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Architectural Solution for
Community and Critical Facility
Resilience

Master Thesis in Architecture,
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1 INTRODUCTION

2016 was according to NASA scientists, the hottest year on record . (NASA, 2017) This is just one of the more visible effects of climate change, one of the greatest challenges of our times. Another very visible effect is the change in global disaster patterns, with more frequent, more intense and less predictable disasters challenging especially developing countries with a lack of preparedness and response capacities (IPCC, 2012).

There is a lot of discussion going on how to adapt to this changing climatic conditions, especially in countries where financial resources are limited. The built environment has been identified as a key area of intervention. As disasters, such as typhoons, can devastate entire cities, it is essential that the most important buildings in these cities, the lifelines so to speak, are resilient and can withstand major hazards.

The aim of this thesis is to show ways architecture can help to create disaster resilient communities with a focus on critical facilities. Specifically, as an example, a school and a health facility for a neighborhood in the Philippines, one of the most disaster-prone countries of the world, will be developed.

Often, architecture focuses on appearance rather than actually sheltering people and protecting them from the destructive elements of nature.

aegis
noun

classical Mythology: the shield or breastplate of Zeus or Athena, bearing at its center the head of the Gorgon.

protection; support /

sponsorship; auspices /

Disaster resilient planning and architecture are very important as frequent repairs and maintenance or complete replacement after disasters put pressure on public and private resources as well as the environment, including energy, waste, and emissions. Additionally, buildings made from weak materials tend to benefit less from retrofitting than newer buildings constructed with appropriate materials (Bestari et al., 2013).

Humanitarian architecture has been focusing a lot on disaster relief by building temporary structures for shelter after a disaster. Although these structures are needed, they are no long-term solution. It has to be ensured that affected people can return to their old lives and homes. Moreover, a lot of disaster resilient architecture is developed for the wealthy with expensive materials and building methods. This thesis challenges these common practices, by offering a different entry point for architecture in disaster prone areas. It proposes disaster resilient architecture made from local, cheap materials to make it accessible for communities in poorer areas of the world. The disaster-type of concern is hydro-meteorological disasters. The study site serves as an example, where such architecture could be located. The thesis however also aims at creating generalizable findings which can be applied to other sites, as well.

Therefore, this thesis will include a conceptual background on disaster resilience and architecture in the Philippines, general guidelines regarding typhoon resilience and finally a proposal for a resilient community in the Philippines with a focus on a health facility and a school, including construction methods and material.

1.1 GENERAL INFORMATION

TERMINOLOGY

In order to understand how to create disaster resilient architecture, we first need have a look at the frequently used terms in disaster risk management (UNISDR, 2009). First, we need to know what a disaster actually is. This seems obvious at first sight but is in reality quite complex. A predominant view is that a disaster is a natural event, such as an earthquake or a tornado. The natural event is however not the disaster itself, but the hazard. The actual disaster happens during or after a hurricane and can last a lot longer than the duration of the impact of an actual storm. Whether a hazard turns into a disaster depends on many factors, including the level of preparedness of the society, the availability of response

capacities, the planning of communities, and, not unimportantly, the resilience of the built environment. A disaster does not last only for the few seconds of the earthquake but can prolong itself for several weeks or months, with cascading effects following the impact. A hazard can also be manmade, such as oil spills or nuclear accidents (Oliver-Smith et al., 2017). The United Nations Office for Disaster Risk Reduction (UNISDR, 2009) defines a disaster as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources". Additionally, it states that a disaster is often described as

a result of the combination of three factors: 1) (physical) exposure, 2) vulnerability and 3) the capacity to cope with the situation. The vulnerability of a system has many aspects, including poor design and construction of buildings, lack of information and awareness and disregard for environmental management. A disaster cannot exist independently from human systems (Oliver-Smith et al., 2016). A storm which hits an

uninhabited island can never turn into a disaster, as no population is in the path of the hazard. Only if there is an exposed population which can suffer damage from the hazard, there can be a disaster. Thus, vulnerability and exposure shape disaster risk, which manifests itself into a disaster, in case of a hazard. Resilience on the other hand is defined as „the ability of a system, community or society exposed to hazards to resist,

absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” (UNISDR, 2009). Recent research suggests that the recovery component of resilience is more than simply the ability of 'bouncing back' to the pre-disaster state. It should rather be perceived as the ability of 'building back better,' meaning creating a better

system during the recovery phase, drawing on lessons learned during the disaster (Becker, 2014). Resilience also means to be able to resist and absorb a hazard. Here, architecture is especially important. Architecture and urban planning can help increase the coping capacity and decrease the vulnerability of a community which is exposed to hazards, thus making it more resilient. A safe and sound built environment

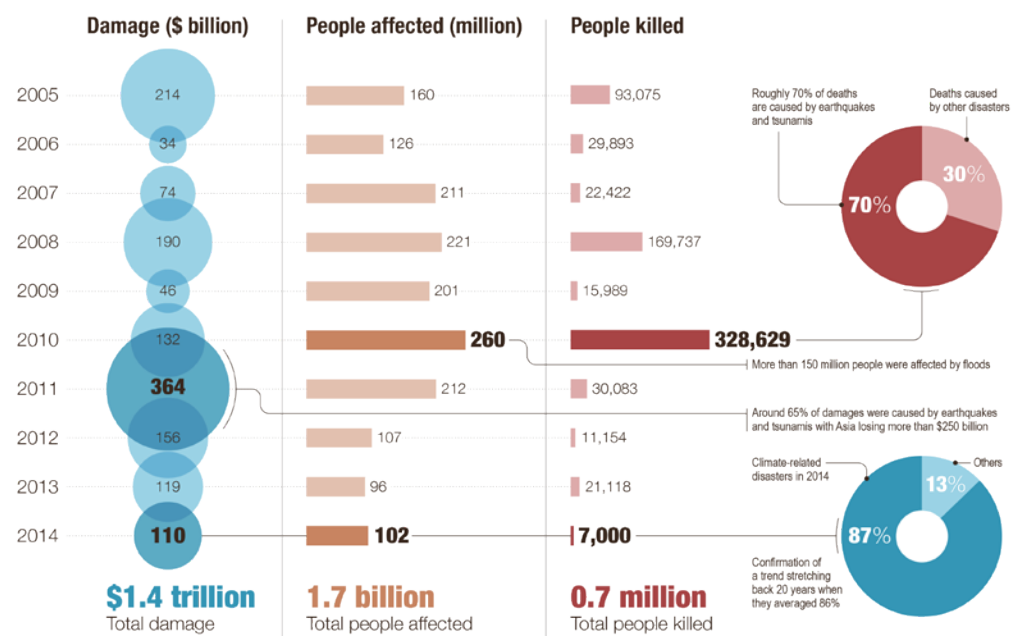


Fig. 1 Economic and Human Impact of Disasters 2005-2014 (UNISDR)



Fig. 2 Countries with most disasters 2005-2014 (UNISDR, n.d.)

can offer protection and shelter in times of need. On the other hand, a weak built environment can worsen the effects of a disaster, as collapsed buildings can injure people. Further, the destruction of key buildings (critical facilities) can interrupt the functioning of response and recovery efforts.

A disaster can happen in every country; however, some are more susceptible to it than others. Disaster risk indices, such as the annual World Risk

Report, indicate a country's disaster risk based on its exposure and vulnerability. The Philippines is ranked as the country with the third highest disaster risk worldwide, after the Pacific island states of Tuvalu and Tonga (UNU, 2016).

HISTORY OF DISASTERS

Disasters happen all around the globe and leave a lot of human suffering and physical damage behind. In recent

years there has been an enormous amount of economic and social damage related to disasters, with climate change and changes in socio-environmental vulnerability patterns being predicted to emphasize this trend further in the future. There is an increasing unpredictability of hazard patterns which makes disaster planning more difficult (IPCC, 2012).

Architecture plays a major role

in the impacts of disasters. Poor building design is not only responsible for a lot of economic damage but social damage as well, as floors and roofs can collapse and flying or falling debris can cause human losses.

Destroyed or damaged buildings that cannot be replaced quickly force people to leave their homes and move away. In the year 2015 alone 98.6 million people have been affected by disasters

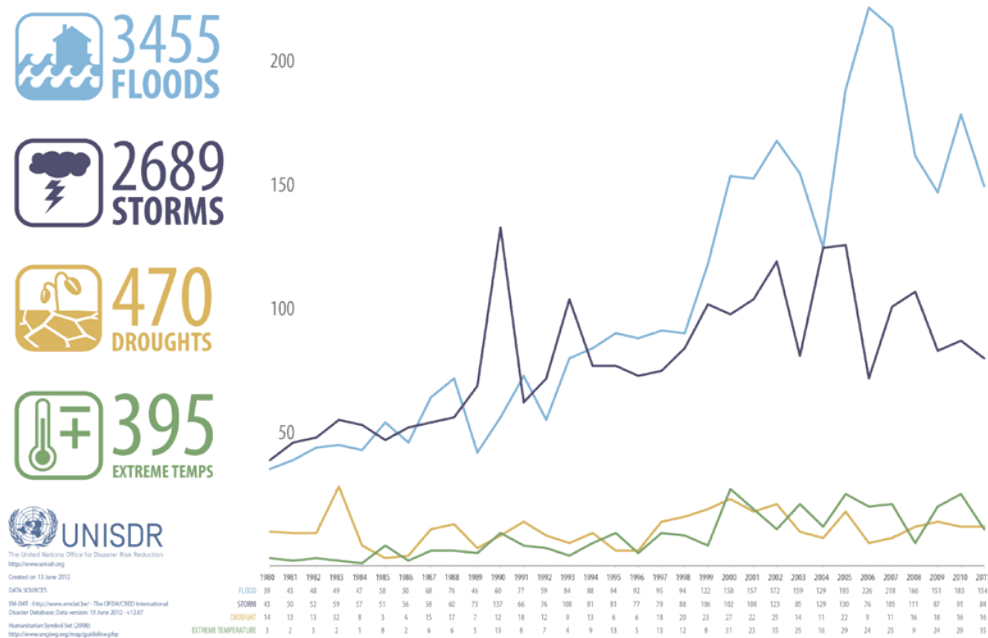


Fig.3. Number of climate-related disasters for each year, 1980 - 2011 (UNISDR, 2012)

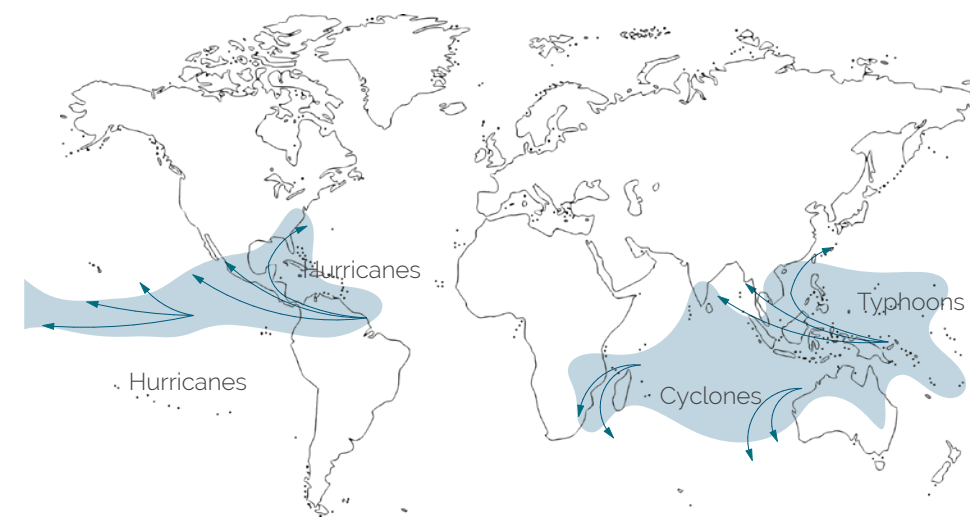


Fig.4. Tropical storm occurrence (learnnc.org, modified)

and between 2005 and 2014 0,7 million people were killed (IFRC, 2016).

TYPES OF DISASTERS

There are many different types of disasters, and they are differentiated based on the triggering hazard. Generally, they are classified as being hydrological (e.g. floods), meteorological (e.g. extreme weather events such as storms), climatic (long-term impacts, e.g. sea level rise), geophysical (e.g. earthquakes) or biological (e.g. epidemics) (IFRC, 2016).

CLIMATE-RELATED DISASTERS

This will focus on typhoons, which belong to the group of hydro-meteorological

disasters. Typhoons build on the sea, given high water temperatures, humidity and atmospheric instability (NHC, 2010). Typhoons have become more frequent and intense in recent years, and are predicted to increase further in number and intensity in the future as a result of climate change.

Hurricanes, floods, and tornados are the most frequent disasters, accounting for 77.4% of all disasters in 2011. Flooding is the category which caused the most deaths in history (Guha-Sapir et al., 2012). Climate change has contributed to an increased frequency and intensity of floods even in regions that did not use to face catastrophic impacts. Floods are often associated with other types of disasters, such as typhoons. „Hurricane“, „cyclone“ and

„typhoon“ are different words that describe the same phenomenon. These tropical storms are usually accompanied by torrential rain and exceed the maximum wind speed of 119 km/h (33m/s). However, a category five cyclone is referring to a wind speed larger than 249 km/h (69 m/s). Countries that are most affected by these storms include China, Philippines, Japan, Caribbean and Pacific island states, and the United States. Typhoons need high sea surface temperatures to develop (NHC, 2010). Given the average temperature increase due to climate change, it is expected that there will be more typhoons in the coming decades and that they will be more unpredictable (IPCC, 2012).

FUTURE PROSPECTS

The Intergovernmental Panel on Climate Change (IPCC, 2007) found that already today, there is an "increasing tendency in the intensity and frequency of extreme weather events," which is predicted to continue in the future. This applies above all to tropical regions. Especially developing countries face massive disaster losses, which are related to their relative lack of coping capacity and high vulnerability levels. These losses further aggravate poverty and hinder the achievement of the sustainable development goals.

2 DISASTER AND THE BUILT ENVIRONMENT

To understand the connection of architecture and resilience, we have to identify the processes which affect people and buildings during a disaster, both from an urban planning and an architectural perspective. This chapter will introduce the interrelations of disasters and the built environment and how architecture and urban planning can contribute to more resilient communities. It will describe the negative effects on the society of poorly managed disasters and how disasters interact with the built environment.

This chapter will introduce the concept of resilience, with a special focus on urban communities. It will shortly explain which factors influence urban resilience from an architectural perspective. Finally, the importance of critical facilities for resilient communities will be discussed.

2.1 IMPACT OF DISASTERS

SOCIO-ECONOMIC ASPECTS

In the World Bank and United Nations Report "Natural Hazards. UnNatural Disasters – the Economics of Effective Prevention" (2010) it is stated that „ a disaster exposes the cumulative implications of many earlier decisions, some taken individually, others collectively, and a few by default." These decisions taken in land management, construction techniques, sanitation and investment in education and social integration, combined with natural hazard events cause socioeconomic and environmental impacts and losses as in a disaster when the capacity of manmade structures is exceeded. Developing countries are usually hit hardest by disasters due to their low coping capacity. This means a lack of preventive

actions and resources as well as low level of social capital. In addition, natural factors like wind and water can carry the problem further than its origin, distressing local economy and social vulnerability is growing (Mata-Lima et al., 2013). Cascading effects can affect communities which have not directly faced the impact of a hazard. For example, when water-related infrastructure is damaged in a disaster upstream, a community downstream might be affected by an epidemic. To reduce the impact of disasters, one needs to increase resilience and reduce exposure and vulnerability. The concept of disaster risk reduction has gained increasing attention in the last years, especially after the United Nations named the 1990s the official decade for

disaster risk reduction.

The level of negative effects during a disaster depends on economic factors, as well. Low social capital leads to weak economic structures which in turn contribute to difficulties in addressing disaster-related problems.

As it is not possible to eliminate extreme natural phenomena, preventive measures are most important, including disaster-resilient architecture and urban planning. These preventative measures are called Disaster Risk Reduction (DRR) (UNISDR, 2009).

DISPLACEMENT

If people cannot return to their original place of habitation after a disaster for an extended period of time, they are considered 'displaced' (Platform on Disaster Displacement (PDD), 2017). This status can be long- or short-term as well as in a country or cross-border. Often displaced people are described as

'uprooted' (IOM, 2017). This means that peoples' social and economic base – the livelihood – is connected to their place of living and without it they become dependent on outside aid. Additionally, there is a loss of cultural connection between people and the land. Moreover, displacement puts pressure on the hosting community as it often causes conflicts and resource shortages. Displaced people often lack legal protection and in a long-term situation are often overlooked by international humanitarian organizations as they usually leave after an immediate response in the disaster region. When the built environment is destroyed, but people have no place to go they need to stay in the hazard zone which is called „trapped population“ (IOM, 2017).

BUILT STRUCTURES

As all types of built structures, houses are often damaged during disasters. There are many factors during

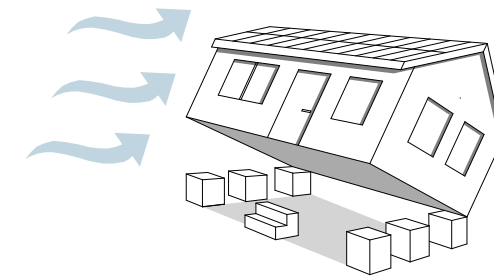


Fig 5: Footings

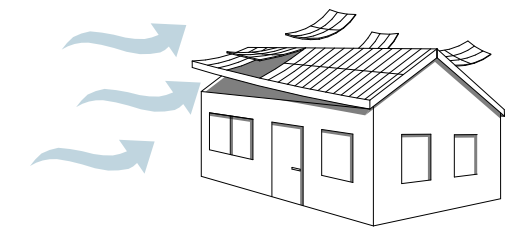


Fig 6: Roof

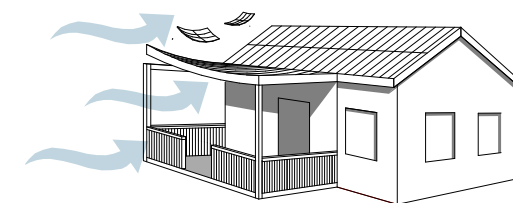


Fig 7: Veranda

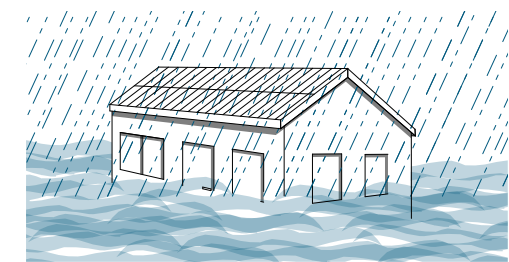


Fig 8: Flooding

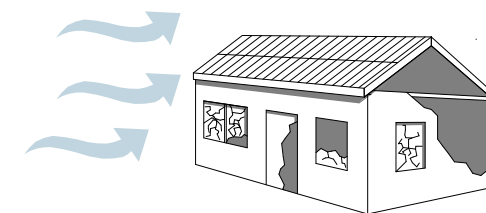


Fig 9: Walls and windows

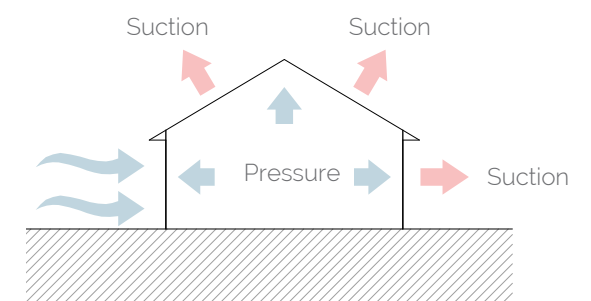


Fig 10: Forces

Fig. 5-10: Damages and effects on houses during a cyclone (Agarwal, 2007, modified)

a typhoon which affect the built environment. Due to strong wind pressure and weak connections of the building to the foundation, houses can be blown away (Fig.5). For light weight structures overturning is a problem as well. Roofing materials that are not fastened properly can be torn off. (Fig.6) Moreover, light weight attachments, like veranda roofs are more vulnerable to damage from wind as they can be easily lifted upwards and torn off (Fig.7). As cyclones are often accompanied by heavy rain for a long period of time, buildings are additionally damaged by flooding or made inaccessible (Fig. 8). Light structures or parts of buildings can be washed away. If the roof has already been damaged, rain can enter the building doing additional damage to the interior of the house.

Lastly, the building envelope is most vulnerable in case of high winds. The pressure can make walls collapse and damage doors and windows (Fig.9). Once the exterior is breached, the interior suffers additional damage, due to pressurization. Depending on the windward side there is a built-up pressure on one side and suction on the other. The roof is subjected to pressure as well as suction forces, also depending on the slope (Fig.10) (Agarwal, 2007). Furthermore, exposed electrical and mechanical equipment can be damaged or ripped off due to high winds. Flooding also disables electrical and mechanical systems both outside and inside buildings.



Fig 11: Destruction of the town Palo by Typhoon Haiyan 2013 (BBC, 2013)



Fig 12. Destruction in Tacloban City by Typhoon Haiyan 2013 (BBC, 2017)



Fig 13. Destruction in Vanuatu by Cyclone Pam 2015 (newfrontierchronicle.org, 2015)

2.2 URBAN AND COMMUNITY RESILIENCE

Urban resilience is defined as the „capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience“ (100 Resilient Cities, 2017). Applying this to the built environment in cities, it means that the buildings need to be able to withstand a hazard. It also means that buildings in hazard-prone areas need to be adapted to the circumstances,

i.e. they need to be constructed differently that buildings in non-hazard zones.

VULNERABILITY

Usually, the buildings most vulnerable to typhoons are light weight structures situated on low-lying islands or in highly exposed coastal areas. The exposure to high winds is worse in open country and plains than in mountainous areas, except houses located on hill tops. However, also urban

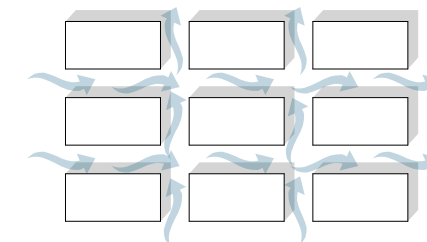


Fig 14: Straight building patterns speed up the wind - channeling effect

structures are susceptible to damage from disasters. Due to high urbanization levels, cities often have cramped up living quarters built with cheap materials that can easily be damaged. In addition, the high density of the city leads to a lot of hard and sealed surfaces that worsen the effects of a flooding. Moreover, certain building patterns lead to „tunnel or funnel effects“ that accelerate the wind speed (see Fig. 14) (Agarwal, 2007).

CASCADE EFFECT

To maintain a resilient community, it is essential that cascade effects are avoided. A cascade effect describes consequential failures of systems. For example, in case of a loss of electricity, life-saving equipment might lose its functioning in hospitals, which increases the number of fatalities. Another example would be poor waste

management combined with flooding, which can expedite the spread of diseases. Insufficient water supply and electricity failures can lead to disarray which extends the geographical direct impact of the hazard. Destruction of roads obstructs the transportation of goods and people, for instance between a rural and an urban zone. Cascade effects worsen the disaster immensely and lead to catastrophic damages affecting people, economy, and environment (Pescaroli & Alexander, 2015). Most infrastructure is dependent on electricity, staff and environmental services (e.g. water).

DEVELOPING COUNTRIES

Developing countries suffer major losses due to disasters. Disasters impact developing countries heavily, due to their relative lack of coping capacity. High levels of vulnerability

arise from a lack of resources to prepare for and respond to disasters. Often, built (infra-) structures in developing countries are of poor quality as a result of lacking standards and building codes or a lack of enforcement thereof. A high percentage of informal housing further increases vulnerability, as informal structures are often of poor quality. Buildings are often constructed illegally on high-risk land which increases damages during flooding and other hazards. For example, communities built on steep slopes are at a great risk of suffering damage from land- and mudslides. Communities located in floodplains, on the other hand, are at risk of suffering losses during floods (Ferrier & Spickett, 2007). Clean water supply and adequate waste management are difficult to achieve especially in cities with a rapid growth of informal settlements (Ensor, 2016).

RESILIENCE

Urban planning is crucial in maintaining a safe community and driving resilience. When building resilience, it is important to not solely look at one building in itself but to consider the urban context as a whole. A resilient community needs to be prepared for a potentially damaging event, know the risk and have response plans in place. For example, early warning systems can help to reduce loss of life, as people can be evacuated in time. However, as stated above, also the built environment, especially critical facilities, need to withstand the hazard and be able to carry out their core functions before, during and after impact. During a disaster, critical facilities are even more needed than during normal times (Mitchell & Lovell, 2015).



Fig 15: Destruction of Hurricane Ivan in Grenada 2004 (cmo.nl, 2010)

2.3 CRITICAL FACILITIES

The UNISDR (2009) defines critical facilities as „the primary physical structures, technical facilities, and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.“

They usually include emergency response facilities (e.g. fire and police stations), custodial facilities, long-term care facilities, hospitals, and other health care facilities, schools, emergency shelters, utilities (water supply, wastewater treatment, and power) and communications facilities.

