welcome selamat datang

michiel mollen ~ an alternate strategy in tsunami mitigation

MSc graduation
explore lab 8
30 minutes presentation

MSc graduation
explore lab 8
30 minutes  presentation
15 minutes  questions & answers

MSc graduation
explore lab 8
30 minutes  presentation
15 minutes  questions & answers
15 minutes  jury assessment
30 minutes  
**presentation**

15 minutes  
**questions & answers**

15 minutes  
**jury assessment**

**conclusion**

MSc graduation  
explore lab 8
30 minutes presentation
15 minutes questions & answers
15 minutes jury assessment

conclusion
drinks at the ‘bouwpub’

MSc graduation
explore lab 8
4 million inhabitants holland is populated 5 times denser

aceh
BLANKE WAPENS
uit de gordel van smaragd

J.G. Dieles
1873 - 1903
war against Dutch army
1873 - 1903
war against Dutch army

1940 - 1945
Japanese occupation
1873 - 1903
war against Dutch army

1940 - 1945
Japanese occupation

1976 - 1979
GAM rebellion
1873 - 1903
war against Dutch army

1940 - 1945
Japanese occupation

1976 - 1979
GAM rebellion

1989 - 1991
renewal GAM activities with support from Libya and Iran

1990
GAM starts peace talks

2003 - 2004
Indonesian offensive in Aceh

2005
peace
1873 - 1903
war against Dutch army

1903 - 1940
Japanese occupation

1940 - 1945
GAM rebellion

1949 - 1959
renewal GAM activities with support from Libya and Iran

1990
GAM starts peace talks

2003 - 2004
Indonesian offensive in Aceh

1999-2004
increasing violence

2005
peace
1873 - 1903
war against Dutch army

1940 - 1945
Japanese occupation

1976 - 1979
GAM rebellion

1989 - 1991
renewal GAM activities with support from Libya and Iran

2003 - 2004
Indonesian offensive in Aceh

2005
peace

2003 - 2004
Indonesian offensive in Aceh

1990
GAM starts peace talks

1999-2004
increasing violence

2005
peace
december 26th 2004
167000 people died
Normal situation

Fault
167,000 people died.
Disturbance

Ebbing tide

Sinking

Earthquake epicenter
Propagation

\[
\text{Velocity} = \sqrt{g \text{[m/sec}^2\text{]} \times d \text{[m]}}
\]
Coastal flooding

Overlapping primary waves

Speed reduction
4 km inland
Banda Aceh population growth

300,000 inhabitants
Banda Aceh population growth

2004 2005 2006

300,000 inhabitants

110,000 dead
Banda Aceh population growth

300,000 inhabitants

340,000 inhabitants

110,000 dead

2004 2005 2006
temporary housing barracks
equitable aid?
equitable aid?

humanitarian relief per beneficiary in 2005:

Figure 1.2  Equitable aid? Humanitarian relief per beneficiary, 2005

1 Source: Development Initiatives – total aid received inside and outside UN appeals, sourced from OCHA FTS, using UN beneficiary estimates.

2 The multi-agency Tsunami Evaluation Coalition reports funding of “around US$ 8,000 allocated per survivor”, based on a total funding figure which includes reconstruction over several years and using a smaller estimate of beneficiaries than that used by the UN.
equitable aid?

humanitarian relief per beneficiary in 2005:

Figure 1.2  
Equitable aid? Humanitarian relief per beneficiary, 2005

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2 The multi-agency Tsunami Evaluation Coalition reports funding of “around US$ 8,000 allocated per survivor”, based on a total funding figure which includes reconstruction over several years and using a smaller estimate of beneficiaries than that used by the UN.

