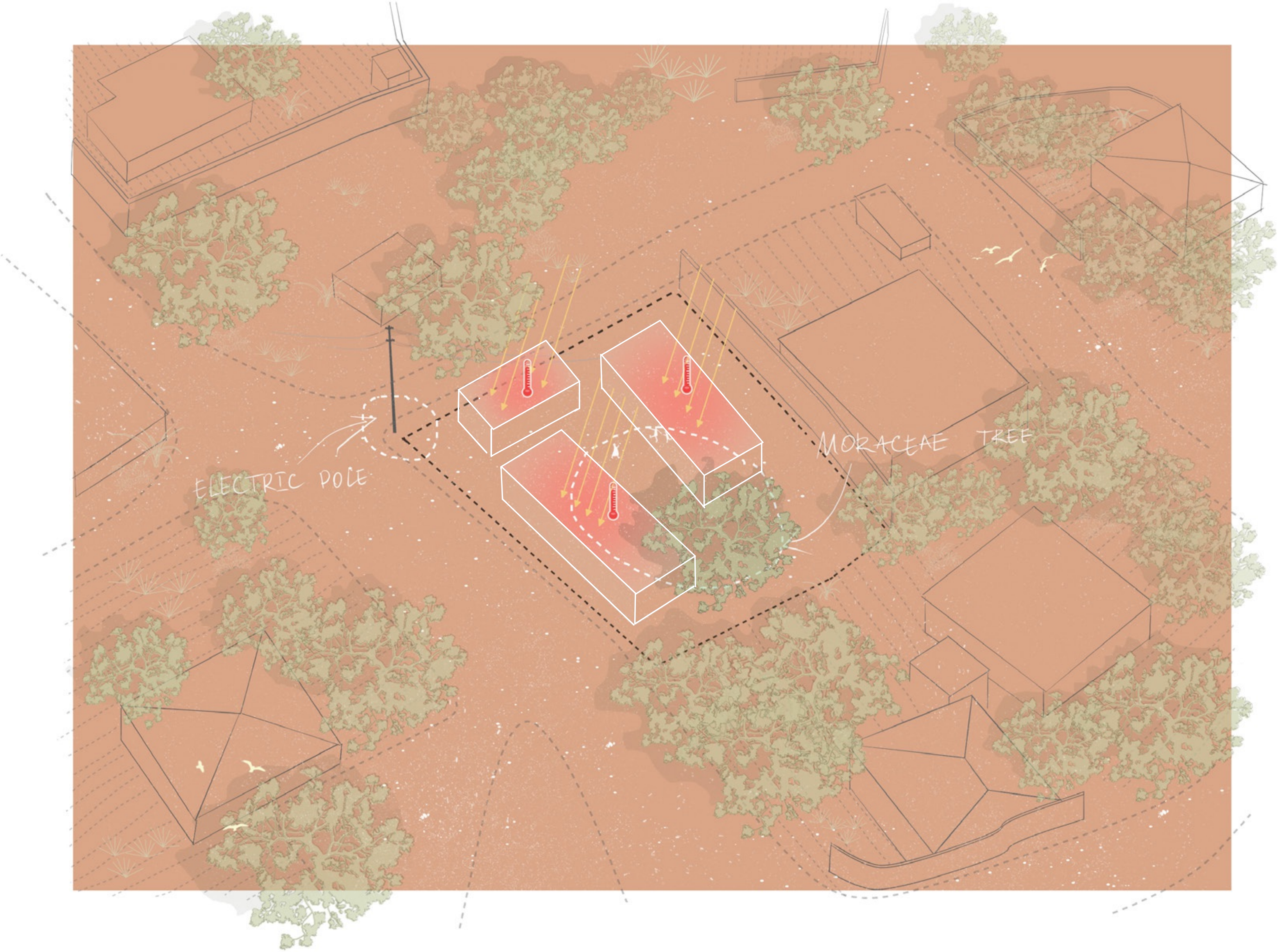


Fig.68: Concept sketch - current school building

4.9 SPATIAL COMPOSITION & CONCEPT FINDING - NEW SCHOOL BUILDING "SAMBOU TOURA DRAME"

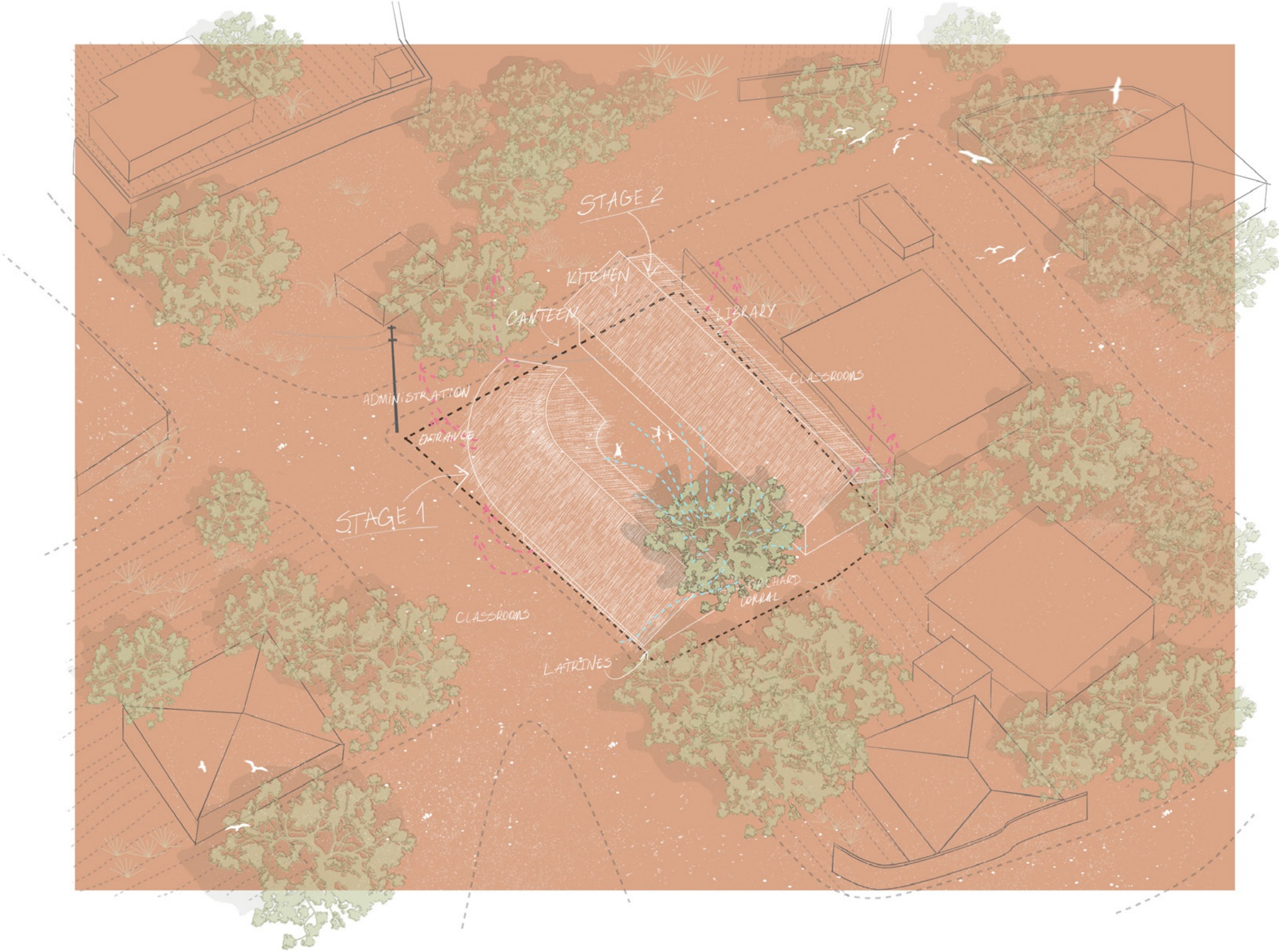
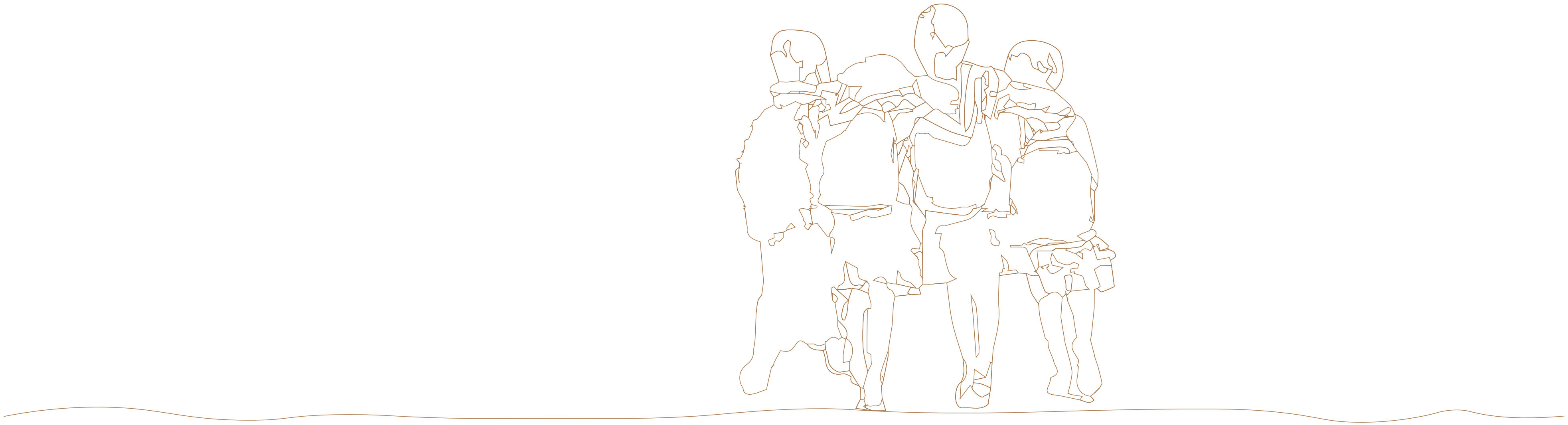


Fig.69: Concept sketch - new school building proposal

5. DESIGN STAGE



> “For me, sustainability is a synonym for beauty: a building that is harmonious in its design, structure, technique and use of materials, as well as with the location, the environment, the user, the socio-cultural context. This, for me, is what defines its sustainable and aesthetic value.”
>
> - Anna Heringer

