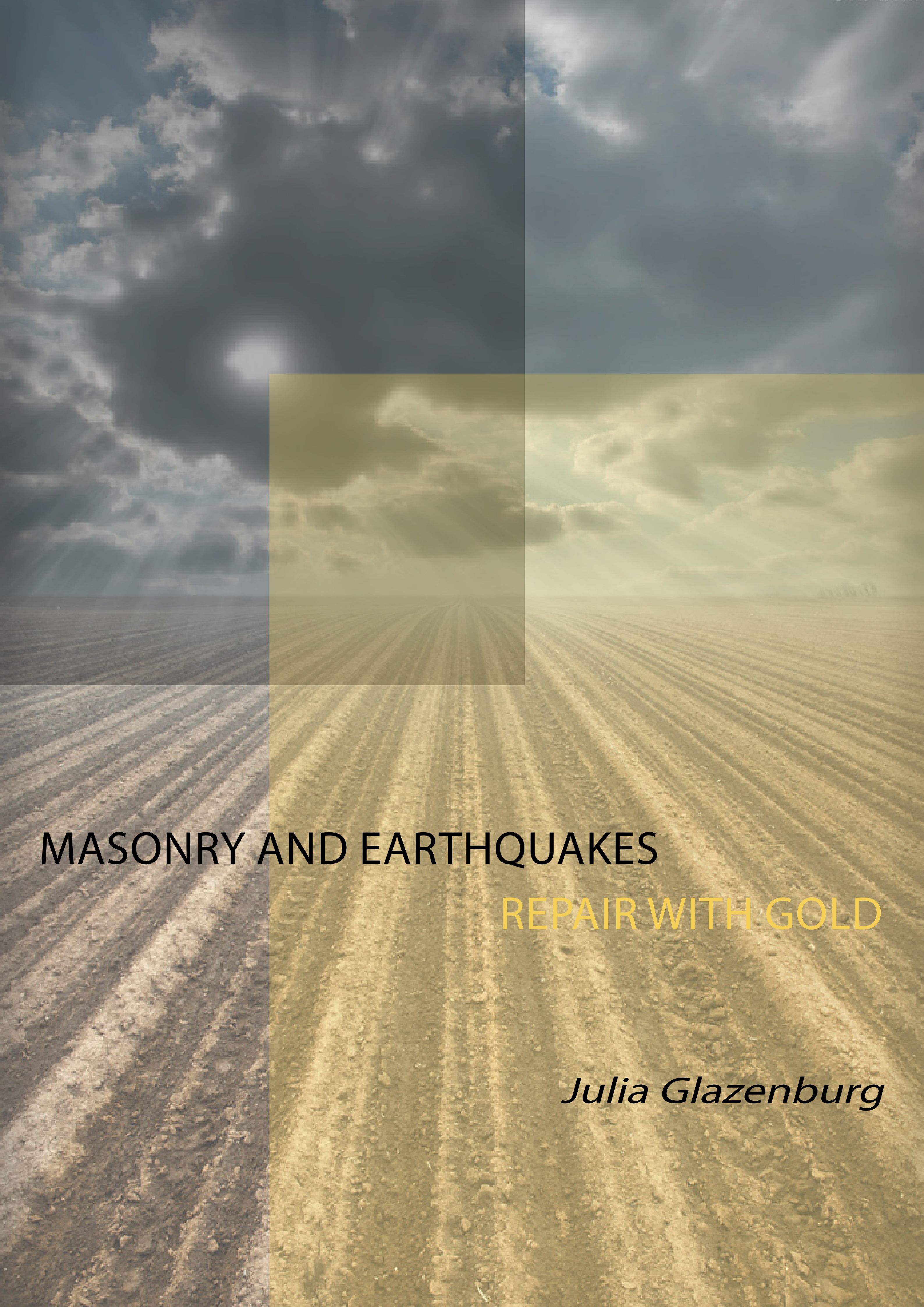

MASONRY AND EARTHQUAKES

REPAIR WITH GOLD

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Masonry and earthquakes
repair with gold

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Abstract

Earthquakes, as a result of commercial extraction of natural gas out of deep soil, has become a frequently recurring phenomenon in the province of Groningen. Historically earthquakes have never been an issue in the Netherlands. The Netherlands is not prepared for this phenomenon. A lot of buildings in Groningen are damaged as a result of earthquakes. Excising buildings lose their value because of these damages. Several, mostly wooden, auxiliary constructions are placed to support the walls. Currently there are solutions, but most of them are temporary instead of permanent.

Most of the Groninger buildings are made out of brickwork. But masonry is the worst you can have during an earthquake. It looks like an easy solution to think about new materials. But how do we keep the existing stock, with a tradition in brickwork, in its monumental quality, while on the other hand we have to think about an earthquake-resistant solution? My goal is to look for a solution to retain the identity of the Groninger brickwork and look for a way to make this brickwork earthquake-resistant as well.

Contents

1. Problem statement

1.1 Location

The seismic area is located in Groningen. Groningen is a province located in the North of the Netherlands(Figure 1). The figure shows in red the province and in dark red the seismic area. The capital city of the province is also called Groningen. In this paper I will discuss the seismic area in the province Groningen. The province of Groningen got its present size in 1814. Since the reorganization of the municipality in 1990 the province exists out of 25 municipalities. For the survey, the province is divided into five areas: Gorecht, the Hogeland, Oldambt/Westerwolde, the Veenkoloniën and Westerkwartier. The Hogeland is the area where earthquakes mostly occur. This area consists out of nine municipalities called: Appingedam, Bedum, Delfzijl, Eemsmond, Loppersum, De Marne, Slochteren, Ten Boer and Winsum. In all municipalities are earthquakes measured, but the municipality Loppersum is the one most affected.[1]

1.2 Company, inhabitants and government

The NAM(Nederlandse Aardolie Maatschappij) is the company that produces the gas. The NAM and the Government are the ones that get profit out of it. The inhabitants are the ones that have to live with the consequences of living in a seismic area created by the gas extraction. In 1960 a natural gas reservoir was found. It turned out to be that under the fields of Groningen, the largest gas reservoir of that time in Europe was located. Until today, this reservoir delivers energy and heat to all of the Netherlands. Since 1960 the NAM is running the gas extractions in Groningen. Back then, the inhabitants were told that those extractions will bring money and employment.[2] In 1986 Dr. Meent van der Sluis concluded that there was a relation between the gas extraction and the earthquakes in Groningen. This was vilified by the head of the NAM. It was in 2013 that the NAM admitted for the first time that there was a direct relation between the extraction and the earthquakes. It is not scientifically proven, but the expectations are that the earthquakes in Groningen come with delay. This means that even 15-30 years after the NAM would stop with gas extraction the area would have to deal with aftershocks and the effects of this.[3] According to the documentary 'Groningen beeft' the strength of the earthquakes increases logarithmically if they will not stop. Until today, the gas extraction still continues. It is the duty of the Government, the NAM and the municipality to ensure that the inhabitants are safe. But the inhabitants say they doubt this because their importance of money and economy is above everything. The inhabitants of Groningen feel powerless, not understood and depending on the NAM and the Government.[4]

Figure 1: Seismic area in Groningen province

1. Panman, M. & Possel,J. (1992) Architectuur en stedebouw in Groningen 1850-1940. [Zwolle, Nederland] Uitgeverij Waanders.
2. Koppen, N. (Producer), de Ruiter, J. (Producer) & Stokvis, K. (Director). (2013). Groningen beeft [documentary]. Netherlands: Selfmade Films & NCRV.
3. Tomale, M. (2015). Bevingen: Aardbevingen in Groningen; ervaringen, gevolgen, emoties. Groningen: Leander. p. 5-23
4. Koppen, N. (Producer), de Ruiter, J. (Producer) & Stokvis, K. (Director). (2013). Groningen beeft [documentary]. Netherlands: Selfmade Films & NCRV.

1.3 Timeline gas extraction

1810
Napoleon signed the first mining code

Napoleon needed coal and steel in order to wage war. To avoid claims of landowners he signs in 1810 the first mine code. From this moment a landowner has nothing to say about the mineral resources under its soil. Until today this is still in the Dutch law

1959
The first bores

The first gas field where it all started lies in the land of the farmer Boon in the village Kolham. At that time no one knows how large the size of it is. The farmer Boon could have been a millionaire but because of Napoleon he's not the one that receives the money.

1963
Gas warfare

Energy companies from all over the world try to get profit out of the gas from Groningen.

