THE METI SCHOOL ENVIRONMENTAL IMPACT

Embodied carbon and embodied energy analysis.

Master’s degree in architecture for the sustainability design

Politecnico di Torino

Author: Maria Alejandra Mora Rivera

Tutor: Andrea Bocco

Abstract EN

Nowadays, reflection on environmental care and the conscious use of natural resources has led architecture to review the professional practice, which is the source of around half of the CO2 emissions produced worldwide and the consumer of between 45 and 60% of the raw materials.

This thesis consists of the analysis of the work of the architect Anna Heringer, who stands out with projects of social and environmental impact. Through the study of the METI School, I studied in detail the construction techniques of bamboo and earth constructions in marginal environments, where cooperation with the community is essential for the solution of everyday needs.

Likewise, the sustainable performance of the project has been evaluated with environmental impact calculations such as Embodied Energy and Embodied Carbon using the Ökobaudat and ICE (Inventory of Carbon and Energy) databases.

Abstract **IT**

Attualmente, la riflessione sulla cura dell'ambiente e l'uso consapevole delle risorse naturali hanno portato l'architettura a rivedere la pratica professionale, che è la causa di circa la metà delle emissioni di CO_2 al mondo e consuma tra il 45 e il 60% delle materie prime.

Questo elaborato consiste nell'analisi del METI School dell'architetto Anna Heringer, che si distingue per i suoi progetti d'impatto sociale e ambientale. Attraverso lo studio di questo edificio sono state approfondite alcune tecniche di costruzione in bambù e terra in ambienti marginali, dove il lavoro con la comunità è essenziale per risolvere i bisogni quotidiani.

Allo stesso modo la performance sostenibile del progetto è stata valutata con calcoli d'impatto ambientale come l'energia e il carbonio incorporati, usando i database Ökobaudat e ICE (Inventario del carbonio e dell'energia).

Abstract **ES**

Actualmente la reflexión sobre el cuidado al medio ambiente y la utilización consciente de los recursos naturales han llevado a la arquitectura a una revisión del ejercicio, siendo este el origen de alrededor de la mitad de las emisiones de CO2 producidas mundialmente y el consumidor de entre el 45 y 60% de la materia prima.

Este trabajo consiste en el análisis de la obra de la arquitecta Anna Heringer, quien se destaca por sus proyectos de impacto social y ambiental. A través del estudio del METI School se profundizará en las técnicas constructivas del bambú y tierra en entornos marginales, donde el trabajo con la comunidad es indispensable para la solución de necesidades cotidianas.

Así mismo, se evaluará el rendimiento ambiental y sostenible del proyecto con cálculos como la Energía Incorporada y el carbón Incorporado usando las bases de datos Ökobaudat y ICE (Inventario del carbón y energía).

CONTENT

This thesis aims to study the METI school. Its geographic, urban, and social context; Its timeline; Its materials and building techniques; and Its environmental impact. To define Its sustainable performance in comparison with other existing case studios and determine whether it is possible or not to decrease its Embodied energy and Embodied carbon with the substitution of some materials.

The text is divided into five main sections that encompass and deepen the aspects mentioned above. The first part of this work focuses on the project architect Anna Heringer. Her ideology, work, and training through lectures, interviews, articles, and the Laufen manifesto. The second segment contains a general approach to Bangladesh architecture. In particular, I focused on the social and urban conditions where the project stands.

The third chapter places architecture and urbanism on the project's timeline where I reported on the changes that the building and its immediate surroundings have undergone over the years. The fourth part concentrates on the building materials and techniques, where bamboo and earth are prominent. several of their advantages, disadvantages, and regulations among other characteristics are mentioned.

The last chapter is the environmental building impact with the calculation of the Embodied Energy and Embodied Carbon of the building. This includes an approximate inventory of the construction that along with the Ökobaudat and ICE (Inventory of Carbon and Energy) databases allowed the calculations.

In the conclusion, I hope to determine the environmental performance of the building. Mention the importance and effectiveness of traditional building techniques for sustainable development and the virtue of earth and bamboo as building materials. Also, I want to criticize the current regulations that hinder the use of these and other materials with high environmental performance.

ANNA HERINGER

“The vision behind, and motivation for my work is to explore and use architecture as a medium to strengthen cultural and individual confidence, to support local economies and to foster the ecological balance.”

Among the architects celebrated for their sustainable practices is German architect Anna Heringer the designer of the METI school.

Heringer graduated in 2004 as an architect from the University of Art and Design in Linz, Austria. Just after that started working with architect Eike Roswang on her diploma work titled “School: handmade in Bangladesh”. A project for the construction of the Modern Education and Training Institute or METI School in Rudrapur, Bangladesh.

The project was her first construction work and later in 2007 won the Aga Khan Award for architecture. This building is one of the most important projects in the architect’s career, not only for the details mentioned before but also because was the beginning of a social work through architecture.

In addition, it can be said that the critical fortune of this building is responsible for Heringer’s success and recognition in architecture. This is partly because the information and photographic archive of the building was curated by the architect, and the accessibility of the project makes it difficult to obtain contrasting material.

The choice of the territory for the project takes place in the architect’s adolescence. She lived in Rudrapur for a year because of a voluntary program and there she realized that it was the most sustainable year of her life. since then, Heringer has had a close relationship with the community in Bangladesh and a penchant for sustainability in her work.

Chapter I **Figure 1** *Anna Heringer, who is also professor of the UNESCO Chair of Earthen Architecture, in her Laufen Beer Hall home and office. Credit: Peter Untermaierhofer. From https://www.ribaj.com/culture/anna-heringer-profile-rammed-earth-social-purpose-anandaloy-obel-award*

For her architecture is a tool to improve lives and this is how she named her lecture at the Aga Khan Program at Harvard SGD (Heringer, 2018) In this performance, among the most important things she expressed those resources are given by nature and all that an architect need is the sensitivity to see it and the creativity to use it. That is the reason why she tries to use local materials in all her projects. In addition, she highlighted the recognition of the existence and incentivizes people to find their potential and try to do the best out of it.

On the other hand, she focuses on architecture sustainability in different fields of action. She defined the building as a catalyst for people's development. For example, she talked about the budget of the METI School that moves the village economy. Also, she quotes "don't think that I am that important that my buildings need to stand forever. The biggest honor for me is that if one day my buildings must be returned to the earth it could be like that". This statement matches with what for her is the problem of sustainability, that is how to deal with decade and death, and her solution is to understand that death is part of nature.

The same year she got an interview on the podcast Talking Practice of SGD with Grace La as host (La, 2018). There she told how she ended up involved in the construction of materials such as earth or bamboo and her proximity to territories with difficult economic situations such as Bangladesh. Also, she talked about the construction drawings of her projects. In the case of her last project, she said she had almost no drawings because she was on-site, so she had just hand sketches done for the next construction day, and details are drawn on the mod.

Further, she explained the evolution of her building's form, and how at the beginning she used to make boxes or linear designs, but she realizes that mud is a plastic material that allows exploring fluid forms. that is why on the building she was working on at the time, the Anandaloy, "the walls are dancing". Despite this, she remarked that the steps were all essential. At the start, it was important to show mud how people used to imagine architecture and elevate a material that used to be conceived as dirt to a valuable and qualified material like all the others.

She adds that understanding the local materials and local climate is decisive to creating architecture that respects the places' identity, and earth is a local material almost everywhere. Piteously there are two main issues when mud is proposed as a construction material. First, people do not like earth because they feel vulnerable or poor, and second, there is a lack of knowledge from architects and other technical figures about mud construction techniques.

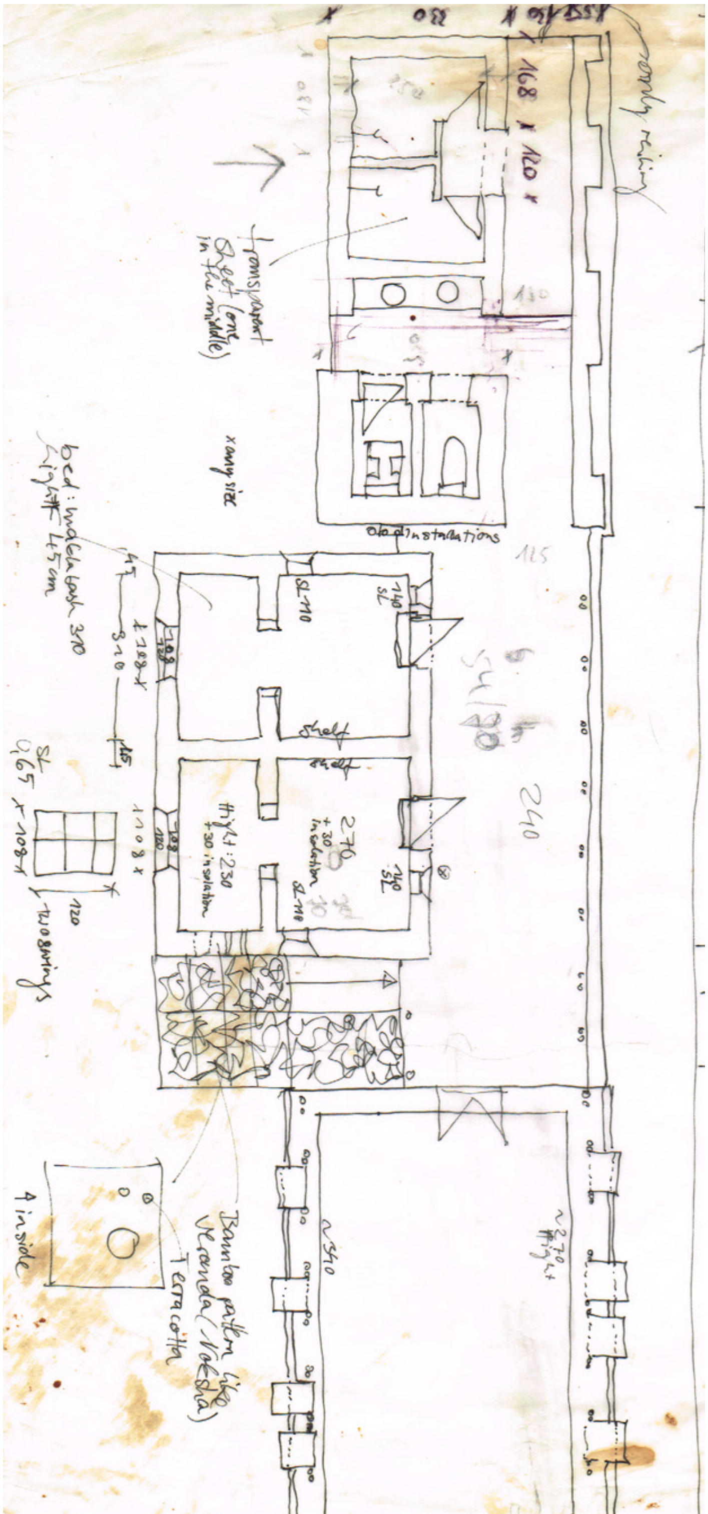
About the last statement, Heringer mentioned one year before in her TED talk (The warmth and wisdom of mud buildings, 2017) that mud is not considered worthy of being studied at universities and students use to design more with technology than with materials comprehension. Additionally, she shows videos of her installation of 2012, Mud Works – A different shade of green, in front of Harvard's Graduate School of design which was done with the participation of over 150 students, including Loeb Fellow and Martin Rauch. In the video, it can see how people stop feeling and live the walls that look like concrete, Atypical Behavior among bystanders.

In addition to these the architect has performed other important lectures and workshops such as Handmade Architecture as a Catalyst for Development at the UNESCO CHAIR FOR EARTHEN ARCHITECTURE (Heringer, 2014), Exploring the role of history in contemporary architectural practice at the MIT (Hedrick & Basrai, n.d.), EcoTopia the potential of local materials in Domaine de Boisbuchet (Heringer, 2013), Formal Launch and presentation of the Global Urban Lecture in Medellin (Heringer, 2014), among others.

Furthermore, her ideas, her architectural installations, and fabric products by her brand Dipdii Textiles created in 2012, have been exhibited in spaces with great international importance. To name a few, there are Architects build small spaces exhibition, V&A Museum London 2010, Austria Under Construction and Sehnsucht at Venice Biennale 2010, Small Scale – Big Change MoMA New York 2010, Museu de Arte Moderna Sao Paulo 2011, Exhibition Re-enchanting the world at ROYAL Abbey of Fontevraud France 2016, Mud Works 15th International architecture exhibition, Venice Biennale 2016, International Bamboo Architecture Biennale Baoxi china 2016 and the Artigliere Venice Biennale 2018.

She has projected in countries such as China, Germany, and Morocco but, most of her work is in Bangladesh, in collaboration with the NGO Dipshikha she has carried out several projects. Among her most outstanding projects in Rudrapur, besides the METI school, can be mentioned the DESI center that was constructed in 2008.

Chapter I ***Figure 2*** *The so-called "Pepita" and its entrance. Credit: Peter Untermaierhofer. From https://www.anna-heringer.com/installations/venice-biennale-2016/*



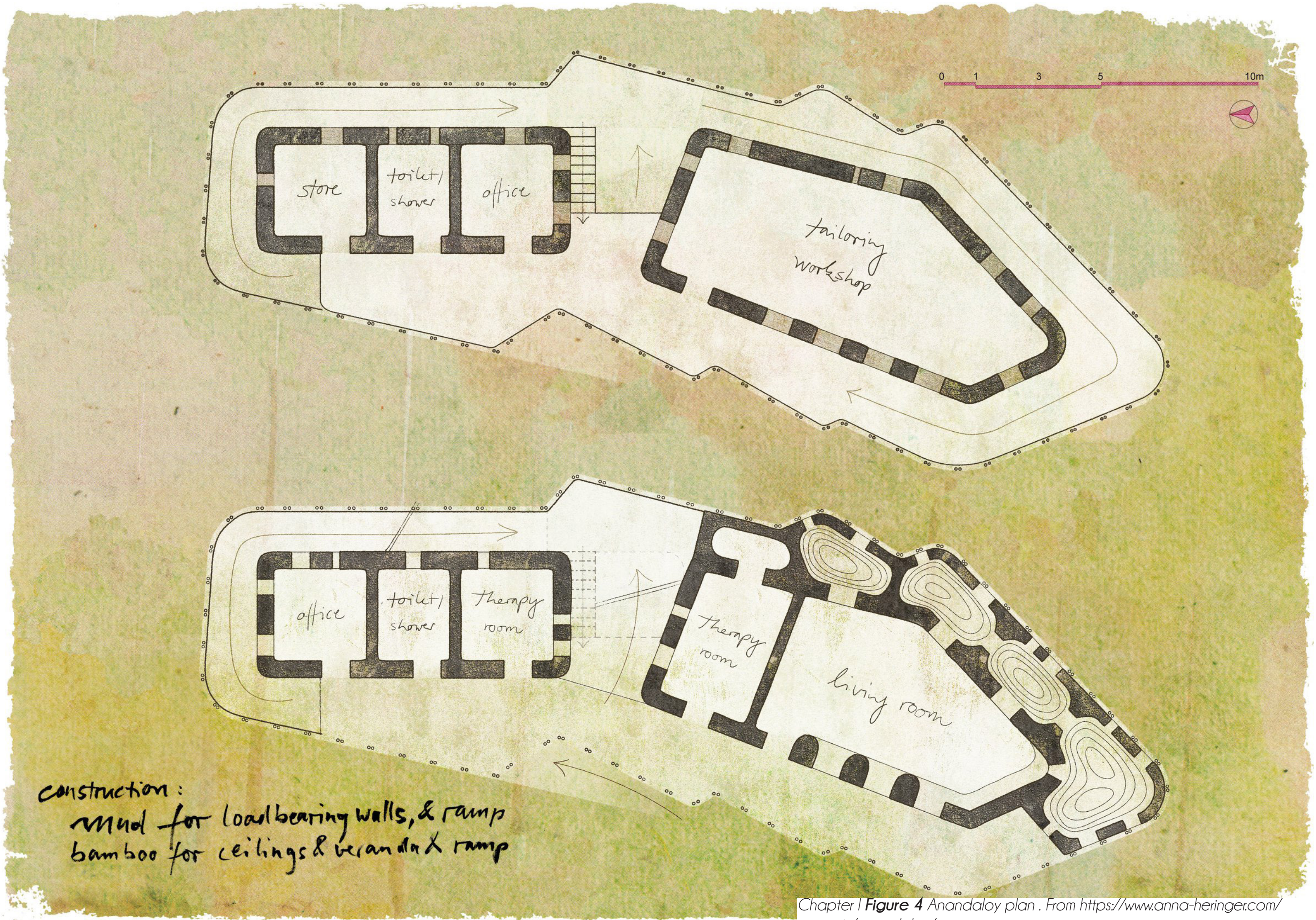
Chapter I **Figure 3** *The design is geared toward a lifestyle that is no longer linked with agriculture, but still linked to the rural context and culture. From https://www.anna-heringer.com/projects/desi-centre-bangladesh/*

DESI CENTER

The Dipshikha Electrical Skill Improvement center "is a new interpretation of the traditional Bangladeshi homestead" (Heringer, 2008) with a couple of classrooms, offices, and two residences with services for the educational staff of the institution. The architect's concept is a container space to join the functions instead of having separate structures around a central courtyard.

The building has an area of 300 m2 and is composed of 3 volumes of rectangular plan that are articulated by a veranda on the first floor (figure xx). The central volume hosts the teacher's flats, the offices, and a storage area. The classrooms are located at the right volume while the services, including the toilets, showers, water tank, and technical room are in the left volume. The first floor is accessible through stairs located between the central and the right volume and arrives at a large veranda.

The building has a high and low-tech approach to sustainability since it combines natural materials and traditional construction techniques with alternative energy power systems. The project is equipped with solar panels that produce 100% of the building's energy needs (González, 2020). The solar installations and electrical concept were made by Jakob Schaub while the electrical concept was made by Oskar Pankratz. Like in the METI school the project included the participation of Martin Rauch as an advisor in earthen structures. In addition, they have Professor Walter Liese as an advisor in bamboo treatment and quality management.



*Chapter I **Figure 4** Anandaloy plan . From https://www.anna-heringer.com/projects/anandaloy/*

Another project to mention is the Anandaloy, a center for people with disabilities constructed between 2018 and 2020 in the Dipshikha center, Bangladesh. The building had 174 m2 of interior space and 180m2 more for the veranda and ramp. The program of the building is an innovation in the rural area of Rudrapur since it is rare to find therapy centers in the country more in rural areas where they are inexistent. (Anna Heringer Architecture, 2020)

Eventually, the building was able to get extended to include Dipdii Textiles, a female textile studio for the village's tailors. The initiative was created and managed by Studio Anna Heringer to generate work opportunities in the territory as well as complement the treatments with learning and productive activities.

The construction is a two-floor building connected by a big ramp as a sign of inclusion, that seems to hug the interior. The architecture concept works with the mud plastic abilities to break out the mold in an area that is mostly constructed in a rectangular layout. This old material is creatively used in a contemporary way to create a project that dances in curves. "On a symbolic level the building signals: it is great that we human beings are all different. With its joyful curves it radiates the message: diversity is wonderful" (Anna Heringer Architecture, 2020)

The project is an accumulation of knowledge learned in the process of all the projects done before in Bangladesh including the METI School. The materials implemented in the project are, as mentioned before, mud walls in a cob technique fired brick in the foundation, bamboo for columns and roof structure, straw for the lower roof, and metal sheets for the upper roof.

Chapter I ***Figure 5*** *Anna Heringer, Edificio Anandaloy en Rudrapur (Bangladés) © Kurt Hoerbst . From https://arquitecturaviva.com/obras/anna-heringer-edificio-anandaloy-en-rudrapur-banglades-gye86#lg=1&slide=1*

THE THREE HOSTELD IN BAOXI

The last project I want to hint at is the Three Hostels in Baoxi China (Heringer, 2016), although it is not in the study area, Bangladesh, it is one of her most recognized projects. The design phase of the project starts in 2013 and the construction of the buildings ends in 2016.

The construction is composed of three bamboo structures of circular plants with different heights and shapes between them that contains inside the real buildings mostly made in materials like stone and mud.

In comparison with the other projects already mentioned this project implemented more advanced elements, like the formwork for the creation of the walls on earth or the suspended metal structure balconies, to mention some.

Chapter I ***Figure 6*** *The three building from outside. Photos: Julien Lanno From https://www.anna-heringer.com/projects/bamboo-hostels-china/*

In the last years, Heringer has received many recognitions such as the Obel Award in 2020, the Design and Build Awards of Germany's Leading Architect in 2020, the building Sense Now Global Award in 2019, the Biennale di Pisa Award in 2019, The Architecture Drawing Prize in 2019, the Global Award for Sustainable Architecture in 2010 and the first award she won the Aga Khan Award for Architecture Award in 2007 among others.

Besides this, she won the RIBA International Fellowship in 2012 (James et al., 2012) and the Loeb Fellowship at Harvard GSD in 2011 (Harvard University Graduate School of Design, 2011). The architect also wrote her fourth book in 2019 with her colleagues Rauch and Lindsay Blair Howe entitled Upscaling Earth.

Also in 2013, together with Rauch and 18 other professionals, including architects, urban planners, designers, and editors from different countries wrote the Laufen manifesto for human design culture.

THE LAUFEN MANIFESTO FOR HUMAN DESIGN CULTURE

Chapter I **Figure 7** *In search of a process - Laufen Manifesto for Human Design Culture From https://www.anna-heringer.com/installations/laufen-manifesto/*

"Too many people worldwide subsist in undeserving living conditions, and their ranks are growing by the day. (...) We must produce spaces that counter exploitation, control, and alienation, whether in urban or rural landscapes. With all our expertise, creativity, and power, we need to contribute more dynamically and consequently to the global quest for equality.

Across a range of pilot projects, we have begun to initiate a more humane design culture, working with a robust network of communities, craftsmen, planners, builders, and organizations. (...) we must urgently multiply our efforts to improve the ecological, social, and aesthetic quality of the built environment while developing more effective design strategies to anticipate predicted future growth on a global scale." (Heringer et al., 2013)

From this introduction, a reflection on the professional disciplines of design as planners of the built environment is developed. The approach of architecture to society and current needs must be reoriented, and for this purpose 7 key points were written that must be implemented in the construction of the contemporary world.

1. Collaborating Eye to Eye

The first point they mentioned, and the most important for me, is the relation between the professional role and society, the users of our ideas. They proposed a different approach in which planners do not work in isolation as masterminds, but allied with the community to create a world more in tune. generate a balance between technical-theoretical knowledge and experiential knowledge.

"We must commit ourselves to respectful communication and cooperation with residents and communities as key partners in achieving positive, measurable

Chapter I ***Figure 8*** *Studio Anna Heringer meets the community and sponsors, Rudrapur 2018 Photo: Benjamin Stahli From https://www.anna-heringer.com/projects/anandaloy/*

change. The impact of a participatory process extends beyond actual design outcomes - it should empower individuals and cultivate a constructive atmosphere with lasting effects. The process should allow sufficient time to facilitate a dialogue striving for respect, curiosity, flexibility, and care." (Heringer et al., 2013)

2. Designing Work

The second statement revolves around projects in a way that benefits the small scale, especially in a production aspect. Support local businesses with aspects such as materials, labor, construction techniques, and training of local people.

"Projects must be conceived in a way that creates meaningful work. A thoughtful approach to designing buildings, places, landscapes, and products can nurture small-scale enterprises like construction, farming, and crafts. By opting for labor-based techniques and non-standardized materials, we can foster a decentralized form of construction and production. Creating an atmosphere of entrepreneurship and innovation is essential in forming value chains connecting local craftsmanship and global industries.

New models of self-construction for low-income populations must be explored, combining education, training and long-term income generation. The creation of work is foundational for greater equality and peace." (Heringer et al., 2013)

Chapter I ***Figure 9*** *Dipdii textiles workshop Photo: Kurt Hoerbst From https://www.anna-heringer.com/projects/anandaloy/*

3. Unfurling Beauty

My way to interpret the third point that focuses on the relationship of beauty to dignity and ownership is to enhance the elements that identify the place and recognize them as beautiful.

"We believe that beauty is an essential human need, linked strongly to dignity. We must strive for an authentic harmony that resonates with people, the genius loci, and their territory. The longing for beauty can be stronger than fear and thus a crucial catalyst for humane development." (Heringer et al., 2013)

Chapter I ***Figure 10*** *The small pavilion in rammed earth Photo Tommy Schaperkotter From https://www.anna-heringer.com/installations/workshop-with-harvard-students/*

4. Identifying the Local

The next point continues with the local theme and talks about architecture with context. projects that take into account what is within reach and where they are located, creating coherence with the territory and leaving aside the current of contemporary architecture that makes equal buildings in different conditions.

"Modernization has leveled cultural differences globally and hampered context specific design. Individual projects must be based on careful observation of geophysical conditions, local building traditions, and space hierarchies.

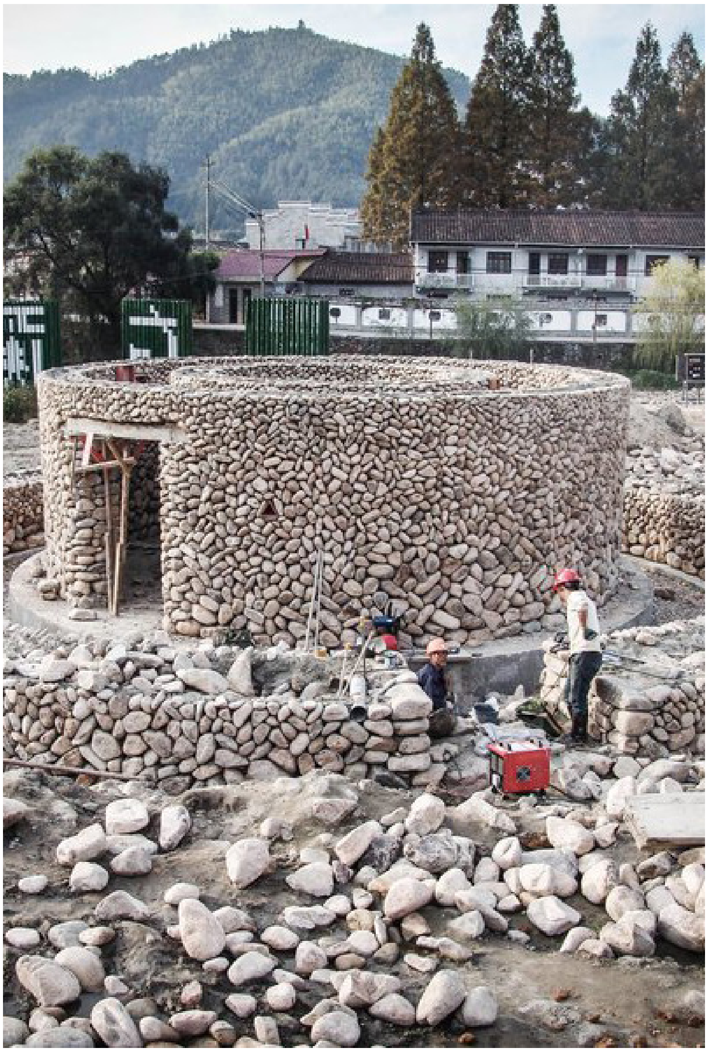
Global knowledge on building techniques must be adapted to the local climate, available materials, skill base, and energy sources. Site and culturally sensitive design contribute to self-sufficiency and more sustainable local economies." (Heringer et al., 2013)

5. Understanding the Territory

Point 5 talks about scalarity. Planning should not concentrate only on large cities but on the contrary on all scales to create well-connected networks without deficits between cities and small urban centers.

"While designers and policy-makers devote significant attention to mega-cities and high-density environments, larger agglomerations are deeply dependent on smaller living units and their landscapes.

Truly humane design projects understand zones of impact and influence on many scales. They operate between the local, the regional, the continental, and the global, thereby revealing a rich network of dynamic social, economic, and ecological relations that must be respected, adjusted for, and improved as needed." (Heringer et al., 2013)



*Chapter I **Figure 11** Construction of Three hostels in Baoxi Photo Jenny II From https://www.anna-heringer.com/projects/bamboo-hostels-china/*

*Chapter I **Figure 12** Masterplan Rudrapur By Anna Heringer From https://www.anna-heringer.com/projects/meti-school-bangladesh/*

6. Educating Designers

The sixth point makes a call to the educators of future architects, stating that the preparation in the institutions is insufficient to move from the idea to the built product, in addition to saying that there is a lack of social empathy in the profession. I believe that this point depends a lot on the institution and the environment in which one is being formed.

"Designers are not trained sufficiently to achieve positive change for people living in undeserving conditions. Design education has to evolve radically to ensure young designers have the capacity to bridge the gap between design and construction, understand the nuances of diverse sites and territories, and communicate more profoundly with local communities and stakeholders.

In short, instill greater social empathy. Manual skills must be developed on the same footing as digital and intellectual skills. Designing the right process must be equally important as the outcome." (Heringer et al., 2013)

Chapter I ***Figure 13*** *Mood works a different shade of green Harvard From https://www.anna-heringer.com/installations/mudworks-harvard/*

7. Shaping Policy

The last point talks about the relationship between planning and politics
"Integrated infrastructure, new collaborations, and innovative approaches to project development and financing must be translated into a global policy strategy. A vast change is necessary for the way we conceive, distribute and construct human habitats.

We must connect top-down and bottom-up processes, with a view to fostering more productive exchanges between residents, policy-makers, financial institutions, the design profession, and executing bodies. This will require the mobilization of both human and financial resources. We need broader and better solutions, at a lower cost, for a larger number of people." (Heringer et al., 2013)

"These principles provide necessary impetus for a radical reorientation of all professional design disciplines. It is critical to shift current self-perceptions from top down planning to transparent cooperation throughout the cycle of planning, design, construction and usage. Design imagination is our primary instrument to define how we want our world to be."

This concludes this manifesto, which aims to reorient the profession. While I believe that many of the points are important, I think that nothing new was said. Some of the points such as 3 Unfurling Beauty and 7 Shaping Policy were not clear to me and although I tried to contact some of the authors to deepen the content I did not get a response from any of them.

In any case, it was important to mention this work because it is a sample of how the projection should be according to Heringer, besides, seeing some of these concepts in the case study.

BANGLADESH

“For centuries Bengalis have called their homeland Bangladesh (land of the Bengalis). In the cultural context, this homeland stretches from Purulia in the west to Cachar in the east. Politically, however, it is fragmented between various Indian states and the newly formed people’s Republic of Bangladesh.” (Rashid, 1977 - 2018)

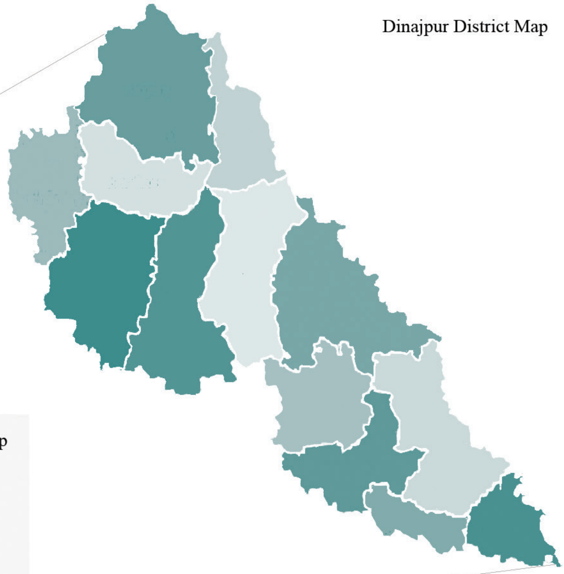
Bangladesh is located more precisely between latitudes 20°35’N and 26°75’N and longitudes 88°03’E and 92°75’E, the country is divided into 7 major administrative units known as Jila or districts. These are further subdivided into 62 smaller units called Mahakuma which are made up of smaller administrations known as Thanas, of which there are 412 in the country. The smaller geographical units that make up the Thanas are called Unions or Mouzas and are the minimum urban unit that makes up the territory.

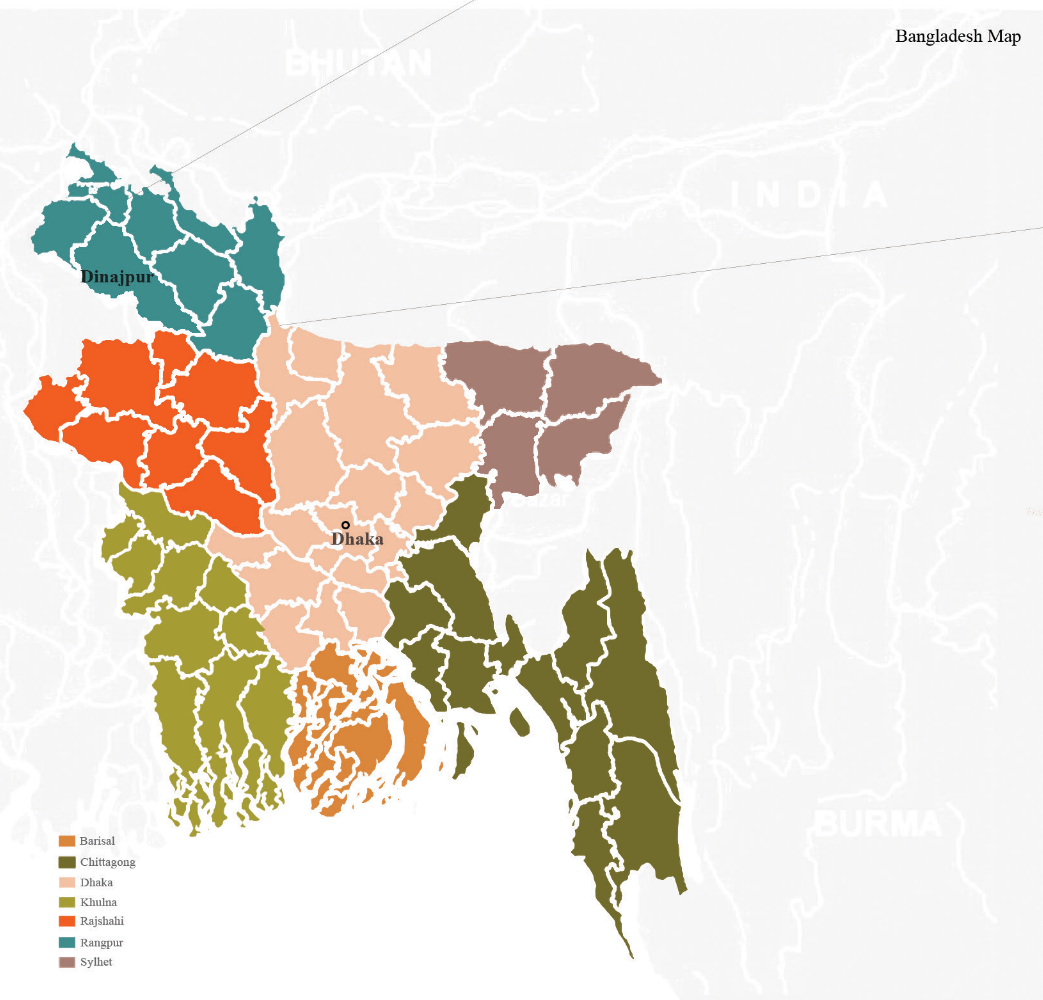
The METI School is located in the district of Dinajpur, about 350 kilometers from the capital of the country, Dhaka. In the Mahakuma Biral Upazila, on the border with India, in the Thana Mangalpur, and the junction of Mouza Rudrapur to the northwest of the Thana.

This nation is the eighth-most populous country in the world. In 1974 it had 75 million people in an area of only 142775.6846 square kilometers, and according to World Bank figures for the period 2010 – 2014, there was a population increase of 1.5% - 1%, approximately 1’600,000 people.

According to a study by the Bangladesh Bureau of Statistics (2015) 54% of the country's households are in rural areas with a population density of 1000 people/km2.

87% of the population attended some form of education, but only 10.32% attended SSC and HSC levels, and only 2.93% graduated with a degree, technical or vocational qualification. This is related to the nation's poverty levels, which despite a one-third reduction since 1992 more than 47 million people living in poverty or extreme poverty.





Chapter II ***Figure 1*** *Bangladesh MAP. Own elaboration.*

CLIMATE

Another factor to mention briefly is the climate information of Bangladesh, which provides ideal conditions for the success of the project. The country is divided into two climatic zones, the subtropical in the north and the tropical in the south. The average annual temperature is 32°C in the hottest months from March to June and 26°C in the cool season between December and January.

The wet months are from April to October. The month with the most days of rainfall is July with an average of 22 days, 247 mm, and a 73% probability of rain, November to February has an average rainfall of only 6 mm per day. parallel to this the period of highest humidity lasts almost nine months from March to November, qualifying the thermal sensation as "unbearable" 26% of the time.

Average wind speed

Max and min temperature

Rainfall average

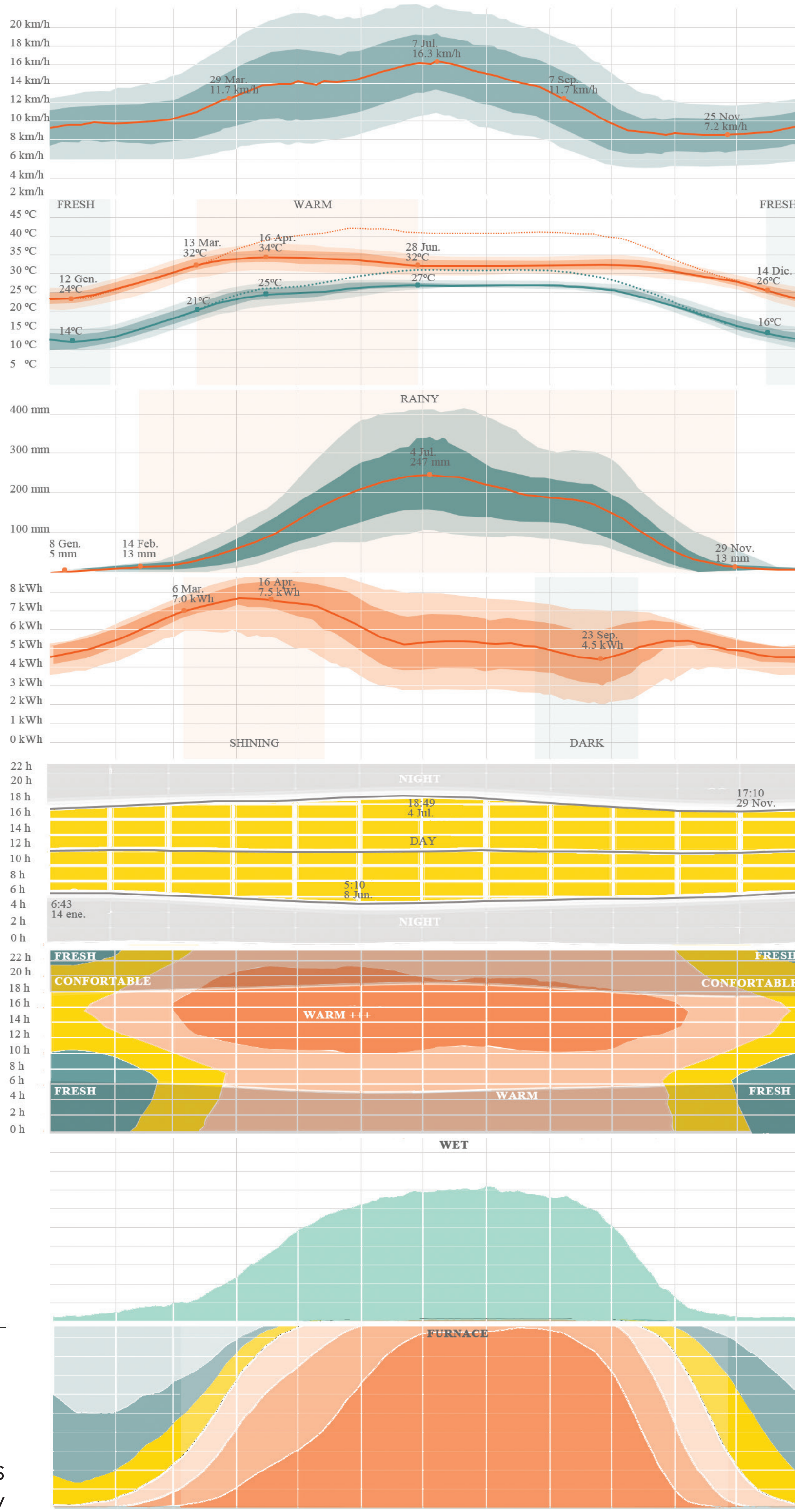
Shortwave solar energy

Sunrise and sunset

Hourly average temperature

Rainfall

Moisture comfort



The highest temperature recorded since the 1940s was 39.5°C in August 2020, the measurement was taken by the Chittagong Airport station, the average summer temperature normally hovers around 28.4°C. On the other hand, the Ishwardi station reported the lowest temperature at 14.2°C in the same year, being almost seven degrees below the average winter temperature of 21.6°C.

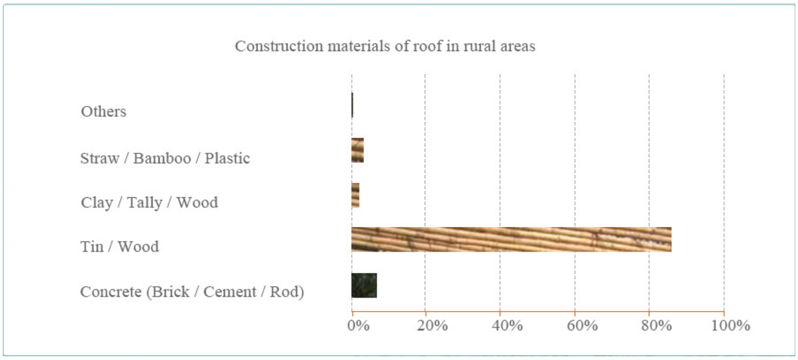
Chapter II ***Figure 2*** *Bangladesh Climate graphics. Own elaboration based on the world meteorological organization taken from https://worldweather.wmo.int/en/city.html?cityId=1166*

BUILT ENVIRONMENT

As we can see in the graphs above, the built environment of rural Bangladesh is largely made of accessible and natural materials. According to the Bangladesh Bureau of Statistics (2015), more than 50% of rural houses have walls made of wood, 15% are made of wood and mud; and 10% of bamboo, straw, and plastic. The remaining 25% of the constructions are made of common industrialized materials such as concrete and brick.

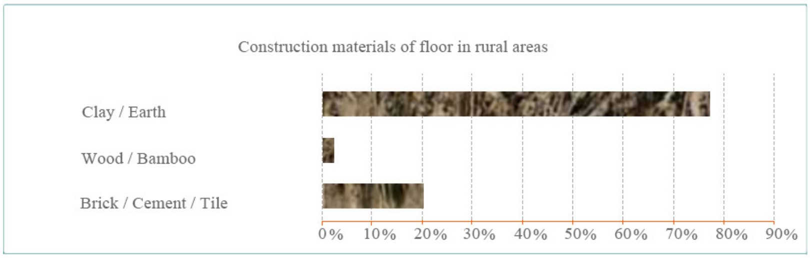
The roofs are mostly made of wood and tin; other materials such as concrete, cement, brick, mud, straw, or bamboo are used in less than 15% of the constructions. Floors are made of earth or mud in more than 75%, around 20% are made of cement, brick, or tiles and the remaining are made of wood and bamboo.

This material is not because of a sustainable objective, but because of the socio-economic impossibility of obtaining commonly used materials such as concrete or brick. This increased the idea that the material of a façade defines the purchasing power of the people who live there, making materials as noble as earth, bamboo, and wood are less used in the construction.



Chapter II ***Graphic 1*** *Percentages of roof materiality in rural houses. Own elaboration based on* Bangladesh Bureau of Statistics (2015)

Chapter II ***Graphic 2*** *Percentages of wall materiality in rural houses. Own elaboration based on* Bangladesh Bureau of Statistics (2015)



Chapter II ***Graphic 3*** *Percentages of floor materiality in rural houses. Own elaboration based on* Bangladesh Bureau of Statistics (2015)

Chapter II ***Figure 3*** *Rudrapur - Village study. By Team Rudrapur. Taken from https://www.anna-heringer.com/projects/rudrapur-village-study/*

Chapter II **Figure 4** Rudrapur - Village study. By Team Rudrapur. Taken from https://www.anna-heringer.com/projects/rudrapur-village-study/

THE DIPSHIKHA METI SCHOOL COMPLEX

On the first of September 1999 was born The Modern Educational and Training Institute as a very special kind of educational concept created by a voluntary organization called dipshikha. This space took place at 3.1 km from the nearest urban center Mangalpur in a rural area of around 2.19 ha according to google earth measurements.

The school aims to realize the independence of the rural people through education, and the knowledge is taught from two complementary perspectives. The first is the normal education in which from 8:30 to 13:00 the students follow the government syllabus, and the second is the 14:30 to 16:30 session that is dedicated to extracurricular knowledge. Is not clear to me the academic modality for youth and adults, but thanks to my youtube audiovisual sources I know that there are spaces for the creation of elements in bamboo, weaving, and electrical skills.

Although what is currently known as the METI School, anna heringer's building, was built in 2005; this complex began its activities earlier and has other facilities in addition to the architect's work. So it is important to clarify that the name of the entire campus is Dipshikha METI School as this causes various confusion.

This is because when searching for the Heringer building on the internet and google earth the result may not always be the 2005 building, but another of the architect's buildings. which made me think at first that the building was changed, replaced, or no longer exists.

The fact is that the Dipshikha METI school had at least 11 buildings of which 3 were designed by heringer, and 6 other possible constructions that are shown in the architect's master plan, but in different videos and google earth satellite images I could not see.

Understanding the context of the METI building was a long process for me because of the lack of information. For me, a reiterative characteristic in the communication of Heringer's projects in Bangladesh is the decontextualization of them. Even though the buildings use local materials and are self-built, all the photos and facades make them look like solitary buildings. This is probably because they were designed in this way as the new architecture seems to completely ignore the existing architecture.

