MASTER

Life saving design

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Life Saving Design
The result of this thesis is a working design of a house which protects against natural disasters in Japan. A house which protects against an earthquake, typhoon and a tsunami. The event of the natural disaster can be called as a natural disaster process. This natural disaster process consists of three different stages: ‘Sense stage’, sensing the threat, ‘Act stage’, react in time of a natural disaster and the ‘Progress stage’, this is also known as the rebuilding stage. This thesis is mainly focused on the two last stages by protecting against the three natural disasters and prepare for the post disaster period. Using the ‘toolbox method’ I found answers to protect against heavy earth shocks during an earthquake, protect against uplift, losing stability, flying debris and flooding during a typhoon and the big wave during a tsunami. This toolbox gave me the tools to protect. Tools like seismic base isolation, bamboo scaffolding, elevated living space, window shutters, wind flow manipulating forms and an emergency capsule. This emergency capsule will also be the temporary shelter during the post disaster period. These tools are combined and integrated in a well working house in Japan.

Keywords in this thesis are protect and prepare.
Introduction

The term ‘Smart Living’ can be placed into a broader context. At the first meeting of this graduation studio I noticed that the first thought most of my colleagues had, when hearing the term ‘Smart Living’, is an easier way to do daily routines in the daily living. Easier daily routines like automatically opening the front door at the command of your voice. ‘Smart Living’ in a luxurious context. This luxurious thinking of smart living is more based on living in the Western world. This luxury does not apply for everyone in this world. For some people, life itself is the luxury they have.

People who live in areas where earthquakes happen very often, are lucky when they survive these earthquake attacks. The chance to survive certain natural disasters can be extended in a smart way. The way we build our houses, the way we do our daily routines in these houses and being prepared for a natural disaster can extend the chance of survival.

For me ‘Smart Living’ means ‘Survival’.

It seems like natural disaster occur more regularly than used to be. And these natural disasters causes much damage and the lost of many lives. In this thesis I focus on these natural disasters. Natural disasters which can occur in Japan. Disasters like the earthquake, typhoon and the tsunami. During hurricane Katrina many lives were lost because inhabitants were not prepared. This was not the only impact, many inhabitants lost their homes. And until today many of them still live in their temporary house. My goal in this thesis is to research how a house can protect its inhabitants during an earthquake, typhoon and tsunami. And when a house does not survive such a disaster how can that house be prepared for the aftermath? Prepare for the rebuilding stage after a natural disaster.
Smart Living: Anti Disaster House
Natural Disaster Process

Natural Disaster Process: Problems that Occur

In August 2005 hurricane Katrina was formed on the coast of the Bahama's as a tropical storm. The next few days this tropical storm grew into a devastating hurricane and was heading towards the mainland of the United States. The hurricane left a trail of enormous material damage and caused flooding in the historic city of New Orleans. 1300 people lost their lives and many became homeless. (White House Katrina report, 2006)

By studying the natural disaster process of Katrina I can see that this process can be divided in three stages. The first stage is the ‘sense stage’. In this stage incoming threat of a possible natural disaster is detected and monitored. In the ‘act stage’ the natural disaster impacts on the affected area and inhabitants react to save their lives. The ‘progress stage’ is the post disaster stage. In this part rebuilding of the devastated area takes place. These three stages are well connected to each other and by adjusting one of the stages it can have an effect on another stage in a good or bad way. Nowadays the disaster process of all kinds of different natural disaster has still got a too large third stage. The progress stage still has got a relatively large extent on economic field but also in time of rebuilding.

Stage 1: Sense

To protect people against a natural disaster it is very important to detect an incoming threat. In case of Katrina this hurricane was detected by weather stations connected to weather satellites. The hurricane season is in the period from half July till half November. These hurricanes are caused by collisions between cold winds from Alaska and warm winds from the tropical regions in South and Central America. These wind flows are being detected and monitored by weather stations. In case of Katrina the collisions of these warm and cold winds caused a tropical depression on the coast of the Bahamas and later it evolved into a tropical storm and Katrina was born. The weather stations monitored this hurricane how it evolved into a stronger hurricane and the path it will follow threatening the cities in her way. When they made a prediction of the hurricane path the disaster response protocol was activated for the area that will be affected the coming days. (White House Katrina report, 2006)
In case of Katrina, a hurricane, the detection of the natural disaster is quite simple. Every day weather stations monitor weather behavior to make daily weather forecasts. In case of Katrina there is a relative long period to respond to the threat. It takes a few days after detection before the hurricane impacts in habitable area, but because of the enormous scale of the natural disaster, that few days is still too little to respond. That is why the government of the United States set up a central respond command agency that can react and coordinate in time of disaster. But what if an earthquake happens? Or a dam breakage that causes flooding in a large habitable area? Or in case of a tsunami? Surprise causes deaths. And we are still far too depended of human actions in detecting possible incoming threats. People make mistakes but if it comes to an incoming threat of a possible natural disaster such mistakes cannot be made. The technology of detection is already developed on an automated stage but this process, to warn inhabitants of a threatened area, is still depended on human actions. Which is an important part of the process. Automation of the whole process can warn inhabitants much quicker. But that automated stage, the Sense stage must cooperate with the next stage, the Act stage to make life saving more effectively.

STAGE 2: ACT

When the threat is detected and the incoming natural disaster did not impact yet, we respond and start doing actions to prevent deaths and minimize property damage. In case of Katrina, while monitoring the behavior of the hurricane, disaster response protocols were enabled. These protocols were executed by the FEMA (Federal Emergency Management Agency) that was set up by the government. FEMA is responsible for the execution of these protocols and had command over the entire operation during the natural disaster. Before Katrina impacts inhabitants were warned and requested for evacuation to relatives or friends living outside the emerging disaster area. Large public buildings became available for people who could not evacuate outside the disaster area. Public buildings like football stadiums, high schools and sport halls. FEMA coordinated the transportation of supply like food and water to these public shelters. Inhabitants of a threatened area, is still depended on human actions. Which is an important part of the process. Automation of the whole process can warn inhabitants much quicker. But that automated stage, the Sense stage must cooperate with the next stage, the Act stage to make life saving more effectively.

When Katrina hits the city of New Orleans a dam breakage happened. 80 percent of the city flooded and 300,000 houses were completely destroyed or became inhabitable. Many people became homeless and there was a huge demand for temporary shelter. Because Katrina was one of many hurricanes New Orleans experienced, many people just stay at home and let the storm pass by. The flooding surprises and caused death of many. Isolated survivors had to be rescued and evacuated to the public shelters which became large collective temporary shelters. Dead people were collected and identified and until today there are still people missing. Among the deaths are many old people or sick people who needed special transportation to evacuate during the hurricane, but because of the absence of the kind of transportation they are left behind. FEMA (Federal Emergency Management Agency) had command over the entire operation during the natural disaster. But what if an earthquake happens? Or a dam breakage that causes flooding? Or in case of a tsunami? Surprise causes deaths. In case of Katrina that period was long enough to get a great amount of inhabitants to shelters and other safe areas. In case of an earthquake, a dam breakage or a tsunami the time of impact will be very short or nothing at all. This will result in no time for evacuation and surprise causes death. In this stage there should be a better alternative than evacuation to protect inhabitants against natural disasters.