1963
The Gas in use

Slochteren produces for the first time, useful gas. After one year there is already 3600 kilometres of pipeline through the Netherlands.

1965
Closure of coal mines

Due to the closure of the coalmines in Limburg increases the importance of the gas in Groningen.

1976
Record amount of gas

The NAM(Nederlandse Aardolie Maatschappij) wins a record amount of gas: 87,8 billion cubic meters of gas. Never they won more gas in the gas extraction history. In 2013 this was 53,9 billion and in 2015 this was 22,2 billion.

1986
First measured earthquake in Assen

On December the 26th the shock was felt in Assen and has a strength of 3.0 on the Richter scale. The earthquake is the result of gas extraction, but at that time a lot remains unclear. Since then over 1100 earthquakes were recorded.

1992
Protests against gas extraction

People saying the 'gas extraction has to stop', that 'the government should give money to the people of Groningen' and that 'the government let them down' sounds like something we hear today. However this is not new and is already said for years.

1993
Middelstum shakes

The village Middelstum was hit by an earthquake with the strength of 2.2 on the Richter scale. Meent van der Sluis, member of the states of Drenthe, alarms. At the same time the independent geologists platform was established and already in 1993 warns for more and heavier earthquakes in Groningen. They feel not taken seriously by the NAM, the KNMI and the Empire. The connection between gas extraction and earthquakes is denied by them.

2000
20,3 billion cubic meters

The NAM mines 20,3 billion cubic meters. Since the seventies there has never been so little gas extracted from the ground.

2006
Agreement for extracting gas from the Wadden Sea

The NAM is allowed to extract gas from the Wadden Sea. After years the government agrees.

2009
50 years of Groningen gas

The natural gas has been an essential part if the Dutch energy for 50 years.

2009
Establishment
Groninger Bodem Beweging
(Groningen soil movement)

The Groningen Bodem Beweging is an initiative of the citizens of Loppersum and strives for the interests of the victims.

2012
Earthquake in Huizinge, a tipping point

An earthquake with the strength of 3.6 on the Richter scale. This strong earthquake was seen as a tipping point for the position of politicians; they can't ignore the seismic area Groningen anymore. Different investigations are launched. The conclusion is that the earthquakes will come more often and stronger in future.

2013
Admission relation between earthquakes and gas extraction

Minister Kamp explains the conclusions of the investigations to the inhabitants. He says the earthquakes will come more often and stronger in future. He also says that there will be more investigations to prepare for the decisions there will be made around the gas extraction. The director of the NAM tells in the same day 'not to be proud on the fact that his predecessors have denied the relation between gas extraction and the earthquakes.

2013
Insurance claim

Max van den Berg, the commissioner of the King wants at least one billion euro from the NAM in order to compensate direct and indirect damage by earthquakes.

2014
Presentation about the decision for gas extraction

Minister Kamp tells the decisions made for the gas extraction. Five gas wells should be closed for 80%. The people were still not satisfied and demanded that the gas extraction would be closed even more.

2014
More earthquakes due to the closure of gas wells

The reduction of gas extraction in the area Loppersum has a negative impact. Research by TNO shows that the probability of earthquakes increases elsewhere.

2014
First house demolished due to earthquakes

A farm in Middelstum is so badly damaged by earthquakes, that it has to be demolished. The elderly residents of the farm had to leave their house some time before already because it was too dangerous.

2015
Apologies from the Government

Minister Kamp acknowledges on behalf of the government that there should have been more attention to the safety of the inhabitants of Groningen in the gas extraction. Kamp officially apologizes.

2015
Appeal against the gas extraction

21 municipalities of Groningen appeal against the decisions for the gas extraction from Minister Kamp. Also the safety region and the province are appealing.

2015
Apologies from the NAM

After two months after the publication of the report of the investigation board for safety the NAM apologizes.

2015
Lawsuit against NAM

Prosecutors want the NAM to compensate the depreciation of damaged houses. Eventually the judge demands the NAM to pay for those depreciations.

2015
Burden of proof is reversed

At first inhabitants should indicate that the damage was caused by the NAM. Now the NAM has to indicate that the damage is not caused by gas extraction.

2016
Lawsuit against NAM and the state

Inhabitants of the seismic area have taken the NAM and the state to court. They claim that their enjoyment to live in the area is affected and that they have psychological complaints due to the earthquakes.

5. http://iframe-gasdossier.rtvnoord.nl/#Tijdlijn, *retrieved 12-1-2017*

1.4 Stock: identity and value

The typical Dutch building stock is not prepared for earthquakes. Damaged buildings get auxiliary constructions in order to protect against further damage and prevent to collapse. Of course this is a necessary tool right after an earthquake. But so far, there are no permanent solutions. Imagine what this does to the traditional identity of Groningen. A whole province full of auxiliary constructions that stand in front of the original facades. The identity of Groningen will be lost. But what to do with the damaged buildings? Break them down and build an earthquake-proof building on the same place? If so, again the question; what will happen to the identity? Or restore the building and wait what will happen? Until today those questions are still not answered. This is why I think architects should take this problem seriously and start developing ideas how to deal with this situation. How to keep identity and work with the new seismic situation as well. Inhabitants should express their identity. A home is 'a self-made environment, where the inhabitants can shape their own lives in the way they want'. The notion of the home can be extended to the scale of the neighbourhood, because it is part of the living environment.[6]

Figure 4:
Auxiliary construction in Groningen

When there is the need for a monument, or a building, the involvement of the architect in the process is inevitable. Many architects have taken positions in restoration. It always has been that restoration has raised a lot of questions concerning what the role of the architect is. One of the biggest problems nowadays is the filling of a different gap which has not always been taken into account in the history of restoration: the introduction of a new function. Or in the case of Groningen; the introduction of new issues where existing buildings are not build to. Heritage has to include not only physical monuments that can be felt and that are part of the cultural heritage.[7] For example the Stari Most Bridge in Mostar, Bosnia Herzegovina, has been reconstructed, because what they present goes beyond the physical authenticity of their stones or bricks.
When we talk about heritage, we talk about value. But how do we define this value? Alois Riegl addresses the issue in 1903 and defines two categories of values: commemorative values (age value, historical value, deliberate commemorative value) and present-day values (use value, newness value). According to him, unfortunately these diverse values do not complement each other and, on the contrary they often exclude one another. Riegl defines it as a hopeless conflict but we should try to avoid the conflict between these values. For how hard we try to set objective criteria to find the right balance of the aforementioned set of values, there will always be subjectivity in every judgement (i.e. merely beauty or ugliness).

There are monuments that will always be there because they have commemorative values that are universally outstanding (cf. UNESCO definition). As in Groningen, there are also less valuable monuments but they have a great value for the context and identity of the place. Another example besides Groningen is the New York High Line.[8] The railway almost was demolished but for the people of New York the railway represented the remnant of the industrial development of the district. Because of this reason they decided to keep it. A new function was given and with this it gave the railway the necessary boost to keep it in tact. In this case, the value of use, that is its involvement in the daily life of the citizens, enhanced its commemorative values.[9]

6. Leupen, B. (2008). Het ontwerpen van woningen. Rotterdam: NAi Uitgevers. p. 67-69
7. Jerome, P. (2008). An introduction to authenticity in Preservation. Ibid.39, 2/3. p. 3-7
8. David & Hammond, R. (2011). High line; the inside story of New York City's Park in the Sky. New York: Farrar, Straus and Giroux. p. 125
9. Goldberger, P. (2011). 'New York's High Line: Miracle above Manhattan. 'National Geographic Magazine, April, p. 122-137

1.5 Position

According to de Vries the attractiveness of an area largely is determined by the 'quality of life'. In Groningen this quality and liveability have been affected due to the earthquakes caused by gas extraction. The earthquakes lead to material and emotional damage and, indirectly to depreciation of property and damage of the identity of Groningen.

The NAM and the Government seem to be more interested in the profit of gas extraction, while the inhabitants have to live with the consequences. Although Dr. Meent van der Sluis concluded that there was a relation between the gas extraction and the earthquakes in Groningen, at first this was vilified by the head of the NAM. It took some years before the NAM admitted that there was a direct relation between the extraction and the earthquakes. The expectations are that the strength of the earthquakes will increase logarithmically if the NAM will continue. So far, it seems unlikely the NAM will stop the gas production.

In Groningen new issues arise where existing buildings are not built against. But those buildings have value for the context and identity of the place. Because of the earthquakes, a new way of building is needed. But this new way of building should embrace the identity of Groningen next to the need of being earthquake-proof.

