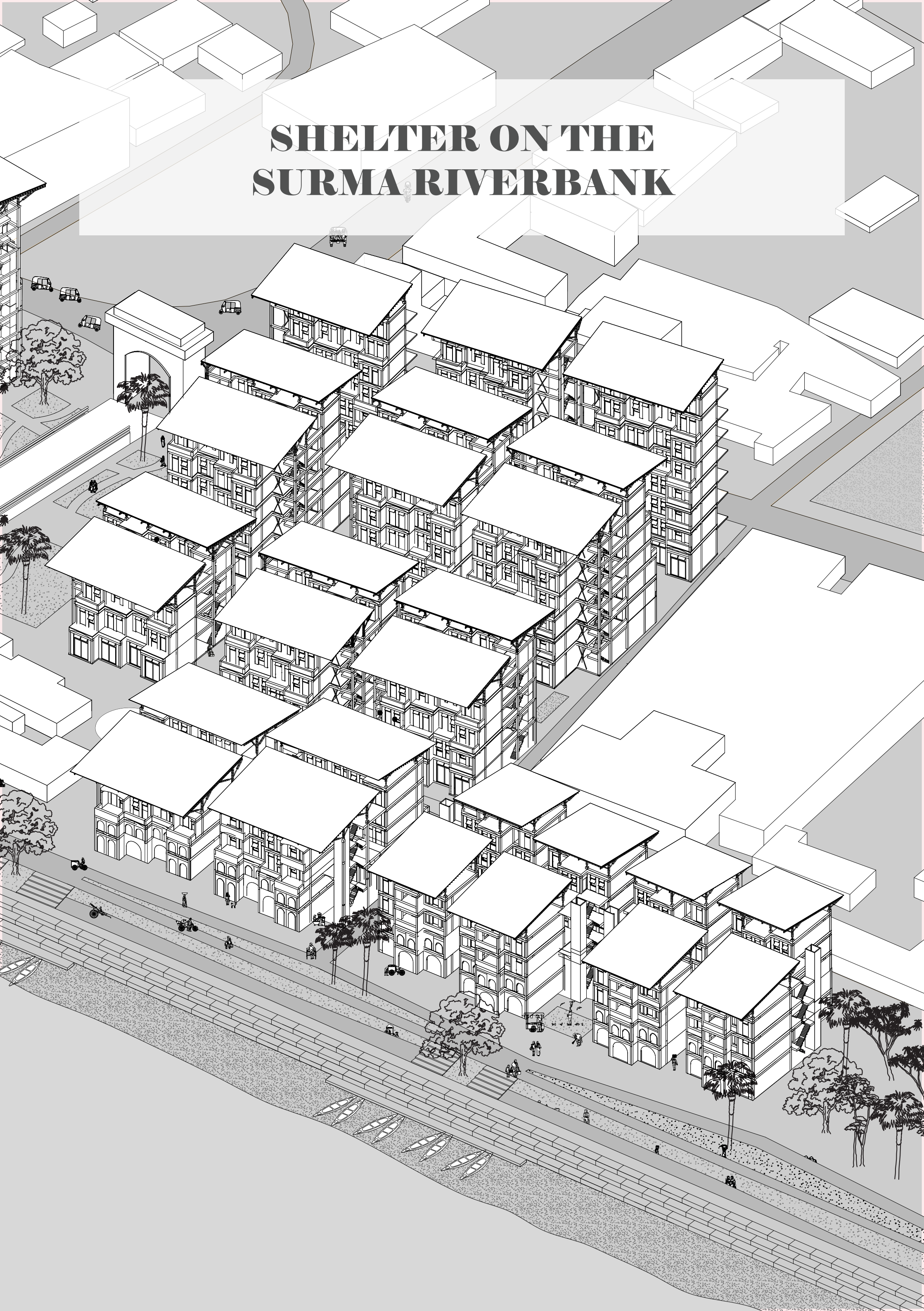
SHELTER ON THE SURMA RIVERBANK



SHELTER ON THE SURMA RIVERBANK

Sylhet, Bangladesh

Mascha Gerrits

Supervisors: Nelson Mota, Ludovica Cassina, Antonio Paoletti
and Marina Tabassum

1. Design on the Surma Riverbank. Source: Author, 2025

Colophon

Shelter On The Surma Riverbank, Sylhet

Research question:
How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished Hindu and Muslim communities living on the erosion-prone Surma riverbank in Sylhet?

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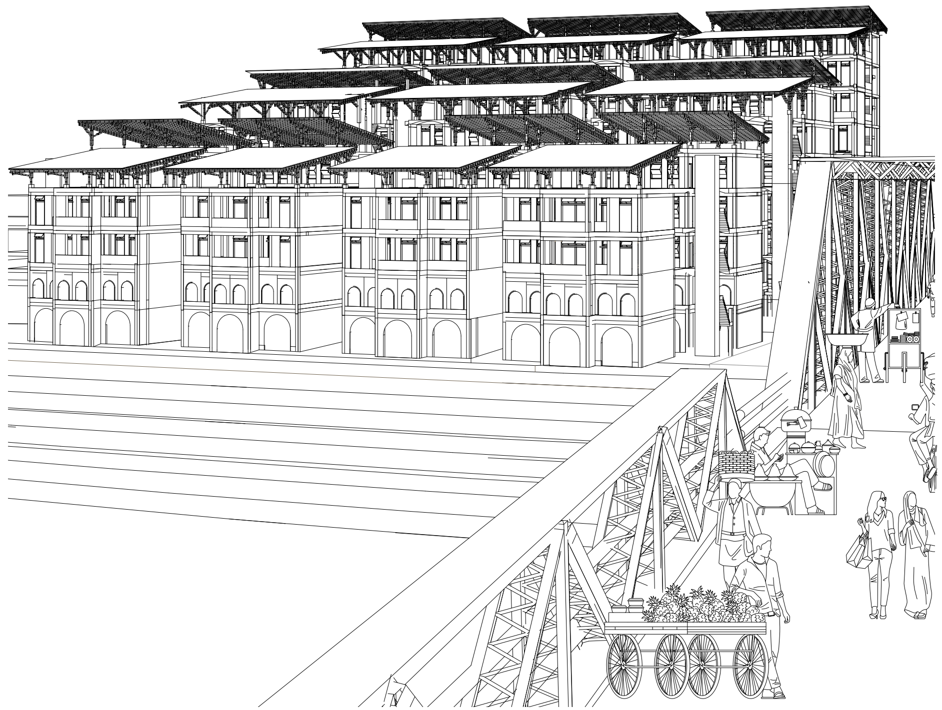
Key words – Environmental driven migration, High-Density Housing, Seasonal Adaptability, Impoverished Communities, Sweepers Colony, Sylhet, Surma Riverbank



2. New development on the Surma riverbank. Source: Author, 2025

Abstract

Bangladesh is one of the most densely populated urban areas globally. Due to environmental, social, political, demographic and economic migration drivers still half a million individuals are migrating to the urban areas annually. In this research the combination of seasonal adaptable housing, affordable housing and high-density housing are investigated to reduce impoverished people from moving to other areas. This research is conducted on the Surma Riverbank, because while certain hazard-prone regions receive considerable assistance from the government, erosion-prone areas, such as riverbanks, are often neglected.

Furthermore, the impoverished population living on the riverbanks of Bangladesh faces significant challenges due land loss caused by erosion, which has left many without secure housing.

This research aims to investigate the question: “How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished Hindu and Muslim communities living on the erosion-prone Surma riverbank in Sylhet?” The methodologies, fieldwork and case studies are used to address this issue and implemented in an Architectural Design.

Content

1. Introduction

In 2023 Bangladesh counted 173 million inhabitants, which makes it one of the most dense countries of the world with the most dense urban areas globally. Still every year half a million individuals migrate to the urban areas within their country (Martin et al., 2013). The article “Climate Change and Migration in Bangladesh” identifies five drivers for this migration, namely economic, environmental, social, demographic and political drivers (Martin et al., 2013). Many Bengali migrants are moving from rural to urban areas to find a job that comes with a better salary.

An increasing factor contributing to mass migration are the environmental drivers. Bangladesh is one of the most climate change affected countries in the world. The environmentally driven mass migration is mainly taking place in the areas most affected by climate-related hazards, such as the coastal and riverbank areas. These areas have to deal with erosion, cyclones, fresh water scarcity, and crop failure resulting from flooding. Riverbank erosion alone displaces between 50.000 to 200.000 people in Bangladesh annually. This not only results in the loss of dwellings, but also displaces agricultural land, causing communities to experience multiple displacements over time (Martin et al., 2013). People affected by environmentally driven migration often migrate close to their hometown, because of a lack of resources, such as money and different skillsets for in the urban areas (Martin et al., 2013).

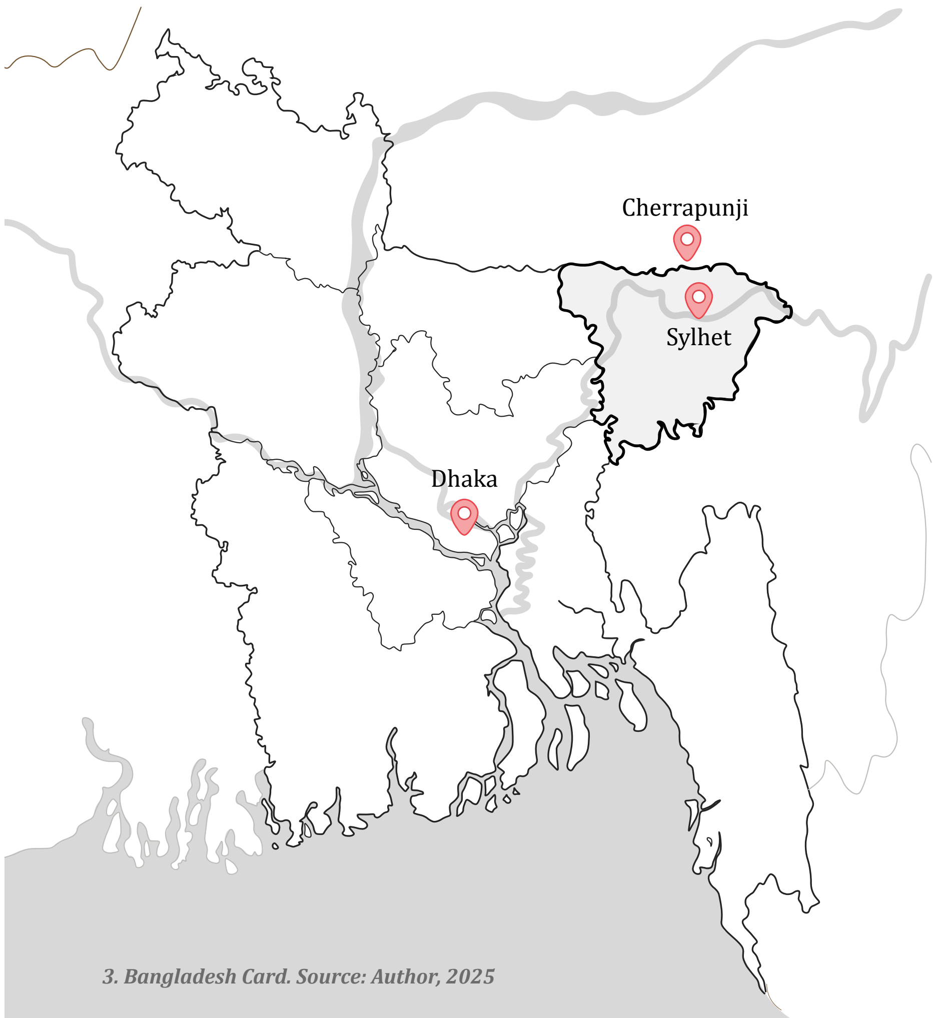
One of Bangladesh most climate-related affected cities is Sylhet, due to its location just below Cherrapunji in the Indian state of Meghalaya. Cherrapunji is often called the wettest place on Earth (Partha, 2024). A significant volume of glacial meltwater flows from this region into Bangladesh, which makes Sylhet even more vulnerable for floodings during the monsoons. This sudden increase of water will occur in one to three days, which will cause a waterlevel increase of three to four meter in all the rivers (Dash, 2024). In 2022 there was a record rainfall. This resulted in devastating floods that submerged 80 percent of Sylhet and displaced millions of people which caused widespread economic losses and damage to croplands (Tabassum et al. 2024).

Due to climate change, predicting water levels has become increasingly difficult. In the past, it was possible to measure the amount of water approaching their land, but in recent years, rainfall has occurred in intense bursts over just two or three days. This unpredictable pattern of flooding and rainfall makes it impossible for the residents to prepare in advance, worsening their situation (Dipak Ranjan Dash, 2024). These kind of floods occurs three to four times per year in Sylhet. They can’t raise their economy because of the agriculture loss.

Furthermore, Sylhet City is undergoing a technological, social, cultural and demographic transition which is creating an even bigger gap between the rich and the poor (Tabassum et al. 2024). Most of the displaced families, 72%, living along the riverbanks have a monthly income of 10.000 dbt (Abdullah Kaiser, 2023), indicating that these areas are primarily home to the low-income communities. This is why the design site is located on the riverbanks, with the goal of improving the living conditions of Bangladesh’s most vulnerable families. Specifically, the chosen design site is the southside of the Surma Riverbank next to the Keane Bridge, because this area experience a lot of poverty and is in a urgent need of adaptation to the rising water levels.

The location is home to two established impoverished communities, the Hindu and Muslim communities, who reside on land owned by the railway company. The land is very important for the communities, as they have lived there for a many years. However, they face several problems regarding the location and the current design of their dwellings. Each year, they experience several floodings, forcing them to live on the streets. The houses are limited to a single floor, providing no shelter within their homes during a flooding. Furthermore, beneath the Keane Bridge, several homeless individuals also occupy the area.

By investigating design strategies that address the needs of the communities that are residing on the site the livelihoods of these people can be increased.



3. Bangladesh Card. Source: Author, 2025

4. Surma Riverbank. Source: Author, 2024

5. Surma River. Source: Author, 2024

2. Literature Review

In the literature review, theories related to climate change hazards, environmentally driven migration and its causes, problems regarding support for erosion affected communities and an affordable and seasonal adaptable housing strategy will be elaborated.

To start this literature review the theories related to climate change hazards in Bangladesh will be elaborated. Bangladesh is one of the most climate related hazard-prone countries of the world (Islam, 2021). Different theories are elaborated to understand and mitigate the climate-related problems that Bangladesh is facing. The theory of Abdul Malak et al. (2021) argues that riverbank erosion has a long-term impact on the livelihood security of displaced people, whereby erosion affected people have scattered all over their hometown or migrated to the cities.

According to the article “Policy analysis: Climate change and migration Bangladesh” 88 per cent of environmentally driven agricultural migrants in Bangladesh remain within two miles of their previous residence after experiencing riverbank erosion (Martin et al., 2013). Similar trends were found on cyclones too. Due to a lack of resources, such as a different skillset for in the urban areas and capital, they could not move further to safer land. Furthermore, they prefer to stay close to their family and friends. Nevertheless, the influence of the other four migration drivers – economic, social, demographic and political – continues to encourage many people to migrate to urban areas (Martin et al., 2013).

Moreover, the causes of the riverbank erosion are discussed in the research by Md. Shofiqul Islam and Farjana Hoque (2014). They identifies several major causes of the erosion in the area of Sylhet, including groundwater pressure destabilizing slopes, loss of vegetation, exhaustion of soil nutrients and structure, erosion due to river or ocean wave action, saturation of the riverbanks by snow melting, glaciers melting or heavy rains, added loads due to earthquakes and volcanic eruption. Additionally, human activities such as deforestation, cultivation, construction, vibrations from machinery, blasting, earthworks and agriculture activities are worsen the riverbank stability (Islam, 2014). Despite the seriousness of the issue, only a fraction of the riverbanks are adequately supported, while many remain unsupported due to a lack of financial resources.

Furthermore, the Bangladeshi government is selective in its support for hazard-affected communities. By only providing temporary shelters, early warning system and evacuation processes for cyclone-prone and flood-affected communities, it fails to assist families impacted by erosion (Masum, 2019).

A way of supporting the impoverished communities living on the erosion-prone riverbanks could be with an affordable and sustainable housing strategy, such as an adaptability housing strategy (Itma, 2019). In his paper ‘Strategies of Adaptability: An approach for Affordable Housing Design’ he states that adaptability strategies are considered as social, environmental and economic concepts, whereby the values, such as decreasing the area of housing-unit, decreasing the amount of building materials and simplicity of implementing methods are highlighted in his research.

To understand better how seasonal adaptability influence the inhabitants livelihood a study of Nyilas and Kurzaumi (2017) is done. They mention the importance of the study by Maslow (1943), who has written the first book on comprehensive study on human needs in general, he states that the physiological, safety and aesthetic needs applies also for the built environment, whereby the indoor temperature, air, light and noise conditions are depending on the building structures.

In vernacular architecture, buildings where built to have optimum indoor environmental conditions due to the appropriate orientation, architectural form, proportion, spatial layout and building materials (Nyilas & Kurazumi, 2017).

With the development of technology, the traditional passive methods where gradually replaced by efficient building equipment for an additional increase of indoor comfort, making architectural form free from the environmental circumstances. However these active methods proved to be immensely energy-consuming (Nyilas & Kurazumi, 2017). Wherein the passive vernacular architecture is a more sustainable way of living.

In contemporary architecture, the main principles of sustainable architecture are rooted in the environmental conditions of the building site, including its climate. The form of a building can differ a lot depending on its site, because the design site requires extremely different considerations for energy efficiency, health and indoor comfort depending on its seasons. Passive methods of vernacular architecture encourage natural ventilation, which provides comfortable indoor conditions for the hot and humid summers.

However such buildings are cold in the winter. In order to provide also a comfortable indoor condition in winter, active energy-consuming equipment is implemented or the structure will be insulated airtight, which can be very expensive or cause health problems. For solving the problem with the energy efficiency, health and indoor comfort/livelihood, seasonal adaptation was invented (Nyilas & Kurazumi, 2017).

Seasonally adaptive buildings are buildings that can adapt to the seasonal changes of their environments, and are therefore reasonably expected to maintain healthy and comfortable indoor conditions throughout the year while consuming only minimum amount of energy.

The idea of adaptive architecture is originated on the concept of adaptation in nature. Seasonally adaptive buildings can adapt to seasonal changes through their environmental change response machanisms, just like living organisms (Nyilas & Kurazumi, 2017).

Nyilas and Kurazumi (2017) discuss various approaches to designing buildings that adapt to different seasons, such as creating dwellings that change with the seasons, implementing flexible building layouts, and incorporating smart building envelopes.

According to Nyilas and Kurazumi (2017) traditional architecture in Japan demonstrates seasonal adaptability through the use of two building types: pit dwellings for winter and raised-floor dwellings for the warmer months. pit houses were built over underground spaces with soil-covered wooden frames that retained summer heat, helping to keep interios warm in winter. In contrast, raised-floor houses featured elevated floors and open structures that allowed air to circulate underneath, providing cooling and moisture protection during hot, humid summers (Nyilas, Kurazumi, 2017).

Another example of a seasonal adaptive housing strategy is the Khudi Bari designed by Marina Tabassum. The modular system can be moved from one to another location, due to its easy way of assembling and disassembling. Furthermore, the dwelling could withstand heavy floods, whereby the inhabitants can stay in their home. The costs of the house, including laber, are $450 (Khudi Bari: A climate-prepared solution to rising flood threats, 2024).

Furthemore, other resilient and affordable housing strategies have been developed, such as amphibious dwellings in Bangladesh. This type of dwelling can float on the water (Varkey, 2022).
However, these design strategies are small-scale solutions, meaning that only a limited number of residents can benefit from them. More research needs to be done on large-scale, high-density and seasonal-adaptable housing strategies to explore the possibility of designing resilient and high-density housing for the people living on the riverbanks.

3. Problem Statement

Substantial research has been conducted on resilient housing strategies in disaster prone areas, such as Bangladesh, to mitigate the loss of dwellings and land. Unfortunately, many impoverished families on the erosion-prone riverbanks can not afford these types of dwellings due to its high building and maintenance costs (Kashem, 2019). For example, a resilient auto constructed house costs US$150 with an annually maintenance of US$25-$40 (Kashem, 2019). The Bangladeshi have an average income of US$20 per month (Akter, 2013), which will make it very difficult to afford a house like this.

Another issue are the costs of rehabilitating erosion-induced people away to safer grounds, because it requires a lot of money and resources to facilitate proper resettlement schemes (Malak et al., 2021). So, many impoverished families are trapped in their original region. If they manage to migrate, they often can only afford housing on the lowlands, which are also fragile for floodings. Therefore, the problem is only shifted to another erosion-prone area (Martin et al., 2013).

These climate related hazards are also a big issue for the communities living on the Surma riverbanks in Sylhet city. Due to climate change the heaviness of the floodings in Sylhet are increasing every year (Partha, 2024). Therefore, the risk for erosion will also increase (Islam, 2014), which will cause many housing and land destructions on the Surma riverbanks.

According to the residents living along the Surma Riverbank near the Keane Bridge, the site will flood approximately three times per year. Last year they experienced three floodings, forcing them to move out of their houses and live on the streets. When the flooding was over they could move back into their houses. This shows that their houses are not suitable for the conditions on the riverbank.

Moreover, the design site is a very important place for the current residents, the Hindu and Muslim community, because they already live here their whole lives. On top of that, due to mass migration and population growth in Sylhet finding a livingplace in the city center is becoming more and more difficult. Due to a lack of money and different skillset of these communities it is difficult to migrate to another place

Living on the riverbanks makes the communities vulnerable to climate-related hazards, such as erosion (Marine et al., 2014). As a result, these communities may be compelled to migrate and abandon their livelihoods, including occupation, potentially leading to extreme poverty in other areas.

A suitable way of building along the riverbanks, that mitigate the loss of dwellings caused by climate related hazards, are adaptable housing strategies, such as the Khudi Bari designed by Marina Tabassum. This innovative solution mitigate the destruction of homes and reduces reconstruction costs, as it is designed to withstand floodings and is constructed using locally sourced, demountable and cost-effective materials. Due to its ease of assembling and disassembling, the Khudi Bari can be relocated to another area at minimal cost (Khudi Bari: A climate-prepared solution to rising flood threats, 2024).

However, due to overpopulation and environmentally driven mass migration in Bangladesh, including Sylhet city, these small-scale resilient solutions may prove insufficient to accommodate all those in need. As a result only a part of these impoverished communities who are living on the Surma Riverbank, next to the Keane Bridge, have access to resilient housing. To facilitate the current residents the adaptable houses need to be densified. So, more impoverished communities are able to live in a resilient house and to mitigate the environmentally driven mass-migration.

6. Source: Sylhet Flood Photos 2022. Asgar Azwad.

4. Theoretical Framework

The theory of how “high-density, seasonal-adaptable housing designs for the impoverished erosion-prone communities could reduce the environmentally driven migration” will be substantiated by other theories and case studies. The article of Varkey and Philip (2022) provides an exploration of the theory of amphibious housing. Furthermore, various case studies, including the Khudi Bari by Marina Tabassum, an amphibious dwelling by Zahrun Zannat offer support for the concept of high-density, seasonal-adaptable housing design.

The article of Varkey and Philip (2022) gives more insights into flood threat assessment concepts and adaptive flood living, whereby they made a design concept of an amphibious flood resilient building. In normal conditions, an amphibious home stands on the ground, but during a flooding the dwelling floats as high as required. Due to a floatation mechanism underneath the dwelling, the dwelling can float on the water. Varkey and Philip (2022) states that the water conservation solution aims to work together with the flood regions natural flood cycle rather than attempting to prevent them.

To design a fast and easy amphibious dwelling, experiments where done with new revolutionary lightweight materials, as well as regular, sustainable measures, with their benefits and drawbacks. This study shows that fiberglass pontoons are a durable and cost-effective material to be used for the foundations (Varkey, 2022).

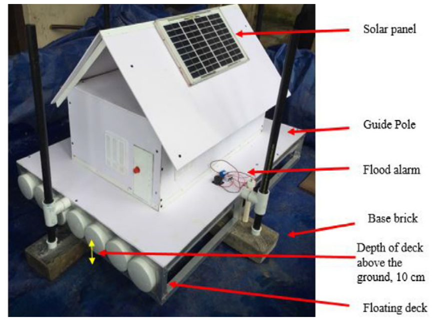
These amphibious houses with floating floors could help Sylhets residents stay dry during floods. In Bangladesh there are already some amphibious houses realised. Zahurn Zannat, a graduate student in urban planning at the Bangladesh University of Technology and Engineering, designed a low-cost amphibious house in Dhaka. Normally the expensive floating floors are made in the Netherlands. However, according to Zannat, these floors could be produced at a lower cost if manufactured locally in Bangladesh. This amphibious house, featuring a floating floor constructed in Bangladesh, remained habitable throughout the flood season (Zannat, 2022).

As said before the Khudi Bari by Marina Tabassum is an example of an adaptable housing design. The building-concept is a cheap structure, made out of local bamboo stilts, steel joints and metal sheeting, that can be built, dismantled, transported and reassembled elsewhere by the residents themselves (Canova, 2024). Also due to this construction the residents could stay in their homes during a flooding (Canova, 2024). By constructing the Khudi Bari on a riverbank, sandbags, also called geobags, could be employed to reinforce the riverbank, providing support against erosion (Thompson, 2019).

Another example of a floating house village is the floating housing district in IJburg in Amsterdam designed by Marlies Rohmer, Architecture & Urbanism. This is the largest floating housing district in Europe, complete with alleys, bridges and a range of housing types. For european standards this district has a high density comparable with the Jordaan in Amsterdam. According to an inhabitant, of one of the dwellings in IJburg, the adaptability of the houses are noticeble in the dwelling. “Our house tilts a bit when we reposition the bookcase. We can tell because the drawers tend to slide open and the shower doesn’t drain properly.” (Waterwoningen IJburg, 2011).

In Bangladesh most climate resilient housing designs are small-scale, characterized by low density and seasonal adaptability. By examining a high-density floating district from the Netherlands and integrating Sylhet’s local materials and construction techniques, this study could provide an answer to the feasibility of high-density, seasonal-adaptable housing on the riverbanks in Sylhet.

Furthermore, in this thesis other case studies regarding seasonally adaptability, high density dwellings and affordability will be investigate to investigate the possibilities of a high-density, affordable and seasonal adaptable dwelling on the Surma Riverbank.



7. Scaled working model. Source: Varkey M.V., Philbin M Philip (2022)

8. Amphibious dwelling. Source: Zahrun Zannat (2022)

5. Research Question

This research is exploring if high-density, affordable and seasonal-adaptability in housing design could be a possible strategy to mitigate the environmentally driven migration of the impoverished communities that are living on the hazard-prone riverbanks in Sylhet. The research question is as follows:

How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished Hindu and Muslim communities living along the erosion-prone Surma Riverbank in Sylhet?

The first sub-question, "How do seasonal variations on the erosion-prone Surma riverbank in Sylhet influence the livelihoods of the impoverished Hindu and Muslim communities living along the riverbanks?", will clarify how the livelihood of the current communities, the Hindu and the Muslim families, and the new communities, the fishermen families, is adapting to the changing climate conditions.

Furthermore, the second sub-question, "How can seasonal adaptability in housing design increase the livelihood of the communities living along the Surma Riverbank.", will clarify how seasonal adaptability of a housing design can increase the livelihood of the residents within the dwelling and prevent the loss of dwellings and land due to floodings and erosion.

The last sub-question: "To what extent can a seasonal-adaptable housing design for the impoverished communities along the Surma riverbanks be densified to address the increasing population of Sylhet?", will clarify whether it is possible to increase the density of people living on the riverbanks, ensuring that the dwellings are not only resilient to changing climate conditions, but also affordable for the impoverished Hindu and Muslim communities living on the site.

6. Hypothesis

To prevent the impoverished communities from unwanted migration to safer grounds a high-density and seasonal-adaptable housing strategy need to be implemented. This large-scale resilient housing design need to prevent the impoverished communities from losing their houses, land and occupation caused by climate-related hazards, such as erosion.
The dwellings along the riverbanks of the Surma river in Sylhet need to be resilient to erosion. This can be achieved through the use of geobags filled with sand. Furthermore, it is important that these dwellings are affordable for the impoverished communities, so their livelihood will increase. This can be achieved by using local materials, building techniques and an easy way of assembling and disassembling of the construction.

Furthermore, this dwelling must be adaptable to seasonal fluctuations in water levels and flexible enough to accommodate the shifting dynamics of the Surma riverbank. This can be achieved by designing an amphibious dwelling that can function both on land and in water. The proposed house will initially be constructed on land. However, due to its vulnerability to erosion and its possibility of flooding, it must also incorporate water-resistant features.

However, these solutions need to be scaled up to bigger housing projects, so all the impoverished communities in need, such as the Hindu, Muslim and fishermen communities, are eligible for these seasonal-adaptable and affordable housing types.

7. Goal

The primary goal of this research is to reduce the environmentally driven mass-migration for the impoverished communities living on the erosion-prone Surma riverbanks in Sylhet. This can be achieved by establishing a high-density, seasonal-adaptable and affordable housing scheme that can withstand the erosion of the riverbanks caused by climate related hazards. This approach aims to ensure that impoverished communities in Sylhet remain on their original location rather than being forced to migrate to other areas.

8. Methodologies

In this research, different kinds of methodologies are used to address the research question. First, existing literature is reviewed to understand the underlying issue of migration in Bangladesh and to identify the research gap in the field of affordable and climate-resilient housing strategies for the riverbanks of Sylhet. This study will examine how seasonal-adaptable and affordable housing for the impoverished communities living along the Surma riverbanks in Sylhet can be densified, enabling these communities to continue living in the area.

The first sub-question, “How do seasonal variations on the erosion-prone Surma riverbank in Sylhet influence the livelihoods of the impoverished Hindu and Muslim communities living along the riverbanks?”, aims to clarify the factors needed to improve the livelihood of people living along the riverbanks. The methodology used to address this question will include field interviews and observations. During the fieldwork, an analysis of the livelihoods of inhabitants living along the Surma riverbanks in Sylhet will be made. In the first stage of the methodology, observations and sketches will be made. In the second stage, questions regarding their way of life across different seasons will be asked. In the final stage, graphical analyses of the observations and interviews will be conducted, including an examination of the advantages and disadvantages of living on the riverbanks, to visualize the livelihoods of the Hindu and Muslim families.

Furthermore, for the second sub-question, “How can seasonal adaptability in housing design increase the livelihood of the communities living along the Surma Riverbank?”, the methodology will involve case studies wherein seasonal adaptable strategies are used, such as passive systems or changing dwellings according to the season.

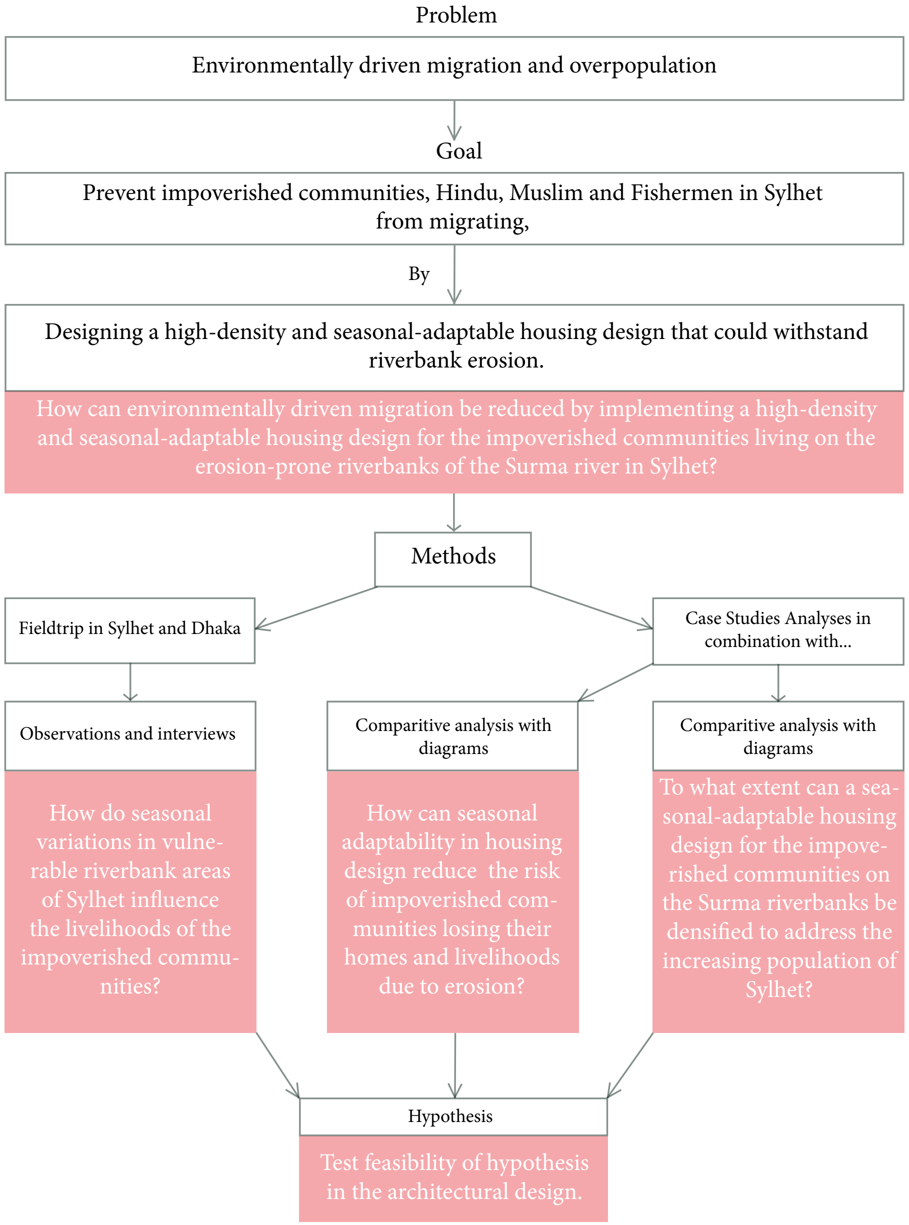
The case studies that will be analyzed include the Khudi Bari, a resilient tiny house in Bangladesh by Marina Tabassum (Canova, 2024); amphibious housing in Bangladesh by Zahurn Zannat; (2019); The Student Hostel in Sylhet by Muzharul Islam, Stanley Tigerman regarding a large scale building in Sylhet.

The analysis will cover various factors, including seasonal adaptability, materials, construction techniques, site conditions, the inhabitants’ experience and affordability.

Finally, the sub-question, “To what extent can a seasonal adaptable housing design for the impoverished communities along the Surma riverbanks be densified to address the increasing population?” will be explored through architectural design methodologies. By applying the design principles developed in response to sub-questions 1 and 2, the hypothesis can be tested and evaluated withing the architectural design framework.

The research question “How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished communities living on the erosion-prone riverbanks of the Surma river in Sylhet?”, will be addressed through a site-specific architectural design. The conclusions derived from this study will be evaluated for feasibility.

9. Research Scheme



10. Relevance

Research has been conducted on various resilient adaptable housing strategies and their affordability in hazard-prone areas in Bangladesh and other countries. The literature review shows that due to a lack of financial resources, many impoverished people struggle to maintain climate-resilient homes, which makes them more vulnerable to climate-related hazards. While there are resilient and affordable dwellings in Bangladesh, almost all of these are small-scale, housing only a limited number of people. Due to overpopulation and environmentally driven mass migration, these affordable and resilient housing designs need to be densified in order to reduce migration, particularly for the most vulnerable communities, such as the Hindu and Muslim communities living along the riverbanks.

Due to the severe poverty faced by these communities, they are left with few viable options for migration. The flash floodings and possibility for erosion of the riverbanks threatens both their livelihoods and living conditions. This research explores how high-density, seasonally adaptable and affordable housing strategies could mitigate environmentally driven migration, with the aim of enabling these communities to remain on the riverbanks and sustain their way of life.

11. Definitions

Seasonal adaptability - Dwellings designed to adapt to seasonal changes, maintaining comfort and livability throughout the year by utilizing flexible building layouts and/or passive climate systems.

Environmental Drivers - Migration caused by climate change related hazards (Martin et al., 2013).

Riverbank erosion - the removal of materials, such as soil and vegetation, from the riverbanks when flowing water forces exceed bank resisting forces (riverbank erosion, 2023).

Flash Floods - Sudden and severe flooding

Impoverished - Monthly income per household in the low-class. National level: 12.900 BDT. Urban Level: 12.950 BDT. Rural Level: 12.875 BDT. (Fidah, 2024)

BDT - Bengali Taka. 1 BDT is according to the current exchange rate 0,0078 Euro.

Affordable housing - Impoverished people are able to afford this house.

Amphibious house - A house that is able to function normally on land and on water (Varkey, 2022).

FSI - Floor Space Index, measurement used in urban planning and architecture to calculate the density of buildings in a given area (Dichtheid en functiemenging in beeld, 2018).

12. Sub-Question 1. Livelihood Surma Riverbank:
"How do seasonal variations on the erosion-prone Surma riverbank in Sylhet influence the livelihoods of the impoverished Hindu and Muslim communities living along the riverbanks?"

12. Livelihood Surma Riverbank: *Introduction*

The key question that will be addressed in this chapter is: "How do seasonal variations on the erosion-prone Surma riverbank in Sylhet influence the livelihoods of the impoverished Hindu and Muslim communities living along the riverbanks?" By investigating this question, it will be clear how the communities respond to these challenges and identify the areas that require investment to improve their livelihoods and resilience.

This chapter explores the livelihoods of Bengali communities, with a particular focus on those residing on the design site, along the Surma riverbank. It will examine the economic activities, challenges and opportunities that shape their daily lives. This site was selected for this project due to its strong potential for densification, its vulnerability to flash flooding and its current use by an impoverished community known as the Sweepers Colony.

However, first it's important to also examine the overall livelihood of people living in Bangladesh, as this reveals how individuals live in both urban and rural areas, the conditions they endure, their daily routines, work opportuntities and the cultural values that shape their way of life.

This chapter is based on investigations conducted through interviews with locals living in various places, such as the design site along the Surma Riverbank in Sylhet, in a smaller village Ekduaria and in the capital city Dhaka, each providing valuable insights into local perspectives and livelihoods. These different perspectives give a better understanding of the livelihood of the people living in Bangladesh.

12.1. Livelihood Bangladesh: *Ekduaria, Dhaka, Sylhet*

Various interviews are conducted with locals and experts regarding the livelihood of the residents living in villages such as Ekduaria and cities, such as Dhaka and Sylhet. These interviews gave insights in the daily routines of the residents and their response on the flooding and erosion risks. This chapter begins with a comparison between life in Dhaka city and the village of Ekduaria, highlighting how livelihood varies depending on one's place of residence.

12.1.1. Dhaka vs Ekduaria
Interview Jafar Tuhin

In the village Ekduaria, located near Dhaka, an interview was conducted with Jafar Tuhin, the CEO of the travel agency Taabu Tours, in collaboration with Coco de Bok, Joelle Steendam and Lotte Bijwaards. Jafar Tuhin grew up in the village Ekduaria and moved to Dhaka after completing high school to pursue higher education and employment opportunities. After 15 years of living in Dhaka he returned to Ekduaria, where he has now been living for four years. Due to his travels in Bangladesh he has a lot of knowledge from different kind of areas in the country, which makes this interview very helpful.

Opportunities Dhaka City
According to Jafar Tuhin 70% of the workforce in Bangladesh is concentrated around Dhaka City, making the surrounding environment one of the most significant hubs for economic activity. Due to this concentration many people migrated from their villages to Dhaka.

In addition, Dhaka offers a wide range of essential amenities, such as healthcare, education and other services, which are largely absent in many rural areas. Tuhin notes that villages typically lack these amenities. It is important to implement a school, a mosque and a hospital in the villages too (Tuhin, 2024).

The migration of students to Dhaka for educational purposes also contributes to the city's rapid expansion, as many individuals remain in the city after completing their studies to pursue employment. This caused an ongoing effort to expand the city's infrastructure, with many wetlands being filled in with sand to make space for new development (Tuhin, 2024).

Opportunities Ekduaria Village
However, Tuhin argues that the living conditions in rural areas tend to be more favorable compared to the city. Villages are generally less polluted and less densely populated. Moreover, the quality of food and water is often more desirable to that found in the urban environment.

Vulnerabilities within Cities
If Tuhin could implement changes in the city, he would prioritize improvements in drinking water quality and the overall sanitation of buildings. Another pressing issue he identifies is the inadequate natural light and ventilation in many urban homes. Due to the lack of sufficient daylight, artificial lighting is often required even during the daytime. Tuhin emphasizes the importance of increased access to sunlight and the fresh air in urban residences, as these are essential for both physical and mental well-being.

Vulnerabilities within Villages
However, villages are highly vulnerable to flooding, which leads to a significant number of climate refugees migration to urban areas. Flash floods, which can occur suddenly in the middle of the night, pose a particular challenge for residents, as it becomes difficult to protect their homes, belongings, livestock, and even their lives. In contrast, slower floods are somewhat easier to manage, as they provide residents with a chance to prepare and take preventive measures. In some cases, families are divide due to differing economic interests and work opportunities, weaking the strength of the family bond. For example, some family members may seek employment in various sectors, including the vegetable market, construction, cleaning, brick manufacturing or fishing (Tuhin, 2024).

Seasonal Jobs
Due to the floodings in the monsoon season many people need to seek for another job which is causing seasonal jobs for many impoverished people. For example, fishing is more prevalent during the wet season, while in the dry season, many fishermen seek alternative employment, such as agriculture. Due to the availability of work only during specific seasons, many fishermen hold two jobs. In the off-season for fishermen, they will involve themselves in other occupations, such as agriculture (70%), business (15%) or other income-generating activities (Marine, 2014).

Other job opportunities are factory work, restaurant services, work on the market or CNG/Rickshaw drivers. Many fishermen, for instence, migrate to areas with brick factories during the dry season for around 6 months, where they will earn between the 7 and 8 dollar per day (Tuhin, 2024). In some cases, their wives and children accompany them. These brick factories often provide living accommodations for their workers, allowing families to reside close to the workplace. Additionally, some factories offer going to school for the children of the workers. The workers will move back in the wet season to their houses and will work again as a fisherman. Due to these seasonal jobs, family bonds can be at risk, as they often lead to separation within the family.

Still, many people choose to work this way because of their existing skills and expertise within that field of work. Most likely, they learned the trade from their parents and grew up immersed in the occupation. It is difficult for them to transition to other types of work where they possess the same level of skill and experience.
For example for fishermen they are skilled in all aspects of fishing, from cathing the fish to selling them at the market and are familiar with every step of the process. As a result, continuing in this profession is the easier choice for them. Learning a new trade and building a livelihood from it would be much more challenging.

However, being a fisherman is becoming increasingly difficult each year due to the declining fish populations in the rivers (Jafar Tuhin, 2023) and the climate related hazards, such as floods and erosion (Hussain, 2012). The floods and erosion are causing a varying degrees of destruction to their land and houses, forcing fishermen to either repair their homes annually or migrate to safer areas, which cost them more money then they can afford (Hussain, 2012).

Monsoon Season Job: *Fishermen*

9. Fishermen. Source: Author, 2024

Dry Season Job: *Brick Factory Worker*

10. Brick Factory Worker, Source: Author, 2024

9. Geneva Town, Dhaka City. Source: Author, 2024

12.1.2. Composition Houses: *Bangladesh*

12.1.2. Composition houses

To better understand the living conditions of impoverished people, a general floor plan of a village home and a city home are sketched for comparison. The sketches show that rural homes typically offer more space than city homes. In urban areas, people often have to share their living space with more inhabitants compared to those in rural settings. Furthermore, from interviews with locals the composition of typical house in Bangladesh is explained.

Private Areas

The kitchen, bathroom, and washing area are typically located on the west side, as these spaces where people don't spend extended periods of time. Additionally, the kitchen is considered a private area, which residents usually prefer not to share.

Sanitation

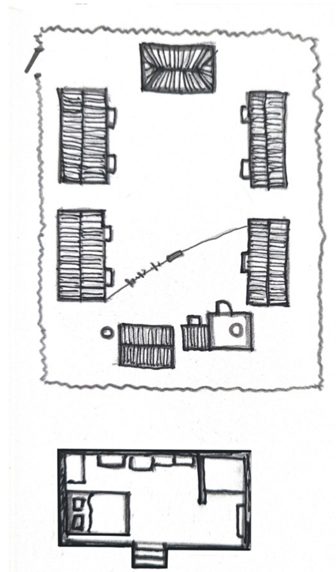
Toilets are often located outside the main building. However, in apartment complexes, they are usually placed inside. This can lead to odor issues, so it's important that toilets are positioned along the facade to allow for direct ventilation.

Orientation regarding weather

Thicker walls are recommended on the west side, as it receives the most intense sunlight in Sylhet. It's uncommon for houses to be oriented toward the south or west, because these directions bring in the strongest heat. Most homes are typically oriented to the east, where sunlight is less intense throughout the day.

Sometimes lintels are necessary due to changing angle of rainfall. To be protected from flooding, a building should be constructed on an elevated foundation at least 5 feet (152 cm) above ground level.

10. Floor plan Tin houses in Ekduaria. Source: Author, 2024



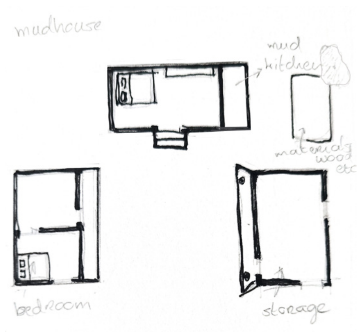
11. Floor plan, houses in Geneva Town, Dhaka. ource: Author, 2024

In these two examples it is also shown that in the rural areas more space is available then within the cities.

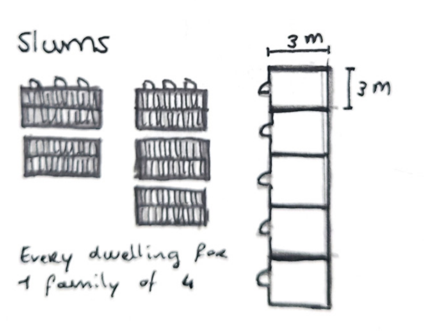
Mud houses in the village offer around 90 square meters for one family and include private outdoor space, often used for activities like outdoor cooking. In contrast, outdoor space in city dwellings is more limited and typically shared among residents.

12. Village Mud House. Source: Author, 2024

13. Slums in Dhaka. Source: Author, 2024



14. Village floor plan (Village Mud House) Source: Author, 2024



15. City floor plan (Dhaka, slums). Source: Author, 2024

16. Outside Cooking, Village life. Source: Author, 2024

Potential Solutions Floodings
For communities living along the riverbanks, some solutions have already been implemented in the city. Many houses are built slightly elevated above the road level, which helps prevent water from entering the homes during floods. However, if the road itself is submerged, water can still enter the buildings (Tuhin, 2024).

Additionally, the municipality is working to assist impoverished communities, particulalry government workers, such as municipal cleaning staff, by relocating them to high-rise buildings, providing safer living conditions. According to Tuhin, these high-rise buildings are designed to withstand flooding. In a densely populated country like Bangladesh, high-rise buildings could offer a viable solution to the housing crisis, accommodating a growing population in urban areas (Tuhin, 2024).

16. Elevation Plinth
Source: Author, 2024

17. Elevation Plinth
Source: Author, 2024

18. Elevation Plinth
Source: Author, 2024

12.1.3. Conclusion: *livelihood Bangladesh*

The contrast between urban life in Dhaka and rural life in Ekduaria reveals a balance of opportunities and vulnerabilities shaped by geography and climate. While cities offer greater acces to education, healthcare and employment, they also present challenges, including overcrowding, poor sanitation and limited natural light and ventilation. In contrast rural villages provide cleaner environments and more space. However, the rural life also faces challenges regarding flooding and erosion, which can destabilize families and force seasonal migration.

To improve the livelihood in Bangladesh elevated housing, better sanitation, education facilities are crucial. Solutions such as high-rise housing for vulnerable urban populations and elevated construction in flood-prone areas will help already a lot.

12.2. Livelihood Sweepers Colony: *Surma Riverbank*

The design site is situated on the south bank of the Surma River, adjacent to the Keane Bridge, with a size of 3 ha. At the site an interview was conducted with local residents to gather insights into their livelihoods. Together with Joelle Steendam, Kasper ter Glane, Youri Doorn and Hyosik Kim we engaged with the community living on the riverbanks of the Surma River to understand their living conditions and socio-economic circumstances.

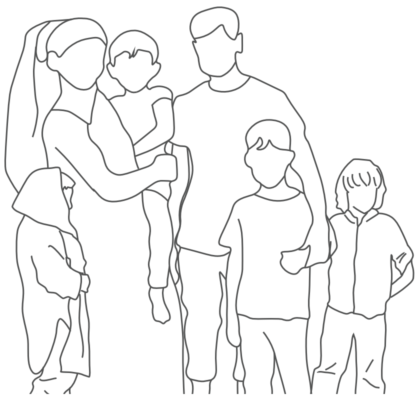
Hindu and Muslim Community

The area is home to both Muslim and Hindu communities, who reside on land owned by the railway company. Each family exists out of one family with six individuals. The community consists of appproximately 35 people, while the entire area is home to around 2500 residents. Moreover, the communities pay a monthly rent of 1500 to 3000 BDT to the railway company for their housing.

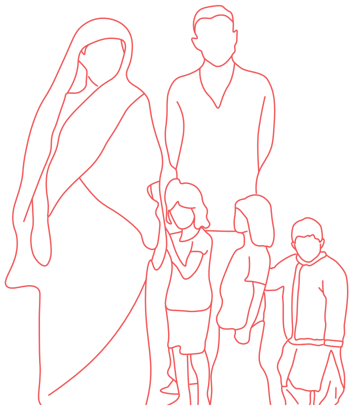
In addition to the dwellings, the site has several key facilities, including a temple, a school, a wood sawmill, a CNG parking area near the bridge and a local market where vegetables and fish are sold. The housing is organized around a central courtyard and residents share sanitation facilities.

Occupation

The Hindu residents engage in occupations such as street sweeping within the city or working as drivers of rickshaws, CNG vehicles, trucks and cars. In contrast, the Muslim community tends to persue different forms of employment, with some individuals involved in plastic recycling or working in the local market situated near their homes.



