LIFE AROUND CIRCLES

Passive design strategies for a secondary school in benga , Malawi

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Passive design strategies for a secondary school in benga , Malawi

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ABSTRACT

Africa is a big continent with large population growth while it reminds us of poverty, diseases, and some other problems. At first, as architects, we wanted to define design criteria for buildings and build some affordable houses with the help of passive technologies to move people from slums to houses but with further research, we found out that the problems are much deeper than we thought, so we decided to work and improve infrastructure there like education, which has a lot of importance for improving a country.

In this thesis, the ultimate goal is to design the high-performance secondary school building through climate-responsive strategies and nZEB technologies for 100 students in total, which can popularize in many African countries. The aim of this project is to provide a better education to the youngest citizens of the country and gender equality by giving them the opportunity to access a decent secondary school infrastructure. The school will not be a simple school with classrooms it would be a place mix of academic education and skill workshops and helps families also to earn money by technologies which will be apply. We want to use local materials, easy constructive systems (low tech buildings) and energetic technologies in order to make proposals as efficient as possible.

INTRODUCTION

This thesis is based on a competition which is about a secondary school in Benga, Malawi, Africa.In this thesis, the goal is to design the high-performance secondary school building through climate responsive strategies and nZEB technologies for 100 students in total, which can popularize in many African countries. The aim of this project is to provide a better education to the youngest citizens of the country and gender equality by giving them the opportunity to access a decent secondary school infrastructure.

The school will not be a simple school with classrooms it would be a place mix of academic education and skill workshops which will also available for student of primaray school which is located on the other side of the site. We want to use local materials, easy constructive systems (low tech buildings) and energetic technologies in order to make proposals as efficient as possible.
The school must be designed to accommodate four academic years. At first only one classroom per academic year will be constructed, but it would be a long term project in the future which have to consider that the school could be extended in the future to three classrooms per academic year, which means twelve classrooms could be built at some point .

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CHAPTER 1
The CONTEXT

1.1 WHY AFRICA?

Africa, the second-largest and second most-populous continent, is also home to the youngest population in the world. These young men and women are the future of Africa, but their future is also uncertain. Due to major limitations in education and other mitigating factors, the students of Africa fight an uphill battle to obtain their education.

School, a school desk, a notebook, or a teacher are still only a dream for more than 38 million children in Africa. By not being able to experience the empowerment that comes with education, they lose the chance to reach their potential, escape poverty and build a better future for themselves, their family and community. Globally there are still 67 million children out of school, 43% of whom live in Africa.

In 2010, there were still approximately 9 million children of primary school age unable to atend schools in Africa due to various reasons.Girls, nomadic peoples, orphans, children with disabilities, children affected by HIV/AIDS, children affected by armed conflict and children affected by natural disasters are at a particular risk of missing out on education. Young girls are in significant danger due to the threat of bodily injury and sexual abuse while traveling to and from school. For every two children who attend school in Africa, one will drop out graduating.

Regional primary enrollment rates now stand at 89% for boys and 86% for girls. Rates for secondary school enrollment are significantly lower than primary schools. Regional enrollment averages 32% for boys and 29% for girls and many do not actually attend school. Approximately 28% of both boys and girls will attend secondary schools in Africa. Enrollment in percent education programs is expanding throughout Africa. It nearly doubled between1999 and 2012.

Primary school attendance has more than doubled between 1999 and 2012. Enrollment rose from 62 million to 149 million during this time.Parents often can't afford the cost of education, including books, uniforms, and tuition fees for their children to attend schools in Africa. In response, 15 countries have abolished school fees since 2000,enabling more children to attend primary school.

There are a multitude of reasons to explain why these children are not in schools – lack of facilities,culture, the need to be in employment and so on, but sometimes simple measures can make a huge difference. A Save the Children initiative in South Sudan increased school attendance considerably by building permanent classrooms with sanitary facilities.Children understandably preferred this environment to learning 'under the tree'.

1.2 WHY SCHOOL?

Getting an education is not just a fundamental human right. It is pivotal to increasing employment and income opportunities. It is fundamental to breaking the cycle of poverty. Education is the key to unlocking the golden door of freedom for all in Africa. It is the bedrock of social and economic development. Education is crucial as it is an investment in human capital. This yields tremendous benefits at many levels and spheres. It benefits the individual, family community, and nation. Education is a sustainable means to alleviate poverty and bring lasting change. Consequently, to effect permanent change, any effort to bring lasting change must include education, in one way or the other.

Providing quality education to children reflects the fact that every child is entitled to fundamental human rights and should be treated with dignity. Where children lack access to education, this results in poverty, violence, abuse, exploitation, and other undesirable results. Poverty and its related challenges contribute to high dropout rates. Therefore, one of the goals of Develop Africa is to create opportunities for promising but impoverished African children and youths.

Universal education, gender equality and empowering women are vital components of the mission in developing countries. Educating children helps reduce poverty and will give the next generation the tools to fight poverty and conquer disease. School also offers children a safe environment, with support, supervision and socialization.Many countries have committed themselves to more than the achievement of universal primary education. They are also looking at expanding universal education so that it includes several years of secondary school and a new basic education. The challenge of keeping children in school after primary school is great.

Education is one of the most significant investments a country can undertake in terms of its development and thus every child/citizen deserves to receive a good education that will reduce the long-term effects of poverty.

There is a saying that "Education is a powerful agent for change" and with good education, health and livelihoods will substantially improve.Help Reduce Poverty: The lack of good education is also considered the root cause of poverty and to reduce poverty, African countries and their leadership should create avenues where every child will have access to proper education. When more people are educated, the poverty rate in Africa will drop, the reason being that most of the people will have diverse knowledge and skills whereby employment and job creation become easier thus accelerating the country's development process.


Figure 1.1 Education in Benga

Improvement in Health Service: The lack of proper education has resulted in the abysmal health sector in Africa. In Africa, certain illnesses and other treatment complications must be treated overseas in western countries. Thus, in situations where a particular patient cannot afford such high expenses of overseas medical treatment, he or she is left to die of the illness. When more people get educated, the health sector also improves.

In Africa, the infant mortality rate is high. If more people receive a good education in the health domain such as nursing, pharmacy, pediatrics, and others, infant mortality rates will drop drastically.Reduction in Crime Rate: Many people are living in abject poverty due to lack of education and they become vulnerable,hence they turn to illegal activities for daily survival. However, access to quality education will imbibe in them a sense of right and wrong that would deter them from carrying out criminal activities. Reduces Child Marriage: Child marriage is prevalent in most of African countries due to absence of basic education. With access to good education, this dangerous practice will reduce or cease to exist in our society. People's awareness will expand and those advocating the practice will be aware of the importance of education which will further encourage them to send their children to school.

1.3 THE MAIN GOAL

The aim of this project is to design a Low-Tech school with using the potential of the area to provide a better education to the youngest citizens of the country by giving them the opportunity to access a decent secondary school infrastructure. Through the project, the main goal is to:

- EDUCATE: allowing children to access school and make them understand what improvements could they reach if they work hard on learning not only history, math or languages but also in everyday activities such as agriculture or livestock. Another fact is that many of these children live without access to proper healthcare and teaching them how they can protect their own health is crucial. Many common health issues, such as malaria, dysentery, respiratory infections and nutrition-related illnesses are preventable by simply making small lifestyle changes.

-INVESTIGATE: study about what should their country's society do to improve socially and economically. Education is particularly important to communities that are fragile or rebuilding. Education provides stability, structure, and hope for the future, helping children and youth to overcome trauma caused by war, disaster, or conflict. Having a safe learning environment also makes children and youth less vulnerable to exploitation, kidnapping, and recruitment by militant groups or organized crime.

- CONTRIBUTE TO THE CONSERVATION OF THE ENVIRONMENT: it is a fact that people in Malawi do not worry about the deforestation. The aim is that through education, we could raise awareness of that huge problem. The deforestation in the hills is causing a major change to the landscape and to the climate. As soon as the trees are cut down, the soil is exposed to the rain and, in many places, most of the topsoil is washed away into the rivers and eventually into Lake Malawi.
This is leaving the hills infertile so that trees and crops do not grow well, and the soil that is being deposited in the lake is affecting fish stocks which, together with over-fishing, is causing a dramatic reduction in the number of fish that are being caught in the lake.

1.4 GEOGRAPHY

Malawi is a landlocked country in southeast Africa. It is wholly within the tropics; from about 9°30S at its northernmost point to about 17°S at the southernmost tip. The country occupies a thin strip of land between Zambia and Mozambique, extending southwards into Mozambique along the valley of the Shire River. In the north and north east it also shares a border with Tanzania. Malawi is connected by rail to the Mozambican ports of Nacala and Beira. It lies between latitudes 9° and 18°S, and longitudes 32° and 36°E.

Figure 1.2 Malawi Distirbution cities

The Great Rift Valley runs through the country from north to south. Lake Malawi lies within the rift valley, making up over three-quarters of Malawi's eastern boundary.The Shire River flows down the rift valley from the south end of the lake to join the Zambezi River farther south in Mozambique.

Plateaus and mountains lie to the east and west of the Rift Valley. The Nyika Plateau lies west of Lake Malawi in the north of the country. The Shire Highlands lie in southern Malawi, east of the rift valley and Shire River and south of Lake Malawi. The Zomba and Mulanje mountain peaks rise from the highlands to respective heights of 2,100 and 3,000 metres.

West of the Great Rift Valley, the land forms high plateaus, plateaus rise generally 910 to 1,220 m (3,000 to 4,000 ft) above sea level. In the north, the Nyika Uplands rise as high as 2,400 m (8,000 ft). The area to the west of the lake in northern and central Malawi has been categorised by the World Wildlife Fund as part of the Central Zambezian miombo woodlands ecoregion.

Figure 1.3 Malawi Lake

1.5 POPULATION

Malawi is a country with a population of 16 million people where more than a million are orphans.It is one of the most densely populated countries in sub-Saharan Africa and one of the least developed and poorest countries in the world.

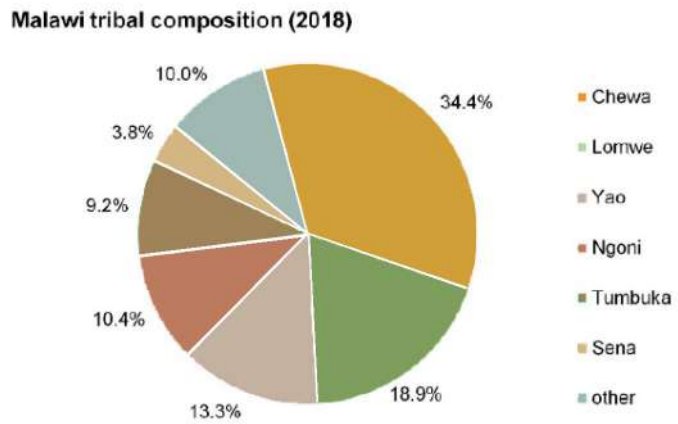
It is also one of the least urbanized,with more than four-fifth so fits people living in rural locations.It is urbanizing at a very rapid rate,however,with movement toward urban areas taking place at a pace far swifter than either the African or global averages.

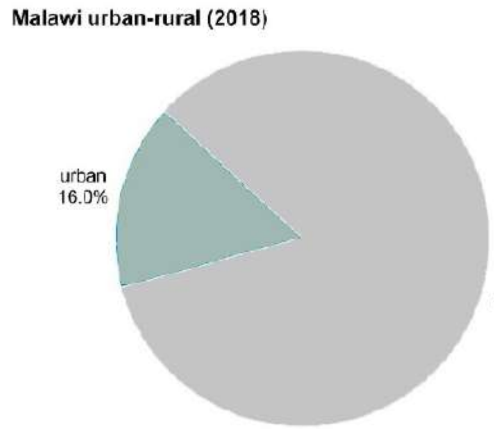
All the African languages spoken are Bantu languages. From 1968 to 1994, Chewa was the only national language; it is now one of the numerous languages used in print and broadcast media and is spoken by a majority of the population.

In 1996 government policy indicated that education in grades 1–4 would be provided in the students' mother tongue or vernacular language; from grade 5, the medium of instruction would be English, which, though understood by less than one-fifth of the population at independence

in 1964, continues to be used widely in business, administrative and judicial matters, higher education, and elsewhere. Other major languages include Lomwe, Yao, and Tumbuka.

The population is growing at a rate above average for sub-Saharan Africa. The birth rate is among the highest on the continent, but the death rate is also high, and life expectancy for both genders is significantly lower than the average for sub-Saharan Africa, primarily because of the incidence of HIV/AIDS. Nearly half the population is younger than age 15, and about three-fourths of the population is 29 or younger.





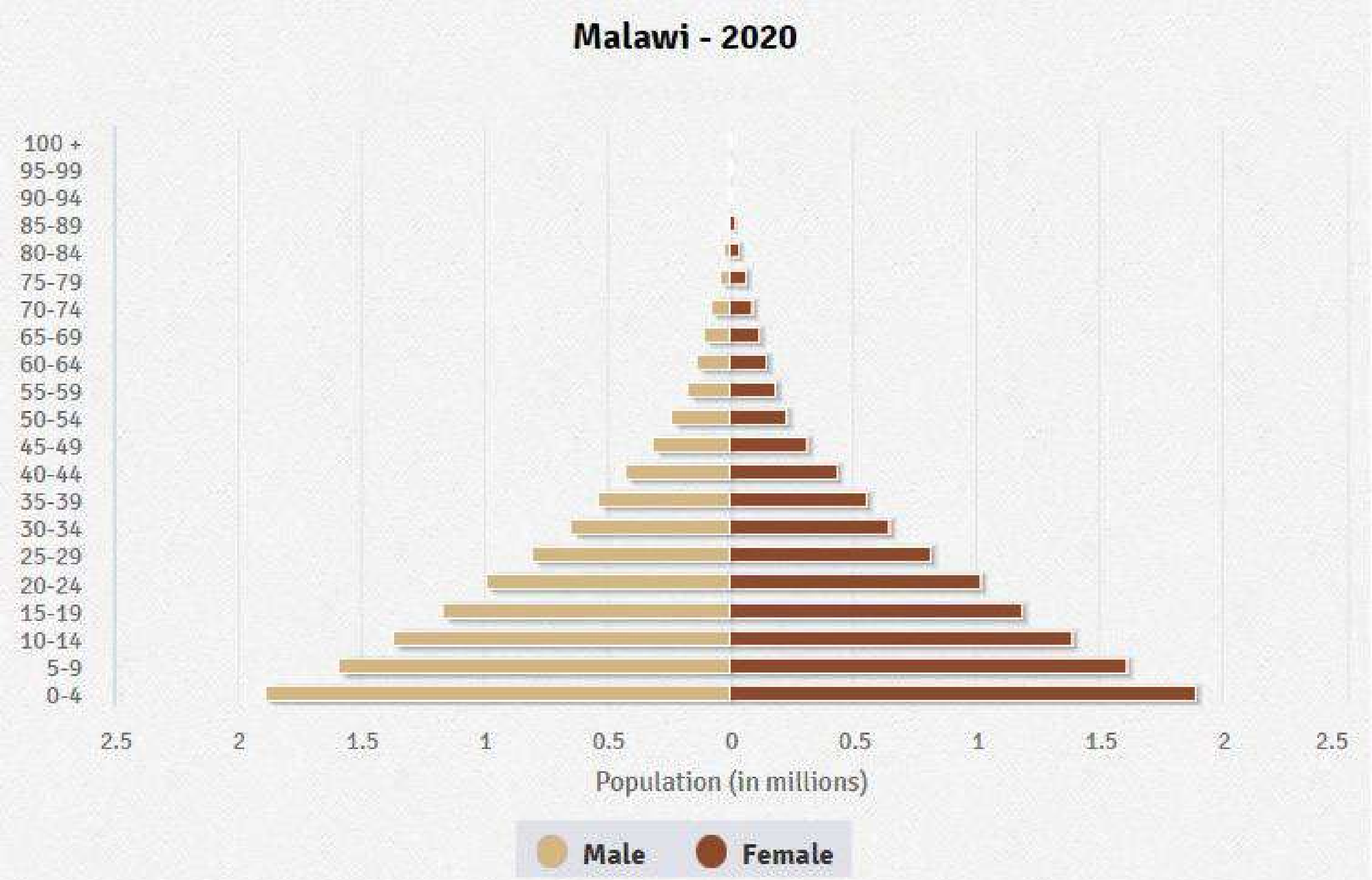
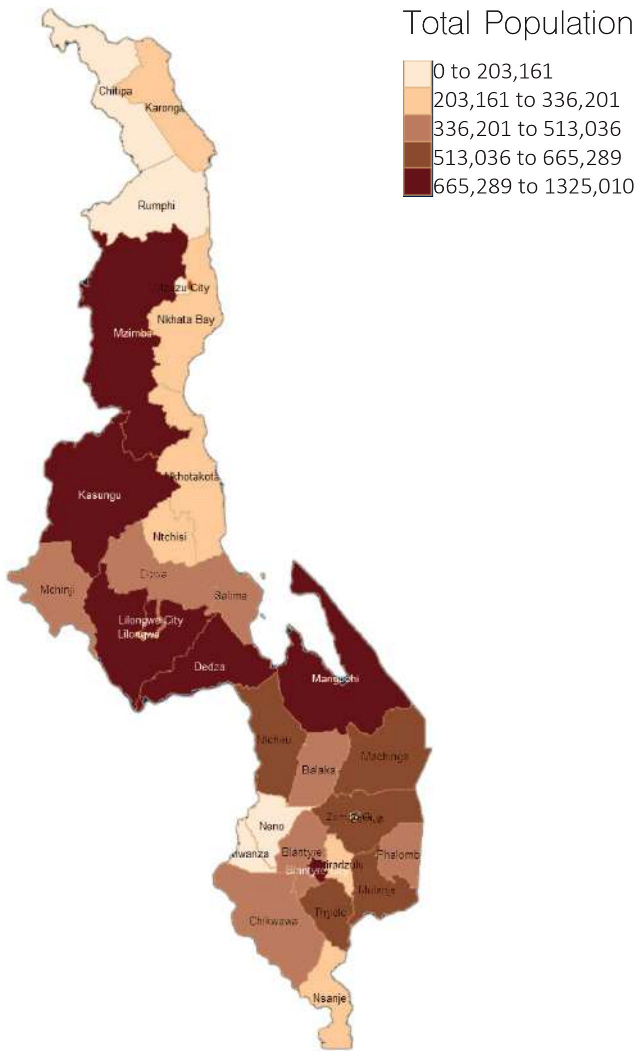


Figure 1.4 Malawi population according to the gender



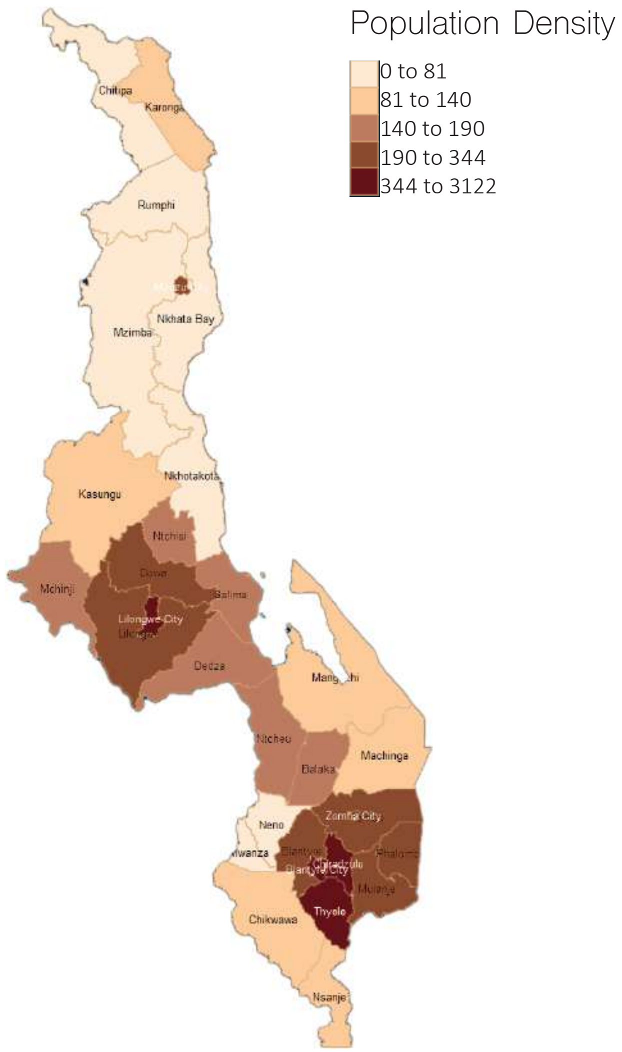


Figure 1.5 Malawi population distribution

Figure 1.6 Malawi population density

1.6 ECONOMY

The backbone of the Malawi economy is agriculture, which in the 2000s employed more than four-fifths of the working population and accounted for about one-third of the gross domestic product (GDP) and most export earnings. Tobacco, the most important export crop, accounts for a major portion of the country’s trade income; tea, sugar, and cotton—all mostly grown in the estate sector—are also important.

Since the mid-1960s the government has sought to strengthen the agricultural sector by encouraging integrated land use, higher crop yields, and irrigation schemes.

In pursuit of these goals, several large-scale integrated rural-development programs, covering one-fifth of the country’s land area, have been put into operation. These projects include extension services; credit and marketing facilities; physical infrastructure such as roads, buildings, and water supplies; health centers; afforestation units; and crop storage and protection facilities. Outside the main program areas, advisory services and educational programs are available.

However, these schemes have brought little benefit to the smallholders, real growth instead being largely concentrated within the estate sector, which has been favored by the government.

Many smallholders have remained poor and indebted, and smallholder production has generally not increased enough to meet the demands of the rapidly growing population.

1.6.1 Agriculture

Agricultural products constitute a large proportion of Malawian export revenue; the most important of these are tobacco, sugar, tea, and cotton. Tea is grown on plantations on the Shire Highlands; coffee is produced mostly in the Shire Highlands and in northern Malawi, especially in the northeastern Viphya Mountains, and near Rumphi and Misuku. Tobacco, by far the most important export, is raised largely on the central plateau on large estates and by smallholders in various parts of the country. With the rise of worldwide campaigns against smoking, however, farmers have been increasingly encouraged to diversify so as not to be wholly dependent on tobacco.

Corn (maize) is the principal food crop and is typically grown with beans, peas, and peanuts (groundnuts) throughout the country by virtually all smallholders.

Other important food crops include cassava (manioc), bananas, pulses, sweet potatoes, and rice; chickens, cattle, pigs, sheep, and goats are raised.
Tea is grown on plantations on the Shire Highlands; coffee is produced mostly in the Shire Highlands and in northern Malawi, especially in the northeastern Viphya Mountains, and near Rumphi and Misuku. Tobacco, by far the most important export, is raised largely on the central plateau on large estates and by smallholders in various parts of the country. With the rise of worldwide campaigns against smoking, however, farmers have been increasingly encouraged to diversify so as not to be wholly dependent on tobacco.
Corn is the principal food crop and is typically grown with beans, peas, and peanuts throughout the country by virtually all smallholders.
Agriculture is important in Malawi because agriculture significantly contributes to employment, economic growth, export earnings, poverty reduction, food security, and nutrition. Turning the country's agriculture sector into a robust one is therefore a major development target for Malawi.

Figure 1.6 Agriculture in Malawi

1.6.2 Foresty

There are 71 gazetted forests managed by the Forestry Department. They cover an estimated 0.87 million ha. comprising 22% of forest cover in Malawi. Most of them are on hills and mountains protecting fragile catchment and watershed areas from environmental degradation. Between 1990 and 2010, Malawi lost an average of 32,950 ha or 0.85% per year. In total, between 1990 and 2010, Malawi lost 16.9% of its forest cover.
The rapid rate at which wooded areas have been disappearing in Malawi is a source of grave concern. Between the early 1970s and the early '90s, more than half of Malawi's forested area was depleted, and, although the deforestation rate modestly decreased in the following decade, it nevertheless remained extremely high by relative standards.
The use of wood as fuel is one major factor in the depletion of the country's woodlands. In rural areas, wood has always been used to provide fuel for cooking, and, as the population grows, more of it is used; in the urban areas, charcoal is the main source of energy, adding more pressure on woodlands. The heavily dominant tobacco industry has resulted in further denudationof forests, as trees have been regularly felled both as timber for the construction of sheds to dry or cure the crop and to fuel the curing process itself.
Another source of the problem is brick making, which relies heavily on firewood to fire the kilns.
The reduction of casual labour and the number of civil service positions at the behest of the International Monetary Fund (IMF) and the World Bank has meant forest reserves no longer have personnel to guard them from abuse.
In Malawi, deforestation is estimated to be responsible for the loss of 33,000 hectares per year, and is mainly attributed to agriculture expansion, tobacco growing, and excessive use of biomass.

Figure 1.7 Forestry in Malawi

1.6.3 Fishing

Fishing is practiced for subsistence as well as by artisanal and commercial fisheries. The lakes and rivers of Malawi provide a diverse catch. Lake Malawi in particular is a rich source of fish within easy access for most of the country's population and accounts for some three-fourths of the country's catch. Other important sources include Lakes Chilwa, Malombe, and Chiuta and the Shire River. Although aquaculture is practiced, much of the country's total catch is obtained by capture, with artisanal fisheries accounting for the greatest proportion of that take. Some fish are exported to neighbouring countries.

Since the late 20th century, the fish population has dwindled because of overfishing, the use of nets with a mesh size smaller than those recommended by fisheries experts, and the disregard of the ban on fishing in the breeding season.In response,natural resources committees have been formed in lakeshore communities to participate in the management of fisheries and the enforcement of

1.6.4 Resources and power

Most of Malawi's mineral deposits are neither extensive enough for commercial exploitation nor easily accessible. Some small-scale mining of coal takes place at Livingstonia and Rumphi in the north and quarrying of limestone for cement production is also an important activity. Precious and semiprecious stones are mined on a small scale; these include agate, aquamarine, amethyst, garnet, corundum, rubies, and sapphires. Exploration and assessment studies continue on other minerals such as apatite, located south of Lake Chilwa; bauxite, on the Mulanje massif; kyanite, on the Dedza-Kirk range; vermiculite, south of Lake Malawi near Ntcheu; and rare-earth minerals, at Mount Kangankunde northwest of Zomba. Deposits of asbestos, uranium, and graphite are known to exist as well.

Also under investigation are base metals, gold rutile, and ilmenite sands. Arable land is considered one of Malawi's most significant natural resources, although it is strained by both the country's high population density and its agriculture-based economy. Forests and woodlands cover about one-third of the country, and almost 4,000 square miles (10,300 square km) are in state-controlled forest reserves.

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Malawi's water resources are plentiful, although some rural areas are inadequately supplied. Treated water for the major cities of Blantyre and Lilongwe is supplied by the Walker's Ferry Scheme and the Kamuzu Dam, respectively. Most of the rivers are seasonal, but a few large ones, particularly the Shire River along its middle course, have considerable potential for irrigation and electricity generation. Power demands are met by hydroelectric schemes, including those at Nkula Falls, Kapichira, and Tedzani Falls, and by diesel plants. Major consumers of electric power include the industrial areas of the south near Blantyre, where electricity consumption has steadily multiplied, and the industrial area of Lilongwe; the vast sugar estates at Nchalo and Dwangwa also consume much electricity. By contrast, only a fraction of Malawians themselves have electrical access, and almost all domestic energy needs are met by firewood.

Power availability has been hindered by different factors. The drying of rivers due to deforestation near their sources and along their courses has resulted in a reduction of water flow into Lake Malawi, which in turn has adversely affected the currents of the Shire, on which the Nkula and Tedzani hydroelectric plants are located.

Figure 1.8 Solar panel in Malawi

1.7 CULTURE

1.7.1 Religious

Protestant Christianity 44% of the entire population in Malawi are Protestant Christians. The country has experienced a rapid growth in Protestantism in recent times. The main aim of the churches is to bring out holistic growth in which Christians are committed to both the church and making a difference in their country and society.

Sunni Islam is the second largest religion in Malawi. It was introduced in Malawi by the Arabs and the Swahili traders during the barter trade of ivory, gold, and slaves. Traders from the Kilwa Sultanate and two other Muslim teachers played a significant role in its spread before the 19th century. Over the years, missionary work by Muslim groups has been done to promote the religion in Malawi. Mosques have been built in every town, Islamic schools and learning centers, and a Muslim broadcasting station. 19% of the country's population adhere to this religion.

The Roman Catholic Church in Malawi is part of the worldwide Catholic Church in Rome under the leadership of the Pope. Catholicism was introduced in Malawi byThe Roman Catholic Church in Malawi is part of the worldwide Catholic Church in Rome under the leadership of the Pope. Catholicism was introduced in Malawi by the first Catholic missionaries in 1889.

Five years after the arrival of Catholicism in Malawi, three mission stations were permanently set up to enhance its spread. The first Malawian priest was ordained in 1938 by the white fathers. Roman Catholics comprise 18% of the nation's total population.

Apart from Protestants and the Roman Catholics, there are other small denominations like Baptists, seven-day Adventists, Jehovah's witnesses, and Anglicans forming 13% of the population. Several missionaries like bishops encouraged the spread of other forms of Christianity and translated the Bible into the Chichewa language. Under the rule of Malawi's first president, Christianity was favored and several churches built.

1.7.2 Art

Various traditional arts and crafts, including sculpture in wood and ivory, form part of Malawi's material and aesthetic culture. A variety of musical forms, both local and international, are also important. One of the most distinctive features of Malawian culture is the enormous variety of traditional songs and dances that feature the drum as the major musical instrument. Among the most notable of these dances are ingoma and gule wa mkulu, performed by men, and chimtali and visekese, performed by women.

Through domestic broadcasts and international broadcasts received by way of shortwave radio, Malawians—especially those of the younger generations—have always been part of world pop culture and enjoy many international musical artists. Western popular music forms a major repertoire on local radio. It is associated with the more modern urban nightclubs, and most town-based local artists play it rather than music with a strictly African-sounding beat. African styles of pop music are also very popular among all ages in Malawi, however, and, because significant place in the Malawian musical culture. Equally notable is the popularity of Congolese music (a mixture of traditional African rhythms and instruments and those borrowed from other cultures), which, along with mbaqanga, tends to be played in both villages and bars in the urban centers.

1.7.3 Dance

Dance in Malawi comprises the varied styles of dances in the country. As with other aspects of Malawian culture, different forms of dances originated in different parts of the country, developed according to the local traditions and also imbibed elements from other parts of the country.

Music and dancing is an important part of Malawian culture. Like in other parts in Africa, the people of Malawi have several musical instruments for different dances. These dances are perfumed at different occasions such as weddings, funerals, initiations, entertainments etc. In Malawi there are over eighty (80) traditional dances but described below are a third of the dances. Tchopa is a performing art practised among Lhomwe communities in southern Malawi. The dance is usually performed during celebrations after good harvests andsuccessful hunting trips and during offerings to ancestral spirits after calamities such as droughts and outbreaks of disease. Tchopa entails knowledge of particular dancing skills and singing, and employs three different sizes of drums.

Twenty to thirty dancers perform in a circle while criss-crossing each other. Some dancers carry packs on their backs holding farming tools, animal skins, puppets, hunting gear and old kitchen utensils. Each village headman has a small group of Tchopa dancers.

Although primarily performed by older Lhomwe men and women, who function as the bearers and practitioners and principal custodians, Tchopa is now also increasingly performed by children. Knowledge and skills for the dance are transmitted during practice sessions and occasional performances. Other key roles among the group include the makers of dancing costumes and drums, drummers, whistlers and dancers. Tchopa dance strengthens social cohesion among Lhomwe communities with members providing mutual support in times of need, such as during ill health and bereavement, and coming to the assistance of overburdened practitioners by providing communal labour in the field.

Figure 1.9 Group dance in Malawi

1.8 EDUCATION

Education in Malawi stresses academic preparation leading to access to secondary school and universities. However, few students go on to high school or university. The dropout rate is also very high particularly among primary school pupils.

Since 1994 Primary education has been free but not compulsory. Most children start formal education at primary school at the age of six and most of them will not have attended any pre-school education. The children attending primary school are generally between the ages of 6 – 14. Primary education takes 8 years (Standards 1 to 8) and falls in the category of basic education which is meant to equip children with basic knowledge and skills to allow them to function as competent and productive citizens in a free society when they grow up .

Primarily schools are mostly in two categories of assisted (public) and unassisted (private) schools. Villages and hamlets throughout the country have such schools. By 1970, there were approximately 2,000 primary schools for 35 percent of primary school aged youth. About 12 percent of all primary school students attended private, predominantly church run schools.

Secondary education developed late in Malawi, because of little effort or neglect in secondary education during the colonial era. Malawi has five types of secondary schools. These include aided boarding schools, aided day schools, government boarding-secondary schools, government day secondary schools, and private secondary schools. Most secondary teachers are qualified and hold either degrees or diplomas.

In the curriculum, Agriculture is a compulsory subject for all students. Wood working, metal work, and technical drawing are encouraged for boys, and home economics is encouraged for girls. One of the biggest criticisms of secondary schools in Malawi is that they are too university-oriented and needs more technical skills taught. Most students immediately enter the workforce and need a different orientation. Therefore, Secondary schools do not produce as many graduates as the labor market demands. In fact, only one-fourth of Malawi's youth end up attending secondary school.

1.8.1 Education Finance

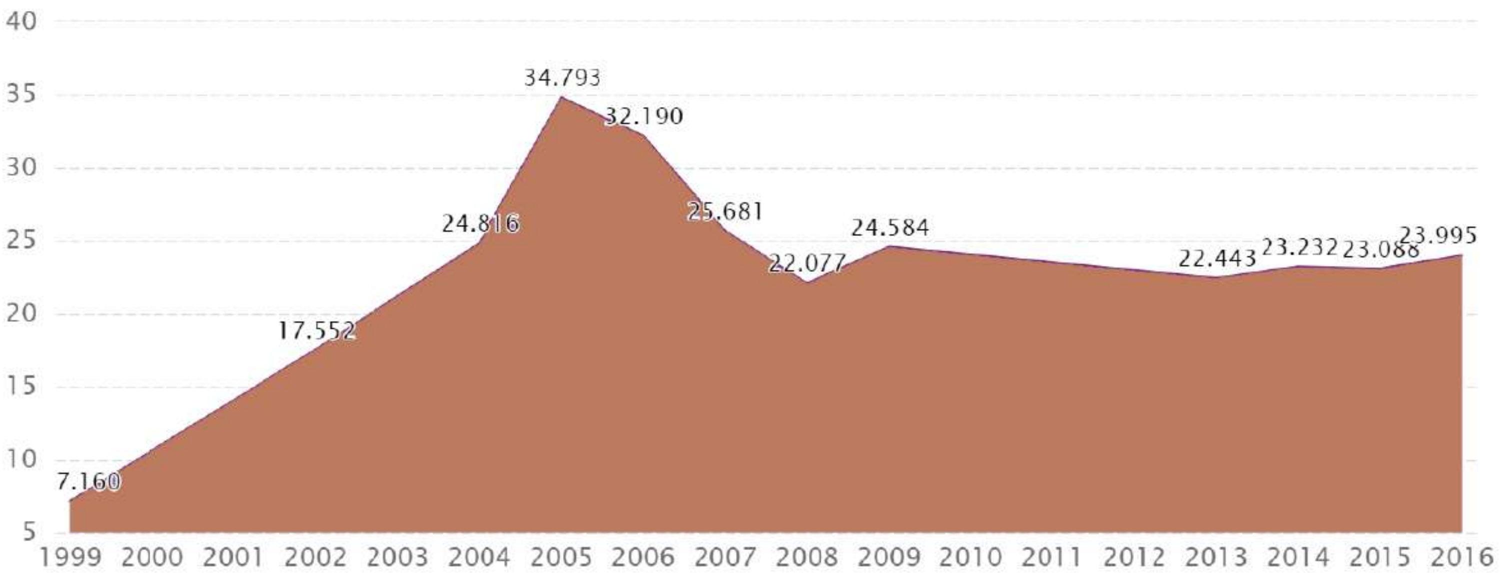
The financing of education in Malawi is largely the responsibility of the Government. External donors continue to play a significant role in education financing, especially the purchase of teaching materials, equipment, and furniture and the building of educational institutions, their renovation and maintenance. All of Malawi's schools have been deemed Community Schools, which in effect places the community in a position of central partnership with the Government. Local communities and parents are increasingly playing a role in educational finance especially sharing in the cost of buildings and their maintenance, transport to schools, uniforms, learning materials and extra-curricular activities. Community participation is particularly significant at the primary level where more than 75% of Malawi's primary schools have been built with the support of local communities.

1.8.2 Children's Attitude To Education

Most children love to go to school. They are keen to learn and explore but they also need more guidance.

The general behaviour of primary school children in Malawi is good and results in a high pass rate in the Primary School Leaving Certificate Examinations. Most of the children are willing to listen to their teachers and learn from them, but it is very challenging to teach and control a class of over 100 children and hence some rowdy behaviour still develops. Most problematic behaviour is seen in higher classes (e.g. standard seven and eight) where young girls have to dropout of school due to teenage pregnancies. Most of this also results from the fact that some children are starting school at an older age and therefore reach adolescence while still in primary school.

Adolescents Out of School: % of Lower Secondary School Age from 1999 to 2016 in the chart:



1.9 PROBLEMS

Development of human capital contributes to the full participation of the socio-economic and political development of the country. Malawi has recognized that it has poor social indicators, especially in the areas of health and education. This is evidenced by the high child and maternal mortality rates, child and maternal malnutrition, low life expectancy, poor access to water and health facilities, and low education quality.

In Malawi, the male-female ratio in schools, universities, and higher positions in public service and industry generally favors the male gender. In the past, parents assumed that the destiny of daughters was to get married, have children, and serve their husbands and society. Although such attitudes are changing rapidly, they partly explain why the gender imbalance exists. Matters concerning family planning were considered to be too sensitive to most Malawians, and government was reluctant to intervene in spite of the growing population. Women, many of whom not only raised children but also tended food crops to support their families in some cases without the assistance of their husbands often bore the greater burden.

1.9.1 Agriculture

Current situation and major challenges of the sector:

The economy of Malawi is predominantly agriculture based. Agriculture accounts for 30 percent of Gross Domestic Product and generates over 80 percent of national export earnings. The agriculture sector employs 64 percent of the country's workforce and contributes to food and nutrition security1. Although there is potential for better production and productivity, the agriculture sector operates below its capacity.

As a result, the country continuously faces food shortages at national and household levels. Malawi has also been hit by fall army worm attack in recent past and this has significantly affected production of maize. Some of the challenges the sector faces include vulnerability to weather shocks; poor management of land, water, and soils; low adoption of agricultural technologies; low access to finance and farm inputs; low mechanization and technical labor skills; a limited irrigation system and weak linkages to markets.

In recent years, Malawi has made efforts to develop agricultural markets. These include increased liberalization, development of rural marketing infrastructure and agricultural market information systems, and the establishment of commodity exchanges. Despite these efforts, agricultural marketing systems in Malawi are still rudimentary, and in some cases, missing markets persist, especially in rural areas. Most farmers continue to have limited information on prevailing market prices. As a result, traders take advantage of this and purchase from the farmers at a lower price far much below the set farm gate prices by the government.

1.9.2 Education

Current situation and major challenges of the sector:

The Malawi education system is classified into basic, secondary and tertiary levels which follows an 8-4-4 system. Primary education takes 8 years, secondary 4 years and tertiary ranges from 2 years for a certificate to 4 or 5 years for a first degree. Basic education comprises of early childhood development, out of school youth, adult literacy and primary education. Early Childhood Development caters for children aged zero to eight. ECD is under Ministry of Gender, Children Development and Social Welfare. Entry age to primary is 6 years. Reinforcement of this policy has been a daunting challenge leading to entry of underage children who overcrowd the schools and classrooms which are already direly resourced with teachers and teaching and learning materials causing effective teaching and learning challenging.

Currently, overall enrolment for 2020 is at 5.4 million registering an annual increase of 3 percent from enrolment of 5.1 million in 2019 (MoE 2020). High enrolments are experienced at primary with 91% percent net enrolment rate but as low as 55 percent completion rate and 38 percent transition rate to secondary education.

Higher education is over restrictive less than 1 percent gross rate of eligible candidates attending higher education.

Double shifting, open learning and distance learning have been some of the solutions to increase access. However, quality of these services has been a challenge and many students shun away from these education modes.

1.9.3 Water

Current situation and major challenges of the sector:

In Malawi, there is a growing national demand on water resources and concern on its availability due to national population growth and dwindling water sources, particularly during the dry season hence there is need for bettermanagement of the water resources. The government has placed a high priority on irrigation and water resources management in order to ensure food and water security at household level through among other things enhancing water-harvesting technologies,promoting catchment protection and management including disaster risk reduction measures.

Overall, 88.3% of the national population has access to improved water source.

A household is considered to have access to improved drinking water source if it’s piped into the dwelling, piped into the yard or plot, collected from a communal standpipe, a protected well in yard or plot,protected public well, borehole, tanker truck or bowser and bottled water, according to the Fifth Integrated Household Survey (IHSS) 2020 Report. This is a higher access as compared to 85% in 2018/2019 financial year which was lower than in 2017-18, the decline was attributed to damage caused by floods and drought which casted some doubt if Malawi is to achieve the SDG’s.

Currently water resources development accompanying rapid water demand in urban and peri-urban areas due to rapid population growth is a serious problem in Malawi. A total Malawian population increased by 35% between 2008 and 2018 representing an intercensal growth rate of 2.9% per annum and for Lilongwe city, it is 3.8% and Blantyre city 2.0% according to National Statistics Office (NSO), 2018.

According to Water, Sanitation and Hygiene (WASH) sector Joint Review Meeting Report (2019) the sector faces daunting challenges in meeting its objectives, and key among them are:

(a) poor revenue collection efficiency for the water boards due to huge government unpaid bills.

(b) there is an increase in non-functionality rate of rural Water Supply Systems due to the occurrence of the Cyclone Idai which damaged most of rural water supply infrastructures.

(c) inadequate allocation of finances to the water department by the GoM;

(d) limited capacity in the water and sanitation sector at the Ministry and in the districts with a vacancy rate of 62.2%, there are few local NGOs active in WASH sector;

(e) deforestation and environmental degradation of catchment areas for water supply which is rendering quantity of water insufficient and quality of water bad, dwindling water sources; (f) high levels of non-revenue

water for water utility companies which are estimated to be around 35% due to ageing infrastructures;
(g) vandalism of water supply facilities and water monitoring equipment
(h) inadequate evidence based formative research to support policy formulation, and
(i) inadequate coverage due to increasing water demand as a result of population growth especially in urban areas and in peri-urban areas.

Figure 1.10 Water resources in Malawi

1.9.4 Energy

Current situation and major challenges of the sector:

Malawi has a very low national electrification rate estimated at 12.0 percent - the lowest in the Southern AfricaDevelopment Community (SADC) region. It trails
Madagascar and Mozambique which are at 23% and 24% respectively. Rural and urban electrification rates are estimated at 3.9% and 48.7%, respectively1. Installed generation capacity (as of October 2017 was 367.3 MW (350.8 MW being hydro and 16.57 MW thermal diesel generators run by the Electricity Generation Company (EGENCO) Limited against a peak demand of over 470 megawatts2. The main source of electricity is hydropower which generates about 95% of the power in this country. In order to meet the fast-growing demand for energy, EGENCO has projected to increase generation capacity to 521.5 MW by 2024 to 1,256.5 MW by 2029 and to 1,631 MW by 2034. Three of the four hydropower generating stations are situated along the Shire River in the southern region of the country.
Apart from the low energy generation capacity, there is also a problem of insufficient transmission and distribution facilities. As a result, of all these problems, the country faces frequent power outages rendering economic and social development difficult.

Two natural challenges have emerged in the sector, namely:
(i) effects of climate change which are leading to less rainfall and therefore less water available for generating power; and (ii) environmental degradation. One of the causes of this environmental degradation is deforestation which is leading to siltation of water intakes at hydropower stations.

1.9.5 Environment

Current situation and major challenges of the sector:

The environment and natural resources play a very significant role in influencing social and economic development at both household and national levels.
Environment and natural resources form a bedrock of Malawi's agro-based economy. However, the degradation of the environment and natural resources in Malawi is due to many factors including deforestation, decreasing soil fertility and increasing erosion, water depletion, loss of biodiversity, increasing pollution and increased vulnerability to climate change. The degradation of the environment and natural resources continue to be a major threat to the social and economic development of Malawi. The success of many important sectors of the economy relies on
environment and natural resources to enhance their productivity. It is estimated that Malawi is losing about $190 million annually due to unstainable use of natural resources. Therefore, it is important to address the factors that lead to environmental degradation and work to conserve and restore the environment.

Environment and natural resources comprise of many components. This paper mainly focuses on forest conservation, with emphasis on soil and water conservation. The main drivers of forest degradation in Malawi are charcoal production, firewood production, infrastructure development, timber production and agricultural expansion. Forests provide essential services that are critical to preventing land degradation and climate change as well as conserve wetlands and freshwater systems, which are a foundation of rich biodiversity. The soil and water conservation play an important role in supporting sustainable livelihoods and reducing environmental degradation.
Malawi continues to lose soil and water due to unstainable use of these natural resources. Improved land management practices like soil and water conservation have been suggested as a key strategy to reduce land degradation and sustain soil quality. The loss of soil and water cause the decline in the productivity of these resources capacity to perform their functions. This among others, affects the generation of electricity due to low water levels and silt deposits in Shire River. Improved land management practices like soil and water conservation have been suggested as a key strategy to reduce land degradation and sustain soil quality.

1.9.6 Disaster

Current situation and major challenges of the sector:

Disasters are distinguished in terms of their nature andextent of impacts. Globally, disasters continue to increase in many countries, affect the economy of the affected countries and attack vulnerable areas where it affects those in lower income brackets. The report by Economics of Climate Adaptation Working Group (2009) on 'Economics of Climate Adaptation, Shaping climate-resilient development', projected that the global average for annual economic losses resulting from natural disaster is expected to increase from US$340 billion in 2009 to US$415 billion by 2030 for urban infrastructure alone. These disasters are considered to be caused due to climate change, increasing urbanization and environmental degradation. The United Nations International Strategy for Disaster Reduction, in its 2015 report on "The Future of Disaster Risk Management, Global Assessment Report on Disaster Risk Reduction" projected that globally, on average, about 218 million people are affected by disasters each year.

Malawi is highly vulnerable to the impacts of disasters given its location along the great African Rift Valley, rapid population growth, unsustainable urbanization, poor settlement patterns, weak buildings/ infrastructure, lack of access to information and knowledge, climate variability and environmental degradation.

The most common weather-related shocks affecting Malawi include floods, drought, stormy rains, and hailstorms. Climate change further exacerbates the frequency and severity of disasters in the country. These disasters cause damage to infrastructure, food insecurity and increase poverty, loss of lives and property, decline in health status, poor environmental conditions, and a decline in the quality of education of affected populations.
Although there are many types of disasters, this paper mainly focuses on flood related disasters. The reason is that Malawi has experienced more floods than any other natural disasters. According to the 2019 Post Disaster Needs Assessment (PDNA) report, over the past five decades, Malawi has experienced more than 19 major floods and 7 droughts. Furthermore, the report from the National Disaster Risk Management Communication Strategy (NDRMCS) 2020 -2023, mentioned that about 15 out of 28 districts (which represent 54% of the districts) in Malawi are considered flood prone.

The main challenges this sector face include: (i) Insufficient levels of implementation for each planned activity due to inadequate financial resources. (ii) Poor coordination among stakeholders and lack of information sharing, including with respect to risk assessment, monitoring and evaluation, early warning, disaster response and other Disaster Risk Management (DRM) activities.


Figure 1.11 Flood in Malawi

1.10 ARCHITECTURE

1.10.1 Bamboo

Malawi is a very linear country, it stretches from north to south with Lake Malawi hugging most of the eastern side. the country was divided into three areas; North, Central and South Malawi. The south is hilly and densely populated; the architecture is mainly constructed of burnt bricks. The central area is fertile land with well-populated plains. Many areas had homestead structures constructed of rammed-earth. The northern area of Malawi is mountainous and sparsely populated.

Vernacular architecture in Malawi is like most countries in Africa — it is disappearing, being abandoned in favor of western materials and techniques. And that is unfortunate, since vernacular structures are a part of a country's culture as much as language, music or food.

Vernacular architecture is composed of local materials and derived from local customs, techniques that have been passed on from generation to generation.
There are plenty of local materials in malawi that is used in most of their construction and we study about them and introduce some of the briefly.

Bamboo fabric has a soft touch and a stronger fabric. Due the fabric's structure, the fabric is very breathable to stay cool in the summer and warmer in the winter. Also, it can absorb 3-4 times more water than the traditional cotton fabric without sticking to your skin. It is very good for sports wear or casual wear. bamboo is used for roof structure , wall frames ,granaries and windows.

⊖ **They require preservation.**
Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
Durability: Bamboo should be sufficiently treated against insect or fungus attack before being utilized for building purposes.

⊕ Bamboo has high tensile strength as compared to Steel because of its fibres runs axially.
Bamboo has good elastic property so that it is widely used in the earthquake-prone areas.
Bamboo has high fire resistance and it can withstand up to 4000 degree Celsius.
Weight of bamboo: Bamboos due to their low weight are easily displaced or installed making it very easier for transportation and construction.

Figure 1.12 bamboo construction

1.10.2 Thatch

Thatch is a natural grass material that is cut, dried and fabricated into roofing material. For centuries, thatch has been used around the world to build shade structures, Palapas, huts, Tiki bars and more. Today, thatch remains a popular product for its aesthetic appeal as well as its sustainability. Thatching is done right before the rains start, which is the end of October. The research was conducted between August and September.

⊖ **Fire hazard :** Without the proper precautions, thatched roofs can be a fire hazard. Fortunately, sophisticated and effective fire retardant processes are available.
Decay : Because thatch is an organic material, it is susceptible to decay and decomposition.
Maintenance is required : To keep a thatched roof at its best, regular maintenance is needed.
Higher insurance costs : Due to the higher risk of fire damage, home insurance is higher than houses with tiled, steel or aluminium roofs.
Animals can cause damage : Birds looking for food, gathering nest-making materials or nesting in the roof itself becomes a greater possibility when the thatch is not processed appropriately for its intended use. Rodents can also cause extensive damage.

⊕ **Environmentally friendly:** One of the most environmentally friendly roofing materials available is thatch.
Excellent insulation : Thatched roofs provide excellent insulation, so your home will stay warm when it's cold outside and cool during the hot summer months.
Durability : Thatched roofs are typically last longer and are very durable. With appropriate maintenance, they can last up to 60 years or more.

Ages well : Thatched roods age well and will shape into natural forms that add to their charm. As it darkens with age, thatch tends to blend into the surrounding greenery.

Adds character : A thatched roof adds warmth and character to a property. Brick, steel and glass can create a clinical atmosphere, which is softened by thatch to produce a welcoming ambience.

Figure 1.14 Thatch roof

1.10.3 Burnt bricks

Burnt bricks are bricks that are formed in molds, laid out to dry for some time and then stacked to form a kiln. They are then burned to harden and thus becomes more durable.

The “mud” for the bricks usually is obtained right at the homestead. The pit, overtime will be filled with compost and covered over.
Mud is packed into a wood form and laid out in rows to dry. Once the bricks are stiff enough, they are piled up in order to be stacked.

Once the bricks have sufficiently dried, stiff enough to be moved, they are stacked together to form a kiln. The bricks are stacked in a particular style which creates openings at the base.

Wood is piled into these openings and then set ablaze. Once the wood is burning the openings are sealed off with bricks and the wood will burn until it is exhausted.
The heat from the fire is intensified by being enclosed. It is this process that hardens the bricks.

When the fire has died out, the bricks are ready to be taken from the kiln and used in construction.

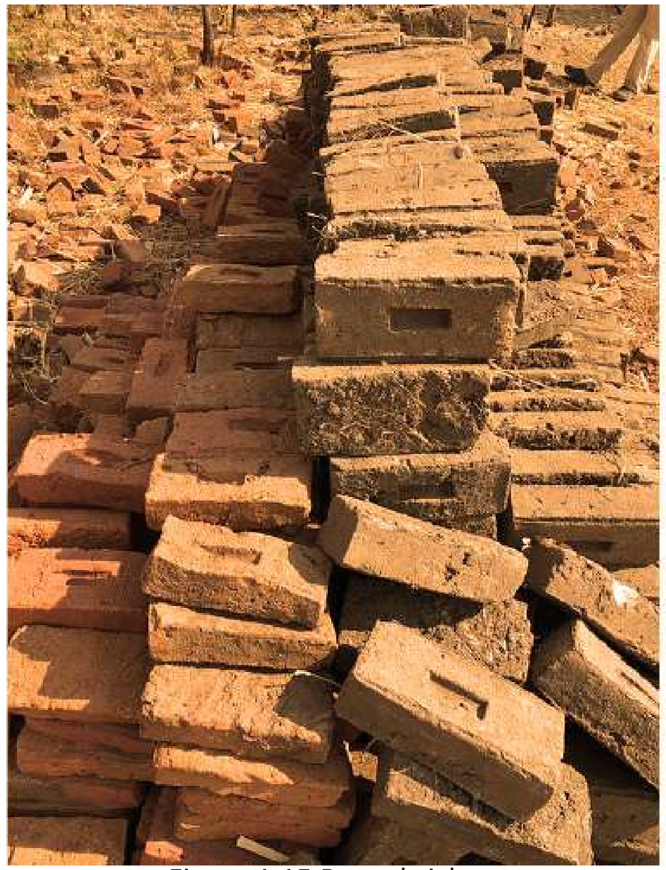


Figure 1.15 Burnt brick

1.10.4 Mud

Burnt bricks are bricks that are formed in molds, laid out to dry for some time and then stacked to form a kiln. They are then burned to harden and thus becomes more durable.
The “mud” for the bricks usually is obtained right at the homestead. The pit, overtime will be filled with compost and covered over.
Mud is packed into a wood form and laid out in rows to dry. Once the bricks are stiff enough, they are piled up in order to be stacked.

⊖ They can be easily destroyed by wind, rain and flooding if it is not protected well enough.

They require more care and maintenance as they are a weak building material that would even be affected by dampness or dry weather.

It may also have a musty smell when first finished construction.

⊕ Mud has other inherent advantages: It is extremely malleable and offers better insulation than steel-and-concrete structures, it decentralises the construction process because it utilises local material and technology and thereby obviates the need for a contractor, and it costs much less to maintain mud buildings.

Figure 1.16 Mud

1.10.5 Rammed Earth

Rammed earth construction is the technique of compressing mud into a wood frame. Two or three layers are completed, left to dry and then repeated till the desired height is met. a mixture of sand, loam, clay, and other ingredients rammed hard within forms as a building material.

⊖ Soil selection is critical. Not any soil can be used. If using it from your own site, you'll have to figure out what to do with the large holes.

If you don't do it yourself, the labor costs can be expensive. Count on it costing 5-15% more than a conventional home.

Colder climates may require added insulation, like a foam wall with stucco on the outside.

Due to the difficulty in designing the forms, circular shapes are usually out. Most rammed earth construction is box shaped.

⊕ Easy to work with. Can be built with little to no experience.

Expense : Done right, you can easily put a lot of "sweat equity" into the building process and save bundles on the construction cost.

Easy to acquire building materials that can be had locally.
Can stand the test of time, and has proven it.

Figure 1.17 Rammed earth material in african house

1.10.6 Plaster

Plastering, sometimes called "smearing", is the technique of applying mud to the walls and floors. Plastering is completed once a year. The plaster adds a layer of protection against the wind and rain.
A mixture of mud and water is the basic components for the plaster. In many cases it was stated that the mud was gathered from a place off site. This was mainly done to have a specific or unique color.
The task of plastering is done once a year in order to protect the structure from sun and wind but mainly the rain. Water hitting a mud surface has a great impact on the structure. Walls, floors and verandahs all receive a fresh coat of plaster.

⊖ **Installation :** Drywall produces copious amounts of dust when cut and sanded. Finishing the drywall to a smooth surface takes multiple days because the joint compound that seals the seams between boards needs to dry before another coat is added.
Difficult to Repair : When plaster cracks or crumbles due to shifting foundations or a strong blow to the wall, repairing the problem is tricky.
Cost : Despite the extra labor of hanging and finishing drywall, it tends to be less expensive than plastering.

⊕ **Durability:** If properly mixed and applied, a plaster coating creates a stronger and more durable wall finish than drywall. The chemical reaction that occurs when water evaporates out of the plaster mixture develops strong bonds in the mixture. Plaster is more resistant to knocks and dents in most cases

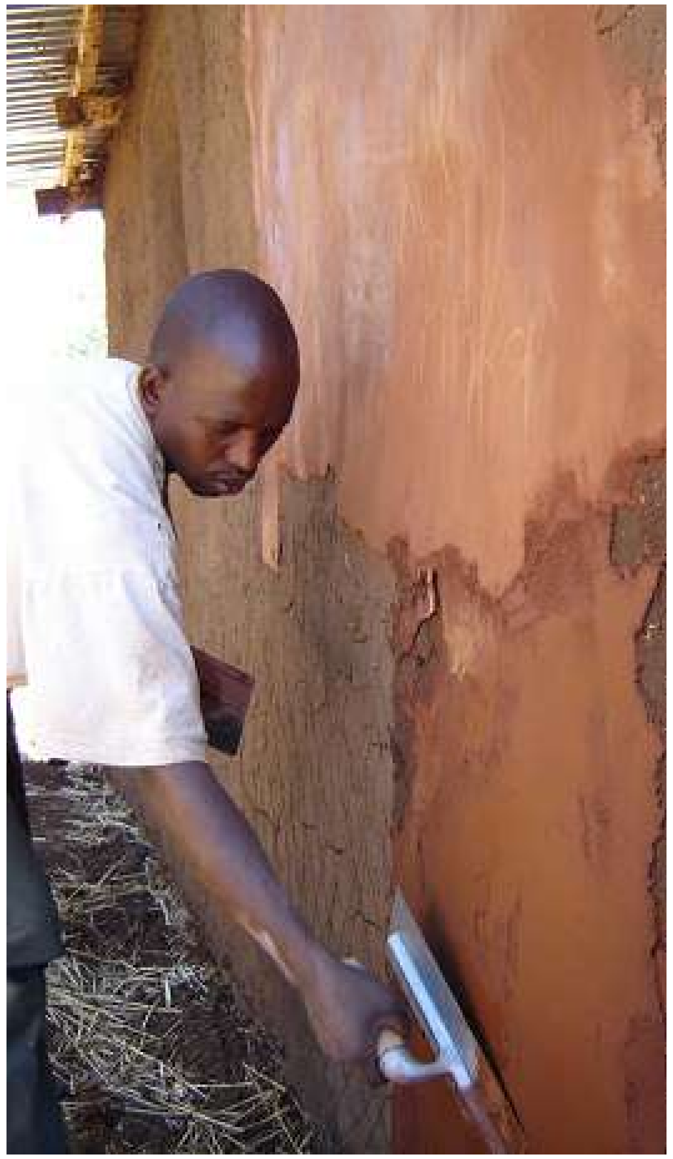


Figure 1.18 Plaster walls in africa

1.11 CASE STUDIES

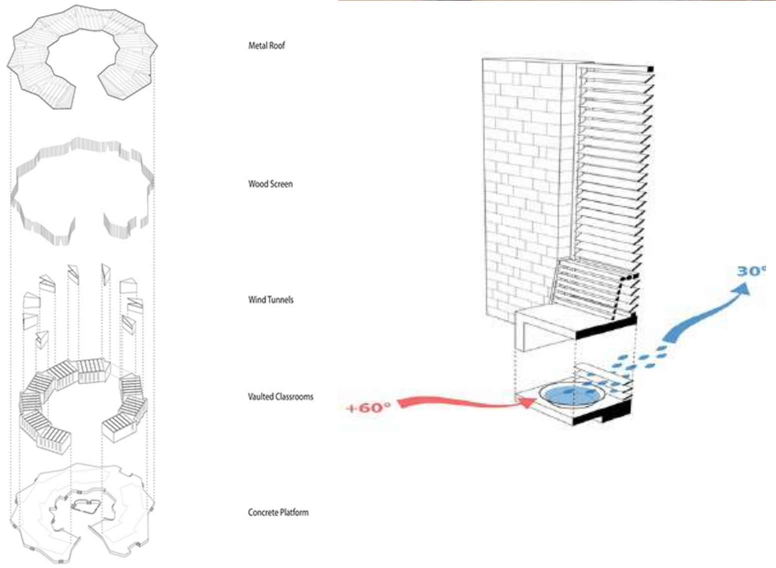
1.11.1 Lycee Schorge Secondary School

Architects: Kéré Architecture
Area : 1660 m²
Year :2016

Architectural Part

Located in the third most populated city in Burkina Faso, the Lycée Schorge Secondary School will not only set a new standard for educational excellence in the region, it will also provide a source of inspiration by showcasing locally-sourced building materials in an innovative and modern way.