STAGE 3: PROGRESS

When Katrina hit the city of New Orleans a dam breakage happened. 80 percent of the city flooded and 300,000 houses were completely destroyed or became inhabitable. Many people became homeless. Infrastructure was blocked by water. Supply lines for food and water was cut off. There was no electrical power and connection for communication. Nowadays New Orleans is still in the third stage. The city is still rebuilding. The wounds are still healing. (White house Katrina report, 2006)

The houses we now live in cannot withstand to certain natural disasters. Lives of residents cannot be protected and they have to evacuate to safer location. A shelter or a place outside the disaster area. But what if an earthquake happens? Or a dam breakage that causes flooding? Or in case of a tsunami? In case of Katrina there was a period between sensing the threat and impact of the hurricane. That period was long enough to get a great amount of inhabitants to shelters and other safe areas. In case of an earthquake, a dam breakage or a tsunami the time of impact will be very short or nothing at all. This will result in no time for evacuation and surprise causes death. In this stage there should be a better alternative than evacuation to protect inhabitants against natural disasters.
The disaster process has different problems at every three stages. Problems at the first stage (Sense) and the second stage (Act) affect on how large the third stage (Progress) will be. Nowadays if a natural disaster approaches, the third stage is still too large. In the third stage, there are too many things that has to be restored that could have been prevented by solving it in the first two stages. But also the first stage needs to work better and be connected with the second stage. Sense the threat in time to react effectively. In the second stage, we need a better alternative than evacuation. An alternative that ensures evacuation is no longer necessary. Protecting human lives and property in the second stage ensures the reduction of the third stage. Houses we live in has to be shelters in time of a natural disaster.

STAGE 1: SENSE

The process in this stage is still depended of human interaction. Sensing the threat and warning the threatened area is still depended on human actions. In case of a hurricane a weather station calls security institutions to warn for an incoming threat so they can sound sirens and broadcast on television and radio to warn a threatened area. But this can be done if there is enough time between sensing the threat and impact of the natural disaster. What if that period is very short or is not there at all? In case of an earthquake the sensing and the impact happen almost equally. Therefore, the process has to be fully automated. When sensing the threat the automated system warns the threatened area. Houses react directly and automatically on incoming warnings. No need of human interactions, houses adept on threats and thereby stage three reduces. By detecting and warning in the first stage, the house react and get into a protective stance in the second stage. In the third stage, the house should be rebuild but because of the cooperation of the sense/warning device and the house, the house is protected and rebuild will be excluded.

For example: In Japan they are accustomed to earthquakes. They can protect themselves well against them but they are still inventing new technologies to protect against them. The Japanese company Air Danshin Systems inc. invented airbags for houses. This system consists of a warning device that send an alarm if it senses an earthquake. On that moment an air tank pushes air into large air bags underneath the house. The house gets inflated and the air bags absorb the vibrations of the earthquake. After the earthquake the air flows out and the house gets back into position. In this way the house will be protected and no human interaction is involved. The first and second stage cooperates automatically.

STAGE 2: ACT; THE HOUSING SHELTER

In case of Katrina the second stage mainly consists of evacuation. Inhabitants cannot be protected in their homes so evacuation to shelters and other safe places is the only option. The possibility to evacuate depends on the amount of time between sensing the threat in stage one and impact of the natural disaster in stage two. In case of a tsunami there is little time to evacuate and in case of an earthquake there is no time. That means that the house you live in also has to be the shelter for protection during a natural disaster. The house we live in also has to be a shelter which means that the house we live in must withstand a natural disaster or rather it must survive with acceptable damage. A house can protect lives of the residents and itself in two ways: By an Adapted Form or an Adaptive System.

The use of an adapted form has the advantage that it is already adapted to a threatening situation. Like the houses on poles in tropical areas where flooding occur on a regular basis. Flooding caused by a Typhoon or a raging Tsunami. Or entire neighborhoods built with dome shaped houses which can withstand strong seismic vibrations of earthquakes. The adaptive system is a system which can be applied on the moment a natural disaster is threatening. It can be an easy system like window shutters to protect windows against flying debris during a typhoon.

STAGE 3: PROGRESS; STAGE REDUCTION

The scale of the third stage is greatly reduced. Activities which normally occur in this third stage are already taken care of in the second stage. Important issues which determined the size of the third stage are evacuation, search and rescue, identifying the deaths, rebuilding houses and provision of temporary shelters for survivors. By making houses resistant to natural disasters these issues will be taken care of. When actions be done rightly in the second stage these actions will have a positive effect in the third stage.

If all houses in a city are also shelters during a natural disaster than the activities of rebuilding in the third stage mainly consist of clearing debris to free infrastructure. Houses can reconnect to the city grid and the second stage (Act) affect on how large the third stage (Progress) will be. Nowadays if a natural disaster approaches, the third stage is still too large.
The link between stage 1 and 2 is weak. Information of the sensors is 'manually' transmitted to the people. Sensor -> InfoCentre -> Alarm Emergency Facilities -> Sound Alarm -> Warning by patrol cars in the streets. Too slow! Warning not on time!

Stage 2 only exits of EVACUATION!

to many lives lost in economy lost in stage 3

The link between stage 1 and stage 2 is automated. Automated system in phase 2 reacts directly when sensing threat in phase 1

Acting in stage 2 consist of pre-made preparations and good protection

Adapted acting in stage 2 ensures very less lost of lives and economy.

My thesis is mainly focused on the last two stages. In this thesis I design a house which can withstand the force of three different natural disasters that can occur on a specific location. This is what I call the Anti Disaster House. This housing shelter can withstand the forces of an earthquake, typhoon and tsunami.

The use of this housing shelter is an important adjustment in the second stage of the natural disaster process. The housing shelter is the anti disaster house. A house which can withstand the devastating force of a natural disaster or rather survive with minimum damage. The housing shelter is the key for a better natural disaster process. The main goal of this thesis is to find out how a house can protect the lives of its residents. But during the research I found out that the after shock, the post disaster situation, is also an issue which has to be taken into account. Natural disaster response protocols ensure that lives can be saved during a critical situation. But our protocols to save houses are either missing or in a very poor stage with the result that the third stage will be immensely. Building our houses in a way we can protect ourselves means that evacuation to a safer place is no longer necessary. Our houses are those safe places. The house is the shelter that protects us. The house survives during a natural disaster which means the need of temporary sheltering in the progress stage reduces. Key issues which will be solved during the second stage by using the housing shelters are:

- less need for evacuation
- more protection of lives
- less search and rescues
- less rebuilding houses
- less provision of temporary shelters for survivors.