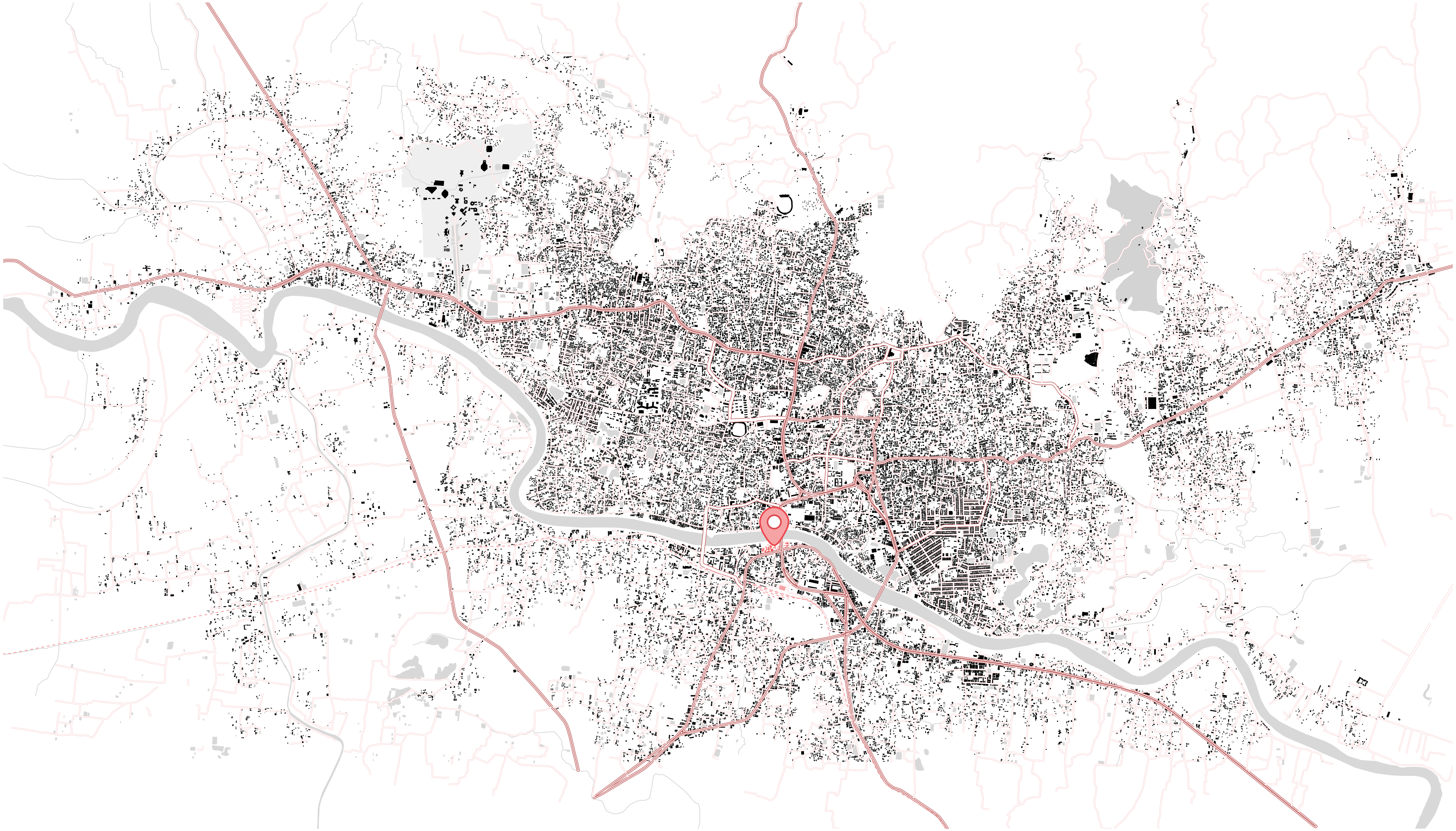
19. Hindu Community
Family of 5 to 7 persons
Source: Author, 2024



20. Muslim Community
Family of 5 to 7 persons
Source: Author, 2024

21. Local from the Hindu Community who we interviewed. Source: Author, 2024

12.2.1. Location: *within Sylhet City*



22. Map of Sylhet: In collaboration with Joëlle Steendam, 2024

12.2.2. Current Situation: *with functions*

23. Current Functions Design Site. Source: Author, 2025

12.2.3. Road Map: *Surma Riverbank*

24. Road Map Design Site. Source: Author, 2025

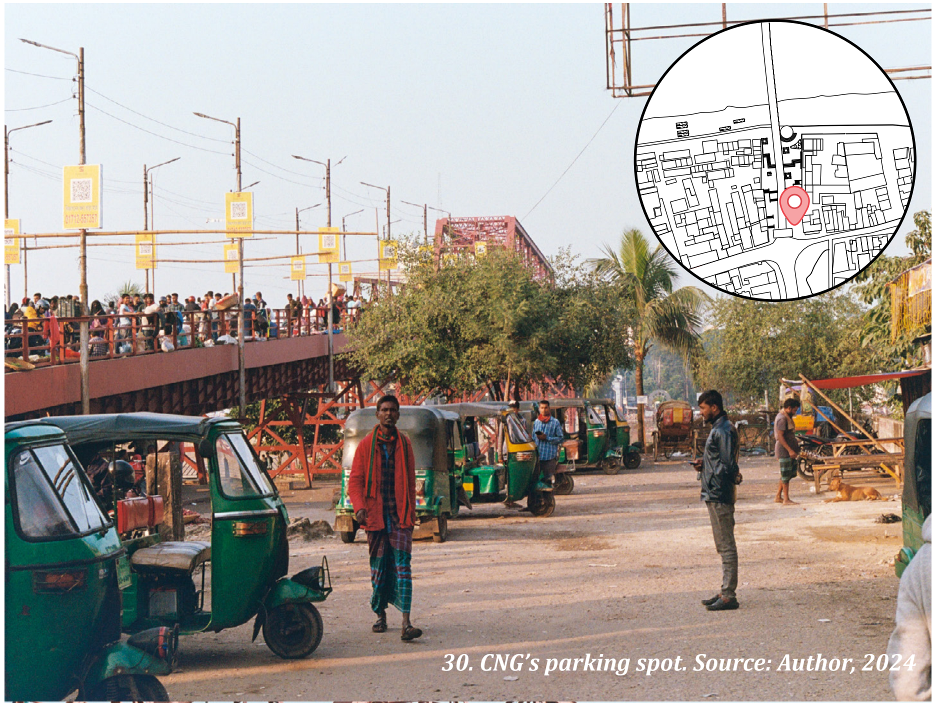
25. Market on the Keane Bridge. Source: Author, 2024

26. Market on the Keane Bridge. Source: Author, 2024

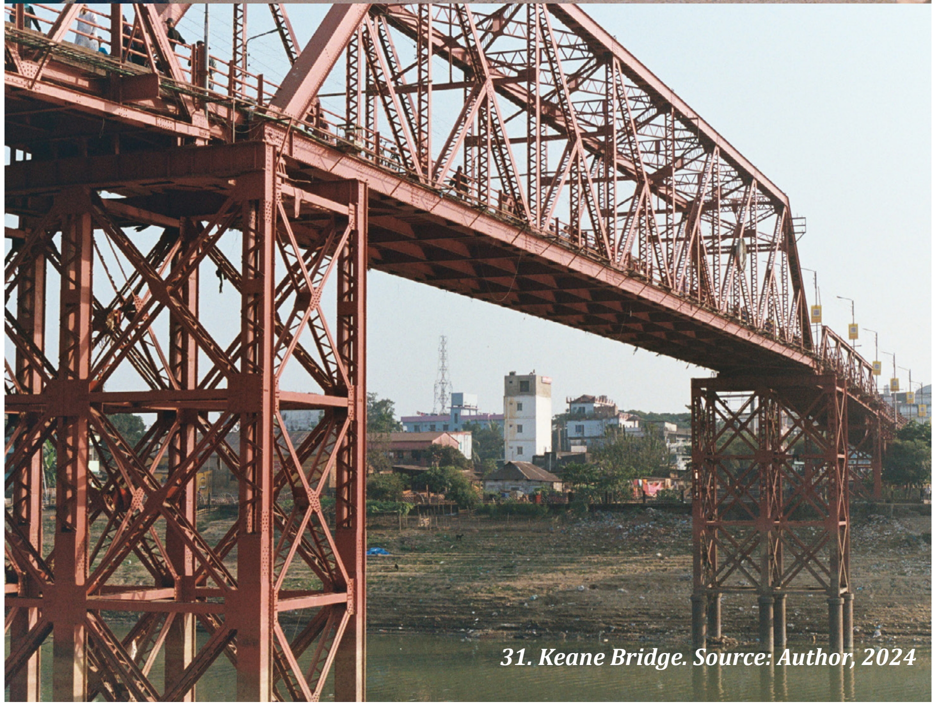
27. Hindu Community. *Source: Author, 2024*

28. Market on the Keane Bridge. Source: Author, 2024

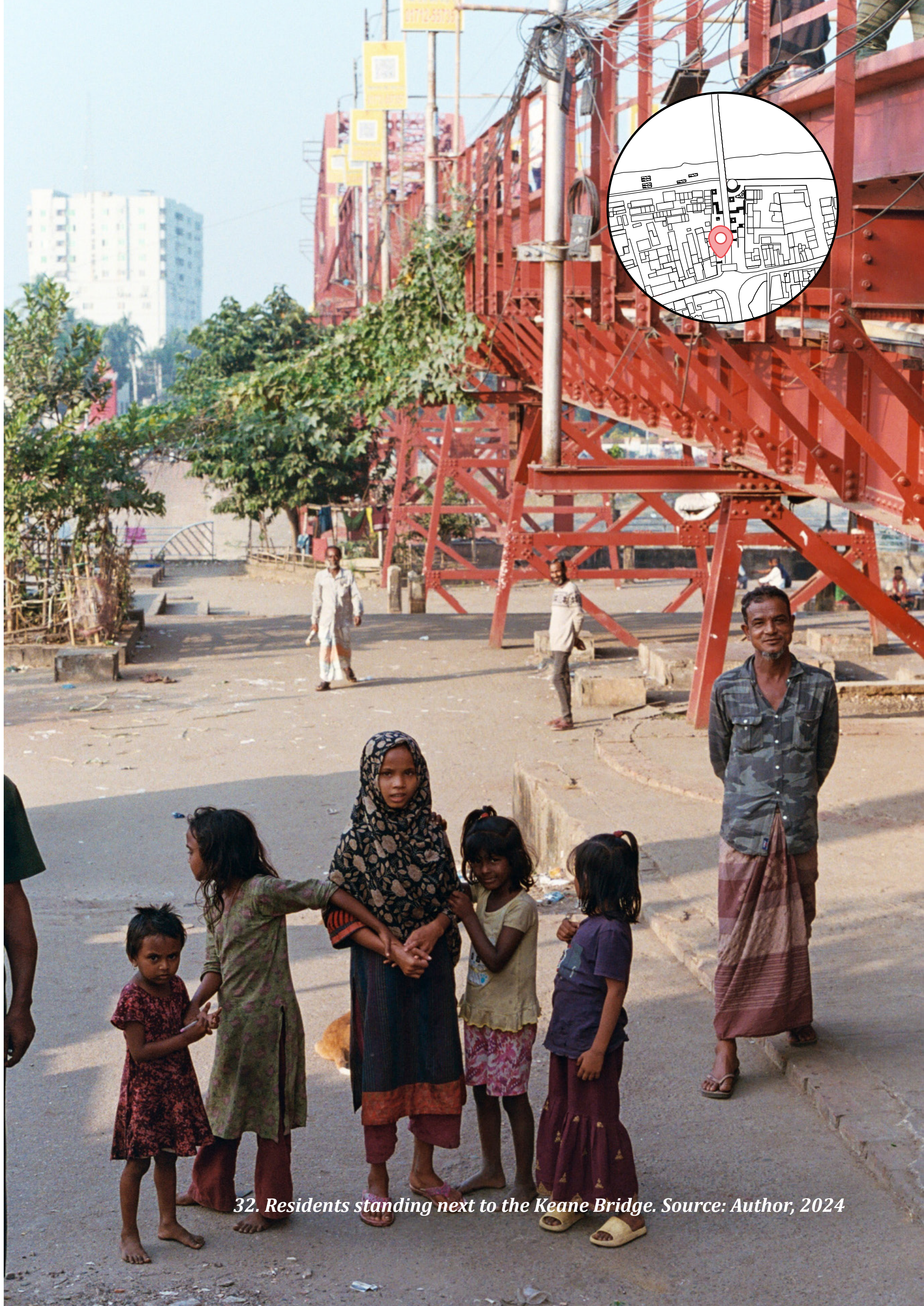
29. Saw Mill. Source: Author, 2024



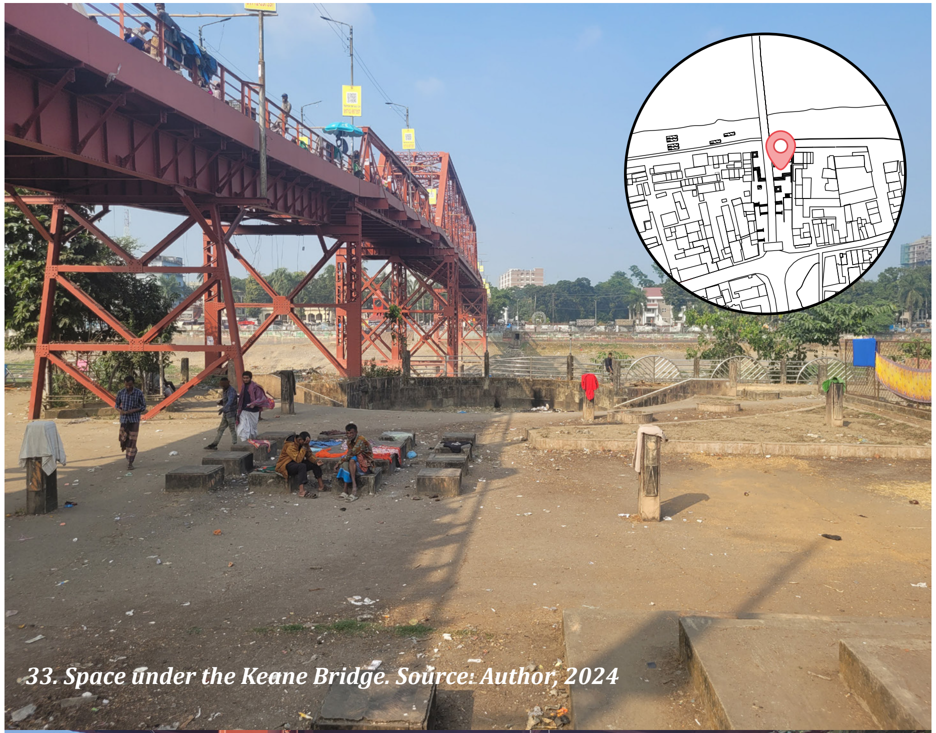
30. CNG's parking spot. Source: Author, 2024



31. Keane Bridge. Source: Author, 2024



32. Residents standing next to the Keane Bridge. Source: Author, 2024

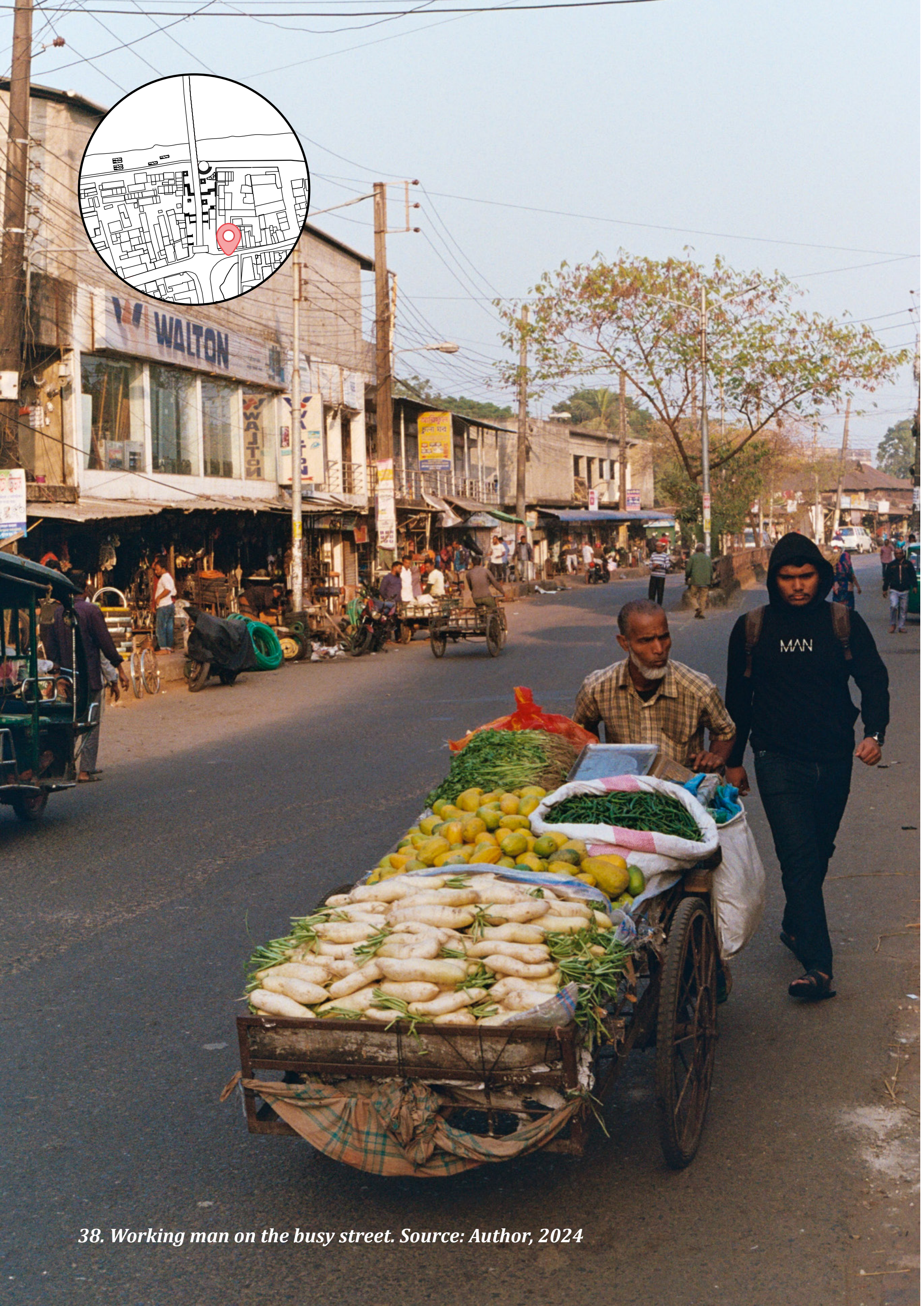

33. Space under the Keane Bridge. Source: Author, 2024


34. Space under the Keane Bridge. Source: Author, 2024

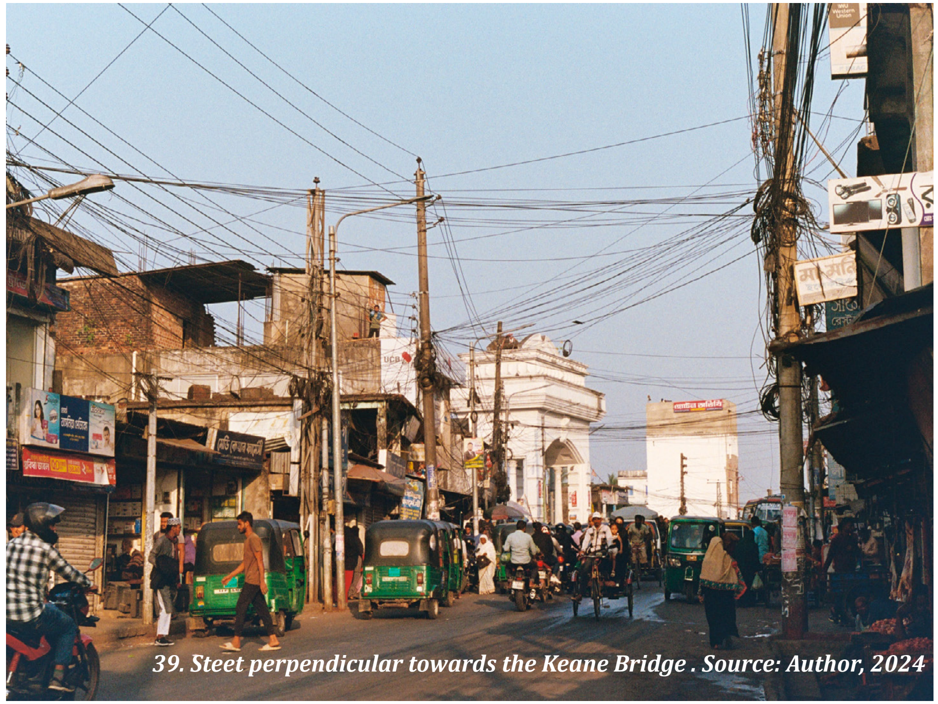

35. Child with broom (Sweepers Colony). Source: Author, 2024

36. Surma Riverbank with Agriculture. Source: Author, 2024

37. Path within the design site (Sweepers Colony). Source: Author, 2024



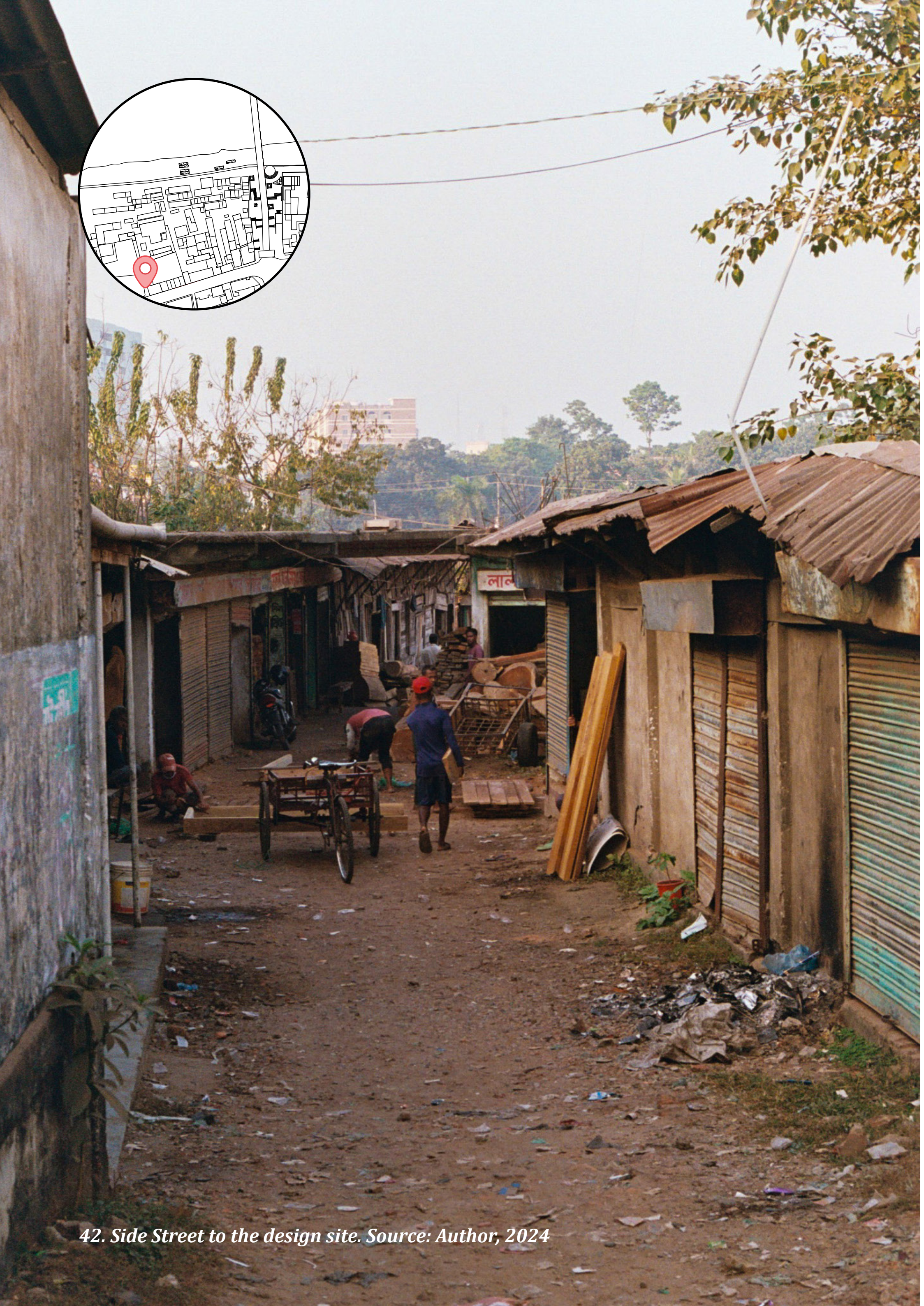
38. Working man on the busy street. Source: Author, 2024



39. Steet perpendicular towards the Keane Bridge . Source: Author, 2024

40. *Working next to the street. Source: Author, 2024*

41. *Working next to the street. Source: Author, 2024*



42. *Side Street to the design site. Source: Author, 2024*

43. *Side Street to the design site. Source: Author, 2024*

12.2.4. Current housing: *on the Surma riverbank*

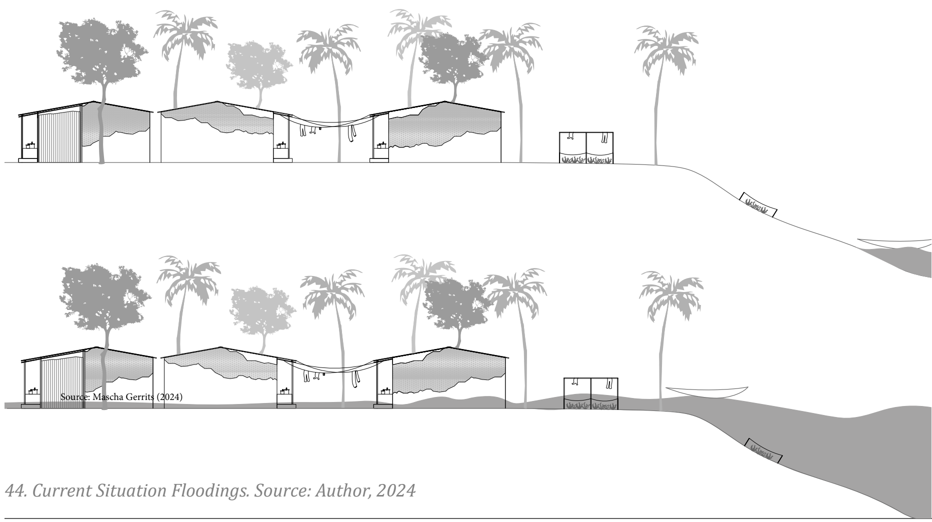
The current housing along the Surma Riverbank near the Keane Bridge consists of small dwellings occupied by both Muslim and Hindu communities. These communities are also called the Sweeper Colony and their families exist out of 5 - 7 people. Their homes are typically constructed from corrugated steel sheets (Muslim community) and bricks (Hindu community), providing just 4.2 m2 of living space per person.

The area experiences flooding approximately three times per year, often caused by sudden and unpredictable flash floods. As a result, residents are frequently forced to evacuate and live on the streets, with their belongings damaged or destroyed due to the lack of secure shelter and the absence of a second floor. Household items, sanitation facilities, and schoolbooks are often damaged during floods. Replacing these items is financially draining for them. They return to their houses once the water level recede. However, since the water level fluctuates multiple times a year, on average, they are displaced around three times annually.

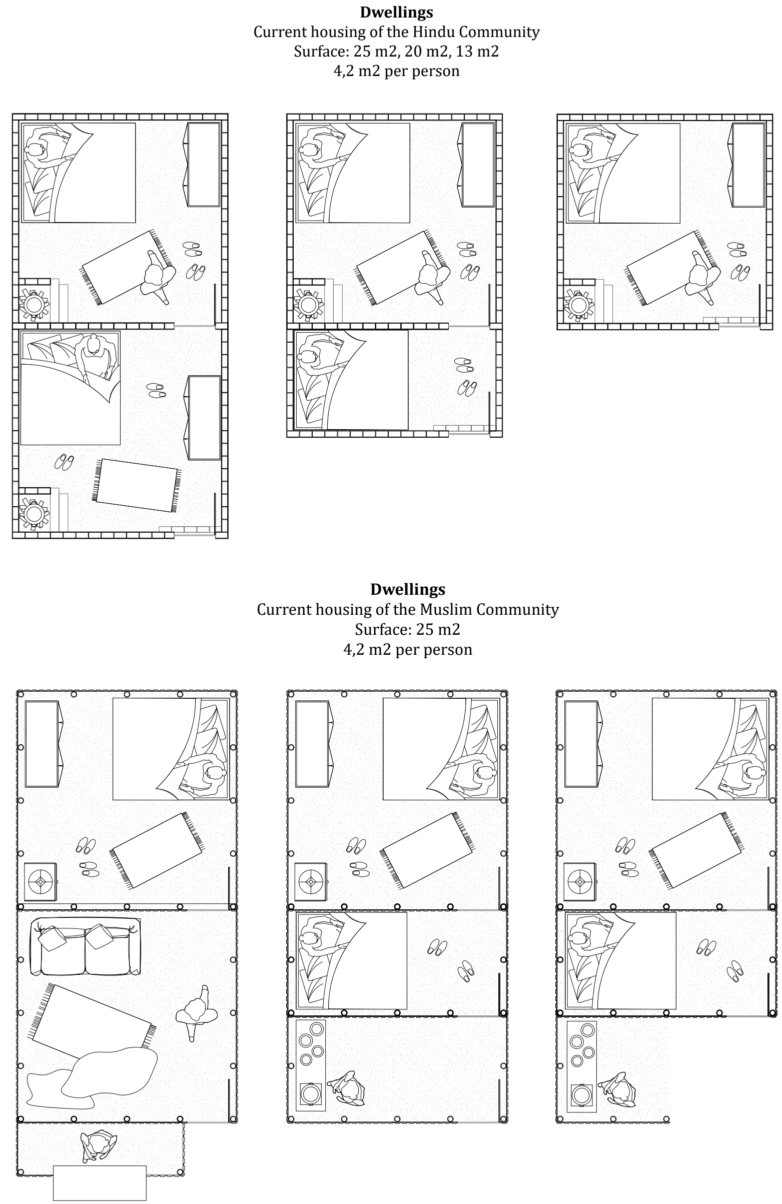
Given that floodwaters can reach up to 80 cm, the addition of a second floor would significantly reduce these risks and offer much-needed protection for both people and possessions.

Condition of the riverbank

The relation between the community and the Surma River is currently neglected. A significant amount of waste is disposed of directly into the river, while residents also wash themselves, their clothes and dishes in the river. Additionally, small-scale agricultural activities are practiced along the riverbank, which can undermine the structural integrity of the riverbank, increasing the risk of erosion. The area is subject to annual flooding, forcing inhabitants to temporarily relocate to the streets. Furthermore, the site suffers from inadequate sanitation facilities.



44. Current Situation Floodings. Source: Author, 2024



45. Current Hindu and Muslim Dwellings. Source: Youri Doorn, 2024

Current housing and its potential

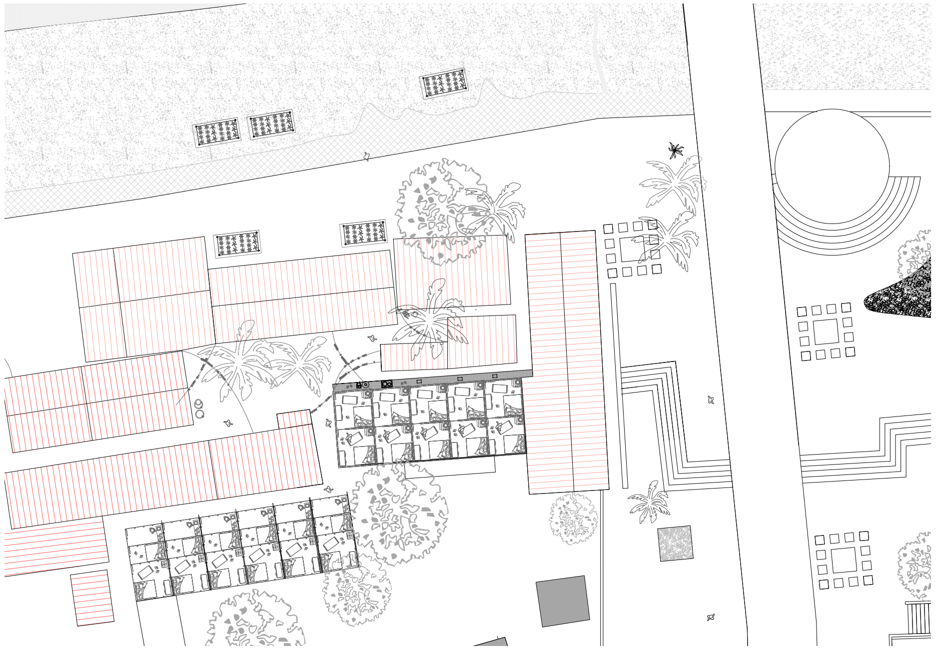
There are two types of dwellings on the site, belonging to the Hindu and Muslim communities. These differ in their construction materials, as seen in image .... The Hindu houses are built with bricks, while the Muslim houses are constructed from tin sheets, making them especially vulnerable to flooding. Neither type of dwelling currently provides adequate shelter during floods.

However, the brick Hindu houses hold potential for adaptive reuse. They could serve as a community center, or other public functions. Given this potential, along with their historical value, it is important to preserve these structures and avoid demolition.

In contrast, the tin-sheet Muslim houses offer less potential for long-term use. The land they occupy has the opportunity to be transfromed into a vibrant space that can also cater to visitors.

During an interview with a local resident, it became clear that both communities have a strong desire to remain living on this site. Therefore, the new masterplan will include designated residential areas to ensure they can continue to live here.

Spatially, the Hindu houses are primarily located near the bridge, while the Muslim houses are more concentrated around the market area.



46. Current Situation. Source: Author, 2024

During interviews with local residents, it became clear that a strong connection to the ground floor is very important. It provides opportunities for people to meet easily outside. The outdoor space is also used for drying clothes.

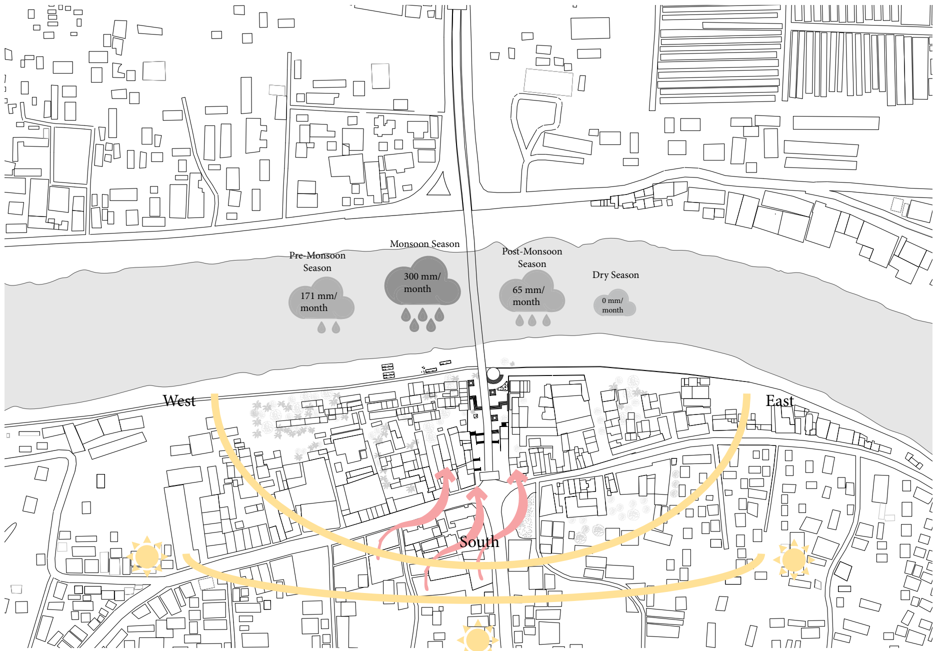
47. Livelihood Site. Source: Author, 2024

12.2.5. Climate Conditions: *Surma Riverbank*

To design comfortable dwellings on the site, it is essential to take the local climate conditions into account. The buildings must respond not only to the risk of flooding during the monsoon season and the challenges of the dry season (watershortage), but also to sun exposure and prevailing wind directions.

The sun can heat up the buildings quickly, creating overheating issues within the apartments. The strongest sunlight comes from the south and west, so these facades should be carefully designed to mitigate heat gain. For example through shading or strategic placement of openings.

In addition, Sylhet experiences its strongest wind forces from the south. To provide natural cross-ventilation, it is crucial to orient windows, towards the south, allowing cooling breezes to flow through the buildings and improve indoor comfort.



48. Climate Conditions Design Site. Source: Author, 2025

12.3. Conclusion: *Housing Preferences*

While the residents are content with their current living situation, which allows them to stay united as a family, they do seek a safer and more stable home. The locals suggested that having a second floor in their homes would be helpful. This would allow them to store important items, such as schoolbooks, above flood levels and provide a shelter during floods. Unfortunately, adding another floor is too expensive for them, and since the land is owned by the railway company, they face extra challenges in making changes in their houses.

Many residents prefer living close to the ground, because they can easily meet their neighbours. So, it's important to design the project in a way that maintains this interaction between residents. However, due to flood risks, placing housing directly on the ground floor is not ideal. Instead, ground-floor spaces are better suited for functions such as shop. Still, it remains essential to provide outdoor areas where people can meet and interact. These communal spaces do not necessarily have to be located at ground level, as long as they are easily accessible and foster social interaction.
Furthermore, the ground level spaces can still function as a place where people can meet eachother, but in a more commercial way.

Furthermore, education for the children is a top priority for the adults, as they are determined to give their children the best opportunities in life. A key advantage of their location is the primary school, which is situated near their homes, as well as a courtyard and a temple on their land. They feel a deep emotional attachment to this place. So, it is important to retain both the temple and the school in the new masterplan.

Furthermore, to mitigate the environmentally driven migration to other areas in Bangladesh it is not only important to secure the dwelling of the residents, but also their workplace, because without a place to work, the residents can not earn money, which will decrease their livelihood significantly and can cause migration to other areas.

The site spans 3 hectares and must also be accesible to the public. During the interview with Jafar Tuhin (2024) he stated that it is important to be close to amenities, such as restaurants, shops, kindergartens, offices and other public spaces. These spaces should be incorporated into the design. Currently, the area is not accessible to the broader public, with many homeless individuals taking shelter under the bridge. Concerns have been raised about safety, making it challenging to visit the site.

Lastly, it is crucial to consider local climate conditions when designing these dwellings to ensure a comfortable indoor environment for residents. This is espicially important in a hot and humid climate like that of Bangladesh.

13. Sub question 2. Seasonal Adaptability Small- and Large-Scale:

How can seasonal adaptability in housing design increase the livelihood of the communities living along the Surma Riverbank?

The key question that will be addressed in this chapter is: "How can seasonal adaptability in housing design reduce the risk of impoverished communities losing their homes and livelihoods due to floodings and erosion?" This will be achieved through interviews with experts in water management and analysis of relevant case studies.

There isn't a single solution for seasonal adaptability; instead, it depends on the specific design site and context. There are multiple different approaches to designing buildings that adapt differently to seasonal changes (Nyilas, Kurazumi, 2017), such as changing dwellings regarding the season, a flexible layout and a smart building envelope.

13.1. Changing Dwellings

There are multiple examples of a dwellings that are adjusted to the seasonal changes. In countries with dry and wet seasons, such as Bangladesh, housing structures that are adjusted to withstand heavy rainfall and flash floods will increase the livelihood of the inhabitants. In this chapter these different typologies will be elaborated.

Amphibious Dwellings

The first structure that will be elaborated is the amphibious dwelling. This structure can rise with the rising seawater, but is also able to stand on dry land. Designing an amphibious housing design offer flexible response to the rising water levels, however the height of the building plays an important role in the feasibility of incorporating this structure in a affordable housing project.

For a floating structure the most important aspect of static stability is the location of the center of gravity. The wind force is the most influential force, since it has generally been regarded to be the main force that must be counteracted. When external forces as wind act on the floating dwelling, the free-floating body tilts due to the heeling moment introduced. The height of the building will influence the balance of the building (Nakajima, T., Saito, Y., & Umeyama, M. 2021).

The most common approach for amphibious dwellings is a single-story design, which allows for flexibility to fluctuation water levels. For a single-story amphibious dwelling it is possible to use low-cost materials, such as plastic waste for the floating machinism.

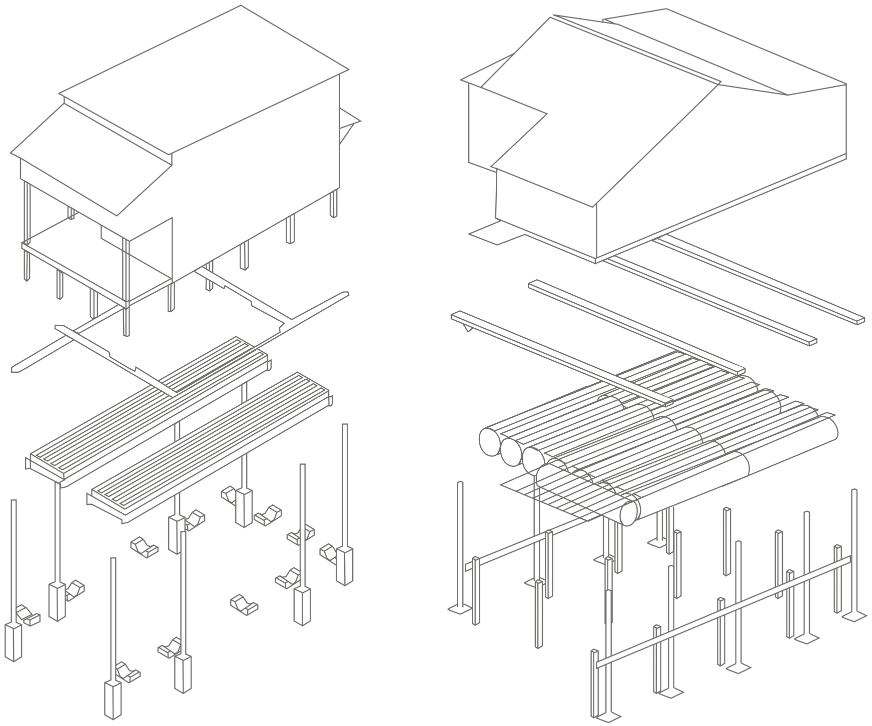
More weight above the floating structure results in a greater load. (Endangsih, Ikaputra, 2020). This static load needs to be well distributed to prevent rotation and tilt of the structure. According to Endangsih and Ikaputra (2020) in planning low-rise floating buildings, it is important to know that the total area available for floating buildings is estimated to be 50% of the floating structure.

In planning high-rise floating buildings, it is important to know about the number of occupants who will live in one flat, the number of floors, floor to floor height, and the total height of the structure. The floating structure will be tilted if the eccentric strength is large, so the building is placed in center of the floating structure (Endangsih, Ikaputra, 2020).

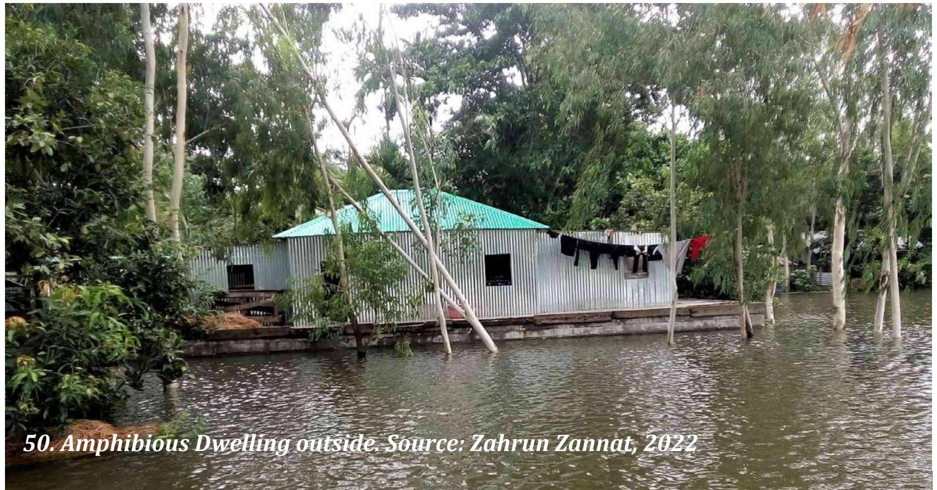
13.1. Amphibious Dwellings

So, it is possible to have a multi-story design of three or more floors. These large-scale floating infrastructures faces several challenges. From a technical perspective, designing structures capable of maintaining stability in dynamic environments presents singnificant engineering hurdles (Won Choi, 2025). From an economic perspective, high initial costs and uncertain long-term benefits will make it more challenging (Won Choi, 2025).

In summary, small-scale amphibious dwellings can be constructed using low-cost materials such as recycled plastic bottles. However, for larger-scale projects, these materials may no longer be structurally or functionally sufficient. As the scale increases, it becomes more challenging to control the center of gravity, requiring the use of more expensive materials. This can make such solutions less suitable for affordable housing developments.



49. Changing Dwellings: Amphibious system. Source: Author, 2024



50. Amphibious Dwelling outside. Source: Zahrun Zannat, 2022

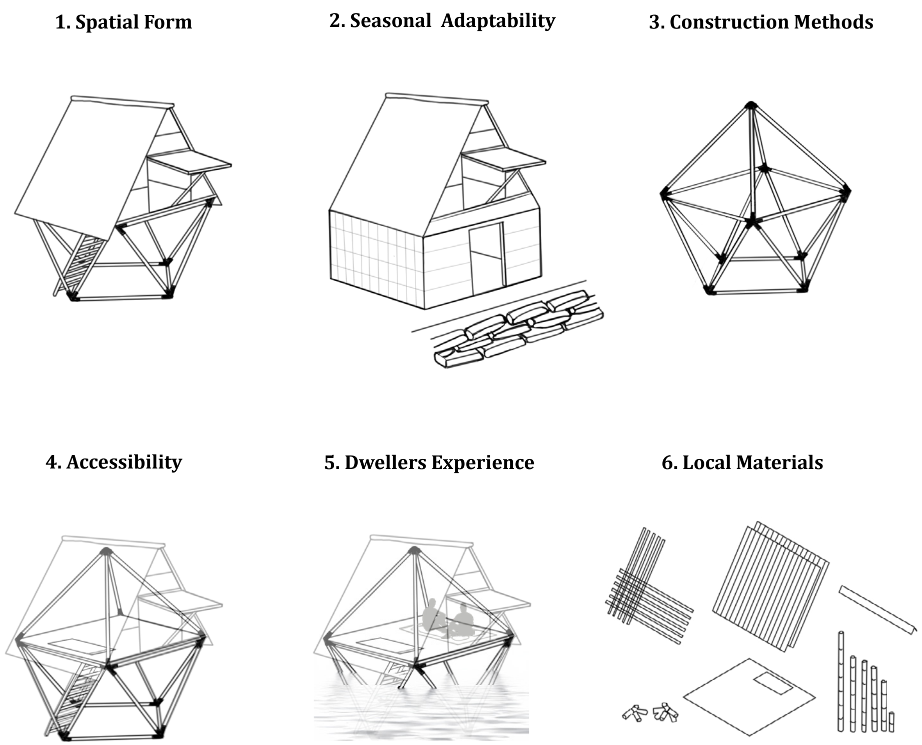
51. Amphibious Dwelling indoors. Zahrun Zannat, 2022

13.2. Structure on Stilts: *Khudi Bari, Small Scale*

The second structure that will be elaborated in this chapter is the structure on stilts. Many impoverished people in Bangladesh build their houses on stilts to withstand heavy rainfall and flash floods.

The Khudi Bari, designed by Marina Tabassum, follows this principle. It allows residents to remain in their dwelling during flash floods, thereby supporting and improving their livelihoods. While this seasonally adaptable approach is well-suited for small-scale structures, it can also be applied to larger-scale projects. However, in such cases, the structure must support greater loads, making it essential to assess whether the columns and overall structural system can safely bear the increased weight.

This will lead to an increase in the overall construction costs. By calculating the material requirements and associated expenses, it will be possible to test whether such a structure remains financially feasible for impoverished communities.



52. Structure on Stilts, Khudi Bari. Source: Author, 2024

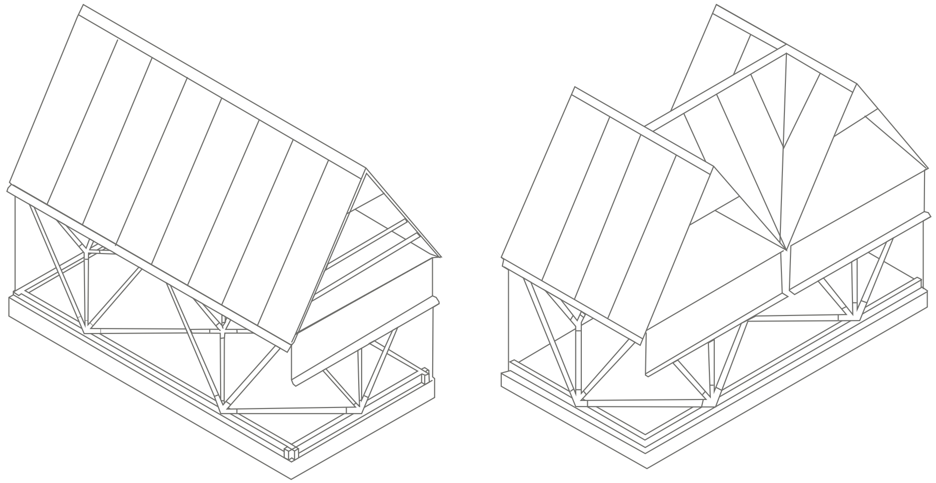
53. Khudi Bari outside. Source: Author, 2024

54. Khudi Bari indoors. Source: Author, 2024

13.3. Modular and Flexible: *Khudi Bari, Small Scale*

The Khudi Bari is not only designed to withstand flooding, but it can also be easily relocated in response to erosion. Thanks to its dry connections, using steel joints to connect the bamboo structure, residents can dissamble the house themselves and reassemble it on safer ground (Canova, C.A. 2024).

Additionally, the modular and flexible design allows the dwelling to be expanded by combining multiple Khudi Bari units. This makes it possible to accommodate larger families while maintaining affordability and adaptability (Canova, C.A. 2024).

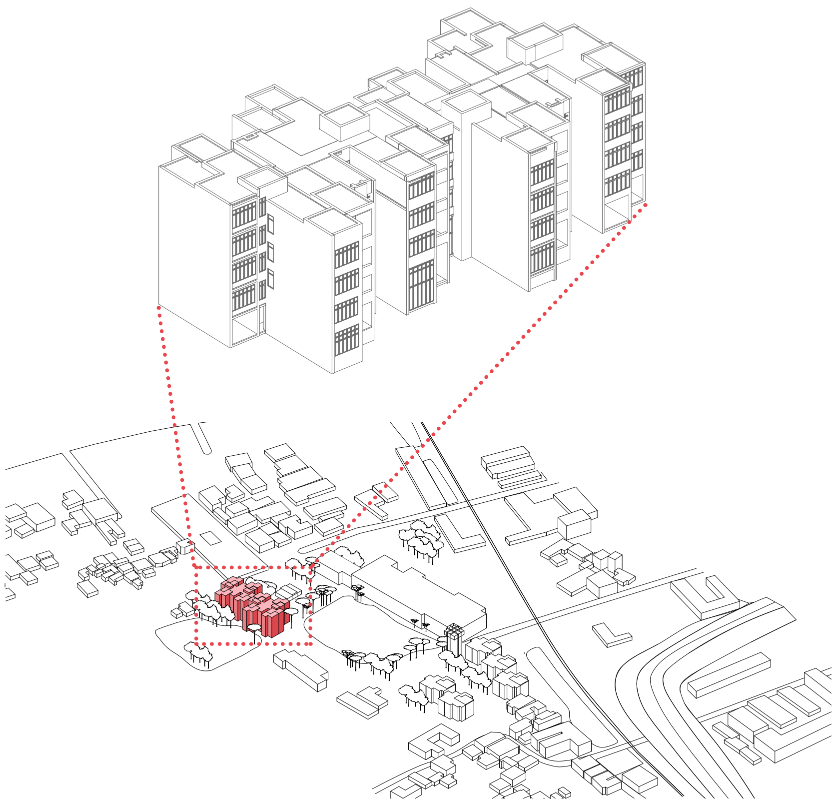


55. Small-scale Modular Building: Khudi Bari. Source: Author, 2024

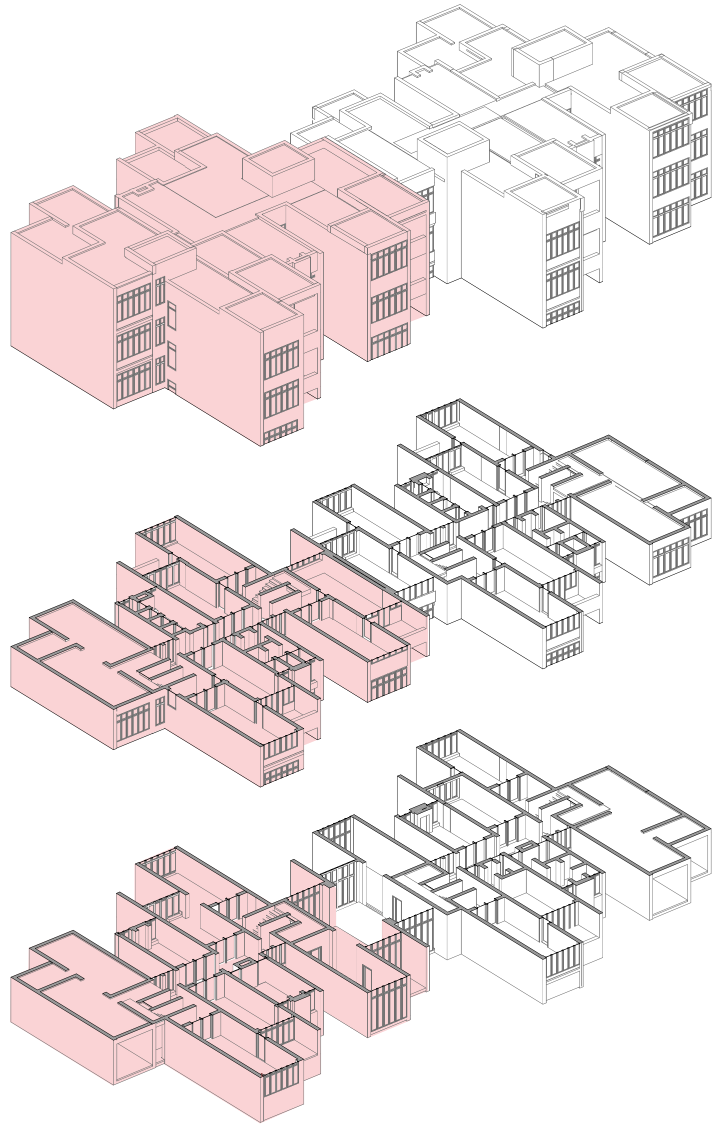
13.4. Modular: *Student Hostel Sylhet, Large Scale*

A similar design approach is seen in the Polytechnic Student Hostel in Sylhet, designed by Muzharul Islam and Stanley Tigerman. The use of repeatable, modular units made the building more efficient, simple and cost-effective to construct. However, unlike the small-scale Khudi Bari, the hostel's permanent materials and high-denisty layout make it far less flexible when it comes to relocation in response to environmental risks such as erosion. However the private spaces, such as bedrooms, are situated on the upper floors and the public areas are on the groundfloor, which provides shelter in their bedrooms during a flooding

Using a modular approach in the design of a high-density project enhances construction efficiency and reduces overall building costs.



56. Polytechnic Student Hostel in Syhet. Source: Author and Coco de Bok, 2024



57. Large-Scale Modular, Polytechnic Student Hostel in Syhet. Source: Author, 2024

13.5. Flexible Layout: *Student Hostel Sylhet, Large Scale*

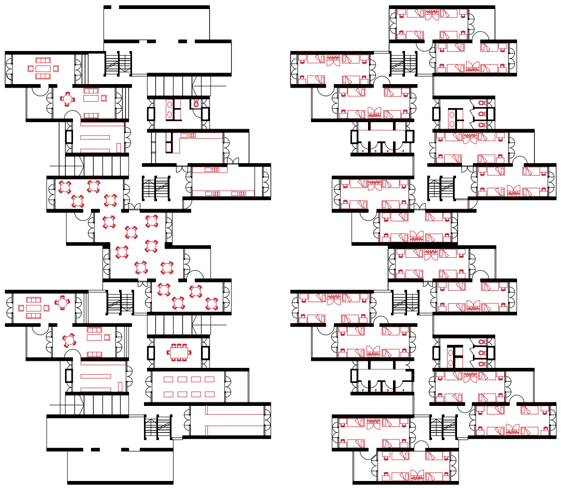
Furthermore, by implementing a flexible layout in the building the indoor climate can be optimized in extreme climate conditions. Strategies like changing bedrooms, limiting bedroom only to sleeping or rearranging the room layout seasonally have been commonly used for making the livelihood more comfortable in the hot-summer/cold-winter zone (Nyilas & Kurazumi, 2017).

There are several key considerations that are important for designing structures for hot summers. The heat and intense sunlight can have a significant impact on the comfort and functionality of a building, making it crucial to adapt the design accordingly. It is important to employ passive cooling techniques such as natural ventilation, shading devices and reflective materials to minimize the need for excessive air conditioning (Admin, 2023).

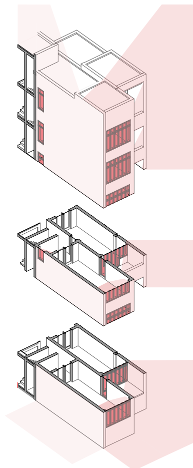
One important aspect is the building's orientation. By strategically positioning the structure to the path of the sun, it is possible to minimize the amount of direct sunlight that enters the building during the hottest parts of the day. This can be achieved through the use

of shading devices, overhangs and louvers, which help to block the direct sunlight while still allowing natural light and ventilation from entering the building (Admin, 2023).

Furthermore, when it comes to extreme wind conditions it is important to desgin the structure to have a streamlined shape, implementing wind resistant materials, and implementing structural systems that can absorb and dissipate wind forces (Admin, 2023). These strategies are also used in the casestudy, the Student Hostel in Sylhet.



58. Floorplan, Polytechnic Student Hostel in Syhet. Source: Author, 2024



59. Sunlight within the Unit: Source: Author, 2024

60. Polytechnic Institute Student Hostel Sylhet. Source: Google Maps

13.6. Smart Building Envelope: *regarding heat and wind*

A potential solution to the changing conditions of the extreme climate conditions could be the seasonal adaptable smart building envelope. There are different examples of a smart building envelope, such as a removable skin, a double skin facade, a self-orienting solar roof , movable elements in the facade, Brise Soleil, and the use of smart materials within the facade (Nyilas & Kurazumi, 2017).

Removable Skin
The first proposal, the removable skin, provides an extra building layer for the winter and can be adjusted or removed within the summer to enhance a cooler climate. The sliding skin can be moved to cover up parts of the building. The air inside the facade can be kept warm in winter (Nyilas & Kurazumi, 2017).

Double Skin
The second proposal, the double skin facade, has a ventilated cavity, which can have a width which range from several centimetres to several metres. The movement of the air within the cavity can be controlled mechanically and helps the building to adjust to different climate conditions. In the summer fresh air enters the cavity between the two skins. As it warmed up by the sun through the outside glass skin the air will raise and leaves from between the double skin at the top of the facade. This way of airmovement reduces the amount of energy necessary for cooling. In the winter, the upper side of the cavity can close automatically. The air layer also works as insulation, reducing the amount of necessary energy for heating (Nyilas & Kurazumi, 2017).

Self-orienting Solar Roof
The third proposal, a self-orienting solar roof, is discused. This roof is based on the recognition that the angle of the roof should be flexible to catch the maximum amount of solar energy (Nyilas & Kurazumi, 2017).

Moveable parts on facade
The fourth proposal, moveable parts on glass facades, called a Brise Soleil, will reduce heat gain by shading glass facades in hot summers. The moveable panels works as a curtain wall that respond to the movement of the sun in order to reduce solar gain within the building (Nyilas & Kurazumi, 2017).

Smart Materials
Furthermore, the proposal of smart materials is a way of seasonal adaptability. These materials can react to its environment by itself, without using electronics. Smart materials can respond to a change in temperature, stress, electrical current of magnetic field, which can cause a change in volume, colour or viscosity (Nyilas & Kurazumi, 2017).

Stack-effect (ventilation)
Another proposal, for a large-scale building envelope would be to implement the stack-effect within the building, to provide a better air-circulation within the building. When two high buildings are standing close to eachother the poluted air from one apartment can enter the next apartment, which is not preferable. So by implementing holes in the gallery of the building and designing one of the sides of the building higher then the other building the poluted air can go out of the building and new fresh air will enter the next apartments (Onsharp. Admin, 2019).

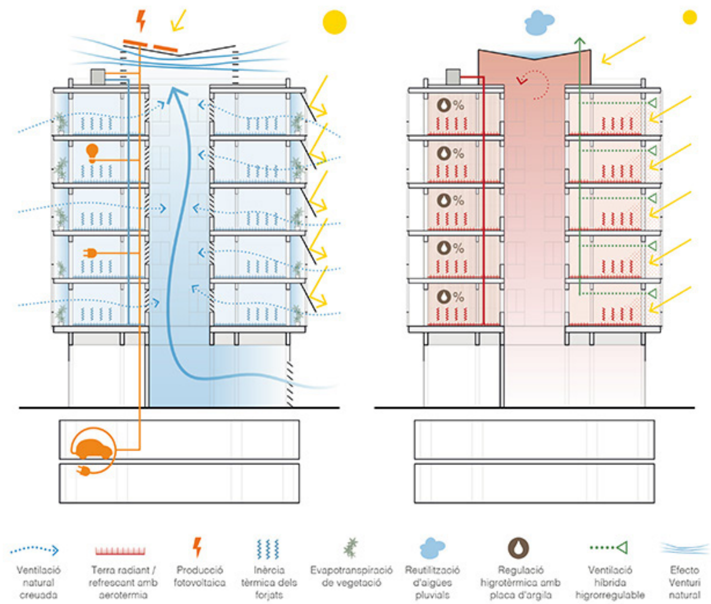
Stack-Effect

The air movement is caused by thermal differences. Higher-temperature air is less dense than cooler air. As the warmer air rises, it creates a pressure difference, with lower pressure below and higher pressure above (Therma, 2021).

During the winter, the lower pressure allows cooler air from outside to move into the bottom floors. During the summer, the stack effect is reversed. The hot air outside enters the upper portion of the cooler building and creates a draft down (Therma, 2021).

In a single-story, single-family residence the effect may be unnoticeable. But in a tall high-rise building the stack effect is significant and should be considered in the design (Onsharp.Admin, 2019).

Furthermore, when a fire would occur within the building the smoke and hot air rise up and will go out of the building (Onsharp.Admin, 2019).



61. High-rise building, with and without Stack-Effect. Source: Estudio DIIR for INCASOL

13.7. Watermanagement: *Protection Riverbank Erosion*

An affordable solution for protecting riverbanks against erosion is the use of sandbags. This method is widely used across Bangladesh, particularly by low-income communities living in erosion-prone areas. Sandbags are relatively easy to obtain, transport, and install, making them a practical choice for immediate and low-cost protection. While they may not offer the long-term durability of engineered structures, sandbags provide a crucial buffer against riverbank collapse during monsoon seasons, helping residents safeguard their homes and livelihoods with limited resources available to them.
This small-scale solution may not require the terms for a large scale housing project. So a different solution needs to be implemented in a large scale housing project to protect the houses from collapsing.