Focus on neglected crises
UE research output 3 topics
research output 3 topics

1. housing vacancy
over 50 % empty
electricity
tapwater
sanitation
agriculture
employment
cut off from city infrastructure
5000 houses built **99% inhabited**
$ 7 billion assigned
$ 7 billion assigned
research output 3 topics

1. housing vacancy
research output

3 topics

1. housing vacancy

2. loss of resilience
networks
networks collapse resilience is lost
village structure gampongs
village structure gampong
village structure gampongs
village structure
gampongs
village leader keucik
village schools
mosque
research output

3 topics

1. housing vacancy
2. loss of resilience
research output

3 topics

1. housing vacancy
2. loss of resilience
3. another tsunami?
another tsunami? sumatra fault line
another tsunami? sumatra fault line
another tsunami? sumatra fault line

pressure builds for 200 years
another tsunami?  sumatra fault line

pressure builds for 200 years

released over 40 years
another tsunami? sumatra fault line
another tsunami? sumatra fault line
another tsunami? sumatra fault line

mitigation?
3 topics

1. housing vacancy
2. loss of resilience
3. another tsunami?
tsunami
tsunami
  help
  do nothing
tsunami

- help
- prevent
- do nothing
- cure
move people away
tsunami alarm
mangrove bufferzone
tsunami proof housing

escape building

shelter + wat-san

housing
roads + bridges
fishing boats

microfinance

do nothing
help
prevent
cure

help
prevent
cure

prevent
cure

help
do nothing
tsunami?
tsunami escape building
no tsunami?
no tsunami? social functions
no tsunami? social functions

aula
no tsunami? social functions

aula soccer
another tsunami?
another tsunami?
another tsunami? people are temporarily locked in
another tsunami?
another tsunami?

shelter becomes aid center
location?
inhabitants before: 7500
after: 400

LHOKNGA
LHOKNGA
2004 tsunami
5 km/h 5 min. 416 m
last man closes the door
last man? .....
no door
no door
dive bell  air pocket
air pocket
bubble how much air do we need?
bubble  how much air do we need?
bubble  how much air do we need?

400 people  in Lhoknga
bubble how much air do we need?

400 people in Lhoknga

1.5 hours submerged
bubble how much air do we need?

400 people in Lhoknga

1.5 hours submerged

2700 m³ air content
shape a ship shaped dive-bell bunker
a ship shaped dive-bell bunker
shape a ship shaped dive-bell bunker
shape a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker
shape a ship shaped dive-bell bunker

2700 m³ air
shape  a ship shaped dive-bell bunker

2700 m³ air

1:4

12 m
shape a ship shaped dive-bell bunker

2700 m³ air

12 m

1:4
shape a ship shaped dive-bell bunker

2700 m³ air

16 m

64 m

12 m

1:4
shape a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker

soccer stand
shape  a ship shaped dive-bell bunker

soccer stand

bamboo

70 mm diameter
10 m maximum length
shape  a ship shaped dive-bell bunker

soccer stand

concrete
reinforced
26 x 1 x 1 m
shape  a ship shaped dive-bell bunker

soccer stand
**shape**  a ship shaped dive-bell bunker

soccer stand

**ball joint**
glued in hardwood end tip
soccer stand

ball joint

glued in hardwood end tip
shape  a ship shaped dive-bell bunker

soccer stand
shape  a ship shaped dive-bell bunker

soccer stand

bamboo
70 mm diameter
10 m maximum length
shape: a ship shaped dive-bell bunker

soccer stand

lashing: narrow bamboo strips
shape

a ship shaped dive-bell bunker

lashing

narrow bamboo strips
shape  a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker

400 people
shape  a ship shaped dive-bell bunker

400 people

3 door openings
2.5 m tall
2 m wide
shape a ship shaped dive-bell bunker

400 people

3 door openings
2.5 m tall
2 m wide

5 min.
1800 people
shape  a ship shaped dive-bell bunker

tsunami waves
shape  a ship shaped dive-bell bunker

fully submerged
shape  a ship shaped dive-bell bunker

interior
shape a ship shaped dive-bell bunker

fully submerged
shape a ship shaped dive-bell bunker

fully submerged

air pocket bubble
shape  a ship shaped dive-bell bunker

fully submerged

tsunami water
**shape**  a ship shaped dive-bell bunker

fully submerged

- air pocket bubble
- tsunami water
shape  a ship shaped dive-bell bunker
shape a ship shaped dive-bell bunker