5.1 CONCEPT CREATION - NEW SCHOOL BUILDING "SAMBOU TOURA DRAME"

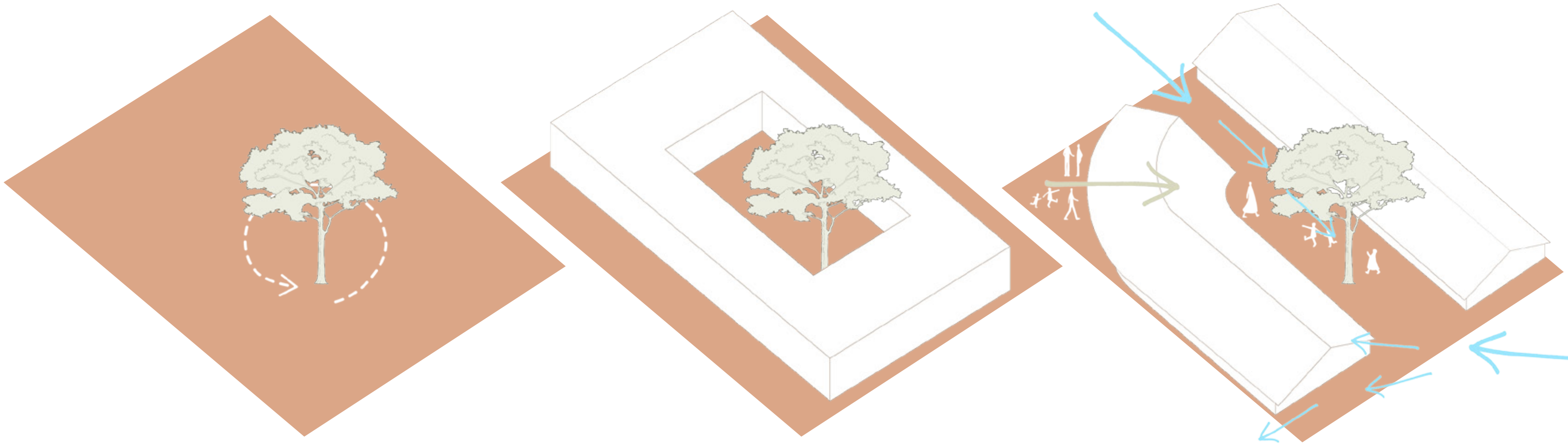


Fig.70: Concept diagrams - form finding

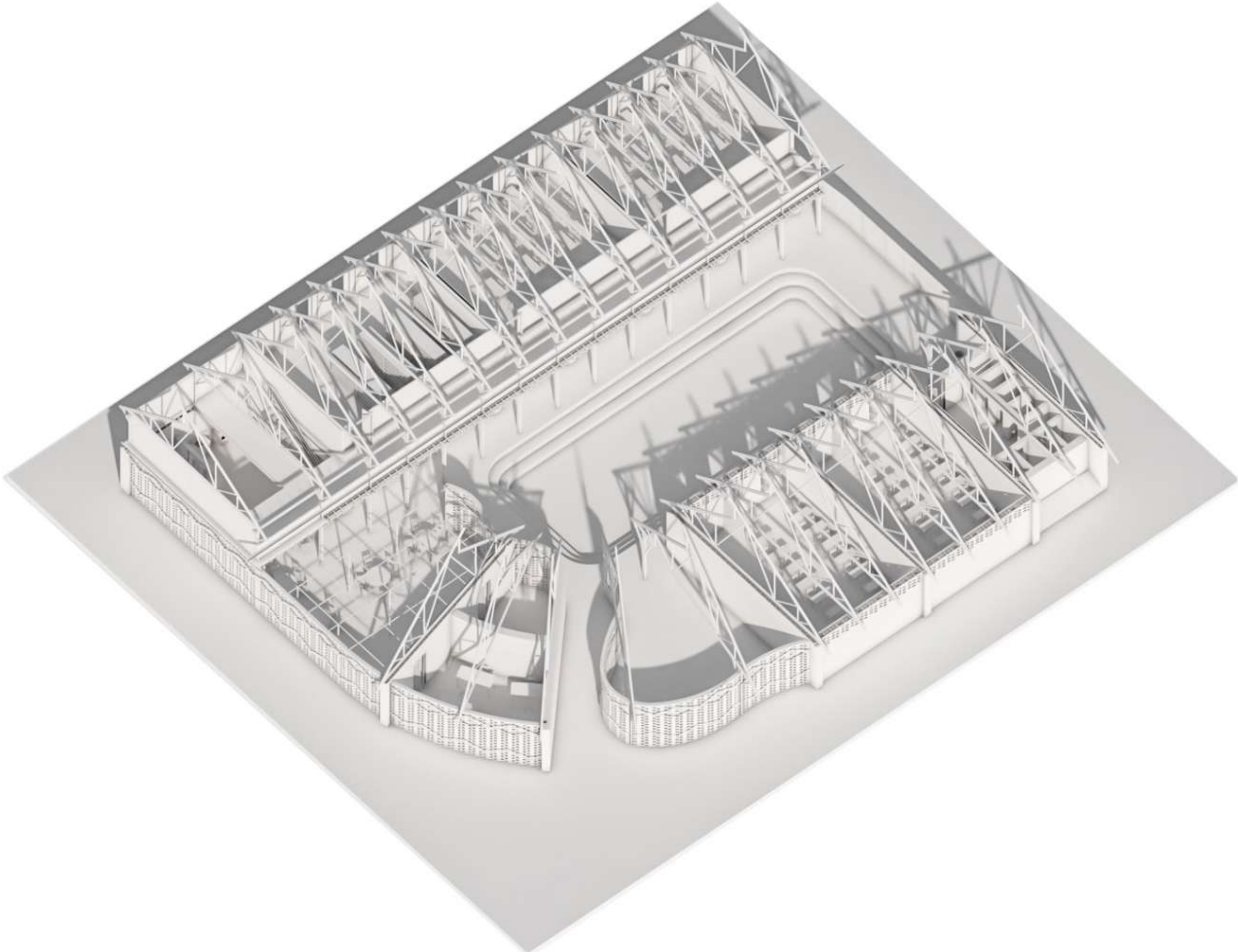


Fig.71: 3D visualisation of the new school proposal

5.2 PROJECT DESCRIPTION

The design project topic was created as part of a competition to design a school in Marsassoum, Senegal. The building is to be situated on a plot of land that was already given.The target group are pupils between 7 and 13 years. The designed school should therefore be an alternative to the current building, which can be described as a temporary, given the current conditions of its structure.
The space programme is divided into two structures separated by a shaded canteen zone. One of them is one-storey volume that shelters 2 classrooms, an office, a storage room and the dry-compost latrines module. In addition to vthat, its large roof overhang helps shading partly the canteen area as well. The other one is two-storey high and serves as the main learning environment – 3 classrooms and a kitchen on ground level. A a bamboo staircase serves as a connection with 2 additional classrooms on the upper level, a library and a shaded children's space next to it, equipped with an enormous hammock made of sisal rope in which the children will daydream while reading their books. Compared to the massive mud-brick walls of the ground level, the lightweight bamboo construction of the upper story allows for a more open and light-filled space. The building's shape and roof was inspired by vernacular precedents – and in particular the impluvium huts, typical for Casamance region. Thick thatch roof, resembling the traditional pitched roof, reinforces climatic comfort by providing an effective insulation against extreme heat. A stack effect allows hot air to rise into the peak of the roof while inviting cool air into the spaces, while an angle of 34 degrees ensures rainwater runoff, diverting water via bamboo gutters, installed along the roof, into the underground water tanks. To provide additional targeted ventilation, window openings are designed as jute fiber screens, rotating around a pivot and doors as colourful woven panels made out of upcycled plastics from discarded praying mats and similar.

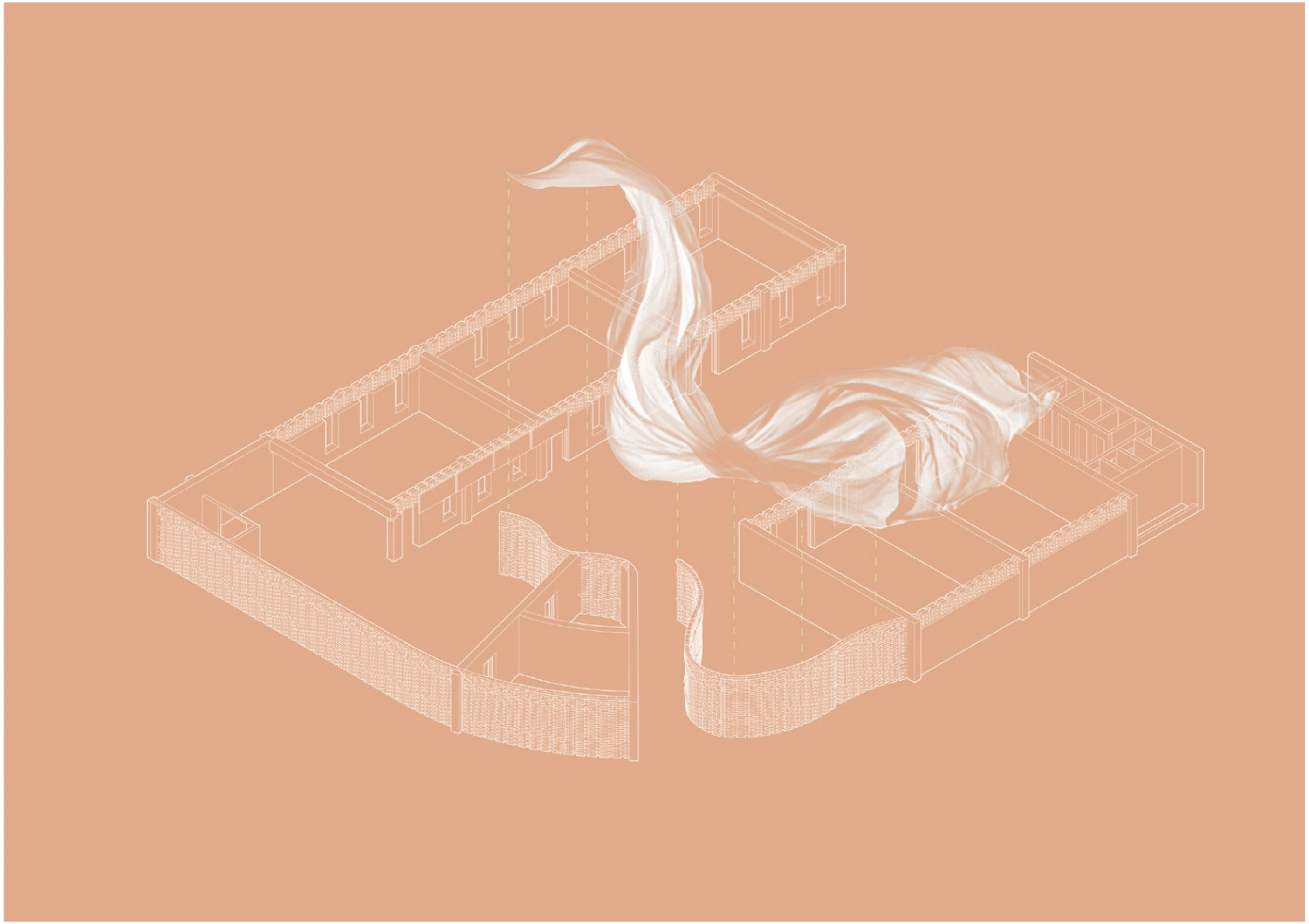


Fig.72: Concept diagram - dynamics of the facade

5.3 FACADE CREATION

The facade represents a subtle juxtaposition between clean graphic lines and gentle curves. In reference to the traditional Senegalese fabric dying techniques and patterns, the perforated facade imitates the free-flowing movement of a draped fabric and accentuates the local weaving craft patterns with its latticed brickwork pattern, thus allowing fluidity and natural light to continue towards the heart of the building.

Fig.73: 3D visualisation of the facade

5.4 SPATIAL PROGRAM

The focus is to address all the parameters studied in each of the research workflow stages and to create a school environment that is conducive to learning and teaching process. Based on all these aspects, the general form of the school is the result of structural logic, derived on one hand from the material choice – sun-dried adobe blocks, and on the other - from the findings of the research. Applying these design guidelines facilitates the organisation of learning spaces into a compact design, given the limited plot size, while at the same time allowing natural cross- and stack ventilation and providing the occupants with enough shaded areas which may be used as outdoor learning environment as well. What I have noticed from the site pictures and from my personal observations is that Senegalese people spend a lot of their time under the trees, so having in mind that, one of the goals of the project was to create not only indoor spaces that are shady and cool but also outdoor areas that will help manage the heat and be comfortable and attractive all year round. All 7 classrooms are situated in North-South axis and arranged around the courtyard and the existing moraceae tree. In addition to this, a small orchard on site and the permaculture activities related with it are implemented in order to educate the pupils from an early age the importance of taking care of plants, being gentle with soil and understanding the needs of the nature. Last but not least, 2 water tanks - each placed underground, are designed as means for harvesting and collecting water, that is being channelled from the thatched roof through the bamboo gutter into the water reservoires. By placing 2 containers which use bio-sand water filters for treating the harvested water, it can be further used safely for trinkwater or cooking needs of the occupants of the school. Another smaller tank is placed at the attic level above the dry compost latrines to provide the handwash basins with water for basic sanitation needs.