The integration of old and new is possible and can create a continuum in the history of the place thanks to the achievement of a dynamic architect. In order to fulfil the desire of maintaining the identity and to build earthquake-resistant, architects need to have other skills. These other skills do not say that the traditional way of architecture is redundant, but do say that architects should think in a different manner than is done traditionally.

As a result, this research will mainly be focussed on the following topics:

- Identity of Groningen
- Earthquakes in Groningen
- Seismic behaviour of buildings
- Seismic behaviour of masonry
- Re-use in seismic area

1.6 Research questions

Research Question:

- How to bring back value to damaged buildings and make sure the new design will be earthquake-resistant as well?

Sub questions:

- What is the identity of Groningen?
- What kind of earthquakes do we deal with in Groningen?
- What are the damages?
- How to build earthquake-resistant?

Design assignment:

- How to fit a new design into the identity of Groningen?

2. Background Groningen

2.1 History

2.1.1 Genesis of the land

Boulder clay and sand
In the epoch if the Pleistocene, starting 2 million years ago and lasted up to 8000years BC, the foundation of the province of Groningen arises. Especially the last two ice ages had a major influence on the nature and sandy soils in the province. The ice came to the Netherlands and dragged material, such as sand, mud and boulders, which mixed with the existing surface. In a later period of history the temperature rose and thus it became warmer and more humid, whereby the vegetation increased. Because of the melting ice, there was a gradual rise of the sea level and ground water. The land became marshy and thus peat originated. Due to the emerging and retreating sea the higher and lower parts of Groningen are influenced differently from each other. This resulted in a formation of two different areas: the 'clay area' and the 'sand area'.

Clay area
Starting from 5000 BC till the beginning of our era the sea repeatedly flooded large parts of the clay area. In the first centuries BC a marsh area developed on the seaward side of the bigger clay area. Due to the relatively high location of the salt marsh, habitation was possible. To counter the recurring storm surges, the residents made artificial living hills: 'wierden'. From 1100 AC the sea became less aggressive and the erection of dikes began. The whole salt marsh area was closed by dikes around 1250.

Sand area
While in the clay area the peat growth repeatedly was interrupted, the peat growth in the sand area continued undisturbed. The improvement in the climate had the result that the peat itself gradually was spreading over the higher parts of the area. Slowly a bug(higher peat) developed that was depending on the nutrient-poor rainwater, in contrast to the fen(lower peat) that in contact was with the nutrient-rich groundwater.

2.1.2 Reclamation of land

At first man sought for occupation in the higher areas of the land. A variety of landscapes are formed in which each, in conjunction with the cultivation of the ground, got their own prestige. The seismic area is located in the 'wierden landscape' and the 'region villages landscapes on clay'. For this reason there will be more attention given to those two landscapes.

The wierden landscape
The inhabitants of this kind of landscape were protecting themselves from the sea by heighten up their residential areas. These raised areas where called 'wierden'.

Use of the land
The condition of the soil was determined for the farmers from Groningen when taking it into use. From 1800 other factors were starting to play a part, whereby soil and use no longer inextricably linked to each other. Since the end of the nineteenth century agriculture was characterized by modernization and rationalisation which led to a more efficient way of business and custom farm construction.

Agriculture
The evolution of agriculture was continuing in the second half of the nineteenth century. The demand from abroad for agriculture products increased. The most important crops where oats, barley and rye. At this time of prosperity the image of the 'rich Groninger farmer' arose. This is a somewhat distorted image because the word 'rich' only applied to a small part of the farmers. But

10. Panman, M. & Possel,J. (1992) Architectuur en stedebouw in Groningen 1850-1940. [Zwolle, Nederland] Uitgeverij Waanders.
11. www.statline.cbs.nl

generally the farmers where doing pretty well.

Regional differences
Despite the fact that Groningen became an agriculture province, there were big differences in the province itself. In the north and east of Groningen the development in agriculture was clearly visible, while in the western and southern area they had their own developments in keeping livestock.

Farm types
The developments in agriculture had a direct connection with the design of the farms. There are different types of farms in Groningen that are in close relation to the kind of land they stand on.

There are five types of farms:

- Kop-hals-romp
- Oldambtster
- Stelp
- Westerwoldse
- Gorendrechtse

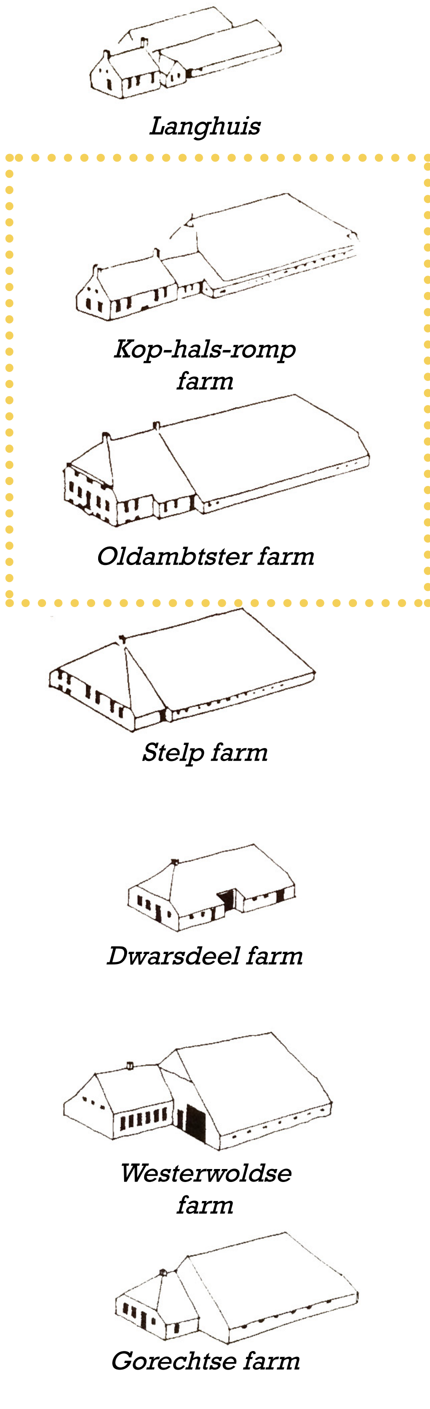


Figure 5: Types of farms in Groningen

Last two types came from influences of the province of Drenthe, while the others came from influences from the province of Friesland. Due to the increasing depend for agriculture, more place for storage was needed. This is where the 'Friese schuur' was introduced and mostly was used in the kop-hals-romp farm. In the seismic area the 'kop-hals-romp' and 'Oldambster' farm are most common.

Separation house and business
The rich farmers spend a lot of money and time on the appearance of the property. People were guided by the tendency of that time. After 1800 different neo-styles were leading. Symmetry and decoration was the most important feature. The persuit of symmetry had consequences for the mapping of the fronthouse. In most of the time the fronthouse of older farms had two quarters next to each other, and the entrance on the side. Now the entrance was placed to the front and to the middle. The quarters where positioned on each side of the entrance. The entrance was richly decorated and the simple top facade was replaced by a facade with wolfsend. For the sake of symmetry, the before elongated front house was replaced with a transverse house. This created a variant of the kop-hals-romp and the Oldambstster: the cross house. The set-up of both of these farm types was maintained. At the kop-hals-rop, the cross house was places in front of the 'hals'. At the Oldambtster it was placed against the firewall. The cross house separated the house from the farm. Change and modernization of business kept the urge the keep the house and shed under one roof less important.[10]

At the end of the 19th century the dairying moved from the farm to the factory and the servant who lived with the family got his own house. Because of these kind of developments the farmer's wife had less interference with the farm and could focus more on the household and the children. At the beginning of the 20th century, the villa began to replace the traditional 'fronthouse' (voorhuis). Depending on the prevailing style, the villa's got for example an Art Nouveau, Amsterdam school or one of the Berlage inspired look. Especially in the wealthy areas like Usquert where in the 20's about 12 farmers where millionaires. Because of the increasing scale of the farms, most of old farm types do meet the requirements of today. Also less younger people choose the farmers life from economical reasons. Vacancy and decay of a lot of these traditional farms as result.