The design for the school consists of 9 modules which accommodate a series of classrooms and administration rooms. One of these modules also houses a dental clinic which will provide a new source of dental care for the students.
Creating a sort of autonomous 'village' condition, the radial layout of classroom modules wrap around a central public courtyard. This configuration not only creates privacy from the main public domain, it also shelters and protects the inner courtyard from wind and dust. An ampitheater-like condition at the center of the courtyard will accommodate informal gatherings as well as formal assemblies and celebrations for the school and community as a whole



The walls of these modules are made from locally-harvested laterite stone, which, when first extracted from the earth, can be easily cut and shaped into bricks. When the stone is left exposed to the atmosphere above ground, it begins to harden. The material functions really well as a wall system for the classrooms because of its thermal mass capabilities. This, in combination with the unique wind-catching towers and overhanging roofs, lowers the temperature of the interior spaces exponentially.
Wrapping around these classrooms like a transparent fabric is a system of wooden screens. This secondary façade is made from a local fast-growing wood and acts as a shading element for the spaces immediately surrounding the classrooms.

The screens not only function to protect the earthen classrooms from corroding dust and winds, they also help to create a series of secondary informal gathering spaces for the students as they wait to attend their classe
-The wave-like pattern of plaster and concrete components are slightly offset from each other, allowing the interior space to breathe and expel hot stagnant air. The off-white color of the ceiling serves to diffuse and spread around indirect daylight, providing ample illumination during the day while keeping the interior learning space protected from direct solar heat gain.

1.11.2 Green School South Africa

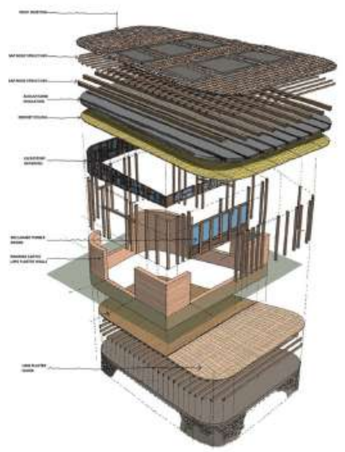
Architects: GASS Architecture Studios
Area : 3313 m²
Year : 2021

Architectural Part

Green School South Africa, is an eight-hectare sustainable schooling campus located in the low-lying Paarl Valley in the Western Cape, spatially defined by the Paarl Berg to the north, Drakenstein Mountains to the east and south, and Simons Berg towards the southwest. The spatial arrangement at a macro level is what inspired the space making, but also down to the individual buildings and spaces between them.

-The reoccurrence of multiples at incremental scales is an idea that defines the behavior of most natural systems.
-Upon arriving at the school, a landscaped gabion wall leads the visitor to the Administrative Building that sits on the main axial circulation spine of the campus, linking the more public buildings together.
-The positions of the different zones and buildings have been carefully considered, taking into account passive design principles, feng shui and the seven petals provided by the Living Building Challenge. The result is harmonious spaces where humankind and nature can reconnect.

the building walls are kept to a minimum to allow for big expansive openings ensuring the visual connection between inside and outsideas well as formal assemblies and celebrations for the school and community as a whole



Technology Part

All buildings are constructed from naturally and locally sourced materials, such as dek-riet ceilings, clay and soil harvested from the site to create rammed earth walls and lime plaster walls and floors, the pebbles retrieved from the site used to construct gabion walls, and reclaimed tique doors from the larger Drakenstein region.

These organic-shaped stereotomic buildings with large oversailing leaf-like roof structures for rainwater collection, punched openings to frame vistas, bay windows, thick rammed earth or clay brick walls, clerestory windows for filtered natural light and ventilation, textured screening elements, all create enticing and playful spaces.

1.11.3 Community Primary School

Architects: Orkidstudio
Area : 1000 m²
Year : 2016

Architectural Part

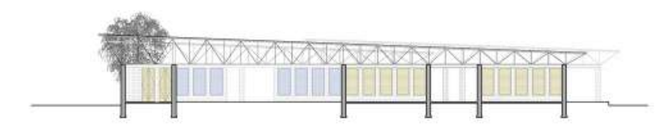
The Swawou Layout Community Primary School for Girls was set up in 2009 to offer a free primary education to girls from disadvantaged backgrounds. The school is located in an area called Swawou Layout in Kenema town, eastern Sierra Leone. All of the girls reside within the local community with their parents, guardians or other family members.

On the Swawou School project, his team employed about seventy men and women from the local community every day on the site, equipping them with architectural techniques that can be taught to others and used to build more community facilities or homes.
The school has been built to respond to climatic conditions of the region.

Technology Part

The floating metal roof has been structured to optimise natural ventilation, and its angled gradient works to deflect monsoon rain into a series of water collection channels below.
A woven ceiling beneath the roof helps quieten the sound of the rain on the metal during class time in the rainy season.

Shuttered openings provide added ventilation and a method of controlling the amount of natural light in the classrooms. The size of the classrooms are significantly larger than what is commonly found in Sierra Leone and they have been arranged to form a large sheltered courtyard and various outdoor spaces. These areas are important for providing external circulation and spaces for socialising. The uncovered courtyards serve as school gardens, which involve the children in growing plants.



1.11.4 Langbos Children's Centre

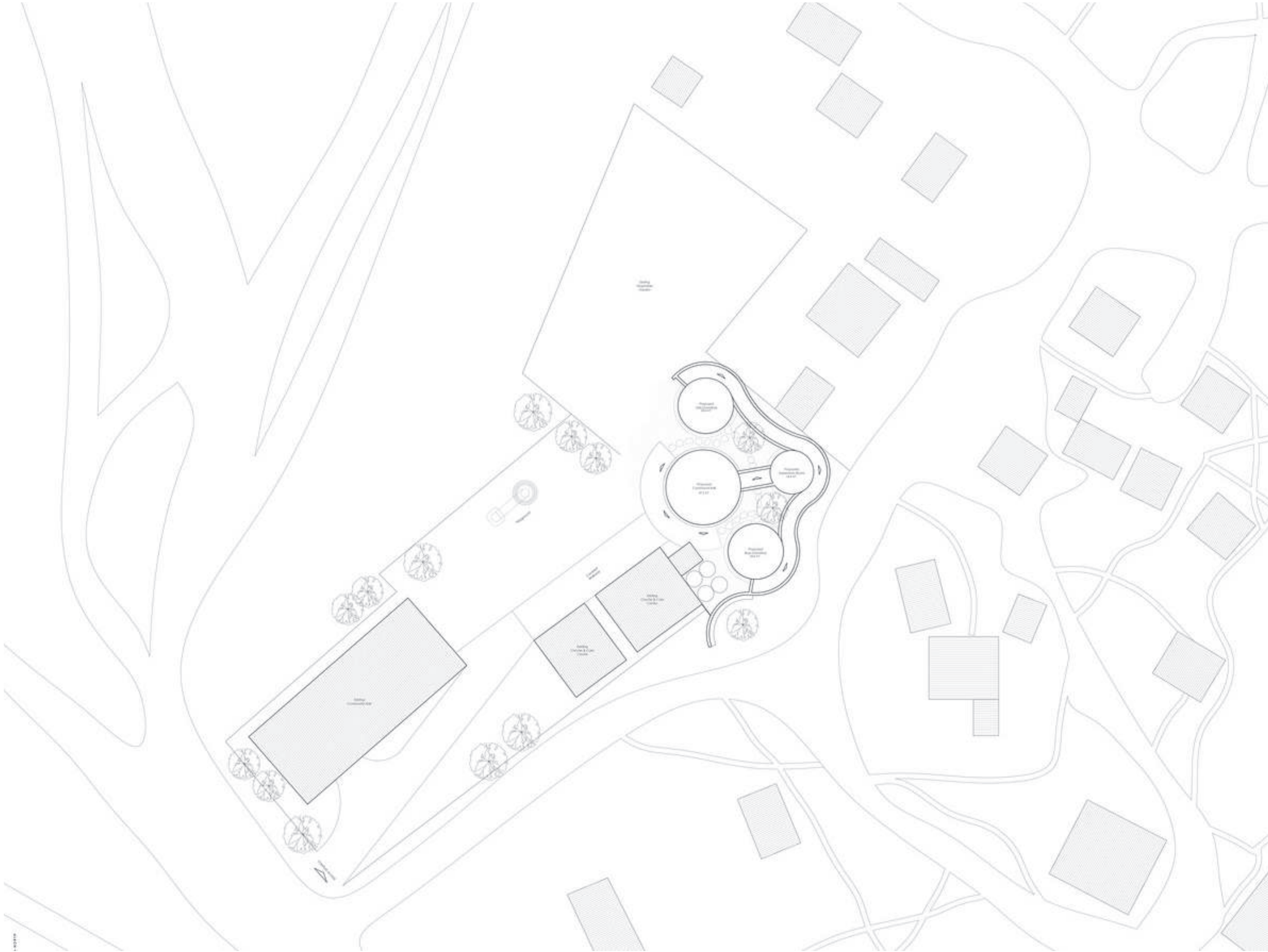
Architects: Jason Erlank Architects
Area : 217 m²
Year : 2018

Architectural Part

Langbos is an undeveloped "informal settlement" with no formal housing, running water, roads, or electricity. The Langbos Children's Centre in 2018— a project that trained and employed local community members to construct a sustainably-designed centre to provide support to vulnerable children and families in Langbos.

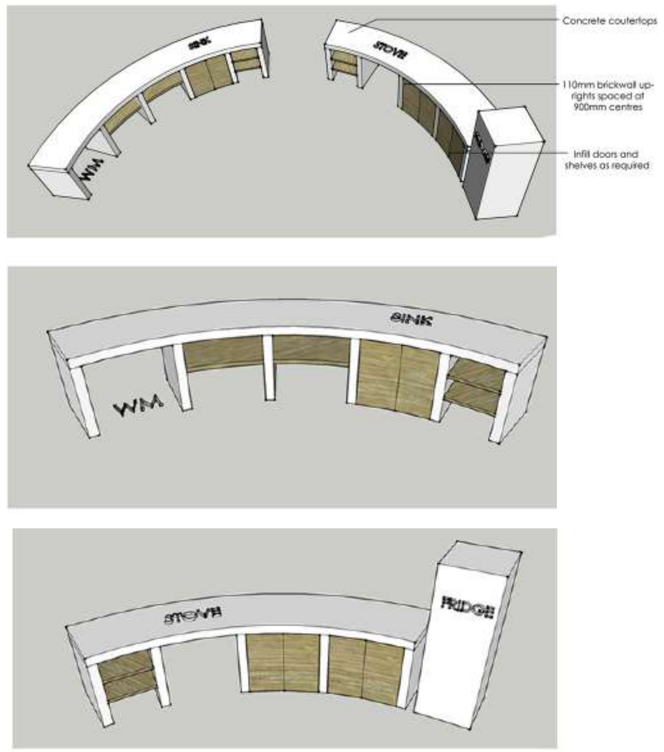
The building was designed to provide a multi-functional space for community-driven initiatives in Langbos. In constructing the Langbos Children's Centre, we utilized a labour intensive, environmentally conscious, resource-efficient building method called Superadobe as a way to involve the local Langbos community and make the best use of our limited material resources on site.

Superadobe is a simple building method that uses local soil mixed with a small amount of cement to build elegant and strong dome structures based on simple geometry and engineering principles. The use of Superadobe allowed us the opportunity integrate traditional earth architecture with contemporary design ideas to create an architecture which is intriguing, sculptural and functional.



Technology Part

The Langbos Children's Centre also has an off-grid design, utilizing solar power for electricity and water heating, as well as a unique gutter around the base of the domes to harvest rainwater. Greywater from the centre is also directed into an adjacent community garden, which is managed by Langbos residents. The dense, monolithic Superadobe walls provide high thermal mass to aid in natural heating and cooling, keeping the domes warm in winter and cool in summer.



1.11.5 Gangouroubouro Primary School

Architects: LEVS architecten
Area : 295 m²
Year : 2013

Architectural Part

The architecture of the school reflects a connection to the local building traditions, culture and function. Compared with the rich architectural areas near the rocky walls in the Dogon area, particularly at this location the plain offers the possibility of a different architectural appearance.

The ensemble consists of a school, blocks with sanitary facilities and a communal outdoor space. The structure of the school building consists of an enlarged front porch of more than 3 meters parallel to the three classrooms.

Technology Part

The walls are constructed with newly developed and locally produced hydraulic compressed earth blocks (HCEB) in alternating strips. They determine the rhythm of the facades and provide a cool inside climate.

The roof is constructed of overlapping steel plates, each hanging 1 meter over and creating extra shade spaces. By means of thin steel shaft profiles, the mass of the roof
is being transferred to the buttresses.

The Poligny rafters stretch across the class rooms and create a free floor surface
Wind forces are prevented from pushing up the roof by a wide stroke of semi-open masonry for ventilation and by the use of several openings of long and narrow windows. The openings in the facade with its tilt window frames are painted in an ochre yellow colour. The office and the storage facility have been built with curved roofs and on a smaller scale, corresponding to the function of the space.

CHAPTER 2
CLIMATE ANALYSIS

2.1 LOCATION

Malawi, landlocked country in southeastern Africa. Endowed with spectacular highlands and extensive lakes, it occupies a narrow, curving strip of land along the East African RiftValley. Lake Nyasa, known in Malawi as Lake Malawi, accounts for more than one-fifth of the country's total area.

Malawi stretches about 520 miles (840 km) from north to south and varies in width from 5 to 100 miles (10 to 160km). It is bordered by Tanzania to the north, Lake Malawi to the east, Mozambique to the east and south and Zambia to the west.

Benga is located in Nkhotakota District and situated at 10 km from Lake Malawi to the east and 30 km to the Ntchisi Forest Reserve to the west. It is 60 km south of Nkhotakota Township and 50 km north of Salima Township. It is situated halfway on the tar road connecting both towns. Though the area is near Lake Malawi and Chilwa Lagoon.

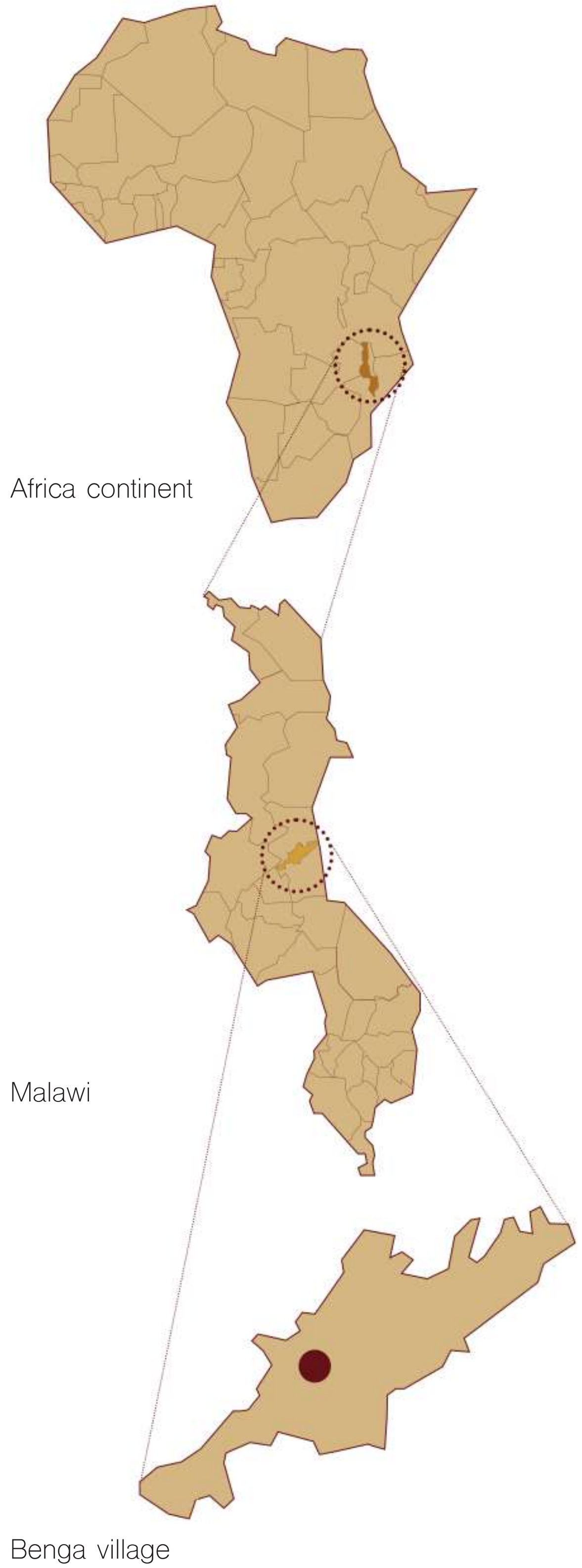


Figure 2.1 Project site location

LOCATION

The school will be located next to Benga Parish, a Missionary Community of Saint Paul the Apostle. They already have a primary school and are planning to build the secondary school in the other side of the road.

2.2 CLIMATE ANALYSIS

The climate analysis has been performed using the climate data from the Lilongwe capital of malwai, located 140 km away from the project site, and at a similar altitude.
Malawi has two main seasons, namely the cool dry season between May and October with mean temperatures of around 13°C in June and July and the hot wet season between November and April with temperatures between 30°- 35°C.

The climate of Malawi varies widely because of the terrain. Near the lake, the mean annual temperature is 24ºC. November is the hottest month where temperatures are ranging from 17 to 29ºC. The coldest month, July, has a temperature range of 7 to 23ºC.

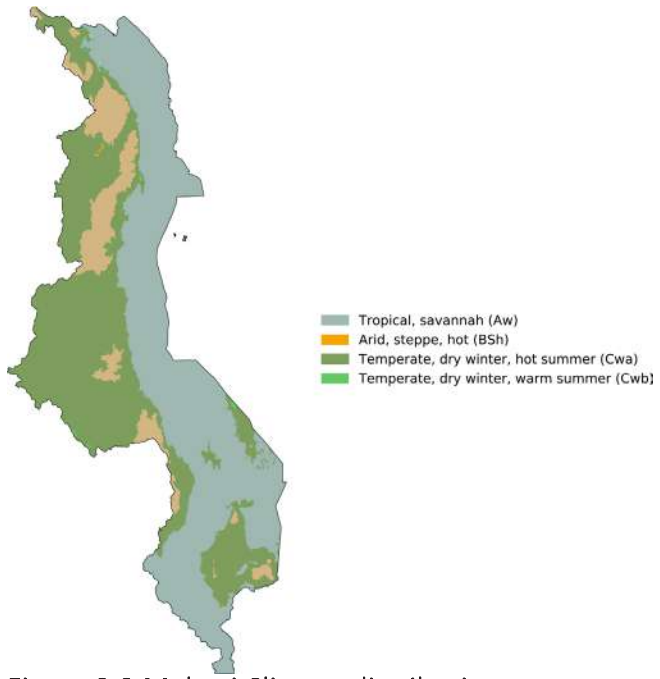


Figure 2.2 Malawi Climate distribution

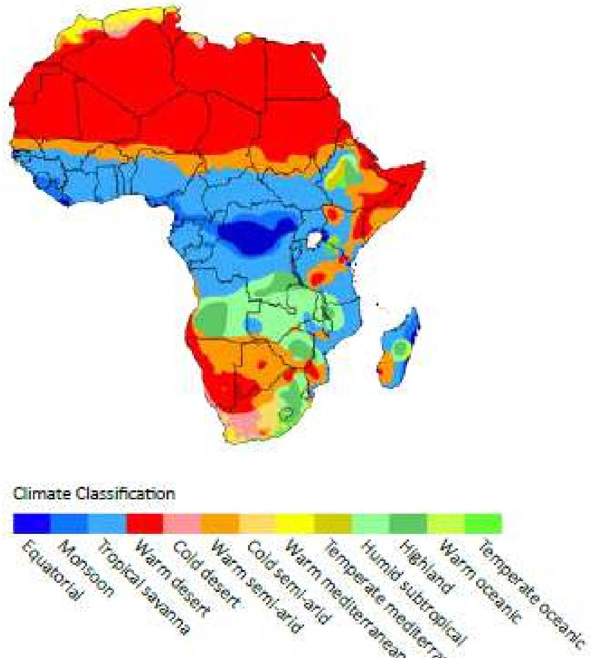


Figure 2.3 African Climate classification

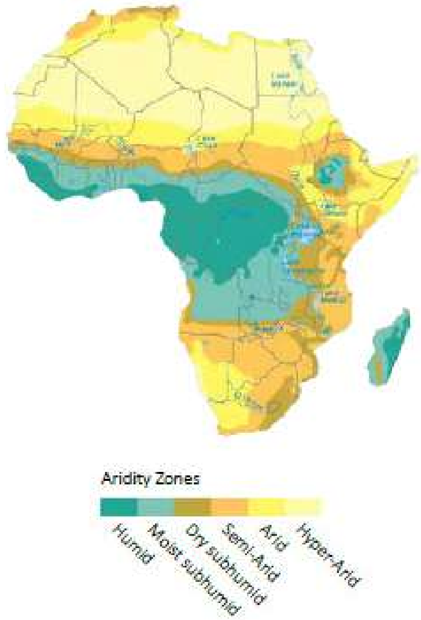


Figure 2.4 Africa aridity zones

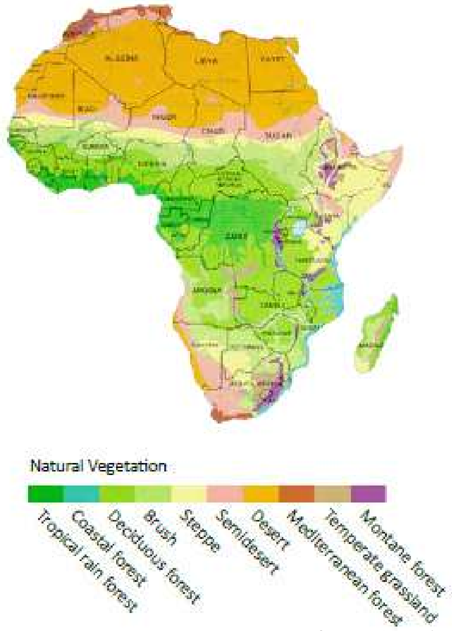
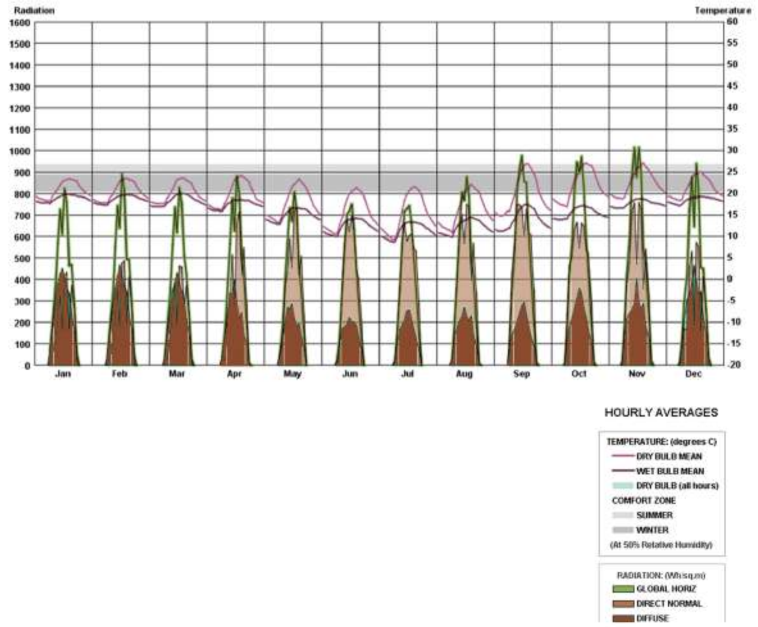


Figure 2.5 African natural vegetation

2.2.1 Monthly Diurnal Averages

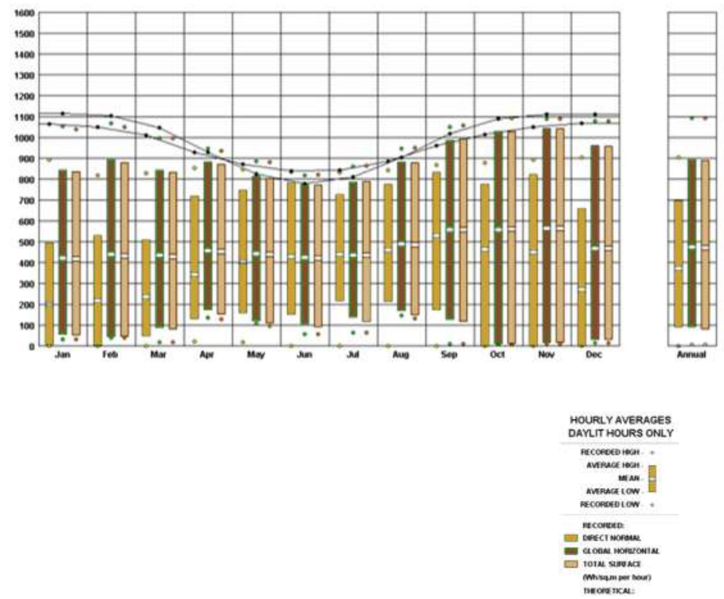
ASHRAE standard chart 55-2004
using PMV

By comparing the Global horz with the Dry Bulb temperature curves in this chart we can understand the thermal lags effect for example we have the most Global Horiz in September and we have the hottest point of the day around 7 8 hours later.
Also, by comparing dry bulb temperature curve vs. wet bulb temperature we can understand which months we have higher or lower RH. (Greater difference= lower RH, smallest difference= higher RH).



2.2.2 Radiation Range

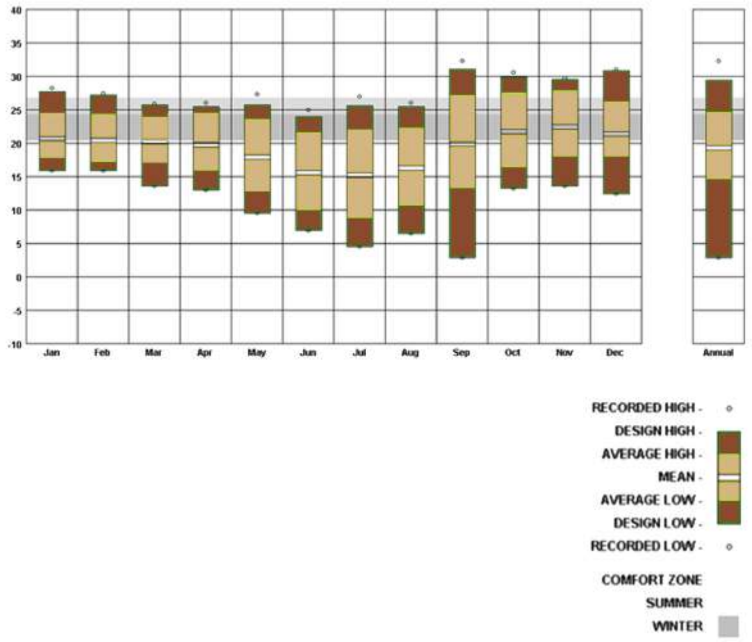
This chart could be very useful in our further steps of our design to investigate the possibility of using solar photovoltaic panels or solar photovoltaic thermal systems according to the total surfaces and their angles and average energy can receive by them.



2.2.3 Temperature range

ASHRAE standard chart 55-2004
using PMV

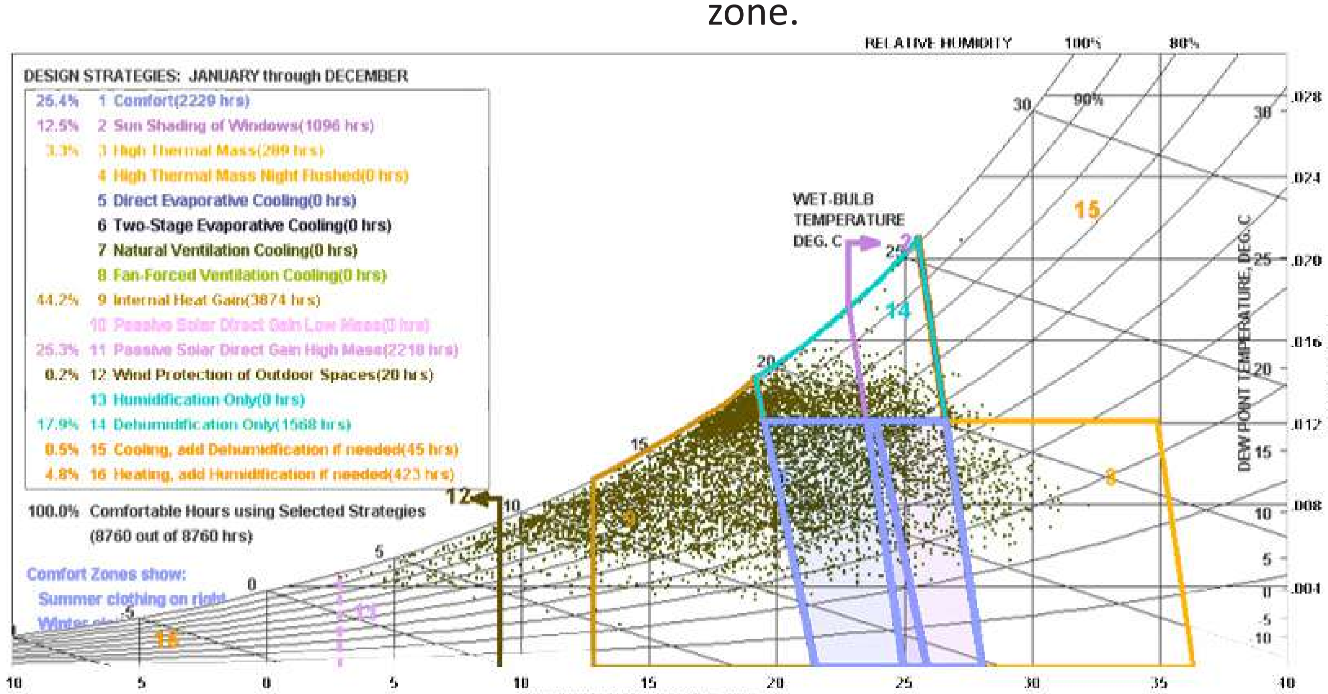
As we can observe from the chart the climate temperature is almost in temperate range, so we are not to have to struggle with very cold winter or very hot summer and in most of the months of the year the average is in comfort zone (yearly temperature average is near 18-19 Celsius)
According to the Design Low value we should take care of the heating strategies more than cooling.



2.2.4 Psychrometric Chart

ASHRAE standard chart 55-2004
using PMV

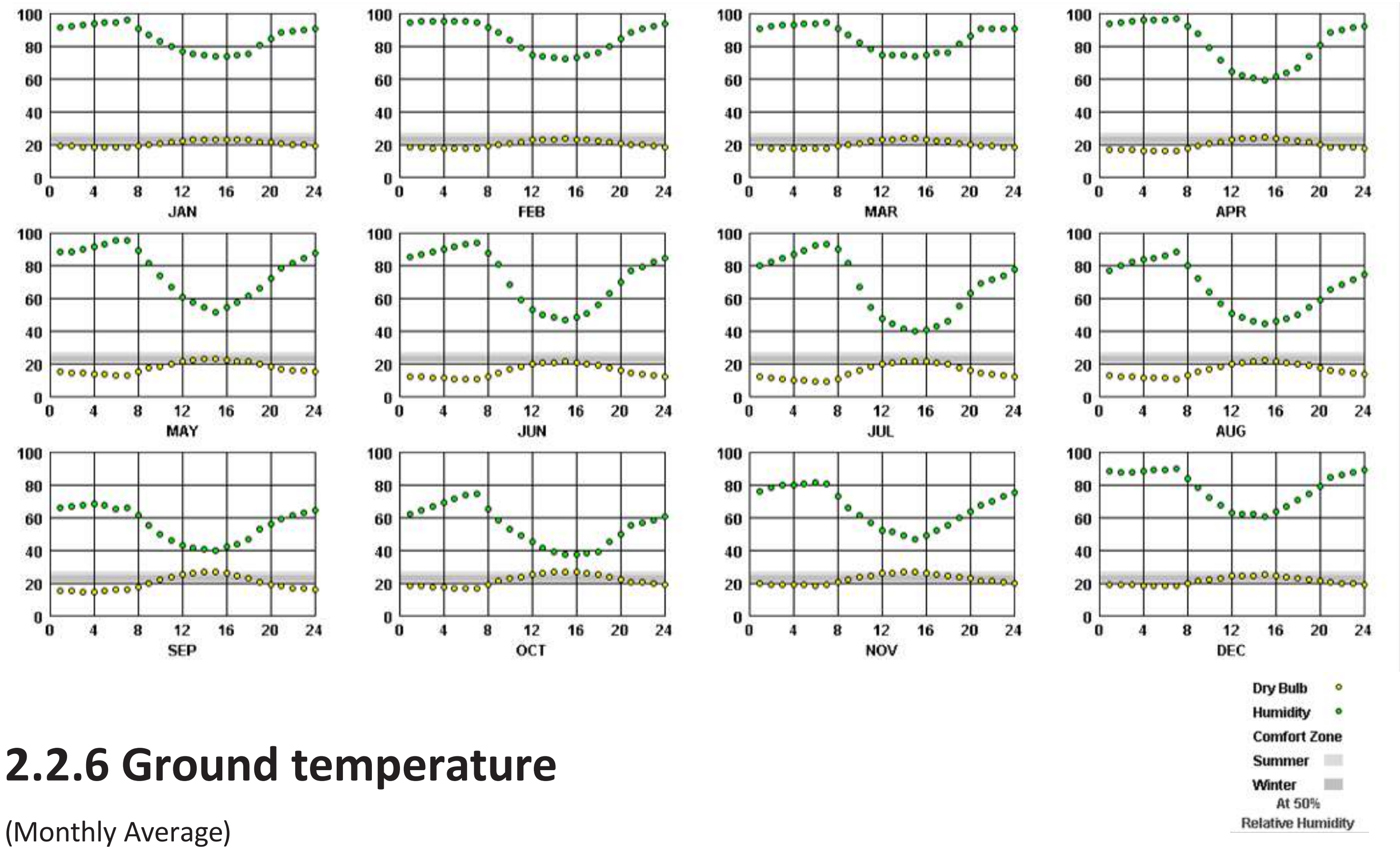
By using the psychrometric chart we can see practically how we should use the strategies to have the most optimum passive strategies to cut down the cooling and heating hours in our design.
Already without having any strategy 26% of the year we are in comfort zone.



2.2.5 Dry Bulb Vs. RH

ASHRAE standard chart 55-2004
using PMV

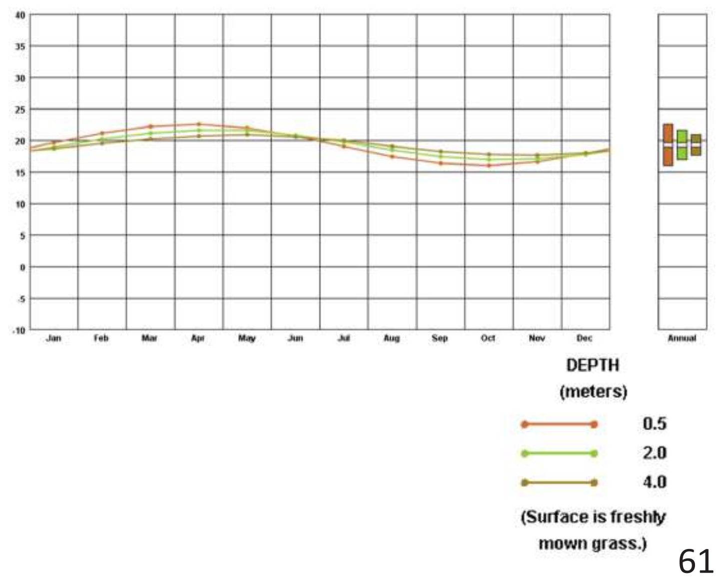
The reverse relation between Dry Bulb and RH shows us as we have higher T, we would have lower RH and reverse. As we mentioned at first the temperature during the year is in temperate range and the most challenging and bothering factor that we should struggle with is very high RH which make the choices for active and passive strategies limited.



2.2.6 Ground temperature

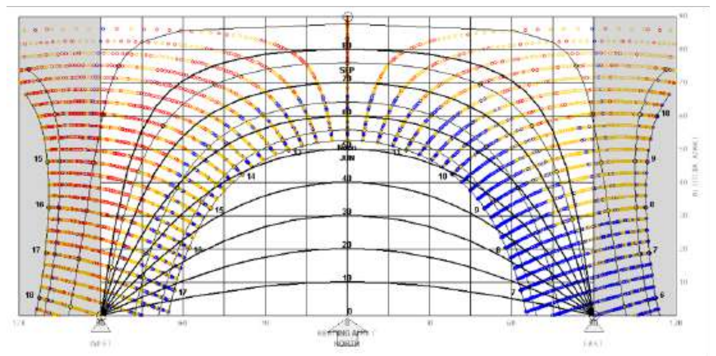
(Monthly Average)

This chart also could be very helpful if we going to consider basements or ground heat pump exchangers and as we can see in deeper part of the ground the curve is more constant and has less variety.



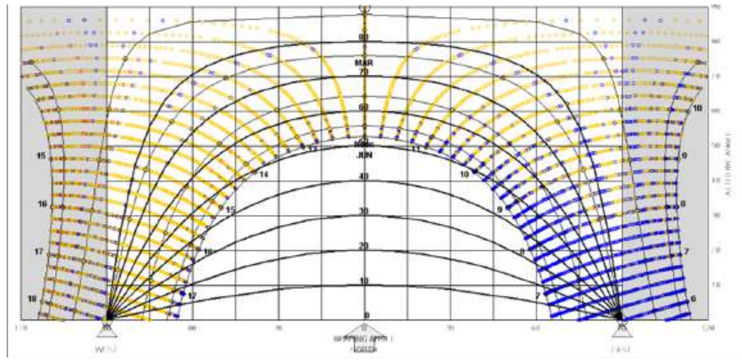
2.2.7 Sun Shading Chart

This is one of the most helpful charts which can help us in design the façade and deciding about windows and need of shading. As it can observe from the chart unexpectedly, we can see in Summer and fall we are mostly in comfort zone and there is no need of shading but in spring we may need a horizontal shading with 70 degree .



Winter spring

21Dec-21Jun

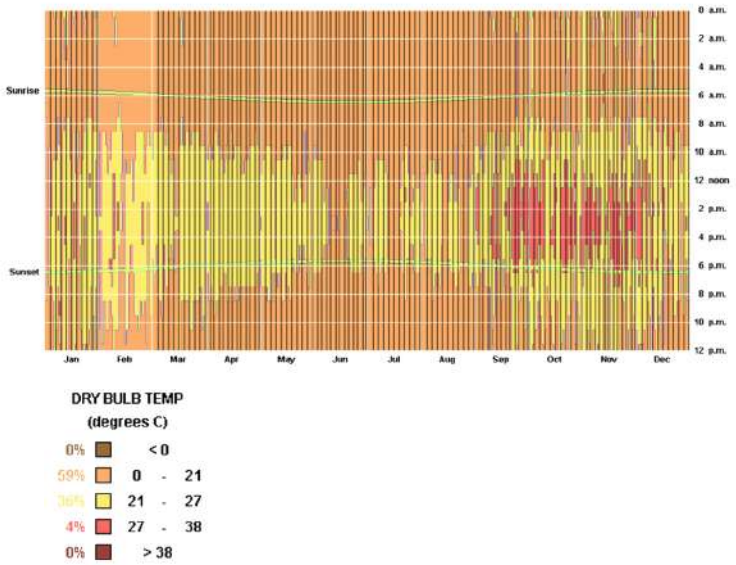


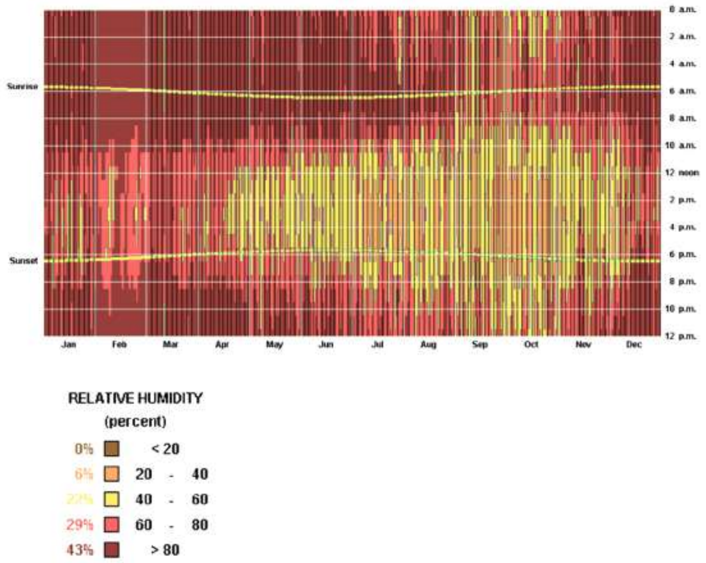
Summer Fall

21Jun21Dec

2.2.8 Timetable Plot

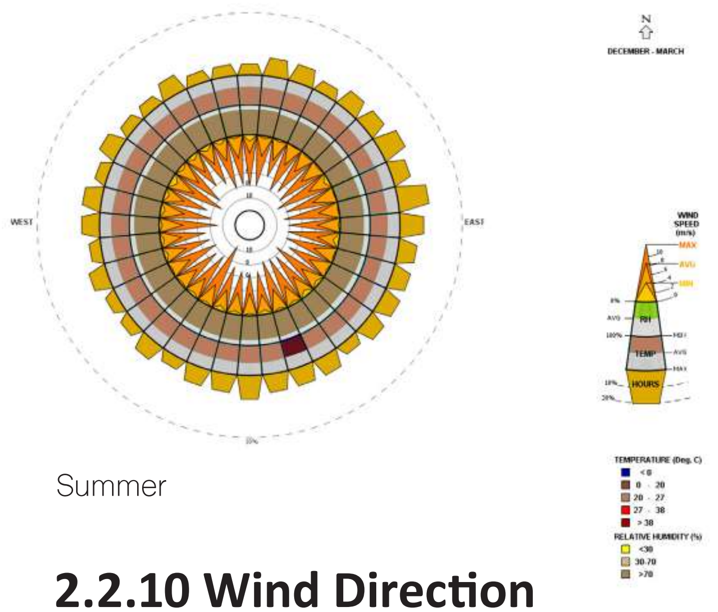
As we can see the most challenging part of our design is to how to control the high RH during the year which is above 60% around 70% of the year.



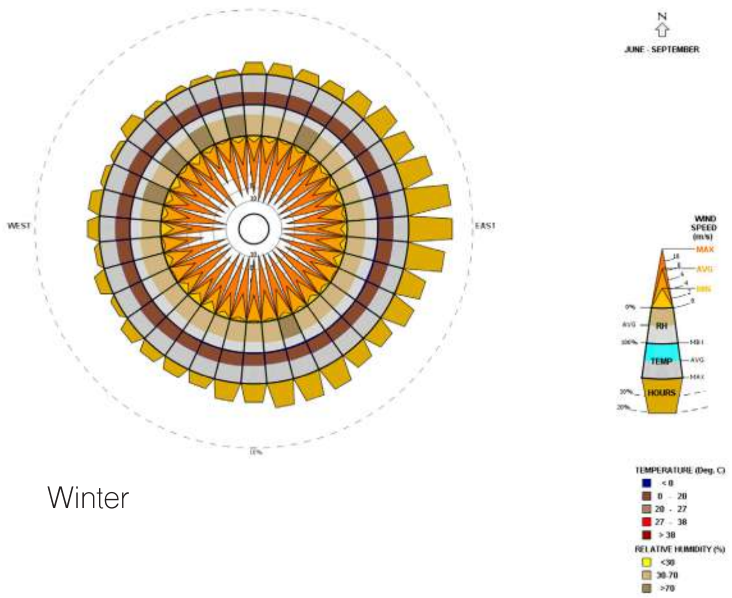


2.2.9 Wind wheel

The maximum wind speed is 10m/s and the dominant direction is from the east which is not so annoying in terms of temperature but again RH.



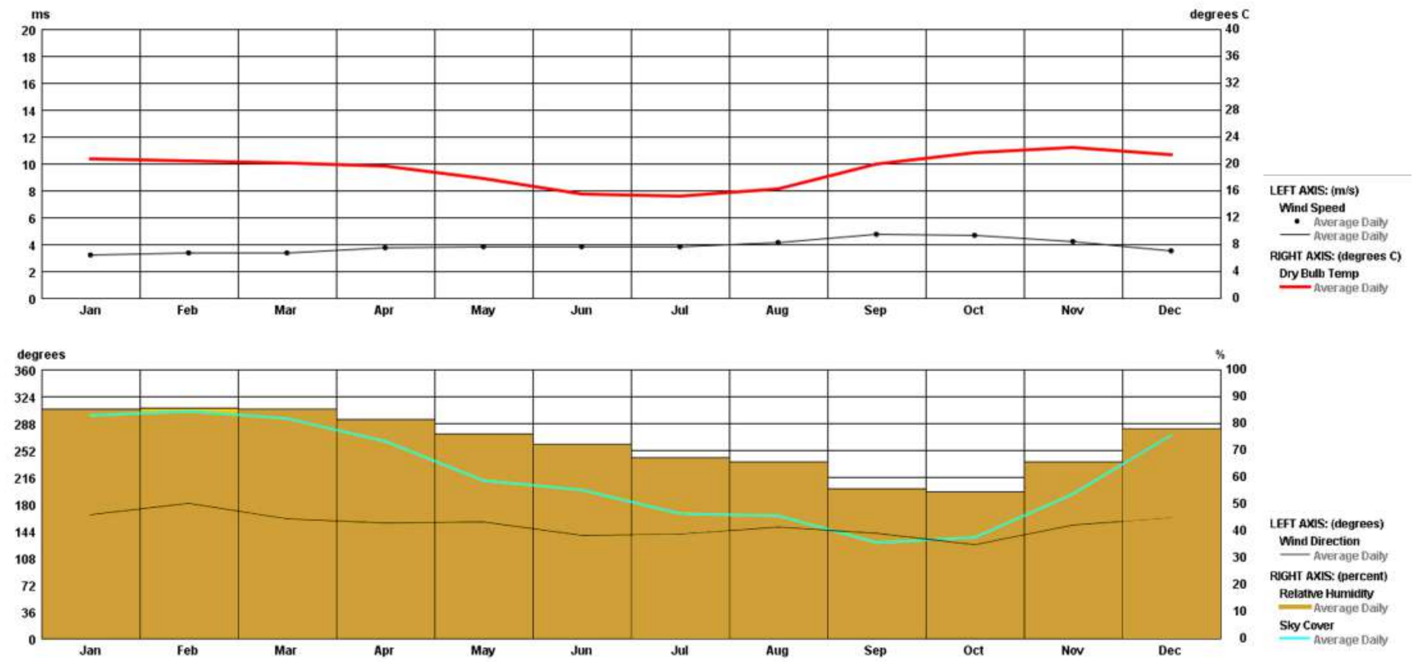
Summer



Winter

2.2.10 Wind Direction

The direction of the wind is not changing significantly through out the year also Relative humidity is less from the end of the winter to the end of spring.



2.3 ANALYSIS CONCLUTION

After analyzing all the data about the area and thinking about our design we reached to the set of primary strategies for the first steps to apply in our design to put it more in comfort zone.our goal is to design the low tech building to take the advantage of all the possible potential of the site.

CONCLUTION

- There are some months with good rainy days so its is a possibility to find startegies to drain the water for domestic usage.

- as matter of high humidiy in some days of years construction could started above the ground for natural ventilation.
- with potential of wind direction , naturl ventilation is the good strategy to having confort zone inside the buildings .

- Using local construction with slab in grade and operable walls and shaded outdoor spaces.
- This is one of the most comfortable climates, so shade to prevent overheating, open to breez in summer and use passive solar gain in winter.
- Internal heat gaing (people, lights, equipment,...) really help to reduce the heating needs so we should keep the building well insulated.
- Low pitched roofs with wide overhangs.

2.4 REQUIREMENT

According to the brief of the competitionprovided for this project, the following spaces are the ones required to fulfill theneeds of the local community.

Four classrooms:
with a capacity of twenty-five students per
classroom. Your school project should consider that in the future
each academic yearX could be extended to three classrooms per
academic year (meaning twelve classrooms in total). But, for now,
only four classrooms will be built.

Teacher office:
a space where teachers can have their personal space. Only one office will be needed.

Computers room:
the computer room will be used to teach the students how new technologies can help them. Approximately 25 computers will be used in this space.

Library:
a place where students can do their homework and have access to some books and additional knowledge out of school time.

Laboratory/research area:
this space is where students will learn Science.

Animal area:
since agriculture is a main point of the country subsistence, it is important for the youth to learn from animals, plants and land cultivating systems.

Multipurpose space:
we can think about this space as a performance and adaptive area, depending on the activity planned
to be done there:dance show, performance,exposition, conference...

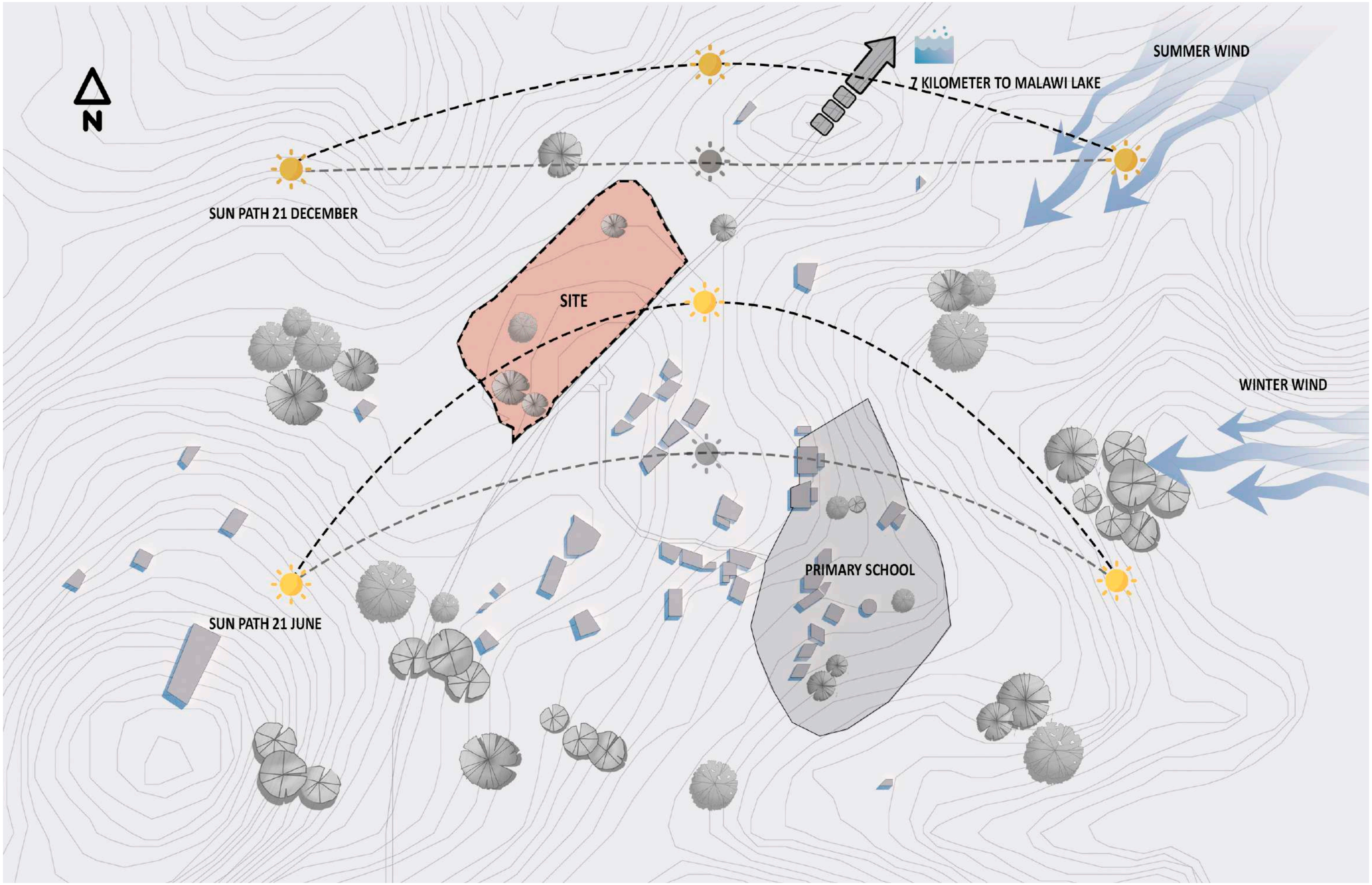
Dry latrine:
since there is no current water provision in the country, they will have to use latrines as bathrooms.

Director and secretary office:
an independent space for the
director and his or her secretary.

Meeting room:
to attend new student families, internal staff meetings, or external visitors.

Storage room:
a space where cleaning and school material can be kept.It is also important to have outdoor space inbetween the areas. It is
not mandatory to have all the spaces on an only construction.
Keep in mind that, because of the cost and constructive complexity,
in the villages of this countries they only construct one floor buildings.

2.5 SITE ANALYSIS



CHAPTER 3

ARCHITECTURE DESIGN

3.1 CONCEPT

Africa is a great continent in the terms of culture and architecture . we study a lot about the history of the malawi , from vernacular architecture to dance and music which are the main charectricstic of the area.
we understand that the from past safty has a great impact in the formation of architecture and since people where use to live as group of people this safty became more important to them . as a consequnce of this reason most of the tribes where formed in circural shap to bring the safty .

Figure 3.1 African Taditional architecture

Then we goes deep through their culture , we understand the music and dance plays important roles in their community , after watching several dance videos of this area we came up with one of the important instruments for playing traditional music for dance. Drums ! these drums divided to three different sizes for producing different sounds .
With all of this information we started to work on the form of our building and the relation of it with surroundings.

concept process :

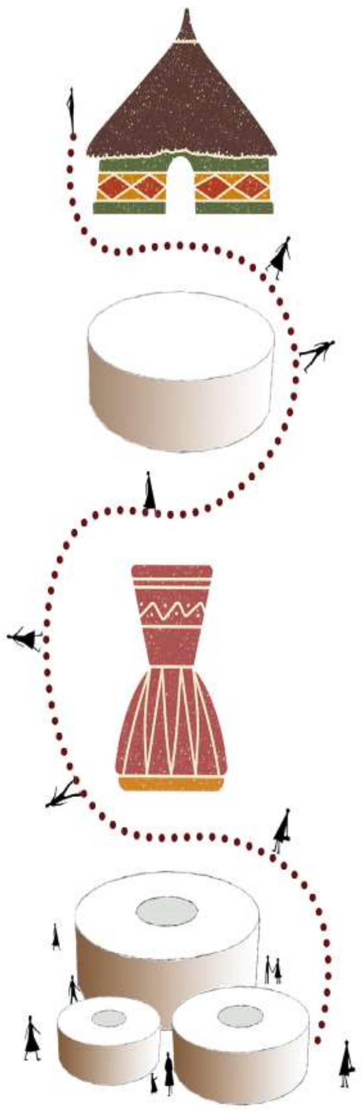
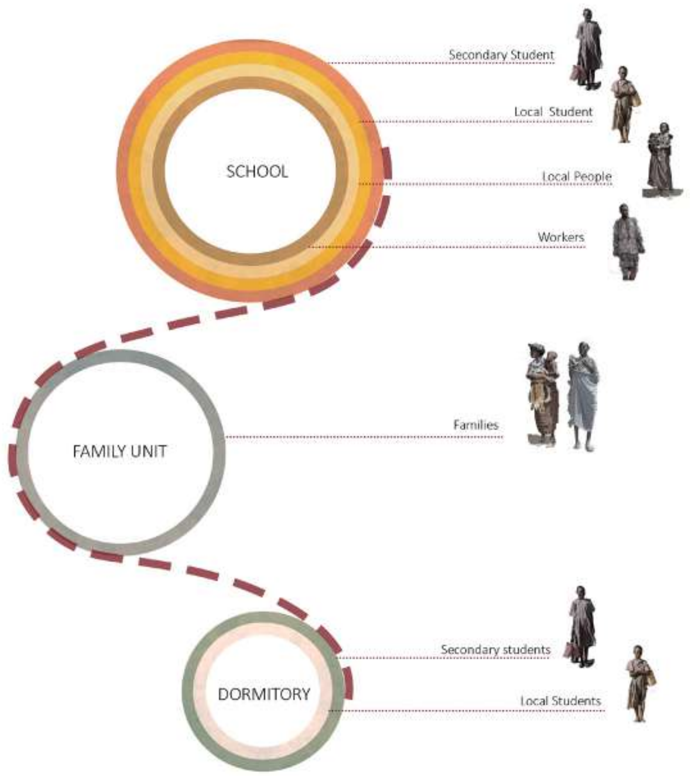


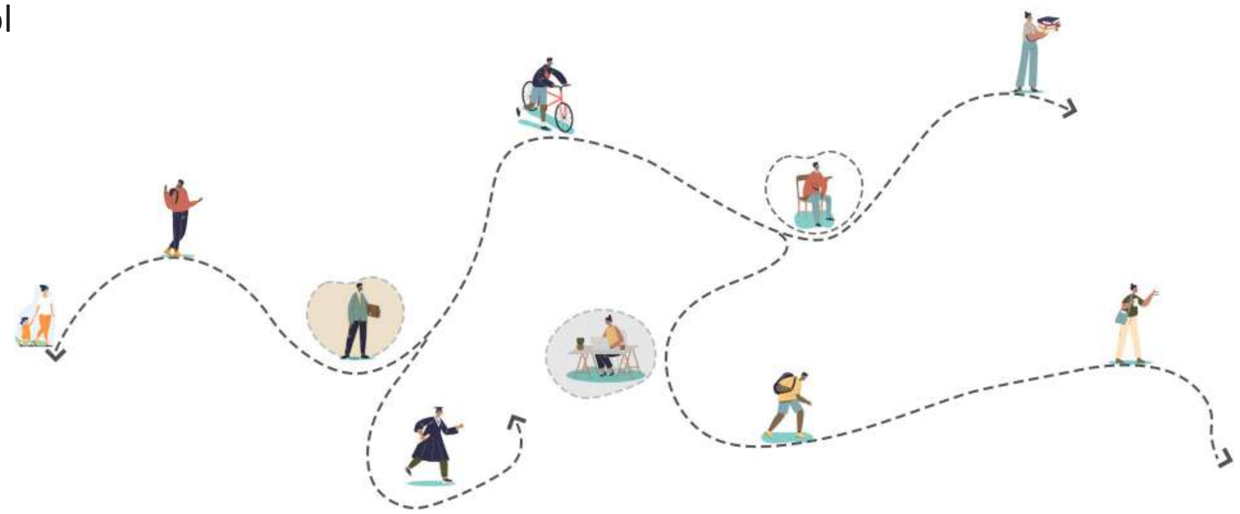
Figure 3.1 Malawian drums

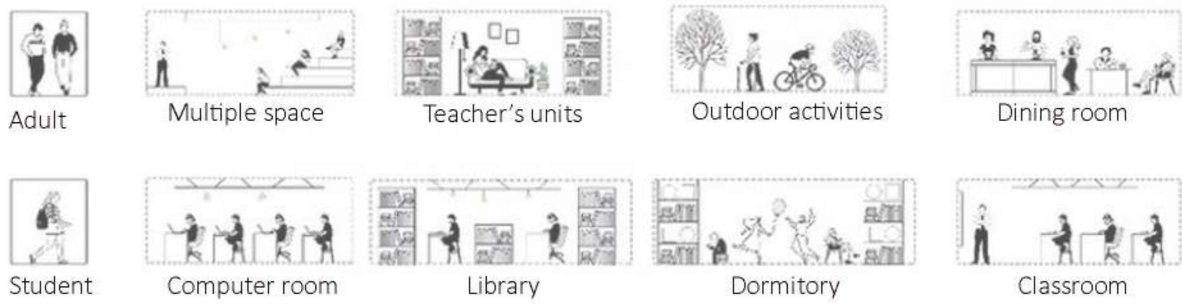
3.2 USERS TYPOLOGY

The aim of our project from the primary step was not to provide the space only for the secondary students , we had always in our mind that accorrding to the life style of african people , they are always conncered to each other.
On the other hand we wanted also to connect the secondary school to the primary school which is located in front of our site , so during our design process and in addition to the what is writen in the brief of competition we consider some public spaces for all walks of people.