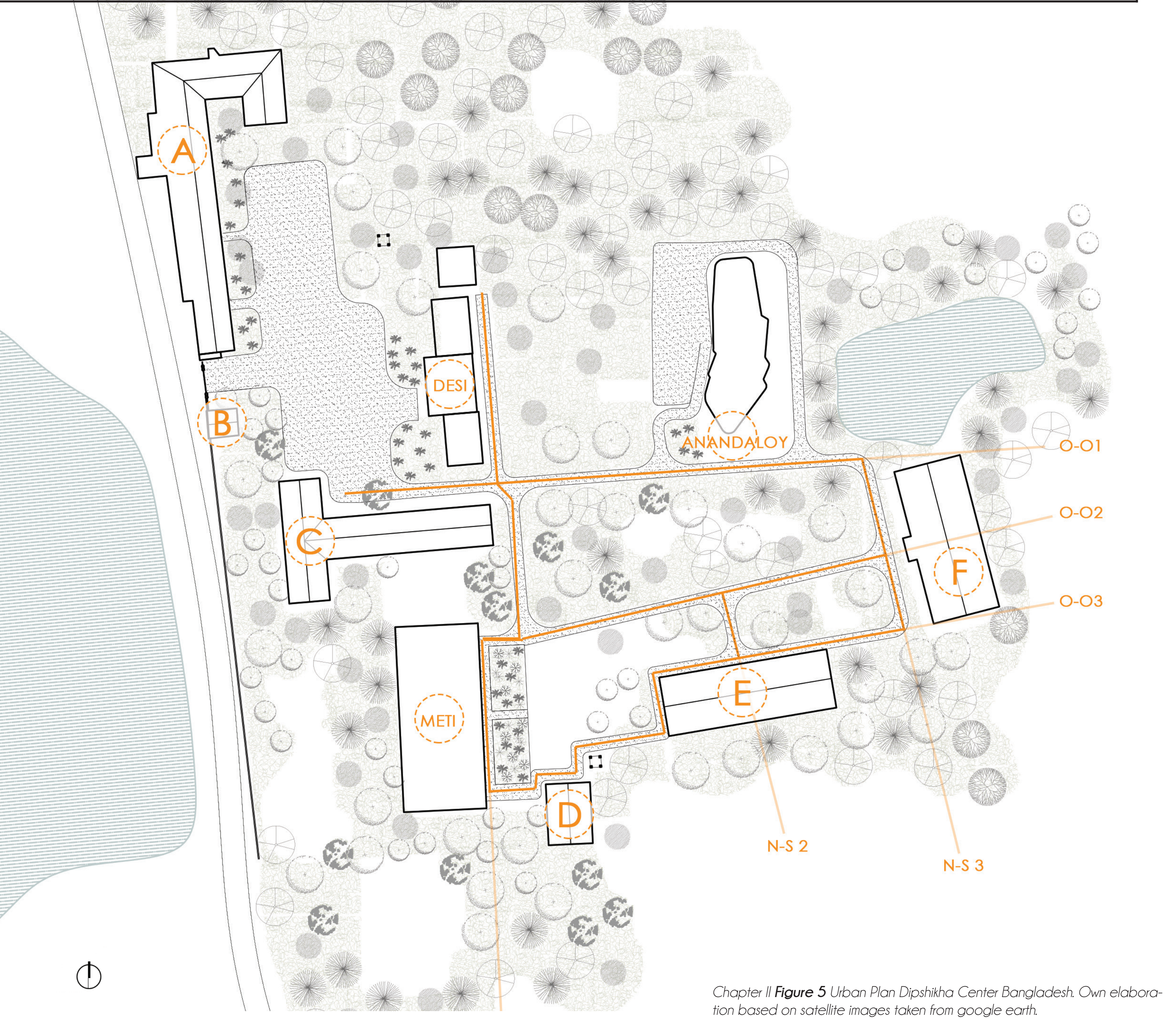
Due to the difficulty of going to the site, I decided to approach it through digital media. Different youtube videos made by content creators of the place allowed me to understand how the school is organized. I watched different videos that show different paths and spaces of the school, allowing me to gather information and understand a great part of the complex. Thanks to the videos I was also able to give an image to the existing architecture that until now I had only seen as rectangles in the master plan and heringer.

The entrance to the Dipshikha METI School is located directly on the vehicular access road in the middle of two buildings which I will call A and B [figure 6]. People enter a large and unoccupied area and right in front of it is the Heringer DESI center [figure 8].

On the left, it can be seen the entire building A and a roof that serves as a parking lot, and on the right, you can see a long building that I will call C [figure 8]. Between the DESI center and building C, there is a path (O-O1) that leads to the rest of the center.

At the end of the C building there is a fork [figure 9] (N-S1) on the right side, this way leads to the METI Building of Heringer. [figure 10,11] In front of the METI School building, on the right side next to a water tower is another square building which I will call building D. This is for sanitary use. [figure 12] A few steps further following the path (O-O3) on to the left is another building that in the video is shown as 3 circular buildings that share the same roof, I will call this one building E. [figure 13]

From the center of building E there are two paths, one parallel to the building and one perpendicular. The parallel one (O-O3) to its left side leads to building D and its right side leads to the corner of a new building.



Chapter II **Figure 5** *Urban Plan Dipshikha Center Bangladesh. Own elaboration based on satellite images taken from google earth.*

Chapter II **Figure 6** *Entrance of Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0bIrS_s.*

On the other side (N-S2), the perpendicular path leads to a large green island formed by the paths (N-S1, O-O2, N-S3 & O-O1) where the school park is located. [figure 15] Taking the road (O-O2) to the right towards the farthest part of the entrance people arrive at a building used as a teacher's dwelling, I will call it building F. [figure 17] towards the north façade of building F there is a body of water. [figure 14] also towards this side is the end of the main road (O-O1).

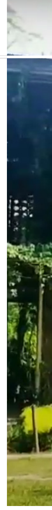
Taking this road (O-O1) again in the direction of the exit, on the right-hand side, there is a path that leads to the ramp of the last building of the center, the Anandaloy [figure 16], also designed by the architect. It is facing the DESI Center but is separated from it by a large green area.

It should be clarified that the other spaces and buildings shown in the architect's master plan as existing, I did not mention them because no video or image allowed me to verify that they were still standing.

Chapter II ***Figure 7*** *Building A Dipshikha Center Bangladesh. By SailoRider. Taken from https://www.youtube.com/watch?v=LZy2rkBtneY.*

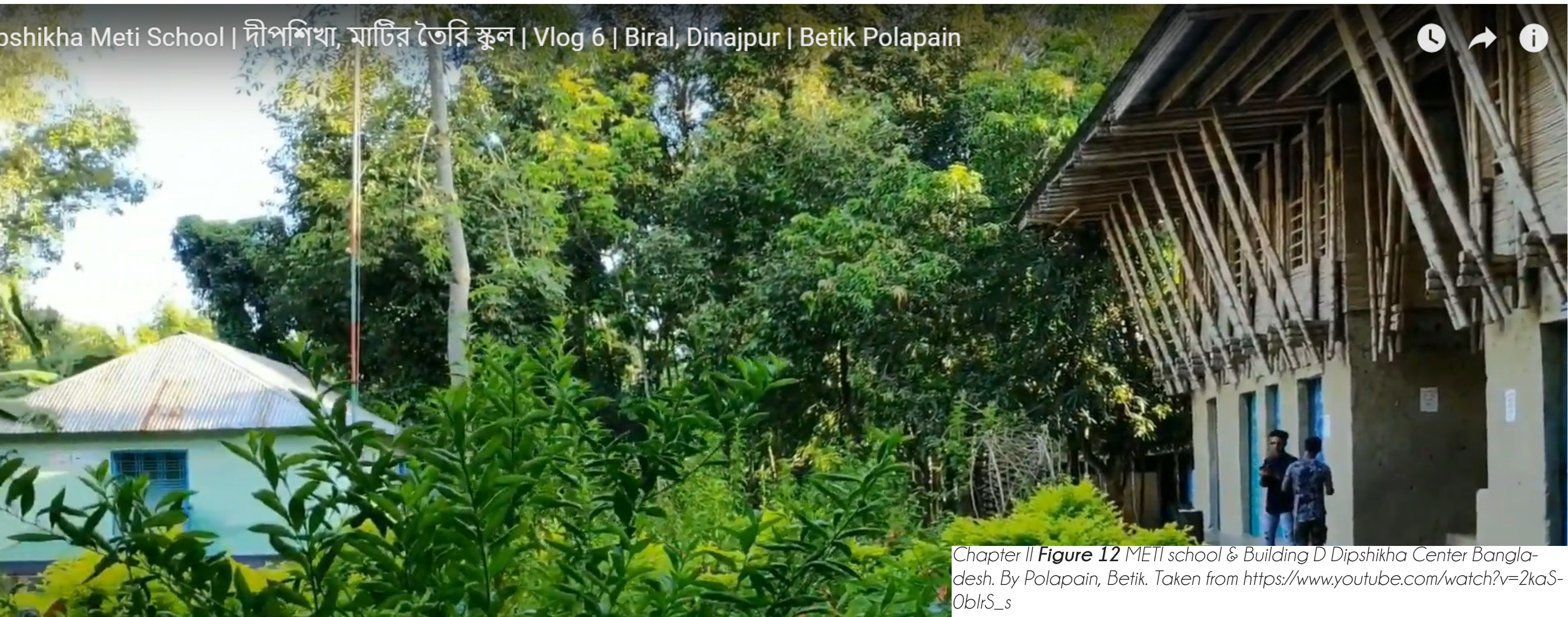
Chapter II ***Figure 9*** *Building C Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0bIrS_s*

Chapter II ***Figure 11*** *METI school Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0bIrS_s*



Chapter II **Figure 8** DESI center & Building C Dipshikha Center Bangladesh. By Rifat, Musavvir. Taken from https://www.youtube.com/watch?v=hNN0y-oKUClw

Chapter II **Figure 10** Path N-S1 Dipshikha Center Bangladesh.By Bong HD TV. Taken from https://www.youtube.com/watch?v=sHdF8i6YDQI



Chapter II **Figure 12** METI school & Building D Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS-0blrS_s

Chapter II **Figure 13** Building E Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0blrS_s

Chapter II **Figure 15** Dipshikha Center Bangladesh park. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0blrS_s

Chapter II **Figure 17** Building F Dipshikha Center Bangladesh. by Freedom 2022. Taken from https://www.youtube.com/watch?v=Q46GzV-ALs0

Chapter II **Figure 14** Lake Dipshikha Center Bangladesh.By Bong HD TV. Taken from https://www.youtube.com/watch?v=sHdF8i6YDQI

Chapter II **Figure 16** Anandaloy building Dipshikha Center Bangladesh.By Bong HD TV. Taken from https://www.youtube.com/watch?v=sHdF8i6YDQI

Chapter II **Figure 18** Desi & Anandaloy Dipshikha Center Bangladesh. By Polapain, Betik. Taken from https://www.youtube.com/watch?v=2kaS0bIrS_s

THROUGH THE YEARS

As I mentioned previously, information about this building and, in general, about Anna Heringer's work in Bangladesh is scarce. Despite having a report on the construction of the METI School with an extensive photographic bank, obtained from the architect's studio. The information was not detailed or specific enough to generate an analysis of the building's age, context, and construction techniques.

After searching and collecting information from other sources, I realized that most of the articles and publications about the building have as their main source the material provided by the architect, so only a few articles gave me useful new information. Due to this and thanks to the impossibility of physically accessing the site at the time to collect data in the first person, I had to look for alternative and perhaps uncommon sources that would allow me to collect as much information as possible.

By implementing the indexical method, I managed to reconstruct with a good degree of certainty the reality of the building based on secondary data and banal sources. The first data was obtained through google earth, which not only allowed me to access the satellite photos generated by the page in different years but also gave me a whole photographic record published by users and visitors of the building. Thanks to this I was able to see angles and periods of the place different from the year of completion of the work.

The next step, after having reviewed all the material on the platform until the beginning of this year, was to divide the material into two different scales: the architectural scale with all the images published on the site, even if they were not of the building itself but of other constructions; and the scale of the complex, which I will call urban, in which all the satellite images were included. Subsequently, I classified these images by year in order to select the material that will show changes in the urban composition, showing the development of the complex over the years. As in the architectural object showing different periods of degradation, improvement, or change with respect to the original project.

Transversal to this process I continue my search for sources that would allow me to understand more in-depth certain aspects, such as the environment of the METI School, since so far in the satellite images I could only see some apparent constructions among the trees. Thanks to youtube and content creators who are dedicated to visiting important places in Bangladesh, I was able to get a good amount of videos that led me to relate the urban and architectural scale from a user perspective going through the whole complex. which allowed me to find the sense of the whole and have a general understanding.

After this, I started my planimetric reconstruction. I took each video and generated a plan of the route I was taking, marking the buildings with letters and generating the paths that connected them, as a convergence point at least one building by Anna Heringer appeared in all the videos. each video broadened my vision of the place because it showed me an angle I had not seen, a new building, or reaffirmed some clue. The union of the common points of all these videos allowed me to create the general planimetry of the complex and to see its connections, uses, materials, volumes, forms, and users, allowing me to be in the place in a certain way.

The last step was to compare all this new information with the preceding or official documentation, creating a contrast to establish the common points, the differences, and the unknowns that remain, thus forming a hypothesis of the complex that allowed me to generate the analysis of the timeline, the building and its surroundings that I will show in the following chapters.

Chapter III ***Figure 1*** *Plan Dipshikha Center Bangladesh 2005 Own elaboration based on satellite images taken from google earth.*

As I showed previously, the METI building is in the Dipshikha School complex. In between a rural area. In this chapter, to understand the variations over time of the project and its context I will present the changes that the space has had through the years until obtaining the current configuration and building condition.

I have been able to map the configuration and development of the Dipshikha School since 2005. This year, as is shown in [figure 1], there are five existing structures in the complex, buildings A, B, C, E, F, and the METI School construction is finished. Most of the facilities are near the access of the school, which is located between buildings A and B in front of the road. Assuming that the prevalent use of the buildings is the same as the current one, the buildings C, E, and the METI are for classrooms, building F near the lake

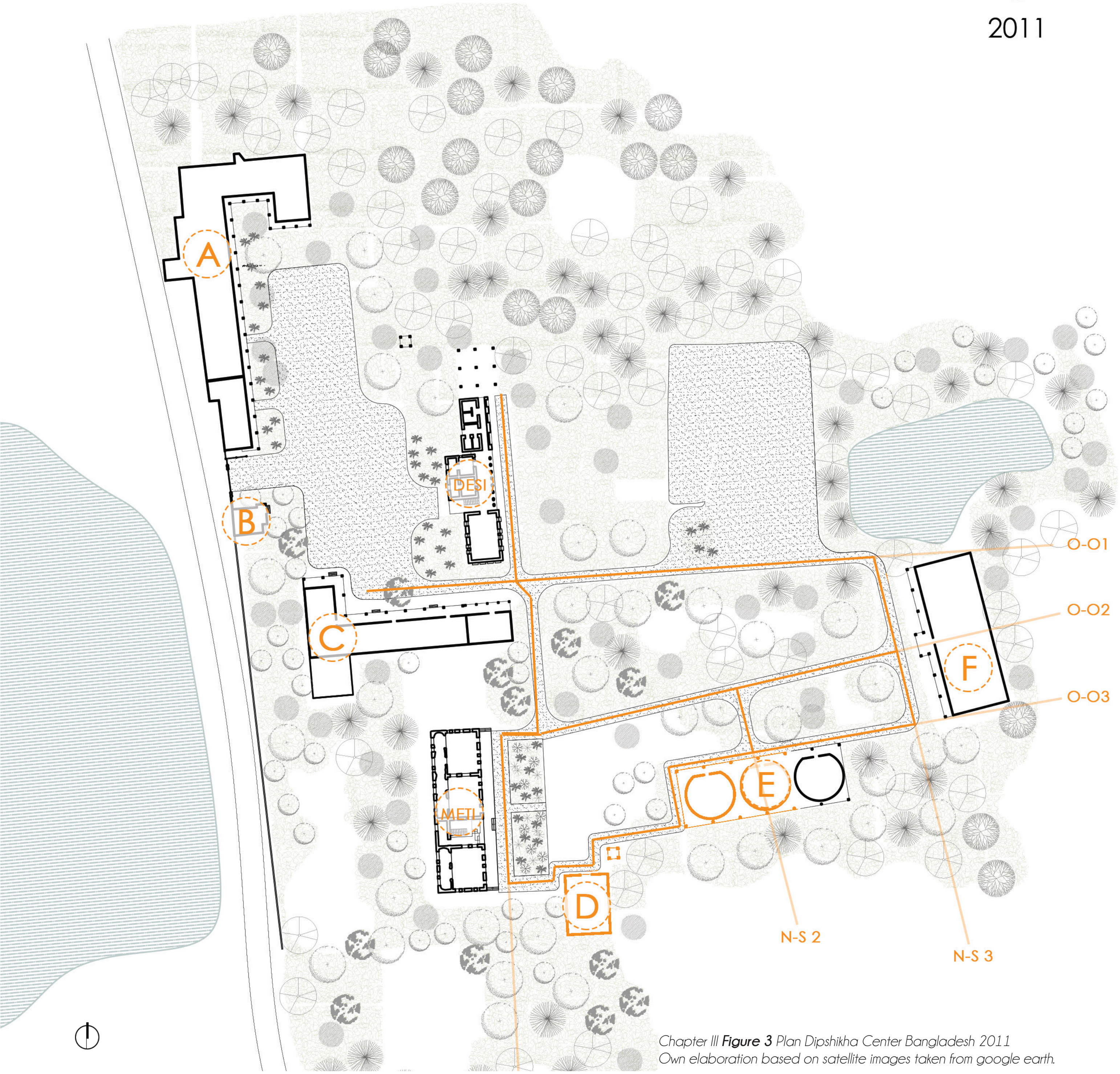
2008

Chapter III ***Figure 2*** *Plan Dipshikha Center Bangladesh 2008 Own elaboration based on satellite images taken from google earth.*

apparently residential, and the A and B are unknown.

The next relevant date is 2008 [figure 2] when Anna Heringer does her second building in the complex. Right in front of the access was constructed the DESI Center. A two-level building with three different volumes articulated by a balcony on the first floor and a terrace on the ground floor. As opposed to the METI school, this building has hydraulic and electrical installations since it contains restrooms. As is shown in [figure 7] on the roof are photovoltaic panels and a water tank.

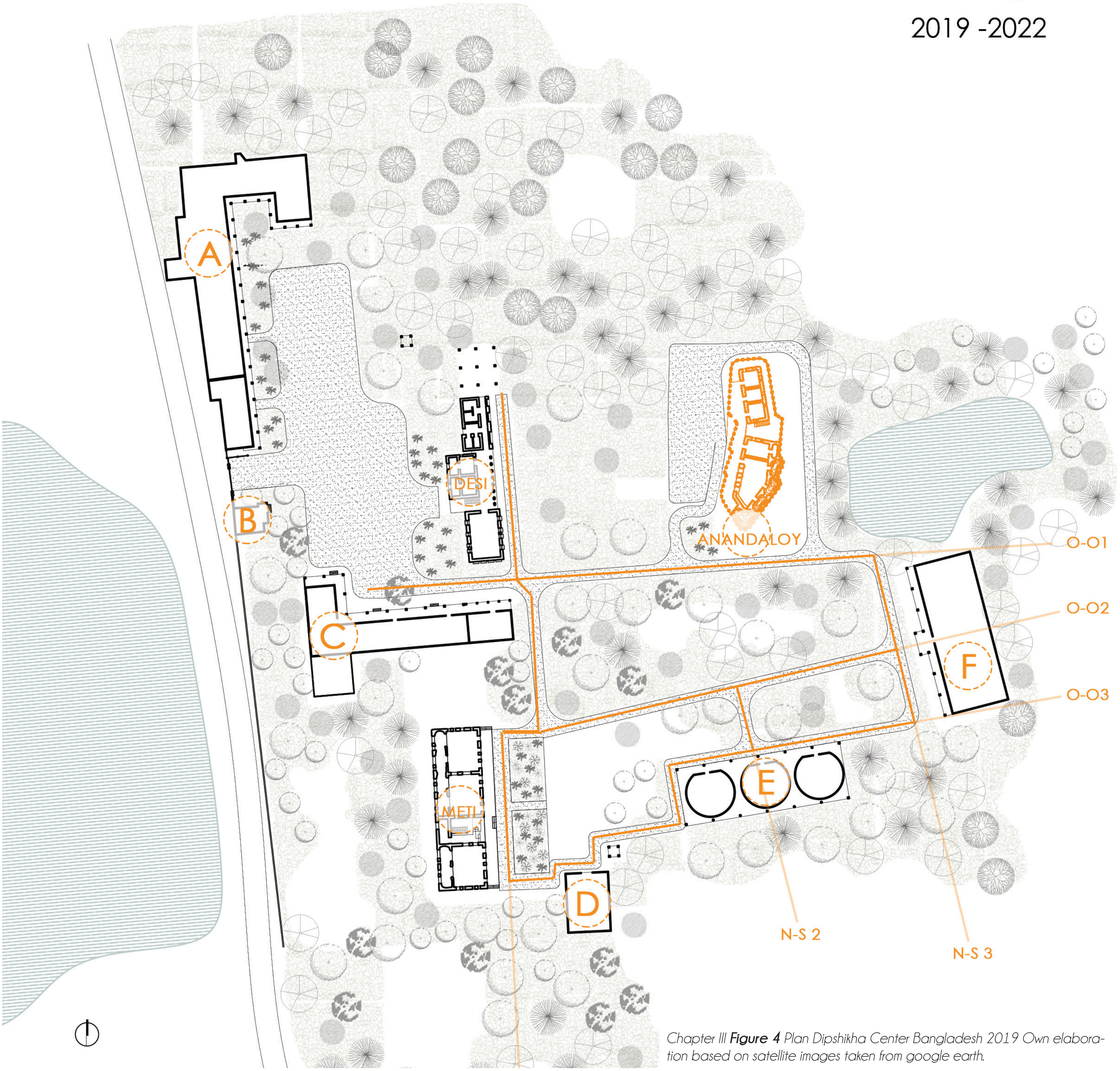
2011



*Chapter III **Figure 3** Plan Dipshikha Center Bangladesh 2011*
Own elaboration based on satellite images taken from google earth.

Three years later, in 2011 [figure 3], are added 2 more structures. building D and an extension of the E building, both construed in industrial materials in front of the East façade of the METI building. Due to its proximity to the water tower (W), I infer that building D is destined for restroom use. On the other hand, the E building, which despite being composed of 3 volumes with a circular plan still only one, since they share the same roof, is composed of classrooms for the child. Furthermore, landscape work connects the facilities and delimits specific areas. is delimited by a big open space in front of the entrance from which can be seen diverse spaces like the DESI Center, the parking zone just next, and some existing buildings. from here begins a pedestrian walkway that brings to the rest of the structures and the lake. Amidst these paths are created green islands for different destinations. The big one has a children's playground

2019 -2022



Chapter III ***Figure 4*** *Plan Dipshikha Center Bangladesh 2019 Own elaboration based on satellite images taken from google earth.*

and the one in front of the METI school is destined for presentations.

The last year that brings a significant change to the complex is 2019 [figure 4] when architect Herringer's last building is completed. In between the DESI Center and the lake is located Anandaloy, a center for people with disabilities.

This building with an irregular plan incorporates elements previously used in the other projects, like the caves from the METI school and the columns and panels of the Desi center. While new elements like a roof made of straw and ramps that allow access for persons with reduced mobility also appear.

Chapter III ***Figure 5*** *Master plan of Dipshikha Center Bangladesh 2005.*
Own elaboration based on Anna Heringer plan.

Regarding, the master plan that the architect made in 2005 [figure 5] and the current composition of the complex [figure 6] it can be noted that five of the water bodies that the architect drew in her master plan do not currently exist, or at least are not visible in any of the visual sources consulted. Just one of the buildings planned by the architect was constructed, the teacher's flats, but with what looks like another architect's project.

The assembly hall mutated and nowadays is the open space in front of the METI school. The guest house, studios, and library/ administration seem not to exist whereas the preschool, from what I saw through my research is in building E.

There are some existing buildings within the boundaries of the complex, marked on the map as N/A [figure 5], that I was unable to see in my research. for which reason

Chapter III **Figure 6** Current Plan Dipshikha Center Bangladesh.
Own elaboration based on satellite images taken from google earth.

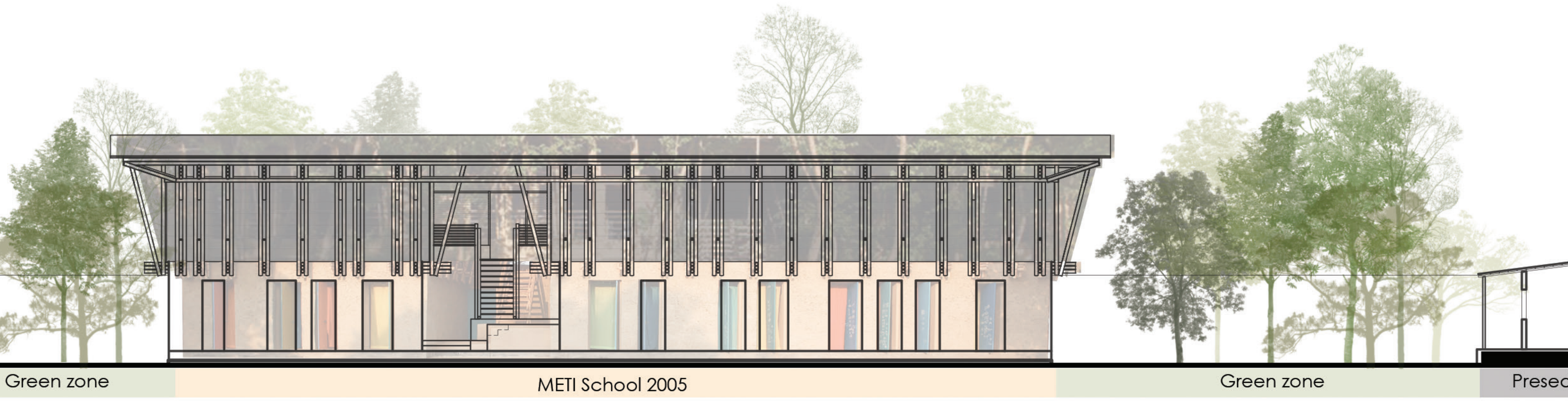
they were not considered for the present analysis.

In place of the guesthouse was constructed the Anandaloy building with a completely different morphology than the one planned in 2005, and in place of the library/ administration the DESI, the center was built following the regular form previously planned. The paths planned by the architect are almost the same with some variations to adapt them to the new constructions.

In conclusion, the master plan of the architect has the normal variations that adapt the project to the passing of the years and the new necessities but the zonification proposed remains the same. The most recent buildings features made as solar energy, new roof materials, and greater complexity in terms of composition and installations are implemented, but still concrete foundations.

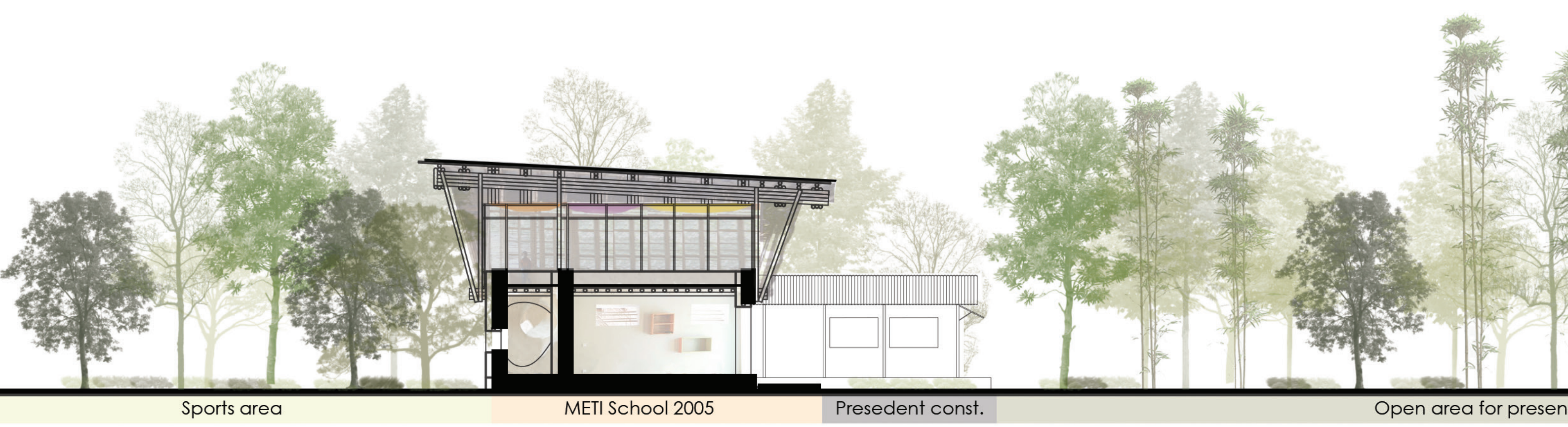
Section A-A'

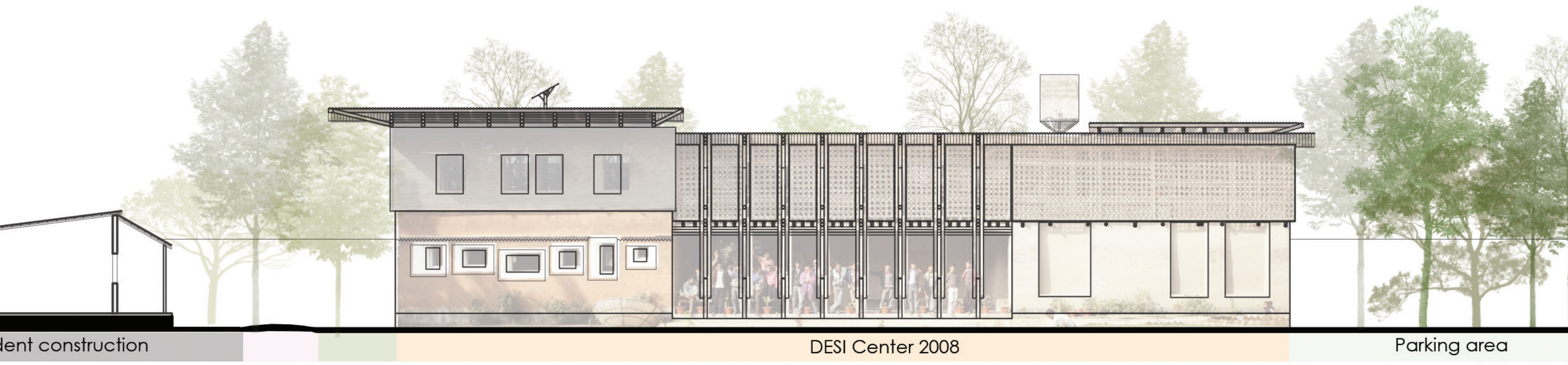
SC 1:250



Section B-B'

SC 1:250





Chapter III ***Figure 7*** *Section A-A' Dipshikha Center Bangladesh 2022. Own elaboration.*

Chapter III ***Figure 8*** *Section A-A' Dipshikha Center Bangladesh 2022. Own elaboration.*

Chapter III **Figure 9** METI School caves, PH Marcel Dykiert, May 2011, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

2011

The oldest image I could find [figure 9], besides the official images of the recently finished project, is from 2011. The photo of the inside shows some unevenness in the ceiling of the cave, which could represent a change in the construction technique that differentiates the lower part of the cave from the upper part.

2015

The next pictures I took from [Rahim, 2015] show the landscaping process of the western side of the school, where the vegetation is removed to plant new gardens delimited by bamboo barriers as seen in [figure 14]

Chapter III **Figure 10** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)

Chapter III **Figure 11** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)

Chapter III **Figure 12** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)

Chapter III **Figure 13** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)

Chapter III **Figure 14** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)


Chapter III **Figure 15** METI School est façade, PH Nipon Shaha, Sep 2016, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

2016

In the next year, as is shown in [figure 15] the landscape works pass to the eastern side, where were created two gardens following the edges of the building. There is some deterioration in the building which is most evident in the doors of the ground floor. Finally, in [figure 16] there is a noticeable difference between the lower part of the wall and the upper part, as indicated by the orange line and the beams are embedded, which could show possible post-2005 works.


Chapter III **Figure 16** METI School west façade, taken from the video METI SCHOOL (দীপশিখা মেটি স্কুল), made by SETU EXPRESS, Nov 2016, YouTube (https://www.youtube.com/watch?v=p_FnCOvwdxY&t=229s)


Chapter III **Figure 17** METI School west façade, taken from the video METI SCHOOL (দীপশিখা মেটি স্কুল), made by SETU EXPRESS, Nov 2016, YouTube (https://www.youtube.com/watch?v=p_FnCOvwdxY&t=229s)


Chapter III **Figure 18** METI School west façade, taken from the video METI SCHOOL (দীপশিখা মেটি স্কুল), made by SETU EXPRESS, Nov 2016, YouTube (https://www.youtube.com/watch?v=p_FnCOvwdxY&t=229s)


Chapter III **Figure 19** METI School first floor PH Syfur Sajib, Sep 2017, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

2017

In 2017, on the first floor textiles were removed from the ceilings, while on the ground floor the walls are folded in some areas [figure 20-21], such as the lower part of the wall that gives access to the caves from the classrooms. It appears that the building needs routine maintenance due to the deterioration of sensitive points of the building such as corners and angles, which is exacerbated by natural conditions such as rain.

Chapter III **Figure 20** METI School ground floor PH Syfur Sajib, Sep 2017, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

Chapter III **Figure 21** METI School ground floor PH Rehan Noyon, Feb 2017, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

2018

In 2018 there is a restructuring work on the building, as can be seen in the pictures, on the first floor structural elements were replaced, for which it was necessary to remove at least a part of the roof [figure 22-32].

The soil on the floor is removed to access the structure and change some of the beams and girders that support it [figure 23]. the low wall of the first floor in which the beams that support the columns are embedded is reconstructed, to replace some beams and columns. some of the upper beams that support the roof were also changed, and the fastening between them was with metal elements [figure 24].

The ties between the changed beams and columns were made with the blue rope [figure 27]. although there are no explicit photos that show that there was also work on the ground floor, from the photos of later years it could be intuited that there was.

Chapter III **Figure 22** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

Chapter III **Figure 23** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

Chapter III **Figure 24** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

Chapter III **Figure 25** METI School west façade, taken from the video HOME-made - family houses in Bangladesh, made by fazle rahim, Apr 2015, YouTube (https://www.youtube.com/watch?v=XK_R3OHijHw)

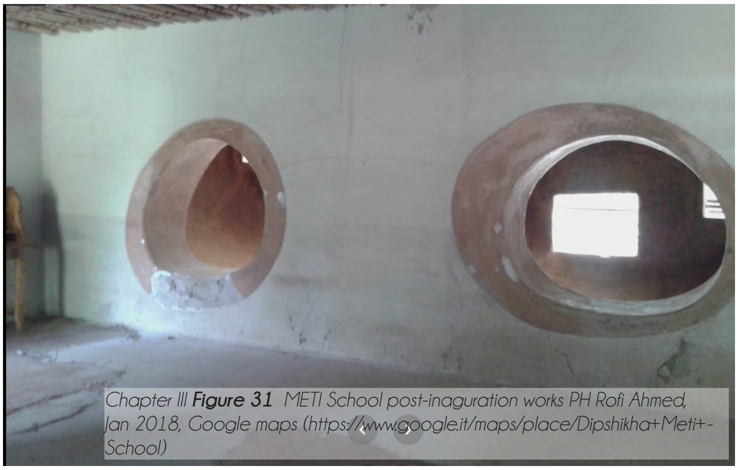

Chapter III **Figure 26** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 27** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 28** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 29** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 30** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

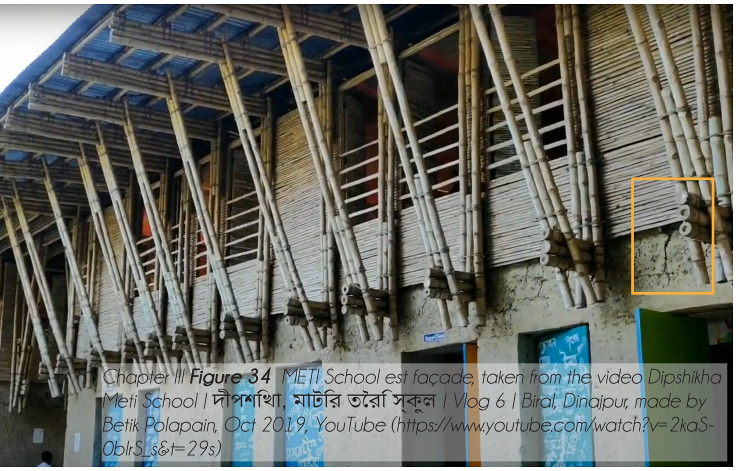

Chapter III **Figure 31** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 32** METI School post-inaguration works PH Rofi Ahmed, Jan 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 33** METI School northern facade PH Mahabub Nahid, Jun 2018, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

2019

In this year's photos, it is possible to see different signs of decay and wear on the building. There are cracks at the top of the earthen walls [figure 34] and some bamboo used as barriers on the windows has fallen [figure 35]. Bamboo has spots and a white color that may be a sign of rotting due to lack of treatment or a pathology like white rot. in addition to this, the use has exposed the shape of the bricks on the floor of the caves [figure 39]. On the other hand, the garden is still growing.

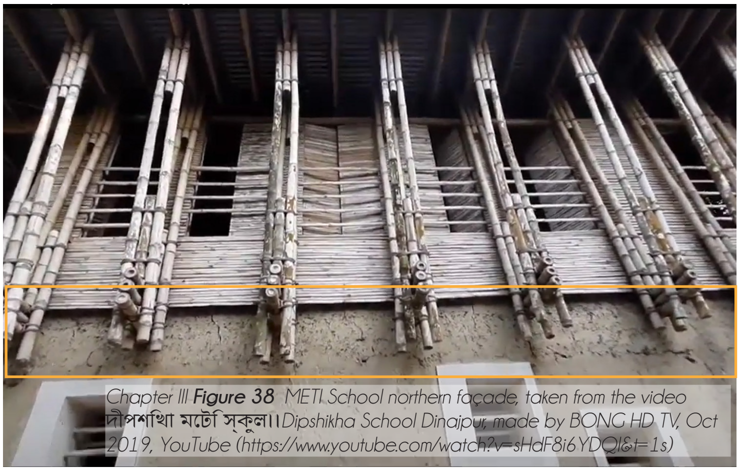


Chapter III **Figure 34** METI School est façade, taken from the video Dipshikha Meti School | দীপশিখা, মাটির তৈরি স্কুল | Vlog 6 | Biral, Dinajpur, made by Betik Polapain, Oct 2019, YouTube (https://www.youtube.com/watch?v=2kaS-ObIrS_s&t=29s)

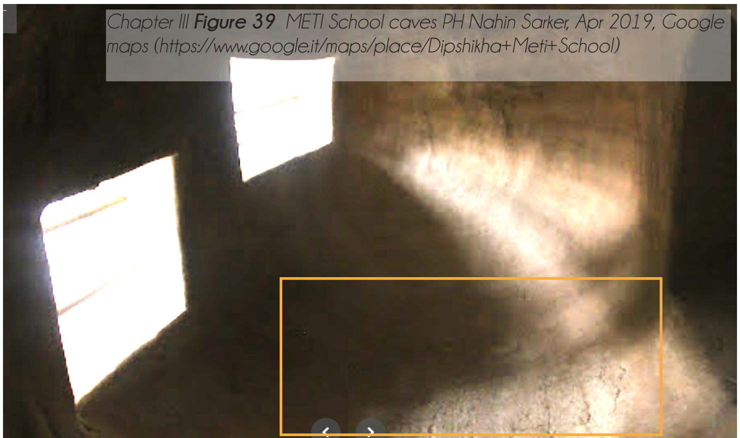
Chapter III **Figure 35** METI School est façade, taken from the video Dipshikha Meti School | দীপশিখা, মাটির তৈরি স্কুল | Vlog 6 | Biral, Dinajpur, made by Betik Polapain, Oct 2019, YouTube (https://www.youtube.com/watch?v=2kaS-ObIrS_s&t=29s)

Chapter III **Figure 36** METI School est façade, taken from the video Dipshikha Meti School | দীপশিখা, মাটির তৈরি স্কুল | Vlog 6 | Biral, Dinajpur, made by Betik Polapain, Oct 2019, YouTube (https://www.youtube.com/watch?v=2kaS-ObIrS_s&t=29s)

Chapter III **Figure 37** METI School northern façade PH Hiji Biji, Jul 2019, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)



Chapter III **Figure 38** METI School northern façade, taken from the video দীপশিখা মাটৈ স্কুল।। Dipshikha School Dinajpur, made by BONG HD TV, Oct 2019, YouTube (https://www.youtube.com/watch?v=sHdF8i6YDQI&t=1s)



Chapter III **Figure 39** METI School caves PH Nahin Sarker, Apr 2019, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)


Chapter III **Figure 40** METI School ground floorPH Mahmudul Hasan, Jan 2020, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

2020

in 2020 the wear of the bamboo is more evident and there are also some patches on the north side, which may represent possible repairs and periodic maintenance.


Chapter III **Figure 41** METI School northern facade PH Mithun Datta, Apr 2020, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)


Chapter III **Figure 42** METI School bamboo PH Hazmul Hasan, Jun 2020, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)


Chapter III **Figure 43** METI School exterior PH Medical and tourism, Jun 2020, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)


Chapter III **Figure 44** METI School western façade PH Mahbub Ui Islam Khan Nibir, Dec 2020, Google maps (https://www.google.it/maps/place/Dipshi-kha+Meti+School)


Chapter III **Figure 45** METI School cave ceiling PH MD Fardin Fattah, Feb 2021, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

2021

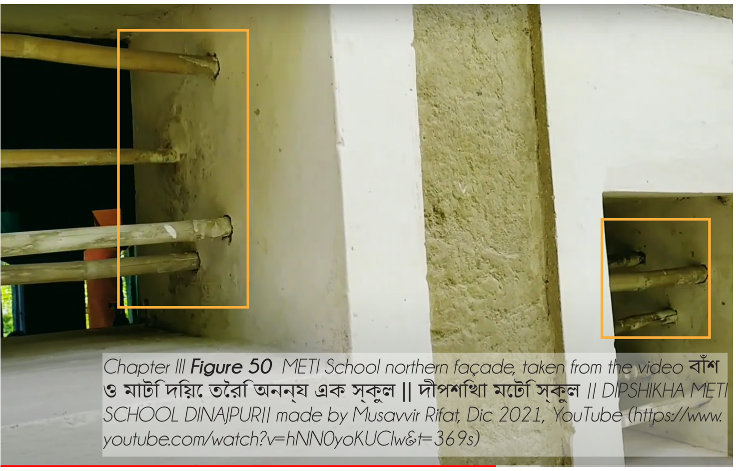
In 2021, wear and tear can be observed in the ceiling of the cave, which shows the plaster peeling off [figure 45]. It is also possible to notice the installation of fans in the ground floor rooms supported by large beams that were not part of the original project. Some green bamboos suggest that some structural elements were changed again [figure 49]. The walls in which the bamboos that serve as a barrier for the windows are embedded are giving way due to the usual erosion of the material. [figure 50]. Some stains show new plastering at some points of the exterior. thanks to the material, periodic maintenance of the building is facilitated at a low cost.

Chapter III **Figure 46** METI School ground floor ceiling PH MD Fardin Fattah, Feb 2021, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)

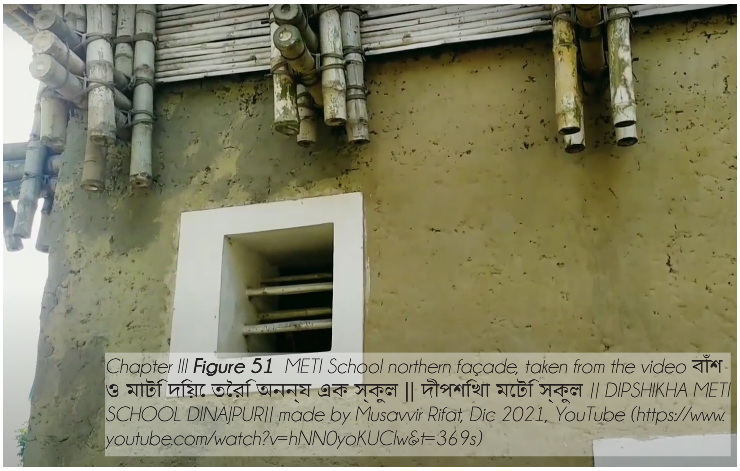
Chapter III **Figure 47** METI School bamboo PH Yamin Alam, Feb 2021, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

Chapter III **Figure 48** METI School staircase PH Esteham Hasan, May 2021, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+School)

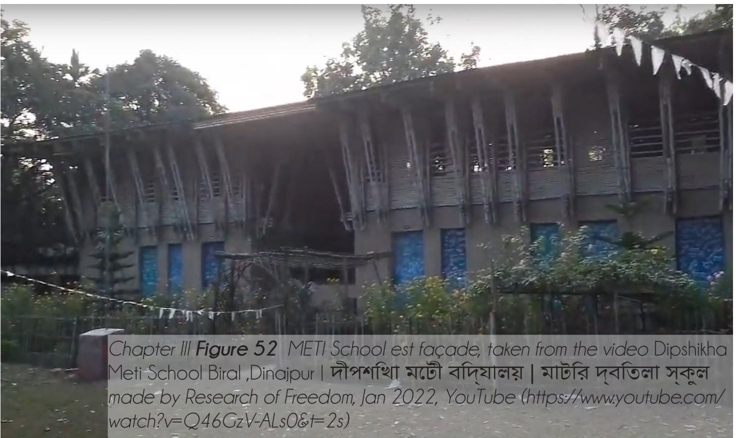
Chapter III **Figure 49** METI School staircase PH Asaduzzaman Noor, Dic 2021, Google maps (https://www.google.it/maps/place/Dipshikha+Meti+-School)



Chapter III **Figure 50** METI School northern façade, taken from the video বাঁশ ও মাটি দিয়ে তৈরি অনন্য এক স্কুল || দীপশিখা মেটি স্কুল || DIPSHIKHA METI SCHOOL DINAJPUR|| made by Musavvir Rifat, Dic 2021, YouTube (https://www.youtube.com/watch?v=hNN0yoKUClw&t=369s)



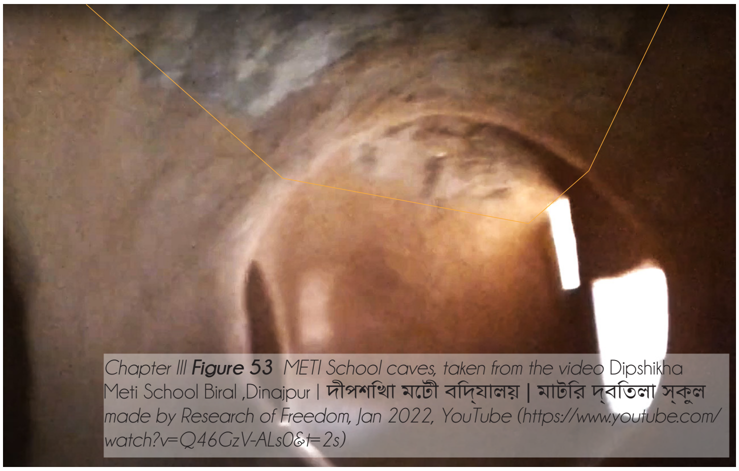
Chapter III **Figure 51** METI School northern façade, taken from the video বাঁশ ও মাটি দিয়ে তৈরি অনন্য এক স্কুল || দীপশিখা মেটি স্কুল || DIPSHIKHA METI SCHOOL DINAJPUR|| made by Musavvir Rifat, Dic 2021, YouTube (https://www.youtube.com/watch?v=hNN0yoKUClw&t=369s)



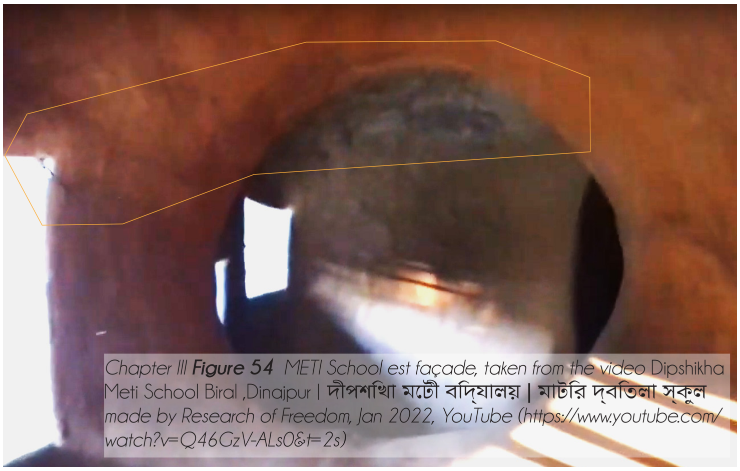
Chapter III **Figure 52** METI School est façade, taken from the video Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALsO&t=2s)

2022

Currently, the decay of the cave ceilings still exists, as well as the bamboo. Because the earthen walls are unfinished and the thatch is exposed, some pieces fall off, creating holes in the walls. On the other hand, the garden on the eastern side is maintained.