Reduction of the population
From that moment until today there is a strong reduction of the population. Due to its geographical location, the economic malaise and the trend of urban migration, the province of Groningen suffers fromdeclination of it´s population, incomes that are below average and high rades of unenployment.[11]

2.1.3 Masonry

Almost every building has masonry facades. Groningen has its own red-coloured brick. Brickwork came for the first time in Groningen around 1150, while it was elsewhere in the country in 1170. The name of those thick bricks, used until 1300, is kloostermoppen. From the early 13th century the first masonry houses arose. Possibly because of the use of the thick clay(knikklei) of Groningen, until the 17th century there was build with bricks of a relatively large size. This had to do with the slow drying process which caused many small cracks. In other places they already used smaller bricks by that time.

Mid 19th century the building materials development increased strongly. Mechanization, standardization, and prefabrication were introduced. The brick itself experienced strong developments. Due to the 'ringoven'(ring furnace) the baking process modernized from 1870. The mixing and forming of the clay was mechanized by the 'strengpers' from 1880. Around 1895 smooth bricks could be made.[12]

One after the other entrepreneur starts a brick factory. Also farmers sometimes started a factory in addition to their business. In 1900 there were around 80 producing brick factories in the province of Groningen. Those companies were located next to canals or rivers were at least one of the materials (clay or peat) was present. In that time peat was used as fuel and thus the factories are mostly located in the Veenkoloniën(peat colonies).[13]

Figure 6:Former stone factory

Figure 7: Traditional Brickwork

12. Stenvert, R. et al. (1998) Monumenten in Nederland : Groningen [Zwolle, Nederland] Uitgeverij Waanders. P 38-40
13. http://www.steenfabriekceres.nl/kleibaksteeningroningen.php, retrieved on 23-12-2016
14. Hartman, T. & Kornack, F.C. (1994) Groningen : gids voor cultuur, landschap en recreatie. [Bedum, Nederland] Uitgeverij Profiel. P 38-41

2.2 Identity

The development of the land had a strong influence on the design of the farms. Farmers were at that time the most powerful inhabitants of Groningen. I suspect this has led to forming the foundation of the typologies in the architecture of Groningen.

2.2.1 Types of farms in the seismic area
As discussed in the chapter of history there are different kinds of farms in Groningen province. There is also said that it always is a mixture of different types, but in the seismic area two types stand out. These are the traditional kop-hals-romp type with a dwarshuis(house in crosswise direction) and the Oldambster type.

2.2.2 Structure
Characteristic are the narrow elongated floorplans with high rising roofs. The roofs served only to keep the house dry and windproof. The roof slopes are necessary to prevent rainwater or snow to blow inwards.

2.2.3 Roofs
There are two types of roofs used in the area. One is the 'schildkap' and the other is also the 'schildkap' but then it ends with a 'wolfseind'

2.2.4 Symmetry
In chapter 2.1 History is also spoken about the strive for symmetry. This is clearly visible in the farms and houses of Groningen. In the front facade the door is located in the middle. On both sides of the door are two windows located.

2.2.5 Masonry
The seismic area is the place where a lot of buildings are made out of brickwork with the characteristic red colour. The stones were made from a calcium-poor but iron-rich clay. The iron-rich clay gets from baking a bright red colour. Lime cement mortar is used in order to keep the stones in place. Nowadays cement mortar is used, which is much harder than the traditional lime cement mortar.

2.2.6 Mustard yellow
During an excursion to Groningen I saw that the mustard yellow colour is visible in the front facades in Groningen as decoration. I assume this has to do with the traditional Groningen mustard. The mustard flower fields occur a lot.

Figure 8: Oldanbster farm with 'dwarshuis'

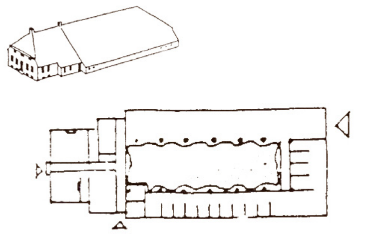


Figure 9: Elongated floorplan

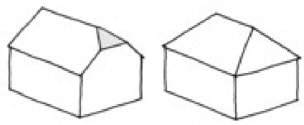


Figure 10: Schilddak and wolfseind

Figure 11: Symmetry

Figure 12: Traditional Brickwork

Figure 13: Mustard yellow

3. Seismic area Groningen

3.1 Earthquakes

3.1.1 What is an earthquake?

When two blocks of the earth suddenly slip past one another an earthquake occurs. The surface where they slip is called fault or fault plane. In the hypocenter the earthquake starts. This is located below the earth's surface. The location directly above it on the surface of the earth is called epicentre. Sometimes an earthquake had foreshocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. It cannot be determined that an earthquake is a foreshock until the larger earthquake happens. The larges, main earthquake is called the main shock. Main shocks always have aftershocks that follow. Depending on the size of the main shock, aftershocks can continue for weeks, months and even years after the main shock.[15]

3.1.2 Measuring an earthquake

The intensity of an earthquake is best described by its magnitude measured at the epicentre of the quake. The commonly used scale for this purpose is the Richter scale. The observation of damage and human reactions are the measurements for the intensity at a particular location. The commonly used scale in Europe to measure intensity is the European Macro seismic Scale. The measured intensity and the associated damage to buildings usually correlates with the ground acceleration in a geographic area. This acceleration can be measured with accelerographs and is and is expressed as PGA, Peak Ground Acceleration.

Three components are important in order to be able to calculate the seismic threat[16]:

1. *Measurements of earthquakes in the past with regard to the distribution in time and locations.*
2. *Knowledge of how the surface reacts to the seismic energy that is released during an earthquake.*
3. *The maximum magnitude that might be expected to occur.*

3.1.3 Earthquakes in Groningen

The type of earthquakes as talked about above are natural earthquakes. Originally earthquakes don't occur in Groningen and thus we don't talk about natural earthquakes. As discussed in 'chapter 1: Problem statement' earthquakes are rare for Groningen and are caused by gas extraction. Gas is pumped from 3km depth up to the surface. Above the gas bag in Groningen lays a salt layer that weakens the vibrations. The shallow surface is partly consisting of peat, clay and sand that can strengthen a vibration.[17] The gas itself is trapped in porous rock layers. Without interference these rock layers are stable and will stay in place. The porous rock layer becomes instable when mining the entrapped gas. The rock layers will be compressed. This compression can occur slowly and gradually, but the layers can also crack and fracture. If so, the abrupt subsidence can cause an earthquake.[18]

3.1.4 Seismic hazard

A seismic hazard is the probability of an earthquake occurring within a given period of time in an given geographic area and will exceed a predetermined magnitude. ''Seismic hazard is the frequency with which a specified level of ground motion (for instance 20% of ground acceleration) is exceeded during a specified period of time."[19] It cannot be predicted what the exact moment and magnitude of the earthquakes can be. The probability of earthquakes of a certain magnitude on the other hand can be calculated statistically. Research executed by Dr. A.G. Muntendam-Bos and Dr. J.A. de Waal shows that the number of earthquakes in the province of Groningen and their magnitudes are increasing in time.

15. https://earthquake.usgs.gov/learn/kids/eqscience.php, retrieved on 15-12-2016

16. https://www.knmi.nl/kennis-en-datacentrum/achtergrond/nieuwe-hazardkaart-groningen-daling-seismische-dreiging, retrieved on 15-12-2016

17. https://www.knmi.nl/kennis-en-datacentrum/achtergrond/nieuwe-hazardkaart-groningen-daling-seismische-dreiging, retrieved on 15-12-2016

18. Deltares: de Lange, G. et all. (2011) Gebouwschade Loppersum. [Groningen, Nederland] In name of Provincie Groningen Stuurgroep Onderzoek Gebouwschade. P 5