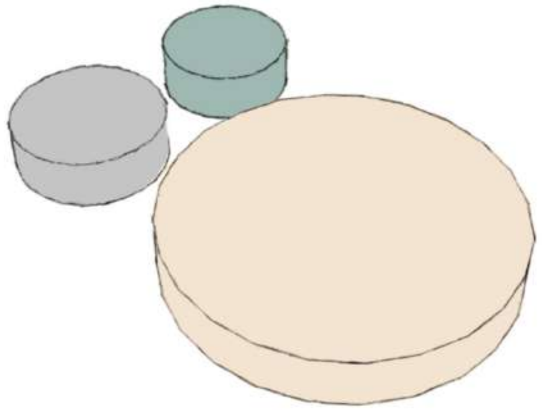
These spaces involve people from outside of school to join for learning and working with other students because we believe that this dynmic which will be created by differet type of the people will also bring livabl



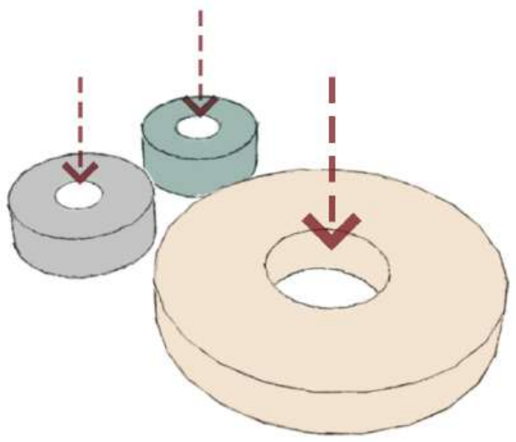




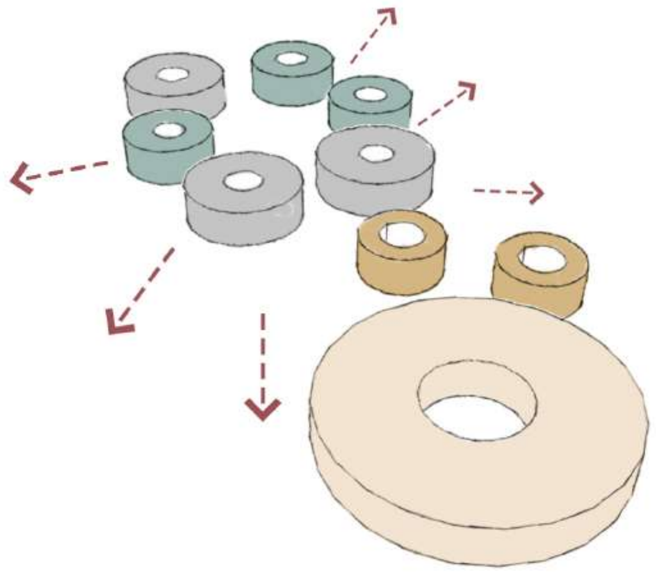
3.3 DESIGN PROCESS



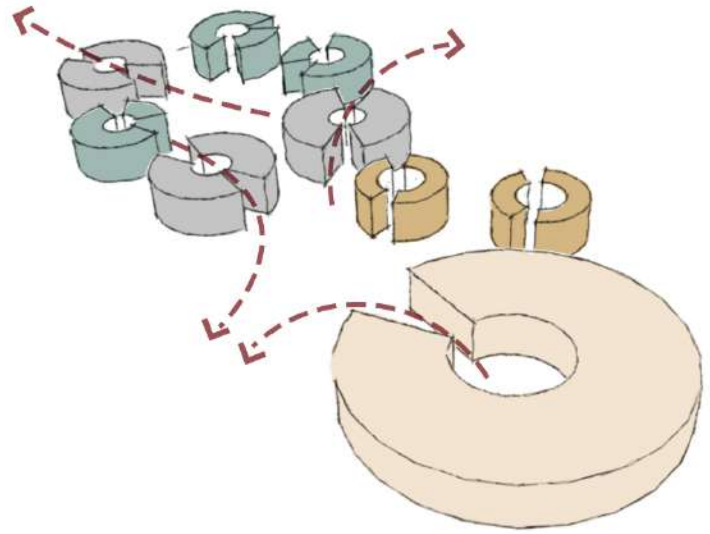
1.Choose the base shape accourding
to the traditional Malawian houses



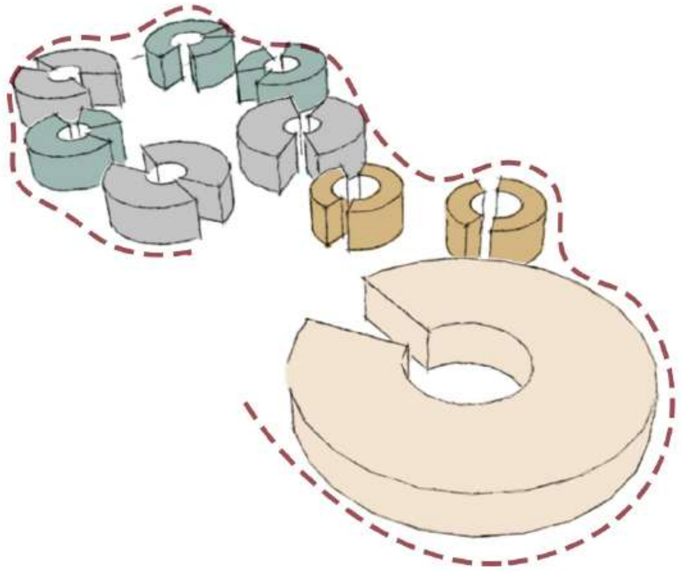
2.Eliminate the center of shape to provide
Agriculture field , better circulation and
energy point of view



3.Distributed shapes among the site to fullfil
all the functions



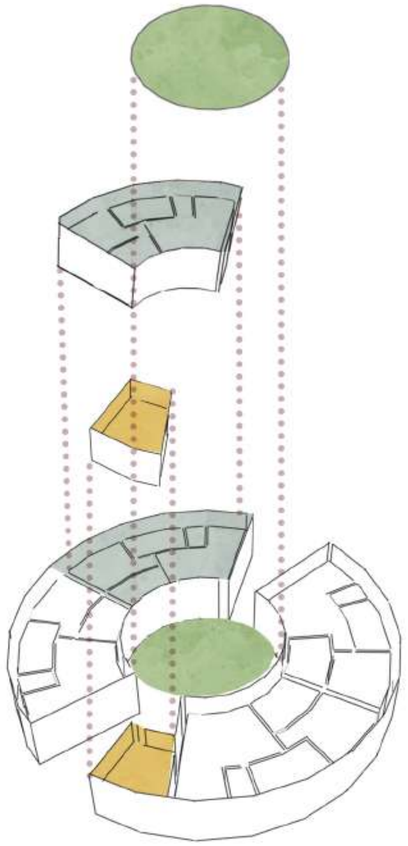
4. Define entrance for each unit to provide
circulation and also ventilation.



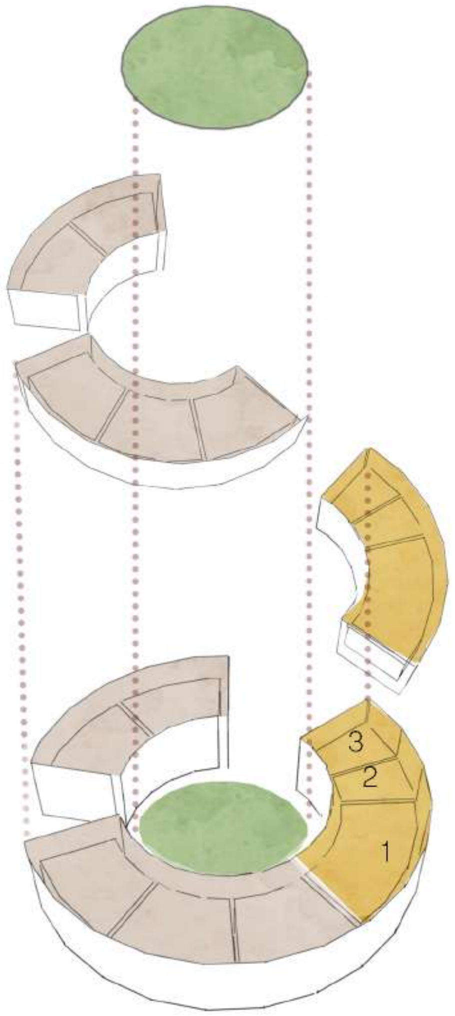
5.bamboo barrier which goes around the site to
provide unity and shade place and also a strategy
against cold winds.

4. Instal Second roof for preventing from over
heating and also ventilation

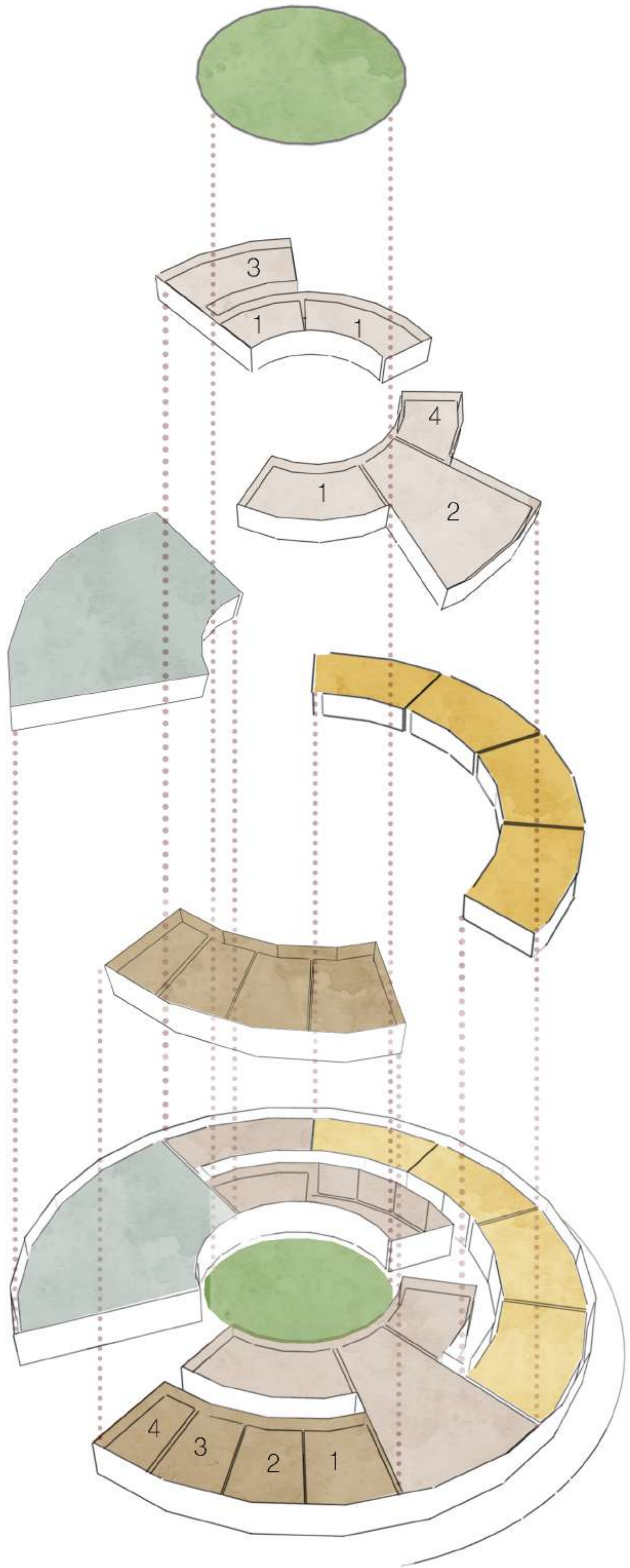
3.4 FUNCTIONS



- Garden
- Family units
  - -3 bedrooms
  - -Kitchen
  - -Living room
  - -Shower
- Water Tank room

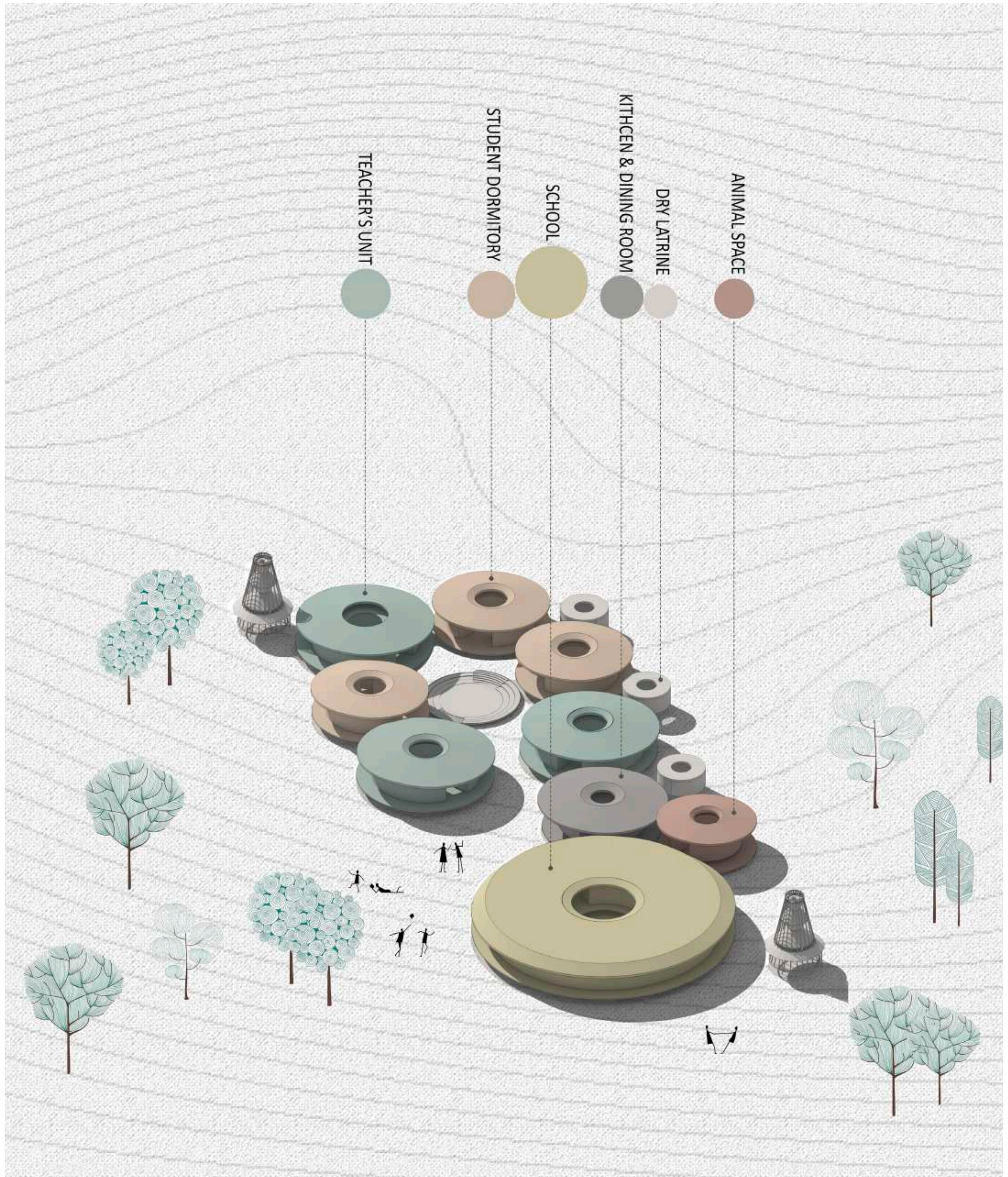


- Garden
- Dormitary rooms
- 1.Showers
- 2.Storage
- 3.Water Tank room

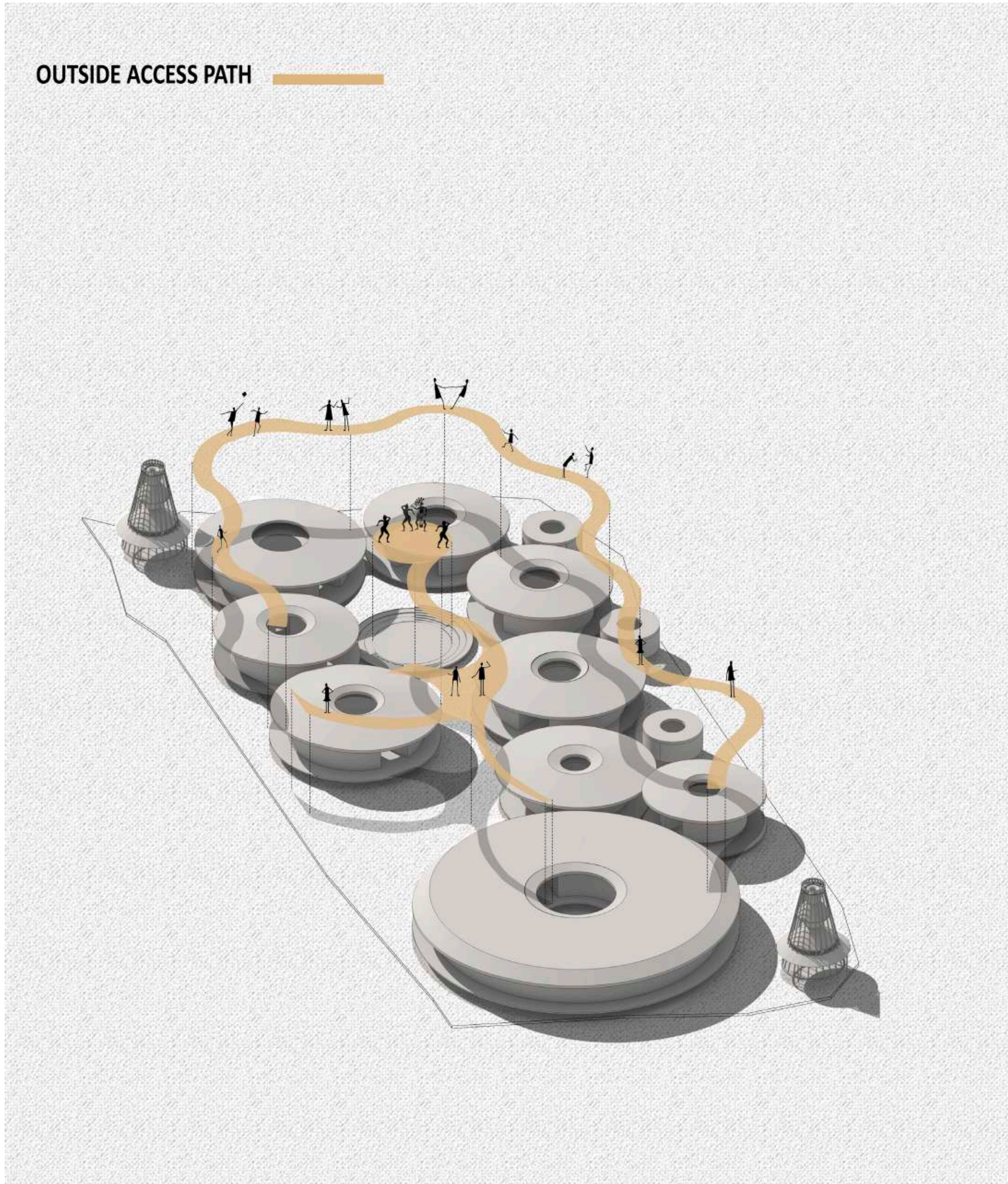


- Garden
- 1.Workshop
- 2.Multipurpose Space
- 3.Computer room
- 4.Labrotary
- Library
- Classrooms
- 1.Meeting room
- 2.Teachers room
- 3.Director and secretary office:
- 4.Water Tank and Storage room

3.5 SITE DISTRIBUTION

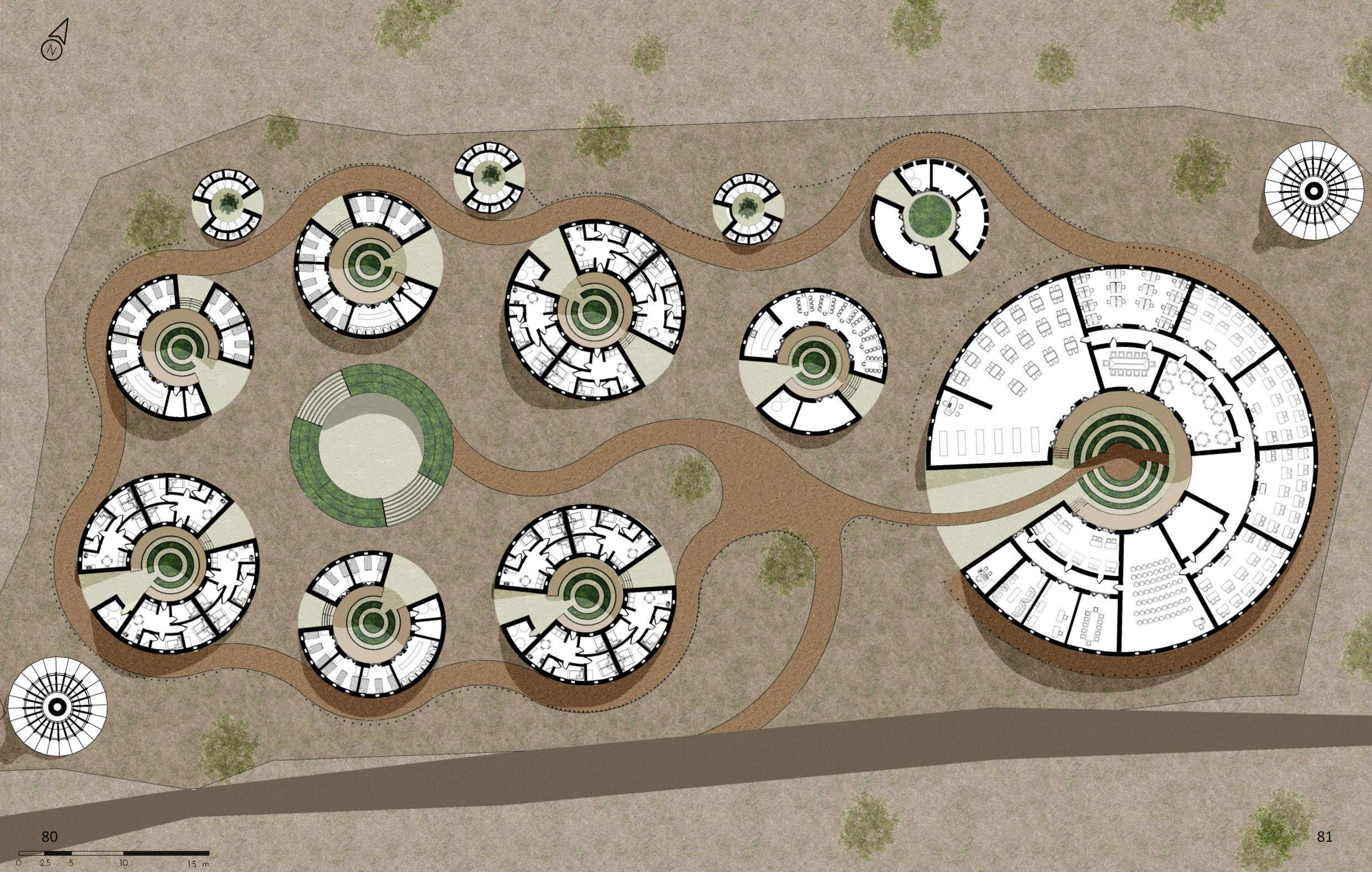


3.6 CONNECTION



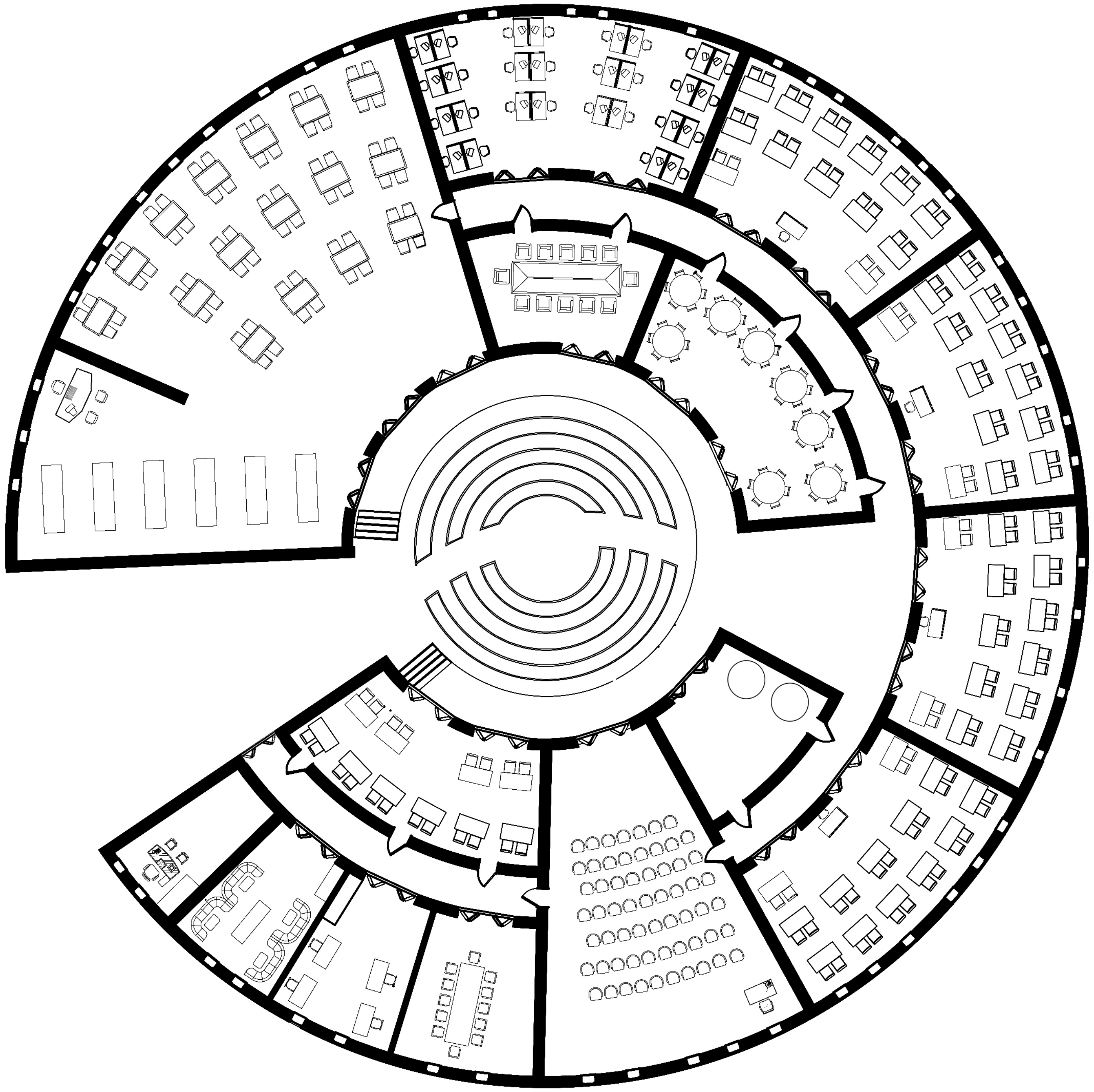
3.7 MASTER PLAN

3.8 PLAN

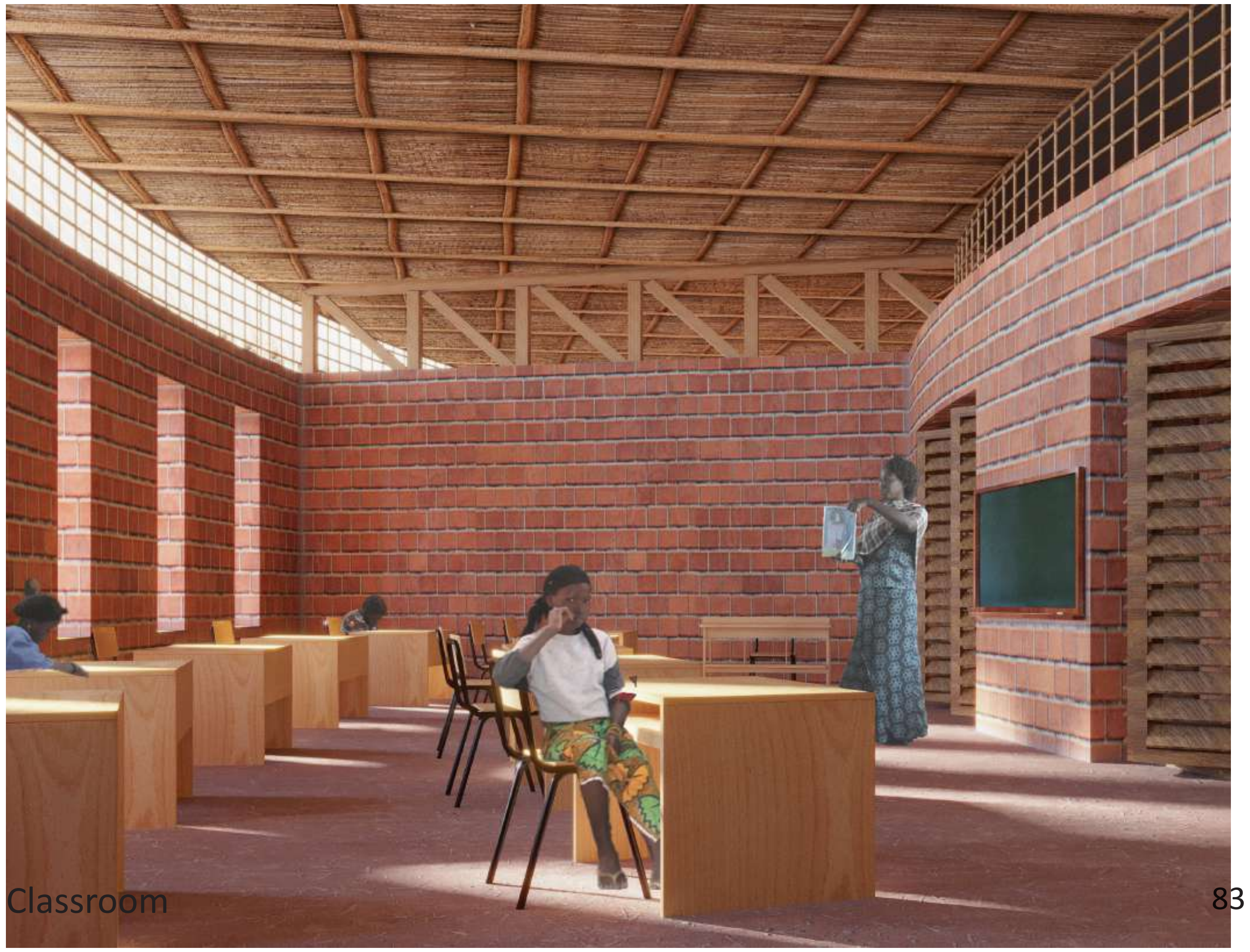


3.8.1 Plan Typology

SCHOOL



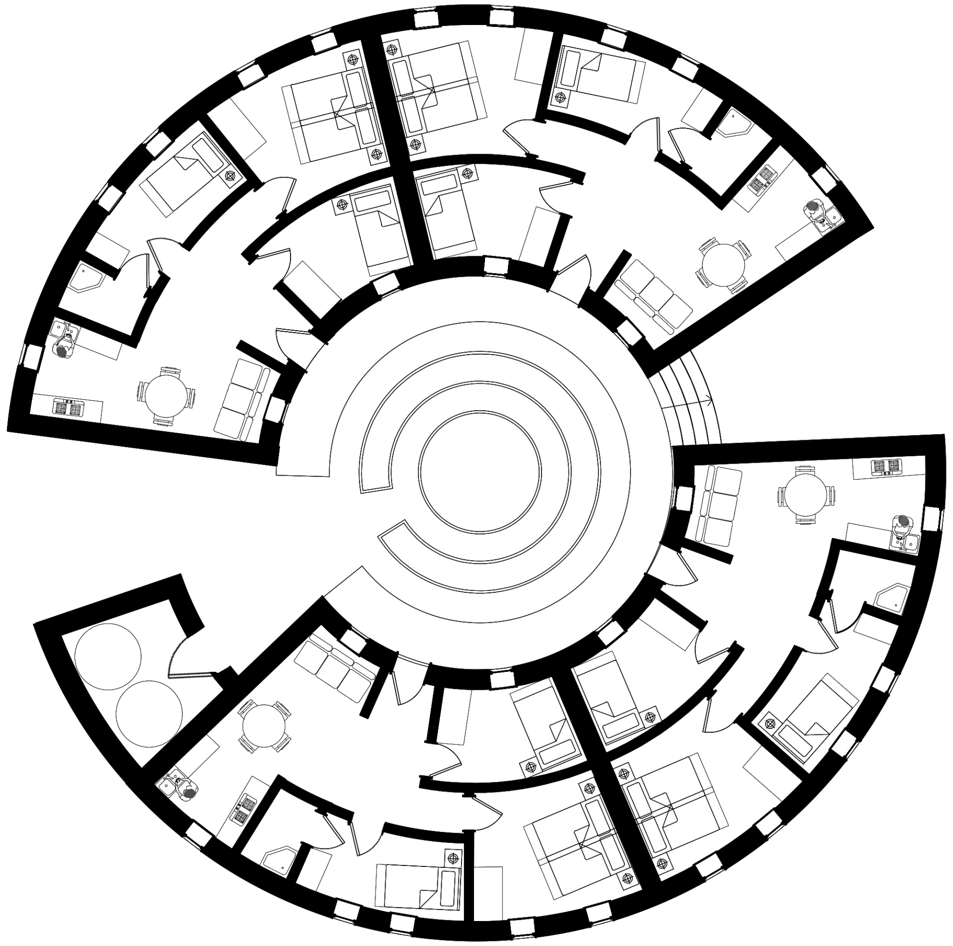
Library



Classroom

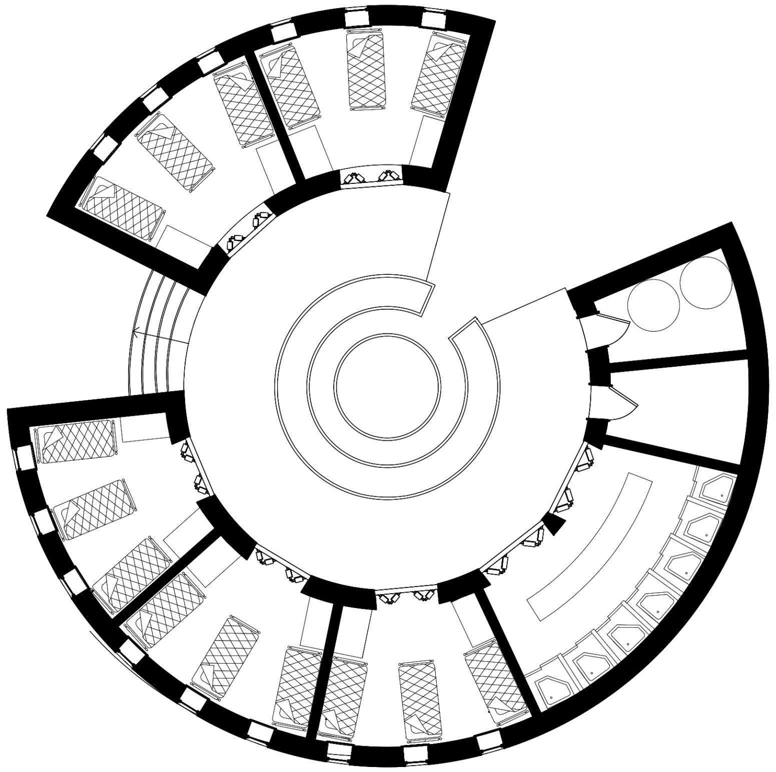
3.8.2 Plan Typology

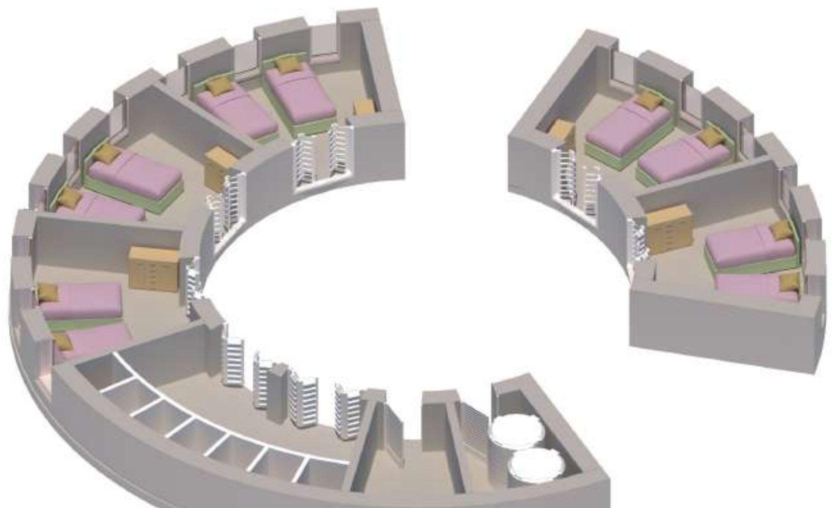
FAMILY UNITS



3.8.3 Plan Typology

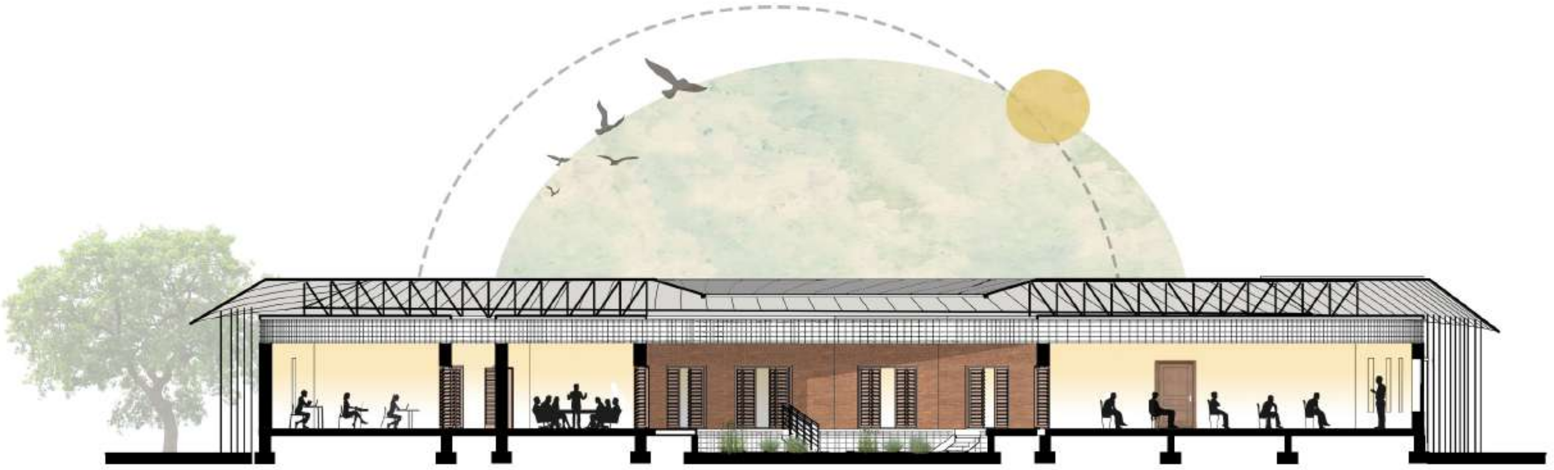
DORMITORY

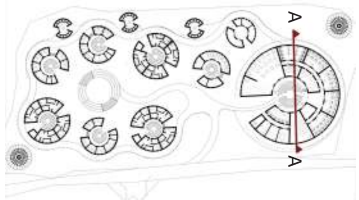




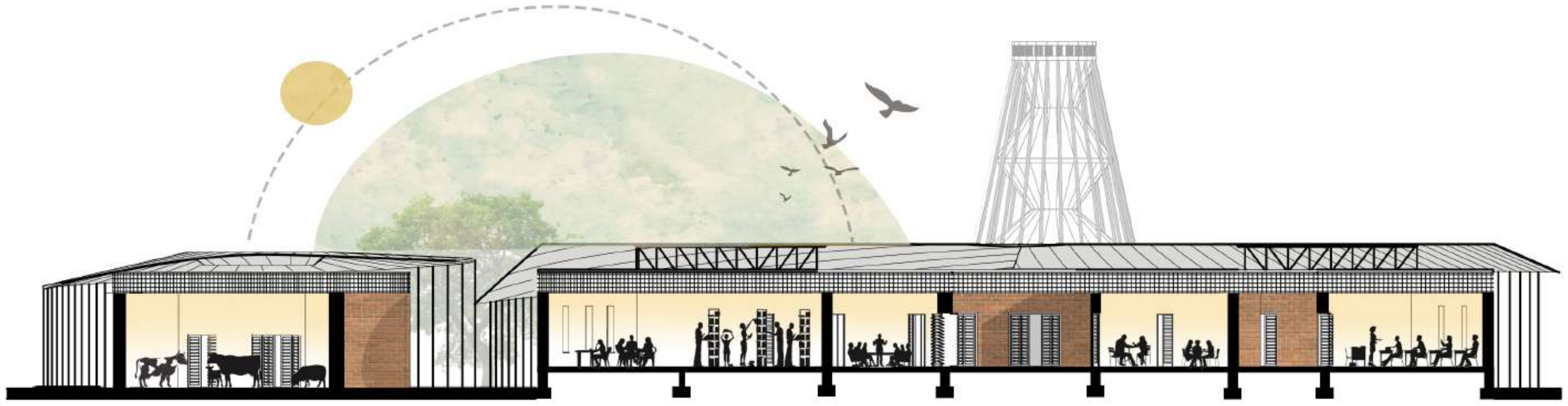
3.9 SECTION

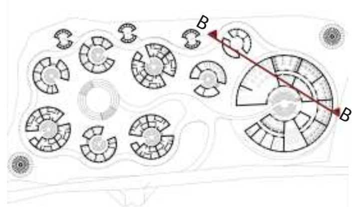
SECTION A - A



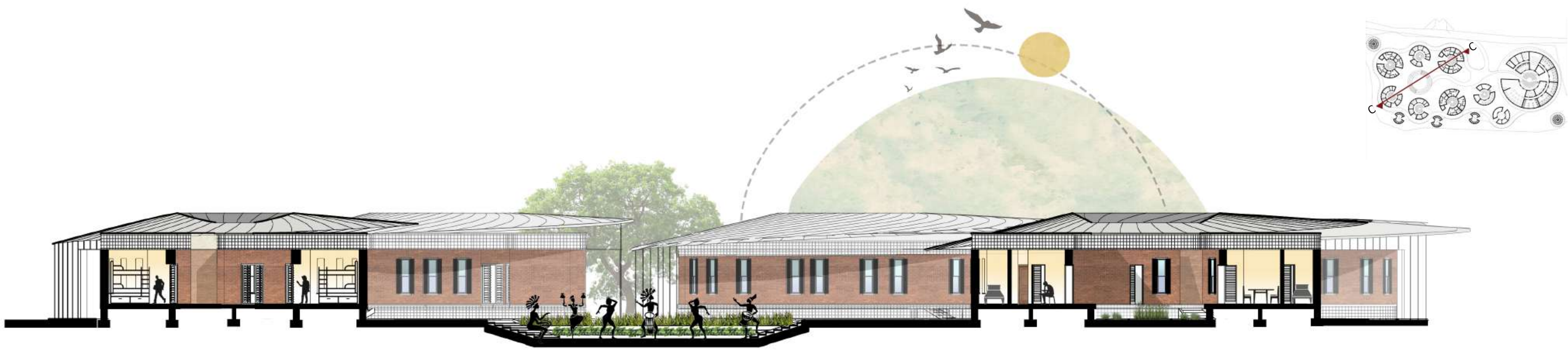


SECTION B - B



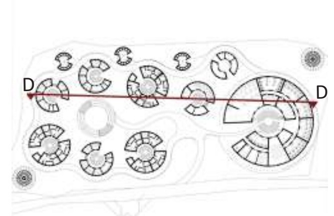


SECTION C - C

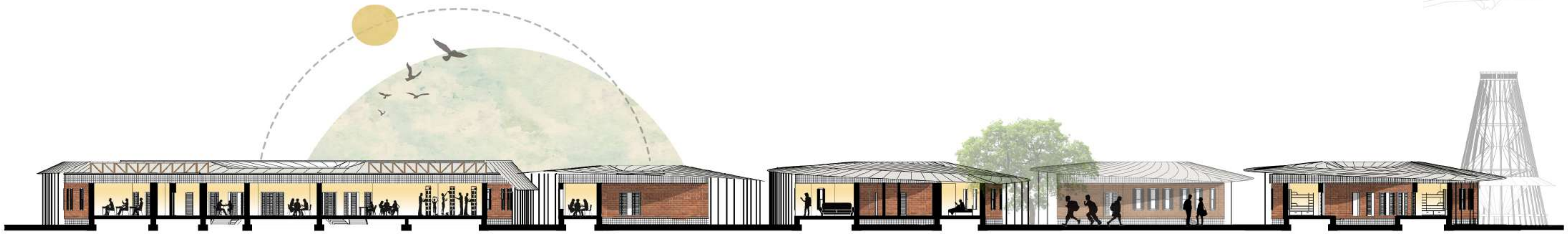


0 2.5 5 10 m

3.9.1 Section and Elevation

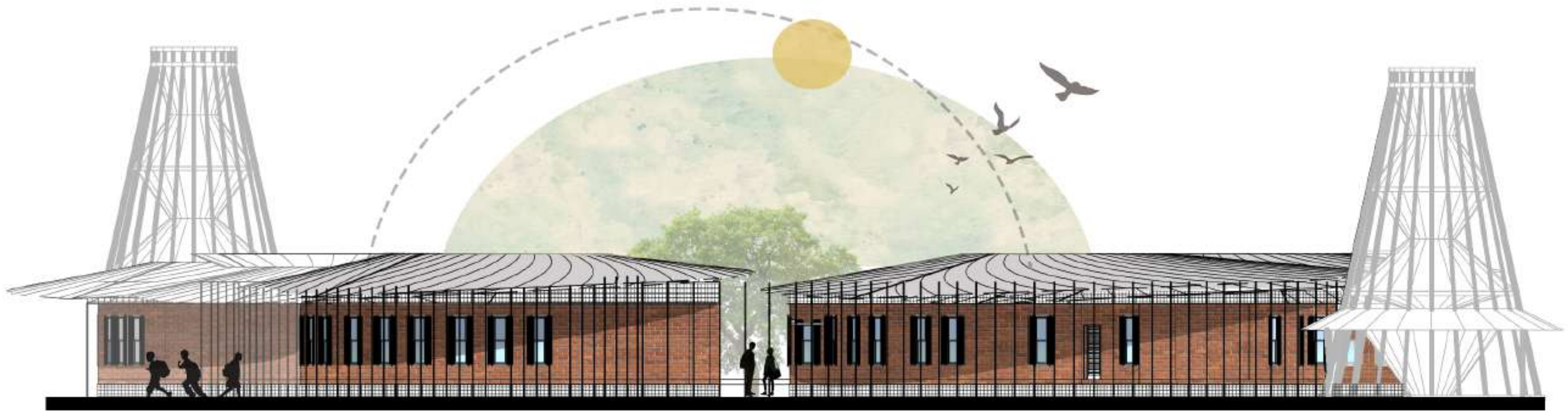


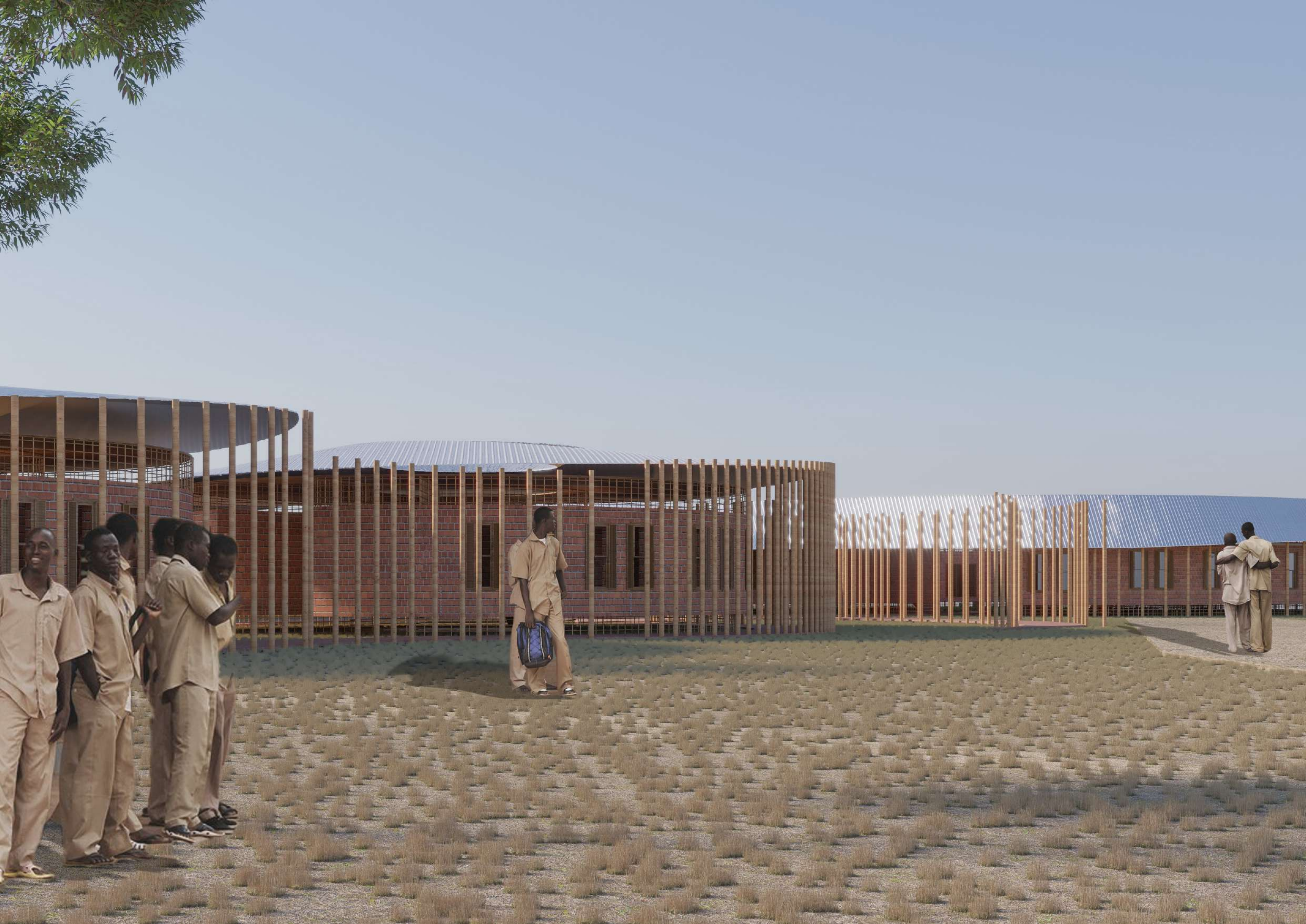
SECTION D - D



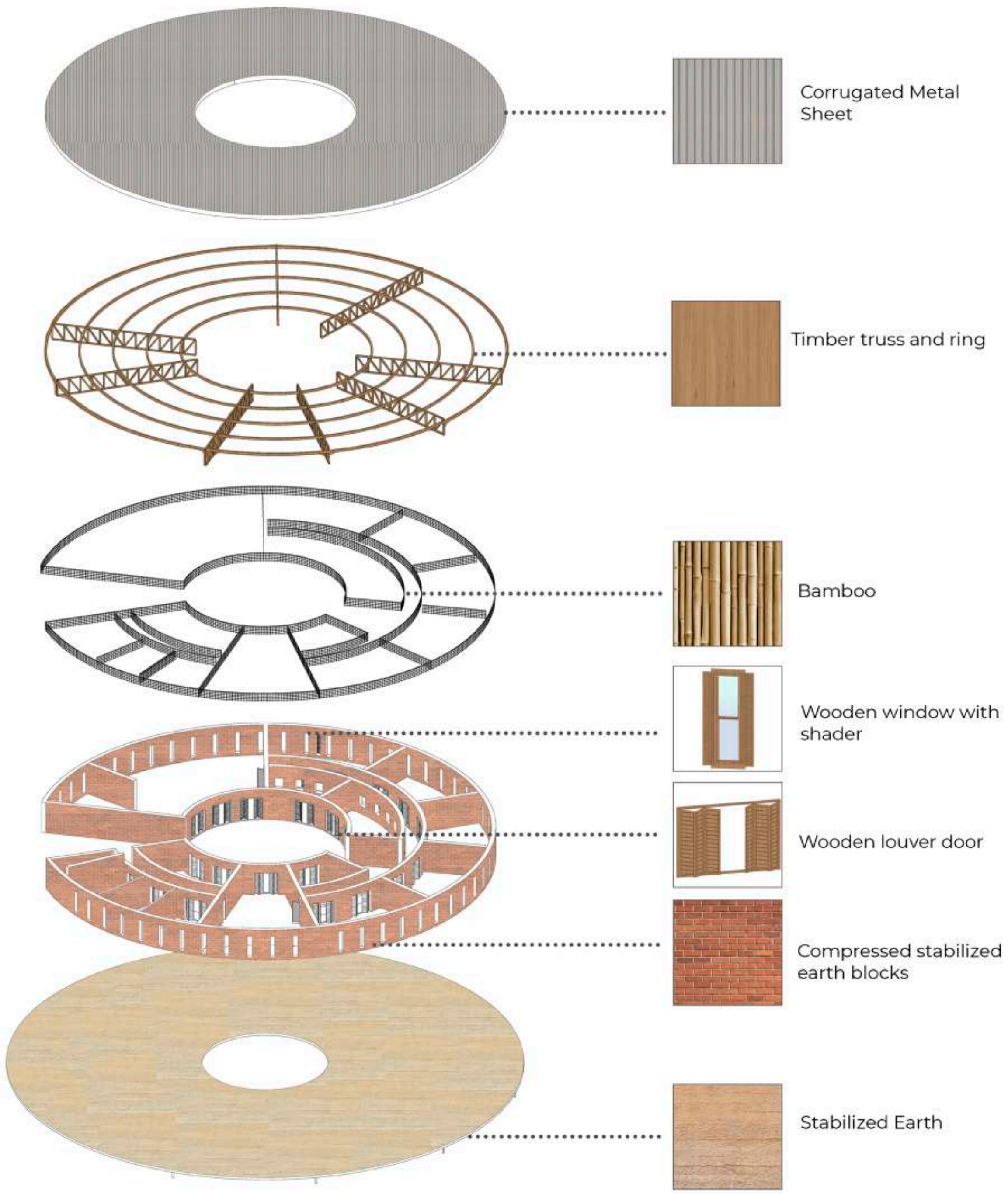
SOUTH ELEVATION

WEST ELEVATION

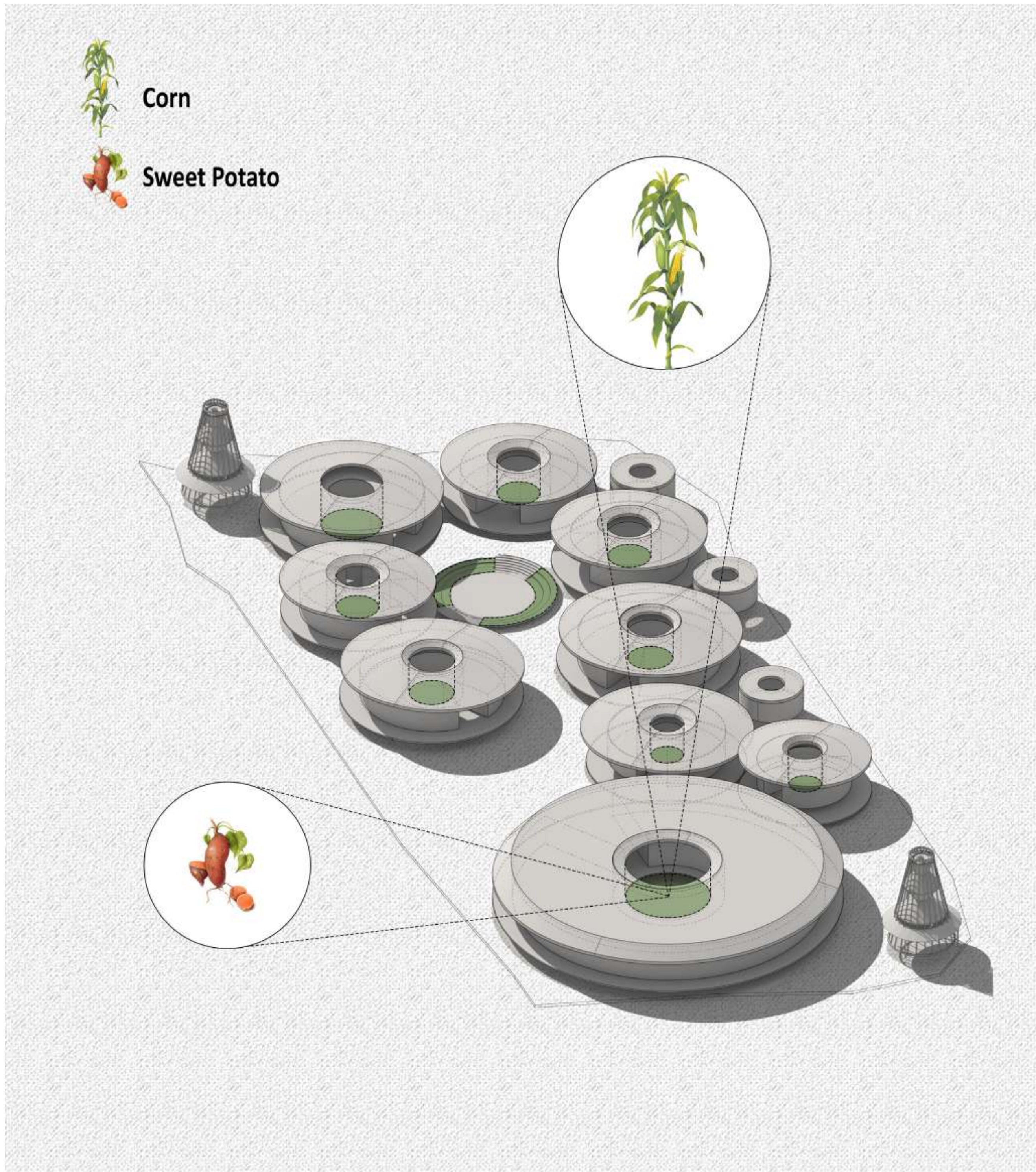




3.10 MATERIAL



3.11 GREEN SPACES




sports
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CHAPTER 4
MATERIAL

4.1 BAMBOO

Bamboo, as a green building material, is revealing its potential in modern architecture practice. The amazing thing about bamboo, besides being a totally natural material,is that it is sustainable, lightweight, flexible, and inexpensive.
The use of Bamboo enables original and attractive beauty of its form, texture and the sense of rhythm.
In Africa, bamboo has always been an importance construction material referring to their vernacular architecture. Nowadays, considering the issues of global warming and the poverty in Africa. Bamboo, as one kind of low cost, low energy consumption and sustainable material,has great potential to be promoted in building construction in Africa.

4.1.1 Structural properties

Mechanical performance
Bamboo can be harvested every three to six years for construction purposes, depending on the species. It is important to harvest the bamboo at the right time to reach their greatest strength and when sugar levels in the sap are at their lowest, as high sugar content increases the ease and rate of pest infestation. Mechanical properties are highly correlated to the percentage and distribution of bamboo fibers within the culm cross section. These properties are influenced greatly by the specific gravity, which depends on fiber content, fiber diameter, and cell wall thickness.material,has great potential to be promoted in building construction in Africa.

4.1.2 Flextural strength

Commonly, it can be estimated the bending stressat failure for air-dry bamboo as 0.14 times the density in kg/m3. And The density of most bamboos is 700 – 800 kg/m3 but depends on species. However, in typical bending tests, the mode of failure is not fracture of the fibers but rather longitudinal splitting of the material due to fracture of the weaker lignin bonding the fibers together. Therefore, a critical longitudinal strain of 0.00373 is given and an ultimate bending stress of 62 N/mm2 are estimated.

4.1.3 Compression strength

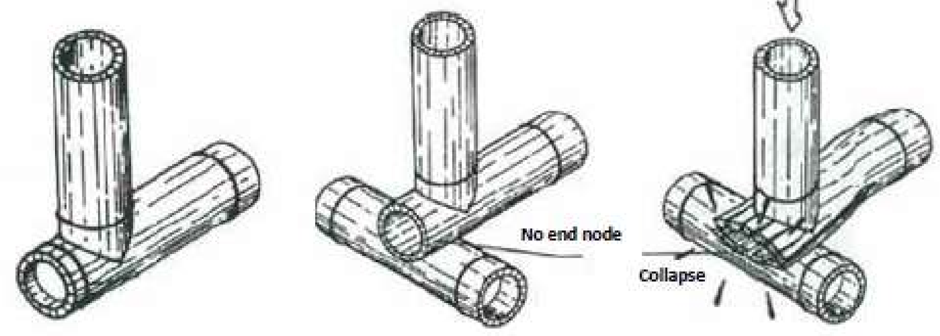
Bamboo is an extremely strong fiber with twice the compressive strength of concrete. The compression strength of full-culm bamboo has been studied by multiple authors, one of them estimated the ultimate compressive stress of air-dry bamboo as 0.094 times the density in kg/m3.

4.1.4 Tensile strength

The tensile strength of bamboo has been shown to be quite high and vary widely between species. Bamboo has been cited as having tensile strength similar to mild steel in some cases. As with Young's modulus, tensile strength is influenced primarily by the bamboo fiber volume ratio. There was a study on tensile specimens of two-year-old Mousou bamboo and found that the tensile strength of the bamboo (140-230 MPa) was greater than that of common woods such as fir, pine, and spruce (30-50 MPa).