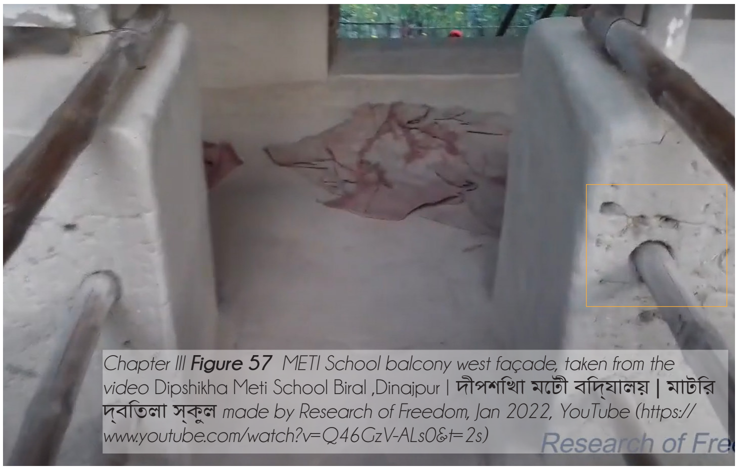
Chapter III **Figure 53** *METI School caves, taken from the video* Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল *made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s)*



Chapter III **Figure 54** *METI School est façade, taken from the video* Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল *made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s)*

Chapter III **Figure 55** *METI School West façade, taken from the video* Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল *made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s)*

Chapter III **Figure 56** *METI School bamboo, taken from the video* Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল *made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s)*



Chapter III **Figure 57** *METI School balcony west façade, taken from the video* Dipshikha Meti School Biral ,Dinajpur | দীপশিখা মেটী বিদ্যালয় | মাটির দ্বিতলা স্কুল *made by Research of Freedom, Jan 2022, YouTube (https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s)*

In conclusion, over time the METI School has had several periods of deterioration. Assuming that before 2018 no changes were made to the building structure, the life cycle of the bamboo was 13 years. This means that for this building we have to count 3 times the emissions from the construction of the bamboo structure because in addition to the change in 2018 while on-site the structure was initially made with green canes, which were later changed to dry canes.

The image of the cave ceiling and its deterioration compared to the cave floor suggest that the structure is different at the top and the bottom. The floor has been resurfaced on several occasions and in different parts of the building, but the material made it easier due to its price and availability. In addition, fans were installed, which may infer that the thermal comfort in this space was not ideal or, being a recent development, that the idea of thermal comfort has changed over time. the landscape continues to exist and grow to this day.

Finally, it is important to recognize that the limited durability of the building should not be perceived as something negative. Traditionally, performance is always accompanied by maintenance. What is important is that the design and architectural solutions facilitate the replacement of elements. Taking into account the economic possibilities of the school, it could be that due to the impossibility of paying for the bamboo treatments and its maintenance, the architect designed her project to facilitate the periodic replacement of the structure, recognizing the labor as affordable.

BRIEF INTRO TO SUSTAINABILITY

Sustainable development “is a form of development, which considers all human activities, to meet the needs of the present without compromising the ability of future generations to meet their own needs”. (Malthus, 1798)

In the field of construction and architecture, sustainability has been a booming topic in recent years, due to the responsibility and impact of our design decisions. Contemporary architecture with other fields of knowledge has developed various ways to mitigate this problem, seeking to comply with the various agreements, treaties, and protocols that have been made to protect the environment and reduce, or at least slow down global warming.

With strategies such as the reduction of energy consumption from non-renewable sources in buildings, the recycling of construction materials, the use of local materials, more sustainable means of transport, the reduction of construction emissions, and materials, among others, architecture evolves to make more sustainable spaces.

Materials and products for sustainable architecture

As I said previously the choice of materials in a project is a key point for its success. Some of the criteria for selecting materials for a sustainable building can be (Ashby,2013)

-Reusable materials, are those that after their useful life in a building is over can be easily recovered and used in the same or different functions.

-Materials with recycled content, reduce waste and avoid the consumption of new resources.

-Renewable materials, such as wood, plant fibers, earth, and others.

-locally adapted materials, which have the right characteristics to have a good performance in the context in which they are inserted.

-Local materials, reduce transport costs, both economically and ecologically, and have low embodied energy. This is the approach heringer usually implements in her works.

*Chapter IV **Figure 1** Balneario Vitina, Colombia 2021. Photo by Felipe Santana*

Chapter IV **Figure 2** OMICRON 2015, Photo by Stefano Mori. Taken from https://www.anna-heringer.com/projects/omicron-monolith/

EARTHEN ARCHITECTURE

"Even today, one-third of the human population resides in earthen houses; in developing countries, this figure is more than one-half. It has proven impossible to fulfill the immense requirements for shelter in the developing countries with industrial building materials, i.e., brick, concrete, and steel, nor with industrialized construction techniques. Worldwide, no region is endowed with the productive capacity or financial resources needed to satisfy this demand." (Minke, 2009)

Different names are usually attributed to this material. Among the most commonly used terms are "mud bricks", "loan", "rammed earth", "adobes" and "earth blocks". According to Minke (2009), there are ten essential points to keep in mind when talking about earthen construction.

First of all, the earth is a non-standardized material, since, depending on the geographical location of the extraction, the physicochemical components change. Although in some countries, such as Germany, work is being done to standardize the material, (The New DIN Standards in Earth Building—The Current Situation in Germany, Lehm), and tools have been developed that allow the classification of soils, earth construction materials, and their construction systems; the earth cannot be a material for the construction of commercial projects until all its properties are reproducible in standardized test procedures. (Schroeder, 12(2018))

In other words, to become an everyday material in current construction it must be industrialized, thereby losing some of its sustainable characteristics such as embodied energy and emissions.Secondly, (Minke, 2009) points out that there are two types of mixes, wet and dry, if the percentages of the mix are not correct, the walls tend to crack.

The third point refers to water, which must be considered for two related aspects, the durability of the construction, since this material is not water-resistant, and to avoid problems such as erosion it is necessary to protect from it.

"A rammed earth wall needs a good hat and good boots," says an old saying referring to the fact that the roof must be designed in such a way that rainwater cannot drain, permeate or accumulate on any surface made of earth, and although this has great validity in the sustainable branch there are other technical and technological solutions to avoid this, although not all of them avoid the use of materials such as concrete.

(Kapfinger, et al., 2015)

Water is also an important factor when trying to understand, analyze and predict the long-term behavior of earthen architecture. “Water is the key parameter variable in the life cycle of the building in the case of unstabilized earth architecture.” (Morel, et al., 2019).

This is because it will affect its performance, its maintenance, and the years of the useful life of the construction which is directly linked to the life cycle cost of the building. It should be noted that, although the cost of maintenance in an earth construction will probably be lower than that of another material, a good design phase is essential to avoid this.

(Minke, 2009) cites as a fourth point the earth’s ability to balance the humidity in the air. Experiments carried out by the BRI (Building Research Institute) reveal that adobe bricks absorb 30 times more moisture than fired bricks and that a house built in adobe has a constant relative humidity of 50% all year round, fluctuating only 5% to 10% to adapt to the seasonal climate. [1]

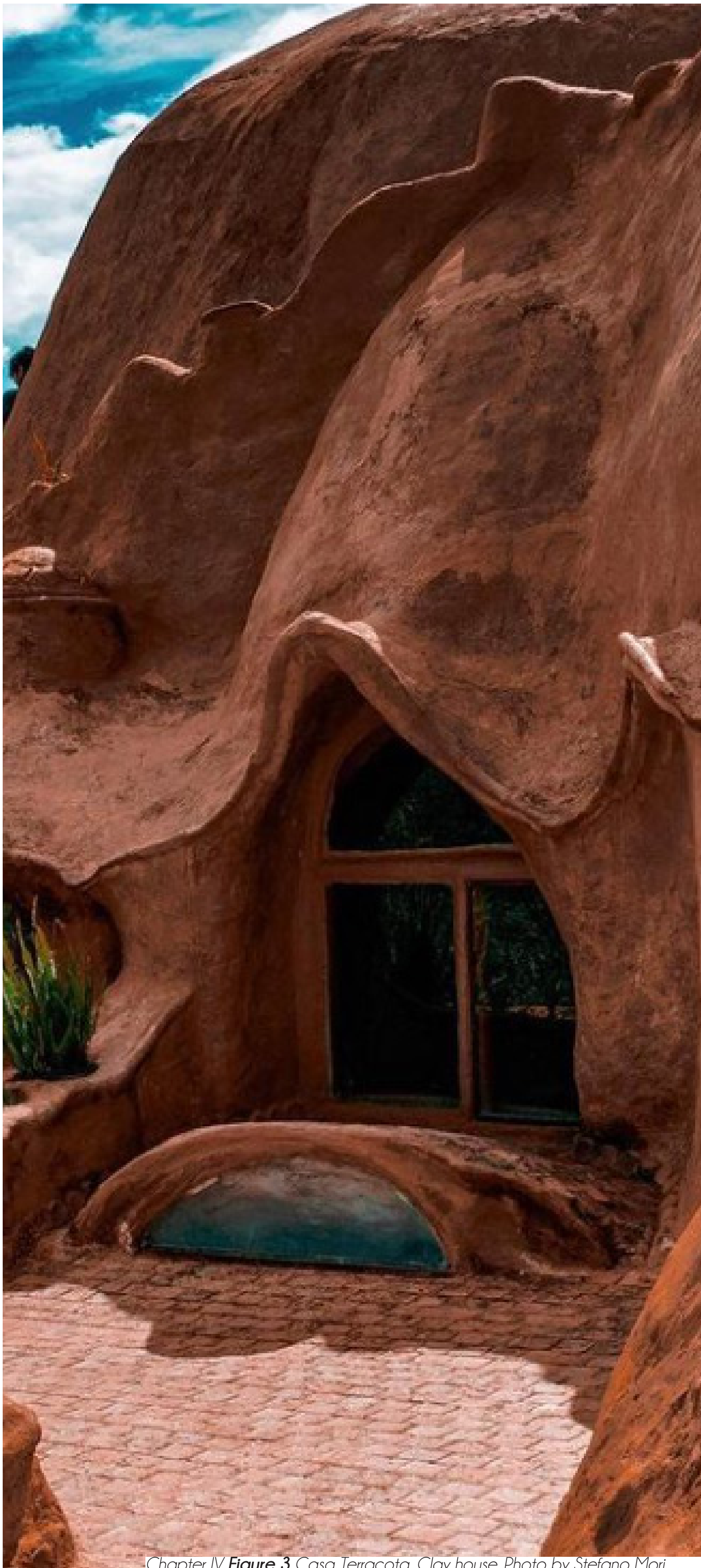
A fifth point, earthen constructions store heat. This makes it an excellent material for areas with high temperatures throughout the year, such as La Guajira, Colombia, or Dinajpur, Bangladesh, where it is necessary to absorb heat to cool the indoor environment.

Another quality mentioned and particularly important in the case study of architect Heringer is self-construction, as this material and its construction techniques have been used by communities long before architects were technically trained in them, being an excellent option for those who need to meet their housing needs and cannot access an actor with technical knowledge.

Currently, a large portion of Latin American households live in self-built homes, some of them in adobe or Tapia pisada thanks to the knowledge acquired from the constructions of the indigenous groups.

The last aspect that the author talks about refers to the sustainability of the material. The seventh point is that the soil can be reused an indefinite number of times, avoiding it becoming a waste material. The eighth point is the reduction of costs of materials and transport, this under the perspective of being a locally extracted material, preferably from the same site excavations.

The ninth point, is the earth also can preserve the wood and other organic materials, thanks to its capacity to absorb humidity that keeps wood and other materials dry, thus avoiding fungus and other deterioration caused by living organisms. Finally, (Minke, 2009) says that the soil absorbs pollutants, helping with the cleaning of polluted indoor air.



*Chapter IV **Figure 3** Casa Terracota, Clay house. Photo by Stefano Mori.*

Bamboo is a herbaceous plant that, unlike other species classified as grass, after a few years develops a structure as hard as wood thanks to the lignin in its tissues, but much more ductile and lighter. There are six genera of bamboo commonly used in construction: Bambusa, Chusquea, Gigantochloa, Phyllostachys, Dendrocalamus, and Guadua; These grow on one or all continents except Europe, which has no Bambusae tribe.

Some of the environmental properties of bamboo to enhance are the production of biomass, thanks to the fact that it is a fast-growing natural resource, the reduction of soil erosion thanks to its roots, and water retention that can reach 30,000 liters in species such as Guadua Angustifolia, the capture of CO2 that is greater than that of trees, with an absorption of 149. 9 tonnes of CO2 per hectare in Guadua Angustifolia plantations, the production of primary energy that doubles that produced by wood with 600 MJ/m3 and its diversity of uses. (Minke, 2016)

Among the most recurrent problems, can be singled out as the deterioration of insects because of the high levels of sap or starch, and the appearance of fungi because of humidity. To ensure the durability of the structures with this material, it is essential to focus on the cutting, drying, and curing of the bamboo.

To prevent the rotting of the rhizome, it should cut the bamboo at a slant. For the structural function, it is cut within 3 to 5 years of growth and above the second or first striation above the ground.

There are different drying methods, among which the simplest and most effective are the method in the bush and the air-drying method. In Bangladesh, they used an easy soil curing method in which they cover the canes with clayey mud for a few weeks to extract the starch. This process is important to avoid water absorption through the porous walls of the bamboo, ensuring the mechanical properties of the bamboo, the use of metallic brushes or elements that could weaken the shell is not recommended. It can be used as a fire barrier the same treatments used in wood.

Depending on the geographical area of origin of the bamboo its physical properties vary, and its size is related to its relative humidity, which in the first stage of growth of a cane should be approximately 70%, while years later it usually decreases to 20% or less. This loss of water makes a bamboo pass from its green state to its woody state, contracting its diameter between 3 and 12%.

The admissible forces depend on different factors. According to chapter G12 on Guadua structures of the Colombian seismic resistance standard of 2010 (NRS-10), about the Guadua Angustifolia species, the cane has high tensile strength in its outer layer, withstanding 40 kN/cm² as well as steel. In terms of seismic performance, bamboo is the ideal material because of its strength-to-weight ratio.

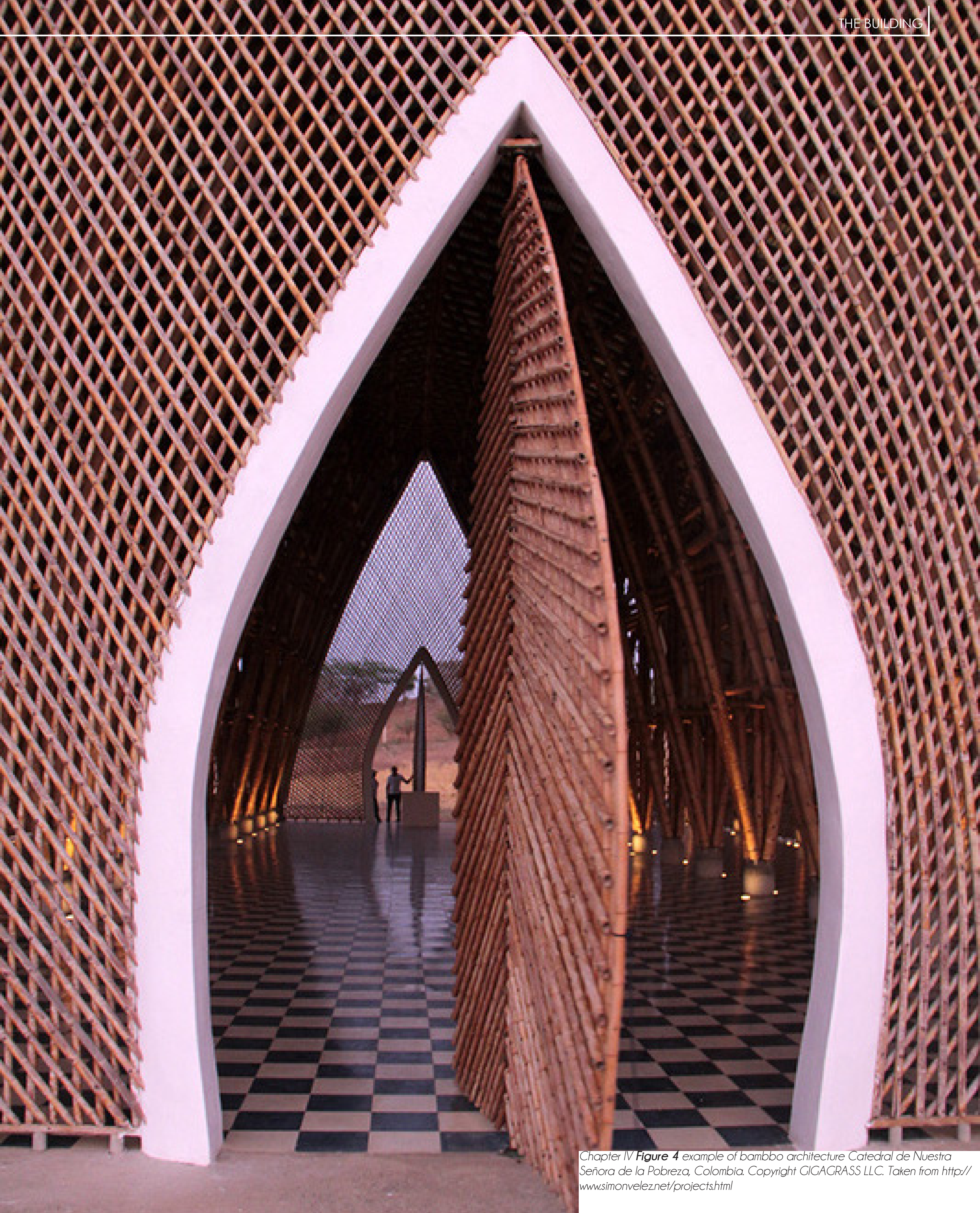
In Europe, there is no standard for the use of bamboo as a construction material, so a specific approval for its use must be requested on a case-by-case basis. Among the general recommendations to take into account when building with bamboo, It must be highlighted that it is essential to build skirtings and eaves to avoid rain damage, aligning the pegs in the internodes can produce breaks, and the uncovered knots must be protected from the rain with asphalt, stucco or metal panels if the joints are subjected to higher loads the screw will crack the bamboo.

Among the elements of bamboo apart from the cane, there are the strips which are longitudinal strips taken from cuts parallel to the cane fibers, and the thinner belts, 1 cm wide segments of the outer part of the cane used for fastening strips or fabrics.

The most important factor in the construction of this material is the joints, as the transfer of forces between elements depends on them. Due to the hollow and round section of the canes with only longitudinal fibers, it is necessary to be very precise and methodical in the joints, as introducing screws without prior drilling in the internodal areas can cause the cane to break longitudinally.

For the perforations, the axis on which they must be aligned must be taken into account. They must also exceed the diameter of the screw by 1.5mm and if they are on the outside, they must have an anticorrosive treatment. The joint internodes and those adjacent to the joint must be filled with mortar when they are subjected to loads that may cause cracks. Tensile bolts should be spaced 150 to 250 mm apart, no more and no less, and compression bolts less than 100 mm apart. Traditional joints are made with natural fiber ties, but there are also different alternatives ranging from wooden elements to metal connectors. The most common cuts for bamboo joints due to their cross-section are “fish mouth” and “flute point”.

For the beams, it is most common to have beams composed of two or three canes, one on top of the



Chapter IV ***Figure 4*** *example of bambbo architecture Catedral de Nuestra Señora de la Pobreza, Colombia. Copyright GIGAGRASS LLC. Taken from http://www.simonvelez.net/projects.html*

Chapter IV ***Figure 5*** *example of bamboo architecture Puente peatonal calle 80 Bogotá Colombia. Copyright GIGAGRASS LLC. Taken from http://www.simonvelez.net/projects.html* other, joined with pins at the point of support, this increases the resistance to bending, as a single cane is usually inadequate and weak for large spans or not reduced loads.

Finally, bamboo can also be used for walls in two different ways, the first as light walls composed of a skeleton of cane and bamboo planks, these are commonly used in hot areas as they allow the passage of air helping with the natural ventilation of the space and the second in the reinforcement of walls in rammed earth or adobe, an example of these is Chan Chan in Peru, a pre-Columbian city with conical walls of 2. 50 m wide and 9 m high reinforced with Guadua Angustifolia vertically on the sides and horizontally at the ends and in the center.

Chapter IV ***Figure 6*** *example of bamboo and bahareque architecture Mexico 2018 Copyright © Lucila Aguilar. Taken from https://www.archdaily.com/904269/the-go-to-guide-for-bamboo-construction* choice of materials manages to anchor the building and blend in with the context.

The building was designed in collaboration with a group of experts in different fields, who advised on the construction and use of materials. The choice of the technical team, which was chosen by the architect, gives rise to some questions, because as far as the report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007) suggest, the specialists involved are Austrian and German, and although the capabilities of these specialists are not questioned, it is not clear why no local specialists were involved. This weakens the discourse of participatory processes that declare the Laufen manifesto, for although the community was very involved in the project, it remains doubtful whether their participation was exclusive as a labor force.

Its schedule was rather short compared to normal construction times, thanks to the low complexity of the project, both compositionally and in terms of networks, installations, and finishes.

The project was assigned to the architect in early 2004 and had no specific functional requirements, nor a formal program. The only instruction given was to build some classrooms. The design phase lasted from March to August 2005 when the client's approval was obtained. The construction lasted fourth months, being delivered in December of the same year. The total cost was 22,835 USD, of which 68% went to materials, 22.3% to site work, and 9.7% to landscaping.

In terms of composition,the building goes for a minimalist, orthogonal floor plan, with a good proportion of spaces. The architect gives the materiality and the structure all the prominence. For the locals the project is a work of luxury with its height that allows natural lighting and ventilation.

The client's request to use local materials prompted the architect to explore new ways of building. The project consists of five classrooms and additional interactive spaces in the form of caves that the architect proposed to encourage the children's creativity. On the ground floor, the three classrooms are contained within the thick earthen walls that open up into windows and doors to allow light and ventilation. On the other hand, the first floor has a thin perimeter made of bamboo slats panels, which allows air and diffused light to enter the two upper classrooms.

The territory is well irrigated, which was fundamental for the construction of rammed earth. These same wells were used as a ventilation mechanism on the hottest summer days, helping to induce air movements. The

THE BUILDING

According to the official project report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007), that was shared by the Anna Heringer studio and is the main source for this introduction to the building. The METI School is a project that gained recognition by adapting its building materials, earth and bamboo, into more durable materials. The most important technical advance implemented in this construction is the damp proof course, which is achieved from a foundation made of bricks and concrete; and adding straw to the mud mixture as an additive to improve its strength.

In addition to this, the work highlights the potential of bamboo as a construction material, which is implemented on the first floor. The structure of bamboo beams and columns on which the roof rests creates an airy and ventilated floor. The school was self-built by the community.

The motivation of Heringer to work in such a context stems from her participation in a one-year voluntary service with the NGO Dispshikha in 1997. There, as she said in TED talk (The warmth and wisdom of mud buildings, 2017), she realized that she had experienced the most sustainable year of her life. Thanks to the fact that the architect never lost contact with the community, the Modern Education and Training Institute was born out of a research project and in collaboration with the planning body of the NGO Dispshikha in 2002 to obtain her diploma at the school of architecture and industrial design in Linz, Austria.

The project was sponsored by the German NGO Shanti, which donated 35,000 USD for the construction. which as mentioned in the context and timeline chapters wanted to expand the METI program. Initially, the construction of the additional classroom was intended to be a monumental concrete building, but this changed for the persuasion of Heringer and Dipshikha director Paul Cherwatigga, who was always interested in the use of local materials.

The METI school has a ground floor area of 275 square meters and a total area of 325 square meters, the height of the floors is about 3 meters. In the rural environment in which it is located, the volume breaks the profile of the building, especially because of its sloping roof, which leaves aside the traditional gable roof. But the

Chapter IV **Figure 7** "Form follows love." Anna Heringer. Photo by Stefano Mori. Taken from https://www.anna-heringer.com/vision/

Chapter IV **Figure 8** Bamboo construction METI School Copyright fotografie & medienarbeit Kurt Horbst climate as mentioned in previous paragraphs is a facilitating factor for the project. Due to its proximity to the tropic of Cancer, Bangladesh has a relatively constant climate throughout the year.

In traditional earthen constructions, the stacked balls of mud with straw are not well compacted, leaving holes through which rats from the rice fields can sneak in. The METI implemented a new method for the construction of the mud walls. This consists of creating a layer of straw placed along the length of the wall, which is then woven with the straw arranged perpendicularly.

The main engineering elements, the bamboo trusses, and frames are joined together using mainly steel pegs and nylon rope. A questionable choice gave the traditional and sustainable jute rope as an option. The roof was made of zinc-coated iron sheets.

On the first floor, the beams are formed with three bamboo canes joined vertically and anchored at both ends to the mud wall that functions as a balustrade. There is no finish per se, the surfaces of the rammed earth walls were ground with shovels, leaving the thatched reinforcement exposed.

The facades start with a small concrete plinth on which rest the sturdy earth walls where the structural elements made of bamboo are embedded. Rhythmically spaced columns are juxtaposed with bamboo beams that go from being merely structural elements to fundamental elements for the architectural composition. The light passing through the trusses accentuates the aesthetic effect of the structure, while for a polished effect the window frames on the first floor are internal, allowing them to be camouflaged in the bamboo slatted wall on the facades.

The north, south, and east facades have a series of offset windows on the ground floor. The east façade, on the other hand, reveals two volumes in the foreground with a staircase in the middle and blue pivoting doors on the ground floor.

The building has no water supply or discharge points. The galvanized tiles of the roof conduct the rainwater so that it drains into the ground and is absorbed naturally, avoiding possible damage to the mud walls.

The energy supply in the territory is limited. At night, although not every night, the site is illuminated by a diesel generator. The school has energy-saving light bulbs in the classrooms with conduit wiring routed in the bamboo.

The METI school could be classified as technically assisted self-build because the labor for the project was provided by the community and the technical design by Anna Heringer's European contacts.

In summer, according to the report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007), a cool and pleasant temperature inside the classrooms, thanks to the cross ventilation and its bamboo walls, the natural light filters through the openings in the mud walls and the organic shape of the caves.

The performance of the building in an emergency, should not represent danger in the event of a natural disaster of any telluric movement type, while the first floor can withstand winds and earthquakes thanks to the bending of bamboo.

The plinth on which the building is settled was made to prevent water from touching the mud walls so that flooding should not be a threat. Since fire should have no presence in the building due to the inexistence of a kitchen decreases the likelihood of a fire.

The project is an appellant example of sustainable construction. It has a lower impact on the natural environment than most constructions with industrialized materials. As with any building, regular maintenance is necessary to extend its life and to ensure its good functioning.

The community's way of habiting the space means that the project lacks furniture. Because the lessons are attended sitting on the floor, mats made of cane and straw were used. The interior color is provided by the colorful cotton fabrics hanging from the first floor ceiling.

The community has benefited from the project. The classrooms are used by children between 6 and 10 years of age from low-income families, who work as farmers in the area and earn less than 60 takas, (0.62 euros) per day. The teachers as well as the pupils enjoy the bright environment and having been part of the process created a great sense of belonging in them. (Lim, 2007) Despite this children and teachers still take advantage of the existing structures shown in the previous chapters for complementary activities, but the facilities are not as comfortable as they are dark, hot, and congested.

The whole community is happy with the school. Parents feel a sense of satisfaction knowing that their children have a pleasant place to study, while the children enjoy it and feel more motivated in their academic work. On the other hand, the caves proposed by the architect provide a joyful space for the children to explore their creativity and recreate.

The building over the years seems to sustain both positive and negative aspects in terms of maintenance. The earthen walls of the lower floor dried out properly, taking on the consistency and firmness that comes with the maturity of the material over time. The bamboo is already showing signs of wear and tear, some architects and workers agree that this is due to the way the bamboo was cured. (Lim, 2007)

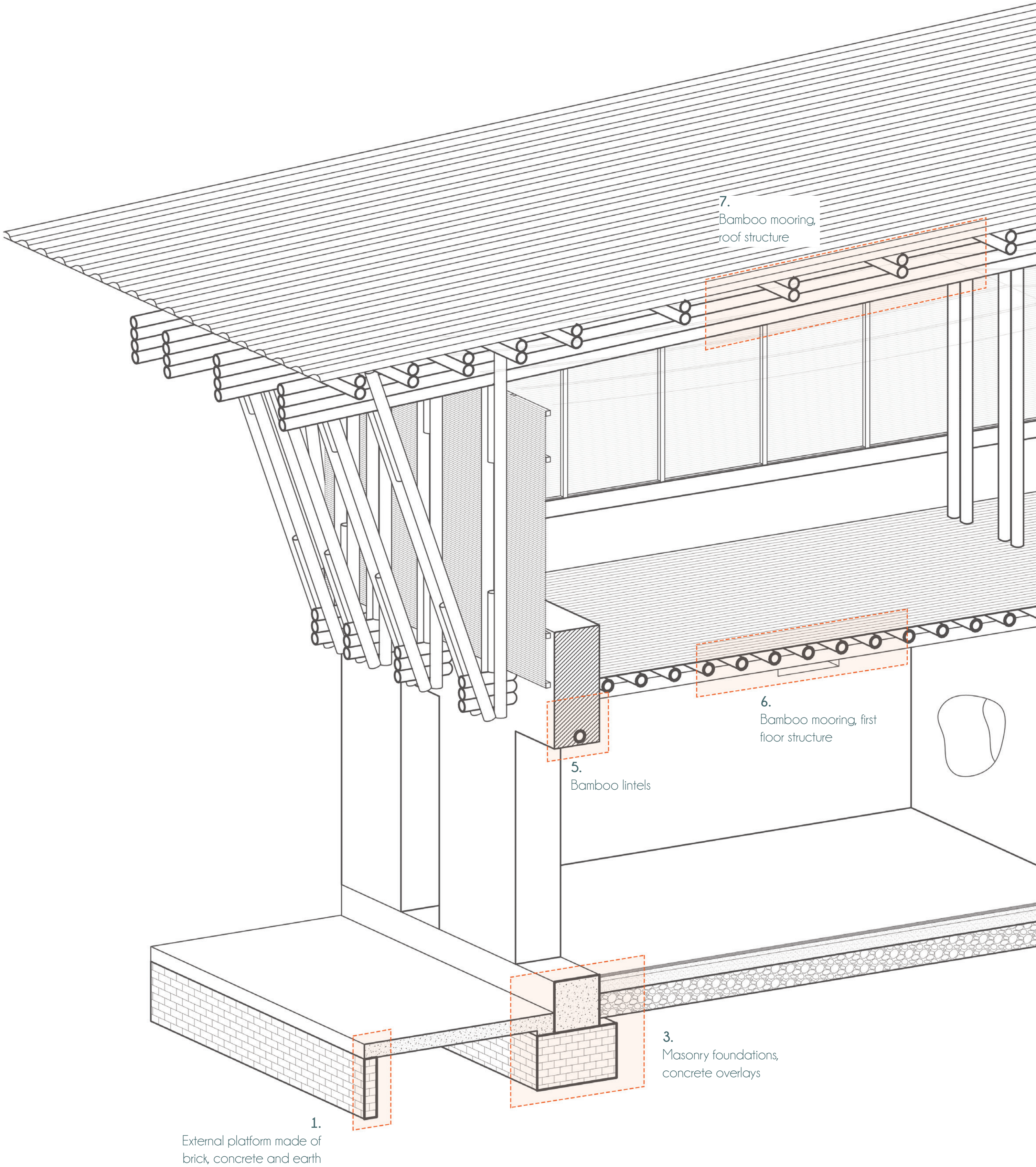
Instead of being cured by immersion in flowing water, as is traditionally done, was cured by immersion in stagnant water. This was not the first problem with bamboo, as the canes that had been firstly used, mostly green, had to be replaced due to the appearance of pests and other pathogens as soon as the project was completed.

Overall, the project was well-received, and the NGO Dipshikha was satisfied with the new classrooms and the attention the project attracted, as it is an internationally recognized and award-winning building. The teachers involved in the project enjoy being able to teach on the site, although they believe that the project's objective of transmitting technological knowledge about mud construction was not successful.

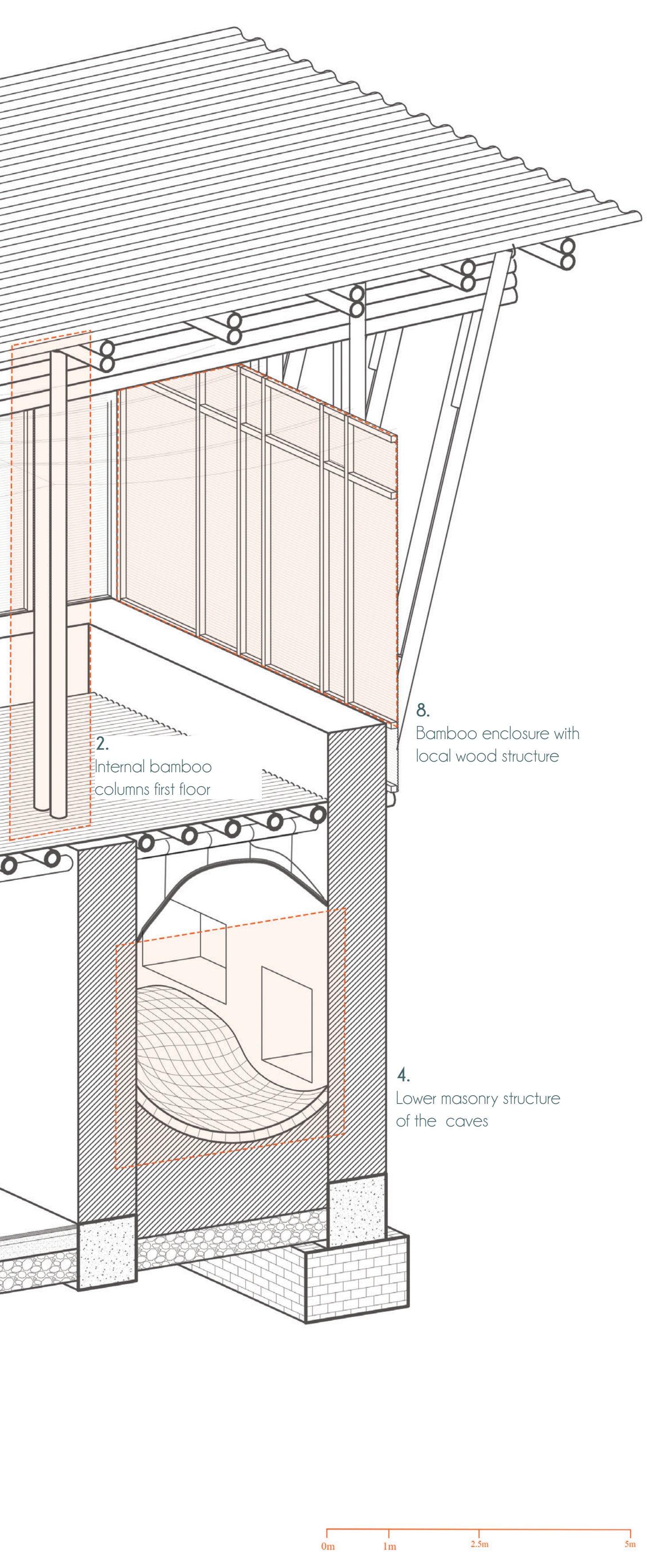
According to the report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007), most of the workers agree that, although it was an interesting and intellectually enriching experience for them, they do not have the necessary equipment and resources to repeat a similar project. The question remains as to whether any of the knowledge gained can be implemented and passed on in the ordinary constructions on site.

Chapter IV **Figure 9** METI School. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

3D MODEL



Chapter IV **Figure 10** 3D model. Own elaboration bas



ed on Anna Heringer plans & report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

Chapter IV ***Figure 11-18*** *METI School. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

FOUNDATIONS

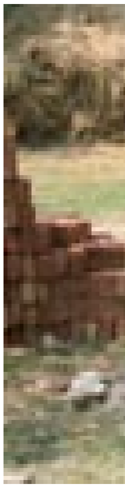
"ground-breaking ceremony 09/2005: The brick foundation was erected and plastered. The "mati department" (mati = earth/) began with the first trials of making the "weller" mixture and walls and were helped by water buffalos and cows. Even two days of heavy rain could not hamper the progress of the construction work" (METI school handmade in Bangladesh, n.d.)

As can be seen in the plan and photograph, the foundation of the METI school is made of brick. With about 100 m, the foundation has a perimeter cordon and three transverse rows, which are positioned on axes 9, 10, and 17. They are height 55 cm (5 cm less than recommended by article 7 of the Peruvian standard E.080 of design and construction in reinforced earth current reference standard for earth construction), and a thickness of 90 cm (40 cm thicker than the supporting wall).

Although the general recommendations for earthen construction foundation (cyclopean concrete, compacted stone of the pyramid type, laid with small stones, cyclopean adobe, or stone masonry with cement mortar) the architect opted for masonry walls for no apparent reason. This choice is a bit questionable since it is almost the only part where the architect uses industrialized materials instead of something more sustainable, or local materials.

Between the walls and the foundation, there must be waterproof insulation, or an overlay, whose function is to transmit the loads to the foundation and to protect the wall from erosion and capillary rise. Cutting off capillary moisture is key to the durability of the work. In general, the standard for other earth techniques like ADOBE, Guía de construcción parasísmica (Carazas Aedo, 2002) states that it is appropriate for the surcharge to be raised at least 30 cm above ground level and to have a minimum thickness of 40 cm. Recommended materials for this structural element include stone masonry with cement or lime mortar and coarse sand, cyclopean concrete, or asphalt adobe.

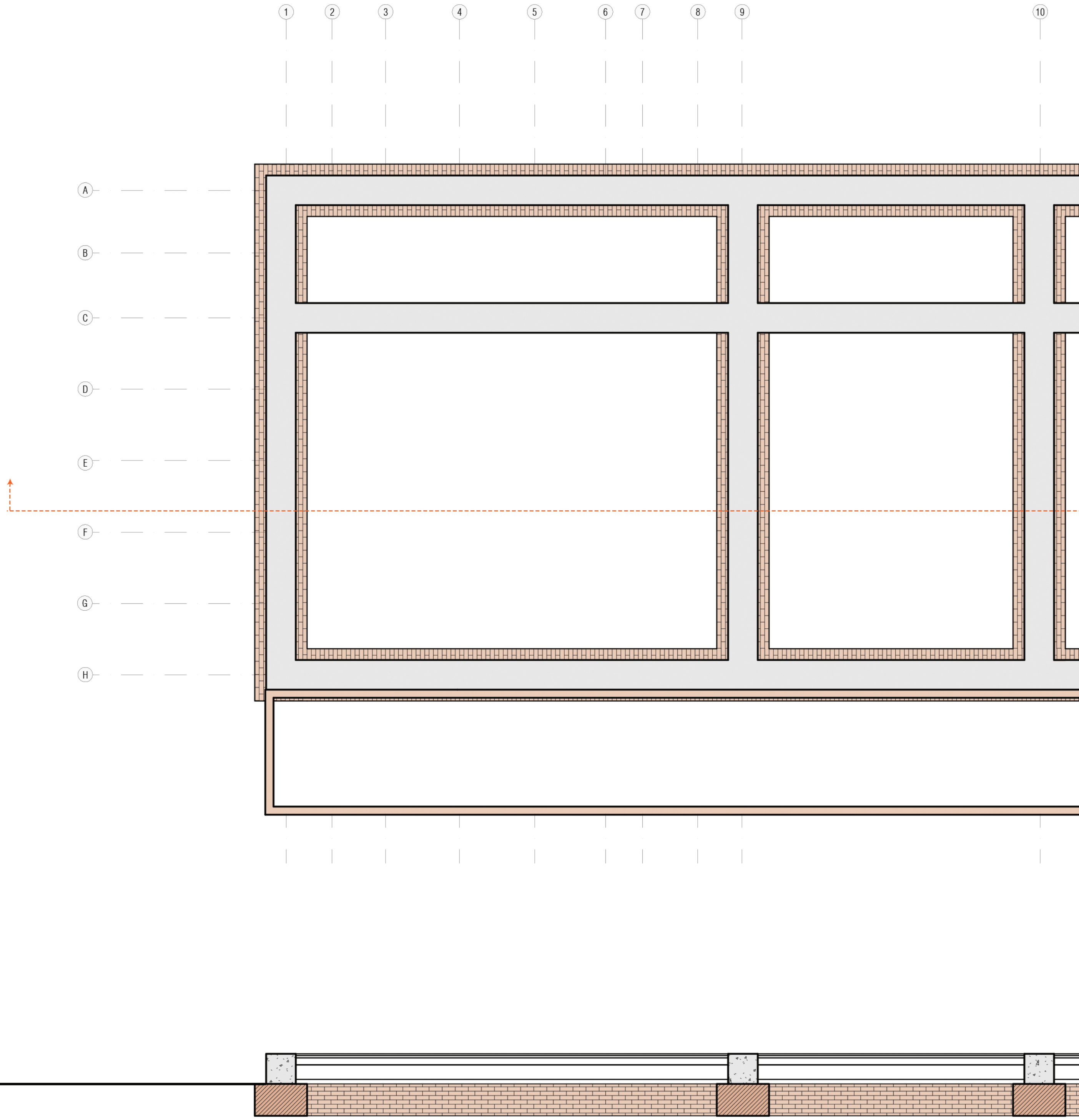
In this case, the building has a 130 m concrete overlay with a thickness of 51 cm, just like the walls, and a height of 52 cm, having a height of 40 cm above ground level, thus avoiding problems of flooding or absorption of moisture that could weaken the walls. In addition to this, the project has an external concrete platform with an area of 63 m2 and 15 cm in height, which is supported by 33.5 m of masonry 14 cm thick, and a height of 60 cm.