19. Arup. (2013) Groningen 2013 Implementation Study. Amsterdam.

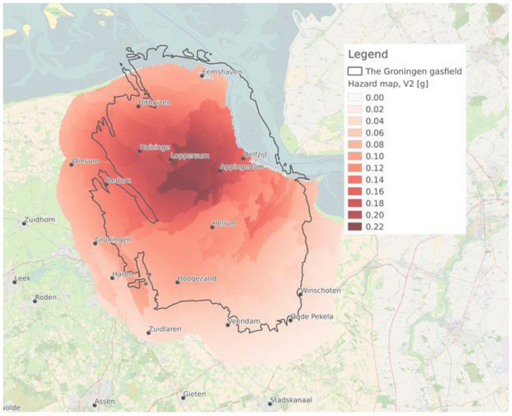


Figure 14: Seismic hazard map

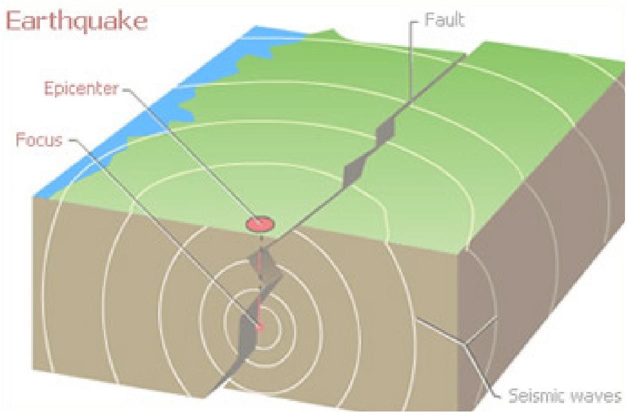


Figure 15: How an earthquake works

EMS-98 Intensity	Felt	Impact	Magnitude (Approximat Value)	Building Damage (Masonry)
I	Not felt	Not felt	2	
II-III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.	3	
IV	Light	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.		
V	Moderate	Felt indoors by most, outdoors by few. Many sleeping people wake up. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open or shut.	4	
VI	Strong	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and falling of small pieces of plaster.		
VII	Very strong	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well-built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings may show large cracks in walls and failure of in-fill walls.	5	 
VIII	Severe	Many people find it difficult to stand. Many houses have large cracks in walls. A few well built ordinary buildings show serious failure of walls, while weak older structures may collapse.		
IX	Violent	General panic. Many weak constructions collapse. Even well built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.	6	
X+	Extreme	Most ordinary well built buildings collapse, even some with good earthquake resistant design are destroyed.	7	

Figure 16: Twelve-stage European Macroseismic Scale 1998 (EMS-98)

3.2 Buildings and earthquakes

3.2.1 Building vulnerability

Lateral loads are the loads acting on a building by wind or earthquakes. Their effect is mainly in horizontal direction. The weight of the building, and the occupants in it, act in vertical direction. Forces, due to earthquakes are called 'seismic forces'. Seismic forces in buildings are induced by heavy masses present at the different floor levels. Without mass there is no force. Those forces are called inertial forces. The inertial forces can be calculated by the product of the masses and their respective accelerations. When an earthquake occurs the building behaves as a vertical cantilever and swings horizontally like an inverted pendulum. The higher the level, the more it swings because seismic forces increase at higher floor levels. Accumulation from top to bottom, acting as a sum of forces on the ground walls or columns.

3.2.2 Structural stiffness

The deflection of a building under lateral loads depends on the stiffness of the building. The stiffer the building, the less it will deflect. Ideally, it is desirable to behave elastically under lateral loads, but the design of a building that acts like this under strong lateral loads is economical not feasible. Therefore, to avoid buildings from collapse, engineers allow the building the behave elastically at high load levels and thus dissipate the energy. To prevent buildings to be damaged, the stiffness needs to be adequate.

3.2.3 The damages

In case of Groningen we talk about a different kind of earthquake. So do we talk about different damages as well? For instance earthquakes in Japan or Italy have caused much greater damage due to the much heavier earthquakes. In Groningen the duration of an earthquake is 5-6seconds, while elsewhere in the world it can be much longer. This doesn't mean the earthquakes in Groningen are not a problem. As discussed in the position I take (chapter 1 Problem statement) people should go to Groningen because earthquakes lead to material and emotional damage and, indirectly to depreciation of property and damage of the identity of Groningen.

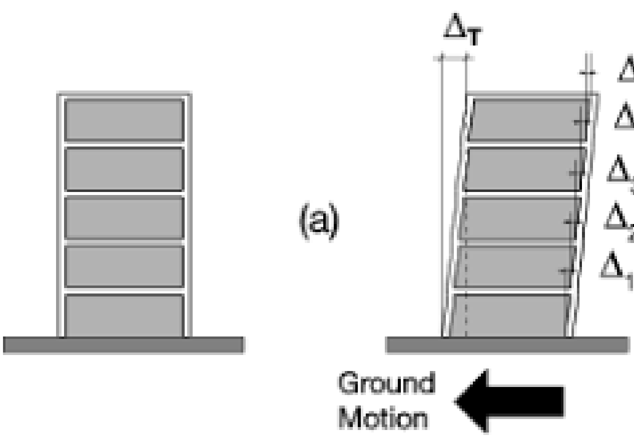


Figure 17: Seismic forces generated by masses vibrating

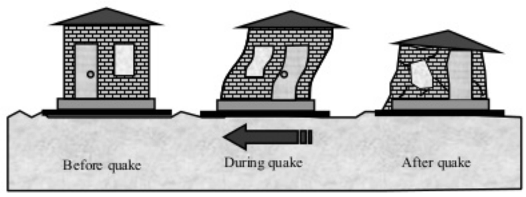


Figure 18: Drift generated by seismic forces

Figure 19(above): Damage after earthquake in Italy

Figure 20(under): Damage after earthquake in Groningen

3.3 Seismic design principles

The behaviour of a building during an earthquake can be influenced by its shape and configuration. Buildings designed following the general principles of an earthquake resistant building will be less likely to get damaged.
General principles for seismic resistant buildings are:

1. Limited mass
2. Regularity in plan
3. Regularity in elevation
4. Choice of material and detailing
5. Continuity
6. Distribution of live loads
7. Redundancy
8. Distribution of seismic-resisting elements

Arup. (2013) Groningen 2013 Implementation Study. Amsterdam.

3.3.1 Limited mass
The mass of the building is accelerated in case of an earthquake. The multiplication of the acceleration and the mass determine the total force (F = M . A). The higher the mass, the bigger the force will be. To decrease the risk of damage in a building reducing the mass in a building is preferred.

3.3.2 Regularity in plan
During an earthquake the forces act in all directions. In case of an unequal distribution of mass and irregular shape, the buildings' parts are allowed to move in different directions. This movement will cause torsion which can tear building elements apart. Symmetric floor plans with an even mass distribution are preferred; plans with L,T, U, V, Z shapes introduce significant torsional stresses and should be avoided.

3.3.3 Regularity in elevation
During an earthquake horizontal movement causes forces that need to be disturbed to its foundation. A smooth distribution is possible if all floors are approximately equal in stiffness, or if the changes are gradual. Sudden changes in stiffness should be avoided. Flexible levels, with large openings or open ground floors with columns should be avoided.

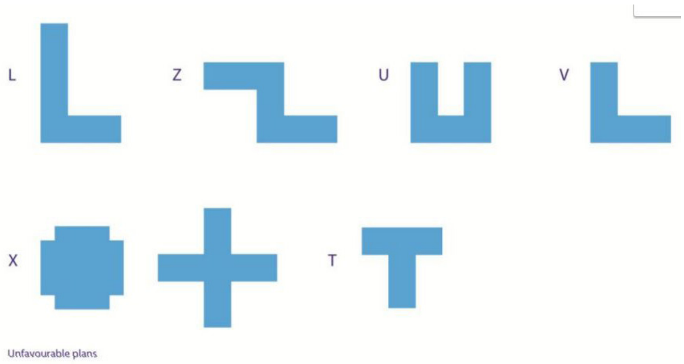


Figure 21: Unfavourable plans

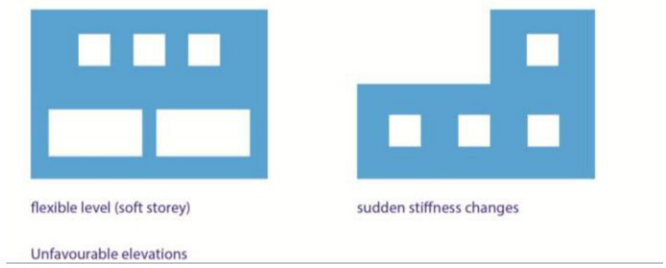


Figure 22: Unfavourable elevations

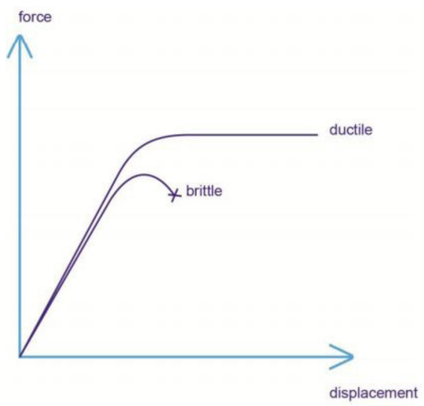


Figure 23: Ductile and brittle behaviour of materials and structure

3.3.4 Choice of material and detailing
Detailing is very important in earthquake design. Adequate connections made out of ductile materials are preferred, since ductile materials are less likely to collapse under the displacements due to earthquake loads. (Figure 23) Well-detailed steel, reinforced concrete or reinforced masonry buildings are preferred; unreinforced masonry is known to exhibit more brittle behaviour and to be particularly vulnerable to earthquakes

3.3.5 Continuity
Buildings should be well tied together to distribute forces to load resisting members and to assure overall response. Without these connections elements can move separately from each other, colliding into each other or falling over causing damage.