62. House collapsed due to erosion. Source: Author, 2024

63. Sandbags as protection against floodings and erosion. Source: Author, 2024

13.7.1. Watermanagement Riverbank: *Interview*

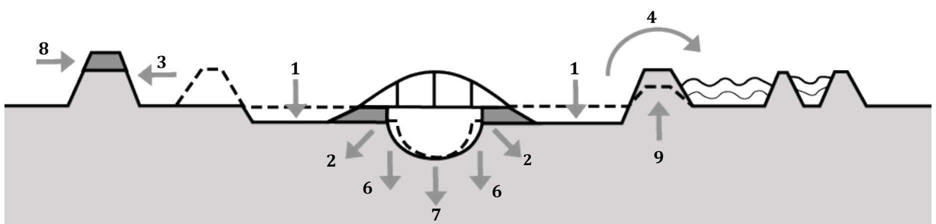
To investigate how the riverbank can be protected for a large scale housingproject an interview was conducted with Dipak Ranjan Dash, the Executive Engineer, at the Water Development Board Office in Sylhet. This was done in collaboration with Joelle Steendam, Lida Chrysi Ganotaki and Danai Makri, focused on the development of the riverbanks in Bangladesh. In this interview more insights in how the riverbank can be protected will be elaborated.

Strengthen the Riverbank with Concrete
Ir. Dipak Ranjan Dash and his team are working on a project aimed at reducing the impact of flooding in Bangladesh. They are protecting the riverbanks and surrounding land from erosion by reinforcing the banks with cement concrete blocks measuring 40 cm by 40 cm, which are designed to las for 50 years. So far, they have succesfully implemented this solution at 100 points along the rivers. However, according to Ir. Dash, these solutions are costly, making the project highly dependent on funding from the government. Additionally the governmet's slow approval process complicates their ability to determine when - and even if - they can begin the work.

Ir. Dash outlined nine strategies for managing rising river water levels, which are based on approaches used in the Netherlands. These strategies are part of the project "Room for the River", which has been successfully implemented along the Waal river in Nijmegen.

Room for the River
In the "Room for the River" research, nine strategies were employed to manage rising water levels, including: (1) lowering of the floodplains, (2) removal of obstacles, (3) relocation of the dyke, (4) waterrentention and storage, (5) adding a by-pass, (6) height reduction of groynes, (7) deepening the summer bed, (8) heightening of the dykes and (9) dyke improvement.
However, in Bangladesh, only strategies 7 (deepening of the summer bed) and 8 (heightening of the dykes) are being implemented due to limited available land. By excavating the surface of the river bed, the depth is increased, providing more space for the river to flow. In areas where creating more room for the river is not feasible, heightening and strenghtening the dykes is an alternative solution to prevent the water from overtopping the banks. (Verweij, 2021)

According, to Ir. Dash it is already challenging to implement these two strategies effectively, as many people are constructing homes and businesses along the riverbanks due to a lack of empty land



64. Strategies, Room for the River. Source: Author, 2024

and overpopulation. This makes it difficult for those living on the riverbanks to find available land further away from the river to relocate.

Suggestion
Ir. Dash has strongly advised against building homes directly on the riverbanks, as the river has the natural right to change its course each year. However, rivers are losing their natural floodplains and property due to the increasing number of people constructing homes along the banks. Therefore, Dash suggests that people should build their homes at least 200 to 300 meters away from the river. Additionally, homes should be designed to be sustainable and easily relocatable in case of an emergency. Lastly, elevating the homes above ground level is recommended. According to Dash, these measures will provide residents with safer land that can remeain viable for at least 20 to 30 years.

According to Ir. Dash, community involvement is crucial for the succes of water management strategies. Educating the population about how they can benefit from these development projects is key. Currently, many residents focus only on their own immediate interests, rather than considering the development of the country. The municipality is working hard to raise awareness, but unfortunately, moest people remain uninterested in collaborating on these issues.

65. Strengthen Riverbanks, Bangladesh. Source: Asaduzzaman Akash, 2020

13.7.2. Watermanagement Strategies: *Interview*

This sub-chapter explores what kind of water management strategies already are happening in Bangladesh to prevent communities from losing their land due to floodings and erosion. Different kind of strategies will be discussed, whereby some strategies are permanent, but also how seasonal adaptability in housing design can help impoverished communities with keeping them safe.

Solutions regarding water management regarding the riverbank erosion, agriculture and housing, which are investigated through interviews with experts on this field and casestudies from Bangladesh, the Netherlands and Thailand. These are important for designing a resilient housing strategy.

Irrigation and Water Management
At the Sylhet Agricultural University (SAU), an interview was held with Dr. Ashutus Singha and Dr. Pijush Kanti Sarkar, both working at the Department of Irrigation and Water Management. These conversation, conducted with Joelle Steendam, Lida Chrysi Ganotaki and Danai Makri, focused on the impacts of flash floods on agriculture in Bangladesh and the measures available to mitigate crop failure caused by such events. Furthermore, in this interview some key considerations about the water management systems into housing design in flood-prone areas are mentioned.

Moreover, floodings does not follow a predictable pattern anymore. Flash floods can occur at different times during the wet season, making them highly unpredictable. Flooding is a common occurrence each year, but the timing of these events remains uncertain, with water levels sometimes rising by as much as three meters.

When water flows through steep areas, it causes erosion, while in flatter regions, the velocity decreases, leading to siltation. During flash floods, the water velocity is particularly high, which can exacerbate erosion. Additionally, people often thake soil from one area and deposit it elsewhere, a practice that is harmful to both the environment and the land. A potential solution to mitigate these issueas is strengthening the riverbanks. However, this presents a significant economic challenge due to the large numbers of rivers in Bangladesh (Sarkar and Singha, 2024).

According to Dr. Pijush Kanti Sarkar there are some challenges regarding the design site next to the Surma River, such as the small-scale agriculture and the dumping of trash in the water. On the design site there are some small agricultural plots that will get flood during the rainy season, whereby agricultural losses can happen. These riverbank plots are only used temporarly for cultivation. Unfortunately, this temporary farming contributes to the weaking of the riverbanks, increasing the risk of erosion.

To mitigate agricultural losses, some measures have been implemented, such as growing short duration, low-yielding crops. These crops are typically planted in January and harvested by the end of April.

However, farmers generally prefer to cultivate smaller areas with high-yielding varieties. While these varieties offer higher returns, they have a longer growing season, making them more vulnerable to flash floods.

Another issue on the design site is the dumping of trash into the river, which will weaken the rivers. Many people remain unaware of the direct and indirect consequences of this behavior, and it continues to be a common practice.

What are the key considerations for integrating water management systems into housing in flood-prone areas?
Integrating water management systems into housing in flood-prone areas requires a combinaiton of structural, functional, and community-oriented considerations to enhance resilience and sustainability. Structurally, housing should be elevated on stilts or raised platforms to protect it from floodwaters while incorporating water storage systems, such as elevated tanks, to ensure access to clean water during floodings. Rainwater harvesting systems should be integrated into roofing designs to provide a reliable source of water for domestic and agricultural use. Drainage systems must be designed to prevent waterlogging around the house, with proper outlets to channel excess water into nearby canals or reservoirs.
Functionally, homes should be equipped with flood-resistant sanitation facilities, such as raised latrines, to minimize contamination during floods. Water filtration systems, either portable or built-in, are critical for ensuring safe drinking water. Solar-powered pumps can provide energy-efficient irrigation and water supply solutions during flood recovery periods (Sarkar and Singha, 2024).

Are there specific floor-resistant water storage or irrigation systems that have proven to be effective in rural Bangladesh?
Several flood-resistant water storage and irrigation systems have proven effective in rural Bangladesh (Sarkar and Singha, 2024).

1. Raised tube wells instaled on elevated platforms ensure access to safe drinking water by protecting the wells from contamination and submergence during floods.
2. Rainwater harvesting systems, which collect water from rooftops into elevated tanks, provide a reliable source of water for domestic and agricultural use when other sources are inaccessible.
3. Floating water storage tanks, made from lightweight materials like plastic drums, remain operational even during prolonged flooding.
4. Solar-powered irrigation systems, often installed on reaised platforms, are gaining popularity for their ability to provide sustainable and cost-effective water solutions, especially after floods when conventional systems may be damaged.
5. Submersible pumps are also widely used to extract water from submerged areas for irrigation or to drain flooded field.
6. Additionally, community-based elevated water reservoirs serve as shared resources for irrigation and household needs, enhanving resilience in areas with limited infrastructure.

13.8. Conclusion

This chapter has explored how seasonal adaptbility in housing design can mitigate the risk of impoverished communities losing their homes and livelihoods due to flooding and erosion. Through expert interviews, analysis and case studies it becomes clear that there is no one-size-fits-all solution. Instead, a context-specific, multi-scalar and integrated design approach is essential.

Small-scale amphibious dwellings and stilt house like the Khudi Bari, show great promise for individual families, offering affordability, resilience and flexibility to relocate in response to erosion. However, for scaled-up housing projects, many technical challenges, such as ensuring static stability, controlling the center of gravity, and meeting load requirements, demand more advanced materials and structural systems, which increase in costs. This tension between affordability and structural feasibility must be balanced in large-scale developments.

Innovations in modular construction and smart building envelopes, such as double-skin facades and passive ventilation strategies combined with the stack-effect, further demonstrate how climate-responsive architecture can improve comfort and reduce energy demands and costs across the seasons in a large-scale housing project.

From the water management perspective, strengthen the riverbanks with concrete blocks or the strategies used in ‘Room for the River’ provides valuable long-term protection. However, these measures are resource-intensive and often depend on government funding.

Incorporating resilient water systems, including elevated tube wells, floating tanks, rainwater harvesting and solar-powered irrigation, into housing design is another crucial layer of adaptability. These systems ensure continued access to water, hygiene and food security in extreme weather events.

In summary, seasonally adaptable housing can be made affordable for impoverished communities within large-scale housing projects, not necessarily by altering the building each season, but by integrating passive design strategies, such as the combination of cross-ventilation and the stack-effect. These strategies create safe, comfortable living environments that allow residents to find shelter within their own homes throughout the year.

14. Sub-question 3.

To what extent can a seasonal-adaptable housing design for the impoverished communities along the Surma riverbanks be densified to address the increasing population of Sylhet?

14. Seasonal Adaptability Large Scale: *Introduction*

The key question that will be addressed in this chapter is: "To what extent can a seasonal-adaptable housing design for the impoverished communities along the riverbanks be densified to address the increasing population of Sylhet?

This question will be addressed through an architectural design fitted to the Surma Riverbank site. This design site was chosen for several key reasons:
- It offers strong potential for densification, which is essential in addressing environmentally driven mass migration.
- It is highly vulnerable to flash flooding, requiring seasonal adaptable design solutions.
- It is currently inhabited by an impoverished community, Sweepers Colony, in urgent need of safer and more secure housing.

These three key reasons are important, because it will help with answering the research question: "How can **environmentally driven migration** be reduced by implementing a **high-density** and **seasonal-adaptable** housing design for the **impoverished** Hindu and Muslim communities living along the erosion-prone Surma Riverbank in Sylhet?"

To address this question, a set of design principles has been established to guide both the design process and the underlying research. The approach begins with general principles for the masterplan, outlining the basic foundations of the project. To specifically respond to the issue of affordability for the impoverished communities living along the Surma Riverbank, additional design principles have been developed for different income groups, based on insights gatherd from interviews and case studies.

Implementing these principles requires initial material research to identify the most suitable and cost-effective materials for creating a highly densed, affordable and seasonal adaptable housing solutions.

14.1.
Design Principles

14.1. Design Principles: *Large-Scale, Affordable and Seasonal Adaptable*

Combining a highly dense and affordable masterplan with seasonal adaptability presents a significant design challenge. Incorporating a floating system beneath a large-scale building is costly, as the larger the structure, the more complex and difficult it becomes to ensure its stability. So, the seasonal adaptability will be implemented within the building in a more permanent way.

Given that the site is highly vulnerable to flooding and erosion, the design emphasizes seasonal adaptability and long-term climate resilience. While small-scale solutions such as amphibious or flexible modular housing offer flexibility, they are not well-suited for achieving the higher densities envisioned on the site. Instead the masterplan adopts a more permanent approach. One capable of withstanding extreme weather conditions, including heavy rainfall, flash floods and ongoing erosion.

Riverbank
In an interview with watermanagement engineer Dipak, it became clear that strengthening the riverbanks permantly with concrete is essential to reduce erosion risks. this measure will be implemented as part of the project, with government support and funding.

Adaptability
To make the dwellings both resilient and adaptable, the design includes a floodable plinth at the base of each building. Critical spaces such as kitchens and sanitation facilities are elevated within the plinth to protect them from floodwaters. The plinth itself will be constructed using water-resistant materials designed to withstand the seasonal fluctuations of the water without structural damage.
Residential units will be located above the plinth, safely elevated above flood levels, so the residents can find shelter in their dwelling itself and the sanitation and important stuff, such as schoolbooks are protected against the floodings. The overall structure will be built with reinforced concrete, chosen for its high strength and durability in extreme conditions. Combined with the stabilized riverbank made out of concrete, this ensures the buildings are protected against both flooding and erosion over time.

Indoor Climate
Furthermore, to design a comfortable indoor climate for the residents passive systems, such as shading via shutters and loggia's and cross-ventilation in combination with the stack-effect will be implemented within the design. These passive systems are cost-effective which makes the building more affordable for the residents.

However, to ensure the design remains affordable across different income groups, specific choices have been made based on each group's financial capacity. Insights from case studies and interviews have played a key role in shaping the design principles to affordable housing for low-, middle-, and high-income groups.

14.1.1. Design Principles: *Low-income group*

From various case studies, it became clear that many low-income families live in extremely cramped conditions, sometimes with just 4 m2 space per person. To offer a more comfortable yet still affordable solution, the proposed units will provide around 10 m2 per person, offering a better quality of life while keeping costs manageable.

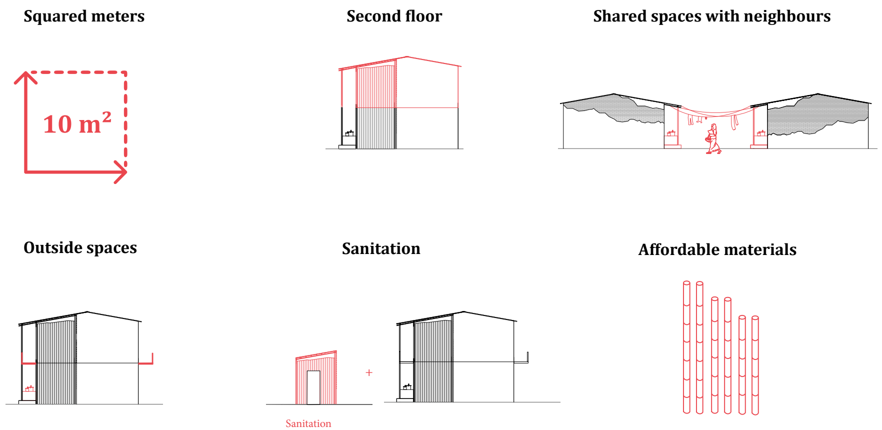
An important insight from a local resident emphasized the need for safe shelter within the building. The families who are living on the design-site right now are forced to live on the streets three times a year, due to floodings. To address this, the desing focuses on resilience, by placing kitchens and sanitation areas above ground level to reduce the risk of health issues due to floodings.

Social life is also an important aspect of the community. Residents value spending time with neighbours and family outdoors, but because private outdoor space is limited due to their budget, shared outdoor and communal areas are included in the design. These shared spaces aim to increase comfort in the extreme heat in Bangladesh and encourage social interaction with their neighbours.

Another important factor is the building's location and the opportunity it provides for residents to work locally. By placing the building closer to the main street, it ensures easy acces to the shops in the plinth.

Material choice is another key factor in keeping housing affordable. By using cost-effective and locally available materials, construction costs can be kept low, making the homes more accessible to those with lower budgets.

To make housing even more affordable for the lowest-income families, a cross-subsidization strategy is used. This means higher-income residents help offset the housing costs for lower-income groups, allowing the most vulnerable people to access decent and secure homes.



66. Design Principles, Low-income group. Source: Author, 2025

Case studies Low-income

For the low income housing analysis, four case studies were examined: the slums in Dhaka, Geneva Town in Dhaka, village housing in Ekduaria and workers' housing in Ekduaria. These studies revealed that, on average a low-income family has about 4 m2 of living space per person and often shares sanitation facilities with multiple families, which can lead to health-related issues.

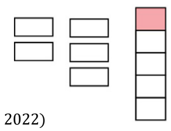
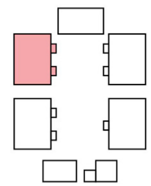
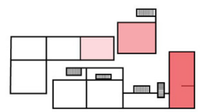
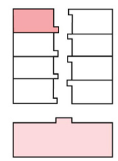
Low income Housing	Location	Surface	Sanitation	Diagram of the floorplan
	Slums, Dhaka	9m2 for a family of 4 persons (1:2.25)	1 toilet for 50 people	 (Nobel, S. 2022)
	Village Housing, Ekduaria	15 m2/ 20 m2 (1:5) for a family of 3 to 4 persons	One shared toilet, shower and kitchen for 15 people	
	Small part of Geneva Town, Dhaka	48 m2 for a family of 10 persons (1:4.8)	Shared sanitation: 270 toilets for 25,000 (1:93) in the whole Geneva town	 (Rashid, M. U. 2020)
	Workers Housing, Ekduaria	10m2 for a family of 4 persons (1:2.5)	Two shared toilets for 32 persons	

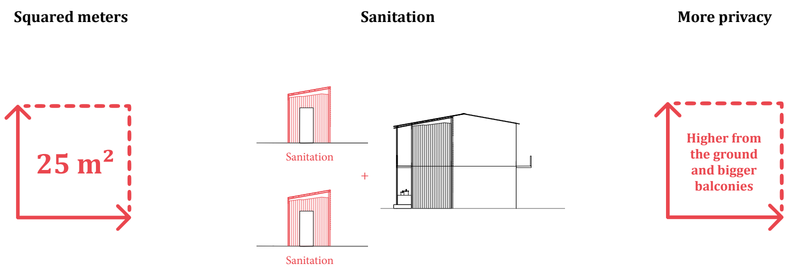
Table 1. Low-income Housing. Source: Author, 2024

14.1.2. Design Principles: *Middle-income group*

Analysis of case studies shows that middle-income housing typically provides around 17 m2 of living space per person. To enhance comfort and livability even more, the proposed dwellings will offer approximately 25 m2 per person.

In line with the needs of middle-income families, the design includes private bedrooms for children, as well as more private outdoor spaces such as loggia's and more sanitation. Fewer shared communal areas will be incorporated, reflecting a greater preference for privacy within this income group.

Additionally, the dwellings will be positioned closer to the river, offering improved views and a more desirable location for this group.



67. Design Principles, Middle-income group. Source: Author, 2025

Case studies Middle-income

For the middle income housing analysis, three case studies were examined: the Bangla Baton House, the Mud housing, nearby Ekduaria and the Kazedewan Apartment in Dhaka. These studies revealed that, on average a middle-income family has about 17 m² of living space per person and do not need to share sanitation and kitchens with other households. It is common for family members to share bathrooms within the household.

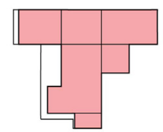
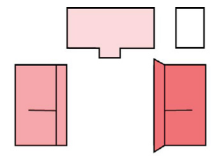
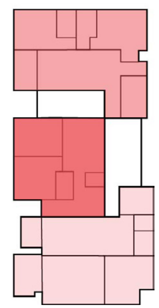
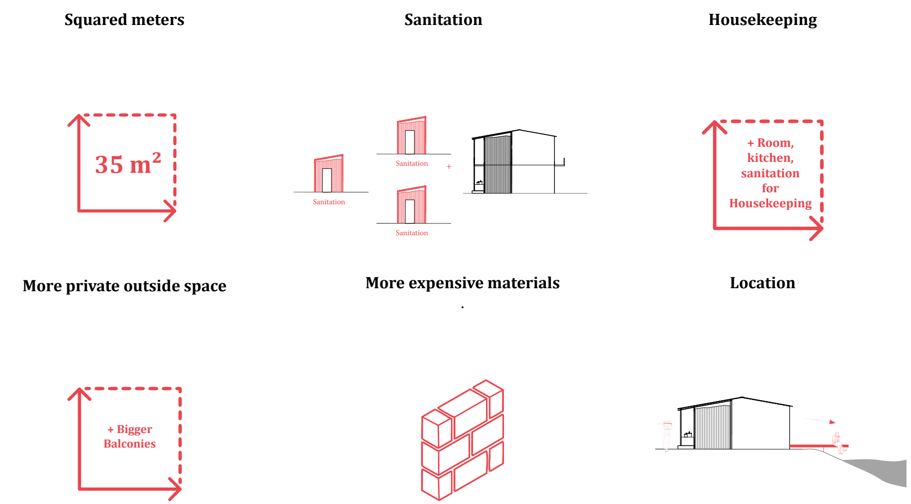
Middle income Housing	Location	Surface	Sanitation	Diagram of the floorplan
	Bangla Baton House	50m2 - 150 m2 for a family of 4 to 10 persons (1:14)	incl. sanitation and kitchen	
	Mud Housing, nearby the village Ekduaria	30 m2 for 1 a 2 persons (90m2 for family of 4) (1:22.5)	incl. sanitation and kitchens	
	Kazedewan Apartment, Dhaka	50 - 60 m2 for a family of 4 persons (1:13.75)	incl. sanitation and kitchen	

Table 2. Middle-income Housing. Source: Author, 2024

14.1.3. Design Principles: *High-income group*

The final group accommodated on this site is the high-income group. As they play a key role in supporting the provision of adequate housing for lower-income residents through cross-subsidization, it is important that they receive appropriate value in return. Their dwellings will offer larger floor areas, generous private outdoor spaces, multiple bathrooms/sanitation, guestrooms, higher quality materials, a more preferable location with a direct view on the river and optional services such as housekeeping to meet the lifestyle expectations of this group.

Case study analyis shows that high-income housing typically offers around 35 m2 per person. In this project, that space will be increased to approximately 45 m2 per person to provide a higher level of comfort and meet the expectations of the target group even more.



68. Design Principles, High-income group. Source: Author, 2025

Case studies High-income

For the high income housing analysis, two case studies were examined: The Government Housing in Dhaka and the Kalindi Apartment in Dhaka. These studies revealed that, on average a high-income family has about 30 m² of living space per person and do not need to share sanitation and kitchens with other households. It is common for family members to have their own private toilet and/or shower as well.

To conclude the income analysis it is compared to the average livingsurface per person in the Netherlands, which is 53 m2 per person (Centraal Bureau voor de Statistiek, 2018). This shows that the average surface amount is way lower in Bangladesh. To meet the preferences more of the residents the amount of floorspace will increase a bit.

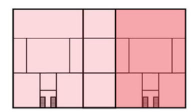
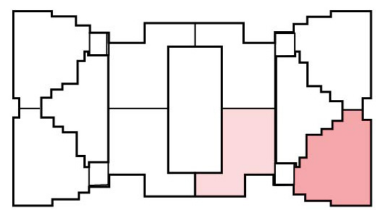
Middle income Housing	Location	Surface	Sanitation	Diagram of the floorplan
	Government Housing, Dhaka	80 m2 - 100 m2 for a family of 4 persons (1:22.5)	incl. sanitation and kitchen	
	Kalindi Apartment, Dhaka	150 - 200 m2 for a family of 4 to 6 persons (1:35)	incl. sanitation and kitchens	

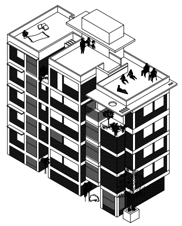
Table 3. High-income Housing. Source: Author, 2024

Low income	**Middle income**	**High income**	Average Surface per person
Average Surface per person Shared facilities	Average Surface per person	Average Surface per person	in the Netherlands
3,6 m2 per person	16,8 m2 per person	28,8 m2 per person	53 m2 per person

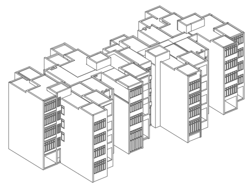
14.2. Design Process

14.2.1. Design Process: *P1 presentation, Pilot Project*

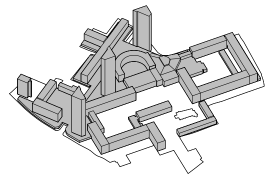
To explore the potential of a large-scale project for the P1 presentation, I investigated how a Floor Space Index (FSI) of 4,5 would be applied to a 1-hectare plot using three existing case studies from previous research, namely the Student Housing in Sylhet, the apartmentcomplex Kazedewan in Dhaka and the Barbican in London. This challenge was to design a livable environment within such a high-density context using by mixing existing buildings. By designing a single housing "pixel" and duplicating it, I was able to test various compositions and assess whether such repetition would be feasible and spatially effective. This exercise provided valuable insight into what level of floor squared meters constitutes a densely built-up area, and how to balance density with quality of life.



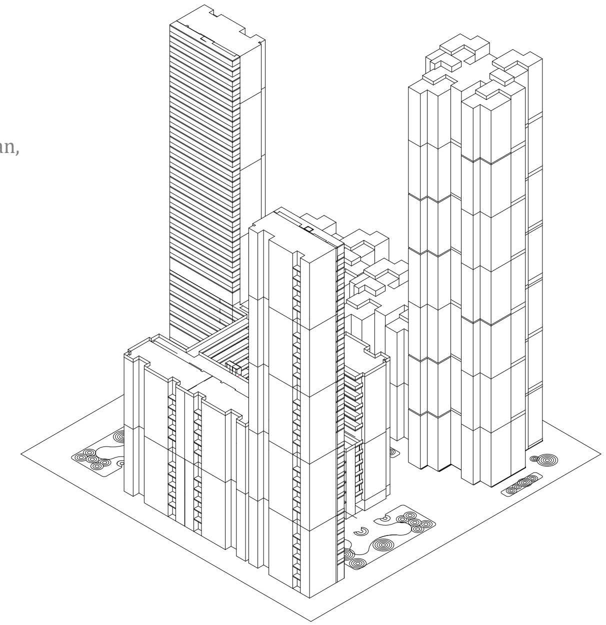
69. Kazedewan Dhaka.
Source: Makri, Ganotaki, Schuurman, 2024



70. Student Hostel Sylhet.
Source: Author, 2024



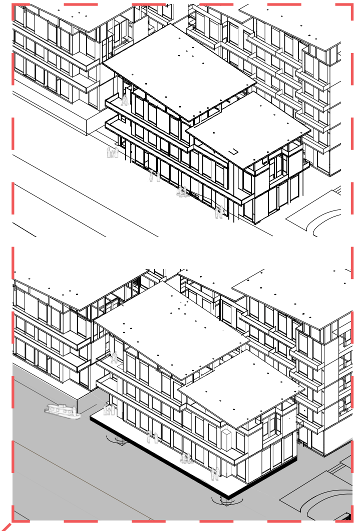
71. Barbican London.
Soure: Wijnen, 2024



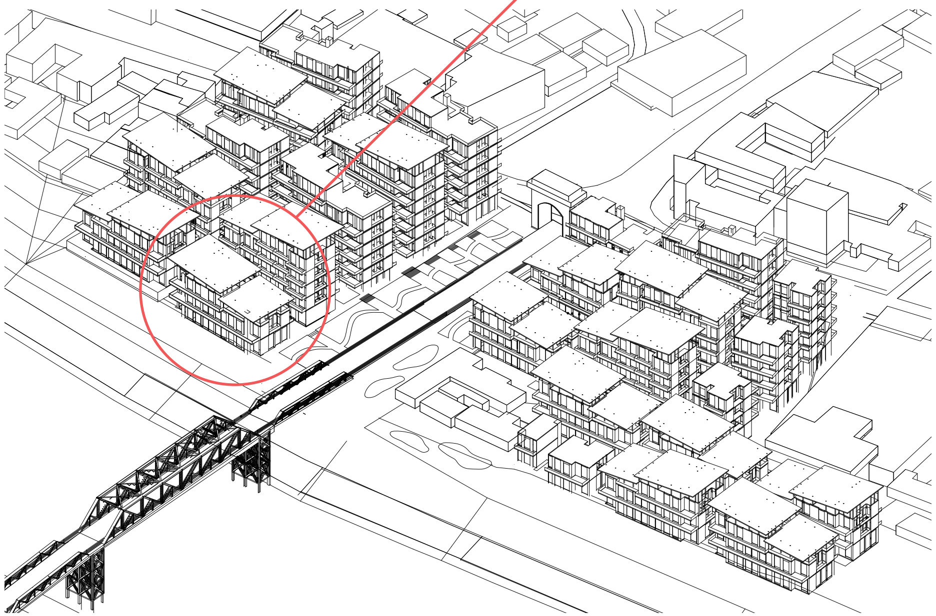
72. Pilot Project.
Source: Author, 2024

14.2.2. Design Process: *P2 presentation, amphibious dwellings*

After visiting the design site and selecting the location, initial attempts were made to develop a large-scale, affordable and seasonally adaptable design. However, implementing amphibious dwellings on this site revealed significant challenges.
It became clear that this system is not viable in a context where many residents must be accommodated at an affordable cost, resulting in large and heavy buildings. The floating structure would need to suppot substantial weight, making it difficult to ensure stability without the use of expensive and technically advanced floating systems.
Furthermore, the design site experiences flooding of only 80 cm, making it possible to address the issue with more affordable and practical solutions. As such, the amphibious approach is not suitable given the specific conditions of the site.



74. Apartment Complex, on land and on water. Source: Author, 2025



73. Masterplan P2. Source: Author, 2025

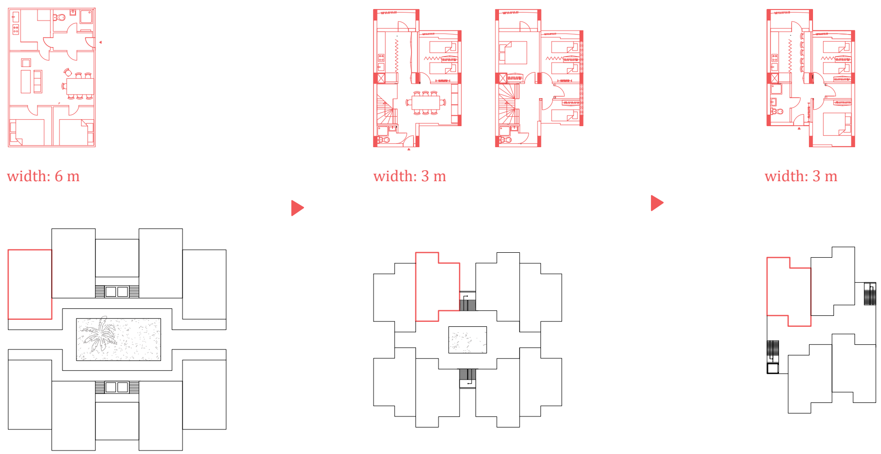
Design Process: *P3 presentation*

The focus shifted from amphibious dwellings to permanent modular construction, using specific measurements to develop unit types tailored to different income groups and the size of the family, so the masterplan could facilitate a divers group of people. The designprinciples based on the preferences of the different targetgroups are implemented in the units.

The apartment design begins with two base modules: a public unit, kitchen and sanitation, and a private unit, bedrooms, each measuring 3000 mm by x mm. While the width of the units is fixed, the length can be adjusted depending on the household size or income group, allowing for flexible and adaptable layouts.

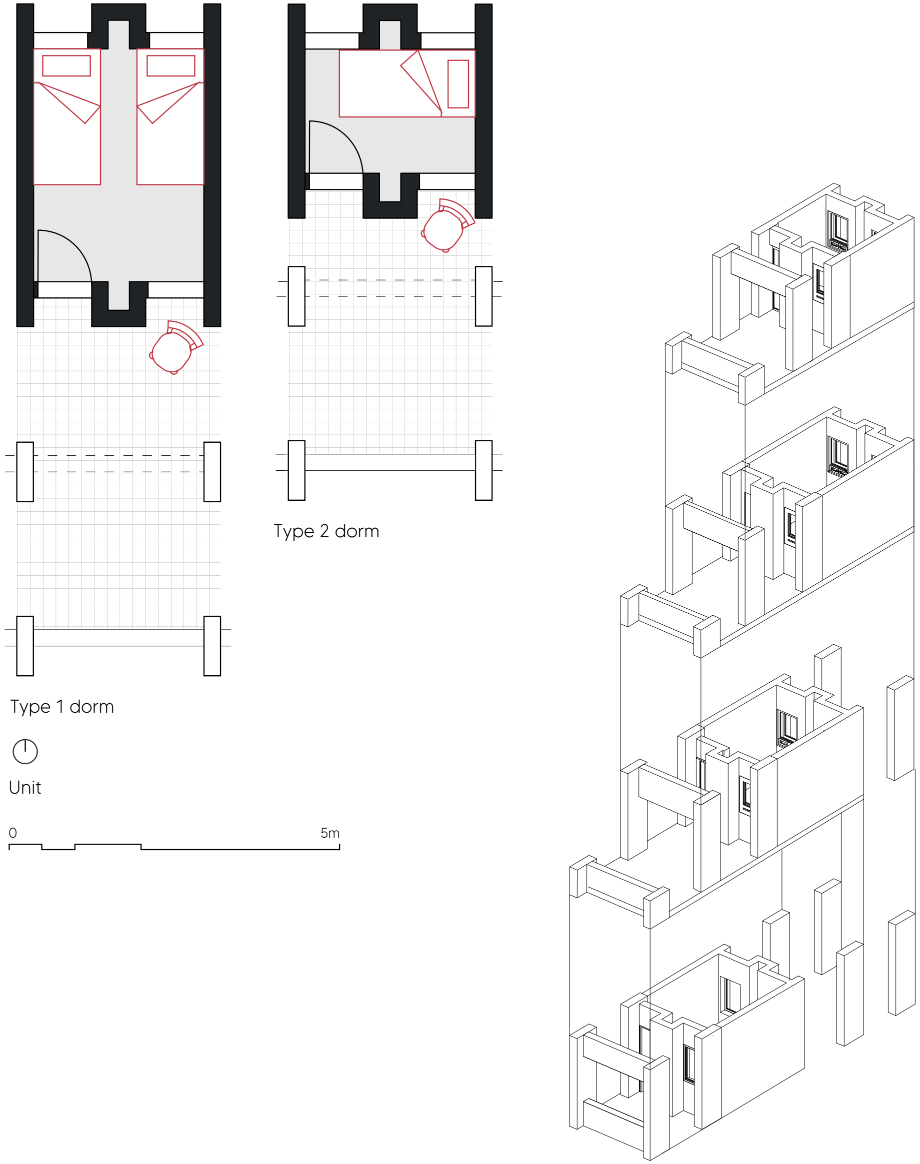
The feedback from the P3 presentation highlighted that the modules were too narrow and that a better balance between public and private spaces within the units was needed.

Furthermore, the clusters were arranged around a central courtyard, but the design was found to lack variety and playfulness. To make the design more interesting, inspiration was drawn from examples like the student Hostel in Sylhet and the Student Hostels at Chittagong University, which demonstrates a more dynamic and engaging spatial composition with setbacks in the facade, shown in image .... and ....



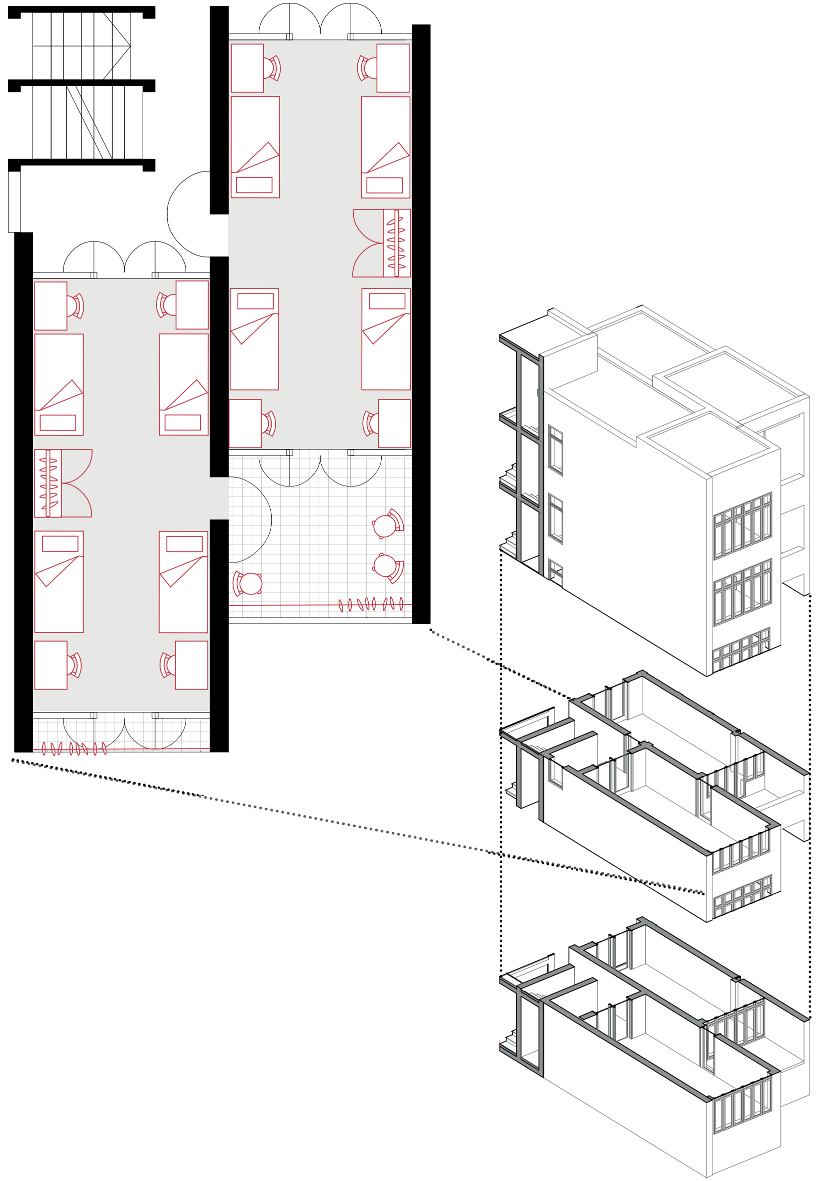
75. Design process, Unit and Cluster. Source: Author, 2025

P3 presentation: Case Study Student Housing Chittagong

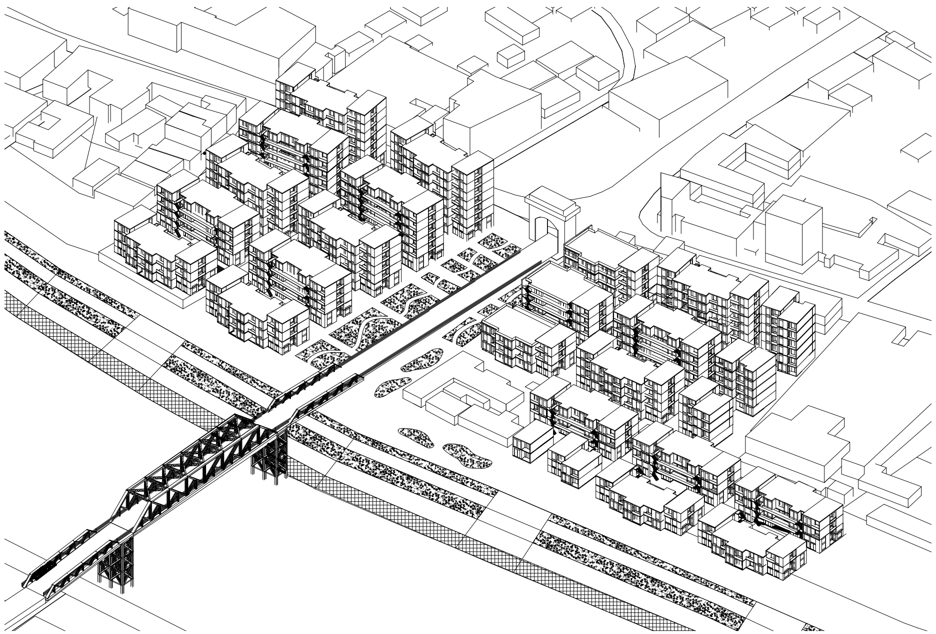


76. Student Housing Chittagong, Unit with setbacks. Source: Coco de Bok, 2024

P3 presentation: Case Study Student Housing Sylhet

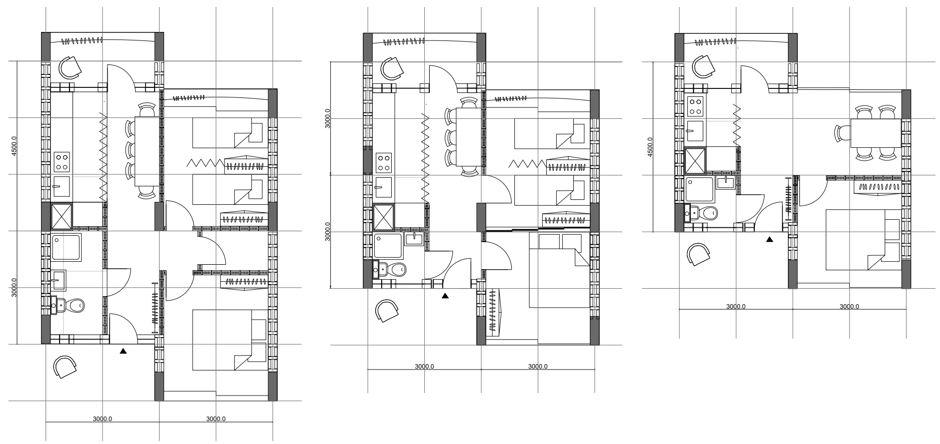


77. Student Housing Sylhet, Unit with setback. Source: Author, 2024

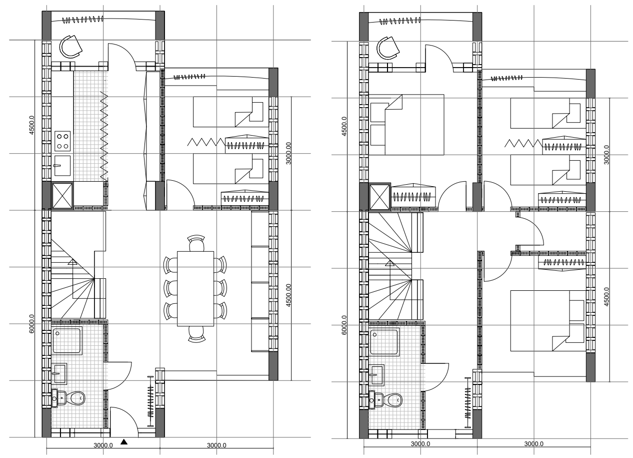


78. Masterplan P3. Source: Author, 2025

Low income units



High income units



79. Units P3. Source: Author, 2025

14.2.3. Design Process: *P4 presentation*

The feedback from the P3 presentation led me to revisit the unit design. I explored various unit widths to find the most suitable dimensions that balance human scale and comfort, while remaining compact enough to ensure affordability for impoverished communities. After extensive testing and iterations, the unit width was ultimately fixed at 3800 mm.

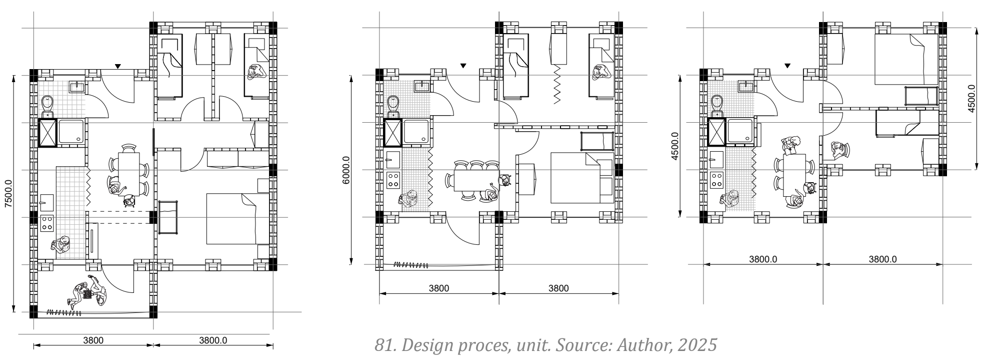
This module will make the building process much easier and more cost-effective, due to its easy way of dublicating and construction, which will make the design way more affordable for the lower income groups.

Furthermore, these modules offer the flexibility to easil densify the plan through duplication. However, by incorporating subtle variations in the modules and clustering them playfully, the design avoids creating a monotonous, repetitive layout. This approach results in a dynamic and engaging masterplan, rather than a large, uniform block.

Seasonal adaptability is addressed in the building design by using the plinth for temporary functions such as shops, restaurants, or communal spaces, ensuring that no dwellings are located at ground floor level. Additionally, essential services like sanitation and kitchens are placed on the first floor within the plinth to protect them from flood damage. In the event of a flash flood, residents can use the stairs to safely evacuate either to their own dwellings or to the roof.

Furthermore, the building is passively cooled through the use of cross-ventilation and effective shading strategies.

80. Design proces, unit and cluster P4. Source: Author, 2025



81. Design proces, unit. Source: Author, 2025

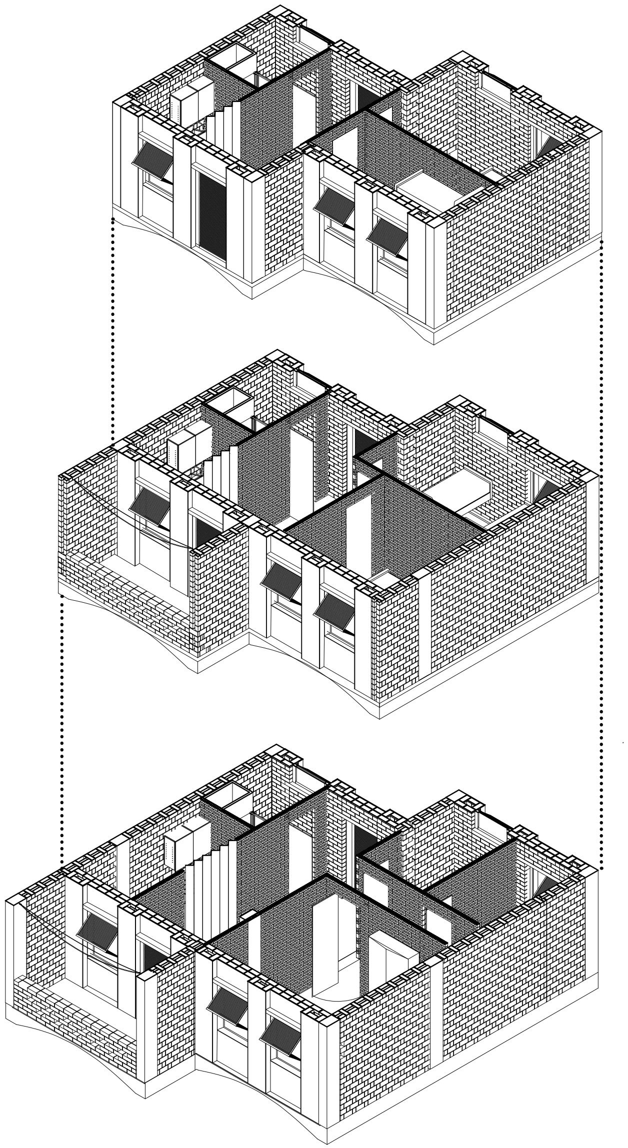
P4 presentation

Three different building types were designed to accommodate distinct income groups. In this phase of the project, each of these building types needs to be fully developed and integrated into the masterplan, including detailed floor plans, sections and elevations.

Simultaneouosly with the design process, building technology was integrated into the project, with a focus on materialization and its costs, construction methods and detailing. The following chapter will elaborate on the building technology behind the high-densit, affordable and seasonally adaptable design.

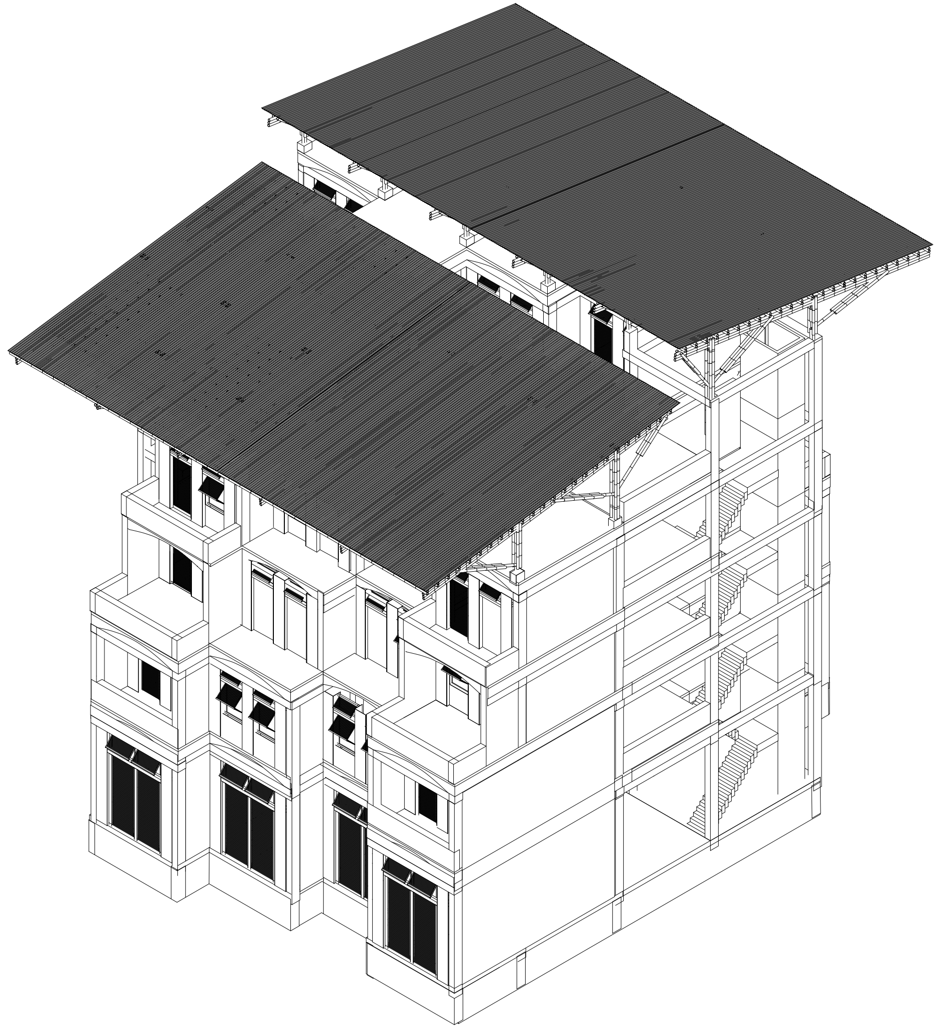
82. Final Masterplan. Source: Author, 2025

14.2.4. Final Design Unit: *Set Backs in Y- and Z-as*



83. Units with setbacks. Source: Author, 2025

14.2.5. Final Design Cluster



84. Cluster. Source: Author, 2025

14.3. Urban Strategy

14.3.1. Urban Strategy: *Design Principles*

Public Riverbank
Make the riverbank public by redesigning the area with sidewalks and many greenery to create a seamless connection between the three bridges.

Public plinth
The area needs amenities, such as stores, supermarkets, schools, offices and restaurants, so the area will be appealing for visitors.

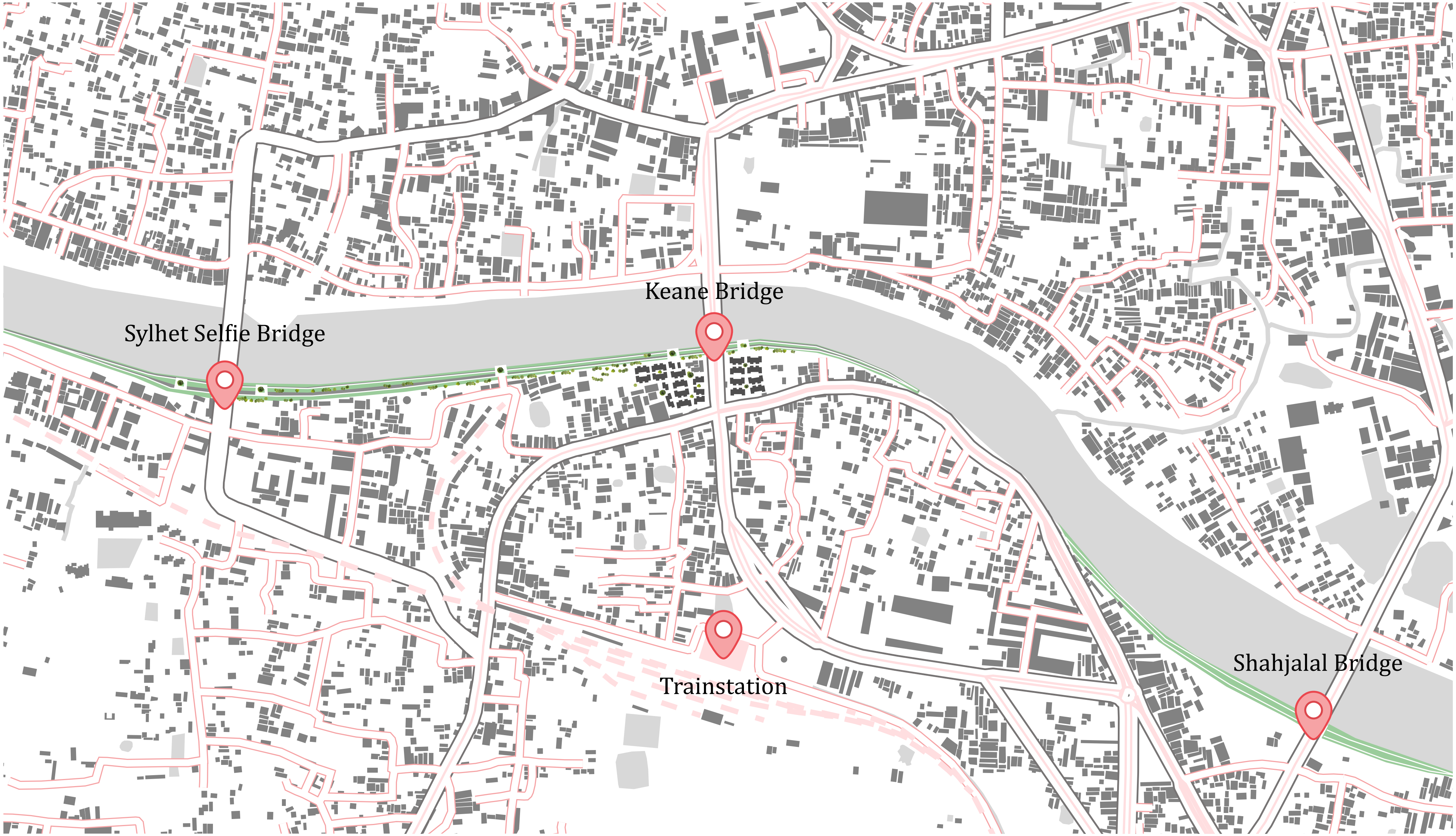
Courtyards
Designing courtyards as semi-public, private spaces for the residents of the plot allows them to meet and interact, fostering stronger social cohesion within the area.

View on the river
The buildings are taller closer to the streets, gradually giving way to lower structures as they approach the river to give the dwellings a nice view on the river.

Preserve buildings of historical importance
Some buildings are in decent condition and could be repurposed for other uses, such as converting the dwellings of the Hindu community into stores. The Hindu community will have a place in the new dwellings.

Private Loggia's and shared roof terraces
Residents can enjoy the privacy of their own balconies, while also having the opportunity to meet and interact with each other on the shared rooftop terrace.

14.3.2. Urban Strategy



85. Urban Strategy. Source: Author, 2025

14.3.3. Masterplan

86. Masterplan. Source: Author, 2025

14.4. Building Technology: *Material Strategy*

In the design of affordable housing, selecting the right materials is crucial for meeting the needs of lower-income communities while also ensuring long-term sustainability. An effective material strategy for affordable housing should prioritize not only cost-effectiveness but also environmental sustainability, promoting the use of locally sourced materials that reduce both economic and ecological footprints. In a flood resilient housing design it is important to chose a material that include factors like water resistance, strenght and durability.

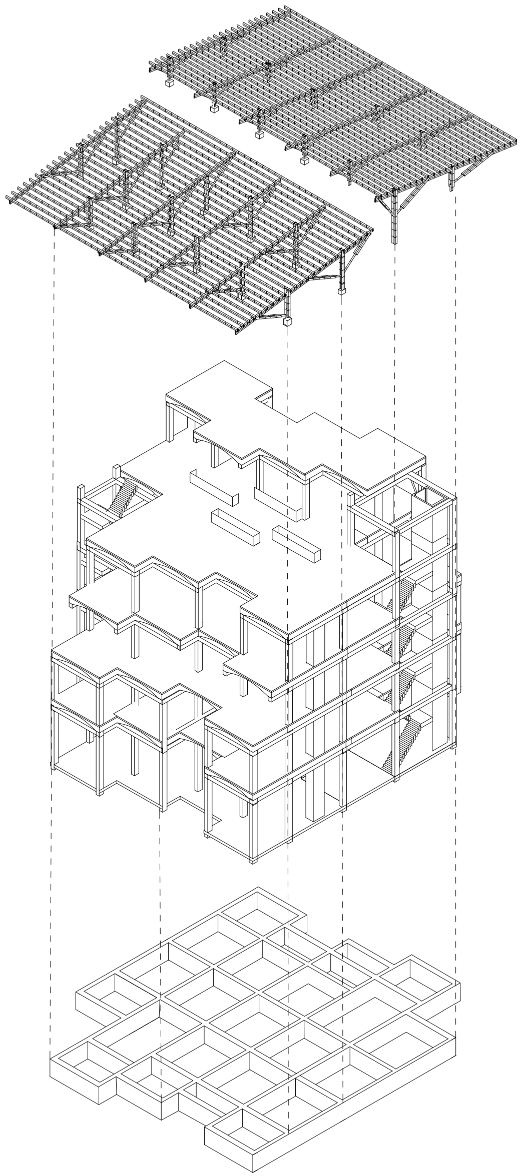
Furthermore, it is important to choice a heat resistant material with high reflectivity. This can help reduce the amount of heat absorbed by the building. Light colored, or reflective roof surfaces can help reflect solar radiation and prevent excessive heat build up in the building. Proper insulation and ventilation systems are essential in ensuring the interior spaces to stay cool and comfortable during the hottest months (Admin, 2023).