5.5 SUN STUDY AND ORIENTATION

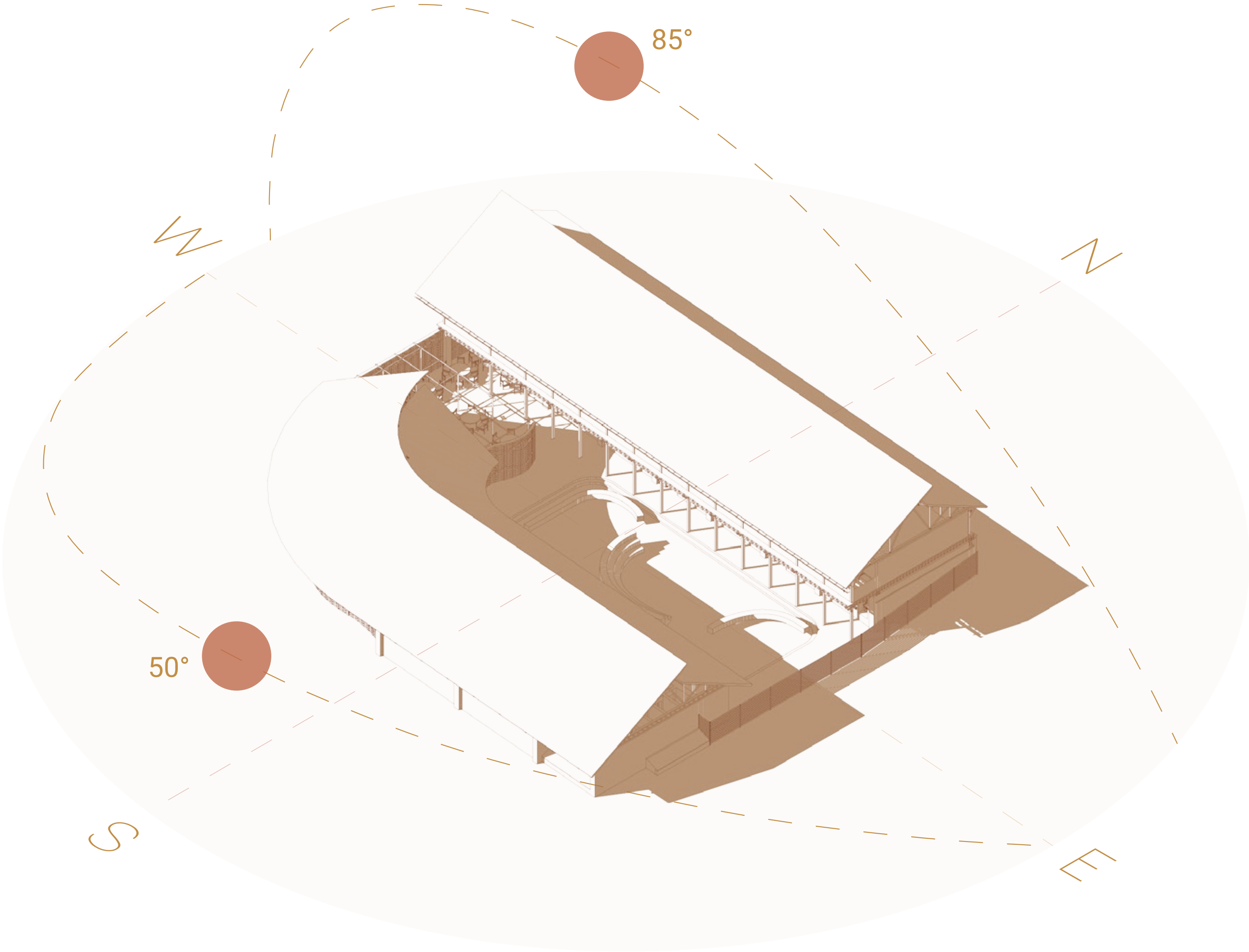


Fig.74: Sun-shading diagram showing low winter and high summer sun angles

A. Classrooms
B. Office
C. Storage
D. Canteen
E. Kitchen
F. Pantry
G. Shaded area
H. Latrines
I. Playground
J. Orchard
K. Entrance