3.3.6 Distribution of life loads
Seismic resisting elements should be distributed as close to the perimeter of the building as possible, creating the largest possible lever arm and thereby the largest overall resistance. If not, heavy loads can cause torsion or increase the seismic forces in the building.

3.3.7 Redundancy
Different load paths will enable the building to resist seismic forces even when some members fail.

3.3.8 Distribution of seismic-resisting elements
Seismic resisting elements should be distributed as close to the perimeter of the building as possible, creating the largest possible lever arm and thereby the largest overall resistance.

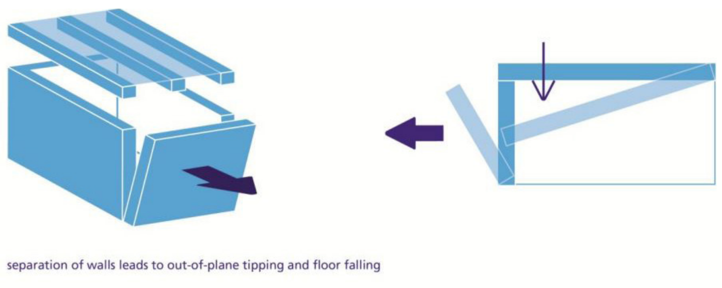


Figure 24: Disconuity of walls leads to out-of-place tipping and floor falling

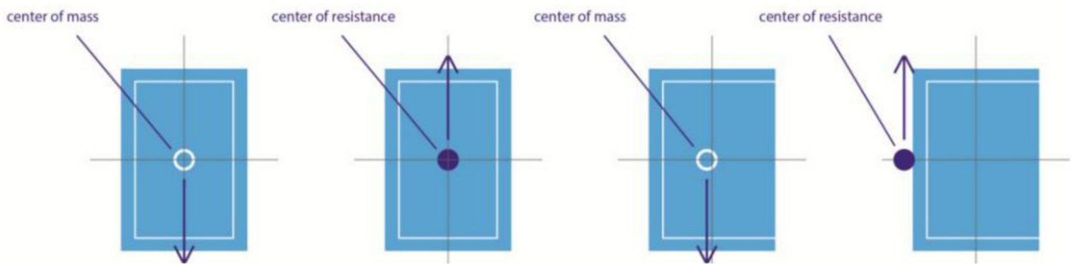


Figure 25: No essentricity, no torsion : Essentricity, torsion

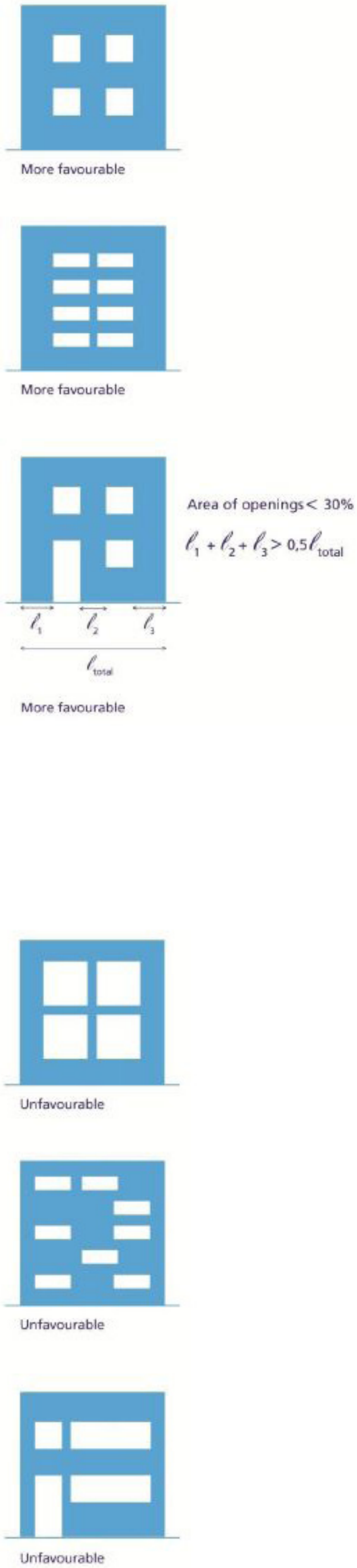


Figure 29: Openings configuration

3.4 Unreinforced masonry buildings

3.4.1 Box behaviour

Buildings in the Groningen area have not been engineered for seismic loads, like most masonry buildings worldwide. Non-engineered buildings resist wind and earthquakes by their box behaviour. The box offers resistance by the combination of its elements – floors, walls and roof.

Distribution of the horizontal forces ideally acts on the in-plane direction of the walls, since in the out-of-plane direction masonry walls are less stiff and weaker. The distribution of seismic loads and wind loads are different. Wind loads are proportional to the mass of the building, while earthquakes are not. Reinforcing buildings against earthquakes therefore might be necessary.
Forces are generated by the accelerations of the mass of these elements. The different elements have different functions in this resistance:

• Floors and roofs distribute the forces, generated by their mass and imposed loads to the walls;

• Floors and roofs tie the walls together, restraining them against collapsing out of plane;

• Walls offer high in-plane resistance in the direction of the ground motion and transmit the forces to the foundation;

• Walls offer low out-of-plane resistance in the direction perpendicular to the direction of the ground motion.

3.4.2 Stiffness of diagrams

The floor and roof diaphragm configurations have different behaviours depending on the stiffness of these diaphragms. Stiff diaphragms distribute the forces in relation to the stiffness of the walls. In this case the loads are primarily resisted by in-plane resistance of walls, in the direction of the earthquake. Flexible diaphragms distribute the forces in relation to the tributary mass assigned to each wall. Consequently, some walls have to resist significant loads in the weak out-of plane direction. This is a very unfavourable behaviour. In addition, they do not transmit forces caused by overall torsion of the buildings, and the diaphragm offers less restraint to the walls for out-of-plane failure. Consequently, stiff diaphragms are favoured over flexible diaphragms for their superior behaviour. See figure 26

3.4.3 Wall distribution

Plan proportions and the wall distribution must be compatible to react like a box or a combination of boxes. Elongated plans should therefore have additional walls in the short direction distributed along the long side of the building. See figure 27

3.4.4 Seismic damage

Earthquake damage is frequently recorded and reviewed. Most significant damages result from the following causes:

• Lack of connections, between wall/wall, walls/roof and wall/floors;
• Out-of-plane collapse of walls in direction perpendicular to earthquake direction (especially the outer leaf of cavity walls); and
• In-plane wall failure. In-plane failure depends primarily on:
• Load on top;
• Opening configuration
• Length of walls;
• Wall thickness; and
• Material properties.

3.4.5 Masonry damage

There is a great variety in masonry damage patterns. In many cases it is hard to say whether cracks are caused by an earthquake. Cracks can be caused by many factors such as soil compaction, rusty wall ties, thermal expansion, shrinkage, lack of dilatations, weak foundation, insufficient lintels, etc. Damage patterns do not necessary have to be caused by earthquakes.