In a disaster, it is of great importance that critical facilities maintain their functioning, as they can help to save lives and restore order. The 2015

Sendai Framework for Disaster Risk Reduction specifically points to the need of reducing damage to critical facilities, with a special emphasis on medical facilities and school, in a disaster context.

NEGATIVE EFFECTS OF WEAK CRITICAL FACILITIES

Communities that cannot rely on their critical infrastructure are extremely vulnerable to disasters (FEMA 543, 2007)

The cascade effects which follow the breakdown of critical facilities are especially dangerous. For instance during cyclone Nilam in the Maldives, water and sanitation problems affected 12 islands and after Hurricane Ivan (2004) essential governmental structures and electricity supply were wiped out in Grenada. Only two of the Grenada's schools withstood

the hurricane undamaged, and eleven health facilities, including major hospitals, were destroyed (World Bank, 2005).

These examples show that the design of critical facilities deserves special attention. It is important to improve their resistance to damages and ensure their continuous functioning before, during and after a disaster. Critical facilities are essential for the functioning of the society in general, and for relief activities specifically. For examples, after a disaster there will be many injured people who have to be treated in medical facilities. Therefore, these facilities need to be made resilient to ensure that lives can be saved.

HEALTH FACILITIES

Public health and access to medical services are essential especially during a disaster. Damaged, destroyed or not

accessible health services aggravate the suffering of people during a disaster as an example from the Philippines shows. In 2008, Typhoon Fengshen destroyed or damaged 89 hospitals and health facilities in central and southern Philippines, further aggravating the suffering of disaster victims and their families due to lack of medical services (Government of the Philippines, 2008).

SCHOOLS

Schools are occasionally built on inexpensive land that is usually affected by floods, earthquakes, or landslides (Bestari et al., 2013) Additionally, poor construction and weak materials lead to damages. For example, Typhoon Ondoy (Ketsana) brought down a total of 42 primary and secondary schools in the Manila metropolitan area 2009 (Siddique, 2009). The quick

continuation of the education is of high importance after disasters. Education can create a feeling of normality for the children in times of suffering. Schools are in this sense a safe haven for children who were impacted by the disaster. Especially in developing countries, education is key for development, which is why it is even more important that the education continues rapidly.

While the children are at school, parents are given some time to take care of rebuilding their lives (Save the Children, 2016). According to a 2016 report by the NGO Save the Children, "Schools can have a catalytic effect on strengthening humanitarian effectiveness, reducing vulnerabilities and supporting risk mitigation for future hazards".



Fig 16: Ziga District Hospital in Tabaco destroyed by Typhoon Rammasun (Glenda) 2014 (Direct Relief, 2014)



Fig 17: School after Typhoon Ketsana (Ondoy) 2009 gettyimages.com, 2009

EVACUATION

Evacuations are often necessary to keep people out of harm's way. Sports facilities or schools are frequently used for this purpose. Therefore, it needs to be ensured that buildings with the secondary purpose of being evacuation centers, can withstand the impacts of a disaster (Bandana & Hodgson, 2008). For example, during Typhoon Haiyan, the first floor of the City Convention Center was used as an evacuation site. Due to massive flooding, it, however, became submerged, with many people being trapped in it and dying (Mullen, 2013).

SOCIAL VULNERABILITY

Some groups need special attention in reducing disaster risk as they have a higher social vulnerability. This includes the elderly and sick, children

and youth as well as ethnic minorities (UNISDR, 2012)

The UNISDR (2009) states that „people in unsafe schools, hospitals, and health facilities are at the greatest risk of losing their lives. Children in schools and the sick in hospitals and health facilities are the most vulnerable people in times of disaster“.

RESILIENCE

In 2010, the UN launched a large-scale worldwide initiative in Manila with the goal of making schools and hospitals resilient to disasters. Ex-secretary-general Ban Ki-moon's Special Representative for Disaster Risk Reduction Margareta Wahlström states that „making sure that schools, hospitals, and other key public infrastructure meet certain safety standards are key steps to ensure that natural hazards do not turn into disasters.“

Health facilities should be built considering principles of disaster resilience with an uninterrupted power supply, secure access routes and water and sanitation. In schools and hospitals, one usually finds the most vulnerable population groups together in a confined area, namely the young and the sick. Therefore, by making these buildings resilient,

one can reduce society's vulnerability and save lives.

This idea is at the core of this project. By developing a disaster resilient community center, including a school and a medical facility, it is hoped to show a way of how the most vulnerable in a society can be protected from disasters by using architectural design.



Fig 18: Flood evacuees at a sports complex of a school used as evacuation center in Pasig City after Typhoon Ketsana (Ondoy) 2009 (xinhuanet.com, 2009)



Fig 19: Hospital Davao Oriental, municipality of Cateel, Typhoon Bopha 2012 (ICRC, 2012)

3 BACKGROUND

In this chapter, a short overview on the Philippines with a special focus on the country's architecture will be given. After providing a short history of the Philippines and a description of its climate and natural environment, a background on the country's disaster risk will be presented. Next, traditional Philippinan building techniques will be described, and it will be assessed to what levels these traditional structures are disaster resilient.

In the second part of this chapter, the site where this project is located, Tacloban City, will be intrpduced. After a short overview of the city's geography and climate, one of the most destructive disasters of the city's history will be described – Typhoon Haiyan.

The Philippines is a South Asian country which comprises 7641 islands of which only about 2000 are inhabited by approximately 100 million people. It belongs to the most disaster-prone areas of the world. In the 2015 World Risk Report, it is ranked as the country with the third highest disaster risk worldwide, after Tuvalu and Tonga (UNU-EHS, 2015).

3.1 THE PHILIPPINES

History

In the pre-colonial time, the islands which make up the Philippines today were independent maritime states that were ruled either by autonomous barangays (functioned like a city-state) or by association with bigger countries by Datus (Malay), Wangs (Chinese) or Rajahs (Indian) (Abinales & Amoroso, 2005).

During the 16th century, the islands were colonized by the Spanish, with a huge influence on architecture and the culture. In 1898 the Spanish-American War reached the Philippines, and the first Philippine Republic was established in 1899 after Emilio Aguinaldo declared independence from Spain.

The islands were given to the United States by Spain as a result of the loss in the war.

After the war, the Americans

suppressed sub-states on the islands until in 1935 the Philippine Commonwealth was established. However, the desired independence was interrupted by the battle against the Japanese during World War II (Francia, 2013). In 1946, the Philippines gained independence after being one of the founding members of the United Nations a year before. Around 1986 democratic reforms changed the governmental system of the Philippines. Challenged faced by the young democracy included high levels of corruption, poverty and frequent disasters (Francia, 2013).

Today, the Philippines is a constitutional republic which has a democratically elected government and president (Government of the Philippines, 2017).

3.2 LOCAL ARCHITECTURE

Climate

The islands are located in a warm-humid climate zone. The average annual temperature is around 26.6 °C. The climatic year is divided into northeast monsoon (November to April) and southwest monsoon (May to October) (PAGASA, 2015).

Natural Hazards

The Philippines are one of the most hazard-prone countries in the world. They are subjected to cyclones, tsunamis, earthquakes, landslides and volcanic eruptions (Manila Observatory, 2005).

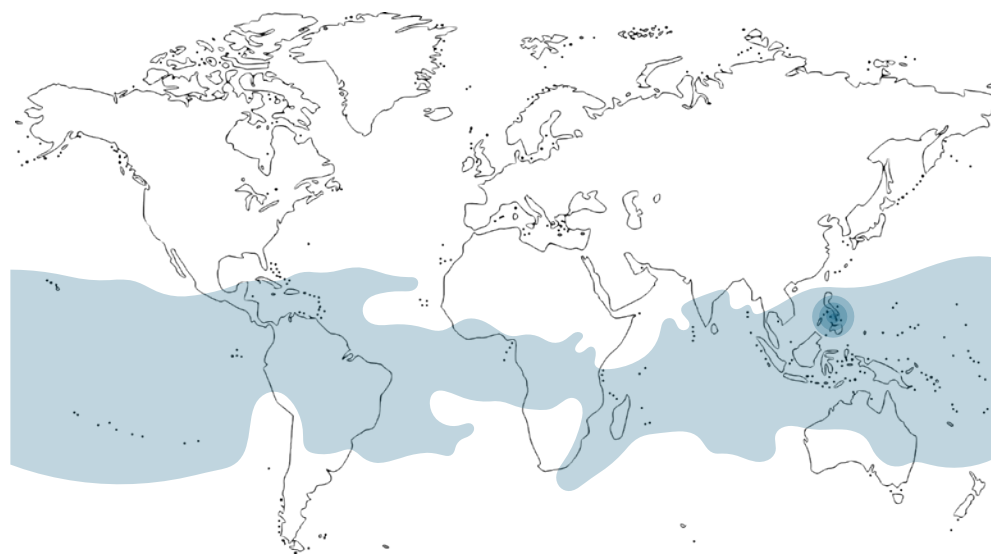


Fig 20: Warm-humid climate zone (Johansson, 2017, modified)

The Philippines are known for their traditional wooden houses as well as the colonial influence on the architecture. This creates a fascinating mix of separated and merged architectural styles which can be observed in the Philippines today.

BAHAY KUBO

The „Bahay Kubo“ or „Nipa hut“ is one of the earliest types of houses in the Philippines. It is still used today. These building types are mostly seen in traditional rural areas.

It is usually made from natural materials like wood, grass, bamboo and large logs and adapts very well to the climate of the Philippines. The shape of the building is usually cubic which seems to have inspired the name (Spanish: cubo - cube). The structure is raised up from one to two meters on stilts, which

protects the inhabitants from wild animals (Gardner, n.d.).

A typical floor plan consists of a large multi-purpose room, called bulwagan. Underneath there is a cellar, called silong, which is usually used as storage and workspace. There is a ladder (hagdan) which can be removed easily, and some huts have a porch (batalan) (historyofarchitecture.com).

There are various reasons why these huts are still being used today. They are easily constructed with materials found in the environment. The ventilation in these buildings is perfect for the tropical climate due to windows on all sides and openings at the top. The roof can withstand a lot of rain and sun.

Disaster Case

Although the huts are easily repaired when damaged during a storm, the construction is too weak



Fig 21: Traditional Bahay Kubo (bahayofw.com, 2017)

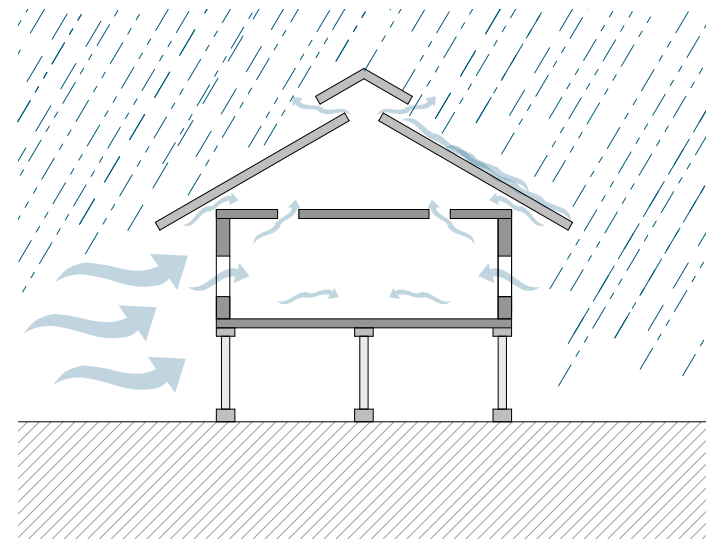


Fig 22: Ventilation and rain protection - Traditional Architecture (Johansson, 2017, modified)

to withstand high wind speeds for an extended period. This means there is a constant danger of destruction during a typhoon. Due to the roof overhang, it is easily lifted off. However, the stilt construction protects the house from flooding.

KOTA

The Kota was used as a stronghold or fort that was first introduced when scholars from Indonesia arrived. In addition

to being a military base, it was typically inhabited by a lord. These buildings were usually made of stone or bamboo. The use of light materials made them very easily destroyable during fights, especially during the American expeditions. As a result, there are not many kotas left today (Madale, 1997).

TOROGAN

These buildings were especially built for the family of a Sultan



Fig 23: Fort of Kota Park



Fig 24: Torogan (flickr.com, 2012)

(also called "Datu"). It was a multi-family home as the Datu had several wives and many children. It consisted of only one big room without any partitions in between. The building is lifted off the ground, and the stilts are often huge tree trunks. It is usually rich with decorative designs and has a very high gable roof (Madale, 1997).

BAHAY NA BATO

With the arrival of the Spaniards in 1571 new architecture was brought to the Philippines. The Bahay Kubo was substituted by the Bahay na bato, a stone house. Typically raised to two stories, it is known to be the Filipino Noble House.

The living area was on the second



Fig 25: Bahay na Bato (historyofarchitecture.com)

floor. The main materials of the bottom floor are brick and stone, while the upper floor often is constructed in wood. It has large windows, and the upper floors have panes (capiz shells) that can be closed for privacy or during storms. Openings underneath the roof let in the air even during rainy weather. Ventanillas are openings below the big windows covered with grillwork that can be left open during the night (Gardner, n.d.).

Disaster Case

These types of houses might not be good during an earthquake but show some good strategies during a storm. Closing the windows with shutters is a good way to protect the inside of the house. As the ground floor is closed, there is no wind pressure underneath the house to lift it up.

However, the tiles on the roof are easily torn away.

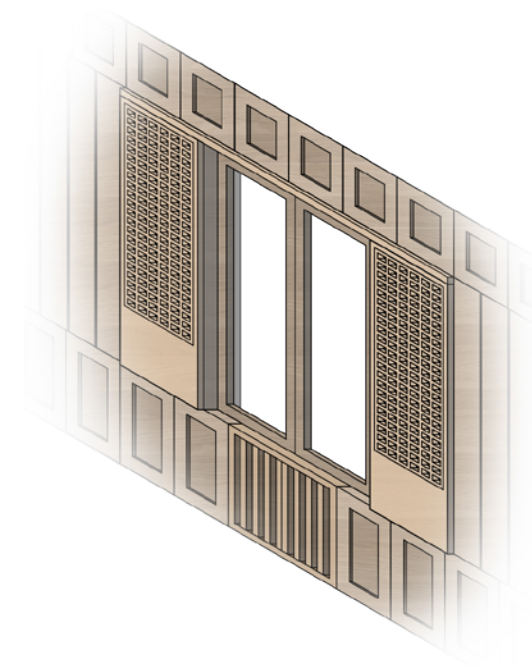


Fig 26: Open facade during sunny weather

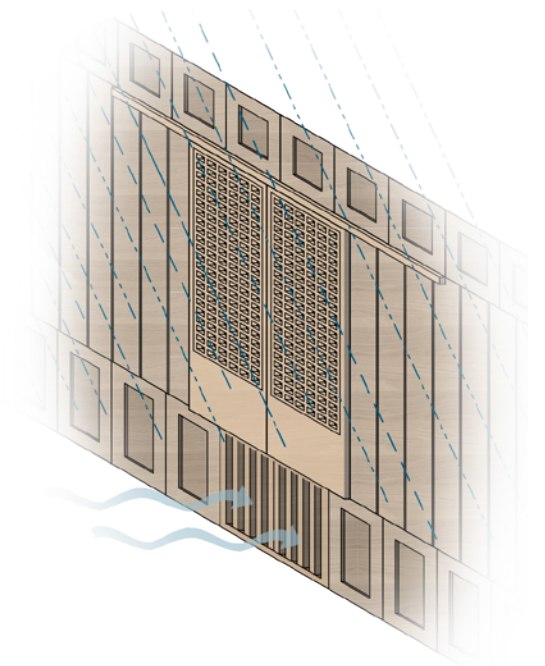


Fig 27: Closed facade with ventilation through ventanillas

3.2 THE SITE

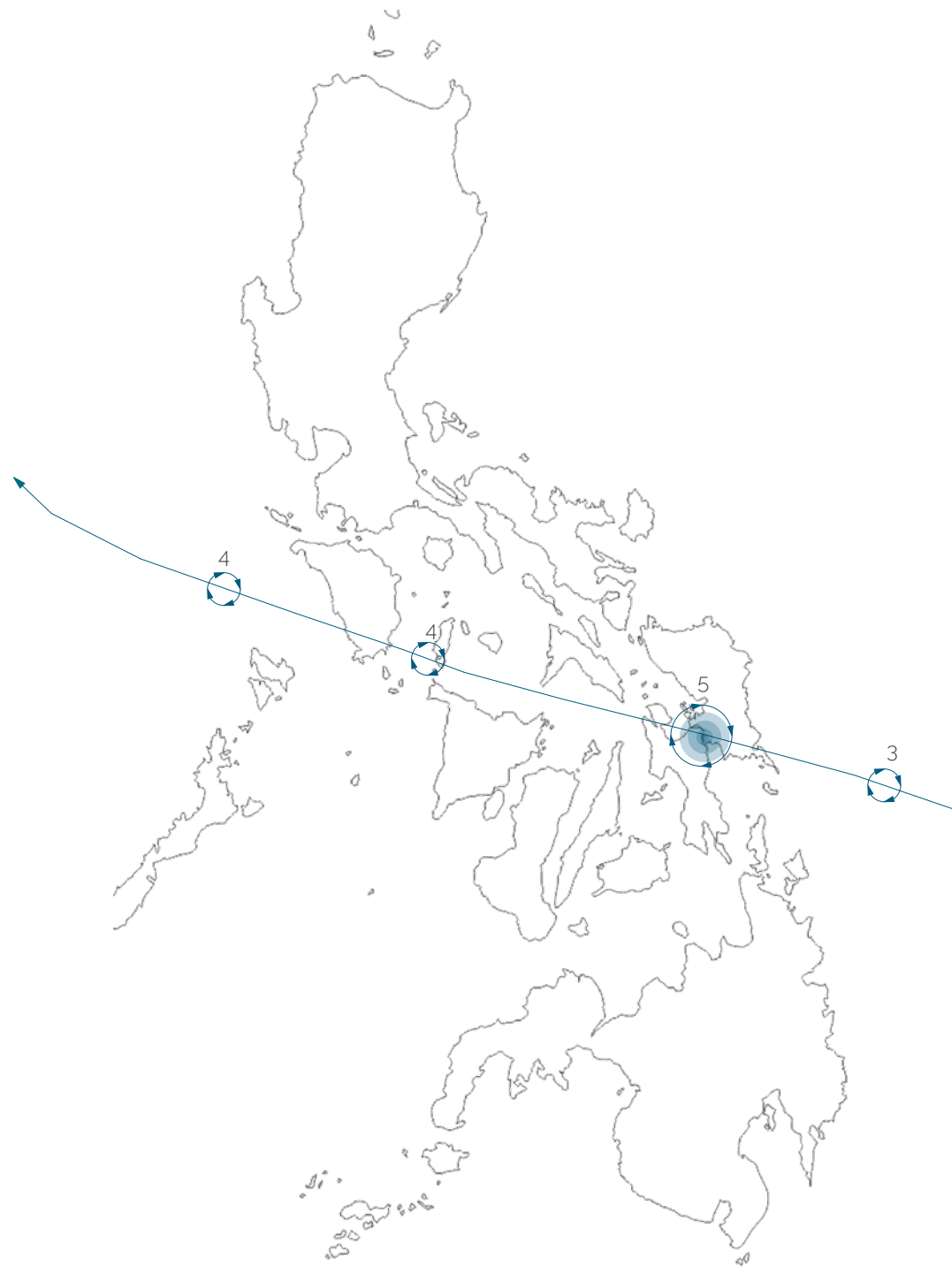


Fig 28: Philippines map with storm path (Haiyan) (Washington Post, 2013)

TACLOBAN CITY

Tacloban City (Fig. 32) is located on Eastern Visayas, which is one of the Philippines major island groups. It is the capital of Leyte province, although being governed independently. With around 240,000 inhabitants it is the most populated city in this region. The economy is growing fast with one of the

lowest poverty rates in the country (Government of the Philippines, 2015).

Geography

The coastal city is very low-lying, with elevation ranging from 2 to 21 meters (BBC, 2013) which makes it very susceptible to storms and floods, especially in the context of climate-driven sea level rise.

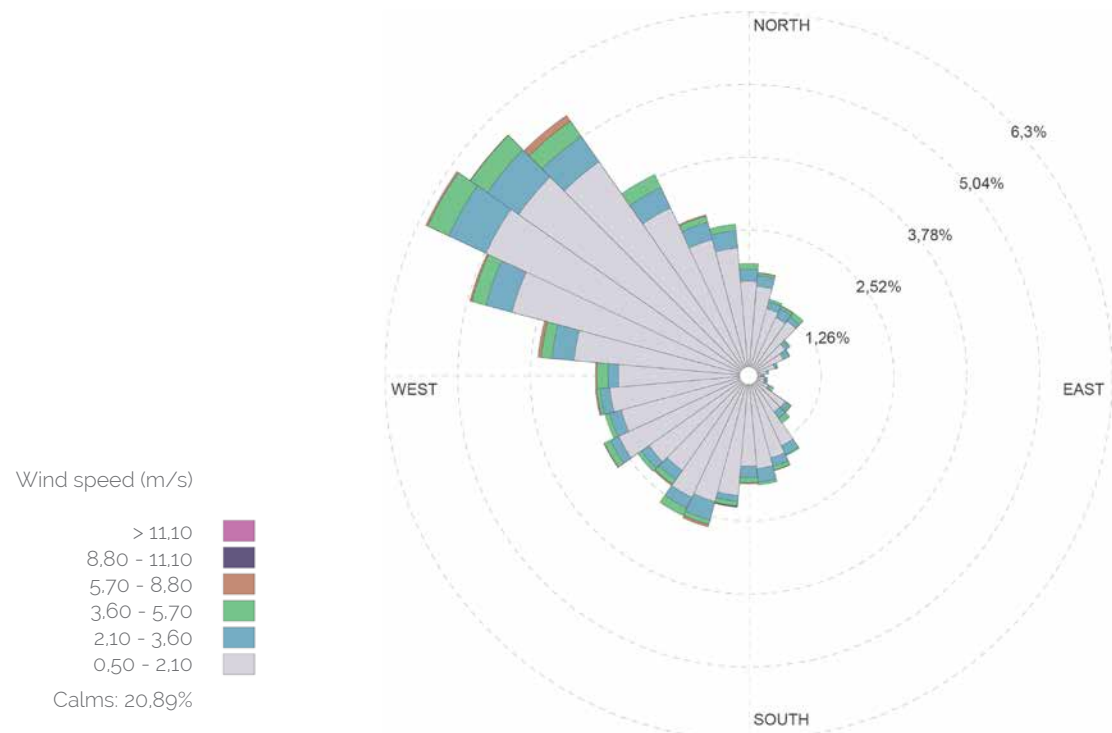


Fig 29: Wind rose Tacloban City - Visualization with WRPlot(Meteonorm)

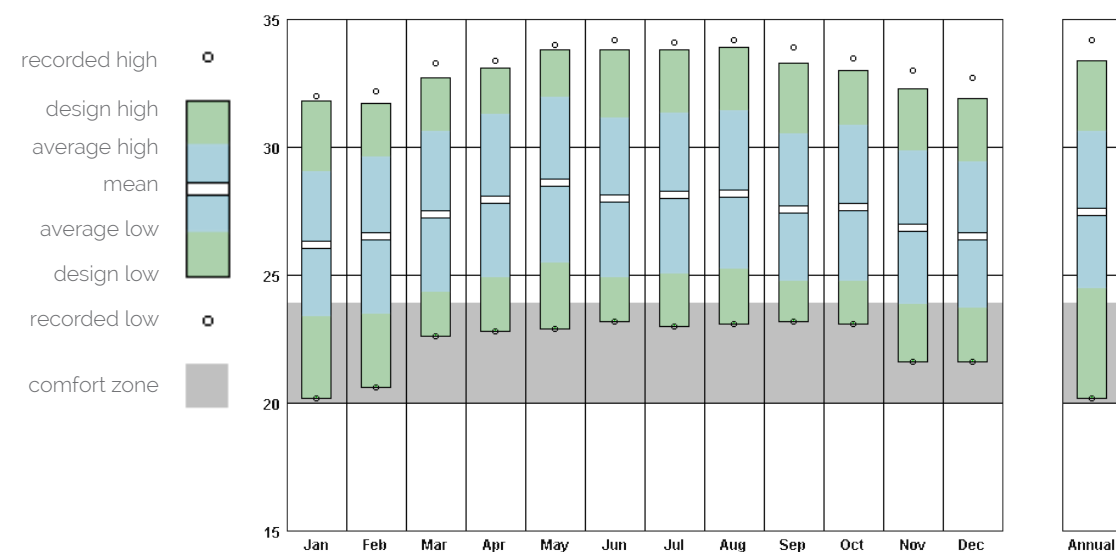


Fig 30: Temperature range Tacloban City - Visualization with Climate Consultant 6.0 (Meteonorm)

CLIMATE ANALYSIS

As the rest of the Philippines, Tacloban City has a warm-humid climate with high temperatures, a lot of rain and usually low wind speeds throughout the year. The average wind speed lies between 2-3 m/s with the primary wind directions being

northwest and southeast (depending on monsoon season). The highest speeds are usually recorded in January and February. Temperatures range from 20 to 35°C, with a relative humidity between 70 and 90%. Temperatures are slightly higher during the southwest monsoon (May to October). The average rainfall