dam

slope
shape a ship shaped dive-bell bunker

air quality
shape  a ship shaped dive-bell bunker

air quality

stale air
shape  a ship shaped dive-bell bunker

air quality

stale air
shape  a ship shaped dive-bell bunker

V shaped columns
shape  a ship shaped dive-bell bunker

V shaped columns
shape  a ship shaped dive-bell bunker

forced ventilation
shape  a ship shaped dive-bell bunker

natural ventilation
**shape**
a ship shaped dive-bell bunker

natural ventilation
shape a ship shaped dive-bell bunker

fully submerged
shape  a ship shaped dive-bell bunker

forced ventilation
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact

weak spot
shape  a ship shaped dive-bell bunker

roof impact

bijlboeg  ax  bow
shape  a ship shaped dive-bell bunker

roof impact

lijnenplan  hull lines
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact

lijnenplan  hull lines
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact

lijnenplan  hull lines
shape a ship shaped dive-bell bunker

roof impact
shape  a ship shaped dive-bell bunker

roof impact
**shape**  a ship shaped dive-bell bunker

floorplan
shape  a ship shaped dive-bell bunker

floorplan
shape  a ship shaped dive-bell bunker

3 x 2 m door openings entrance
shape a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker

stage
shape a ship shaped dive-bell bunker
shape  a ship shaped dive-bell bunker

V shaped columns
shape  a ship shaped dive-bell bunker

ventilation shafts
shape  a ship shaped dive-bell bunker
construction of a concrete monolith
construction of a concrete monolith

3 directional reinforcement
construction of a concrete monolith

on location wood cast mold
construction of a concrete monolith

wood cast mold
construction of a concrete monolith
construction of a concrete monolith

prevent bulging by heavy liquid concrete
construction of a concrete monolith
construction of a concrete monolith
construction of a concrete monolith

tighten bolts and nuts on centerpen
construction of a concrete monolith

reinforcement first, then liquid concrete
construction of a concrete monolith

stainless steel endcones on centerpen
construction of a concrete monolith

90 mm diameter centerpen tube fill-in perspex core
interior  entrance hall
interior entrance hall
exterior
terima kasih  thank you
bamboo ball-joint

Concrete wall 1 m thick

Rounded cone gap diameter 210 mm

Bamboo pipe diameter 70 mm maximum length 10 m

45° slot prevents splitting

Hardwood tip diameter 70 mm glued in
centerpens and tiling

900 x 900

900 x 780 = 0.7 m²

150 mm diameter
perspex centerpen core replacement

- Perspex rod
  - Length: 980 mm
  - Diameter: 90 mm

- Stainless steel cone, 25 mm inward thread
  - Length: 50 mm
  - Diameter: 150-90 mm

- Steel pipe with 25 mm outward thread at endtips
  - Length: 950 mm
  - Diameter: 100-90 mm

- Metal springclip
handrail

bamboo pipe
diameter 70 mm

hardwood core
diameter 50 mm
bolted on

 glued in

steel pipe
30 mm diameter
welded framework

concrete
cast in situ

300 mm
1500 mm
500 mm
200 mm
M8
Welcome to this final thesis presentation. For those of you who don’t know me, my name is Michiel Mollen.

In the coming thirty minutes I will give you a summary of the work I have been doing over the last year. My story tells about both research and design. After this half hour there will be 15 minutes for questions and answers. Following these 45 minutes, the examiners will discuss their verdict, hopefully resulting in a Master of Science degree in Architecture. If so, there will be drinks at the faculty café after that. But before we can head for the pub, there is still some work to do. There is a lot to tell, so let’s get started.

First of all the story takes us to Indonesia. One of the bigger Indonesian islands is called Sumatra. On the most northern tip of Sumatra we find the province Aceh, with its capital city Banda Aceh. When compared to the Netherlands, Aceh has a 20% bigger land surface area, but it has just 4 million inhabitants. In other words: Holland is populated five times denser than Aceh.