The Housing Shelter also known as the Anti Disaster House determines the reduction of the third stage. The Progress Stage
Problem Statement
**Research Question**

**MAIN RESEARCH QUESTION**
How can a house prepare its occupants for the impact of the ‘Progress Stage’ of the natural disaster process by protecting that house against strong winds of a typhoon, heavy earthquakes and a tsunami?

**SUB RESEARCH QUESTIONS**
- How can a house protect its occupants against strong winds of a typhoon?
- How can a house protect its occupants against heavy earthquakes?
- How can a house protect its occupants against the impact of a wave of a tsunami?

If the house cannot withstand the forces of the natural disasters, how can the house provide for temporary shelter for its surviving occupants?
Design assignment

The research question states the design assignment. In this design assignment I will search for the right combination of techniques and methods to protect against the typhoon, the earthquake and the tsunami. Developing the right combination of technique and methods which will not affect the three different disaster scenarios in a bad way but should harmoniously cooperate with each other. The right combination which ensures the best protection during the three natural disasters.

During this assignment I will also develop a good preparation in case the house which I will design fails to protect during a disaster scenario. Preparation which can be done during the 'Act stage' to be prepared for the 'Progress stage'. In this part I will develop a temporary shelter which can be used in the rebuild stage when the house is completely destroyed.

Keywords: PROTECT and PREPARE

Method

There are two methods I use to research guidelines to design a working anti disaster house which will answer my research question.

First part is the theoretical part. In this part I try to understand what sort of damages the different disasters can do and how to protect against them. I also investigate the use of temporary housing especially the position of temporary housing in the 'Progress stage', the post disaster stage.

After I have knowledge about design principles for protecting against these natural disasters I do case studies of already used methods and technologies which are implemented to protect against natural disasters.

After this research I have an overview of design principles and examples of methods and technologies to protect. These are my 'tools'. By trial and error I am trying to combine these tools to eventually make the right combination to design the anti disaster house. This 'toolbox method' will be an important part of the design process.
Theoretical
CHARACTERISTICS OF EARTHQUAKES

According to Ambrose, earthquakes are essentially vibrations of the earth's crust caused by subterranean damaging effects on structures, which are generally movements in a direction parallel to the ground surface. During an earthquake, the movements will be in horizontal direction. This movement is devastating for structures which are designed for gravity load in the vertical direction. An earthquake is rather short in duration and will often last for several seconds. Although the earthquake only takes a short moment during this moment, there are several peaks in the magnitude of the vibration. These peaks are the critical moments during this disaster. The intensity of the vibrations of the earthquake depends on the distance from the origin where the earthquake takes place, which is called the epicenter. Longer distance to epicenter from a certain location will ensure less intensity of the vibrations of the earthquake. The vibrations are strongest at the epicenter.

CONSEQUENCES OF EARTHQUAKES

According to Dowrick, there are two basic results of earthquakes (Dowrick, 1977, p3):
- Loss and impairment of human life.
- Lives lost by collapsing buildings and impairment of lives for survivors who lost everything during the earthquake and are in the rebuilding stage.

Ambrose divides these consequences in (Ambrose, 1987, p.49-50):
- Direct movement of structures
- Ground movements of the ground causes a delayed horizontal movement of the structure caused by inertia. This causes a wavelike movement of the structure which can be devastating.
- Ground surface faults
- Earthquakes that cause landslides and therefore cause collapsing of buildings attached to that piece of land
- Tidal Waves
- Ground movements in the water at the shore can set up large waves. These waves are called tsunamis.

Earthquake Resistant Design

In this thesis, the focus is on how to prevent the loss and impairment of human life by studying and understanding the direct movement of structures during the heavy vibrations of an earthquake.

EARTHQUAKE RESISTANT DESIGN

Key words: STRONG, FLEXIBLE

When it comes to earthquake resistant design, there are two things the structure of the house should be. It should be strong enough so it will not collapse or it should be flexible so the structure can move with the vibrations of the earthquake.

There is no universal ideal form how a structure of a building should be to withstand the vibrations of an earthquake. But there are certain guidelines to be taken into account while designing the structure which can withstand the vibrations. The following design principles are described by Dowrick (Dowrick, 1977, p88-90) and the structure should be:
- Simple
- Symmetrical
- Not to be elongated in plan or section
- Have uniform and continuous distribution of strength
- Horizontal members should fail before vertical members

In this thesis the focus is on how to prevent the loss and impairment of human life by studying and understanding the direct movement of structures during the heavy vibrations of an earthquake. There are two reasons: First, our understanding for structural behavior under the influence of an earthquake is for a simple structure easier than understanding the structural behavior of a complex structure. Therefore simple structures can be well designed without complex structural calculations. Secondly, we understand simple structural designs.
better than complex once. It is just a matter of choosing for reliability and knowing this structure can work than choosing for invention and not knowing if this structure will work. Only the use of an complex structure will tell us if it does not work when this structure fails.

Symmetrical
Symmetry is very important in both directions of the plan. A lack of symmetry can produce a torsion effect. Maintain symmetry in the plan ensures for a central gravity point of the building. This is very important to prevent tilt.

The overall shape should not be too elongated
The danger with long building plans, is that there is more chance of different earthquake movements that will be applied to the both ends of the building at the same time. Opposing movements of both ends of the building can be devastating.

A to elongated form in the elevation direction causes swerve on the top of the building. This swerve is caused by a combination of inertia and horizontal movement of the earthquake. Longer buildings have more swerve. For most buildings the height should be less than four times of the width of that building. The slenderness has to be limited. The more slender a building will be the greater the effect of an earthquake will have on the outer columns of a building.

Uniform and continuous distribution of strength
Uniformly distribution of load bearing members will keep the gravity point of the building in the middle to prevent tilt.

All columns and walls have to be continuously from roof to foundation.

The structure has to be as continuous and monolithic as possible

Horizontal members should fail before vertical members
In framed building structures horizontal members should fail before vertical members. This is a life saver to delay the collapse of a structure. If a horizontal beam fails the structure will not collapse completely. If a vertical column fail, every structural member which is resting on this column will collapse immediately.

Horizontal member should fail before vertical members to give occupants of a building more time to evacuate outside the building.

Typhoon

CHARACTERISTICS OF TYPHOONS
A typhoon is a grown tropical storm. All tropical storms develop over water of which the temperature is in excess of 27⁰ (Sinnamon, 1977). A tropical storm is called a hurricane in the western Atlantic or a typhoon in the western Pacific when wind speeds exceed over 120 km an hour. A tropical storm transforms into a cyclone. The cyclone season in the northern hemisphere is between the months July and October and in the southern hemisphere between January and April. A typhoon can have a diameter of 15 km when the typhoon is on an early stage but can exceed to 250 km when growing. Near the centre of a typhoon wind speed can reach and sustain 160 km an hour and there are even higher wind speed measured in the past with speeds of 330 km an hour.