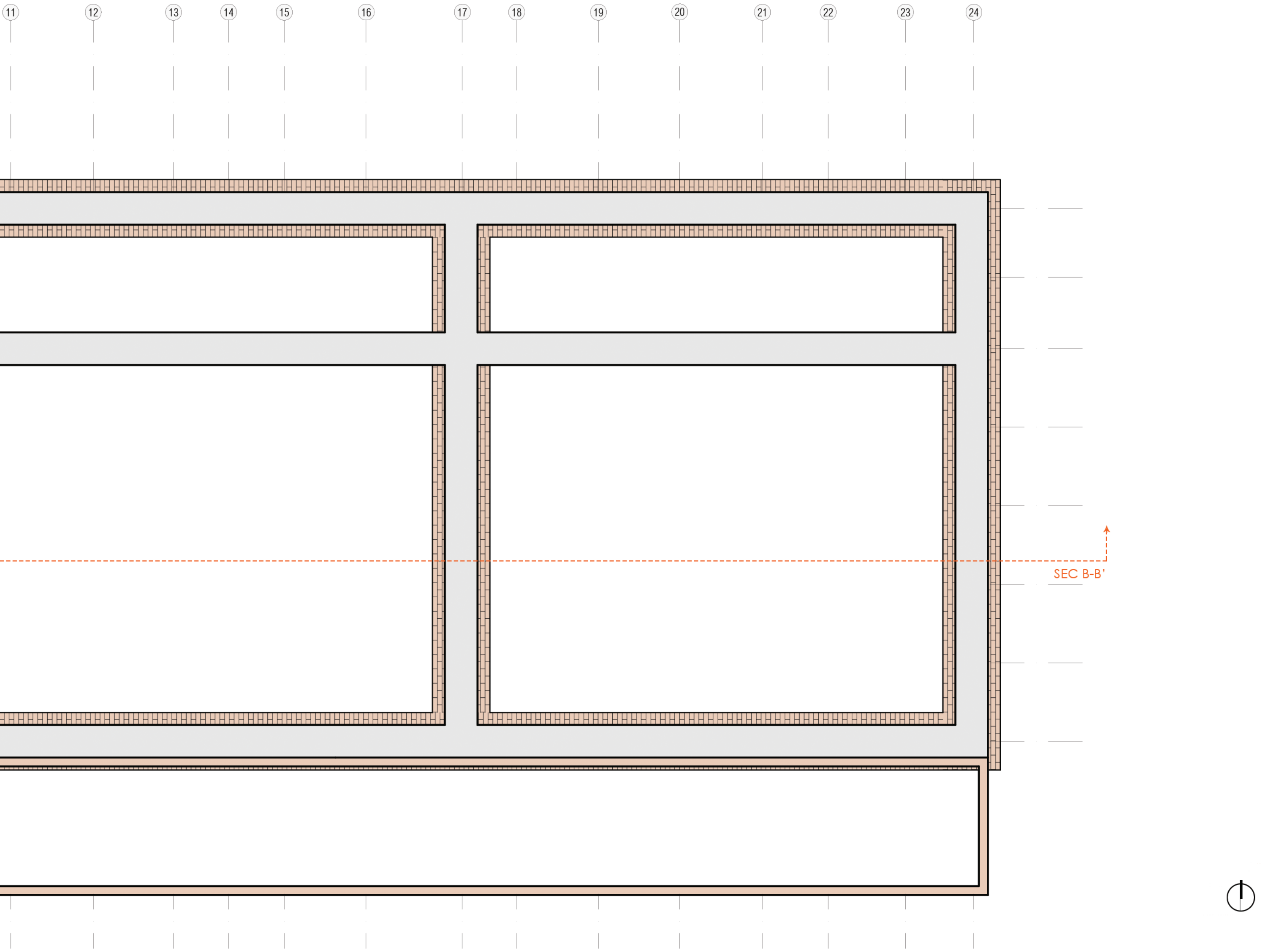
From left to right Chapter IV ***Figure 19 - 24*** *Images of co*

onstruction site, foundation phase September 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_baubeginn_e.htm

Chapter IV **Figure 25** METI School cimentation. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

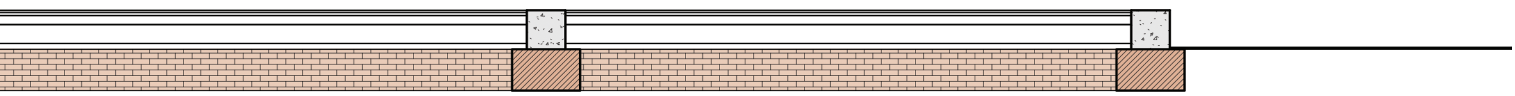

1
2
3
4
5
6
7
8
9
10
A
B
C
D
E
F
G
H

Foundation plant
Scale 1:100

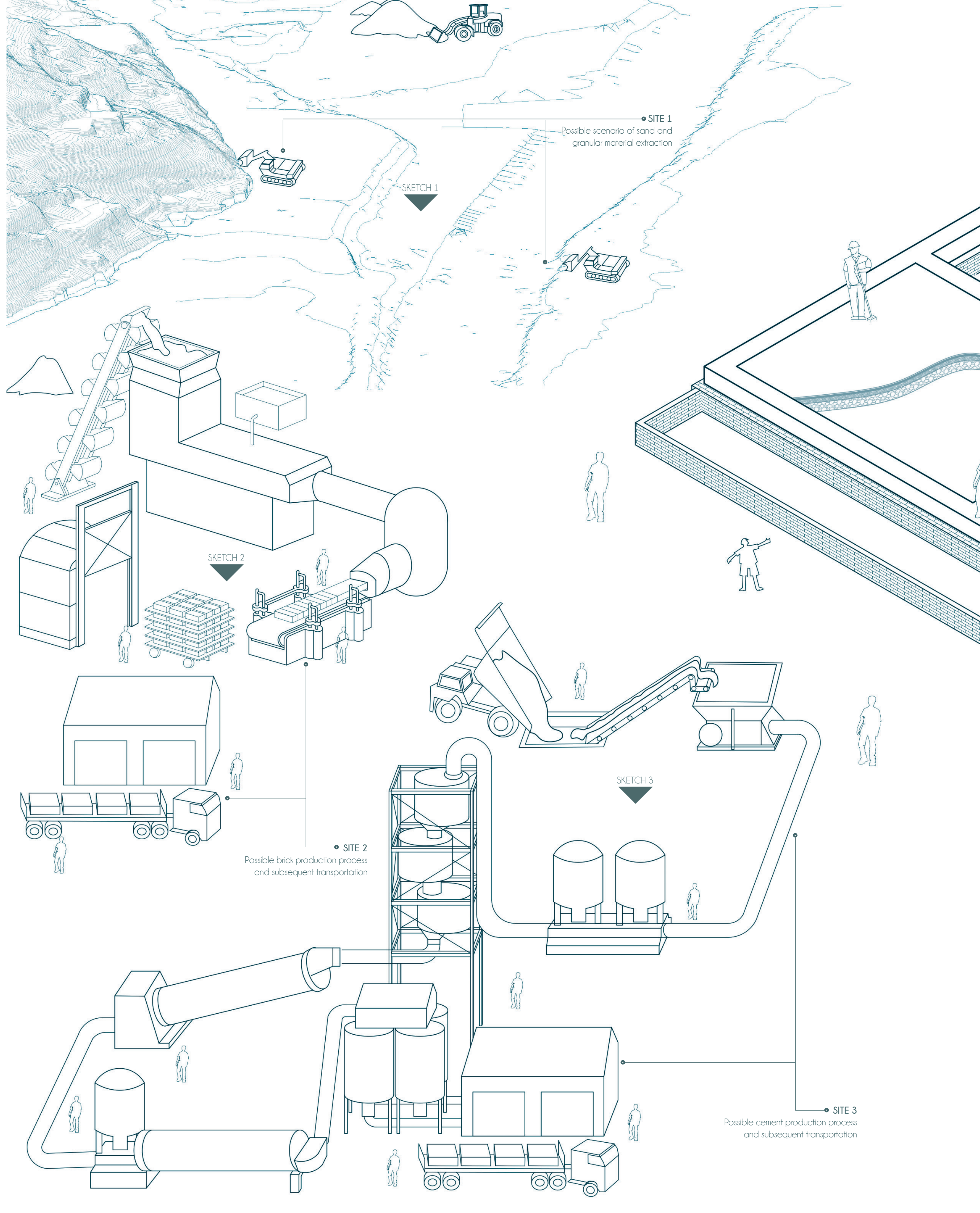


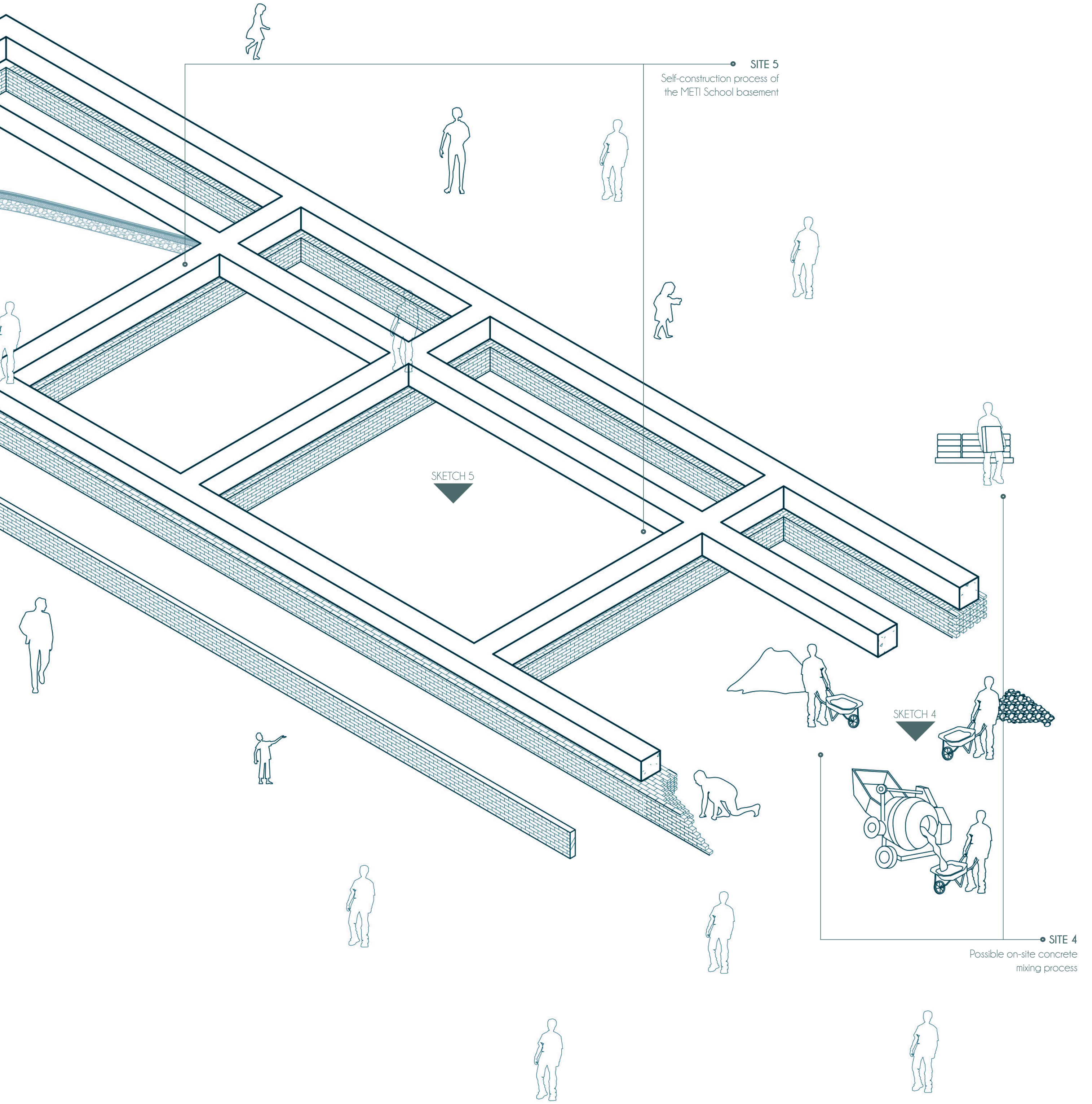
Chapter IV ***Figure 26*** *Cimentation plan. Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

Foundation section
Scale 1:100



Chapter IV ***Figure 27*** *Cimentation section. Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*


SITE 1
Possible scenario of sand and granular material extraction
SKETCH 1
SKETCH 2
SITE 2
Possible brick production process and subsequent transportation
SKETCH 3
SITE 3
Possible cement production process and subsequent transportation



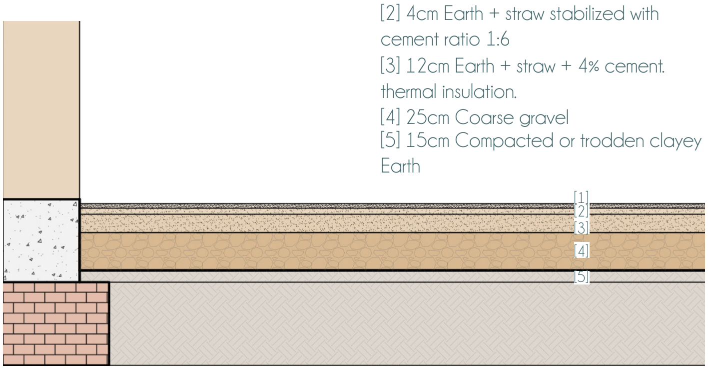
Chapter IV ***Figure 28*** *Possible scenario for Meti school cementation site. Own elaboration based on nna Heringer plans, immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007) and common processes of the used materials*

GROUND FLOOR

The ground floor of the METI school has three elements. The first thing to analyze is the flooring, the exterior platform made of concrete and the floors of the classrooms, and the staircase made of earth.

Although from the site report Hand-Made School Rudrapur, Bangladesh (Lim, 2007) and the photographic documentation it can be noted that the floor material is earth, none of the documents specify the technique used, nor the proportions or additives. Because of this, the following description is a hypothesis of the soil stratigraphy.

[1] 3cm Earth and straw + cement + sawdust + two coats of sodium silicate
[2] 4cm Earth + straw stabilized with cement ratio 1:6
[3] 12cm Earth + straw + 4% cement. thermal insulation.
[4] 25cm Coarse gravel
[5] 15cm Compacted or trodden clayey Earth



*Chapter IV **Figure 29**. Detail of floor made in earth in traditional technique Own elaboration based on Gernot Mike book*

The previous construction detail, which is believed to be the one used in the METI school by architect Heringer, shows the ground conformation based on the improved traditional system of Gernot Mike's book (Building with Earth : Design and Technology of a Sustainable Architecture, 2009).

In this technique, the layer that limits the ground is coarse gravel, which has a thickness of 25cm and serves to prevent capillarity, then there is a thin layer of plastic or bituminous sheeting that functions as a waterproofing layer, on top of this there is 12cm of soil reinforced with additives such as straw and 4% cement that serve as thermal insulation, then the mixture of soil and bituminous sheeting is repeated with a mixture of soil and bituminous sheeting.

The mixture of soil and straw is repeated and stabilized with cement in a 1:6 ratio in a 4 cm thick layer, and then 3 cm is finished with a mixture of soil, straw, cement, sawdust, and sodium silicate to stabilize the soil and reduce its plasticity index.

In addition to this, the floor is covered with mats which are used to sit since, in the Bangladeshi culture, furniture is not used. It is worth mentioning that the floor is finished with a riser at the bottom of the floor covering around

*Chapter IV **Figure 30 - 35** Images o*

of construction site, Ground floor paving September 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_baubeginn_2_e.htm

Chapter IV **Figure 36 and 37** METI interior floor. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

The second element to be analyzed is the earthen walls.

"A test section of the wall 06/2005: small wall section was built to test the building techniques, procedures and time requirements.

1. Mixing of the straw, earth and water mixture and subsequent piling of the mixture up to a height of 60 cm.

2. After a drying period of about a week the wall was trimmed to its desired dimensions by cutting off excess material with a sharp spade.

3. The process was then repeated for the next layer which was applied on top of the first one." (METI school handmade in Bangladesh)

From top to bottom Chapter IV ***Figure 38 and 39*** *Images of earth wall test June 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_lehm_e.htm*

From top to bottom Chapter IV ***Figure 40 - 43*** *Images of earth wall test June 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_lehm_e.htm*

The earth construction process in general has three main phases according to (Carazas Aedo, 2002) the preparation of the mix, the laying or plastic stage, and the drying. To make the mixture it is recommended to use three portions of sandy soil for each portion of clay soil, the water should be 30% of the volume of the dry soil and it should be clean of organic waste, finally, the straw should be dry and should be used in a 1:10 ratio with the soil.

The mixing process of the above materials is carried out in two stages. In the first stage, the soil must be mixed with water until all the soil is well moistened, then comes the second stage where the straw must be added to the previous mixture until the mixture is homogeneous. This action can be carried out through different methods of which two will be named.

The first is the mixing with the feet in which one or several people achieve the state of plasticity in the mixture by walking on it, for a small scale work and with low budget is the most common way of mixing on average a man can mix 4m3 of soil per day.

The second is the mixing with horses, cows, or as in the METI school water buffaloes, which go around in circles to generate the mix. According to some sources, four hundred tons of wet mud and straw were needed to make this construction.

The shaping of the project's earth walls began with the arrival of the mixture on site, which was transported in baskets carried by the locals on their heads. Later balls were formed, agglutinated, and stacked along the foundations to shape the load-bearing walls traditionally.As mentioned above, the first layer of soil for the walls is made at the foundation stage and reaches a height of 60 cm.

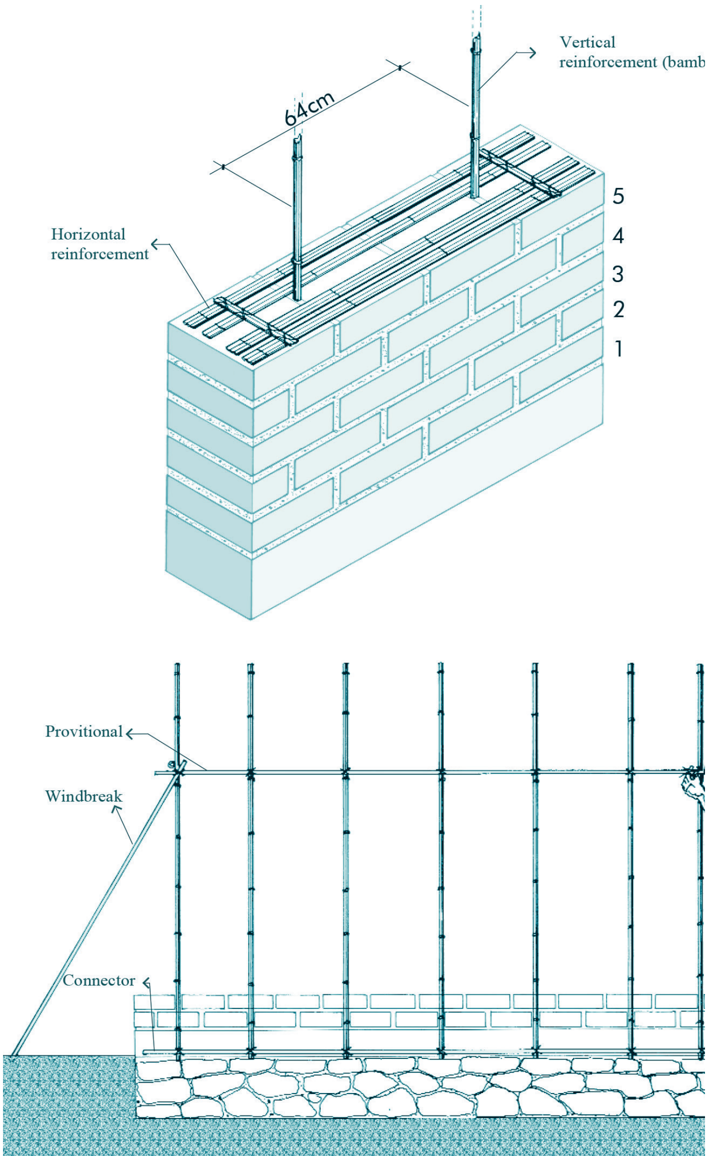
"The second layer of mud wall 10/2005: With the second layer of "weller" mixture, the walls have now reached a height of 1.40 m.The first layer was trimmed with a spade to the dimensions desired after a short period of drying" (METI school handmade in Bangladesh, Weller-loam / Bamboo Preparation)

"Completion of the third layer of earth 11/2005: Another period of heavy rainfall delayed progress on the site. The "mati department" worked hard to finish the third layer at a height of 1.90 m. Many details were required for the openings and lintels. The prefabrication of the bamboo beam and frame construction started in parallel to help keep the building process on track after the walls have been built. Sophisticated auxiliary constructions were necessary to straighten the curved bamboo sticks. The bamboo workers ("bash department") had been trained for the 3000 lashings that were needed" (METI school handmade in Bangladesh, Third layer / Meti-kids on site)

From top to bottom Chapter IV ***Figure 44 - 46*** *Images of earth wall construction October / November 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_lehm_e.htm*

According to ADOBE, Guía de construcción parasísmica (Carazas Aedo, 2002,) to improve the resistance of the structure and durability of the walls, it is recommended to implement vertical and horizontal reinforcements inside the wall. In principle, the vertical reinforcements must be installed, which can be bamboo rods as in the METI school, spaced 70 cm to 1m from each other. These must be supported by a horizontal connector that will be placed on the overlapping. In addition to this, it is recommended to have another connector in the upper part that will allow maintaining the vertical rods fixed during the construction of the wall.

In the case of METI school from the images of the construction process, this second provisional connector was not. The horizontal reinforcements are a type of stretcher made of bamboo strips woven or secured with wire, which is recommended to be made every 60 cm. According to the report Hand-Made School - Rudrapur, Bangladesh(Lim, 2007) , this horizontal reinforcement was implemented on-site, but its composition, materiality, or technique is not clear.



*Chapter IV **Figure 47** METI School earth walls. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

For the lintels of the doors and windows, boards and pieces of bamboo were used, as can be seen in the following image. The boards are supported by vertical bamboo rods that are inside the opening, which suggests that they were used only as a formwork for the bamboo, otherwise they were covered with a mixture, making them invisible in the finished project.
The wall is finished layer by layer when the mixture

Chapter IV **Figure 48** METI School earth walls. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

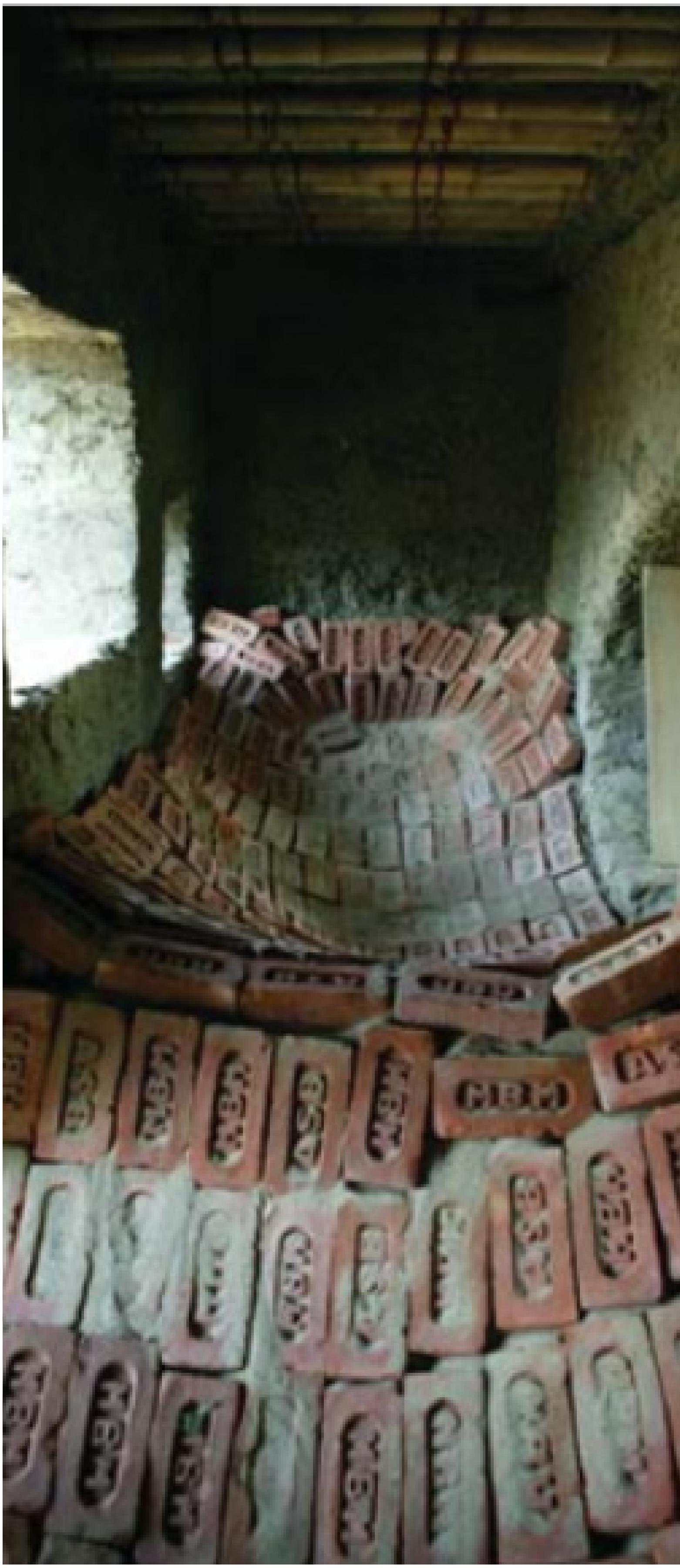
is stacked, at which point the wall is shaped and smoothed until a homogeneous surface is achieved. Subsequently, a water-repellent treatment can be applied, based on linseed oil and some plastering with clay soil or fine sand and lime. In the case of the METI school, no finish was applied, and the smooth walls leave the straw reinforcement exposed.

"Interior 12/2005: The classrooms on the ground floor are plastered with a clay-earth plaster. The earth-floors on the ground floor are rammed and the earthen surface of the first floor are treated as a clay screed. The curved floors of the 'cavespaces' are formed with sand, bricks and a final layer of weller earth material" (METI school handmade in Bangladesh, Interior)

The third and last element to analyze on the ground floor are the caves, this space proposed by the architect is an organic piece where children and teachers sit to read, play and exploit their creativity. This welcoming environment located along the western façade has two series of small caves connected and accessed through the classrooms. Each classroom has two entrances to the caves, which in turn have openings that allow views of the outside.

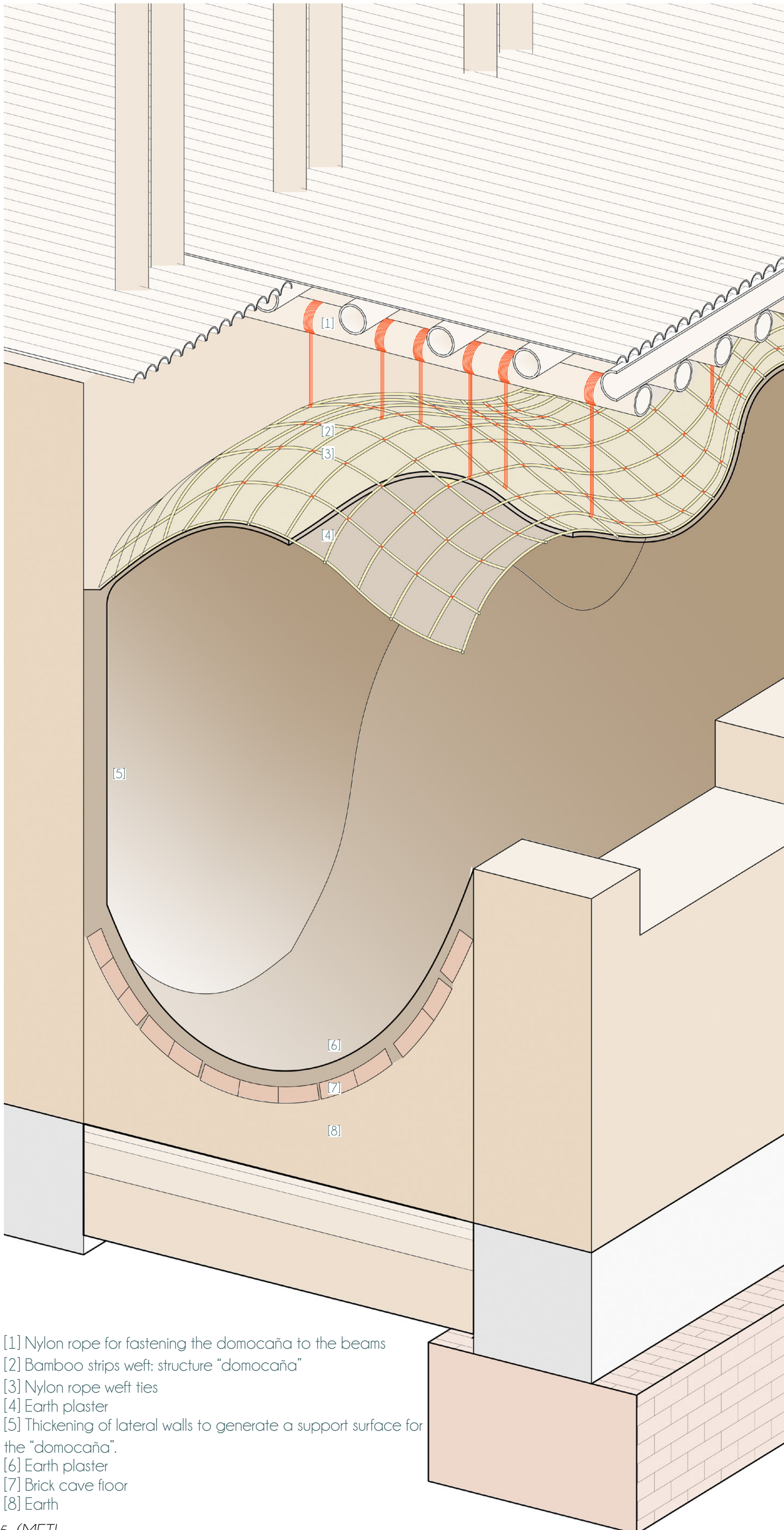
The construction technique and materiality of this space are a bit of an unknown because there is no information about it, and the photographic documentation is generally only of the finished project. To try to analyze this space, the caves will be divided into two parts, the floor, and the roof, on the assumption that the roof is not solid due to the weight involved.

The floor structure was built with bricks as a kind of inverted dome that was later plastered, and finished with a mud mixture like the rest of the floor. On the other hand, the roof, under the hypothesis previously put forward and taking into account the architect's later projects, seems to have a light mesh-like structure made of bamboo sticks, possibly with the same technique used in "pepita", the exhibition at the Venice Biennale in 2016, or a bareque type where there is a formed fabric to which the mud is agglutinated, subsequently seeking to homogenize the whole with the mixture to create the final unitary element [Figure 56].



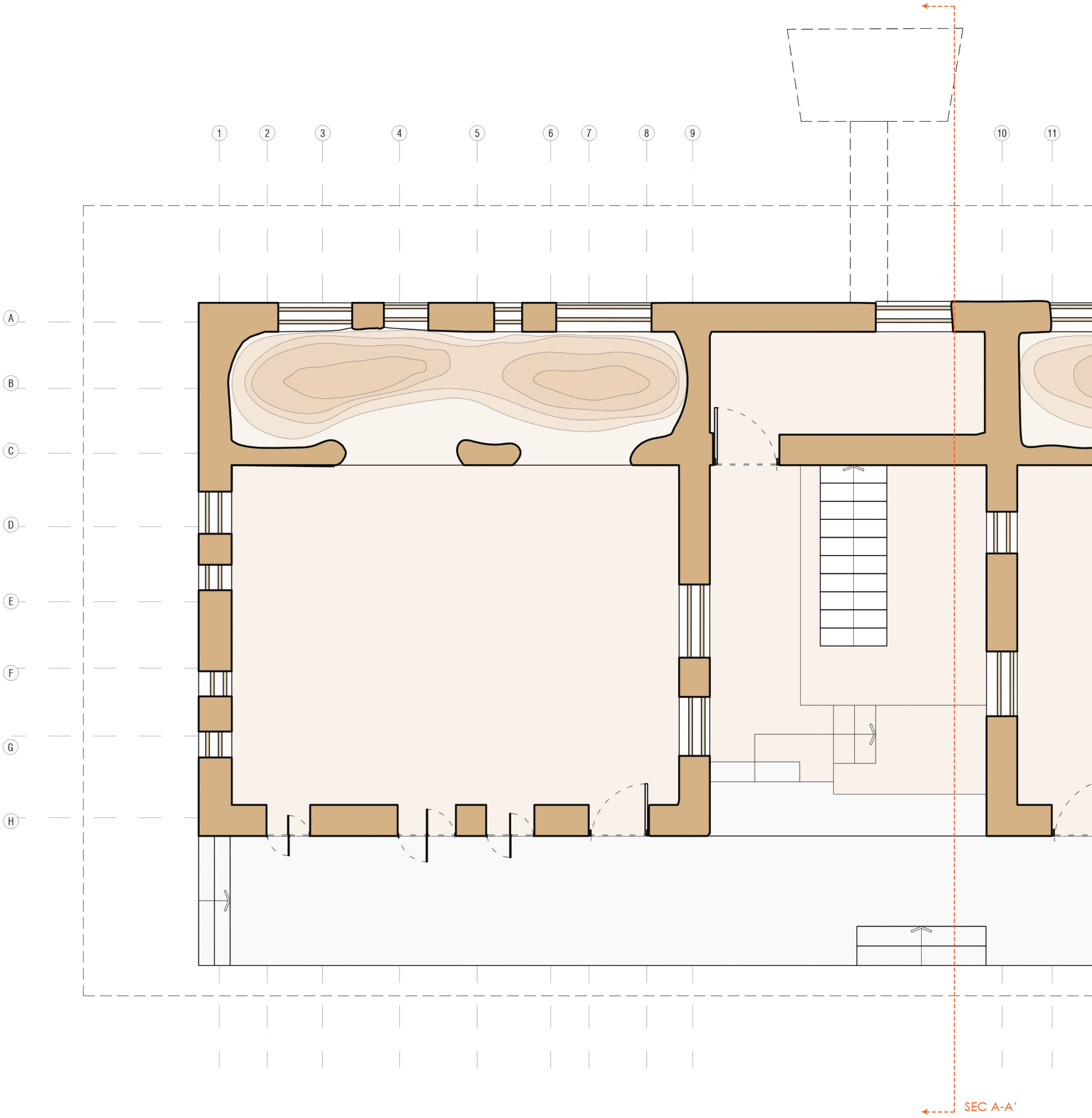
Chapter IV ***Figure 49*** *METI School caves structure. Photo by Kurt Hoerbst and Anna Heringer (construction team) Taken from Verano 2012, Circuito Arquitectura*

From top to bottom Chapter IV **Figure 50 - 55** Images of caves construction 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_lehm_3l_e.htm & http://www.meti-school.de/daten/bericht_ausbau_e.htm



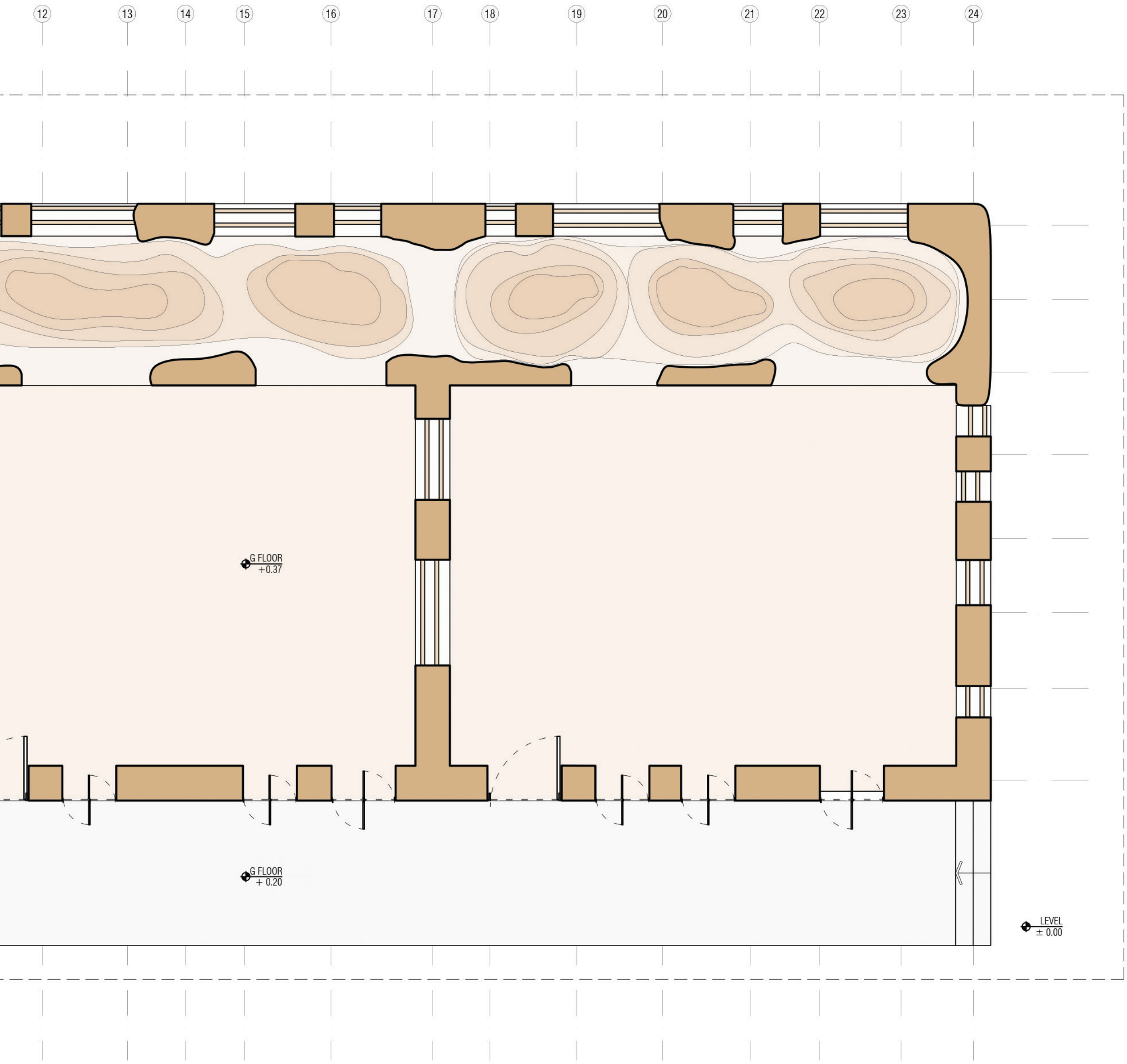
[1] Nylon rope for fastening the domocaña to the beams
[2] Bamboo strips weft: structure "domocaña"
[3] Nylon rope weft ties
[4] Earth plaster
[5] Thickening of lateral walls to generate a support surface for the "domocaña".
[6] Earth plaster
[7] Brick cave floor
[8] Earth

Chapter IV **Figure 56** Hypothesis of the construction of the caves. Own elaboration based on METI School images and the article ("Aplicación de la guadua para la construcción de cubiertas con tierra, basadas en el "domocaña")



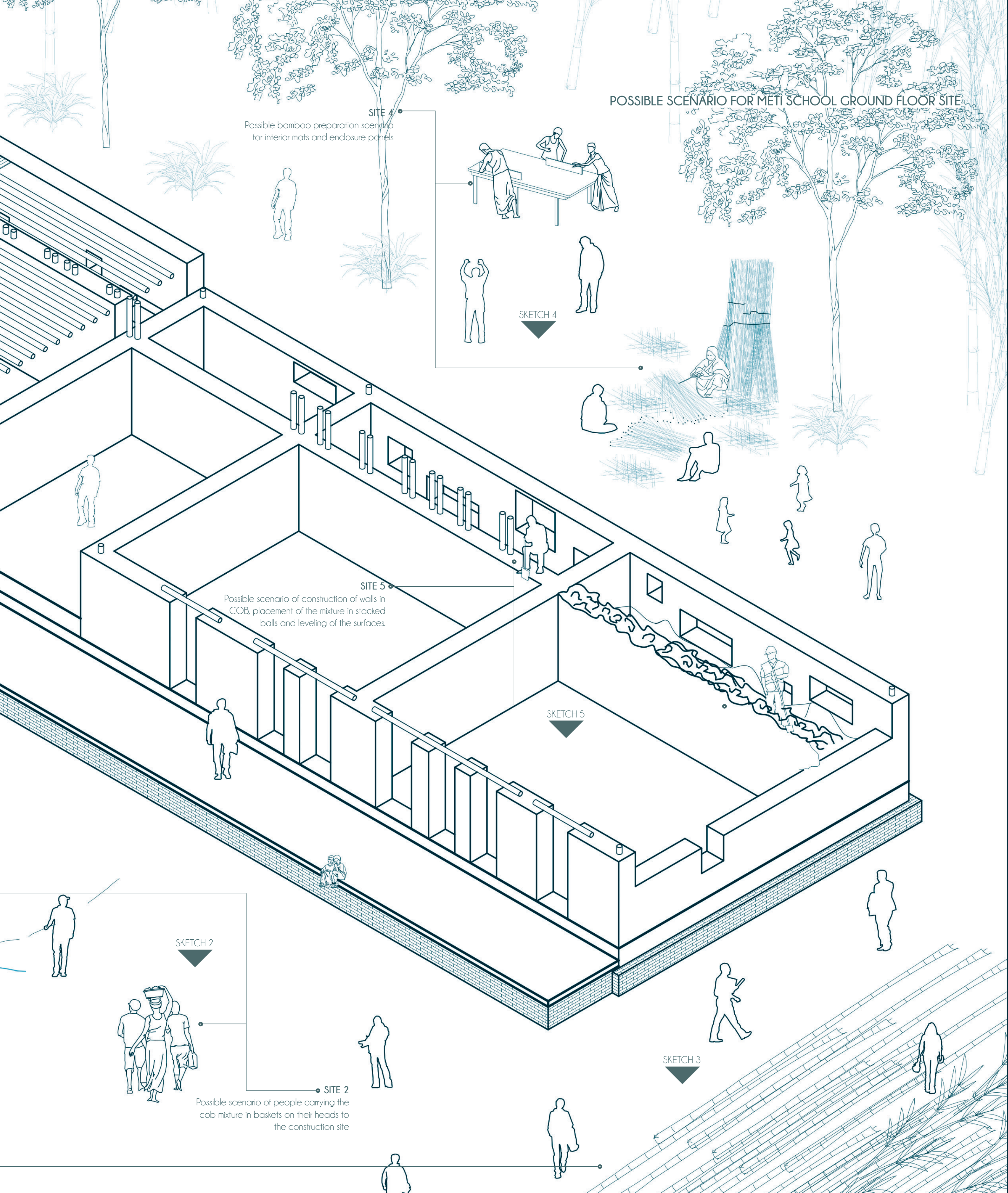
1
2
3
4
5
6
7
8
9
10
11
A
B
C
D
E
F
G
H
SEC A-A'

Ground Floor
Scale 1:100



*Chapter IV **Figure 57** Ground floor plan. Own elaboration based on Anna Heringer plans.*

SITE 3
Possible bamboo preparation scenario
for lintels and structural elements
SITE 1
Possible scenario of water buffaloes
mixing soil, water and straw
SKETCH 1



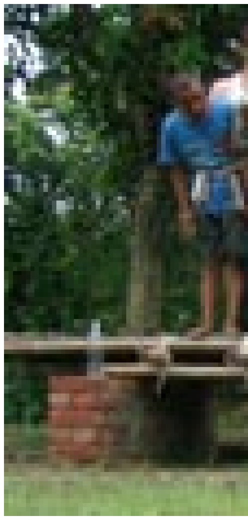
Chapter IV ***Figure 58*** *Possible scenario for Meti school Ground floor site. Own elaboration based on nna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

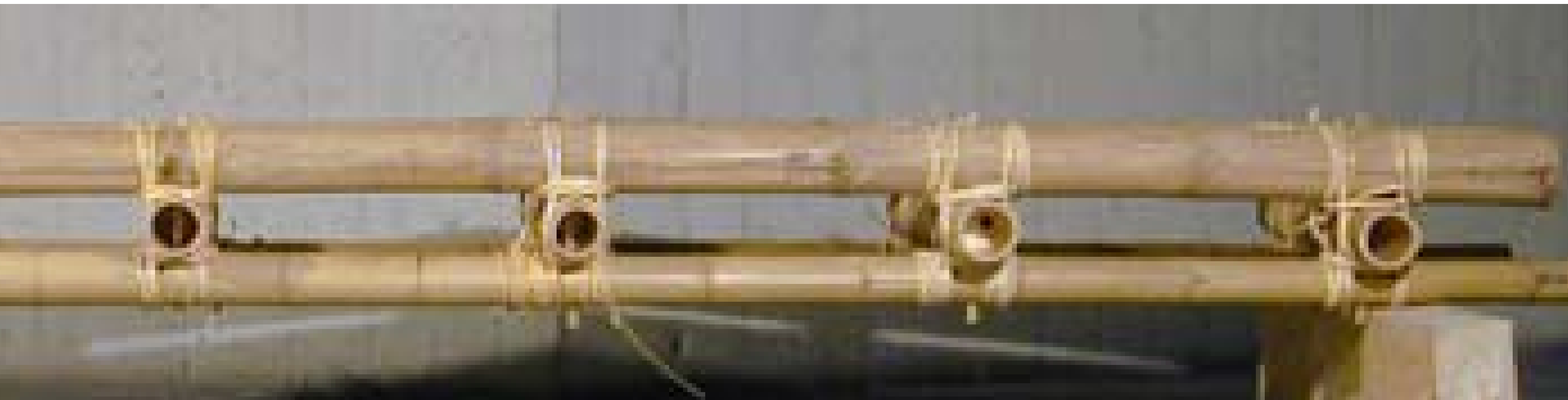
FIRST FLOOR

"Testing the ceiling and roof construction 07/2005
To test the construction techniques, joints and bearing strength of the ceiling, a 3 m long test section was built as well as small part of the roof beam construction. These constructions were then tested and analysed in the laboratory to ascertain their structural capacity. The results of the tests led to modifications in the construction technique." (METI school handmade in Bangladesh, n.d.)

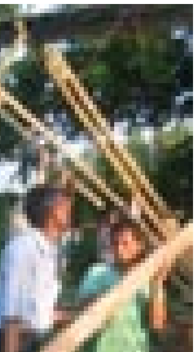
"1:1 model of bamboo ceiling and frame construction 10/2005
The biggest challenge so far: the first floor construction. The bamboo poles sourced locally are thinner than expected and not straight. As a result modifications to the planned construction had to be made. Together with our local bamboo workers we built a second 1:1 model and tested it with the maximum load" (METI school handmade in Bangladesh, n.d.)

*Chapter IV **Figure 59** METI School bamboo enclosure. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*





Chapter IV **Figure 60 - 63** Bamboo test July 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_bambus_e.htm



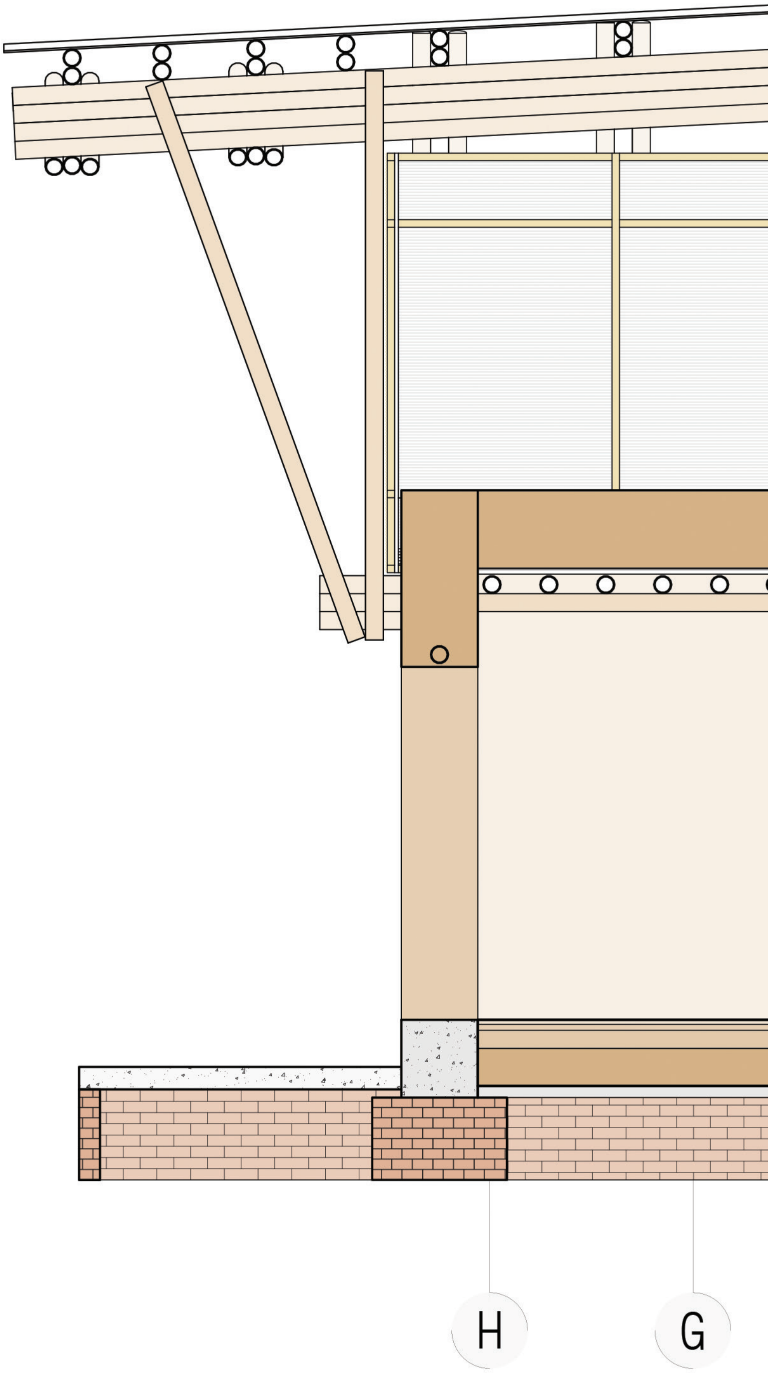
Chapter IV **Figure 64 - 68** Bamboo 1:1 model test October 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_lehmbau_2_e.htm

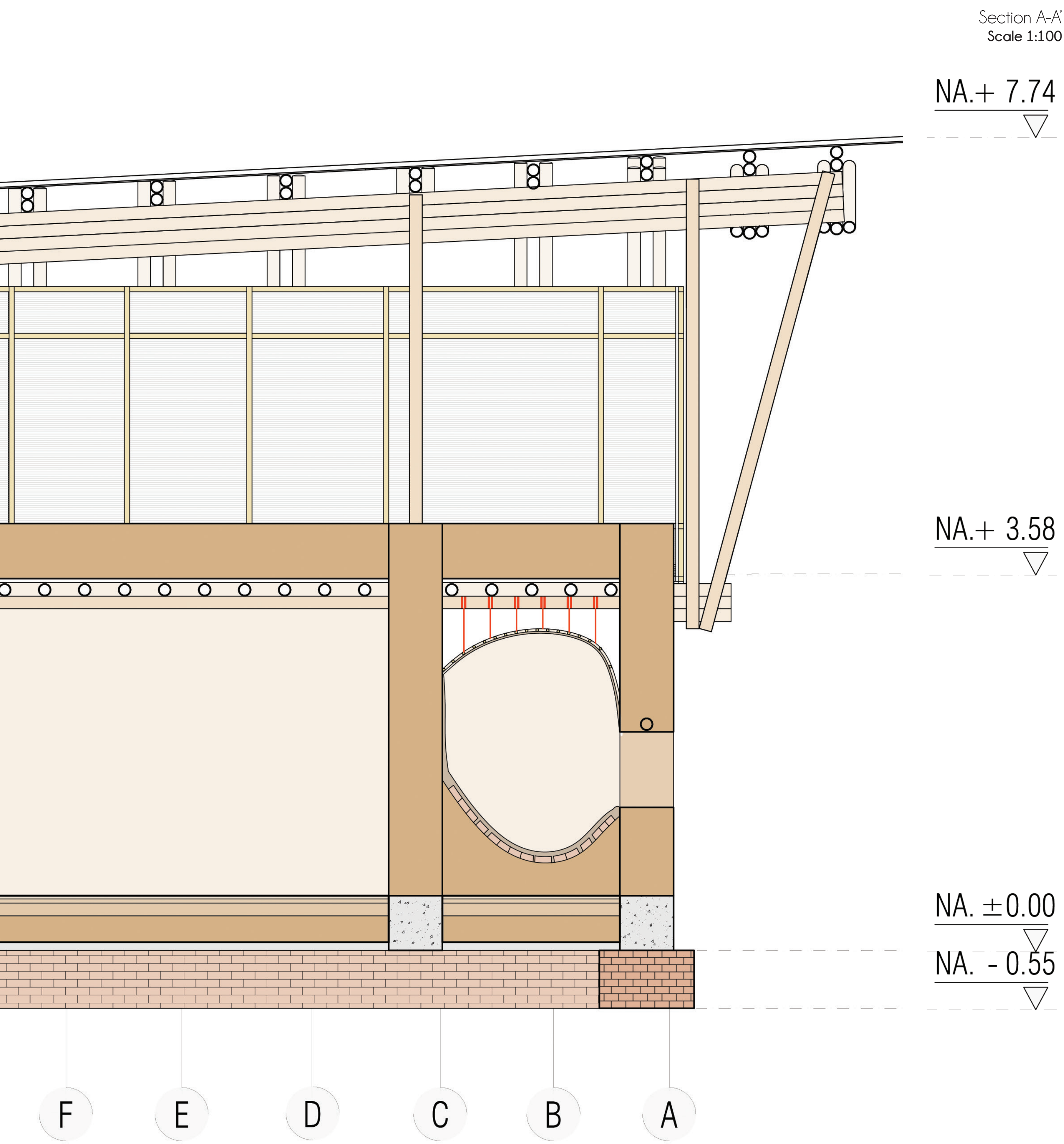
"Ceiling 11/2005: The work on the ground floor walls is finished. A special levelling construction was made to adjust the height of the ceiling and fix it in place. Bamboo poles are fixed in three orthogonal layers and tension belts are used to position them accurately before fixing them with steel pins and nylon lashing. After the auxiliary construction was removed, a layer of bamboo boards was laid upon the central layer of bamboo poles placed and filled with "Weller" straw-earth mixture" (METI school handmade in Bangladesh, n.d.)