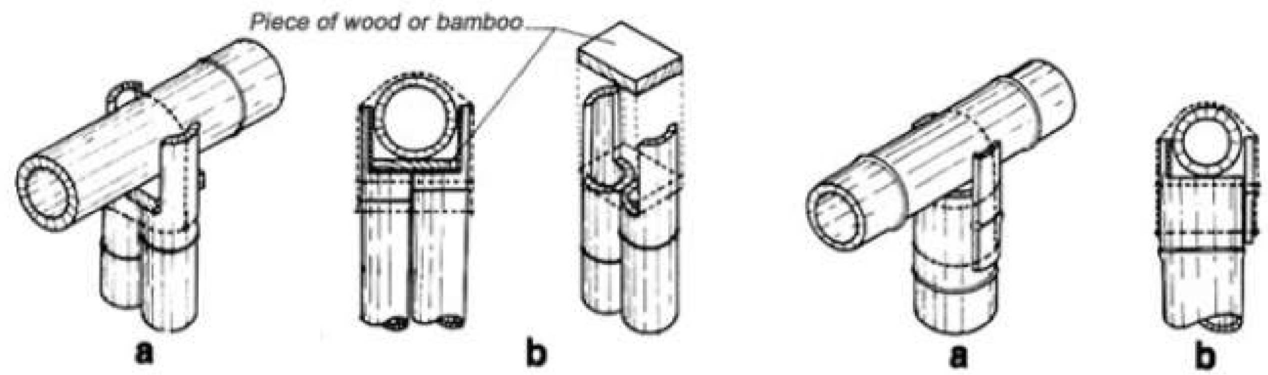
4.2 BAMBOO JOINT

Designing bamboo joints is rather complicated because bamboo is hollow, tapered, has nodes at varying distances, and it is not perfectly circular.
Although traditions, local practices and publications give some information on bamboo joinery, this information is far from complete as essential data is missing in most cases. Before bamboo gets widely adopted in modern architecture the problem with bamboo joints and universal joining systems have to be solved.
Before introducing the techniques of bamboo joints, one thing have to mention is that it is very important to use bamboo nodes in construction. Bamboo columns or beams need to have a node at both ends (or as close as possible towards the ends), if not the pressure of a structure on the joint may crush the bamboo.

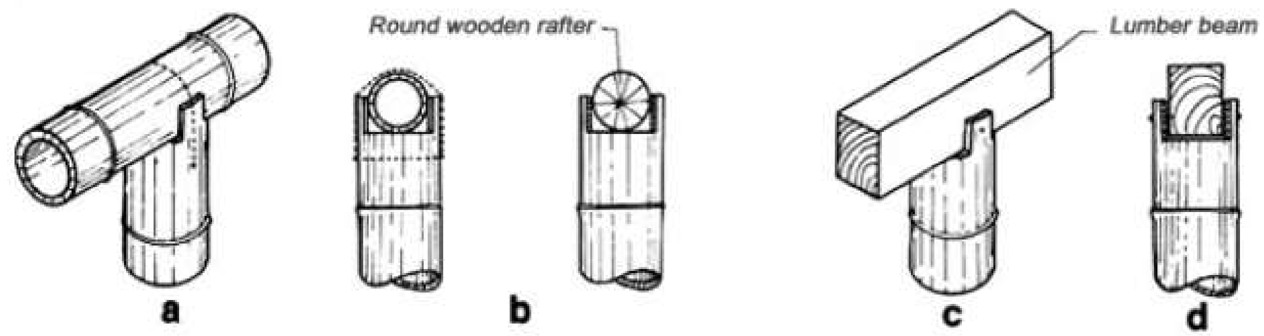


There are some examples and illustrations of traditional bamboo joinery techniques.

1. Joining horizontal with vertical elements



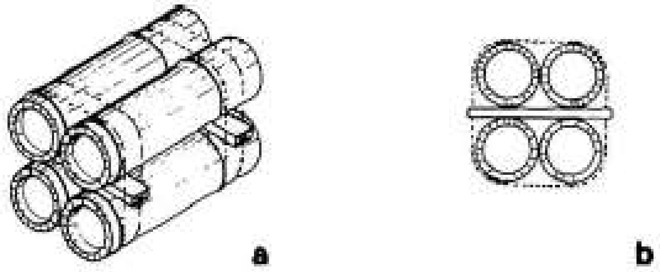
Joint with one or two ears, which is used to join bamboo rafters, logs or lumber.



2. Double and quadruple bamboo rafter support

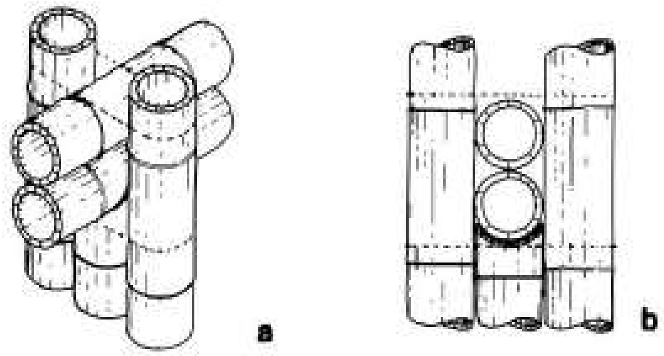
Beams formed by 4 or 6 members

The top row is separated from the bottom with bamboo or wood slats so that the upper bamboos do not slide over the lower.



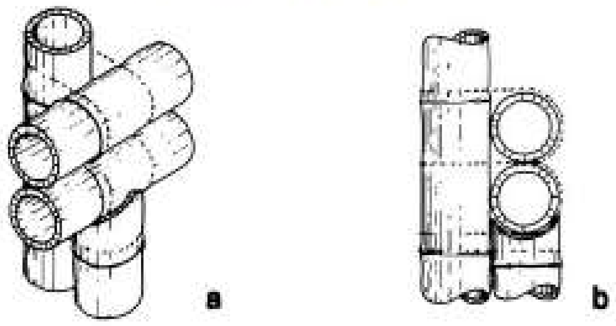
Central double rafter

It has a wide range of applications in the construction of bridges and structures for rural facilities.



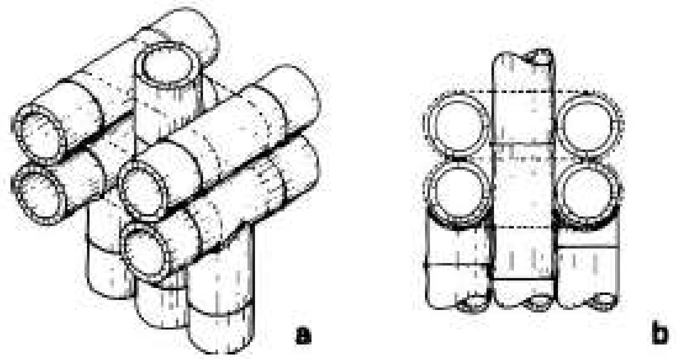
Lateral double rafter

Each of the rafters is secured independently at the side support and each other. It is often used in the construction of bridges and structures for rural facilities.



Lateral double rafters

Is often used as a central support for bridge structures or sheds.



4.3 CONNECTION

There are many modern bamboo connections have well developed, but considering the actuality in Africa, technique which is inexpensive and easy to implement should be used.
Friction-tight rope connections are the common connecting method. Traditionally natural materials are used: coco/sago palm fiber, bast, strips of bamboo and rattan. For tight connection, green bamboo strips are used, the fibers are watered before tying around the bamboo. While drying, the fibers shorten and the connection becomes stronger. Nowadays also industrial materials are used like iron wire and plastic tapes.

This connection is easy to build and simple for bamboo manufacturing. Besides, it can almost serve all the circumstances we need in building with bamboo. Although it is a simple technique, it can be very strong with sufficient lashing techniques. Moreover, it can drastically reduce the possibility of bamboo cracking because no notches or holes are in need in making such connections.

Plug-in/Bolt connections are constructed with secondary interlocking elements are often used in context with rope connections. In this case the bolts have to transfer tractive and compressive forces. In wooden connection, this is done by different kinds of profiles. To make the plug-in bamboo connector, at first, we should drill on both sides of the vertical and horizontal bamboo poles; note that the vertical one which will be interlocked with a timber pin needs larger holes than the horizontal one. Secondly, we use a timber pin (also can be made of bamboo) to connect the two bamboo poles, which is then followed by interlocking a bamboo wedge to strengthen the connection. At last we should cut the waste part of the wedge and make the connector surface smooth. And if it is necessary, we can also apply adhesive or rope to further strengthen the joints.

Figure 4-1 bamboo connection

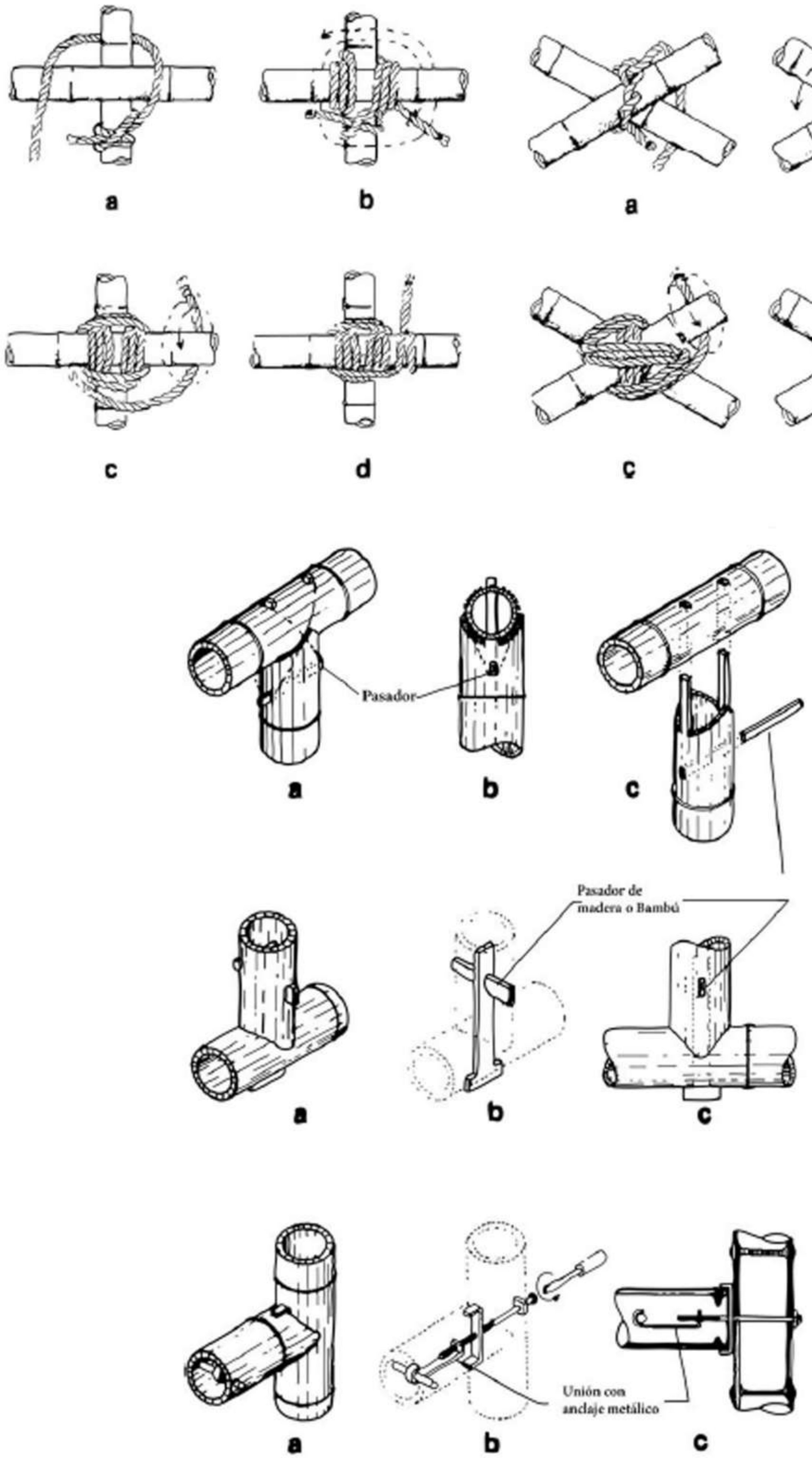


Figure 4.2 Joining and fixation of bamboo poles

4.4 COMPRESSED STABILISED EARTH BLOCK

The first attempts for compressed earth blocks were tried in the early days of the 19th century in Europe. The architect François Cointereaux precast small blocks of rammed earth and he used hand rammers to compress the humid soil into a small wooden mould held with the feet.

The first steel manual press which has been produced in the world in the 1950's was the Cinvaram. It was the result of a research programme for a social housing in Colombia to improve the hand moulded & sun dried brick (adobe). This press could get regular blocks in shape and size, denser, stronger and more water resistant than the common adobe. Since then many more types of machines were designed and many laboratories got specialised and skilled to identify the soils for buildings. Many countries in Africa as well as South America, India and South Asia have been using a lot this technique.

The soil, raw or stabilized, for a compressed earth block is slightly moistened, poured into a steel press (with or without stabiliser) and then compressed either with a manual or motorized press. CEB can be compressed in many different shapes and sizes. For example, the Auram press 3000 proposes 18 types of moulds for producing about 70 different blocks.

Compressed earth blocks can be stabilised or not. But most of the times, they are stabilised with cement or lime. Therefore, we prefer today to call them Compressed Stabilised Earth Blocks (CSEB).

The input of soil stabilization allowed people to build higher with thinner walls, which have a much better compressive strength and water resistance. With cement stabilization, the blocks must be cured for four weeks after manufacturing. After this, they can dry freely and be used like common bricks with a soil cement

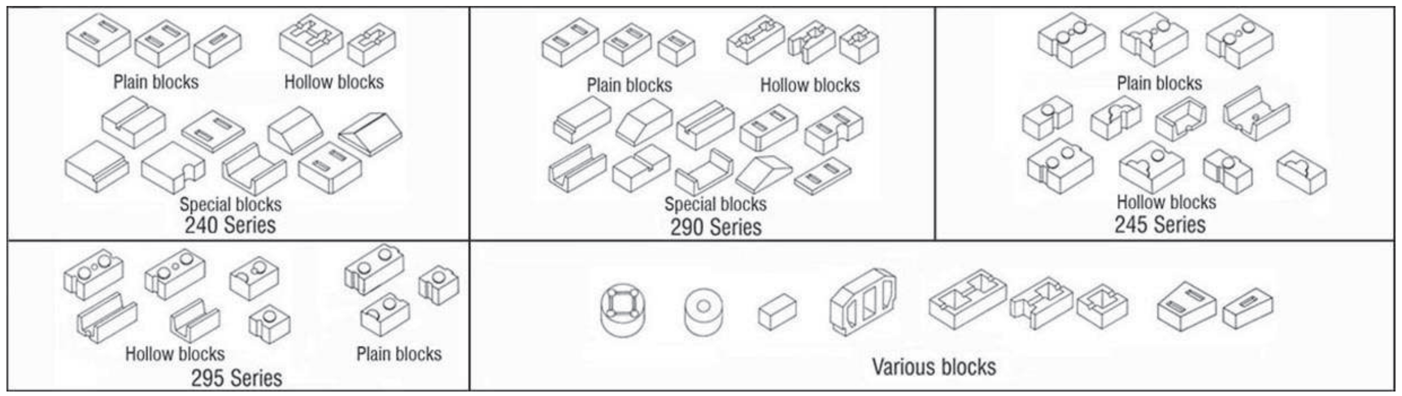


Figure 4-3 CSEB classification

4.4.1 Sustainablity and environmental friendliness of CSEB

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<tr><td colspan="2">

- Earth is a local material and the soil should preferably be extracted from the site itself or not transported from too far away
- Labour costs for CSEB production amount to 40 to 45% of the total cost. This promotes endogenous development.
- It is a cost and energy effective material.
- The embodied energy of CSEB is 10.7 times less than country fired brick.
- Carbon emissions of CSEB are 12.5 times less than country fired brick.

</td></tr>
<tr><td>INITIAL EMBODIED ENERGY PER M^3</td><td>CARBON EMISSIONS (Kg of CO_2) PER M^3</td></tr>
<tr><td>CSEB = 572.6 MJ / m^3
Country Fired Brick (CFB) = 6,122.5 MJ / m^3</td><td>CSEB = 51.5 Kg / m^3
Country Fired Brick (CFB) = 642.9 Kg / m^3</td></tr>
</table>

4.4.2 Energy effectiveness

Initial embodied energy (MJ/m^3 of materials)	Carbon emission (Kg of CO2 /m^3 of materials)
CSEB are consuming 11 times less energy than country fired bricks: CSEB produced on site with 5 % cement = 548.32 MJ/m^3 Country fired bricks = 6,122.54 MJ/m^3	CSEB are polluting 13 times less than country fired bricks: CSEB produced on site with 5 % cement = 49.37 Kg of CO_2 /m^3 Country fired bricks = 642.87 Kg of CO_2 /m^3

4.4.3 Good soil for compressed stabilised earth blocks

The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil, but will take a longer time to harden and to give strong blocks.

Soil for cement stabilisation:
it is more sandy than clayey Gravel = 15% Sand = 50% Silt = 15% Clay = 20%

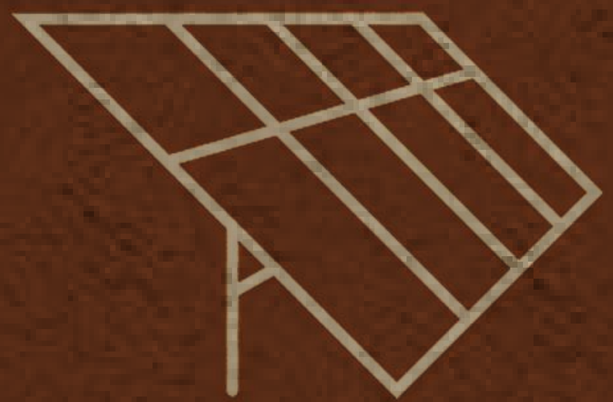
Soil for lime stabilisation:
it is more clayey than sandy Gravel = 15% Sand = 30% Silt = 20% Clay = 35%

4.4.4 Advantages of CSEB

• A local material Ideally, the production is made on the site itself or in the nearby area. Thus, it will save the transportation, fuel, time and money. • A bio-degradable material Well-designed CSEB houses can withstand, with a minimum of maintenance, heavy rains, snowfall or frost without being damaged. The strength and durability has been proven since half a century. But let's imagine a building fallen down and that a jungle grows on it: the bio-chemicals contained in the humus of the topsoil will destroy the soil cement mix in 10 or 20 years… And CSEB will come back to our Mother Earth! • Limiting deforestation Firewood is not needed to produce CSEB. It will save the forests, which are being depleted quickly in the world, due to short view developments and the mismanagement of resources. • Management of resources Each quarry should be planned for various utilisations: water harvesting pond, wastewater treatment, reservoirs, landscaping, etc. It is crucial to be aware of this point: very profitable if well managed, but disastrous if unplanned!	• Energy efficiency and eco friendliness Requiring only a little stabilizer the energy consumption in a m^3 can be from 5 to 15 times less than a m^3 of fired bricks. The pollution emission will also be 2.4 to 7.8 times less than fired bricks. • Cost efficiency Produced locally, with a natural resource and semi skilled labour, almost without transport, it will be definitely cost effective! More or less according to each context and to ones knowledge! • An adapted material Being produced locally it is easily adapted to the various needs: technical, social, cultural habits. • A transferable technology It is a simple technology requiring semi skills, easy to get. Simple villagers will be able to learn how to do it in few weeks. Efficient training centre will transfer the technology in a week time. • A job creation opportunity CSEB allow unskilled and unemployed people to learn a skill, get a job and rise in the social values	• Market opportunity According to the local context (materials, labour, equipment, etc.) the final price will vary, but in most of the cases it will be cheaper than fired bricks. • Reducing imports Produced locally by semi skilled people, no need import from far away expensive materials or transport over long distances heavy and costly building materials. • Flexible production scale Equipment for CSEB is available from manual to motorized tools ranging from village to semi industry scale. The selection of the equipment is crucial, but once done properly, it will be easy to use the most adapted equipment for each case. • Social acceptance Demonstrated, since long, CSEB can adapt itself to various needs: from poor income to well off people or governments. Its quality, regularity and style allow a wide range of final house products. To facilitate this acceptation, banish from your language "stabilized mud blocks", for speaking of CSEB as the latter reports R & D done for half a century when mud blocks referred, in the mind of most people, as poor building material

4.4.5 Some limitations of CSEB

• Proper soil identification is required or unavailability of soil. • Unawareness of the need to manage resources. • Ignorance of the basics for production & use. • Wide spans, high & long building are difficult to do.	• Low technical performances compared to concrete. • Untrained teams producing bad quality products. • Over-stabilization through fear or ignorance, implying outrageous	• Under-stabilization resulting in low quality products. • Bad quality or un-adapted production equipment. • Low social acceptance due to counter examples (By unskilled people, or bad soil & equipment).



CHAPTER 5
STRATEGIES

5.1 INTRODUCTION

The main goal of our project from the primary step was to identify the potentials and design the building These strategies focus on the increasing the comfort inside the school and other buildings , taking advantages of the sun gains and wind, while providing an efficient system of protection and collection of the rainwater .
After studing about some new technologies which are green technologies and mainly they are compatiable with the context we decided to consider them in our project as a sustainable solutions beside the others strategies that we thought in our design ,to reach that confort that we expected for our final result.

There are some starategies that we consider in our design like each building block is provided of an independent roof, with sufficient slope to rapidly drain the rainwater. The lower roof, continuous around all the spaces, allows to collect the water coming from the top roof, addressing it to the collection tank. All the pavement surfaces are made of permeable materials, either stabilized earth, gravel or grass, to avoid the problem of flooding.
The temperature in the mild climate season, constant throughout the year, is not high enough to provide an adequate thermal comfort. To increase the temperature inside of the classrooms the high thermal mass of the rammed earth wall will slowly release the heat stored throughout the day providing a more constant temperature inside the classes.
In case of overheating due to the high number of people inside the building, it can be taken advantage of the natural cross ventilation, thanks to the position of the windows on both sides.

5.1.1 challanges

-Deforestatio: Malawi was previously heavily forested with much of the country under forests. However, according to Index Mundi, in 2015 forest cover was just 33.38% of the total land area of Malawi (falling from 41.4% in 1990). The Northern Region, where Ripple Africa is based, has more forested areas than the heavily populated Southern and Central Regions combined.
REASONS: -Lack of knowledge abour farming(“slash and burn agriculture”)
- Wood is the main fuel in Malawi, and 95% of homes still use wood or charcoal for cooking

5.1.2 Our Project Aim

we are trying to apprise people of the the area about the world’s new methode of sustainable agriculture and also training local farmers and new generation to plant more efficient products which needs less water and grow much more sooner to provide for them food and money for promoting the quality of their life throgh the one the main goal of our project :education

5.1.3 SDGs

Sustainable Development
Goals Communications Workshop
31 May-2 June 2016
Lilongwe, Malawi
Mrs Asha Kannan,
Senior Economics Advisor
UNDP, Lesotho
The Sustainable Development Goals (SDGs) comprise of 17 goals and 169 targets
which are integrated and indivisible.
(The Millennium Development Goals (MDGs) comprised of 8 goals and 21 targets).

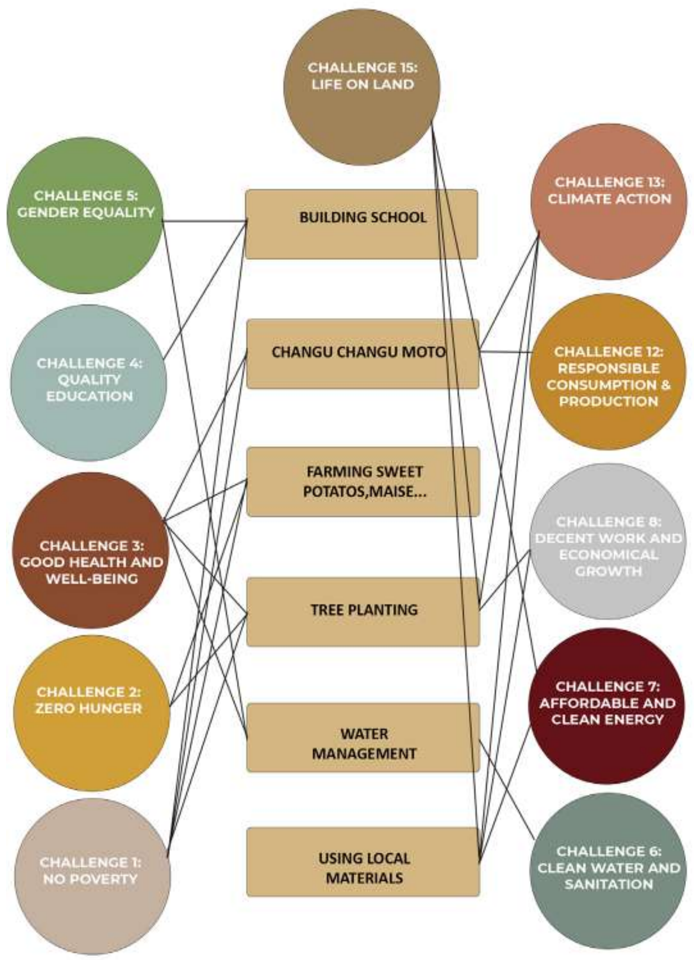


Figure 5.1 Challanges in the project

Figure 5.2 Goals according to SDGs

5.1.4 Choosen goals

• **Goal 1**. End poverty in all its forms everywhere

•**Goal 2.** End hunger, achieve food security and improved
nutrition and promote sustainable agriculture

•**Goal 3.** Ensure healthy lives and promote well-being for all at
all ages

• **Goal 4.** Ensure inclusive and equitable quality education and
promote lifelong learning opportunities for all

• **Goal 5.** Achieve gender equality and empower all women
and girls

•**Goal 6**. Ensure availability and sustainable management of
water and sanitation for all

• **Goal 7.** Ensure access to affordable, reliable, sustainable and
modern energy for all

• **Goal 8.** Promote sustained, inclusive and sustainable
economic growth, full and productive employment and
decent work for all

•**Goal 9.** Ensure sustainable consumption and production
patterns

• **Goal 10**. Take urgent action to combat climate change and its
impacts

• **Goal 15**. Protect, restore and promote sustainable use of terrestrial
ecosystems, sustainably manage forests, combat desertification, and
halt and reverse land degradation and halt biodiversity loss
UNDP, Lesotho

5.1.5 Actions

BUILDING SCHOOL:
However, access to quality secondary school education in Africa is a critical factor to the development of the continent and in our case, in Malawi too. Only 38% of children in Malawi transition from primary to secondary school – (36% for girls and 41% for boys). This is partly due to expensive school fees, but is equally an issue of local access. There are fewer secondary schools than primary schools meaning that in rural areas, distances that students have to travel to reach school are greater.

CHANGU CHANGU MOTO:
The Changu Changu Moto:

reduces household wood use from three bundles of wood per week to just one
contains the fire within the cookstove at the side of the kitchen, reducing injuries from burns
has a double burner so that two pots can be cooked simultaneously, saving time
produces substantially less smoke than the traditional three-stone fire, reducing coughing and breathing problems
takes just one hour to make and is made from free local and readily available materials, and
is LOVED by all the women who use it!

The Changu Changu Moto is a sustainable and locally produced fuel-efficient cookstove made out of just 26 mud bricks and a mud mortar mix. It is an adaption of a 16-brick design by Dr Larry Winiarski and has been specially modified by Ripple Africa for Malawi after lots of positive trials and community feedback.

FARM'S PRODUCTION SUBSTITUTION AND TREE PLANTING :

Malnutrition is a major problem in Malawi as the staple diet is nsima, a porridge made from cassava or maize flour, with little protein and very few vitamins. Although sweet potato farming in Africa is not uncommon and some white-fleshed sweet potatoes are grown in our area, the higher yielding orange-fleshed sweet potatoes which are higher in Vitamin A and other nutrients, are not grown in the north of Malawi.

Sweet potatoes are not an indigenous plant in Malawi. The variety we are helping communities to grow is an improve orange variety developed by CIP (International Potato Centre) who have a research and sweet potato farm in Mulanje, southern Malawi. The orange-fleshed sweet potato is not genetically modified but has been developed through conventional breeding techniques to produce a variety higher in Vitamin A and higher yielding than the varieties of sweet potatoes usually grown in Malawi

TREE:

Our tree farmers also plant fruit trees to provide food and income for their families. They grow mango, papaya, guava, avocado and citrus fruit trees. We also have a specialist fruit tree nursery to raise additional fruit trees which are distributed to schools to plant and teach students the importance of tree planting and the environment.

CLEAN WATER

Repairing the old bareholes and take the help of technology to saver rainwater and produce drinkable water from the humidity.

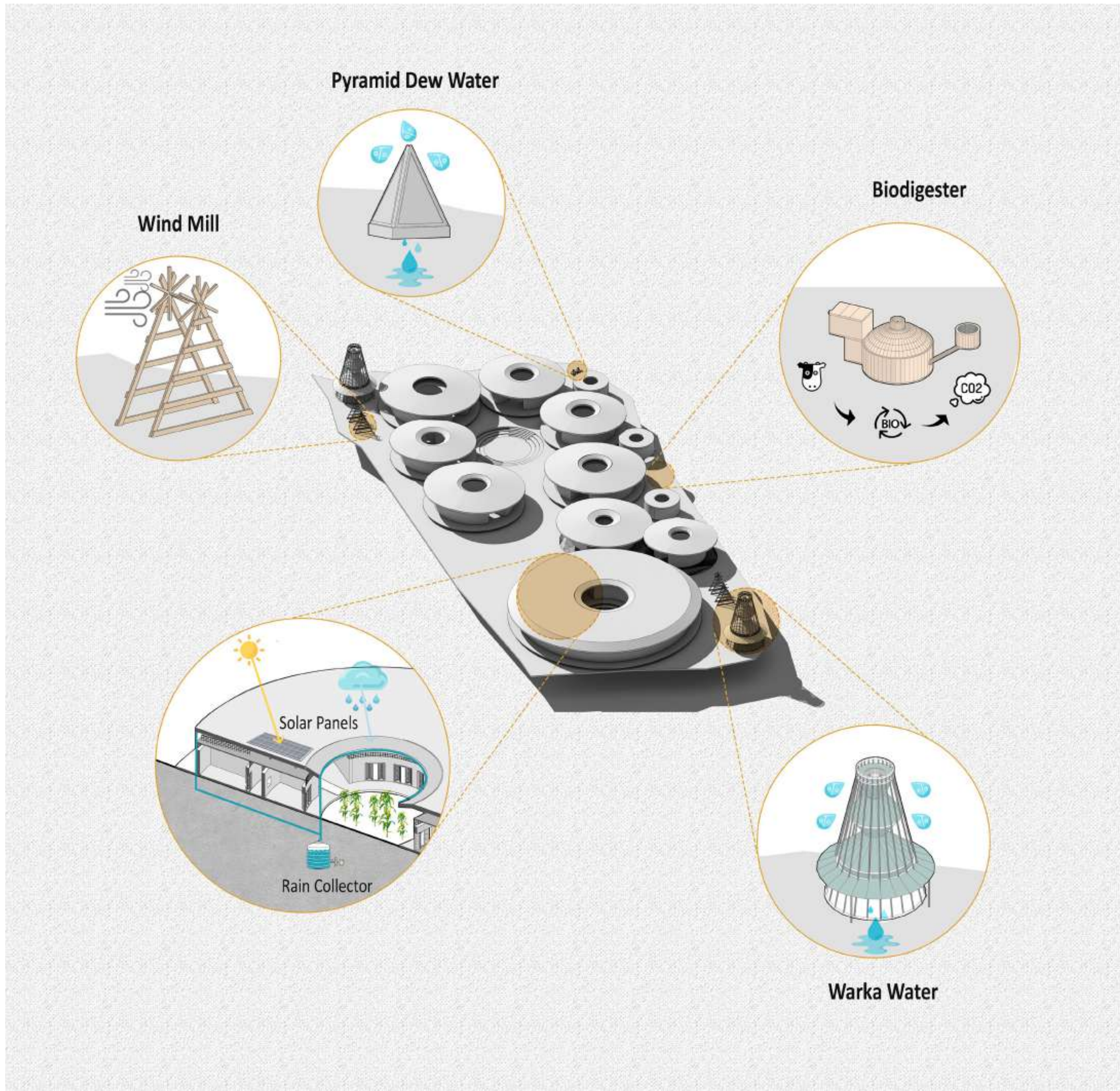
ENVIRONMENTAL CHALLANGES IN MALAWI

There are many environmental challenges in Malawi including deforestation and over-fishing.

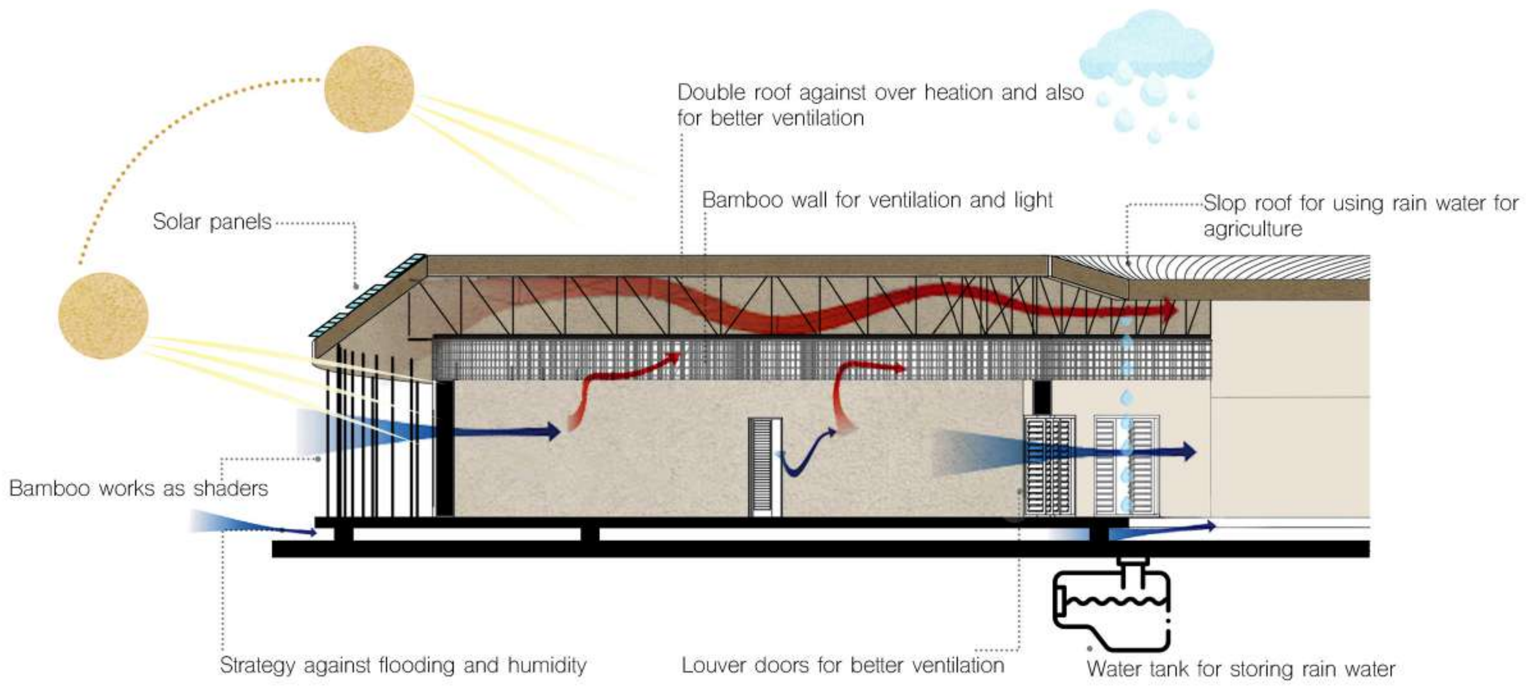
Malawi is a landlocked country in south-eastern Africa, bordered by Tanzania, Zambia, and Mozambique. Malawi is 118,000km², but one fifth of the country is made up of Lake Malawi, so the actual land area is 94,000 km², roughly the size of Scotland and Wales combined. The Great Rift Valley runs through the country from north to south, and Lake Malawi lies to the east of the main land area. Land is made up of mountains, plateaux, hills, valleys, flatlands, and lakeshore. Malawi has a sub-tropical climate, and experiences a rainy season from December to March, a colder dry season from April to August, and a hot dry season from September to November.

Around 70% of people in Malawi live below the international poverty line.

Technology Distribution in the site



5.1.6 Schematic design



5.2 Water collection

In our design for the second roof of buildings we tried to define a stategy for collecting the rain water for the domestic usage. since the rain season is good opportunity to drain the water , the shap of the roof in the middle part has a light slop to conduct rain water to the pipes which are located in some part of the roof and it leads to save tha water in tanks which are located underground and also some of them are loacted in the water tank room on the ground.
Then by using a pump the water will be usable. The exceeds water will export to the underground.The power which is needed for water pump will provide by PV panels.

Wind pump will extract water from the underground resources by using a semi-rotary pump which will work with wind power. This type of water is drinkable water, therefore, will be connected to water tank of Warka water.

Pyramid glass desiccant material will absorb moisture during the night and by solar radiation will release it during the day. Also, this type of water will be drinkable and will be connected to the water tank of Warka water.

The size of the tank depends on two factors:

First: the net supply of water, related to the intensity of precipitation, receiving surface, and discharge coefficient.

S = A (m2) x Vp (liters/m2) x Vr

where:
- S is the supply of water
- A is the horizontal project of the roof surface
- Vp is the recipitation value. In Addis Ababa the recorded annual precipitation is 1165 L/m2

Vr is the roof coefficient according to its material. For metal sheet roofs a value of 0.9 is used.

S = 822m2 x 1165 L/m2 x 0.9 = 861,000 L/year

The need of collected water in the building, according to its specific use.
Second, the usage of water for school building is assumed as 1000 L/pp per year. Assuming a maximum capacity of the building of 200 students, the usage of water is 200,000 L/year.

Other than this, 450 L/m2 are used for irrigation of the playing field and garden. The total usage is 526,000 L/year
The minimum of these two values is multiplied by the constant value for contemporaneity K = 0.0625.
The tank size will thus be:
V = 526,000 L x 0.0625 = ~ 30,000 L = 30 m3

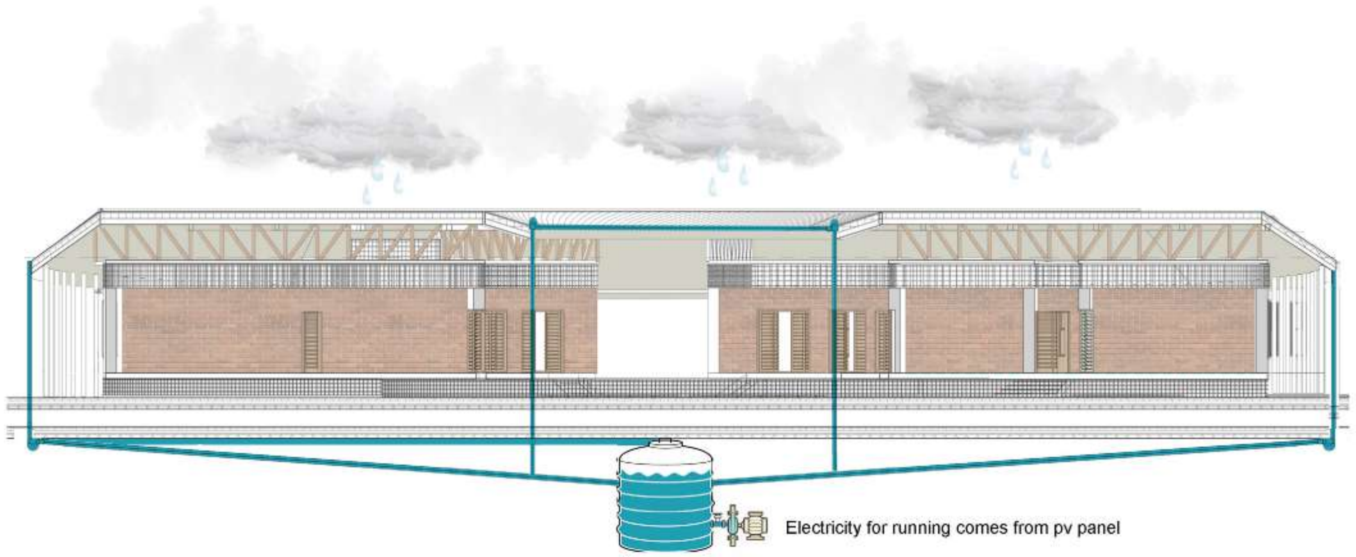


Figure 5.3 schematic design of rain water collection

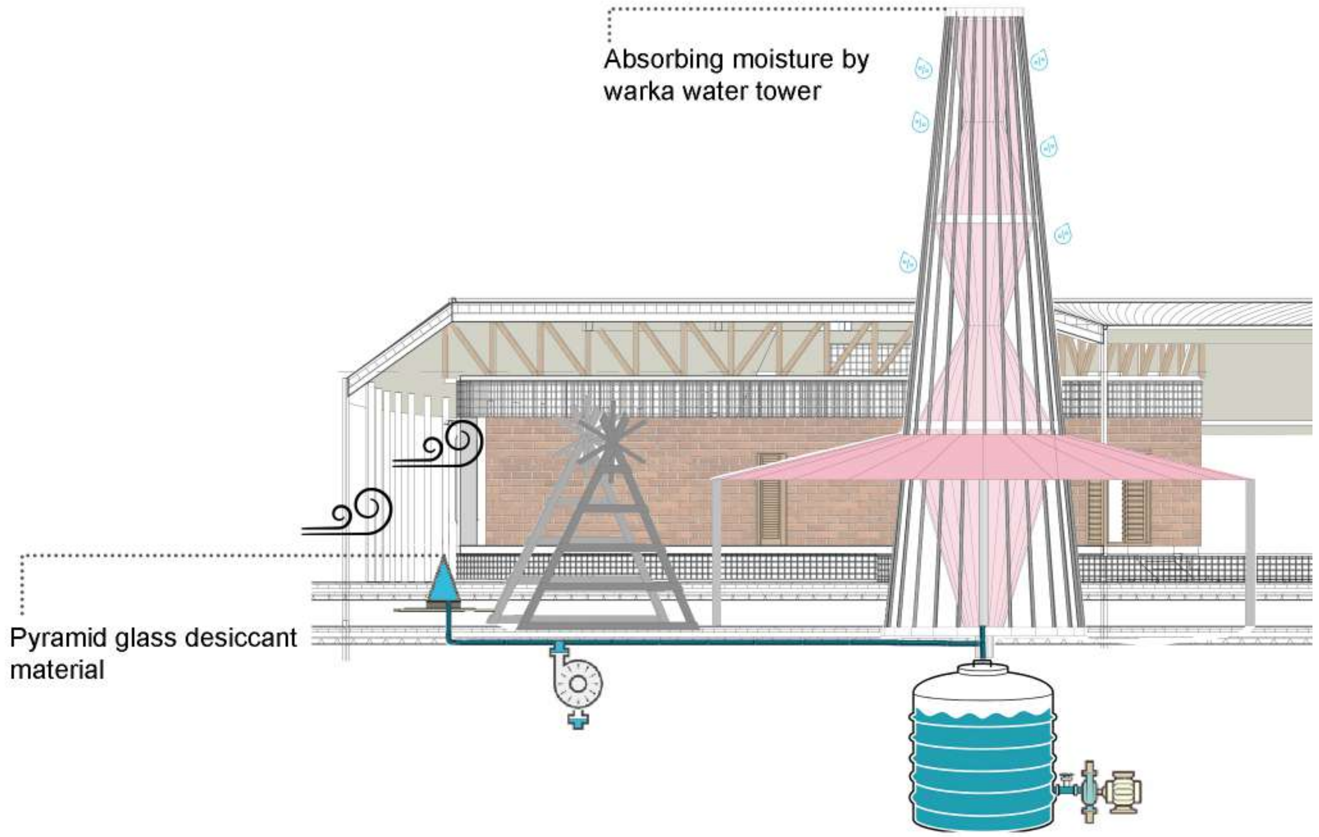


Figure 5.4 Schematic design of wind pump, Warka water and Pyramid glass

5.2.1 GLASS PYRAMID COLLECTOR

Dew water is water droplets formed due to condensation of atmospheric water vapor on surfaces of temperature below its dew point temperature. Dew water can be seen as a nonconventional source of water and may be exploited in regions where weather conditions favor dew formation and inadequate supply and quality of water is a prevalent problem.

Dew water collection can be considered as a non-conventional source of water which can enhance water supply in certain climates/regions. Hence, it can be considered as a possible alternative or supplementary source of water in many water scarce regions of the world where weather conditions favor dew formation. The atmospheric air can be considered as a huge renewable reservoir of water which can be used as a water source everywhere on the earth.

The covers over the beds are open overnight so the desiccant can absorb water vapor from the air. During the day, the covers are closed so the beds are heated by solar radiation driving off the absorbed water, which condenses on the sides and especially at the pyramid apex water, where it is collected by a central cone and flows through a tube to an external container. The reported water yield is 2.5 l/day/m3; the cloth bed showed better performance than the sawdust bed system.

Position:
The position of the dew condenser, in terms of its inclination, shading and exposure, influences the condensation of water. First, it was found that an angle of 30° with respect to the horizon was the optimal inclination to minimize the heat exchange effect caused by wind, increase the water recovery by gravitational force and not hinder the visibility to the sky

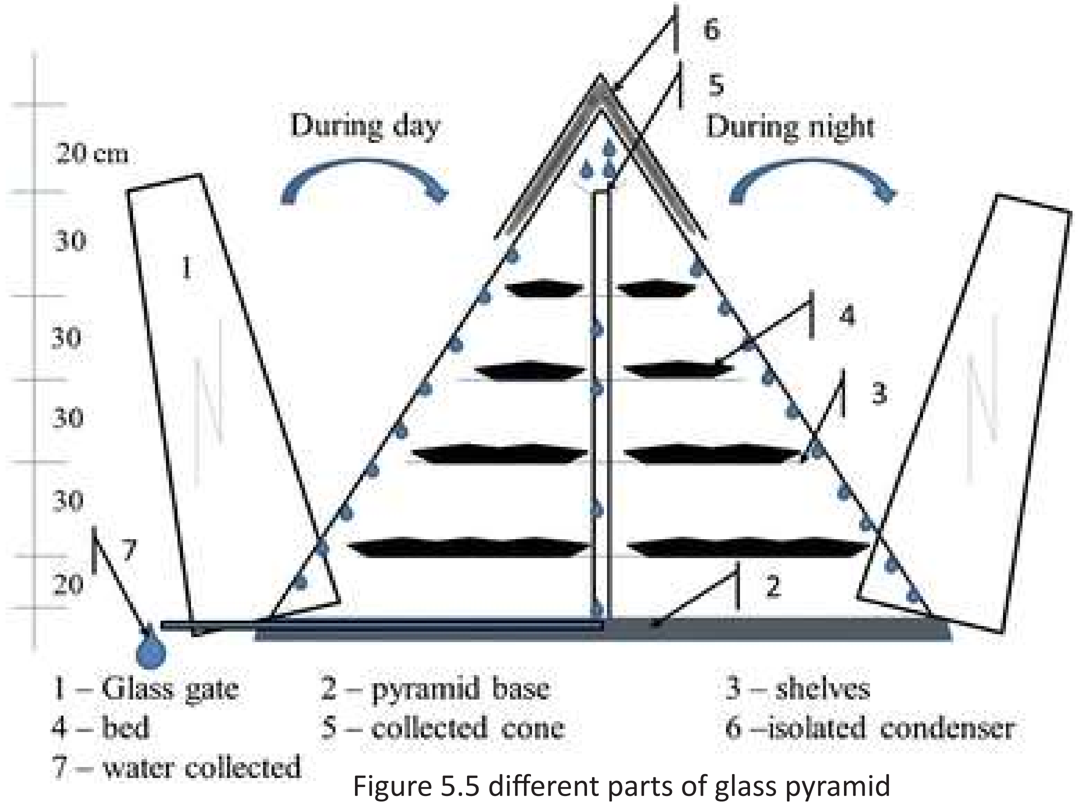


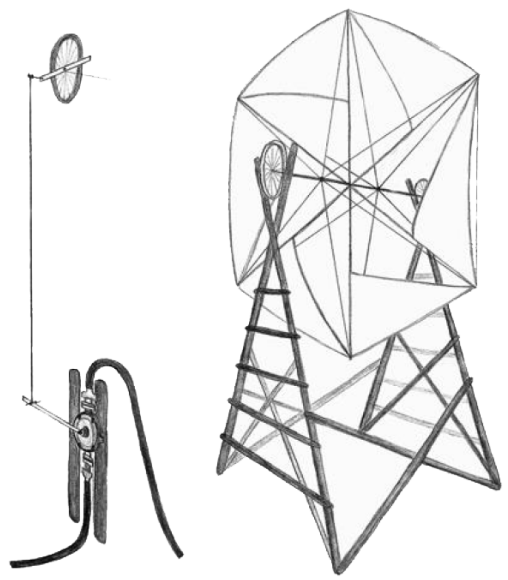
Figure 5.5 different parts of glass pyramid

that is needed for radiation cooling. Second, studies of dew condensation showed different results for condensers in the sunlight and in the shade. Finally, studies showed that exposure to the sky also affected condensation rates by being related to radiative cooling. A site surrounded by high altitude topography will have the infrared radiation that the condenser emits reflected back by the hills or mountains.

Size:
The size of the condenser has been found to influence its performance. For example, an on-ground 900 m2 condenser showed a decrease in yield of 42 % compared to four 1 m2 standard condensers. It was suggested that the large size of the condenser allowed the foil to fold, which increased water stagnation, thus affecting the radiative cooling effect (Sharan et al. 2007). However, Kidron (2010) found that a decrease in size from a 0.16 to a 0.01 m2 condenser reduced the yield from 0.25 to 0.15 L. The reduction in size on both axes (e.g., from 10 cm by 10 cm to 5 cm by 5 cm) showed a greater decrease in yield than when one axis was kept constant (e.g., from 20 cm by 10 cm to 10 cm by 10 cm). This suggests that there is a border effect that reduces the efficiency of the condenser surface toward the edges. This issue has not yet been explored in detail.

5.2.2 WINDMILL CONSTRUCTION

windmill construction (following figure) consists of a wooden frame, a steel axis with six steel bar wings stabilized by strings, two bicycle wheels used as bearings, and a bar and connecting rod (conrod) used for power transference. The sails should be made of a fabric that does not let too much wind through or absorb too much water. The sails are then tied to the wings with strings. There are different ways to anchor the frame in the ground. It can be dug down in the sand and hold in place with heavy stones or tied to nearby trees or stumps.
The bar is fastened on one of the bicycle wheels, so when the wheel rotates, the conrod is driven up and down in a pumping motion (following figure). A pump can be attached to lower end of the conrod, and thus the pump will be driven by the windmill when the wind blows. It will pump one stroke per rotation of the windmill.



It stands on a concrete foundation and is composed of one wooden frame that holds up the wheel and axis. The pump is attached to the axis through a conrod. When the wind is captured by the six triangular sails, the wind energy is converted into kinetic energy that makes the axis rotate. The conrod is then moved up and down in a pumping motion, making the water flow through the pipes from the well to the tank.

The diameter of the wheel that holds the windmill blades (formerly sails) depends on the depth of the well and how far up the water must be pushed and on the flow rate to be achieved. The structure's height and the construction materials used are especially dependent on the maximum wind speed and any obstacles that may be located nearby (none of which must be located within a radius of at least 150 meters). The flow rate achieved by a windmill varies significantly depending on the wind and on pump characteristics. It may sometimes vary from 200 liters per hour to 6 or 7,000 liters per hour.

Figure 5.6 watermill construction

5.2.3 WARKA WATER

The tower consists of a bamboo frame supporting a mesh polyester material inside. Rain, fog and dew condenses against the mesh and trickles down a funnel into a reservoir at the base of the structure. A fabric canopy shades the lower sections of the tower to prevent the collected water from evaporating.

Aiming to harvest water from the atmosphere to supply fresh drinking water to the community in the developing world, a unique wooden atmospheric water harvesting project called Warka Water has been founded by Arturo Vittori. The project won the World Design Impact Prize 2015–16 at World Design Capital(R) Taipei 2016 Gala. Arturo and his team have developed 12 different prototypes since 2012. Following figure shows an example of the prototype and its working principle.
The team's target is to develop a prototype that is lightweight (about 80 kg), easy and quick to build using local materials without using scaffolding and power tools. They intend to use bamboo for the frame structure, while the water catchment system will be made from biodegradable mesh 100% recyclable materials. Fog and dew, and rainwater, will be collected when they strike the mesh and then trickle down a funnel into a reservoir at the base. To prevent water evaporation, a fabric canopy will be used to cover the lower section of the water collector. There is no indication of the amount of water that can be produced by the prototype since the project is still in the exploratory phase. However, the aim of the project is to produce water from fog or highly humid places between 50 to 100 litr per day.

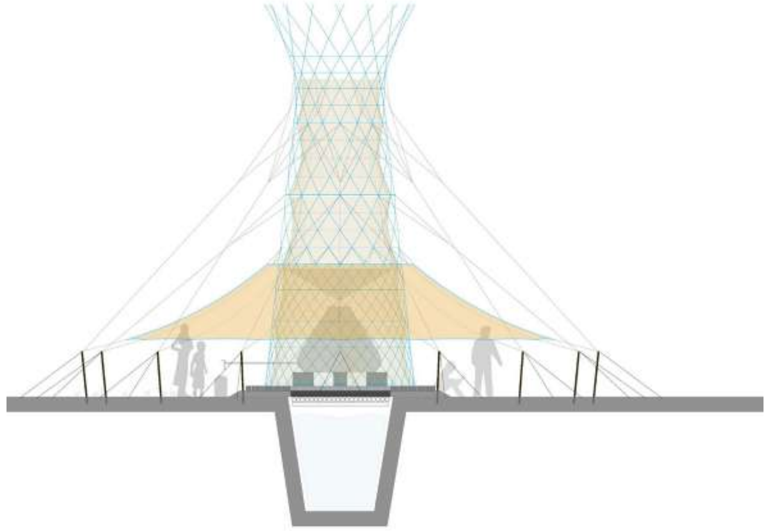


Figure 5.7 warka water supply water

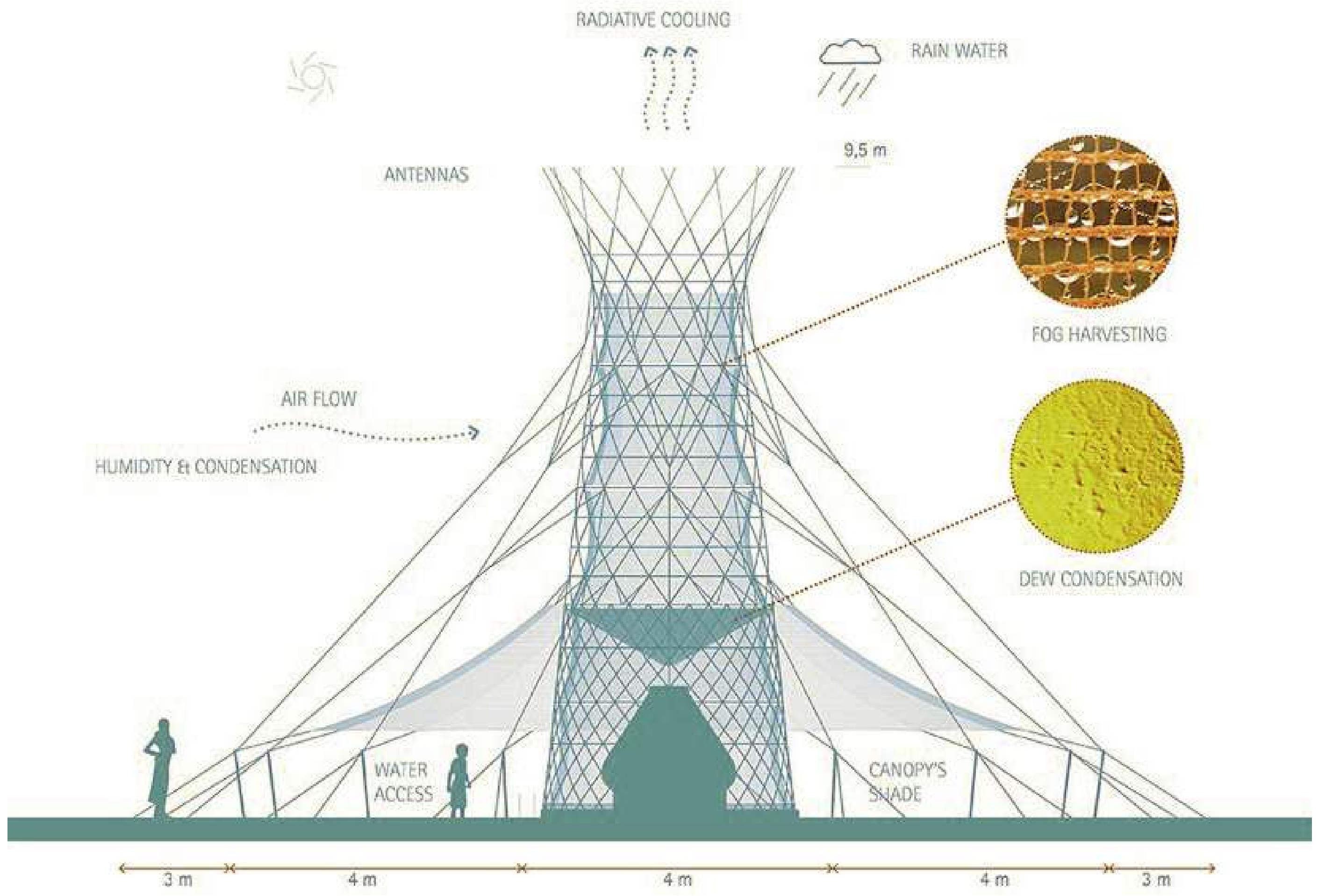


Figure 5.8 warka water section

Figure 5.9 warka water

5.3 WATERLESS TOILET

Since there is no current water provision in the country,they will have to use latrines as bathrooms so we study about the solutions that not just solve the bathroom problem but also have some advantages according to our sustainable approach.
The Enviro Loo is a dry toilet system that functions without water or chemicals. It can be installed almost anywhere. One of the great advantages that the Enviro-Loo has over other larger capacity compost toilet systems is the fact that - as the main body is buried - the toilet bowl is level with the ground. This does away with the need to have a raised toilet building to allow for the usual 'split system' configuration.
This means that no ramps need to be installed for disabled access – saving a great deal of money in construction/set up costs.