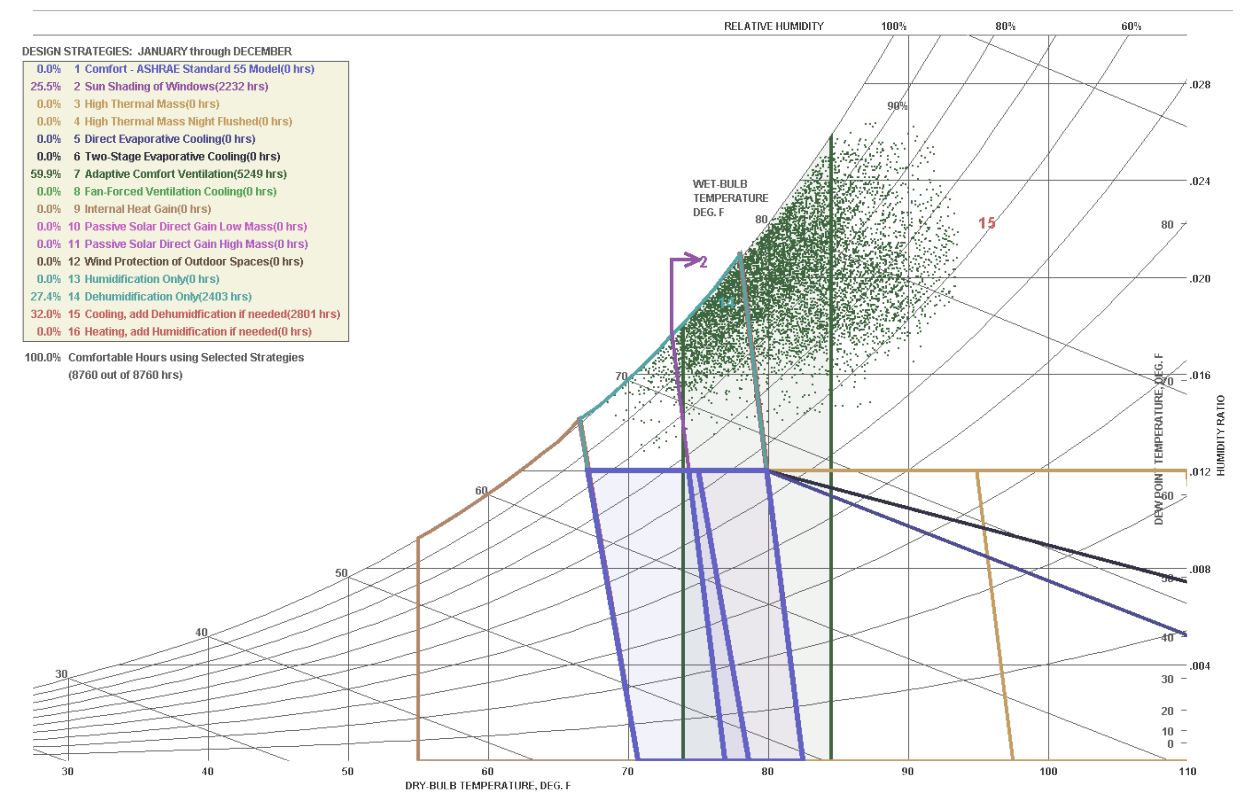


Fig 31: Psychrometric chart Tacloban City - Visualization with Climate Consultant 6.0 (Meteonorm)

in a year is 2293 mm, with monthly variations and usually highest amounts of rain during November, December and January (Climate-data.org, n.d). The psychrometric chart, created with Climate Consultant 6.0 takes into consideration humidity as well as dry and wet bulb temperature to estimate how many comfortable days in a year are possible without any design considerations. In this case, the ASHRAE Standard 55 Adaptive Comfort Model was used which is the North American comfort model. The green dots are the days throughout the year and the blue shaded part the comfort zone. Additionally, it shows what measures should be taken to improve comfort throughout the year. In this case, it is suggested that the main factor for creating comfort lies in sun-shading, adaptive comfort ventilation and cooling with dehumidification. Adaptive ventilation means that the people who live there are used to higher temperatures, and this shows how much can be

done by natural ventilation to have more comfortable days.

TYPHOON HAIYAN

In November 2013, the Philippines were hit hard by Super-Typhoon Haiyan (Yolanda). This category five tropical storm sustained wind speeds of up to 230 km/h (10 minutes) or even 315 km/h (1 minute). The destruction was vast, and one of the cities that was distressed most was Tacloban City. As the storm hit the city from the south-east, it was one of the first ones of the islands to be affected. The regions of Samar and Leyte belonged to the country's most destroyed areas. The numbers of how many people were affected or died and how many houses were destroyed vary widely from source to source. However, in the final report of the National Disaster Risk Reduction and Management Council (NDRRMC) of the Philippines, a total of 16,078,181 people were affected with 6,300 people

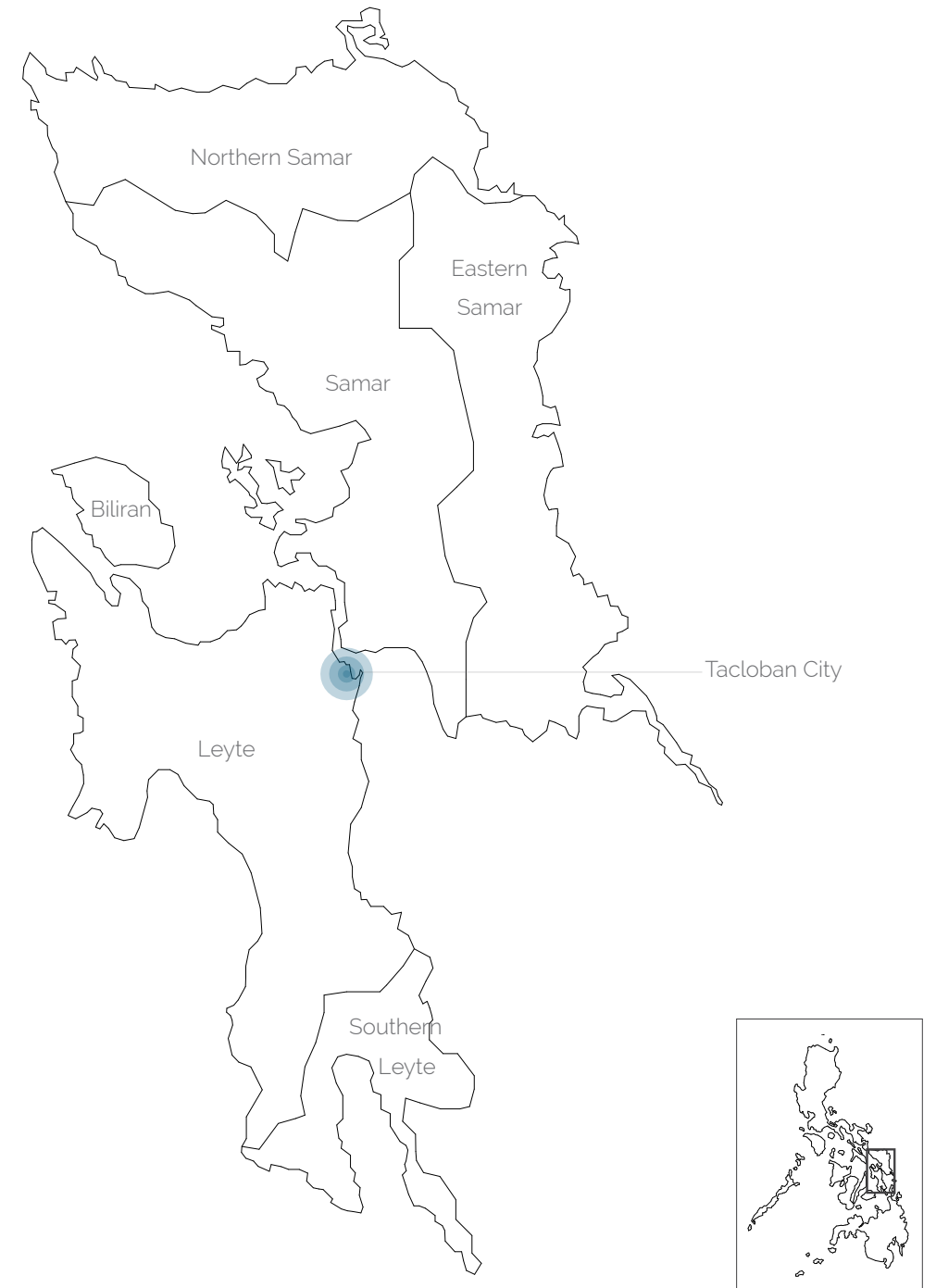


Fig 32: Map of Eastern Visayas Region



dead and 28,688 injured. Over a million houses were damaged, with half of them being completely destroyed. Utilities like water and power supply were disrupted, and damages to critical facilities and infrastructures like telecommunications, school buildings, health facilities and government buildings made the situation worse (Reliefweb, 2014). According to the Photobook on the Rehabilitation and Rebuilding of Yolanda-Ravaged Hospitals „Rising Anew, Health at the Heart of Healing,” published by the Department of Health Philippines 42 hospitals, 95 community health centers and 427 village health centers were damaged.

Secondary effects

Heavy rain following the storm aggravated the situation even more. Many fatalities were caused by drowning. Furthermore, injuries sustained for example from falling debris became easily infected in the dirty waters. Together with the

shortage of food, shelter and medical supplies, this led to many fatalities. Especially in the poorest parts of Tacloban City, such as Barangay 88, thousands were displaced and had to live in emergency tents or shelters. (the northern part around the airport), partially for extended periods. One year after Impact, it was estimated that still, 25,000 people lived in temporary sites, and almost 100,000 in unsafe makeshift arrangements (Reliefweb, 2014).

Built environment

Looking at the damages done to the built environment (Fig.33), we can see that most damages have occurred close to the sea towards the east, where the storm first made landfall. Most of the buildings in this area were made of wood with metal sheeted roofs, which can be easily torn apart by a storm. Buildings that survived the storm better were usually made of concrete. Roof structures were one of the weak points in all of the buildings as

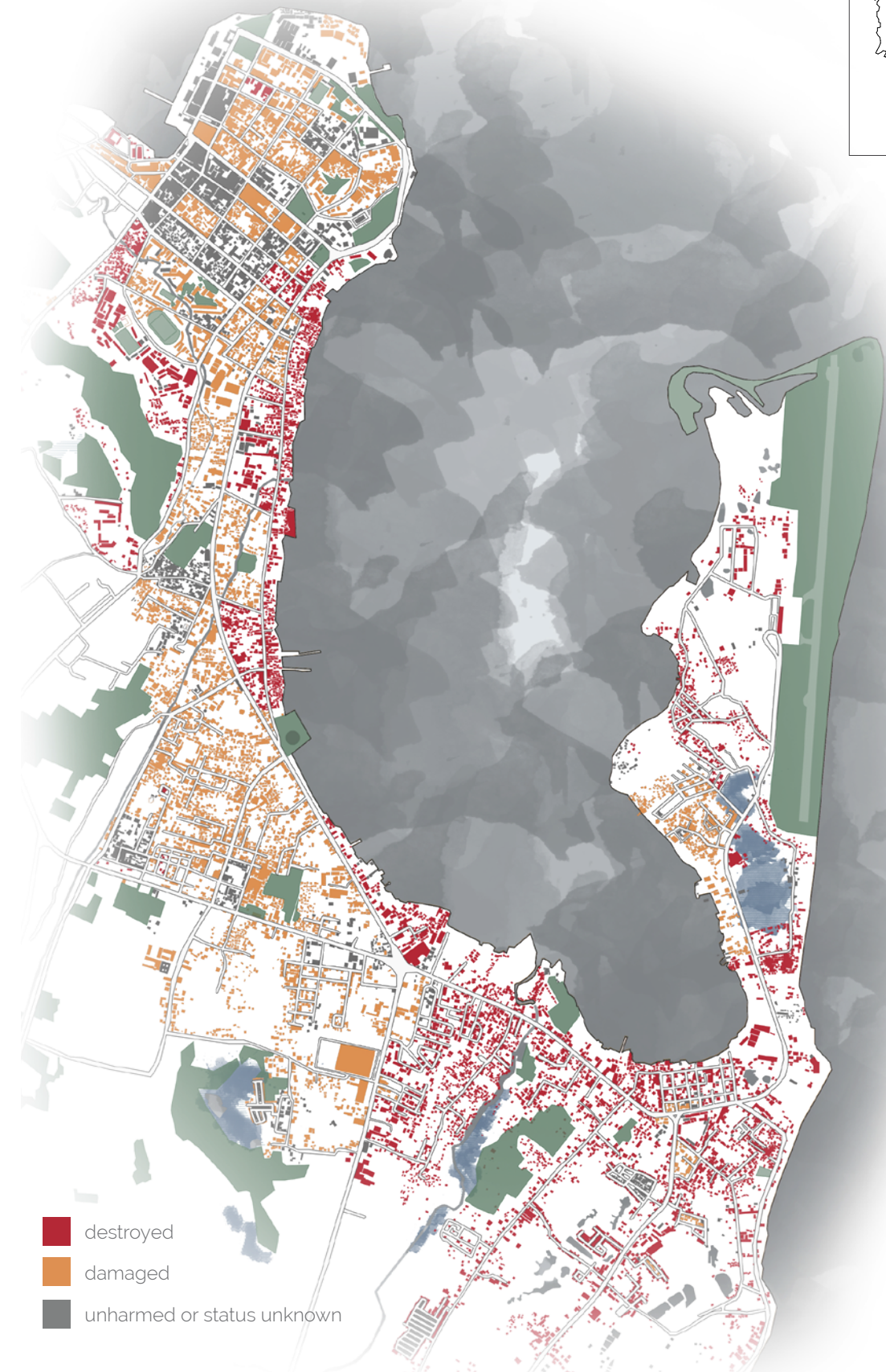


Fig 33: Map of destruction (New York Times, 2016, modified)

residential buildings, hospitals and schools all struggled with proper construction, most roofs collapsed during the storm. Additional flood damage cut off some of the buildings making them not accessible (Jangnarine-Azan, 2014).

Consequences

After the typhoon, new policies and rules were set in place for building health facilities. There was a new administrative order with the subject „Policies and Guidelines on Hospitals Safe from Disasters“ from the Department of Health, that aimed at increasing resilience. The Department of Environment and Natural Resources (DENR) declared a 40-metre no-build zone along the coastlines of Eastern Samar and Leyte, two of the worst-hit areas, which was based on the water code that protects mangroves and beach forest. However, this leads to people being displaced for a prolonged

time. They could not return home to rebuild their houses as these were located in the newly declared no-build zone. One family previously living in Barangay 88 had to live in a tent for almost a year. As a result, families decided to form homeowners' associations and housing committees to defend their rights and find a new place to live (Santos, 2014).

Properly built structures and resilient community planning can help to reduce displacement and fatalities in case of a disaster.

If we look at the houses on a black and white plan only mapping the built structures and compare Tacloban City before (fig. 34) and after the typhoon (fig 35 and 36) the destruction is even more visible. The last map is a worst-case scenario if we consider that damaged buildings were not usable during or after the disaster.



Fig. 34: Before the typhoon



Fig. 35 Remaining buildings without destroyed ones



Fig. 36: Remaining buildings without destroyed and damaged ones



Fig. 37: Buildings that survived in Tacloban (globalnews.ca, 2013)



Fig. 39: Flooding in Tacloban (New York Times, 2013)



Fig. 38: Vast destruction in Tacloban (Frankfurter Rundschau)



Fig. 40: Only half a house standing in a neighbourhood in Tacloban (Spiegel online, 2013)



Fig. 41: Nothing left at the east coast of Tacloban (New York Times, 2013)



Fig. 43: One of the remaining buildings: The convention center (CNN, 2013)



Fig. 42: Collapsed roof (NBC News, 2013)

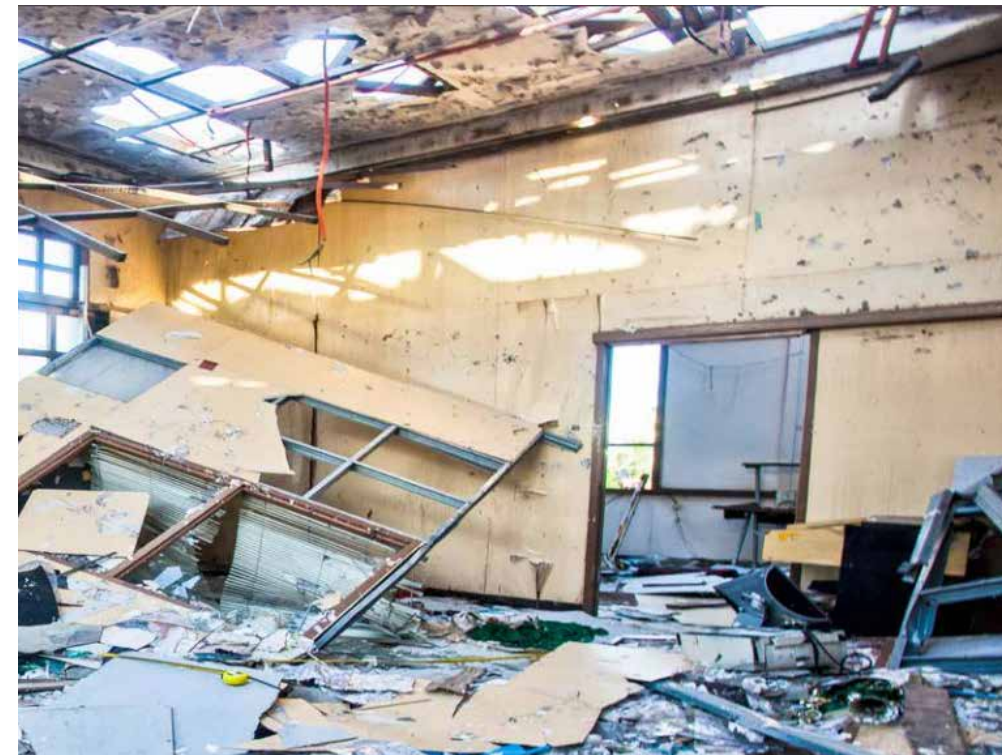


Fig. 44: Damaged University building (World Health Organization)



Fig. 45: Collapsed structures of Leyte Provincial Hospital (World Health Organization)



Fig. 46: Roof damage at Tacloban main health center (World Health Organization)

4 TYPHOON RESILIENCE

The concept of resilience is a widely discussed one, with no universally accepted definition (Becker, 2014). Resilience can only be achieved when all spheres of society do interact towards a shared goal. A resilient community knows the risk it faces and cooperates to reduce it, to protect citizens and assets. Having a safe and sound built environment is key to achieving resilience in a community.

This chapter will outline guidelines on how to create a resilient built environment from an architectural perspective. It will describe shapes and structures, floor plans, roofs, as well as ways to management natural elements.

4.1 GENERAL GUIDELINES

Many guidelines of cyclone-resilient architecture include choosing the site carefully and avoiding exposed areas. Problematically, this is difficult to achieve in many areas of the world. For example, more than 90% of Asia's population live in a cyclone-prone zone (IPCC, 2014a). Simply not building in exposed areas is therefore not enough. Cascade effects can also affect buildings which are not directly exposed to hazards.

Therefore, we need to combine different approaches towards resilient communities and develop guidelines that do not only take architecture, but also

urban planning into consideration. Disasters do not only affect single households, but rather entire communities, through direct physical destruction and the socio-economic side-effects. One should not only focus on a single building to create resilience but on how communities function and interact. General guidelines always bear the risk of ignoring specific local circumstances. Thus, these general guidelines should not be understood as a blueprint, but need to be adapted from community to community.

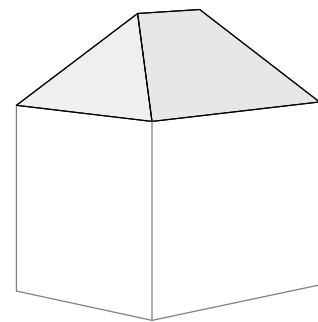
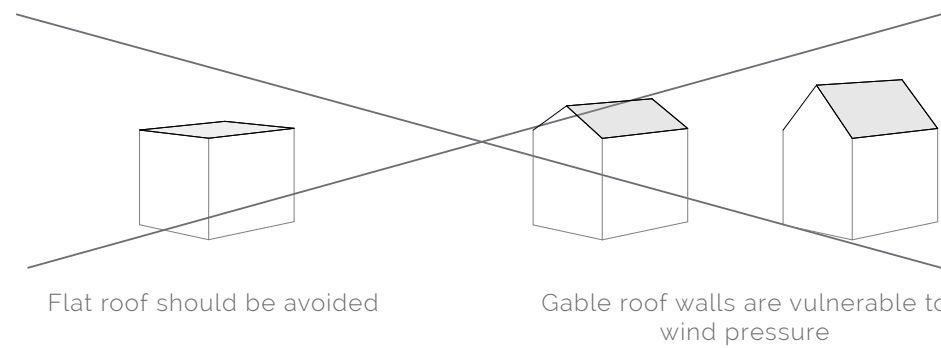
In my proposal, I will try and use as many of these guidelines as possible to create a cohesive disaster resilient project.

Roof Shape

Most architectural guidelines agree on the importance of roof shapes for resilience. There have been a large number of studies regarding the shape of roofs and their resistance to high wind speeds.

Hip roofs are more stable than gable roofs, as high wind pressure

can easily damage the side wall of the gable roof. In case of the hip roof, the wind gets deflected over it, and the pressure is reduced. The ideal roof pitch lies between 30° and 45° to keep the suction forces as low as possible. The flatter the roof is, the higher are the suction forces (Agarwal, 2007).

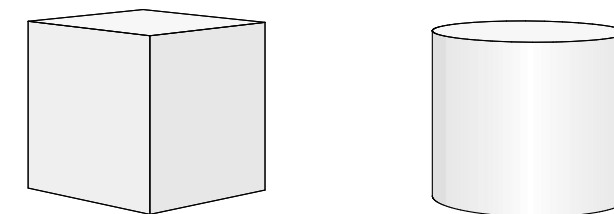
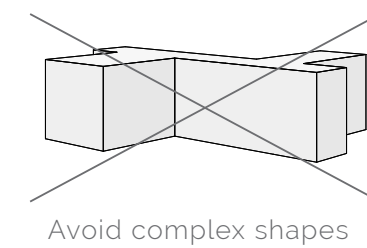


Hip roof are the most stable during high wind speeds
The ideal roof pitch lies between $30-45^\circ$

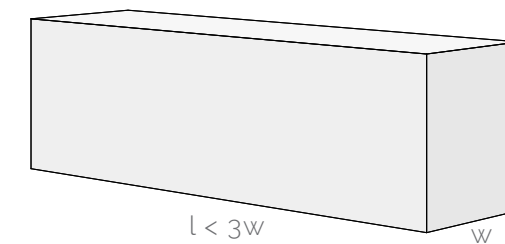
Building Shape

The building shape should have a simple geometry. A large number of corners and complex shapes lead to more pressure and higher wind speeds that can damage the building (Sazzad & Azad, 2015). Square and round shapes

are most durable. Rectangular shapes should follow the rule that the length is not longer than three times the width. Very long buildings are more susceptible to wind forces (Agarwal, 2007).



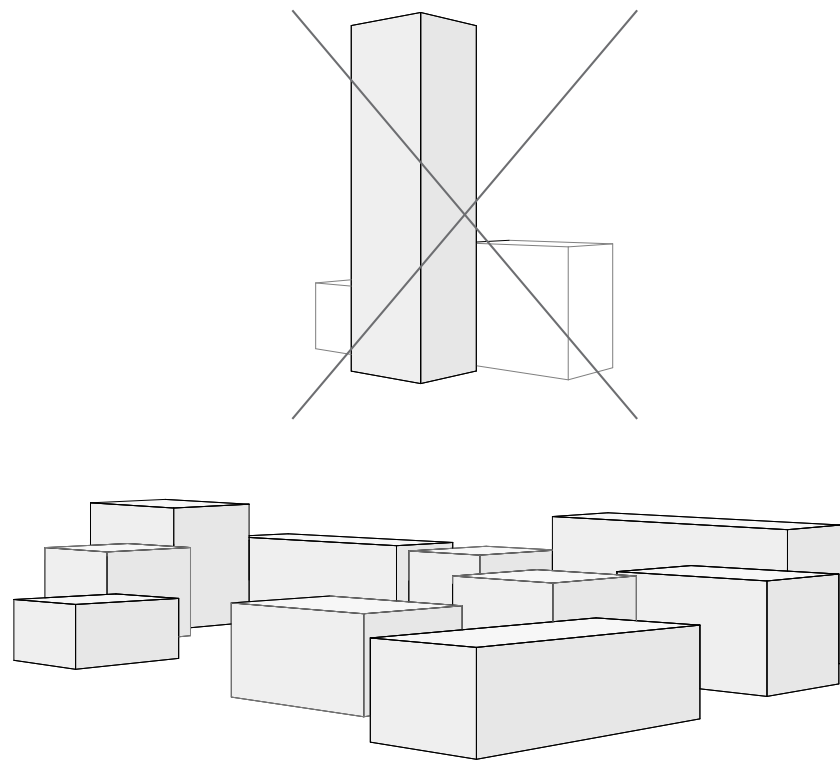
Choose simple geometries



Building Height

The height of the building is an important factor as well. Very high, free standing buildings are exposed to more pressure and turbulences, which are formed around the corners and close to the ground (Mendis et al., 2007).