Due to its strategic geographical position at the entrance of the Malacca Strait, Aceh was already connected to the global shipping routes quite early. Several colonists, like the Arabs, Chinese, Portuguese, British and Dutch have set foot on Aceh. The main trading commodities were pepper and coffee. The Arabs brought Islam to Indonesia through Banda Aceh. Banda derives from their word for ‘gateway’. Since then Indonesia has developed into the largest Islamic country worldwide, with 270 million Muslims. Aceh recently has been submitted to the super strict Shari’a laws, making it one of the few places worldwide where medieval practices revive and people get sentenced to public caning or stoning. Specialized Shari’a police arrests ladies for wearing jeans in public, and breaks up romantic couples in the park. Alcohol, gambling, adultery, all of it is strictly forbidden and harshly punished, including the violent involvement of neighborhood posses.

The Acehnese have always been warriors, fighting for their independence and pirating the shipping routes along their coast. For centuries the Dutch had ruled Indonesia, except for Aceh. The 19th century brought a deal between the Netherlands and the UK, allowing the Dutch to start a war there, without having to fear any British interference. The price the Dutch paid the Brits for this deal was their last African colony in Goldcoast. The province of Aceh has been suffering from many periods of violence ever since. First there were the decades of war with the Dutch, then the Japanese occupation during WW II, and after that, several decades of armed resistance against Indonesian annexation. In 2005 a peace treaty between the Indonesian government and the Acehnese rebel army was signed under remarkable circumstances.
On December 26th 2004, Aceh was hit by the biggest natural disaster in recorded history. There was a massive earthquake, followed by a major tsunami. The epicenter of the December 2004 quake was close to the Sumatran west coast. The most affected area was the province of Aceh. An estimated 167,000 people died that day, equaling the immediate death toll of the Hiroshima and Nagasaki bombings combined. Tsunamis are caused by sudden movement in the earth’s crust, like with this big earthquake. Strong waves are formed, that start breaking violently when they reach the shores. Their endless power destroys almost everything they meet. The waves completely stripped a three kilometer wide area from all built structures. At some places the water ran up to ten kilometers inland, taking tons of debris, cars, boats, and people with them. This large ship was left in the middle of the city Banda Aceh, 4 kilometers inland. The scale of the destruction is hard to imagine. The capital Banda Aceh lost one third of its earlier population of 300 thousand, while some villages even lost 95% of their inhabitants.

Both the Indonesian Army and the rebel army got involved in the early stages of the recovery work, leading to the 2005 peace agreement I mentioned earlier. The global response led to an enormous influx of aid money and organizations, followed in their wake by fortune hunters, companies, media, and researchers, all contributing to the chaos. Half a year after the tsunami the Indonesian government created a coordination agency, called BRR, or Buro Rekonstruksi Rehabilitasi. It was operational for five years, attempting to streamline the work done by the many organizations. At some point an estimated 500 aid organizations where operational in Aceh, and the population of Banda rose rapidly from 200 thousand to 340 thousand. One of the daunting tasks for the aid organizations was to swiftly supply the homeless with shelter. Inflation soared through the roof. To illustrate the amount of money sent to Aceh: there were countries in Africa that received less than $30 per beneficiary that year, while in Aceh that was $1200, forty times as much.

I travelled to Aceh February 2009, as a part of the Urban Emergencies research project. You can read a lot more about our research through www.indonesia-urbanemergencies.blogspot.com. Our three months of research in Aceh taught us a lot of reconstruction work has been done in the past five years. Over 100 thousand houses have been built, roads and infrastructure have been restored, a lot of it under the supervision of the BRR. The new built areas resemble strange bungalow parks, with countless little houses in rows, all identical. Some of the new villages are vibrant, while others aren’t.