In flood-resilient architecture, there are various approaches to designing homes that can withstand or adapt to flooding. One strategy involves creating temporary, movable structure that can be relocated quickly during a flood, while another focuses on more permanent immovable buildings designed to endure flood conditions.

The choice of materials plays a crucial role in how residents along riverbanks respond to flooding. Lightweight materials allow for greater flexibility, enabling homes to be moved within a day or two to avoid flood damage. On the other hand, homes constructed from heavier materials like concrete or brick are not as easily relocated. Despite this, many residents would choose for concrete or brick due to socio-economic value the represent. These materials are often seen as symbols of financial stability and social status. When used properly brick and concrete can be a durable and sustainable choice for construction (Dash, 2024).

In this chapter the structure, infills and finishing of the project will be elaborated starting with the structure.

14.4.1. Structure: *Reinforced Concrete + Bamboo roof*



87. Construction Method, Axonometry. Source: Author, 2025

14.4.2.1. Reinforced Concrete: *Properties and costs*

Concrete, is often reinforced with steel (rebar) to strenghten houses, particularly in flood-prone areas along riverbanks. While concrete provides durability, it shared similar limitations with brick: it is an expensive material and it is not easily movable if erosion occurs. Additionally, concrete is not locally produced in Sylhet, especially prefabricated concrete, leading to high transportation costs.

However, in-situ poured concrete is used often in Bangladesh. This way of producing concrete columns and beams is known in Bangladesh, which makes it more feasible to implement it in a housing project. Furthermore, by incorporating in-situ poured concrete, local Bengali workers would be employed, creating job opportunities for the community instead of relying on foreign labor.

88. Pouring Concrete in-situ. Source: mitra10.com

The main components that are used in almost all types of concrete are cement, water and aggregates. Cement is a key ingredient in concrete and mortar and it consists of a mix of lime, clay/shale, gypsum and silica.

Furthermore, to produce Reinforced Concrete other materials are necessary, such as Cement, Sand, Water and Lime and Rebar. For one kuub concrete 325 kg cement, 660 kg sand, 1300 kg Lime and 160 L water is needed.
The formule to calculate the price of concrete per m3 is: 0,325 x 88 + 0,66 x 13,69 + 1,3 x 87 + 0,16 x 1,81 = 151,025 USD kuub = **18.355,47 BDT/m3**

Properties High-Strength Reinforced Concrete

Compressive strenght	40-80 MPa
Thermal Conductivity	1.00-1.50 W/mK
CO2	400-600 kg
Lifespan	50-100 years
Water Absorption	

Table 4. Properties reinforced concrete. Source: Author, 2025

Reinforced Concrete

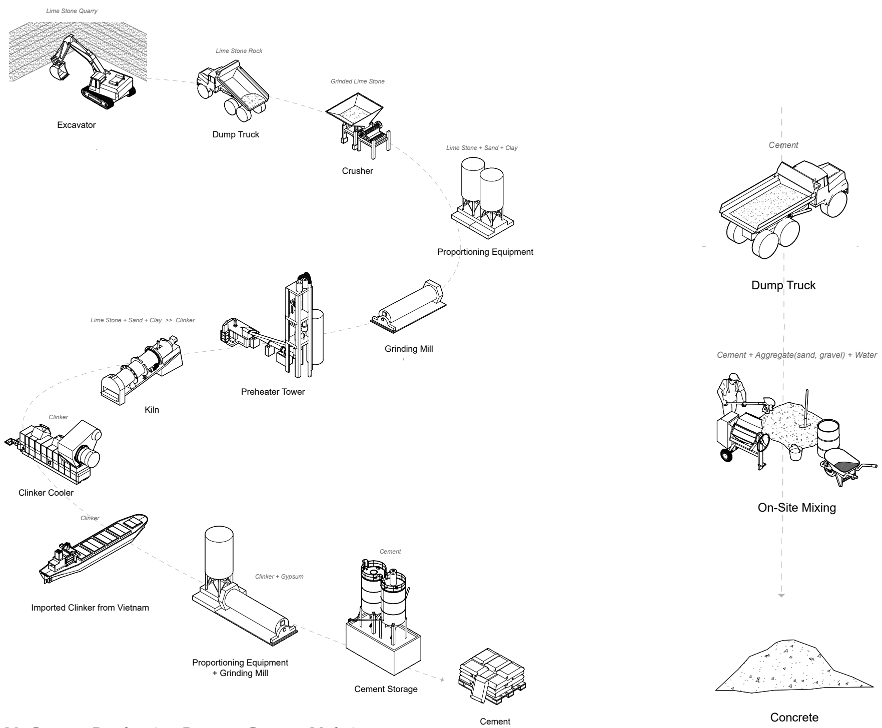
Material	Amount	Price
Cement	325 kg	88 USD/Tonne
Sand	1300 kg	13,69 USD/Tonne
Lime	1300 kg	87 USD/Tonne
Water	160 L	1,81 USD/Tonne
Concrete		151,025 USD/m3 = 18.355,47 BDT/m3
Rebar	350 kg/m3 steel per m3 concrete	739,38 USD/Tonne

Table 5. Reinforced concrete. Source: Author, 2025

14.4.2.2. Reinforced Concrete: *Production process*

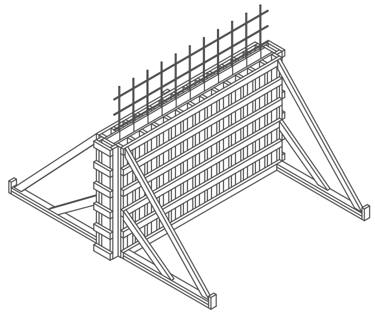
The most widely used method in Bangladesh is in-situ casting. In many cases, ready-mix concrete trucks are delivered to the site. It is also common to mix the cement on-situ using a cement mixer. Concrete is a mix of cement, water, sand and aggregates. The amount of aggregates has a significant impact on the strength of the concrete. The cement acts as a binder, water facilitates mixing and strength adjustment and sand helps manage shrinkage and expansion. The proportion of these materials vary depending the intended use of the concrete at the construction site. The in-situ casting process will transform the cement into concrete (Makri, Kim, Wijnen, ter Glane, van Poppel, 2025).

The main component of concrete, namely cement, is made out of limestone. Limestone is extracted from quarries and will be transported to crushing plants. This will be mixed with clay and sand, followed by a moisture removal process and preheating. The mixture will be heated in a rotary kiln, transforming it into clinker, which will be cooled to from spherical raw materials. The imported clinker is mixed with 5% gypsum at factories to produce cement. Then it will be transported to construction sites to proces it into construction materials (Makri, Kim, Wijnen, ter Glane, van Poppel, 2025).



89. Cement Production Process. Source: Makri, Kim, Wijnen, ter Glane, van Poppel, 2025

The concrete will be used as the structural elements in the project, such as the columns, beams and foundation. In one direction the span of the beam differ between the 3 and 6 meters in the project. In the other direction the span is always 3,8 meters. The concrete and the rebar rods will be cast in a timber formwork, which will be removed after the concrete hardens.



90. Concrete building Proces. Source: Makri, Kim, Wijnen, ter Glane, van Poppel, 2025

The building regulations for a concrete building in Bangladesh are as follows:

Foundations:
Sylhet is earthquake prone area, so a strong foundation is necessary on this site. A strip foundation made out of reinforced concrete makes the building more prone for earthquakes.

measurments foundation: **300 mm width x 1000 mm depth**

Beams: Typically, beams have a minimum width of 225 mm, with a depth ranging from 1/12 to 1/15 of the span length. Reinforcement consist of at least two bars at both the top and bottom.

Due to the measurements of the brick of 240 mm the width of the beams is also 240 mm > mimimum width of 225 mm. The span differ between the 3 and 6 meters, so to define the depth of the beam it is calculated with 4,5 meters. 1/15 x 4500 mm = 300 mm.

To conclude the measurements of the beams are **240 mm x 300 mm.**

Columns: A minimum width of 300 mm is standard for residential buildings. The rule of thumb for the measurements of a concrete column in a project of 6 floors with a floor height of a maximum of 5 meters in a grid of 8 by 8 meters will be 700 x 700 mm (Vademecum). The amount of floors differ in this project between the 3 and 8 floors, so to calculate the measurements of an average column it will be calculate with this rule.

The width of the brick wall is 240 mm, so this measurement for the column is fixed. To calculate the other side with this rule of thumb:

3m x 3,8m = 11,4 m^2	700mm x 700mm = 490.000 mm^2
8m x 8m = 64 m^2	(64 x 490.000)/ 11,4 = 87.281 mm^2

87.281 mm^2/ 240 mm = 364 mm
Measurements columns: **364mm x 240 mm**

14.4.3.1. Bamboo Borak: *Properties and Costs*

Bamboo has been chosen for the roof structure, because it is a locally sourced and cost-effective material. Additionally, its ease of assembly and dissambly makes the building more adaptable and flexible for future changes. Specifically, the type of bamboo used will be Borak (*Bambusa Balcooa*), as it is one of the most durable, heaviest and most water-resistant species compared to other types of bamboo (Halleran, Soentiono, Jankee, Darweshi, Schuurman, Doorn, 2024).

Nowadays bamboo is utilized in the construction of risers and, in some cases, as a primary building material. However, due to a misconception regarding its durability, many considering bamboo as a short-term material. Without proper seasoning, bamboo may have a lifespan of only 1 to 2 years. Nevertheless, with appropriate treatment and seasoning, bamboo can be transformed into a highly durable material that can last up to 20 - 30 years.

Furthermore, bamboo remains one of the most cost-effective materials due to its widespread local availability, even when compared to more conventional building materials (Tuhin, 2024). The government is now trying to raise awareness regarding bamboo's sustainability and long-lasting construction material, so more people are going to use it (Tuhin, 2024).

Properties Bamboo Bambusa Balcooa

Compressive Strenght	57,3 MPa
Water Resistance	Resistant
Durability	25 - 30 years when treated
Insect Resistance	Resistant
Weight	Heavy (950 kg/m^2)
Stability	Stable
Costs	160 - 210 TK/Culm = 185 TK/Culm
Diameter	10-18 cm
Height	12-25 m
Usage form	Construction, scaffolding
Color	Green to yellow
Branching	Multiple
Form Characteristic	Robust
Surface Texture	Smooth

Table 6. Properties Bamboo. Source: Author, 2025

91. Bambusa Balcooa. Source: Catchfoundation

14.4.3.2. Bamboo Borak: *Production Process*

1. Harvesting
Bambusa Balcooa needs to be harvested after 4 - 6 years to ensure maximum strength and durability.

It will be cut at the base using machetes, saws, or chainsaws, avoiding damage to the remaining roots, which will allow regrowth.

2. Cutting and Drying
Bamboo is initially left standing upright for several weeks to allow natural depletion of starches, which helps reduce its attraction to pests.

Traditional treatment methods may also involve submerging the bamboo in water for an extended period to leach out sugars and starches.

After these treatments, the bamboo is either air-dried or kiln-dried to lower its moisture content, increasing its stability and reducing the risk of cracking.

3. Preservation and Protection
Various methods such as boric acid, borax or pressure treatment with preservatives are used to enhance durability.

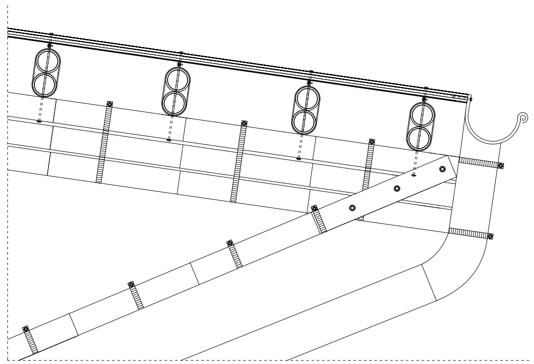
Heat Treatment: applying heat can help seal bamboo fibers and protect against pests.

Smoking: In some traditional practices, bamboo is smoked to repel insects and fungi.

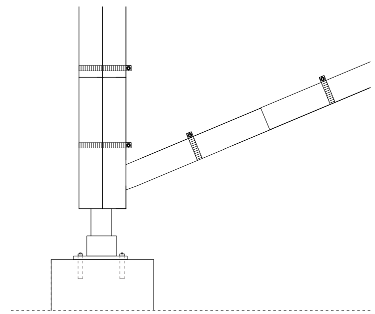
4. Processing and Shaping
For this project the bamboo will be split in poles. After this the outer layer will be smoothed for aesthetic and functional purposes.

5. Joinery and Assembly Preparation
By cutting, drilling and adding stelen joinery elements the bamboo elements will be assembled to eachother.
This type of joinery is durable and require minimal maintenance.

(Halleran, Soentiono, Jankee, Darweshi, Schuurman, Doorn, 2024).



92. Detail 1:5 Bamboo. Source: Author, 2025



93. Detail 1:5 Bamboo. Source: Author, 2025

94. Bamboo as climbers in construction. Source: Author, 2024

95. Bamboo as climbers in construction. Source: Author, 2024

14.4.4. Corrugated Steel Sheet: *Process, Properties and Costs*

It is important to protect the building from rain with a roof due to the use of earth materials in the facade, which are sensitive to erosion and moisture. Corrugated steel sheets are installed on the bamboo structure, as they are cost-effective, durable, weather-resistant and commonly used in Bangladesh for roofing.

Process:
The steel production and rolling of corrugated steel sheets is done in India. The first stage involves a complex, high-carbon process. The raw iron is mixed with other metals in the Rourkela Steel Plant to melt them into steel.

Before the iron ore can be efficiently used in steel production, the iron ore particles are agglomerated through sintering. In this process the material is heated just below the melting point and fused into porous, solid chunks, called sinter. This will improves permeability in the blast furnace, allowing for better gas flow and more efficient iron reduction.

In the blast furnace, sintered iron ore, coke, and limestone are heated to around 1500 °C Coke removes oxygen from the ore, while limestone binds impurities into slag. Molten pig iron collects at the bottom, with slag floating above. The iron is refined in a Basic Oxygen Furnace, where oxygen is blown in and scrap steel is added (Ambagts, Ganotaki, Ringel, Tietzsch, van Duinen, 2025).

The resulting liquid steel is cast into slabs, cooled and reheated to about 1200 °Cfor hot rolling. It passes through roughing and finishing mills to achieve desired thickness, then is coiled into Hot Rolled coils for export and further processing in Bangladesh.

Properties CI Sheets

Origin	Industrial plants across Bangladesh
Material composition	Steel or Iron with protective coatings
Surface	Bright or Matte finish
Coating	Galvanized (zinc), Galvalume (Al-Zn), Painted
Thickness	0,12 - 1,2 mm
Thermal Conductivity	Varies
Density (g/cm3)	7,8
Strength	High tensile strength, reinforced with corrugation
Corrosion Resistance	Rust and corrosion-resistant, especially in coastal and humid regions
Uses in Bangladesh	Roofing for homes, commercial building, industrial sheds, temporary structures and fencing
Thermal and Acoustic	0,22 k. Cal/m.h. - °C
Durability	Multiple
Weather Resistance	Damp-proof & Rust resistant, Acid & Salt Resistant, Fire-resistant
Costs	120 - 600 BDT/sheet

Table 7. Properties CI Sheets. Source: Author, 2025 (Ambagts, Ganotaki, Ringel, Tietzsch, van Duinen, 2025).

96. METI School. Source: Benjamin Staehli, Peter Bauerdick

14.4.5.1. Brick: *Properties and Costs*

Brick is a commonly used material in Bangladeshi architecture, with numerous brick factories producing up to 6 million bricks annually. Bricks are made in different kind of factories, such as the Fixed Chimney Kiln, The ZigZag Kiln and the Tunnel Kiln. The bricks produced in the Fixed Chimney Kiln and the ZigZag Kiln are hand made, which will lower the costs of the bricks. However, this production proces is energy consuming, which is polluting the Bangladeshi environmental a lot.

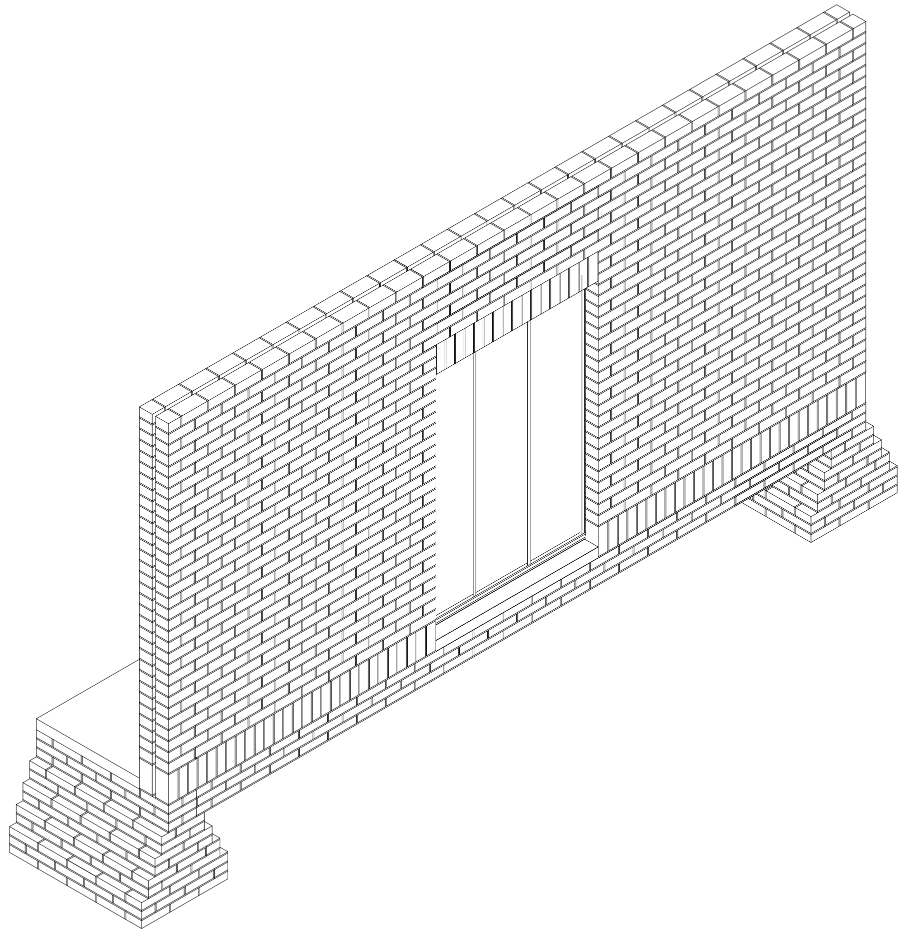
The bricks produced in a Tunnel Kiln are more friendly regarding the CO2 emmisions, however these bricks are three times more expensive, which makes them not affordable anymore for the lower-income families.
In all of these factories the bricks needs to be fired, which involves energy-intensive processes, and will drive up to production costs of the material (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Load Bearing Masonry Wall
Load-bearing masonry construction is a traditional building method wherein wall elements serve as the structural framework of the building. This technique primarily serves the construction of smaller buildings but has evolved over time with advancements in materials and engineering. These developments have enhanced the reliability of load-bearing masonry, allowing for its application in larger structures that can endure the test of time (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Bricks, are stacked layer by layer, and are bound together using a binder, typically mortar. The mechanical properties of the wall are significantly influenced by the type of mortar used, which can include cement, mortar, lime mortar, or synthetic adhesives. The primary function of the masonry wall is to transfer the loads to the foundation, which in turn distributes these loads to the ground (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

	Material composition	Compressive strength Mpa	Thermal conductivity W/m-K	Price per brick Taka
Manual (bangla) brick first class	Clay (50-60%) Sand (20-30%) Silt (10-15%)	10-15	0.6-1	7-15
Manual (bangla) brick second class	Clay (50-60%) Sand (20-30%) Silt (10-15%)	7.5	0.8-1.2	4-7
Ceramic/auto brick	Clay (50-70%) (Higher quality clay) Silica (20-30%) (found in sand)	15-23	0.5-1	20-30
Hollow brick	Clay (50-70%) (Higher quality clay) Silica (20-30%) (found in sand)	3.5-10	0.3-0.6	50

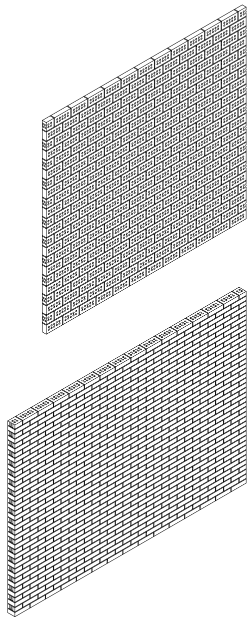
Table 8. Properties Bricks. Source: van Kats, de Bok, Steendam, Bijwaard, Gerrits, 2025



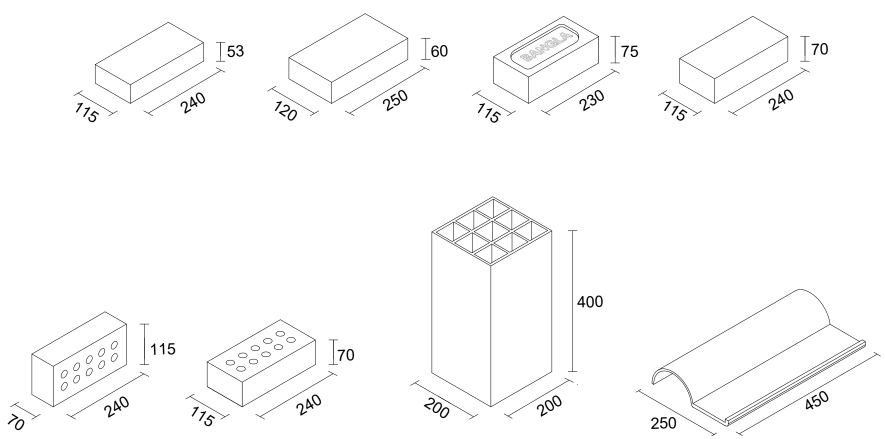
97. Load Bearing Masonry Wall. Source: Author, 2025

Perforated Ceramic Bricks
Perforated bricks are lightweight, energy-efficient, and offer excellent thermal and sound insulation due to their holes. They are easy to handle and transport, reducing construction time and labor costs. These bricks are ideal for non-load-bearing walls, partition walls, as well as for creating ventilated structures. Additionally, they are used for aesthetic purposes in places like restaurants or on roofs, enhancing the visual appeal of buildings (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Openings in facades
In Bangladesh it is common to create openings in the facade for natural ventilation, daylight and aesthetics. The Bangladesh's National Parliament House is an example how to make an opening in the facade (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).



98. Perforated Brick. Source: Author, 2025



99. Different type of Bricks. Source: Author, 2025

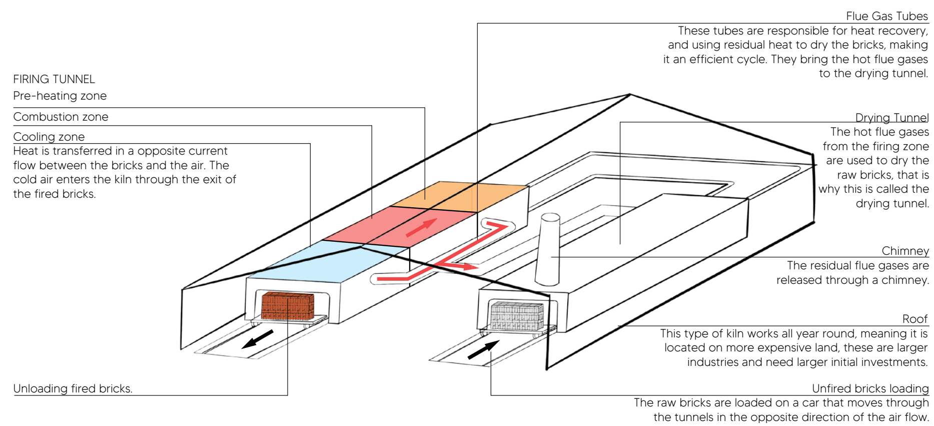
14.4.5.2. Brick: *Production process*

In Bangladesh, bricks can be produced in different types of factories, such as manually in the Chimney Kiln or Zigzag Kiln, and by machinery in the Tunnel Kiln. Manually made bricks are of lower quality than those made by machines. Furthermore, machine-made bricks, also called Auto Bricks, are more eco-friendly due to their lower CO2 emissions (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Bricks made via the manual process can have some imperfections. These bricks are categorize into three classes, namely classification 1, 2 and 3. Class. 1 bricks are used for long lasting structures and structures that are exposed to corrosive environments. Class. 2 bricks are used for the construction of one-story buildings and temporary sheds with a durability of up to 15 years. Lastly, the Class. 3 bricks are used as non-load-bearing walls and temporary structures. Due to the automated process of Auto Bricks these bricks do not have any imperfections, which make them ideal to build with (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Due to the higher quality, good water resistance and lower CO2-emissions the choice of using Auto Bricks in the project is made.

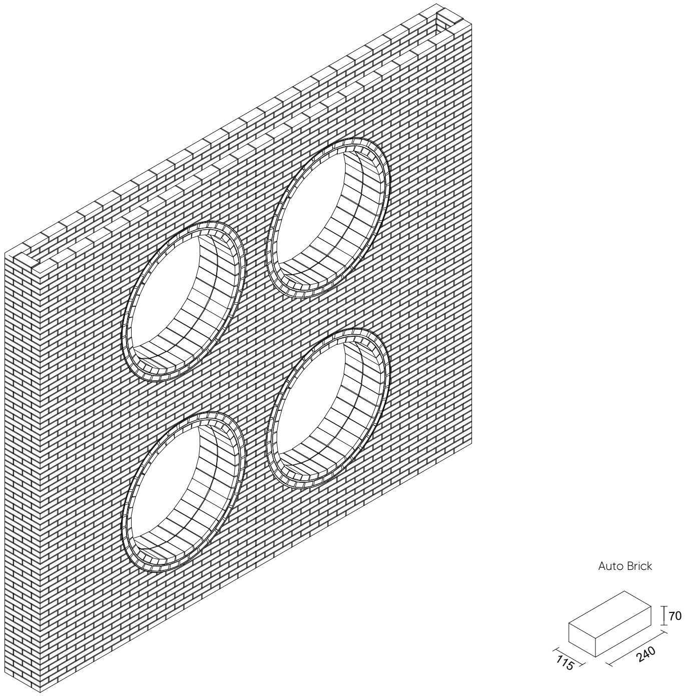
The Tunnel Kiln is a continuous kiln, where the bricks are transported on cars through a long tunnel. In this method the bricks are moving trough the different zones. The firing process takes place in the central section of the tunnel. The length of the tunnel can range from 60 to 150 meters and the duration of the firing cycle can range from 30 to 72 hours (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).



100. Tunnel Kiln. Source: Coco de Bok, 2025

14.4.5.3. Brick: *Bangladesh's National Parliament House*

The National Parliament House is located in Dhaka and designed by Louis Kahn, together with local architects Muzharul Islam and Alam Syed Zahoor. The exterior and interior are marked by large walls deeply recessed by porticoes and regular geometric openings. The geometric shapes are abstract forms found in traditional Bengali culture that are meant to create a connection between old and new cultural identities. Furthermore, these openings provides natural ventilation and daylight into the interior of the building. The Auto/Ceramic Brick walls are functioning as load bearing walls (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).



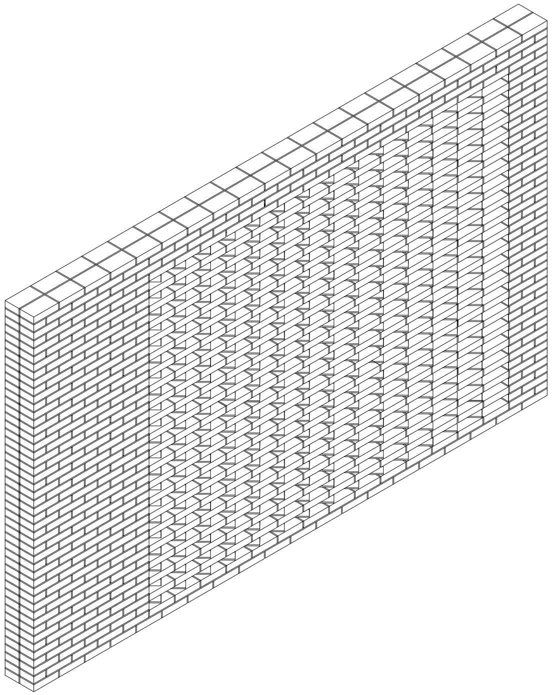
101 Facade with openings. Source: Author, 2025

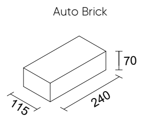
102. National Parliament House. Source: Author, 2024

14.4.5.4. Brick: *Baitur Rouf Mosque*

In the Baitur Rouf Mosque, ceramic bricks, also known as auto bricks, are used throughout the structure and left exposed on both the interior and exterior. The brick facades serve as load-bearing elements, although certain sections of the mosque are non-load-bearing due to the rotation of the bricks in the facade. This rotation not only adds aesthetic appeal but also allows for daylight and natural ventilation to enter the mosque (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).

Furthermore, the Ceramic bricks are locally manufactured by the Mirpur Ceramic Bricks company. (Tabassum, 2025).



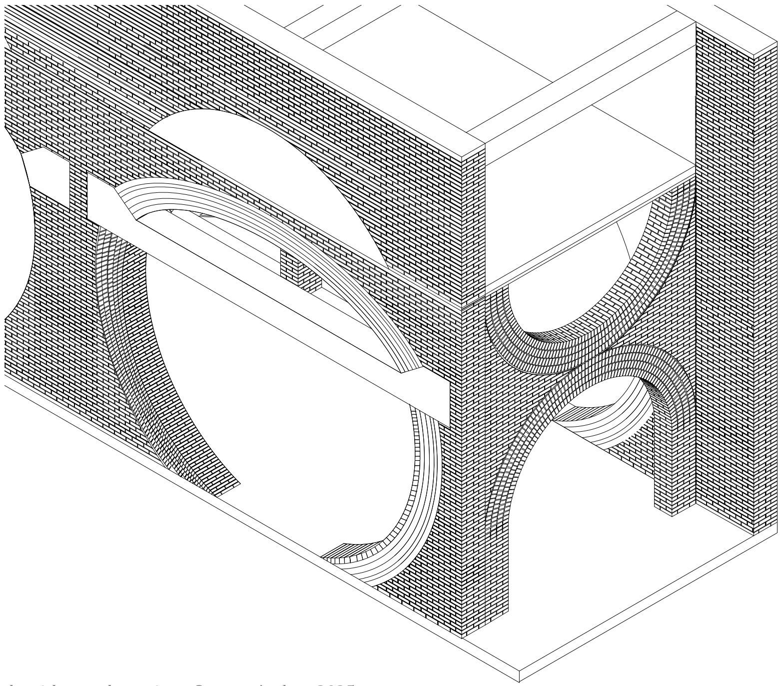


103. Facade with rotated bricks. Source: Author, 2025

104. Baitur Rouf Mosque. Source: Author, 2024

14.4.5.5. Brick: *Ayub National Hospital*

The Ayub National Hospital, located in Dhaka and designed by Louis I. Kahn, features sections of the brick facades that function as load-bearing walls with concrete beams. Numerous round openings in the facade creates entrances and allows natural ventilation and daylight to enter the building. The bricks in the round openings are causing a pulling force to the walls, so the facade will be stable. The round openings in the facade were created using a temporary structure (de Bok, Steendam, Bijwaard, van Kats, Gerrits, 2025).



105. Facade with round openings. Source: Author, 2025

106. Ayub National Hospital. Source: Author, 2024

14.4.6.1. CSEB and CEB: *Properties*

A more environmentally friendly building material is the Compressed Stabilized Earth Block (CSEB). CSEBs and CEBs are made primarily from locally available resources, including sand, clay, water and a stabilizer, such as cement (not locally available) or lime (locally available). Left over cement from the construction of the structure of the project, and Lime will be used for the CSEBs. One kg of a CSEB with a mixed stabilizer will cost 1,24 BDT, so one CSEB will cost 3,5 kg x 1,24 BDT = **4,34 BDT/CSEB (bron)** One kg of CEB will cost 0,4 BDT/CEB, so one CEB will cost 3,5 kg x 0,4 BDT = **1,4 BDT/CEB**

Furthermore, no firing is required. This reduces the emission of hazardous gases like CO2. This building material is used often in Low-cost housing, because of the low production costs of the material. CSEB's are less expensive than burned bricks or concrete blocks, because there is now need for a firing kiln of the bricks and the raw materials are locally available, which reduces transportation costs. A study stated that CSEBs are 15% cheaper than FCBs, fired clay bricks, and the construction costs can be reduced by 20 to 50% (Anik, Mozumder, Islam, Islam, Haque, Hossain, 2024).

Furthermore, CSEBs typically require less energy to manufacture than burned bricks or concrete blocks. Also CSEBs offer great thermal mass and serve as natural insulation. This can help buildings save energy by maintaining appropriate temperatures (Anik, Mozumder, Islam, Islam, Haque, Hossain, 2024).

However the water absorption of CSEBs is lower then of an FCBs, so it is important to properly manufacture and cure the CSEBs to have a long-lasting and weather resistant building material. When done correctly a CSEB can have a similar durability as a FCB and it will have a low maintenance, which can save long-term maintenance costs (Anik, Mozumder, Islam, Islam, Haque, Hossain, 2024).

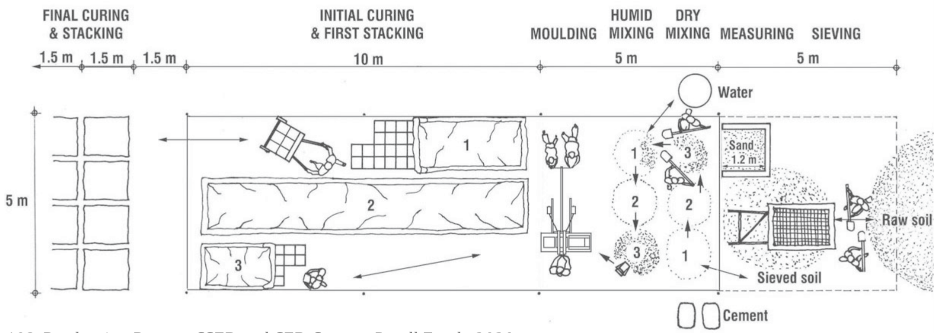
A limitation of CSEBs and FCBs compared to concrete is their inability to support as many stories. In high-density housing projects, however, CSEBs can function as secondary structure alongside a primary concrete framework. This strategy minimizes the use of concrete, with the CSEB structure complementing and filling in the concrete framework.

Properties	Compressed Stabilized Earth Blocks (CSEB)	Compressed Earth Block (CEB)	Fired Brick (FCB)
Compressive strength	3-7 MPa	1-3 MPa	10 -140 MPa
Tensile strength	0.5 - 1 MPa	0.1 - 0.3 MPa	Max. 2.8 MPa
Apparant Bulk Density	1750 - 2000 kg/m3	1600 - 2000 kg/m3	1800 - 2200 kg/m3
Total Water Absorption	8 - 15% (standard)	10 - 20% (Best Quality)	7 - 15% (Best Quality)
Production Carbon emission	22 kg CO2/Ton	? kg CO2/Ton	200 kg CO2/Ton
Manufacturing Costs	4,34 BDT/CSEB	1,4 BDT/CEB	30 BDT/FEB

Table 9. Properties CSEB, CEB, FCB. Source: Author, 2025

107. Compressed Earth Block. Source: Structural guide, Kalkionline, 2024

14.4.6.2. CSEB and CEB: *Production Proces*



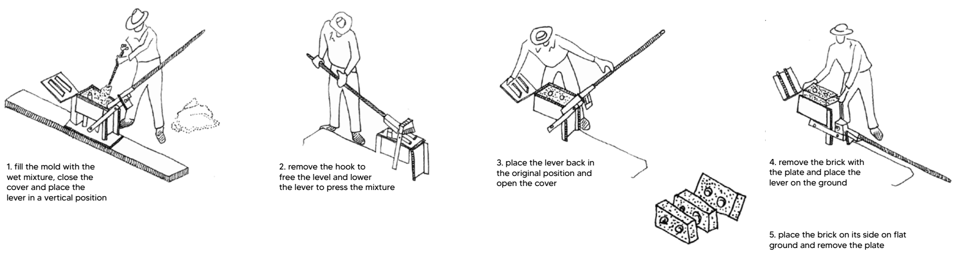
108. Production Process CSEB and CEB. Source: Dwell Earth, 2020

1. Selecting the mixture
The production proces of CEBs start with selecting suitable soil, sand and clay, ensuring the right balance of particle sizes and moisture content. For CSEBs also an aggregate will be needed, such as cement or lime. A sufficient amount of clay is essential for effective binding, helping to maintain structural integrity and durability.

2. Adding water
Once the soil, sand and clay are selected, they are mixed with water to create a homogeneous mixture. The ideal water content in a CEB varies between 5% to 20%.

3. Building Process
The prepared mixture will be placed into a mold and compacted using a hydraulic press or manual compression machine. The pressure removes air voids and enhances the density of the blocks. This will ensures uniform shape and structural integrity.

4. Curing Process (drying)
After compaction, the eart blocks are left to cure and harden naturally, either under the sun or in a controlled environment. The curing process will develop strength and stability, which will allow the blocks to reach the necessary durability for use in construction. (Ambagts, Ganotaki, Ringel, Tietzsch, van Duinen, 2025).



109. Production Process CSEB and CEB. Source: Ambagts, Ganotaki, Ringel, Tiezsch, van Duinen, 2025

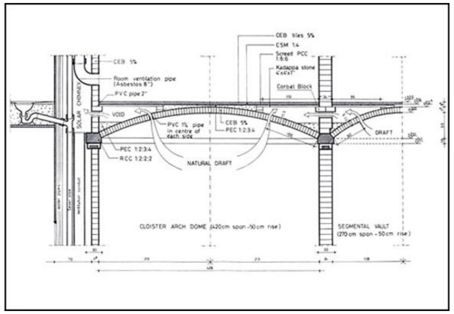
110. Compressed Earth Block press. Source: Author, 2025

14.4.6.3. CSEB: *Vikas Community, Auroville*

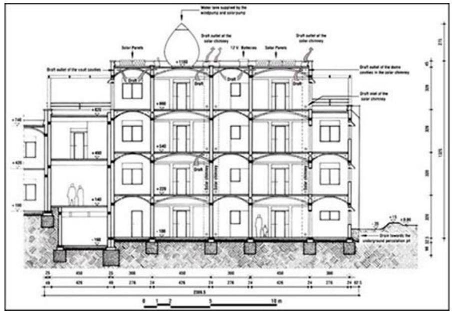
The Vikas Community was built in Auroville by the Earth Institute in several periods from 1992 to 1998. It was the first development in Auroville which used stabilised earth from foundations to roof.

The foundations were done with stabilised rammed earth and the walls were done with CSEB of 24 cm thick. All floors and roofs were made of ver flat vaults and domes for the living rooms (Auroville Earth Institute, 2024). These vaults and domes were built with CSEB, by using the Free-spanning technique. All stabilisation used 5% cement by weight.

To supply the earth needed for the soil for the building materials, the volume of the basement floor was used. The amount of soil generated by the basement was enought to build 819 m2, carpet area, on 4 floors.
To protect the basement form the inflow of rainwater the immediate surrounding landscape has been shaped like a shallow crate to drain rainwater into e percolation pit (Auroville Earth Institute, 2024).



111. Ventilation system through the vaulted structures towards the solar chimney. Source: AurovilleEarthInstitute



112. Section AurovilleEarth. Source: AurovilleEarthInstitute

113. Auroville Earth Institute. Source: AurovilleEarthInstitute_©auroville.org

14.4.7. CSEB, CEB, FCB: *Application*

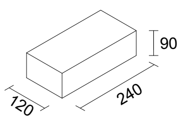
The CSEBs, CEBs and FCBs have different functions within this project. The Fired bricks (FCB) will function as the waterresistant material of the plinth. This material will withstand floodings, which makes it suitable as a material for the plinth. However, FCBs are expensive and have a high CO2-emmission. To make the project more environmentally friendly and affordable CSEBs and CEBs are used as the infills on the upper floors of the project.

Compressed Earth blocks (CEBs) are more cost-effective than Compressed Stabilized Earth Blocks (CSEBs). Therefore, CEBS have been selected as the infill material for the low-income housing project, while CSEBs are used for the middle- and high-income projects. CSEBs do not require an additional protective layer against water, due to the stabilizing aggregated mixed into the blocks. In contrast, CEBs are more vulnerable to rain and will be protected with a lime plaster coating to improve their water resistance.

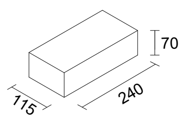
To maintain the simplicity and logic of the project, it is important to use CSEBs, CEBs and FCBs with similar dimensions. This ensures consistency in modularity across the different buildings within the masterplan.

In Bangladesh FCBs with dimensions of 240 mm x 115 mm x 70 mm are widely used. There are pressing machines that can produce CSEBs and CEBs with dimesions of 240 mm x 120 mm x 90 mm (Aurom 3000 Block Press). The columns in the project follows the length (240mm) of the brick/ blocks, so this will maintain the modularity within the project.

The CSEBs and CEBs can be made in the Auram Press 3000 with a mold for plain 240. The pricing for this mold is 620 dollar (Aurom 3000 Block Press)



Half plain 240 CSEB/CEB

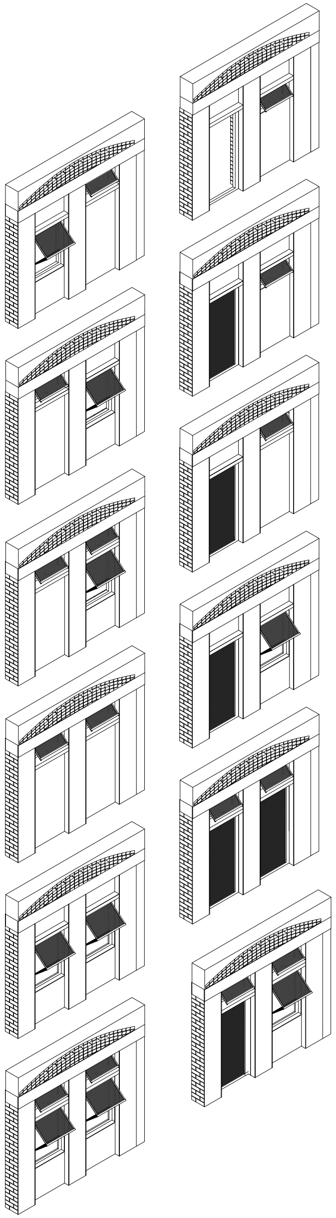


FCB

114. CSEB, CEB vs. FCB. Source: Author, 2025

115. Compressed (Stabilized) Earth Block Press. Source: Author, 2025

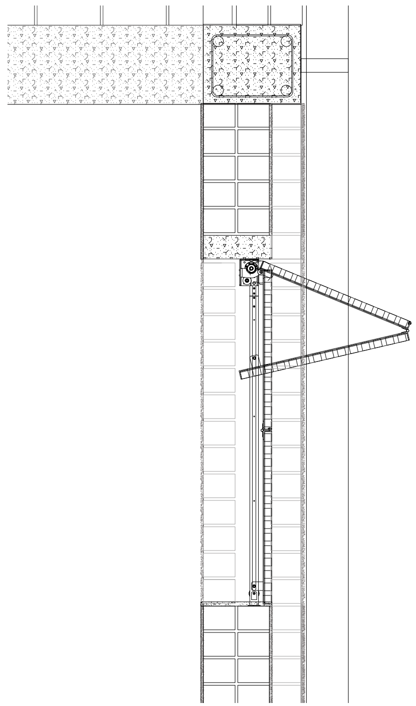
14.4.8. Material Strategy: *Facade Design*



116. Various Facade options. Source: Author, 2025

14.4.8.1. Material Strategy: *Facade and windowshutters*

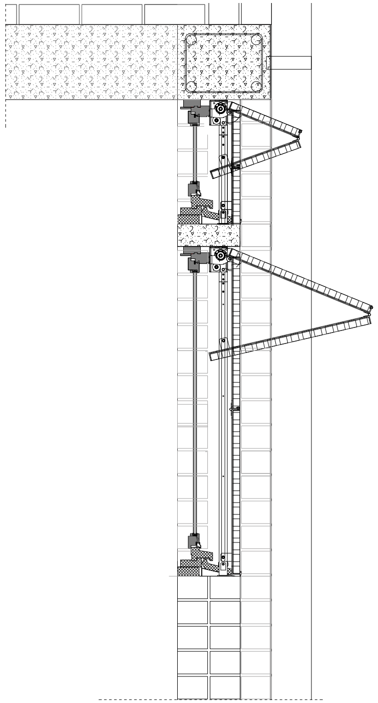
To create a playful facade, various compositions of windows and doors can be used, as shown in image 116. Residents can choose whether they want a small window above the lintel, a larger one below, or both, based on their preferences. Each opening includes a shutter for protection against sun and rain (image 117). Behind the shutter, residents have the option to add a glass window, which can be made of wood or aluminum, depending on their budget.



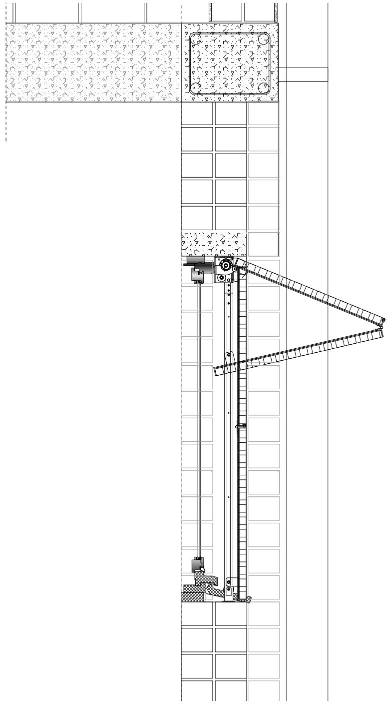
117. Window Detail 1:5. Source: Author, 2025

14.4.8.2. Material Strategy: *Wooden Shutters*

As shown in image 118 and 119 a wooden window fram is used. In Bangladesh wooden window frames are often used in higher income buildings. This is because this material is more expensive. To protect the frames from moisture and mold it is important to treaten the frames.



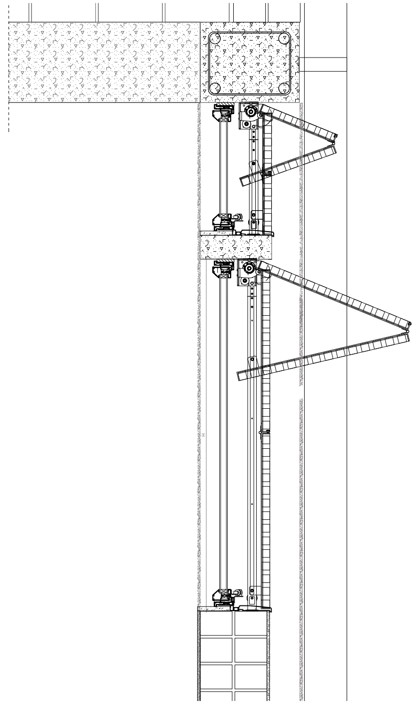
118. Window Detail 1:5. Source: Author, 2025



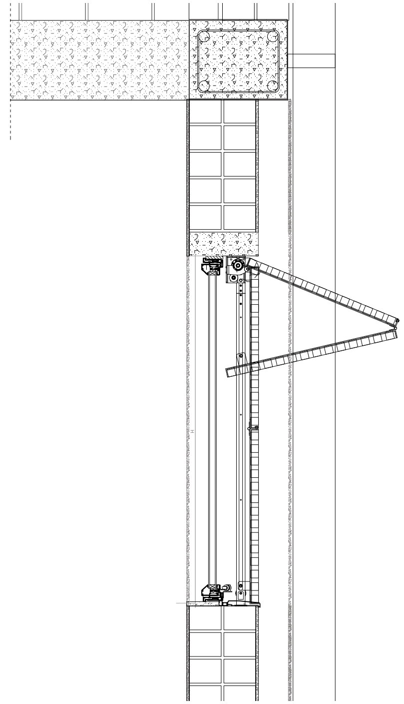
119. Window Detail 1:5. Source: Author, 2025

14.4.8.3. Material Strategy: *Aluminum Shutters*

As shown in image 120 and 121 aluminum frames will also be used behind the shutters. The aluminum is transported from India and processed into frames locally in Bangladesh. While aluminum is not the most sustainable option, it offers a more affordable solution for low-income families. By providing this alternative, even impoverished communities have the opportunity to include windows in their homes, enhancing comfort and livability withing their homes.



120. Window Detail 1:5. Source: Author, 2025



121. Window Detail 1:5. Source: Author, 2025

14.4.9. Building Construction

Construction
The construction consists of a reinforced concrete frame with columns and beams, used as minimally as possible to reduce both costs and environmental impact. However a structure made out of reinforced concrete can withstand floodings well in a high density project. The foundation is also made of concrete, providing a strong and stable base capable of withstanding flooding.

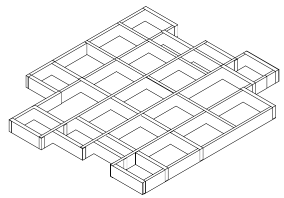
Infill
For the infill bricks are used at the plinth level to address flood risk. Above that, different materials are chosen based on affordability: Compressed Earth Blocks (CEB) with a lime plaster are used for low-income housing, while Compressed Stabilized Earth Blocks (CSEB) are used for middle- and high-income buildings. These materials are locally sourced, making them both sustainable and cost-effective.

Floors
In line with the aim of using as many local materials as possible, the floors are also made of CSEB instead of reinforced concrete, as this is more accessible and economical in the local context.

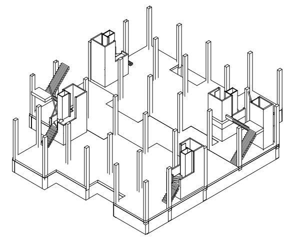
Cantilevers
Due to the building's setbacks, some cantilevers are required to maintain a logical and simple structural system. This approach helps minimize the number of columns, which is prefereable for the project's design and functionality.

Roof structure
The roof structure is made of bamboo, a local, sustainable and highly cost-effective material. Additionally, this system allows for future flexibility, if modifications or vertical extensions (top-ups) are needed, the bamboo roof can be easily dismantled, facilitating future development. Corrugated steel sheets are placed on top of the bamboo structure, offering an affordable roofing solution. The roof design allows rainwater to easily drain off the building.