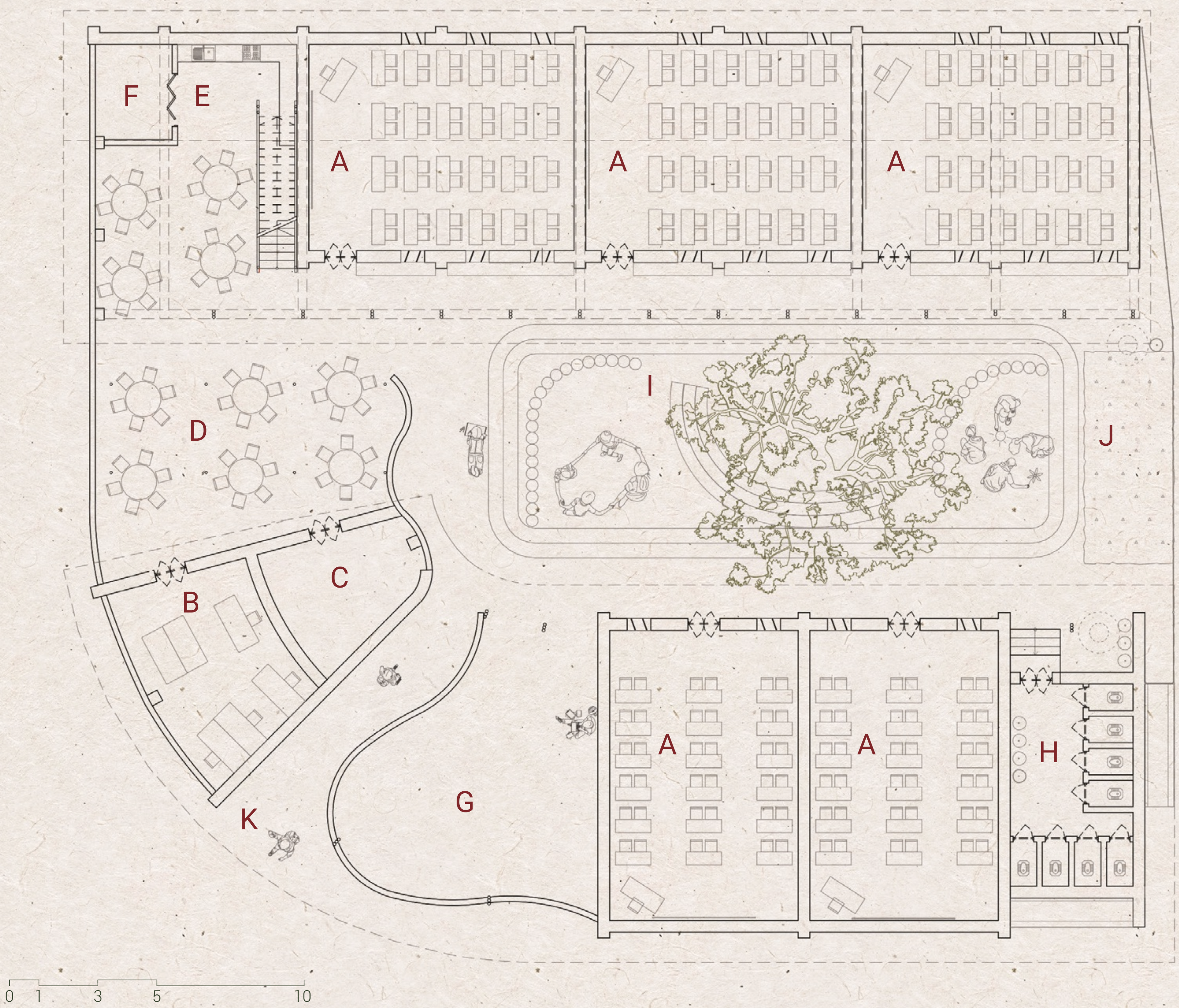


Fig.75: Plan - Ground Level, 1:200

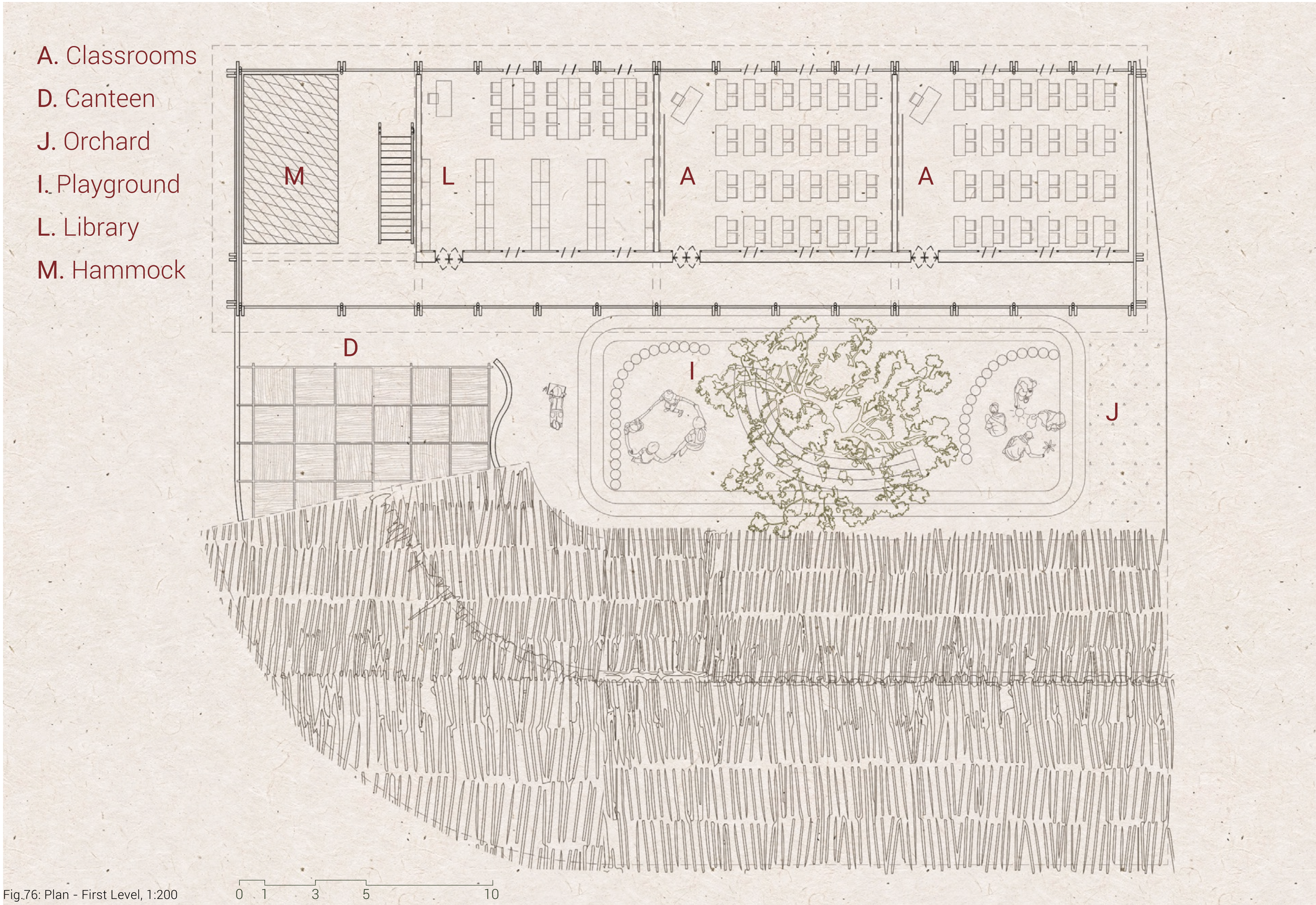


Fig.76: Plan - First Level, 1:200

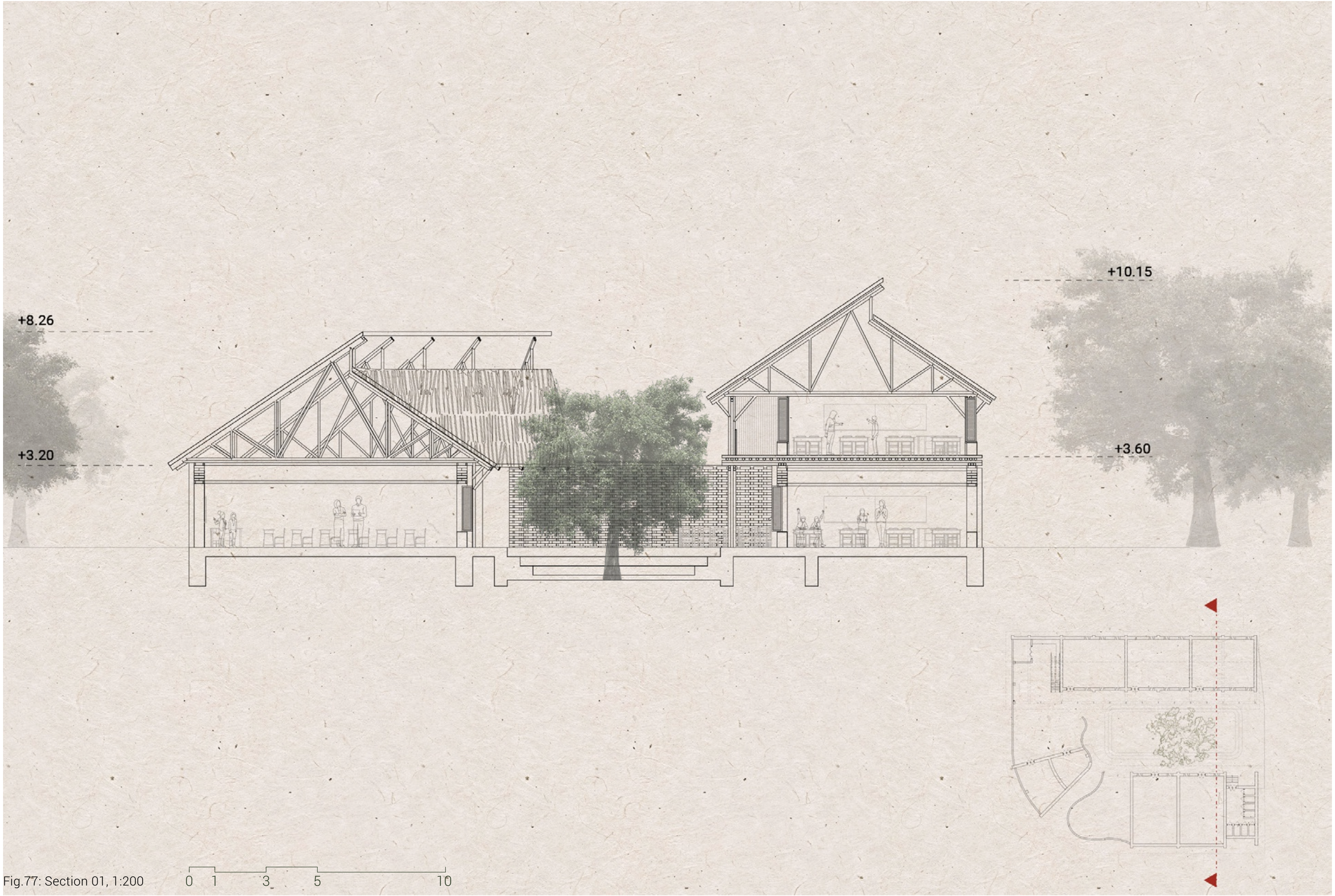


Fig.77: Section 01, 1:200

Fig.78: Section 02, 1:200

Fig.79: Section 03, 1:200

5.7 SECTIONS

Fig.80: Section 04, 1:200

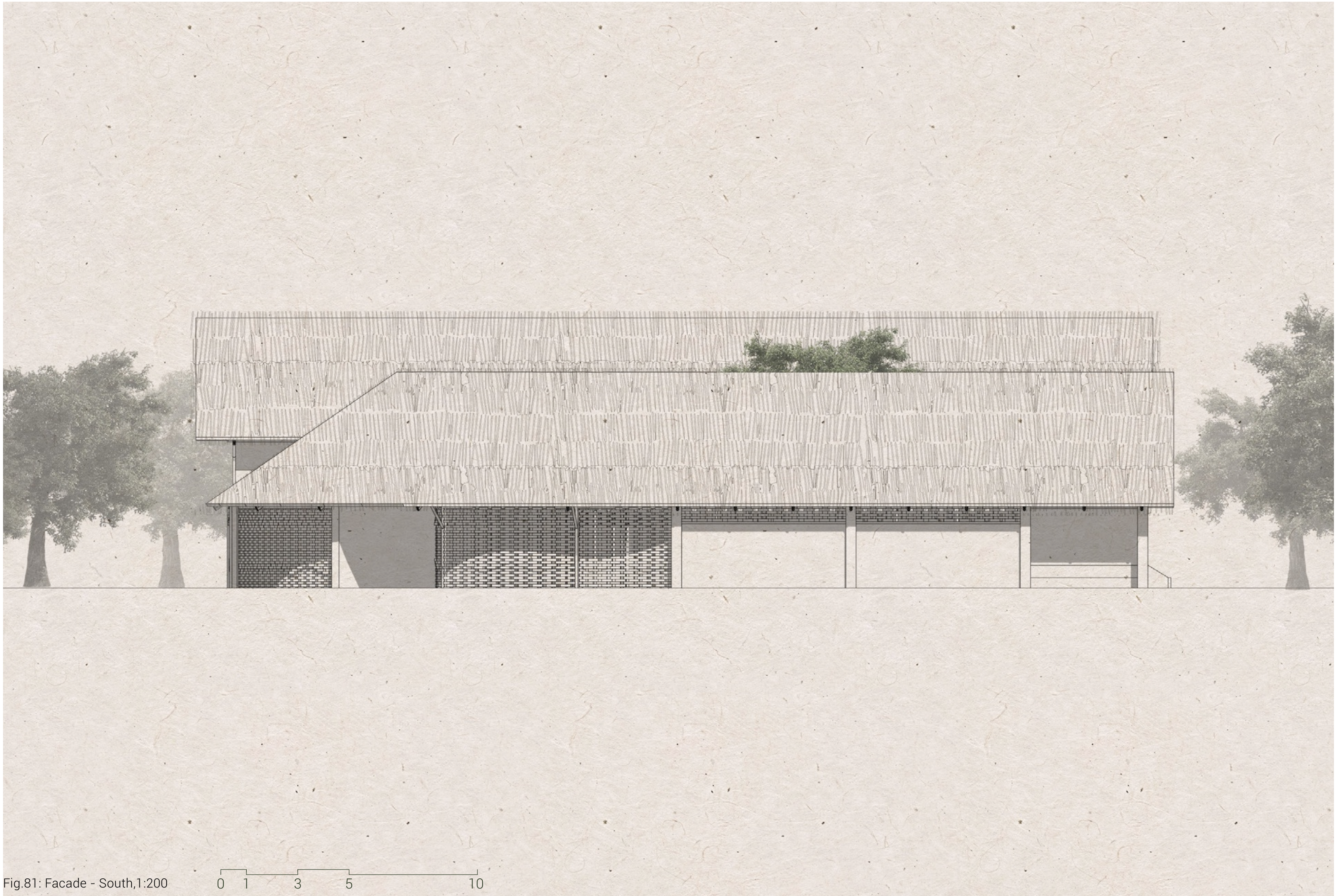


Fig.81: Facade - South,1:200

5.8 FACADES

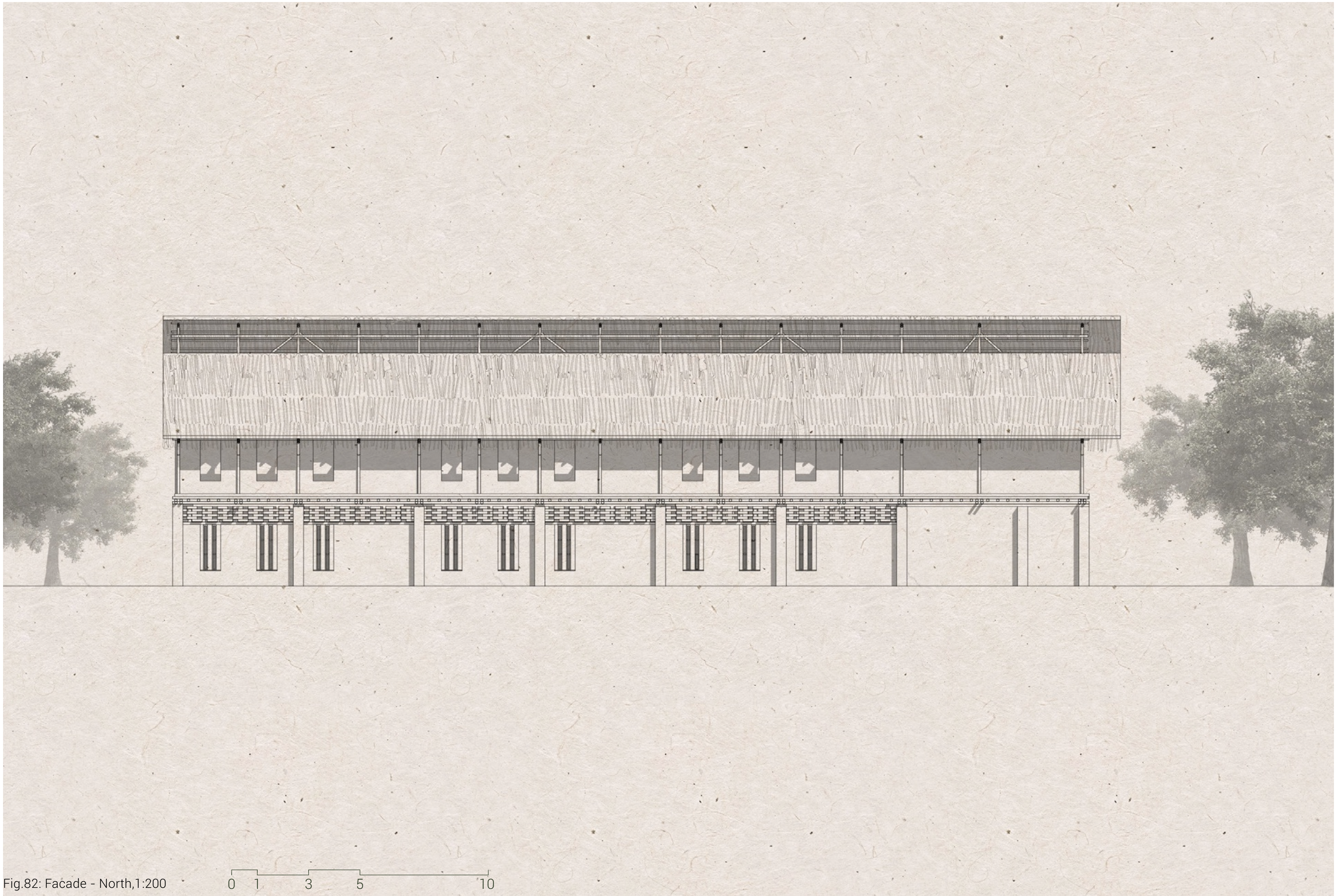


Fig.82: Facade - North,1:200

5.8 FACADES

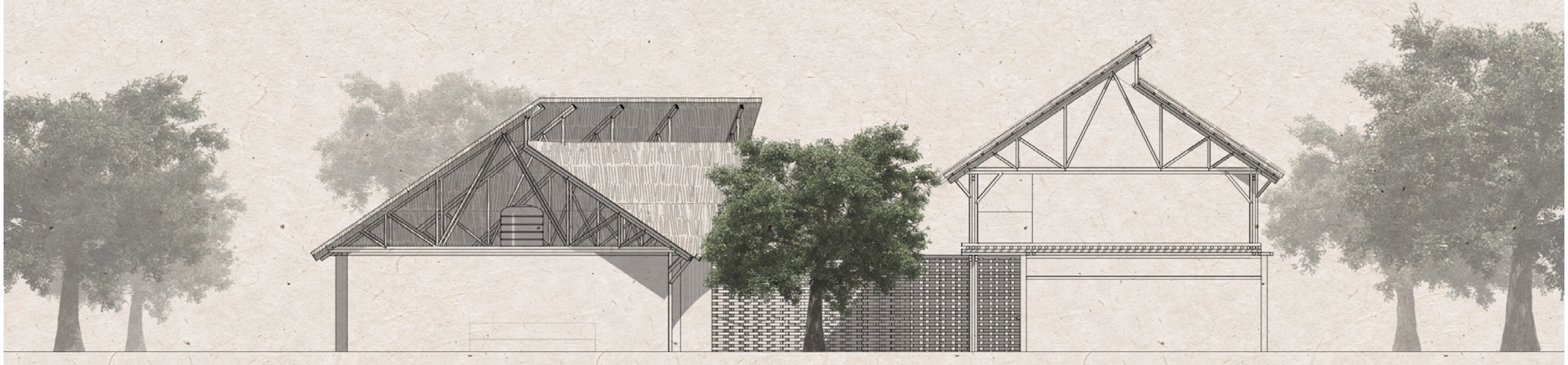


Fig.83: Facade - South,1:200

0 1 3 5 10

Fig.84: Facade - North,1:200

5.9 VENTILATION, NATURAL LIGHTING & WATER COLLECTION

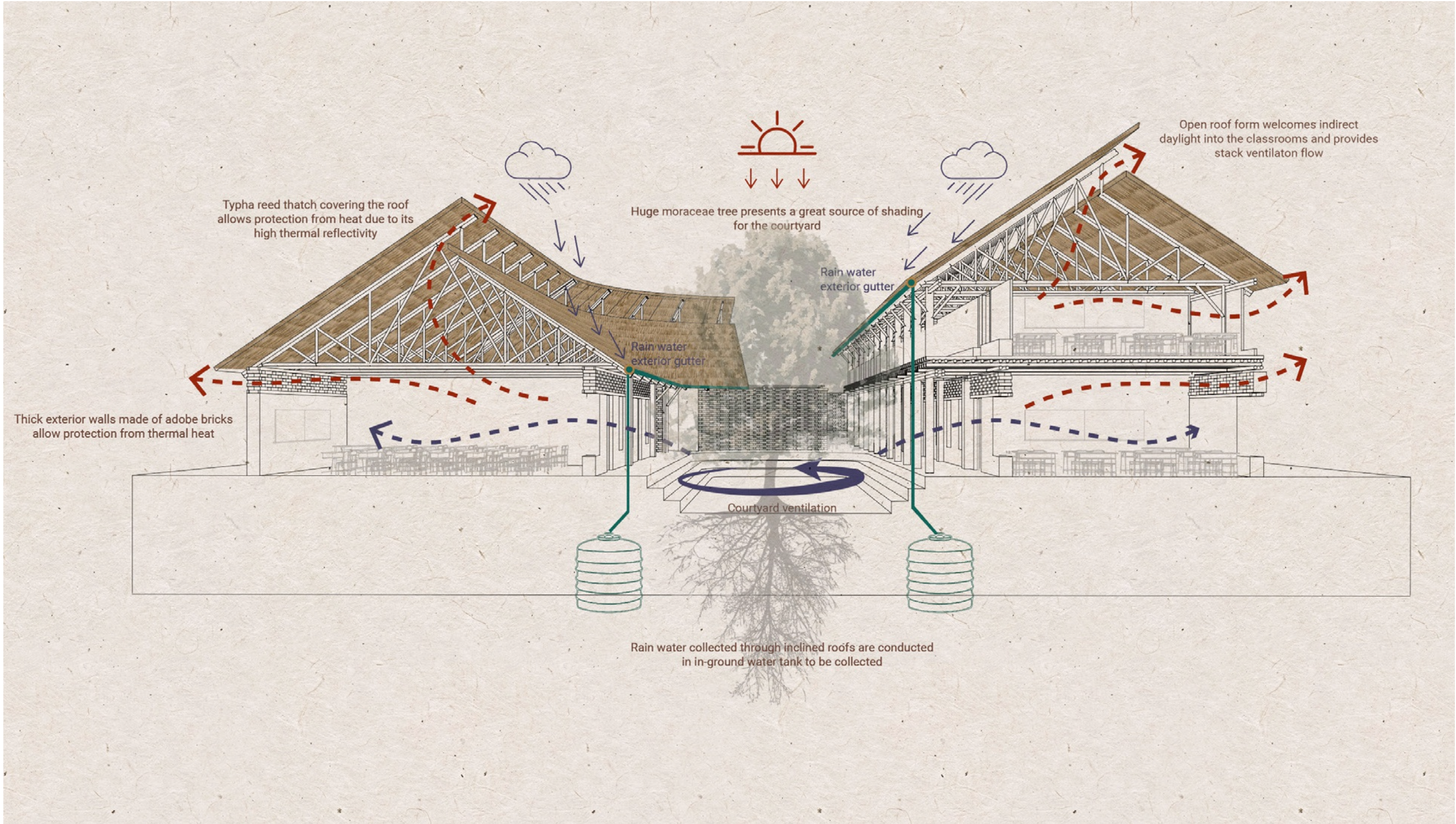


Fig.85: Section-perspective - courtyard view

5.10 CONSTRUCTION