We concluded our research with three main observations. The first and most striking fact was that over half of the reconstruction housing is empty. We discovered there were simply too many houses built. A lot of different estimates circulated on how many new houses
were needed. Lots of people received more than one house, and young orphans even got their own house, while now living with relatives. There is another issue causing the high vacancy rates: the poor quality of the 36 m² houses, combined with the poor urban planning of these areas. Another cause was that people can’t find any ways of developing a livelihood in these desolate neighborhoods. There is no room for agriculture or shopkeeping. Water and electricity connections aren’t available, houses lack kitchens and sanitation, whole blocks are cut off from the rest of the city by crude sewer constructions that permanently obstruct entrance roads. But there are a few successful examples of reconstructed neighborhoods. UN Habitat for instance took the approach of having survivors rebuild their own houses under guidance. This might seems a slow and difficult approach when compared to ‘simply’ handing out houses, but it led to the construction of nearly 5000 houses, that are practically all in use, since they closely match the wishes of their occupants.

When we look at the effectiveness of the global aid money, things look rather grim. An estimated $7 billion was assigned to tsunami recovery. In the end $2 billion ended up as built houses, but over half of those houses are useless. In general we can say there are many reports of corruption and scams related to reconstruction money. Piracy apparently isn’t just a phenomenon from history. Some other costly initiatives, like the construction of coastal tsunami buffer zones, are downright daft. They consist of freshly planted mangrove forest areas that will never withstand the impact of future tsunamis. This is what happened to a full-grown coastal forest in last tsunami.

A second remarkable fact surfaced. Even though a lot of the aid effort and money has gone into replacement of the material things lost in the disaster, the biggest loss in the disaster wasn’t material. With the death of so many people, a far more important thing was lost: resilience. If so many people die, you can imagine all kinds of social networks collapse. Abilities, knowledge, experience, labor force, access to supply chains are all destroyed. Those surviving will have a hard time recovering; now they first have to reconstruct a society and its networks, before they can start rebuilding their material world. This makes them highly dependent on imported aid. You can imagine a recovery approach similar to the one taken by UN Habitat would be even more successful if a cohesive society still has its networks running and with that still has a fair share of resilience.

One of the existing stronger social cohesion units, is the gampong, which is a mixture between a neighborhood and a village. A lot of the social networks I was just telling you about extend to the scale of a gampong. Each gampong has its own village leader, entrance gates, schools, mosques, shops, coffee bars, and even soccer team.
A third fact made me question the existing reconstruction strategies even more. We came across a seismology report predicting more tsunamis in the next 35 years. It explains fault lines, like the Sumatran fault line, build up pressure over 200 year time spans. Then the pressure is violently released in several seismic events during roughly 40 years. This could mean all the stuff that was built since 2005, might be wiped off the face of the earth in the coming 35 years. That sounds like an awful waste of time and money to me. Former US president Bill Clinton coined the slogan “build back better” for the tsunami recovery effort. It remains very questionable whether this actually has been achieved. Aside from some tiny, Japanese constructed, wave breakers we haven’t come across any real interventions that might actually achieve any level of tsunami mitigation. A simplified road layout, with easily understandable getaway routes in it, would already be an example of measures that could have been taken to diminish the death toll in future tsunamis, but the contrary has been realized, by randomly sprinkling signage across a maze of narrow winding streets.

These 3 facts gave rise to the design I will be explaining to you in the next part of this presentation.

I posed myself the question what I would do for this tsunami prone land. The first might sound crude, but I find it as valid and important as any question. To act, or to not act at all? The answer to this is purely personal, and mine is to act. The next divide occurs between preventing and curing, because I believe preventing is better than curing. Nevertheless I’ll mention a few strategies of both approaches, since both are needed.

Curing has led to projects in providing shelter-water-sanitation, housing and infrastructure reconstruction, livelihood redevelopment programs, like microfinance or the fishing boats that were handed out.

From the perspective of prevention the mangrove forests were made, fishermen were moved kilometers away from the coast, so-called tsunami proof housing was built. To my opinion all of these prevention or mitigation measures cannot be called very effective.

There is an intervention that might actually accomplish something though: the tsunami-shelter. If realized correctly, it might actually succeed in keeping a society alive. The material assets of that society will certainly take a beating from any future tsunamis, but at least its networks, knowledge and manpower remain, and with it a fair share of its resilience.