Another characteristic of typhoons is the heavy rainfall. This rainfall is produced around the eye of the storm. The amount of rain that falls during a mature typhoon varies widely and depends on the speed, size and intensity of the rain-producing centre and the topography of the land (Sinnamon, 1977).

Generally it will be 250 to 350 mm per square meter.

In the eye of the storm is also a strong reduction of atmospheric pressure. This can lead to rise of the water level. This is called the ‘storm surge’. The combination of low pressure and the strong winds which blow the water at the shore land inwards can cause flooding in parts of the city near the coastline. During Hurricane Sandy in October 2012 several parts of New Jersey was flooded because of this.

Keywords:
STRONG WINDS
HEAVY RAINFALL
FLOODING
Emergency shelter, Temporary housing, Permanent housing.

In the ‘Progress stage’, the rebuilding stage, one part of the stage is really important. The provision of enough temporary shelter for the affected survivors. According to Quarantelli, emergency sheltering and temporary sheltering correspond to the immediate protection of the survivors against weather conditions during the emergency and the first few days after the disaster. (Quarantelli, 1995)

Temporary housing in the rebuilding stage is also divided in stages. Johson describes (Johnson, 2010) that after the disaster provision of emergency sheltering is needed for the affected survivors. Once the height of the emergency has passed, temporary sheltering is given a few days after the disaster. Next are temporary housing provided where survived families can rebuild their daily lives. This is also called transitional housing. And eventually permanent housing will be provided. But this stage can take several years before it can be established. Especially when many people are affected and the funding is scarce.

Temporary housing is needed because families need to continue and rebuild their lives. This cannot be done in emergency shelters. Families cannot live for years in tents. Weather conditions and other building physical limitations are reasons which make rebuilding lives in tents nearly impossible.

Key concerns regarding to Johnson (Johnson, 2010) are the speed of delivery of emergency shelters and eventually temporary housing. This is accompanied by the provision of these shelters especially when many are affected. Also a key concern are the cost. And what about the function of this temporary housing when permanent housing is established? Can it be reused or recycled?

In this stage looking at the provision of housing. Houses will be built two times just for one family to rebuild his life.

Points of attention
- Temporary sheltering should already be provided in a house. The house should be prepared, in this way, for a post disaster scenario
- The emergency shelter and temporary housing should be one. No transitions in between. Temporary housing with enough protection against different weather conditions.

Stabilty
- Prevent uplift
- Protect against flying debris
- Adapt on flooding

Key words:
- Stability
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Structural principles in school building design: Wall and foundations, Sinnamon (1977)

Patterns of shelter and housing in US disasters, Quarantelli (1995)

Planning for temporary housing, Johansen (2000)

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TYPHOON RESISTANT DESIGN

In the following text are some principles according to Sinnamon explained (Sinnamon, 1977)

Strong winds vs. roofs
The amount of load on a roof depends on the shape of the roof. The slope of the roof determines what kind of load is working on the roof surface. A roof with a slope of more than 30° will get positive loads (pressure) on a large part of the roof surface. The roof elements should be dimensioned sufficiently to bear the load which causes deflection of the roof. A roof with a slope of less than 30° gets negative loads (suction) on a large part of the roof surface. In this case uplift must be prevented by strong connection to walls and further to the foundations.

When designing a roof, try to prevent roof overhangs and canopies. Protruding building parts will be pulled off by strong winds. When considering using an overhang or canopy, secure that part at more corners to avoid tearing. Another solution is to manipulate the airflow with the intention that the protruding part does not get many loads.

Strong winds vs. walls
Walls should either bear load or frame. A building may have a mixture of both. (Sinnamon, 1977)

This must be done to give the building its stability to prevent collapsing. Try to prevent openings in walls to prevent airflow through the building. Airflow through the building causes wind load from the inside of walls and roofs. When applying openings in walls for any design reasons, give it the possibility to close during a typhoon.

One of the most dangerous effects of strong winds during a typhoon is the amount of shattered glass. Occupants inside a house can be wounded very badly because of this. Protecting the windows to prevent shattering glass is required. These protections can be done by using windows shutters.

During a typhoon is always a chance of flooding. Adapt on these circumstances by keeping the house dry. Build on poles is a common use in typhoon active areas.

Keywords:
- Stability
- Prevent uplift
- Protect against flying debris
- Adapt on flooding

Structural principles in school building design: Roof, Sinnamon (1977)

Patterns of shelter and housing US disasters, Quarantelli (1995)

Planning for temporary housing, Johansen (2000)

Planning for temporary housing, Johansen (2000)
Toolbox Method
In an early stage of this project I was aware I would encounter several difficulties while trying to find the right techniques to protect against the three different natural disasters. Each of the natural disasters has got its own characteristics of ways of destruction and therefore different techniques should be used to protect against them. The challenge in this project is to develop the right combination of techniques to protect against all three. One technique should protect successfully against a certain natural disaster but should not work against another technique which protect against another natural disaster. In this way the house should be protected against all three natural disasters and not just against one.

To prevent an endless continues search of the right combination by finding an analyzing of techniques one by one I used this toolbox method to make my search easier is this design process.

In this toolbox method I explore and briefly analyze different techniques to protect against the earthquake, typhoon and tsunami. Eventually I got an overview of techniques and this will be my toolbox. After developing the toolbox, combining of the different techniques was the next step. Combining of the techniques goes by trial and error. If these techniques do not work harmoniously with other techniques I simply use another technique of the overview. I use another tool from my toolbox.

During the case studies and the theoretic study I learned there are key principles for each natural disaster. In this toolbox I got different technique where one or two of the principles are solved for a certain natural disaster.

Keywords for the different disasters are:

**EARTHQUAKE:**
The structure has to be **STRONG** enough or be **FLEXIBLE**

**TYphoon:**
**STABILITY** against strong wind
**PREVENT UPLIFT**
and **PROTECTION** against flying debris.

**TSUNAMI:**
go to **HIGHER GROUND** and **PROTECTION** against floating debris
Used tools from the toolbox 04.2

ANTI EARTHQUAKE
- Seismic Base Isolation
- Fixed integrated furniture

ANTI TYPHOON
- Window protection against flying debris
- Bracing for stability against strong winds
- On poles against flooding
- Weight to prevent uplift
- Float with the wave to minimize damage
In the next case studies are examples of methods for protection I used in my design of the anti-disaster house.
These football shaped houses are called ‘barier’. The intention for this house is that it is already prepared for a coming flood or a tsunami. This house will simply float on rising water or it will carry away by a tsunami. By moving with the wave it will have less damage. This football form gives the house more strength than a normal rectangular house.

I use the same principal for my anti disaster house. The form of that football shaped house creates limitations in the spaces in the house. Therefore I use this principal only for just a small part of the anti disaster house.

Characteristic of these houses is the strength the dome shape has. A dome shape can take more force than a rectangular shape. In time of an earthquake these houses can withstand the strong vibrations. Even whole districts in Japan consist of these dome houses.