Looking at a neighborhood scale, it is important that the building height does not vary too much from building to building, so the wind is pushed equally over the roof tops.

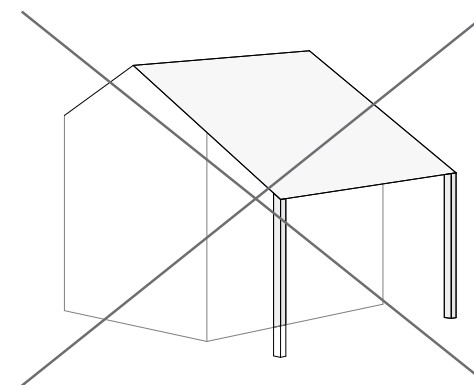


Avoid high buildings and keep the height rather even

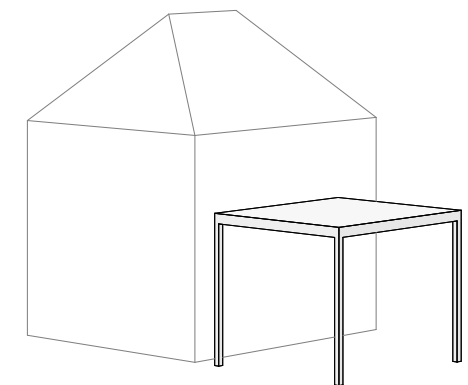
Additional Structures

Any structures that are additional to the building like verandas and balconies are especially susceptible to damages from wind. In highly exposed areas, it is best to avoid additional structure completely. However, if a veranda or balcony is built, the

safest way to do so is to keep them as independent, unattached structures. As the veranda can be easily torn off, it should not be connected to the main building or the roof as otherwise it can rip important structural parts with it (Agarwal, 2007).



Avoid a permanent connection between roof and veranda

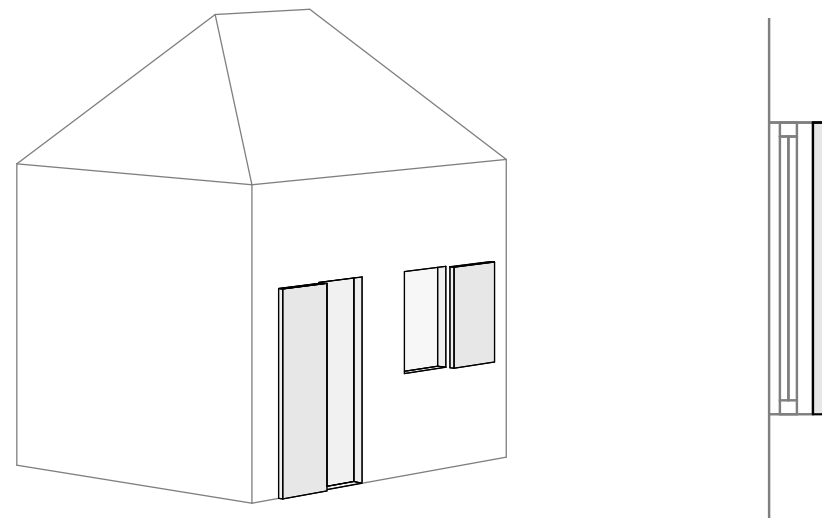


Choose an independent structure

Shutters

Unprotected windows and doors are easily broken by wind forces. This leads to damages inside the building as wind and water can enter the house. Breaking glass from panes in windows and doors can also harm the residents inside. During a storm, windows can be secured with tape on the inside to reduce the splintering of the

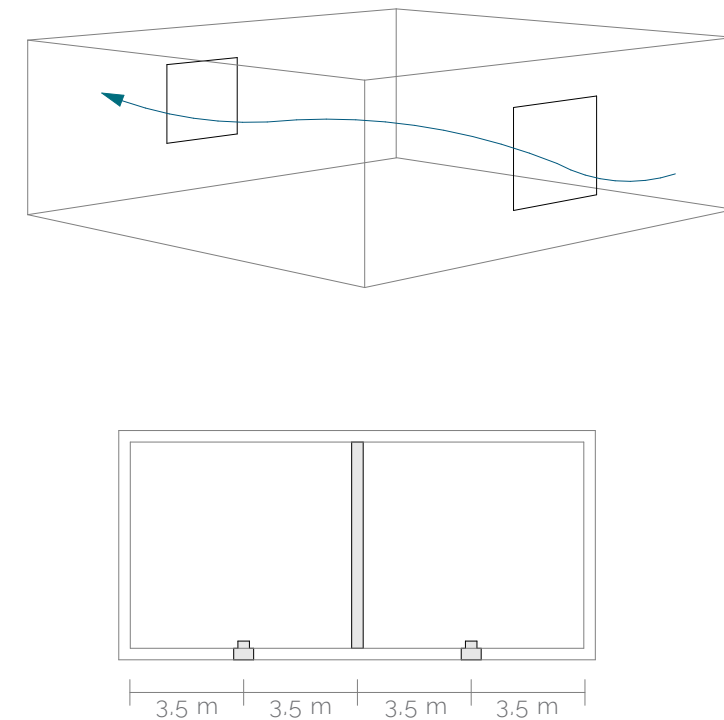
glass. To make the windows safer, all doors and windows on the exterior should have shutters for closing (Agarwal, 2007). However, these should not just be mounted on top of the openings but rather be integrated into the wall, so that they can withstand high wind forces.



Floor Plan

Regarding the layout of the floor plan, it is beneficial to have openings on opposite sides which let the wind pass through. In case the wind actually breaches the building, the openings reduce the pressure on the building.

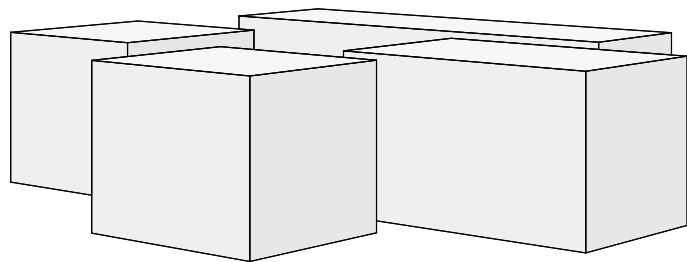
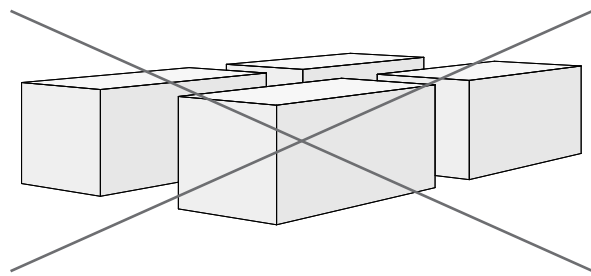
Furthermore, long walls should not be used. If the wall exceeds 3.5 meters, it should be divided by an integrated column or supported through cross walls for stabilization (Patnaik et al., 2015)



Building Patterns

If one looks at the community or neighborhood scale, it is important to avoid row structures that speed up the wind which passes through. Many long buildings next to each

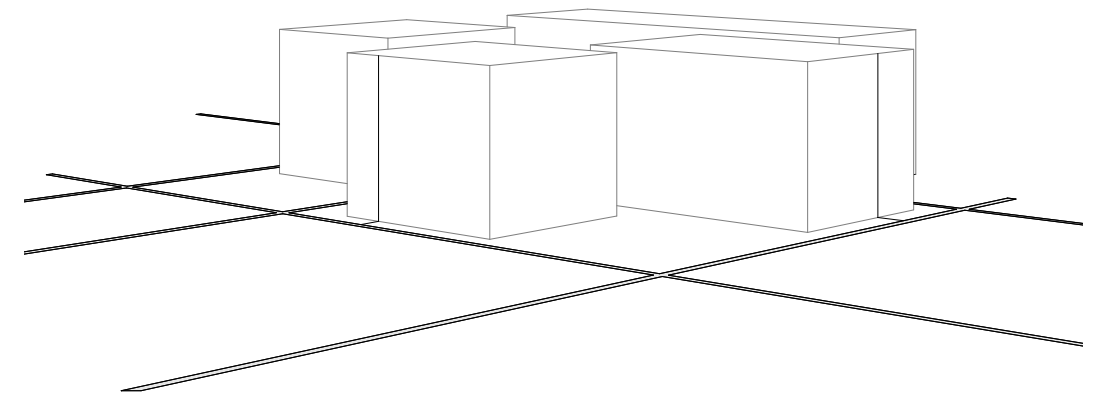
other are susceptible to wind forces. Cluster patterns shield the community from wind and reduce wind speed (Agarwal,2007).



Water Management

Typhoons are associated with massive amounts of rain, which can lead to devastating floods in affected areas. A functioning storm water drainage system is very important to avoid flood related damages to buildings. All buildings should be connected to a central drainage system

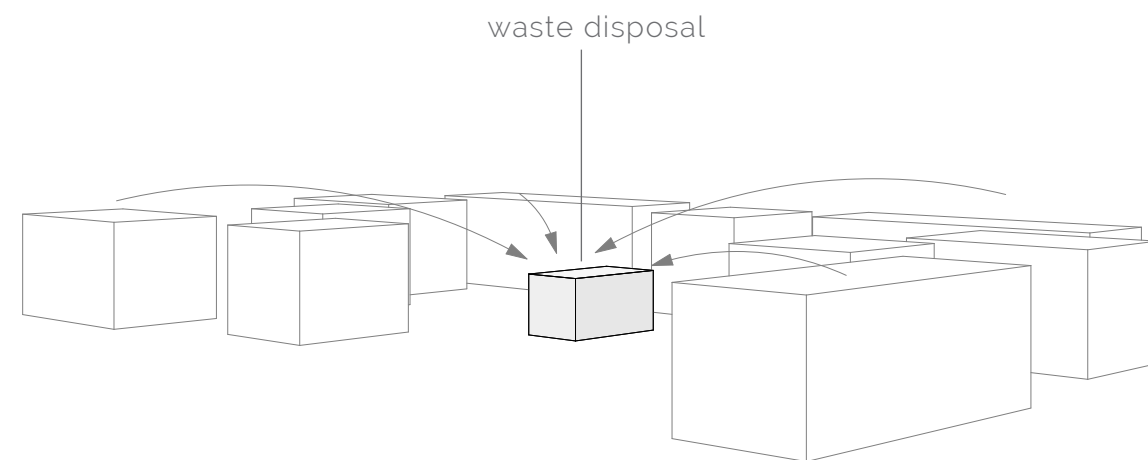
running through the city. The system can take in run-off water as well as excess water from roof tops. These systems can either be underground or built as an open storm water system. Channels and pipes should be measured designed using worst-case scenario calculations.



Waste Management

Insufficient waste management is a major problem in many developing countries. It can lead to diseases that aggravate the suffering of people. Especially in connection with large amounts of storm water, the risk of epidemics outbreaks connected to inadequate waste management is high. There should be waste containers throughout the neighborhood that are easily reachable for everybody. These waste disposal sites should apply

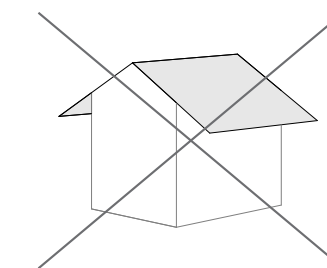
a waste separation system, with segregating organic and non-organic residues. As water and wind can carry the waste around, which leads to a pollution of the neighborhood, it is beneficial to keep the waste disposal protected from the elements. Having specific building guidelines for the disposal sites helps to keep the waste from spreading through the neighborhood.



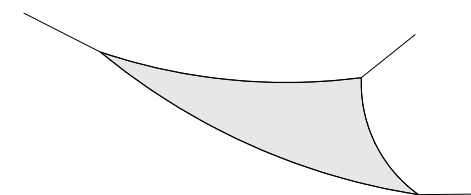
Sun and Rain Protection

Roof overhangs are a good way to keep rain and sun away from the built structure. However, in case of a cyclone, the overhangs become dangerous, wind can lift the roof off. Therefore, the overhang should be as short as possible, but no longer than 0.8m (Johansson, 2017).

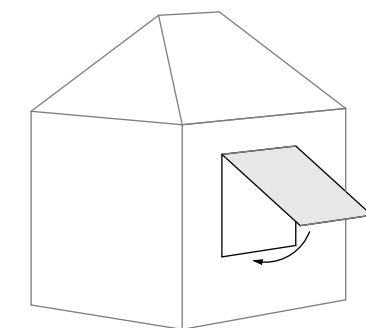
Another good way of shielding a structure from sun and rain is the use of textiles or other temporary structures that can be folded away or taken down during a storm. Additionally, if light materials are torn off they cannot damage other buildings or harm people as much as heavy structures.



Avoid large roof overhangs



Textiles

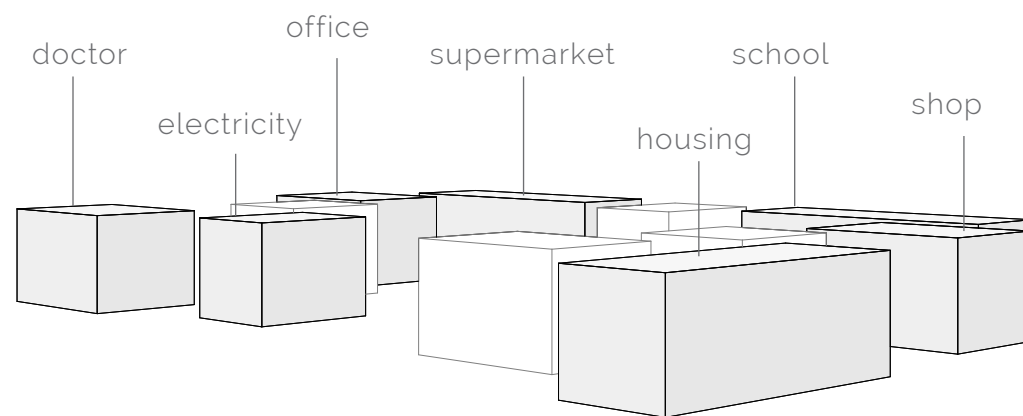


Temporary structures

Self-sustained Community

During disasters, communities are often cut off from roads and essential services, such as water and electricity supply. Often, external help and goods need a considerable amount of time to reach the affected communities, during which the community needs to manage to be self-sufficient to alleviate suffering. That means that a community needs to manage to function

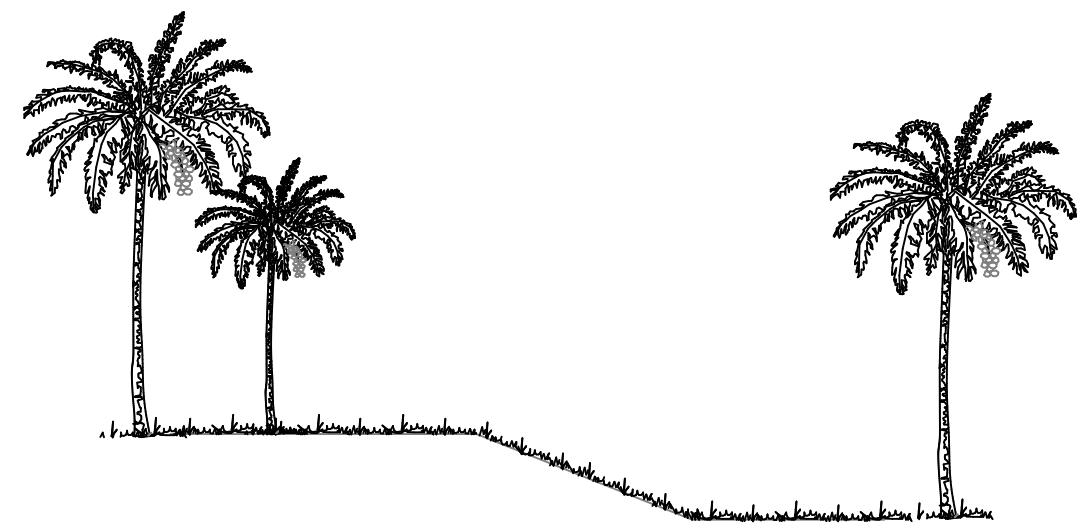
independently for a certain period of time. A community that is not dependent on others but has everything reachable for its people is more resilient during a disaster. There should be enough supplies stored to keep the community running for several days, and a backup system for water and electricity. This helps to keep people safe until external help arrives.



Vegetation

Vegetation can play a major role in shielding a community from flooding and wind. Plants and permeable surfaces can absorb some of the water and reduce the damage of flooding. By changing the height of the ground, some

areas can be used as natural water basins. Green, low-lying areas can first absorb water and if the ground cannot hold it anymore the rising water is contained before reaching built structures.



Material and Construction

Material and construction are very important when it comes to resilience as the load bearing structure and the facade material need to be strong enough to withstand the elements during a worst-case scenario.

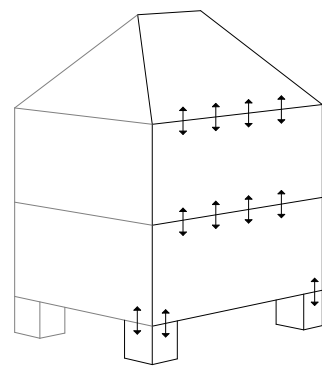
Heavy materials are useful to shield from wind and water. The use of reinforced concrete is especially beneficial to keep the building envelope strong.

Lightweight materials are more easily damaged or torn off, however, are less harmful to other buildings or humans. Wood can be

used in construction as well. The most important factor no matter what material is used is a stable connection between the individual building parts. The roof should be securely connected to the wall and the walls to the foundation (Development Workshop, 1989)

Local Materials

The use of local materials is beneficial if repairs need to be made as these can be transported quickly to the site. Moreover, using these materials help the local economy to develop.



Make sure that all pieces are connected properly

4.2 GUIDELINES FOR CRITICAL FACILITIES

Most of the general guidelines apply to critical facilities as well. However, they are a little special compared to residential buildings as the goal is to keep them secure during a typhoon. Additionally, to the previously mentioned guidelines I added a few extra ones that apply especially for critical facilities.

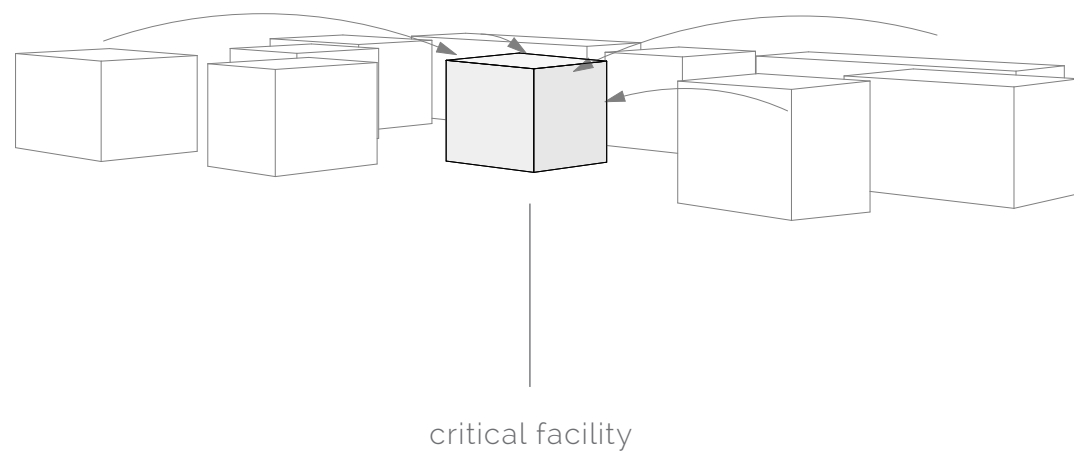
As I have explained before, critical facilities are crucial during a disaster as without them the

suffering of people gets amplified. This means that they need to be able to perform during a storm as well as they do during a normal day scenario. The following guidelines focus mainly on how the facilities can maintain their services during a cyclone. However, these proposed guidelines cannot be applied to all critical facilities which is why I am focusing on health facilities in particular.

Reachability

In order to be useful to the people during a disaster, critical facilities need to be located in reach of everybody. This means they should be in the center of a community and accessible to everybody. Each community needs access

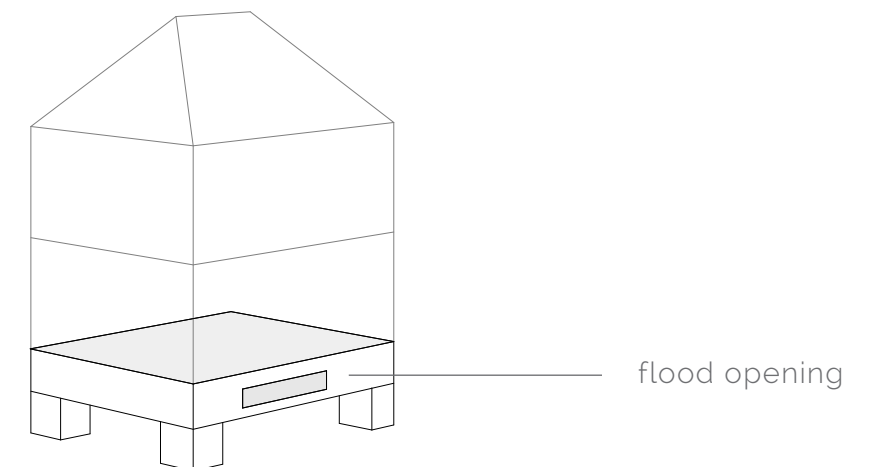
to their own facilities. In case of a disaster people often cannot leave immediately the hazardous region. Making sure important functions are nearby stabilizes the community and helps protect people during a typhoon.



Flood Protection

The foundation and the connection to the ground floor are crucial especially when it comes to flooding. A good way of protecting the ground floor is to raise it up a little. To ensure no wind can go underneath the

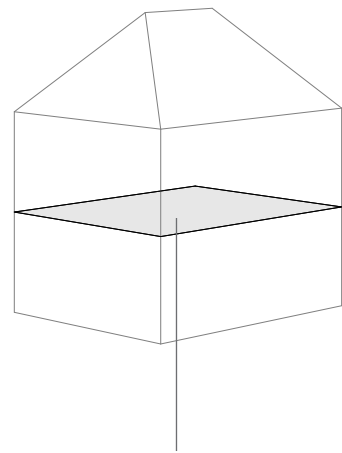
building, it can be closed and flood gates put in place. These usually metal openings can be opened to reduce the pressure on the building as well as protecting the ground floor (FEMA 543, 2007).



Ground Floor

The ground floor in a critical facility is usually the most important one as it is the way to access the building. In a worst-case scenario, the ground floor can be flooded or damaged so it cannot be used anymore. This makes accessing the building very difficult. However, to make sure the building can

still function normally without the bottom floor important functions and goods should be located on the upper floors. For a health facility, this means important medicine and surgery rooms as well as important medical equipment.

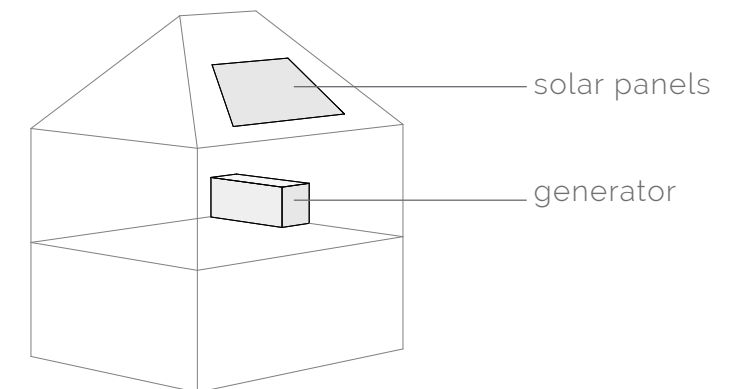


important functions in the upper floors

Emergency Electricity

Most critical facilities are dependent on other functions or services. One of the most important ones is electricity. If there is a shortage of power, critical facilities need to have an emergency electricity supply that is not connected to the general

grid. Good options are emergency generators or solar panels to generate power. However, the position of solar panels on the roof is critical as they are very vulnerable to high winds. In this case, a generator located in the building is the safer option.



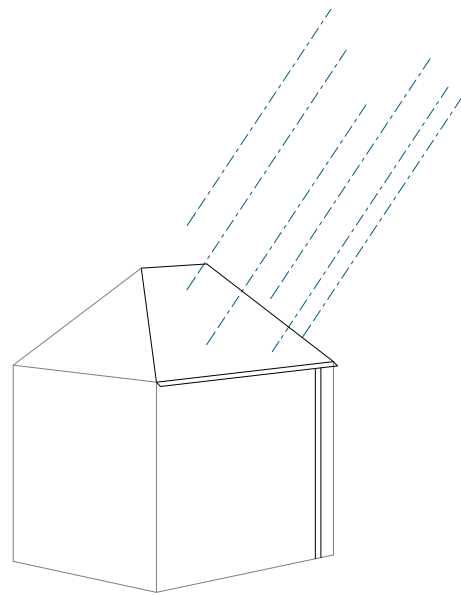
solar panels

generator

Food and Water Supply

A critical facility is especially useful if it can take care of the people in the neighborhood. This includes providing a certain amount of food and water. A small food storage can help people while they are waiting for external help. Moreover, a good way to get

water is in using rain water. If the general water supply is interrupted rain water storages can help secure a continuous water supply. Additional measures for filtering and cleaning the water make sure it can be used as drinking water.