Benefits and Advantages

- Amazing value - 45% to 245% better value than comparable systems!
- Minimum maintenance and servicing costs
- Non-polluting zero discharge system
- Long term sustainable solution – life span in excess of 50 years
- Odourless
- Conserves water resources
-No chemicals used
- Large capacity system
- No expensive treatment plant required

5.3.1 How does it works?

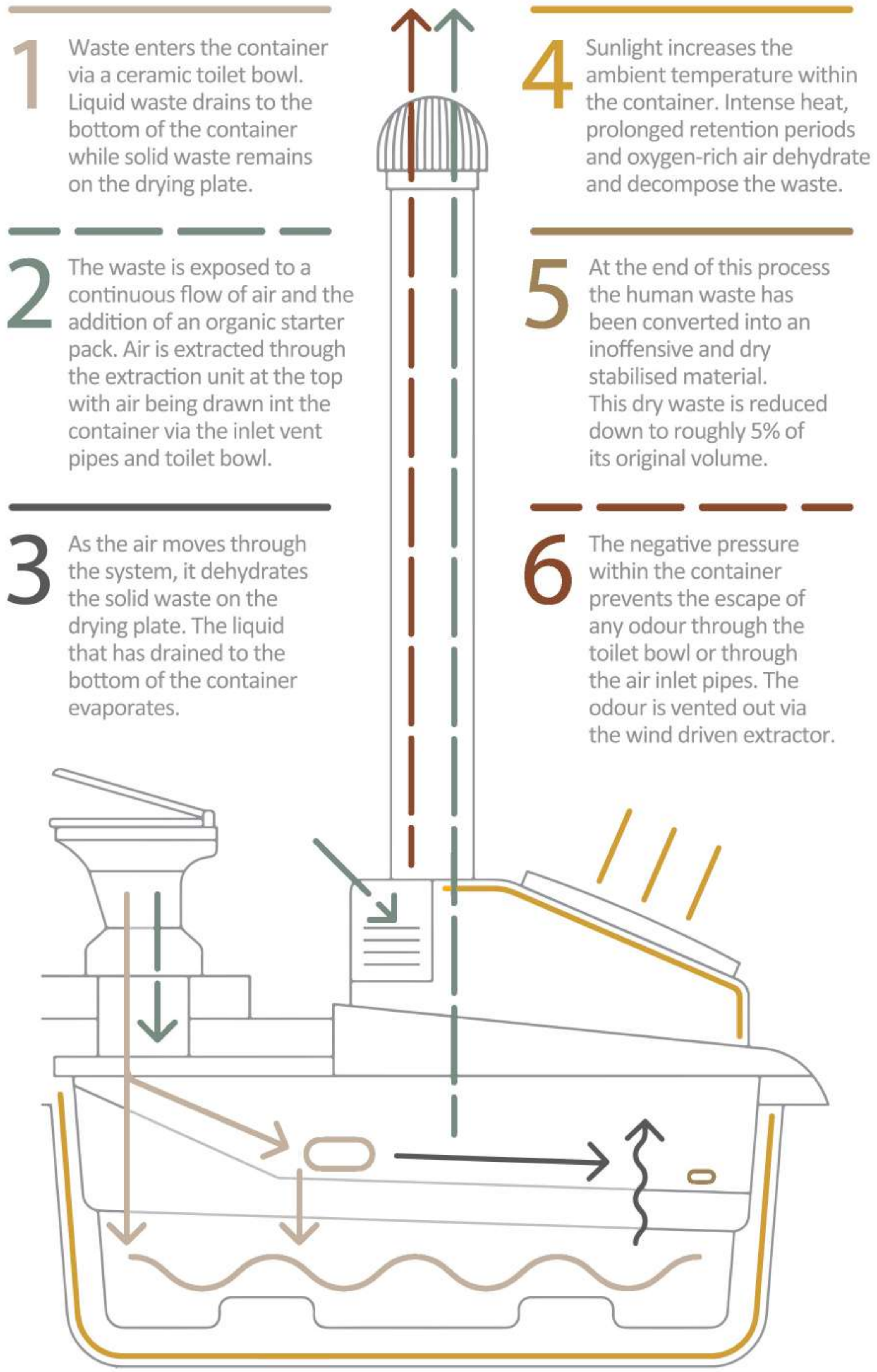


Figure 5.10 waterless toilets constructon

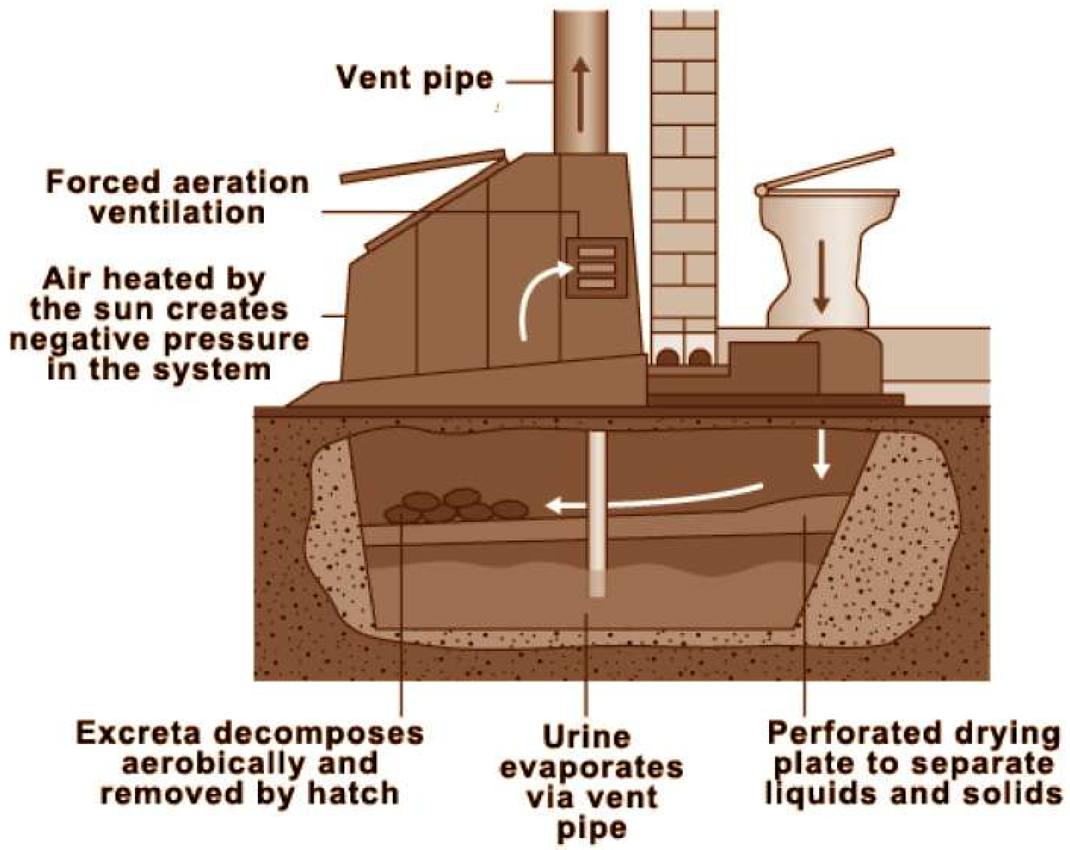


Figure 5.11 waterless toilets Function

5.4 BIODIGESTER

A biodigester is a system that biologically digests organic material, either anaerobic (without oxygen) or aerobically (with oxygen). Microbes and other bacteria break down organic materials in a biodigester. Most food, including fat, greases, and even animal manure, can be processed in a biodigester.

Biodigesters are a closed system; therefore, it gives off no odor from food waste; this will eliminate flies and rodents from the facility, increasing hygiene. Also, eliminating food waste on-site saves money by reducing hauling costs. The capacity of food a biodigester can process depends on the size; larger the digester more food it can handle. Biodigesters are a living system and do require maintenance. However, they are easy to use and maintain.

Of course, one of the great benefits of biodigesters is they are eco-friendly and will reduce a facility's carbon footprint significantly. Food scraps and other organic materials decaying in landfills release methane and carbon dioxide contributing to climate change. Diverting food scraps and other organic materials from landfills, methane, and carbon dioxide can be captured and used efficiently.

Biogas essentials

- A large container to hold the mixture of decomposing organic matter and water (digester)
- A container to collect the biogas (gas holder)
- A way to add more organic matter (inlet)
- A way to move the gas to where it will be used (gas outlet)
- A way to remove the residue (slurry outlet)
- A way to insulate the container and keep it warm, unless the container is already in a tropical country with a temperature around 35˚C.

Converting organic waste into biogas

It is possible to make a free cooking gas by digesting wet organic waste in a sealed chamber. Wet organic waste, such as food waste, should be placed in a sealed chamber with no air inside. As it digests, the waste will release a gas which can be captured and used for cooking. The system needs to be airtight and the temperature close to 35˚C.
A biogas plant needs some methane-producing bacteria to get it started. This is found in animal dung, so a small amount is used to start the process even if it is not the main feedstock. Once the system is producing biogas the bacteria reproduce and keep the process going.

Waste materials

Plant waste that is starchy, sugary, or fibrous; fatty substances including animal fat or oil cake from oil seeds; flour swept from the floor of a flour mill; leftover and stale food; damaged or over-ripe fruits; insect damaged grain; non-edible rhizomes of banana or cane; tea leaves; animal dung, abattoir waste, and human excreta. If necessary, the feedstock must be pulped or ground and mixed with water, so it is like a soup.

Product

After 14-21 days, the process will produce biogas and a nutrient-rich soil conditioner called digestate. About 1-1.5kg starchy material typically yields enough gas to cook the meals of 4-5 people. If the digester is working properly, the digestate will have little smell.

Benefits

Making biogas from organic material is a good way to manage potentially harmful organic wastes. Cooking with biogas does not produce smoke so it is ideal for the home, and it reduces the need to cut down trees for firewood. The digested slurry can be used wet or dry as a valuable soil conditioner, reducing the need for chemical fertilizers.

Since there is a animal place in the site , we come up with this strategy that we can use the animal waste in the way of producing gas for domestic usage .Human waste, animal waste and organic waste will be used in biodigester for proving gas which is usable for cooking and water boilers. The product can be used for agriculture parts as fertilizer.
The other types of waste will be collected in the other part of the site which will be collect by municipality. 300 people will produce around 180 feedstocks.
The volume of digester based on the retention time (30 days) would be 5.4 cubic meters.
If we add 25% for gasholder the total volume of unit 7.2 cubic meters.

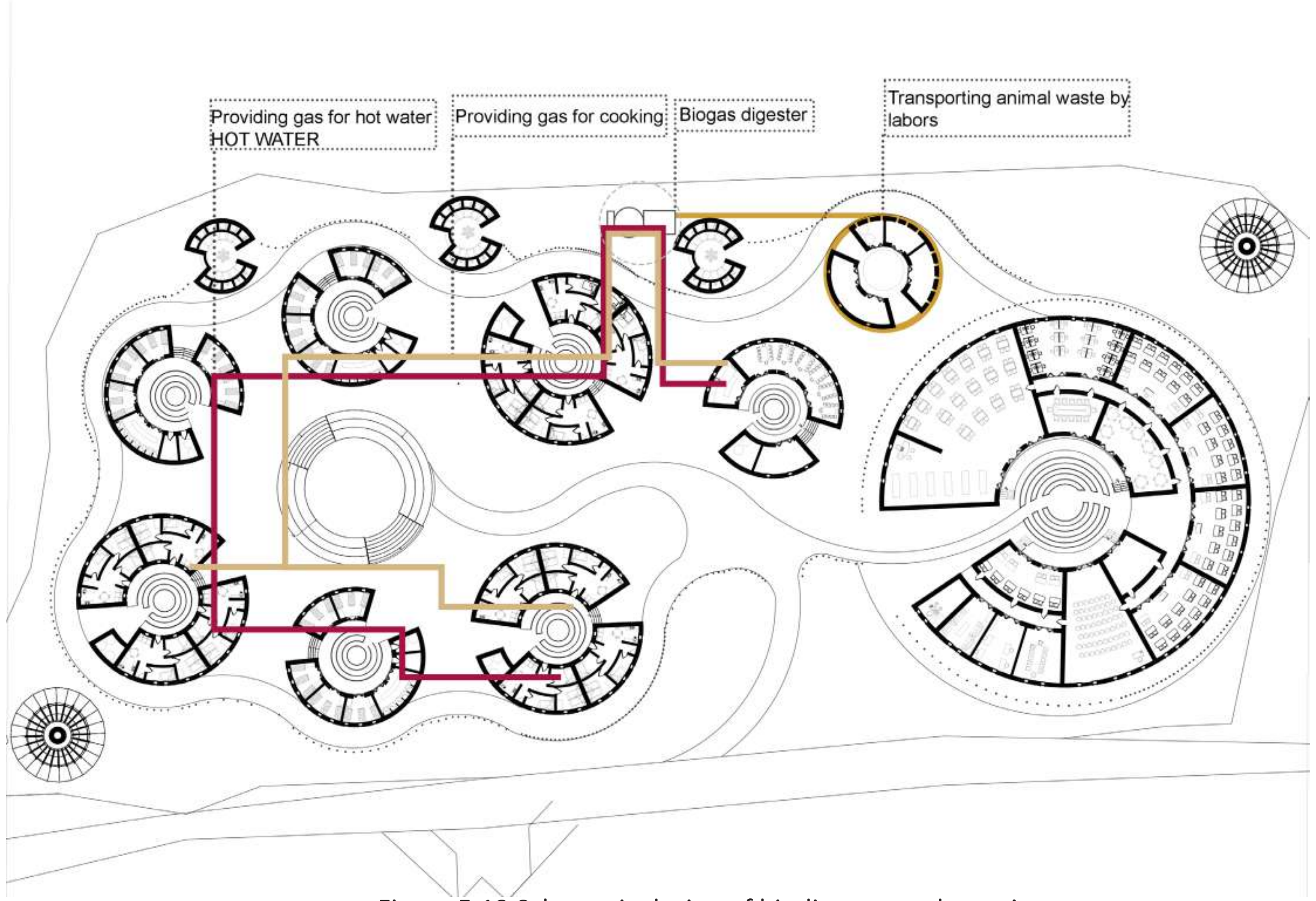


Figure 5.12 Schematic design of biodigester and gas pipes

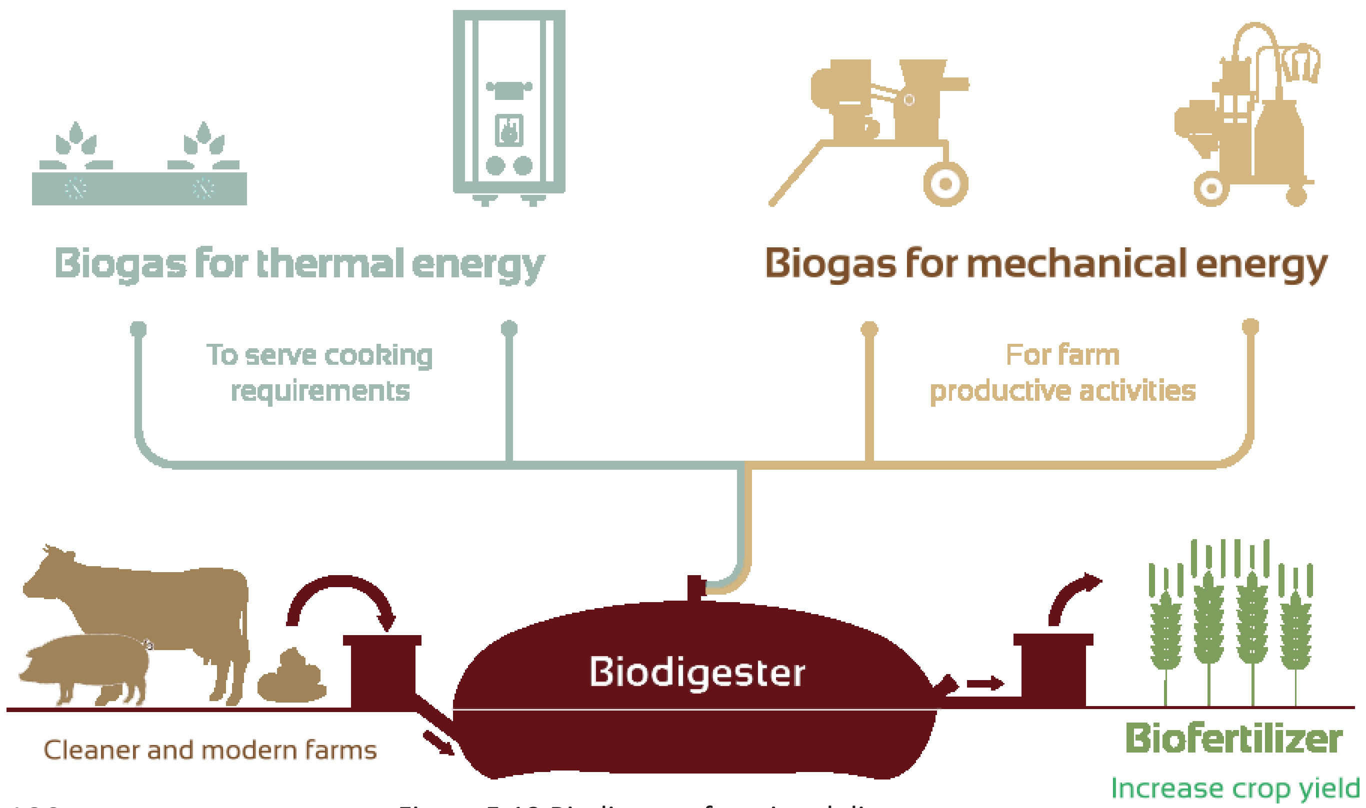


Figure 5.13 Biodigester functional diagram

5.5 THIN-FILM SOLAR CELL

In malawi roofs are mainly made with grass and Iron sheets.since the second roof of our project is something huge and the material of one layer which is proposed to used is metal sheet so we decided to find a light weight proposal for our solar panel technology.
Thin film solar cells are the new generation solar cells that contain multiple thin film layers of photo voltaic materials. The thin film solar cells (TFSC) are also known as Thin Film Photo Voltaic cell (TFPV). The thicknesses of thin film layers are very less as (few nano meters) compared to traditional P-N junction solar cells. According to the type of photo voltaic material used, the thin film solar cells are classified into four types. They are

1) Amorphous silicon (a-Si) and other thin-film silicon (TF-Si)

2) Cadmium Telluride (CdTe)

3) Copper indium gallium deselenide (CIS or CIGS)

4) Dye-sensitized solar cell (DSC) and other organic solar cells

Thin film soar cells provide better ways to produce electricity from sunlight than any other method. We can implement these panels in forest areas, solar fields, traffic and street lights, and so on. The cost of this panel is very less as compared to the older silicon wafer cells.

Structure of Thin Film Solar Cell

The structure of thin film solar cell is shown below. The structure and functioning of thin film solar cells are almost same as that of normal silicon wafer cells. The only difference is in the thin flexible arrangement of the different layers and the basic solar substance used. The thin flexible arrangement of the layers helps to produce very thin form of cells that is much more efficient than the conventional silicon wafer cells.

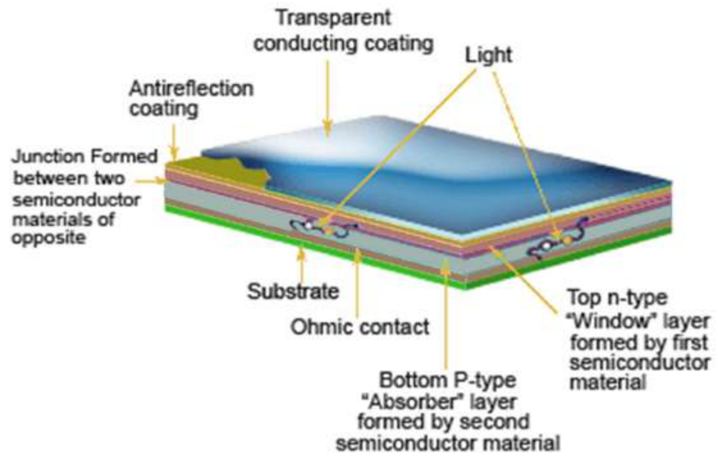


Figure 5.14 Layers of solar panel

Working

The basic substance of a photovoltaic cell is semiconductors. The semiconductor doped with phosphorus develops an excess of free electrons (usually called N type material) and a semiconductor doped with boron, gallium or indium develop a vacancy(called holes) and this doped materials known as P type materials. These n type and p type materials combine (join) to form a Photo voltaic cell. During the absence of light, a very small amount of atoms are excited and move across the junction. This causes a small voltage drop across the junction. In the presence of light, more atoms are excited and flow through the junction and cause a large current at the output. This current can be stored in a rechargeable battery and used for several applications b

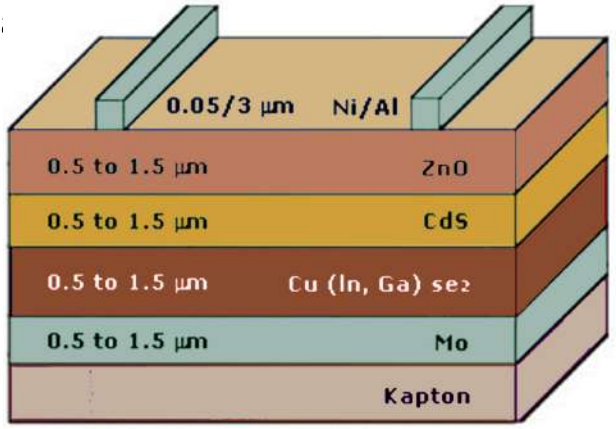


Figure 5.15 Layer arrangement of thin film solar cell

The old solar panel technology use silicon semiconductor for the production of p-type and n-type layers and has several disadvantages. But in the case of Thin Film Layer technology , the silicon semiconductor materials is replaced by either cadmium telluride(CdTe) or copper indium gallium deselenide (CIGS).

1) Easy to handle

2) More flexible than conventional solar cells

3) Available as thin wafer sheets

1) Less efficiency (20 to 30% of light converted into electricity)

2) Complex structure

3) Need to be very careful in handling

4) Can’t be used in astronomical devices.

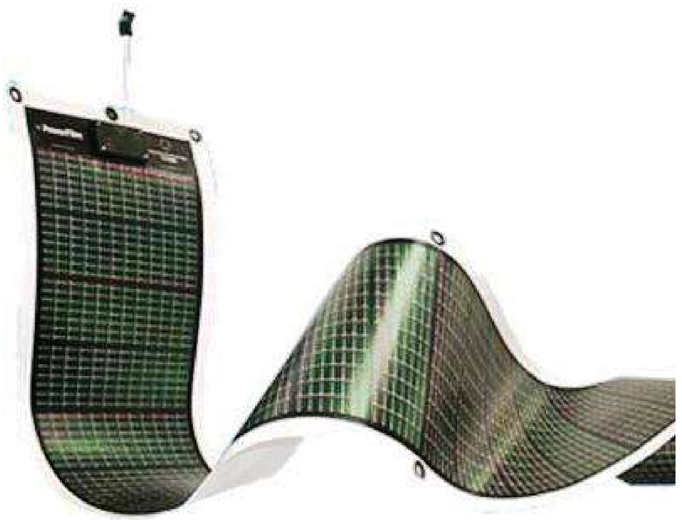


Figure 5.16 Example of thin film solar cell

CHAPTER 6

DESIGN OPTIONEERING

6.1 INTRODUCTION

The quality and thermal comfort of the indoor has a direct affect on the human health and performance and help people to study, work more productive and also help them to feel safer.
The indoor comfort depends on lots of factors and can affected by them.
In this project we are trying to improve the level of life quality in the area. For meeting this goal, we should keep an eye on the :Thermal comfort, visual comfort and acoustic comfort during the different steps of the optimization.
During the optimization we must consider to minimize HVAC demands due to the lack of electricity in that region which also help to reduce the effect of the building to the environment.

6.1.1 Universal Definition of Thermal Factor

Thermal comfort is defined by the ASHRAE Standard 55-2010 and the EN ISO 7730 as "that condition of mind which expresses satisfaction with the thermal environment, and it is assesses by subjective evaluation". Thermal comfort is assessed through an equation of objective and subjective variables, the first being controllable by the designers: air temperature, mean radiant temperature, relative humidity, and air velocity.
We chose the standard of EN 15251 which defines defines three categories, respectively with a level of satisfaction of the user of 90%, 80%, and 65%.
We chose it because in non-conditioned buildings such as ours it's not possible define two fixed range values for measuring the comfort, so we needed to work with an adoptive comfort standard that means: "if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort". Additionally, in natural ventilated buildings, occupants are more likely to adapt themselves based on the recent outdoor temperature, and to take actions to make themselves comfortable.

6.1.2 Universal Definition of Visual Comfort

One of the main issues to solve is the lack of the electricity so we need to maintain and provide enough daylight to have a comfort environment for studying and learning and try to save the electricity which produced by the PV panels for the equipment such as fridge, Pcs, night lightning and etc.
An appropriate daylight in schools has proven to have effect both on the health and concentration of the students. According to a study conducted in European schools in December 2020, "classroom characteristics associated with daylighting do significantly impact the performance of the school children and may account for more than 20% of the variation between performance test scores".
Despite this, more light is not always desirable, as glare may occur. Appropriate shading devices must be provided in the learning spaces, especially the one with windows towards the northeast and West, where the low morning and late afternoon sun enters directly in the building.
To reach a satisfying level of daylight three indicators have been used, sDA (Spatial Daylight Autonomy) and ASE (Annual Solar Exposure) and DF (daylight Factor) as suggested by the Leed v4 certification.

6.1.3 Building model simulation

The optimization of the building divided to three consequent steps as shown in the figure (dast beghalam shodam barat)
-Envelope Optimization
-Ventilation Optimization
-Daylight

In each step change of different parameters made different results to help to find the best choice and strategies.

6.1.4 Setting up the model

The thermal comfort simulation has been performed using Ies ve virtual reality. In order to perform a realist analysis, a building energy model of the project has been created. Other than the essential geometric information, other information contained regard the material properties, usage schedules, orientation, shading elements and local climatic conditions.

6.1.5 Weather Data

The climate data to perform the analysis has been taken from the dataset of the World Meteorological Organization, including the typical wheatear data of the past decades, since the place of the project is a small rural area, we used the closest city to Benga, Lilongwe;Nkhotakota.

6.2 GEOMETRY

For energy analysis process since the shape is circular was a bit hard to import directly from Autodesk Revit to IES VE. To facilitate the process the geometry of the building has been modelled in SketchUp and the thermal properties assigned in IES VE. Each room has been modelled as an individual zone. This approach allowed to control the properties of each room depending on its actual use (classroom, cafeteria, services…), obtaining comfort result for each one.

6.2.1 Envelope materials:

For the base case the envelope properties have been assumed as illustrated in ….. With a U=0.85 W/m2K . WD-ARS-1333 (African Standard). For the CSEB. For the openings, generic single pane windows have been used, with a U = 1.6 W/m2K.

6.2.2 Natural ventilation:

Natural ventilation is a key role in concept at the base of the adaptive comfort specially because of the high RH percentage in the subtropical climate .For improving this point in the project large operable walls and thin tall windows considered in the design also putting the building on a slab with the hight of one meter from the ground to not absorb the humidity from ground and also provide the ventilation under it. For the purposes of this optimization, it has been assumed that natural ventilation is triggered when the indoor air temperature is higher than 22°C, the outdoor air temperature is higher than 18°C and colder than the one inside, and that it is not raining. And the fraction of the windows that is openable is assumed to be 65% of the total area.

6.3 LOADS

With knowing that the building is non-ventilated without any lamps we conclude that the only load present is the one of the users themselves. As per requirement of the project, 50 students are expected in each classroom, resulting in 1 pp/m2. The heat gain for children is assumed as 75% of an adult person as per ASHRAE . An infiltration of 0.0001 m3/s per square meter of façade is assumed, as for leaky buildings. Schedule for presence hours in the school by taking to account the workshops for adults would be from 8-18.

6.3.1 Shading Elements:

Shading objects have been taken into account as well. This includes the shadings from the surrounding site, such as the trees, the shade coming from the building itself, mainly from the top roof and the wall thickness around the openings, louvers, roof hangovers. The bamboo shaders around the walkways has been modelled according the sun direction to provide more shadow open spaces.

6.4 STEP ONE:

During this step the building envelope including walls, roof, windows, floor, evaluated with different technologies. The envelope is the primary thermal barrier between outdoor and indoor. In this Step the main goal is to keep the building with high range of comfort while at the same time the chosen option is low-cost.
For the walls and roof five options are evaluated but, in the report, the best three are expressed. Options are:

- CSEB WALLS, METAL FEBRAL ROOF

-CSEB WALLS+ 5CM INSULATION, METAL FEBRAL ROOF + 5CM INSULATION

-CSEB WALLS+ 10CM INSULATION, METAL FEBRAL ROOF + 5CM INSULATION

-CSEB WALLS+ 10CM INSULATION, METAL FEBRAL ROOF + 10CM INSULATION

-CSEB WALLS+ 15CM INSULATION, METAL FEBRAL ROOF + 10CM INSULATION
-CSEB WALLS+ 15CM INSULATION, METAL FEBRAL ROOF + 15CM INSULATION

Chosen options to represent in the report are :
Base, second
Fourth,sixth

For choosing the best result the options compared by their annual operative room temperature to consider at the same time humidity and temperature of the zones and then put them in classified ranges given by ISO EN 15251, then defined three period of the year coldest, hottest and mid season and look closely how indoor and outdoor temperature behaves in these 3 periods. Although by knowing the subtropical climate doesn't have so much temperature difference during the year.

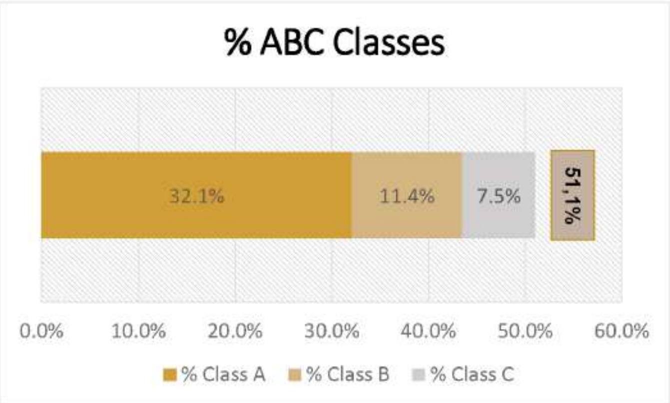
Basic Option wall								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	CSEB	0.4	1000	800	0.4	1	0.85	0.4

Basic Option Roof								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	Metal Febral roof	44.800	7680	418	0.0020	0.10	7.14	0.0020

Basic Option interior wall								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	CSEB	0.4	1000	800	0.4	0.25	2.08	0.1

Table 6.1 Data for basic wall

6.4.1 Base 0 – No Insulation



Minimum temperature time of the year: 11sep-25 sep
Mid season : 21 dec- 05 jan
Maximum temperature of the year: 21 feb- 07 march

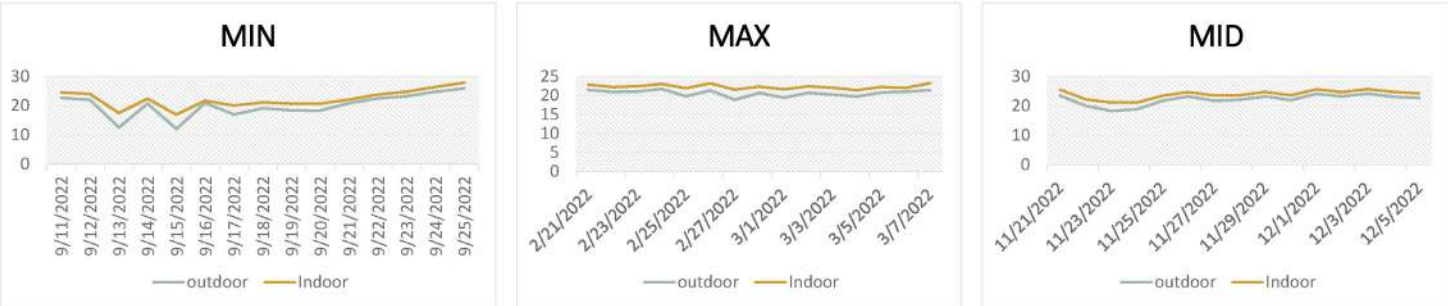
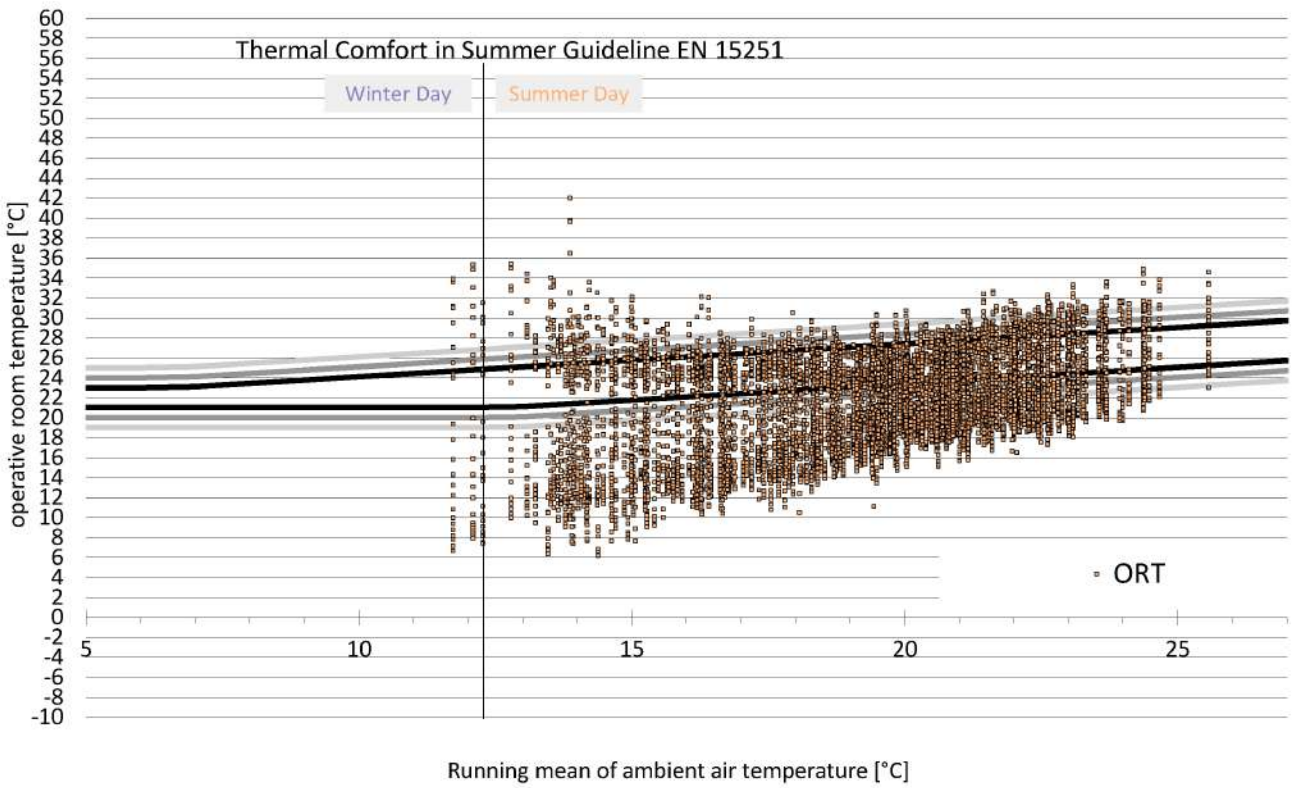


Figure 6.1 Temperature thermal comfort for base 0



CSEB wall + 5CM INSULATION								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	CSEB	0.4	1000	800	0.4	1	0.59	0.45
2	Insulation	0.060	70	1030	0.05	0.833		

Metal Febral Roof + 5CM insulation								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	Metal Febral roof	44.800	7680	418	0.0020	0.10	1.437	0.0520
2	insulation(thatched)	0.090	70	1200	0.05	0.555		

CSEB interior wall + 5CM INSULATION								
N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
1	CSEB	0.4	1000	800	0.1	0.25	0.813	0.15
2	Insulation	0.060	70	1030	0.05	0.833		

Table 6.2 Data for wall with 5cm insulation

6.4.2 5cm Insulation

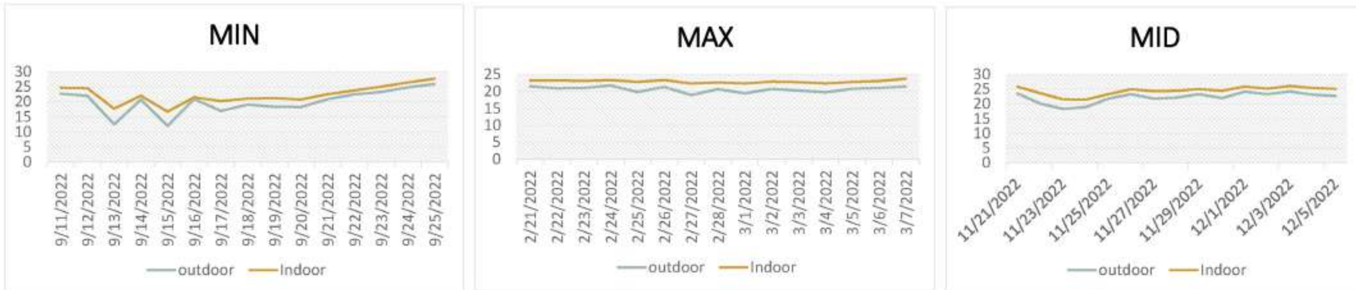
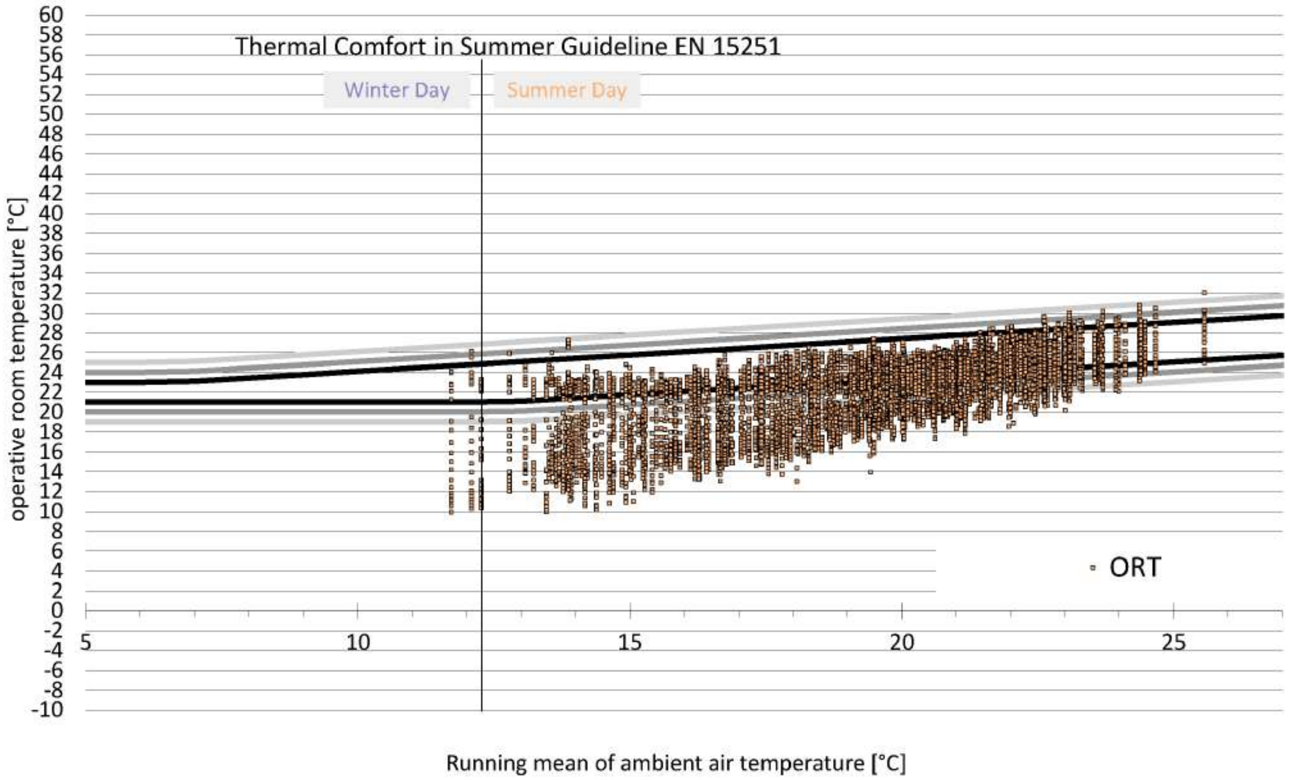
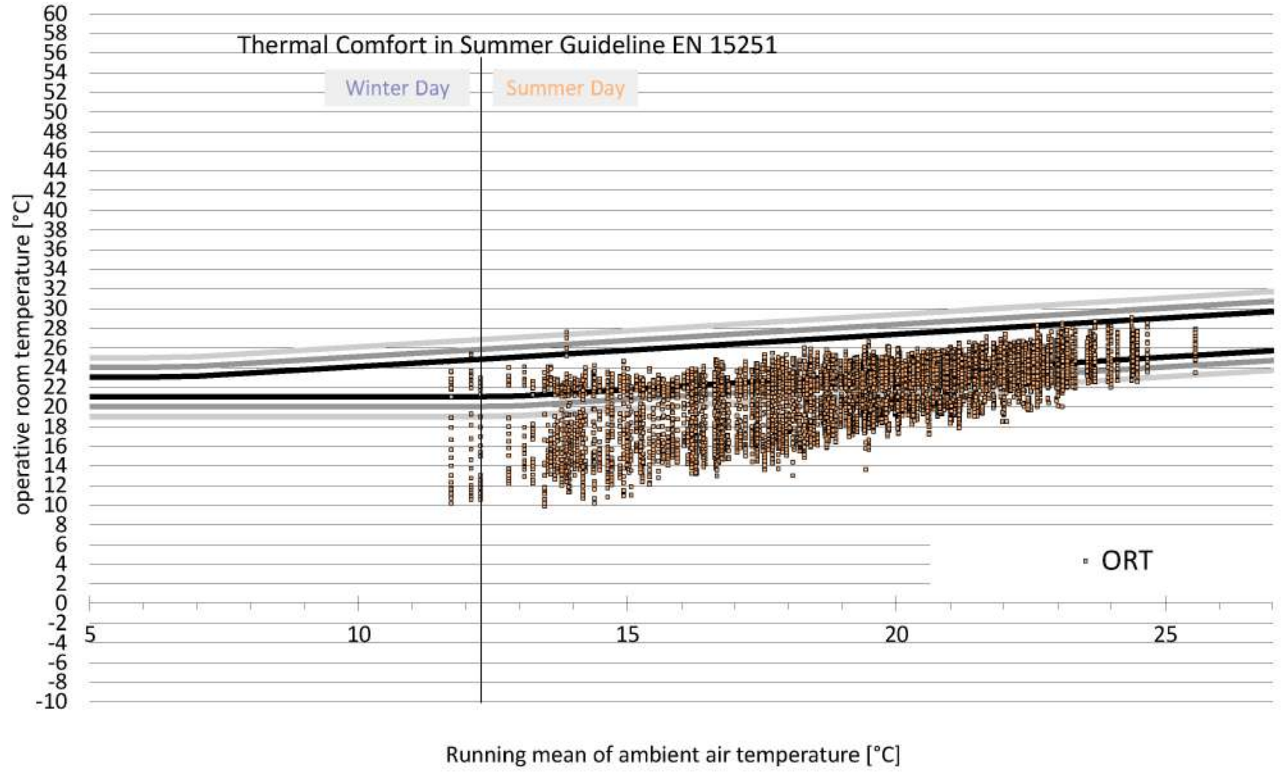


Figure 6.2 Temperature thermal comfort with 5cm insulation





6.4.3 10cm Insulation

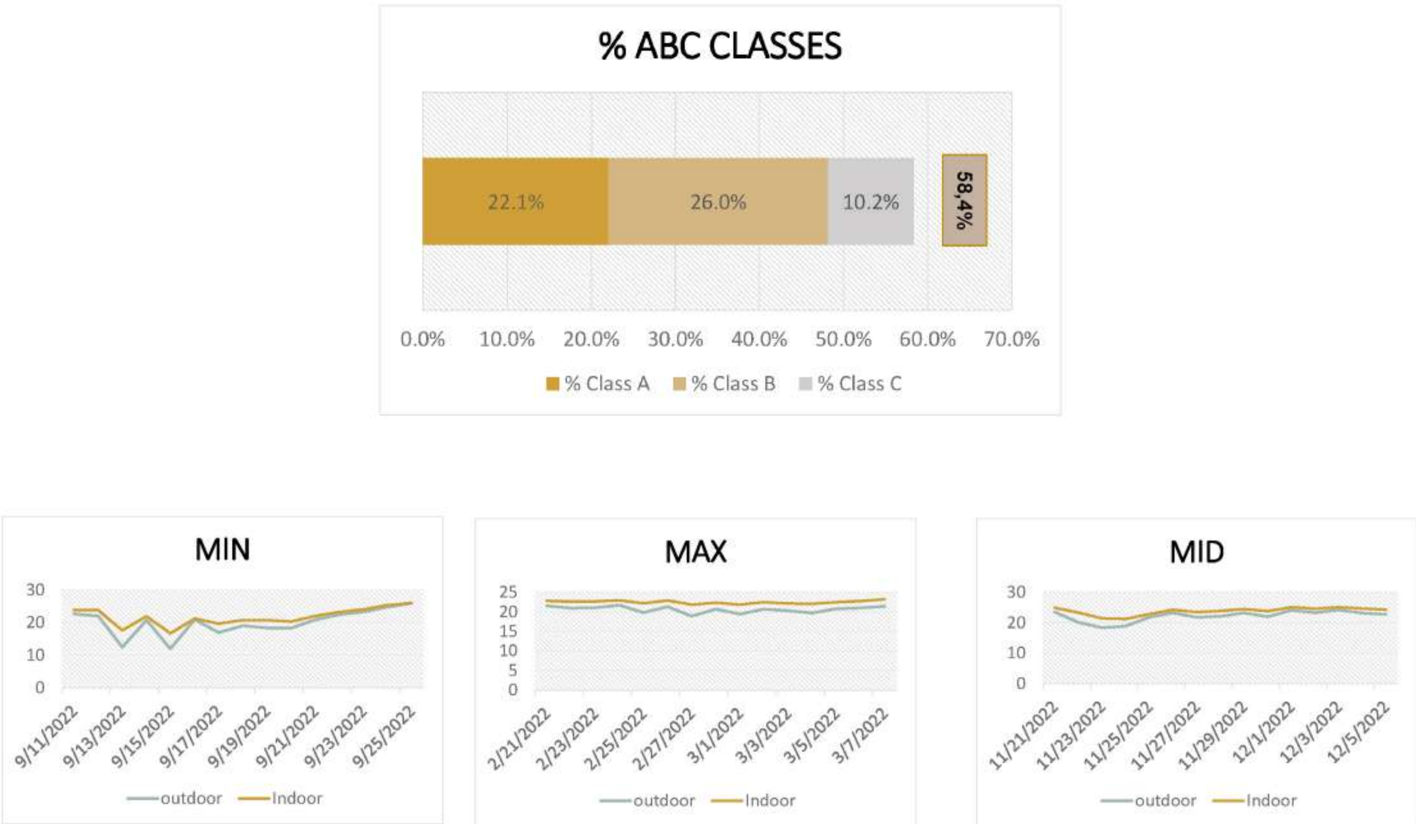


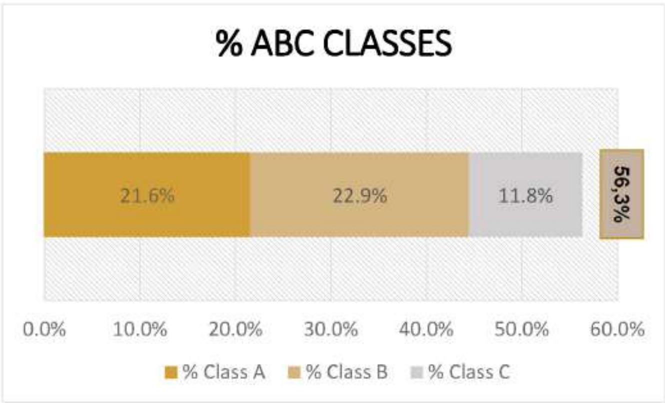
Figure 6.3 Temperature thermal comfort with 10cm insulation

N	Layers	Thermal conductivity [W/m.K]	Gross Density [kg/m³]	Spec. Heat Capacity C [J/kg.K]	Thickness [m]	R [m²K/W]	U Value W/(m²K)	Total thickness (m)
CSEB wall + 15CM INSULATION								
1	CSEB	0.4	1000	800	0.4	1	0.41	0.55
2	Insulation	0.060	70	1030	0.15	1.666		
Metal Febral Roof + 15CM insulation								
1	Metal Febral roof	44.800	7680	418	0.0020	0.10	1.562	0.1520
2	Insulation(thatched)	0.090	70	1200	0.15	1.111		
CSEB interior wall + 15CM INSULATION								
1	CSEB	0.4	1000	800	0.1	0.25	0.37	0.3
2	Insulation	0.060	70	1030	0.15	1.8		

Table 6.3 Data for wall with 15cm insulation

6.4.4 15cm Insulation

In this step the main goal is to promote and have a By comparing the results together from basic we can see that building is already in comfort for the most hours of the year but adding layer of insulation help to control humidity



more so a slight growth in comfort can be observed till the 10 cm insulation and in the last case because of high temperature during the hot season it gets even less So, in respect of remain light and low-cost the final choice is
: WALLS: CSEB 40CM+ 5CM INSULATION
INTERIOR WALLS: 10CM CSEB + 5CM INSULATION
ROOF: 5CM OF CURRAGATED METAL ROOF+ 5 CM OF INSULATION

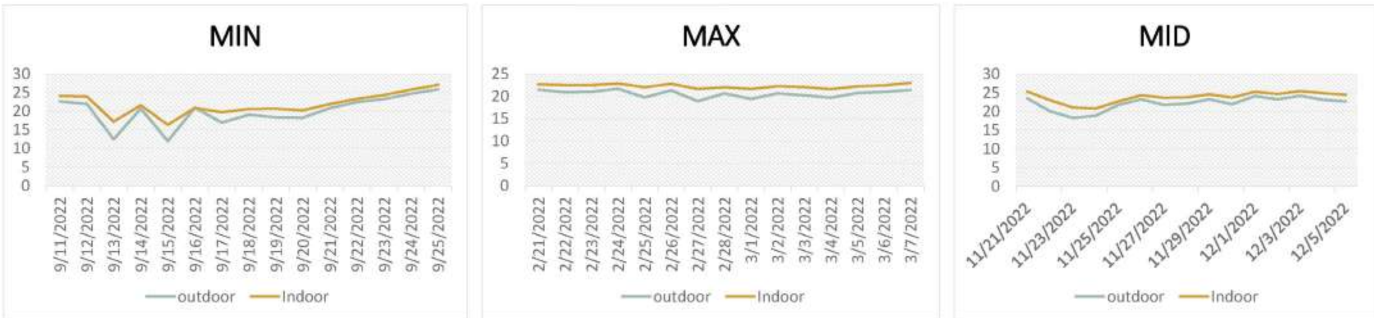
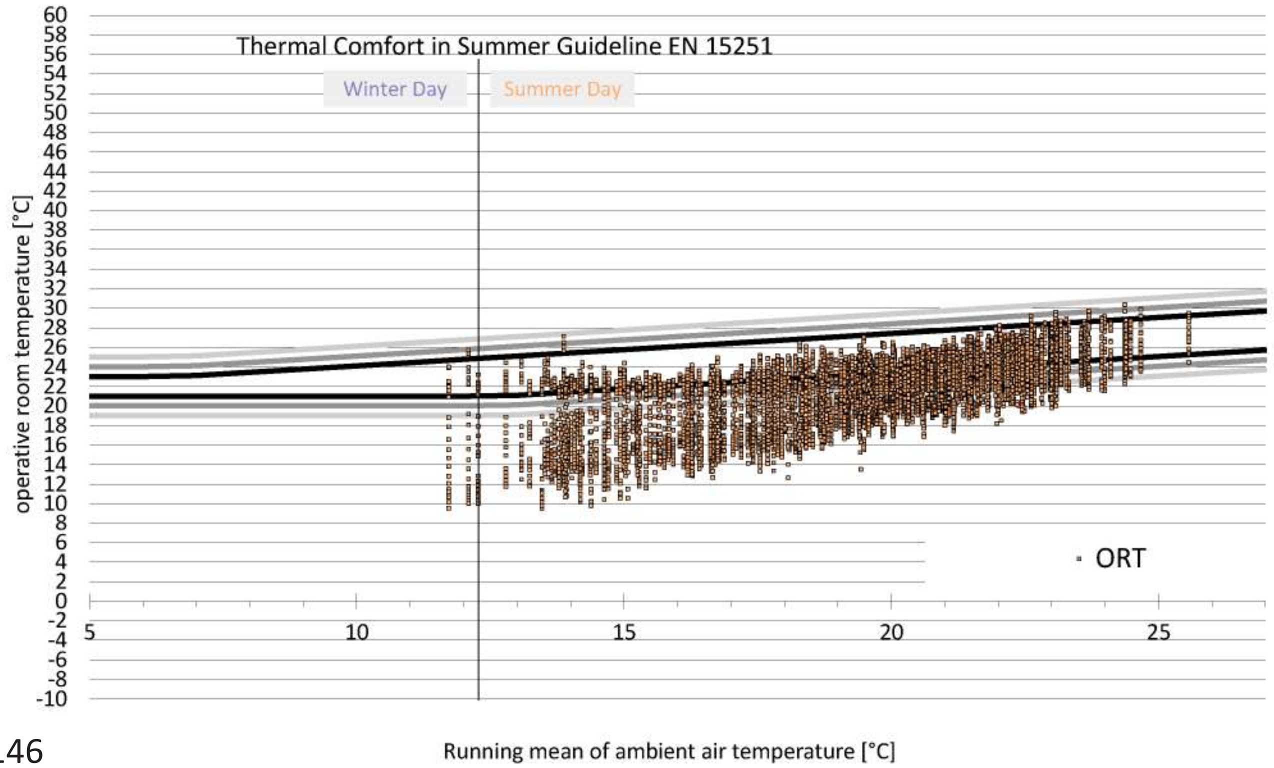


Figure 6.4 Temperature thermal comfort with 15cm insulation



6.5 STEP TWO

In this step the main goal is to promote and have a high range of natural ventilation this step will done in two phases :
1. by making the last one meter of the walls open to make the hot weather exit from the top and the breeze cooldown and dehumidify the spaces
2. Add the second large roof to overhang the walls to protect extra sun rays and also shaded the first roof to prevent over heating and also cool down the space by the ventilation between the empty spaces of the roofs like stack effect.

6.5.1 5cm Insulation + Ventilation

Ventilated walls helped the building to reach more comfort during the year and have less dissatisfied people in the spaces by this consideration in the next phase the second roof will be added to the model to act as the double roof and provides shades and cooling down the surface of the first roof.

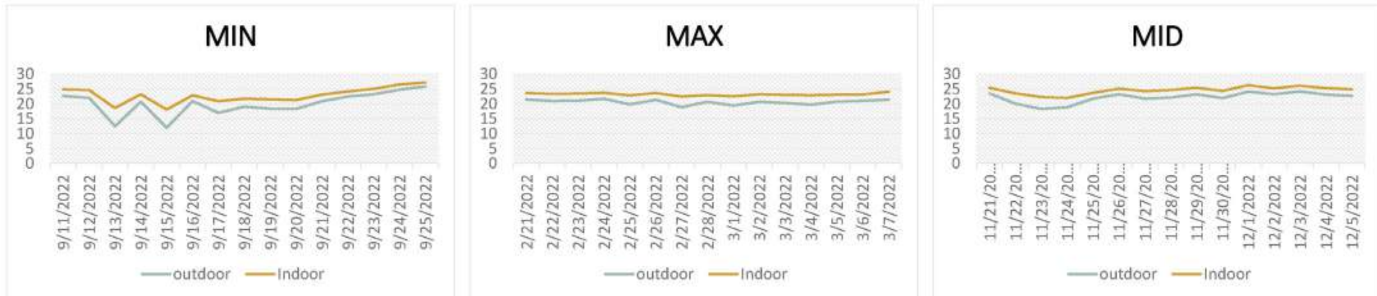
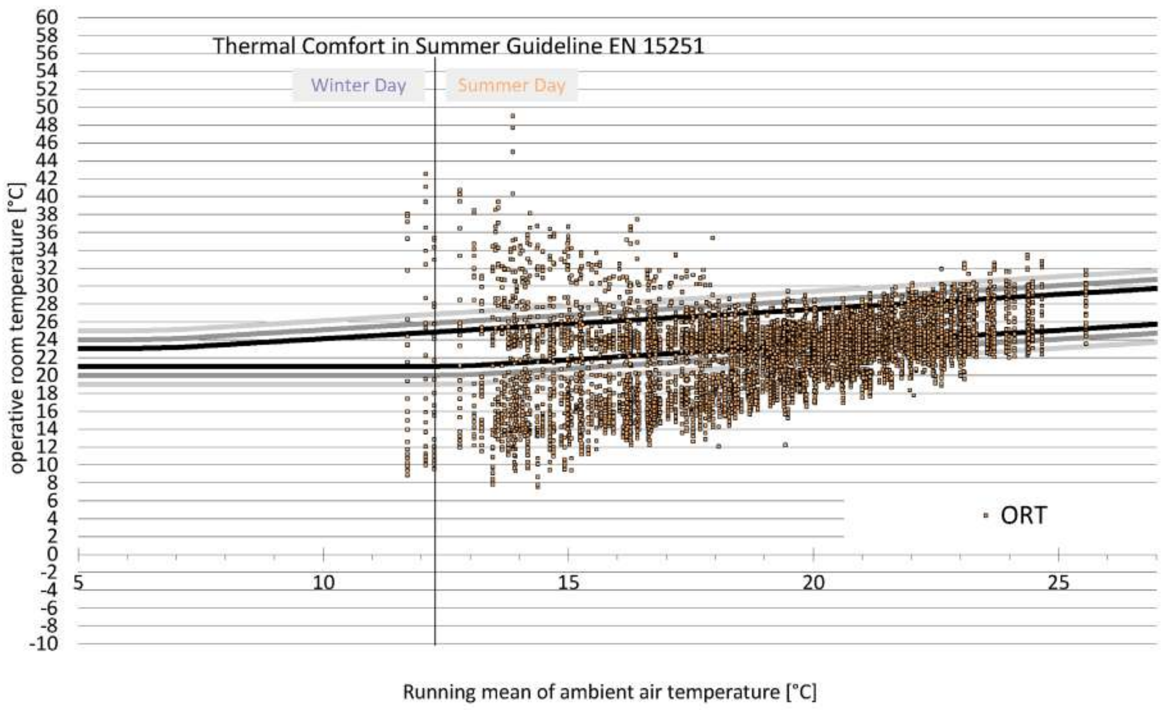


Figure 6.5 Temperature thermal comfort with 5cm insulation+ventilation

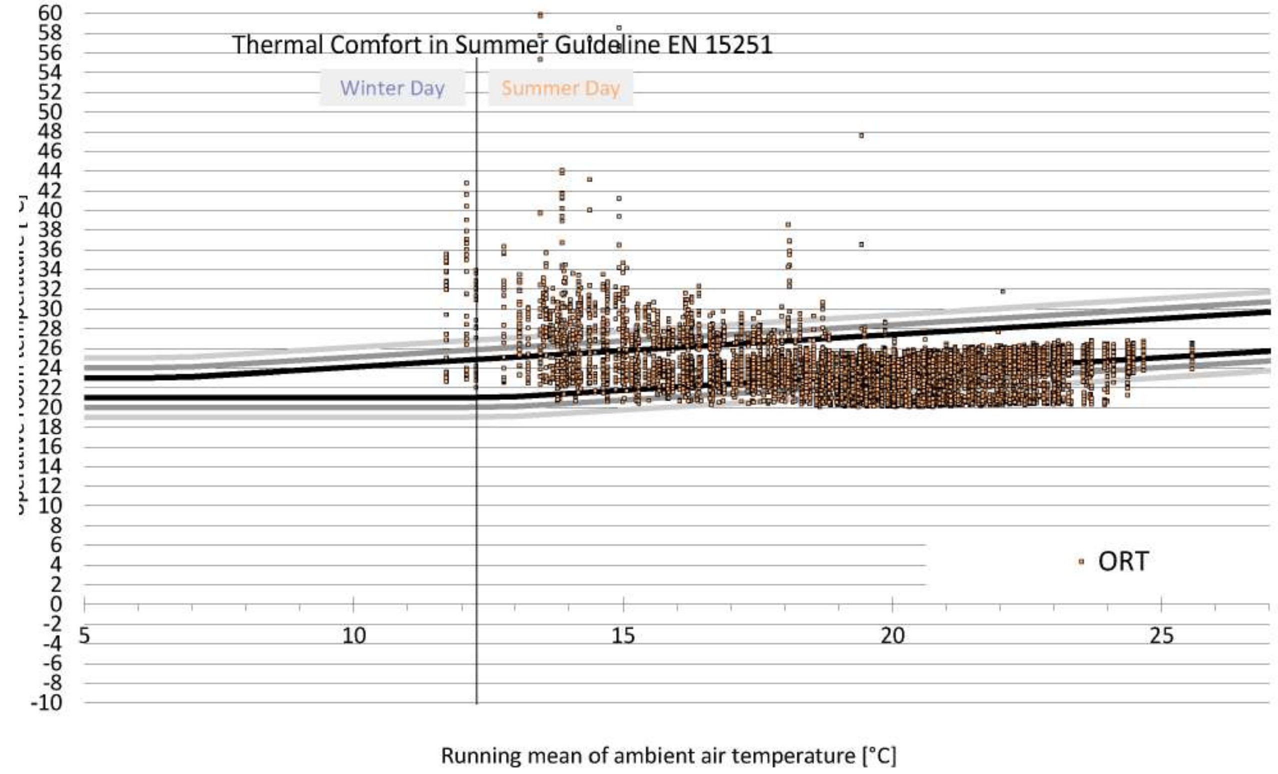


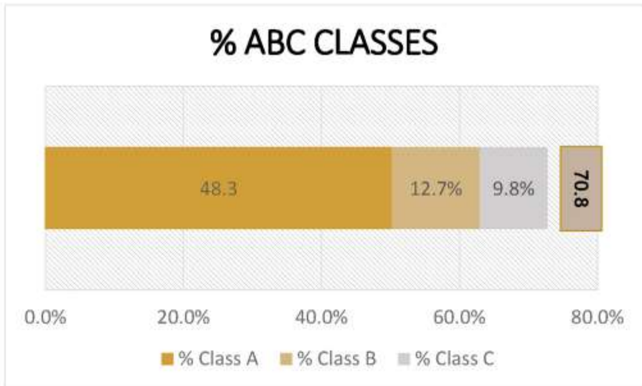
6.6 STEP TWO PHASE 2:

2. Add the second large roof to overhang the walls to protect extra sun rays and also shaded the first roof to prevent over heating and also cool down the space by the ventilation between the empty spaces of the roofs like stack effect.

And the last step to finally complete the envelope optioneering, the windows technology has been analysed, and applied to the last phase as listed below.
•G1 - Single glass windows
(U=5.73 W/m2K)
Only openings with louver and no glazing The solution have a standard openable wood frame. Ideally, being the transparent surfaces the weakest part of the envelope, increasing their performance would benefit significantly on the thermal comfort.
As resulting from the simulation single glaze has good impact both on daylight and thermal comfort situation.

6.6.1 5cm Insulation + Ventilation + Horizental Shading





The results shows that The ventilated roof provides much more comfort during the year and control the operative room temperature more during the critical periods which the change is significant and the noticeable thing is the growth in the class A.so as the chosen and best resul; the design of the buildings would be like this.