The dome shape or rather the bolean form is a form which I use in the floating part of my house. The small part of my house which will float shall be a capsule. This capsule is an important element in the anti tsunami scenario. The bolean form ensures that the capsule can withstand shocks and bumps from floating debris much better when floating on the tsunami.
This house was designed to defend its occupants against danger from outside. Actually not against natural disasters but against criminal activities. Sliding walls and window shutters will secure this safe house by blocking access to the house.

This system of integrated panels to protect widows is an excellent method to protect the windows and doors of my anti disaster house.
Location
In March 2011 Japan was hit by an earthquake which happened in the Atlantic Ocean along the coast of the Japanese island Honshu. Inhabitants of Japan are used to living with experiencing earthquakes in the daily life. During the decades and by experiencing earthquakes in the past Japanese people became expert anti earthquake builders. This day the earthquake caused a tsunami. Japan was not prepared for this and the wave caused the loss of many lives and the destruction of many houses. Until this day, the progress stage is still happening.

The location of the project is chosen, taking into account if the three natural disasters can happen in that specific location. I chose for the Wakabayashi ward in Sendai as the project location. In 2011, 2700 houses were destroyed by the tsunami.

At the coast of this city ward is until today a ‘plane’ landscape with occasionally a few streets or individual houses which survived during the tsunami in 2011.

The house I designed was not designed in the context of the urban area but functionally designed mainly to protect and prepare. Normally in a design process the area will be taken into account. This house will be put into a context afterward. The anti disaster house I designed, is not a house which can stand into a typical normal high dense Japanese district. The house is elevated and in this way the connection with the street will be less. Therefore this house could not fit into a high dense street but should stand on its own. This should fit better in a semi rural area.

Therefore I chose this site in the Wakabayashi ward in Sendai. Many former city blocks were destroyed during the tsunami and in time changed into a grassplot. The chosen city block will be build with several anti disaster houses in green space surrounded with Japanese gardens with on the background surviving houses of the Wakabayashi ward.
Life Saving Design: Anti Disaster House
The general form of the anti disaster house is the cube. I chose for the cube because of its simplicity and symmetry. I kept the structure rather simple to be sure of my understanding of the structural behavior under the influence of the vibrations of an earthquake. I use the cube form to be sure of its slenderness. This form surely passes the test of the chain-rule of slenderness which must be applied to anti earthquake structures. The height should be less than four times the width of the house. In this project the dimension of the house is 8.5m by 8.8 m. So it is more or less a cube and it passes the chain-rule test.

The cube form prevent:
- torsion effects of the structure
- swerve of the top of the house
- simultaneously oppose movements of the ends of the house in the plan direction.

Another reason to choose the cube form is its central gravity point. Symmetrical distribution of floors maintains this central gravity point. The capsule which is the entrance of the house is placed on the ground in this gravity axis. This fixed location of the capsule, to ensure the central gravity point, determines the elevated ground floor of the house. In this way there is still a border between the street and the house while the entrance is in the middle of the house.

The central gravity point is also needed for the seismic base isolation technique.
LACK OF MIDDLE COLUMNS

According to Dowrick, horizontal structural members fail before vertical structural members. (Dowrick, 1977 p80-90) In this structure, I implement this principle of Dowrick. The bedrooms and the bathroom are placed in the upper floors. These floors are equally distributed in the plan but are shifted in vertical direction with 0.5 meter space between the floors. In did this to give the house more diversity in height in the different rooms because of the equal distribution in the plan of the house. The variable height of the different rooms gives a playsful sight when standing inside the house.

Important structural elements should be four inner columns which should carry the weight of the four floor parts and the roof. Four inner columns which should be placed around the central spiral stairs. This gives the following problems:

- The inner columns should be connected with beams to the outer columns to maintain stability of these inner columns. This is very important during an earthquake. The connection of the beams should span the whole width of the house but than those beams will intersect the central spiral stair.
- One of the four columns will block the escape route of the escape capsule.

The inner columns are replaced by diagonal beams which carry the weight of the floor parts and the roof parts one by one. This means when one of those diagonal beams will fail during an earthquake other floors and other roof parts are still maintained so collapsing of the house will be postponed. Now there is more time for evacuation and get all the occupants into safety.

Failure of the discussed inner column will cause collapsing of four attached floors and two attached roof parts. It will probably cause collapsing of the whole house in one moment.

STABILITY

The horizontal stability of the anti disaster house is formed by the diagonal beams and the attached floor and roof elements. The diagonal beams forms with the outer beams in the exterior wall, rectangular triangles. This will prevent torsion effect of the shape of the house.

The vertical stability of the anti disaster house is formed by the stability discs in the facades. These discs consist of a metal frame filled with diagonal placed bamboo sticks. The diagonals maintain stability in the discs and therefore these discs can be used as stability elements in the facades. The discs are connected with a steel substructure which connects them to the corners of the facade. In this way a stiff hull is made.

Stiffness of the shape is needed for the use of seismic base isolation.
Seismic base isolation can be employed to decouple a superstructure from the potentially hazardous surrounding ground motion. (Fey, 2007) In the anti disaster house I also use this technique. The structure of this house is not directly connected to the foundation. It is resting on seismic base isolation elements on the foundation. During an earthquake the house will slowly move in horizontal direction as a whole shape. Therefore it was important to have a simple and symmetric form house, a central position gravity point and a stiff shaped house. Without base isolation the house would vibrate greatly due to the seismic vibrations. Especially swerving of the top of the house will take place because of inertia.

The cubic form, the maintained central gravity point, the absence of the middle inner columns and the stability of the shape has been chosen to eventually use the system of seismic base isolation.
Capturing rainwater
Warned by weather forecast, the anti typhoon scenario is initiated. There is still a few days left before impact of the typhoon. So there will be enough time for preparation.

During the typhoon there is always heavy rainfall. At this preliminary stage of the scenario, water drainage from the roof will be connected to the capsule. This water drainage is integrated in the column of the central spiral stair. The capsule is during this scenario not the entrance anymore but it will be a counterweight to prevent uplift during the typhoon. Rainwater which falls on the roof will be collected into the capsule. The entrance is now based on the left facade at one of the window frames connected with a mobile stair to the street level. In this way access to the outside will be maintained. Meanwhile occupants of this house should do enough grocery and supply themselves just in case there will be a flood and the occupants will be cut off from the outside world after the typhoon.

Protect against flying debris.
A few hours before the impact of the typhoon shutters can be placed in front of the windows. These shutters are integrated in the exterior walls. The shutters are attached to a rail system and can be moved in front of the windows by manually turning down cranks. In this way all the glass windows are protected from flying debris.