Like I explained earlier, the most obvious social cohesion unit in Aceh is formed by the gampong. This is reason for me to make that the suitable scale for a tsunami-shelter.
We’ve already seen some forms of tsunami-shelters constructed in Aceh. Most of them opt to provide a safe haven from the violent waves on top of a structure. But how can we be sure the next quake or tsunami isn’t going to be bigger than the previous one? Hiding from the waves by constructing a shelter underground might lead to being flooded or covered in debris, so that isn’t suitable either. I choose to harbor the people on ground level, indoors.

But what good does a ground-level gampong-based tsunami-shelter do a gampong when there’s no tsunami? How can it still serve a gampong any purpose, so over the years it doesn’t fill up with cows or bags of rice? Well, aside from drinking coffee and smoking kretek cigarettes, the Acehnese are fond of two other things: marriage and soccer. Marriages need a ceremonial hall, normally called an ‘aula’. Only the bigger towns have them, like Banda Aceh. The people that can afford to rent one, will go there. For soccer each gampong has at least one team, but often there is lack of a proper stand for the audience. These two everyday functions will provide a use to the tsunami-shelter when there is no tsunami.

So in time, the tsunami shelter has its social role in the everyday gampong life, providing a place for all sorts of community gatherings. And then another big earthquake hits. People flee, in fear of another tsunami. While those that manage to reach the shelter in time, will temporarily get locked inside by the water, but the surrounding world gets destroyed. Aid organizations are aware of the existence of this tsunami shelter, and will come looking for survivors. The shelter from now on will function as a recovery coordination center, where population and organizations meet. As soon as the aid organizations have completed their work here, the shelter will turn back into the social gathering building it was before the quake hit.

So let’s talk about which people, and what place the design will be for. While in Aceh I spent quite some time in a village close to Banda Aceh, it’s called Lhoknga. This place now roughly has 400 inhabitants, of what used to be 7500. This is what it looked like before and after the tsunami, and on ground level. Basically everything got annihilated, up to a level of 30 meters high. Except this old Japanese bunker. This bunker, plus the local cement factory, just 2 kilometers away from Lhoknga, made me think about a bunker typology for my tsunami-shelter.

Another thing was very prominent in the last tsunami: ships. The coast of Aceh was littered with them. Their shape is designed to withstand the waves, to cut right through them. The ship is another typology I will be incorporating in my design.
When the 2004 earthquake hit Lhoknga, the main road got immediately blocked by crashed traffic and panicking people. So before the tsunami came, there was no escape for those who were trying to reach the mountains. This resulted in the deaths of many. The time span between the earthquake and the tsunami was around fifteen minutes. This would allow people some time to reach a shelter, if the shelter is positioned correctly. Knowing the slowest traffic dictates the speed of movement on the road, I assume the speed at which people are moving will still not be much faster than 5 km/h. So if you allow people to run for 5 minutes at 5 km/h, they can cover a distance of 416 meters. So now I know where to put the building. Double either that time span, or that speed, and you double the radius around the shelter, from where people will be able to reach it before the tsunami comes.

So now another question: how can we prevent the people already safely inside, in fear of their own lives from locking others out, causing them to drown? It simply needs to be a system without doors; the dive bell. Lock air under an open cup, and you can fully submerse it! We know Lhoknga has 400 people, and last time the tsunami water drained from the land within an hour and a half. I looked into human air usage and calculated we need to trap 2700 m$^3$ of air inside. This 2700 m$^3$ is taking a safety factor of 12 in account.

The shape of the shelter will resemble a ship’s hull, so it will slice through tsunami waves. Different shapes lead to different behavior, so a 1:4 profile is needed. Since I don’t want the structure to be washed inland like the other ships, I put it upside down, so it gets pushed to the ground, helped by the fact its weight per cubic meter is bigger than that of water. The research I did into the construction of bunkers, taught me to build it without any form of foundation, so it literally just sits loosely on the sand. Its low center of gravity and symmetry will help in keeping it upright, forces from outside will not succeed in breaking it. The Lhoknga skyline has no structures higher than 8 meters, except a couple of tall radio masts. I decided to build no higher than 12 meters. This combined with the 2700 m$^3$ air content and the 1:4 profile, led to the dimensions of the shelter: it will be 64 meters long, 16 meters wide and 12 meters tall.