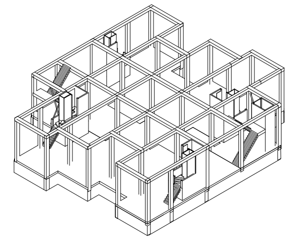
Foundation
Concrete with rebar



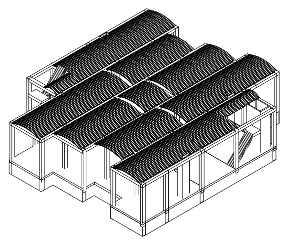
Columns
Concrete with rebar



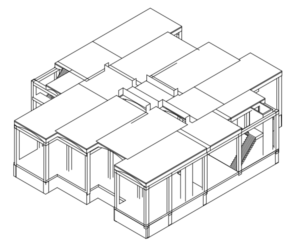
Beams
Concrete with rebar



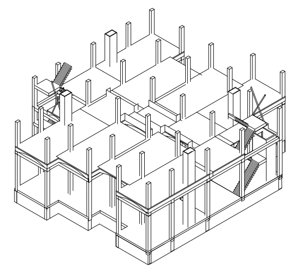
Floor
CSEB Vault



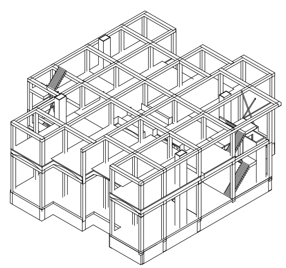
Floor
Gravel + Clay Screed



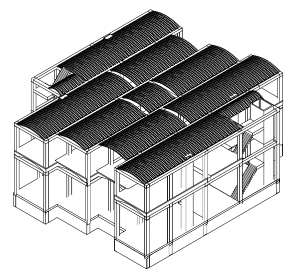
Columns
Concrete with rebar



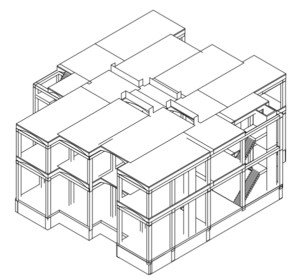
Beams
Concrete with rebar

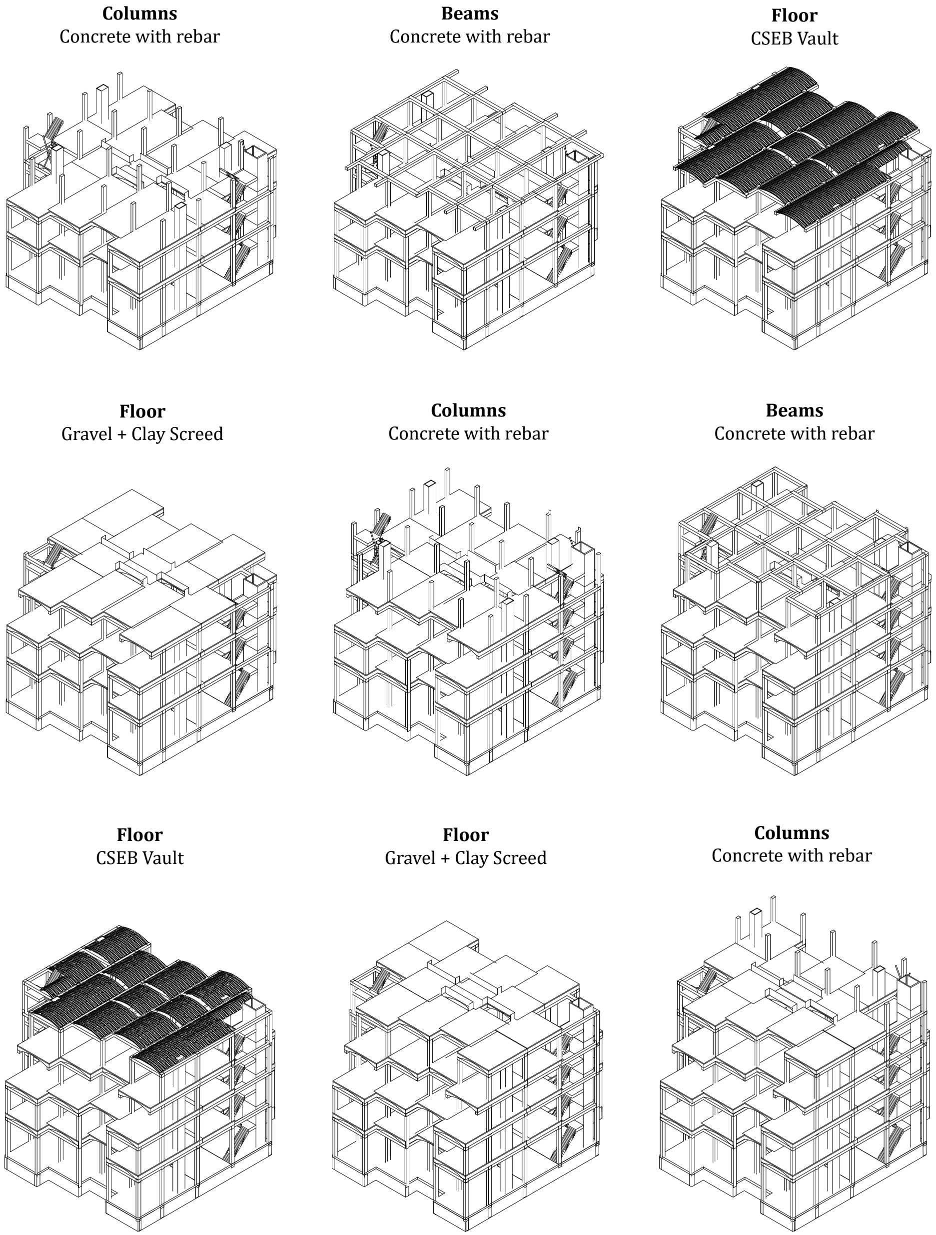


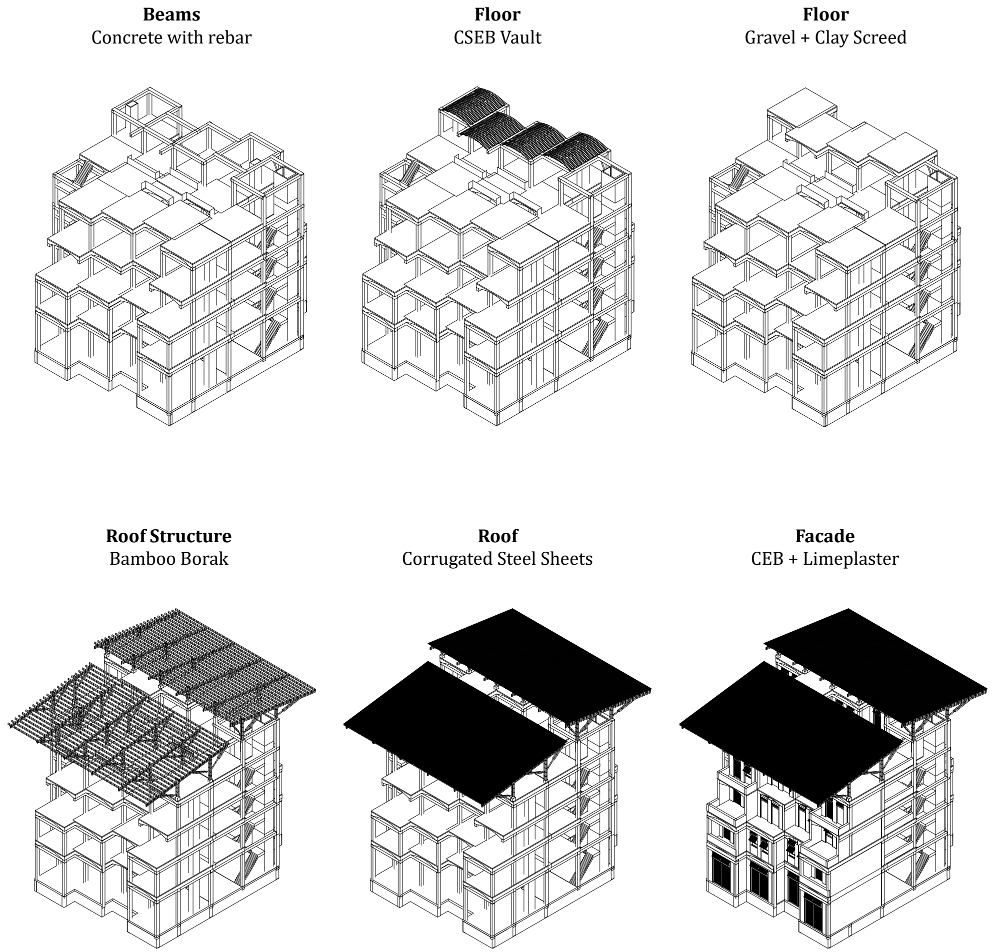
Floor
CSEB Vault



Floor
Gravel + Clay Screed





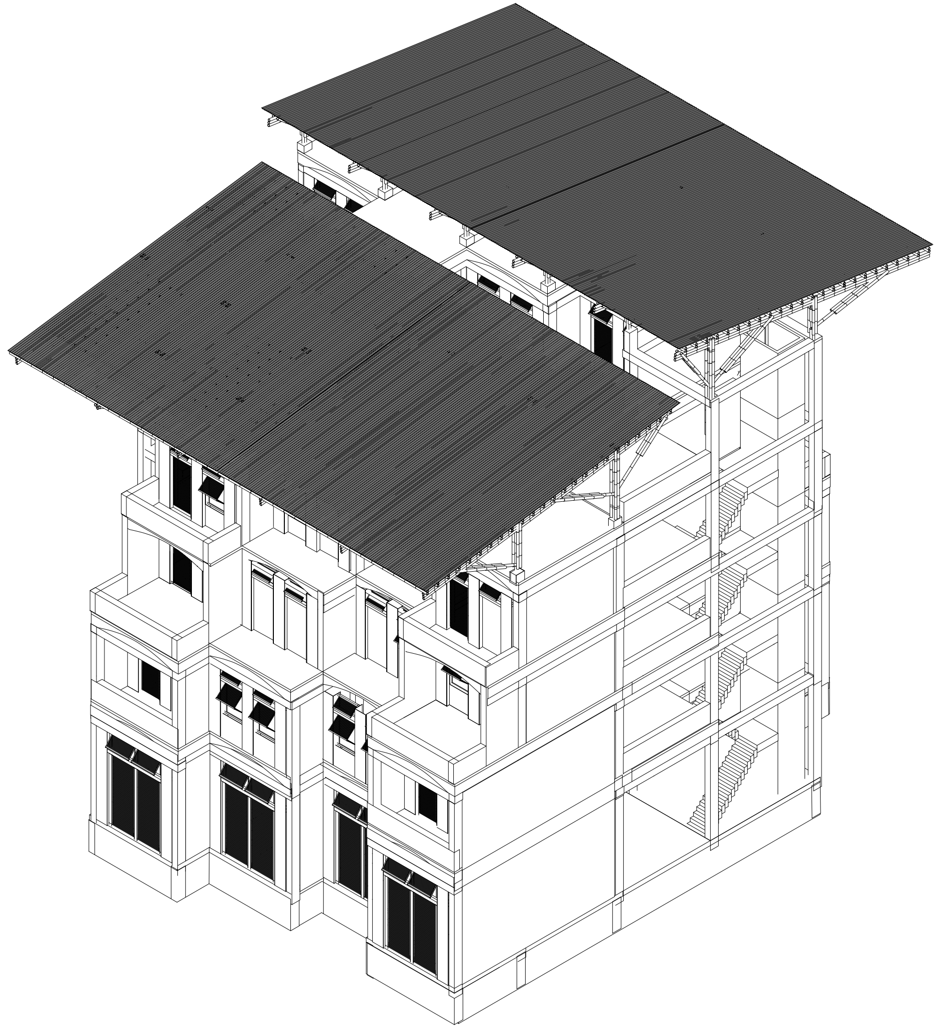


122. Building Construction. Source: Author, 2025

14.4.10. Material Costs: *Building 1*

Materials	Amount	Price
Concrete Columns + Beams	176,9224 m³	176,9224 m3 x 18.355,47 BBT/m3 = **3.247.493,81 BDT**
Rebar	61.922,84 kg	61,92 ton x 739,38 USD/ton = 45.784,51 USD = **5.579.967,30 BDT**
Fired Brick (FEB)	33.912 FEB's	33.912 bricks x 30 BDT/FEB = **1.017.360 BDT**
Compressed Earth Brick (CEB)	115.301 CEB's	115301 CEB x 1,4 BDT/CEB = **161.421,12 BDT**
Lime Plaster	3075,3 m²	3075,3 m² x 10 USD/m² = 30.753 USD = **3.738.389 BDT**
Bamboo Structure	296 culms (l = 10m)	296 culms x 185 BDT/culm= **54.760 BDT**
Corrugated Steel	80 sheets (6m x 1m)	80 x 600 BDT/sheet = **48.000 BDT**
CSEB Vault	255.619 CSEB's	255.619 CSEB's x 4,34 BDT/CSEB = **1.109.366,496 BDT**
Foundation (strip foundation)	93 m³	93 m³ x 18.355,47 BDT/m3 =**1.707.058,71 BDT**
Rebar within the foundation	32.550 kg	32,55 ton x 739,38 USD/ton = 24.066,819 USD = **2.933.065,99 BDT**
Total Costs		**19.569.881,82 BDT** (143.836,75 Euro)
Cost m²		19.560.013,82 BDT / 1938 = **10.092,89 BDT/m²**

Table 10. Material Costs, Building 1. Source: Author, 2025

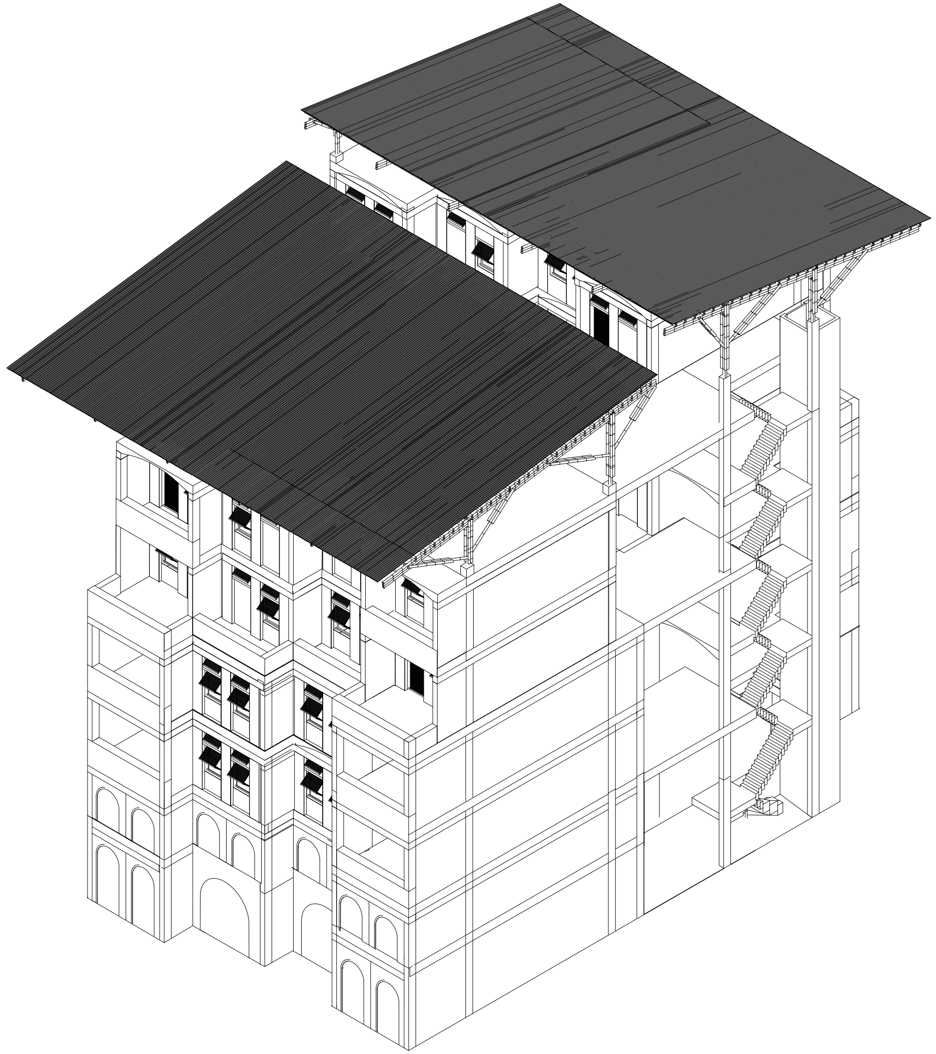


123. Cluster Low-income group. Source: Author, 2025

Building Costs: *Building 2*

Materials	Amount	Price
Concrete Columns + Beams	166,2624 m³	166,2624 m³ x 18.355,47 BDT/m3 = **3.051.824,49 BDT**
Rebar	58.191,84 kg	58,19184 ton x 739,38 USD/ton = 43.025,88 USD = **5.243.711,63 BDT**
Fired Brick (FEB)	58.663,944 FEB's	58.663,944 bricks x 30 BDT/FEB = **1.759.918,33 BDT**
Compressed Stabilized Earth Brick (CSEB)	108.302,67 CSEB's	108.302,67 CSEB x 4,34 BDT/CSEB = **470.033,57 BDT**
Bamboo Structure	327 culms (l = 10m)	327 culms x 185 BDT/culm= **60.495 BDT**
Corrugated Steel	100 sheets (6m x 1m)	100 x 600 BDT/sheet = **60.000 BDT**
CSEB Vault	261.904,75 CSEB's	261.904,75 CSEB's x 4,34 BDT/CSEB = **1.136.666,62 BDT**
Foundation (strip foundation)	131,9 m³	131,9 m³ x 18.355,47 BDT/m3 =**2.420.670,22 BDT**
Rebar within the foundation	41.165 kg	41,165 ton x 739,38 USD/ton = 34.133,48 USD = **4.159.990,91 BDT**
Total Costs		**18.363.310,77 BDT** (134.968,57 Euro)
Cost m²		18.363.310,77 BDT / 1584 m² = **11.593,00 BDT/m2**

Table 11. Material Costs, Building 2. Source: Author, 2025

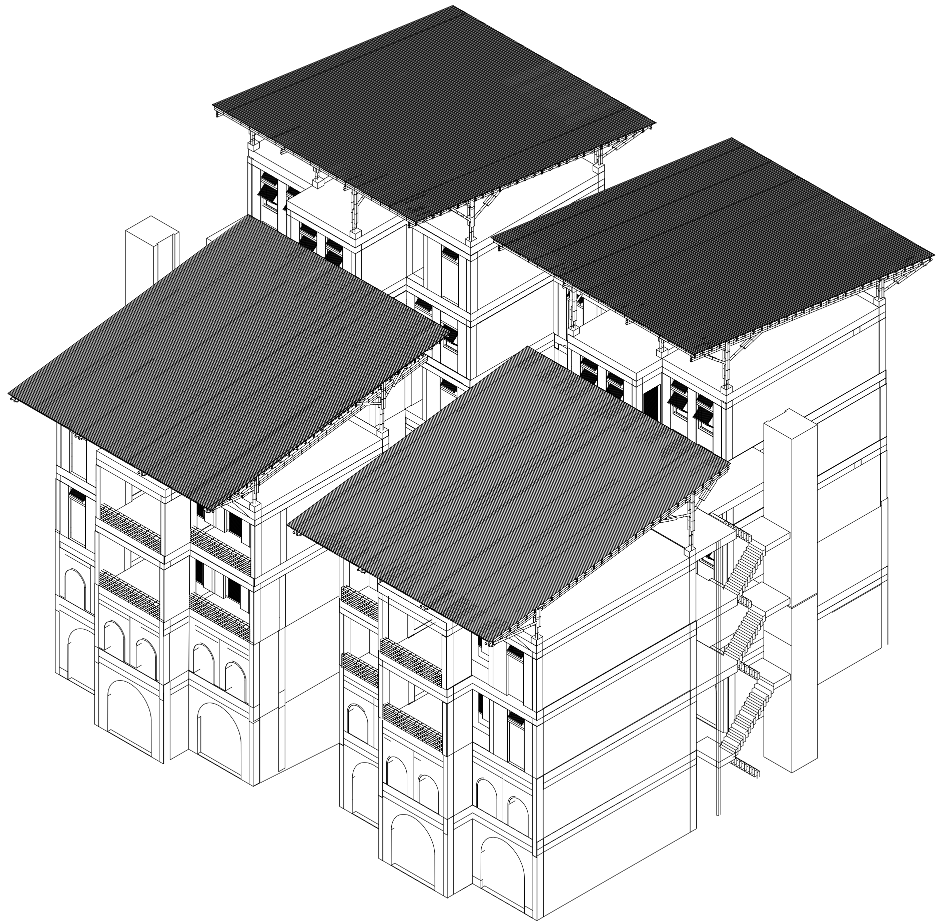


124. Cluster Middle-income group. Source: Author, 2025

Building Costs: *Building 3*

Materials	Amount	Price
Concrete Columns + Beams	66,245 m³	66,245 m³ x 18.355,47 BDT/m3 = **2.431.902,33 BDT**
Rebar	23.185,75 kg	23,185 ton x 739,38 USD/ton = 17.142,5 USD = **2.089.318,97 BDT**
Fired Brick (FEB)	36.874,5 FEB's	36.874,5 bricks x 30 BDT/FEB = **1.106.235 BDT**
Compressed Stabilized Earth Brick (CSEB)	42.547,5 CSEB's	42.547,5 CSEB x 4,34 BDT/CSEB = **184.656,15 BDT**
Bamboo Structure	185,6 culms (l = 10m)	185,6 culms x 185 BDT/culm= **34.336 BDT**
Corrugated Steel	60 sheets (6m x 1m)	60 x 600 BDT/sheet = **36.000 BDT**
CSEB Vault	175.813,25 CSEB's	175.813,25 CSEB's x 4,34 BDT/CSEB = **763.029,5 BDT**
Foundation (strip foundation)	71 m³	71 m³ x 18.355,47 BDT/m3 =**1.310.179,5 BDT**
Rebar within the foundation	24.850 kg	24,85 ton x 739,38 USD/ton = 18.373,59 USD = **2.239.226,35 BDT**
Total Costs		**10.194.883,8 BDT** (74.931,42 Euro)
Cost m²		10.194.883,8 BDT / 664,5 = **15.342,1878 BDT/m²**

Table 12. Material Costs, Building 3. Source: Author, 2025



125. Cluster High-income group. Source: Author, 2025

14.4.11. Conclusion Material study

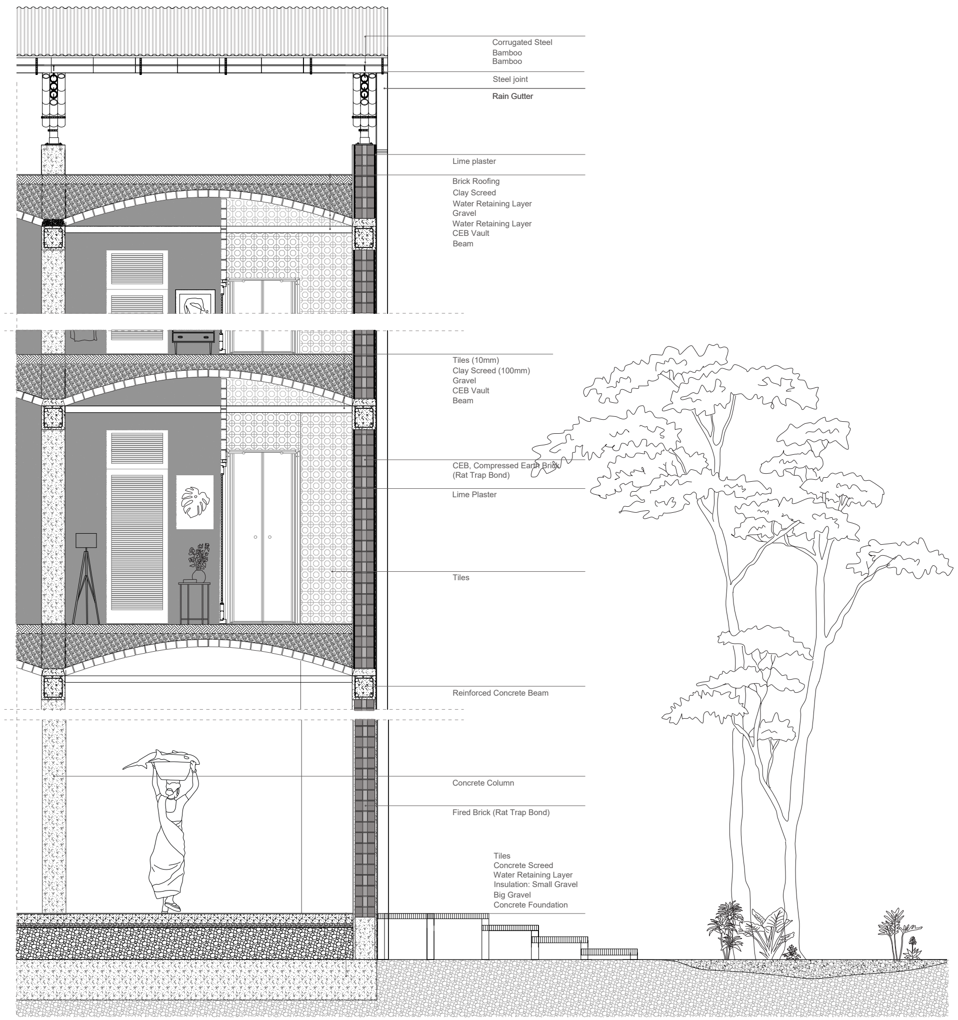
The material and construction strategy for this housing project is rooted in affordability, sustainability and the use of locally sourced resources. By combining a minimal reinforced concrete frame with flood-resilient foundations, the project ensures structural stability in high-density, flood-prone areas. The use of bamboo and Compressed Stabilized Earth Blocks (CSEB) presents a cost-effective and environmentally conscious alternative to concrete, steel and bricks.

Materials are selected based on waterresilience, income level and strength. Brick is used at plinth level for flood protection, while CEBs and CSEBs serve as infill solutions for varying income groups. Locally produced CSEB floors replace more expensive concrete slabs, reducing costs withouth compromising quality.

The roof strucutre, made out of lightweight bamboo and corrugated steel sheets, will procide flexibility in the future. Strategic use of cantilevers minimizes structural complexity and material usage, contributing to a more efficient design.

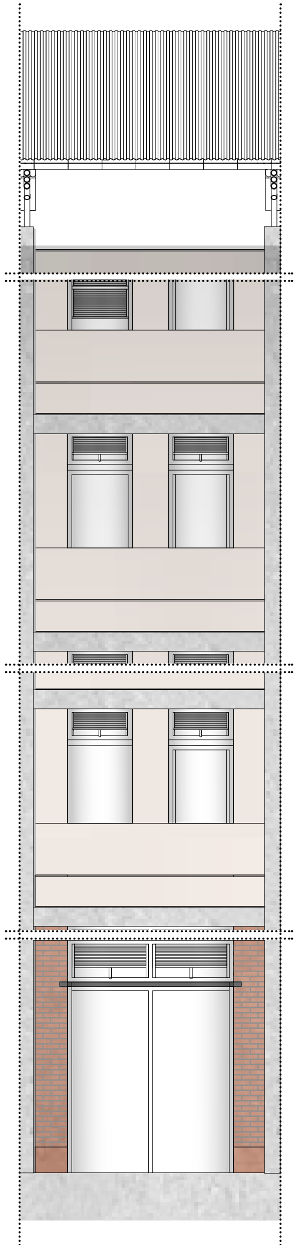
Overall, despite necessary compromises, the material choices balance affordability, resilience and sustainability, making this housing project feasible within this context.

Section



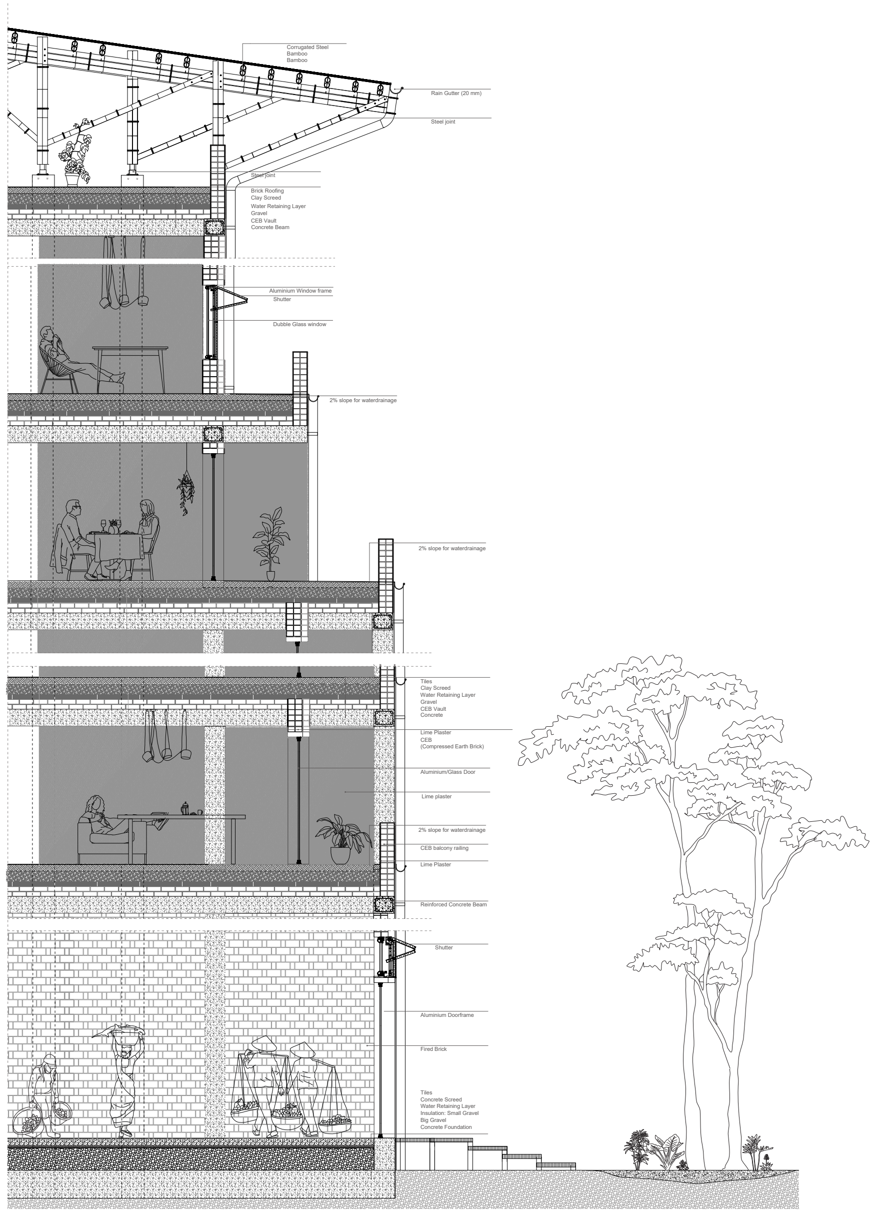
126. Section 1:20. Source: Author, 2025

Elevation



127. Section 1:20. Source: Author, 2025

Section

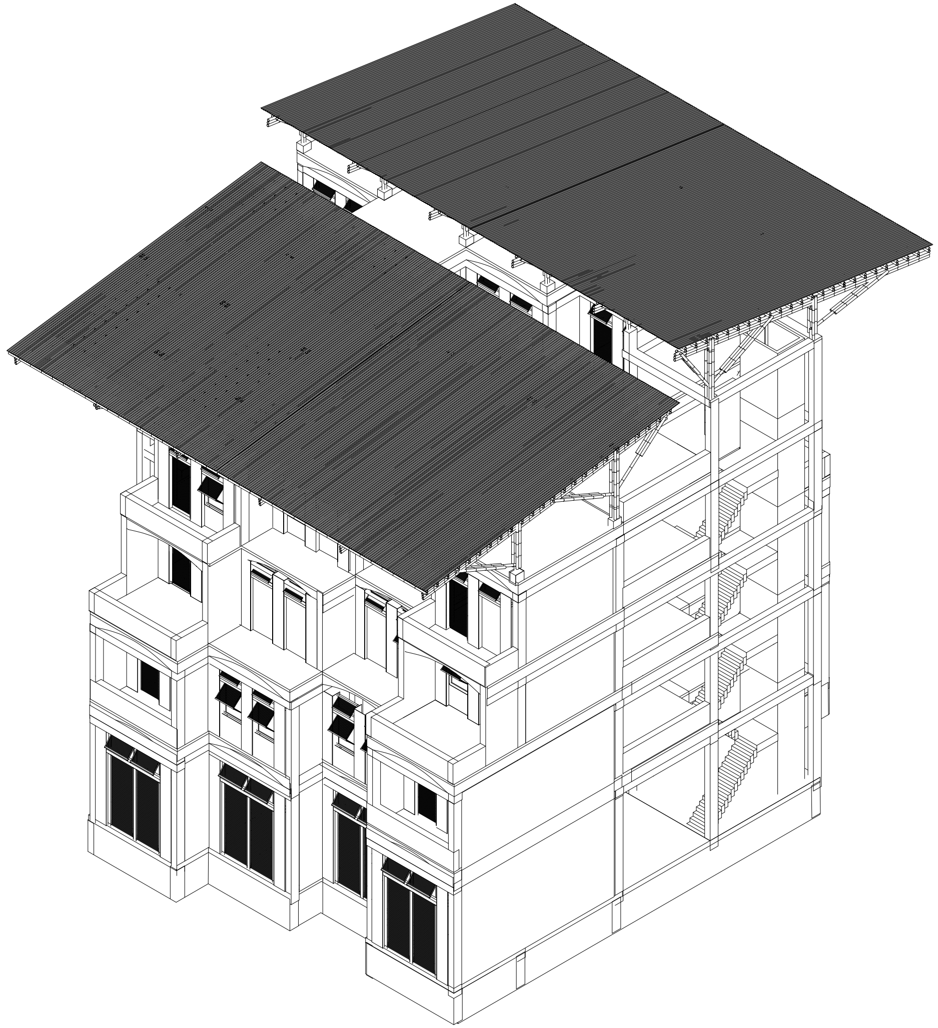


128. Section 1:20. Source: Author, 2025

15. Architectural Design

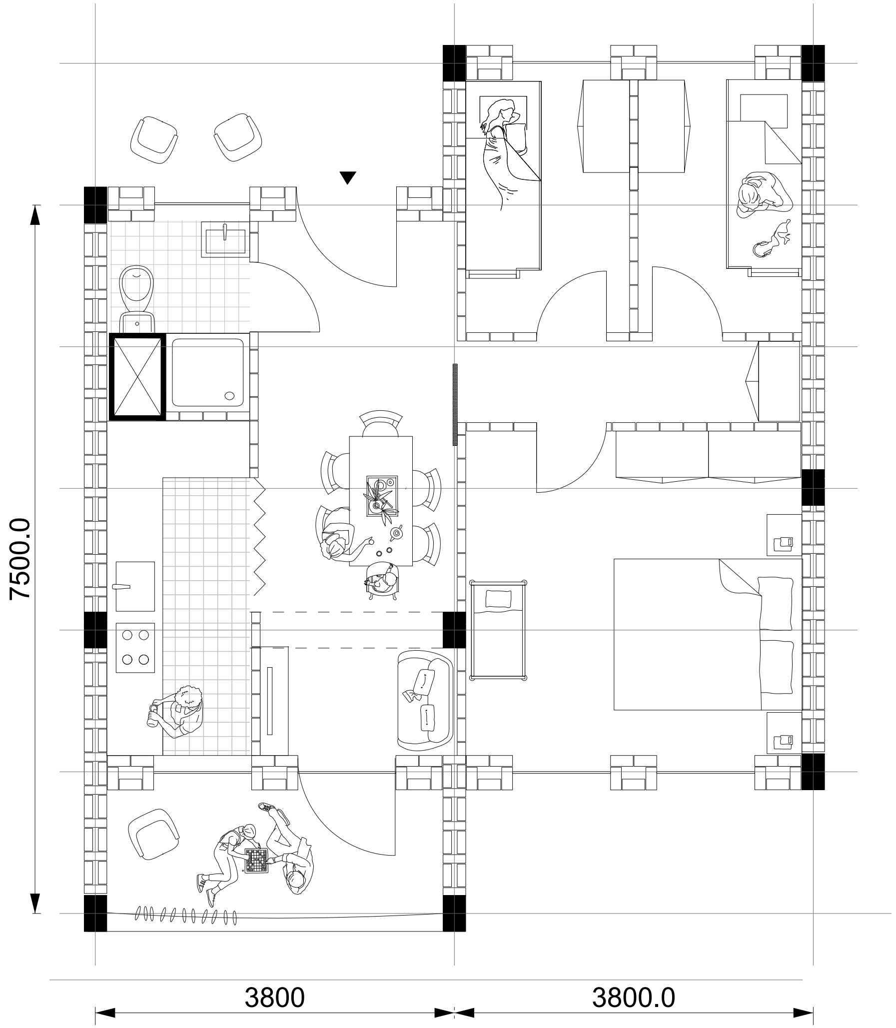
15.1. Building 1

15.1. Building 1: *Low-income group*

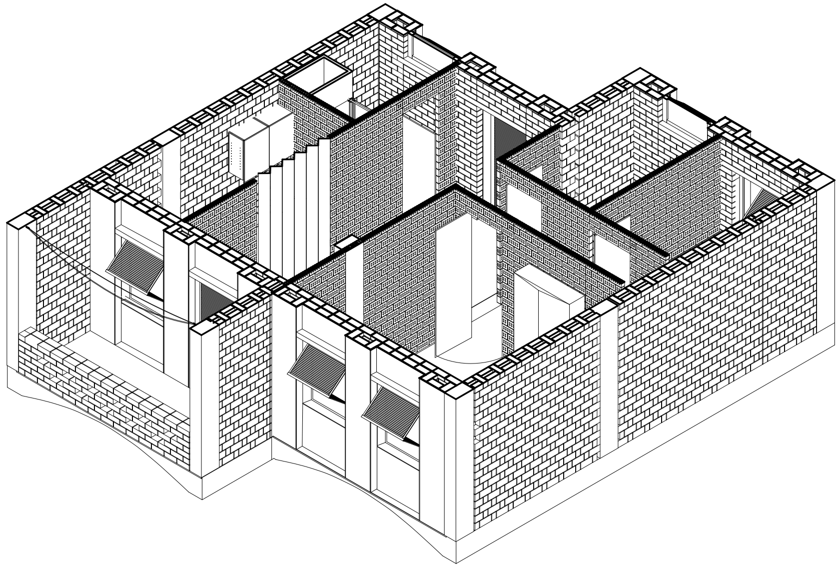


129. Cluster Low-income group. Source: Author, 2025

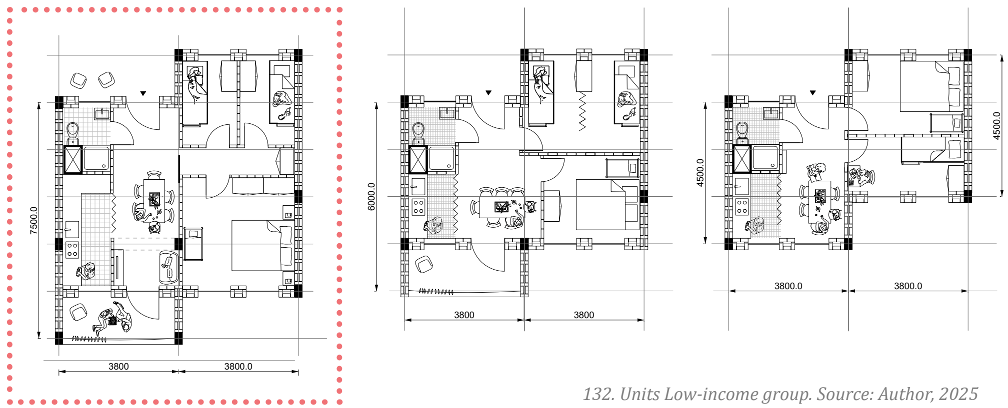
15.1.1. Low Income Unit: *5 - 7 persons, 62 m², 10,3 m²/p*



130. Unit Low-income group. Source: Author, 2025

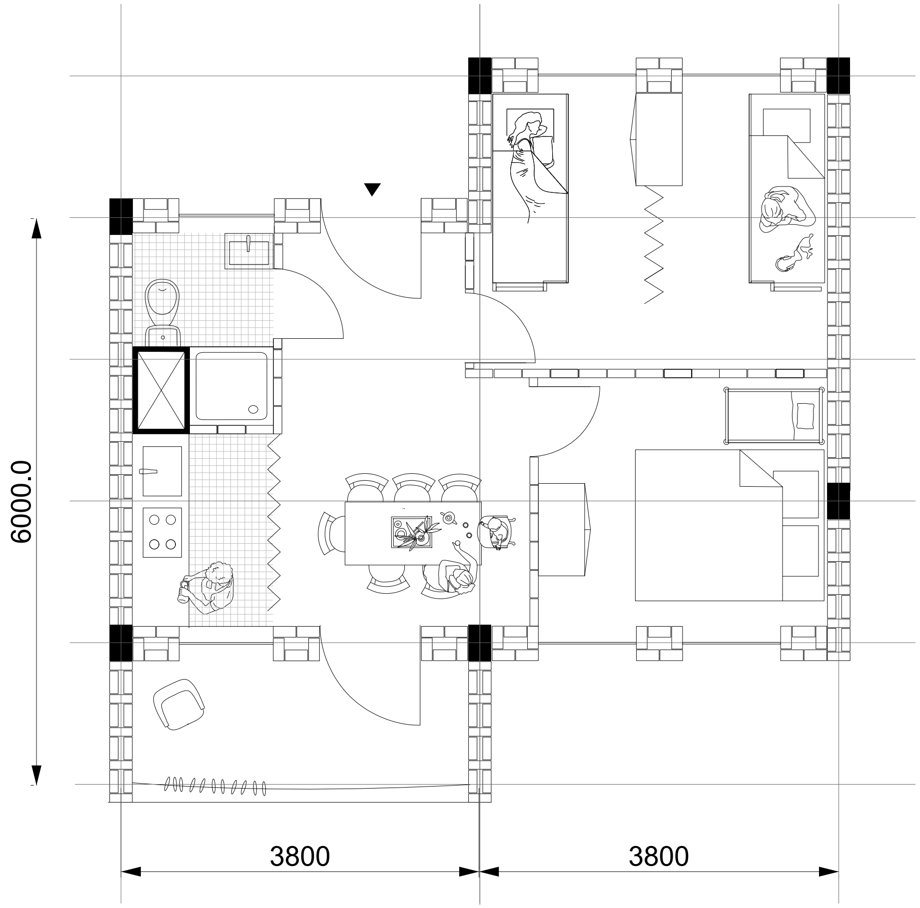


131. 3D Unit Low-income group. Source: Author, 2025

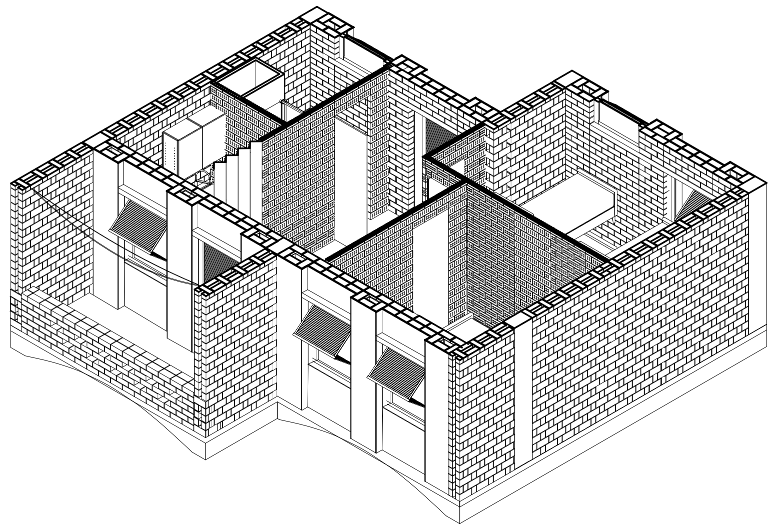


132. Units Low-income group. Source: Author, 2025

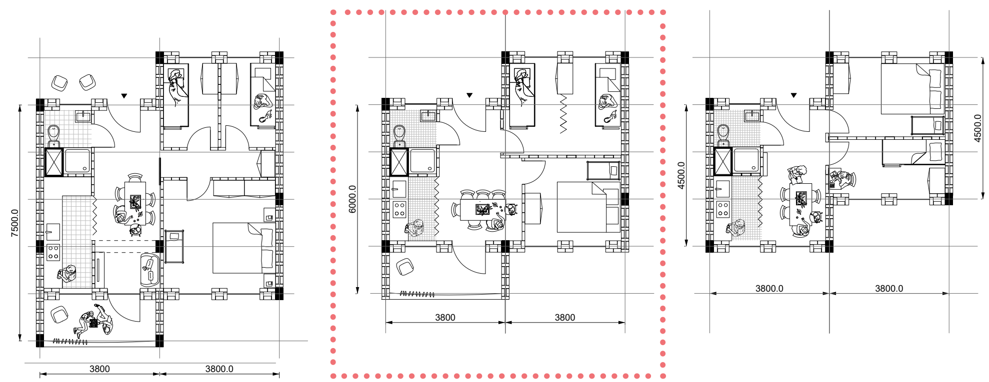
Low Income Unit: *5 - 7 persons, 51 m², 8,5 m²/p*



133. Unit Low-income group. Source: Author, 2025

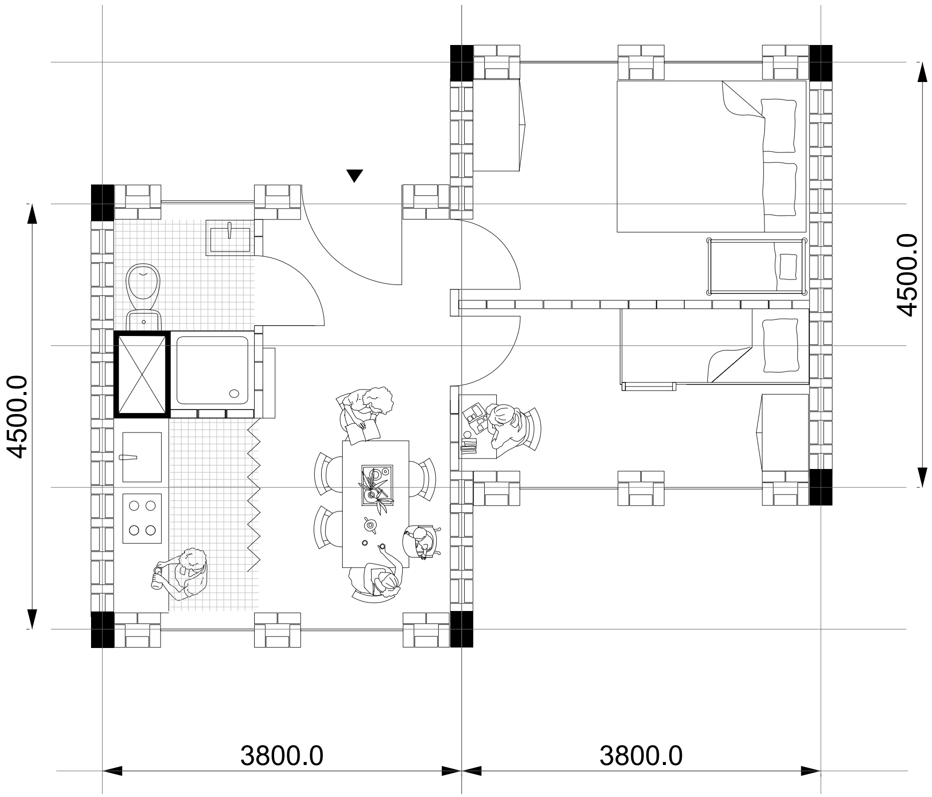


134. 3D Unit Low-income group. Source: Author, 2025



135. Units Low-income group. Source: Author, 2025

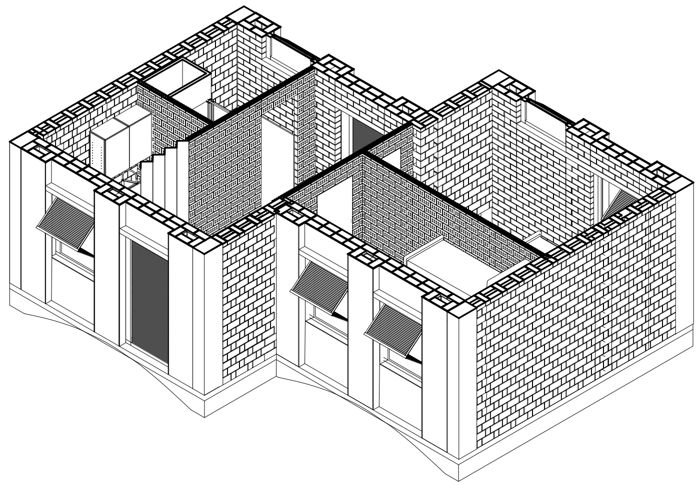
Low Income Unit: *4 - 5 persons, 38 m², 9,5 m²/p*



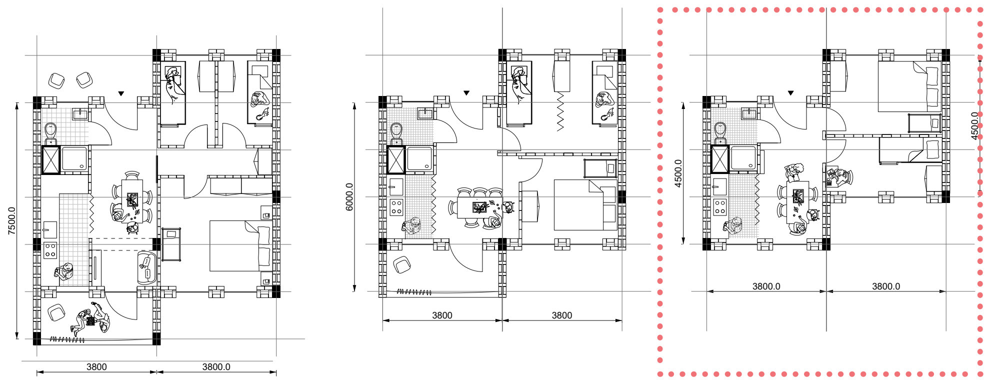
136. Unit Low-income group. Source: Author, 2025

Three distinct low-income housing units have been designed to accomodate households of varying sizes within the masterplan. Each unit consist out of two modules: a public module, which includes the kitchen, living area and toilet facilities, and a private module containing the bedrooms. Both modules have a fixed width of 3800 mm, while their lengths vary depending on the unit type. These dimensions have been carefully considered to ensure the unit provides a compact yet livable living space.

The units are designed to be stacked, creating a dynamic and playful facade.



137. 3D Unit Low-income group. Source: Author, 2025



138. Units Low-income group. Source: Author, 2025

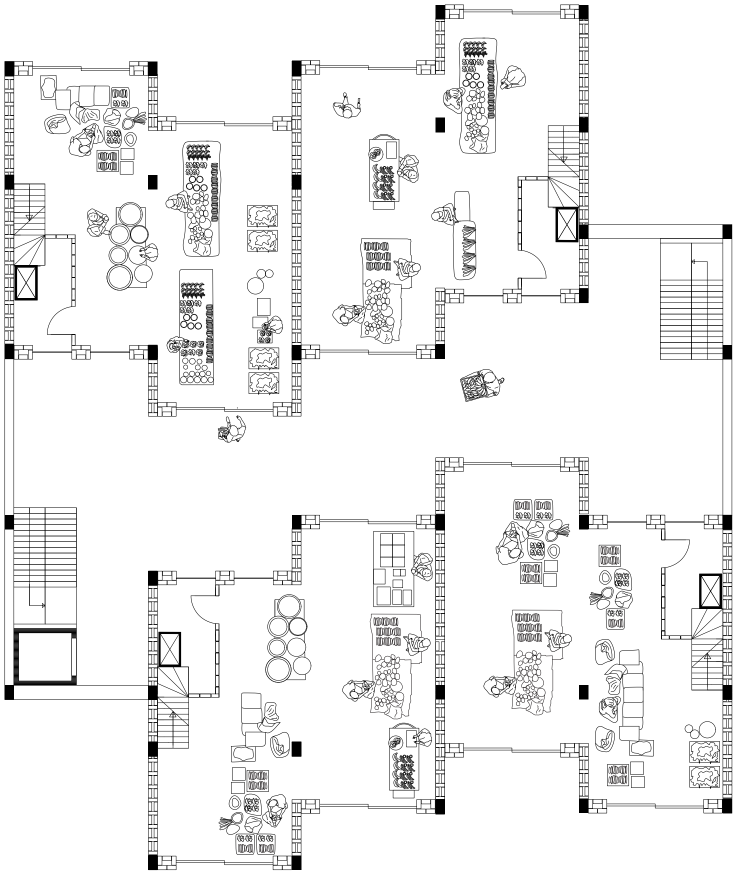
Impression: *Kitchen*

139. Impression Low-income apartments. Source: Author, 2025

Impression: *Bedroom*

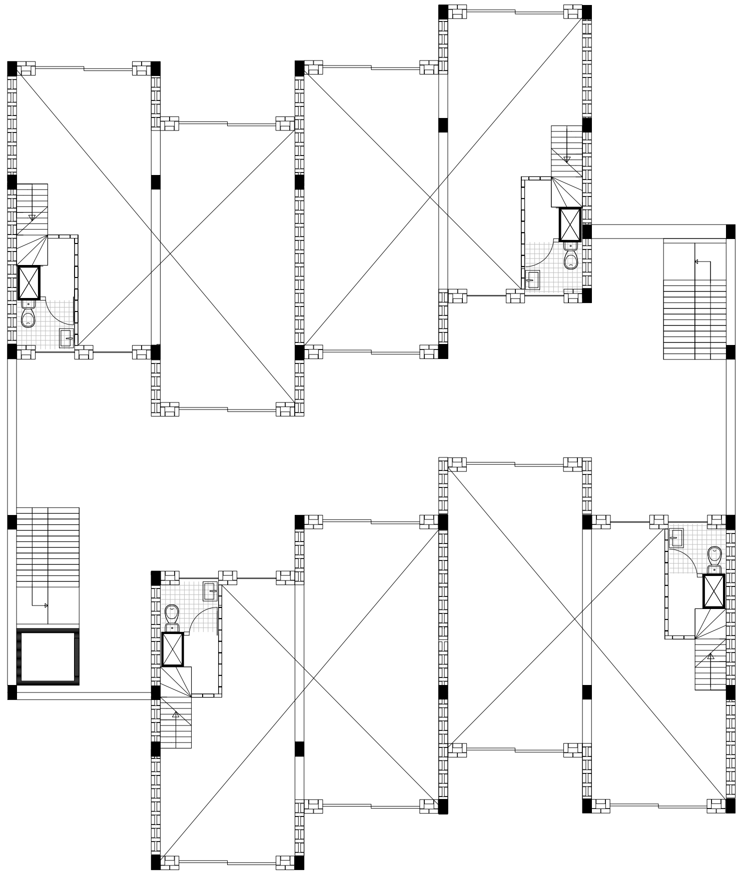
140. Impression Low-income apartments. Source: Author,2025