Close inner canopy
The entrance of the house is situated in the capsule and this capsule is placed in the middle on street level. Because of this placement of the capsule and the accessibility to the capsule an inner canopy is formed. This can also be compared with some kind of a small atrium. This form has got bad influence on preventing uplifting by strong wind flows during the typhoon. In this way a ‘sail effect’ can occur. It is like wind blowing into a sail of a boat. To prevent this, the canopy has to be closed. While closing the shutters in front of the windows, there is also a shutter which will close the canopy at the front side. The open gap in the bottom can be closed by a moving floor in front of the capsule. This floor can move up and down by using a turning crank. After the shutters are closed and the moving floor has been set up, the form of the house will be a solid and secured cube. The wind flow of the typhoon can now be travelling along the cube form without causing a ‘sail effect’
Impact typhoon

During the impact of the typhoon stability will be maintained by the stability elements in the facades. Uplift will be prevented by the capsule counterweight. Shutters protect glass windows against flying debris. The 'sail effect' will be prevented by closing the canopy.

Now the occupants of this house can just sit relax and wait until the storm passes by.

After the typhoon 1

When the typhoon is over, the shutters can be opened. Water can escape out of the capsule. The moving floor can be taken down so the canopy will be open again. Capsule must cleaned up and prepared to use as an entrance again.

After the typhoon 2

When flooding did occur, do not let water escape out of the capsule or else the capsule will float and do some damages to the inner window frames and the spiral stairs. When the floating does not exceed a depth of 130 cm than house stays dry. Now the occupants just wait until the flood sinks. If extraction is needed, this can be done from the roof, which is the terrace of this house.

PREVENT UPLIFT

During the typhoon there is always heavy rainfall. At this preliminary stage of the scenario, water drainage from the roof will be connected to the capsule. This water drainage is integrated in the column of the central spiral stair. The first step in this part of the scenario consists of closing the doors of the capsule. Now the capsule will be the rain collector due to the watertight doors. Next a mouthpiece of the central drainage in the column of the spiral stair must slide down manually. In this way the mouthpiece will penetrate and connect with a socket in the roof of the capsule. The roof angle will be transformed. In this way raindrops will flow in the direction of the drainage in the column of the central spiral stair. Changing the roof angle is done by turning mobile cranks on each corner on the roof terrace. One day of heavy rainfall will fill the capsule. The capsule is during the typhoon not the entrance anymore but it will be a counterweight to prevent uplift during the typhoon. Rainwater which falls on the roof will be collected into the capsule. The entrance is now based on the right facade at one of the window frames connected with a mobile stair to the street level. In this way access to the outside will be maintained.

ANTI FLOODING. ELEVATED LIVING SPACE

During and days before the impact of a typhoon there is always heavy rainfall. And when there is heavy rainfall there is a hazard of flooding. According to FEMA even in areas where floodwaters are less than 60 centimeters deep, a building can be severely damaged if water reaches the interior. Damage to walls and floors by growing mold can be expensive to repair and the building may be inhabitable because of the health risk while repairs are underway. One way to protect a house or place of business from shallow flooding is to add a waterproof veneer to the exterior walls and seal all openings, including doors, to prevent water from entering. This approach is called "dry floodproofing." (FEMA, 2005) When floodwaters exceed the depth of 60 centimeters, pressure on waterproof walls increases and there is a chance the walls of the building cannot hold. Structural damage of the walls and therefore collapsing of these walls can take place.

This house is built on columns to avoid such risks. With an elevated floor of 130 centimeters above the ground the house is safe for any flooding hazard during the typhoon.
In the picture at the right page you can see the house in fully adapted state when a typhoon occurs. Windows shutters are closed. The doors of the capsule are closed and ready to collect rainwater. The roof slope is adjusted and ramps to the drainage inside the column of the central spiral stair. The inner canopy is closed to prevent penetrating airflows. The emergency stair is placed to maintain connection between inside and outside the house.
The roofslope has to be adjusted to use the capsule as a rain collector. Collected rain from the roof will now flow into the drainage in the column of the central spiral stair.
Raindrops from the roof will be collected in the capsule.
Protection against flying debris will be done by closing shutters. These shutters are integrated in the exterior wall and are attached on to rails. The shutters can be closed by turning cranks.

The scaffold bamboo sticks of the stability elements in the facade will cover some windows. Although these stability elements are transparent, these bamboo sticks are the first layer of protection for some windows.
STABILITY

The horizontal stability of the anti disaster house is formed by the diagonal beams and the attached floor and roof elements. The diagonal beams forms with the outer beams in the exterior wall, rectangular triangles. This will prevent torsion effect of the shape of the house.

The vertical stability of the anti disaster house is formed by the stability discs in the facades. These discs consist of a metal frame filled with diagonal placed bamboo sticks. The diagonals maintain stability in the discs and therefore these discs can be used as stability elements in the facades. The discs are connected with a steel substructure which connects them to the corners of the facade. In this way a stiff hull is made.

I chose for bamboo sticks for scaffolding because of the strength of the sticks. Bamboo scaffolding is a tradition in many Asian countries. Bamboo scaffolding is well known for its capacity to resist typhoons. (Janssen, 2000) There are cases of typhoons where bamboo scaffolds survive where steel scaffolds were blown away.
BERNOULLI’S PRINCIPLE

Airflow also has an important role to prevent uplift during a typhoon. In fluid dynamics according to Bernoulli’s Principle the following applies.

An increase of the speed of the fluid occurs simultaneously with a decrease of the pressure of the fluid.

The anti disaster house is built on poles. The house has got a narrow opening underneath the house of 1.30 m. During a typhoon air flow will go around the whole house including underneath the house. The narrow space causes the wind to accelerate. This is also according a principle of Bernoulli. An increase of the speed of the wind occurs simultaneously with a decrease of the wind pressure. Which means the wind pressure underneath the house is lower than the wind pressure above the house. This causes a force from high pressure area to low pressure area. The house will be pushed down to the ground because of the differential pressure. This will help against the uplift danger.
Anti Tsunami

The probability that a tsunami occurs is very small. But if it happens, the damage will be immense. We can prepare ourselves against an earthquake and a typhoon very well, because we experienced those events more regularly compared to the event of a tsunami. Most of the people living in tsunami hazard areas will never experience a tsunami. But if it occurs, it will take a lot of lives and takes massive damages. By studying the behavior of a tsunami it becomes clear that not only the wave is the devastating part of the event but also the debris it carries with it. So can a house be resistant against a tsunami? The floating debris which will be carried by the big wave will reduce the chance a house will survive the tsunami. Eventually houses will be destroyed by stacking debris to the façades of the house and by pushing huge volumes of water to the facade. Even building the house on poles, with the idea that the water will flow underneath the house, can fail. Stacking debris against the poles can break them.

A primary strategy for saving lives immediately before tsunami waves arrive is to evacuate people outside hazard zone according to NTHMP (NTHMP, 2001). Get to higher ground to get into a safety zone. The risk the occupants of this house will not make it to higher ground is still great.

In this design I developed an alternative escape scenario. An important element in this house is the entrance hall of the house. During the daily live this will be the connection with the street, but in case of a tsunami this entrance hall will be the escape capsule which will greatly increases the chance for survival. This capsule is not only designed to escape but also to be the temporary shelter in the post disaster period. A temporary home in time of rebuilding.