The transition between the ground floor and the upper floor is made through bamboo flooring surrounded by earth walls high 110. The flooring made of bamboo and earth is structured in 4 layers.

The first one from the bottom up are parallel bamboo beams distant between them 35-40 cm, placed on the axes indexed with letters. The second layer, which leans on the first one, are parallel bamboo beams distant between them 35-40 cm, placed on the axes indexed with numbers. The first two layers form a mesh on which the third layer is placed. The third layer is a surface made with open bamboos in the way of mats. This surface is covered with the earth mixture that would be the fourth and last layer, with which the floor is leveled and finished.

"Roof construction 12/2005
The difficult process of fitting the frame constructions on the first floor started. Every frame has to be lifted by using manpower as there is no crane. The prefabricated frames consist of a bamboo beam and a pair of vertical and diagonal poles. Laths are fixed on top of the bamboo construction to stabilise and used to fix the corrugated iron panel roofing. A total of 2300 bamboo poles are used for the ceiling and frame constructions." (METI school handmade in Bangladesh, n.d.)





Chapter IV ***Figure 69*** *METI School Section. Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

The first floor is completely made of bamboo. The access to the two classrooms that compose it is through a staircase composed of footprints made of boards (SC_PV01), lateral beams in a double layer of bamboo (SC_ST01), and handrails made of bamboo (SC_SC01 e SC_SC02).

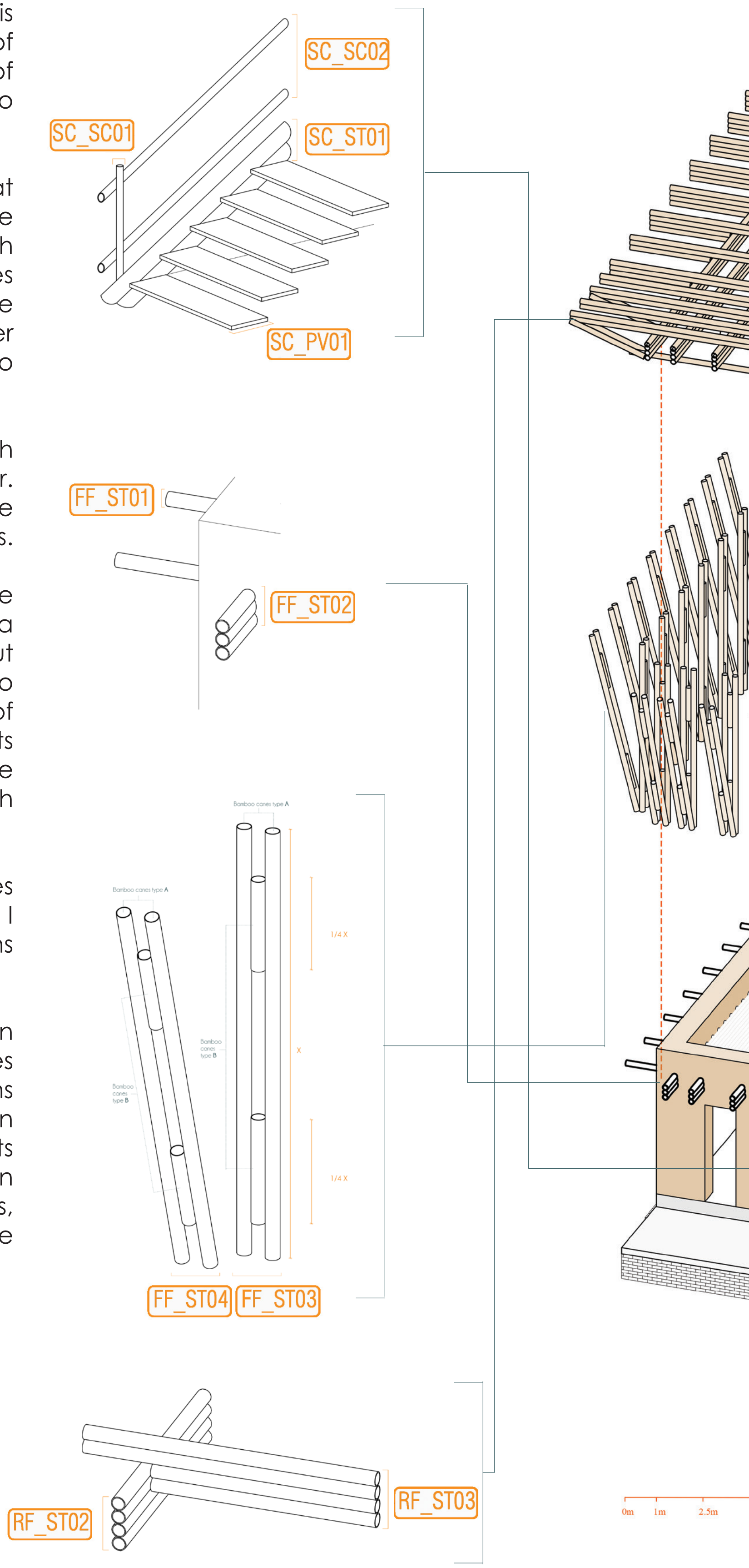
The structure is composed of beams and columns that cross each other forming a kind of mesh on which the roof rests.- The lower beams in the number axes, which I will call FF_ST02, are made of three bamboo canes one on top of the other joined with rope ties to achieve a larger H. On the other hand, the beams in the letter axes, which I will call FF_ST01, have only one bamboo canes.

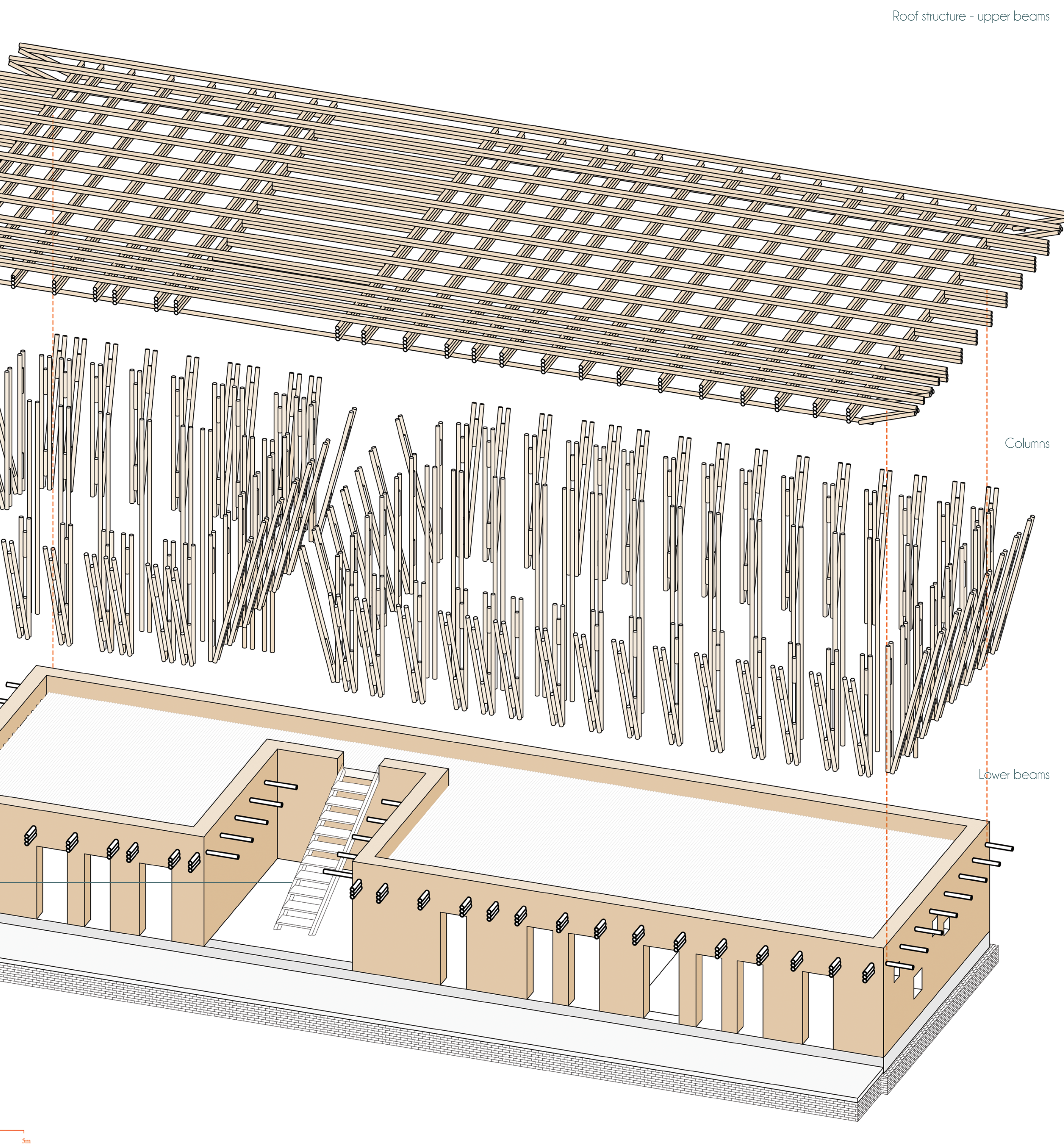
All the lower beams are embedded in the low earth walls that rise along the perimeter of the ground floor. These lower beams carry the columns which are made in the shape of a triangle to support the roof overhangs.

As can be seen from the graphs and pictures, the columns are made up of a vertical (FF_ST03) and a diagonal (FF_ST04) element. Both are the same but their inclination changes, each one is composed of two bamboo canes (A) joined together with two pieces of bamboo (B) at each end. The height of the B elements is ¼ of the height of the A canes. These B elements are attached to the lower beams FF_ST01 and FF_ST02 with rope. (img)

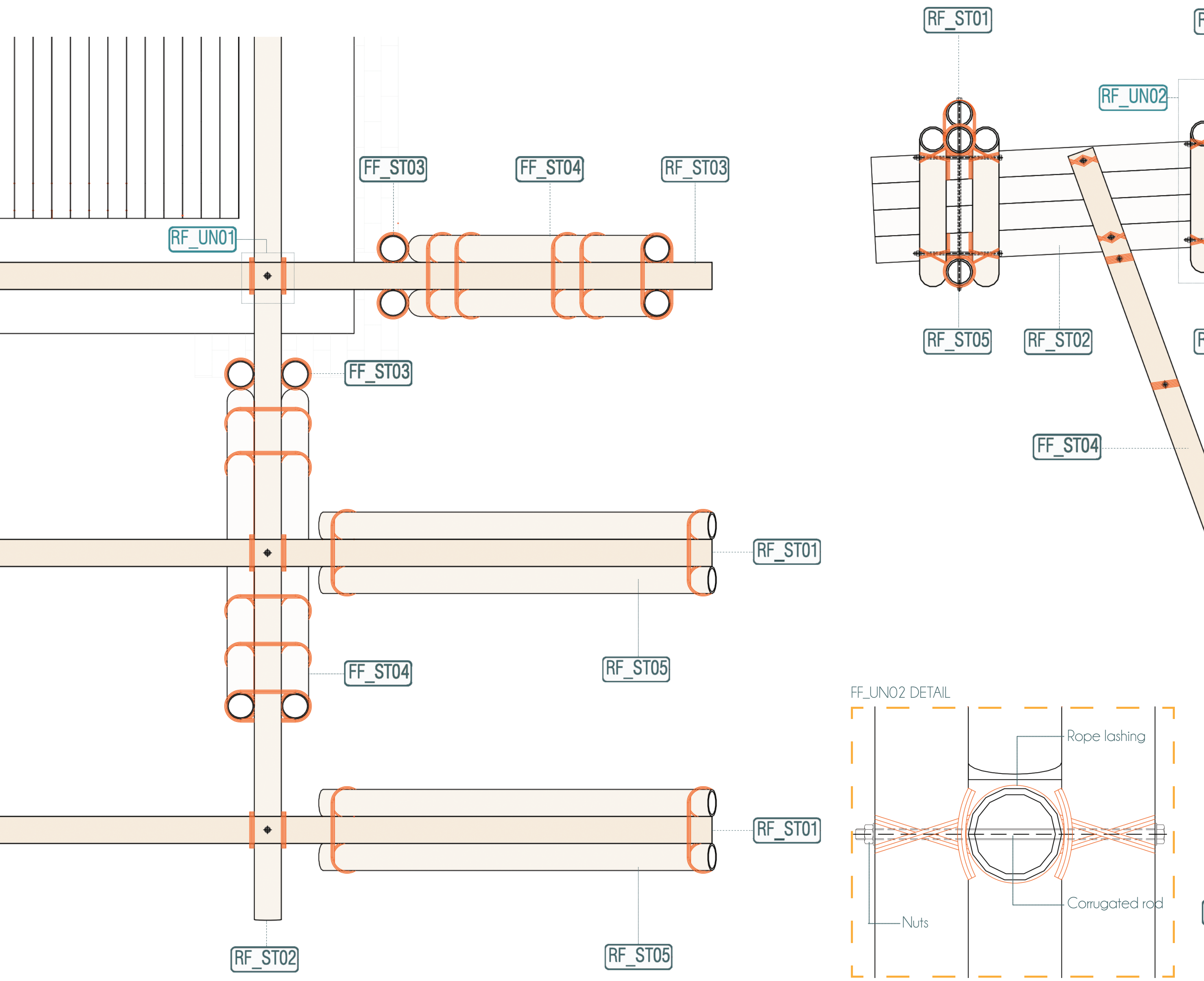
Subsequently, the upper beams in the number axes are composed of 4 bamboo canes joined together, I will call these beams RF_ST02. These rest on the columns FF_ST03 and FF_ST04.

The other roof beams in the letter axes RF_ST03 rest on RF_ST02. These are different from the previous ones because, despite having 4 canes in some sections interrupted to become half their size, 2 canes, when they pass over the shorter beams. All joints and knots (FF_UN01 - FF_UN06, RF_UN01, RF_UN02) between the structural elements are made with nylon ropes, corrugated steel rods, and nuts as shown in the





Chapter IV **Figure 70** *Exploded axonometry first floor METI School . Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

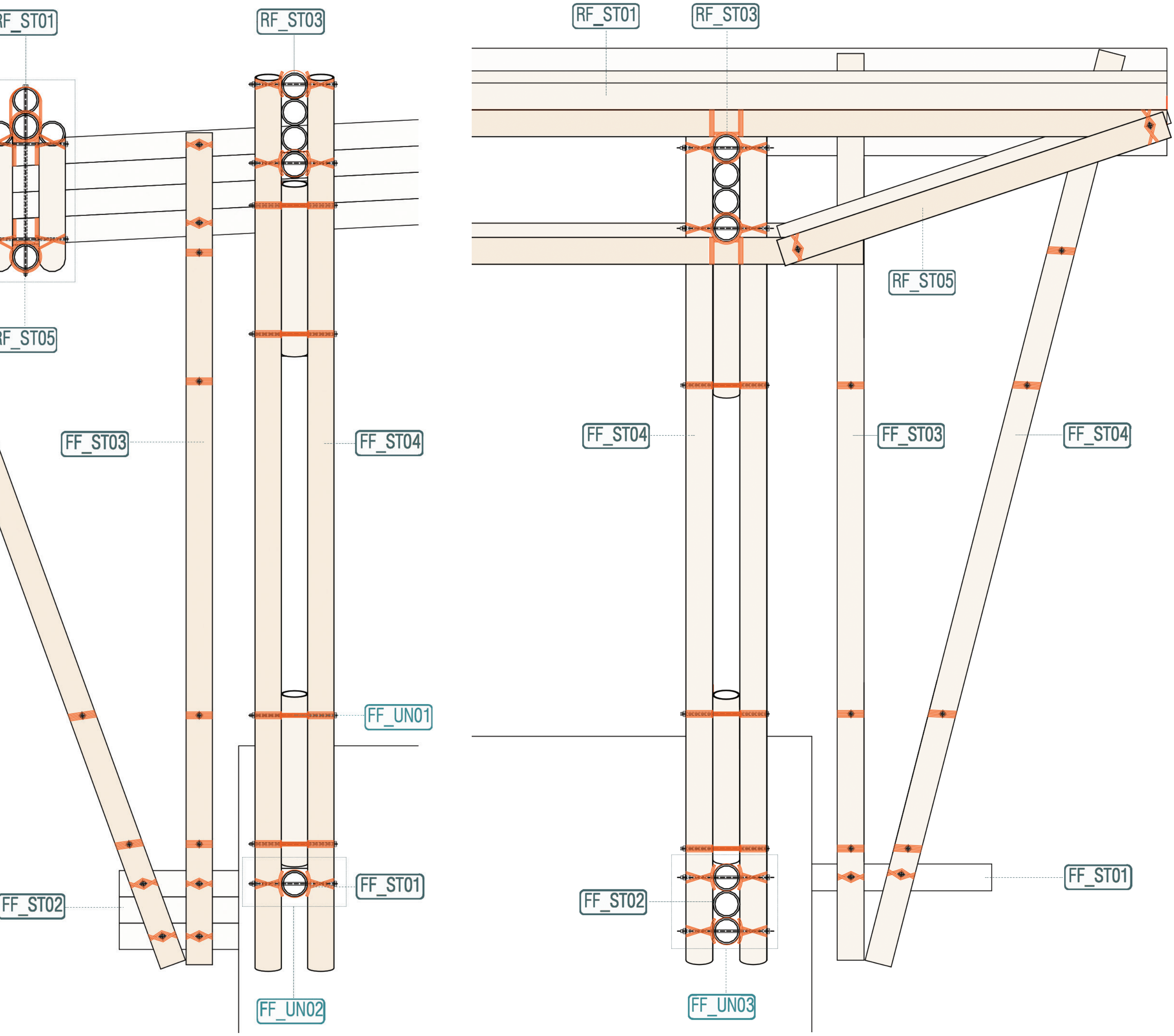


individual details and inventory.
In addition to the aforementioned upper beams (RF_ST01 and RF_ST02), there are joists (RF_ST03) in the cantilever on the letter axes with an upper beam (A) and a lower beam (b) connected with two diagonal beams (RF_ST05) as shown (x-graph).

For the construction of the floor, 48 trusses and 24 beams were implemented in the letter axes, and 26 trusses and 8 beams in the number axes. In addition, 3 roof reinforcement beams and 24 reinforcement columns.

The first floor is finished with a uniform enclosure made of horizontal bamboo strips stacked on internal wooden frames invisible from the outside. The façade has inward-opening panels or windows made with simple hinges that allow a 360-degree view of the outside.

The doors leading to the classrooms on either side of the staircase are also made in the same way. When the panels are open the openings have a kind of railing made of strips that are anchored to the fixed panels of

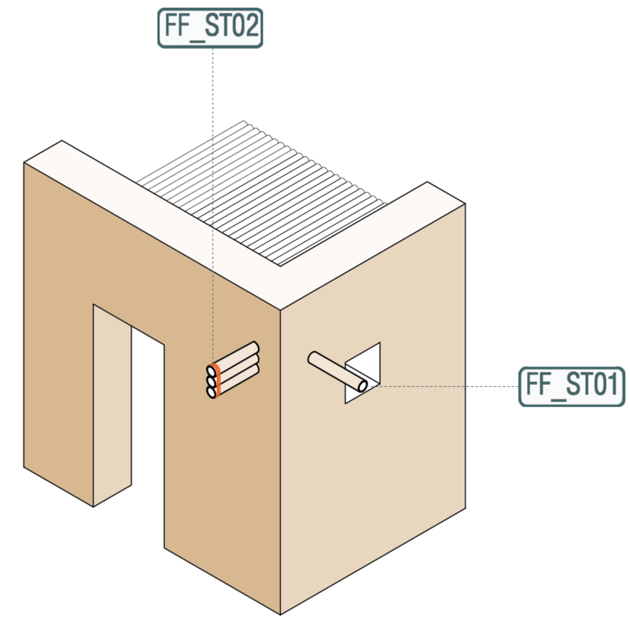


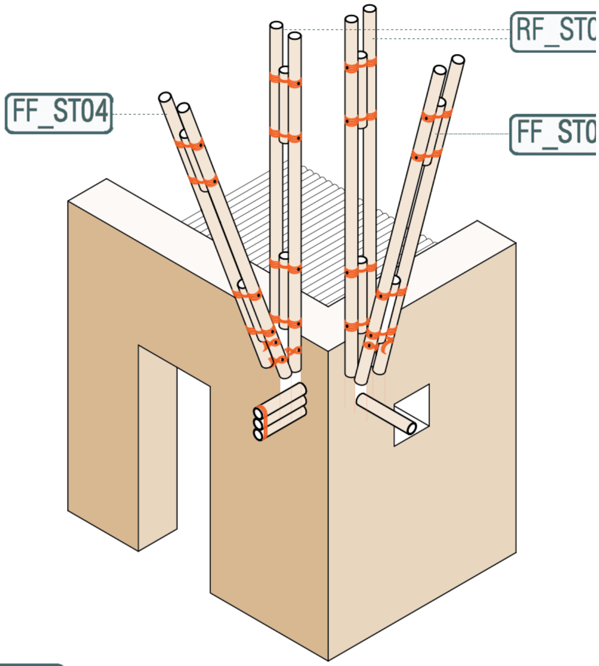
Chapter IV ***Figure 71, 72 and 73*** *plant, side prospect and front prospect, bamboo corner METI School . Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

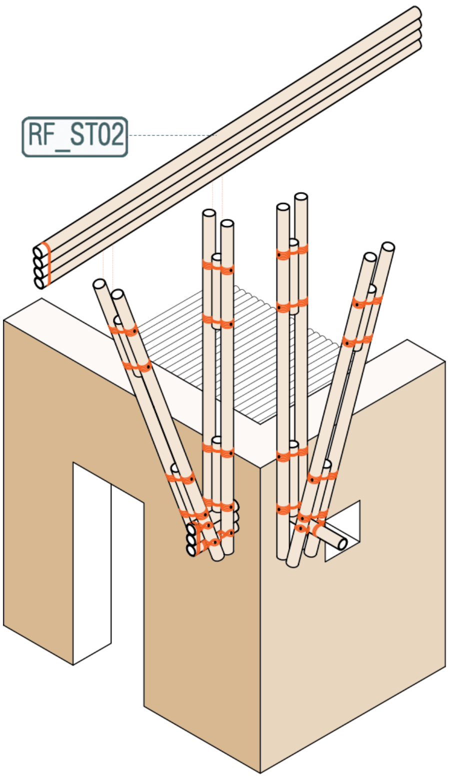
the façade. This same safety mechanism is used on the staircase and the "balcony" of the western façade.

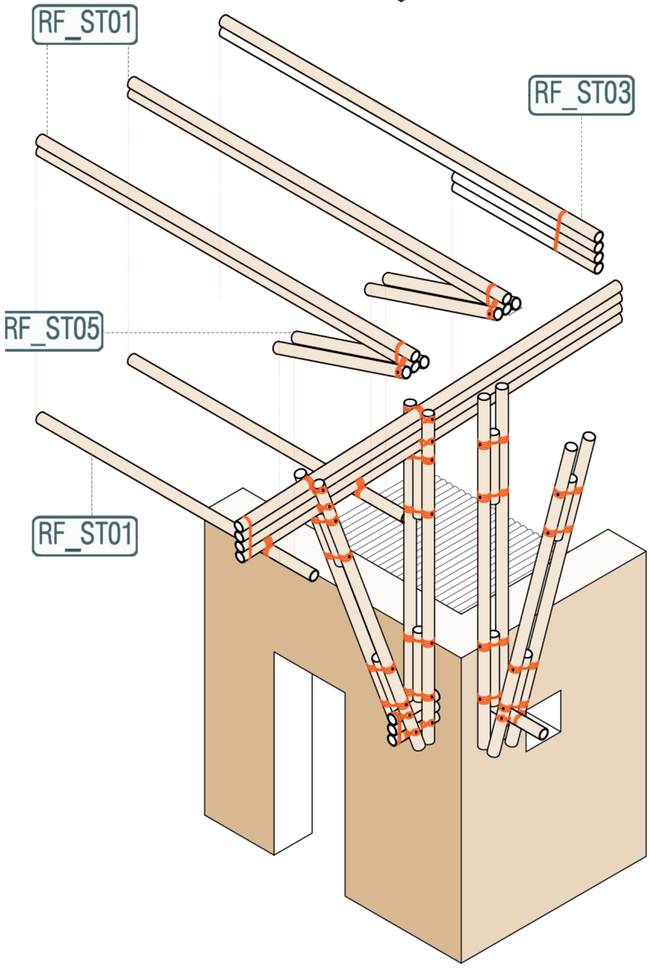
"Interior 12/2005: The doors and windows of the East façade are fabricated by Dipshikha's carpenter Sontosh. He and his 12 trainees set up their workshop beneath the Litchi trees where they produced every single piece of wood we needed, from the spatula (real Mahogany!) to the wood frames for the first floor.

The wooden frames on the first floor are covered with 12,500 bamboo slats that filter the sunlight and allow the wind to pass into the classrooms. A final fifth layer of "weller" is applied on top of the outside walls running the entire perimeter of the upper floor to serve as a bench and to anchor the frame construction" (METI school handmade in Bangladesh, n.d.)



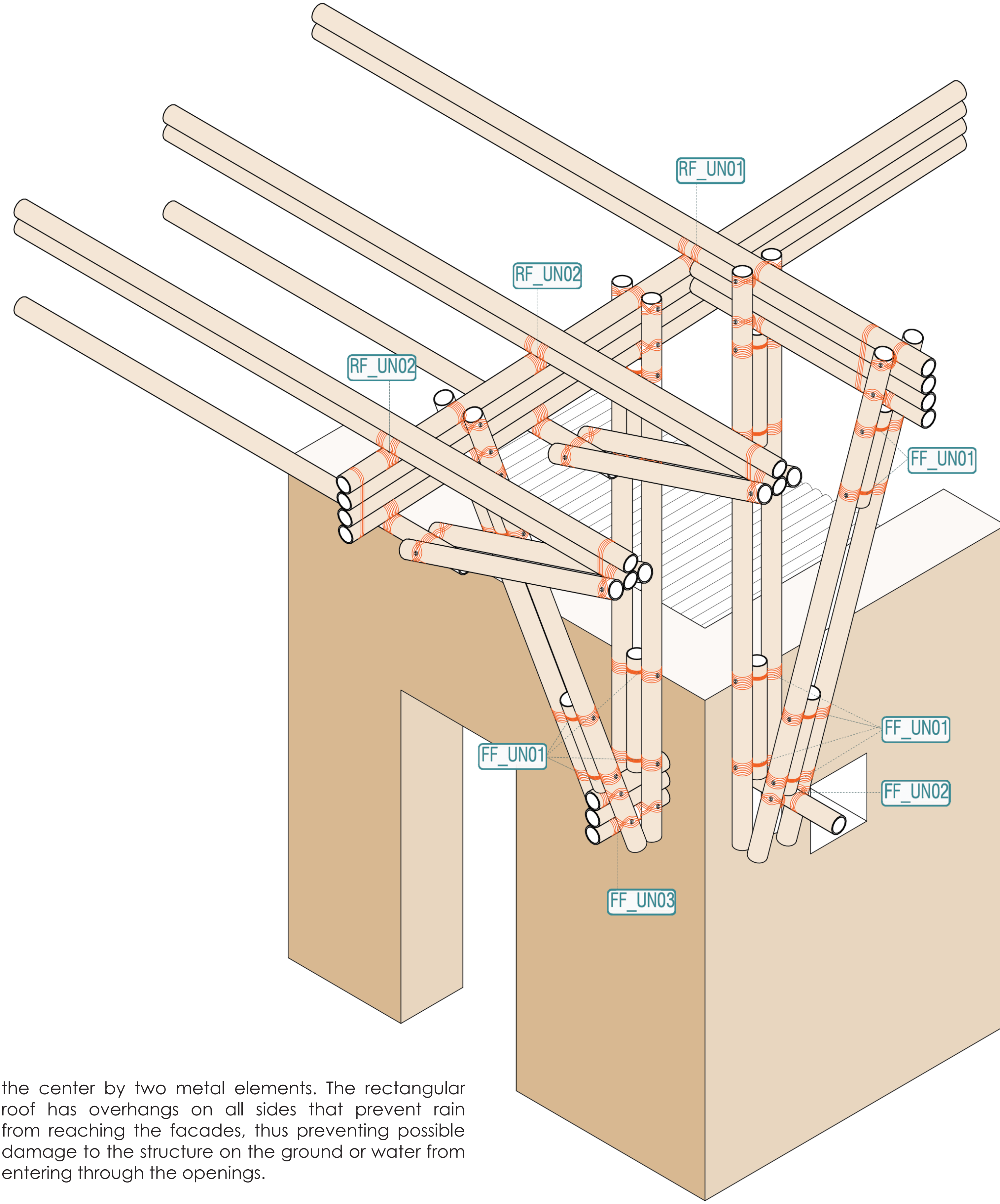






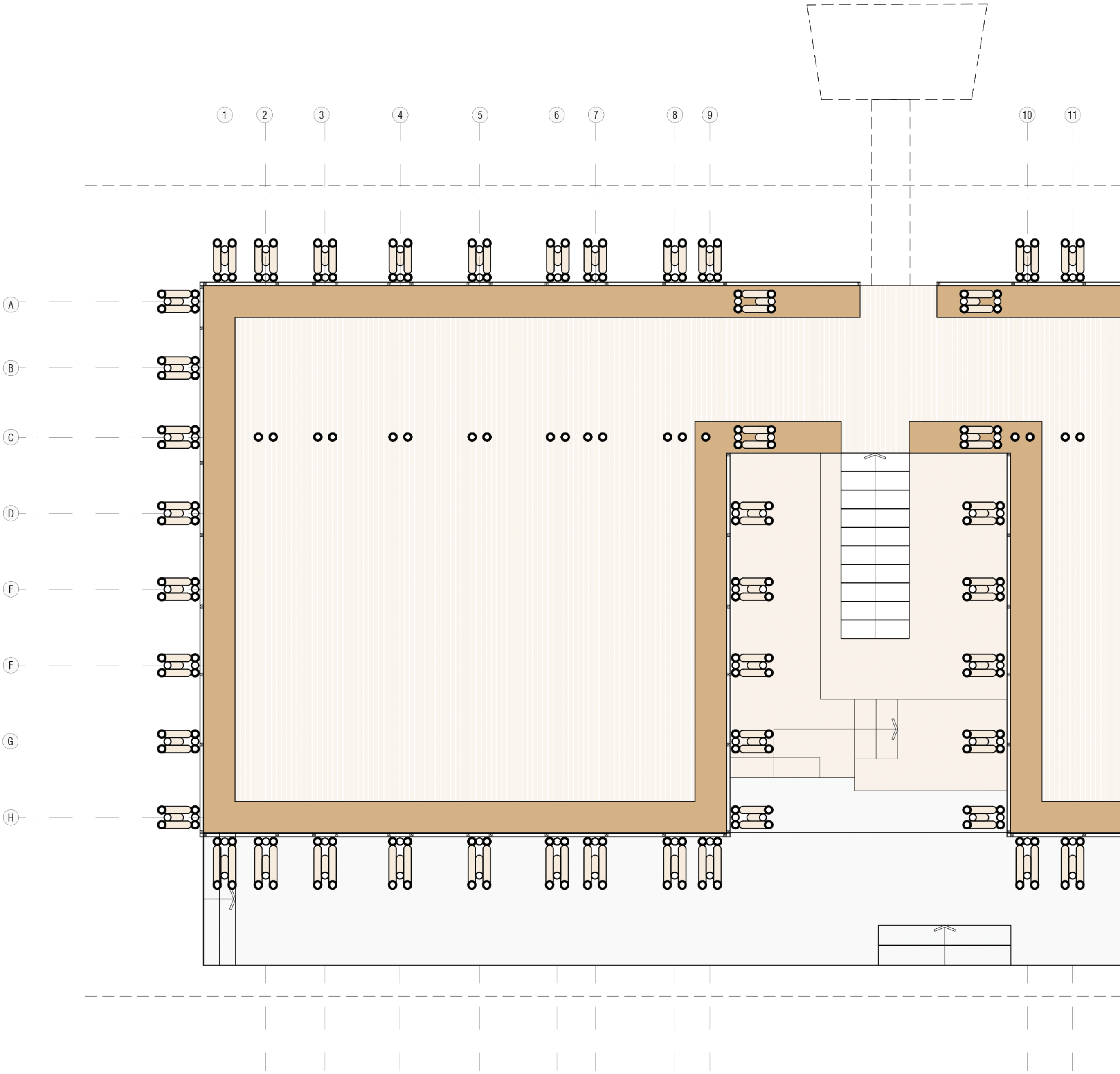
In general, the use of bamboo was done in a rather artisanal way, the joints are made of simple ties and the ends of the canes have straight cuts, instead of lace cuts like the "fish mouth". In addition to this, in some lectures (citaa) given by the architect as in talks, Heringer said that the structure of the first floor had to be changed because it was first made with green reeds, which promoted problems of pathogens such as fungus and pests.

Finally, the metal roof is made of zinc tiles that are anchored to the bamboo beams and are braced in

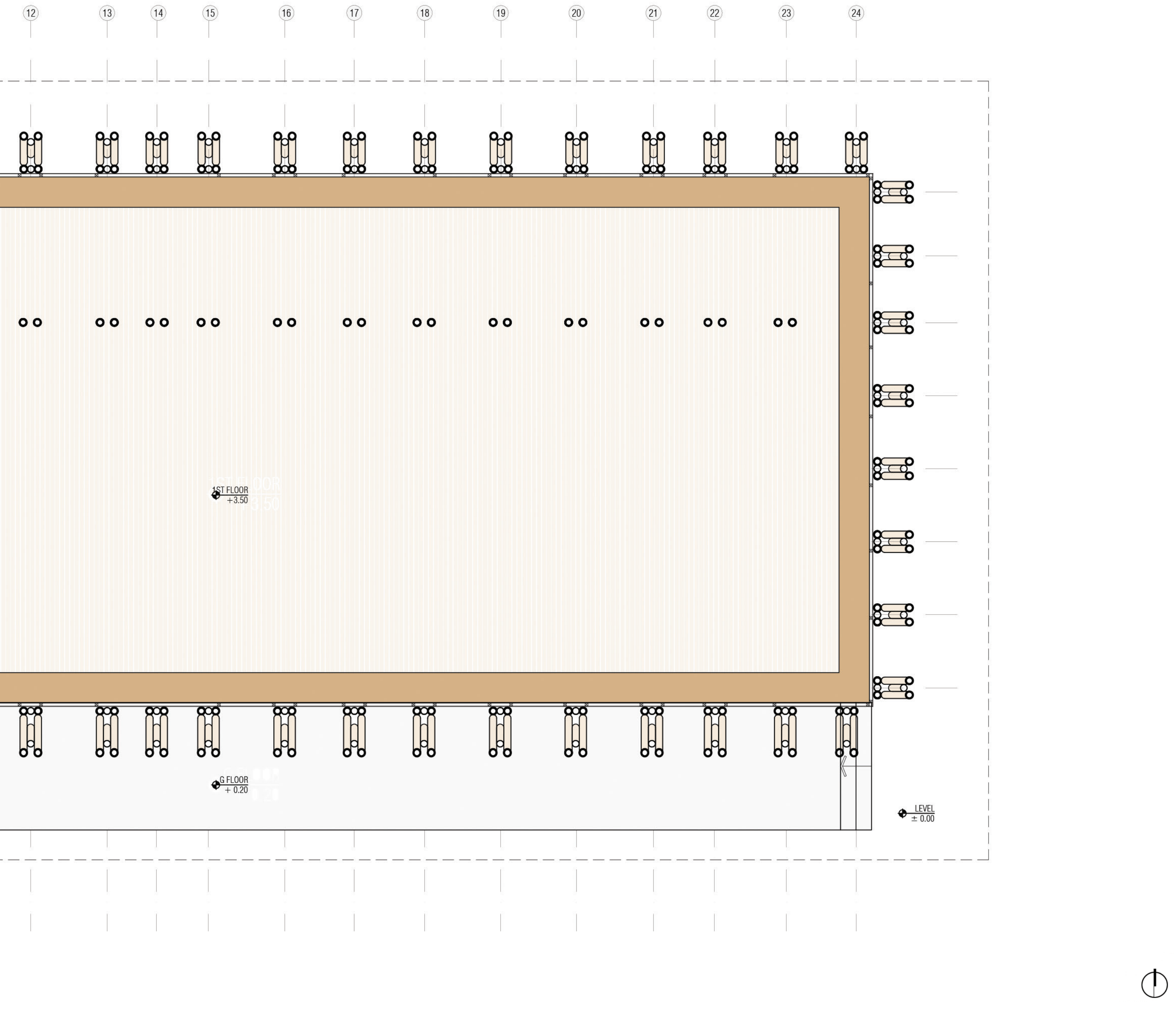


the center by two metal elements. The rectangular roof has overhangs on all sides that prevent rain from reaching the facades, thus preventing possible damage to the structure on the ground or water from entering through the openings.

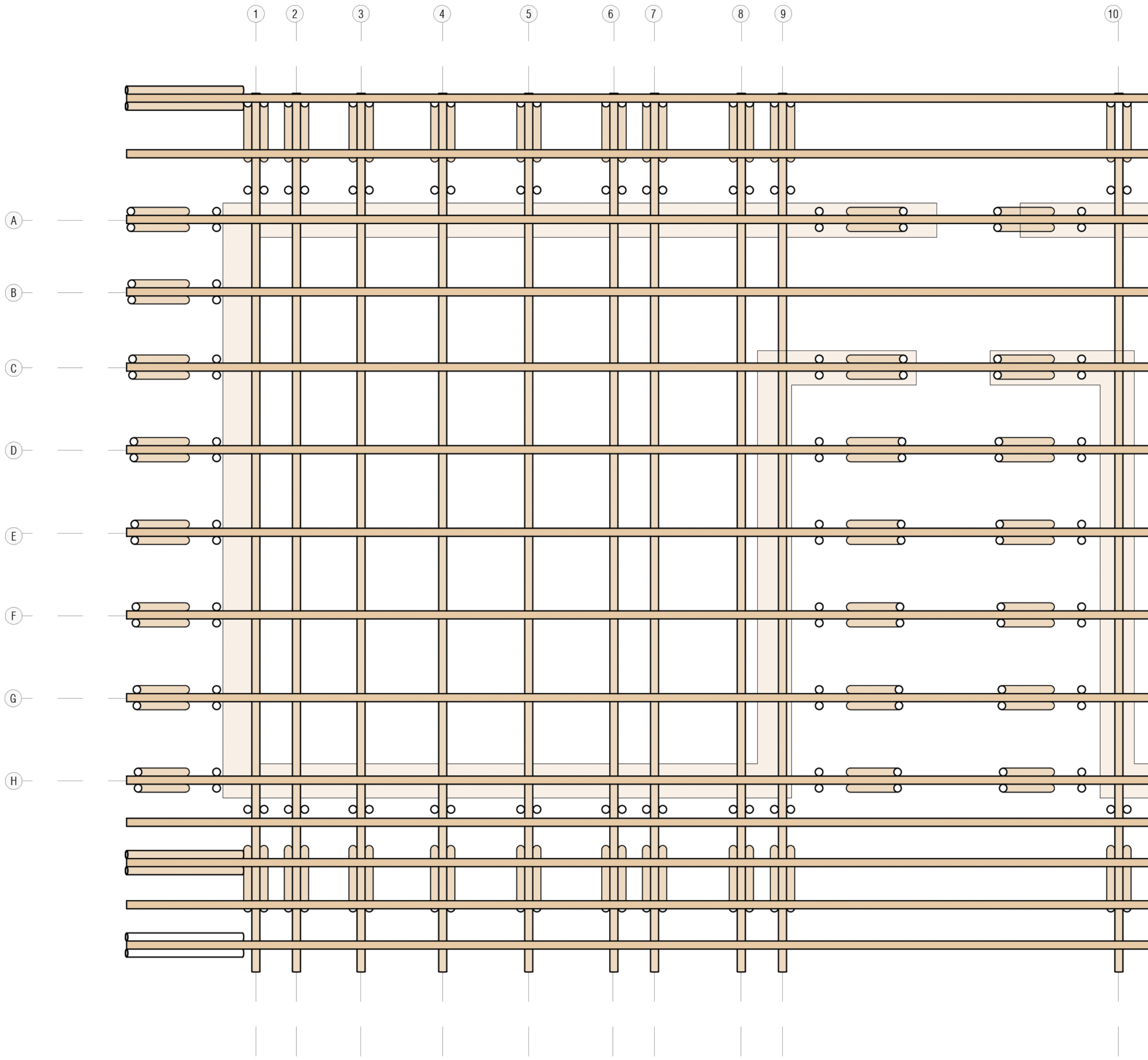
Chapter IV ***Figure 74, 75, 76, 77 and 78*** *progressive axonometry of an angle structure in bamboo METI School . Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*


1
2
3
4
5
6
7
8
9
10
11
A
B
C
D
E
F
G
H

First Floor
Scale 1:100

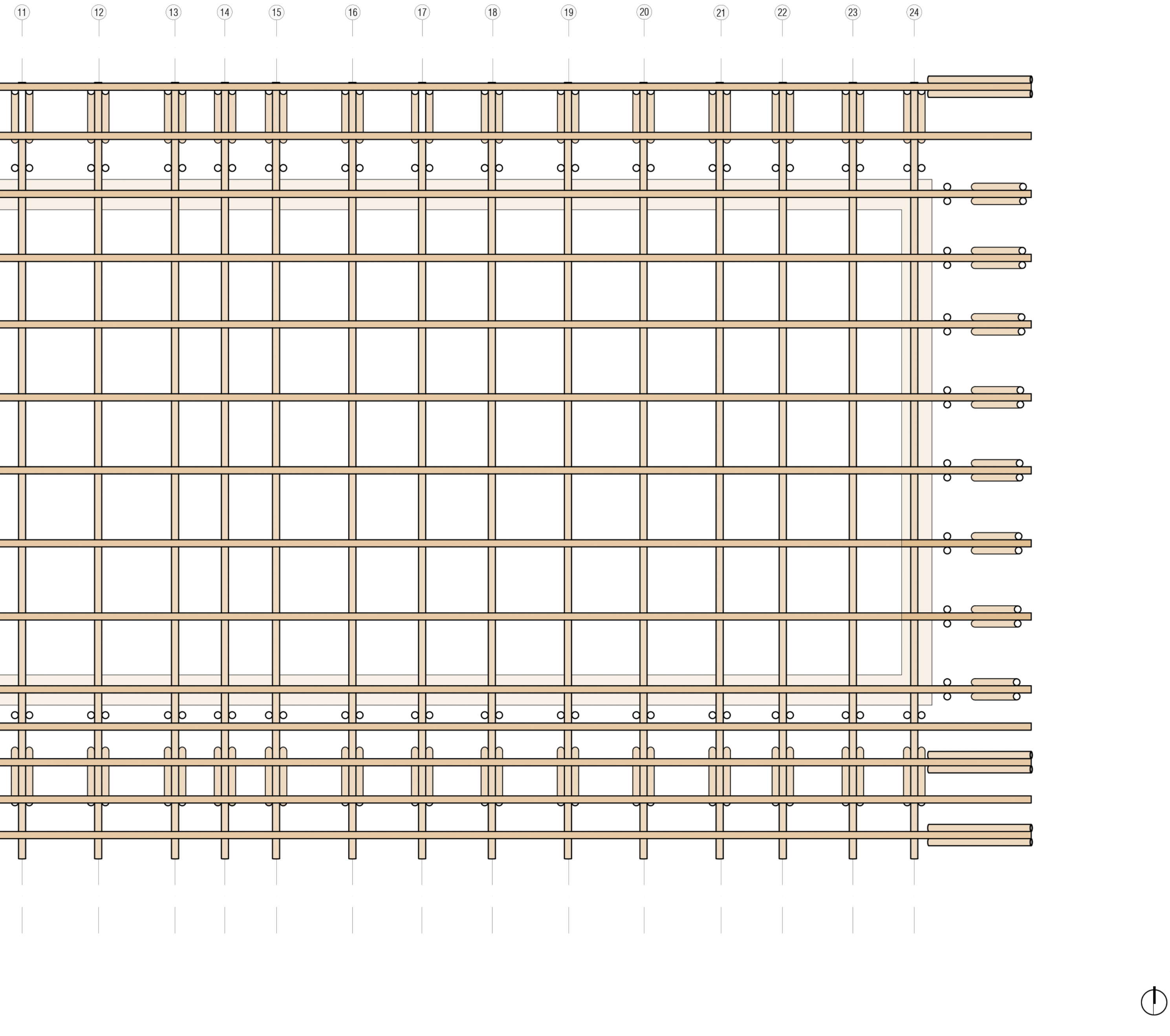


Chapter IV ***Figure 79*** *First floor plan. Own elaboration based on Anna Heringer plans.*