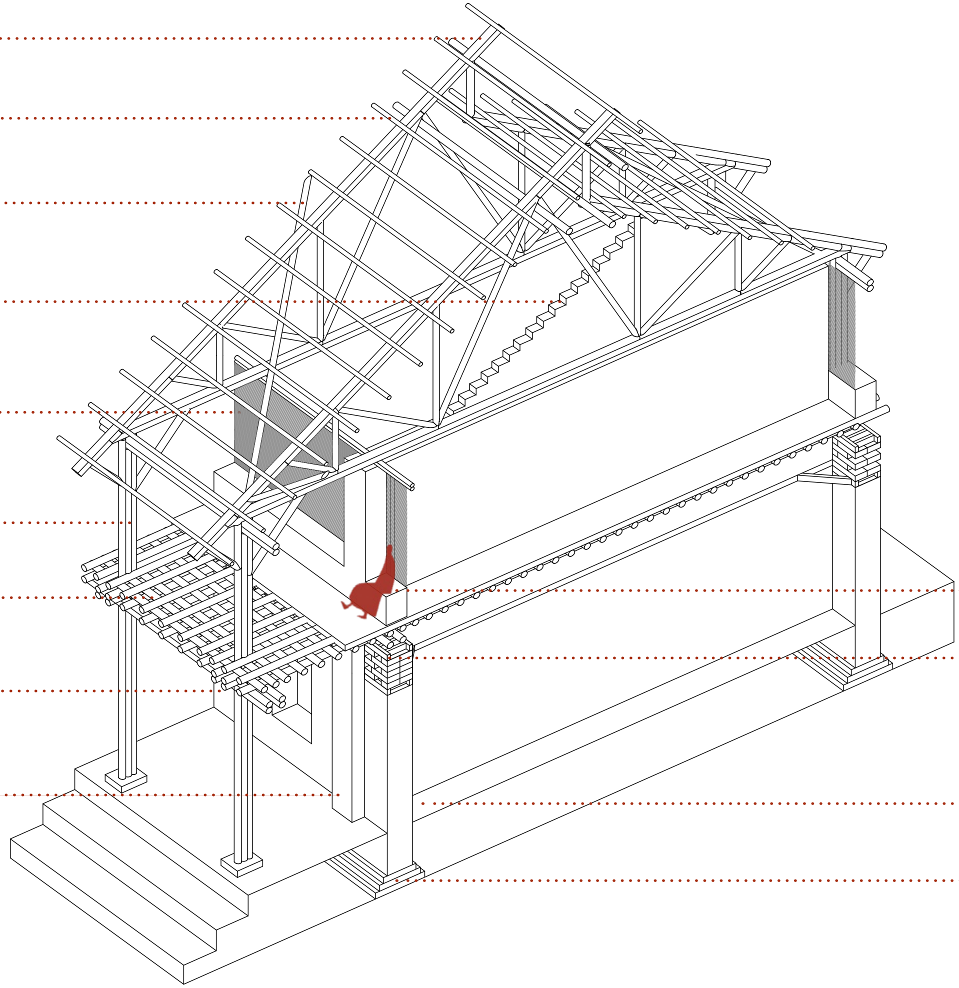


Fig.86: Main construction - axonometric view

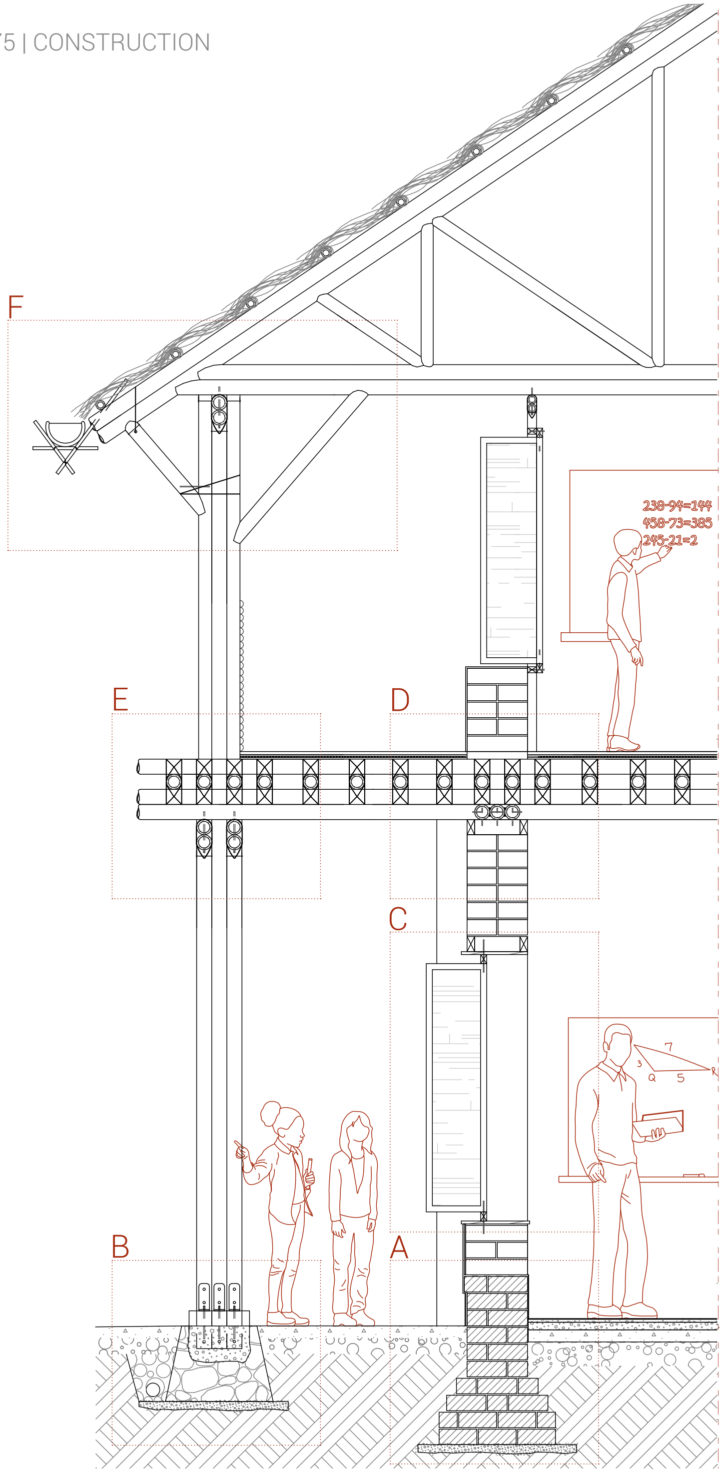


Fig.87: Section, 1:50

Foundations

The job of the foundations is to transmit the load of the construction to the ground. A good connection between the structure and the foundation and a good anchorage between the foundation and the ground must also be guaranteed.
The depth of the foundation is chosen based on the type of soil available on site, yet it should reach a minimum depth level of 50cm below natural ground level. On a bed of compacted sand – 50-75mm thick, a continuous pyramidal footing made of burnt bricks and cement mortar is built, characterised by base width equal to 70cm approximately. The plinth above the continuous spread footing is built using burnt bricks and cement mortar joints and has a width of 1.5 brick thickness. The plinth reaches approximately 25cm above ground level and its height is approximately 70cm. The external face of the burnt brick layer is covered with sand-cement plaster in order to increase its durability. A grade level of minimum 2% is considered for compacted mud platform in order to protect the walls and the foundation from rainwater penetration by diverting it towards the drain in the courtyard, where the ground is terraced and a drainage is considered along its outlines. Crucial for the foundation is a damp proof layer which is placed to prevent moisture rising from the ground. Bamboo posts are cast in concrete footing surrounded stones and a compacted sand bedding as underlayer.