This preparations in the second stage (ACT) of the disaster process, the presence of an escape capsule/ temporary shelter, will not only increase the chance for survival but will also prepare the occupants of this house to be prepared for the third stage of the disaster process (PROGRESS). Temporary sheltering is already provided.

The anti tsunami scenario will be further explained.
Tsunami warning

When tsunami alarms sounds the occupants of this house have an hour time to respond on the incoming threat of the tsunami. During this stage the occupants flee to the escape capsule. This escape capsule is located in the centre of the house on the ground floor. The central spiral stair ensures a good escape route in the house. This central spiral stair is the only traffic space in the house and is well connected to every room in the house. Because of this, the escape route is short and in less than 10 seconds the capsule can be reached by all the occupants.

Preparation of the capsule

When all the occupants take a seat in the capsule the two doors can be closed manually. The occupant take a seat and put on a 4 point seatbelt. And now just wait for the impact of the tsunami.

Launching the capsule

When the tsunami impacts the wave will first push and launch the capsule outside the house. The attached pair of wheels in the front of the capsule will make the launch much easier to ensure that the capsule will escape from the house before the house will collapse by the incoming wave. The tsunami will first lift the back of the capsule and in this way there will be no friction of the body of the capsule with the ground. The pair of wheels can move freely to the direction the wave pushes at. This first movement will be taken over by the wave and eventually lift the capsule to the surface. The capsule starts to float.

Floating on the wave ‘Go with the Flow’

The capsule will float on the water and will be dragged with the wave. The house shall be destroyed by the debris the tsunami is carrying. Because the capsule will float between the debris and just follow the same movement the capsule will not take much damage. The ellipsoid form of the capsule can withstand pressure from outside and can absorb bumps and shocks from floating debris much easier. This ellipsoid form also ensures that floating debris cannot stick onto the capsule. Floating debris like wooden beams cannot puncture the capsule but will simply lead around it because of the curved form.

The center of gravity of the capsule is underneath the vertical symmetric line which ensures stability and prevent capsizing of the capsule. The ellipsoid form also ensures stability. If the form of the capsule was spherical than the capsule would constantly spin around its axis and than for sure this escape ride will be like a rollercoaster ride.

Capsule landing

Once the tsunami has passed the water level will decrease. Once the water level decreases the capsule will land on the ground surface. Stabilized by the low central gravity point and the form of the ellipsoid the capsule will land straight on the ground without cantilevering. The attached wheels on the front of the capsule ensures a stabilized position on the ground surface. Friction between the bottom of the capsule and the ground surface ensures the wheels will not roll and the capsule will not move and stays on the landing spot.
Start ‘Progress stage’
At this moment the third stage, the Progress stage will start. The escape capsule will be from this moment the temporary shelter for the occupants of the destroyed house. On this landing spot the rebuilding stage of the lives of the occupants starts. This will be the spot for temporary sheltering until the debris is cleaned up at the spot of their former house.

Clean up & Pick up
After clearing up the debris at the spot of the destroyed house and after cleaning up the debris on the connected infrastructure this capsule can be picked up and brought back to the same spot this capsule once was placed. This can be done by attaching the capsule behind a car and drag it like a trailer. The attached wheels on the front of the capsule make this kind of transportation possible. Another way to transport this is to attach the capsule to a crane by an integrated hook on the roof of the capsule and place it onto a tow truck and drive it to the spot.

Reconnect
Once put on the same spot the capsule will be reconnected with the former connection lines of the destroyed house. Water, electricity, gas and sewage will be reconnected.

Temporary shelter
On this spot the actual rebuilding stage begins. Rebuilding of the lives of the occupants and rebuilding of their house. The capsule is their temporary shelter. Their living space before reestablishing the ‘permanent shelter’

Rebuild around
While living in this temporary shelter the house of these occupants will be rebuild around the capsule, their temporary shelter. When the house is finished this temporary shelter becomes the entrance hall of the house again.
Temporary Shelter

One of the most important elements of the house is the emergency capsule. During the daily live this capsule will function as an entrance and is the connection with the outside. During a disaster this capsule is the shelter to get protection. During the typhoon this element give another sort protection. It will prevent uplift by being a counterweight. During the earthquake the inhabitants can shelter in this capsule but should not be needed because the house is already earthquake proof. Especially during a tsunami this capsule will be used.

During a tsunami the capsule will be launched by the wave outside the house. Like a boat it will float on the big wave. The movement with the wave and the floating debris causes less damage to the capsule. The capsule is made of a composite of a hard plastic building material with twaron fibre. This composite is much lighter than steel and much stronger. The use of this composite and the use of the ellipsoid form makes the capsule very strong and really resistant against shock and bumps of floating debris. This capsule is not only for protection against the tsunami but it is also an important element for the "Progress stage". This capsule is also the temporary house. Because of this capsule the inhabitants of the house are prepared for the rebuild. They already have an emergency shelter which is also the temporary house where they can live in and rebuild their lives.

This temporary house is for a family with two children. It has got two integrated cabins which are sanitary: one shower cabin and one toilet cabin. Next to the cabins are two heightened elements: one is the sink and one is the kitchen block. In the floor is storage space for sleeping bags and other stuff and from the floor different sitting blocks can transform.
The capsule has got two slide doors. One is the connection with the street and the other is the connection with the anti disaster house. The capsule is during the regular stage the entrance hall of the house and the slide door connected to the street is the front door in this regular stage. The hatches at the front door which are the stair and the canopy are open at all times except in time of a disaster. In disaster mode these hatches can close manually to protect the occupants inside the capsule. The slide door from the capsule to the house is also at all times open except when a disaster occurs.

The toilet in this capsule is the regular toilet which will be used during the normal stage.

On top of the capsule is a rain water socket. The mouthpiece of the drainage in the column of the central spiral will be fitted in this socket during a typhoon. Next to the socket is a gargyle. This opening prevents an outburst by water pressure when the capsule, as a rain collector, gets overloaded. Too much rainwater can escape here.

At the right end of the capsule is an integrated hook. After a tsunami this capsule can be picked up by a car by attaching the integrated hook to the tow bar of the car. The wheels on the opposite side can move freely when the capsule is attached to a car. In this stage the capsule can be transported like a caravan. The wheels on the capsule are not only for transportation but are also for stabilization at a certain place.