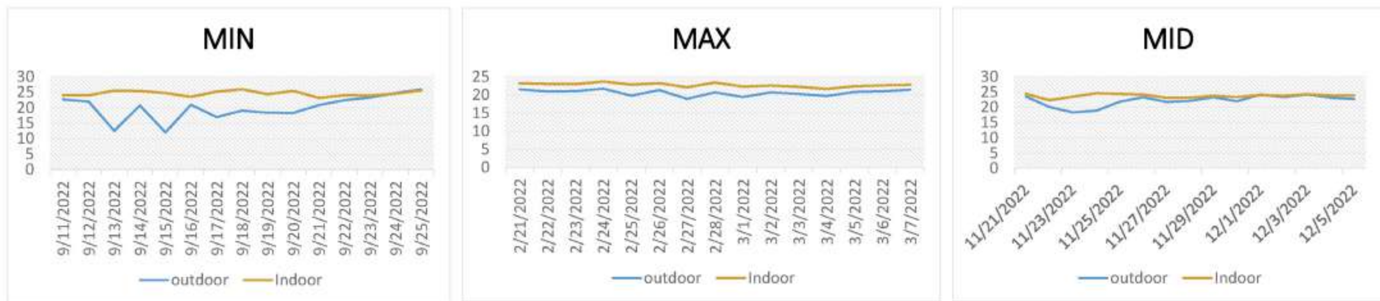
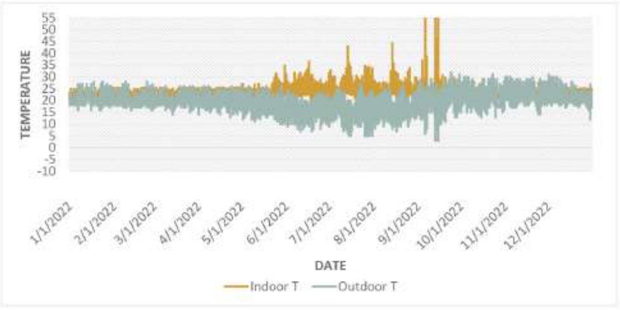
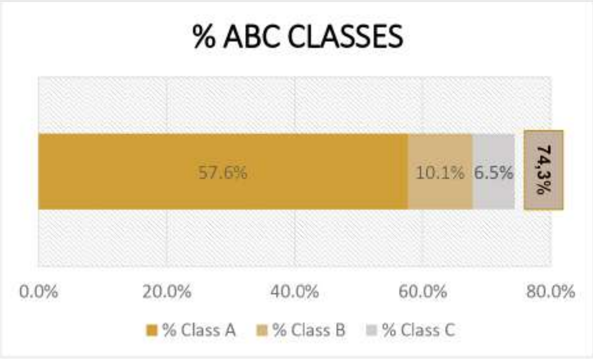


Figure 6.6 Temperature thermal comfort with 5cm insulation+ventila-tion+HS

6.7 FINAL SHAPE:

After the second step daylight analysis were running in parallel to situate windows in best places and reach the most effective WWR and also vertical shadings added. the indoor comfort temperature changed in respect to the new Wwr and vertical shadings with a increase in class A range and total comfort.





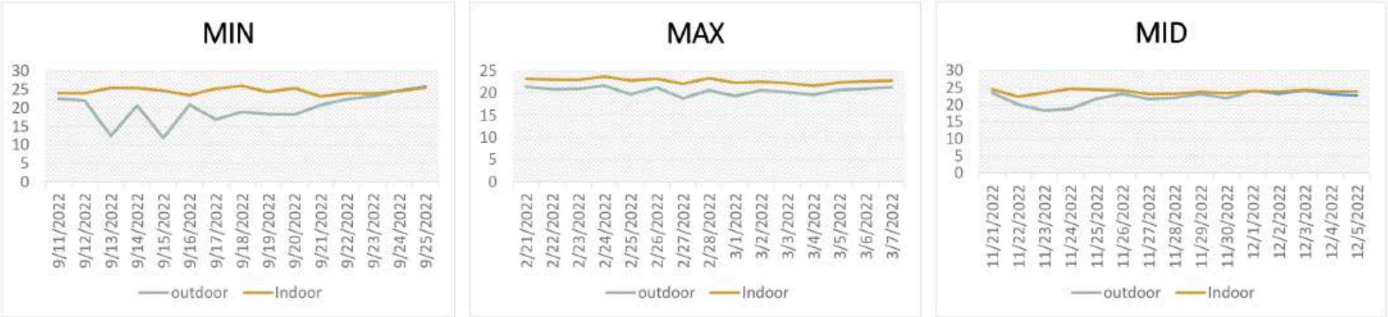
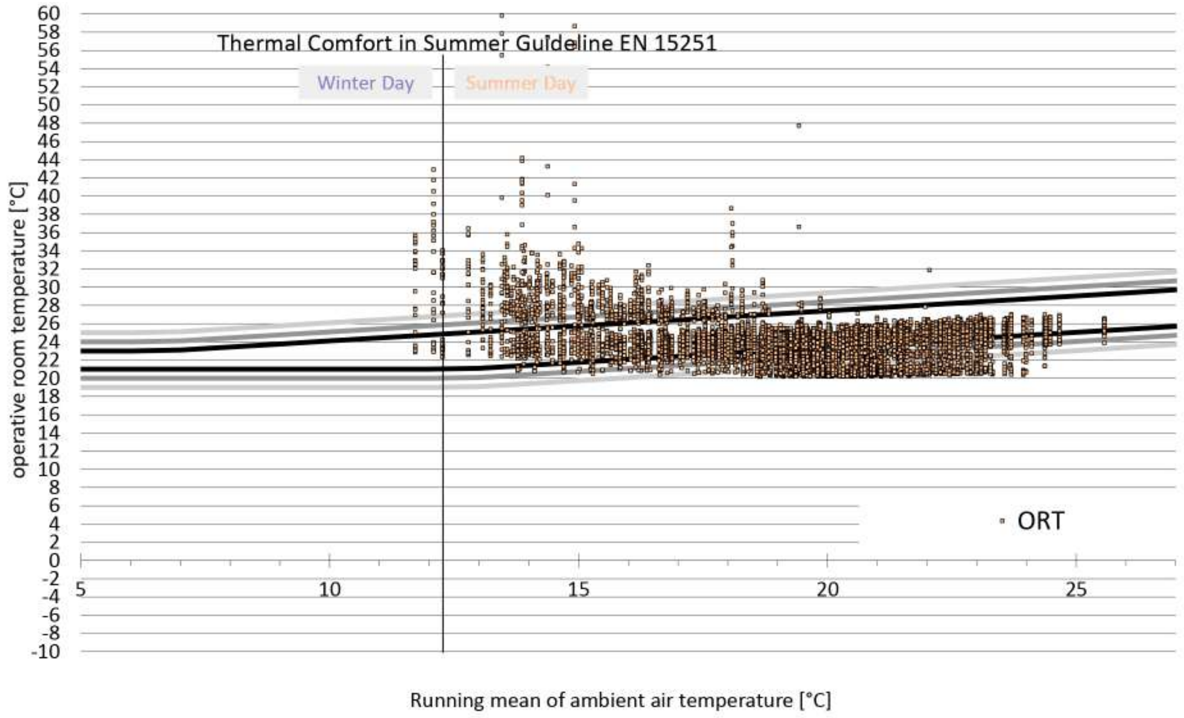


Figure 6.7 Temperature thermal comfort for final shape



6.8 THIRD STEP

The last step of the optioneering is integrated process that studies the impact of opening size, position and shading devices on both the thermal comfort and daylight. Two parameters will be adjusted to find the best solution in both fields:

•Windows to wall ratio: the fraction of transparent surfaces over the whole wall.

•Extension of the shading roof: the size of the secondary roof will influence the amount of direct sun reaching inside the building, and consequentially the daylight and internal gains.

Both parameters are directly linked to architectural and structural topics. Regarding the structure, the openings should not exceed 50% of the wall in length according to the SADC ZW HS 983:2014 guidelines. The space in between them should be more than the width of the window itself. An adequate distance between the openings and the corner of the building should be kept to assure seismic resistance.

Further to meet the privacy and ventilation needs we considered bigger openings (operable walls) face to the courtyards and tall thin openings face to the public area and street. The roof hangover is around at least 2m based on the length we need for shading it is changing to provide covered spaces for the users and also protect the material from the rain and provide more daylight comfort during the year.

6.8.1 Phases of the simulations (Step one)

This step of work was doing parallelly with the envelop optimisation phases, so the same three steps done also here.

The first phase is done on the base line with the WWR as mentioned in the table. The high ration for the windows was considers in favour of high natural ventilation.

The values of the Sda and ASE and DF are visible both in numerical in the tables in in the plans graphically in all the separated zones.

The aim in this context is giving the importance of natural daylight in this context, the 55% limit of sDA must be reached by all the classroom. This is ok for all the classrooms and spaces but also it can be too high even with high potential of GDP if we go through this analysis, there may be the need to provide adequate shading devices.. The glare potential (ASE) is a constintent problem in all the cases. High values are reached in all classes, way above 10% limit suggested by the LEED especially the rooms which face the windows to the northeast and 9.

The comfort is provided by this option is mentioned in energy part baseline

BASELINE			
Rooms	DF	sDA	ASE
1	7	97%	62%
2	5	97%	50%
3	7,5	96%	89%
4	6,7	95%	40%
5	9	97,7%	90%
6	6	95,7%	69%
7	7,5	97%	78%
8	8	96%	85%
9	7,5	96%	87%
10	5,3	94%	49%
11	4,5	93%	43%
12	4,4	93%	32%
13	8	99%	60%

Directio n	WWR
North	20%
South	22%

Table 6.4 Base-line

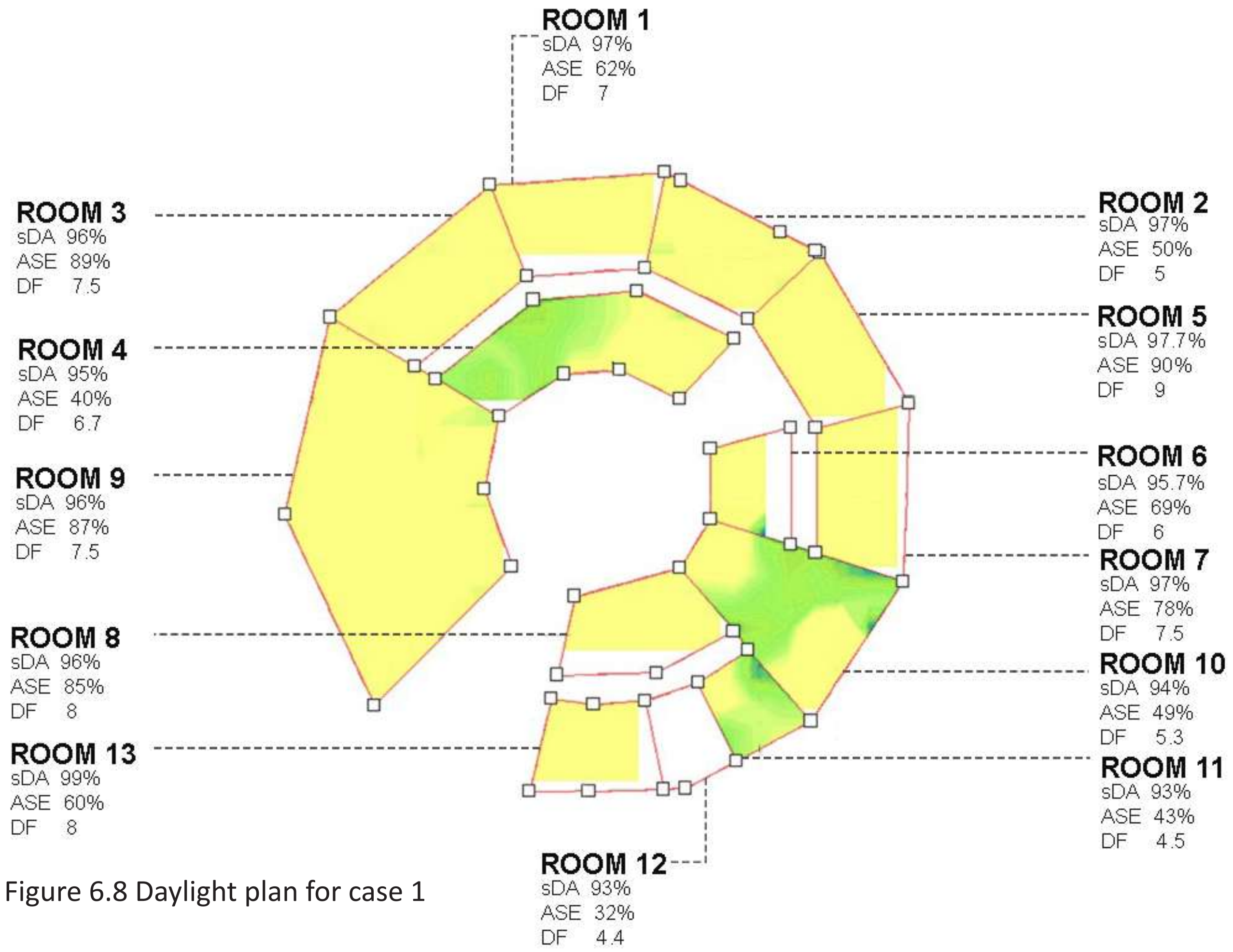


Figure 6.8 Daylight plan for case 1

6.8.2 Phases of the simulations
(Step two)

Direction	WWR
North	20%
South	22%

Simultaneously with second step of optimizing the ventilation and adding the horizontal shading, daylight analysis get done too with the same WWR to respect the ventilation.

The shading overhang is 2m in south and increasing in north and east to 4 and reduced again to 2.5 in west side. These lengths achieved by lots of analysis which done to reach the most optimum option.

Improvement in all metrics is visible but the SDA is much above the LEED suggestion.

Thermal comfort was mentioned

HORIZONTAL SHADING			
Rooms	DF	sDA	ASE
1	3,7	78%	10%
2	4	79%	37%
3	2,9	76%	63%
4	2	40%	8%
5	4	82%	62%
6	3,2	68%	66%
7	5,5	86%	60%
8	2	37%	20%
9	2,5	84%	64%
10	2	77%	24%
11	4	73%	0%
12	3	75,5%	0%
13	4	78%	0%

Table 6.5 horizontal shading

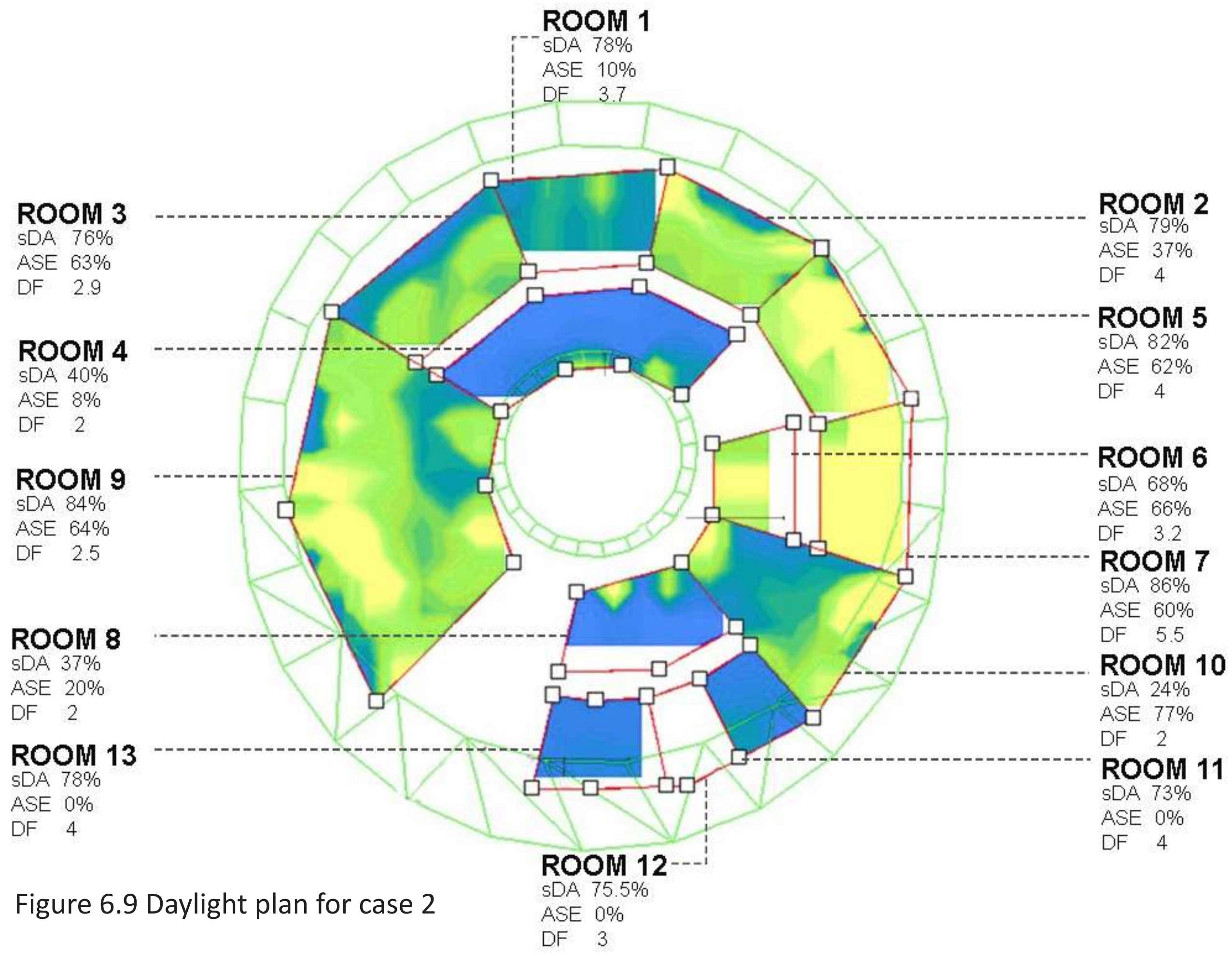


Figure 6.9 Daylight plan for case 2

6.8.2 Phases of the simulations
Third step

The Third and last step is providing net of bamboos around the building to provide covered spaces and vertical shading to reduce the ASE as less as possible without reduction in the other factors.

WWR changed in northern and north-eastern part of the building in the southern part as the ASE already improved the ratios remained the same.

This step was a bit difficult to find the right algorithm for the distances between the bamboos so the most critical rooms Was chosen to get focused on the result and then many analysis get done to find the optimum distances in north, north-east, south and southwest, then the algorithm applied to whole building and last step of daylight analysis and comfort get done.

As it is visible in the table and graphs in the last step significant reduction has happened to all the rooms especially in critical ones (5,3,9) with respect of keeping sDA and DF above the LEED average.

For the chosen rooms GDP analysis get done as conclusion of this part.

Thermal comfort was mentioned

Direction	WWR
North	17%
South	22%

FINAL			
Rooms	DF	sDA	ASE
1	3,7	94%	30%
2	4,8	93%	6,2%
3	2,8	90%	25%
4	3	62%	4,1%
5	4	92%	12%
6	3,2	86%	33%
7	5,5	94%	10%
8	2,4	49%	20%
9	4	89%	22%
10	3	90%	13%
11	3,1	86%	0%
12	3	88%	0%
13	3,7	90%	0%

Table 6.5 Final result

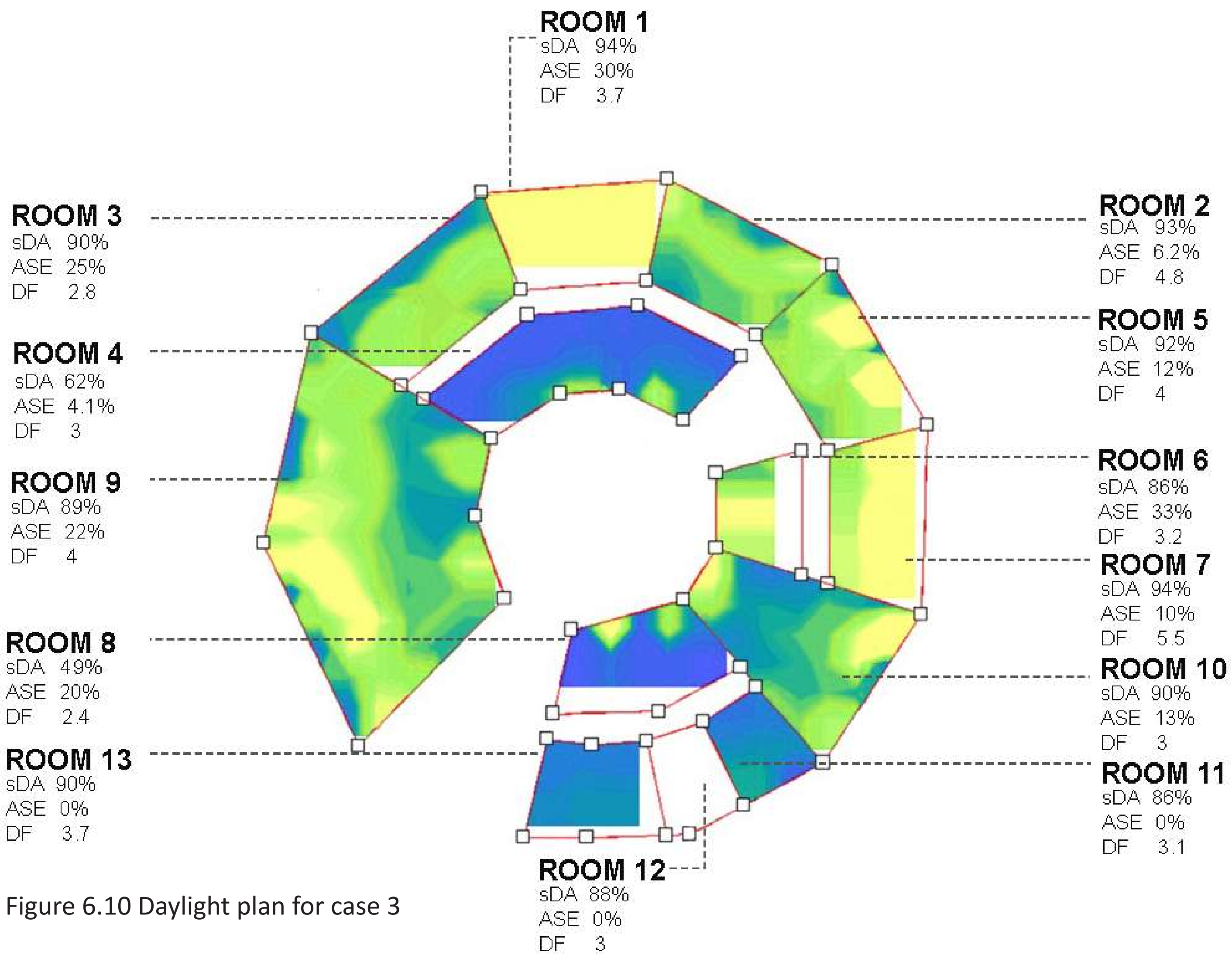
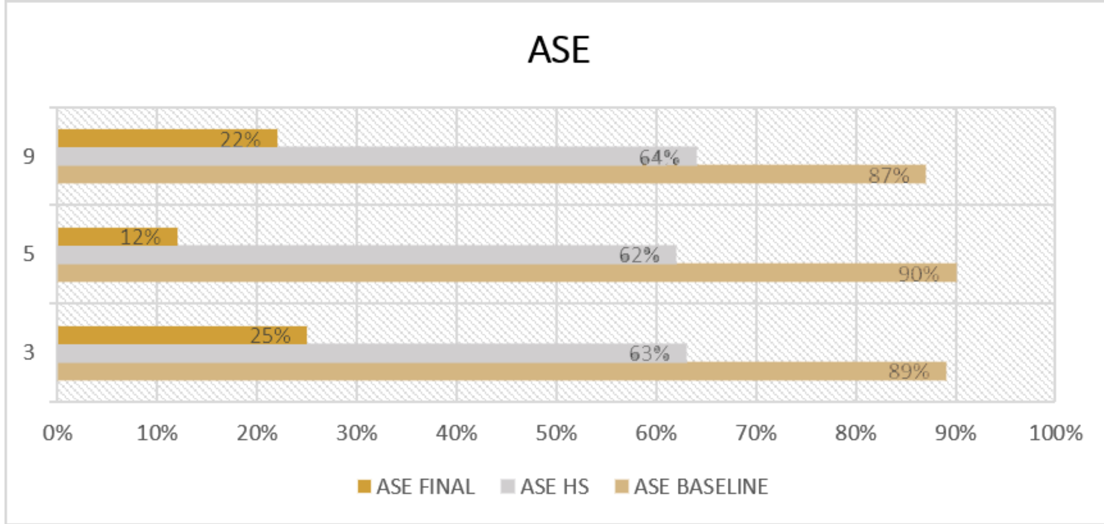
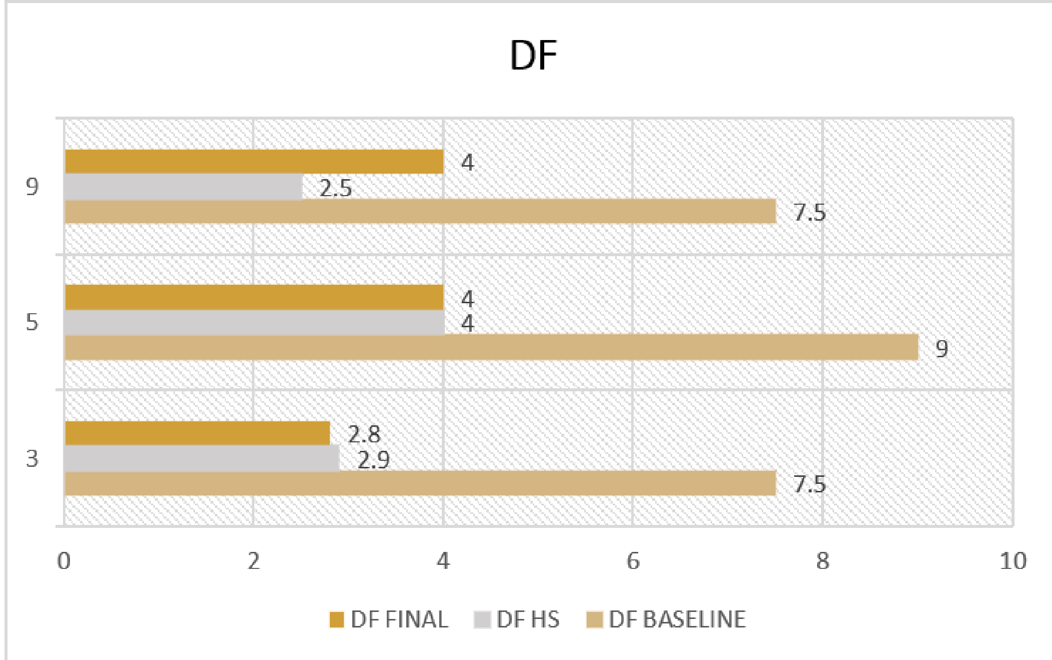
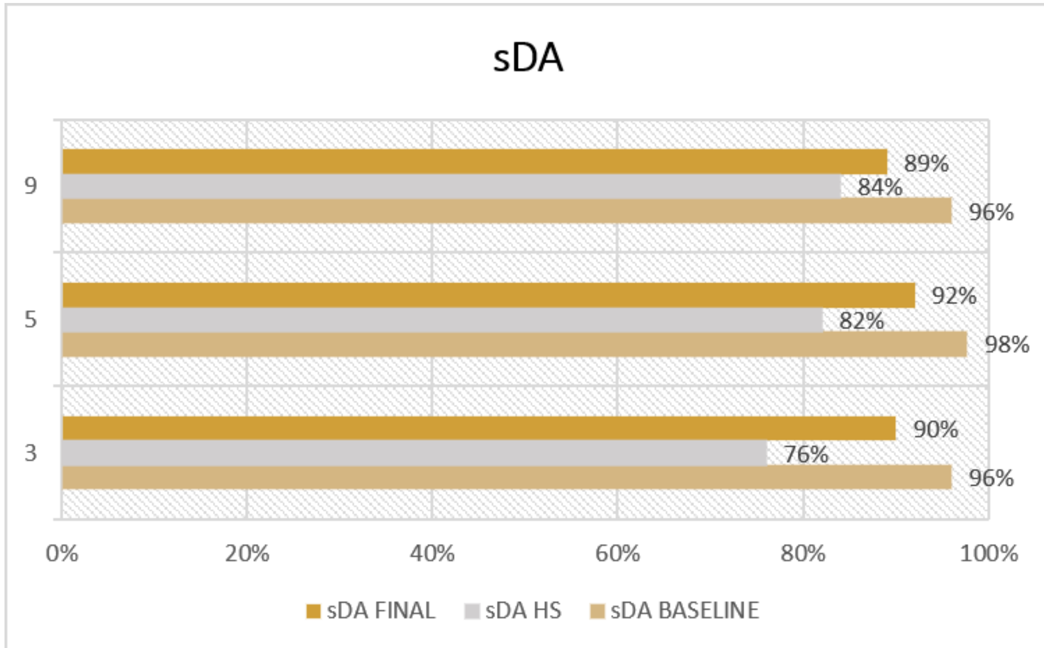


Figure 6.10 Daylight plan for case 3

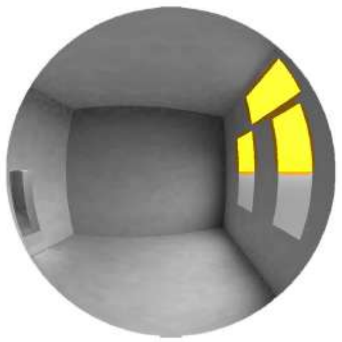




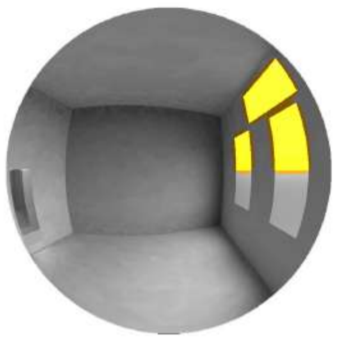


6.9 GLARE ANALYSIS FOR ROOM 3

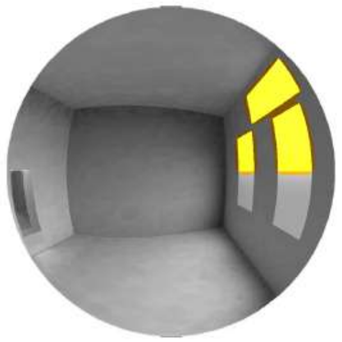
According to the last results of the ASE room number .. was the most critical one. To check if there is any disturbing glare we put a fisheye camera toward the balck board and check the glare during the crital times of the day and months of the year Results we get didn't show any disturbing glare so the visual comfort is ensured even in the most crital space of the school.



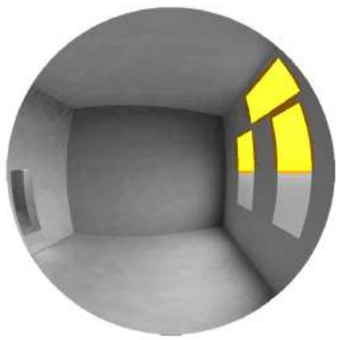
21 March 9.00
GDP: 20.44%



21 June 9.00
GDP: 19.78%



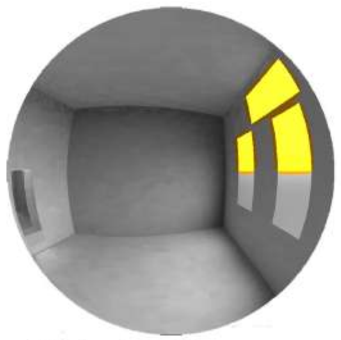
21 December 9.00
GDP: 20.70%



21 March 13.00
GDP: 21.37%

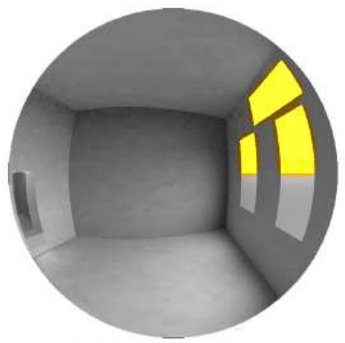
21 June 13.00
GDP: 20.61%

21 December 13.00
GDP: 21.39%



21 March 18.00
GDP: 1%

21 June 18.00
GDP: 0.39%



21 December 18.00
GDP: 0.59%

CHAPTER 7

PRE-STRUCTURAL DESIGN

7.1 INTRODUCTION

In this chapter, the structure is being analyzed to verify it is safe against its self-weight loads and natural loads such as wind and earthquake loads.

The project is comxxxposed of one floor buildings, all with the same span and dimensions. The structure is composed of a roof made of two bamboo trusses with thatched layer and metal fabral roof between them, which are located on load bearing compressed stabilized earth blocks (CSEB) walls. The walls are anchored to the ground by a continuous reinforced concrete wall foundation and strip footing for stability against horizontal actions, as shown below in Figure 7-1.

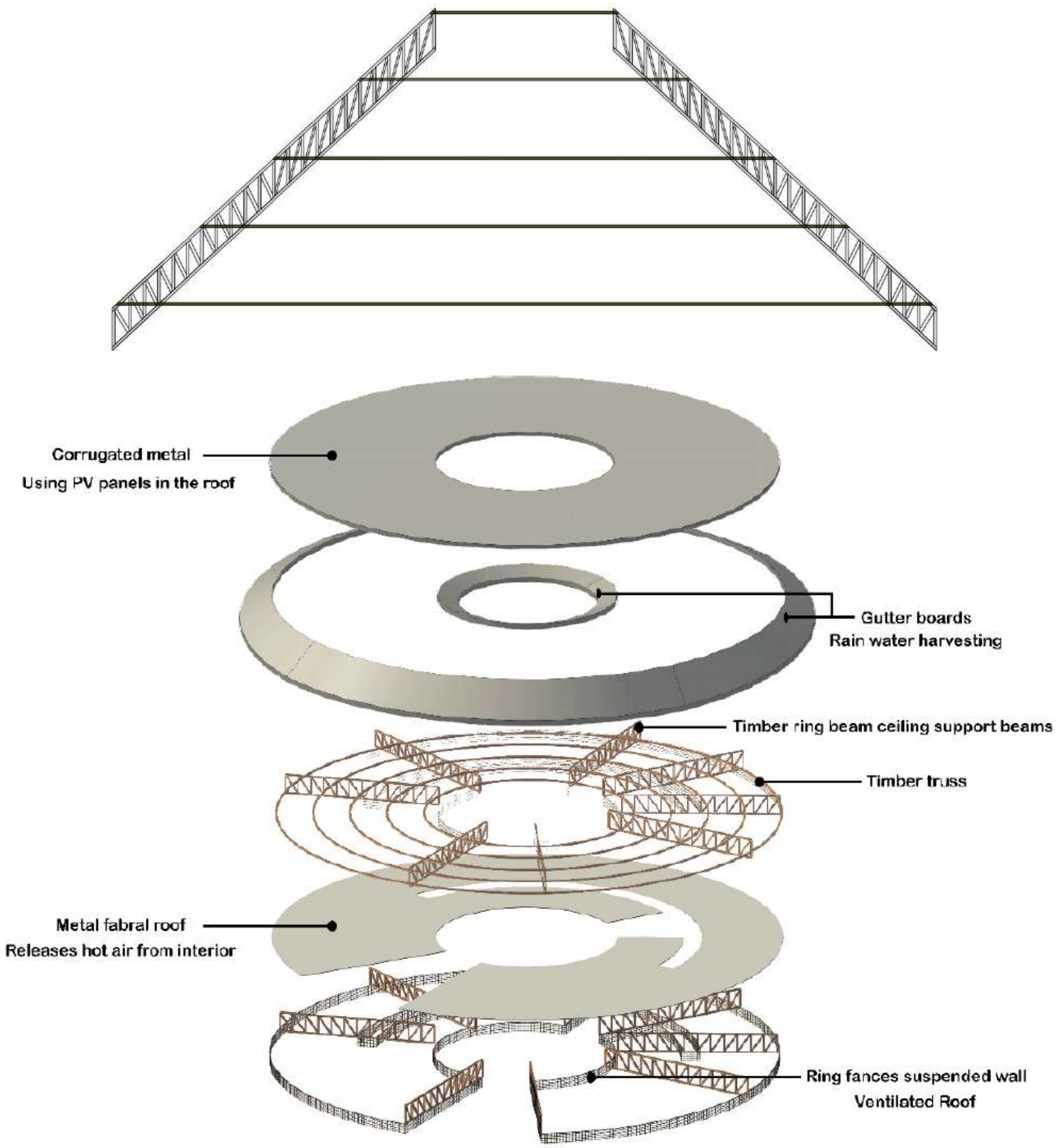


Figure 7-1 Exploded structure diagram

7.2 ACTIONS ON STRUCTURE

The structural analysis has been carried out on the multipurpose building the one indicates in Figure 7-2. This building is divided to 24 sections and the section between I2 and J2 has been chosen for the structural analysis verifications due to the following; in terms of stability all the sections have equal conditions but this section oriented west-east which is the strongest wind axis. All the structural schemes have been studied with the SAP2000 software.

Since the Structural Eurocode is one of the most restrictive in terms of safety margins, it was chosen to be followed to evaluate the actions and loads on the structure; EN 1991, Eurocode 1: Actions on Structures. For each element analyzed, the total self-weight of structural and non-structural members, the imposed loads arising from occupancy and the variable actions induced by wind have been taken into account.

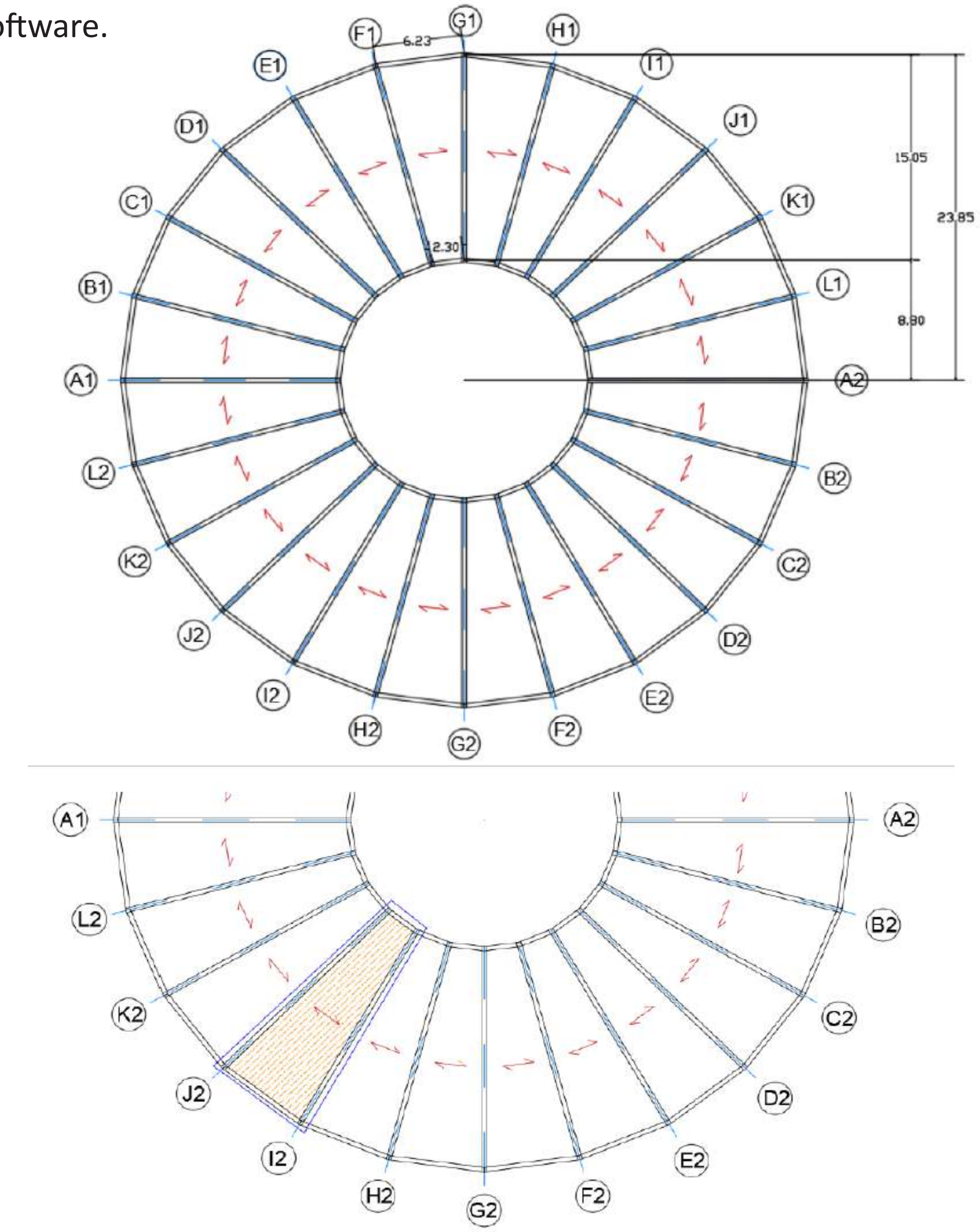


Figure 7-1 Exploded structure diagram

7.2.1 Permanent load

Permanent loads are the total self-weight of structural and non-structural members acting on each analyzed member. The following paragraphs shows the total self-weight of each element, starting with the roof layers, the bamboo truss structure elements, the vertical enclosure of the bamboo roof, the thatched layer, the two layers of metal sheet, and lastly the compressed stabilized earth blocks (CSEB) walls and slab. Each of these elements will later be used as uniformly distributed loads in the load's combination calculations.

Starting with the total self-weight of the roof layers, it is mainly composed of a thatched layer, metal fabral roof, insulation panels and corrugated metal sheet, the total weight would be 0.44 kN/m2 as shown in Table 7-1.

The self-weight of each element of the bamboo truss beams; the bamboo truss columns, and the bamboo truss inclined members would be as shown in Table 6-2 and Table 6-3 for lower and upper truss, respectively.

As it can be seen, other related tables are shown as following.

Table 7-1 Weight of roof layers

Layers	Thickness (m)	Specific Weight (kN/m^3)	Weight per square meter (kN/m^2)	Average Length (m)	Weight per meter (kN/m)
Thatched layer	0.05	1.5	0.08	4.6	0.37
Metal Fabral Roof	0.002	35.3	0.07	4.6	0.32
Insulation Panels	0.05	4.4	0.22	4.6	1.01
Corrugated Metal Sheet	0.002	35.3	0.07	4.6	0.32
Total			0.44		2.02

Table 7-2 Weight of lower truss

Members	Diameter (m)	Specific Weight (kN/m^3)	Area (m^2)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Truss beams	0.12	7.5	0.011	0.085	15.55	2	2.64
Truss columns	0.12	7.5	0.011	0.085	0.76	23	1.48
Truss inclined members	0.12	7.5	0.011	0.085	0.96	22	1.79
Total							5.91
Total per 1meter (kN/m)	0.38						

Table 7-3 Weight of upper truss

Members	Diameter (m)	Specific Weight (kN/m^3)	Area (m^2)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Truss beams	0.12	7.5	0.011	0.085	15.55	2	2.64
Truss columns	0.12	7.5	0.011	0.085	1.11	23	2.16
Truss inclined members	0.12	7.5	0.011	0.085	1.25	22	2.33
Total							7.13
Total per 1meter (kN/m)	0.46						

Table 7-4 Weight of bamboo beams

Members	Diameter (m)	Specific Weight (kN/m^3)	Area (m^2)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Bamboo beams	0.08	7.5	0.005	0.038	4.6	12	2.08
Total							2.08
Total per 1meter (kN/m)	0.45						

Table 7-5 Weight of bamboo walls (fances)

Members	Diameter (m)	Specific Weight (kN/m^3)	Area (m^2)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Bamboo Walls - beams	0.06	7.5	0.003	0.021	15.45	3	0.98
Bamboo Walls - columns	0.06	7.5	0.003	0.021	1.00	53	1.12
Total							2.11
Total per 1meter (kN/m)	0.14						

Table 7-6 Weight of bamboo walls (fances) – External view

Members	Diameter (m)	Specific Weight (kN/m³)	Area (m²)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Bamboo Walls - beams	0.06	7.5	0.003	0.021	6.65	18	2.54
Bamboo Walls - columns	0.06	7.5	0.003	0.021	1.00	23	0.49
Total							3.02
Total per 1meter (kN/m)	0.45						

Table 6-7 Weight of bamboo walls (fances) – Internal view

Members	Diameter (m)	Specific Weight (kN/m³)	Area (m²)	Weight per meter (kN/m)	Length (m)	Number	Total weight (kN)
Bamboo Walls - beams	0.06	7.5	0.003	0.021	2.6	18	0.99
Bamboo Walls - columns	0.06	7.5	0.003	0.021	1.00	10	0.21
Total							1.20
Total per 1meter (kN/m)	0.46						

Table 7-8 Vertical finishing self-weight

Layers	Thickness (m)	Specific Weight (kN/m³)	Weight (kN/m²)
Insulation Panels	0.05	4.4	0.22
Plaster Layers	0.01	20	0.20
Total (kN/m²)	0.42		

Table 7-9 Loadbearing wall self-weight

Layers	Area (m²)	Specific Weight (kN/m³)	Weight per meter (kN/m)
Compressed stabilized earth blocks (CSEB) – Class A	1.4	19	26.60
Total (kN/m)	26.60		

Table 7-10 Horizontal slab's self-weight

Layers	Area (m²)	Specific Weight (kN/m³)	Weight per meter (kN/m)
Compressed stabilized earth blocks (CSEB) – Class A	1.45	19	27.61
Total (kN/m)	27.61		

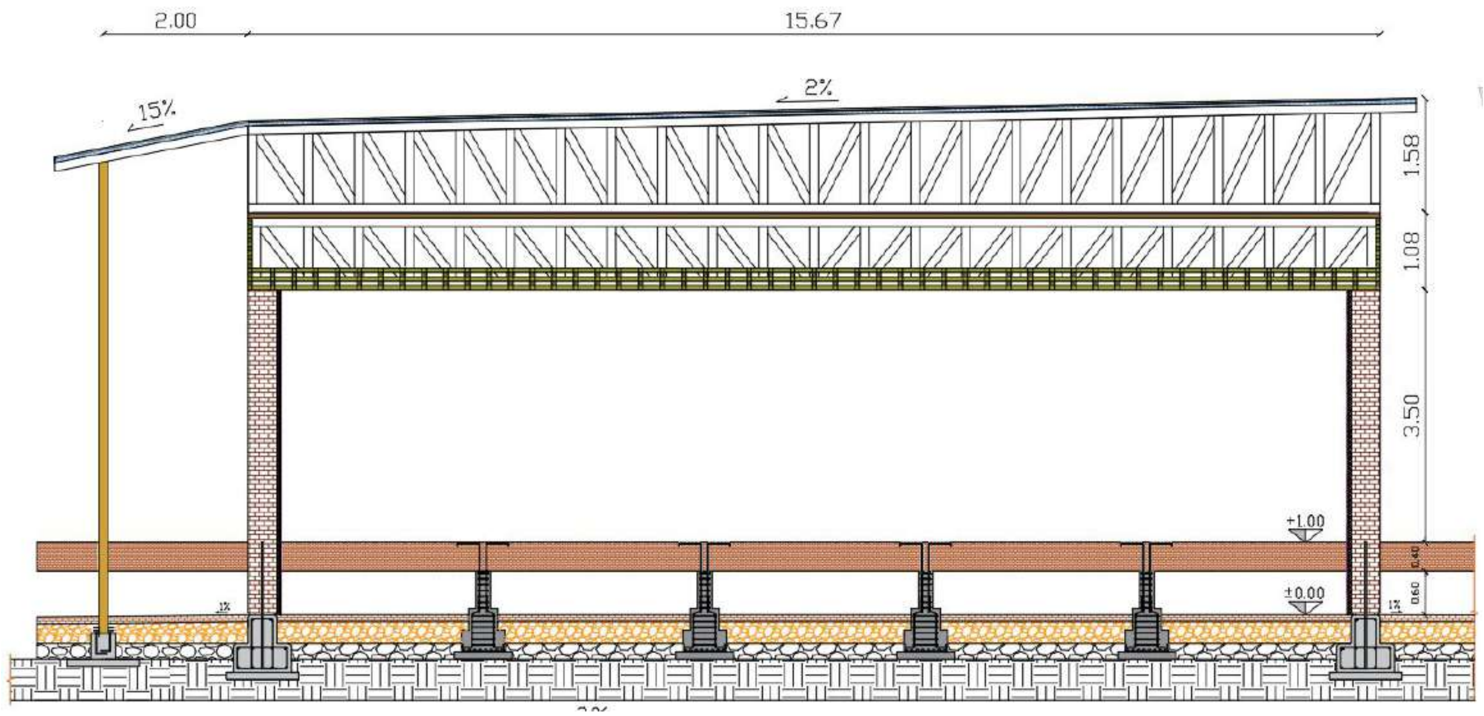


Figure 7-3 Detailed Section

7.2.2 imposed loads

Imposed loads are classified as variable free actions, those arising from occupancy of the spaces such as people, furniture, vehicles, and rare events. In EN 1991.1.1, section 6, it states that the characteristic values for imposed loads differ from a space to the other based on their specific uses. The whole project shall be considered as “category C1 - Areas with Tables” as stated in table 7.1 of EN 1991.1.1.
Considering the roofs, it is categorized according to their accessibility. Since the project is a one storey building with non-accessible roof, it shall be considered as “category H - Roofs not accessible except for normal maintenance and repair” as state in table 6.9 of EN 1991.1.1.

Table 7-11 Characteristic values of imposed loads

Categories	q_k kN/m^2	Q_k kN
Social Areas - Category C1	2.0 – 3.0	3.0 – 4.0
Roof – Category H	0.4	1.0

7.2.3 Wind loads

Wind actions on structural members and structures are specified in “Eurocode 1: Actions on structures: Part 1-4 Wind actions”. The design of buildings is influenced significantly by wind loads. Therefore, it is important to carefully estimate the wind load in accordance with loading codes. Wind loads are both time dependent and space dependent. The estimation of wind loading is relatively complex as it depends on the location and direction of the building being designed, site conditions related to terrain/height, shielding and topography, the shape of the building and the fundamental frequency of the structure.

General

Estimating wind actions is all about probability, not certainty. The speed of the strongest wind that can ever blow is not known, but the longer the time interval, the higher the chance of a stronger wind. By taking measurements over many decades in many places, there is now reasonable scientific agreement as to the probability of a particular wind speed occurring in defined geographic regions.
According to EN 1991-1-4 the following procedure applies.

First Step: Basic Values

– The fundamental value of the basic wind velocity (vb,0) is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10m above ground level in open country of terrain with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights. According to the basic wind speed zone map of South Africa, the basic wind velocity is 40.0 m/s.
– The basic wind velocity (Vb) shall be calculated from the following expression:

Vb = Cdir * Cseason * Vb,0

Where:

– Vb is the basic wind velocity, defined as a function of wind direction and time of year at 10m above ground of terrain category II
– Vb,0 is the fundamental value of the basic wind velocity
– Cdir is the directional factor = 1
– Cseason is the season factor = 1

Vb = 1 * 1 * 40.0 = 40.0 m/s

Second Step: Mean Wind

The mean wind velocity Vm(z) at a height z above the terrain can then be calculated and it depends on the terrain roughness and orography and on the basic wind velocity, Vb [Expression 4.3-EC1-1-4]:
Vm(z) = Cr(z) * CO(z) * Vb Second Step: Mean Wind
The mean wind velocity Vm(z) at a height z above the terrain can then be calculated and it depends on the terrain roughness and orography and on the basic wind velocity, Vb [Expression 4.3-EC1-1-4]:

Vm(z) = Cr(z) * CO(z) * Vb

where:

– CO(z) is the orography coefficient, taken as 1.0 (recommended value).
– Cr(z) is the roughness factor.
• To determine the roughness factor Cr(z), which accounts for the variability of the mean wind velocity at the site of the structure due to the height above ground level, is based on a terrain category.
• According to table 4.1 of EN 1991.1.4, the project site belongs to terrain category II that is area with low vegetation such as grass and isolated obstacles. This leads to:
– Z0,II = 0,05 m (roughness length)
– Zmin= 2,00 m (minimum height)
– Zmax= 200 m
– z0 = 0.05 for terrain category II
• Since the height of the buildings is not constant due to the inclination of the roof of 2°, the full height (z) would be:
– a height of 7.30 m for wind of 0°
– a height of 7.60 m for wind of 180°
• In both situations, Z is bigger than Zmin, so the roughness factor shall be calculated by the following expression:

cr(z) = kr ln (z/z0) for zmin ≤ z ≤ zmax

where:

kr is terrain factor depending on the roughness length z0 calculated using the following:
kr = 0.19(z0/z0,II)0,07
kr=0.19 (0.05/0.05)0.07 = 0.19

• So, the roughness factor cr(z) at each wind direction shall be:

– For 0° wind direction:
cr(z) = 0.19 * ln(7.30/0.05) = 0.94

– For 180° wind direction:
cr(z) = 0.19 * ln(7.60/0.05) = 0.95

• So, the mean velocity vm(z) at each wind direction shall be:

– For 0° wind direction:
vm(z) = 0.94 * 1.0 * 40.0 = 37.6 m/s

– For 180° wind direction:
vm(z) = 0.95 * 1.0 * 40.0 = 38.0 m/s

Third Step: Wind Turbulence Intensity

The turbulence intensity Iv(z) at height z is defined as the standard deviation of the turbulence divided by the mean wind velocity. The recommended rule for the determination of Iv(z) are given as follows [Expression 4.7-EC1-1-4]:

Iv(z) = σv / vm(z) for zmin ≤ z ≤ zmax
The standard deviation of the turbulence σv may be determined using the following:

σv = kr * vb * kI

where:

– kr is the terrain factor = 0.19
– kI is the turbulence factor = 1
σv = 0.19 * 40.0 * 1.0 = 7.6 m/s

So, the turbulence intensity Iv(z) at each wind direction shall be:

– For 0° wind direction:
Iv(z) = 7.6 / 37.6 = 0.2

– For 180° wind direction:
Iv(z) = 7.6 / 38.0 = 0.2

Fourth Step: Peak Velocity Pressure

The peak velocity pressure qp(z) at height z, which includes mean and short-term velocity fluctuations, should be determined [Expression 4.8-EC1-1-4]:

$$q_p(z) = [1 + 7.I_v(z)].\frac{1}{2}.\rho.v_m^2(z) = C_e(z).q_b$$

where
ρ = 1.25 kg/m3 is the air density (recommended value).

So, the peak velocity pressure qp(z) for each wind direction shall be:

– For 0° wind direction:
qp(z) = [1 + 7.0 * 0.2] * 0.5 * 1.25 * 37.62 = 2120.64 N/m2

– For 180° wind direction:
qp(z) = [1 + 7.0 * 0.2] * 0.5 * 1.25 * 38.02 = 2166.0 N/m2

The following Table 5-6 shows a summary of the wind loads calculated for each wind direction, according to Section 4 of EN 1991.1.4.

Table 7-12 Summary of wind actions

Wind Direction	V_b m/s	V_m m/s	$I_v(z)$	$q_p(z)$ N/m^2
0°	44.87	37.6	0.2	2120.64
180°	44.87	38.0	0.2	2166.0

Fifth Step: Wind Pressure

Following on to the next section of the EN 1991.1.4 code, Section 5 gives guidance to determine the wind actions from the basic values of wind velocity and pressure calculated previously.
The wind actions on structures shall be determined considering both external and internal wind pressures. The net pressure on a wall, roof or element is the difference between the pressures on the opposite surfaces taking due account of their signs. Pressure, directed towards the surface is taken as positive, and suction, directed away from the surface as negative as shown in Figure 7-4 below.

where:

– kr is the terrain factor = 0.19
– kI is the turbulence factor = 1
σv = 0.19 * 40.0 * 1.0 = 7.6 m/s

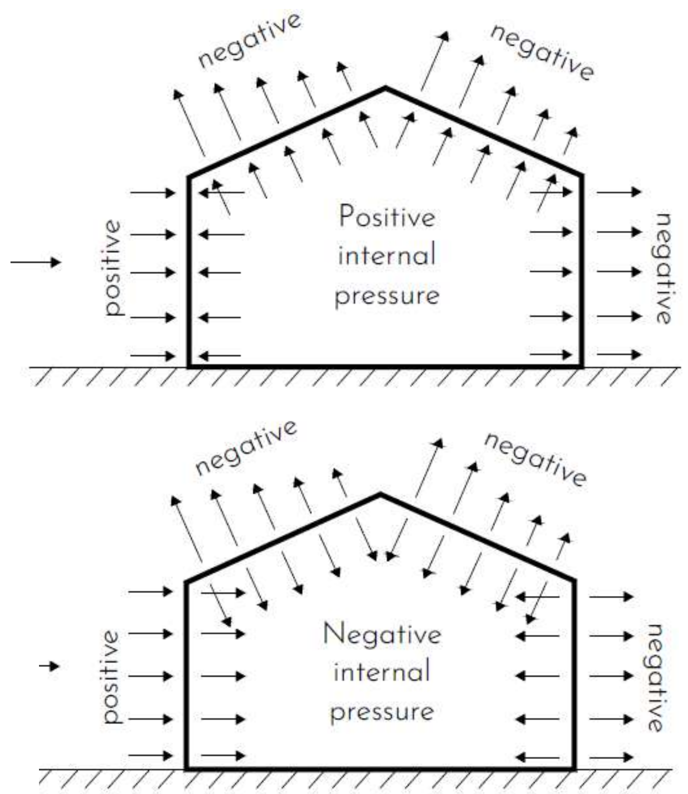


Figure 7-4 Wind Pressure

The wind pressure acting on the external surfaces, we shall be obtained from the following expression:
We = qp(ze) * cpe
Where:

– qp(ze) is the peak velocity calculated before for each wind direction
– cpe is the pressure coefficient for the external pressure
The external pressure coefficients cpe for buildings and parts of buildings depend on the size of the loaded area A, which is the area of the structure, that produces the wind action in the section to be calculated. The analyses have been carried out referring to the overall coefficients cpe,10 which is the recommended coefficient to be used when designing the overall load bearing structure of a building. In the next page, the values of external pressure and its corresponding wind actions are presented for the multifunctional room.

According to EN 1991.1.4, internal and external pressures shall be considered to act at the same time. The worst combination of external and internal pressures shall be considered for every combination of possible openings and other leakage paths. The wind pressure acting on the internal surfaces, wi shall be obtained from the following expression:

wi = qp(zi) * cpi

where:

– qp(zi) is the peak velocity calculated before each wind direction
– cpi is the pressure coefficient for the external pressure
The internal pressure cpi depends on the size and distribution of the openings in the

building envelope. For buildings without a dominant face, the internal pressure coefficient cpi should be determined from Figure 5-5 and it is a function of the ratio of the height and the depth of the building, h/d, and the opening ratio μ for each wind direction θ.

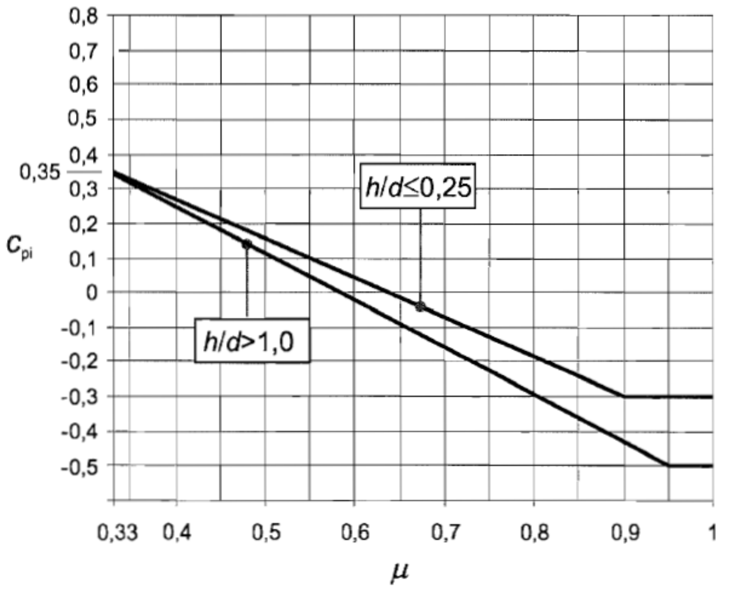


Figure 7-5 Internal pressure coefficients for uniformly distributed openings. Source: EN 1991.1.4

The following table Table 7-13 shows the internal pressure on the internal wall surfaces for the two wind directions, where h/d equals to 0.44 for 0o wind direction and 0.55 for 180o wind direction.