15.1.2. Cluster: *Ground floor, Market*



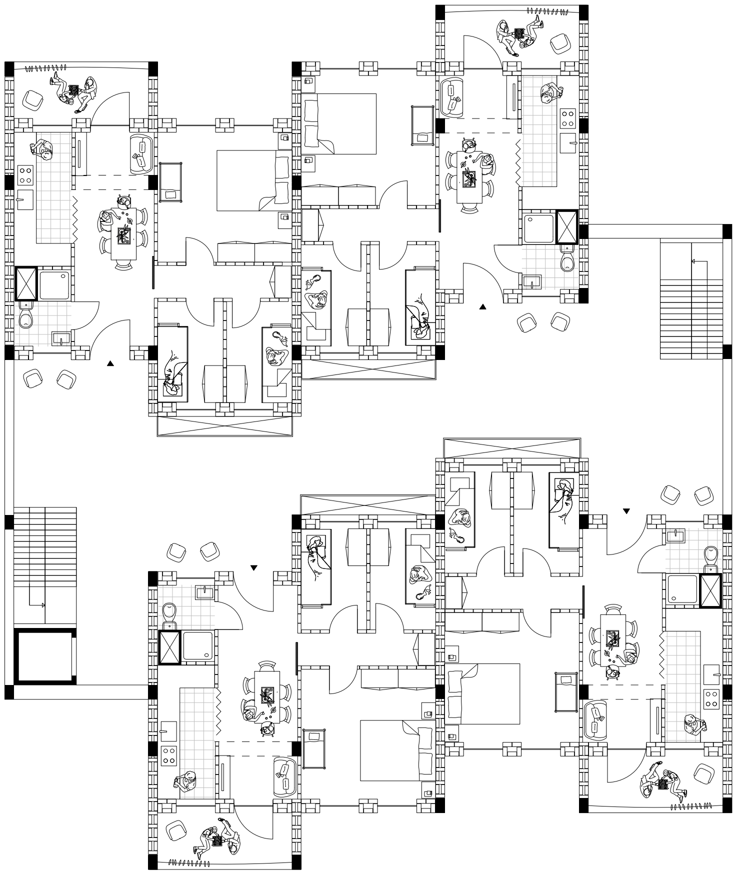
141. Cluster. Source: Author, 2025

Cluster: *First floor, Sanitation*



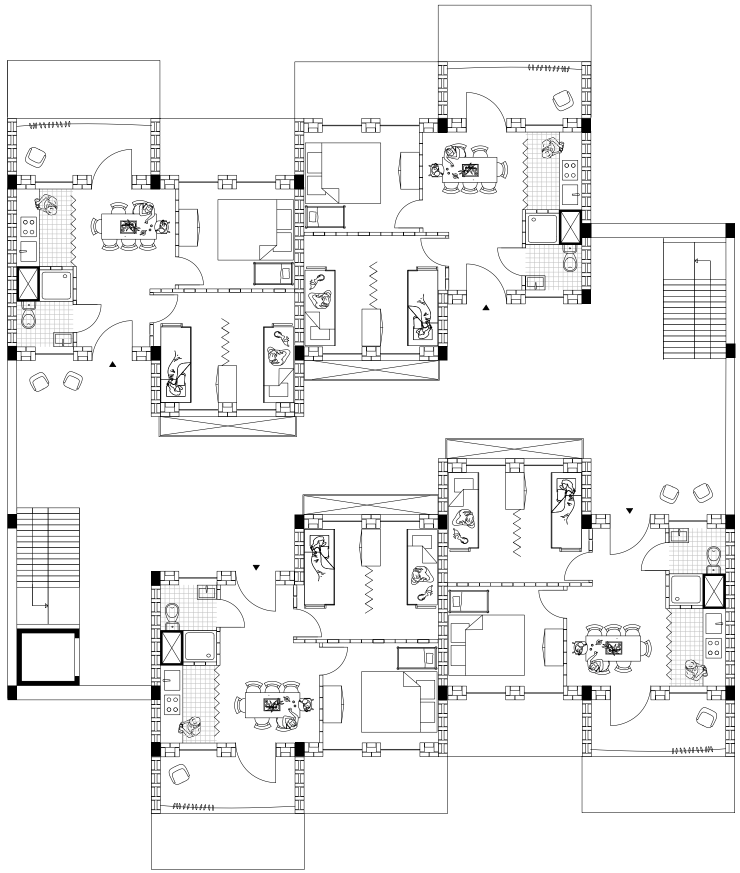
142. Cluster. Source: Author, 2025

Cluster: *Second floor, cluster of unit 1*



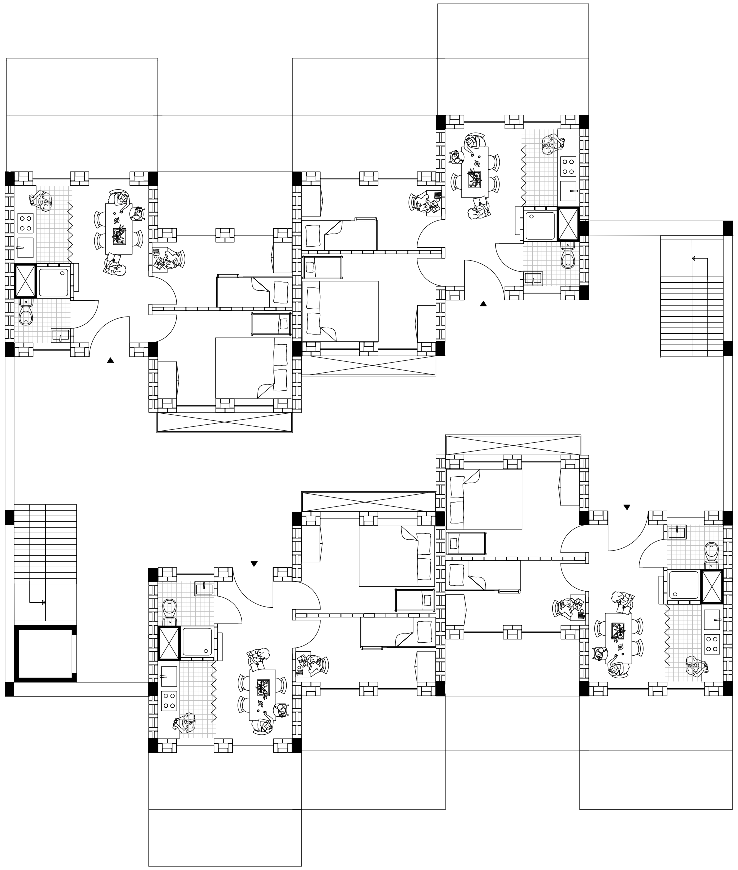
143. Cluster. Source: Author, 2025

Cluster: *Third floor, cluster of unit 2*



144. Cluster. Source: Author, 2025

Cluster: *Fourth floor, cluster of unit 3*



145. Cluster. Source: Author, 2025

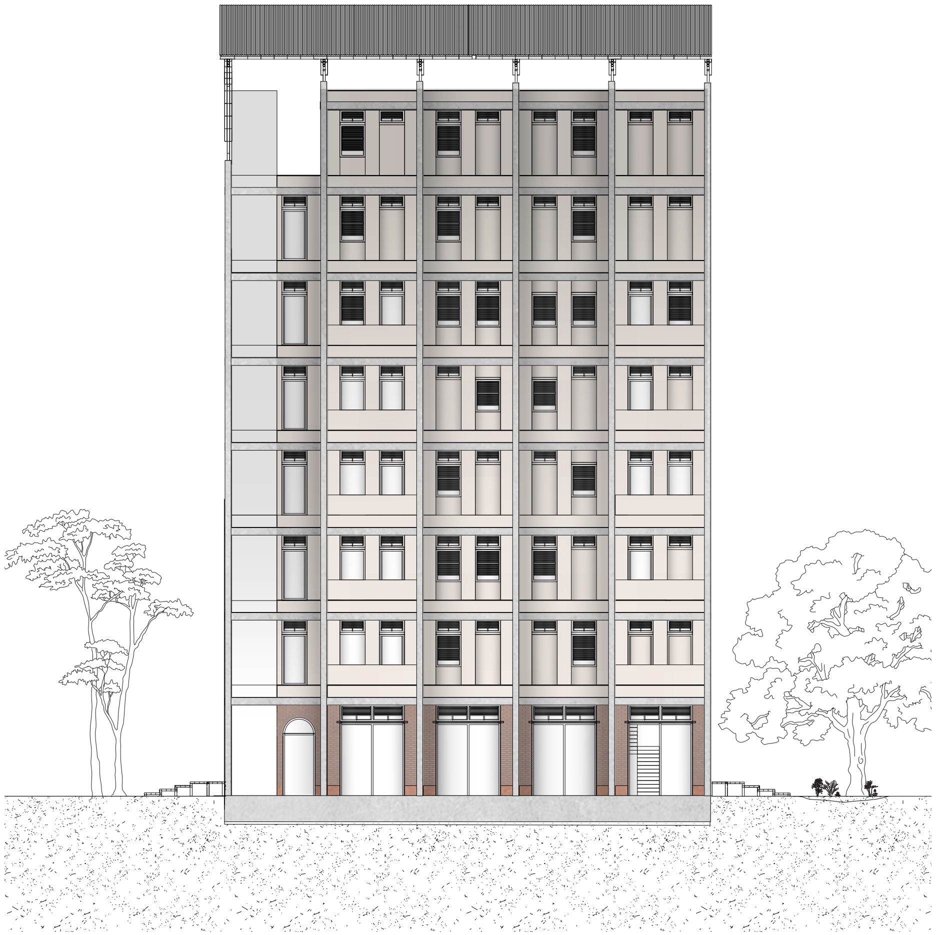
Impression: *Gallery*

146. Impression Gallery. Source: Author, 2025

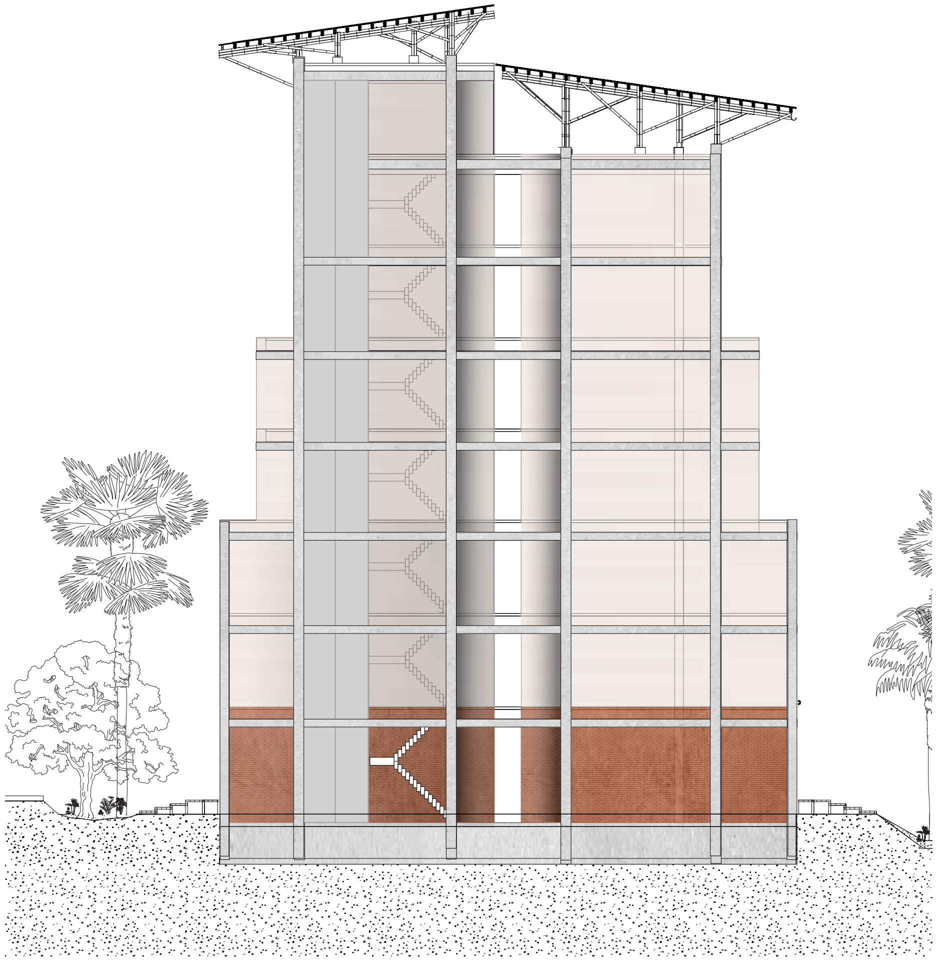
Cluster: *Section*

147. Cluster section. Source: Author, 2025

148. Cluster section. Source: Author, 2025



149. Cluster Elevation. Source: Author, 2025

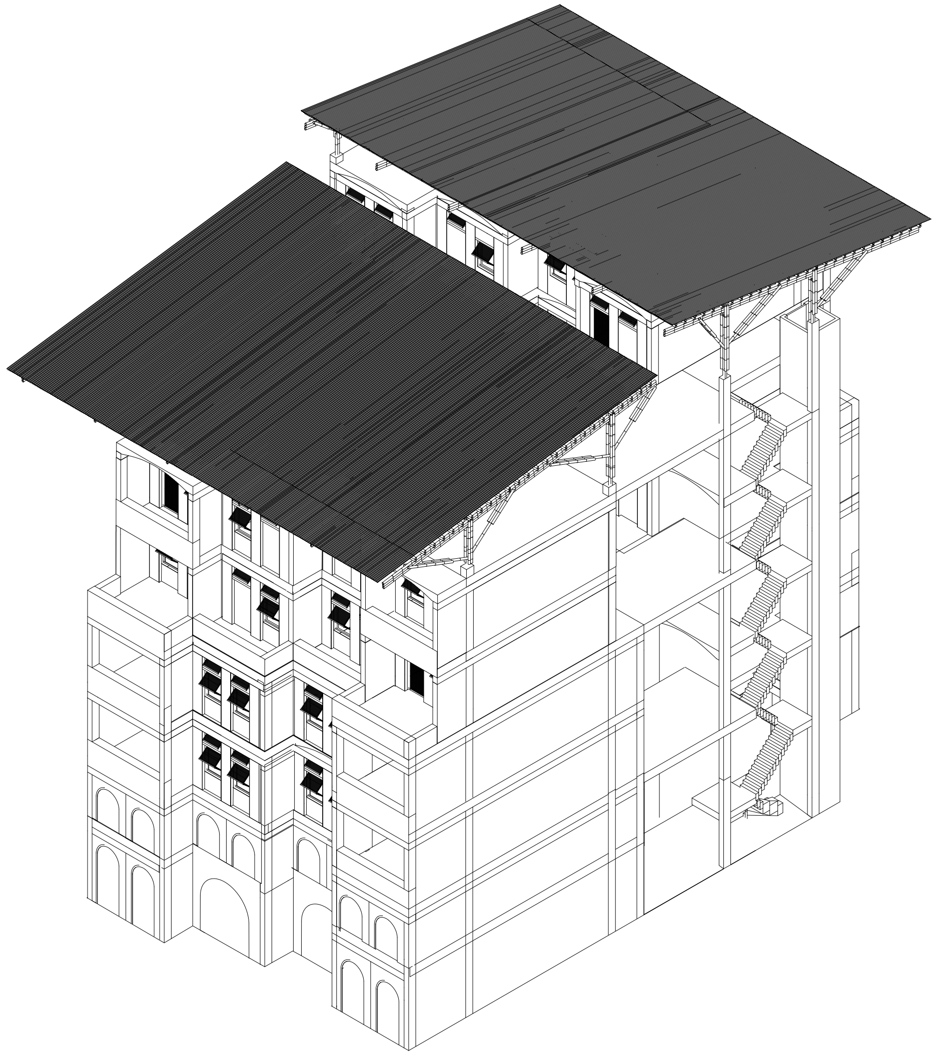


150. Cluster Elevation. Source: Author, 2025

151. Impression. Source: Author, 2025

15.2. Building 2

15.2. Building 2: *High- and Middle-income group*

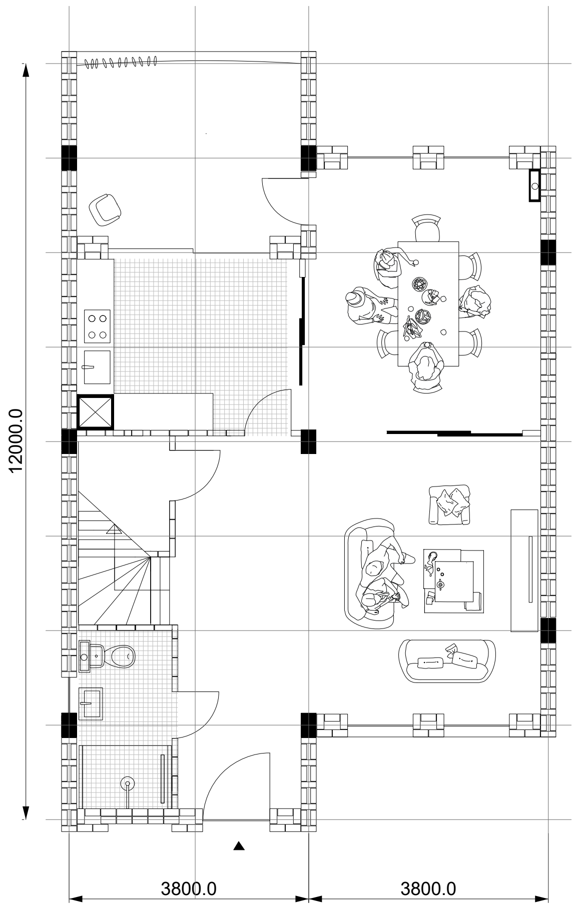


152. Building 2. Middle-Income. Source: Author, 2025

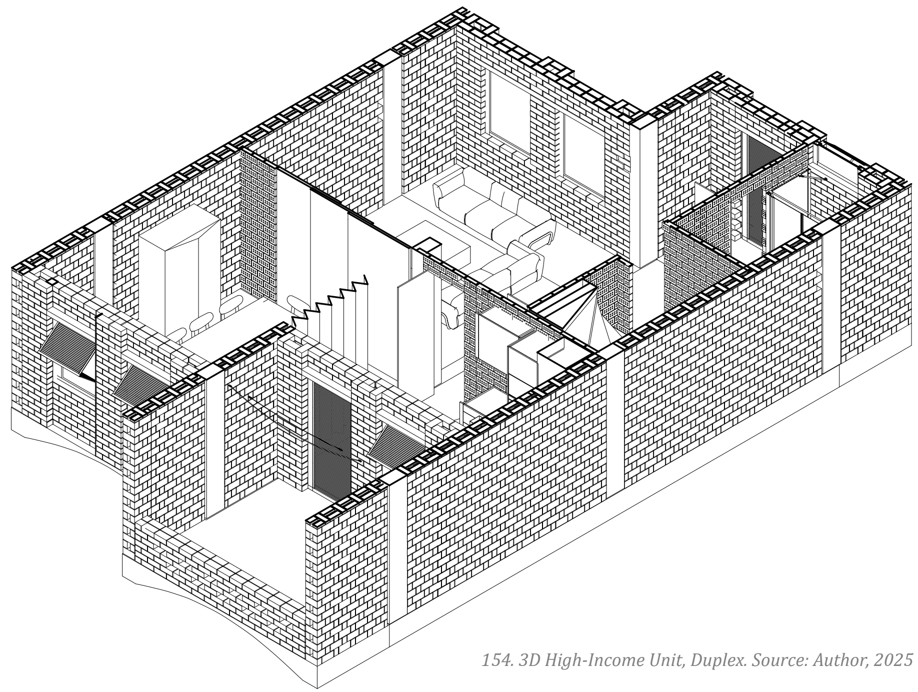
15.2.1. High-Income Unit: *Duplex - 4 persons, 172 m², 43 m²/p*

Building 2 is designed to accommodate middle- and high-income households. These units are configured as duplexes, each composed of four modules: two on the ground floor and two on the upper floor. Each module has a width of 3800 mm, with lengths of 1200 mm and 9000 mm.

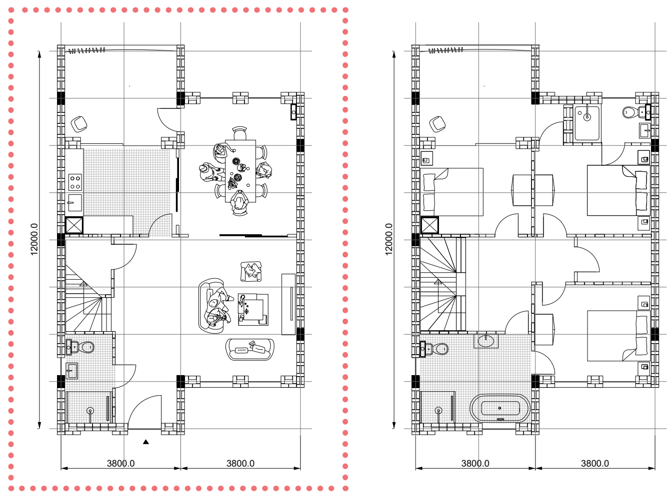
The ground floor houses the public functions, including the living area, kitchen and guest bathroom. The upper floor is dedicated to private spaces, such as bedrooms and bathrooms.



153. High-Income Unit, Duplex. Source: Author, 2025



154. 3D High-Income Unit, Duplex. Source: Author, 2025

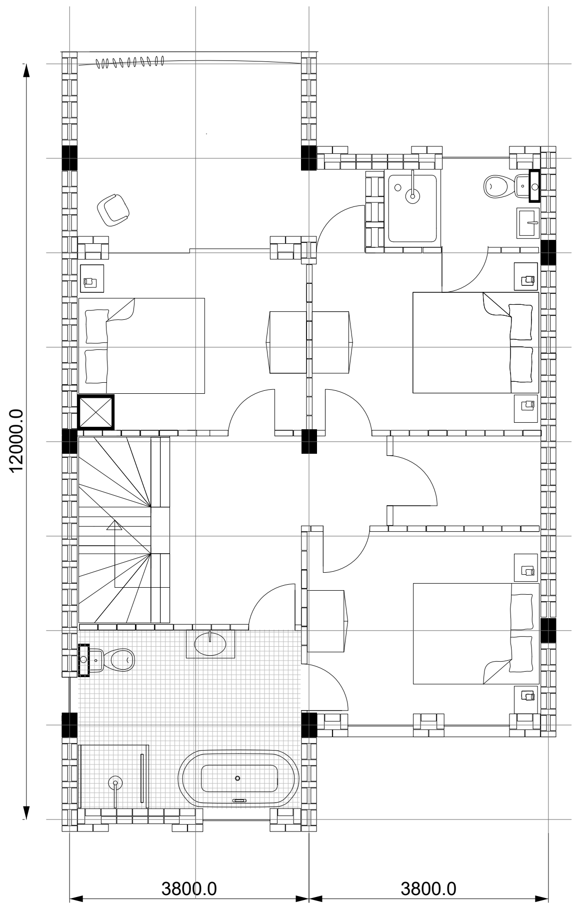


155. High-income units, duplex. Source: Author, 2025

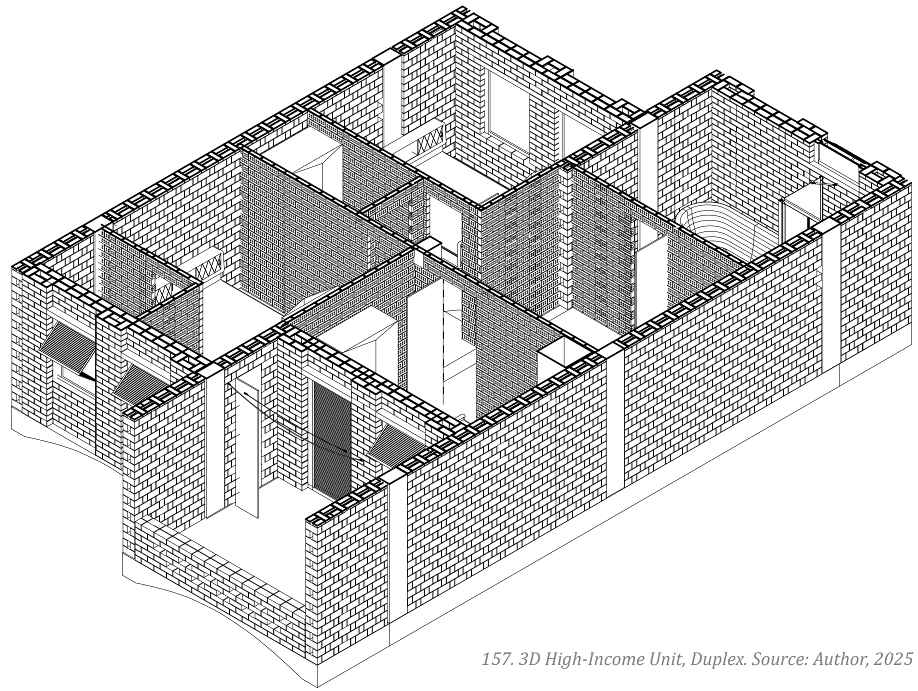
High-Income Unit: *Duplex - 4 persons, 172 m², 43 m²/p*

Compared to the low-income units, these duplexes offer more spacious rooms and increased outdoor space, providing a higher level of comfort and privacy.

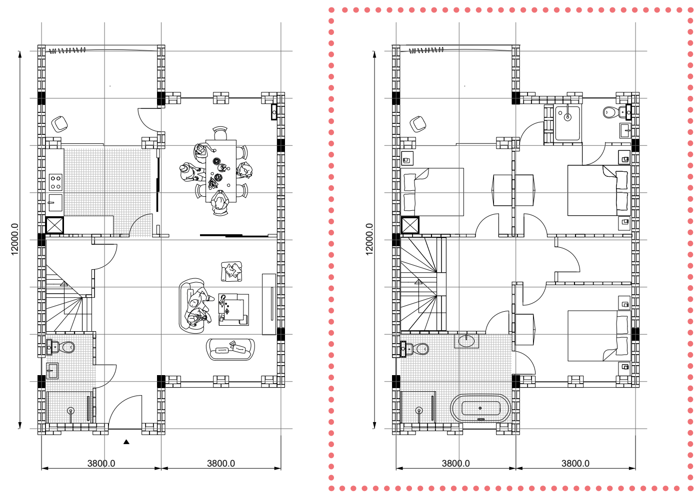
For the middle- and high-income units, CSEBs are used, with the natural texture and outline of the bricks. This material choice reflects the residents' desire to express their financial status, distinguishing these units from the low-income housing through the use of a more expensive construction material.



156. High-Income Unit, Duplex. Source: Author, 2025



157. 3D High-Income Unit, Duplex. Source: Author, 2025

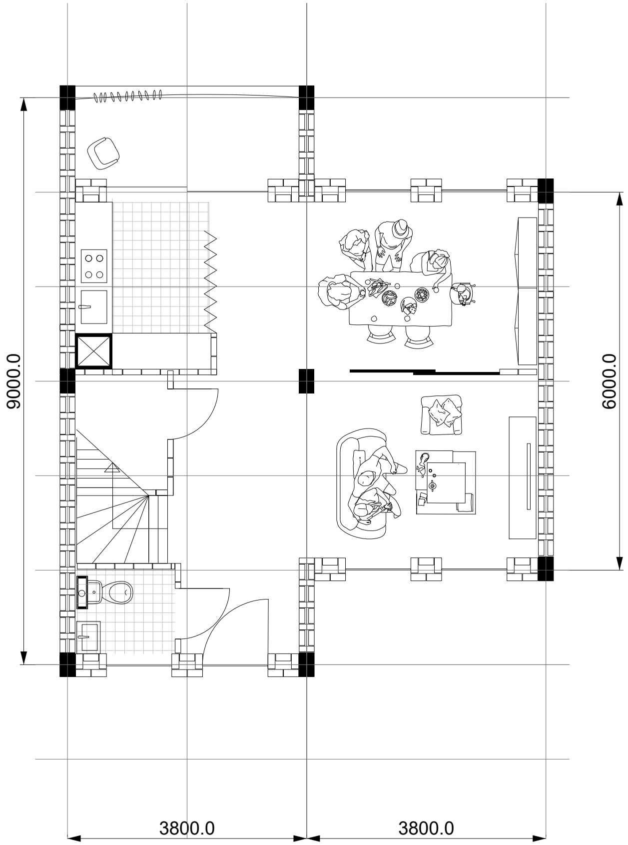


158. High-income units, duplex. Source: Author, 2025

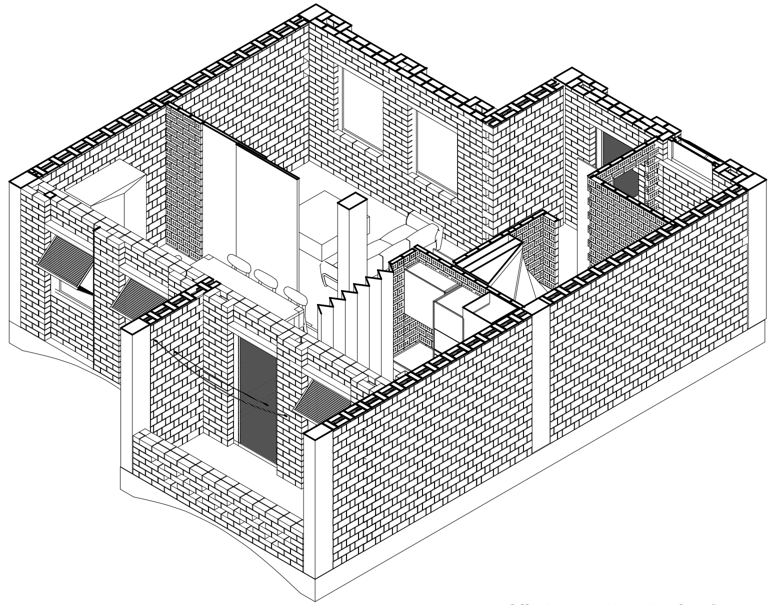

159. Impression. Source: Author, 2025

Middle-Income Unit: *Duplex - 4 persons, 120 m², 30 m²/p*

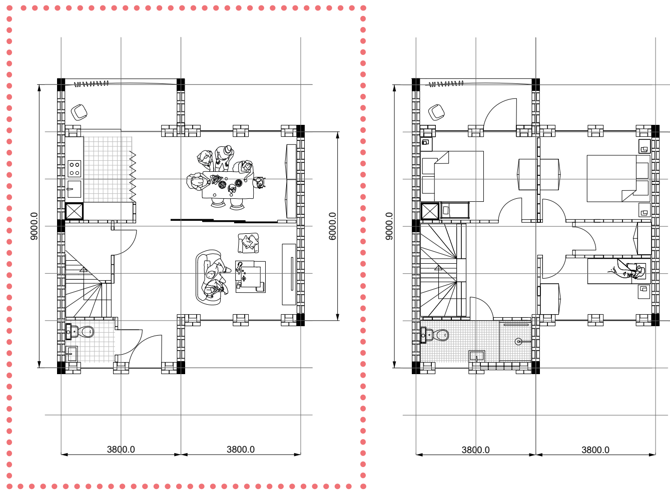
The middle-income units are positioned above the high-income units within the building. These units are composed of smaller modules, each with a width of 3800 mm and lengths of 9000 mm or 6000 mm. Compared to the high-income units, they feature more compact loggia's and bathrooms.



160. Middle-Income Unit, Duplex. Source: Author, 2025

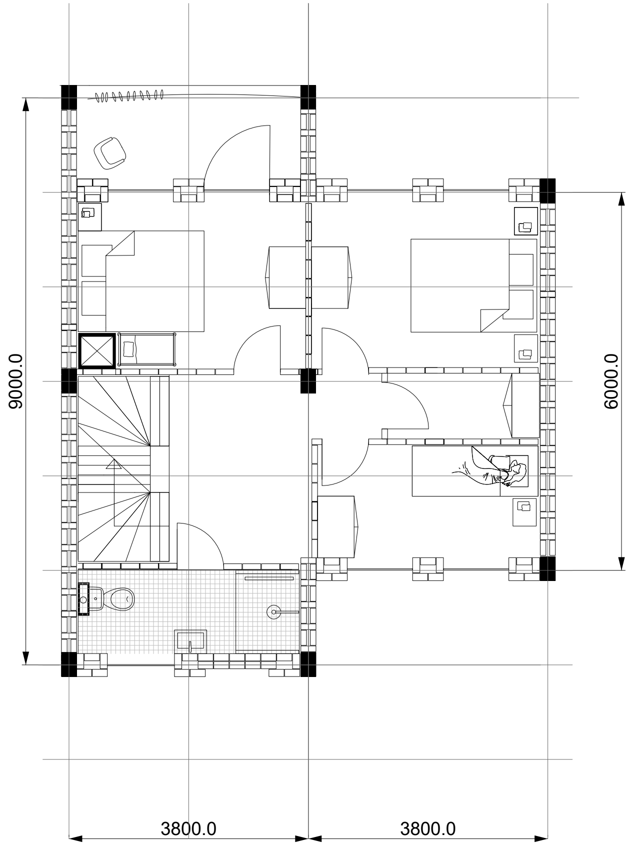


161. 3D Middle-Income Unit, Duplex. Source: Author, 2025

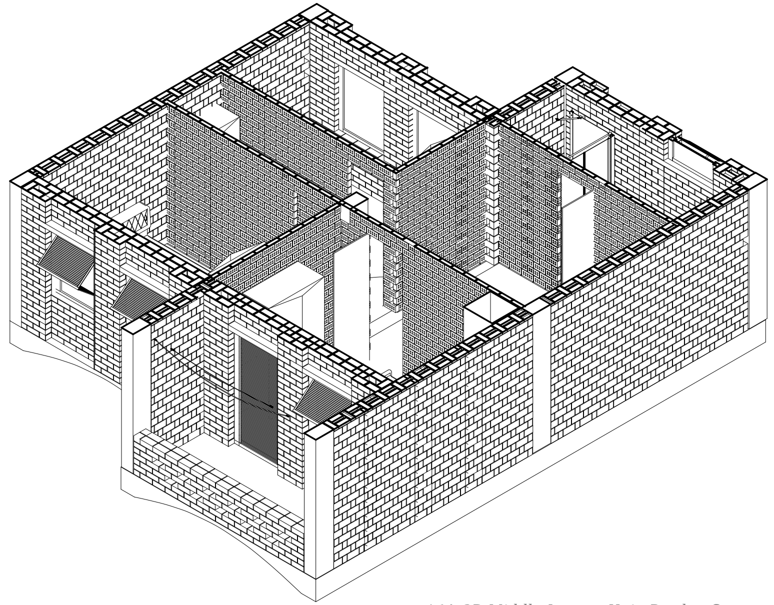


162. Middle-income units, duplex. Source: Author, 2025

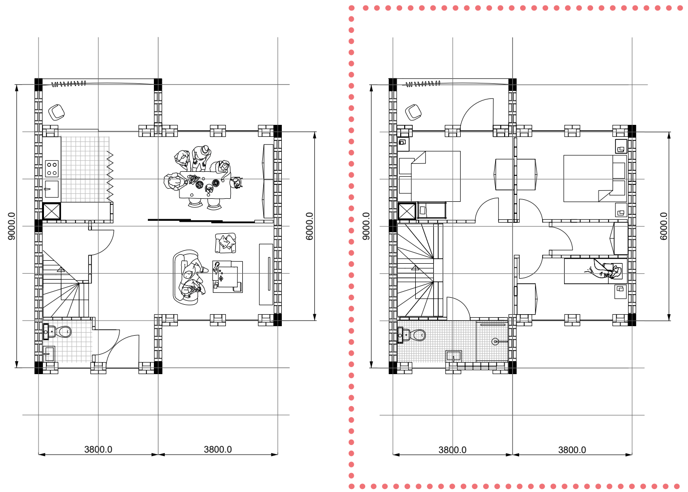
Middle-Income Unit: *Duplex - 4 persons, 124 m², 31 m²/p*



163. Middle-Income Unit, Duplex. Source: Author, 2025



164. 3D Middle-Income Unit, Duplex. Source: Author, 2025



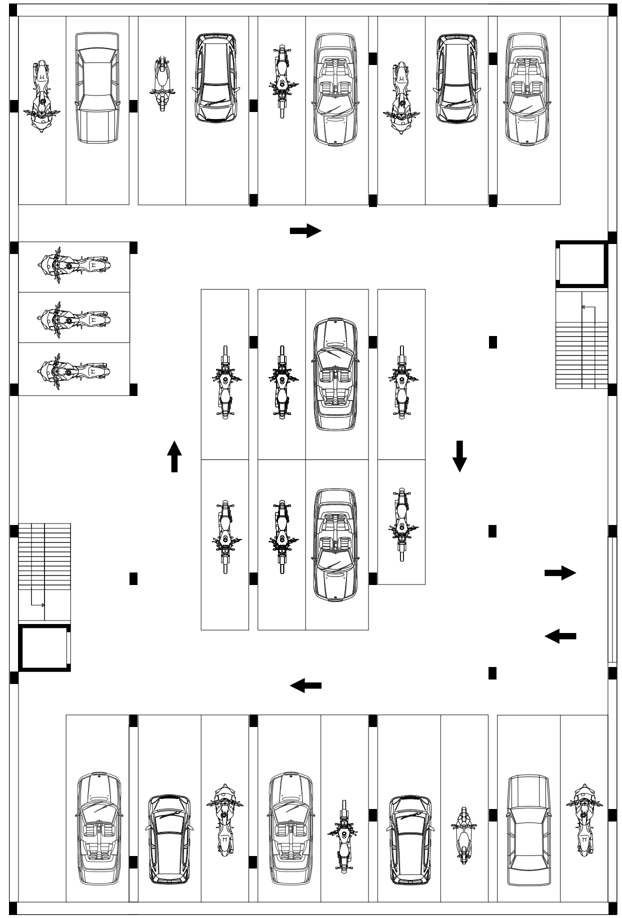
165. Middle-income units, duplex. Source: Author, 2025


166. Impression. Source: Author, 2025

167. Impression. Source: Author, 2025

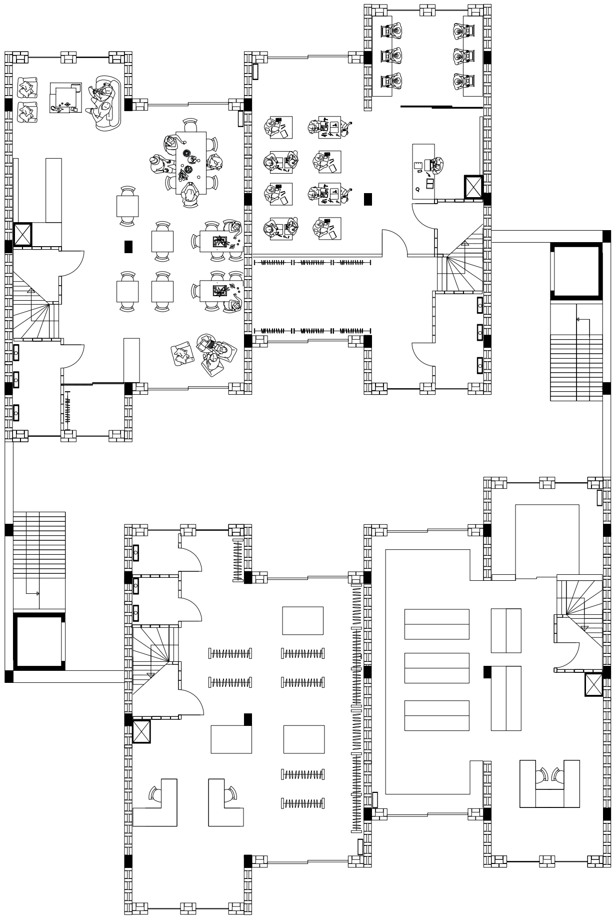
15.2.2. Cluster: *Middle- and High-Income*

15.2.2. Cluster: *Underground Parking*



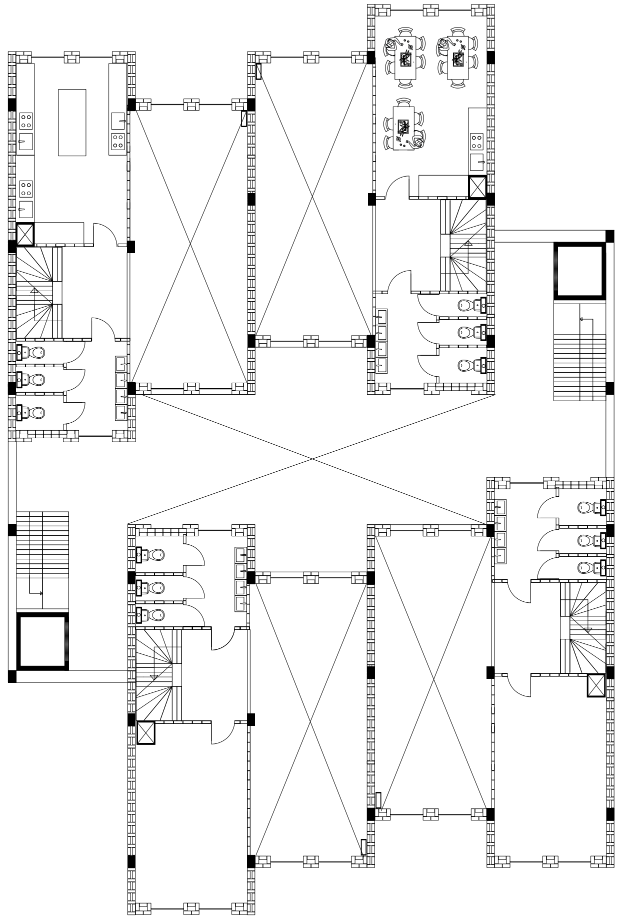
167. Cluster, Underground Parking. Source: Author, 2025

Cluster: *Ground floor, Public Plinth*



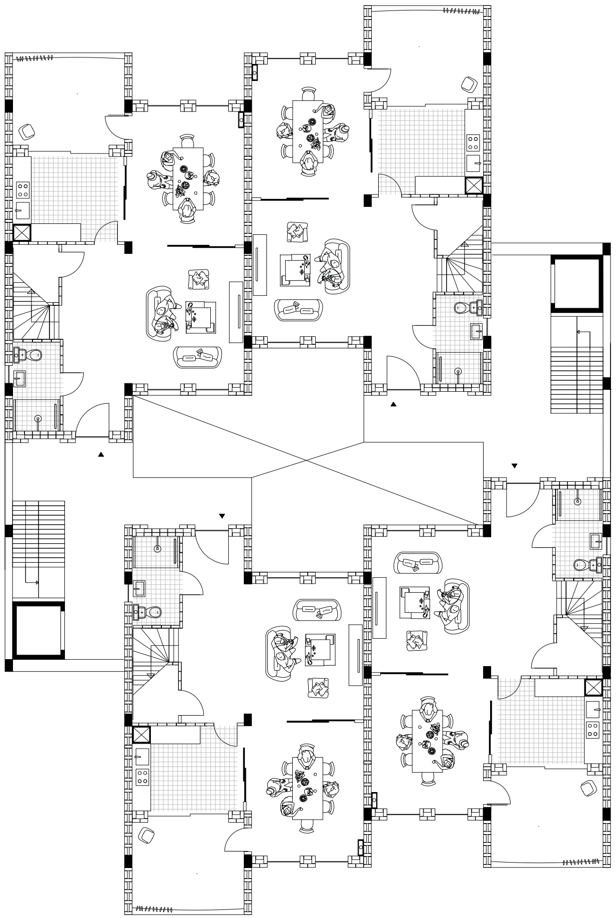
168. Groundfloor, amenities. Source: Author, 2025

Cluster: *First floor, Kitchens and Sanitation*



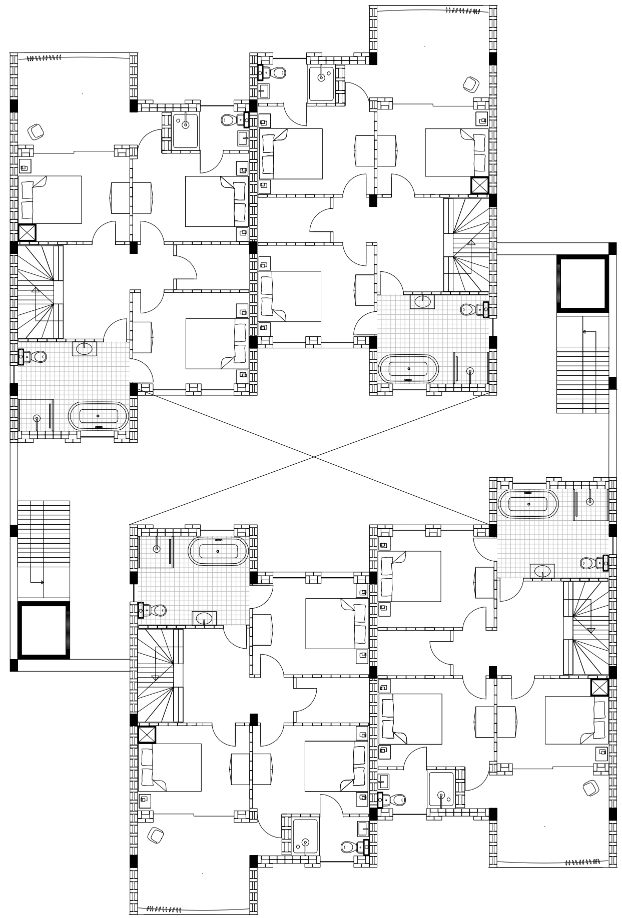
169. First floor, Sanitation and Kitchens. Source: Author, 2025

Cluster: *Second floor, high-income duplexes*



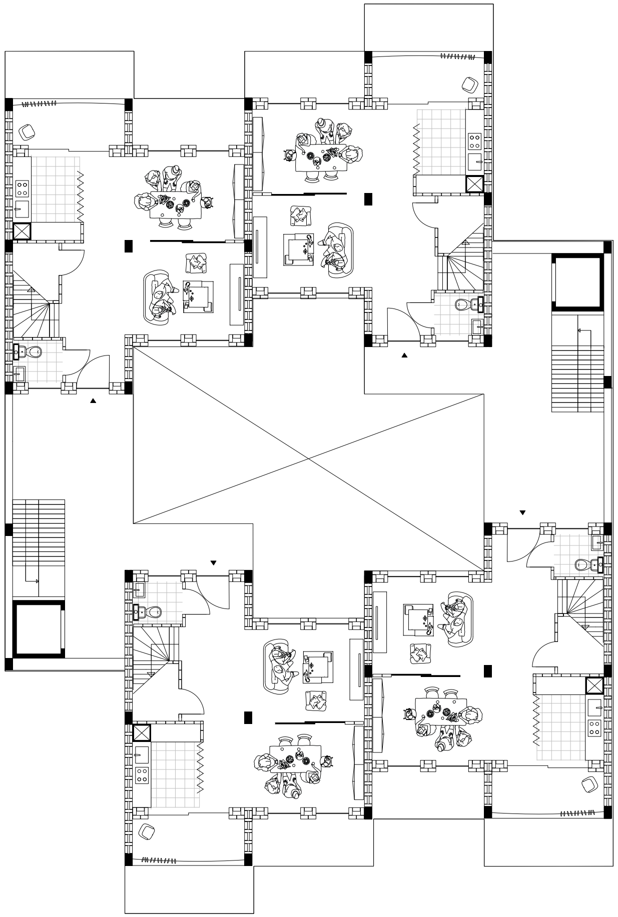
170. Second Floor, High-income Duplex. Source: Author, 2025

Cluster: *Third floor, high-income duplexes*



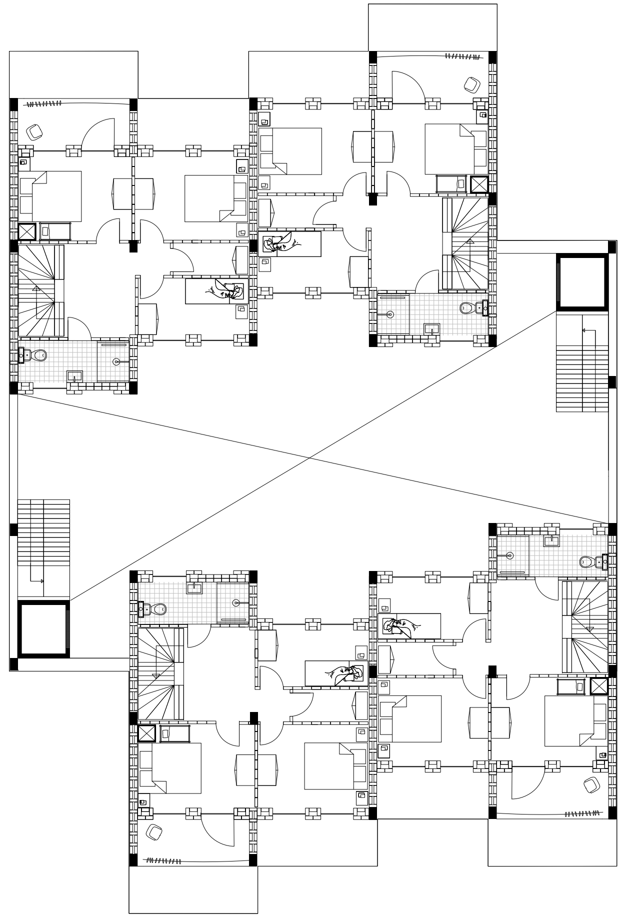
171. Third Floor, High-income Duplex. Source: Author, 2025

Cluster: *Fourth floor, Middle-income duplexes*



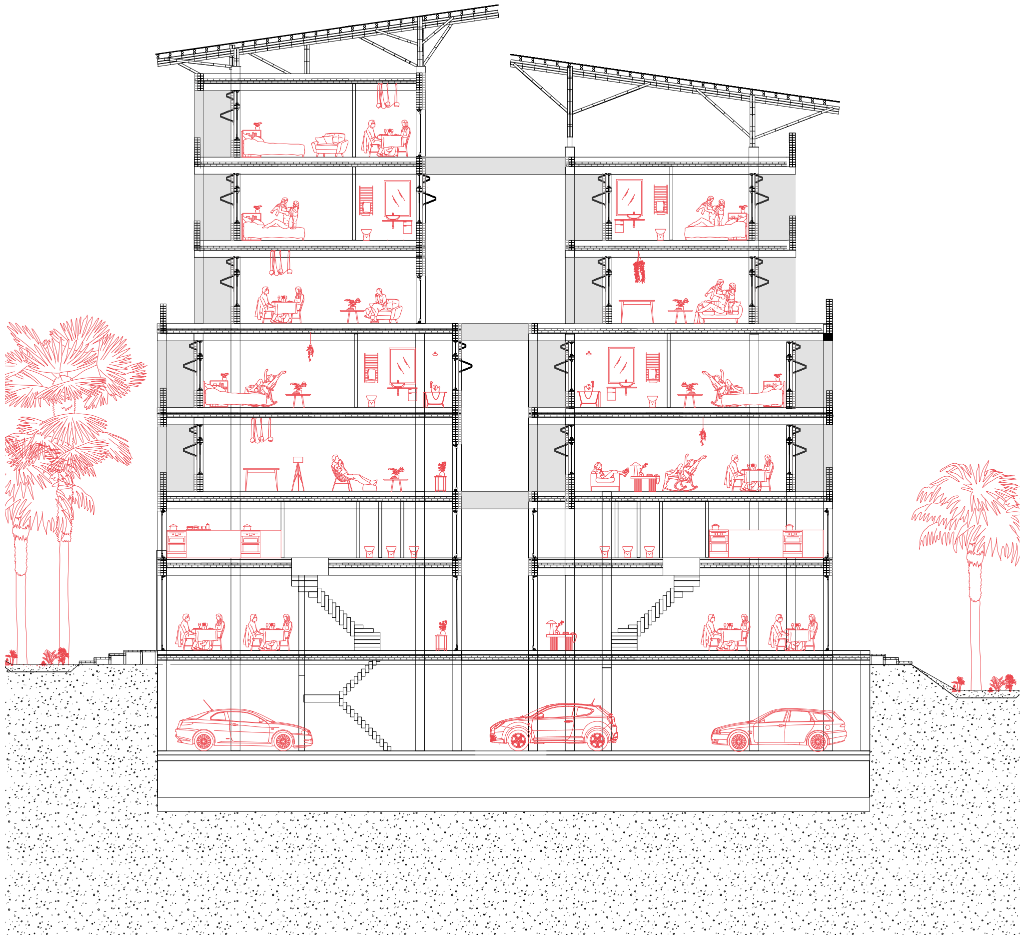
172. Fourth floor, Middle-income Duplex. Source: Author, 2025

Cluster: *Fifth floor, Middle-income duplexes*



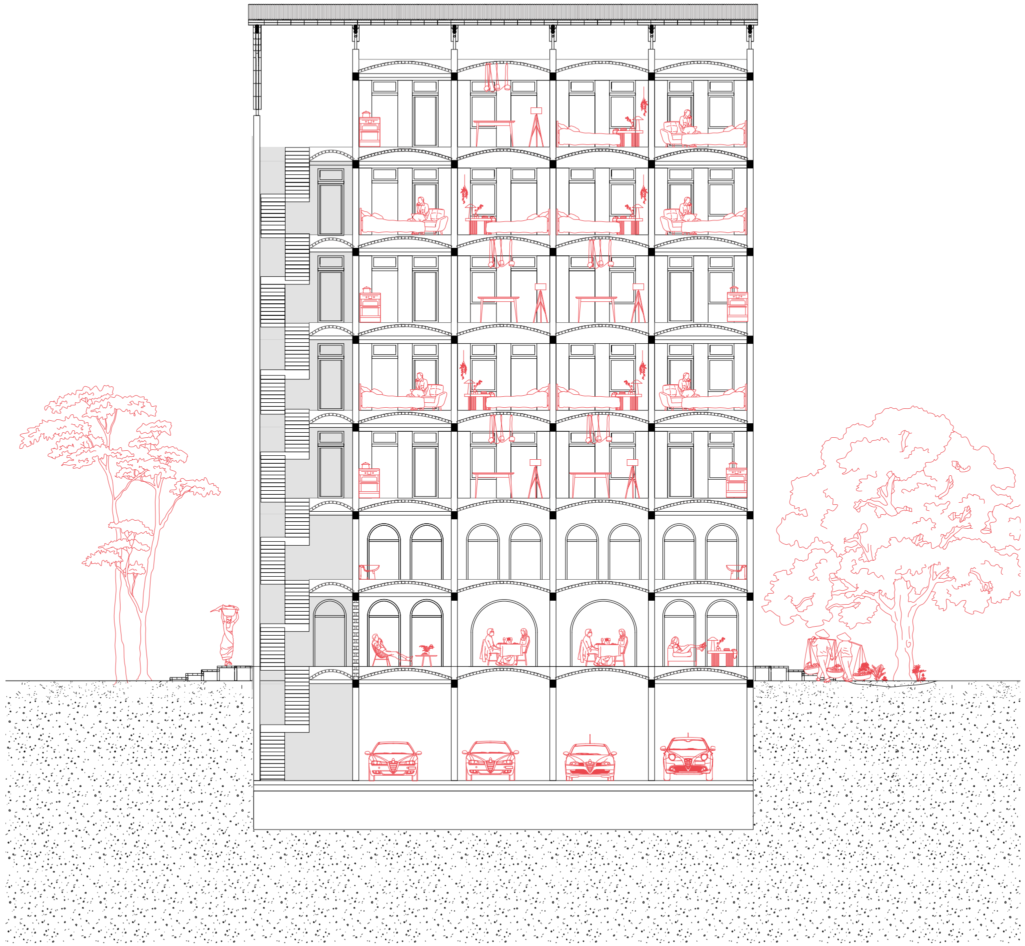
173. Fifth Floor, Middle-income Duplex. Source: Author, 2025

Cluster: *Section*



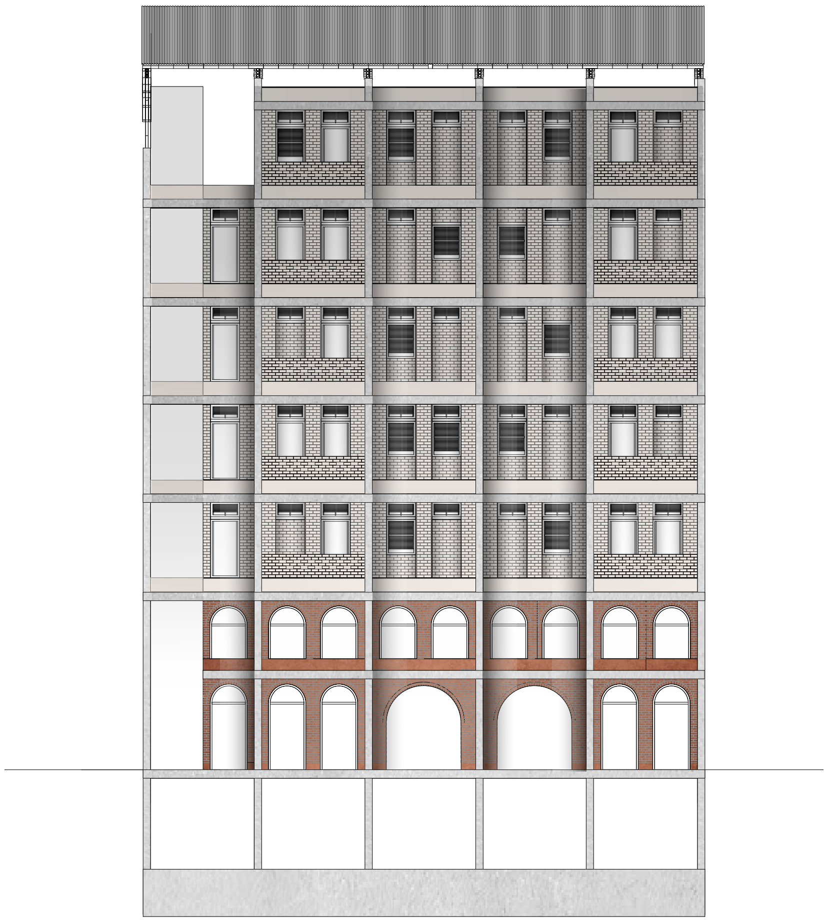
174. Cluster, Section. Source: Author, 2025

Cluster: *Section*



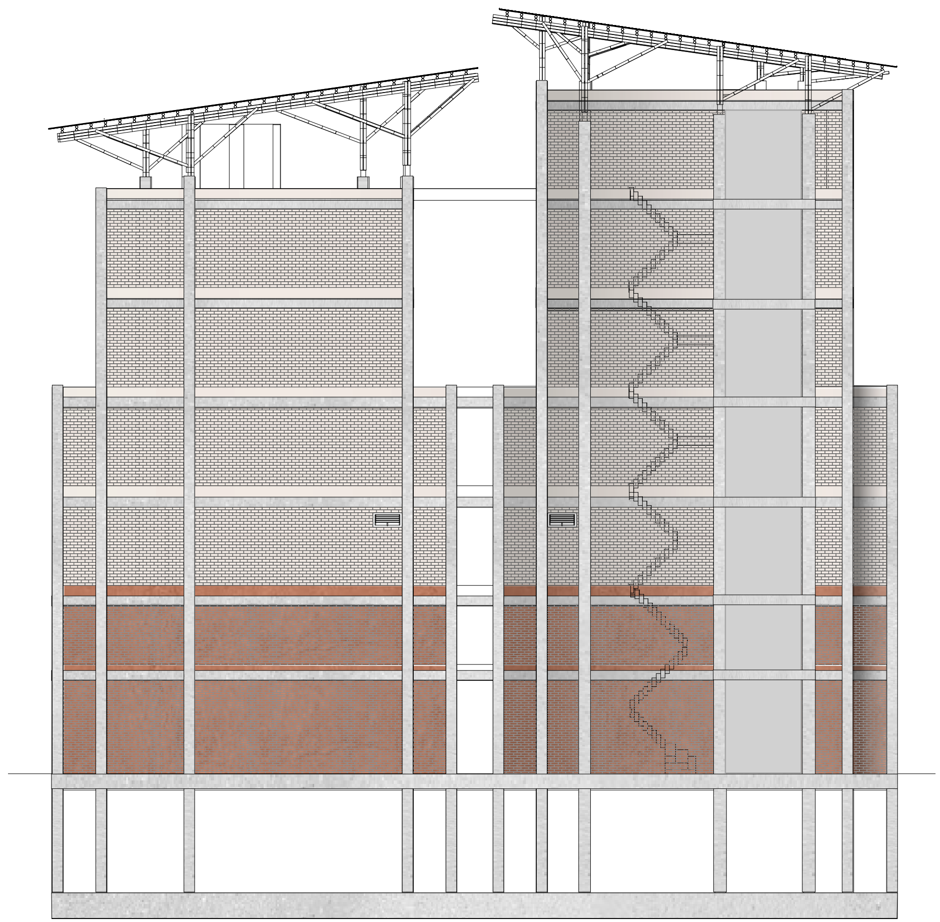
175. Cluster, Section. Source: Author, 2025

Cluster: *Elevation*

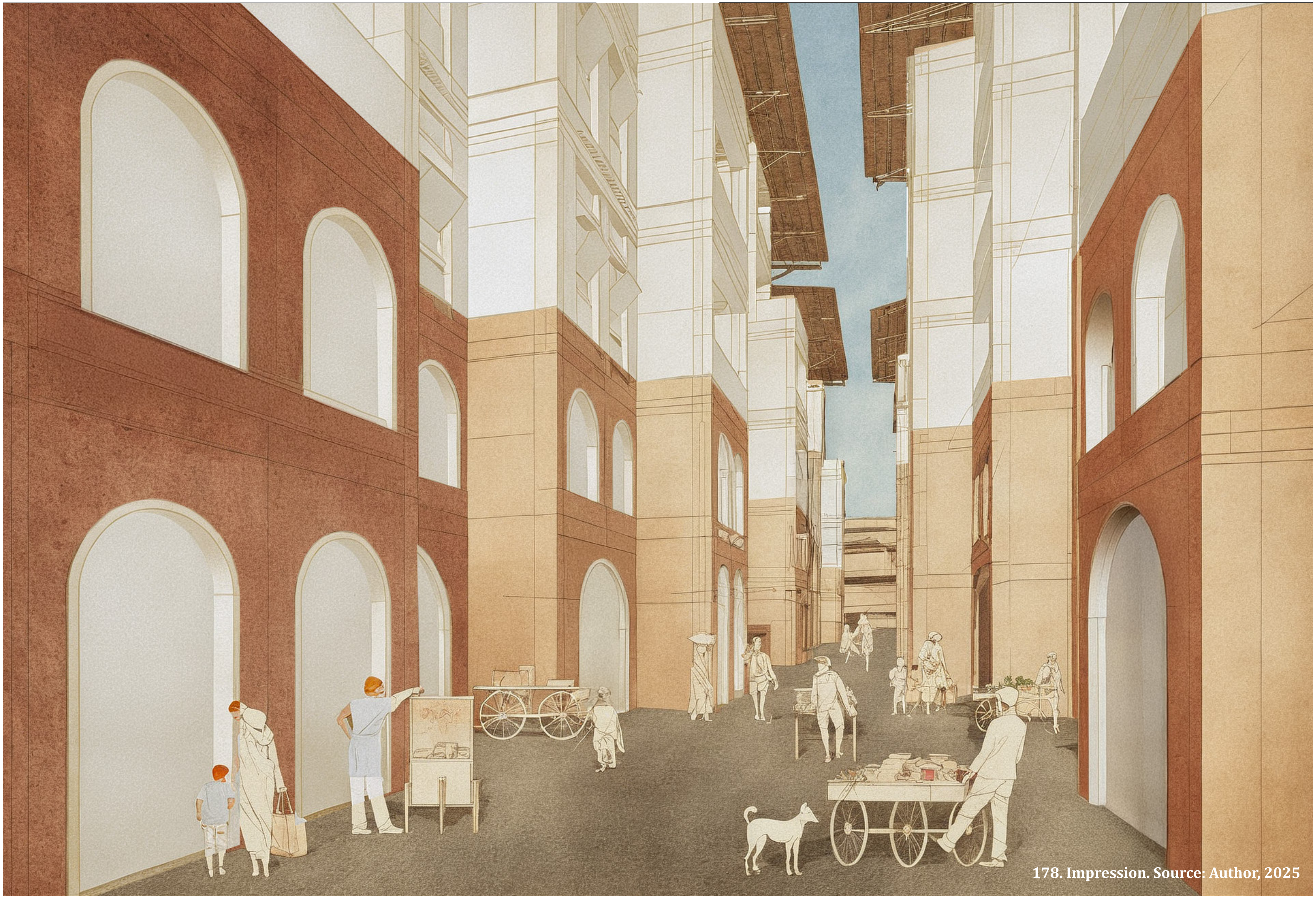


176. Cluster, Elevation. Source: Author, 2025

Cluster: *Elevation*

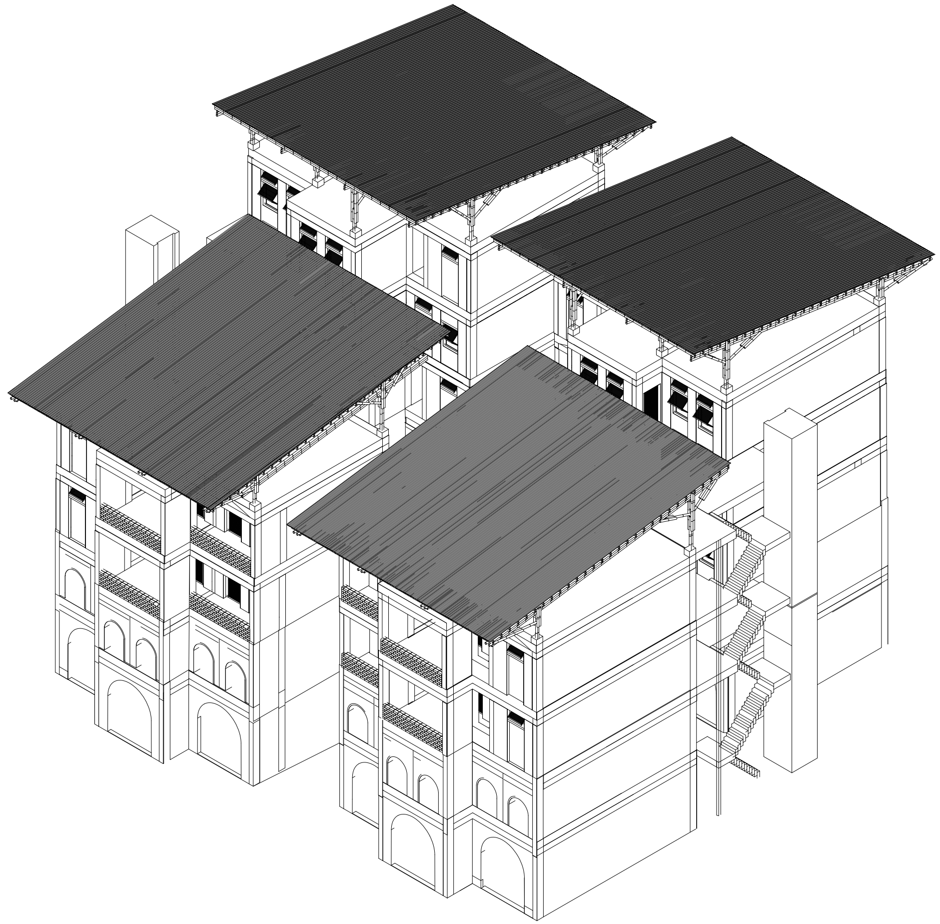


177. Cluster, Elevation. Source: Author, 2025


178. Impression. Source: Author, 2025

15.3. Building 3

15.3. Building 3: *Middle- and High-income group*

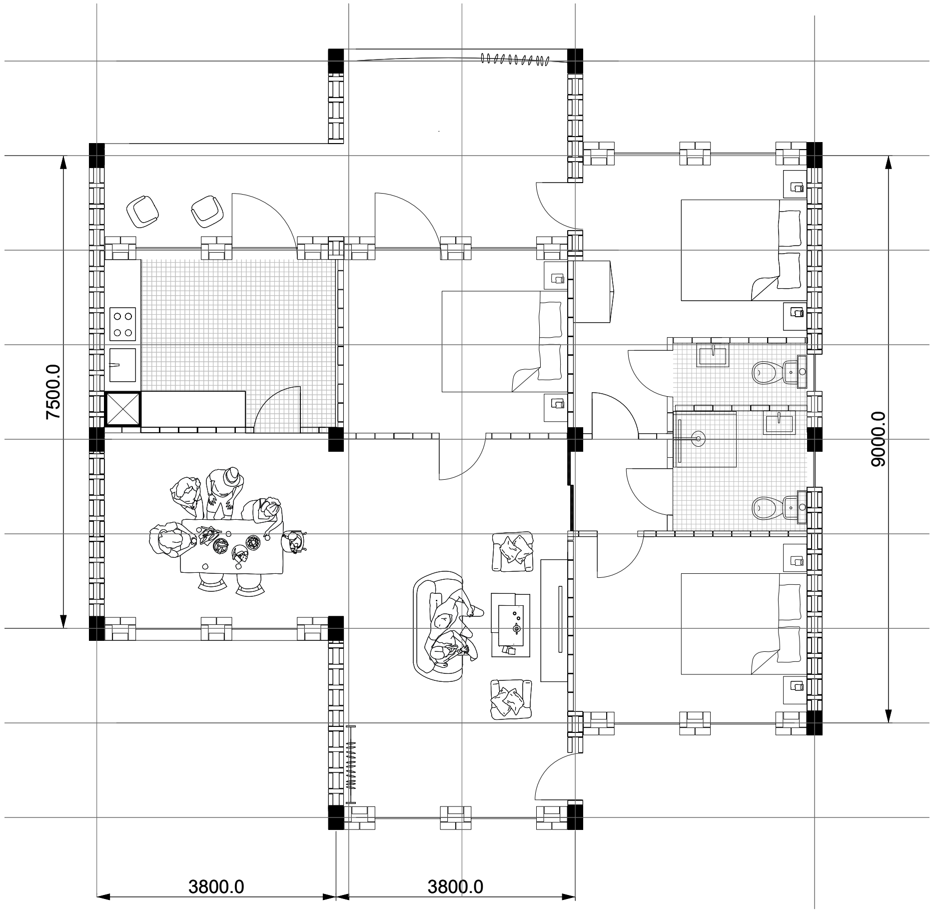


179. Building 3. Source: Author, 2025

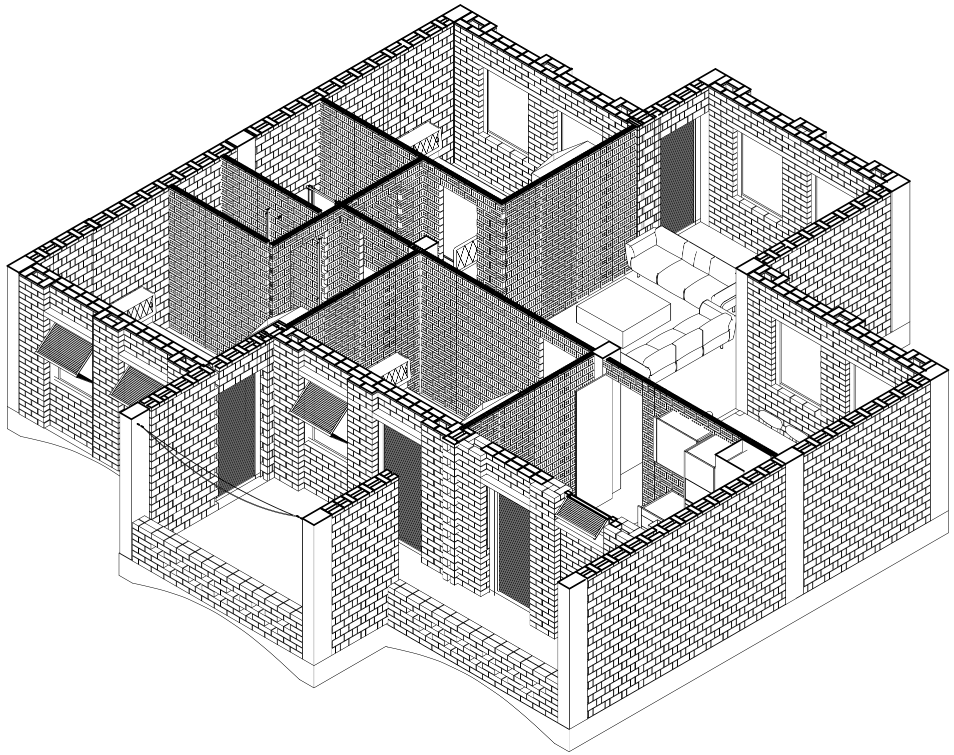
15.3.1. Middle-Income Unit: *4 persons, 115 m², 28,75 m²/p*

Building 3 accomodates two types of units: a single-floor middle-income unit and a two-floor high-income unit. The middle-income unit is designed for a household of four people and is composed of three modules, each with a width of 3800 mm and lengths of 7500 mm, 12000 mm and 9000 mm.