The question who is responsible for damages in the masonry is not answered so far. Different studies are running that should determine who is responsible. According to professor foundation engineering Bram Weele, a large amount of the damages of houses is not done by earthquakes. Guidelines assume to deal with a undamaged building. As soon as the building already has cracks, it is way more sensitive to vibrations because existing crack will get very easily longer. This raised the question whose contribution to the increased damage is the greatest? Is that of the owner, who didn't repair the tears in time, or the cause of the vibrations which increased the crack? [20]

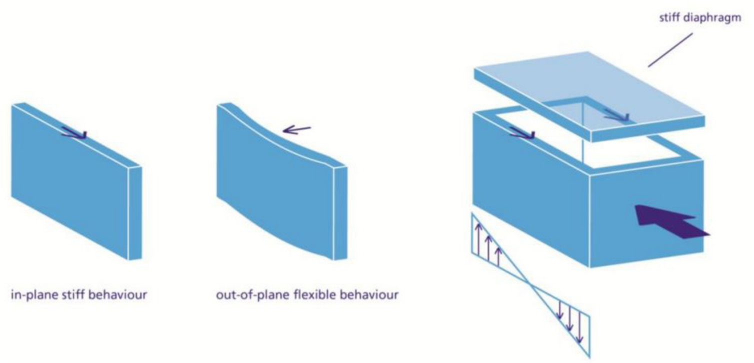


Figure 26: Box behaviour

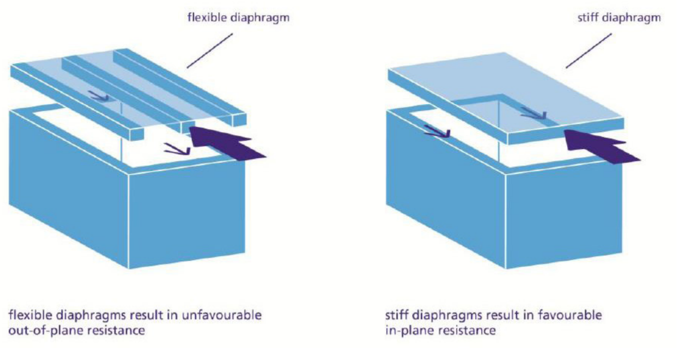


Figure 27: Flexible diaphragms

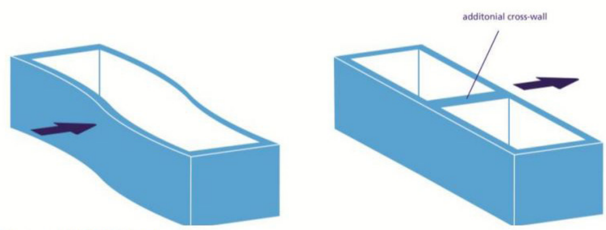


Figure 54: Wall distribution

Figure 28: Wall distribution

20. http://www.volkskrant.nl/binnenland/-meeste-schade-in-groningen-komt-niet-door-bevingen~a3583099/, retrieved 3-12-2016

3.5 Strategies to improve structural performance

To improve structural performance the following strategies may help:

- Local modifications of components: when overall strength and stiffness of the building is adequate.

- Removal of plan and elevation irregularities: Plan irregularities cause unwanted torsion in the building, while stiffness discontinuities and differences can result in force concentrations. The performance of the building can sometimes be improved by disconnection and separation of buildings into regular building parts; or removal of elements to align mass and rigidity centres and to ensure that stiffness changes are gradual rather than abrupt. (see figure 29)

- Decreasing building mass: The forces acting upon the structure during an earthquake are directly proportional to mass

- Increasing building strength

- Increasing building ductility

- Supplementary energy dissipation: The energy delivered by the earthquake is absorbed by the structure. Damping is a measure of energy dissipation. All structures possess some inherent damping. Additional damping can be introduced by installing passive energy dissipating devices, such as hydraulic cylinders, yielding plates or yielding braces (see figure 30).

- Seismic base isolation: The building can be isolated from the majority of seismic motion by mounting it on isolators. The building period would significantly increase, reducing seismic action on the building. In addition, this base isolation system could increase damping by employing special energy dissipating devices into the isolation system (see figure 30).

3.6 Levels of intervention

Structural upgrading of buildings can be distinguished in different levels. Each location and building needs its own level of intervention. This is determined in the seismic risk formula. The levels of intervention are divided in 7 levels of intervention. Level 1 stands for the minor interventions and level 7 is demolition.

Intervention levels:

- Level 1: Mitigation measures for higher risk building elements (potential falling hazards)
- Level 2: Tying on floors and walls
- Level 3: Stiffening on flexible diaphragms
- Level 4: Strengthening of existing walls
- Level 5: Replacement and addition of walls
- Level 6: Foundation strengthening
- Level 7: Demolishion

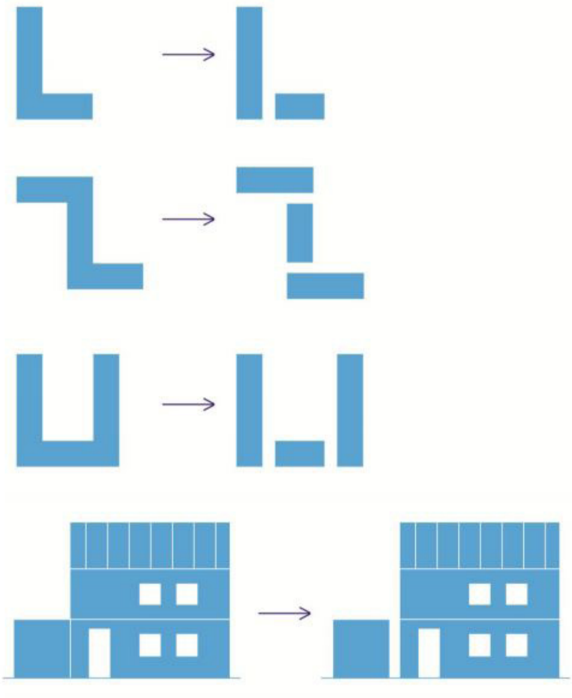


Figure 29: Removal of geometric irregularities

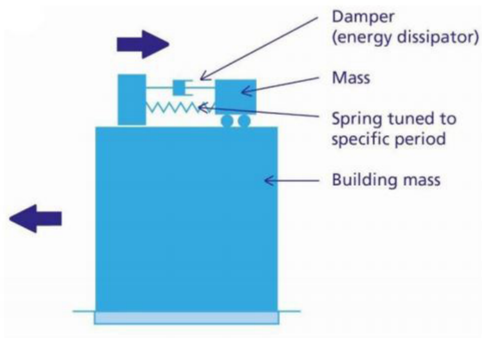


Figure 57 Passive tuned mass damper (TMD).

Figure 30: Passive tuned mass damper (TMD)

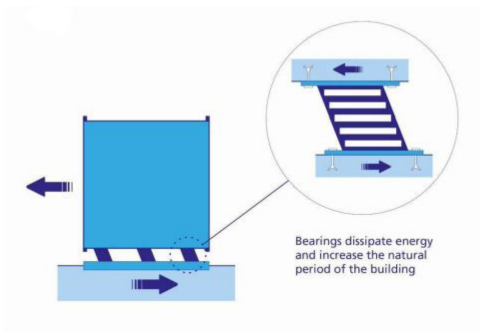


Figure 58 Seismic base-isolation.

Figure 31: Seismic base-isolation

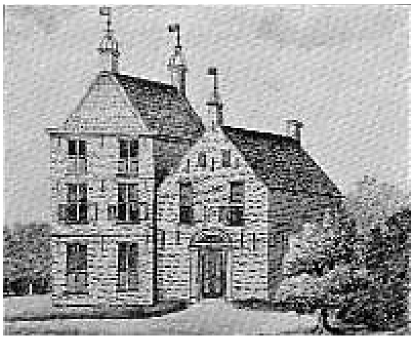


Figure 32: Almaborg

4. Case study: Farm 'Alma'

4.1 Context

4.1.1 History

De farm 'Alma' is build around 1820. The foundation of the living area of the farm is significantly older. The foundation is probably dating from the late middle ages and are made of the traditional 'kloostermoppen'. These are bricks of a bigger size and there is a quit large difference in form. This is the only remaining part of the Almaborg. A 'borg' is a name for a (reinforced) noble house. A home without noble rights is sometimes also called a 'borg' if it has a very beautiful appearance. There is little known about the Almaborg. There are some drawings, but it remains to be too little information to tell more about that building. See figure 32. The current shape of the of the living part has probably occurred mid 19th century. The size of the house of the farm increased in size on the East side. Also a higher front facade was placed. The original cellar is still there, but the vault is missing. The shape of the barn still matches the original design. The one thing they changed is the back facade. The farm is a monument. Every monument has something special. This monument has a door you can't enter because it is 60 centimeters above ground level and the stairs is missing. This door is called: 'death door'. This is the door the inhabitants left the building for the last time.[21]

4.1.2 Location

Farm 'Alma' is located in the municipality of Bedum(figure 33). The red dot shows the exact location of the farm. The municipality of Bedum is located right above the municipality of Groningen. On January 2017 the municipality of Bedum has 10,480 inhabitants. The municipality of Loppersum is located in North-East direction. Municipality Bedum is cut by the Boterdiep river. This used to be a fairway that was of commercial interest. Nowadays that function is not in use anymore, but last years the water recreation is upcoming.[22]

The municipality of Bedum consists the villages Bedum, Noordwolde, Zuidwolde en Onderdendam. Farm Alma is located in the village Bedum on the street called 'Wolddijk', on number 44. Bedum(village) has around 8600 inhabitants and is the largest village of the municipality. The village is only 9 kilometers away from Groningen city.[23] The site where the farm is located is surrounded by a wide canal and trees. When you enter the property you first have to follow the long driveway before you arrive at the farm. See figure 35

4.1.3 Function

The farm is still in use as a farm, but in small scale. Only 70 cows are hold for milk production at the moment. Besides the cows there is no agricultural function anymore. Also the amount of cows in the farm is changing, due to new rules. Last year is decided to bring 200.000 cows to the slaughterhouse to meet the European rules in sustainability. Every cow owner must give up a certain percentage of his cows.[24] Imagine you only have a few cows that bring you just enough money and you have to give up on some of them and the farm you live in is damaged by earthquakes due to gas extraction, what would you do? This is exactly the case the farmer of Alma is dealing with. Of course this is one example, but I am sure this is not the only farmer dealing with those problems.