Table 7-13 Internal wind actions

Wind Direction	μ	$q_p(z_i)$ N/m²	c_{pi}	w_i N/m²	w_i kN/m²
0°	0.50	2120.64	0.15	318.1	0.32
180°	0.50	2166.0	0.15	324.9	0.32

The wind pressure acting on the external surfaces, we, can be obtain by the following expression [Expression 5.1-EC1-1-4]
We = qp(ze).Cpe

Where:
Ze is the reference height for the external pressure;
Cpe is the pressure coefficient for the external pressure;

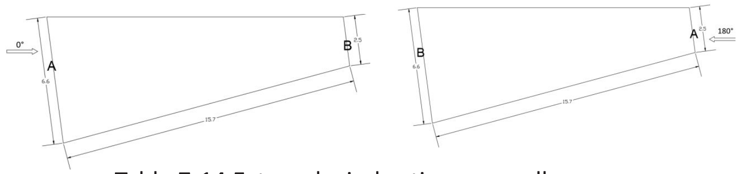


Table 7-14 External wind actions on walls

Wind Direction	Zone	c_{pe}	$q_p(z_i)$ N/m²	w_e N/m²	w_e kN/m²
0°	A	+0.75	2120.64	1590.48	1.59
	B	-0.4	2120.64	-848.26	-0.85
180°	A	+0.75	2166.0	1624.5	1.62
	B	-0.4	2166.0	-866.4	-0.87

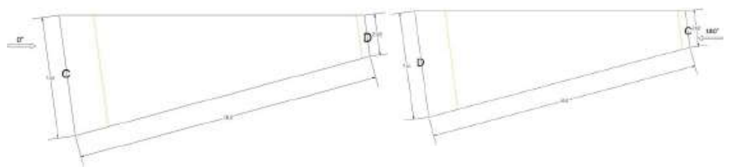


Table 7-15 External wind actions on roof surface

Wind Direction	Zone	c_{pe}	$q_p(z_i)$ N/m²	w_e N/m²	w_e kN/m²
0°	C	-1.2	2120.64	-2544.77	-2.54
	D	-0.6	2120.64	-1272.38	-1.27
180°	C	-1.3	2166.0	-2815.8	-2.82
	D	-0.8	2166.0	-1732.8	-1.73

The wind force

Fw acting on a structure or a structural element may be determined by vectorial summation of the forces acting on their reference surfaces [Expression 5.5-EC1-1-4]:

Fw = Cs Cd Si Wei Ai

where the structural factor Cs Cd (separated into a size factor Cs and a dynamic factor Cd) is taken as 1.0 as recommended;
Ai - reference area perpendicular to wind direction:

For roof: 4.82m * 0.68m = 3.28 m2
For Walls: 4.82m * 6.28m = 30.27 m2
Roof)
For 0°:
WW: Fw = 1.0 x 1.0 x 1.7 x 3.28/18.2 = 0.31 kN/m
LW: Fw = 1.0 x 1.0 x (-1.06) x 3.28/18.2 = -0.19 kN/m

For 180°:
WW: Fw = 1.0 x 1.0 x 1.73 x 3.28/18.2 = 0.31 kN/m

LW: Fw = 1.0 x 1.0 x (-1.08) x 3.28/18.2 = -0.19 kN/m

7.2.4 Load combinations

According to EN 1990, Eurocode: Basis of Structural Design, the load combinations have been calculated. EN 1990 establishes principles and requirements for the safety, serviceability and durability of structures. It is based on the limit state concept used in conjunction with a partial factor method. In the partial factor method, partial factors are used for the basic variables to ensure that no relevant limit state has been exceeded. The load combinations in the two main limit states are the ultimate limit state and serviceability limit state. In the following parts, each one is explained in details.

Ultimate limit state

It represents the failure of the structure and its components are extreme values of actions or action effects. The following expression is the general format applied for load combination at ultimate limit state:

Fd = γgGk + γq [Qk,1+Σi >1(Ψ0,i* Qk,i)]

where:

- Gk is the characteristic value of permanent action

- Qk,1 is the characteristic value of the leading variable action in each combination

- Qk,i is the characteristic value of accompanying variable action in each combination

- γg is the safety coefficient for permanent action. The recommended value is 1.35.

- γq is the safety coefficient for variable action. The recommended value is 1.50.

- Ψ0,i is the combination factor at ultimate limit state to be determined through static considerations

- Qk,i is characteristic value of the accompanying variable action

The recommended values for Ψ factor for the buildings, applied in the calculations are listed in the following Table 6-16.

Table 7-16: Ψ factor for building

Actions	Ψ_0	Ψ_1	Ψ_2
Category C	0.7	0.7	0.6
Category H	0	0	0
Wind loads	0.6	0.2	0

Serviceability limit state

It represents criteria governing normal functional or operational use. The following expressions are the general format applied for load combination at serviceability limit state based to the frequency of the loads:

- Characteristic combination (causes permanent local damage)

$F_d = G_k + Q_{k,1} + \Sigma_{i>1}(\Psi_{0,i} * Q_{k,i})$

- Frequent combination (causes temporary local damage)

$F_d = G_k + \Psi_{1,1} Q_{k,1} + \Sigma_{i>1}(\Psi_{1,i} * Q_{k,i})$

- Quasi-permanent combination (used for long-term effects and the appearance of the structure)

$F_d = G_k + \Sigma_{i>1}(\Psi_{2,i} * Q_{k,i})$

7.3 ROOF STRUCTURE

In this part of the chapter, structural verifications of the roof concerning the multipurpose building is being presented. As shown in the Figure 7-6, the roof is composed of two metal sheet layers, two bamboo trusses, insulation layer and thatched layer. Between the trusses, there are bamboo beams to infill the gaps between the trusses and act as bracing.

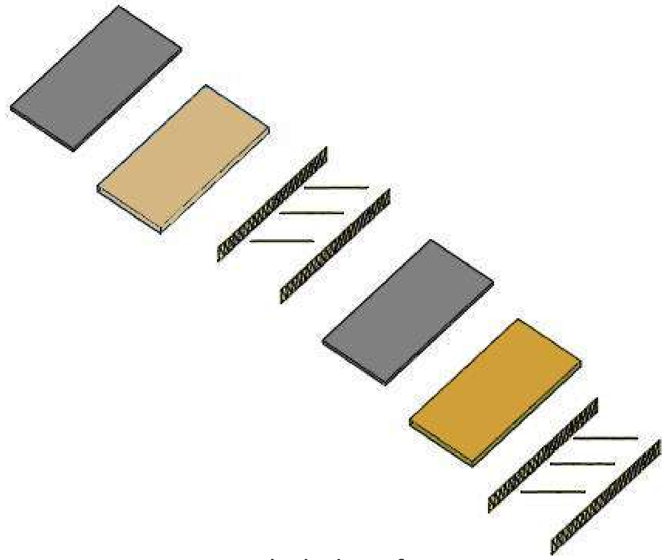


Figure 7-6 Exploded roof structure

The roof structure plan is shown in Figure 7-7. As it can be seen in this figure, the distance of bamboo beams is 75 cm from each other and 35 cm from the edge of the plan.

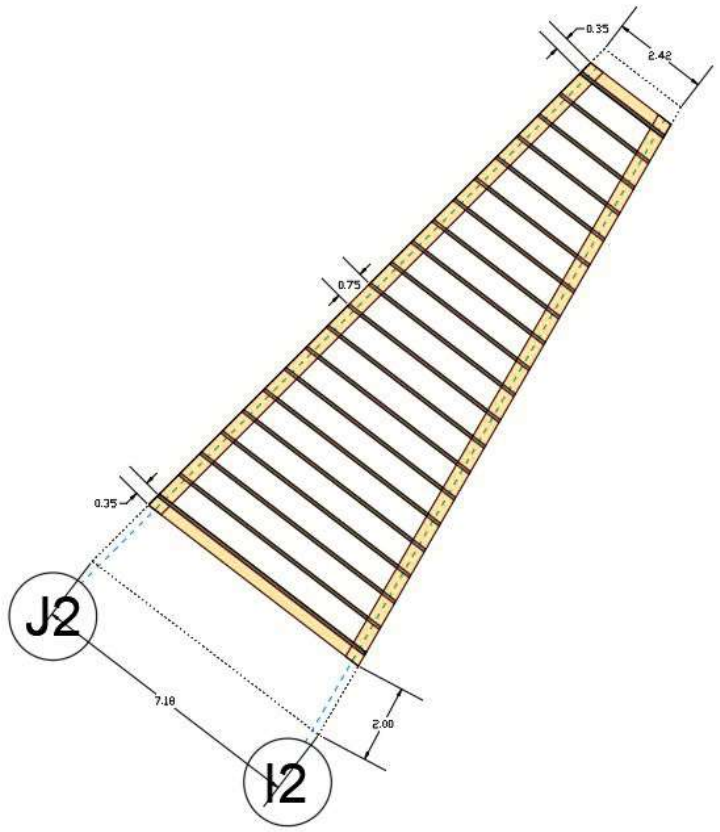


Figure 7-7 Roof Structural Plan

The cross section of the bamboo elements for structural calculations are shown in Figure 7-8. Bambusa balcooa are opted as bamboo type for this project. Outer diameter of bamboo elements is 8, 10, 12 and 16 cm for fances, bamboo beams, upper truss and lower truss, respectively.

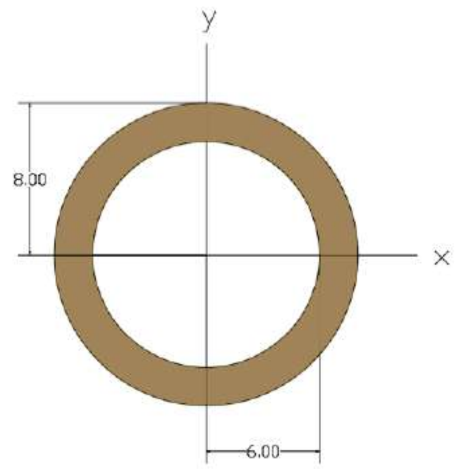


Figure 7-8 Bamboo element cross section

7.3.1 Bamboo design standards

Due to the inaccessibility of the African standards on bamboo construction, the European standards allowed us to assess the structural verifications, with the necessary precautions, following the EN 1995, Eurocode 5: design of timber structures.

To determine the resistance of structural elements, it is necessary to take into account some peculiarities of the wooden material such as:
- Load duration
- Environmental conditions

The load-duration classes are characterized by the effect of a constant load acting for a certain period of time in the life of the structure. For a variable action the appropriate class shall be determined on the basis of an estimate of the typical variation of the load with time. Hence, actions shall be assigned to one of the load duration classes given in table 2.1 of EN 1995.1.1 (2005) as shown below in the Table 7-17.

Table 7-17 Load duration classes

Load Duration Class	Order of accumulated duration of characteristic load	Examples
Permanent	More than 10 years	Self-weight
Long-term	6 months to 10 years	Storage
Medium-term	1 week to 6 months	Imposed floor load
Short-term	Less than 1 week	Snow, wind
Instantaneous		Accidental load

Moreover, to accurately define material strength values, structures shall be assigned to one of the service classes outlined in EN 1995.1.1 (2005). This enables also to correctly calculate deformations under defined environmental conditions.
Given the relative humidity, it is almost 70% most of the year, between 65% and 85%, so the structure can be assigned to class 2. In which according to EN 1995.1.1, Service class 2 is characterized by a moisture content in the materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 85 % for a few weeks per year.
Later on, some factors due to the load duration and service class would be taken into account while calculating the ULS & SLS verifications of the bamboo structure.

7.3.2 ULS load combinations

Three different load combinations have been studied:

1. Only the permanent loads and the imposed load on roof have been considered and maximized.
2. Wind loads at 0°
3. Wind loads at 180°

In the second and third load combinations, the wind loads have been considered as the leading variable action in the load combinations. Thus, the imposed load on roof has been excluded from these calculations, as recommended by EN 1991.1.1. Furthermore, this vertical load would have reduced the wind effects on the structure due to its opposite direction of action.

The dimensions of the structural scheme are as shown in Figure 7-9.

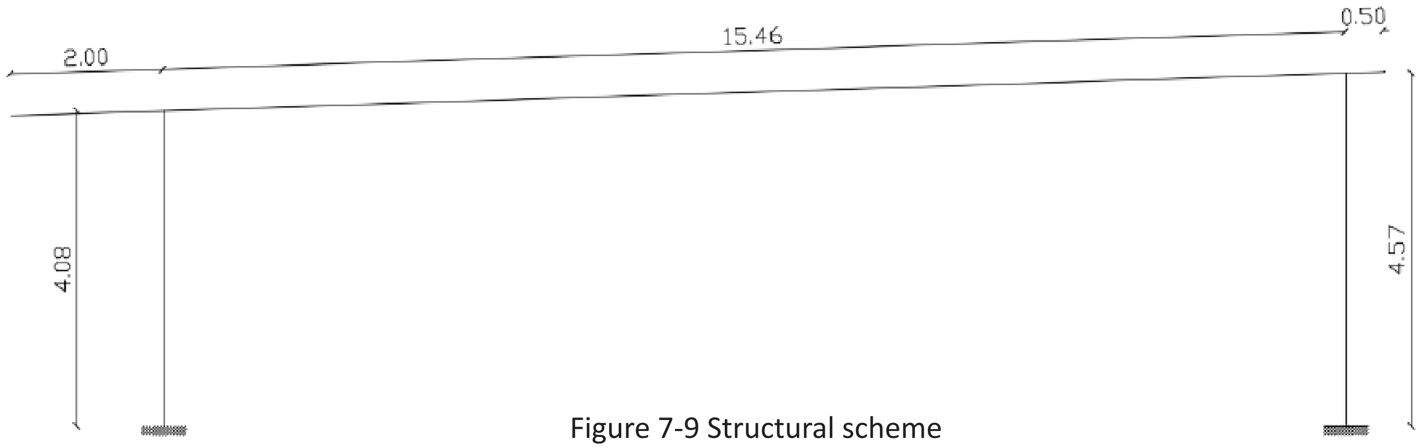


Figure 7-9 Structural scheme

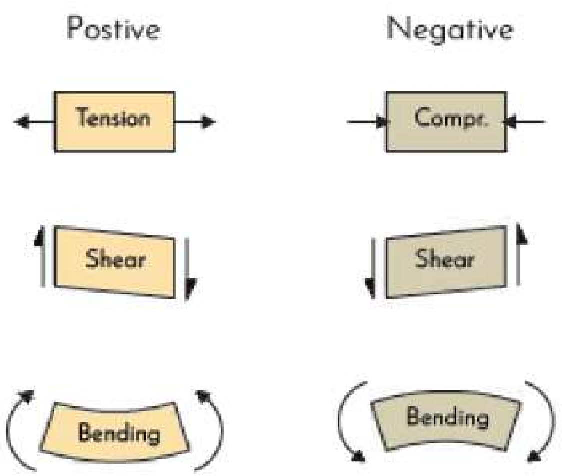


Figure 7-10 Sign convention

Table 7-18 ULS First Combination

Parameters	Permanent Load (G_1+G_2)	Variable Load (Q) – Category H
γ_g	1.35	-
Load (kN/m)	3.37	-
γ_q	-	1.5
Load (kN/m)	-	1.84

$F_d = \gamma_g (G_1 + G_2) + \gamma_q * Q_{cat,H} = 1.35*(3.37) + 1.5*(1.84) = 7.31$ kN/m

Table 7-19 ULS Second Combination

Parameters	Permanent Load (G_1+G_2)	$Q_{wind,0°}$
γ_g	1.35	-
Load (kN/m)	3.37	-
γ_q	-	1.5
Load (kN/m)	-	0.31

$F_d = \gamma_g (G_1 + G_2) + \gamma_q * Q_{cat,H} = 1.35*(3.37) + 1.5*(0.31) = 5.01$ kN/m

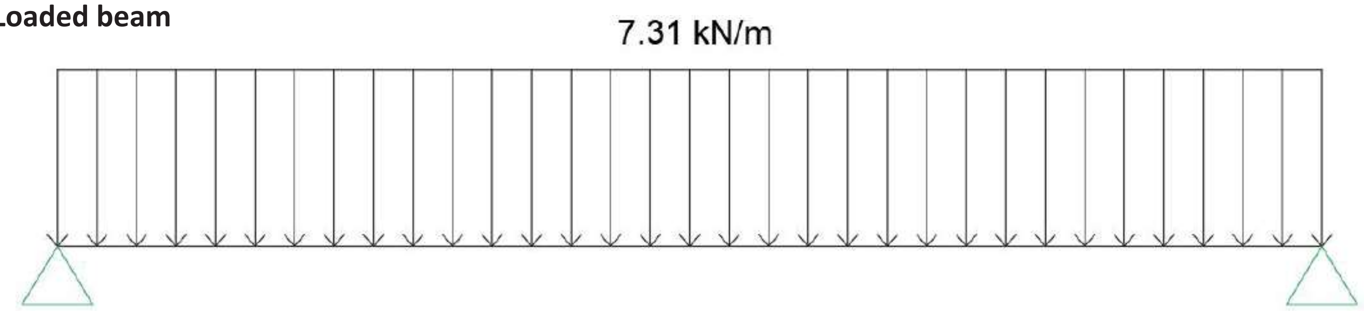
Table 7-20 ULS Third Combination

Parameters	Permanent Load (G_1+G_2)	$Q_{wind,180°}$
γ_g	1.35	-
Load (kN/m)	3.37	-
γ_q	-	1.5
Load (kN/m)	-	-0.19

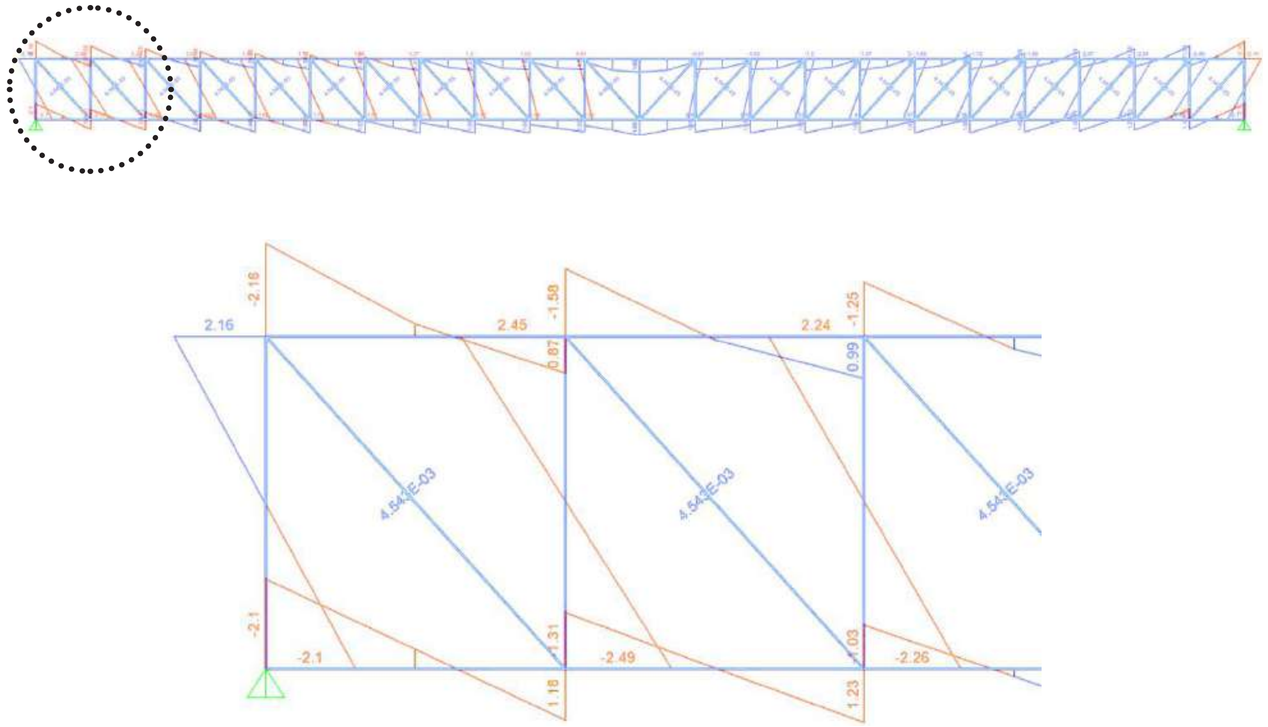
$F_d = \gamma_g (G_1 + G_2) + \gamma_q * Q_{cat,H} = 1.35*(3.37) + 1.5*(-0.19) = 4.77$ kN/m

According to the obtained values for Fd from above equations, it can be concluded that the first combination is the most critical one and if the structure can endure this load, it can endure the other combinations. Thus, just the first combination has been opted for calculations.

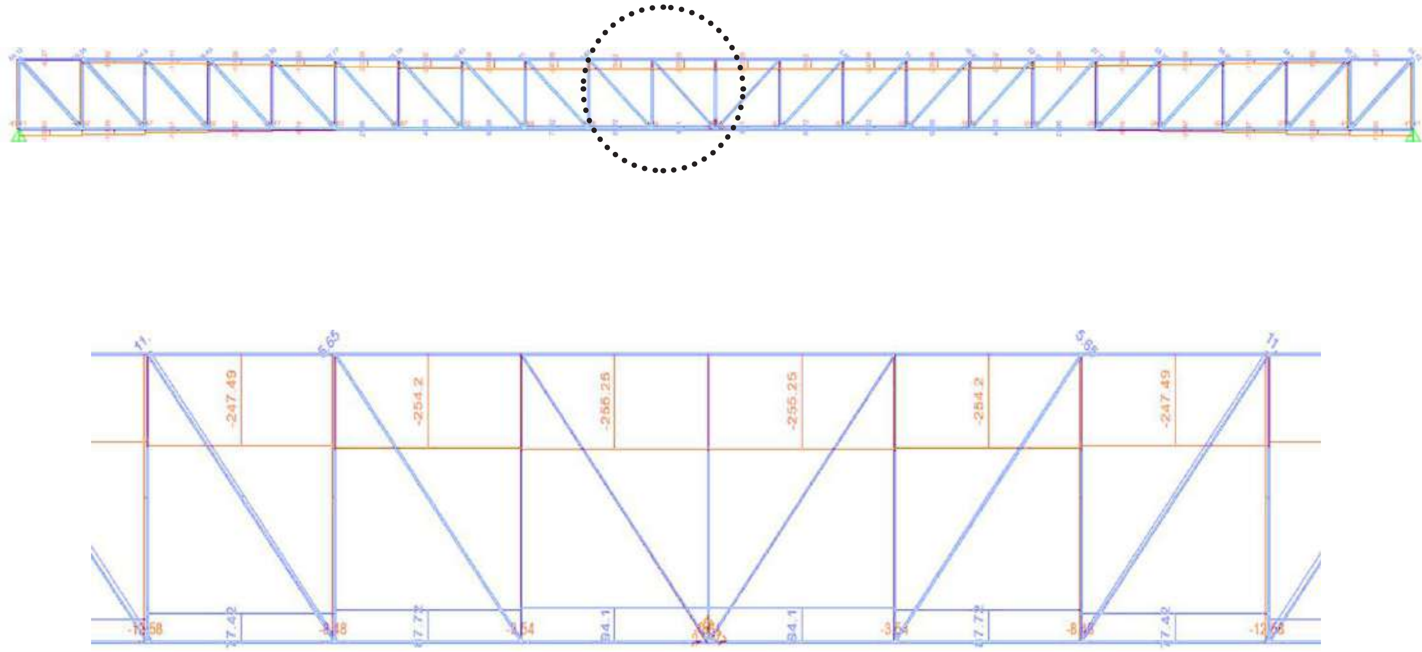
Loaded beam



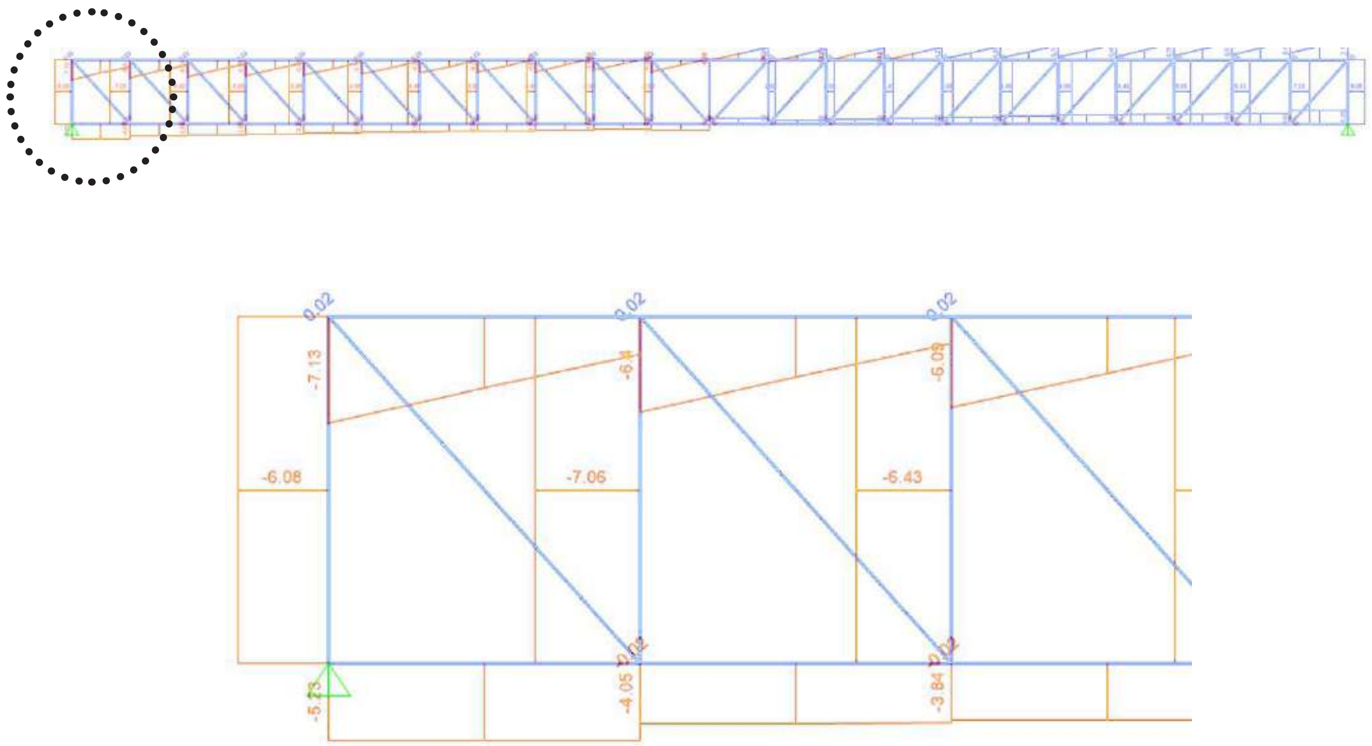
Bending moment diagram (kn.m)



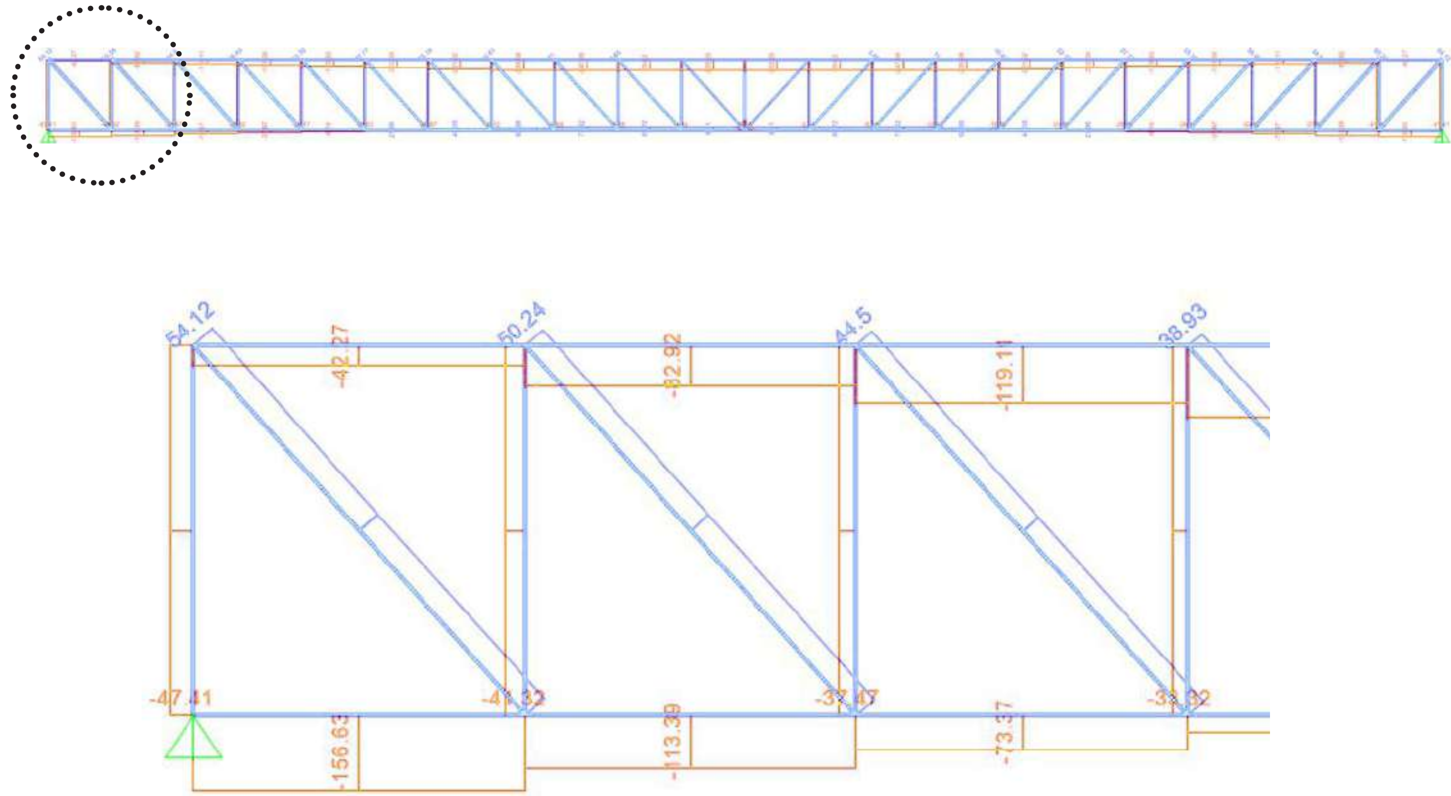
Axial Tension Diagram (kN)



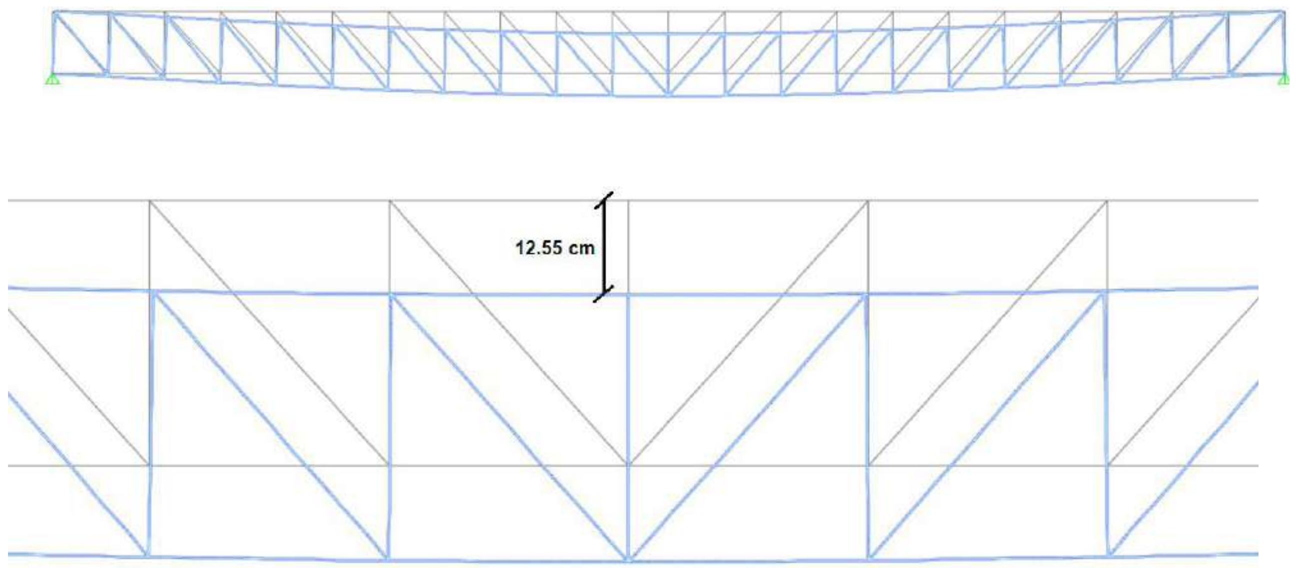
Shear force diagram (kn)



Axial Compression Diagram (kN)



Deformation Diagram



7.3.3 ULS basic variables

Bamboo has a nature form comprising a cylindrical pole with jointed stem known as a culm. There are over 1500 identified bamboo species in the world. As one of the fastest growing plants, bamboo can reach a full height ranging from 15-30m in a period of two to four months. All bamboo species has a similar anatomy, which consists of nodes, internodes, and diaphragm as shown in Figure 1. Each species can be identified according to their root system, in which there are three known root systems including, sympodial, monopodial, and amphodial. The thickness of a bamboo decreases along the height of the culm, while the fibers density increases from the bamboo culm's inner wall to outer wall [1].

In this project, bambusa balcooa is chosen as the bamboo type. The mechanical characteristic properties of bambusa balcooa is as shown in Table 7-21 below.

Table 7-21 Mechanical characteristic properties of bambusa

Characteristic Strength Properties	Symbol	Value (N/mm²)
Bending	$f_{m,k}$	85
Shear	$f_{v,k}$	11
Compression Parallel	$f_{c,0,k}$	80
Tension Parallel	$f_{t,0,k}$	206
Density	ρ	750 kg/m³

To verify the ULS, the applied stresses have to be equal or less than the design strength properties of the section. The design value Xd of a strength property to be used in ultimate limit states verifications shall be calculated as:

Xd = kmod * (Xk / γM)

where:

- Xk is the characteristic value of a strength property

- γM is the partial factor for a material property. For solid timber, the recommended value is 1.3

- kmod is the modification factor taking into account the effect of the duration of load and moisture content for ultimate limit states analysis. For solid timber assigned to service class 2, the recommended values are as shown in the following Table 7-22, according to EN 1995.1.1:

Table 7-22 kmod valuesbalcooa

Load Duration Class	K_{mod} value
Permanent	0.60
Long-term	0.70
Medium-term	0.80
Short-term	0.90
Instantaneous	1.10

The self-weight has been considered as a permanent load, while the wind loads has been considered as a short-term load duration. Accordingly, the design values to be used in the ultimate limit state verifications would be as shown in Table 7-23.

Table 7-23 Design strength values

	Bending strength, $f_{m,d}$ (N/mm²)	Shear strength, $f_{v,d}$ (N/mm²)	Compression Parallel strength, $f_{c,0,d}$ (N/mm²)	Tension Parallel strength, $f_{t,0,d}$ (N/mm²)
Permanent load K_{mod}=0.6	39.23	5.08	36.92	95.08
Short-term load K_{mod}=0.9	58.85	7.62	55.38	142.62

7.3.4 ULS verification of roof

This is a flexural member, in which bending is the most critical criterion for medium-span beams. In the following verifications, it has been verified the ULS combination for bending of roof, axial compression and tension of bamboo beam, and shear.

Bending Verification

σm,d = Mmax/Wxx

σm,d ≤ fm,d

Table 7-23 Design strength values

	M_{max} (N.mm)	W_{xx} (mm^3)	$\sigma_{m,d}$ (N/mm^2)	$f_{m,d}$ (N/mm^2)	Check $\sigma_{m,d}/f_{m,d} < 1$
ULS combination	$2.16*10^6$	$2.36*10^5$	9.15	39.23	0.23 < 1 Satisfied

Table 7-24 Bending verification of bamboo roof at ULS

	$N_{c,max}$ (N)	Area (mm^2)	$\sigma_{c,0,d}$ (N/mm^2)	$f_{c,0,d}$ (N/mm^2)	Check $\sigma_{c,0,d}/f_{c,0,d} < 1$
ULS combination	$156.63*10^3$	$8.17*10^3$	19.17	36.92	0.52 < 1 Satisfied

Table 7-25 Axial Compression verification of bamboo beam at ULS

	$N_{t,max}$ (N)	Area (mm^2)	$\sigma_{t,0,d}$ (N/mm^2)	$f_{t,0,d}$ (N/mm^2)	Check $\sigma_{t,0,d}/f_{t,0,d} < 1$
ULS combination	$255.25*10^3$	$8.17*10^3$	31.24	95.08	0.33 < 1 Satisfied

Table 7-26 Axial Tension verification of timber beam at ULS

	$N_{t,max}$ (N)	Area (mm^2)	$\sigma_{t,0,d}$ (N/mm^2)	$f_{t,0,d}$ (N/mm^2)	Check $\sigma_{t,0,d}/f_{t,0,d} < 1$
ULS combination	$255.25*10^3$	$8.17*10^3$	31.24	95.08	0.33 < 1 Satisfied

Table 7-27 Shear verification of beam at ULS

	V_{max} (N)	Area (mm^2)	$T_{v,d}$ (N/mm^2)	$f_{v,d}$ (N/mm^2)	Check $T_{v,d}/f_{v,d} < 1$
ULS combination	$7.13*10^3$	$8.17*10^3$	1.31	5.08	0.26 < 1 Satisfied

7.3.6 SLS basic variable

The deformation of a structure which results from the effects of actions and from moisture shall remain within appropriate limits, having regard to the possibility of damage to surfacing materials, ceilings, floors, partitions and finishes, and to the functional needs as well as any appearance requirements.
Wood's rheological characteristics play an important role in the overall deformation behavior of an element: it shows an initial elastic behavior that soon, under constant loads, evolves into a viscos-elastic one. This leads the deformation to increase over time. Hence, both the instantaneous and delayed deformations have to be considered to evaluate the final deformation of an element. It is important to specify that the delayed deformation can be calculated as a function of the instantaneous one. According to EN 1995.1.1 (2004), the final deformation µfin of a structure may be taken as:

µfin = µfin,G + µfin,Q1 + Σ µfin,Qi

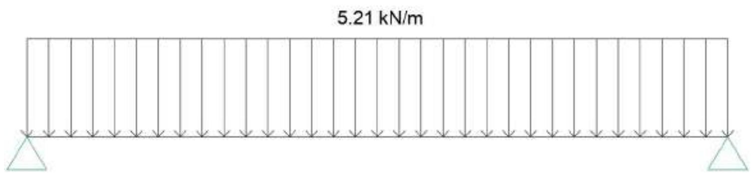
where:

- µfin,G, µfin,Q1, µfin,Qi are the final deformations for permanent actions, leading variable action and accompanying variable action:
µfin,G = µinst.,G (1+kdef)
µfin,Q1 = µinst.,Q,1 (1+ψ2,1 kdef)
µfin,Q,i = µinst.,Q,i (1+ψ2,i kdef)
- kdef is the modification factor taking into account the effect of the duration of load and moisture content. For solid timber assigned to service class 2, the recommended value is 0.80.
The instantaneous deformation, µinst. should be calculated from the characteristic combination of actions as the following:

$$F_d = \sum_{j\geq1} G_{k,j} + Q_{k,1} + \sum_{i\geq1} \Psi_{0,1} * Q_{k,i}$$

7.3.7 SLS load combinations

For the desired load combination to find the deformation, distribution loads would be as follow



Fd = (G1 + G2) + Qcat,H = 5.21 kN/m:

7.3.8 SLS verification of beam

The permanent actions occur during the construction process, therefore, only the variable actions need to be considered in the serviceability verification for the functioning of the structure. According to the following figure, the maximum deformation obtained in software is 4.9 cm which is occurred in the middle part of the bamboo roof.

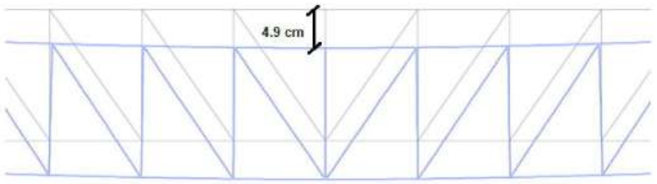


Figure 7-11 Maximum obtained deformation

According to EN 1995.1.1, there is a maximum deformation based on the span that shall not be passed as shown in Table 7-28:

Table 7-28 Maximum deformations for SLS

Check	Deformation between two supports L/200	Obtained deformation by software	Check
$\mu_{inst,max}$	15400 / 200 = 77 mm	49 mm	49 < 77 Satisfied

So, the final deformation does not pass the limit as shown in the above table.

7.4 COMPRESSED STABILIZED EARTH BLOCKS

Generally, walls are designed to resist the compressive forces due to the load being carried above with or without eccentricities, and to resist any short-term variable loads such as wind and earthquake loads.
For this project, the structural design verifications of the bearing walls have been assessed according to New Zealand Standard Codes (NZS 4297:1998) and (NZS 4299:1998) and African Standard Codes (ARS 1333:2018(E)). The standards guide the testing procedures of the samples, the structural design and durability of earth buildings with regards to ultimate limit and serviceability state and sets the minimum limitations to follow.

Table 7-29 Considerations about CSEB

Production	Building blocks made by a mixture of soil with a portion of cement and/or lime added as a stabilizer
Openings	Care should be taken with the structural bonding of frame openings with CEB walls in order to limit the danger of cracking which could lead to water infiltration and therefore a process of erosion.
Floors	Compressed earth blocks allow floors to be made using the building principle of jack-arches on concrete or wooden beams, or even on steel.
Interlocking block principles	The interlocking blocks have tongues and grooves on the top and bottom surfaces of the blocks respectively to restrain horizontal movement when laying interlocking block on top of one another without the use of mortar joints
Reinforcement	The building systems exploited use the principle of a wooden or steel ring-beam sunk into the walls, and also reinforcement of the corners of walls and opening frames.

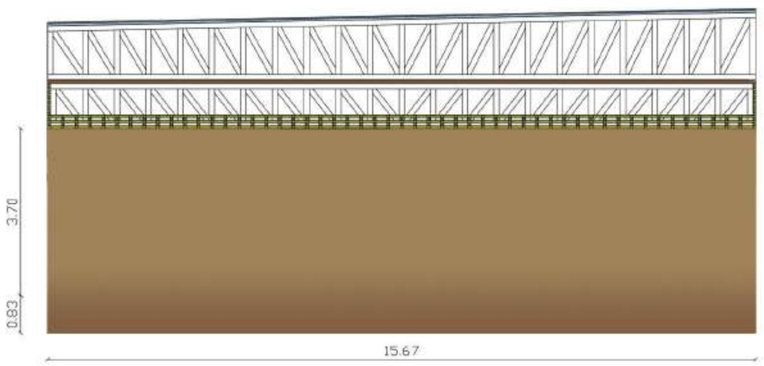


Figure 7-11 Maximum obtained deformation

7.4.1 ULS basic variables

For the design strengths of the load bearing wall, (NZS 4297:1998) specifies the values as shown in the Table 6-30 for the standard grade earth wall, if the samples fulfill the tests requirements of the code. These values are reduced compared to the results obtained from the laboratory tests for aspect ratio, characteristic strength, and mortar effects.

Table 7-30 Design strengths of compressed stabilized earth blocks – Class A

Properties	Strength
Dry Compressive strength @28days, MPa	4
Dry bending/flexural strength/rapture modulus @28days, MPa	0.5
Dry shear strength @28days, MPa	0.08
Density, kg/m^3	2000
Poisson's ratio	0.15
Modulus of elasticity, MPa	900

The design strength of a member or cross section in terms of load, moment, shear, or stress shall be taken as the nominal strength, Sn, calculated in accordance with the requirements and assumptions of this Standard, multiplied by a capacity reduction factor, Φ, which is shown below in. The design strength of a member or cross section shall be equal to or greater than the applied action, S*, where S is replaced by the actions of moment, axial force, shear or torsion as appropriate.

$$S^* \leq \Phi \,.\, Sn$$

Table 7-31 Capacity reduction factor

Strengths	Φ
Axial compression and bearing	0.6
Flexure	0.8
Shear	0.7
Metal connections embedded in earth	0.7

7.4.2 ULS verification

Uniaxial Bending & Compression
A compressed stabilized earth blocks wall shall be designed to resist axial compression at the bottom of the wall such that the following relationship is satisfied:

$$N^* \leq k.\Phi.N0$$

where: 69.53
- N0 = fe.Ab
- k is a reduction factor depending on the slenderness and eccentricity, k = 0.78

Table 7-32 Compression strength variables at ULS

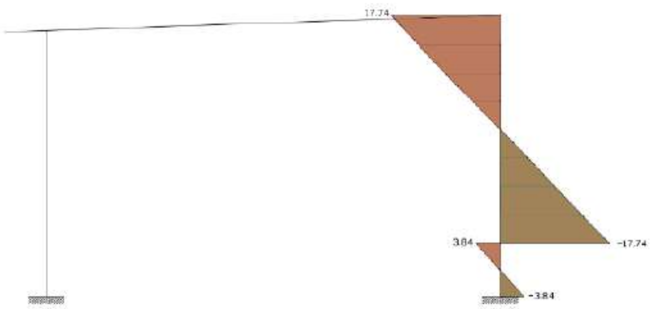
f_e (N/mm²)	Area (mm²)	N_0 (kN)	Φ	k	$k.\Phi.N_0$ (kN)
4	$4.0*10^5$	1600	0.6	0.78	748.8

compressed stabilized earth blocks is carrying the roof layers, lower and upper trusses, bamboo beams, bamboo walls, CSEB slab, CSEB wall and wall finishing layers.
The density of the metal sheet used is 3530 kg/m3, and the compressed stabilized earth blocks 2000kg/m3. That makes the total at the bottom of the CSEB column as shown in the Table 7-33 below.

Table 7-33 Uniaxial bending & Compression Verification at ULS

Item	Weight per 1 meter (kN)	Check $N^*/k.\Phi.N_0<1$
Roof layers	2.04	
Lower Truss	0.68	
Upper Truss	0.83	
Bamboo Beam	0.14	
Bamboo Wall (Fances)	0.15	
CSEB Slab	9.20	
CSEB Wall	36.0	
Wall Finishing	1.97	
Total (N^*)	51.01	51.01/748.8 = 0.07 < 1 Satisfied

Loaded Wall (kN/m)



Shear Force Diagram (kN)

Bending Moment Diagram (kN.m)

Horizontal bending from transient out-of-plane forces Verification

The wind loads on that sub-panel shall be equal to 1.59 kN/m2 which is wind load for 180°-degree direction. When this load is applied on the subpanel wall with width 1.0 m, it will be equal to 2.17 kN/m distributed load on the wall. This combination of roof self-weight and the wind lateral load on the wall, will cause bending moments and shear forces to rise, as shown here.

According to NZS 4297:1998, a CSEB wall shall be designed to withstand horizontal bending from out-of-plane wind loads, earthquake loads or similar forces of a short-term transient nature. The following relationship has to be satisfied under each combination of simultaneously acting design horizontal bending moment M*dh:

$$M^*_{dh} \leq M_{ch}$$

where:

- Mch = Φ . fet . Zu

-Zu = (b.t2)/6

Table 7-34 Horizontal bending verification at ULS

f_{et} (N/mm²)	Φ	Z_u (mm³)	M_{ch} (kN.m)	M^*_{dh} (kN.m)	Check $M^*_{dh} / M_{ch} < 1$
0.5	0.8	9.33×10^7	59.73	10.94	0.18 < 1 Satisfied

Shear Verification

Walls aligned in parallel to wind direction contribute to the overall stability of the structure against horizontal lateral forces transmitting these latter forces to the ground by in-plane shear. According to NZS 4297:1998, the design of an unreinforced earth wall subject to shear forces, with or without simultaneous compressive forces acting across the shear plane, shall be such that the following relationship is satisfied under each combination of simultaneously acting design shear force:

$$V^* \leq 5 \cdot \Phi \cdot f_{es} \cdot A_b$$

7.4.3 SLS verification

According to NZS 4297:1998, members subject to flexure shall be designed to have adequate stiffness to limit deflections or any deformations which may adversely affect the serviceability of the structure under service loads.

The minimum thickness in the horizontal direction, where the walls are not supporting or attached to partitions or other construction likely to be damaged by large deflections, shall not be less than the following Table 7-36 values for one end continuous walls.

Table 7-35 Shear verification at ULS

f_{es} (N/mm²)	Φ	A_b (mm²)	$5 \cdot \Phi \cdot f_{es} \cdot A_b$ (kN)	V^* (kN)	Check $V^*/V_{5\Phi f_{es} A_b} < 1$
0.08	0.7	14.0×10^5	392.0	17.74	0.05 < 1 Satisfied

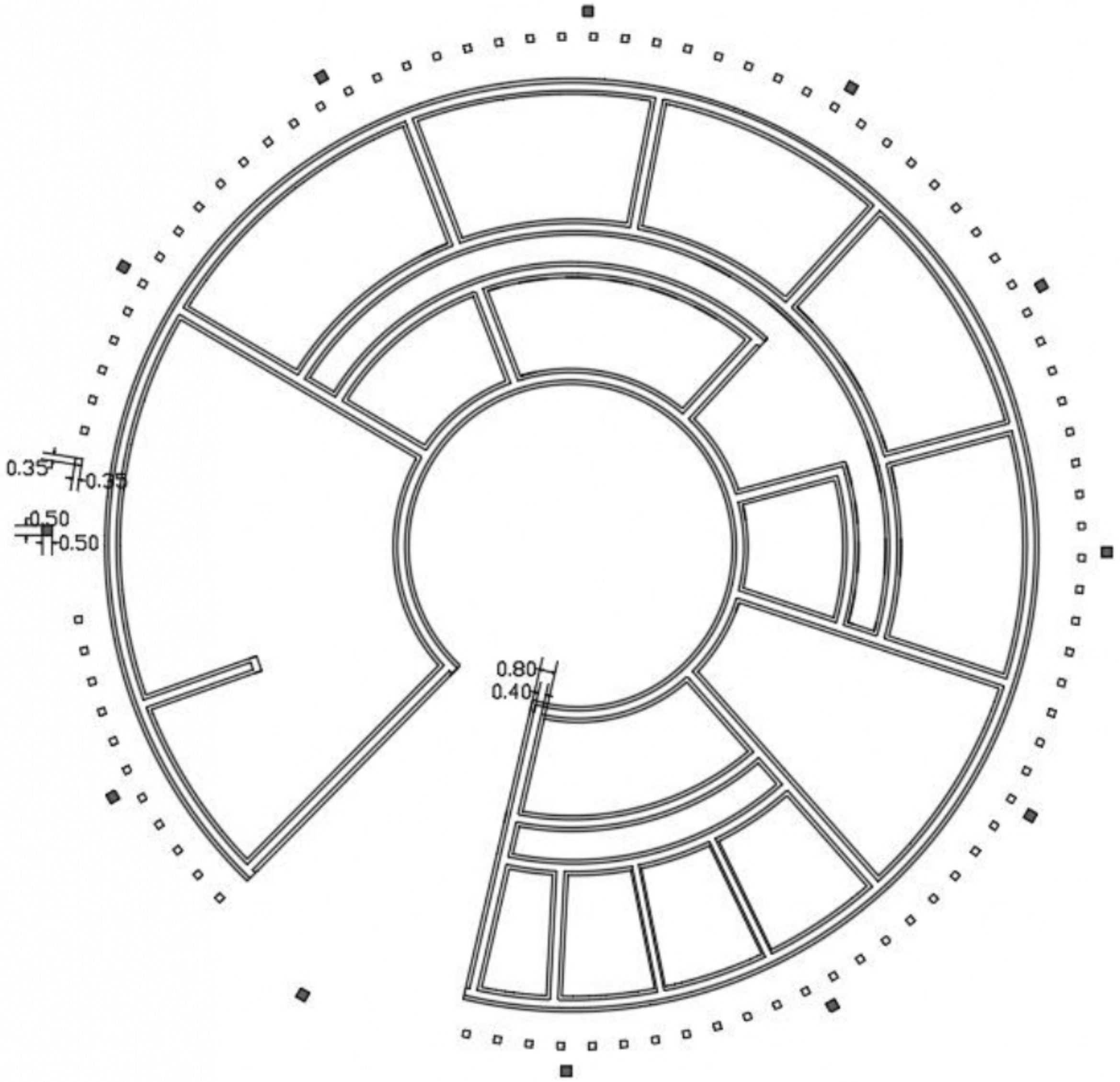
Table 7-36 Deflection Verification at SLS

Supports	Minimum Thickness (mm)	Minimum Wall Thickness (mm)
One end continuous	h/21 or L/21	3500 / 21 = 167
	Check	400 > 167 Satisfied

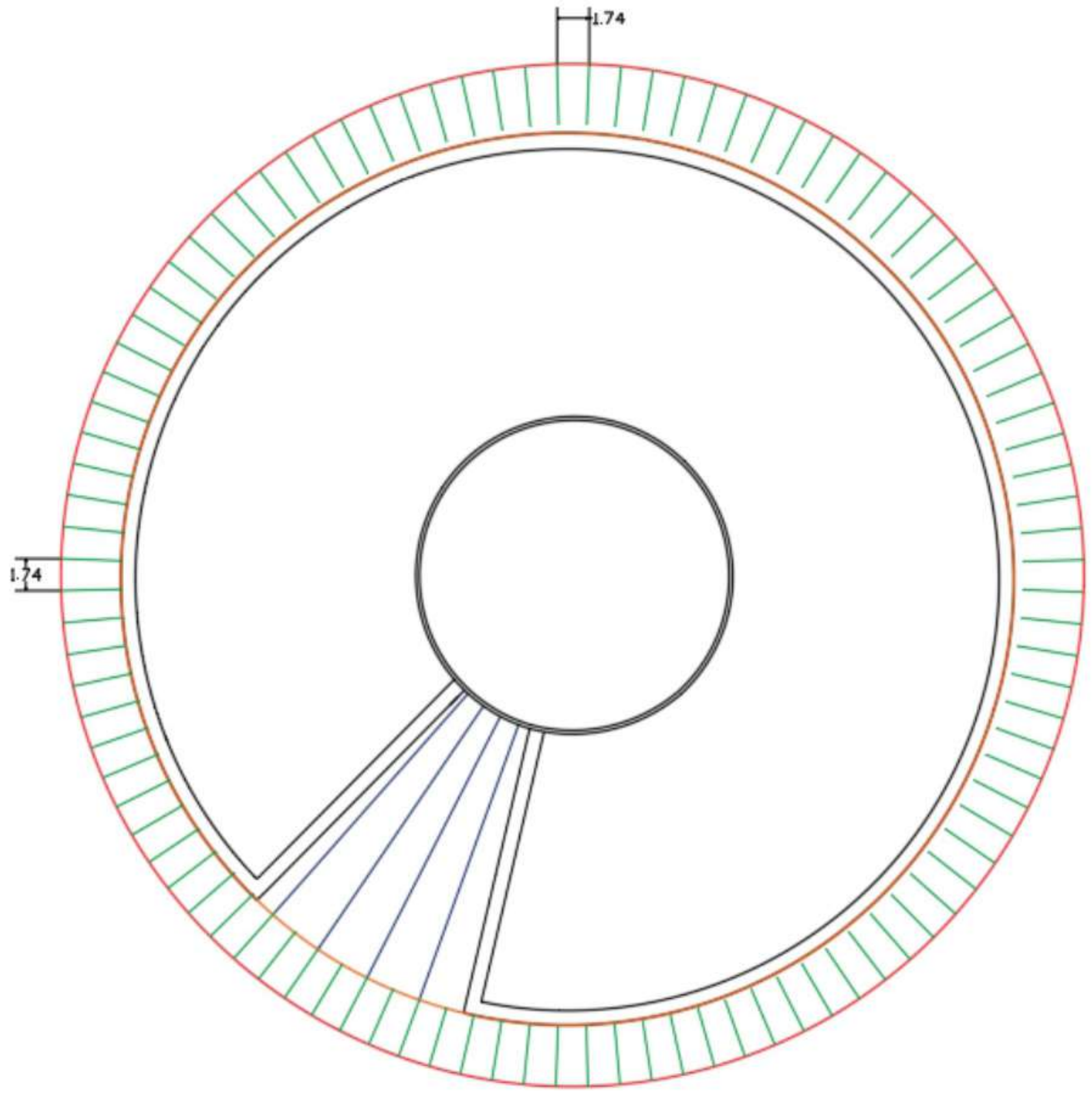
CHAPTER 8

TECHNICAL DETAILS

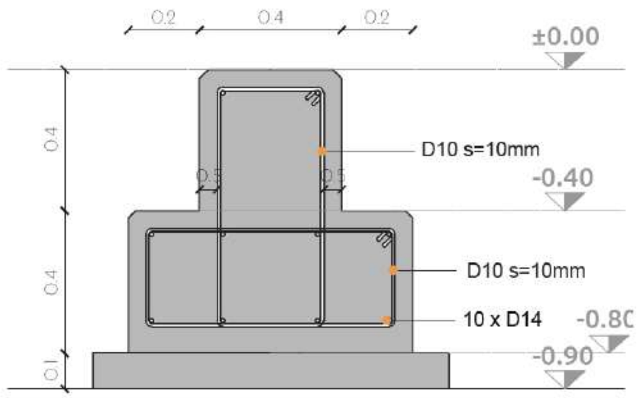
8.1 FOUNDATION STRUCTURAL DRAWING



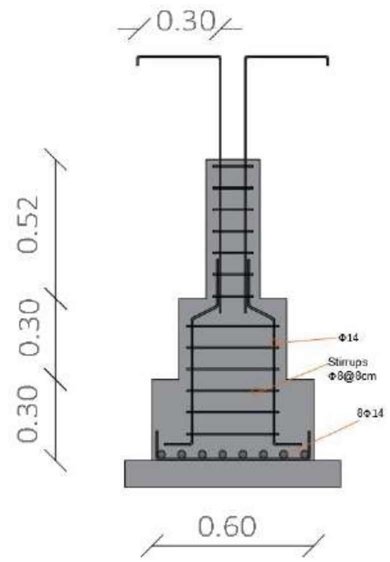
8.2 OUTDOOR COVERING STEEL STRUCTURE



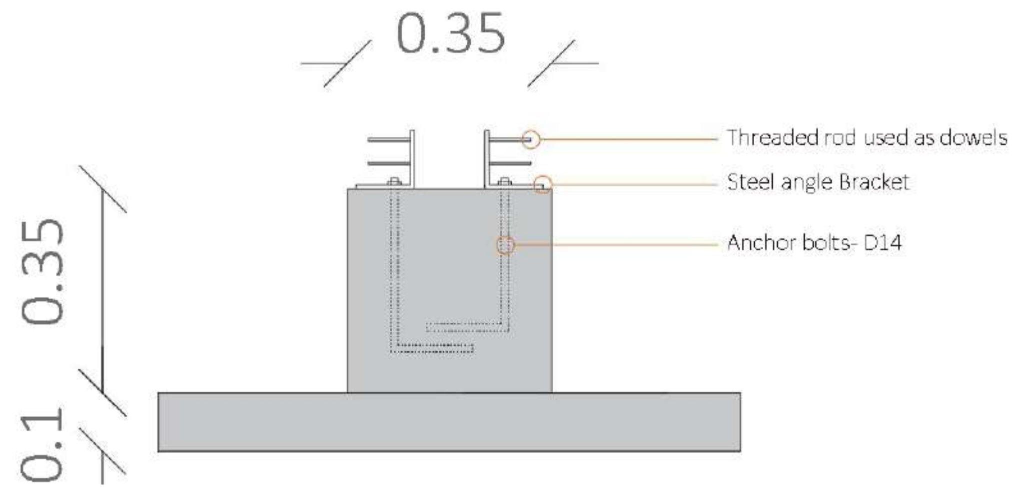
CSEB wall foundation



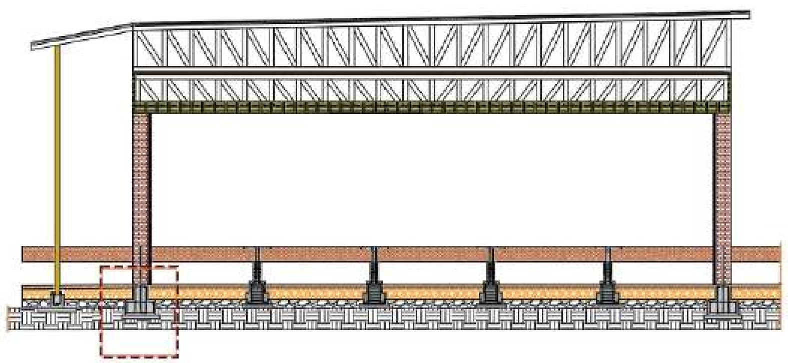
CSEB slab foundation

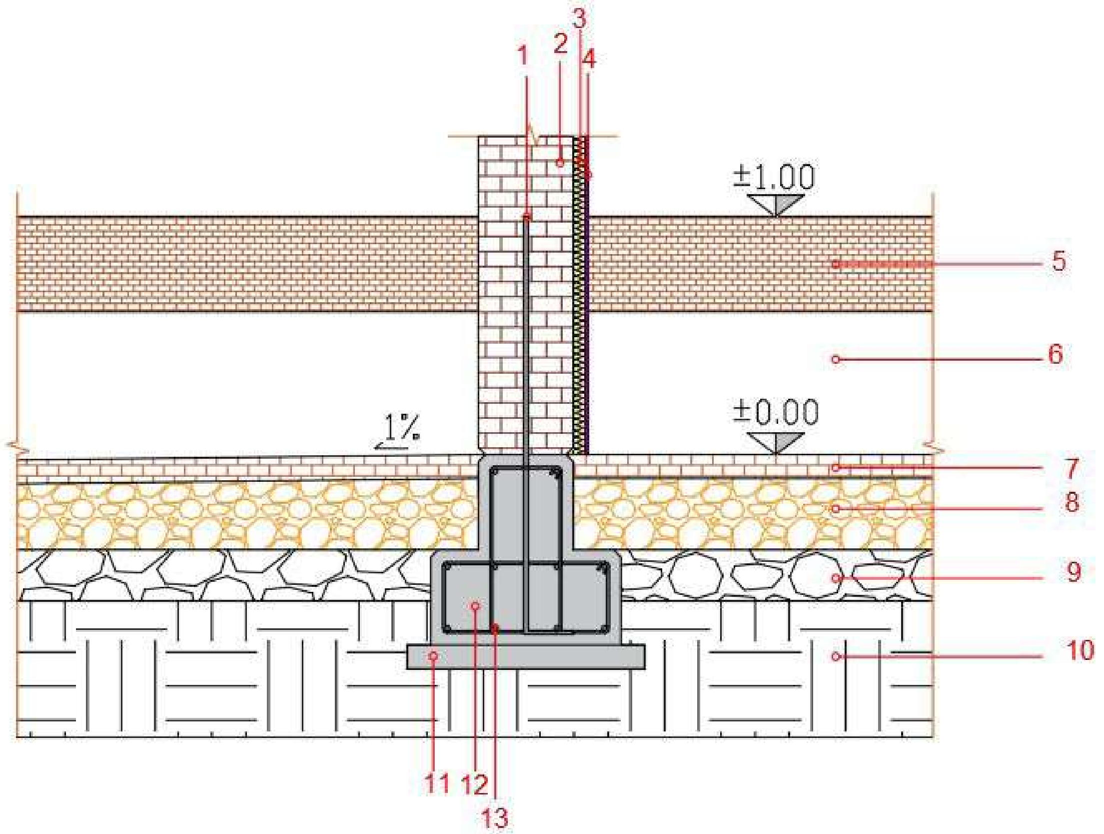


Bamboo column foundation



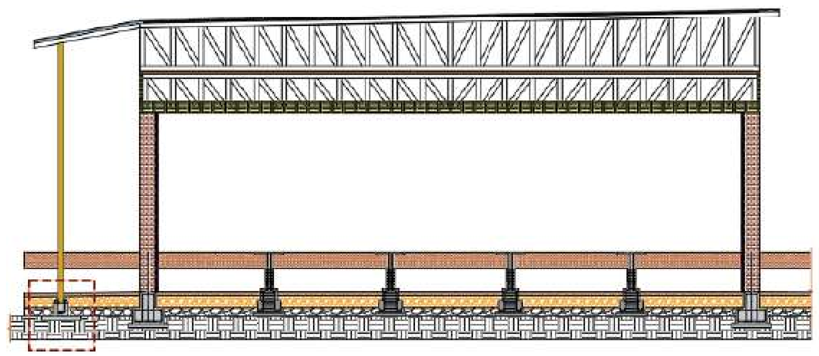
CSEB wall connection to the foundation

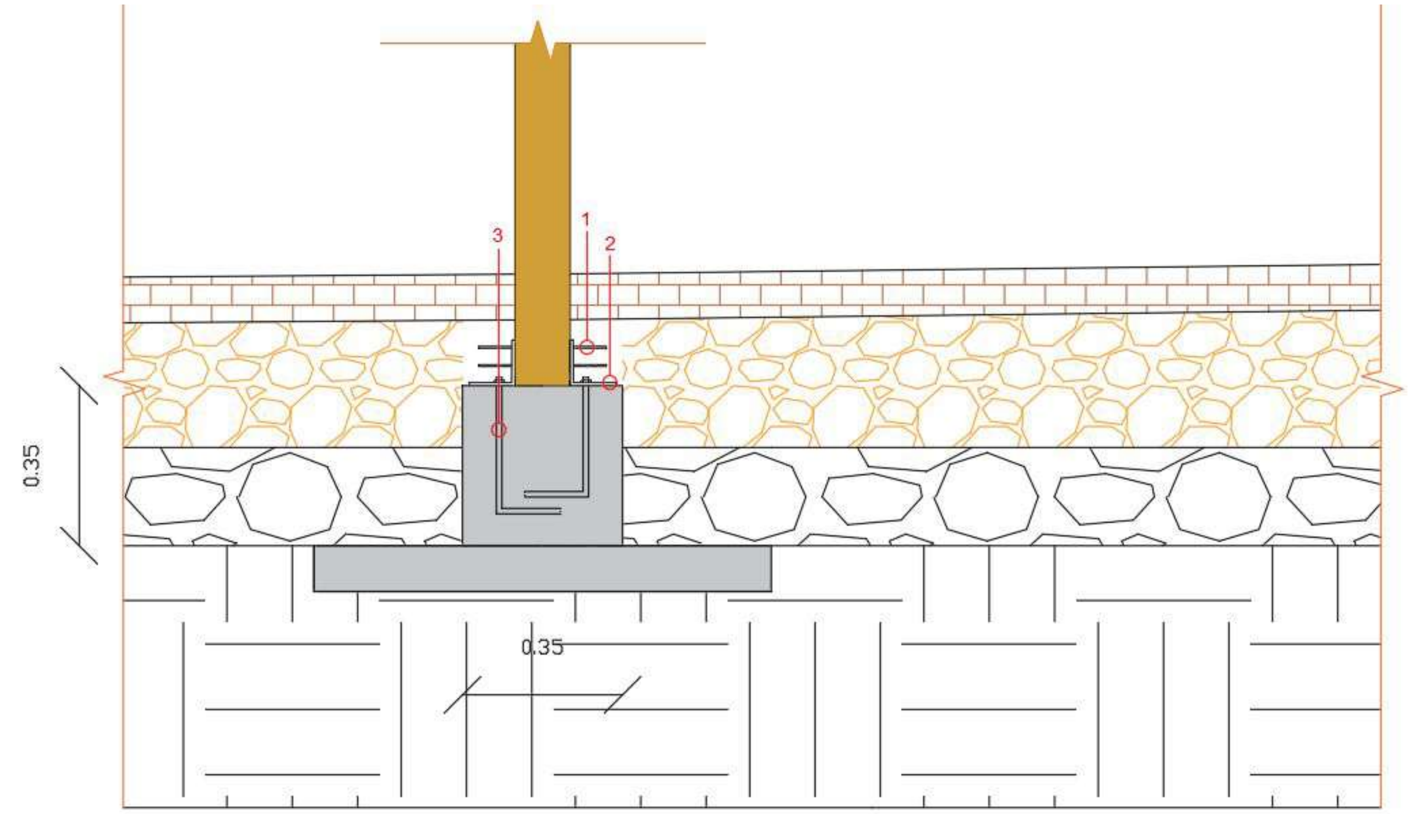




1. Vertical wall starter reinforcement extending 60 cm above the foundation- D16
2. Compressed stabilized earth blocks (CSEB) wall- thick. 40 cm
3. Insulation – thick. 5 cm
4. Plaster – thick. 1 cm
5. Compressed stabilized earth blocks (CSEB) slab – thick. 40 cm
6. Void for drainage
7. Compressed stabilized earth blocks (CSEB) – thick. 10 cm
8. Gravel substrate
9. Stone substrate
10. Ground
11. Lean concrete base – thick. 10 cm
12. Continuous inverted beam foundation – dim. 80 x 40 cm
13. RC foundation rebar 10 x D14