While entering the unit, residents are greeted by an open dining and living area. The kitchen is located on one side of the apartment, while the private spaces, bedrooms and bathrooms, are situated on the opposite side, ensuring a clear separation between public and private functions.



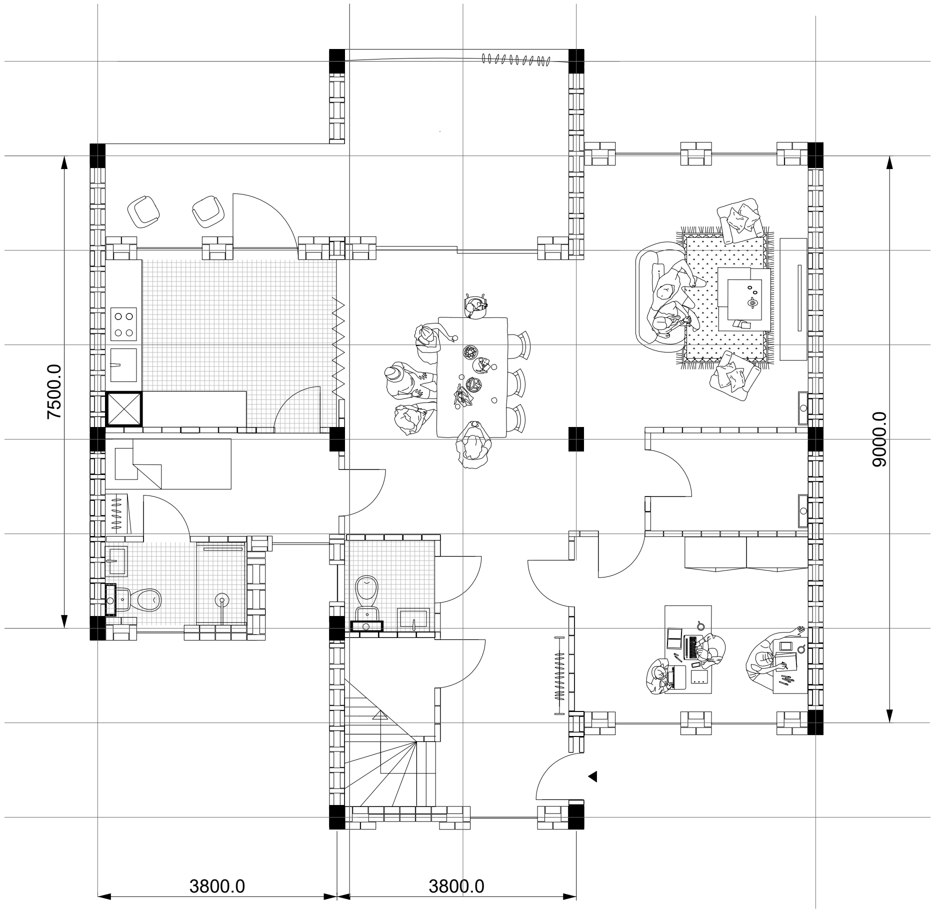
180. Middle-Income Unit. Source: Author, 2025



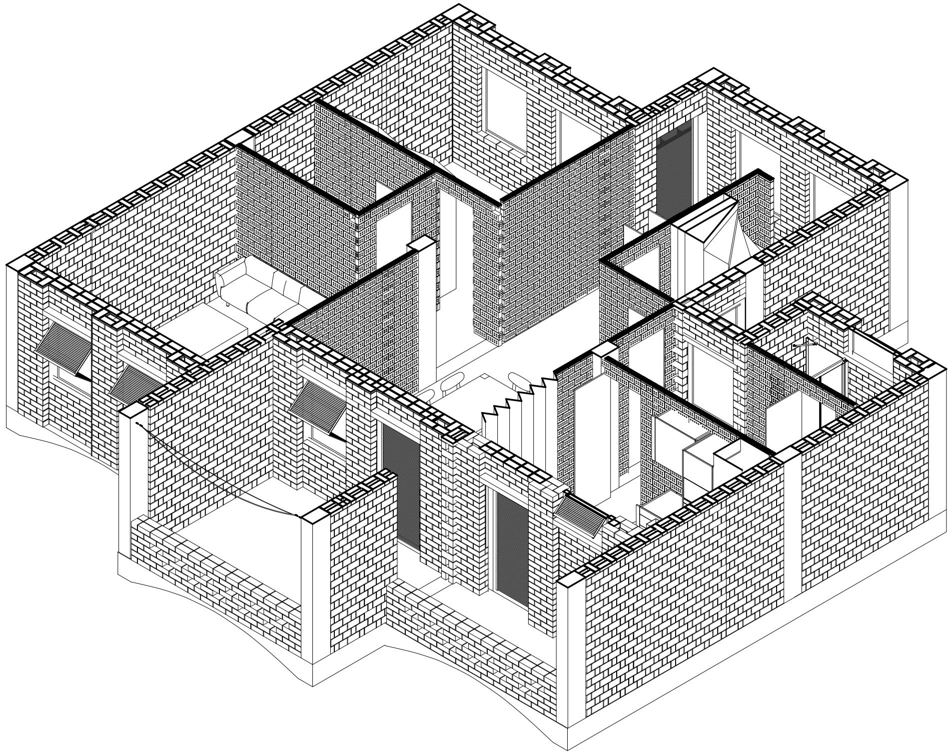
181. 3D Middle-Income Unit. Source: Author, 2025

High-Income Unit: *Duplex - 5 persons, 230 m², 46 m²/p*

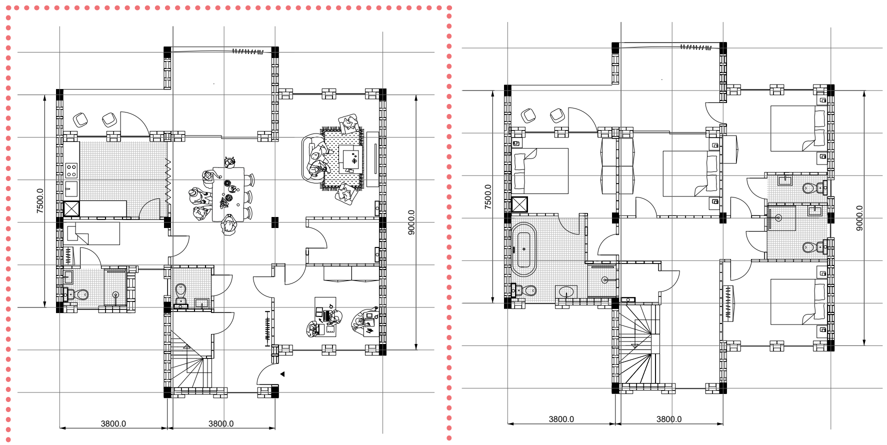
The high-income unit in building 3 is a duplex designed to accommodate a household of five. It consists of three modules on the ground floor and three on the upper floor, each with a width of 3800 mm and lengths of 7500 mm, 12000 mm and 9000 mm. The ground floor serves as the public zone of the home, featuring an open-plan living and dining area, as well as dedicated space for a maid. The maid's room is directly connected to the kitchen and includes a private bathroom. Additionally, a home office is located near the entrance, allowing residents to receive colleagues or guests without disrupting the privacy of the rest of the home.



182. High-Income Unit, Duplex. Source: Author, 2025



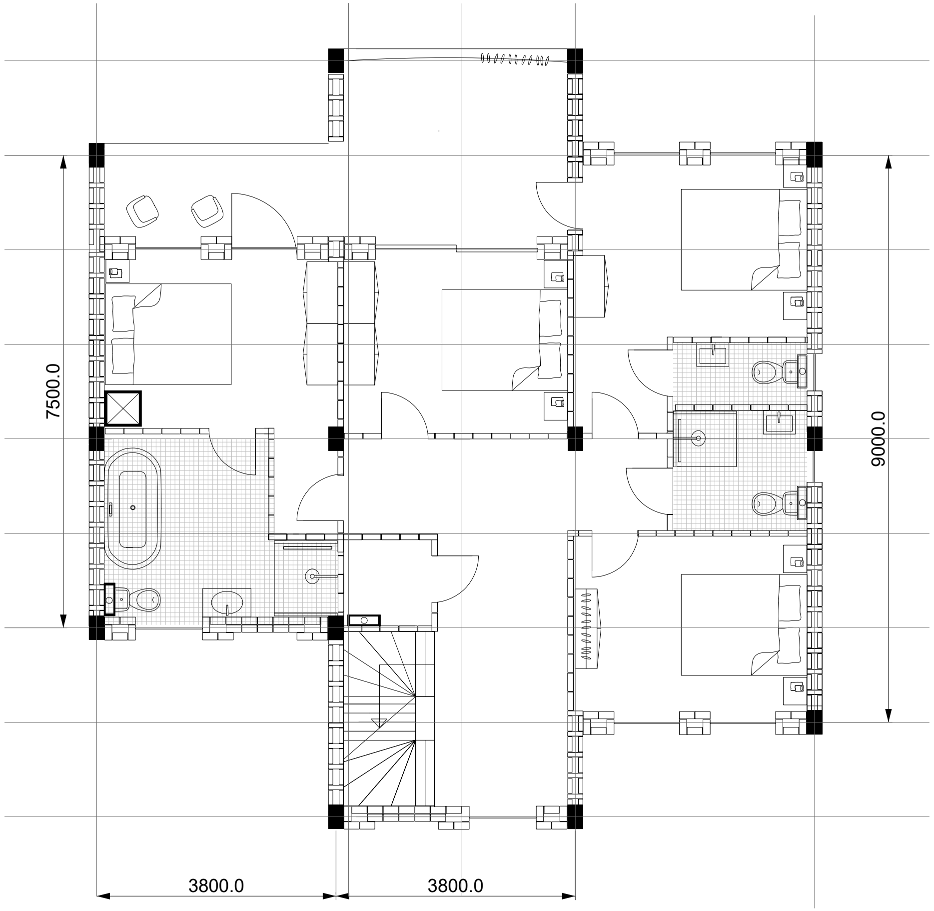
183. 3D High-Income Unit, Duplex. Source: Author, 2025



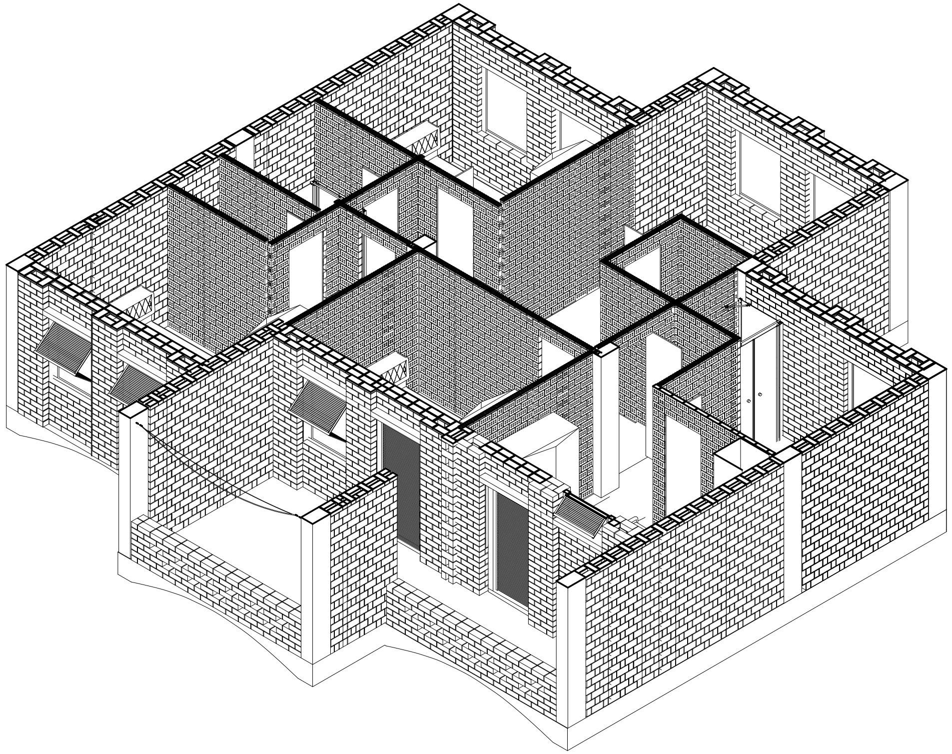
184. High-Income Units, Duplex. Source: Author, 2025

High-Income Unit: *Duplex - 5 persons, 230 m^2, 46 m^2/p*

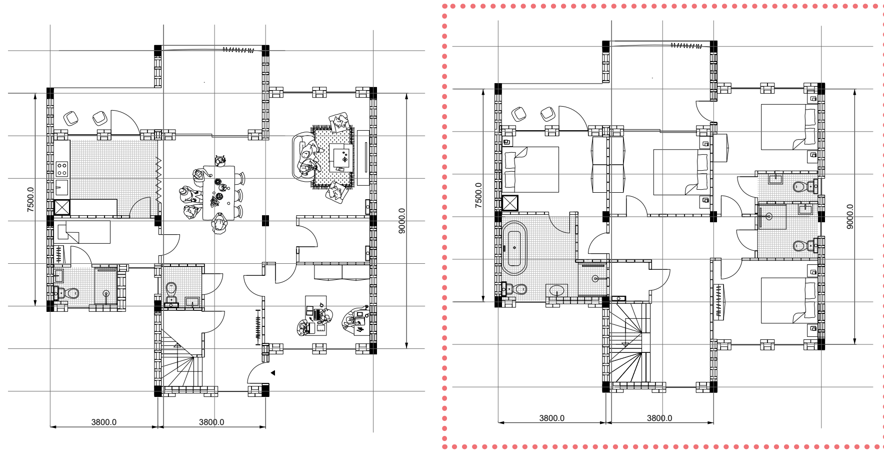
The upper floor of the high-income unit includes one main bedroom for the parents with their own private bathroom and direct entrance to the loggia. Furthermore, there are three bedrooms for the children. One of the children's rooms has a private toilet. The children will share the common bathroom located on the same floor. Three of the bedrooms open onto a shared, spacious loggia, while the fourth room has acces to the loggia on the ground floor.



185. High-Income Unit, Duplex. Source: Author, 2025



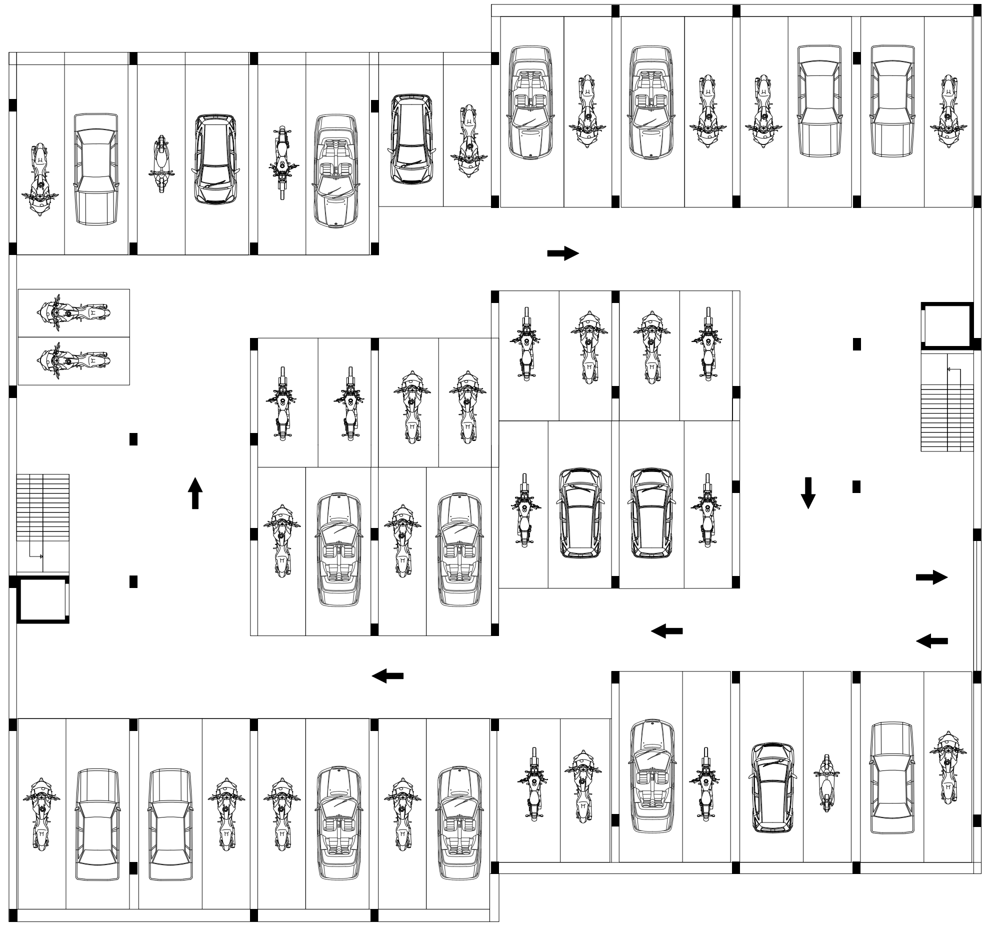
186. 3D High-Income Unit, Duplex. Source: Author, 2025



187. High-Income Units, Duplex. Source: Author, 2025

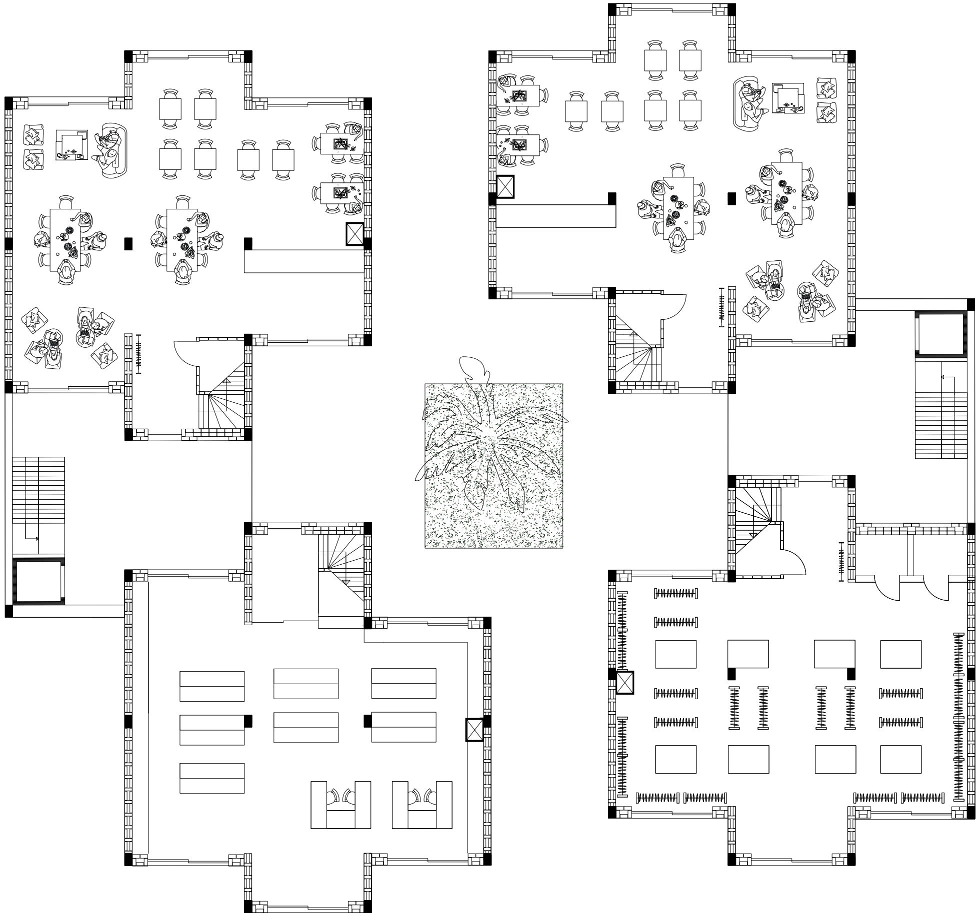
15.3.2. Cluster: *Middle- and High-Income*

15.3.2. Cluster: *Underground Parking*



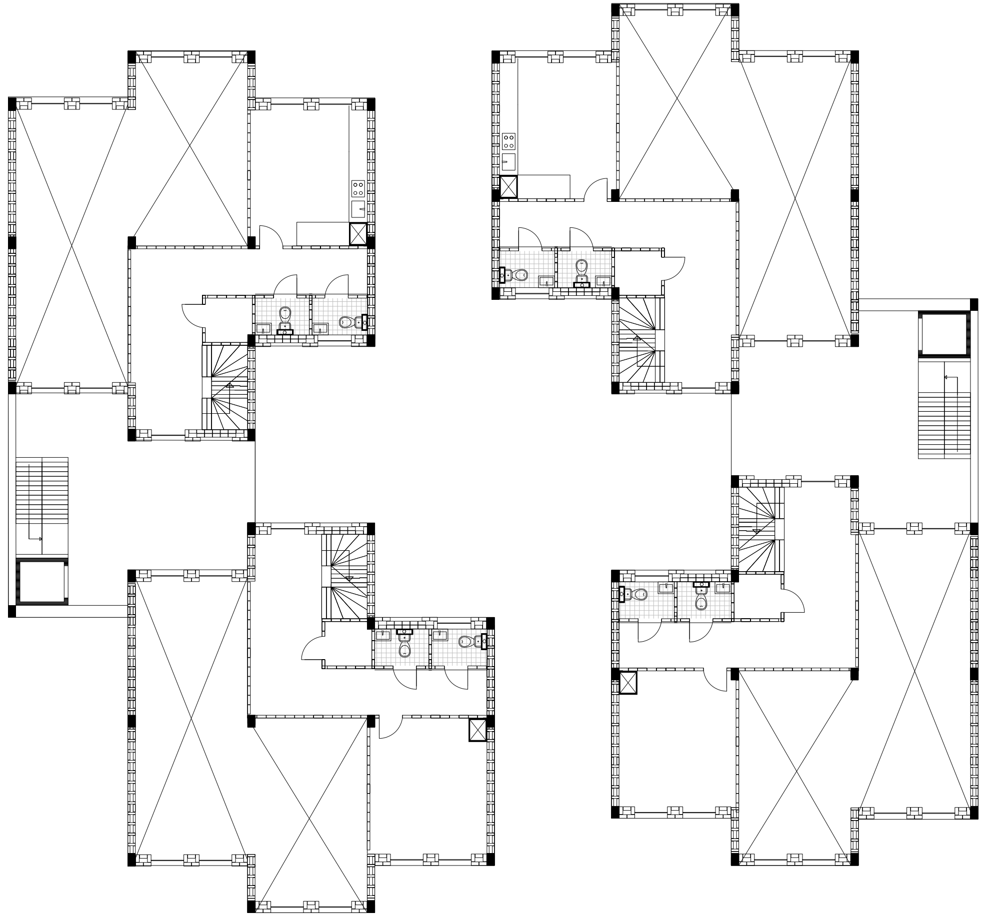
188. Cluster, Underground Parking. Source: Author, 2025

Cluster: *Ground floor, Public Plinth*



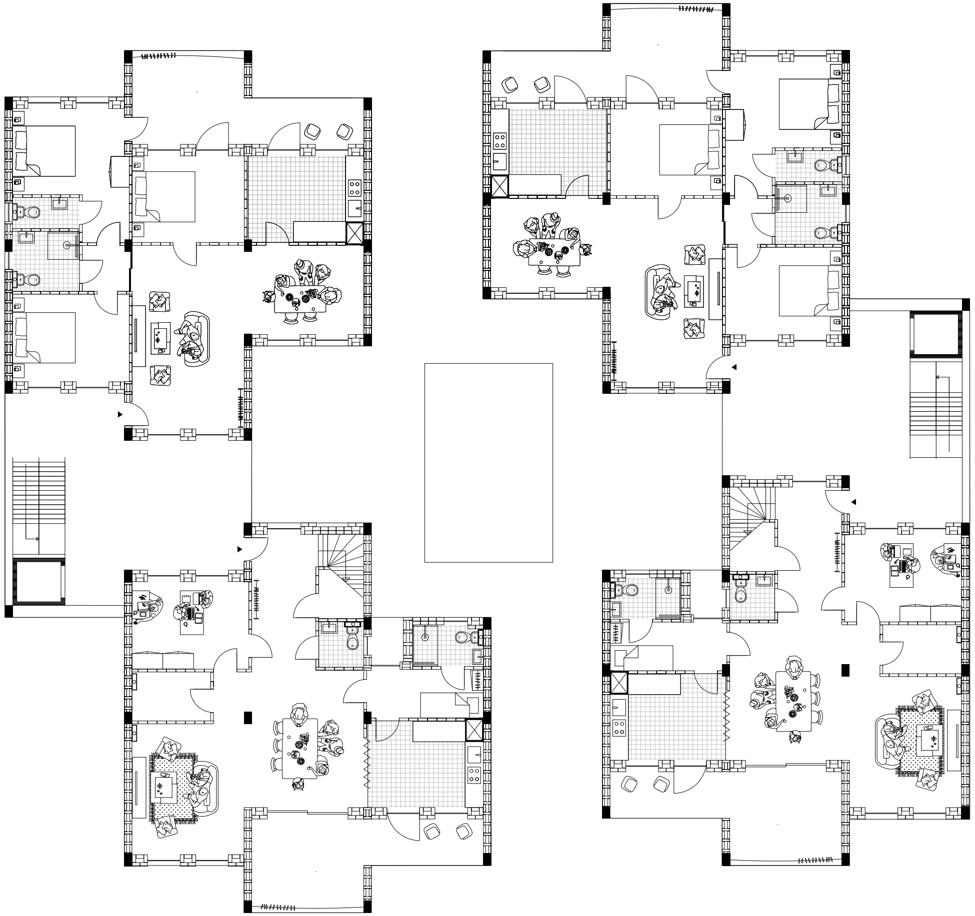
189. Cluster, Groundfloor, amenities. Source: Author, 2025

Cluster: *First floor, Kitchen and Sanitation*



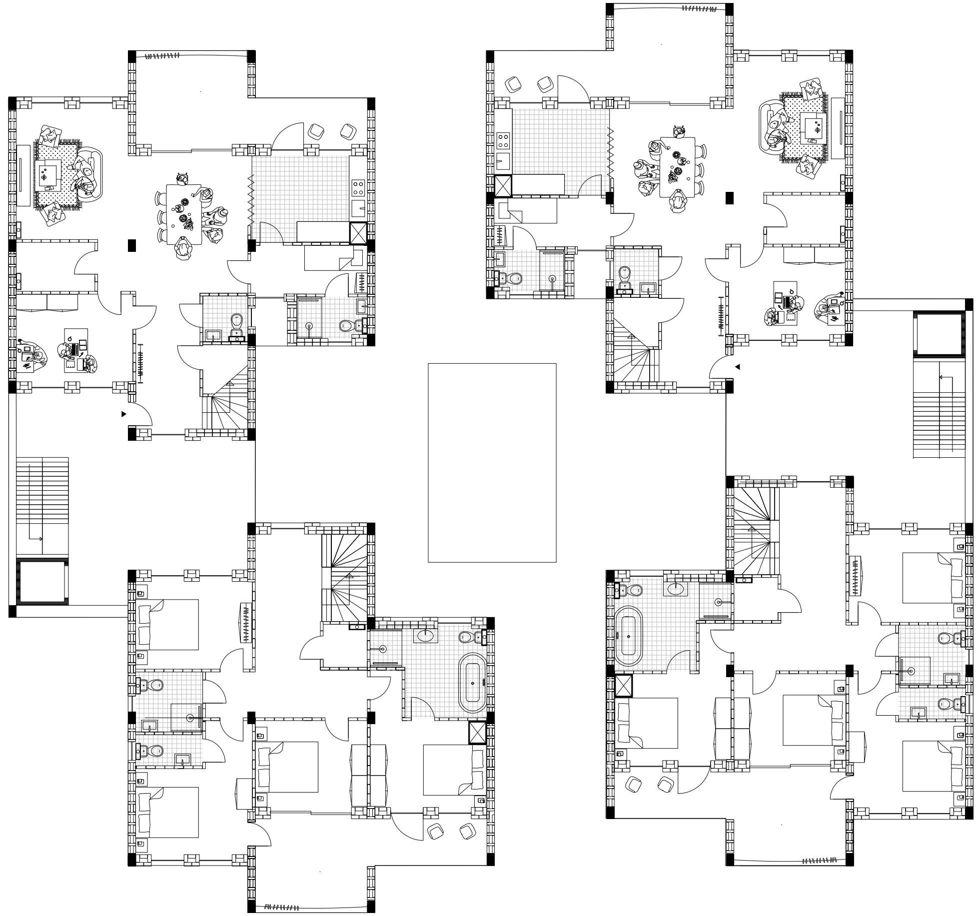
190. Cluster, First floor Sanitation and Kitchens. Source: Author, 2025

Cluster: *Second floor, Middle-income unit and High-income duplex*



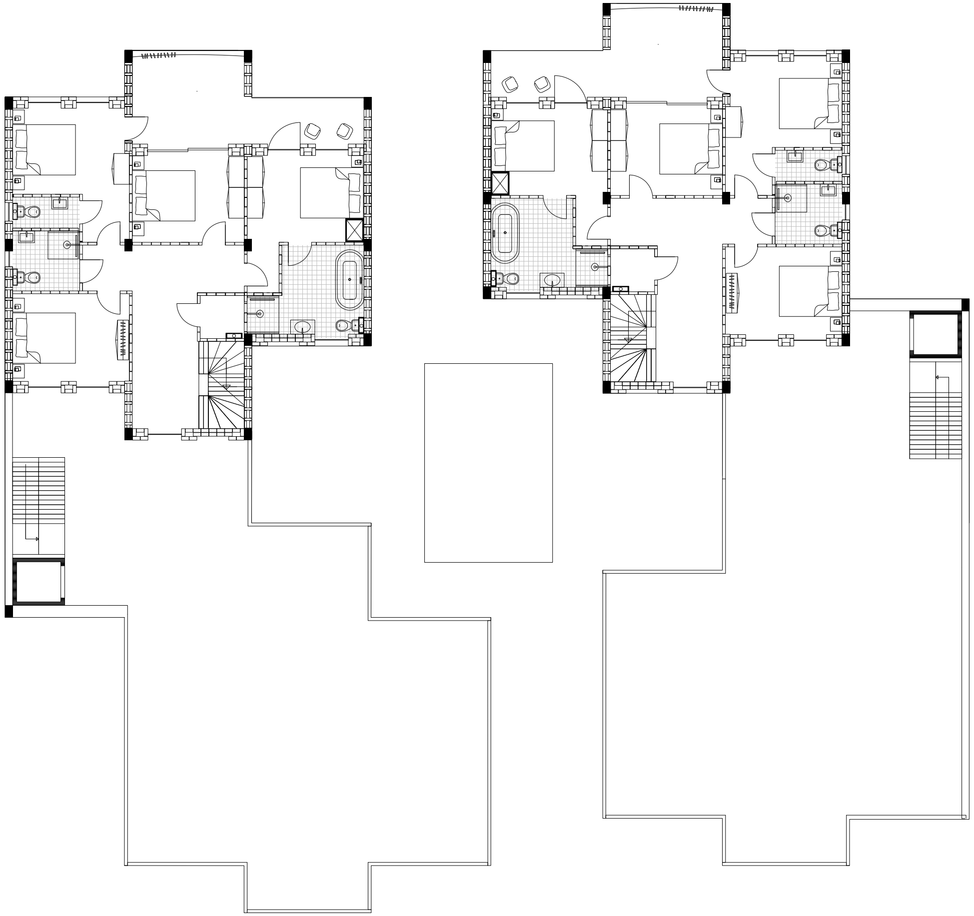
191. Cluster, Second floor, dwellings. Source: Author, 2025

Cluster: *Third floor, High-income duplexes*



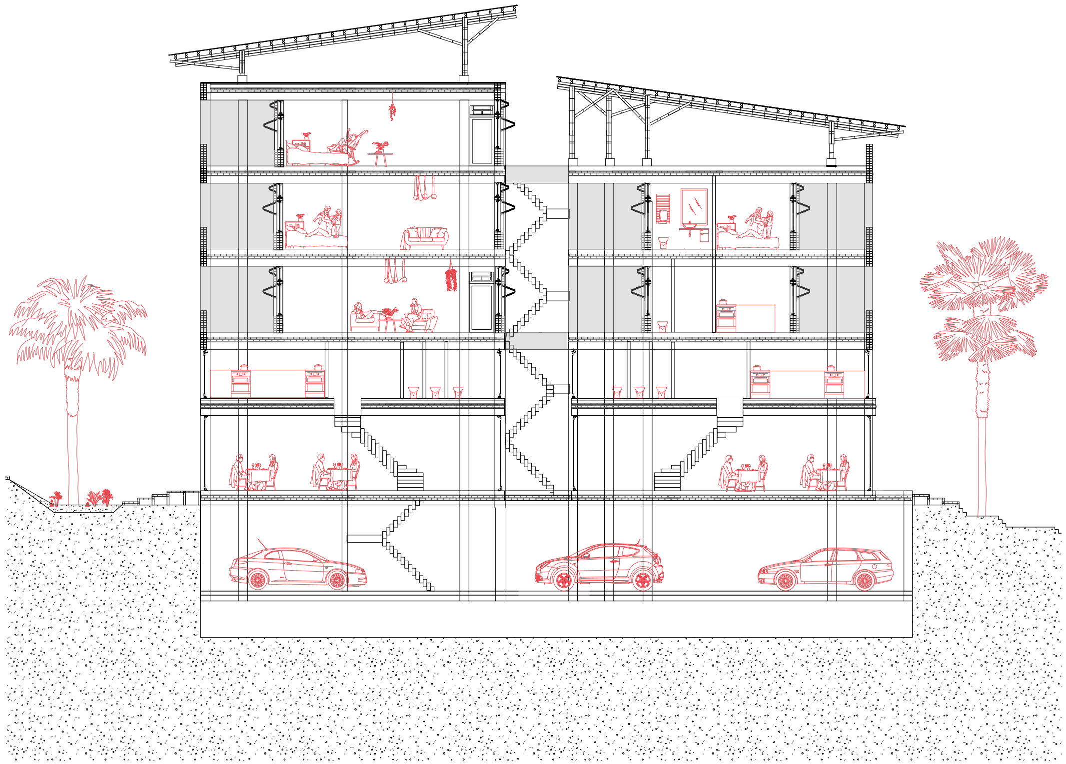
192. Cluster, Third floor, dwellings. Source: Author, 2025

Cluster: *Fourth floor, High-income duplexes*

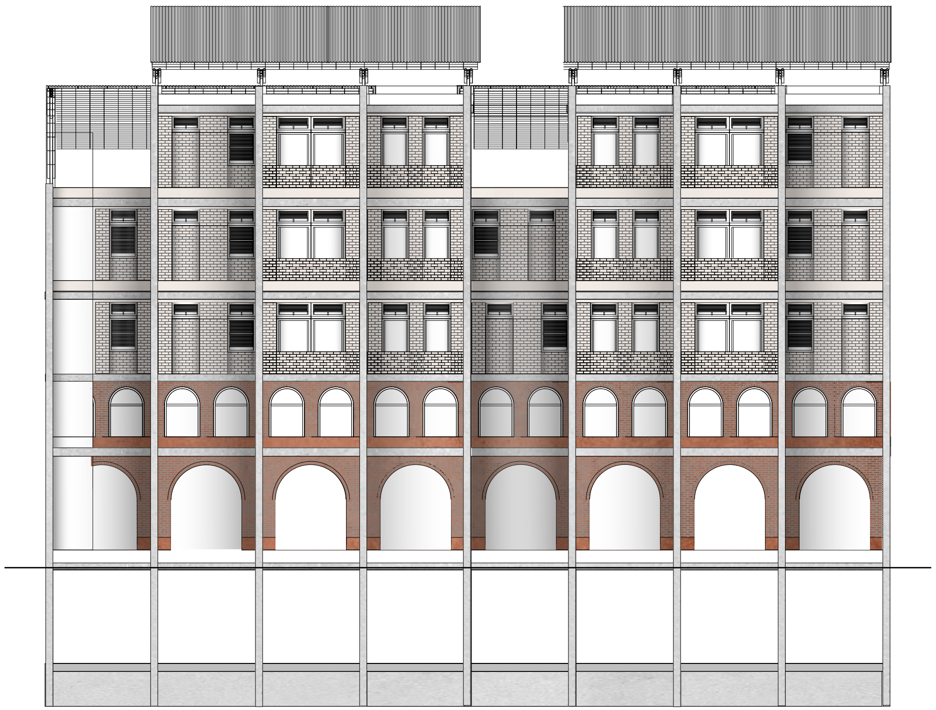


193. Cluster, Fourth floor, dwellings. Source: Author, 2025

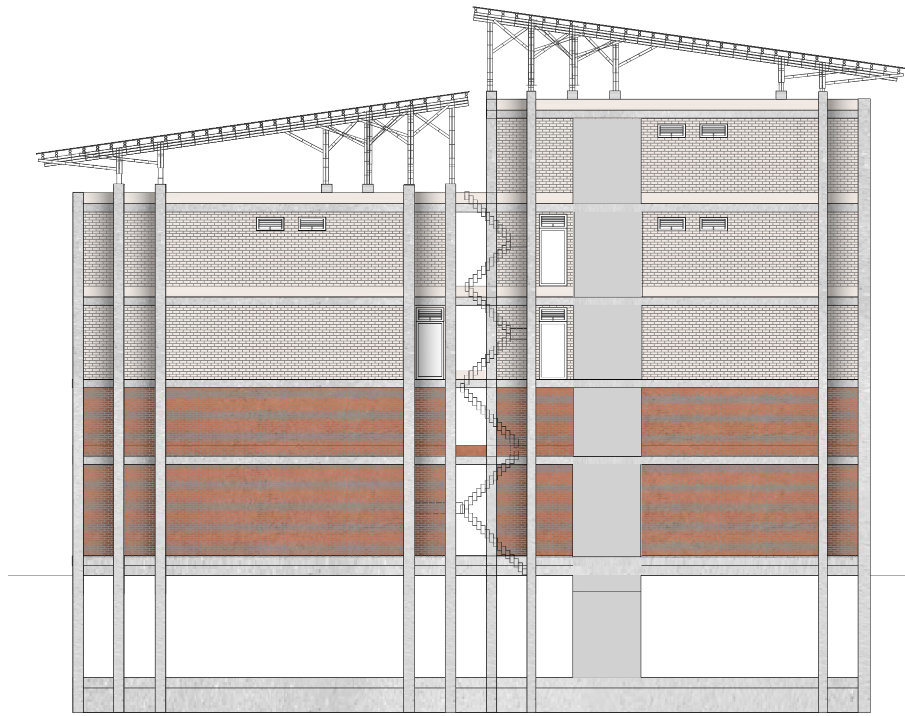
Cluster: *Section*



194. Cluster, section. Source: Author, 2025



195. Cluster, Elevation. Source: Author, 2025

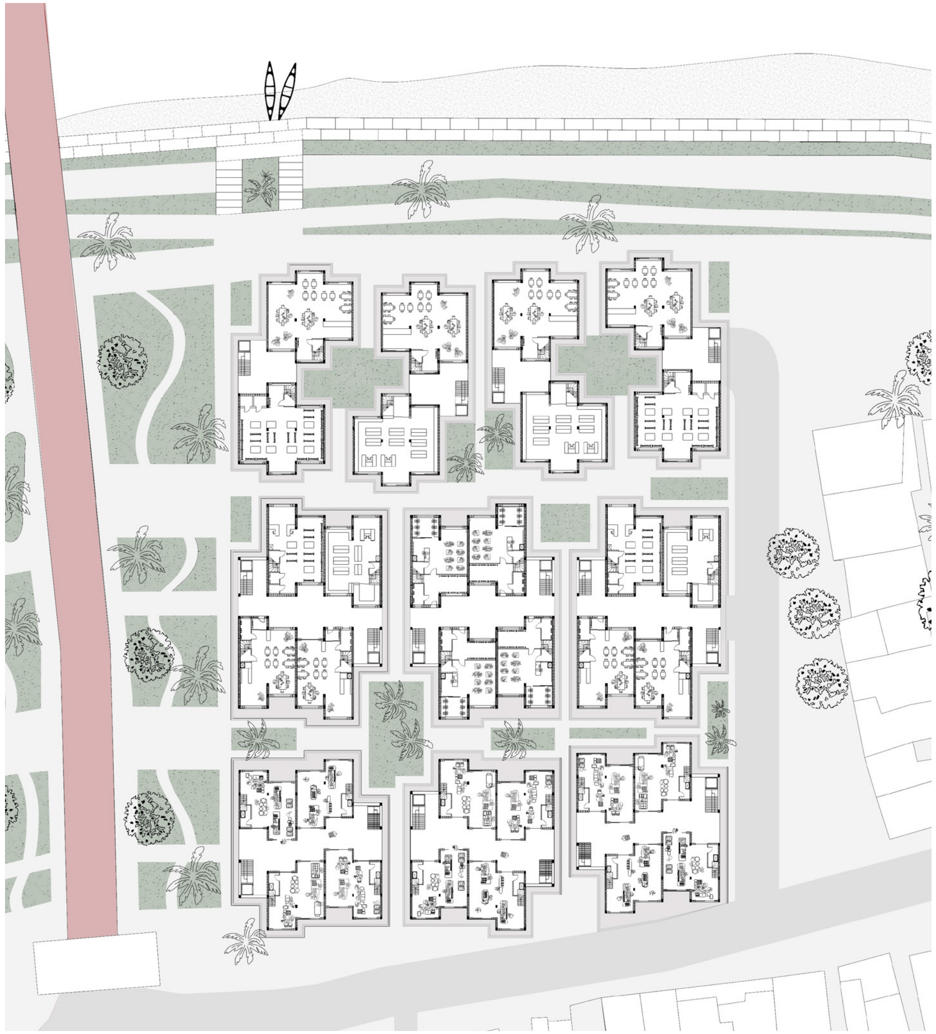


196. Cluster, Elevation. Source: Author, 2025

197. Impression. Source: Author, 2025

15.4. Neighbourhood

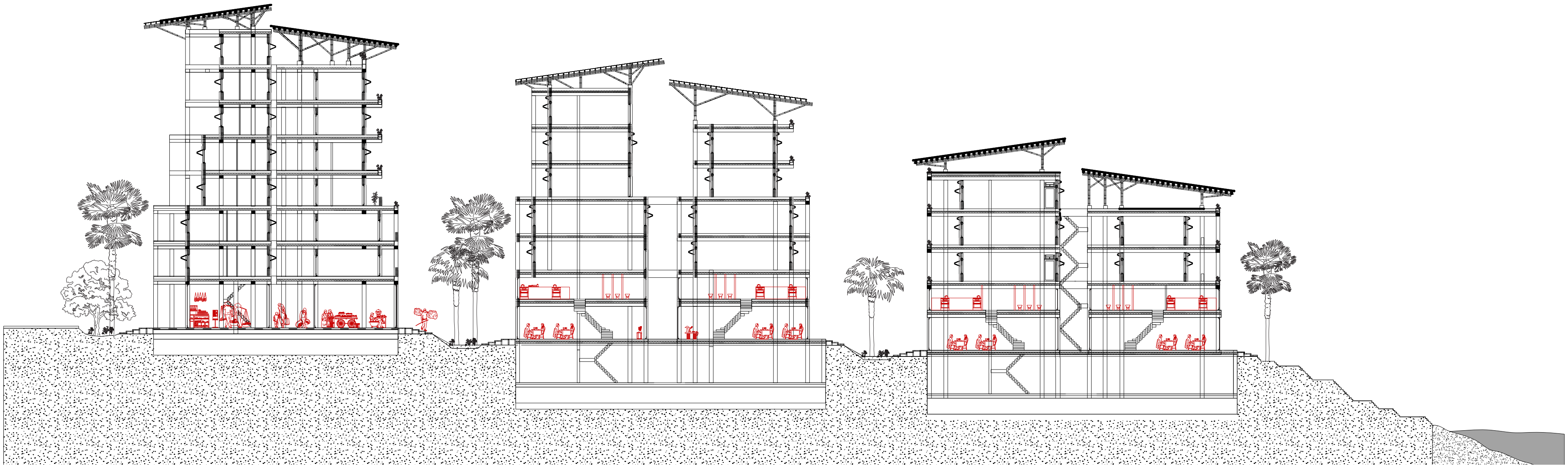
15.4. Neighbourhood



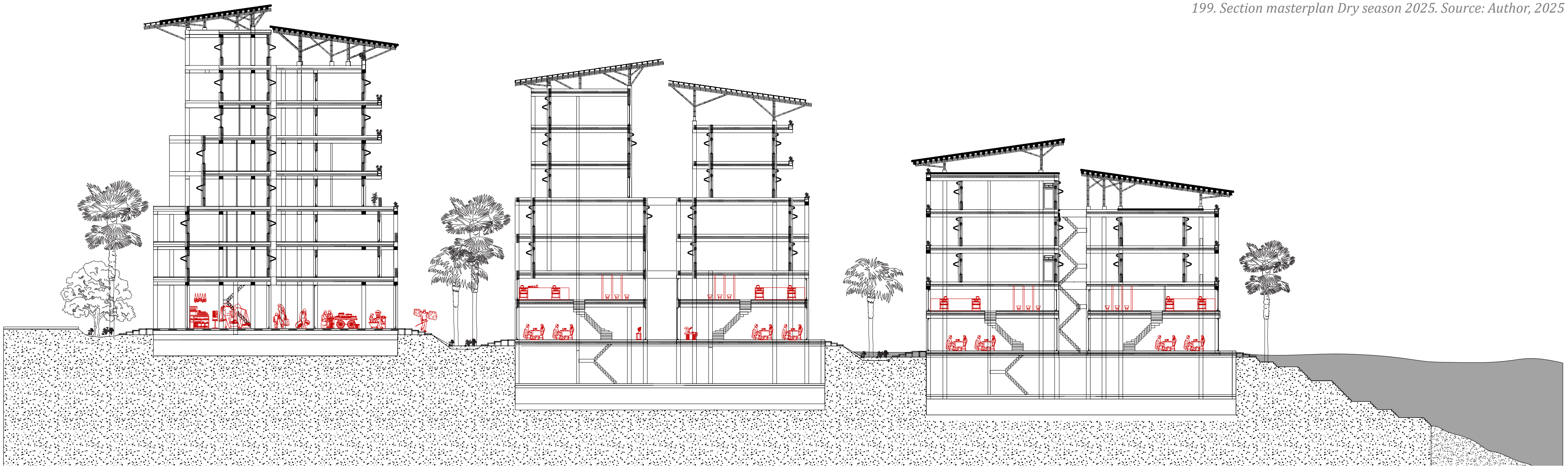
198. Neighbourhood. Source: Author, 2025

15.5. Waterstrategy

15.5.1. Dry and Monsoon Season: *2025*

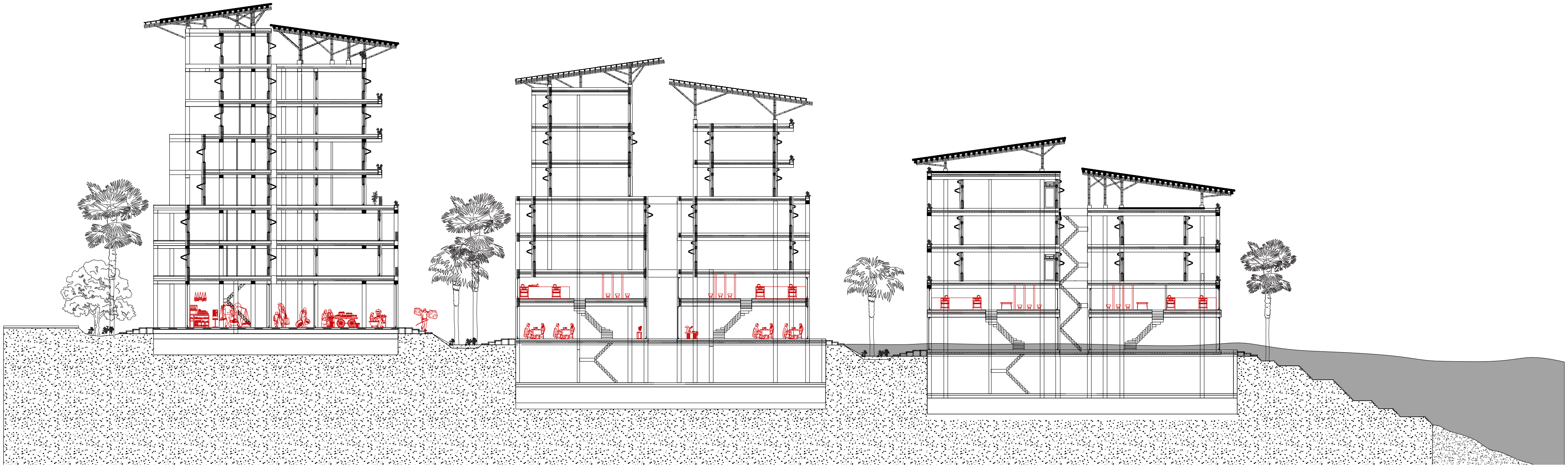


199. Section masterplan Dry season 2025. Source: Author, 2025

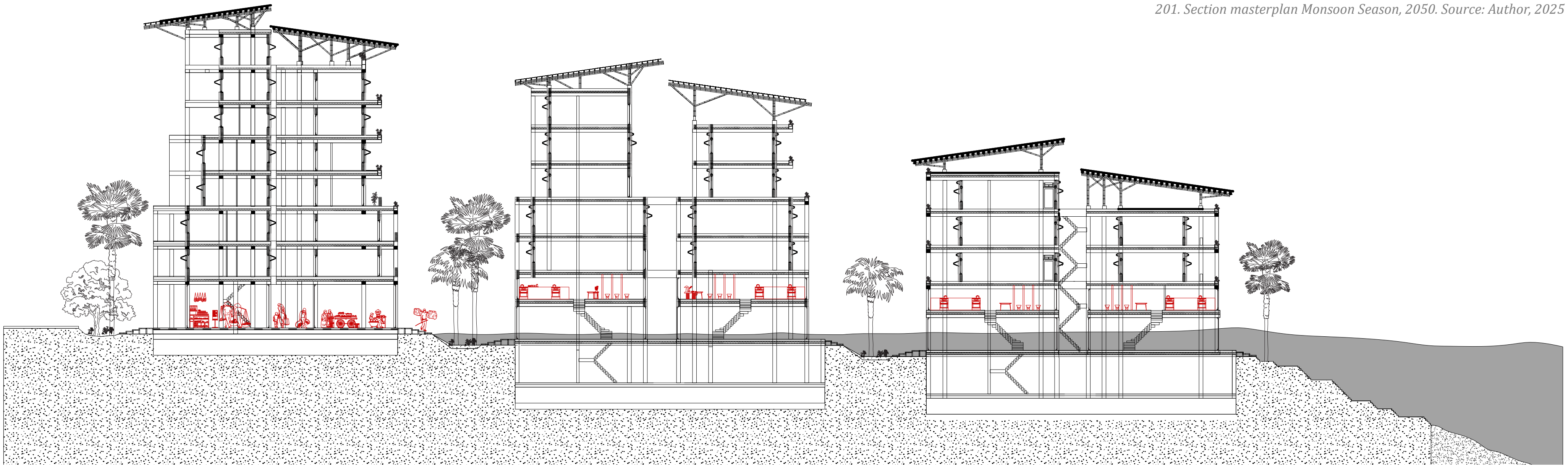


200. Section masterplan Monsoon Season 2025. Source: Author, 2025

15.5.2. Monsoon Season: *2050 and 2100*



201. Section masterplan Monsoon Season, 2050. Source: Author, 2025



202. Section masterplan Monsoon Season, 2100. Source: Author, 2025

15.5.3. Watermanagement: *Waterstorage*

To make the project more self-sufficient rainwater harvesting will be implemented, so the toilets can use grey water for flushing. To know if there will be enough water throughout the whole year watertanks will be stored underneath the buildings. How big the rainwater tanks need to be will be calculated in this chapter, starting with how many rainfall there is in each season in Sylhet.