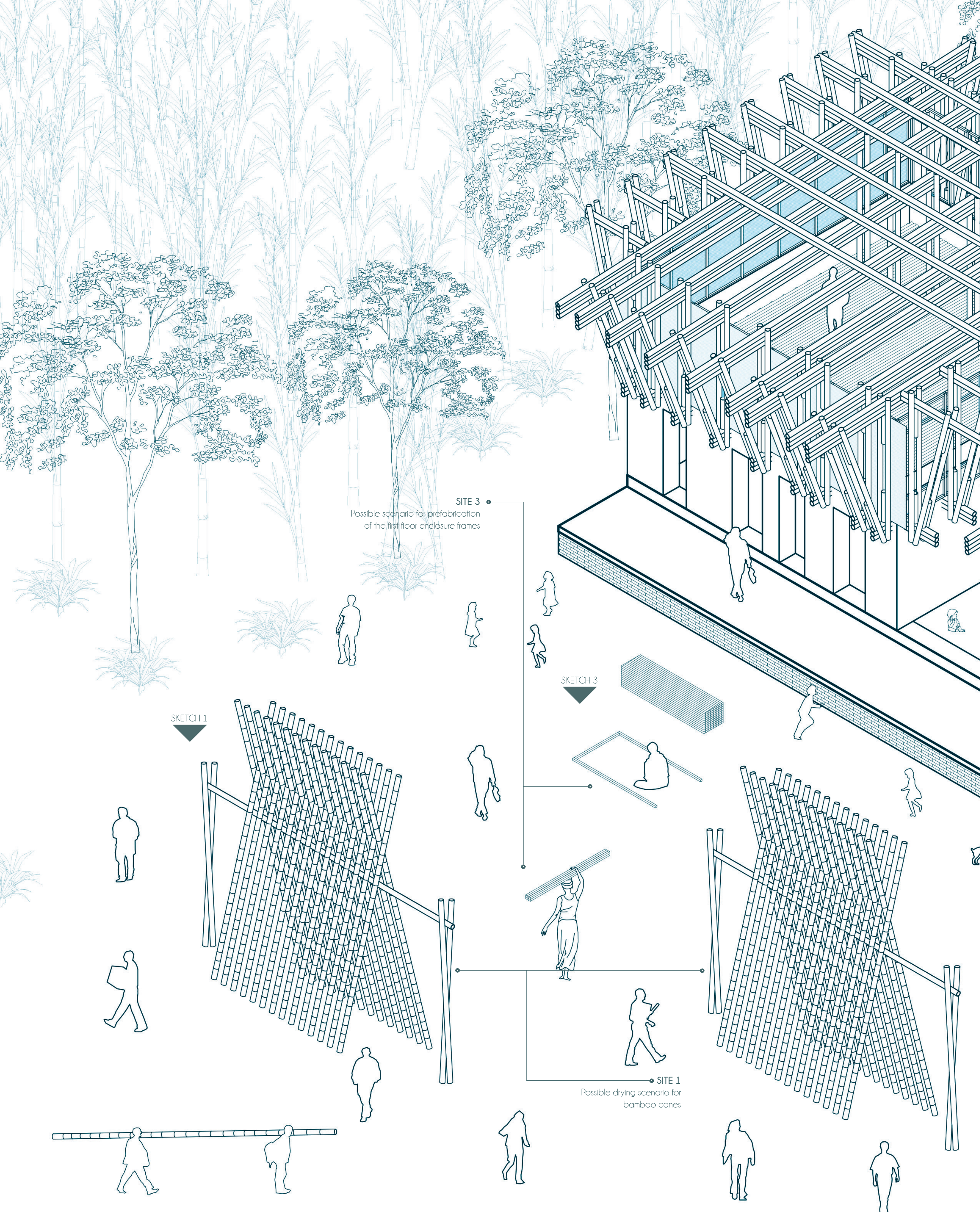


1
2
3
4
5
6
7
8
9
10
A
B
C
D
E
F
G
H

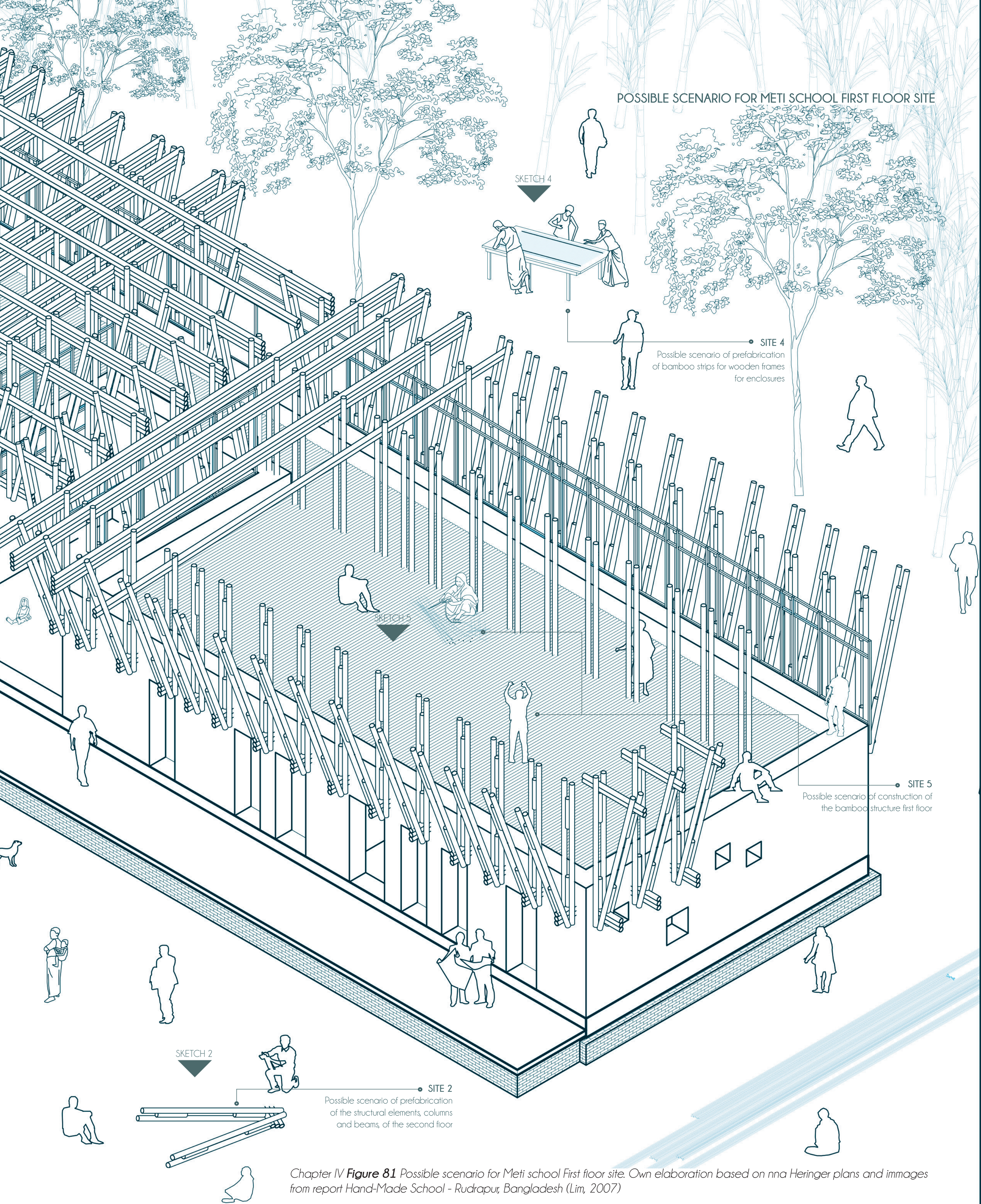
Structural plant first floor
Scale 1:100



Chapter IV ***Figure 80*** *structural plan first floor METI School . Own elaboration based on Anna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

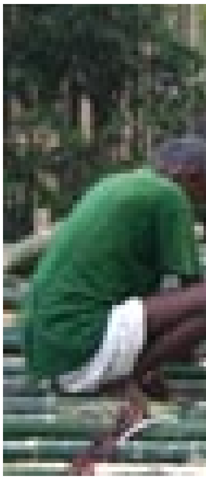


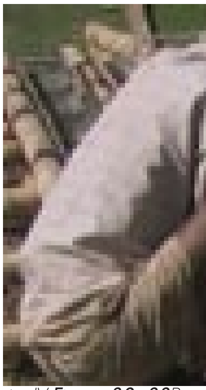
SITE 3
Possible scenario for prefabrication of the first floor enclosure frames
SKETCH 3
SKETCH 1
SITE 1
Possible drying scenario for bamboo canes



Chapter IV ***Figure 81*** *Possible scenario for Meti school First floor site. Own elaboration based on nna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

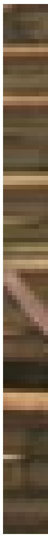






Chapter IV **Figure 82- 88**Bam
http://www.meti-school.de/do





Chapter IV **Figure 89 - 95** Bar
http://www.meti-school.de/do

boo ceiling construction 2005, (METI school handmade in Bangladesh, n.d.) Taken from
aten/bericht_decke_e.htm

mboo roof construction 2005, (METI school handmade in Bangladesh, n.d.) Taken from
aten/bericht_dachkonstruktion_e.htm

"ready to be used!   12/2005: After only a slight delay the building was finished in mid-December. After the holidays, the METI schoolchildren will be able to use the building and take over their new classrooms from mid-January.We want to thank everybody for supporting us in this project – for sharing ideas and making them real! It's been a wonderful time." (METI school handmade in Bangladesh, n.d.)

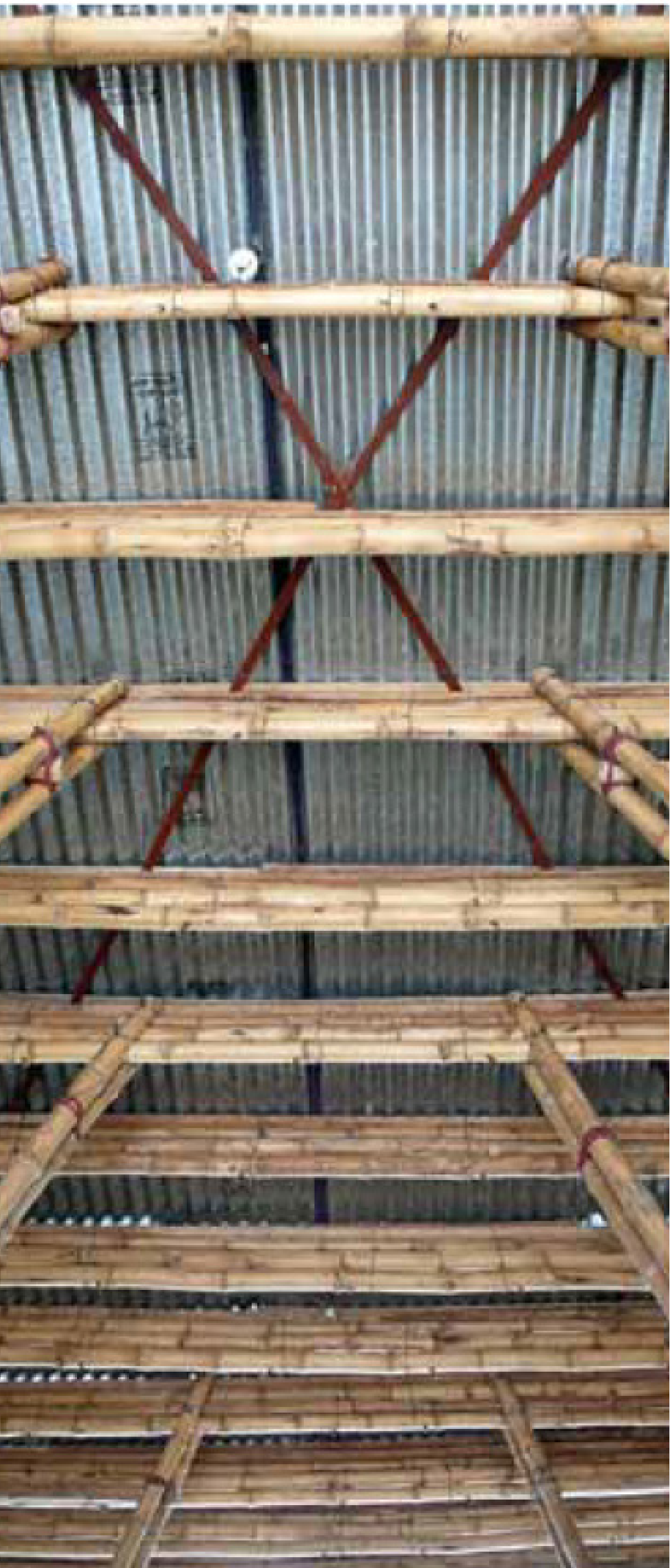
"Final works   01-03/2006: The characteristic surface of the "weller" walls with their rough structure has been left visible from the outside. Only the windows are given white asymmetric plastered frames (a mixture of lime and sand) as a protection against rain. The bamboo construction for the vertical garden on the West side is constructed with piping from old wells and many pieces of sliced bamboo" (METI school handmade in Bangladesh, n.d.)

"Final works   01-03/2006: Inside the walls are plastered with an earth plaster and coloured with lime. The caves are now a warm-red colour, the colour of the earth used to plaster them. Their curved shape has been formed by bamboo splices that have been wrapped with straw and earth. Some cracks need repairing and the surfaces of the floors are finished with a final treatment of palm-oil" (METI school handmade in Bangladesh, n.d.)

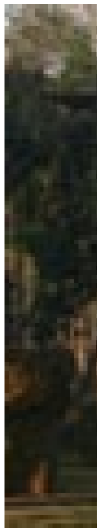
"Tour – ground floor classrooms: The METI philosophy respects the pace and way of learning of each individual and the building provides a variety of settings so that each kind finds an appropriate space for what they are doing. Each of the three classrooms on the ground floor is connected by two openings in the rear wall to the cave spaces behind. The caves form an area where children can retreat to, to read, to concentrate, to reflect … on their own or in small teams" (METI school handmade in Bangladesh, n.d.)

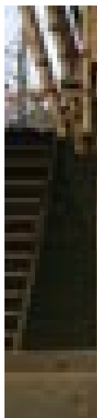
"Tour – first-floor classrooms: The airy first floor affords expansive views across the paddy fields, over the pond, and the mango trees and provides enough space for the children to romp. An exposed climbing tower connected to the classroom on the first floor lets the children conquer the vertical dimension" (METI school handmade in Bangladesh, n.d.)

"Tour – the facade: Bangladesh is the country with the highest population density worldwide. It is vital that buildings, particularly residential buildings, make use of the vertical and use additional storeys. The school is the only two-storey building in the surroundings. All of the METI students inscribed their names in Bengali on the doors of the school. Now the doors look like coloured blackboards after a long day of school work" (METI school handmade in Bangladesh, n.d.)



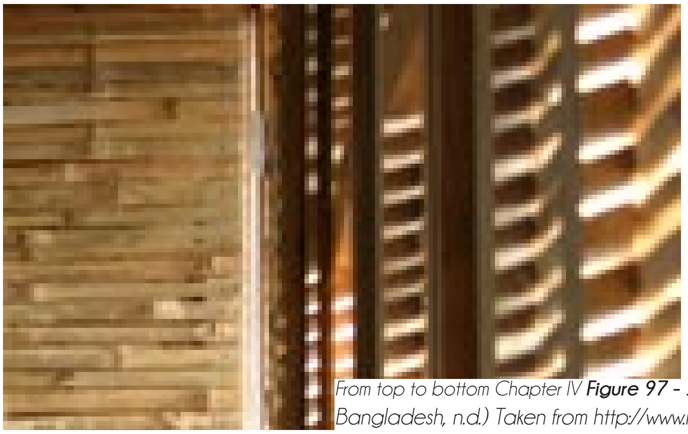
Chapter IV **Figure 96** METI School bamboo roof structure. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)



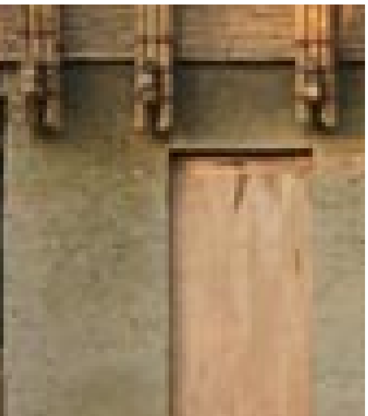




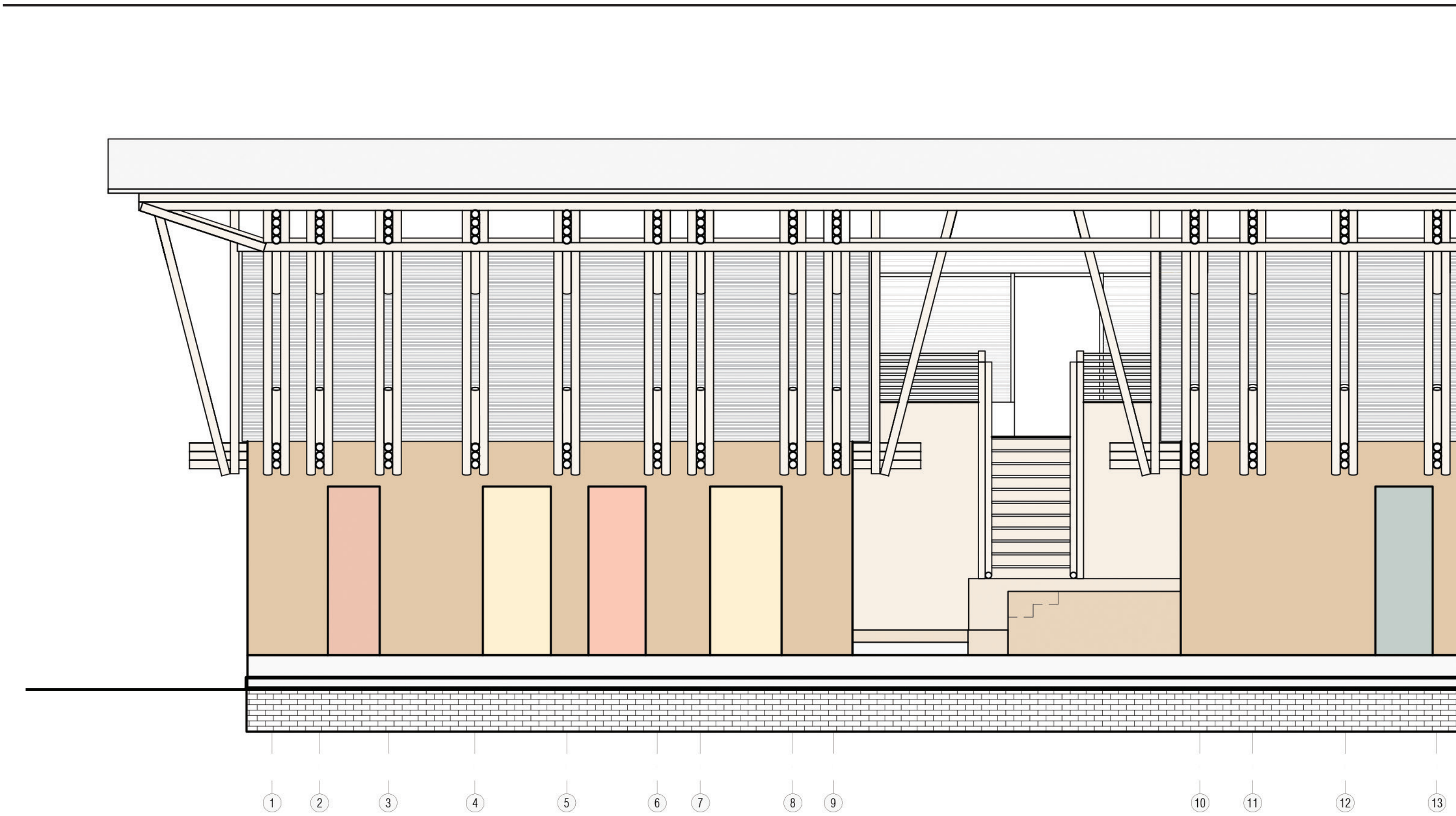


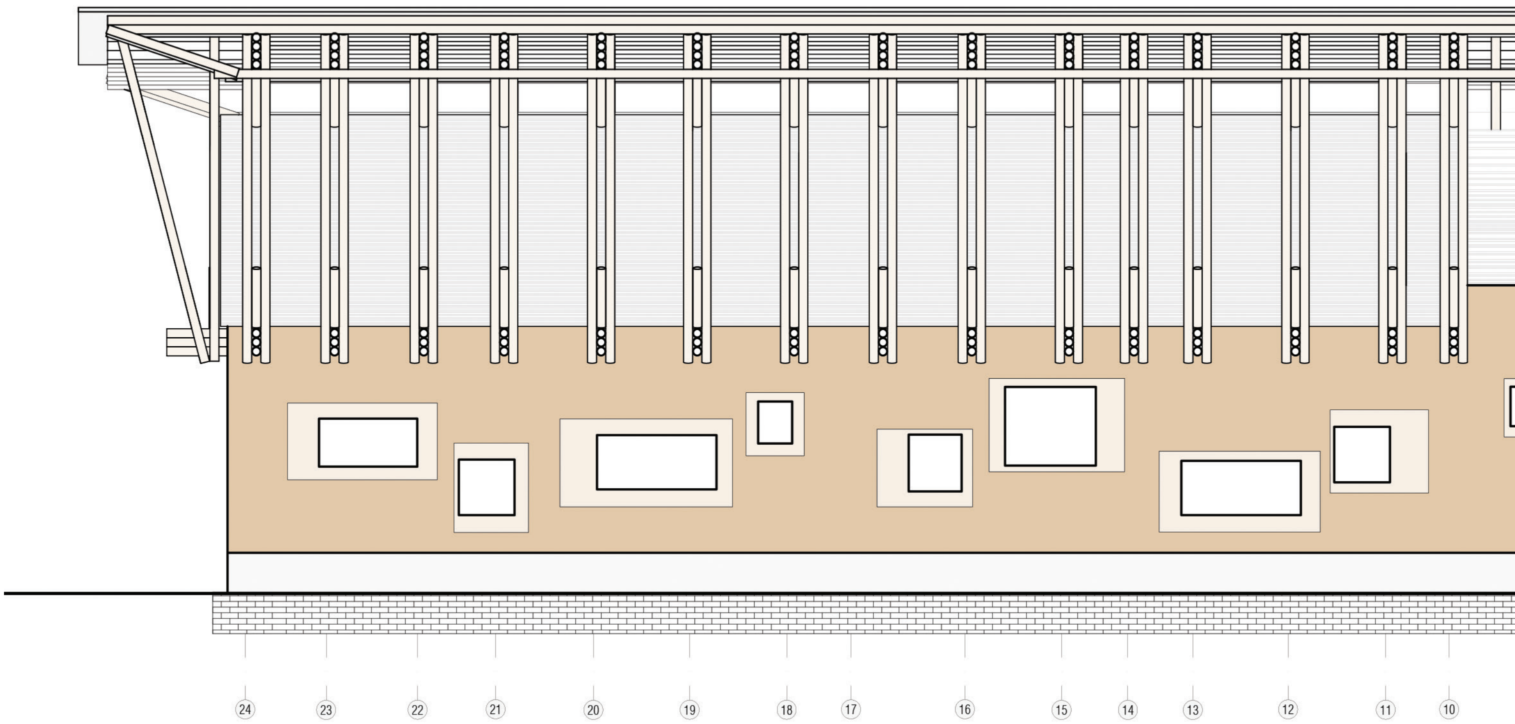



From top to bottom Chapter IV ***Figure 97 - 103*** *construction of the first floor enclosure 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_ausbau_2_e.htm*

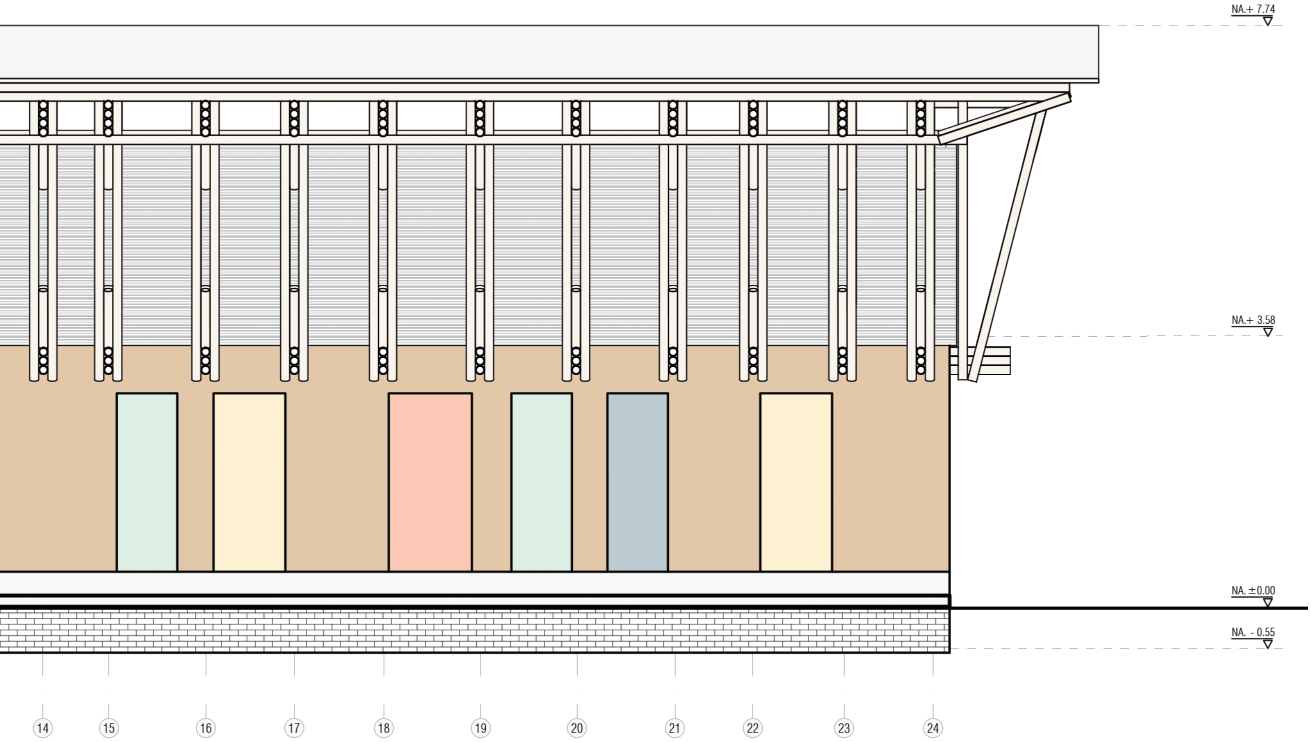



From top to bottom Chapter IV ***Figure 104 - 108*** *METI School december 2005, (METI school handmade in Bangladesh, n.d.) Taken from http://www.meti-school.de/daten/bericht_dezember_e.htm*


1
2
3
4
5
6
7
8
9
10
11
12
13

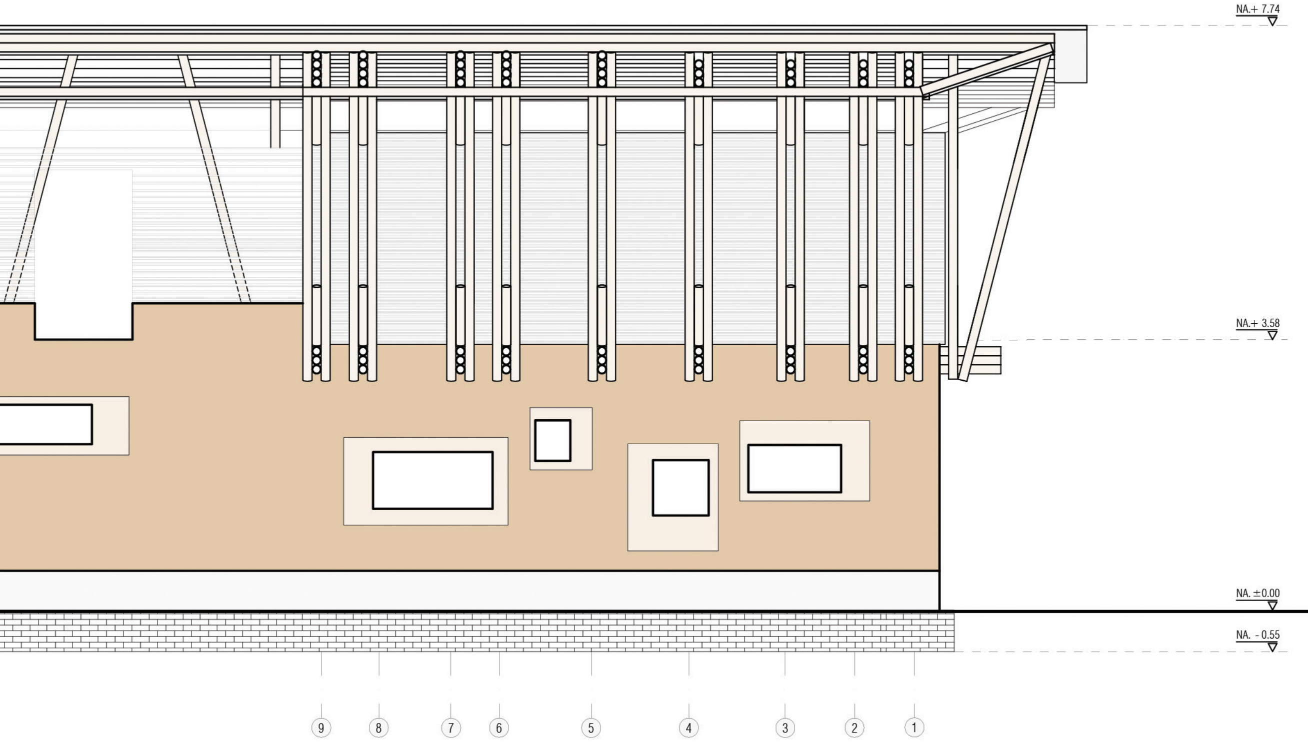

24
23
22
21
20
19
18
17
16
15
14
13
12
11
10

Eastern façade
Scale 1:100

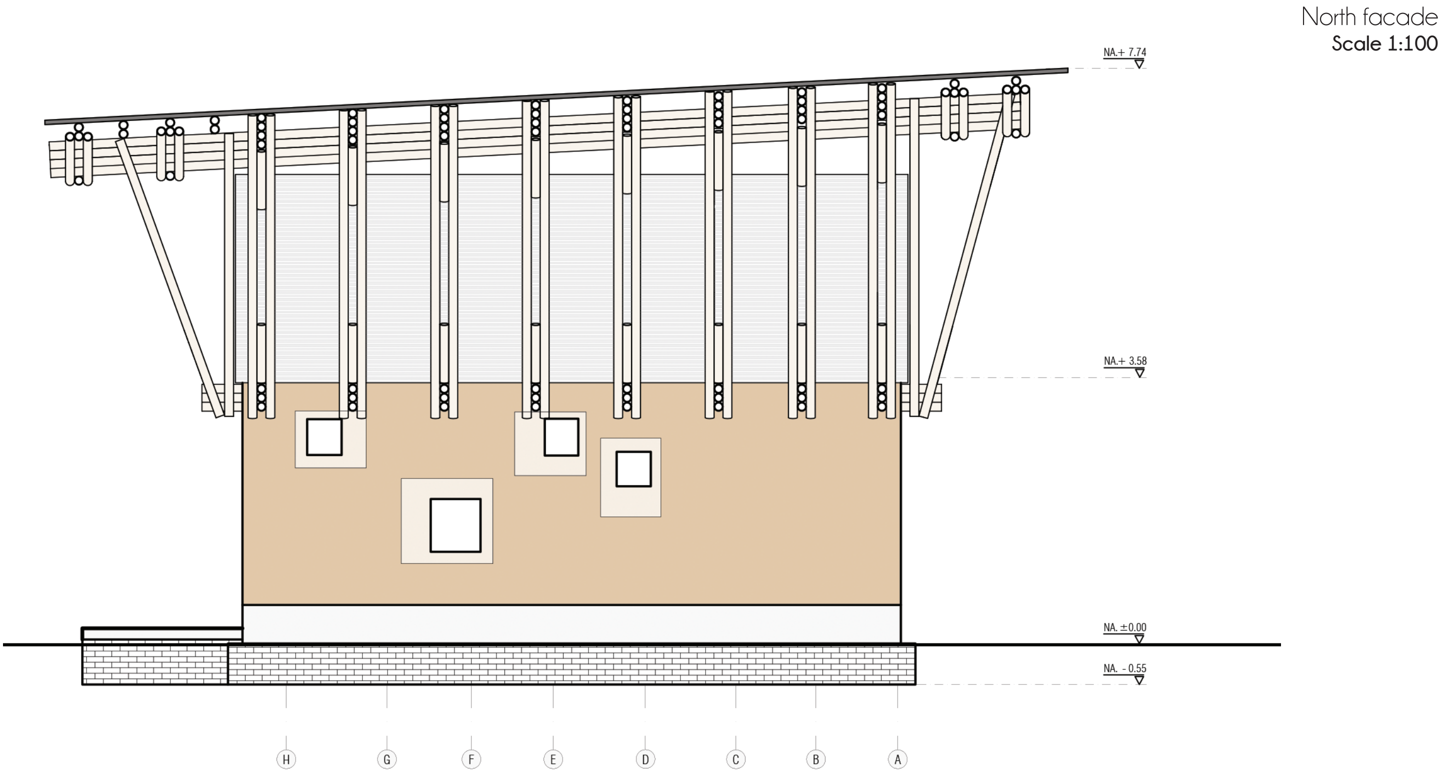


Chapter IV ***Figure 109*** *Eastern Front. Own elaboration based on Anna Heringer plans.*

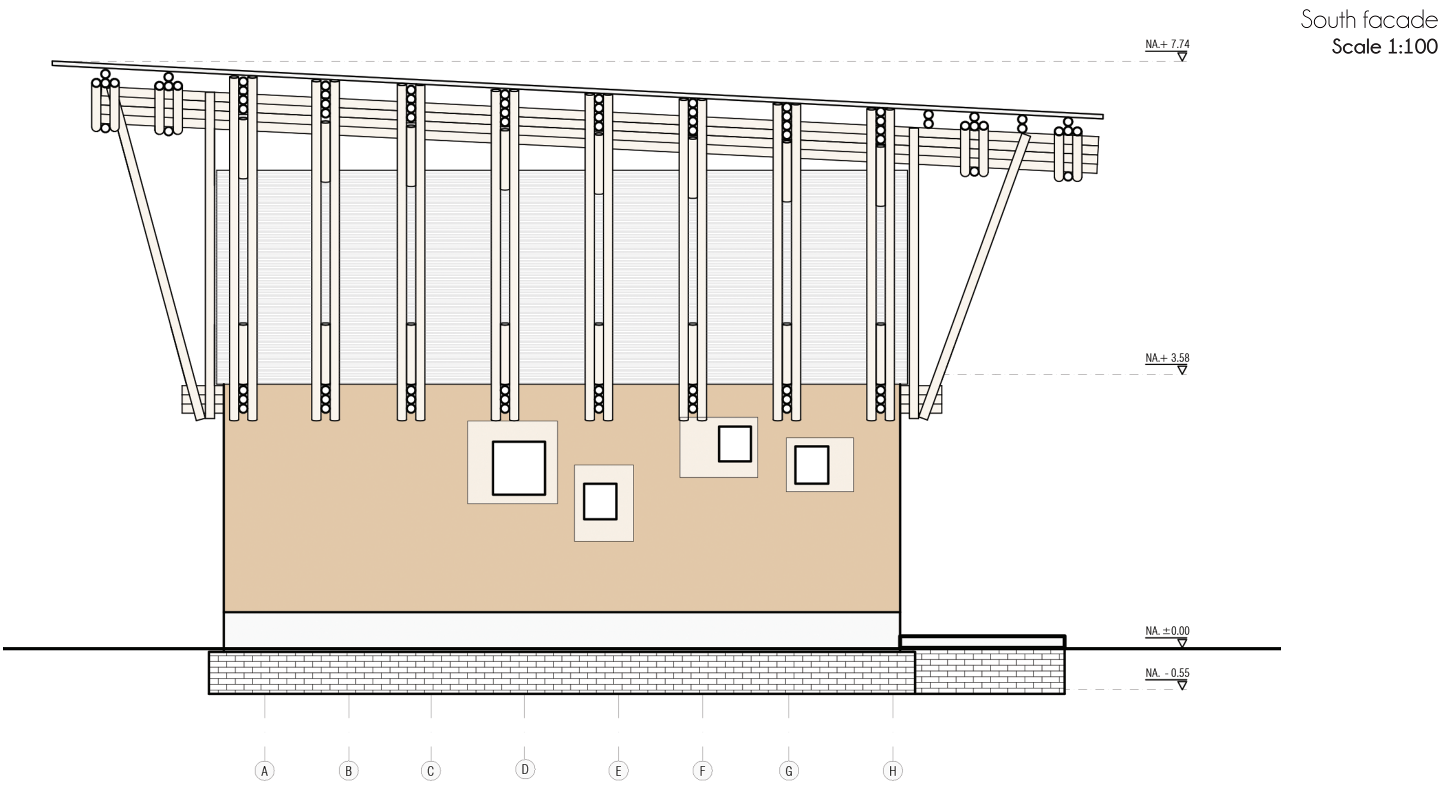
Western façade
Scale 1:100



Chapter IV ***Figure 110*** *Western Front. Own elaboration based on Anna Heringer plans.*



Chapter IV ***Figure 111*** *North Front. Own elaboration based on Anna Heringer plans.*



Chapter IV ***Figure 112*** *South Front. Own elaboration based on Anna Heringer plans.*

Chapter IV **Figure 113** METI School. Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)

METRIC MEASUREMENT, EE AND GWP INDICATORS

The depletion of global resources is inversely proportional to population growth and per capita consumption. Ecological aspects for the production, use, and end-of-life disposal of building materials and products can minimize their environmental impact. Through instruments such as LCA (Life Cycle Assessments) different companies and large industries generate strategies to mitigate pollution and improve their environmental performance.

This instrument, implemented in ISO standards since 1997, makes it possible to trace the vital progress of a material or product, document the resources consumed (energy, raw materials) and the emissions emitted during each phase of its life (acquisition, processing, manufacturing, distribution, transport, etc.).

This analysis is normally developed with the following statements "Defining goal and scope of the assessment, compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential impacts associated with those inputs and outputs; interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study" (Ashby, 2012, #) and some of the eco-attributes of a material include the following indicators:

Global Production, the main component
Reserves
Embodied energy, primary production
CO2 footprint, primary production
Water usage
Eco properties: processing
Casting energy
Casting CO2 footprint
Deformation processing energy
Deformation processing CO2 footprint
End of life
Embodied energy, recycling
CO2 footprint, recycling
Recycle fraction in current supply

In the case of the METI school, I will analyze the indicators of potential environmental impact (PEI) and global warming potential (GWP) that is the mass of CO2 released into the atmosphere per unit mass of material, it's usually measured in kg/kg (Ashby, 2012). The energy used during the construction phases and in the use of the building is not taken into account due to the complexity of quantifying these values.

The analysis will be performed with two different databases the Ökobautdat with the support of the InData platform and the ICE. These databases are European and were chosen to make this building comparable with the other buildings analyzed in the same line of work for the analysis of technological detail of buildings of high environmental quality. It should be clarified that it is likely that the values would be lower if the analysis was carried out with data from materials in Bangladesh.

ÖKOBAUDAT

The ÖKOBAUDAT platform is provided as a standardized database for ecological evaluations of buildings. The platform's core is the online database with life cycle assessment datasets on building materials, construction, transport, energy, and disposal processes. With the help of life cycle assessment tools, such as LCA provided by the BBSR. (ÖKOBAUDAT, n.d.)

The platform is constantly updated (current version 2021-II from 25.06.2021) and allows free access to environmental sheets of generic and specific declarations from different materials, products, and companies.

Chapter V ***Figure 1*** *ökobaudat logo Taken from https://www.ibo.at/en/research/reference-projects/data/oekobaudat*
Chapter V ***Figure 2*** *BMWSB logo Taken from https://www.oekobaudat.de/en/home/assessment-system-for-sustainable-building-bnb.html*

In addition, ökobaudat is part of the working Group "International Open Data Network for Sustainable Construction" (InData, n.d.) which is an informal, non-profit working group of interested stakeholders led by the BBSR. Its main objective is to establish an international network structure for EPD/LCA data in the construction sector – online based and using open-source software. Using a common data format in an open network structure shall allow for open access to data and flexible application options. The InData initiative uses the ILCD+EPD data format developed for the ÖKOBAUDAT.

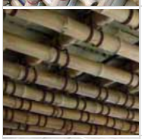
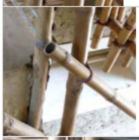
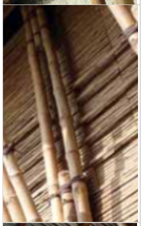
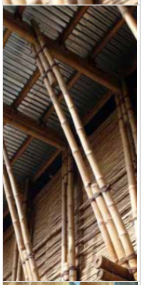
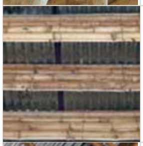
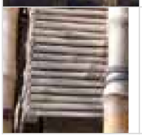
Chapter V ***Figure 3*** *In Data logo Taken from https://www.ibo.at/en/research/reference-projects/data/oekobaudat*

ICE

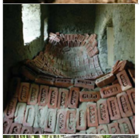
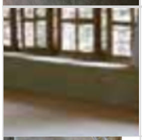
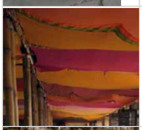
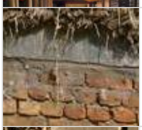
The Inventory of Carbon and Energy (also known as the ICE database) is an embodied carbon database for building materials that is available for free. was founded by Dr. Craig Jones, a researcher at the University of Bath. The database contained embodied energy and embodied carbon factors. It contains data for over 200 materials, broken down into over 30 main material categories (Embodied Carbon Footprint Database, n.d.)

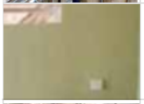
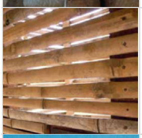
Chapter V ***Figure 4*** *University of BATH logo Taken from https://www.bath.ac.uk/*

The first step in making the environmental impact assessment for the METI school was to conduct an inventory that attempts to identify, classify and list each element used in the construction of the building. Each element type has an identification label that allows me to quickly and efficiently quantify the project. These elements are classified into 2 categories as shown in the label. The first one corresponds to their location in the project. This category includes the foundation, the ground floor, the first floor, the stairs, and the roof. The second corresponds to its function or system. This includes the structure, enclosures, finishes, and others. This is how the label of the element is composed of: the location in the project_system to which it belongs + number.