Underneath the capsule are the sockets for connections with water, gas, electricity and sewerage. Although these are not the first connections with the whole house, these connections are especially needed for the rebuilding stage. These sockets fit in a docking station which is fixed on the floor on street level underneath the house. In case of a tsunami the capsule can detach easily from the docking station. After the tsunami the capsule will be used as a temporary shelter and will be placed back at the same position. The sockets will be reattached to the docking. This can be done by driving the car over the docking station to position the sockets at the right place. When detaching the capsule from the car the socket will automatically click in the docking station. Water, gas, electricity and sewerage are reconnected. In this stage temporary shelter is provided and rebuilding of the lives of the occupants can start.
front sliding door
hatch to storage space
sliding door/ access anti disaster house
transformable furniture blocks
hatch to storage space
front sliding door
docking station in the floor of the house on street level. Connection of water, gas, electricity and sewerage to the capsule
socket for connection with water, gas, electricity and sewerage to the capsule
integrated hook
gargoyle
rain collector socket
The temporary shelters already have a designated place. The place where the house was is now the place where the temporary shelter can reattach itself to the docking station. Normally there is a transition between temporary shelter and permanent housing. The transitional houses have better comfort than regular temporary shelters which are normally tents. In this project temporary shelter and transitional house is combined in one. A shelter which is provided really fast and it has the comfort as a transitional house. Comfort in the way of provision of own sanitary and cooking possibilities and better protection against weather conditions and noise.

The rebuilding happens around the capsule. The capsule is already placed where it can be used in a later stadium, when the permanent house is rebuild, as the entrance again. So in this way you can consider the capsule as a temporary shelter and transitional house and in later stadium a part of you permanent house.

Three stages in the field of temporary housing are already considered. Another preparation for the ‘Progress stage’
Anti Disaster House

“FORM FOLLOW DISASTER FUNCTION”
This anti disaster house is designed with the intention to protect and prepare. The term ‘form follows function’ sure did count for this design.

- Cube
  - Cube form as a stable form to protect against vibrations of an earthquake
  - Central gravity point.
  - The capsule is placed in the middle of the house to maintain the central gravity point. In this way the cube form will move harmoniously in horizontal direction when an earthquake occurs without the danger of cantilevering.
- Elevated living space
  - The house has got an elevated living space. In time of a storm surge during a typhoon this house stays dry until 1,50 meters. The elevated living space is also needed for the launch of the capsule in time of a tsunami. The wave of the tsunami can move underneath the elevated living space to give the capsule that first push for the launch.
- The atrium/ inner canopy.
  - The atrium is needed for the capsule launch. This atrium gives the capsule free space to move when a tsunami happen. The atrium is the connection between the street and the capsule which is the entrance of the house in normal conditions when no disasters occur.
- Diagonal bamboo cladding.
  - The facade is clad with diagonal bamboo sticks to give the house its stability. This scaffolding is done at all four façades to give the house stability in all horizontal directions. Horizontal stability during a typhoon, but also stability during an earthquake when moving horizontally which will be caused by the base isolation.
- Roof terrace
  - During a typhoon there is always a chance that a flooding occurs. This storm surge can cause a water rise of several meters. When the rising water level exceed 1,50 m the occupants are forced to go upstairs to the bedrooms. Cut off from the rest of the city and forced to go upstairs, the rooftop is easy accessible. Extraction of these surviving occupants can take place from the roof terrace.
SPACES AND ROUTING

The entrance of the house is placed in the middle and can be reached by a semi atrium. The emergency capsule is the entrance. By shoving the slide front door you can reach the entrance hall inside the capsule. A stair in the capsule leads to the house. The first thing to notice is the U-shaped ground plan. This U-shape is caused by the capsule which is placed in the middle. The ground floor is divided in two clear spaces. At the left side is the living space and at right side is the space for cooking and dining.

In the beginning I got some problems with the staircase, especially in combination with the capsule. These two elements require a lot of space. The fixed position of the capsule determines almost the whole space distribution. The ellipsoid form of the capsule is a very dominant form in the house. The living space is an elevated space for ‘anti disaster’ reasons. In this way the form of the capsule can be half covered. The ellipsoid form transforms into a dome form inside the house. This dome has got a more tolerant form and can easily be combined with other elements. Combining the stair and the capsule saves space for other program. The stair and the capsule are now positioned in the centre of the house.

The plan of the house has got an overall square form. In the upper level the house need 3 bedrooms and a bathroom. The square form can divide the floor plan in the upper level in four even spaces for the bedrooms and the bathroom. The central spiral stair is connected to the spaces in the upper floor. Because of a lack of the middle columns for ‘anti disaster’ reasons, the floor rest on side beams and a diagonal beam. For this reason, there is a possibility to elevate the spaces in the upper floor from each other. By doing this the spaces from the ground floor gets more transparent in vertical directions. View lines between the floors are created and the ground floor has got different ceiling heights. This gives some spaces at the ground floor more intimacy than other. Centralization of the spiral stair ensures no need of further traffic spaces. This saves space for other program. The spiral stair is also connected to the roof terrace. The capsule can be reached easily from every space in the house to ensure a short escape route in case of a natural disaster.
The capsule in the middle of the house is integrated with other elements of the house. Here you can see how the stair is integrated with the capsule and how the furniture is set up to the capsule. In this way the capsule will be embraced.
This is the right wing of the U-shape ground plan. Here cooking and dining can take place. Although this is a semi-separated space from the living part, it is transparent and therefore it has a better connection with the living space by view. The capsule is in this perspective well observable as a whole form.
This is one of the bedrooms. The bamboo scaffolding cover a part of the house. Every bedroom and the bathroom has got two windows. One covered with bamboo and one total transparent. In this image you can see clearly the crank to move the windows shutters during a typhoon. This crank is demountable.
The central spiral stair which connects to the rooms and the roof terrace.
Another room with playful sunlight rays caused by the bamboo scaffolding. In this image you can also see the open separation closet. Fixed integrated furniture to protect the occupants of the house against falling furniture during an earthquake.
steel plate to connect scaffolding construction to the square hollow column
Reflection

This design thesis gives a scenario how I could protect against the three natural disasters and how I could prepare for the Progress stage of the natural disaster process. By doing this design thesis I answered the research question. Although I answered the question, I am convinced that there are several right answers to these questions. By using the toolbox method, I developed my ‘decision making’ abilities. The toolbox method prevented an eternal quest for finding the right techniques which can answer my questions. But with that large amount of tools I needed to make the right decisions for the perfect combination of techniques to protect against all three natural disasters. During the use of the toolbox method I found several right techniques to protect and prepare which can combined with each other. That is why I think there are several right answers. There are several working scenarios. Eventually the decisions I made was based on a level of interest and not about what is the best protection of a certain natural disaster. The road a chose in the design process, the scenarios I picked, was the base foundation of the overall concept. From that stadium I refine and refine until I got a steady working overall design. Not only in protecting against the natural disasters but also to function as a house. This thesis gave me the opportunity to think more outside of the box and push my boundaries. In the beginning of this graduation studio I had different feelings about the topic I choose. The topic was a bit daring and seems more like a science fiction than reality. But there was a challenge. Now I finished this design thesis I have the feeling it sure can be reality.
Source


Johnson, C. (2010). Planning for temporary housing. Rebuilding after disasters From emergency to sustainability (p.70-87)


FEMA (2005). Protecting against water damage. In, Protecting your home or small business from disasters (p2-8)

Images

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