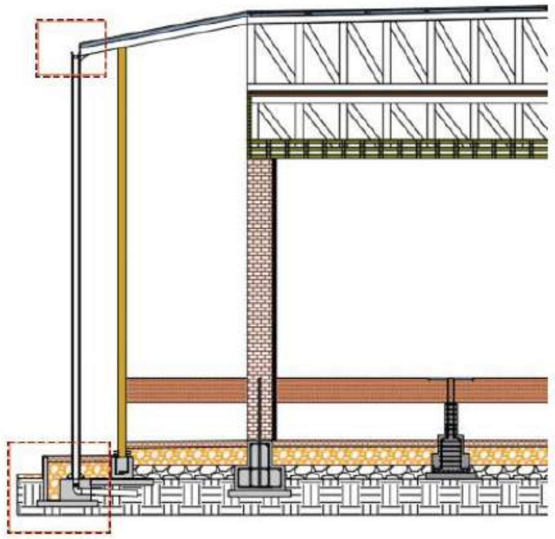
Bamboo column connection to the foundation

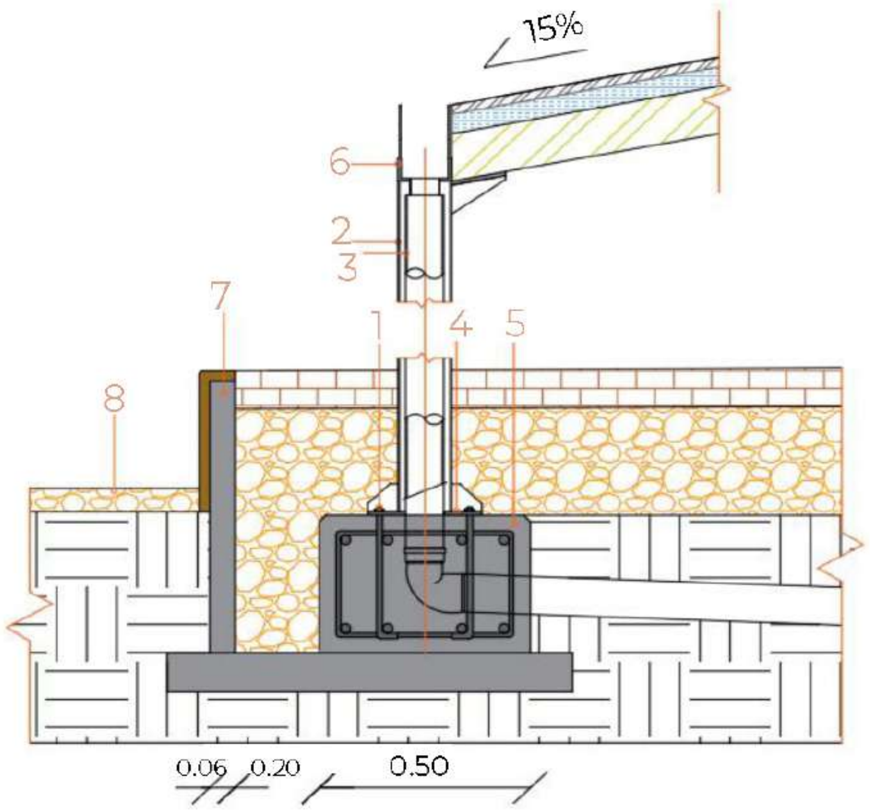




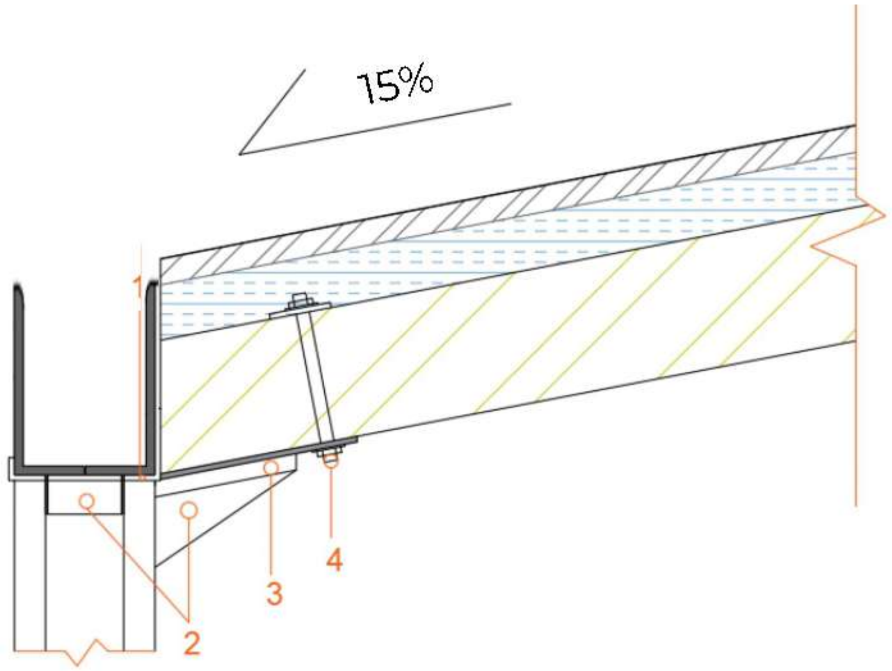
1. Threaded rod used as Dowels
2. Steel Angle Bracket
3. Anchor Bolts – D14

Outdoor covering drainage and connection to the ground

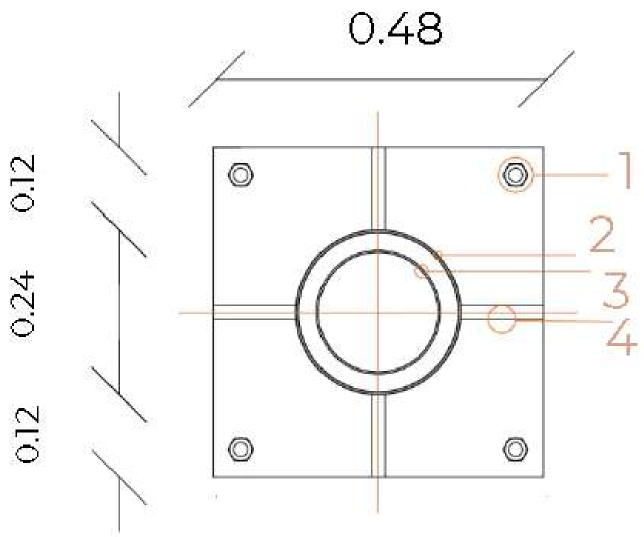




1. Hooked bolts M5 with EPDM gasket
2. Steel plate – th. 6 mm
3. Steel plate – 120 x 120 x 10 mm
4. Bolt – M12
5. Foundation bolts- M16
6. Double L profile dim. 60 x 120 mm- th. 8 mm. Welded together at the base. With separate metal gutter inside for water drainage.
7. Concrete curb
8. Local gravel

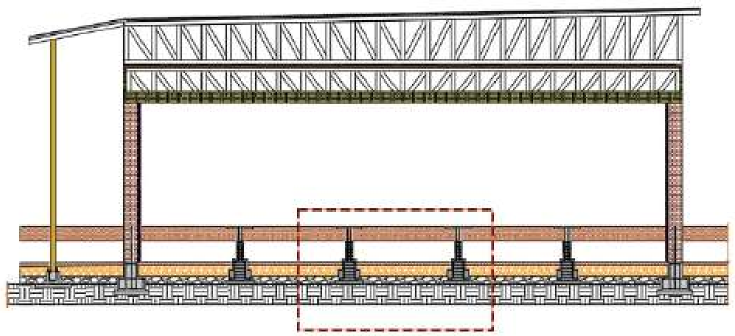


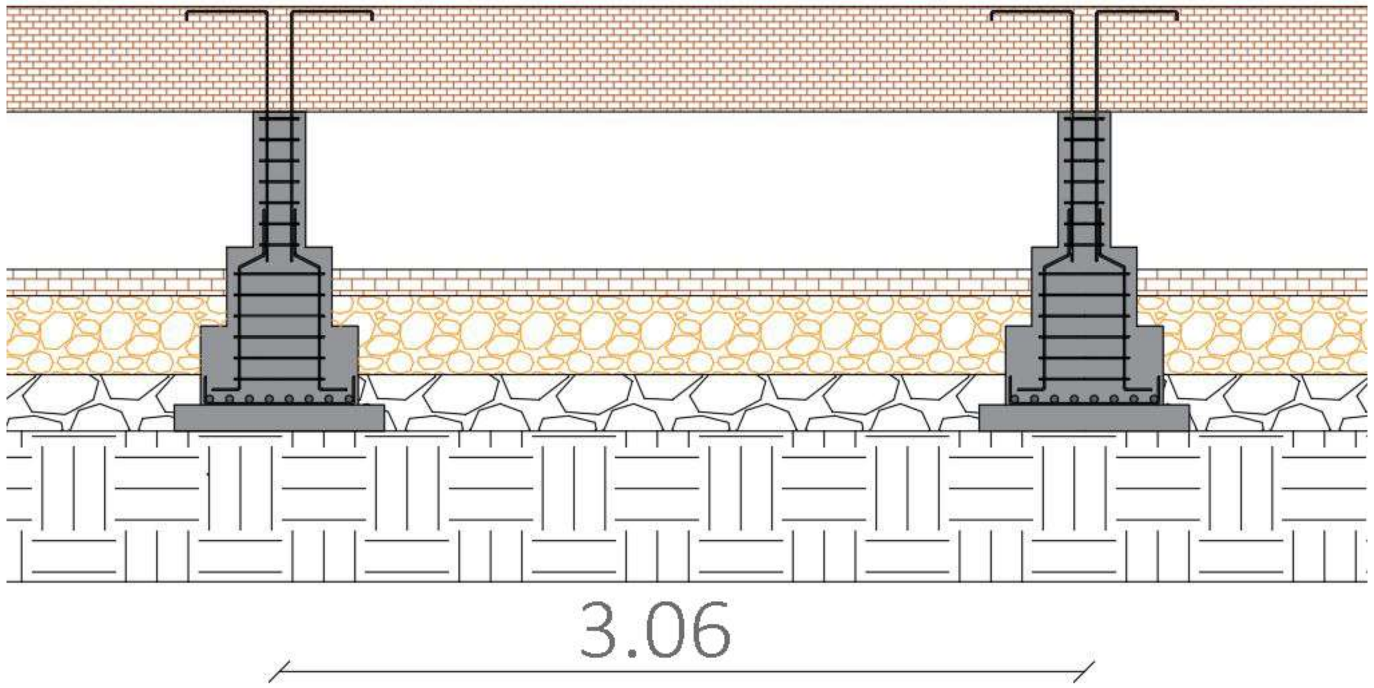
Connection plate between pillar and foundation



1. Foundation bolts- M16
2. Circular steel pipe with anti-rust paint- Ø 120 mm- th. 4 mm
3. PVC pipe for drainage- Ø 90 mm- PN6
4. Steel plate 24 x 24 cm- th. 1 cm

CSEB slab connection to the foundation





CSEB for slap

Most commonly, compressed earth block masonry is intended to support floors of standard design, with wooden beams, or precast concrete beams covered with sand-cement or fired bricks, or even load-bearing concrete floors, either shuttered in place or prefabricated and placed on reinforcements. But compressed earth blocks allow floors to be made using the building principle of jack-arches on wooden beams.From a structural point of view, a floor must withstand static loads caused by use, concentrated loads (and the danger of point-loading) and should transmit these loads down to its support in the load-bearing compressed earth block wall. These loads, through the support, should be evenly spread and directed towards the centre of gravity of the load-bearing wall.

The bonding of a floor with its support (wall or pillars) is ensured by a base which also transmits loads to the support. The main problems are as follows:

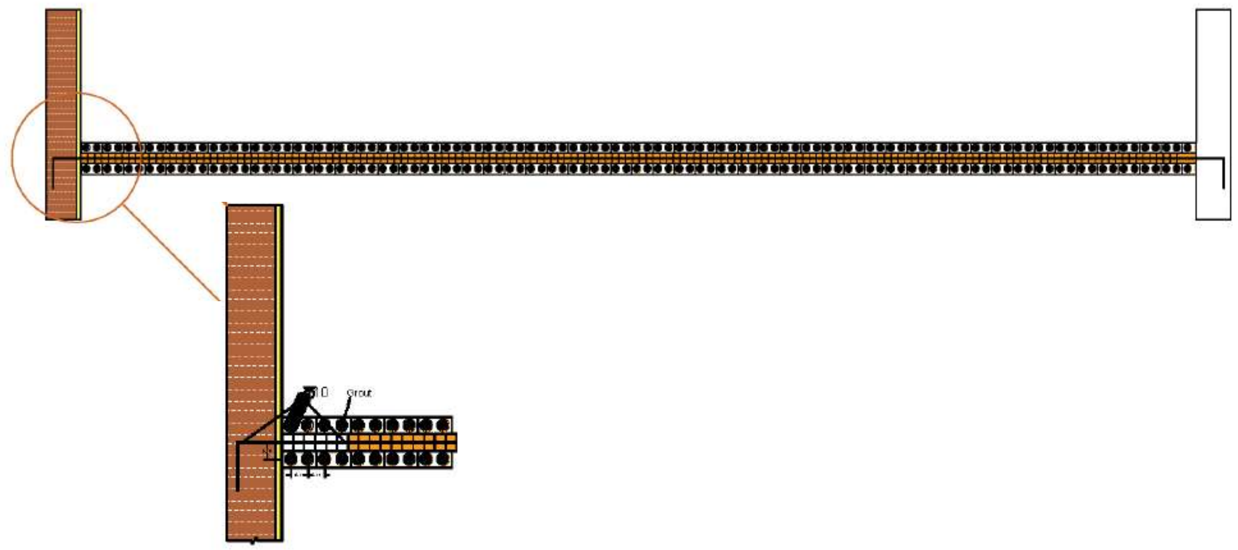
(1) Point-loading: this occurs when the base is too small and when it fails to transmit loads evenly. It takes the form of differential stresses and cracks. To avoid this risk, the surface area of the base should be increased and the loads should be brought back to the centre of gravity of the support.

(2) Rotation: this occurs when the floor flexes. One can then observe lifting, loads no longer being central, cracks and crushing of the support. To prevent rotation, the correct ratio of load to span to section must be re-established and the floor must be laid on a ring-beam.

(3) Dimensional variations: generally these have a thermal origin or result from differential flexing between the floor and its support.

(4) Thermal bridge: this arises because of the variation in hydrous and thermal behaviour of the materials of which the floor and wall are made and provokes condensation. Avoiding direct contact between the body of the floor beams and the wall, reinforcement integrated into the wall leaving an external earth block cladding, limits this risk.

CSEB slab connection to the wall



Connection of Bamboo elements to each other in Bamboo wall (Fances) - connection with bamboo strips

Friction-tight rope connections are the common connecting method.

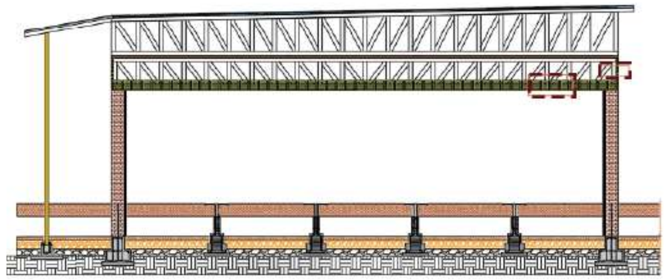
Traditionally natural materials are used:
• Cocos/sago palm fiber
• bast
• strips of bamboo
• rattan

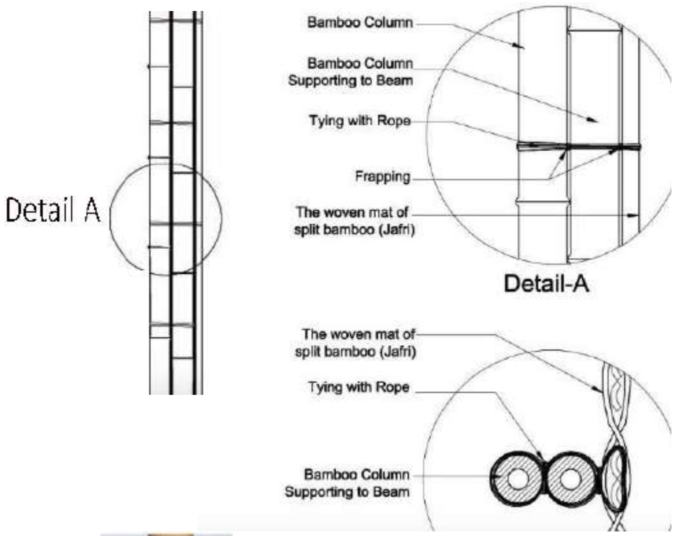
For tight connections green bamboo strips are used, the fibers are watered before tying around the bamboo.
While drying, the fibers shorten and the connection becomes stronger.

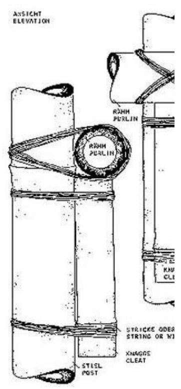
Lashing ties: The common type of connection at a joint is lashing. The ties are also of organic material and therefore provide optimal compatibility between the elements of the construction system.

Cords and ropes are made of bamboo bark, bast, coconut- or sagopalmfibres. Nowadays also plastic cords are used. Bamboo ropes of twisted bamboo fibers are produced in lengths up to 350m. They are more wear-resistant than standard ropes. With a tensile strength of 720 kg/ cm^3 a rope of an arm´s thickness
can bear up to 14 tons.

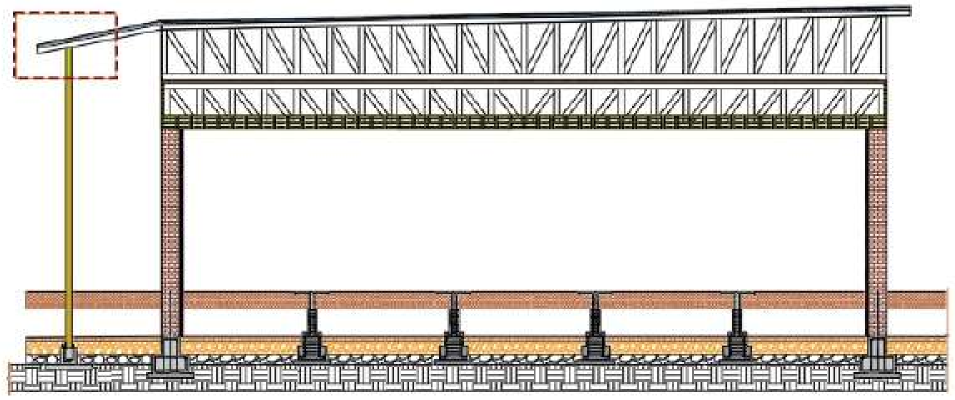
Binding wire is (as plastic cords are) an industrial product. Zinc coated wire has the same lifetime as
bamboo.
Nowadays also industrial materials are used:
• iron wire (zinc coated)
• plastic tapes/ ropes

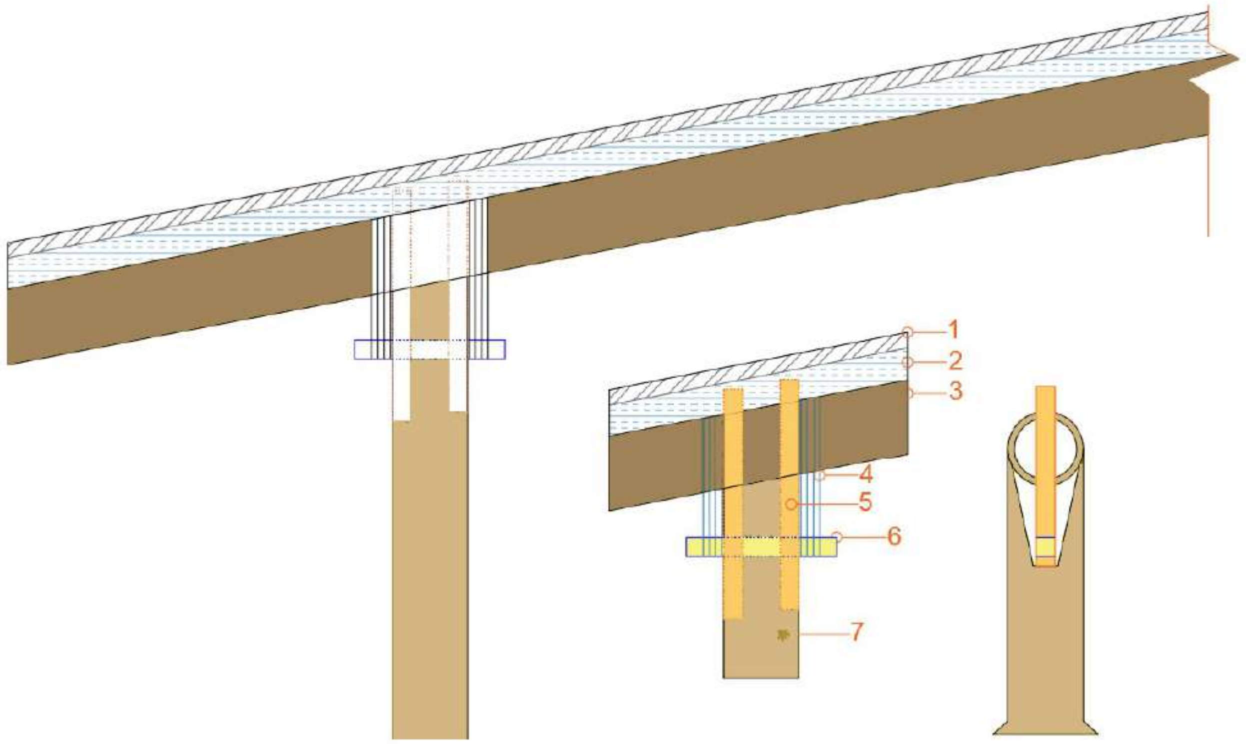






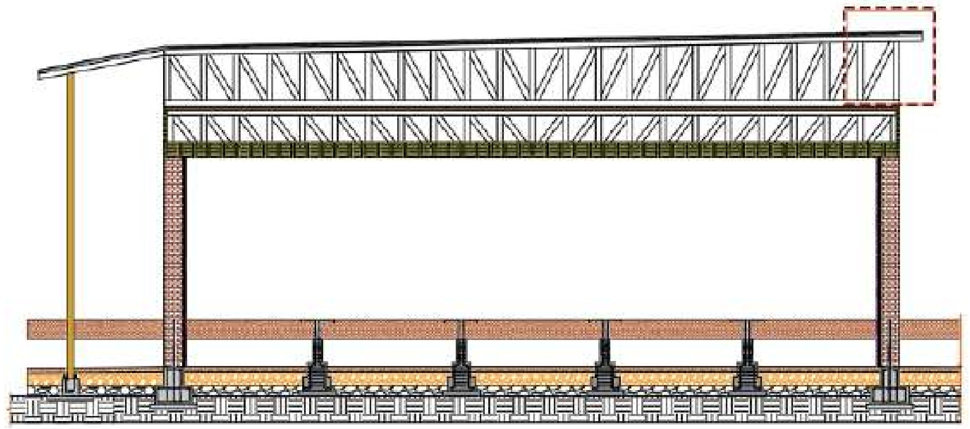
Connection of Bamboo beam to Bamboo truss and Bamboo Column

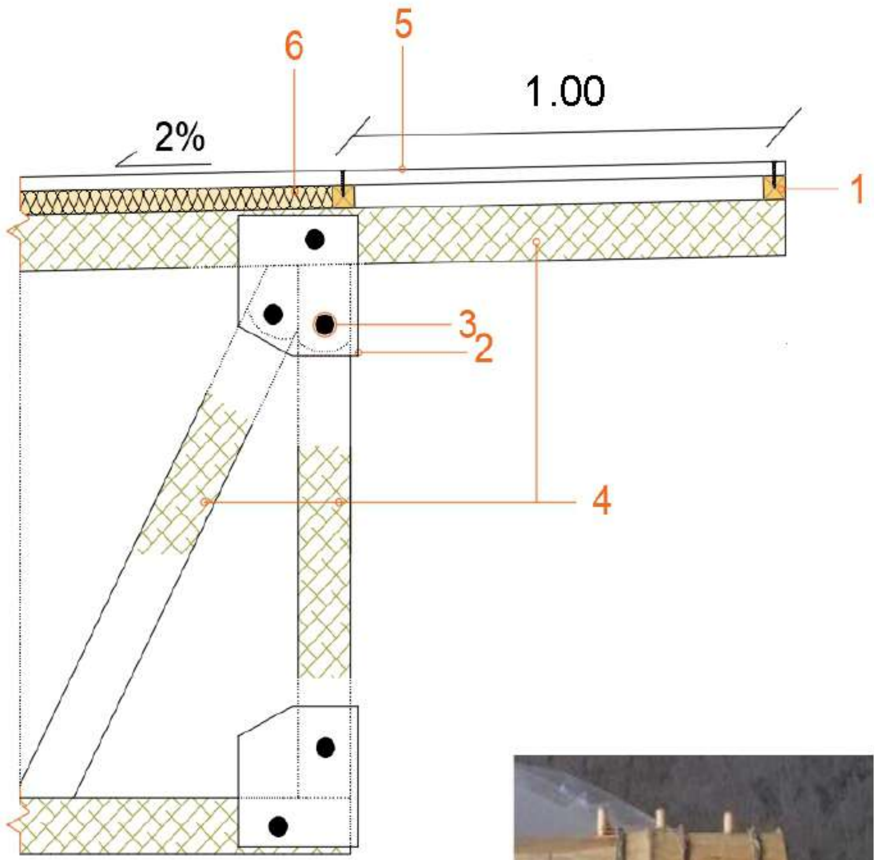


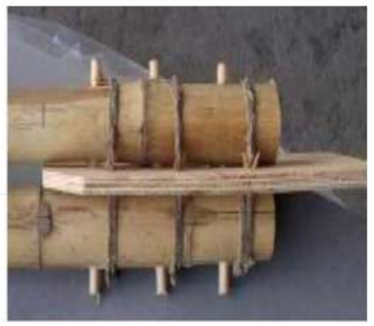


1. Corrugated metal sheet- th. 2 mm
2. Natural insulation- th. 5 cm- λ = 0.06 W/mK
3. Bamboo member – Diameter 12 cm
4. Bamboo ropes of twisted bamboo fibers
5. Wooden nail – th. 3 cm
6. Wooden nail – th. 3 cm
7. Bamboo column – Diameter 12 cm

Roof Connection

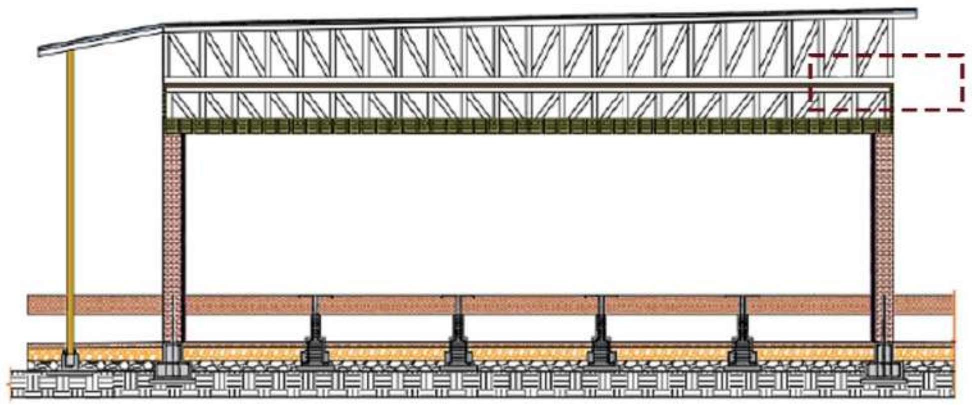


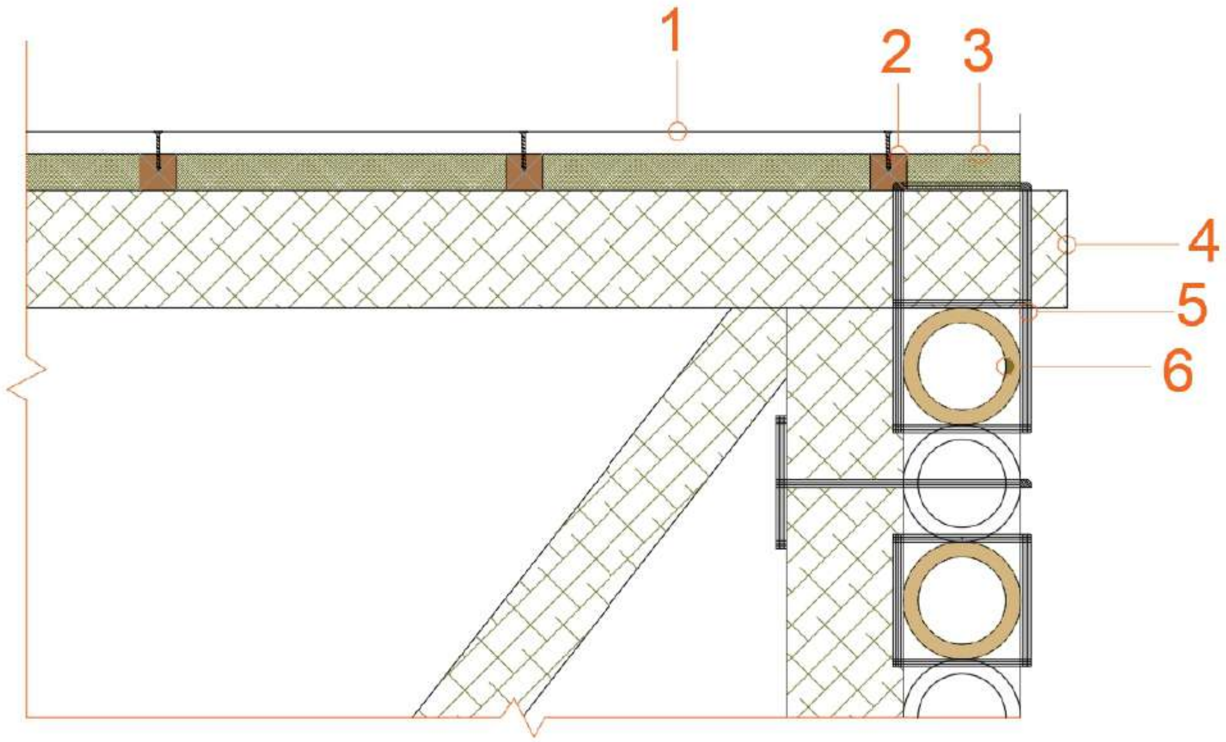




1.Roof battent- dim. 50 x 50 mm
2. Wooden plate – th. 10 mm
3. Wooden nail – Diameter 18 mm
4. Bamboo member
5. Corrugated metal sheet- th. 2 mm
6. Natural insulation filling- th. 50 mm.

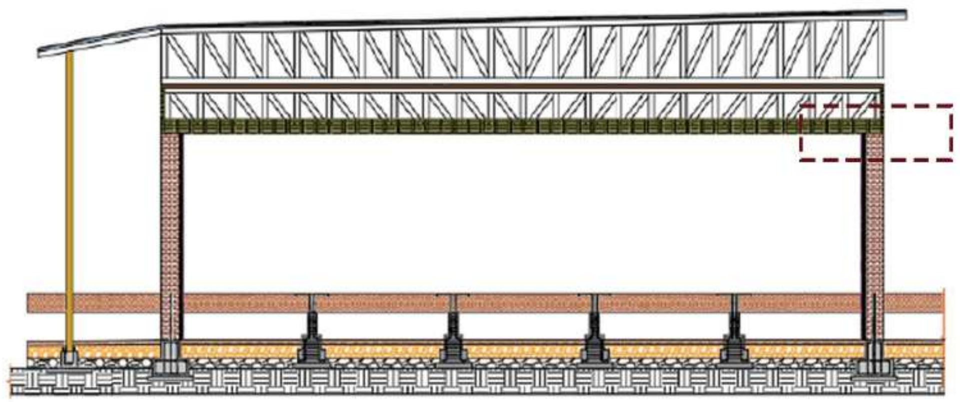
Roof Connection

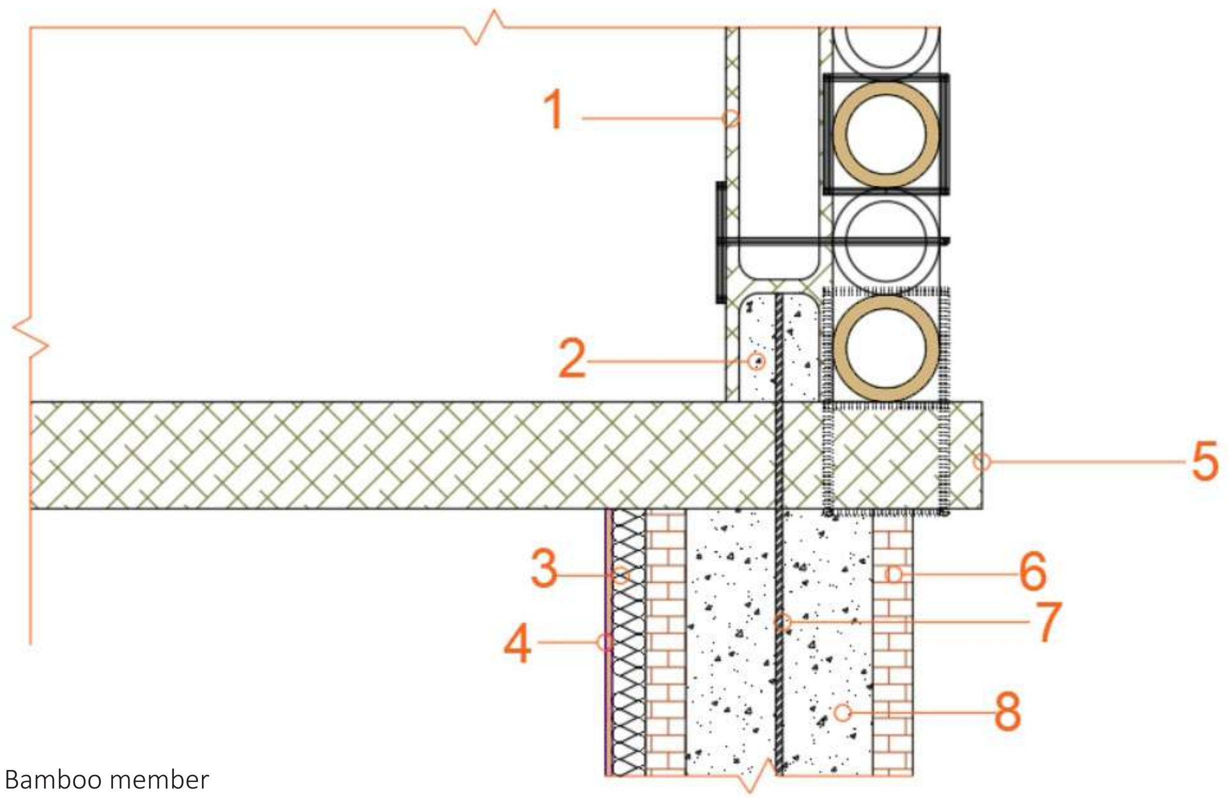




1. Metal fabral layer- th. 2 mm
2. Roof battent- dim. 50 x 50 mm
3. Thatched layer – th. 5 cm
4. Bamboo member – Diameter 16 cm
5. Bamboo ropes of twisted bamboo fibers
6. Bamboo member – Diameter 8 cm

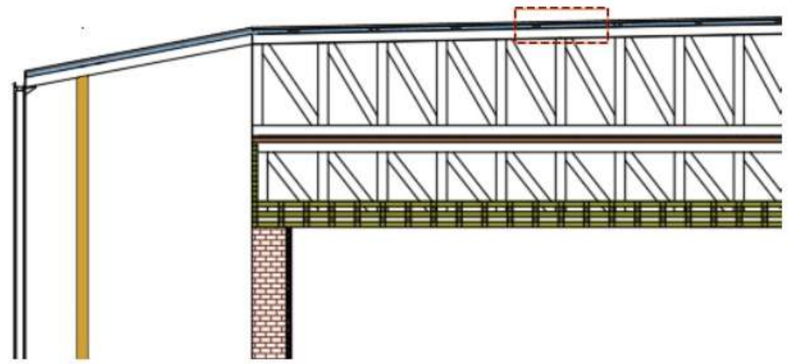
Roof Connection

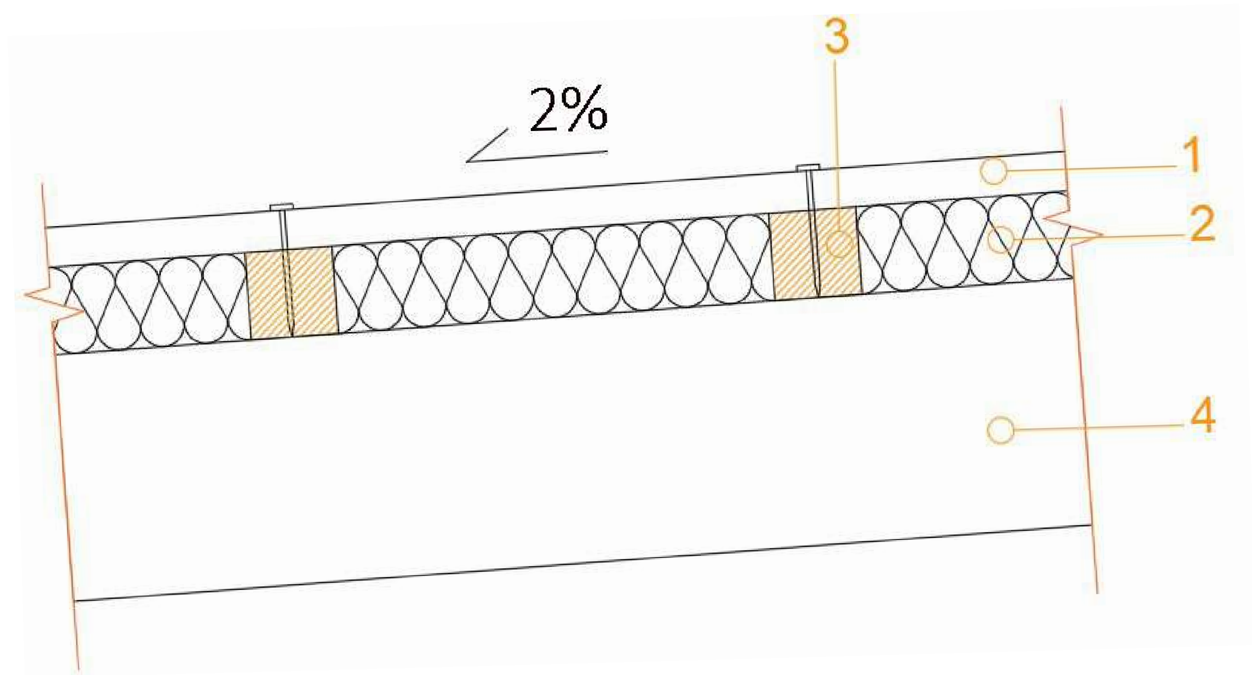




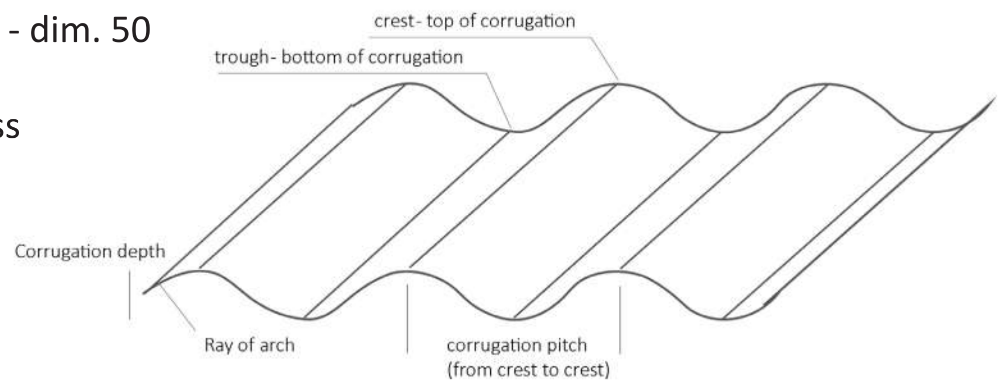
1. Bamboo member
2. High strength grout mixture
3. Insulation layer – th. 5 cm
4. Plaster layer – th. 1 cm
5. Bamboo member
6. CSEB wall – th. 40 cm
7. #4 rebar dowel
8. High strength grout mixture

Connection of Bamboo truss to metal sheet roof (Metal sheet detail)

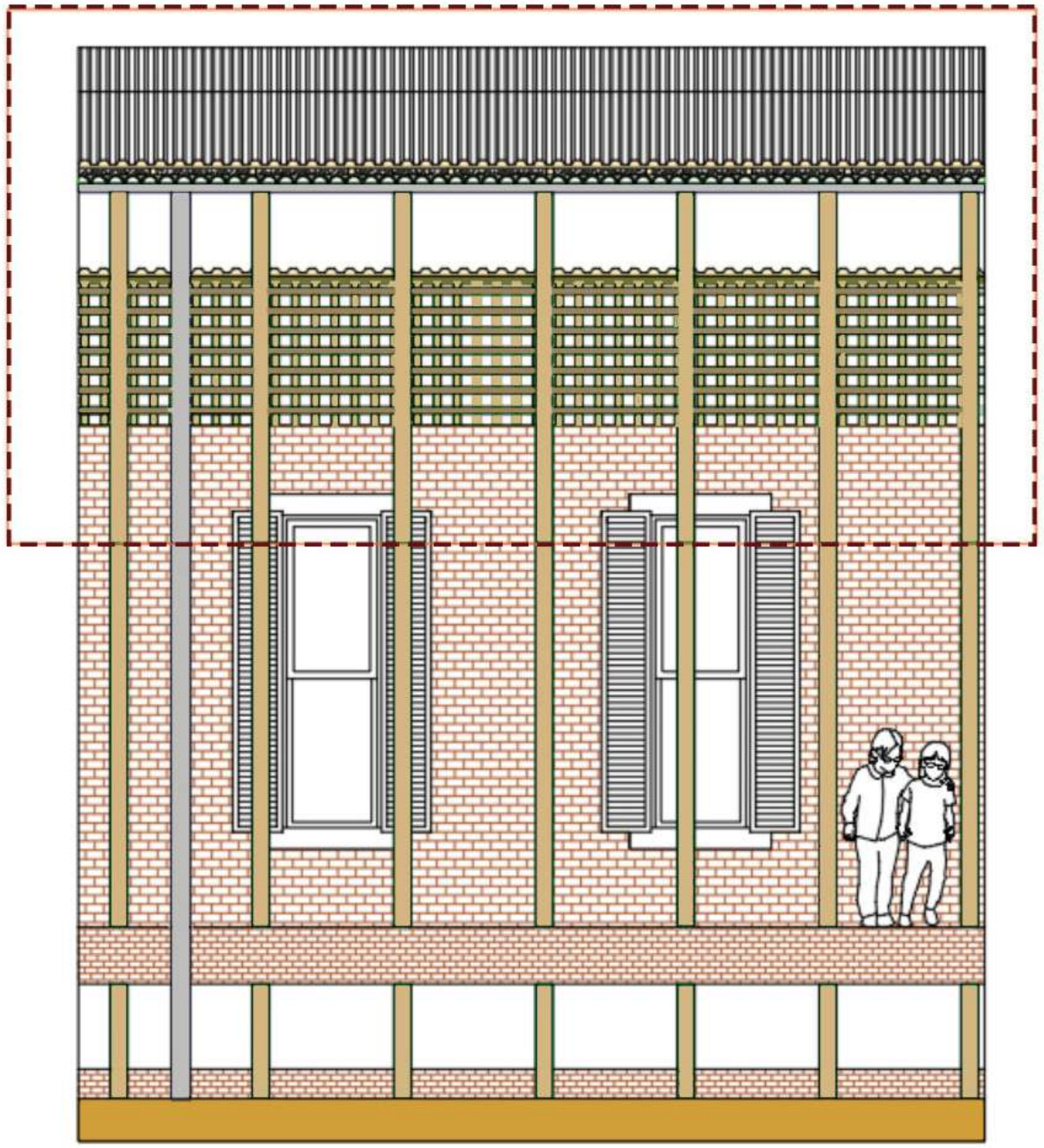


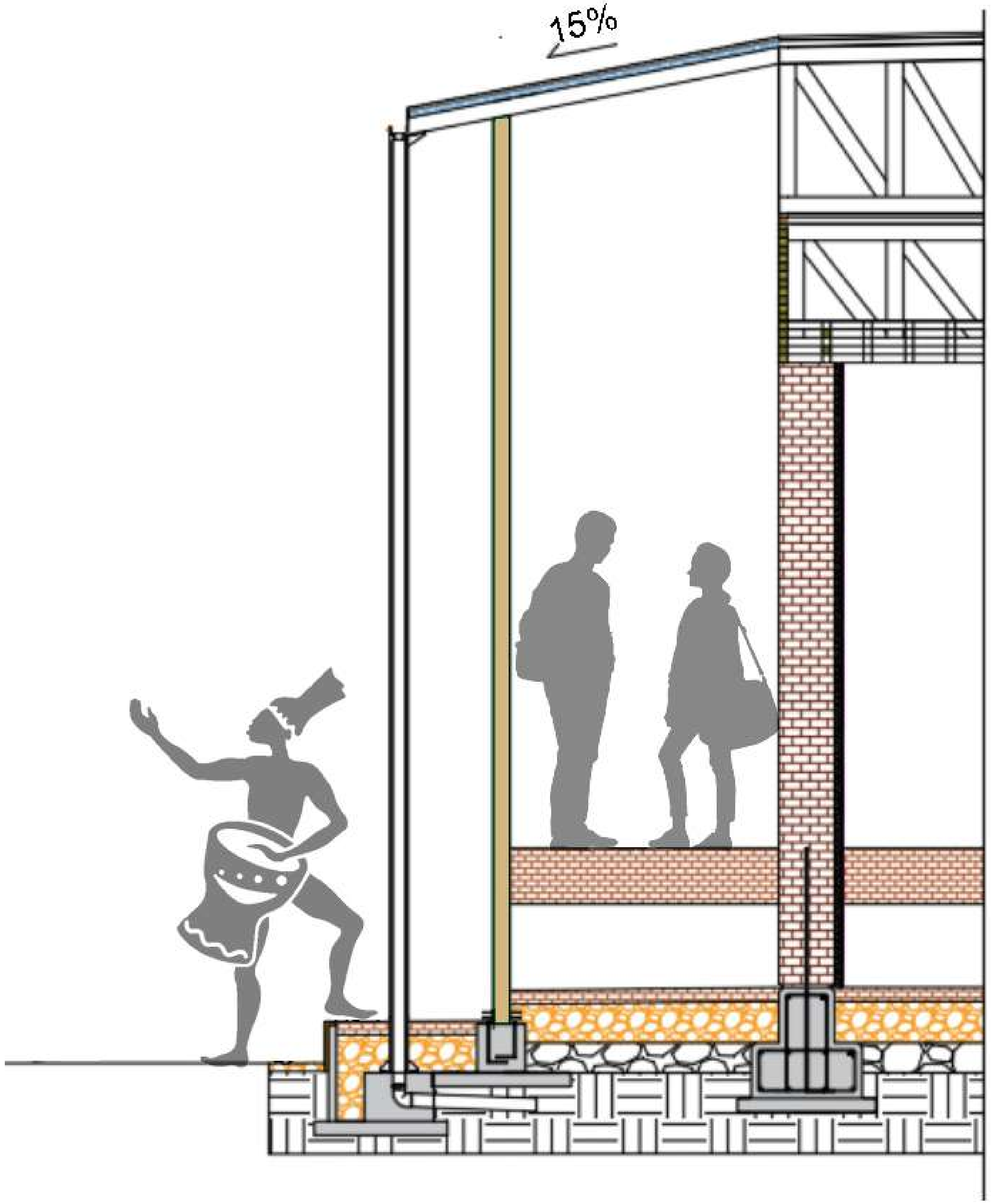


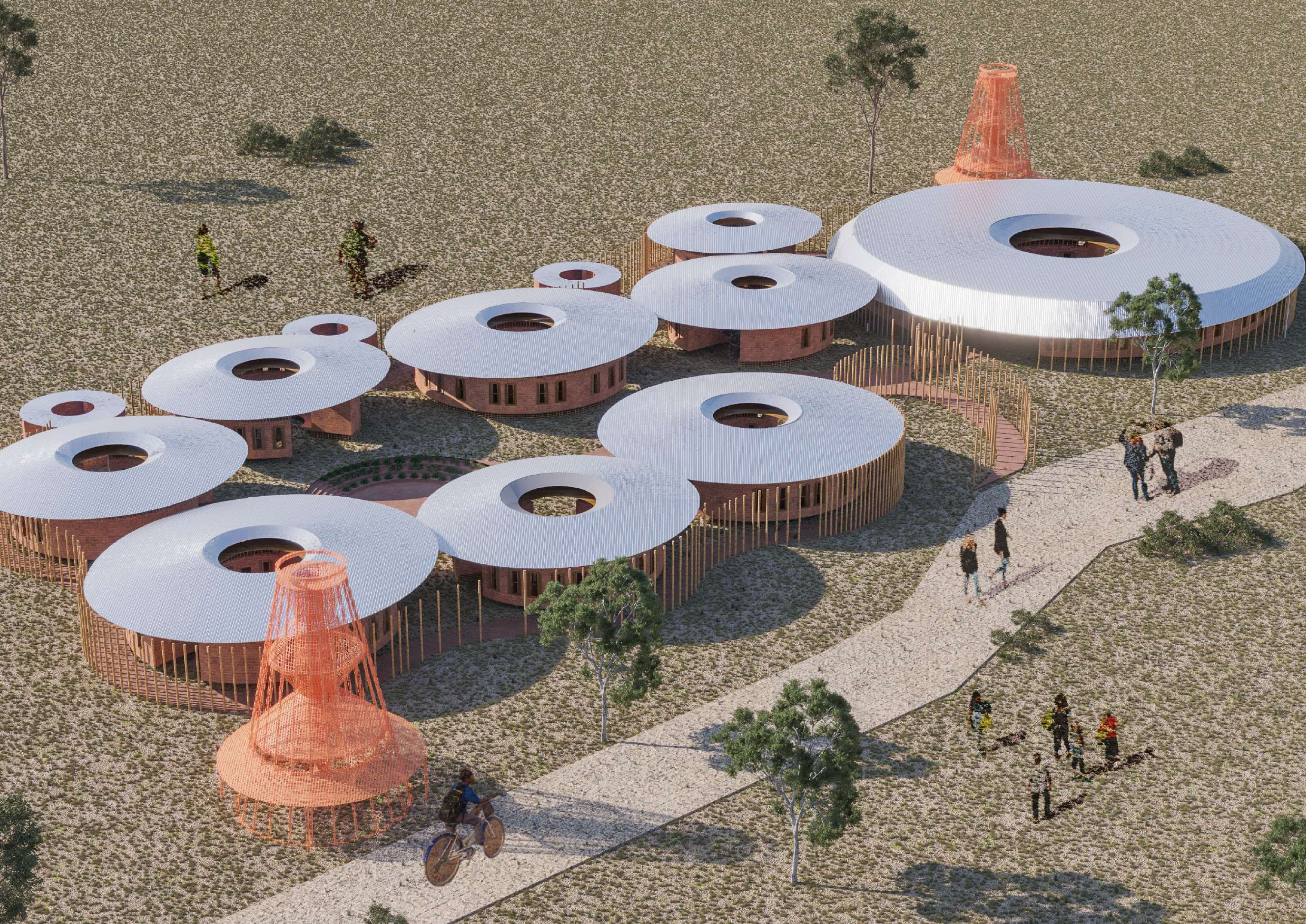
1. Corrugated metal sheet - th. 2 mm
2. Natural insulation - th. 5 cm - λ = 0.06 W/mK
3. Roof battent - dim. 50 x 50 mm
4. Bamboo truss



Blow up of exterior facade







CONCLUSION

Working for the first time in a country like Malawi which was unknown in lots of aspects for us had its own challenges, especially because the site of project was in a rural area “Benga” with more shortages compared to the capital. If we want to mention some major problems which were new for us as designers who worked till now in privileged countries we can name: lack of electricity, hygiene, running water, gas, food, availability of materials, transportation, waste disposal. All these factors together caused that quality of life of the population be under standards. As the results of vast research we did to get know the roots of problems and knowing their past and tradition and culture the idea of designing a multi featured school came up, because results were showing that mostly the problems caused by lack of knowledge which is the result of lack of opportunity of studying and learning life skills because of the economical crisis of the families especially for the females.

With help of the school in different steps we tried to improve situation.

In the first step of design, we imagined a school which can build easily with spending the less amount of money as possible by using the available materials on the site of the project and help of the vernacular architecture of the country which is usually the most responsive one, to merge old techniques with the modern knowledge of modifying materials.

As the concept designing for make connection between tradition and modernity the traditional tribes connections and indoor and outdoor relationships took into account to be more acceptable in the context and more familiar for the users.

For the construction due to the heavy rains avoiding the risk of flooding, using the waste from farming and human and animal waste in producing biogas has been take to the measures. Usage CSEB and bamboos as a renewable and available material in the site suggested to make it widespread around the country as a durable and safe sustainable choice.

In the second step we considered to involve the families in the rural area both in building the school and teach them how to make the cheap and responsive material without importing from abroad and showing them a building could be in a good condition even without spending too much, also we considered some workshops not only for children but also for the older people to tech how we can use the environment in a more efficient way without harming it and make the situation worser. In the same step for providing the opportunity for the children to get educated and make the gender equality expand in country we considered dormitories to solve transportation problems of the student and also produce the required electricity for living and studying, by the help of PV panels and batteries.

Third step was to do deep analysis among the comfort indoor temperature and daylight factor all through the passive strategies which is an important factor in an area with lack of electricity to provide heating, cooling and lightning. The analysis mostly was focused on how to control the humidity, ventilation and indoor thermal comfort and good light gains for the spaces which are using during the day time to cut as much as possible electricity usage.

At the end of optimization, we reached to a comfort above 70% according to standards, but as we know nowadays global warming is increasing faster so the future of comfort of the building is a question that we don’t know the answer. Maybe by improvement of the facilities and knowledge in ten years they can have easy access to the electricity and providing cheap sustainable cooling strategies such as air to air heat recovery systems.

At the end, we believe that architecture is a powerful tool to show to the world how designs and the spaces can affect the environmental crisis, it could be a mechanism to get positive changes and improving the wellness or work in opposite and loose our earth. Circle of life hope to be a loop of improvements and comfort life for all the world.

LIST OF FIGURES

LIST OF TABLES

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