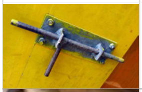
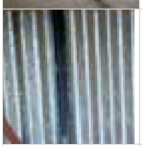
	MATERIALS	COD	ELEMENT
	Aluminium, zinc alloy	FF_AC01	hinges
	Bamboo	GF_ST01	Vertical reinforcements
	Bamboo	GF_ST02	Lintels
	Bamboo	GF_CL01	Bars
	Bamboo	FF_PV01	Beams
	Bamboo	FF_PV02	Joists
	Bamboo	SC_ST01	Staircase beam
	Bamboo	SC_SC01	Vertical bars
	Bamboo	SC_SC02	Diagonal bars
	Bamboo	FF_ST01	Beams h1
	Bamboo	FF_ST02	Beams h3
	Bamboo	FF_ST03	Vertical compound columns
	Bamboo	FF_ST04	Diagonal compound columns
	Bamboo	RF_ST01	Beams h2
	Bamboo	RF_ST02	Beams h4
	Bamboo	RF_ST03	Joists
	Bamboo	RF_ST05	Diagonal beams
	Bamboo	FF_CL01	Strips for panels

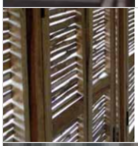
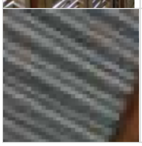
Chapter V ***Figure 5*** *Inventory images Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

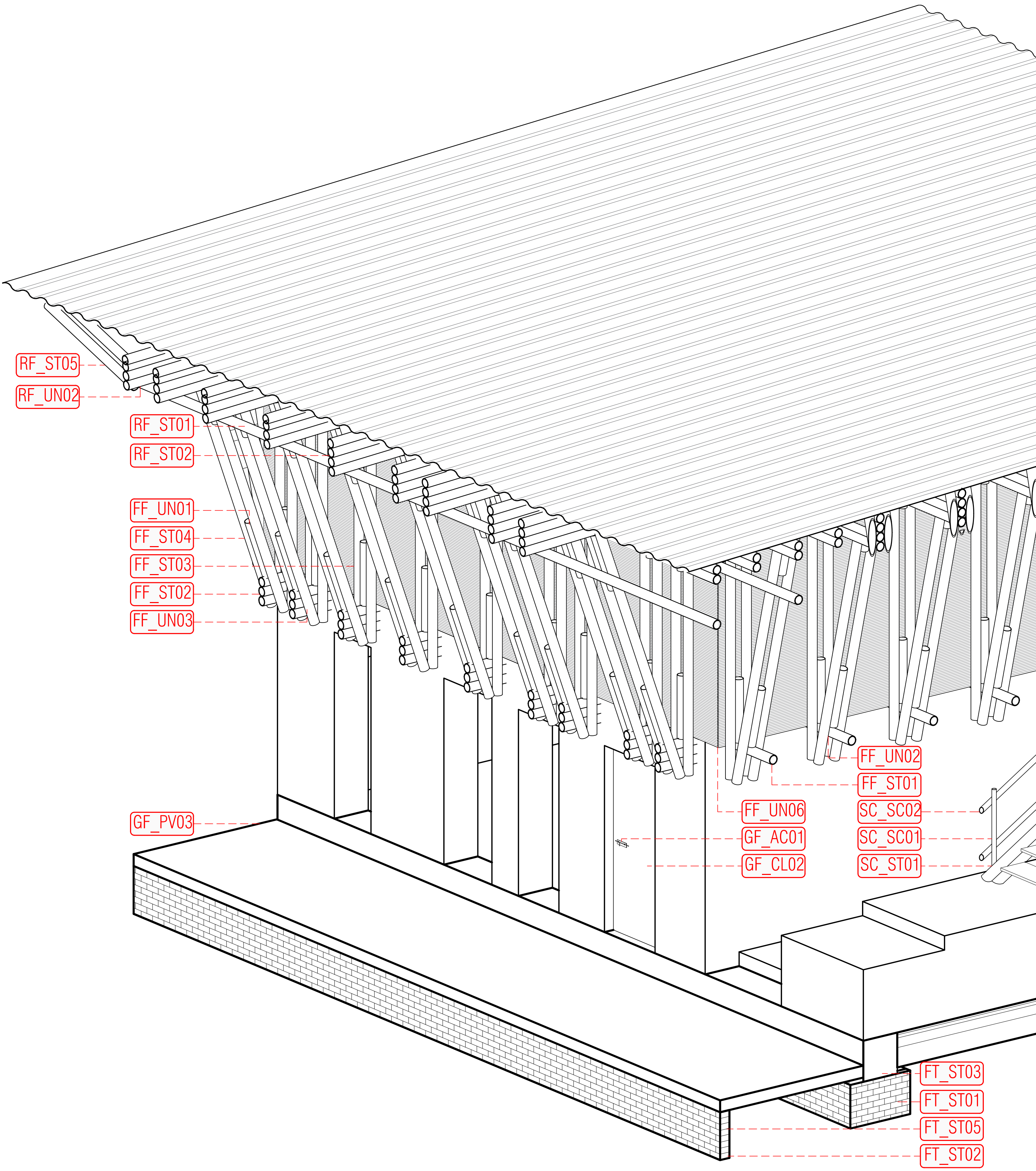
	MATERIALS	COD	ELEMENT
	Bricks	FT_ST01	Continuous foundations
	Bricks	FT_ST02	Base wall
	Bricks	GF_ST03	Caves floor
	Concrete	FT_ST03	Continuous foundations
	Concrete	GF_PV03	Platform
	Earth	GF_PV01	Floor
	Earth	GF_ST04	Walls
	Earth	GF_DC01	Plaster for caves
	Earth	FF_PV03	Floor
	Earth	FF_ST05	Low walls
	Fabrics	FF_CG01	Ceiling
	Mortar	FT_ST04	Continuous foundations
	Mortar	FT_ST05	Base wall

	MATERIALS	COD	ELEMENT
	Mortar	GF_ST05	Caves floor
	PVC	GF_ET01	Conduit pipe
	PVC	FF_ET01	Conduit pipe
			
	Rope	GF_UN01	A joint
	Rope	FF_UN01	B joint (columna- bambu largo - bambu pequeño-bambu largo)
	Rope	FF_UN02	C joint (columna con viga h1)
	Rope	FF_UN03	D joint (columna con viga h3)
	Rope	RF_UN01	E joint
	Rope	RF_UN02	F joint
	Steel "low carbon"	FF_UN05	Lance frame joint
	Steel "low carbon"	FF_UN06	Lance façade panel joints
	Steel	GF_AC01	Door pin

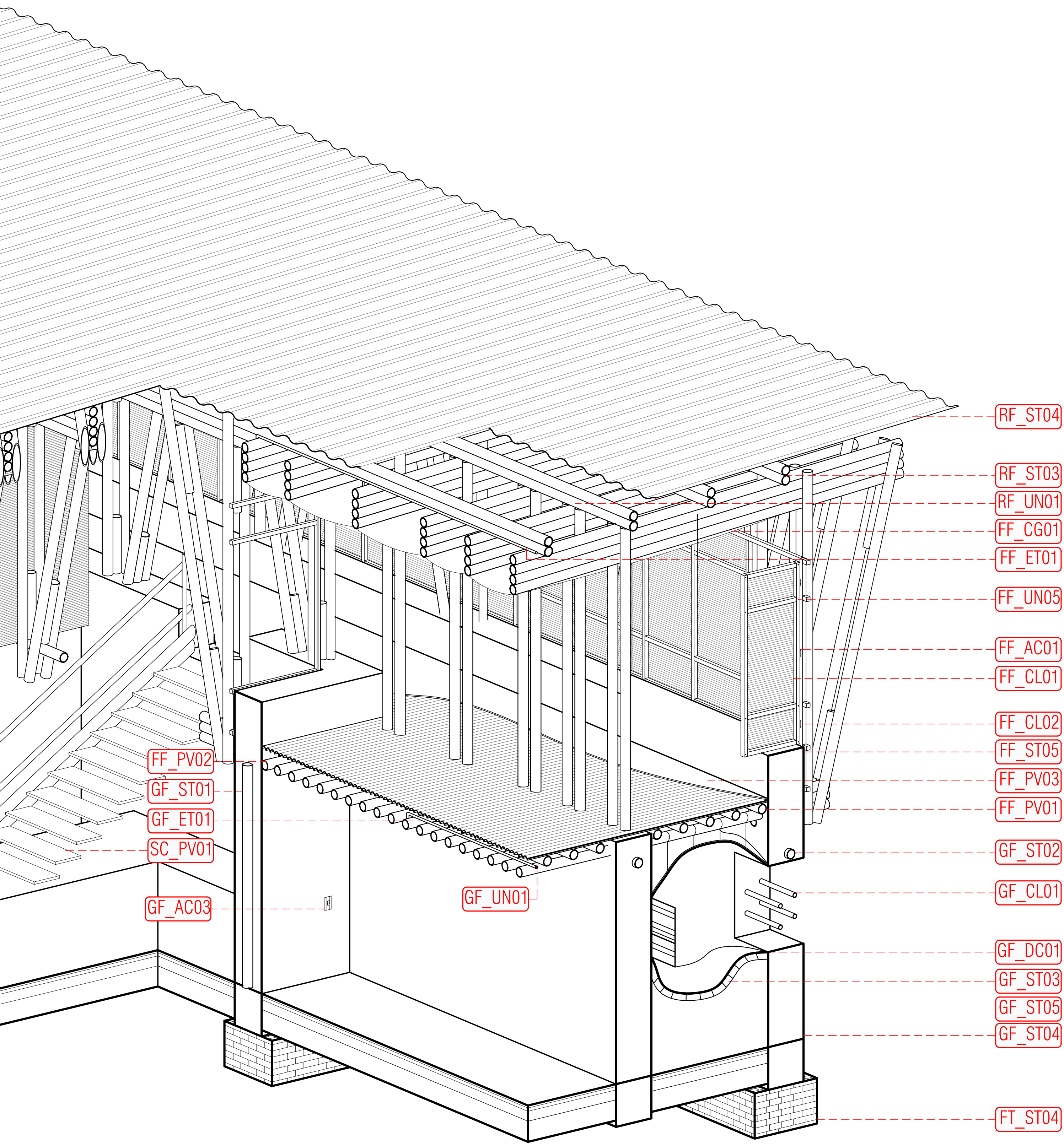
Chapter V ***Figure 5*** *Inventory images Taken from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

	MATERIALS	COD	ELEMENT
	Steel	FF_AC02	Door pin
	Steel	FF_UN05	Corrugated rod JB
	Steel	FF_UN07	Corrugated rod JC
	Steel	FF_UN08	Corrugated rod JD
	Steel	RF_UN04	Corrugated rod JE
	Steel	RF_UN05	Corrugated rod JF
	Steel	FF_UN09	Nuts JB
	Steel	FF_UN10	Nuts JC
	Steel	FF_UN11	Nuts JD
	Steel	RF_UN06	Nuts JE
	Steel	RF_UN07	Nuts JF
	Steel	SC_UN02	Plate
	Steel	RF_AC01	Plate

	MATERIALS	COD	ELEMENT
	Steel	RF_ST06	Struts / braces
	Steel	GF_AC02	Pivot
	Straw	GF_PV02	Mixture reinforcement
	Straw	GF_ST06	Mixture reinforcement
	Straw	FF_PV04	Mixture reinforcement
	Straw	FF_ST06	Mixture reinforcement
	Wire	SC_UN01	G joint
	Wire	FF_UN04	H joint
	Wire	RF_UN03	I joint
	Wood	GF_CL02	Doors
	Wood	SC_PV_01	Stairs
	Wood	FF_CL02	Frames strip panels
	ZINC	RF_ST04	Tiles



Chapter IV ***Figure 6*** *Axonometry for inventory. Own elaboration based on nna Heringer plans and immages from report Hand-Made School - Rudrapur, Bangladesh (Lim, 2007)*

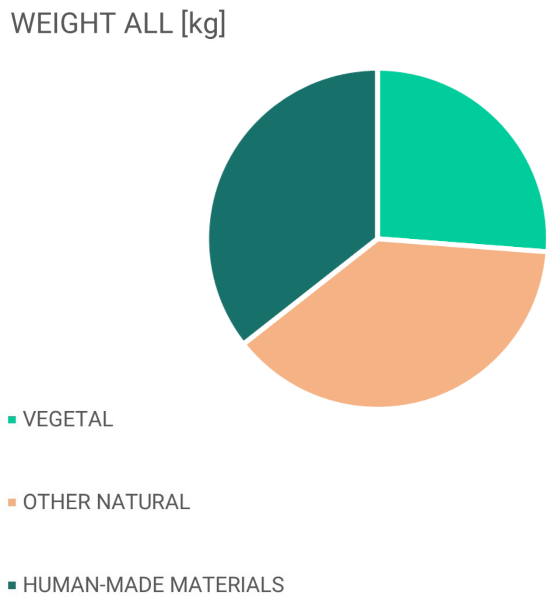

RF_ST04
RF_ST03
RF_UN01
FF_CG01
FF_ET01
FF_UN05
FF_AC01
FF_CL01
FF_CL02
FF_ST05
FF_PV03
FF_PV01
GF_ST02
GF_CL01
GF_DC01
GF_ST03
GF_ST05
GF_ST04
FT_ST04
FF_PV02
GF_ST01
GF_ET01
SC_PV01
GF_AC03
GF_UN01

The building has an area of 325m2 and its total weight is 695 tons. Counting 2.1 tons per square meter. Thirty six percent of the weight is made up of human-made materials and the remaining 64% are natural materials. The last one is divided into plant materials, including wood, bamboo, and straw, which account for 26% of the total weight, and other natural materials, including earth, which account for 38%.

This means that almost a third of the weight is from the earthen walls and floors of the ground floor while the first-floor structure, being made of bamboo, is much lighter and represents only 6.9% of the total weight. it should be noted that this value includes 3 times the amount of bamboo used, due to the replacement of the structure in the construction phase and 2018. It is interesting to see the strong contrast between two types of construction based on natural materials, although it should be noted that the percentage of bamboo described above does not take into account the materials used in the fastenings of the different elements such as corrugated steel rods or nylon ropes because they are human-made materials.

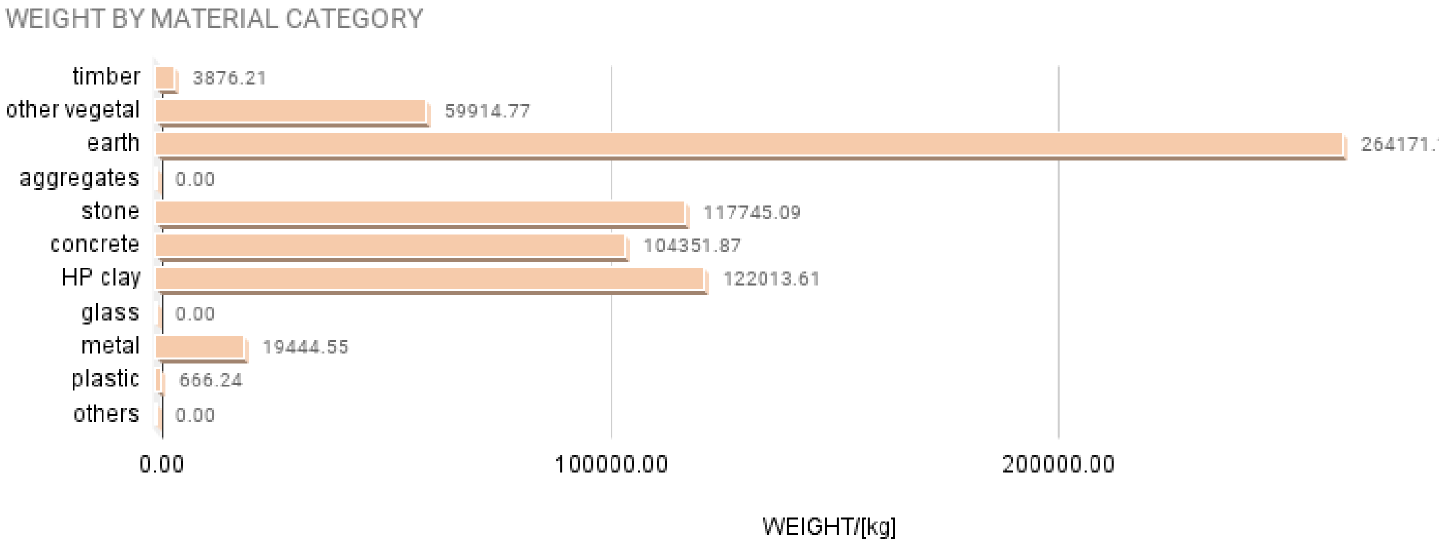
Another interesting thing to highlight is the comparison between the volume and weight of the materials, although in most cases there is a correspondence between both measures. Some materials such as zinc roof tiles have a high weight for the amount used. with only 2.3m^3 in the building this material represents 1.7% of the weight of the building. although it seems little, it is the 10th heaviest element in the list of 72 elements. It is worth remembering that weight is of utmost importance in materials because it is used to measure the GWP of the materials.

It should be noted that the quantities in this analysis are a hypothesis based on the photographic documentation of the building. Quantities may vary from actual due to lack of information. After making the inventory and identifying the materials and products used, with their respective quantities in m^2, m^3, and kg, I search for information on them in the databases.



*Chapter IV **Graphic 2** Weight by macrocategories.*

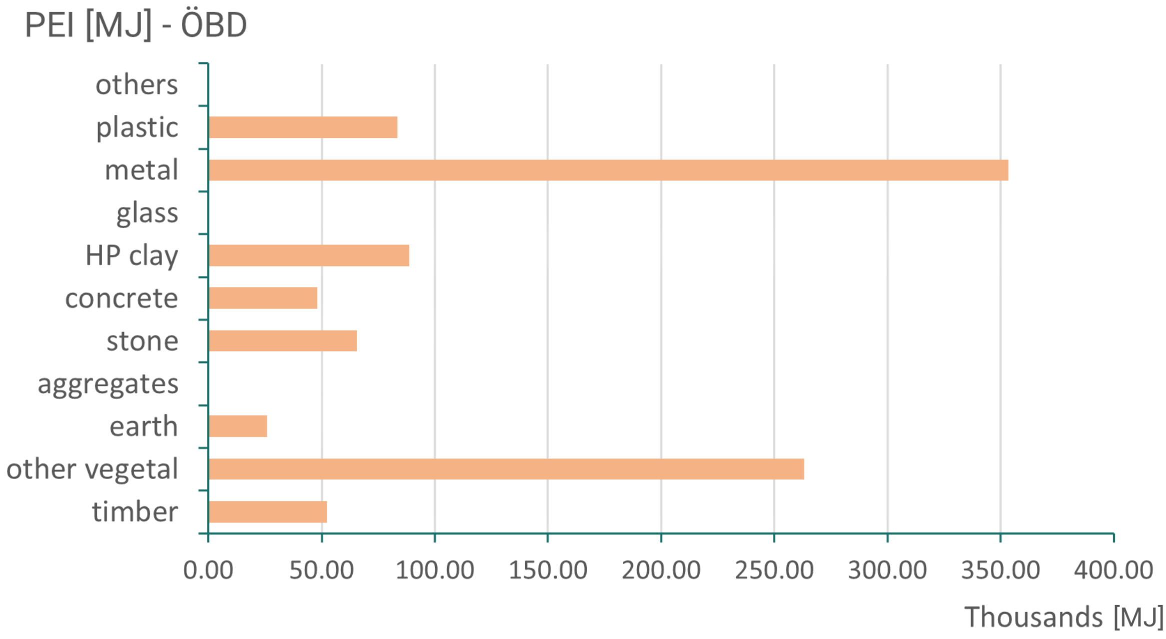
ELEMENT	MATERIAL CLASS	VEGETAL
Bamboo	other vegetal	YES
Bricks	HP clay	NO
ConcreteX3	concrete	NO
Earth	earth	NO
Textile ceiling	other vegetal	YES
Gravel ground floor pav	stone	YES
Mortar	cement	NO
Conduit pipe	plastic	NO
Plastic waterproofing membrane	plastic	NO
Rope	plastic	NO
Steel	metal	NO
Straw	other vegetal	YES
Wire	metal	NO
Wood	timber	YES
Zinc tiles	metal	NO



Chapter IV ***Graphic 1*** *Weight by material category.*

NATURAL	tot length (l*n)	area (l*w*n)	volume (l*w*h*n)	density				WEIGHT
	[m]	[m2]	[m3]	[kg/Un]	[kg/m]	[kg/m2]	[kg/m3]	[kg]
YES	-	-	73.61				650.00	47,845.97
NO	106.00	149.51	65.95				1,850.00	122,013.61
NO	-	126.75	42.59	-	-	-	2,450.00	104,351.87
YES	-	595.45	186.17	-	-	-	1419	264,171.11
YES	-	220.00	0.66	-	-	-	40.00	26.40
YES	-	192.63	48.16	-	-	-	2,445.00	117,745.09
NO	-	-	1.52	-	-	-	2162	3,279.59
NO	73.00	-	-	-	0.15	-	-	10.71
NO	-	192.63	0.19	-	-		1820	350.59
NO	17,852.40	-	-	-	0.02	-	-	342.77
NO	291.20	0.01	-	Various	-	-	-	5,708.75
YES	-	-	150.53	-	-	-	80.00	12,042.40
NO	175.56				0.25			43.54
YES	607.00	24.3325	6.25				620.00	3,876.21
NO	-	459.00	2.30	-	-	-	5,975.00	13,712.63

Chapter IV ***Table 1*** *Inventory*



Chapter IV ***Graphic 3*** *PEI by ökobaudat*

In the case of ökobaudat, Contrary to the ICE, the PEI value of a material is obtained with the sum of the PERNT which indicates the total use of non-renewable primary energy resources, and the PERT indicates the total use of renewable primary energy resources.

As mentioned above, although the platform provides these values for the entire life cycle of the material, this analysis will be based only on the production phase (A1-A3). Another important factor to take into account is the reference unit of the material, since it may present variations.

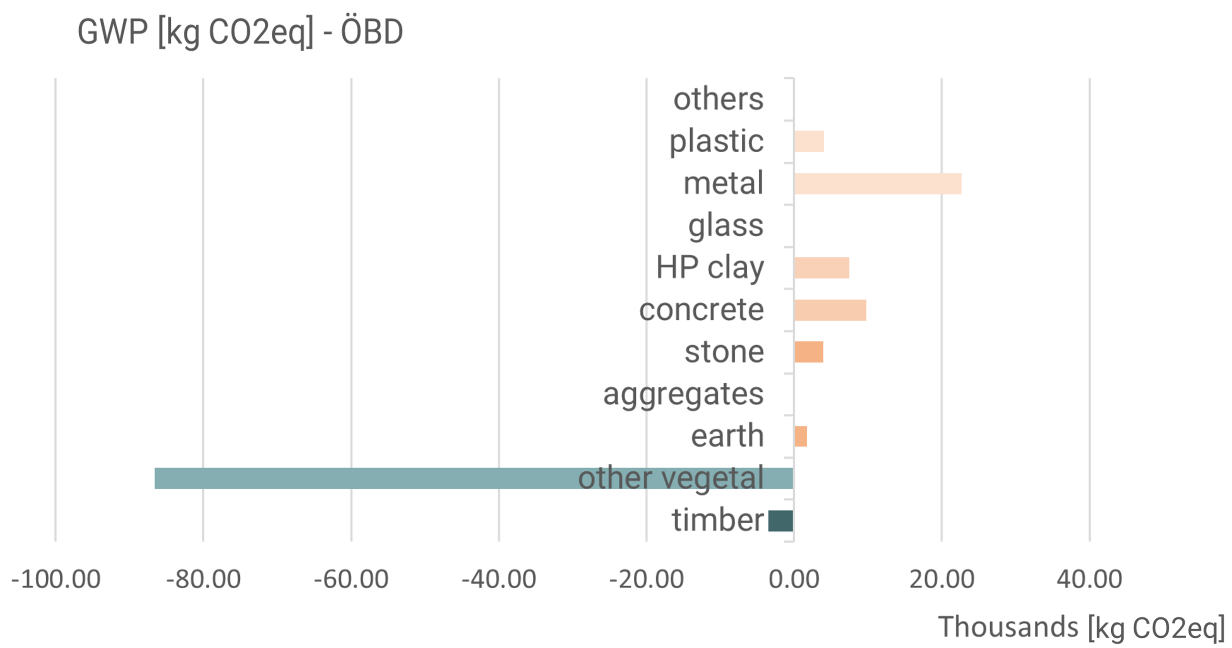
Should keep in mind that this database is provided information on specific products and processes. For this reason, despite looking for the most similar materials to those used in the METI school for reference, the processes may vary depending on the company and geographic location. analyzing it with two different databases creates the possibility of comparison.

Although in the following summary graphs the materials were grouped into general categories such as "metal", actually the analysis includes each element individuated in the images as shown in the annexes. For the bamboo elements, I took the information from InData because there was no information available in ökobaudat. In addition, I only took the data for the raw material supply (A1) and not for the whole production. This is because in the METI School they used just canes and not a manufactured products. For this material, the GWP did not admit negative values, so the carbon sequestered by the bamboo was hypothesized and added to the value given by the platform.

For the masonry works I used the information of unfilled bricks and cement mortar, the wood parts share the same material due to the impossibility of distinguishing different typologies. For the earthen elements I used information of rammed earth wall instead of COB since it was the most similar product. On the other hand in the metallic elements where products such as hinges, handles, nuts, and nails among others are found, look for similar elements or general categories where these are included.

The total PEI value of the building is 981044.11 MJ of which 523914.75 MJ is non-renewable PEI. 981 GJ in relation to the GFA of the building gives a PEI of 3 GJ /m2. The categories with the highest incidence in this result are metallic elements with 36% (353.5 GJ), other vegetation, including bamboo and straw with 26.8% (263.3 GJ), plastics with 8.5% (83.6 GJ), and HP clay, i.e. brick with 9% (88.7 GJ).

It is interesting to see how the earth, which accounts for almost more than a third the weight of the building, represents only 2.6% (25.8 GJ) of the total PEI. Another important factor to highlight is the foundation in masonry and concrete that adds a value of (136.7 GJ) or 13.9% of the PEI; this value could be reduced with the use of the same recycled materials or the alternatives previously presented in the project chapter.



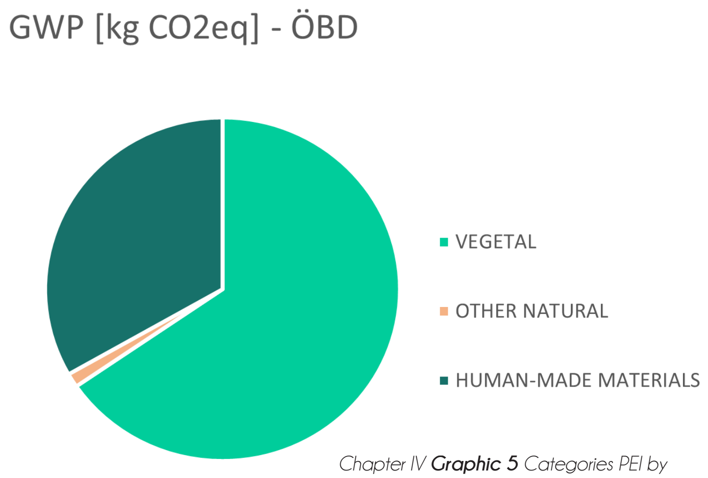
*Chapter IV **Graphic 4** GWP by ökobaudat*

The last element that I want to identify is zinc roof tiles, which are the material in the metals category with the highest PEI (0.78 GJ) since this could be reduced with the use of other materials such as straw, as was done in the Anandaloy center. However, the man-made elements add up to the largest PEI of the building.

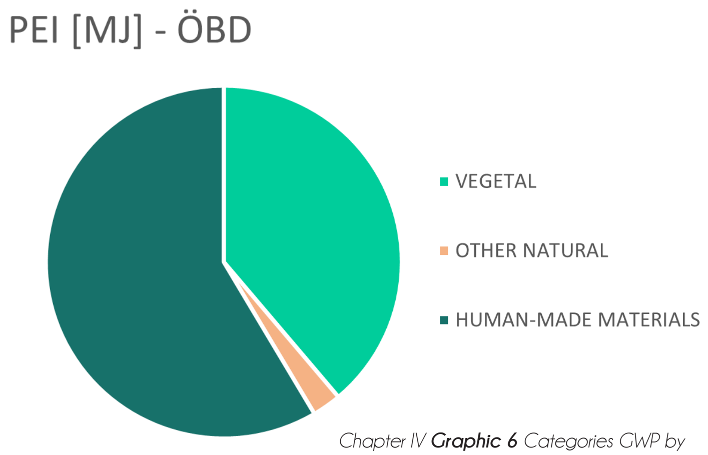
On the other hand, negative values are allowed for the calculation of the global warming potential. This means that the CO_2 capture of the plant building materials in their photosynthesis process is taken into account. due to the fact that the database is being updated, the value of biogenic carbon is not available for all materials. therefore, for bamboo and straw this value was hypothesized following the formula 1.8kg CO_2 sequestered per kg of dry plant material.

In the case of METI School, there are two negative values. The first is timber with (-3498.3 $KgCO_2eq$), and the second is the category of other vegetal with (-86600.73 $KgCO_2eq$), in this category, the values of bamboo and straw are added.On the other hand, the specific values for biogenic carbon are (-107799.07 $KgCO_2eq$) for other vegetal materials, with bamboo being the material with the highest CO_2 storage, followed by timber with (-3770.12 $KgCO_2eq$).

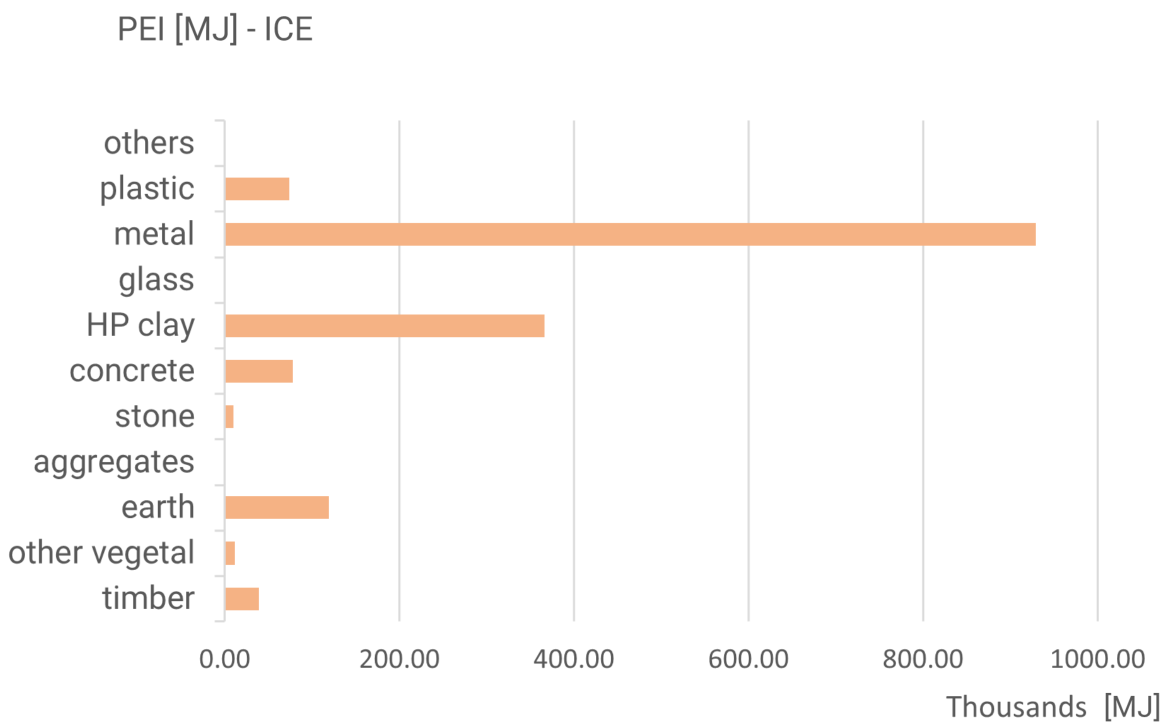
In contrast to these, the category with the highest value in the GWP is metallic elements with (22619.09 $KgCO_2eq$), followed by concrete with (9736.67 $KgCO_2eq$). The total GWP of the building is (-40644.43 $KgCO_2eq$), which gives a value of (-125 $KgCO_2eq/m^2$)



*Chapter IV **Graphic 5** Categories PEI by ökobaudat*



*Chapter IV **Graphic 6** Categories GWP by ökobaudat*



Chapter IV ***Graphic 7*** *PEI by ICE*

After calculating the values with the first ökobaudat database, I repeated the procedure with the ICE database to compare both values. In this case, it was necessary to use two versions of the database, 2.0 from 2011 and 3.0 from 2019.

This is because "since 2019 embodied energy factors are no longer included. The data in the wider literature, which the ICE database relies upon, generally no longer reports the embodied energy of construction products. Instead, embodied carbon has become the main metric. Carbon emissions give a better indicator of the contribution of that energy to global warming and climate change." (Embodied Carbon Footprint Database, n.d.)

The PEI results, in this case, are visibly higher than in the ökobaudat in half of the categories. In this case, the building yields a total PEI of 1626862.81 MJ, i.e. 1626.8 GJ, which concerning the project area would be 5 GJ/m2.

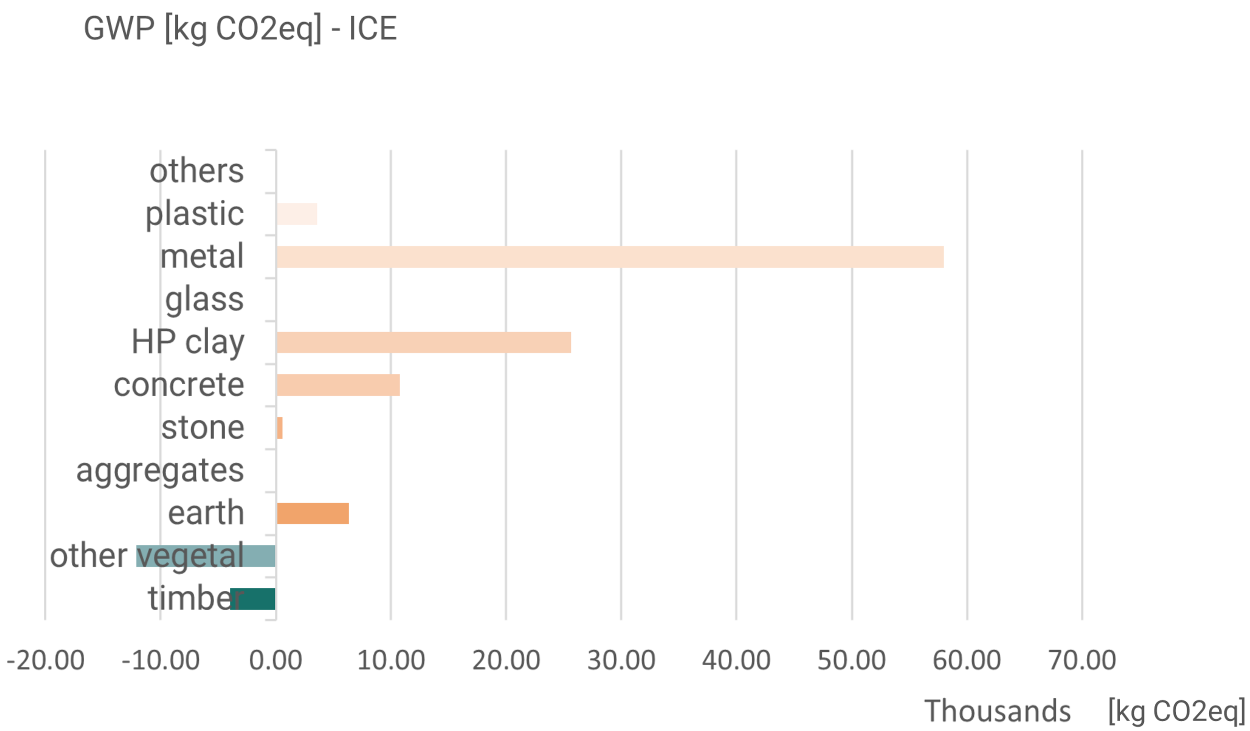
Among the values with the greatest difference, we can highlight metals where the value more than doubles with a value of (929.4 GJ) and represents 57% of the total, HP clay which quadruple compared to the previous calculation, being the second-highest percentage with 22.4% (366 GJ) and soil with (118.8 GJ) which represents 7.3%.

In the other categories that represent less than 5% each, we find the stone with (9.7 GJ), plastic with (74.2 GJ) and concrete with (78.2 GJ), this last one as in the previous case, always has relative low values in the PEI. On the other hand, among plant materials we find wood with (38.7 GJ) representing 2.3%; and other plant materials with straw and bamboo with (11.4 GJ).

For bamboo, I used the values from the Life Cycle Assessment and Carbon Sequestration, the Environmental Impact of Industrial Bamboo Products by P. van der Lugdt. As in the ökobaudat I took into account only the bamboo cut values because the bamboo used in the METI school is local and without apparent treatment. However, when comparing both values the ICE is significantly lower than the ökobaudat.

For the case of the Global Warming Potential GWP, the total value is (88749.70 $KgCO_2eq$) increasing 3 times more than the ökobaudat values, and presenting a positive value. this large increase may be since the information for certain materials is less specific.

The value that increases the most concerning in comparison with the previous values is surprisingly the earth with a value of (6340.1 $KgCO_2eq$), almost 3.5 times the ökobaudat value. The highest value is as usual metals with (58009.34 $KgCO_2eq$), followed by HP clay containing masonry with (25622.86 $KgCO_2eq$) and then concrete with (10748.24 $KgCO_2eq$).

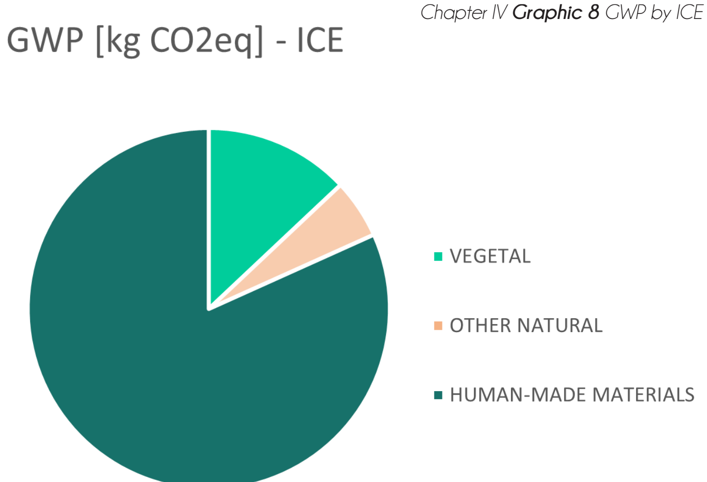


Chapter IV ***Graphic 8*** *GWP by ICE*

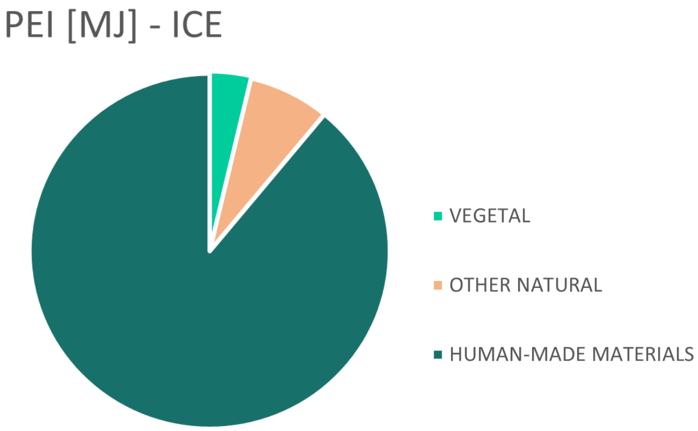
In this case, contrary to the ökobaudat, the value of HP clay is higher than that of concrete, although in both cases these materials used in the foundation are among the highest values.

The next category in the order would be the earth that I mentioned before, after this follows the values of plastic with (3581.7 $KgCO_2eq$) and stone with (580.48 $KgCO_2eq$), it may be strange that plastic has lower values than soil but taking into account the volume of the categories it makes sense.

As in the previous case, the ICE admits negative values for vegetal materials, but it does not specify how much is biogenic carbon and how much is fossil carbon. In contrast to the ökobaudat, the value for other vegetal materials is lower with (-12140.54 $KgCO_2eq$).



Chapter IV ***Graphic 9*** *Categories GWP by ICE*



Chapter IV ***Graphic 10*** *Categories PEI by ICE*

OKOBAUDAT

ELEMENT	number (n)	WEIGHT	Ref unit	PEI renewable	PEI non-renewable	PEI (TOT)	$GWP_{biogenic}$	GW
	[-]	[kg]	[-]	[MJ/unit]	[MJ/unit]	[MJ]	[kg CO2eq]	[kg (
Bamboo	623.00	47,845.97	kg	0.06	0.03	4,545.37	- 86,122.75	-
Bricks	3.00	122,013.61	1m4	215.00	1,130.00	88,707.19	-	
Concrete	1.00	104,351.87	1m4	201.20	926.00	48,010.38		
Earth	5.00	264,171.11	1m4	Various	Various	25,825.17		
Textile ceiling	1.00	26.40	1kg	24.47	11.80	957.53	-	-
Gravel ground floor pav	1.00	117,745.09	1kg	0.01	0.54	65,569.88	-	
Mortar	3.00	3,279.59	1m4	260.00	1,159.00	2,152.52		
Conduit pipe	73.00	10.71	1kg	5.74	50.60	603.18		
Plastic waterproofing membrane	1.00	350.59	1m2	7.26	89.98	18,732.11	-	
Rope	2750.00	342.77	1kg	13.94	196.70	72,200.25		
Steel	14238.00	5,708.75				352,687.11		
Straw	4.00	12,042.40	1m4	1,650.00	62.80	257,827.78	- 21,676.32	-
Wire	94.00	43.54	1m	0.22	1.09	229.23	-	
Wood	631.00	3,876.21				52,395.34	- 3,770.12	-
Zinc tiles	1.00	13,712.63	1m3	23.36	318.80	785.26	-	

ICE

ELEMENT	tot length (l*n)	area (l*w*n)	volume (l*w*h*n)	WEIGHT	Ref unit	PEI	GWP	PEI	GWP
	[m]	[m2]	[m3]	[kg]	[-]	[MJ/unit]	[kg CO2eq/unit]	[MJ]	[kg CO2e
Bamboo	-	VARIOUS	VARIOUS	47845.97	1kg	0.10	- 0.26	4,784.60	-
Bricks		149.51	65.95	122013.61	1kg	3.00	0.21	366,040.82	
Concrete		126.75	42.59	104351.87	1kg	0.75	0.10	78,263.90	
Earth		595.45	186.17	264171.11	1kg	0.45	0.02	118,877.00	
Textile ceiling	-	220.00	0.66	26.40	1kg	143.00	6.78	3,775.20	
Gravel ground floor pav	-	192.63	48.16	117745.09	1kg	0.08	0.00	9,772.84	
Mortar			1.52	3279.59	1kg	1.33	0.20	4,361.86	
Conduit pipe	73.00			10.71	1kg	67.50	3.19	722.70	
Plastic waterproofing membrane	-	192.63	0.19	350.59	1kg	89.30	3.23	31,307.38	
Rope	17852.40			342.77	1kg	138.60	7.92	47,507.38	
Steel	VARIOUS	VARIOUS	VARIOUS	5708.75	1kg	VARIOUS	VARIOUS	200,425.94	
Straw	VARIOUS	VARIOUS	150.53	12042.40	1kg	0.24	0.01	2,890.18	
Wire	175.56		175.56	43.54	1kg	36.00	2.27	1,567.40	
Wood		24.33	4.78	3876.21	1kg	10.00	- 1.03	38,762.09	-
Zinc tiles	-	459.00	2.30	13712.63	1kg	53.10	3.09	728,140.39	

P (TOT) CO2eq]	source
67,462.82	Process Data set: dasso Traditional Bamboo (en) (environdec.com)
7,452.72	Process Data set: Brick (unfilled) (en) (oekobaudat.de)
9,736.67	Process Data set: Ready-mix concrete C20/25; C20/25 (en) (oekobaudat.de)
1,740.48	Process Data set: Rammed earth wall; 2000 kg/m3 (en) (oekobaudat.de)
20.60	Process Data set: Cotton, conventional; 40 kg/m3 (en) (oekobaudat.de)
3,916.20	Process Data set: Gravel 2/32 dried; dried (en) (oekobaudat.de)
523.49	Process Data set: Cement mortar (en) (oekobaudat.de)
21.51	Process Data set: Cable duct PVC, rigid; PVC (en) (oekobaudat.de)
715.04	Process Data set: Butyl waterproofing membrane NovoProof® FAI (en) (oekobaudat.de)
3,653.89	Process Data set: Nylon part (PA 6.6) (en) (oekobaudat.de)
22,549.49	steel strip (en) (oekobaudat.de) Process Data set: Steel sheet (0.3-30mm); Steel sheet (0.3-3.0mm) - 1kg (en) (oekobaudat.de) Process Data set: Reinforcing steel (en) en Process Data set: Reinforcing steel in bars (en) en Process Data set: Window handle; 0,1 kg/part (en) (oekobaudat.de) Process Data set: Stainless steel screws; Stainless steel (en) (oekobaudat.de)
19,117.31	Prozess-Datensatz: FASBA e.V. GaBi Baustroh; 100 kg/m³ (de) (oekobaudat.de)
15.76	Process Data set: Cable 1-wire; 1 piece (en) (oekobaudat.de)
3,498.30	Process Data set: Window frame (spruce); 1,30 kg/m (en) (oekobaudat.de) Process Data set: Coniferous lumber - kiln dried (German average) (en) en de
61.21	Process Data set: Profiled sheets made of steel for roof, wall, deck and ceiling constructions (en) (oekobaudat.de)

Chapter IV ***Table 2*** *ökobaudat calculations*

eq]	source PEI	source GWP
12,439.95	Life Cycle Assessment and Carbon Sequestration, the Enviromental Impact of Industrial Bamboo Products P.van der Lugdt	
25,622.86	v2.0 [SUMMARY TABLE_Bricks_General (Common Brick)]	v3.0 [ICE Summary_Bricks_General (Common Brick)]
10,748.24	v2.0 [SUMMARY TABLE_Concrete_General]	v3.0 [ICE Summary_Concrete_General]
6,340.11	v2.0 [SUMMARY TABLE_Soil_General (Rammed Soil)]	v3.0 [ICE Summary_Soil_General (Rammed Soil)]
178.99	v2.0 [SUMMARY TABLE_Miscellaneous_Cotton, Fabric]	v3.0 [ICE Summary_Miscellaneous_Cotton, Fabric]
580.48	v2.0 [SUMMARY TABLE_Aggregate_General (Gravel or Crushed Rock)]	v3.0 [ICE Summary_Aggregates and sand_general, virgin mixture of land won and marine, bulk, loose]
655.92	v2.0 [SUMMARY TABLE_Cement_Mortar (1:3 cement:sand mix)]	v3.0 [ICE Summary_Cement and Mortar_Mortar (1:3 cement:sand mix)]
34.15	v2.0 [SUMMARY TABLE_Plastics_PVC Pipe]	v3.0 [ICE Summary_Plastics_PVC Pipe]
1,132.39	v2.0 [SUMMARY TABLE_Plastics_LDPE Film]	v3.0 [ICE Summary_Plastics_LDPE Film]
2,714.71	v2.0 [SUMMARY TABLE_Plastics_Nylon{polyamide}6,6 Polymer]	v3.0 [ICE Summary_Plastics_Nylon (Polyamide06,6 Polymer]
15,584.70	v2.0 [SUMMARY TABLE_Steel_General - UK(EU)_Virgin] v2.0 [SUMMARY TABLE_Steel_Plate - UK(EU)_Virgin] v2.0 [SUMMARY TABLE_Steel_Bar & rod - UK (EU)_Virgin]	v3.0 [ICE Summary_Steel_Steel,finished cold-rolled coil] v3.0 [ICE Summary_Steel_Steel,Plate]
120.42	v2.0 [SUMMARY TABLE_Miscellaneous_Staw]	v3.0 [ICE Summary_Miscellaneous_Straw]
98.83	v2.0 [SUMMARY TABLE_Steel_Wire - virgin]	v3.0 [ICE Summary_Steel_Steel, Wire rod]
3,992.50	v2.0 [SUMMARY TABLE_Timber_General]	v3.0 [ICE Summary_Timber_Timber-Average of all data-Including Carbon storage]
42,372.01	v2.0 [SUMMARY TABLE_Zinc_General]	v3.0 [ICE Summary_zinc_General]

Chapter IV ***Table 3*** *ICE calculations*

CALCULATIONS WITH RECYCLED ALTERNATIVES

Once the calculations have been completed with both databases, it is normal that in both cases the highest values are for the human-made materials. As I mentioned before some of these, or almost all of them could be replaced by other alternatives such as stone, cyclopean concrete or recycled concrete in the foundation, steel with recycled content for the metallic elements, straw instead of zinc roof tiles, or jute rope or other natural fibers instead of plastic rope.

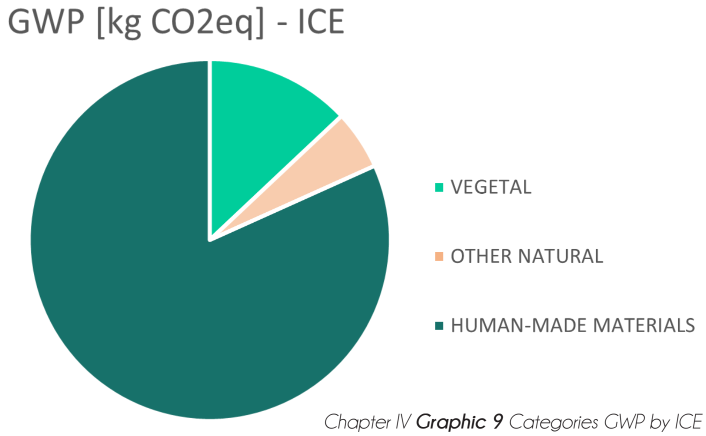
In this last part, I repeated the calculations with ICE because it gave me values for the same materials used for the previous calculation with recycled content, while Okobaudat gives only the value of the recycling potential. I replaced some values of the human-made materials with the same ones but recycled or with recycled content to see how much the environmental impact of the METI School could be reduced. Specifically, the items I changed were: Brick, concrete, rebar, nuts, and zinc roof tiles.

With these modifications for the ICE calculations, since there was no value for the recycled brick, I took the values for the limestone brick. In this case, there are no negative values, but there is also a significant reduction in the values. The total PEI goes from (1626862.81 GJ) to (732924.81 GJ) with a reduction of more than half of the previous value.

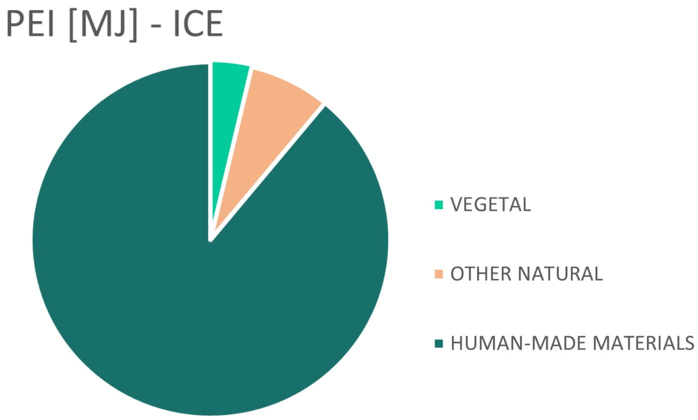
Concrete has a value of (57.3 GJ), Hp clay (103.7 GJ), and metals with (318 GJ), different from the previous ones, which were (78.2 GJ) for concrete , (366.GJ) for Hp clay, and (929 GJ) for metal.Thus, materials made by humans go from (1448 GJ) to (554 GJ) with a reduction of 61.7%. If values of alternative malterials and not recycled materials are taken into account, this value could decrease.

On the other hand, the GWP, in this case, had a smaller reduction than the PEI. The total value of the building goes from (88749.70 $KgCO_2eq$) to (49101.55 $KgCO_2eq$) with a 44.6% decrease. The value for concrete is (6782.87 $KgCO_2eq$), for Hp clay is (25622.86 $KgCO_2eq$) and for metals is (22326.56 $KgCO_2eq$). In general, man-made materials go from (97962.14 $KgCO_2eq$) to (58313.99 $KgCO_2eq$).

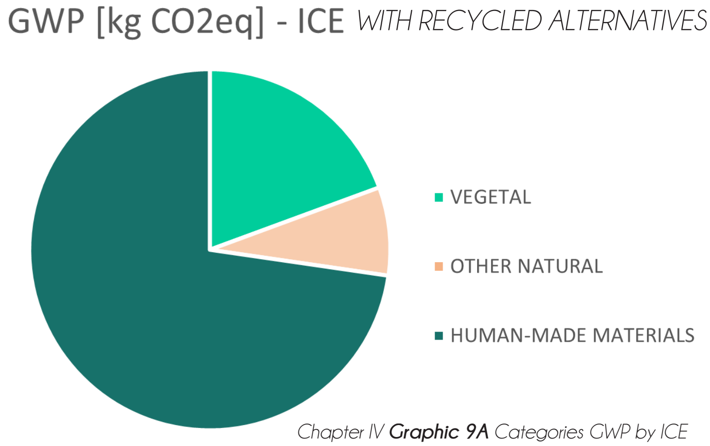
This means that using recycled materials would have reduced on average around 54% of the PEI and 44% of the GWP of the METI School.