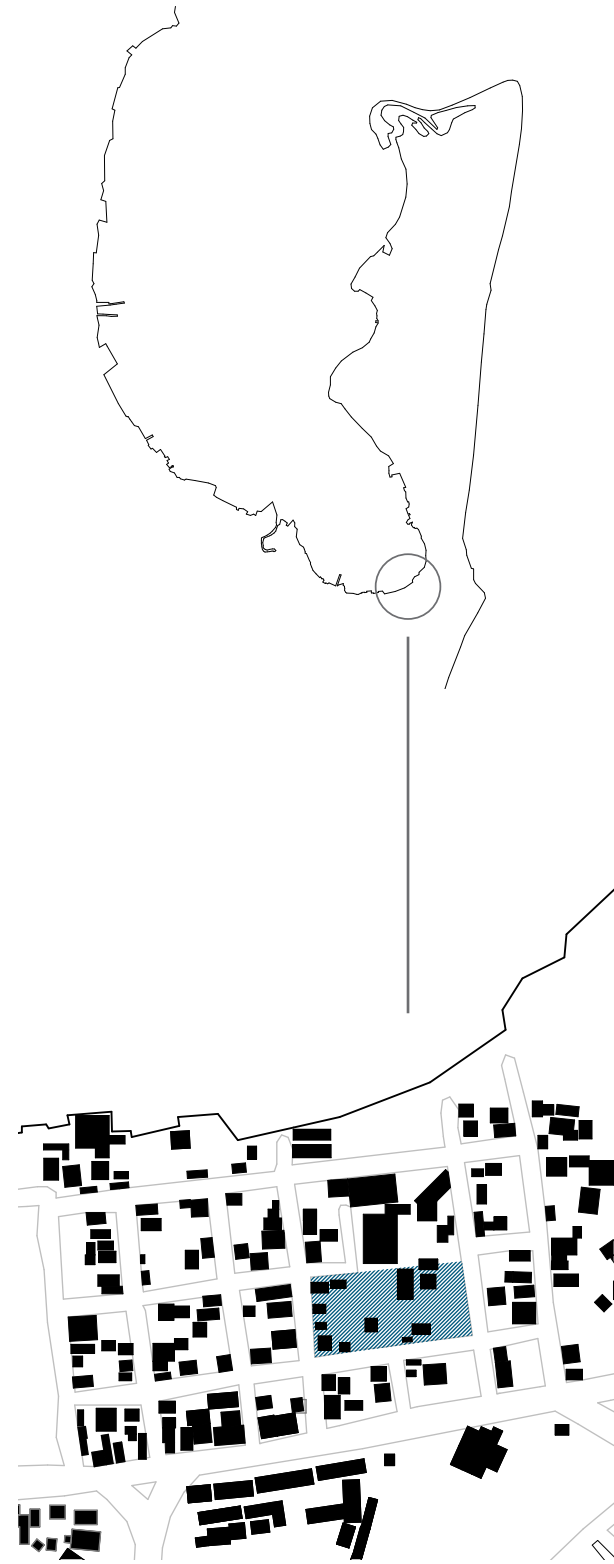


5 THE PROPOSAL

For my proposal, I decided to develop a project at a former disaster site in the Philippines. The proposal aims at designing a disaster resilient community which is adapted to the local climatic conditions. This means finding a functional balance between the normal everyday climate and the typhoon case.

I started developing my project on an urban level to create a community that is disaster resilient. This included the building arrangement, reachability, size and height of the structures as well as strategies for waste and storm water management.

After creating an urban layout, I focused on the critical facilities, in this case a health facility and a school. These two institutions are most important during a typhoon as young and sick people are most vulnerable and an uninterrupted medical service is crucial to saving lives. I attempted to create disaster resilience at various levels of the buildings while still keeping the everyday functioning in mind. Thus, I looked closely at the construction of the buildings, the floor plan layout, interior ventilation and protection during the typhoon.



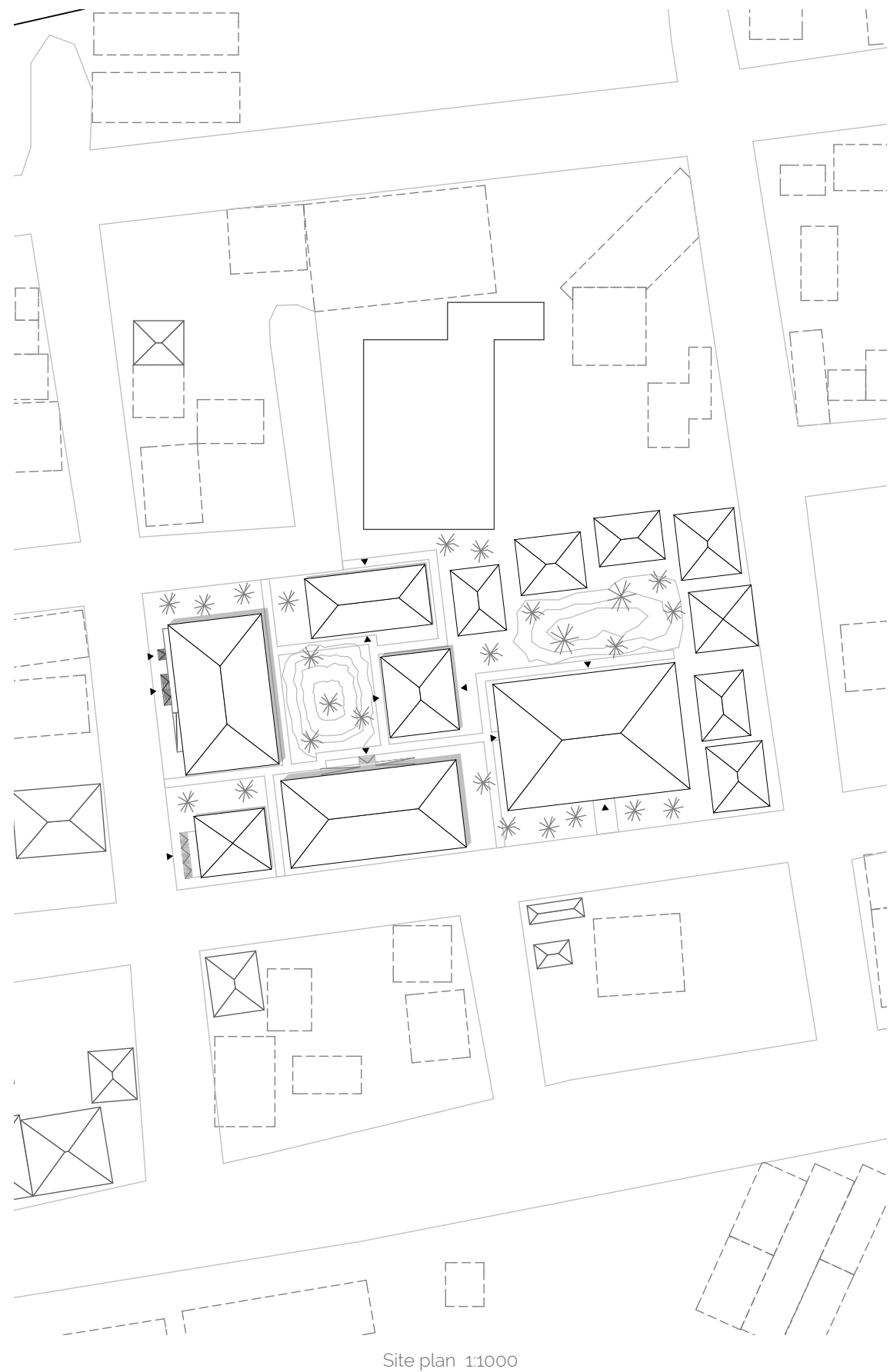
5.1 URBAN PLANNING

First, I looked at the map of Tacloban City to establish a suitable site for my proposal. I decided to pick a spot for the development of a resilient community in the city that was mostly destroyed by Typhoon Haiyan.

The site is located in the Eastern part of the city, close to the north coast. The street layout of the site is very regular similar to the northern part of Tacloban that was rather safe during the cyclone. However, at my chosen site the urban layout consisted of

a lot of open space and less built environment compared to the rather dense northern part.

While developing my project I also wanted to densify the area. The resilient community is centered around the critical facilities, namely a school and the clinic. As I wanted to integrate the buildings into the neighborhood, I developed further buildings to create a cohesive structure. I imagine the church north of my site to be rebuilt as a part of the new community.



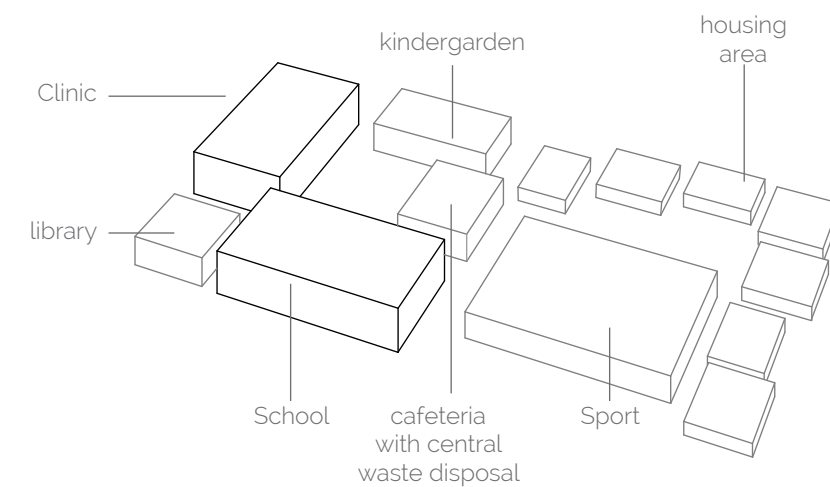
Site plan 1:1000

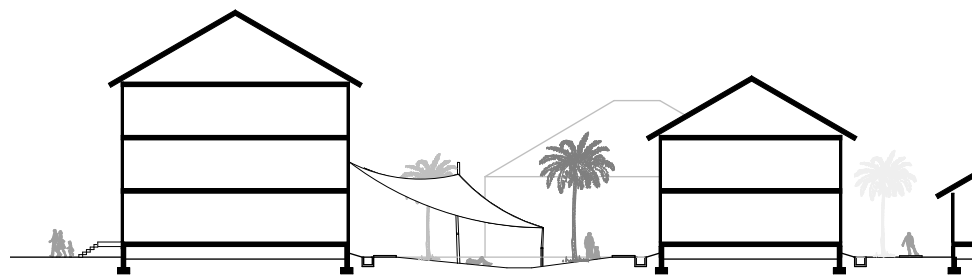
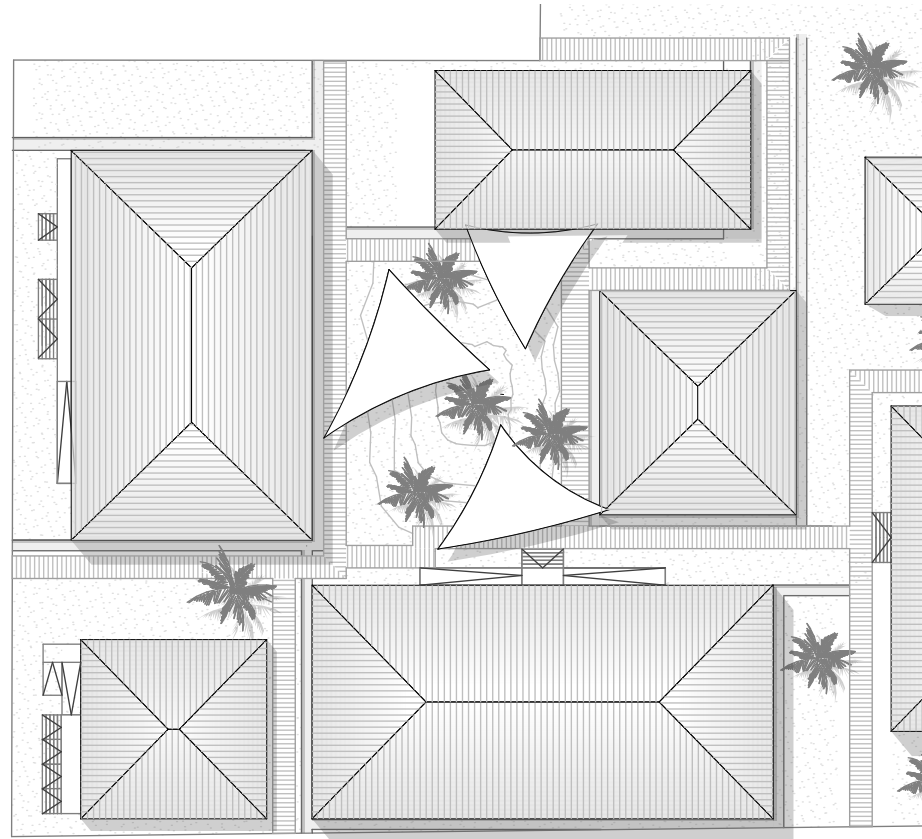
SITE PLAN

General

The area not only includes a clinic and a school but also a public library, a cafeteria and a kindergarten, as well as a sports facility. These public buildings can be used by the whole neighborhood during normal times, as well as during a disaster. These should serve as a meeting point, safe place and evacuation center. The cluster structure leaves open space in the center that is protected by the buildings. The space between the clinic and the kindergarten is larger to let in wind from the northwest. The

sports hall is integrated into the adjacent housing structures with open space that can be used for outdoor activities. Using a cluster structure, instead of a courtyard-type, means leaving open space for wind to enter the site during a normal day, but also holding back the wind during storms. Additionally, the structure has the advantage that in a worst-case scenario, if one building is damaged and may not be usable anymore, other buildings might still function and can take the pressure off the damaged building. While people are hosted in other





Site plan and Section West-East 1:500

buildings, repairs can be made. This is one example of how one can develop a functional balance between extreme weather and the everyday scenario.

Height

The buildings vary between two and three stories to blend in with the neighborhood as most of the houses in Tacloban City were one or two floors high. Moreover, the difference between the heights is small enough to push the wind over the roof tops.

Layout

The shape of the different buildings is kept regular to keep the wind from pressuring on corners. I chose rectangular and square shapes as they fit with the local architecture. The length of the buildings does not exceed three times the width to keep the structure compact enough to withstand wind.

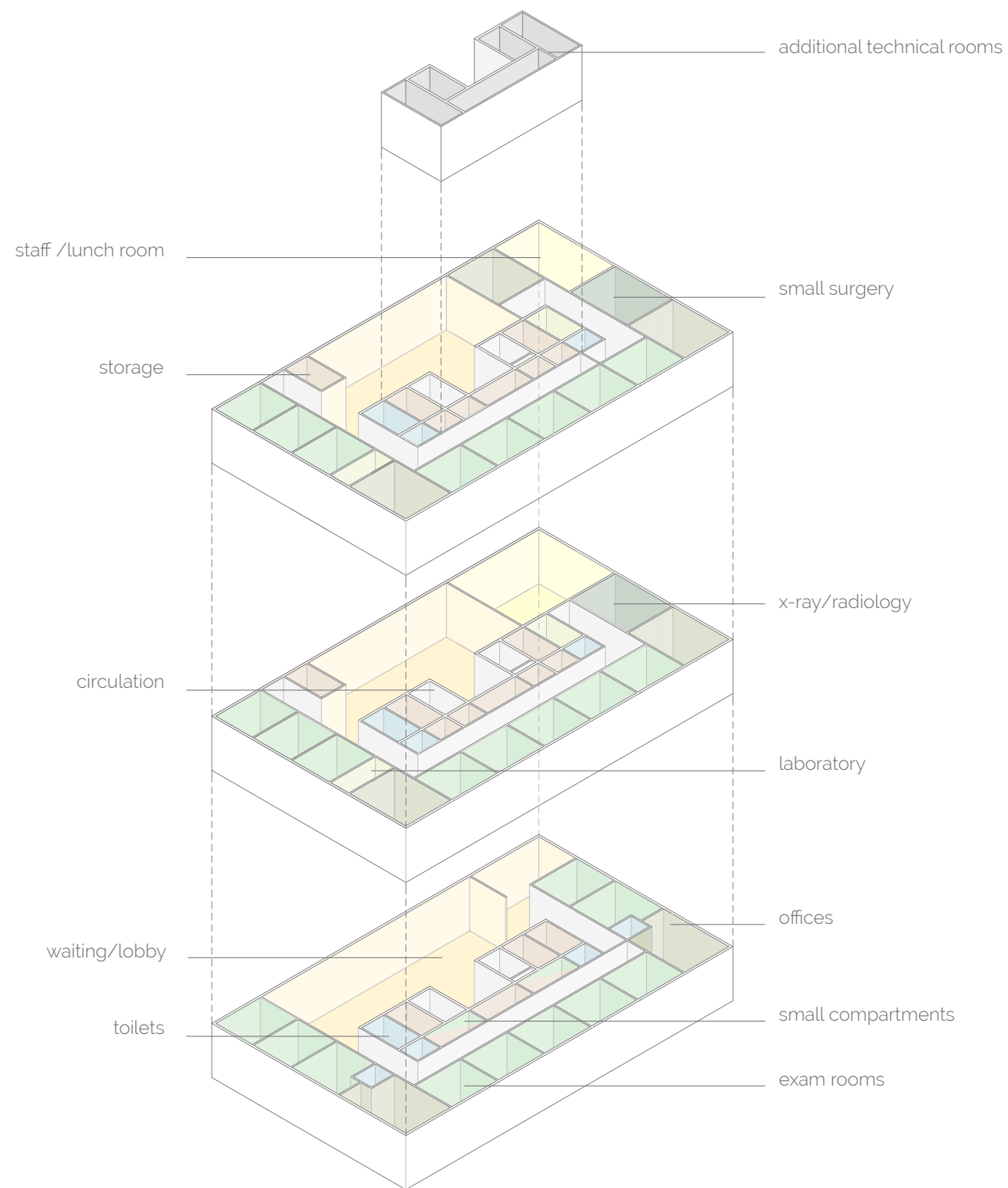
Water Management

Each of the buildings is connected to the open storm water system

as the channels run over the site. The open spaces in the middle are sloped downwards to store some of the water during flooding. Vegetation provides only little shading which is why additional sun shading devices are put up. These textile structures provide sun and rain protection and can easily be taken down during a storm. Even if torn off, they are not harmful to the residents in that area. Wooden paths cross the site. These planks can be placed with small spacing between to let water through to the ground which helps to lead the water away from the buildings. However, the planks should be tied firmly to the soil to keep them from being torn off.

Waste Management

To keep waste from floating off or being blown away and thus increasing the risk of diseases during flooding, a secure waste disposal will be set up in the cafeteria building. It can be accessed from outside but, as it is protected by walls, it will be safe from water and wind.



5.2 CLINIC

I started my architectural design with the health facility as, for me, it seemed to be the most important part of the design. I especially focused on the floor plan layout, the construction, and material as well as interior ventilation.

The clinic should be functional at daytime, provide emergency services during the night and most importantly keep up the functionality during a typhoon. However, finding strategies that balance between everyday scenario and Typhoon proved to be quite challenging.

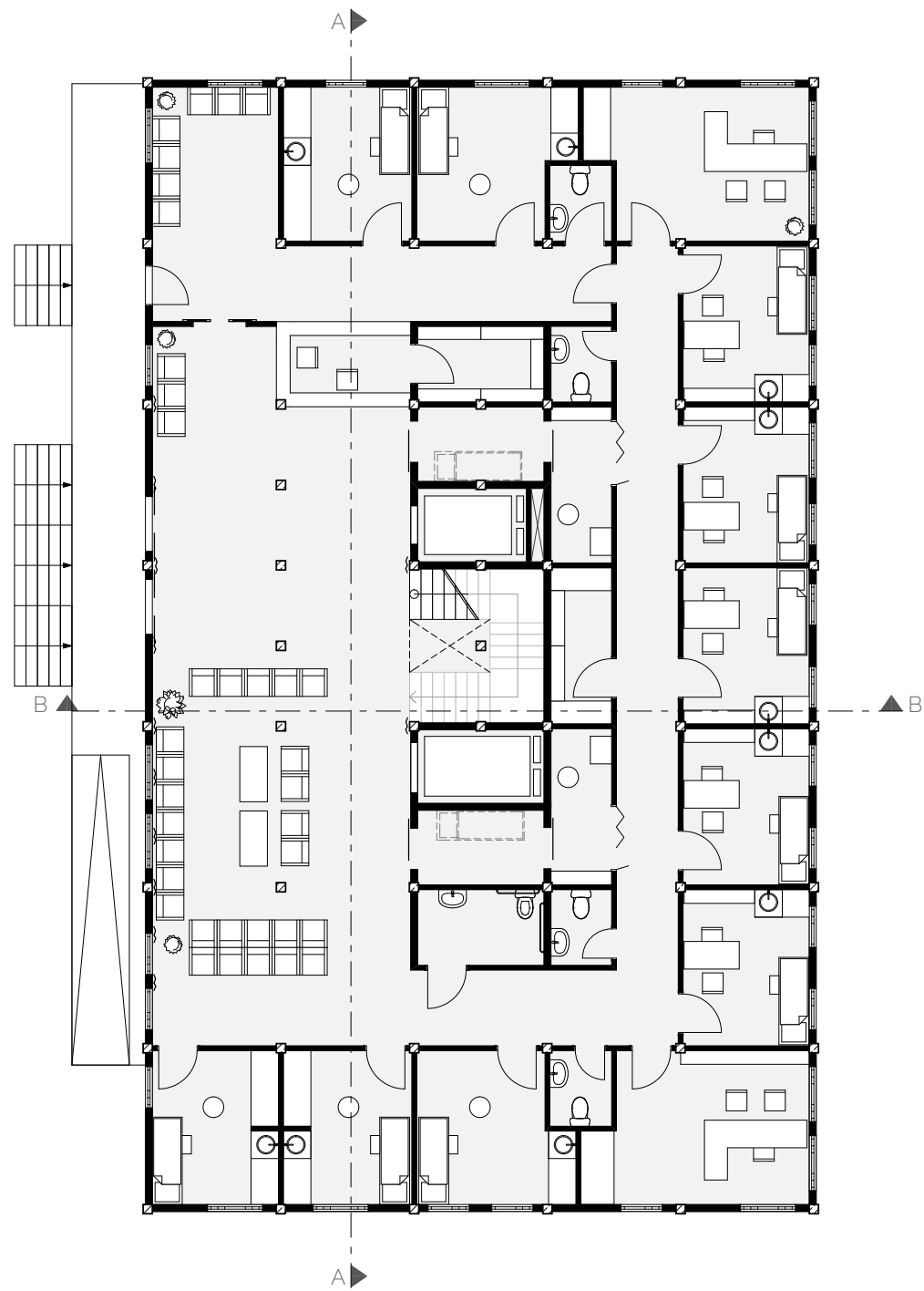
Ground Floor

The building can be reached by a staircase or a ramp for wheelchair access. The entrance on the ground floor leads to an open lobby with reception and a waiting area. In the north of the building, there is an additional entrance as well as a smaller waiting area. This space can be separated from the

regular clinic and be used during the night and in emergency cases. The rest of the ground floor is divided into smaller rooms that are offices and examination rooms. In the middle of the building, there is a circulation core with a staircase and elevators as well as storage rooms. On the right side of the core, there are small areas for weighing and checking blood pressure as well as toilets and small storage compartments.

Transformable Spaces

In case of an emergency or a typhoon, where a lot of people require medical attention, the waiting area can be transformed by moving the chairs into the storage area and putting up beds instead. The room can be divided by curtains that are fixed on rails at the ceiling. Moreover, the small weighing compartments can be used as additional examination rooms.