To maintain the symmetry of the structure, I designed a soccer stand that doesn’t interfere with the shape of the bunker, instead it just uses it as a big rock to lean against. Therefore the stand can be ultra light and will be lost in a tsunami, but can easily be rebuilt. The stand consists of flexed bamboo arches of 70 mm diameter, one every half meter, loosely curved between the bunker and an extra concrete block, each arch pushing itself into ball-joints. Concrete sockets allow free movement in case of earthquakes. By gluing rounded hardwood end-tips into the hollow bamboo, you get a strong component that prevents the bamboo from splitting. In case of a tsunami the arch will snap out of its sockets. Seating is
just provided by 70 mm diameter horizontal bamboo tubes, lashed to the arches by narrow bamboo strips. Lashings like this allow for earthquake vibrations to be absorbed without any damage. A sun cover for the soccer stand provides solar power to batteries inside the shelter. Those batteries power the ventilation and the artificial lighting systems.

The interior of the shelter will allow water to wash into it freely. The air locked inside of the building will stop the water from rising much higher than the top of the three entrance doors. The interior is divided in two halves by a dam. The first half of the shelter is the entrance hall. The central open space and stairs work as wave breakers, handrail frames allow people to climb out of the water. When the tsunami water drains, the sloped center floor will push the last water back out of the building. The second half is the safe zone, the ceremony hall. Here we find a stage that serves ceremonial purposes, but also provides higher ground to get away from heavier polluted air. A wide staircase can be used as a spectator ramp, so the lowest floor can be used for plays and such. Two huge V-shaped columns support the roof at its widest span. At ground level the air is sucked from the room through ventilation shafts under the stage and through the V-shaped columns. Ventilators mounted up safe from water provide the needed air propulsion and blow out into the entrance hall. The under pressure created in the ceremony hall by the ventilators draws fresh air back in. This way all of the enclosed air bubble is in use, maintaining better overall air quality. If the building isn’t submersed in water, wind pressure on the building facades will provide wind suction, mixing stale inside air and fresh outside air in the entrance hall. The building needs to be able to withstand impact from above just as well, since the tsunami waves might break on top of it. Therefore the bunker takes the shape of a ship’s hull, turned upside down. I choose the so-called “bijlboeg” or ax bow as the suitable hull model. The actual floorplan of the escape building is also more fluent than the blocks model I was showing before. It allows for more fluent movement of the crowds. It also shows the ventilation shafts under the podium are connected to the V shaped columns, allowing access for maintenance work.

The concrete structure itself will be a reinforced monolith, cast on location. Reinforcement can be done in such a manner it will prevent rebar to corrode and damage the concrete. By making the rebar 3-directional, the shelter will be able to withstand stresses caused by temperature differences or earthquakes. Massive monolith complexes already existed in the Atlantikwall. The concrete outer shell will be 1 meter thick, able to withstand violent impact from objects or debris in a tsunami. To be able to build this structure, its form will be cast in custom made wooden cast moulds. Those moulds will leave their visual imprint on the surface of the shelter, but also need another item: the center pen. A center pen makes sure
the two faces of a cast mould stay together when the liquid concrete starts putting its weight on them. I’ve redesigned the center pens, so they can be filled with 90 mm diameter acrylic rods after the cast moulds are removed. They will leave the skin of the shelter covered in a grid of 150 mm diameter stainless steel eyes, positioned in 900 mm even sided triangles. Those triangles will be filled in with round tiles of again 150 mm diameter on the vertical surfaces inside. That same grid transmits daylight into its insides and forms a pattern with the round tiles. In darker times those eyes will shine the light coming from the inside of the shelter on Lhoknga.

Thank you for listening.