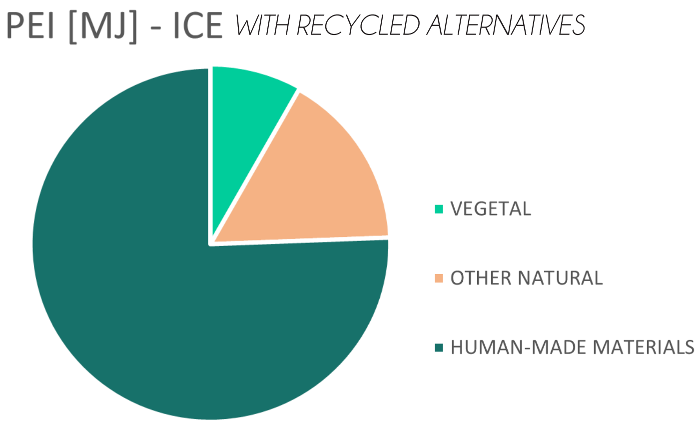
*Chapter IV **Graphic 9** Categories GWP by ICE*



*Chapter IV **Graphic 10** Categories PEI by ICE*



*Chapter IV **Graphic 9A** Categories GWP by ICE*



*Chapter IV **Graphic 10A** Categories PEI by ICE*

SUMMARY TABLE OF RESULTS

	Ökobaudat					ICE	
	WEIGHT	PEI non-renewable	PEI	GWPbiogenic	GWP (TOT)	PEI	GWP
	[kg]	[MJ]	[MJ]	[kg CO2eq]	[kg CO2eq]	[MJ]	[kg CO2eq]
timber	3876.21	3436.55	52395.34	-3770.12	-3498.30	38762.09	-3992.50
other vegetal	59914.77	11391.57	263330.68	-107799.07	-86600.73	11449.97	-12140.54
earth	264171.11	24865.94	25825.17	0.00	1740.48	118877.00	6340.11
aggregates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
stone	117745.09	282.01	65569.88	0.00	3916.20	9772.84	580.48
concrete	104351.87	39440.75	48010.38	0.00	9736.67	78263.90	10748.24
HP clay	122013.61	74527.23	88707.19	0.00	7452.72	366040.82	25622.86
glass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
metal	19444.55	292075.60	353594.42	0.00	22619.09	929400.92	58009.34
plastic	666.24	77895.11	83611.05	0.00	3989.44	74295.27	3581.70
others	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**692183.45**	**523914.75**	**981044.11**	**-111569.19**	**-40644.43**	**1626862.81**	**88749.70**
VEGETAL	181536.07	78704.83	381295.90	-111569.19	-86182.83	59984.91	-15552.55
total natural	445707.18	103570.77	407121.07		-84442.35	178861.91	-9212.44
OTHER NATURA	264171.11	24865.94	25825.17		1740.48	118877.00	6340.11
HUMAN-MADE	246476.27	420343.98	573923.04		43797.92	1448000.91	97962.14

Chapter IV ***Table 4*** *Summary table*

SUMMARY TABLE OF RESULTS
CALCULATIONS WITH RECYCLED ALTERNATIVES

	Ökobaudat					ICE	
	WEIGHT	PEI non-renewable	PEI	GWPbiogenic	GWP (TOT)	PEI	GWP
	[kg]	[MJ]	[MJ]	[kg CO2eq]	[kg CO2eq]	[MJ]	[kg CO2eq]
timber	3876.21	3436.55	52395.34	-3770.12	-3498.30	38762.09	-3992.50
other vegetal	59914.77	11391.57	263330.68	-107799.07	-86600.73	11449.97	-12140.54
earth	264171.11	24865.94	25825.17	0.00	1740.48	118877.00	6340.11
aggregates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
stone	117745.09	282.01	65569.88	0.00	3916.20	9772.84	580.48
concrete	104351.87	39440.75	48010.38	0.00	9736.67	57393.53	6782.87
HP clay	122013.61	74527.23	88707.19	0.00	7452.72	103711.56	25622.86
glass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
metal	19444.55	292075.60	353594.42	0.00	22619.09	318662.54	22326.56
plastic	666.24	77895.11	83611.05	0.00	3989.44	74295.27	3581.70
others	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**692183.45**	**523914.75**	**981044.11**	**-111569.19**	**-40644.43**	**732924.81**	**49101.55**
VEGETAL	181536.07	78704.83	381295.90	-111569.19	-86182.83	59984.91	-15552.55
total natural	445707.18	103570.77	407121.07		-84442.35	178861.91	-9212.44
OTHER NATURA	264171.11	24865.94	25825.17		1740.48	118877.00	6340.11
HUMAN-MADE	246476.27	420343.98	573923.04		43797.92	554062.90	58313.99

Chapter IV ***Table 5*** *Summary table (alternatives)*

#	NAME	GIA	WEIGHT		EE (ÖBD)			
		[m2]	tot [kg]	area [kg/m2]	tot [MJ]	area [MJ/m2]	weight [MJ/kg]	to
1	Hirose House	114	106,880	938	196,714	1,726	1.84	
1(r)		114	81,637	716	196,714	1,726	2.41	
2	Cheia	23	25,738	1,119	119,697	5,204	4.65	
2(r)		23	21,744	945	119,697	5,204	5.50	
3	Casa Steila Mar	572	911,500	1,594	2,098,102	3,668	2.30	1,0
3(r)		572	204,818	358	2,098,102	3,668	10.24	1,0
4	Sandberghof	411	469,598	1,143	1,522,870	3,705	3.24	1,1
4(r)		411	305,981	744	1,522,870	3,705	4.98	1,1
5	Villa Strohbunt	103	106,864	1,038	152,943	1,485	1.43	
6	Createrra	65	166,427	2,560	802,515	12,346	4.82	8
7	Gartist	125	343,872	2,751	2,870,826	22,967	8.35	1,4
8	Hemp cottage	76	129,560	1,700	575,343	7,550	4.44	4
9	Bamboo Ark	176	29,460	167	253,430	1,440	8.60	2
10	Biestøa	153	329,165	2,151	1,373,869	8,980	4.17	9
11	Food Hub	61	67,683	1,110	303,307	4,972	4.48	2
12	Wangeliner Garten	156	340,417	2,182	810,835	5,198	2.38	1,6
13	WISE	2,212	1,966,399	889	15,159,743	6,853	7.71	9,7
14	Maruyama-gumi	183	276,623	1,512	1,412,038	7,716	5.10	1,2
15	METI School	250	692,183	2,769	981,044	3,924	1.42	1,6

After finishing the calculations of the PEI and GWP of the building, and the calculations of the alternative materials that could be used to decrease the environmental impact of the building, I proceeded to the final phase of comparison, to contextualize the results and compare them with other projects that use vegetal or natural materials. For this comparison, I used the results of the buildings studied in Andrea Bocco's book Vegetarian architecture.

It should be noted that for the calculations of the other buildings only ICE version 2.0 was used, while for the METI School, as can be seen in [Table 3], both version 2.0 and 3.0, which admits negative values, were used, which is why the values between the databases have such a big difference.

To begin with, mentioning the two cross-sectional values of the results, it is worth noting that the METI school has a GIA of 250m2 less than the average, but a weight that almost doubles the average of 346 tons. This is probably due to the foundation and the thick earthen walls of the school. In [graph 11] where the materials are grouped by the three macro categories mentioned in all calculations (plant, other natural, and human-made materials), it can be seen that the METI School (15) has about 60% of natural materials being in a middle point between the extremes building (1) and (14).

The PEI value of the METI School according to its ökobaudat is about half (981 MJ) of the average (1714245 MJ). Its value per square meter [graph 17] is the fifth-lowest after buildings (1,1r, 5, and 9). It is curious to see how the METI School is one of the only buildings where the categories are somewhat proportionate. In the PEI by weight the METI School has the lowest value, as mentioned above may be due to its earth walls that have a high weight but a low impact.

On the other hand, the GWP of the building is a little below average compared to the other buildings as 13 of them have negative values generating an average

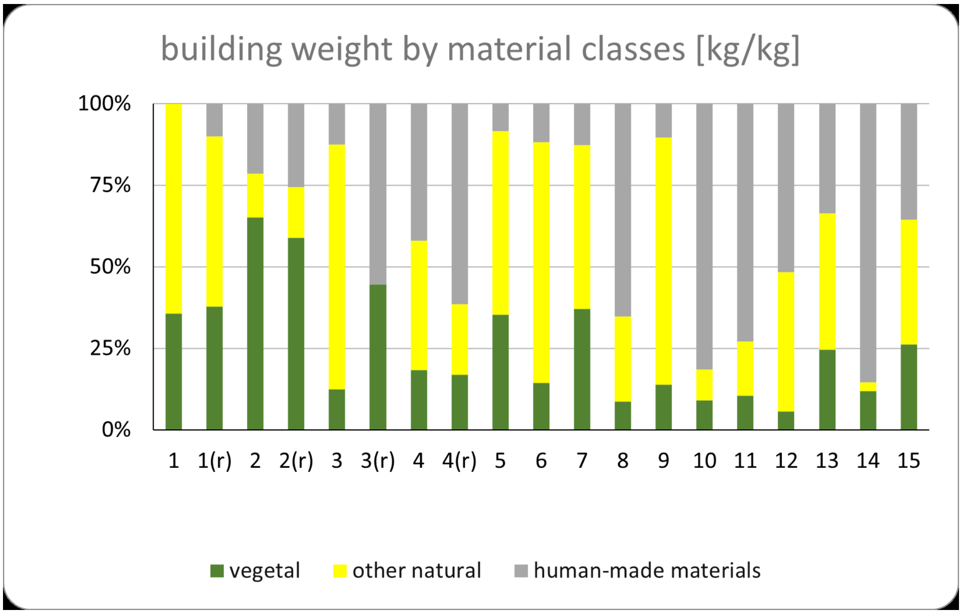
EE (ICE)			GWP (ÖBD)			GWP (ICE)		
ot [MJ]	area [MJ/m2]	weight [MJ/kg]	tot [kgCO2e]	area [kgCO2eq/m2]	weight [kgCO2eq/kg]	tot [kgCO2e]	area [kgCO2eq/m2]	weight [kgCO2eq/kg]
46,891	411	0.44	-19,535	-171	-0.18	2,804	25	0.03
46,891	411	0.57	-19,535	-171	-0.24	2,804	25	0.03
41,458	1,803	1.61	-12,665	-551	-0.49	6,055	263	0.24
41,458	1,803	1.91	-12,665	-551	-0.58	6,055	263	0.28
017,282	1,778	1.12	-104,428	-183	-0.11	71,055	124	0.08
017,282	1,778	4.97	-104,428	-183	-0.51	71,055	124	0.35
129,233	2,748	2.40	-34,911	-85	-0.07	78,847	192	0.17
129,233	2,748	3.69	-34,911	-85	-0.11	78,847	192	0.26
43,035	418	0.40	-47,906	-465	-0.45	22,360	217	0.21
370,105	13,386	5.23	-14,701	-226	-0.09	43,971	676	0.26
462,162	11,697	4.25	-130,775	-1,046	-0.38	110,330	883	0.32
455,543	5,978	3.52	15,990	210	0.12	34,003	446	0.26
253,430	1,440	8.60	4,845	28	0.16	12,223	69	0.41
968,785	6,332	2.94	25,165	164	0.08	66,277	433	0.20
265,489	4,352	3.92	3,604	59	0.05	19,844	325	0.29
545,879	10,551	4.83	8,665	56	0.03	103,322	662	0.30
732,250	4,400	4.95	-178,197	-81	-0.09	687,557	311	0.35
205,822	6,589	4.36	9,941	54	0.04	96,973	530	0.35
526,863	6,507	2.35	-40,644	-163	-0.06	88,750	355	0.13

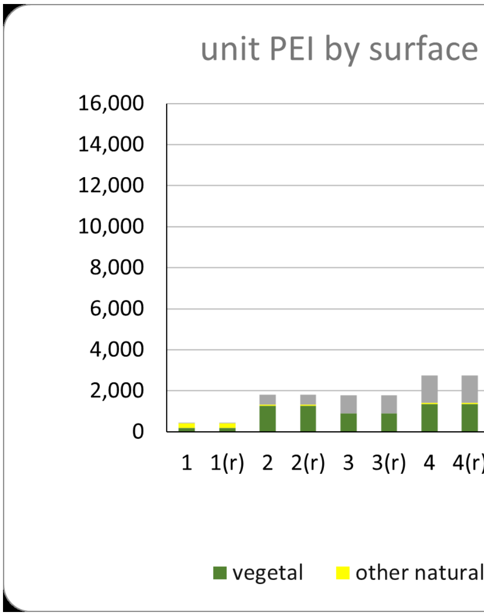
Chapter IV ***Table 6*** *Summary table (comparison)*

of (-36163 $KgCO_2eq$) of which the METI School is below with (-40644 $KgCO_2eq$), the fifth lowest of the entire table . In the analysis per square meter, although the values are still negative the graph changes a little. As can be seen in [graph 19] the METI School turns to the 10th lowest position after the buildings (1-3 and 5-7) that decrease their numbers due to their smaller area. Finally, in the analysis by weight, although METI School maintains a negative value, it continues to increase in value, being much closer to the 0 line.

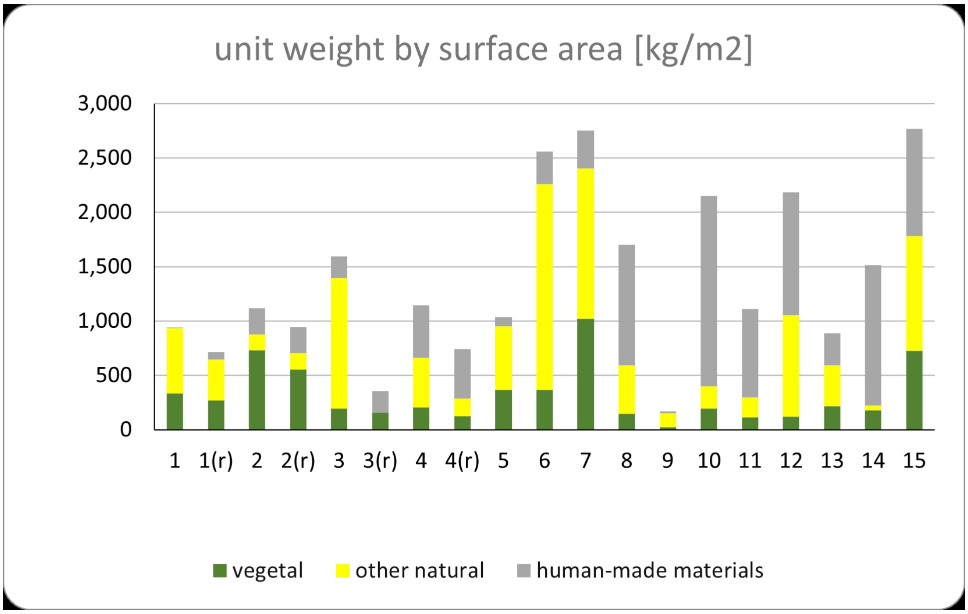
On the other hand, in the calculations with the ICE, the METI School still closer to the average values. The PEI is the fourth highest with 1626863 MJ in an average of 1210478 MJ. [graph 13] shows the PEI per m2 in the METI school is the fifth highest after the buildings (6, 7, 12 and 14), and the category of man-made materials is one of the highest in the buildings. On the other hand, the ICE by weight always favors the METI School dropping to 13th place.

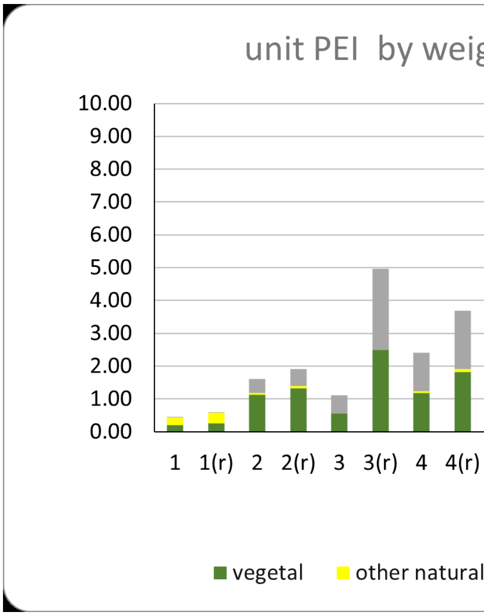
Finally, the GWP with the ICE yields a value of (88750 $KgCO_2eq$) which is slightly above the overall average of (84,375 $KgCO_2eq$). In the case of GWP by area [graph 15], METI is the seventh building with the highest value, in this case, almost the entire column represents materials made by humans. However, it should be taken into account that this value could vary if the values allowed carbon sequestration of plant materials in the other buildings. On the other hand in the GWP by weight [graph 16] the METI school has the fourth lowest value after the buildings (1, 1r, and 3), the first ones being the lowest values along all the graphs.



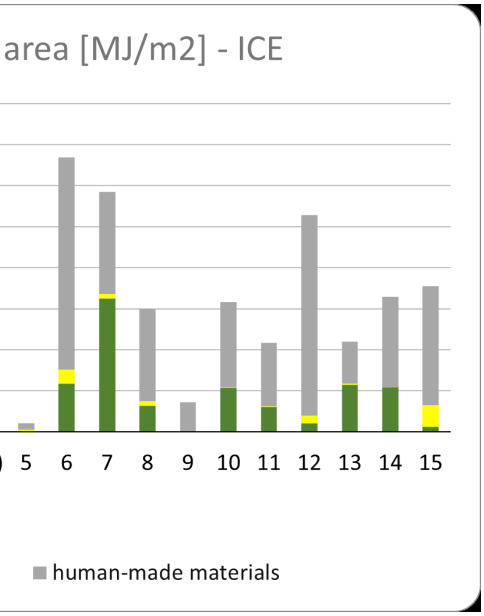


Chapter IV ***Graphic 11*** *Case study comparison building weight by material classes*

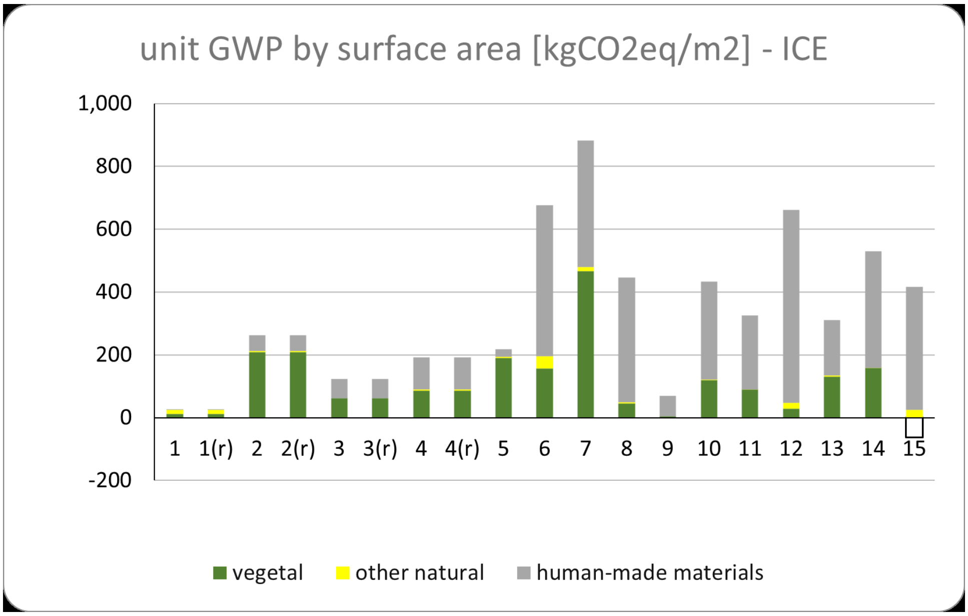




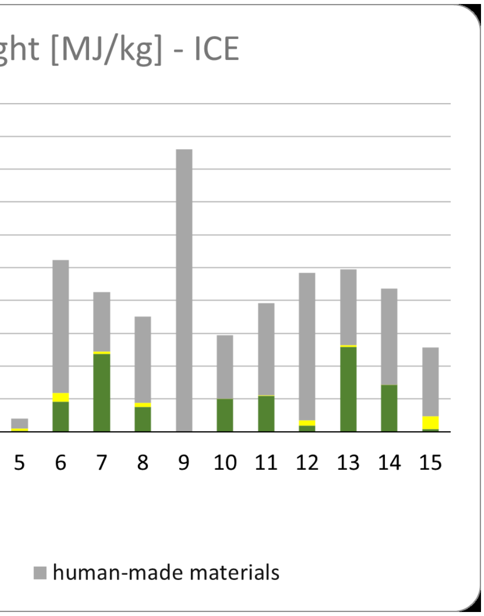
Chapter IV ***Graphic 12*** *Case study comparison unit weight by surface area*



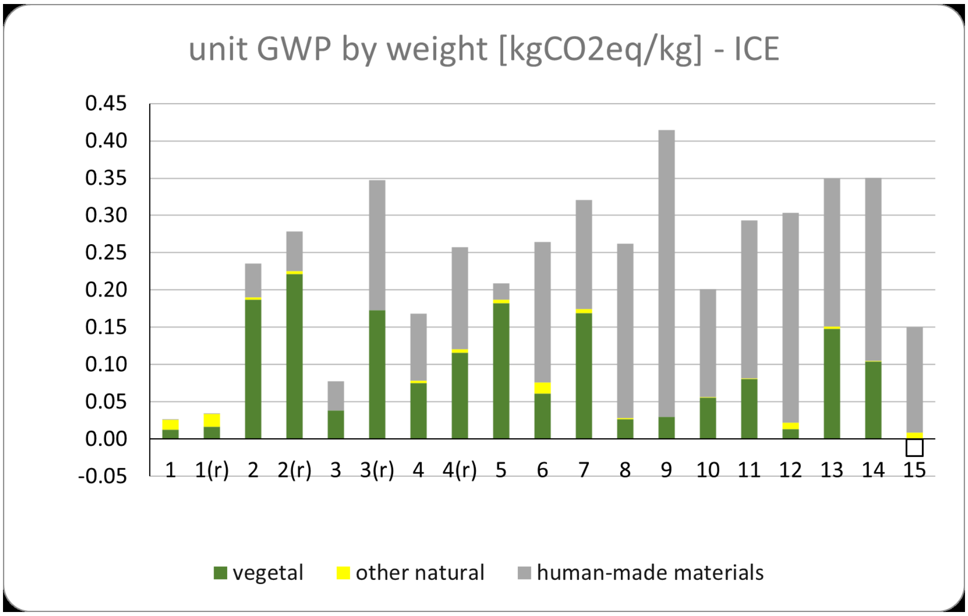
Chapter IV ***Graphic 13*** *Case study comparison unit PEI by surface area by ICE*



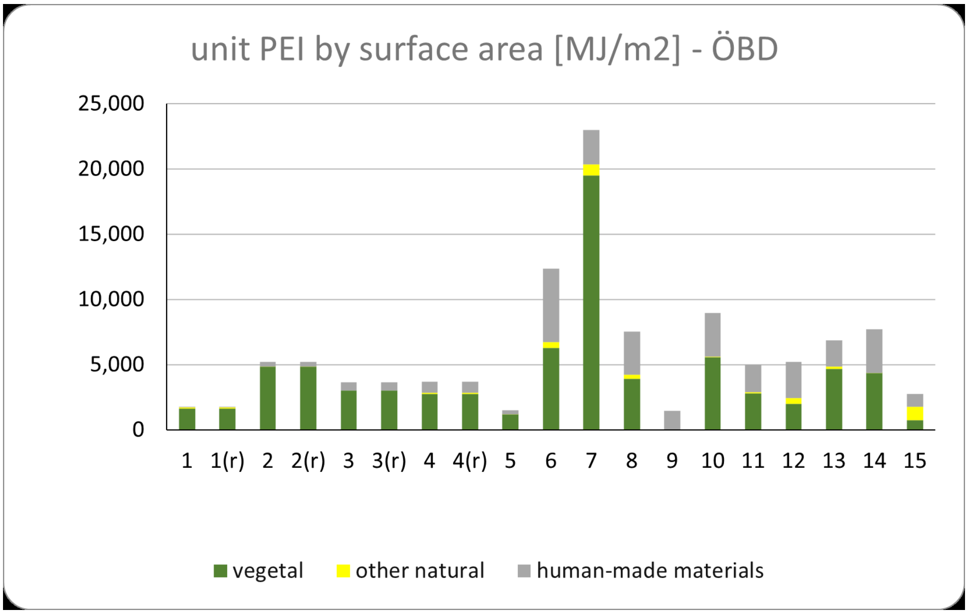
Chapter IV ***Graphic 15*** *Case study comparison unit GWP by surface area by ICE*



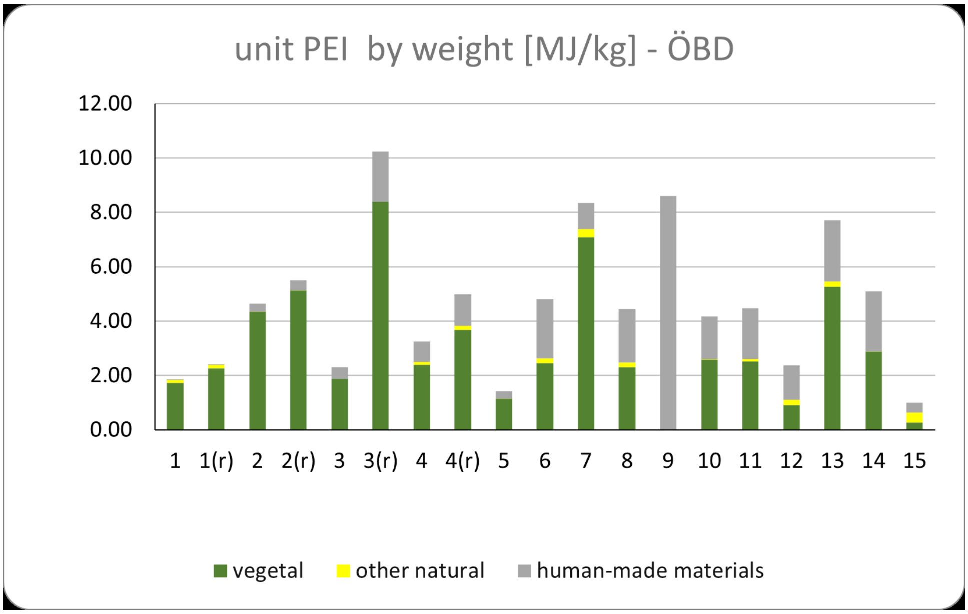
Chapter IV ***Graphic 14*** *Case study comparison unit PEI by weight by ICE*



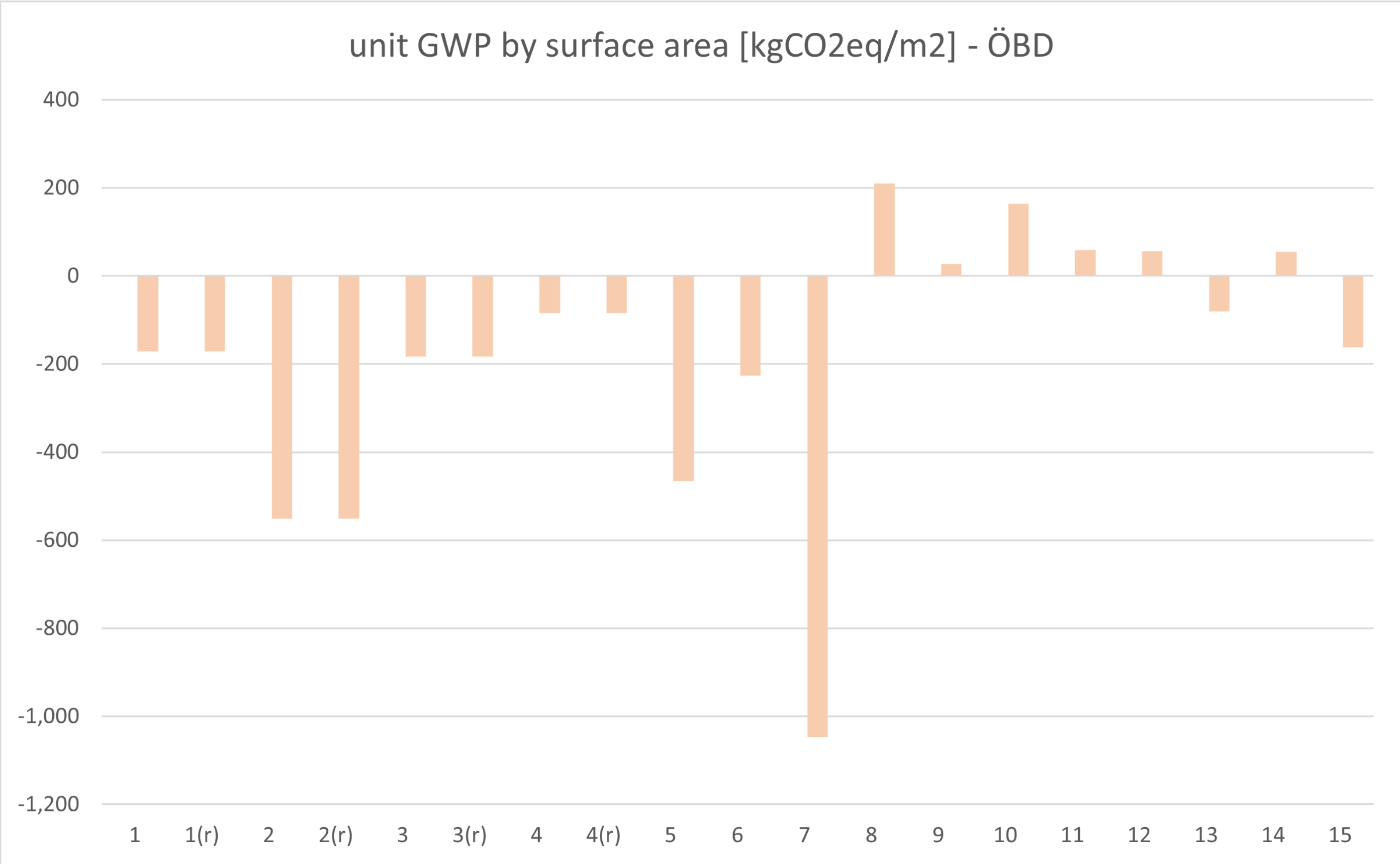
Chapter IV ***Graphic 16*** *Case study comparison unit GWP by weight by ICE*



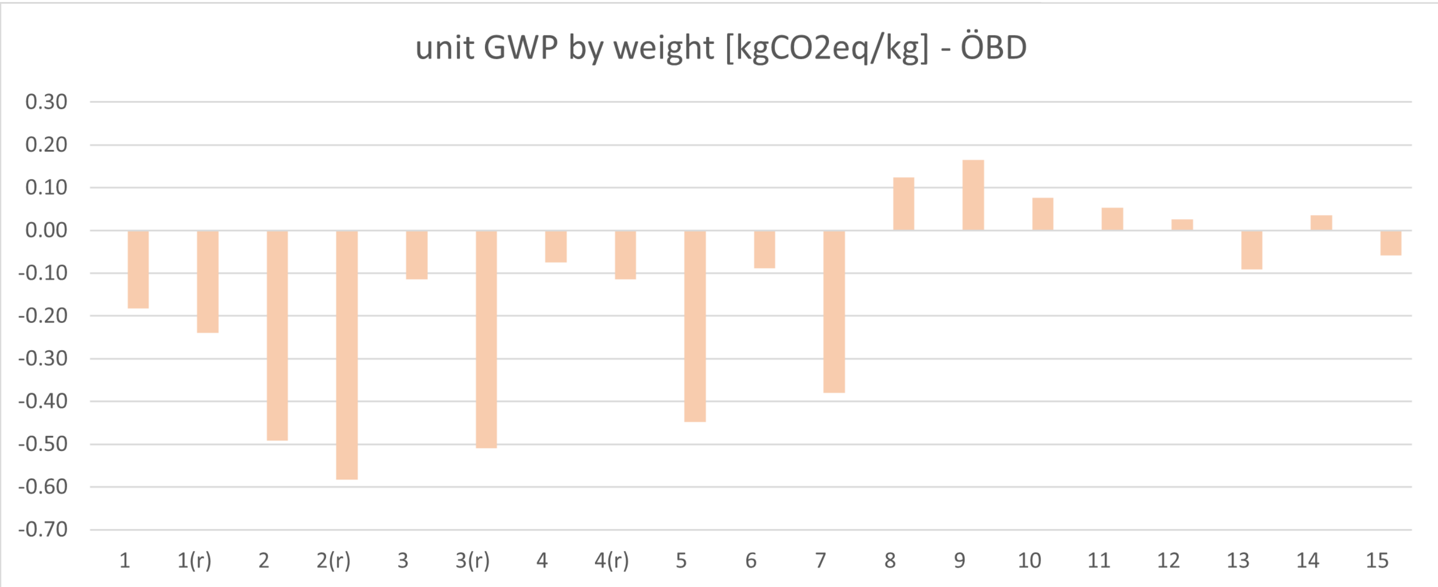
Chapter IV **Graphic 17** Case study comparison
unit PEI by surface area by ökobaudat



Chapter IV **Graphic 18** Case study comparison
unit PEI by weight by ökobaudat



Chapter IV ***Graphic 19*** *Case study comparison unit GWP by surface area by ökobaudat*



Chapter IV ***Graphic 20*** *Case study comparison unit GWP by weight by ökobaudat*

Natural materials have proven throughout history to be quite durable and in today's quest for sustainability have shown to be better than industrialized elements. Despite this, the lack of standardization of materials such as earth or bamboo hinders their implementation in the construction sector. In addition to this, the lack of legislation and regulations for the use of these materials in many countries makes it difficult for architects to design with them.

However, there are regulations in areas of high seismic activity for the use of these materials, such as Title G of the 2010 Seismic Resistance Standard in Colombia (NSR10), the E080 Standard for design and construction with reinforced earth in Peru, last updated in 2017, or the UNDP (United Nations Development Programme) guidelines on technologies for poverty eradication, which serve as a solid basis to enable the use of these materials around the world.

Another challenge facing the use of these materials, especially earth, as a building material is the widespread conception of misery associated with it. Work must be done to eliminate the stigma of poverty and non-durability associated with materials such as earth and bamboo, as architect Anna Heringer attempts to do in her lectures and the Laufen Manifesto.

In the specific case of the METI school, the premise of transmitting the technical knowledge to the people of the community so that it could be implemented in later constructions without the need of the architect remained halfway. Although thanks to the photographic record of the timeline it can be concluded that the community-made repairs in 2018 thus showing the understanding of the building and its construction techniques, the general thought of the community according to (Lim, 2007), is that without the resources provided by the architect it is difficult to replicate a work of the genre.

The last chapter of this thesis is dedicated to the study of the environmental impact of the METI School. I must say that one of the most important aspects of this analysis lies in the proper quantification of the materials implemented in the construction. However, since it was not possible to obtain information from the architect and the inaccessibility of the site, the information reported in the inventory was subtracted from images and videos. A metric computation would have facilitated the work of associating the value of the eco-indicators to the materials and would surely have had more accurate results.

In general terms, the highest PEI and GWP values for METI School are found for the categories of human-made materials. Among these, metals are the highest, followed by HP clay and concrete, both of which are used in foundations. As mentioned in the fifth chapter these materials that have the highest environmental impact on the building could be replaced by recycled materials reducing the environmental impact by 54% for PEI and 44% for GWP. Possibly alternatives with natural materials such as stone in the foundation or straw in the roof could reduce the values even more.

In terms of comparison with other case studies, the proportion of use of natural materials and human-made materials is on average. It could be thought that the foundation may be a common point where buildings use materials with higher environmental impact such as concrete or masonry. On the other hand, the METI School has one of the highest weights per square meter which gives it an advantage in the analyses where the reference value is the weight, leaving it in the average in the calculations of PEI and GWP with ICE; and below the average in the calculations with the ökobaudat.

On the other hand, the GWP with ökobaudat is the only value that, taking weight as a reference makes the METI School obtains the lowest value among the buildings with negative values, however this is still a good result.

In the calculations of PEI and GWP per square meter by ICE, METI obtains higher values, being the fifth building with the highest environmental impact among the 19 cases studied. The GWP per m2 of floor area ökobaudat follows the trend and leaves METI School with the fourth place number of the negative values, it should be noted that there are 6 buildings with positive values, i.e. higher gwp.

Finally, the average PEI and GWP values for the METI School are 1303953 MJ and 24053 kg CO_2eq respectively. It remains to mention that it would be useful to have a general reference value or a European classification in which it is possible to better compare the impact of the building, not only with buildings that seek to implement sustainable materials but also with generic buildings to show how much the impact of construction with materials such as earth and bamboo can be reduced.

BIBLIOGRAPHY

2007 Award Cycle Hand-Made School [Report]. - Rudrapur, Bangladesh : 2007 Award Cycle, 2007.

Aedo Wilfredo Carazas Adobe Guía de construcción parasísmica [Report]. - Villefontaine Cedex : CRATerre, 2002.

Ashby Michael F. Materials and the environment Eco-Informed Material Choice [Book]. - Oxford : Butterworth-Heinemann, 2012. - Vol. Secod edition.

Bangladesh Bureau of stadistics Education Household Survey 2014 [Report]. - Dhaka : Statistics and Informatics Division, Ministry of planning , 2015.

Benjamin David Embodied energy and design Making architecture between metrics and narratives [Book]. - New York, Zurich : Columbia University GSAPP - Lars Muller publishers , 2017. - Vol. 1.

Heringer Anna "Architecture is a tool to improve lives." [Interview]. - Laufen : Luca De Giorgi, march 17, 2020.

Heringer Anna Aga Khan Program Lecture: "Architecture is a Tool to Improve Lives" [Performance]. - Cambridge : Harvard GSD, 2018.

Heringer Anna Handmade architecture as a catalyst for development [Performance]. - [s.l.] : UN-Habitat worldwide, 2014.

Heringer Anna Talking Practice [Interview]. - Cambridge : Harvard Graduate School of Design, October 30, 2018.

Kapfinger Otto and Sauer Marko Martin Rauch refined construction & design with rammed earth [Book]. - [s.l.] : Detail, 2015.

Malthus Thomas Principles of political economy [Conference]. - 1798.

Ministerio de Ambiente Vivienda y Desarrollo Territorial NSR10 Reglamento colombiano de construcción sismo resistente [Case]. - Bogotá, Colombia : República de Colombia, 2010.

Ministerio de vivienda construcción y saneamiento NORMA E.080 Diseño y construcción con tierra reforzada, Resolución ministerial N° 121-2017-Viviendo [Case]. - Lima, Perú : Repúbica de Perú , 2017.

Minke Gernot Building with Bamboo : Design and Technology of a Sustainable Architecture [Book]. - Germany : Birkhäuser Basel, 2016.

Minke Gernot Building with Earth: Design and Technology of a Sustainable Architectura [Book]. - Basel - Boston - Berlin : Birkhäuser, 2009.

Morel JC and Charef R What are the barriers affecting the use of earth as a modern construction material in the context od circular economy? [Conference] // Earth and Environmental science . - United Kingdom : IOP Conference Series , 2019. - p. 225.

Rashid Haroun Er Geography of Bangladesh [Book]. - New York : 1st published by Westview Press, Inc. 2nd published by Routledge, 1977 - 2018.

Schroeder Horst The New DIN Standards in Earth Building - The current Situation in Germany [Journal] // Journal of Civil Engineering and Architecture . - 12(2018). - pp. 113-120.

Lim, J. C. (2007). Hand-Made School - Rudrapur, Bangladesh 3392.BAN 2007 Award Cycle. Retrieved June 14, 2022, from https://www.akdn.org/sites/akdn/files/media/documents/akaa_press_kits/2007_akaa/school_in_rudrapur_-_bangladesh.pdf

Ángel, Clara y Garzón, Lucía (2017). Aplicación de la guadua para la construcción de cubiertas con tierra, basadas en el "domocaña". Revista Nodo, 12(23), 49-61

SITEOGRAPHY

Embodied Carbon Footprint Database. (n.d.). Circular Ecology.
Retrieved July 5, 2022, from https://circularecology.com/embodied-carbon-footprint-database.html

InData. (n.d.). InData. Retrieved July 5, 2022, from https://www.indata.network/

ÖKOBAUDAT. (n.d.). ÖKOBAUDAT. Retrieved July 5, 2022, from http://oekobaudat.de
Elsevier Science.

Harvard University Graduate School of Design. (2011, December 12). Loeb Fellow Anna Heringer elected as International Fellow by Royal Institute of British **Architects. Harvard Graduate School of Design.** Retrieved April 30, 2022, from https://www.gsd.harvard.edu/2011/12/loeb-fellow-anna-heringer-elected-as-international-fellow-by/

Heringer, A. (2016). Architecture: Bamboo Hostels, China. Anna Heringer. Retrieved April 30, 2022, from https://www.anna-heringer.com/projects/bamboo-hostels-china/

Heringer, A., Lepik, A., Klumpner, H., Rich, P., Ramstad, L., Schmal, P., Bäppler, A., Caravatti, E., Steiner, D., Werthmann, C., Rauch, M., Gauzin-Müller, D., Sandman, H., Vianello, E., Mehrotra, R., Restrepo, A., Hofman, S., Ngo, A.-L., Fernandez Galliano, L., & Echeverri, A. (2013, November 19). Laufen Manifesto for a Humane Design Culture. ar.tum.de. Retrieved May 7, 2022, from https://www.ar.tum.de/fileadmin/w00bfl/www/02_Aktuell/01_Meldungen/2013/Laufen_Manifesto.pdf

James, W., Moses, N., Heringer, A., & Chilkoti, A. (2012). Architecture: News. Anna Heringer. Retrieved April 30, 2022, from https://www.anna-heringer.com/news/news-start/

METI school handmade in Bangladesh. (n.d.). Handmade School in Bangladesh. Retrieved June 14, 2022, from http://www.meti-school.de/daten/bericht_lehm_e.htm

METI school handmade in Bangladesh. (n.d.). Handmade School in Bangladesh. Retrieved June 14, 2022, from http://www.meti-school.de/daten/bericht_lehmbau_e.htm

METI school handmade in Bangladesh. (Third layer / Meti-kids on site). Handmade School in Bangladesh. Third layer / Meti-kids on site. Retrieved June 14, 2022, from http://www.meti-school.de/daten/bericht_lehm_3l_e.htm

METI school handmade in Bangladesh. (Interior). Handmade School in Bangladesh. Interior. Retrieved June 14, 2022, from http://www.meti-school.de/daten/bericht_ausbau_e.htm

METI school handmade in Bangladesh. (Weller-loam / Bamboo Preparation). Handmade School in Bangladesh. Weller-loam / Bamboo Preparation. Retrieved June 14, 2022, from http://www.meti-school.de/daten/bericht_baubeginn_2_e.htm

B E T I K - Polapain. "Dipshikha Meti School | **দীপশিখা, মাটির তৈরি স্কুল** | Vlog 6 | Biral, Dinajpur | Betik Polapain." Youtube, https://www.youtube.com/watch?v=2kaS0blrS_s&t=29s. Accessed 1 August 2022.

Discover Beautiful Bangladesh. "Best architect Dipshikha Meti Schoo ||**দীপশিখা স্কুল**, AGA KHAN AWARD, Anna Heringer." YouTube, 22 August 2020, https://www.youtube.com/watch?v=YMnNSL9Xgec. Accessed 1 August 2022.

Fardin Travel Vlogs. "Dipshikha Meti School Vlog Plus MORE | Fardin Travel Vlogs 2021|." YouTube, 25 March 2021, https://www.youtube.com/watch?v=y-ihE-ODTsxE. Accessed 1 August 2022.

Google earth. "Dipshikha Meti School | **দীপশিখা মেটি বিদ্যালয়.**" Cambridge Dictionary | English Dictionary, Translations & Thesaurus, https://earth.google.com/web/@25.75687887,88.55335526,43.69970119a,673.9035814d,35y,12.01292489h,0t,0.00000119r/data=CmEaXxJZCiUweDM5ZTRiNmFjMTI1NmQw-ZWY6MHg2ZmE1NWYyNTFjMmZiNWMyKjBEaXBzaGlraGEgTWV0aQpTY2hvb2wgfCDgpqbgp4Dgpqrgprbgpr_gppbgpr7igKYYAyAB. Accessed 1 August 2022.

Google maps. "Dipshikha Meti School | **দীপশিখা মেটি বিদ্যালয়.**" Cambridge Dictionary | English Dictionary, Translations & Thesaurus, https://www.google.it/maps/place/Dipshikha+Meti+School+%7C+%E0%A6%A6%E0%A7%80%E0%A6%AA%E0%A6%B6%E0%A6%BF%E0%A6%96%E0%A6%BE+%E0%A6%AE%E0%A7%87%E0%A6%9F%E0%A7%80+%E0%A6%AC%E0%A6%BF%E0%A6%A6%E0%A7%8D%E0%A6%AF%E0%A6%BE%E0%A6%B2%E0%A7%9F/@25.757172,88.5527213,3. Accessed 1 August 2022.

Research of Freedom. "Dipshikha Meti School Biral , Dinajpur | **দীপশিখা মেটি বিদ্যালয় বিরল, দিনাজপুর | মাটির দ্বিতলা স্কুল.**" Youtube, https://www.youtube.com/watch?v=Q46GzV-ALs0&t=2s. Accessed 1 August 2022.

SailoRider. "দীপশিখা মেটি স্কুল | Dipsikha METI Handmade School | Dinajpur | Bangladesh | SailoRider." Youtube, https://www.youtube.com/watch?v=LZy2rkBt-neY&t=274s. Accessed 1 August 2022.

SETU EXPRESS. "METI SCHOOL (**দীপশিখা মেটি স্কুল**)." Youtube, https://www.youtube.com/watch?v=p_FnCOvwdxY&t=2s. Accessed 1 August 2022.

Primero que nada quiero dar gracias a Dios por permitirme vivir esta experiencia que me ha hecho crecer, no solo en el ámbito académico y profesional, sino también como persona.

Quiero agradecer a mi director de tesis. El profesor Bocco, por su disposición y guía a lo largo de este año de trabajo, en el que con su ayuda pude profundizar y ampliar mi conocimiento sobre el tema que más me apasiona en la arquitectura.

A mi familia, para quienes no me alcanzan las palabras de agradecimiento por todo lo que me han dado. Gracias por su apoyo, por su amor, por sus enseñanzas, por su compañía, por preocuparse siempre por mi, por acompañarme a llevar las entregas a las 5 am, por la ayudarme a pegar maquetas y cortar terrenos desde el primer semestre, pero más que nada por alentarme siempre a cumplir mis metas.

Gracias a mis amigos, que a lo largo de este proceso se han vuelto una familia en este lado del mundo, por los viajes, por las risas, por los spritz y por su hermosa energía.

Por último, quiero agradecer a esta bellissima cita, Torino, que me ha dado tantos recuerdos, que me ha hecho sentir como en casa, que me ha permitido conocer una cultura maravillosa llena de personas increíbles como Simone a quien le agradezco infinitamente por su apoyo, su amor y su paciencia.

Se que seguramente me quedo corta con las palabras para expresar lo complacida que estoy. Solo me queda decirles nuevamente a todos, gracias.