Ground Floor - regular day 1:150



Ground Floor - emergency after typhoon 1:150



First Floor 1:150

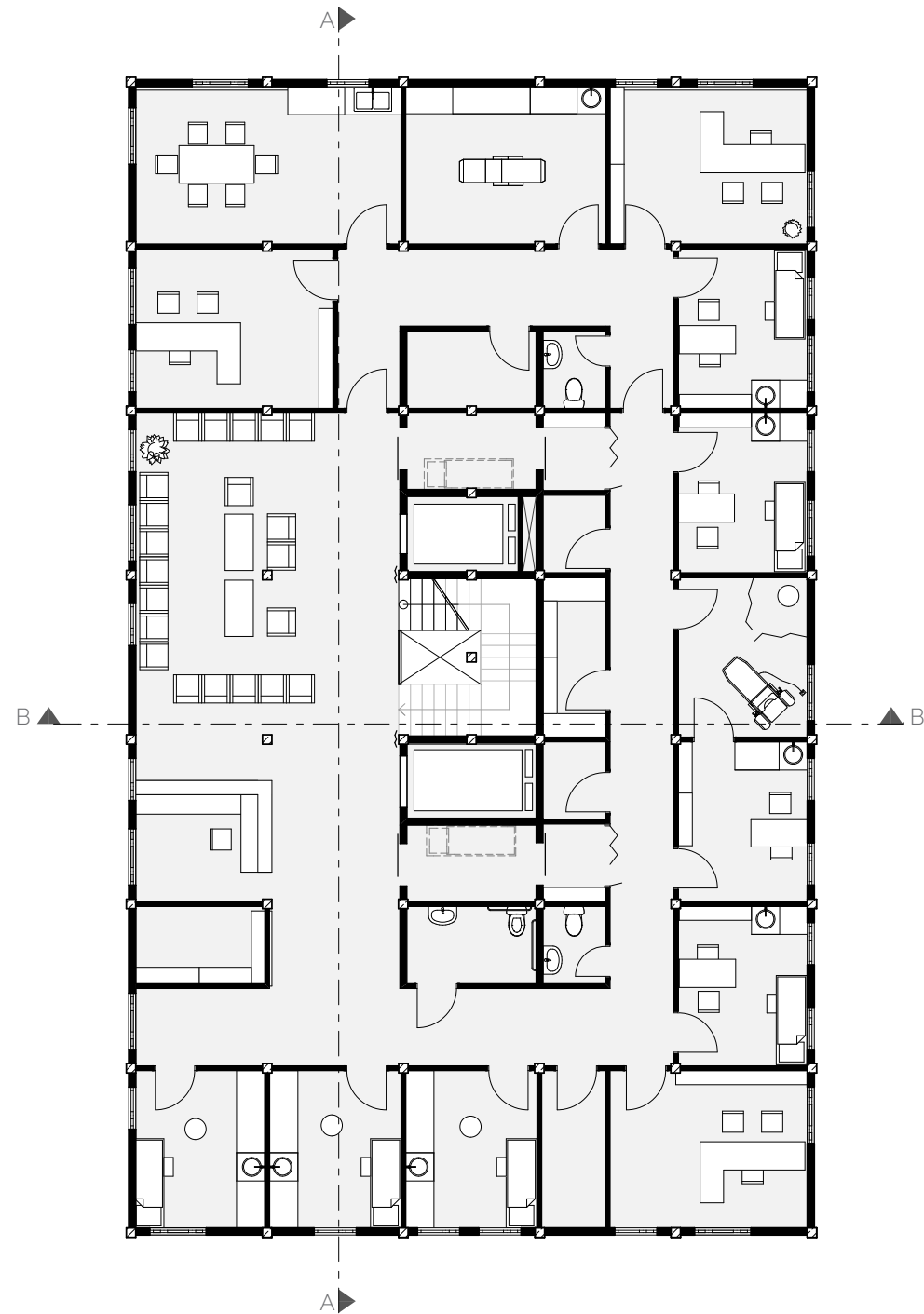
First Floor

The first floor has a similar layout to the ground floor, except for the waiting area. Although it is also an open room, it is a little smaller, and another reception in combination with a records storage is provided. This floor has a radiology department with an X-Ray room. General Doctors and nurses are supposed to be practicing on the ground floor, while specialists are practicing upstairs. However, most of the rooms should have basic general medical equipment so they can be used for all kinds of treatment during a disaster. Important records, medicine, as well as mechanical equipment are found on the upper floors to be kept safe in case of flooding. There are two small laboratories

on this floor to examine blood samples and conduct other small tests. There is a lunch room for the staff in the northern part of the building.

Transformable Space

Like in the ground floor, the waiting area can be transformed by removing the chairs and dividing the space with curtains. In a worst-case scenario when the ground floor becomes unusable, the first floor must be able to take in the patients. As the lunch room of the staff is quite big, people can stay in that room as well. In this floor, the small compartments are used for medicine and general storage and will not be transformed into patient rooms.



Second Floor 1:150

Second Floor

The second floor has more or less the same layout as the first floor. The waiting area with reception and a storage room is the same. The staff room is a little smaller, and an additional office is put in. There is a room for small surgeries. This room and the laboratories, as well as the X-Ray room in the first floor, are the only rooms that will have a permanent access to the air conditioning.

In one of the small compartments, there is an emergency generator. In case of a loss of power, this generator can provide power for the most important rooms and functions. This guarantees the clinic to be able to perform analysis and surgery during an emergency.

The staircase leads up to the third floor under the roof. This area is only accessible for staff and maintenance.

Total Area:

Ground Floor:	
Waiting/Lobby	103 m ²
Office	32 m ²
Exam	102 m ²
Storage/WC	43 m ²
Circulation	63 m ²
First Floor:	
Waiting/Lobby	64 m ²
Office	32 m ²
Exam	86 m ²
Laboratory	10 m ²
Staff	40 m ²
Storage/WC	30 m ²
Circulation	63 m ²
Second Floor:	
Waiting/Lobby	64 m ²
Office	48 m ²
Exam	86 m ²
Laboratory	10 m ²
Staff	20 m ²
Storage/WC	30 m ²
Circulation	63 m ²



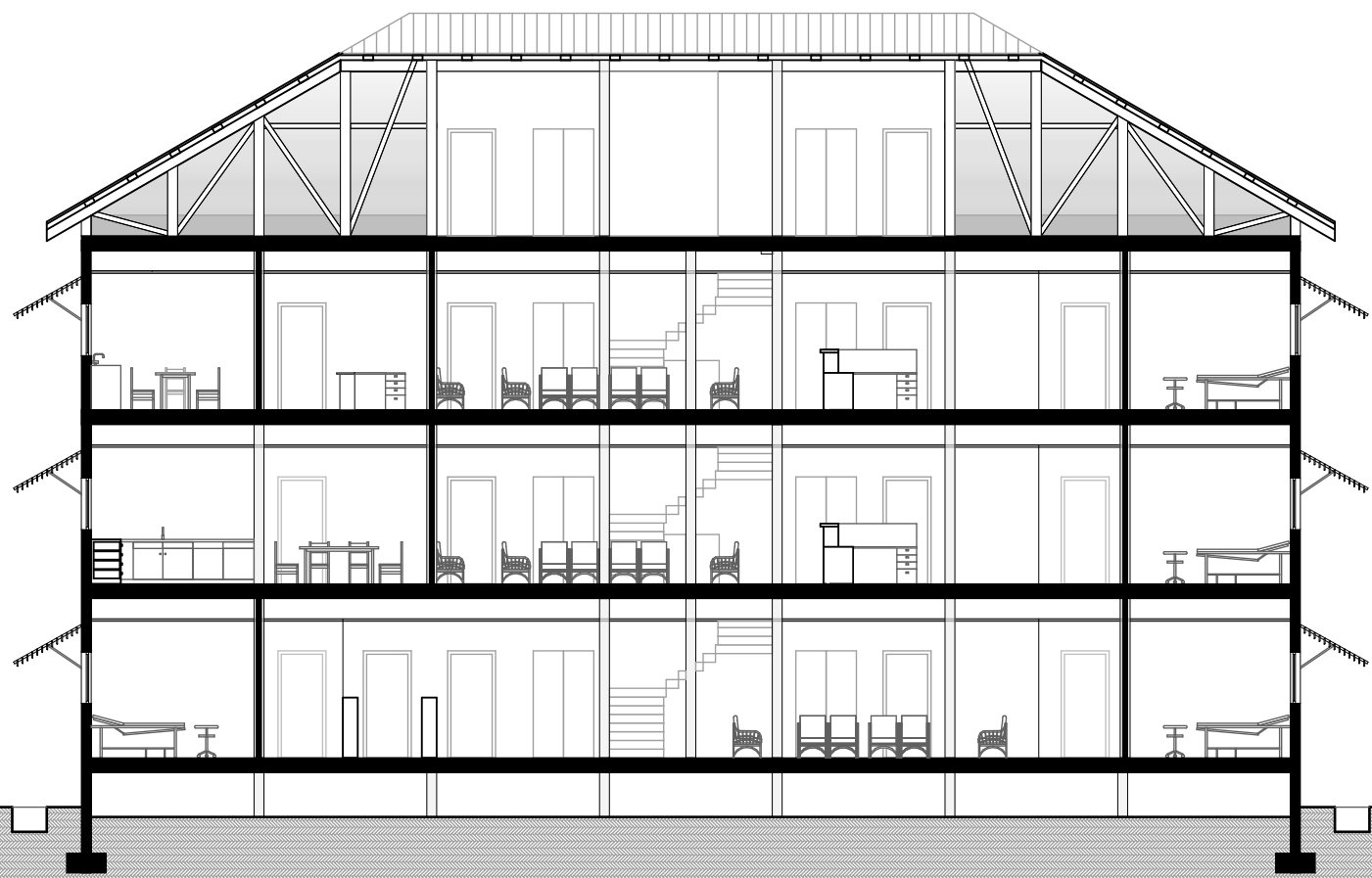




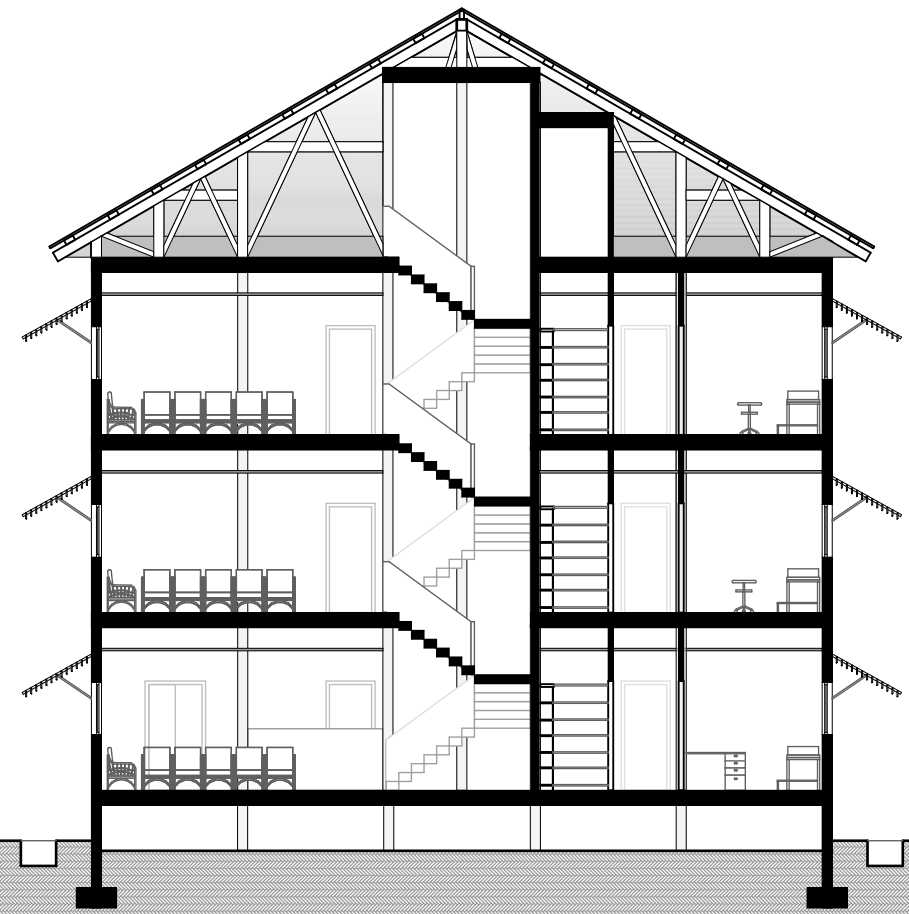
West Elevation 1:150



South Elevation 1:150

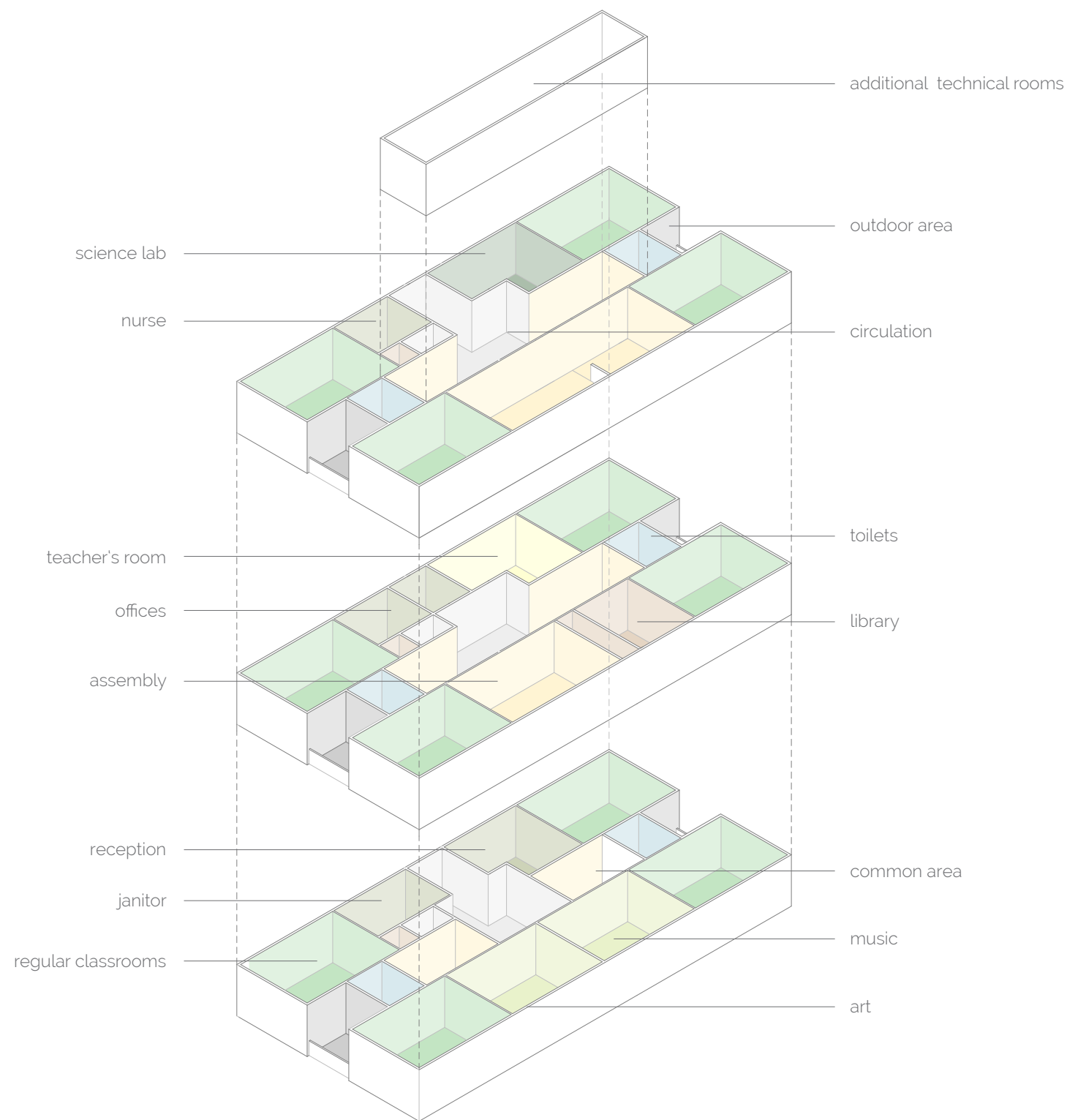


Section A-A 1:150



Section B-B 1:150





5.3 SCHOOL

As a second focus point I decided to plan a primary school next to the public library. As mentioned before, schools are vital in keeping a sense of normality for the children after a typhoon. Not only do they provide a safe haven for the kids but also a possible evacuation space for the residents in the area, although most of the evacuees will be stationed at the sports hall.

The three-story-building itself is very symmetric and there are several similarities between the clinic and the school building regarding construction and interior ventilation.

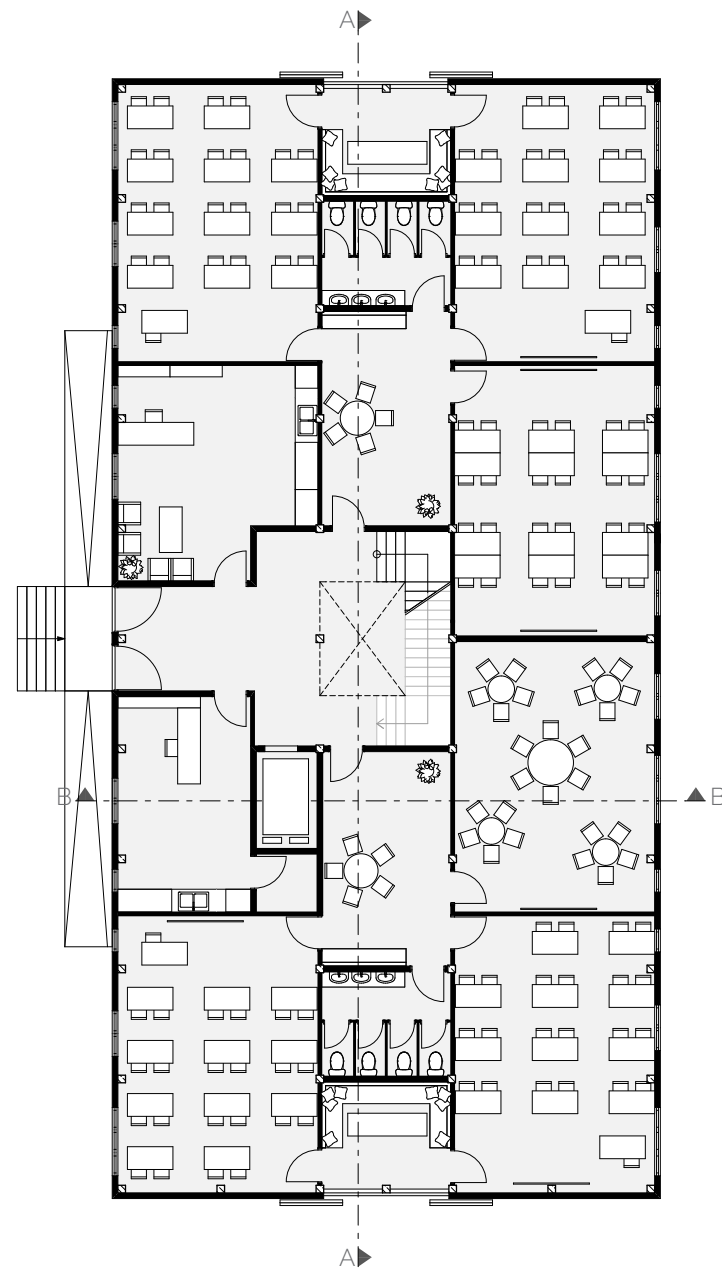
Ground Floor

The entrance of the building is from the courtyard and the two big doors are usually open during the day to keep a good ventilation inside the building. The main circulation is over the staircase in the middle but an elevator is

provided for wheelchair access. Next to the entrance are the rooms for the janitor as well as a reception and a secretary. In each of the corners of the building there are classrooms with toilets in between. The spaces in front of the classrooms can be used before class or during breaks. There are two more rooms for art and music classes that can be used by all students.

Exterior Spaces

To provide the classrooms with cross ventilation, I created outdoor spaces that each can be shared by two classes. These spaces need to be protected in case of a typhoon as they are open on one side. I applied movable panels on the outside that can be slid into the facade to enclose the open area. The panel is divided in two sections; one with movable horizontal planks and another closed panel. This gives the



Ground Floor 1:200

opportunity to have these rooms either completely open, shaded by the panels, or completely closed.

First Floor

The first floor is similar to the ground floor as the position and size of the classrooms, toilets and common areas remain the same. Additionally, there is the teachers room as well as the principal's office. On the south side of the building there is an assembly hall that can be used for special events and during breaks. Large seating steps lead up to the second floor. If people need to be evacuated they can sleep on these. Next to the assembly hall there is a library and a storage room.

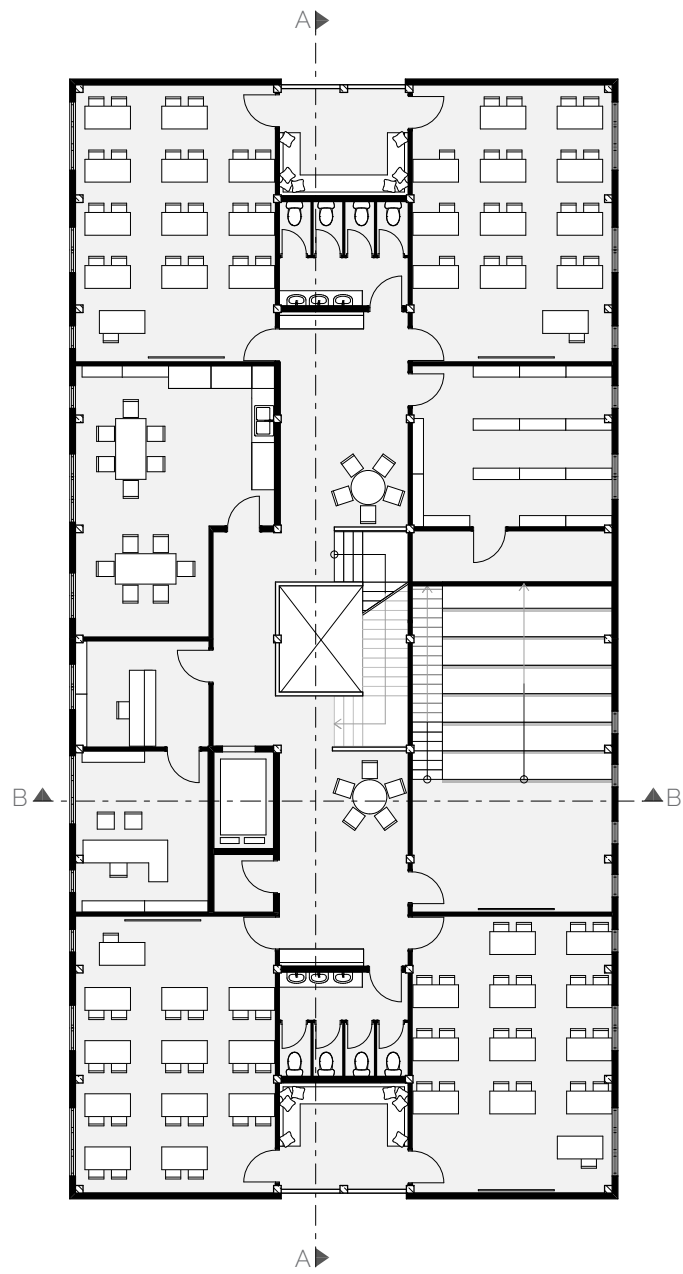
Second Floor

The layout of the second floor is almost the same as the first. In addition to the normal classrooms, there is a science lab where children can experiment. Next to the laboratory there is a nurse's

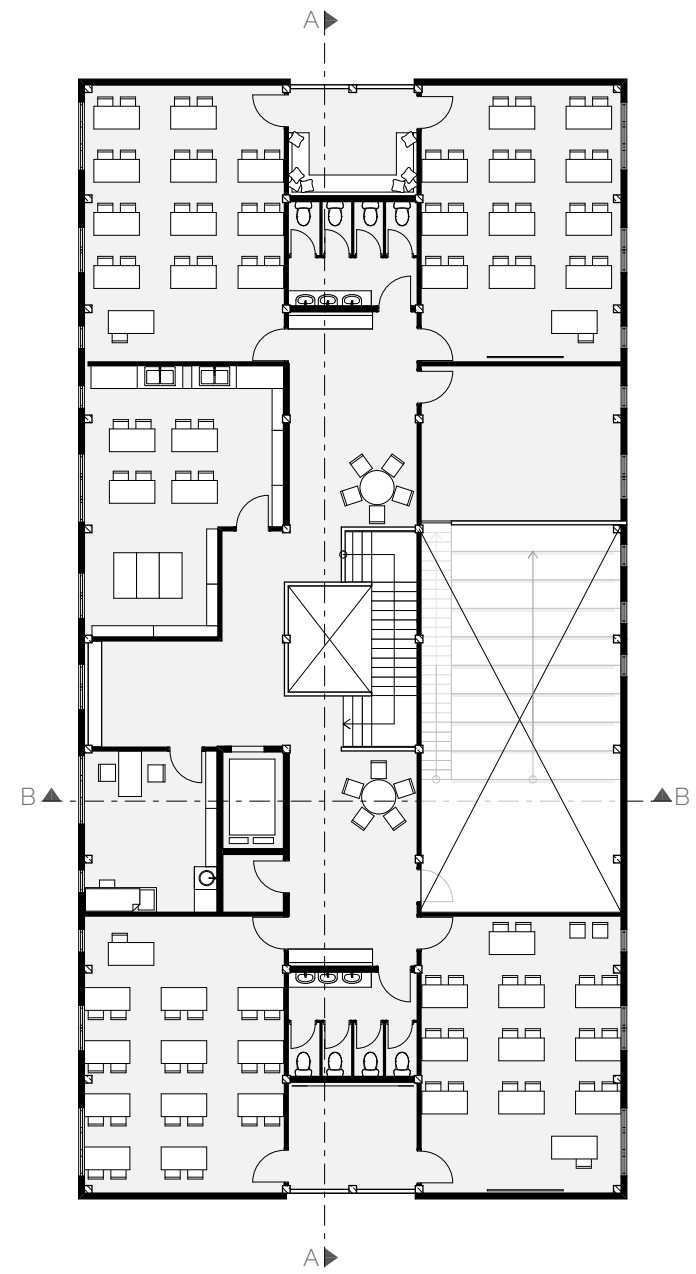
office. This is especially important as medical equipment needs to be provided during a disaster.