Sun-dried brick-adobe-walls

A load-bearing wall receives the loads from the roof plus its own weight and leads them to the foundations. Fundamental for adobe walls are the bonds between the units. Vertical joints must not be aligned. In general, the rules which apply are the same as those for burnt brickwork. The dimensions of the forms must accordingly be adapted to the bond planned in the design of the project in relation to the extrene dimensions of the walls. For adobe bricks the thickness of the joints should not exceed 2cm.[41] Same mixture used for the bricks could be used as mortar, too. It is important to moisten the bricks well before applying the mortar so that the blocks and the mortar bond well. Considered wall thickness in the project is 40 cm, which offers the benefit of great thermal mass. Walls are covered with loam plaster to achieve a smooth finish in contrast to the perforated walls and their dynamic pattern. Natural paint is applied to the bricks forming the pattern – one option for that would be mixing banana juice with soil and applying it after the construction of the wall. Lateritic clays, which are also available on site, would make good rendering in an attractive red or ochre nuances.[42] As reinforcing agent locally available typha could be a good alternative to straw and bonds well with clay. A final protective layer of linseed oil or carnauba wax should be applied to prevent cracking and enhance water resistance.

41 United Nations Centre for Human Settlements (Habitat), Earth Construction Technology, Nairobi, 1992, p.47

42 United Nations Centre for Human Settlements (Habitat), Earth Construction Technology, Nairobi, 1992, p.130

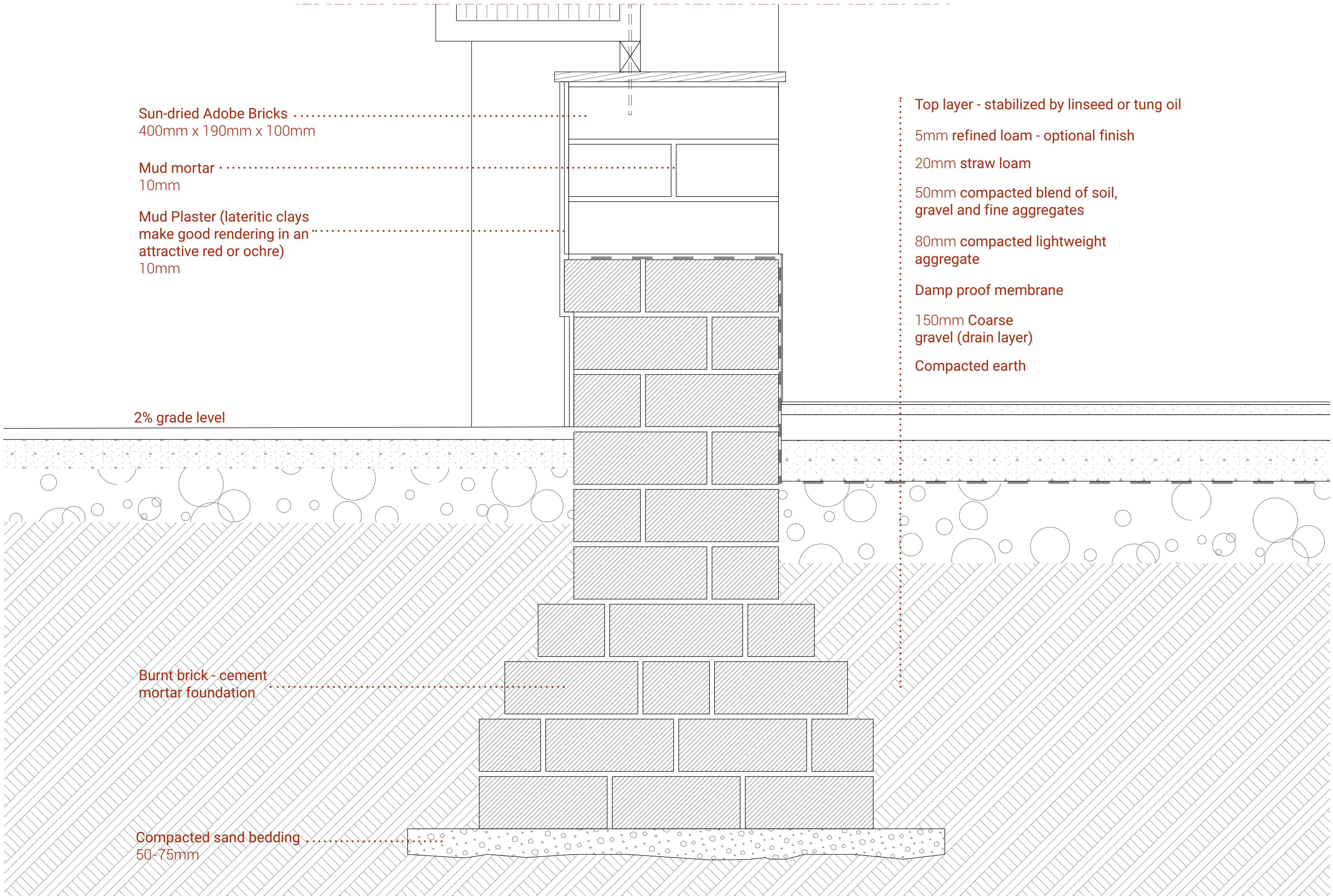


Fig.88: Detail A - Foundation, 1:10

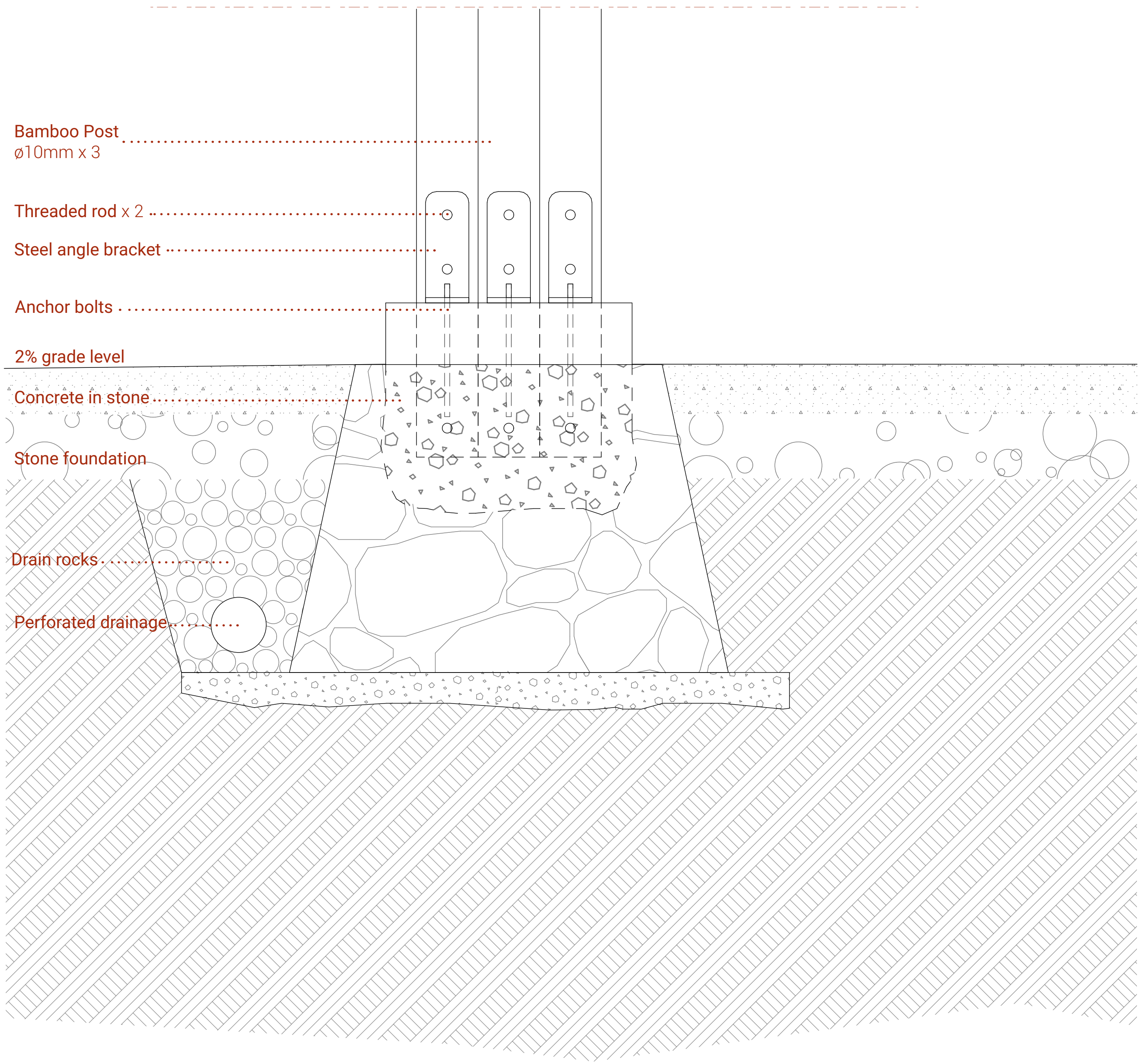


Fig.89: Detail B - Bamboo Post Foundation, 1:10

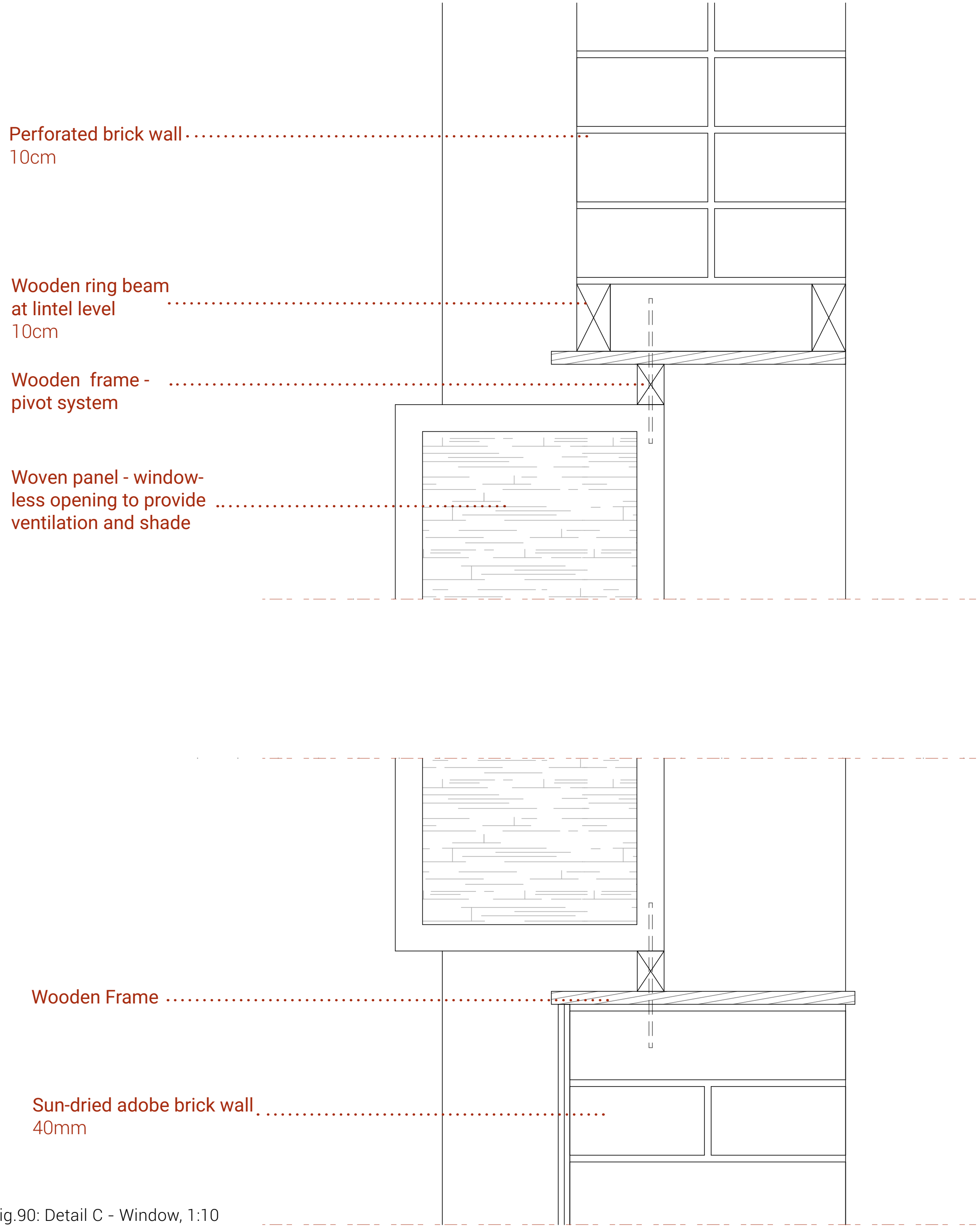


Fig.90: Detail C - Window, 1:10

Openings

To avoid cracking, which would lead to rapid erosion, the structural bond between frames of openings and earth walls must be given special attention, particularly if chronic dampness is present. The openings are dressed in masonry and the tops of all the openings is at the same horizontal level. They are located symmetrically along the long axis of the building. Instead of wooden lintels, a second ring beam at lintel level is installed and incorporates all door and window openings.

Ring Beam

Ring beam is a particularly important belt that surrounds the building at the top in order to correctly transmit the stresses against earthquake, wind-bracing and other horizontal forces. Another function is giving continuity between transverse walls, increasing the resistance to bending. Last but not least, this element acts as continuity between the roof and the walls. The material chosen for the project is wood, since its adhesion with the soil is higher compared to concrete, ensuring the effectiveness of the tie. It is set in the thickness of the wall, after immersion in mortar. Economic and effective sollutions are the use of local wood such as bamboo, blue gum or eucalyptus. It is important to treat those against water, fire and termite damage.[43] All the joints are nailed together firmly and tied to the wall with galvanised steel wire.

Roof

While roof elements are well connected to each other, the trusses that they form must be adequately connected and tied to the walls as well. The suggested roof covering in the project it traditional thatch covering with typha reed panels. They are placed on top of the bamboo purlins which (d = 6cm) and are positioned in a distance of 60 cm from center to center.Galvanised metal wire should be wrapped around the longitudinal bars. The thatch covering should be thick enough to obtain a waterproof roof and it should have an angle of minimum 34 degrees.