Seasons, Bangladesh
According to the research of Akter, Howladar, Ahmed and Crowdhury (2019) there are four different seasons in Bangladesh, namely Winter or also called dry-season (December-February), Pre-monsoon (March-May), Monsoon (June-September) and the Post-monsoon (October-November). Winter is considered as a dry season and the other seasons are considered as the wet season (Akter, Howladar, Ahmed, Crowdhurry, 2019). The annual rainfall in Sylhet varies a lot from a small 4 mm in February to a substantial 353 mm in June (Weather Atlas, 2024).

Pre-monsoon period
The Pre-monsoon period from March to May brings warmth and humidity. The temperatures can reach up to 33.1 °C in May. The rainfall begins to increase in March to 49 mm over 11.3 days and increase even more in April with reaching an amount of rainfall of 175 mm over 21.3 days. In may the volume of rainfall will peak at 289 mm over 26.8 days. The humidity can rise up to 55% in March and 79% in May (Weather Atlas, 2024).

Monsoon Season
In the Monsoon Season from June to September the tempuratures will peak to 34.4 °C in June, with a humidity of very high levels. The amount of rainfall is the highest in this season with rainfalls around 353 mm in June, 287 mm in July over 29.3 days and 308 mm over 29.3 days in August over 30.2 days (Weather Atlas, 2024). in September the temperatures and rainfall start to decline to 254 mm over 28.5 days.

Post-monsoon period
The Post-monsoon period there is a decrease in temperature and rainfall. In October the rainfall drops to 111 mm over 18.3 days and in November it will drop even more to 18 mm over 4.8 days (Weather Atlas, 2024). In December (dry-season) the rainfall drops to 7 mm over 2.5 days. Eventually the rainfall will drop to 4 mm with an average humidity of 66%. Furthermore, In November the temperature can lower to 28.3 °C.

Dry-season
In December and January the climate will by dryer and cooler with temperatures around the 25.5 °C at daytime. At night the temperatures can drop to 12 °C. In extreme situation it will not even rain any mm in the Dry-season.

Grey water usage
In an urban area people from Bangladesh need around 116 L/person/day (Lewis, Scott, Bala, Jahan, Bartram, Radu, 2024). 58% of this usage becomes greywater through bathing, dishwashing, religious practices, handwashing, laundry, and mopping.

Greywater produced ranges from 61-1274 L/household/day and around 78,4 L/person/day. Without services for greywater management greywater disposal may cause public and environmental health implications. Furthermore, when rainwater is harvested it can last for 6 months (Cavallo, 2024).

In the cities an average household size is 4.4 members. One household uses 200L water for flushing the toilet per day based on a household with 4.4 members, so 200/4.4 = 45 Litre per person/day.

The next step is to calculate how many rainwater can be collected on the roofsurface of all the buildings within the masterplan. And how much rainwater this surface can collect within each different season.

Roofsurface for rainwater harvesting:

- High income building: 169,424168 m^2 x 16 = 2710,787 m^2

- Middle/High income building: 266,477118 m^2 x 10 = 2664,77 m^2

- Low income building: 232,523190 m^2 x 21 = 4883,00 m^2

- Total roof surface of the masterplan: 10258,557 m^2

Harvesting rainwater: Surface roof (horizontal projection) x rainwater (mm) x 0.9 (Correction factor for losses)

- ***Harvesting Pre-monsoon rainwater:*** 10258,557 x (0.049 m + 0.175 m + 0,289 mm) x 0.9 = 4736,375 m3 = 4736375000000 cm^3 = 4736375000000 ml = 4.736.375.000 L

4.736.375.000.000 ml / 10.258,557m2 = 461.699.925,2429 ml/m2 = 461.699,925 L/m2

- ***Harvesting Monsoon rainwater:*** 10258,557x (0,353 m + 0,287 m + 0,308 m + 0,254 m) x 0.9 = 11097,7069 m3 = 110977069000000 cm^3 = 110977069000000 ml

110.977.069.000.000 ml / 10.258,557m2= 10.817.999.938,978 ml/m2 = 10.817.999,939 L/m2

- ***Harvesting Post-Monsoon period:*** 10258,557 x (0,111 m + 0,018 mm) x 0.9 = 1191,02 m3 = 1191023000000 cm^3 = 1191023000000 ml
1.191.023.000.000 ml / 10.258,557m2 = 116.100.441,806 ml/m2 = 116.100,441 L/m2

- ***Harvesting Dry Season*** (extreme 0ml rain): 10258,557 x 0 x 0.9 = 110,792 m3 = 0 ml

The three different buildings differ in amount of people that they facilitate, so it is important to calculate the amount of needed water per building seperatly from eachother. The next step is to know how many people are living in the different buildings:

Amount of residents
Low income apartment 1 (5/7 people/ household) -> 6 x 62 = 372 people
Low income apartment 2 (5/7 people/ household) -> 6 x 60 = 360 people
Low income apartment 3 (4 people/ household) -> 4 x 58 = 232 people
Total amount of people: 964

Middle income apartment 1 (4 people/ household) -> 8 x 4 = 32 people
Middle income apartment 2 (4 people/ household) -> 14 x 4 = 56 people
Total amount of people: 88

High income apartment 1 (5 people/ household) -> 5 x 16 = 80 people
High income apartment 2 (4 people/ household) -> 4 x 12 = 48 people
Total amount of people: 128

Harvesting rainwater: Surface roof (horizontal projection) x rainwater (mm) x 0.9 (Correction factor for losses)

1. (Ondergrondse regenwater tank kunststof 10.000 liter - budgettank)
Amount of people in Building 1
(8x4)+(8x6)+(8x6) = 128 people

First Building:
Harvesting Pre-monsoon rainwater (building 1): 232,523190 x (0.049 m + 0.175 m + 0,289 mm) x 0.9 = 107,355 m3 = 107.355.000,00cm3 = 107.355 L
107.355 Lx 2 (roofs) = 214.710 L

Harvesting Monsoon rainwater (building 1): 232,523190 x (0,353 m + 0,287 m + 0,308 m + 0,254 m) x 0.9 = 251,54 m3 = 251.540.000 cm3 = 251.450 L

251.450 Lx 2 (roofs) = 502.900 L

Harvesting Post-Monsoon period (building 1): 232,523190 x (0,111 m + 0,018 mm) x 0.9 = 26,99 m3 = 26.990.000 cm3 = 26.999 L

26.999 L x 2 (roofs) = 53.998L

Harvesting Dry Season (building 1) (extreme 0ml rain)= 0 ml

128 x 45 = 5760 L/day/building
5790 x 90 (days dry-season) = 518.400 L needed per building in the dry season.

10 Cisterns of 50.000 L
XXL .50.000 liter 260cm hoog - 230 cm diameter - 1340 cm lengte - 1326 kg (€ 14.990,00)

There will fit 8 cistern max underneath the low income building (2 next to the building underneath the wadi)

2. Building 2: (4x4)+(4x4)= 32 people:
32 x 45 = 1440 L/day/building

1440 x 90 (days in the dry season) = 129.600 L needed per building in the dry season.

Harvesting Pre-monsoon rainwater (Building 2): 266,477118 x (0.049 m + 0.175 m + 0,289 mm) x 0.9 = 123,032 m3 = 123.032.000 cm3 = 123.032 L

123.032 Lx 2 (roofs) =246.064 L

Harvesting Monsoon rainwater (Building 2): 266,477118 x (0,353 m + 0,287 m + 0,308 m + 0,254 m) x 0.9 = 288,2749 m3 = 288.274.900cm3 = 288.274 L

288.274 L x 2 (roofs) = 576.548L

Harvesting Post-Monsoon period (Building 2): 266,477118 x (0,111 m + 0,018 mm) x 0.9 = 30,9 m3 = 30.900.000 cm3 = 30.900 L

30.900 Lx2 (roofs)= 61.800 L

Harvesting Dry Season (extreme 0ml rain)= 0 ml

Two cisterns: 129.600/ 2 =64.800 L per cistern
Two tanks of 50.000 and one of 30.000

XXL .50.000 liter 260cm hoog - 230 cm diameter - 1340 cm lengte - 1326 kg (€ 14.990,00)

XXL 30.000 liter 260cm hoog - 230 cm diameter - 850 cm lengte - 850 kg (9.695,00)

3. Building 3: (2x5)+4 = 14 people:
14 x 45 = 630 L/day/building

630 x 90 (days in the dry season) =56.700 L needed per building in the dry season.

Harvesting Pre-monsoon rainwater (Building 3): 169,424168 x (0.049 m + 0.175 m + 0,289 mm) x 0.9 = 78,22 m3 = 78.220.000 cm3 = 78.220 L

78.220 L x 2 (roofs) = 156.440 L

Harvesting Monsoon rainwater (Building 3): 169,424168 x (0,353 m + 0,287 m + 0,308 m + 0,254 m) x 0.9 = 183,283 m3 = 183.283.000 cm3 = 183.283 L

183.283 Lx 2 (roofs) =344.566 L

Harvesting Post-Monsoon period (Building 3): 169,424168 x (0,111 m + 0,018 mm) x 0.9 = 19,67 m3 = 19.670.000 cm3 = 19.670 L

19.670 Lx 2 (roofs) = 39.340L

Harvesting Dry Season (extreme 0ml rain)= 0 ml

4 cisterns: 78.220 L / 4 = 19.555 L per cistern
4 cisterns of 20.000 L under the buildings

XXL .20000 liter 260cm hoog - 230 cm diameter - 580 cm lengte - 591 kg (€ 6.990,00)

	Rain-water harvesting in different seasons			
	Pre-Monsoon Season (March - May)	**Monsoon Season** (June-September)	**Post-Monsoon Season** (October-November)	**Dry Season** (December-February)
Building 1	214.710 L	502.900 L	53.998 L	0 L
Building 2	246.064 L	576.548L	61.800 L	0 L
Building 3	156.440 L	366.566 L	39.340 L	0 L

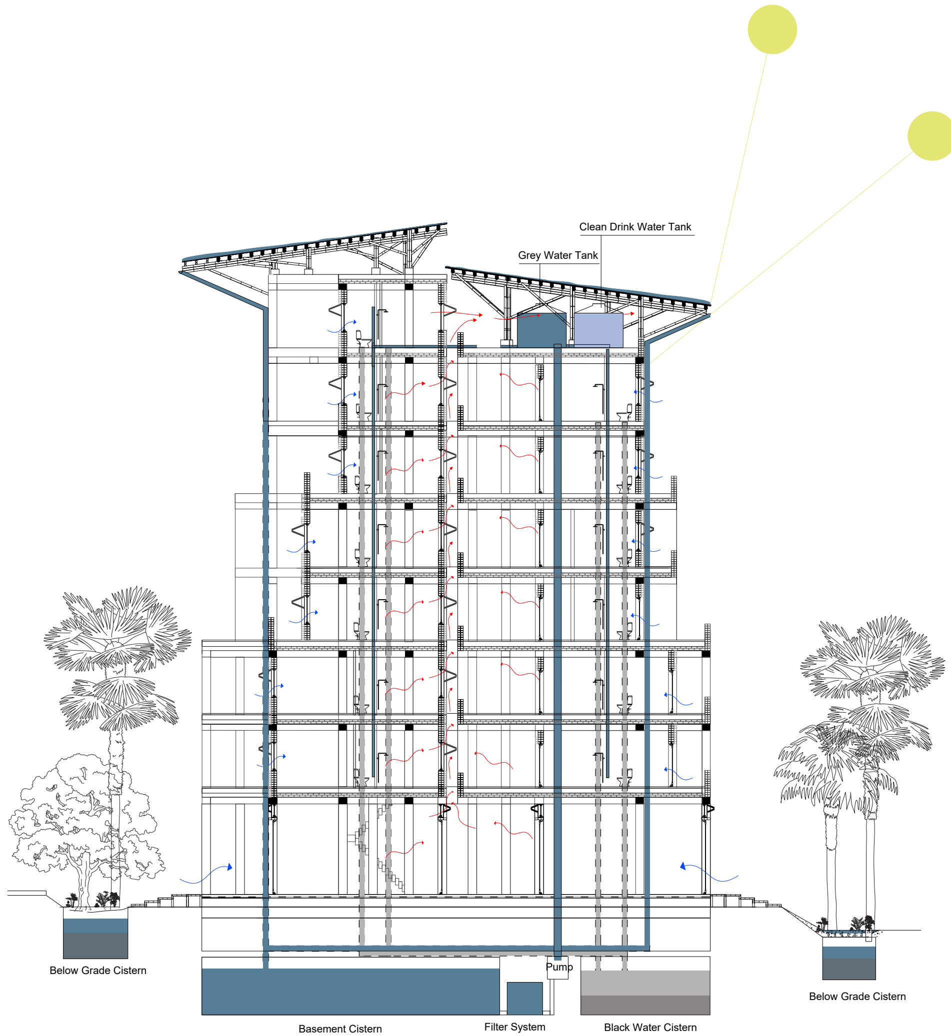
Table 13. Rain-water harvesting. Source: Author, 2025

	Waterusage Dry-season 45L/day/ person	**Watertanks/ building**	**Measurements tank**	**Price/tank**
Building 1	518.400 L	10 tanks of 50.000 L	Height: 260 cm Diameter: 230 cm Length: 1340 cm	€ 14.990,00
Building 2	129.600L	2 tanks of 50.000 L + 1 tank of 30.000 L	Height: 260 cm Diameter: 230 cm Length: 1340 cm, 850 cm	€ 14.990,00 € 9.695,00
Building 3	56.700 L	2 tanks of 30.000L	Height: 260 cm Diameter: 230 cm Length: 850 cm	€ 9.695,00

Table 14. Water-usage. Source: Author, 2025

203. Grey waterstorage under the buildings. Source: Author, 2025

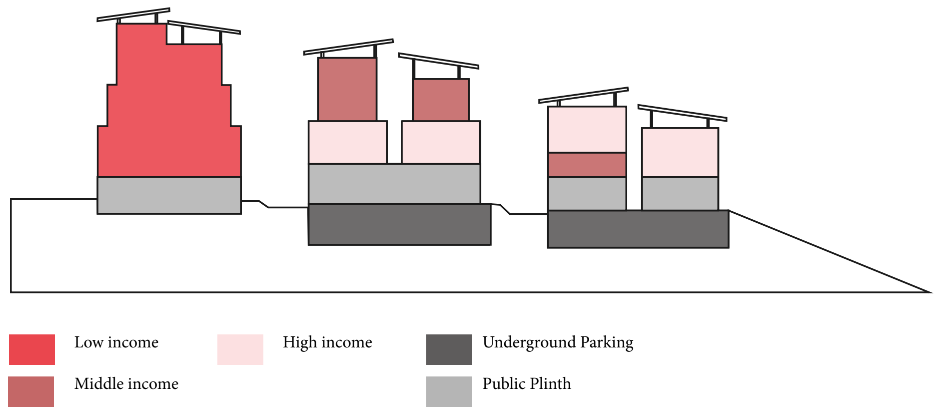
15.5.4. Watermanagement: *Climate Scheme*



204. Climatescheme. Source: Author, 2025

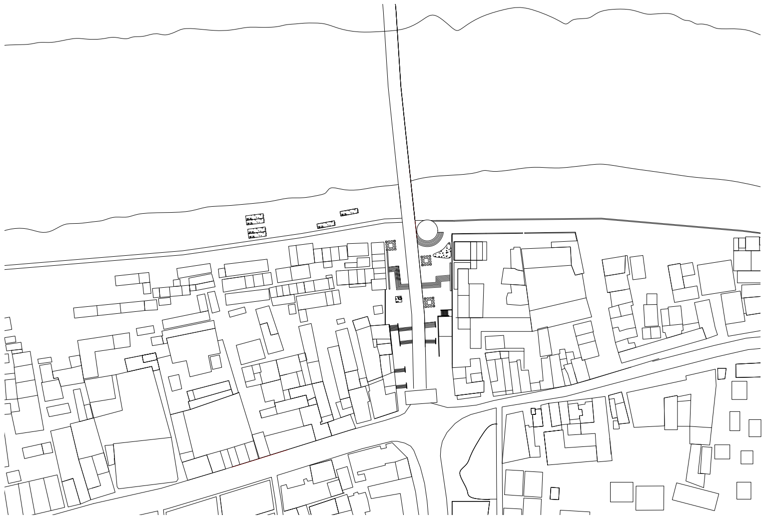
16. Managerial Strategy

16. Managerial Strategy: *Low-, Middle-, and High-income*

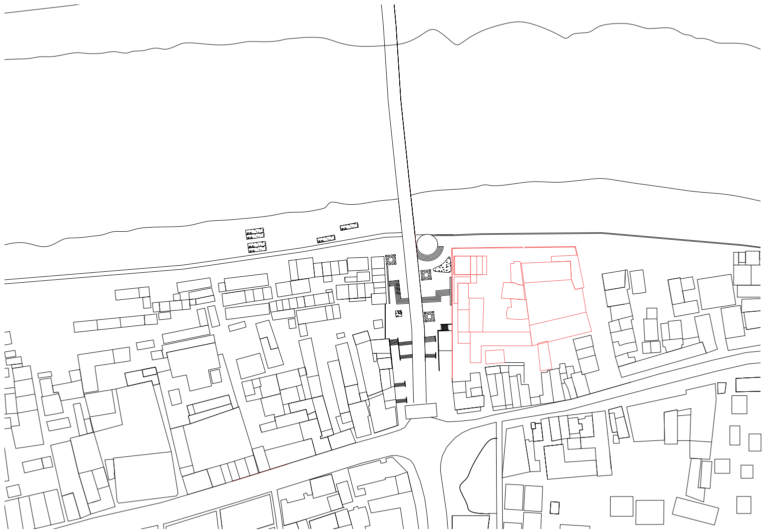


205. Managerial strategy diagram. Source: Author, 2025

16.1. Phasing Masterplan: *Demolishing*



206. Current situation. Source: Author, 2025



207. Phase 1. demolishing saw mill. Source: Author, 2025

Phasing Masterplan: *Development new buildings*

208. Phase 2. Empty land for new development. Source: Author, 2025

209. Phase 3. Developing first buildings, Middle- and High-income Source: Author, 2025

Phasing Masterplan: *Demolishing and Development*

210. Phase 4. Demolishing shops. Source: Author, 2025

211. Phase 5. Developing new buildings, Middle- and High-income. Source: Author, 2025

Phasing Masterplan: *Development and Demolishing*

212. Phase 6. Developing new buildings, Low-income. Source: Author, 2025

213. Phase 7. Demolishing Slums, Muslim dwellings. Source: Author, 2025

214. Phase 8. Developing new buildings, Middle- and High-income. Source: Author, 2025

215. Phase 9. Developing new buildings, Middle- and High-income. Source: Author, 2025

216. Phase 10. Demolishing shops. Source: Author, 2025

217. Phase 11. Empty land for development. Source: Author, 2025

Phasing Masterplan: *Development buildings and riverbank*

218. Phase 12. Developing new buildings, Low-income. Source: Author, 2025

219. Phase 13. Developing and Strengthen of the Surma Riverbank. Source: Author, 2025

Phasing Masterplan: *Development Park*

220. Phase 14. Demolishing courtyard under the bridge. Source: Author, 2025

221. Phase 15. Developing new Park under the bridge. Source: Author, 2025

16.2. Managerial Strategy: *Project's Abacus*

Building 1	
Low income 1	62 units (62 m², 6 residents, 10,3 m²/person)
Low income 2	60 units (51 m², 6 residents, 8,5 m²/person)
Low income 3	58 units (38 m², 4 residents, 9,5 m²/person)
Building 2	
Middle income 1	14 units (120 m², 4 residents, 30 m²/person)
High income 1	12 units (172 m², 4 residents, 43 m²/person)
Building 3	
Middle income 2	8 units (115 m², 4 residents, 28,75 m²/person)
High income 2	16 units (230 m², 5 residents, 46 m²/person)
Total residential area	27.763 m²
Total public area	17.199 m²
Total Dwellings	230 (78% low income, 10% middle income, 12% high income)
Total Residents	1180 people

Table 15. Project's Abacus. Source: Author, 2025

Area	31.922 m² (3,1ha)
FSI	1,4
GSI	0,27
Residents/HA	369
Dwellings/HA	72
Total Built Area (Ground floor)	8200 m² (new) + 567 m² (heritage) = 8767 m²
Total Commercial space	8264 m²
Shops	2885 m²
Market Space	1905 m²
Pharmacy	270 m²
Restaurant Space	1908 m²
Supermarket Space	783 m²
Office Space	513 m²
Religious Space	570 m²
Education Space	670 m²
Community Centre	567 m²
Public open Space	23.648 m²
Underground Parking	7128 m²

16.3. Managerial Strategy: *Building Costs*

Total Construction Costs	28.870 BDT/person/month x 300 workers x 60 months = **519.660.000 BDT**
Construction Costs/m²	519.660.000 BDT / 44.962 m² = **11.557,76 BDT/m²**
Low Income 1	1.342.340,29 BDT
Material Costs	625.759,18 BDT
Construction Costs	716.581,11 BDT
Maintance Costs	30.225 BDT/annualy
Low Income 2	1.104.183,15 BDT
Material Costs	514.737,39 BDT
Construction Costs	589.445,76 BDT
Maintance Costs	24.862,5 BDT/annualy
Low Income 3	824.724,7 BDT
Material Costs	383.529,82 BDT
Construction Costs	439.194,88 BDT
Maintance Costs	18.525 BDT/annualy

Table 16. Building Costs. Source: Author, 2025

Middle Income 1	2.778.091,2 BDT
Material Costs	1.391.160 BDT
Construction Costs	1.386.931,2 BDT
Maintance Costs	58.500 BDT/annualy
Middle Income 2	3.093.493,99 BDT
Material Costs	1.764.351,59 BDT
Construction Costs	1.329.142,4 BDT
Maintance Costs	56.062 BDT/annualy
High Income 1	3.981.930,72 BDT
Material Costs	1.993.996 BDT
Construction Costs	1.987.934,72 BDT
Maintance Costs	83.850 BDT/annualy
High Income 2	6.186.898,8 BDT
Material Costs	3.528.660 BDT
Construction Costs	2.658.238,8 BDT
Maintance Costs	112.125 BDT/annualy

16.4. Managerial Strategy: *Finance Cross Subsidization*

	Total building costs	Rental price	Ownership costs	Annual Revenue	
Low income 1 (62 units)	83.225.080 BDT	8.000 BDT/month	-	5.952.000 BDT	
Low income 2 (60 units)	66.250.980 BDT	4000 BDT/month	-	2.880.000 BDT	Cross-subsidie
Low income 3 (58 units)	47.834.032,6 BDT	2000 BDT/month	-	1.392.000 BDT	Cross-subsidie
Middle income 1 (14 units)	38.893.274 BDT	15.000 BDT/month	80.000 BDT/m² x 120 = 9.600.000 BDT	2.520.000 BDT	
Middle income 2 (12 units)	37.121.927 BDT	18.000 BDT/month	80.000 x 115 = 9.200.000 BDT	2.592.000 BDT	
High income 1 (12 units)	47.783.168,64 BDT	20.000 BDT/month	80.000 x 172 = 13.760.000 BDT	2.880.000 BDT	
High income 2 (16 units)	98.990.380,8 BDT	50.000 BDT/month	80.000 x 230 = 18.400.000 BDT	9.600.000 BDT	
Commercial space	23.900 BDT/m2 x 8264 = 197.510.371,3 BDT	500 BDT/m2/month	-	49.584.000 BDT	
Strenghten Riverbank	32.418.995 BDT			Less maintanence due to no erosion	subsidized by the government
Total	650.028.209 BDT			77.400.000 BDT	Payback time in 8 years

Table 17. Finance Cross Subsidization. Source: Author, 2025

17. Summary

This project explores how a high density, affordable and seasonally adaptable housing project can be designed on the Surma riverbank for the impoverished Muslim and Hindu communities in Sylhet, Bangladesh. The Surma riverbank is highly vulnerable to flooding and erosion due to climate change.

The local community near the Keane Bridge experiences frequent flooding, up to three times per year, forcing temporary evacuations to the streets. This shows how urgent the need is for more resilient housing on this site. This site has the potential to become a vibrant center for sylhet with affordable and resilient housing for all different income groups.

This project addresses affordability, sustainability and resilience via passive climate-adaptive techniques, such as cross-ventilation combined with the stack effect, reducing energy demands and ensuring year-round comfort.

The construction uses a minimal reinforced concrete frame, supported by locally sourced and cost-effective materials, such as bamboo and CSEBs. Brick is used at the plinth level for water resistance, while CEB and CSEB infills are used on the upper levels depending on the income-group.

Community needs are important for the current residents. They express strong emotional attachment to their land, school, temple and neigbourhood. Maintaining social cohesion and access to local amenities is essential. While elevated floors help mitigate flood risks, ground level areas are repurposed for shops and communal interactions to preserve social life.

To address environmentally driven migration, it is not only crucial to secure housing but also to implement work opportunities for the inhabitants. Therefore, the design incorporates accessible public spaces, workspaces and education facilities. The site will be opened to the public improving safety and inclusivity.

To mitigate erosion of the riverbanks, the banks need to be strengthen with concrete blocks. This will be subsidized by the government and will provide a long-lasting and permanent space.

In conclusion, this project presents a realistic and locally grounded approach to a highly-densed, seasonal adaptable and affordable housing in flood- and erosion-prone urban areas.

18. Reflection

1. What is the relation between your graduation project topic, your master track, and your master programme?

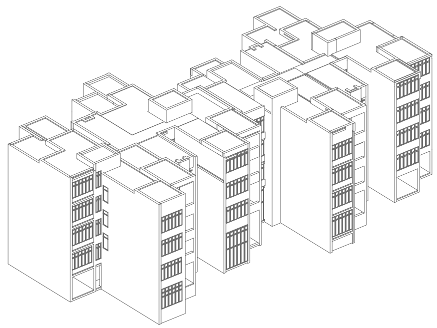
The Architecture track and MSc AUBS relates to my graduation project in the sense that I try to tackle the climate related, technical, spatial and social challenges within a project in the built environment.
The studio, Global Housing, focuses on housing challenges regarding mass-migration, urban growth, social inclusion, affordable housing and environmental justice in the most dense countries of the world. In which it is important to consider both local conditions and the broader context of urbanization.
My graduation project focuses on scaling up small-scale, seasonal-adaptability in water management and affordable housing to a large-scale, seasonal-adaptable and affordable housing project to mitigate the mass migration to the urban areas in Bangladesh. With analytical research regarding existing climate related adaptability in housing and field interviews with locals my goal is to design a spatial plan wherein the inhabitants can find shelter in their own house, which will mitigate the environmentally driven mass-migration.

Researchquestion:
"How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished Hindu and Muslim communities living on the erosion-prone Surma riverbank in Sylhet?"

2. How did your research influence your design/recommendations and how did the design/recommendations influence your research?

Before I went to the design location in Sylhet I studied together with Coco de Bok two casestudies about student housing in Bangladesh, namely the Student Hostel at Sylhet Polytechnic Institute designed by Muzharul Islam and Stanley Tigerman and the Student Hostels at Chittagong University designed by Muzharul Islam. These casestudies where really important for the design I made. Muzharul Islam's designs really react to the climate of

the site, which is shown in the form of the buildings. The design of the Student Hostel at Syhet Polytechnic Institute has many setbacks in the facade to provide shading. Also they implemented loggia's, so the sun will
not come directly into the bedrooms. In a hot climate like Bangladesh this is really necessary.



222. Student Hostel Polytechnic Institute Sylhet. Source: Author, 2024

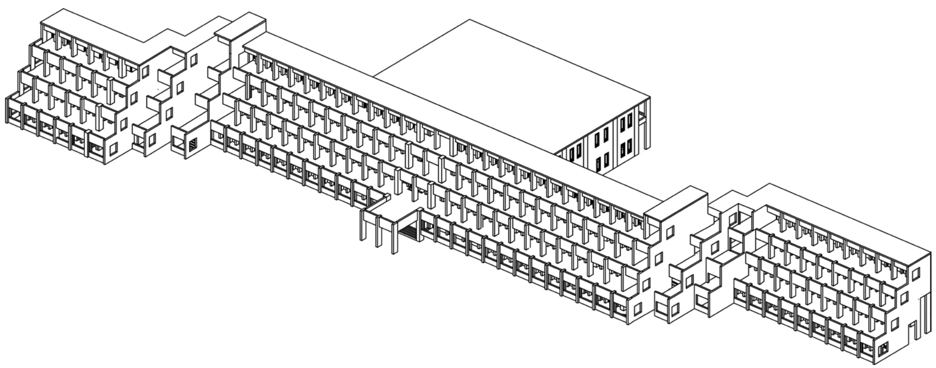
Furthermore, the windows and openings of the building are orientated to the south, so the strongest wind, from the south, can go through the whole building, which provides cross-ventilation. The cross-ventilation helps to cool the building in a passive way, which is an affordable way of ventilating the building.
The Student Hostels at Chittagong University has similarly designchoices based on Bangladesh's climate, such as the windows are orientated towards the south for natural cross-ventilation and the building provides it's own shading against the sun.

In my design it was important to implement a passive climate scheme as well, because this is an affordable way of making the indoor climate of the building comfortable. So the windows of the buildings are orientated towards the south for cross-ventilation. Openings in the gallery in the middle of the building will provide a stack effect to improve the natural ventilation. By implementing loggia's and shutters the direct sunlight will be blocked out of the apartments.

Another important designchoice I made was inspirate by the setbacks of the Student Hostels at Chittagong University to make it possible to create different types of units within the same building. At the Chittagong student hostel on the lower floors bigger bedrooms for 2 persons are situated, when you go higher the units will become smaller for only 1 person. Not only this will provide variation between the units, but also create a playfull facade.

In an interview at the designsite it became clear that the households living along the Surma Riverbank exists out of 5 to 7 people, so I wanted to create different sizes of units according the size of the family. On the first floor a family of 7 people (2 parents, 4 children, 1 baby) could live and when you go higher up a family of 5 (2 parents, 2 children, 1 baby) could live.

Before the trip to Bangladesh I did research on how amphibious dwellings are working and if it is possible to densify this typology. In Sylhet I choice the design site next to the Keane Bridge on the Surma Riverbank, because the inhabitants of this place are struggling with flash floods and need to



223. Student Hostel Chittagong. Source: Coco de Bok, 2024 out of there houses three times per year due to floodings. Another reason why I choice this site was that this site has the potential to become a lively densified neighbourhood.

However, after my P2 my teachers gave me the feedback that amphibious dwellings are not the right answer for this location. The installations of the amphibious dwellings on this site need to be made with high tech and expensive materials to carry the heavy weight of the massive buildings.
For small scale amphibious dwellings it is possible to implement the floathing device with low tech and affordable materials, such as recycled plastic. For this site the amphibious dwellings would be way to expensive. More affordable solutions will work better on this site, such as placing the most vulnerable spaces higher in the building. After every feedback moment I tried to adjust the design to improve it.

The design principles of the Khudi Bari designed by Marina Tabassum where inspiration for my design as well. The structure of the Khudi Bari provides an extra floor, so the inhabitants can find shelter and store important objects for floodings in there own building. In an interview with a local from the Hindu community at the design site they mentioned that a second floor can help them already a lot with storing important items, such as schoolbooks from floodings. Another problem they mentioned is that sanitation will be destroyed as well due to floodings.
So, to solve these problems the apartments are not on the groundfloor situated. The sanitation, kitchens and extra storage within the public plinth are situated higher in the public plinth. So when a flooding occurs these vulnerable items and spaces are protected.

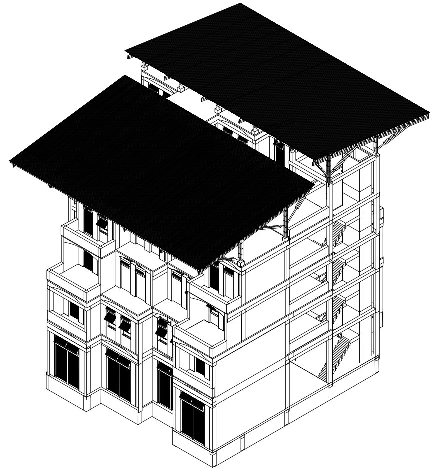
I also did research to flexible and permanent structures in flood- and erosionprone areas. Flexible structures, such as the Khudi Bari, can help the residents with relocating there houses to safer land when the risk of erosion is high. Permanent and strong structures can survive floodings, but can not be moved when erosion will happen. Watermanagement Engineer Dipak gave me the design recommendation to strenghten the riverbanks with concrete blocks to prevent the riverbank from erosion. When the riverbank is protected from erosion the buildings will also be protected from collapsing due to erosion, so now it is possible to implement permanent structures on this site. However, this solution is more expensive and they need to ask the governement for a grant for these interventions.

3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?

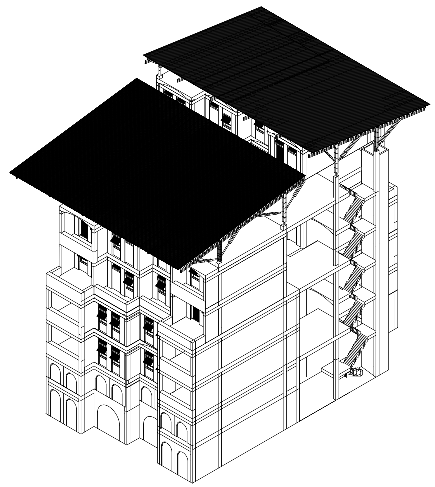
Research done through casestudies within Bangladesh itself have a great value for me, because it is important to know what is realistic and possible at this site with it's specific climate conditions. The climate within Bangladesh varies strongly with the climate in the Netherlands, so different design principles will be made. The Student Hostels in Sylhet and Chittagong and the Khudi Bari helped me a lot with learning more about the Bangladeshi's climate and the design principles to increase the indoor climate of the apartment that is situated in Sylhet.

Furthermore, research done via interviews with locals and experts on watermanagement had great value for me, because I learned more about the livelihood of the locals and how they are dealing with the extreme weatherconditions, floodings and erosion. The watermanagement experts made it clear for me what they can do now against floodings in Bangladesh, such as strenghten of the riverbanks to prevent them of collapsing due to erosion. I made a transcript of the interviews, so I could look back at the interviews and implement them better in my research.

224. Low-Income Cluster. Source: Author, 2025



225. Middle- High Income Cluster. Source: Author, 2025



In Bangladesh I made a lot of pictures and videos. Looking back at this footage after the trip helped me with remembering the livelihood and conversations that I had with people there. From this footage I made a video to explain the livelihood of the residents and the problemstatement. This video helps me also with presenting their ways of living.

After the Studytrip we did a communal materia lresearch with the whole Studiogroup of Global Housing. This had also great value, because with a larger group it is possible to do more research then on your own. It showed more possibilities for different materials that would work in Bangladesh with there advantages and disadvantages.

I think the research method of interviewing people at different locations worked well for me to understand the livelihood of different income groups within the city and the villages. Also the research method of analysing casestudies helped me a lot with understanding how architects deal with extreme climate conditions.
However, I could have done a bit more research on the daily practices of the people living at the design site itself. I have been three times to the design site, 2 times with a student from the SUST University or a teacher, and one time with only two other TU Delft students. The last time we noticed that it was not safe enough to go without someone local, so we did not want to come back at nighttime at the design site. It would have been interesting to see what the residents would do at night at the design site.

4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

My graduation project, which focuses on the seasonal adaptability and affordability in a high-densed housing design for the impoverished communities living along the erosion-prone Surma Riverbank in Sylhet, holds academic and societal value, because it contributes to research on how you can house people on a flood- and erosionprone area in a safe and affordable way, which will mitigate the environmental mass-migration within Bangladesh to the bigger cities and increase the livelihood of the residents.

The current residents on the designsite need to leave their homes three times per year due to the floodings. This cause a distruction of their valuable belongings, such as schoolbooks. These communities are not able to buy these belongings again and again everytime a flooding occurs. This will cause a disadvantage on the schooling for the children of the families. In an interview with a local man of the Hindu community he mentioned that providing a good education for the children is most important, so they will have more opportunities in their live.

Next to providing a safe environment within their houses that can withstand floodings and erosion, it is also important to provide comfortable livingconditions within the home itself, otherwise the inhabitants could move somewhere else.

By designing a passive cooling system, with cross-ventilation and shading, the indoor conditions will improve significantly. Furthermore, passive systems are way more affordable then mechanical systems. This will make it more affordable for lower income groups, which gives also more societal value to the project.

To make this project feasible, affordable and diverse it is important to design also housing for other income groups. With cross-subsidization the higher income groups can help lower income groups with facilitating housing for them. By designing housing for low, middle and high income groups, with their personal preferences within the apartments, the masterplan will become diverse and affordable for the lower income groups as well.

The mix of different income in the masterplan is done by designing the same structure for every building, and within the structures variations can be made to provides everybodies wishes. For example the high income group apartments have bigger floorspace, bigger loggia's, more privacy and more bathrooms.

Furthermore the high and middle income group have a more expensive facade to showcase their financial status to other people, which is important for these income groups. The lower income groups have more compact apartments and more communal outside spaces. When the different income groups are living closer together, they might mix more with eachother and gives some societal value to the project.

For the academical value of this project it was important to collaborate with the SUST university in Sylhet and experts regarding watermanagement in Bangladesh. Because, the Netherlands and Bangladesh are both Delta's, but very different from eachother. In the Netherlands the rivers are more controlled and in Bangladesh they let the rivers more free. The interviews helped me to understand how people react to floodings. Next to the interviews, I also used casestudies as a researchmethod, which helped me with understanding of the site's conditions and design principles.

Ethically, I wanted to use as much local materials as possible, to help the local community earn money and to use as less transport as possible which will reduce the CO2-emmissions. Unfortunately, because the project is very high-densed, the structure is made out of concrete to carry all the weight of the floors. The concrete will be poured on site to support the local workers in Sylhet. Furthermore, I tried to use as less concrete as possible, so only concrete is used for the foundation, columns and beams. The infill material, floors and roofs are made out of local materials, such as Compressed Earth Bricks, Limeplaster, Fired Bricks and Bamboo. Also Compressed Stabilized Earth Bricks are used. A part of this product need to be imported, namely the cement, and another part is locally available, such as the earth. By using more local and sustainable materials, the local communities will be supported and the CO2-emmissions coming from the build environment will be reduced, which will provide a healthier environment.

5. How do you assess the value of the transferability of your project results?

The transferability of this project lies in its potential to adapt with passive methods to seasonal changes regarding weatherconditions which will offer a more affordable way of providing safe and comfortable livingconditions for different income groups.
However, this can be done in many ways depending on the climate itself. For colder climate conditions different strategies need to be implemented. This project is one way of dealing with extreme climate conditions, but for every different climate the problems will be solved in a different way.
So, the transferability of this project is relevant for countries with a hot and humide monsoon-season and with a temperate and dry winter.

6. What would I implement more into my research if I would get another opportunity to go to Bangladesh?

Before I went to Bangladesh I did some research on amphibious dwellings, however when I was in Bangladesh I did not see any amphibious dwellings. This could be because we went in the dry season, so if I would go again I would like to go in the pre-monsoon or monsoon season to see how these type of dwellings are working and also to experience the issues myself. However, for my own safety, I am happy that we went to Bangladesh in the dry season.

Furthermore, In my research proposal I was more focussed on the fishermen communities. I tried together with a guide, Jafar, in Ekduaria to talk to a fishermen community, however this was not possible in the end, because it was hard to find a community in the neighbourhood. In the dry season people are mostly working in factories or in agriculture. In the monsoon season many people switch their job to fishermen, so maybe if I could go back in the monsoon season I could have a conversation with a fishermen family.

7. Is it possible to implement the units in a different location in Sylhet and what would change within the design?

I choice to design my project at the Surma Riverbank in Sylhet. However, I am also curious how my design would have evolved if I had chosen another location. It would have also been interesting to test my research on a designsite that had even more flooding issues, such as the wetlands. I think the units would also work in the wetlands with some adjustments regarding the preferences of the communities and the even more extreme flooding scenarios. In the wetlands people have a different lifestyles than in the cities. For example they need also space for their animals and kitchengardens. Furthermore, I would think if you orientate the unit correctly the passive methods in my research will also work within the wetlands. However a different approach regarding the floodings could maybe work better. Maybe these units would have been amphibious dwellings in the wetlands.

Furthermore, I think the clustering and masterplan would have looked differently in the wetlands than in the city. In the wetlands there is more space then in the city, so the units could have more space towards eachother. In the wetlands the height of the buildings is way lower, so the cluster would have been lower as well.

Nevertheless, I think that this project could also work in different areas within the city of Sylhet if you orientate it correctly according the climate conditions. The units and the cluster could stay the same, however I think the masterplan would change according the site.

Conclusion
In short, the first hypothesis I made in my designprocess on the research question: *"How can environmentally driven migration be reduced by implementing a high-density and seasonal-adaptable housing design for the impoverished Hindu and Muslim communities living on the erosion-prone Surma riverbank in Sylhet?*" is slightly different then the outcome of my research and design.

First hypothesis: *"The dwellings along the riverbanks of the Surma river in Sylhet need to be resilient to erosion. This can be achieved through the use of geobags filled with sand. Furthermore, it is important that these dwellings are affordable for the impoverished communities, so their livelihood will increase. This can be achieved by using local materials, building techniques and an easy way of assembling and disassembling of the construction.*

Furthermore, this dwelling must be adaptable to seasonal fluctuations in water levels and flexible enough to accommodate the shifting dynamics of the Surma riverbank. This can be achieved by designing an amphibious dwelling that can function both on land and in water. The proposed house will initially be constructed on land. However, due to its vulnerability to erosion and its possibility of flooding, it must also incorporate water-resistant features.

However, these solutions need to be scaled up to bigger housing projects, so all the impoverished communities in need, such as the Hindu, Muslim and fishermen communities, are eligible for these seasonal-adaptable and affordable housing types"

The outcome of the design is slightly different, due to the characteristics of its location. A flexible design would not work on the Surma Riverbank next to the Keane Bridge, because this area has more potential to be developed into a permanent busy neighbourhood which will last for a long time.

So it was important to implement permanent seasonal adaptability design choices, such as a long lasting structure, cross-ventilation, strenghten of the riverbanks, shading and rainwaterharvesting, within this masterplan to provide a safe, comfortable, vibrant and inclusive neighbourhood. The use of as many local materials as possible, and the strategy of cross-subsidization made the project also affordable for the low income groups.

19. Other Graduation Process: *Phase 1 Cidade Horizonte do Uige*

Starting my graduation year I researched the case study Cidade Horizonte do Uige situated in Angola designed by Jaime Lerner Arquitetos Associados in 2011.

After the colonial rule by the Portugese in Angola a civil war broke out from 1975 till 2002. The conflicts were namely in the rural areas, which precented the development of a decent social and physical infrastructure. In combination with the lack of opportunities to earn an income in the rural areas, this led to a migration of millions people from these areas to the main cities. The hosing shortage is still rising with a baklog of 2 million dwellings (Mota, 2016).

However, due to the oil revenues made in the period after the civil war the government stimulated the development of a new housing policy in the public and private sector. On the day that the president t won the elections in September 2008 he gave a speech wherein he announced an allocation of $50 billion to solve the housing crisis (Alves, C. 2012). The government was coöperating with the private sector Kora-Angola to develop the Cidade Horizonte-projects. In agreement with the government, Kora-Angola developed a masterplan "Angola's National Plan for Housing and Urban planning" where 15 new urban settlements, with 40.000 new dwellings, would have been situated throughout the country. The brazillian architect Jaime Lerner designed the urban plan for these neighbourhoods. Starting by creating the infrastructure, including water, sewer, roads and connection to the power grid or, in some case, provide power from generators (Thorpe, 2013). His design principles were based on the concept of the urban community, whereby aordable housing, urban infrastructure and social and recreational facilities would be designed. According to Lerner, the neighborhoods must have a clear spatial identity with dierent dwelling types, which can also be expanded later (Mota, 2016).

The plan seemed very promising, however the president might had a false sense of prosperity caused by the election victory and persistent eect of the oil boom (Alves, C. 2012).

The state's role was to guide the national urbanism and housing programme, however it turned out that 685.000 houses of the million houses needed to be constructed through autoconstruction. Whereby, only 115.000 dwellings would be constructed by the government, 120.000 dwellings would have been constructed by the private sector and 80.000 through cooperatives. In the beginning of 2009 the government was scrambling for money, because the oil drices declined after the global economic and nancial crisis in 2008. There was not a provisional budget for the housing programme, let alone the promised 50 billion by the president (Alves, C. 2012).

226. Cidade Horizonte do Uige. Source: Author, 2024

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21. References

- Abdullah Kaiser, Z. R. M. (2023). *Analysis of the livelihood and health of internally displaced persons due to riverbank erosion in Bangladesh.* https://doi.org/10.1016/j.jmh.2023.100157

- Admin. (2023, november 13). *Adapting to the Elements: Tackling Seasonal Shifts in Structural Design. GDI Engineering.* https://gdiengdesign.com/adapting-to-the-elements-tackling-seasonal-shifts-in-structural-design/

- Akter, S. Holadar, M.F. Ahmed, Z. Chowdhurry, T.R. (2019). *The rainfall and discharge trends of Surma River area in North-eastern part of Bangladesh: an approach for understanding the impacts of climatic change.* Via, https://environmentalsystemsresearch.springeropen.com/articles/10.1186/s40068-019-0156-y

- Akter, S. Mallick, B. (2013). The poverty-vulnerability-resilience nexus: Evidence from Bangladesh. *Journal Ecological Economics, 96*, 114-124. https://doi.org/10.1016/j.ecolecon.2013.10.008

- Alves, C. (2012). China & Angola: A Marriage of Convensience? https://www.amazon.nl/China-Angola-Convenience-Marcus-Power/dp/0857491075

- Ambagts, J. Ganotaki, L. Ringel, R. Tiezsch, C. van Duinen, C. (2025). CI Sheets GEO-sourced.

- Ambagts, J. Ganotaki, L. Ringel, R. Tiezsch, C. van Duinen, C. (2025). Earth GEO-Sourced.

- Anik, A.I. Mozumder, H.M. Islam, M. Islam, S. Haque, I. Hossain, D. (2024). A review of compressed stabilized earth block as a sustainable building material for low-cost house setting in Bangladesh. *7th International Conference on Civil Engineering and Sustainable Development*

- Atlas, W. (2024). *Yearly & Monthly weather - Sylhet, Bangladesh. Weather Atlas.* https://www.weather-atlas.com/en/bangladesh/sylhet-climate

- Auram 3000 Block Press. (z.d.-b). Dwell Earth. https://dwellearth.com/auram-3000-block-press/

- Auroville Earth Institute. (2024, 27 mei). Vikas Community, 1991-1998 - Auroville Earth Institute. https://dev.earth-auroville.com/vikas-community-1991-1998/

- BETA. (z.d.). Baetulo, estudio DIIR. https://www.beta-architecture.com/baetulo-estudio-diir/

- Canova, C.V. (26-06-2024). *Khudi bari. An interview with the architect Marina Tabassum.* Vitra. https://www.vitra.com/nl-nl/magazine/details/khudi-bari-by-marina-tabassum?srsltid=AfmBOoqQE0mdm60iG81HL5XxEXPi1IZKLkFHWP-8Hi2NjzsYGu7UE0cZ

- Cavallo, A. (2024, 14 februari). *Hoe lang kun je regenwater in je flexibele regenput bewaren?* Blog Ma Citerne Ecolo. https://blog.maciterneecolo.fr/nl/hoe-lang-kun-je-regenwater-in-je-flexibele-regenput-

- Centraal Bureau voor de Statistiek. (2018, 1 juni). *Woonoppervlakte in Nederland. Centraal Bureau Voor de Statistiek.* https://www.cbs.nl/nl-nl/achtergrond/2018/22/woonoppervlakte-in-nederland#:~:text=Gemiddeld%20heeft%20een%20Nederlander%2053,persoon%20doorgaans%20kleiner%20dan%20daarbuiten.

- Choi, J.W. (2024). *Designing Large-Scale Floating Structure.*

- de Bok, C. Steendam, J. Bijwaard, L, van Kats, M. Gerrits, M. (2025). Baked Brick.

- *Dichtheid en functiemenging in beeld.* (12-12-2018). Planbureau Voor de Leefomgeving. https://www.pbl.nl/publicaties/dichtheid-en-functiemenging-in-beeld

- Dzombak, R. (14-12-2022). *Amphibious houses and floating floors could help Bangladesh residents stay dry during flood season.* https://news.agu.org/press-release/amphibious-houses-and-floating-floors-could-help-bangladesh-residents-stay-dry-during-flood-season/

- Endangsih, T. Ikaputra. (2020). *Floating Houses Technology as Alternative Living on the Water.* doi:10.1088/1757-899X/797/1/012020

- Fidah, M. F. A., Efa, S. S., & Khan, M. A. S. (2024). *Who Belongs to the Middle Class? Identifying Them Using Monthly Family Income.* Qeios. https://doi.org/10.32388/iyl0xz

- Halleran, A. Soentiono, C. Jankee, G. Darweshi, N. Schuurman, T. Doorn, Y. (2025). Wood & Bamboo, BIO-sourced.

- Hussain, M.M. (May, 2012). *The Socio-economic Situation and Occupational Challenges of Fishermen in Sylhet. SUST Studies, 15(1)*, 94-103. https://www.researchgate.net/publication/368461324

- Hossain, Z. (2016, 30 oktober). Life in The Geneva Camp of Dhaka - Sazzad hossain. Sazzad hossain - multimedia journalist. https://www.hossainsazzad.com/2016/10/30/life-in-the-geneva-camp-of-dhaka/

- Islam, N. van Amstel, A. (2021). *Climate Change Impacts, Mitigation and Adaptation in Developing Countries.* Springer Climate. https://doi.org/10.1007/978-3-030-71950-0

- Islam, S. Hoque, F. (2014). River Bank Erosion of the Surma River Due to Slope Failure. *International Journal of Research and Innovations in Earth Science, 1(2)*, 54-58.

- Itma, M.A.F. (2019). Strategies of Adaptability: An Approach for Affordable Housing Design. *European Journal of Advances in Engineering and Technology, 6(10)*, 1-6. www.ejact.com

- Kashem, S.B. (9-09-2019). Housing practices and livelihood challenges in the hazard- prone contested spaces of rural Bangladesh. *International Journal of Disaster, 10(5)*, 420-434. www.emeraldinsight.com/1759-5908.htm

- *Khudi Bari: A climate-prepared solution to rising flood threats.* (02-01-2024). Dhaka Tribune. https://www.dhakatribune.com/world/south-asia/335559/khudi-bari-a-climate-prepared-solution-to-rising

- Makri, D. Kim, H. Wijnen, J. Ter Glane, K. van Poppel, R. (2025). Concrete & Lime.

- Malak, A. Hossain, N.J. Quader, A. Akter, T. Islam, N. (2021). Climate-Induced Natural Hazard: Population Displacement, Settlement Relocation, and Livelihood Change Due to Riverbank Erosion in Bangladesh. *Climate Change Impacts, Mitigation and Adaptation in Developing Countries. Journal of Springer Climate* (pp. 193-210)

- Marine, S.S. Dey, T. Rashid, A. Barman, P.P. Islam, M. A. (August, 2014). Fishing: A Prominent Means of Livelihood of Fishermen on Surma River Basin at Sylhet District of Bangladesh. *An online version journal, 2(1)*, 01-07. website: www.gurpukur.com or www.gscience.net

- Martin, M. hyun Kang, Y. Billah, M. Siddiqui, T. Black, R. Kniveton, D. (2013). *Policy analysis: Climate change and migration Bangladesh. RMMRU, SCMR, University of Dhaka and University of Sussex.*

- Masum, J.H. (2019). *Climatic Hazards in Bangladesh: A Literature Review.* Coastal Development Partnership (CDP), Bangladesh, Coastal Development Partnership (CDP),

- Mota, N. (2026). Cidade Horizonte do Uige, Uige (AO). Jaime Lerner. https://journals.open.tudelft.nl/dash/article/view/5033

- Nakajima, T., Saito, Y., & Umeyama, M. (2021). A Study on Stability of Floating Architecture and Its Design Methodology. In Lecture notes in civil engineering (pp. 273–296). https://doi.org/10.1007/978-981-16-2256-4_17

- Nobel, S. (2022, 13 november). Poor access to sanitation system plagues slum residents, homeless people in Dhaka. Poor Access To Sanitation System Plagues Slum Residents, Homeless People in Dhaka. https://bdnews24.com/bangladesh/nkbe5zehn2

- Nyilas, A., & Kurazumi, Y. (z.d.). *On the Aesthetics of Seasonally Adaptive Buildings – A Morphological Approach towards Climate Responsive Architecture.* 2012 Scientific & Academic Publishing. http://article.sapub.org/10.5923.j.arch.20170704.03.html#Sec3.1

- Ondergrondse regenwater tank kunststof 10.000 liter - budgettank. (z.d.). https://www.budgettank.nl/p/apf20k-aqua-plast-ultra-plat-heavy-duty-7-5-ton-ce-ondergrondse-regenwater-tank-20-000-liter?gad_source=1&gad_

- Onsharp.Admin. (2019, 30 september). *What is the stack effect?* CPP Wind. https://cppwind.com/stack-effect/

- Partha, P. (2024, 22 juni). Flood in Sylhet is the price we're paying for ignoring nature. *The Daily Star.* https://www.thedailystar.net/opinion/views/news/flood-sylhet-the-price-were-paying-ignoring-nature-3638386

- Rashid, M. U. (2020). Approaches for Solutions of Housing Crisis for the Mohammadpur Geneva Camp. Trends in Technical & Scientific Research, 04(3). https://doi.org/10.19080/ttsr.2020.04.555638

- Tabassum, M. van Gameren, D. Mota, N. Varma, R. van Andel, F. Paoletti, A. (2024). *Course Guide, Architecture of Transition in the Bangladesh Delta.* Technische Universiteit Delft. https://brightspace.tudelft.nl/d2l/le/content/679903/viewContent/4003579/View

- Therma. (2021, 8 september). *The Stack Effect: How It Works and Impact On Energy Efficiency.* https://www.therma.com/the-stack-effect/

- Thompson, A. (2019). *Geobag Stability for Riverbank Erosion Protection Structures.* University of Alberta. Master of Science Thesis. https://doi.org/10.7939/r3-e1gb-vz53

- Thorpe, D. (2013, 30 juni) Does impact work? Vital Capital case study shows it does. Forbes. https://www.forbs.com/sites/devinthorpe/2013/06/26/does-impact-investing-work-vital-capital-case-study-shows-it-does/

- Thouvenot, D. (8-04-2019). *Against the tide: Thai 'floating temple' defies coastal erosion.* phys.org. https://phys.org/news/2019-04-tide-thai-temple-defies-coastal.html

- Varkey, M.V., Philip, P.M. (2022). Flood risk mitigation through self-floating amphibious house Modelling, analysis, and design. *Materials Today: Proceedings, 65(2)*, 442-447. https://doi.org/10.1016/j.matpr.2022.02.547

- Verweij, S. (2021). *Effective policy instrument mixes for implementing integrated flood risk management: An analysis of the 'Room for the River' Program.* Via, https://www.sciencedirect.com/science/article/pii/S1462901120314052

- Waterwoningen IJburg. (2011). *Marlies Rohmer Architecture & Urbanism.* https://rohmer.nl/projects/waterwoningen-ijburg/#:~:text=Waterbuurt%2DWest%20ligt%20in%20de,varen%20als%20naar%20open%20water.

- Zannat, Z. Murshed, S.B. Khan, M.S.A. (16-12-2022). *Household Level Adaptation Response to Extreme Flood Events.* ADS. https://ui.adsabs.harvard.edu/abs/2022AGUFMNH35C0505Z/abstract

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