Total Area:

Ground Floor:	
Regular Classrooms	152 m ²
Art/Music	76 m ²
Offices	48 m ²
Common Area	
Interior	40 m ²
Exterior	18 m ²
Storage/WC	22 m ²
Circulation	40 m ²
First Floor:	
Regular Classrooms	152 m ²
Offices/Teachers	60 m ²
Library	22 m ²
Assembly	46 m ²
Common Area	
Interior	40 m ²
Exterior	18 m ²
Storage/WC	30 m ²
Circulation	25 m ²
Second Floor:	
Regular Classrooms	152 m ²
Nurse	16 m ²
Laboratory	32 m ²
Assembly	22 m ²
Common Area	
Interior	40 m ²
Exterior	18 m ²
Storage/WC	22 m ²
Circulation	25 m ²



First Floor 1:200



Second Floor 1:200

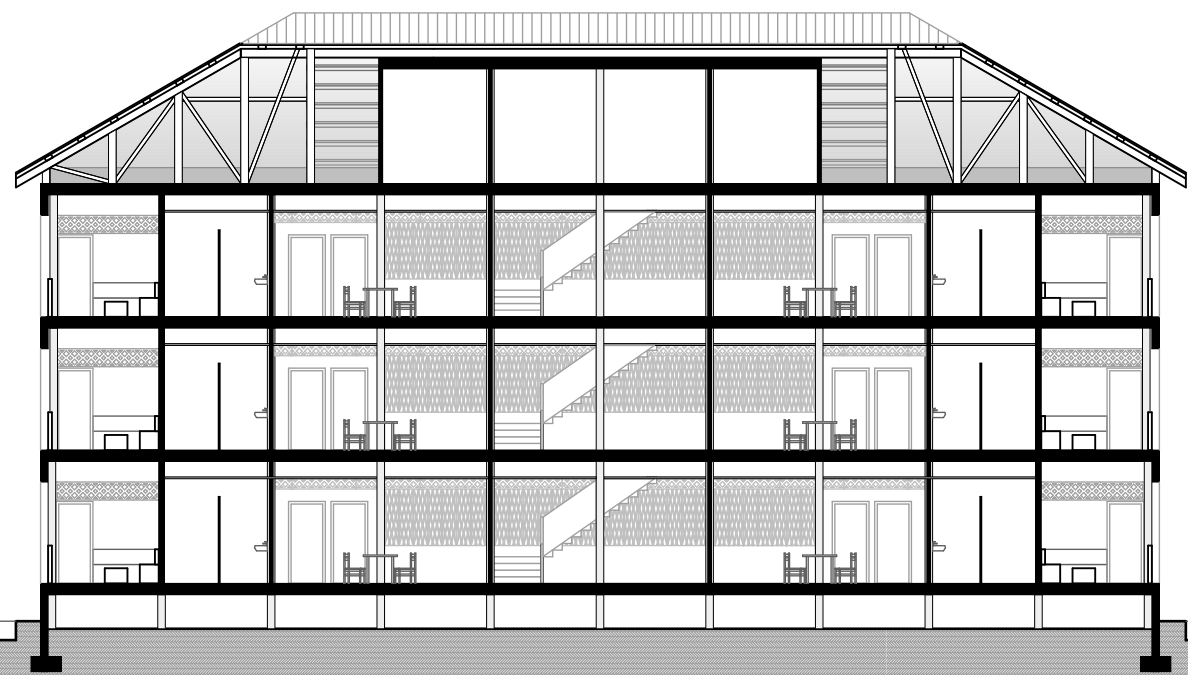




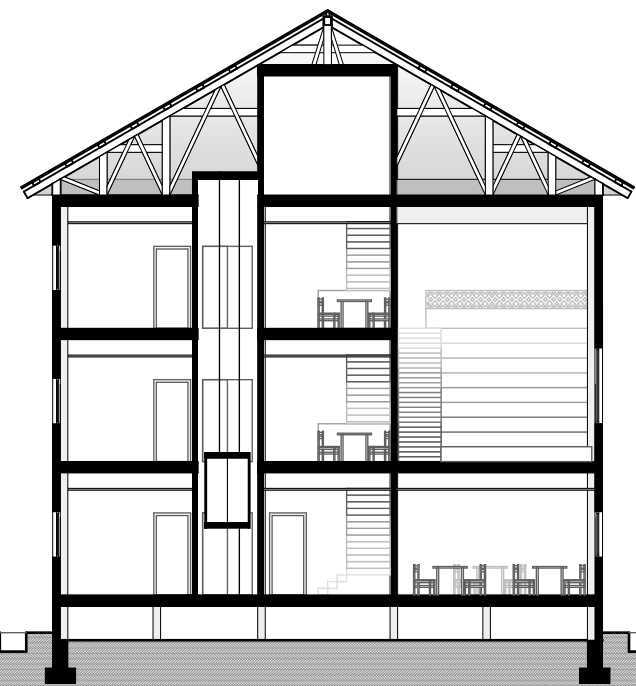
North Elevation 1:200



East Elevation 1:200



Section A-A 1:200



Section B-B 1:200



5.4 DETAILS

The Details for this project are very important as they add enormously to the understanding of how to build typhoon-resilient architecture.

In this section, I will focus on general construction and material, interior ventilation as well as protection from the elements.

The construction will focus on the foundation, the load bearing structure, and the roof. These three elements need to be strong and durable to keep the building safe and functional during a typhoon.

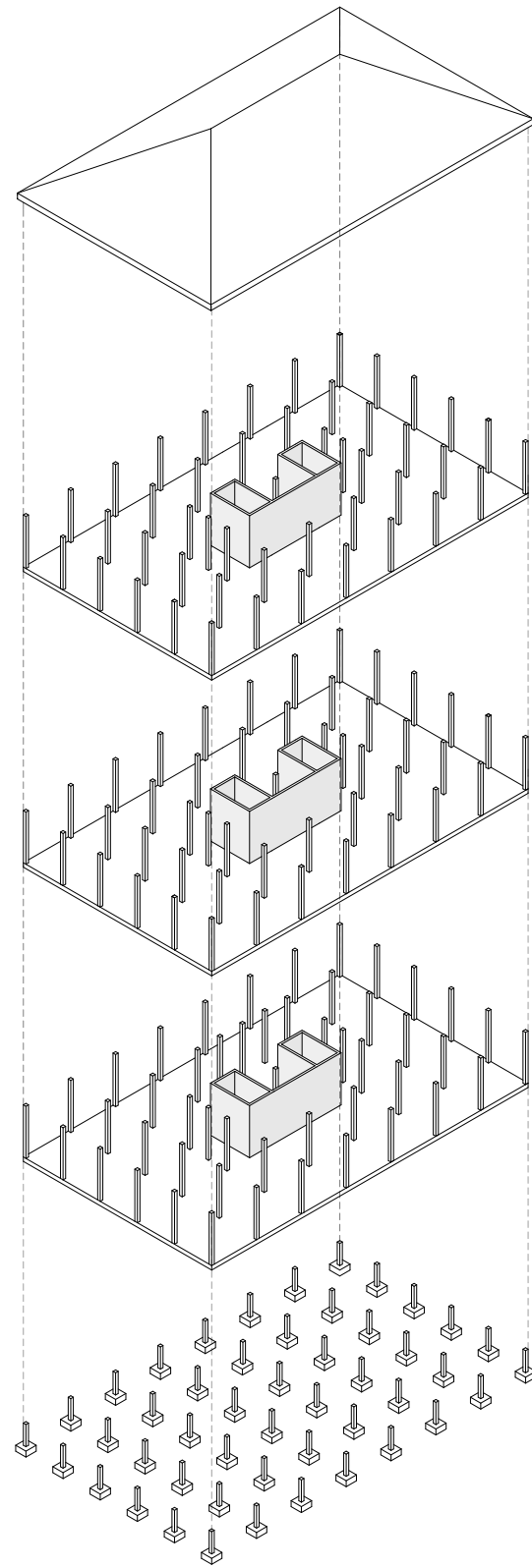
The materials used should be cheap enough to enable poorer communities to be able to build resilient architecture. As

these communities have limited resources, it is difficult for them to immediately repair damaged structures.

The ventilation helps to balance the usually warm-humid climate with the changing conditions in a storm scenario.

Focusing on the protection against the elements helps understand how a building can perform and transform during a storm. These protective measures need to be easy to handle and strong enough to protect the building.

The following details focus mainly on the clinic and add up to a cohesive structure and durable building to shield people from the elements.



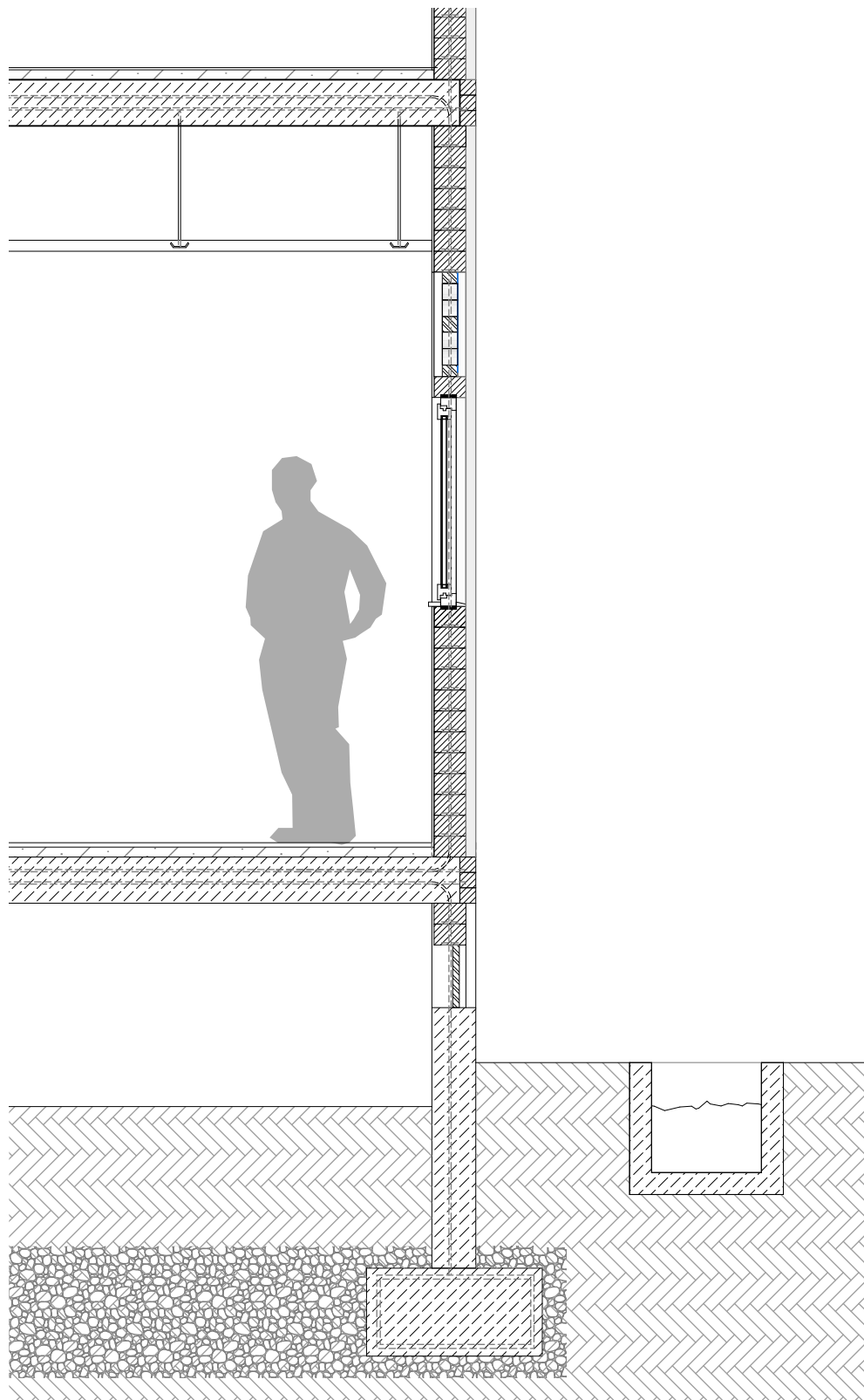
5.4.1 MATERIAL AND CONSTRUCTION

LOAD BEARING STRUCTURE

The main load bearing structure is a grid of columns and slabs, both made from reinforced concrete. The grid spans 3,5 m in one and 2,9 m in the other direction. This kind of construction method facilitates giving equal sizes to the rooms and of course helps to stabilize the building. Walls are susceptible to wind as they have a large exposed surface area. In case a wall is damaged, the columns can still take the load of the structure. The length of a grid section does not exceed 3,5 m as this makes the walls in between more vulnerable to forces from wind and water. The building is stabilized. The circulation core with staircase, elevators, and storage is also made from concrete to secure the building further.

FOUNDATION

The foundation is one of the most important elements in the construction of the building. The footings need to be secured properly and have durable connections to the load bearing structure and the walls. The foundation is made from reinforced concrete. It is a material that is very strong and heavy that gives weight to the structure. I decided to raise the ground floor to about one meter above the ground. As water damage is highly difficult to deal with and the risk of drowning is especially high for vulnerable people like the sick and young, it was important for me to protect the ground floor from water. Moreover, the pressure the water puts on the buildings is dangerous and can breach doors and windows easily. The installation of flood gates at the bottom of the wall can



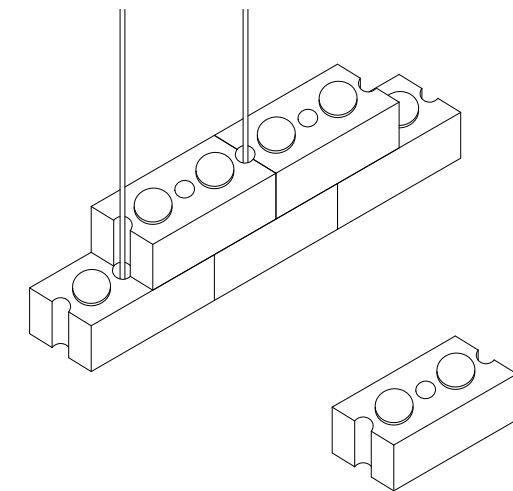
Facade Section 1:30

help reduce the pressure. These gates are made of metal that can be opened and closed either to aid the natural ventilation or let the water flow underneath the building. There is no concrete slab at the ground as the soil can take in some water before actual flooding occurs. However, it is essential that the ground is stabilized with compressed soil, gravel or a metal grid before building the foundation to avoid the earth to sink in.

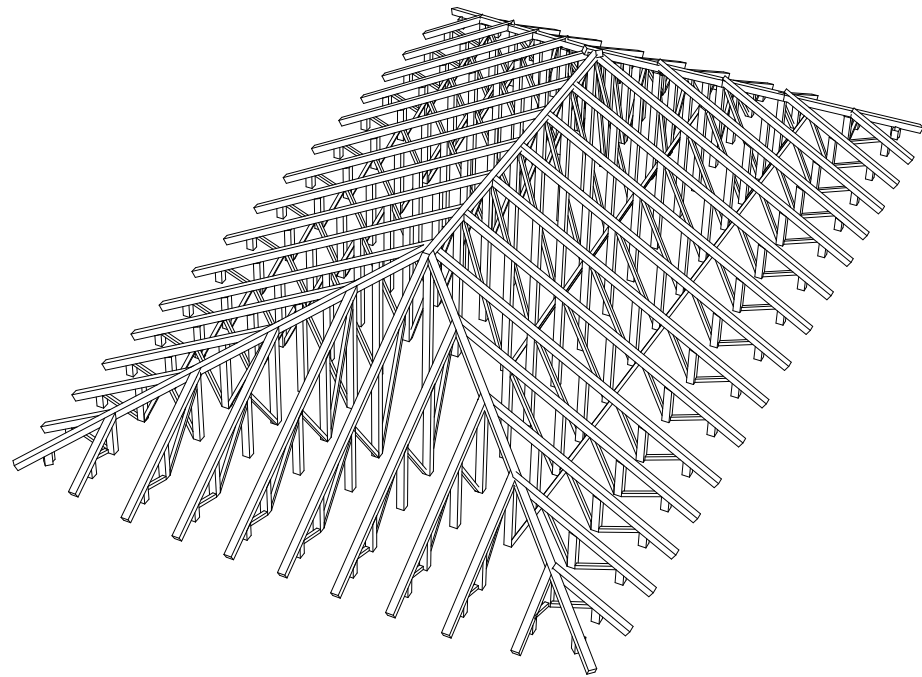
WALL CONSTRUCTION

Although the load of the building is taken by the columns, the walls still

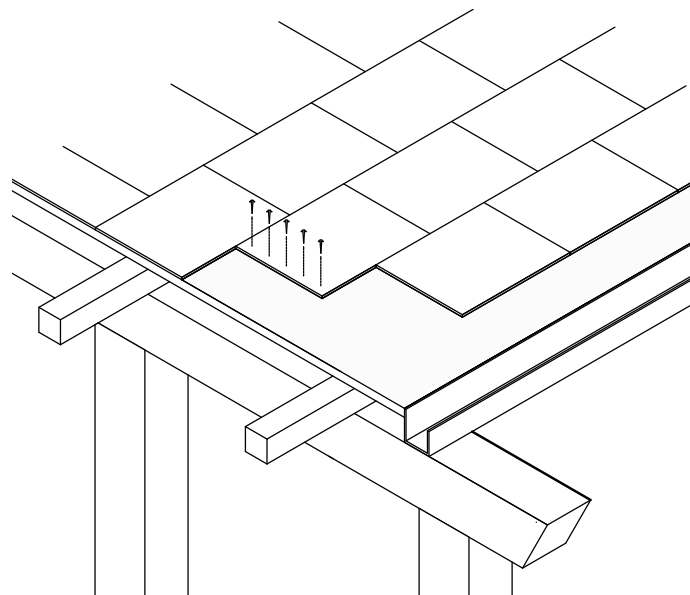
need to be able to take pressure from the elements. Choosing columns gives, however, an opportunity to make the exterior walls thinner to save material costs. I decided to construct the walls from Compressed Stabilized Earth Blocks (CSEB). These bricks come in various sizes and can be used throughout the whole building. The blocks can be made hollow to save material as well as provide space for steel rods. Reinforcing the walls is crucial to brace the exterior walls against forces. The interlocking version of the blocks is additionally stronger during earthquakes (Auroville Earth Institute, n.d).



Compressed Stabilized Earth Block (CSEB) construction



Hip roof truss system



Roof section with cladding and rain gutter

ROOF CONSTRUCTION

The roof is the part of the building that is most exposed to wind forces and needs to be strong enough to withstand these. I chose to create a wood hip roof with a slope of 30° as these have been proven to be durable and reduce the suction forces of the wind. The roof construction is based on the grid of the columns which makes it easy to add additional rooms on the third floor.

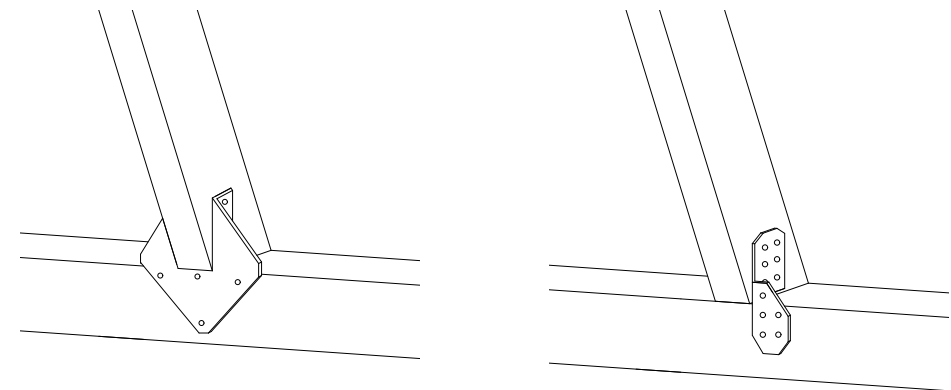
The different beams need to be secured properly. A good way to do this is to use hurricane ties (straps). These metal pieces have different shapes and angles and can easily be fixed to the structure. QUELLE Instead of using a simple column and beam system, it is beneficial

to choose a truss instead. This method is more stable despite using more material.

On top of the load bearing structure, the roofing material can be attached by creating a secondary smaller structure. As the clinic is supposed to have a rain water harvesting system which should function during bad weather with high wind speeds, I embedded the rain gutter in the secondary structure as exterior rain gutters can easily be ripped off by strong winds.

MATERIAL

The choice of material was somehow difficult as the building requires a strong, durable material which has to be enough for poor



Different versions of hurricane straps



Reinforced Concrete¹



Rice Husk Ash²



Solid CSEB³



Hollow CSEB⁴



Coco Lumber⁵



Metal Shingles⁶

¹ [pinterest.com](https://www.pinterest.com), n.d.

² [alibaba.com](https://www.alibaba.com), n.d.

³ [antaiosblocks.com](https://www.antaiosblocks.com), n.d.

⁴ [a2z4home.com](https://www.a2z4home.com), n.d.

⁵ [affordablecebu.com](https://www.affordablecebu.com), n.d.

⁶ [westernohiometalroofing.com](https://www.westernohiometalroofing.com), n.d.

communities to afford at the same time. The obvious choice was to use concrete in the entire structure. However, this is quite expensive but is widely used in the Philippines.

Reinforced Concrete

In my project, I decided to make the load bearing structure out of reinforced concrete as it is a durable material. Although it is expensive, there are ways to make the production cheaper.

Rice Husk Ash

A way to reduce costs of concrete is to substitute parts of the cement with rice husk ash. Rice production is one of the most important economic sectors in the Philippines, making the ash very accessible to everybody. The ash is obtained by burning the outer cover of rice husks (Habeb & Mahmud, 2010).

CSEB

As mentioned before the walls are made from Compressed Stabilized Earth Blocks. The material has great potential but is not frequently used yet, which is why I decided

to use it in this project. The blocks are easily produced either by a small machine manually operated by a single person or in a bigger factory. These blocks do not need to be burned but are just pressed together. The stabilized bricks differ from the other earth blocks in having a small amount of cement inside (Auroville Earth Institute, n.d). This could potentially be substituted partly with rice husk ash.

Coco Lumber

For constructions made with wood, I chose to use Coco Lumber. It is a wood type found in the Philippines and comes in different densities but all from the same tree (Buensalido Architects, 2015)

Metal Shingles

For the covering of the roof, I decided to use metal shingles. They are very thin and light but can be easily nailed down (FEMA, 2009). This has the advantage that one can just add more nails for securing the cladding.

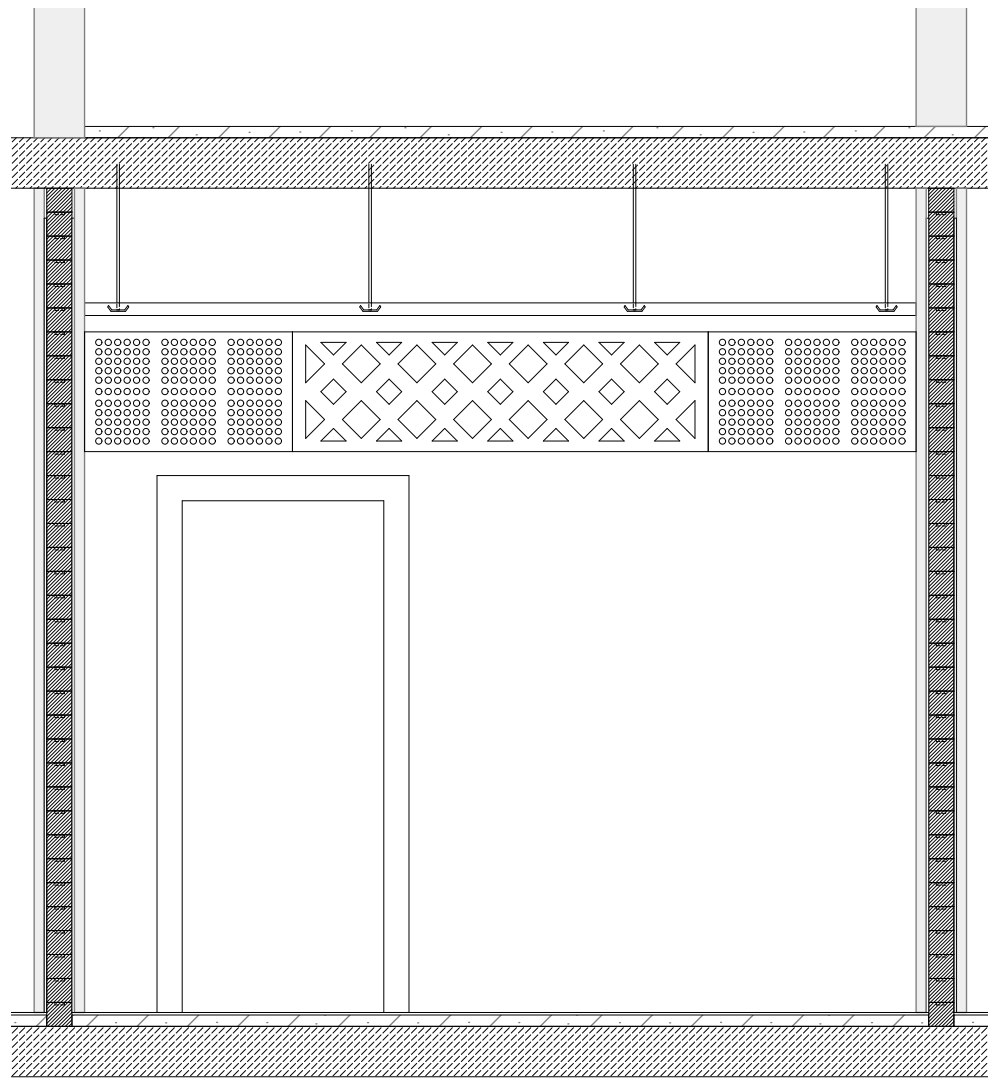
5.4.2 INTERIOR VENTILATION

Interior ventilation is crucial to maintaining a comfortable climate inside the building. As the buildings cannot be too long and narrow, I needed to find another way to keep a flow of air through the clinic.