43 United Nations Centre for Human Settlements (Habitat), Earth Construction Technology, Nairobi, 1992, p.61

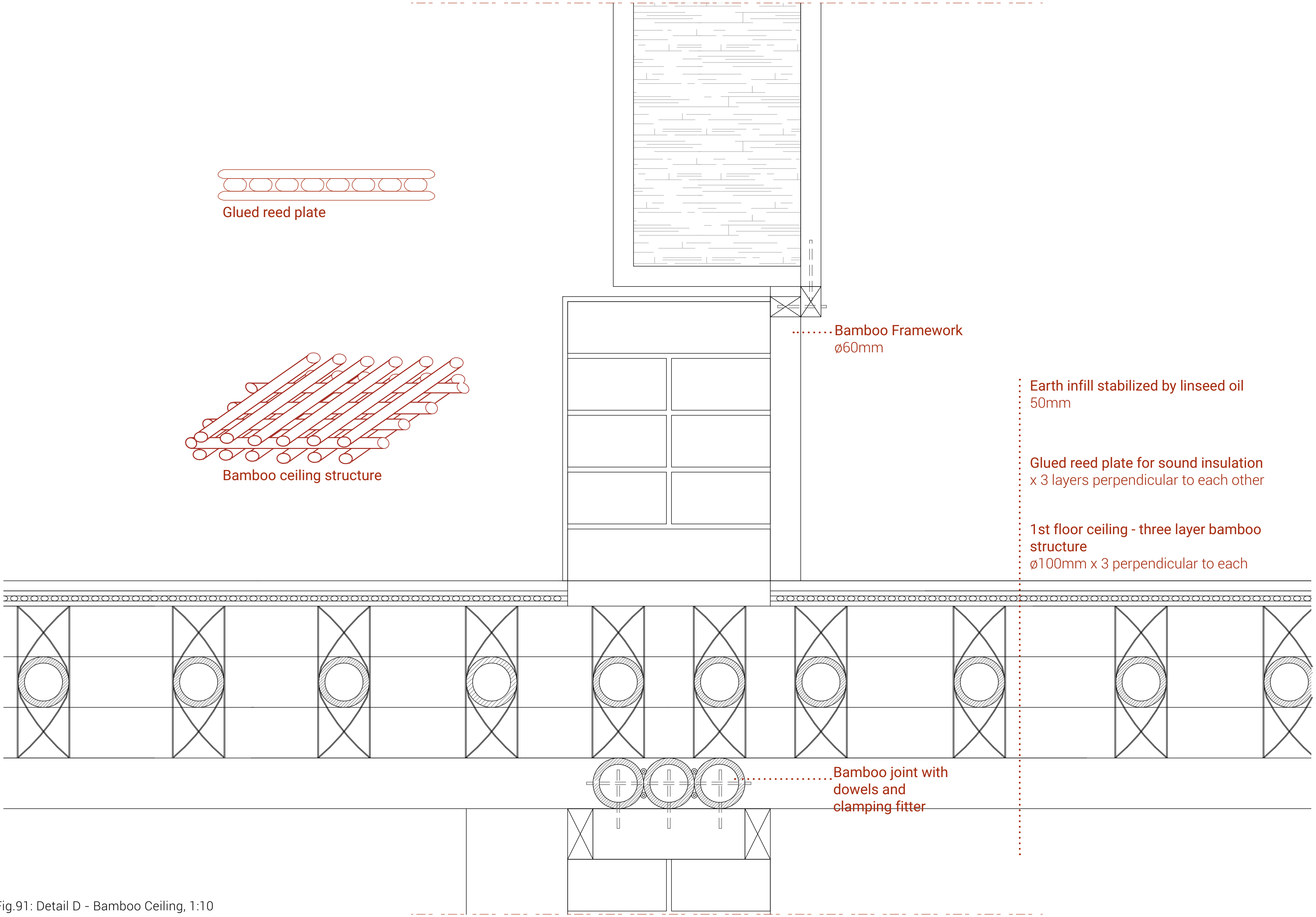


Fig.91: Detail D - Bamboo Ceiling, 1:10

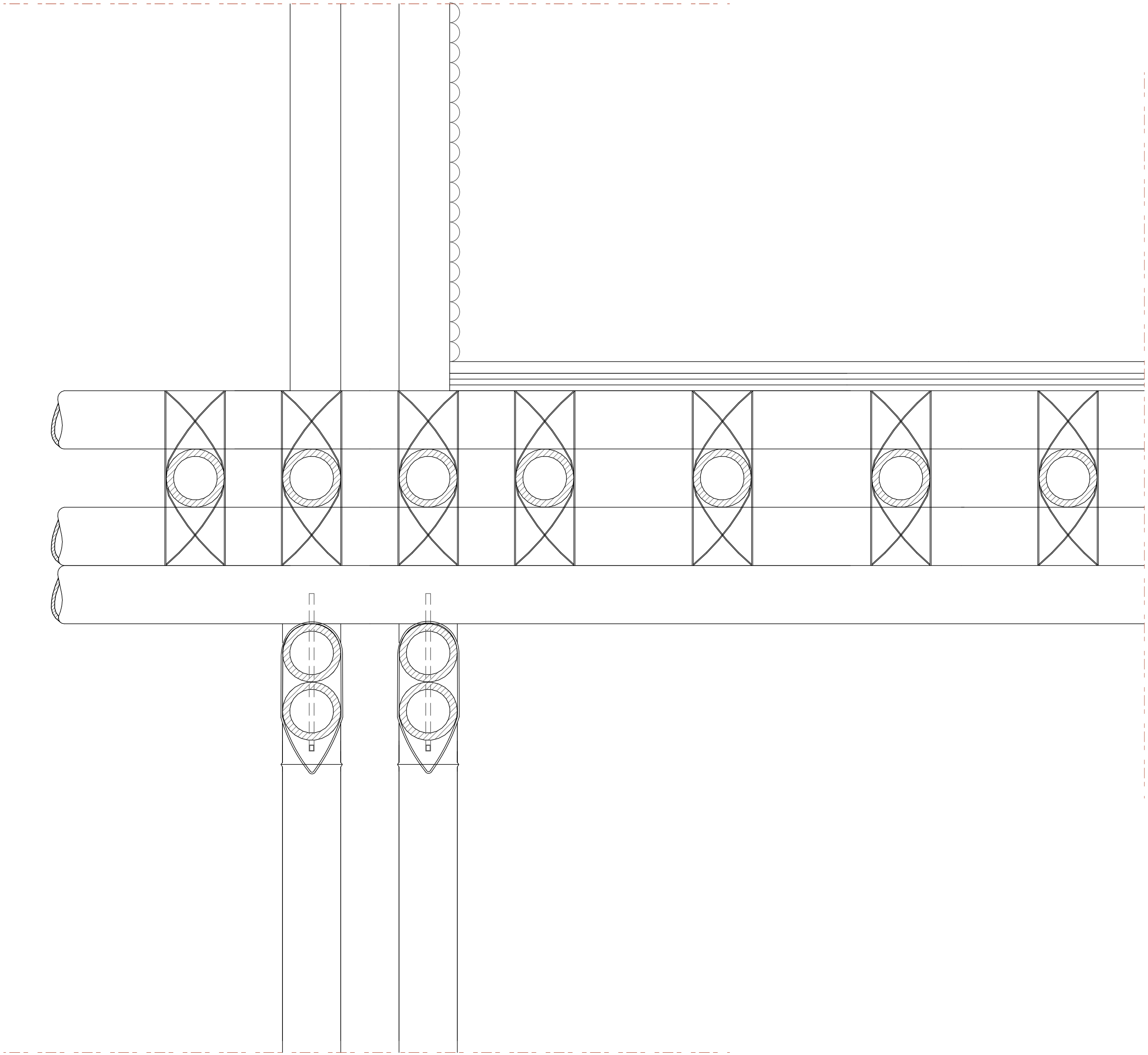


Fig.92: Detail E - Ceiling (Veranda), 1:10

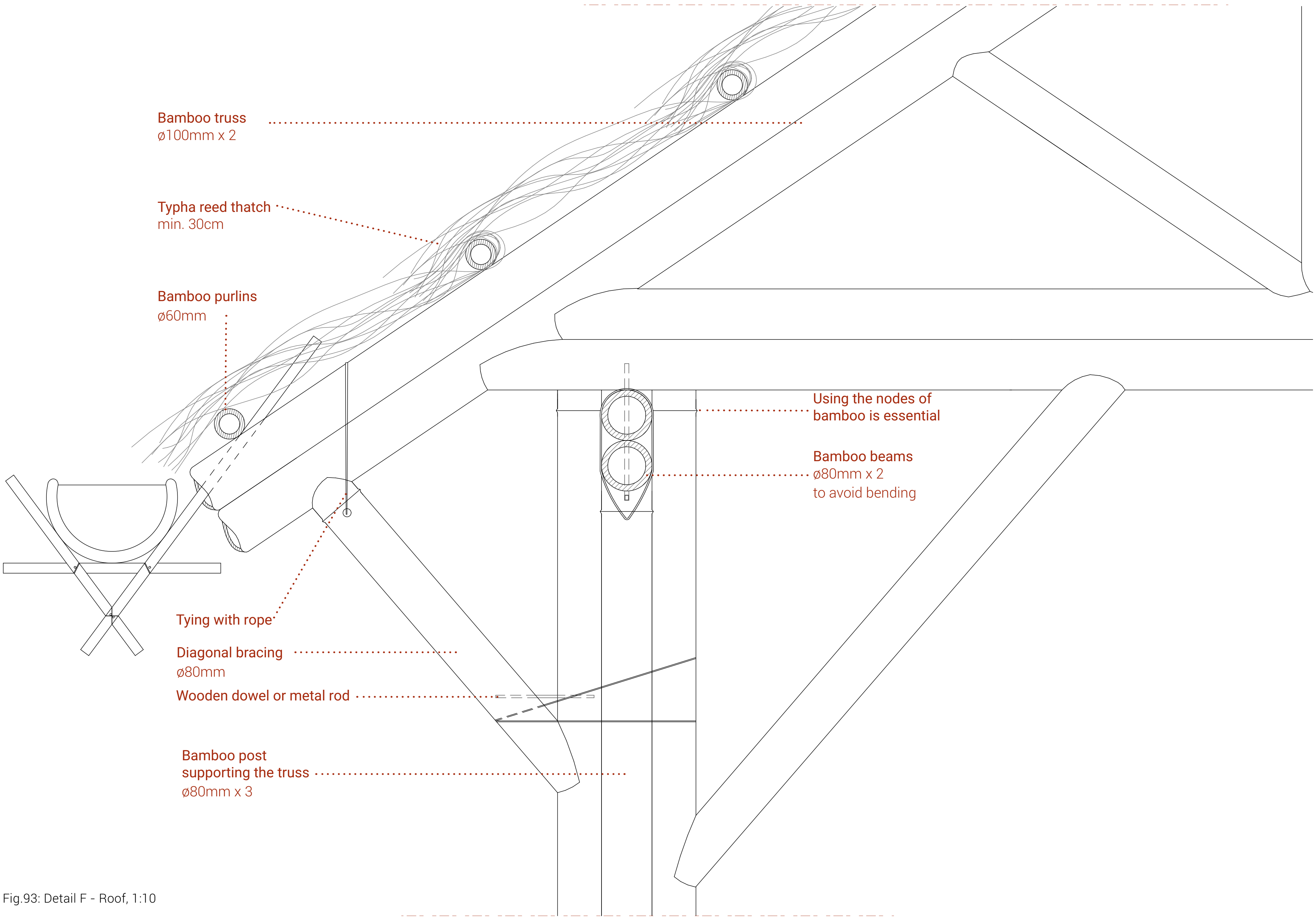


Fig.93: Detail F - Roof, 1:10

5.11 VISUALISATIONS

NEW ELEMENTARY SCHOOL "SAMBOU TOURA DRAME"

Fig.94: 3D visualisation - front area of the school

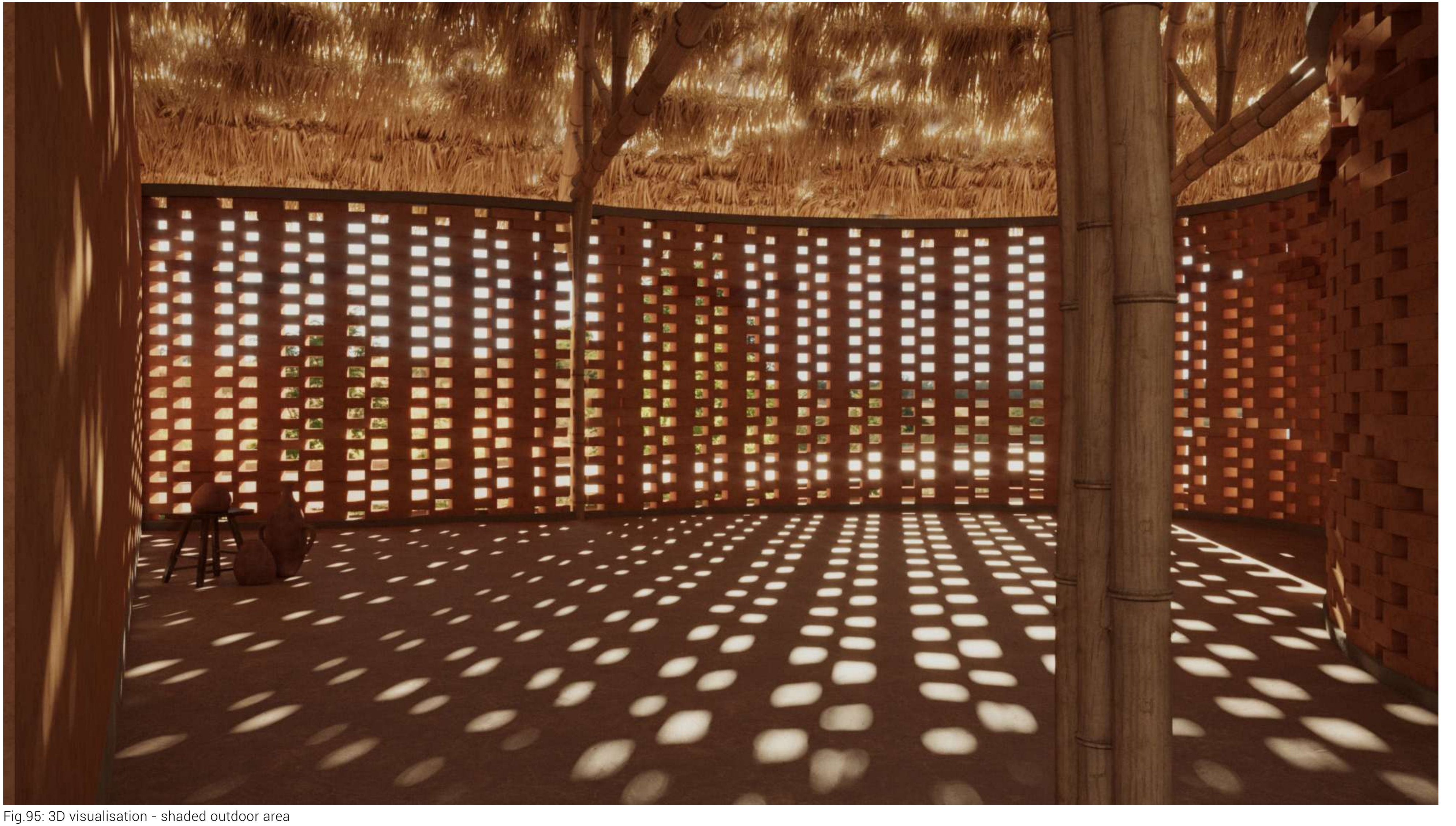


Fig.95: 3D visualisation - shaded outdoor area

Fig.96: 3D visualisation - canteen area

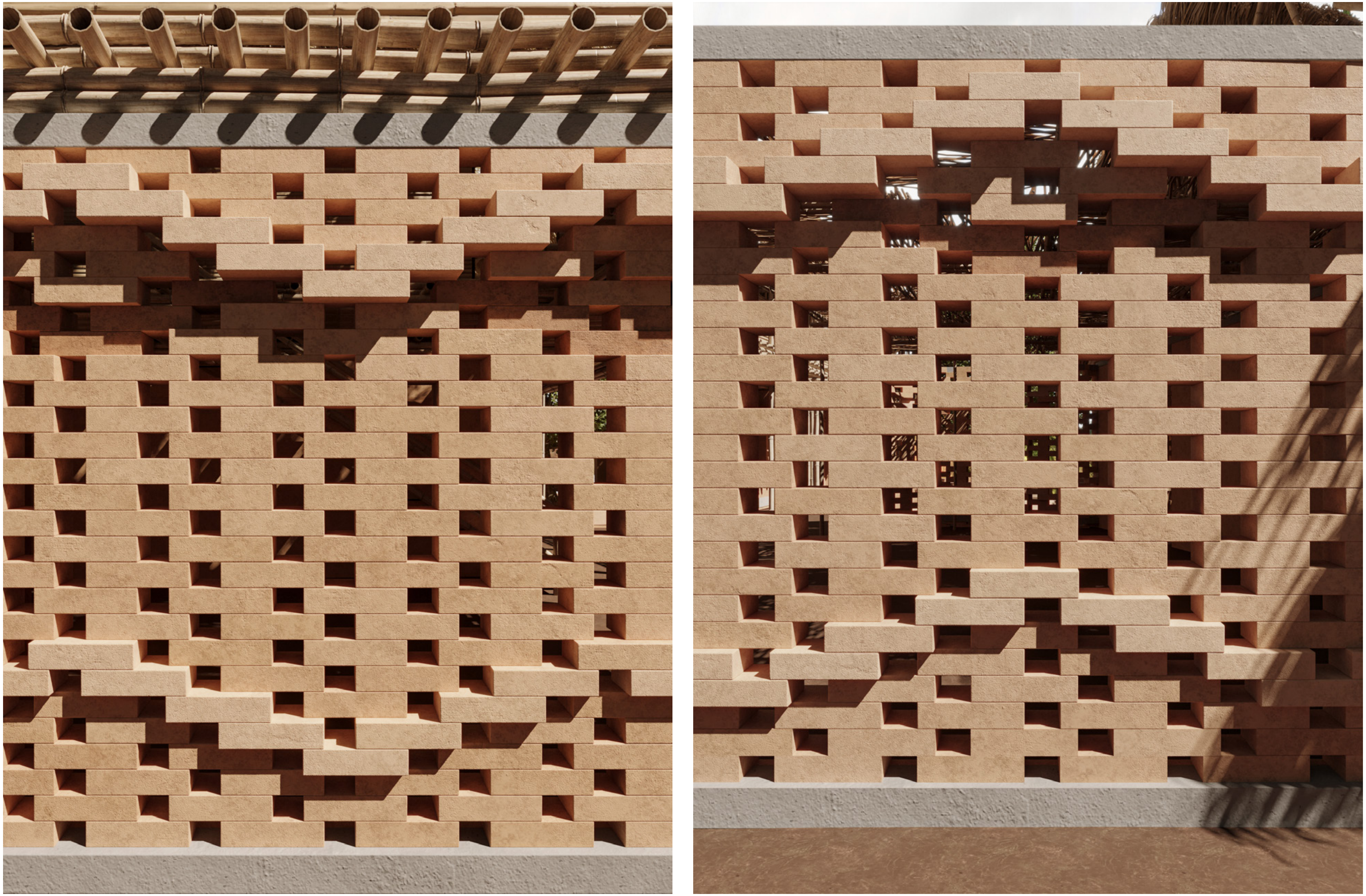


Fig.97: 3D visualisations - brick perforations forming a geometrical pattern

CONCLUSIO

Starting from a competition for a primary school in Marsassoum, Senegal, an extensive analysis of the local architecture, tradition and context was carried out. The company organising it provided has provided the audience with some information as a starting base, but this had to be completed through personal elaborate analysis and research work.

The challenge was not only to find a technically simple solution that can be partly implemented by the inhabitants themselves, but also a solution that respects local building traditions, customs, crafts and social and climatic aspects.

The result is a design proposal for an elementary school building that is developed with the aim of proposing an alternative to the current school building – not only functionally, but also aesthetically, by providing the students and teachers with an attractive and friendly school environment, as well as by giving impulses to the local community and creating a discussion about the myriad of creative possibilities, offered by the local materials and techniques that go hand in hand with sustainability and respect for the Mother Nature.

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