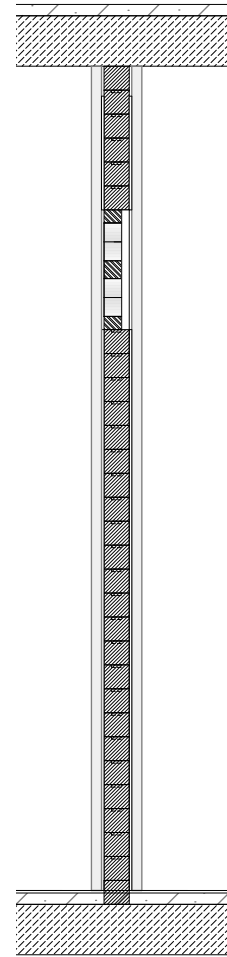
Mobile Panels

I decided to install wooden panels in the walls between the suspended ceiling and the doors and windows. The exterior ventilation openings can be closed by the screens mentioned above. The interior walls need openings to have a continuous flow of air from one room to the next. However, these openings

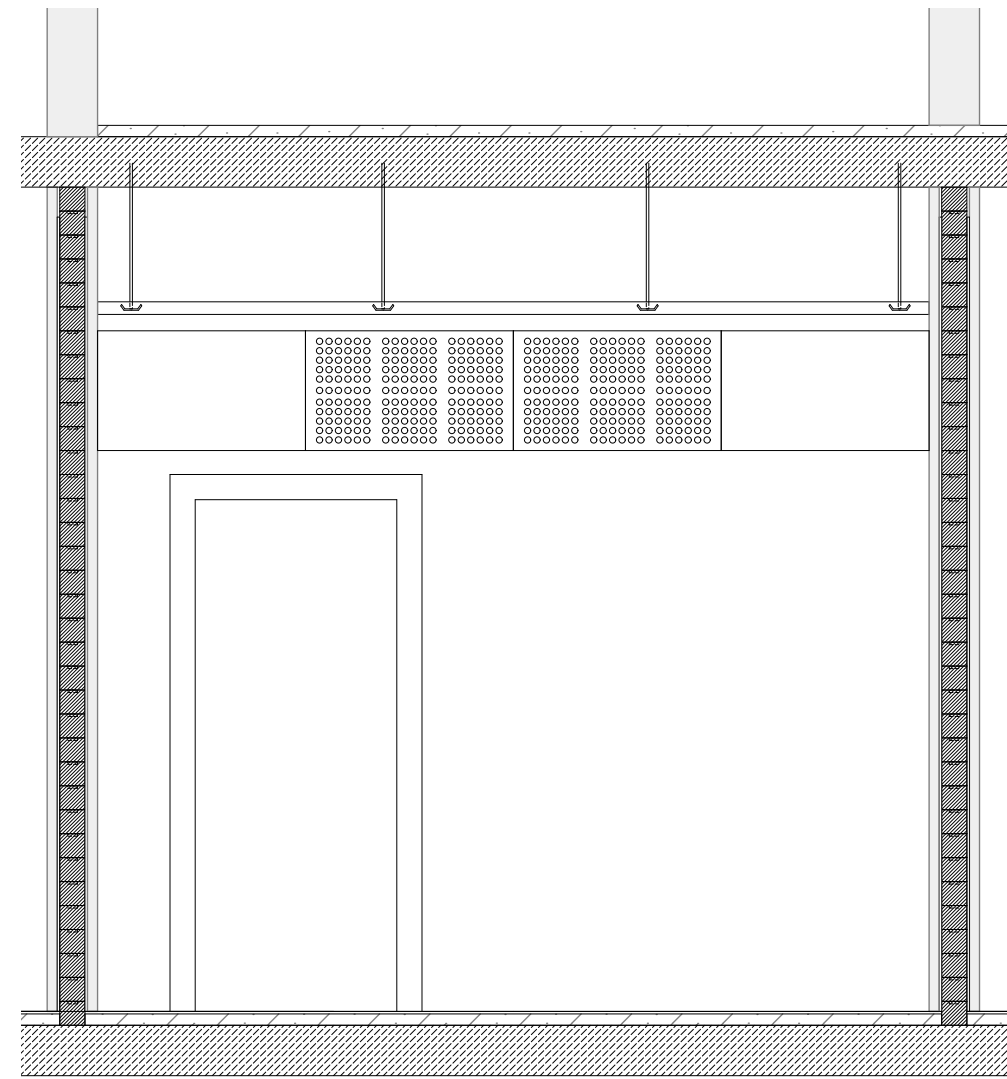
leave not much privacy, which is not beneficial during a doctor's appointment. For this reason, I divided the interior ventilation into two panels. One panel has big openings to let wind through; the other has smaller openings to give more privacy. The second panels can be slid in front of the others to close off the air flow momentarily. These movable panels give the option to regulate how much privacy you want to have. Most of the rooms have these openings except the ones that need to be kept sterile and have access to air conditioning (X-Ray, Surgery, Laboratory).



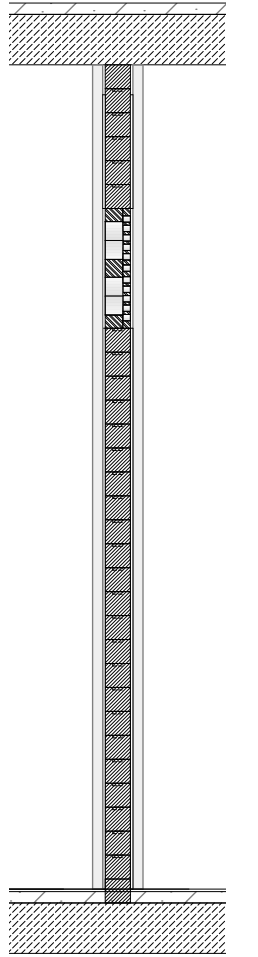
Interior ventilation elevation (open)



Section (open)



Interior ventilation elevation (closed)



Section (closed)



5.4.3 PROTECTION FROM THE ELEMENTS

The climate in Tacloban is quite difficult to handle as it is very humid and h protection from sun and rain is needed, while at the same time one needs to maintain the natural ventilation. In addition, in case of a typhoon, all exterior screens are in danger to be ripped off and blown away. In this regard, my main focus was on the clinic, but I developed another idea for the school.

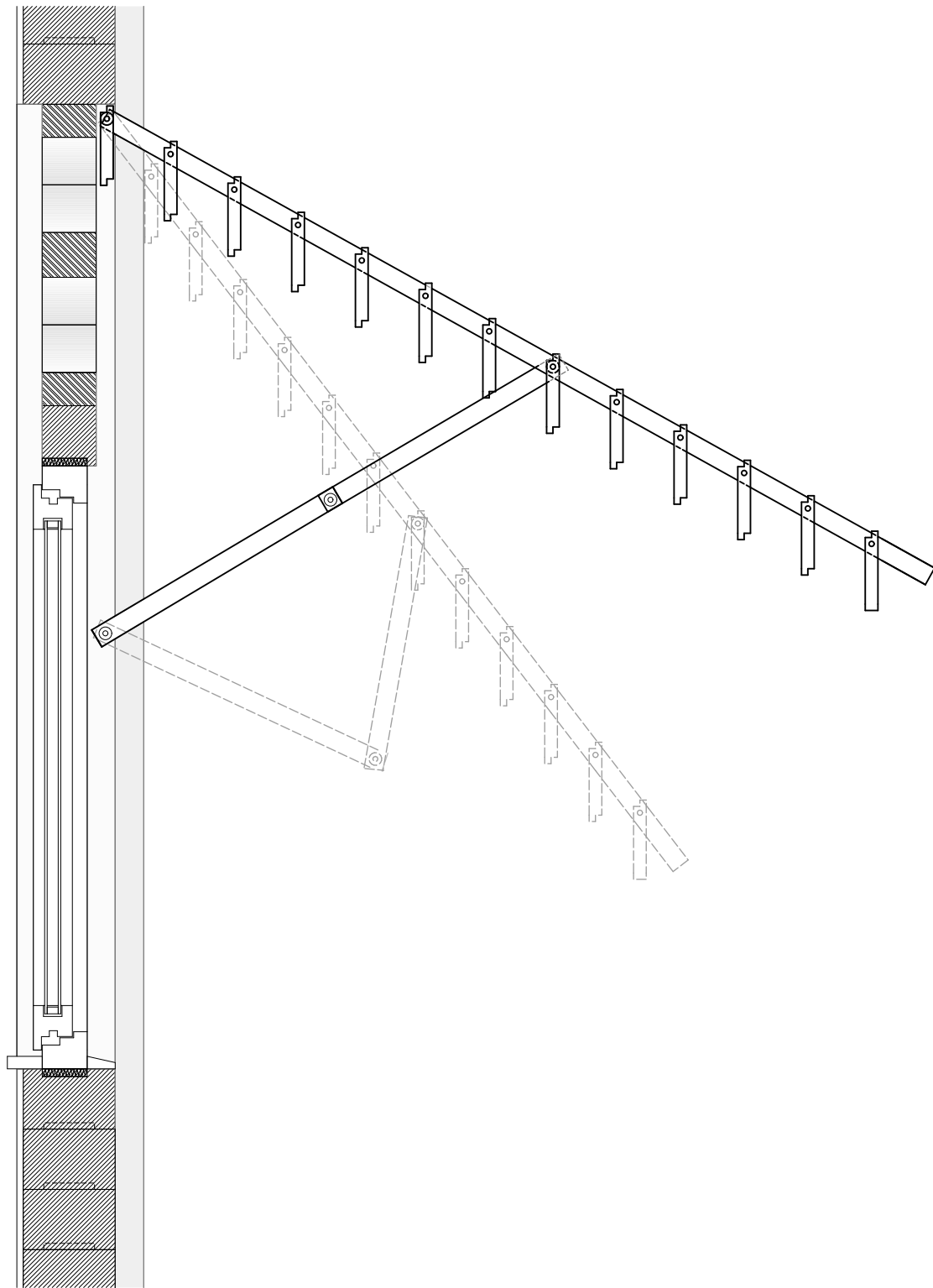
Clinic

My idea was to use the window shutters both as storm protection as well as rain and sun screens. To accomplish this, I developed wooden screens that can be folded up or down depending on the use. The planks between the main structure are movable and interlock when the screen is folded down. These folded panels sit in front of the window in the wall to have a smooth facade. In this

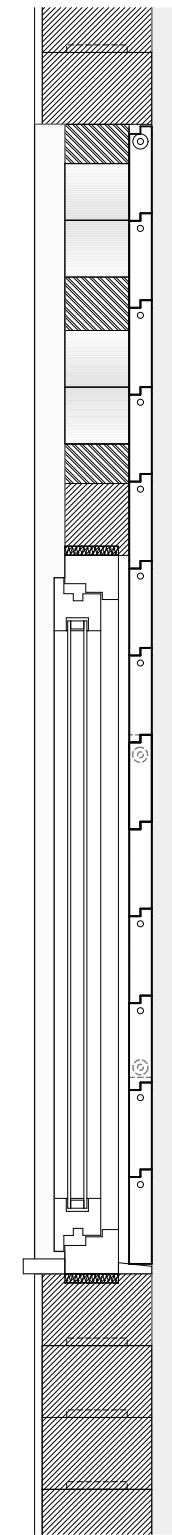
way, the windows are protected, and the screens are not easily torn off. The shutters also cover the ventilation openings on top of the windows.

School

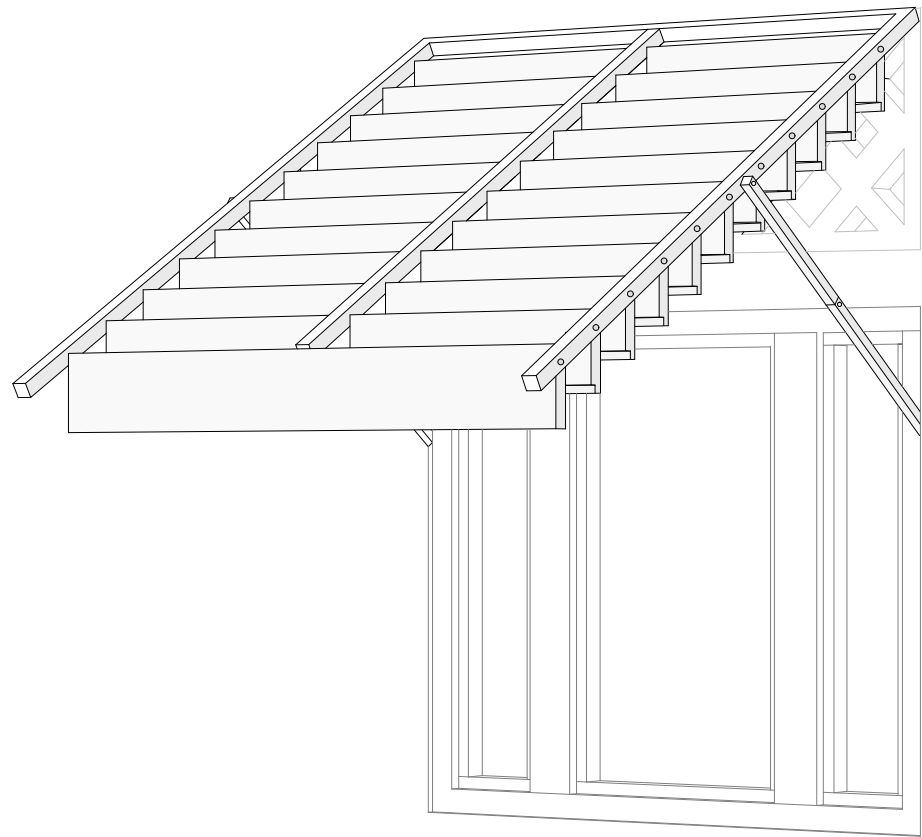
For the school, I decided to use a different system. Here I have slidable panels next to the windows. The planks have the same system as the ones in the clinic and interlock when closed. There have to be additional rails attached to the facade that can be torn off, but when the screen is moved in front of the window, it sits in the wall, not connected to the rail outside. These shutters can be opened completely, moved into the window sill to shade the inside or can be completely closed to protect from wind. The exterior spaces have an extra panel to protect the big opening.



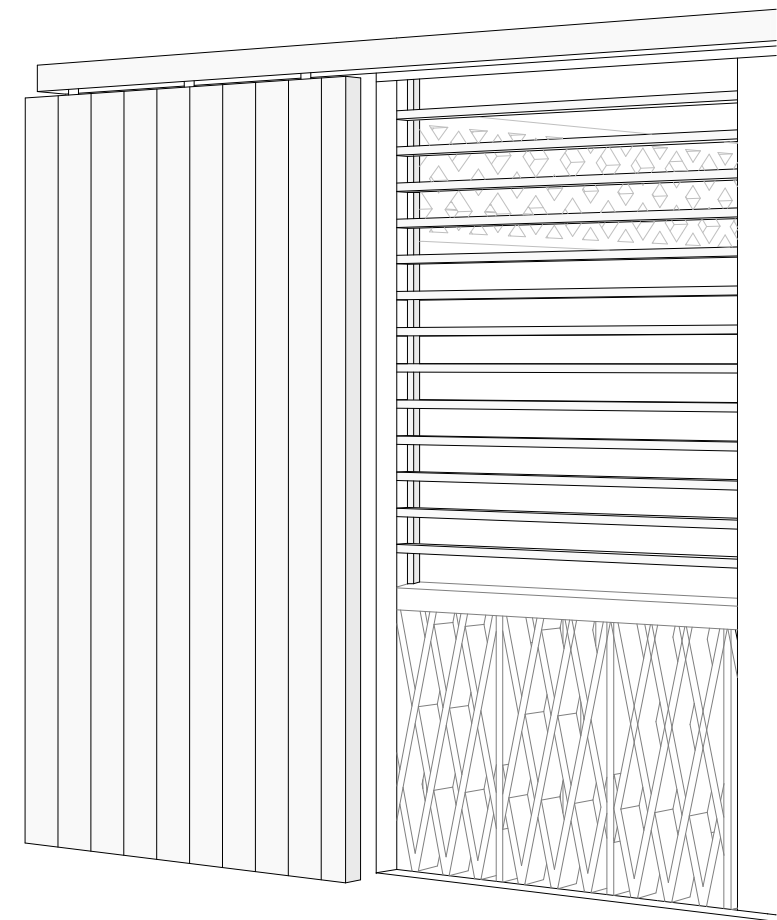
Facade Section with foldable wooden screen (open)



Facade Section with foldable wooden screen (closed)



Facade clinic with foldable screen



Sliding-screen for school (exterior space) - two panels





6 REFLECTION

As we have seen, architecture can strongly influence the effects disasters have on individuals and on communities. Therefore, I would like to conclude my thesis with a reflection about how architects can influence disaster resilience both on a building and on a community level. Already today, humanitarian architecture plays a major role in disaster management. However, as stated before, a lot of organizations focus on disaster relief, mostly in the form of providing shelter for those displaced, instead of building resilience beforehand, and in this way, reduces the effects disasters have on the communities.

Architects should not only focus on the one building they are working on, but rather see the entire context their project is based in. In this chapter, I will discuss how architects can not only contribute to safer communities by creating safer buildings but how they can also help to improve the resilience of an entire community (Booth, 2012). This means that architects have to adapt themselves to the changing environment, with more disasters and environmental extremes worldwide, as well as the access to new programs, materials, construction methods but also new problems arise.

This chapter reflects on the findings of my thesis, and on what they mean for architecture in general. Finally, I would like to draw conclusions on how the work on this thesis progressed, as well as the challenges I faced while writing it.

6.1 ARCHITECTURE AND RESILIENCE

The role of an architect is much more than just taking care of one building. Architects need to find a balance between social responsibility, design, and construction. When it comes to resilience, architects can bring valuable solutions to ensure the safety or functioning of a single building up to entire communities. Resilience can be increased by reducing vulnerability and increasing the coping capacity of communities. I would like to discuss several in which architects can contribute to resilience.

SUSTAINABILITY

First, I would like to introduce the concept of sustainability, and how architects can apply it to reduce disaster risk. Architects can manage to reduce costs in production and construction as well as operating costs.

Additionally, using mostly local and cheap materials creates other advantages. It makes it easier to reconstruct and repair damages done by natural hazards, which gets the affected community back to the normal state more rapidly. Furthermore, in this way, and using environmentally friendly materials and construction techniques, emissions can be reduced, which drive global warming and climate change. As mentioned before, disasters caused by flooding and storms are predicted to become more frequent due to the warmer climate and higher sea surface temperatures driven by climate change (IPCC, 2014b). Use of greenery not only helps to decrease the heat in urban areas but also helps in reducing the damages done by flooding; this is often referred to as ecosystem-based climate change adaptation (Konstantina & Athena, 2016).

Identifying and implementing alternative ways of generating energy (e.g. solar panels) or harvesting rain water helps a building to maintain its function even during a disaster, as in this way it becomes independent from outside support. Therefore, implementing sustainability in different areas of architecture can reduce the risk of a disaster.

ARCHITECTURAL SOLUTIONS

Second, I would like to discuss how architectural solutions for buildings in disaster-prone areas can increase resilience. As mentioned before, critical facilities are most important to ensure the safety of people during a disaster. Architects can ensure that these structures are properly built and still function during a disaster. In my thesis, I attempted to apply different methods to ensure the continuous operation of critical facilities. Architects usually have an overview over all aspects of the design and building process. In this way, architects can influence different areas of the building to generate a resilient design.

Local Knowledge vs. New Technology

It is in most cases those people who have been living in specific environmental conditions for generations who know best about the environmental risk their community faces. For centuries, people have adapted to different environmental conditions (Naess, 2012). To ensure resilience, it is important to make use of the knowledge which is there already. Often local building methods and materials already have good properties that help increase the durability of a building. Traditional building-techniques have evolved based on the local conditions, and are thus also often a reflection of a region's disaster risk. Looking back in history, architects can learn from past structures how to improve resilience even if they are not used today. On the other hand, new technologies and programs help the architect during the design process and offer the architect possibilities which past generations did not have. Using simulation software for natural forces and analysis programs can enhance the design of a building

as they can help finding faults before the building process.

COMMUNITY RESILIENCE

One of the most important factors in securing resilience is making sure a community can still function after the impacts of a hazard. This not only means making sure critical facilities can operate and be accessed but also creating spaces that help people to recover and rebuild after a shock.

Urban Layout

Architects should not only focus on single buildings. They can make use of urban planning techniques to shape a neighborhood in being more resilient (Khare & Beckman, 2013). Many problems that occur during and after a disaster can be avoided or reduced by creating a functioning urban layout that takes many different aspects into consideration. As mentioned in the guidelines in chapter 4, the orientation and location of buildings in a neighborhood, as well as height of built structures, is important to shield the community from strong winds. This is just

one example how to improve resilience within a community. However, as cascading effects are especially dangerous, it is important to not only focus on one aspect but make sure all systems in the immediate surrounding area function properly. In this way, it can be avoided that the failure of one system leads to consecutive failures of other systems.

Common Spaces

Community life is often heavily connected to open and common spaces that are frequently used by all members of a community. During a disaster, the normal life of a community is disrupted. Appropriate community spaces can help to increase the resilience of a community (FEMA, 2014). On the one hand, it is important to design protective spaces in the neighborhood that can accommodate people if their houses are heavily damaged or completely destroyed and serve as evacuation centers. On the other hand, in order to maintain the functioning and the stability of the social fabric of a community, social and spiritual

6.2 CONCLUDING REMARKS

spaces are needed to help recover from the hazard (Ha, 2015). In my thesis, I focused on a primary school, as educational institutions are crucial in keeping up the everyday life. Bringing children back to school as soon as possible after a disaster is important to create a feeling of normality and give the older generation space to rebuild. A fast recovery is important for the community to get back on track and continue with the normal lives (Mutch, 2014).

We need to be aware of the fact that the primary goal of disaster preparedness should be to save lives. While houses can be reconstructed, there is no reversion of the fatalities suffered during a disaster.

We cannot prevent natural

hazards, such as a storm or an earthquake, from happening. Architecture can, however, help improve the safety of people and reduce the risk of people losing their lives and communities losing their social fabric and functionality. There is no one size fits all solution for a resilient community but rather many different ways to improve a neighborhood, and the local context has to be carefully taken into consideration. Guidelines for resilient architecture should thus not only focus on the single building but consider the entire community to drive resilience. Considering climate change and the challenges of today's world, architects have to adapt and accept their responsibility for society, to keep people safe from disasters and reduce human suffering.

Writing this thesis has given me the opportunity to explore a topic which has been entirely new to me. Working on such an unfamiliar topic was both, very interesting and challenging. I quickly realized that such a project has to consider a lot of different aspects, which are all interrelated, and that a focus which lies simply on construction is not adequate.

I am aware of the fact that this research is not capable of solving all problems at once, given the limited time frame and scope. However, I think that the research I conducted is vital in order to show an example of how architecture can contribute to disaster resilience. Some of the methods described in this thesis can be generalized to other contexts and in this way benefit other communities, as well.

I believe that architects can do more when it comes to disaster

resilience than retro-fitting the homes of single persons or families. It is important that we as architects look at the bigger picture, as disaster resilience is a global problem that needs to be addressed, and that it is mostly the poor who suffer from the changing disaster patterns.

However, we have to be aware that creating resilience requires the cooperation of all societal areas. Architecture on its own can only contribute to disaster resilience, not achieve it completely. Yet, architecture is a big factor as buildings and urban structures are directly exposed to the hazard, which is especially true if we consider the rapidly increasing global urban population.

I believe that architects have a social responsibility to protect those in need, and I hope that I will get the chance to continue working in the field of disaster-resilient architecture in the future.

7 ANNEX

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