In Groningen and in the rest of the Netherlands many farms lose their function. This has to do with different reasons. Besides the one I just discussed many farmers can't find someone that takes over their farm. Young people mostly don't stay in the countryside and move to the cities. According to the CBS there were 264.000 farms in the Netherlands in 1965. In 2015 this decreased to the amount of 64.000 farms. You can also see the people moving out of the countryside to the city in figure 34. Bedum (municipality) lost inhabitants while Groningen(city) grew[25]. Due to gas extractions even more people try to leave this area. Also visible in the figure is the amount of inhabitants that decreases in the earthquake area.

21. Beeldbank gemeente Bedum, Groningen
22. https://www.bedum.nl/in_en_over_bedum/ligging_en_verbinding
23. https://www.bedum.nl/in_en_over_bedum/dorpen_en_buurten/bedum
24. https://www.trouw.nl/samenleving/hoe-overleeft-de-boer-de-21ste-eeuw-~ab5ce613/
25. http://sociaalplanbureaugroningen.nl/bevolking/groei-en-krimp-van-de-groningse-bevolking/

Figure 33: Location 'Alma' in Groningen province

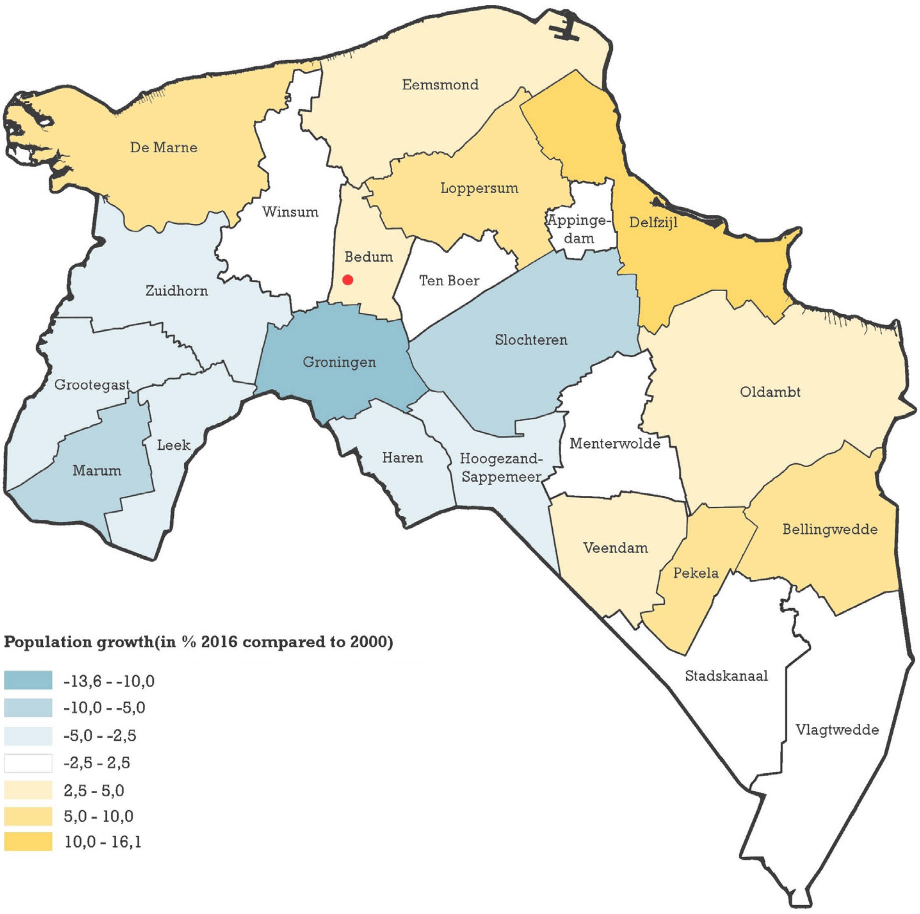


Figure 34: Population growth municipalities Groningen province 2000-2016

Figure 35

Figure 36

Figure 37

Figure 38

Figure 39

Figure 40

4.2 Identity

4.2.1 Typology

This farm is a variation of the original kop-hals-romp type as discussed in chapter 2. Background Groningen, p. 13. The hals(neck) is missing and that's why it actually is a kop-romp type. The exact reason why this farm is a variation is not clear. I think this has to do with the foundation of the Almaborg.
The Alma farm exists out of 3 volumes:

- Voorhuis(living area)
- Big barn
- Small barn

The small barn stands directly next to the big barn. This big barn has with its size a big influence on the appearance of the farm. The mass of the 'voorhuis' is actually shoved into the mass of the big barn. See figure 38 and 44. The big barn and the 'voorhuis' have an elongated floor plan.

4.2.2 Structure

The bearing construction of the barn is made out of wooden trusses. The masonry walls also have a bearing function. The foundation is made out of 'kloostermoppen'. See figure 43.

4.2.3 Roofs

The roof type is the traditional 'schilddak' with 'wolfsend'. See figure 38 and 43. The barn and the 'voorhuis both have such types of roofs. The sides of the roof that don't end with a 'wolfsend', end right above the longitudinal masonry wall with a white wooden gutter that has a little overhang. See figure 37. The sides that do end with the 'wolfsend' don't have any overhang and end with a white wooden fascia. The wall under those parts is higher to make room for the farmer to enter the barn. The big barn and the small barn come together in a typical detail. See figure 39

The height of the roof of the barn is higher than the roof of the 'voorhuis'. This is typical for the kop-hals-romp type, while the Oldambtster type has no difference in height of the roof. The barn has a high roof with steep slopes. The masonry wall is only 1,5 meters high. When you see the farm in elevation, 80% of the view is the roof and 20% is the masonry wall. In the 'voorhuis' the ratio is different. Here is 60% roof and 40% wall. See figure 43. The roof of the barn is traditionally a thatched roof. The slope of the thatched roof ends with roof tiles. The 'voorhuis' still has the original roof tiles. The thatched roof is now covered with a corrugated iron roof.

4.2.4 Symmetry

As dicussed in Chapter 2, there has always been a strive for symmetry. You can see in figure 43 that the 'voorhuis' has a clear symmetric design, while the barn has this not that strongly.

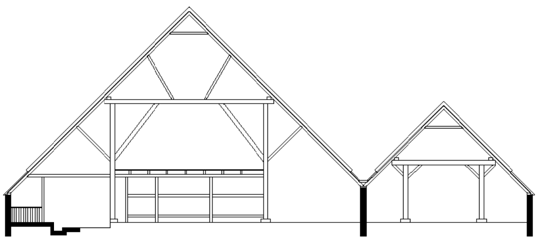


Figure 41: Section

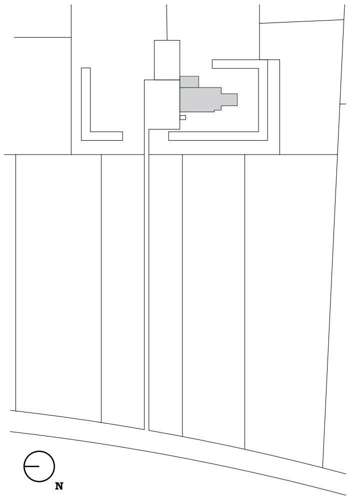


Figure 42: context

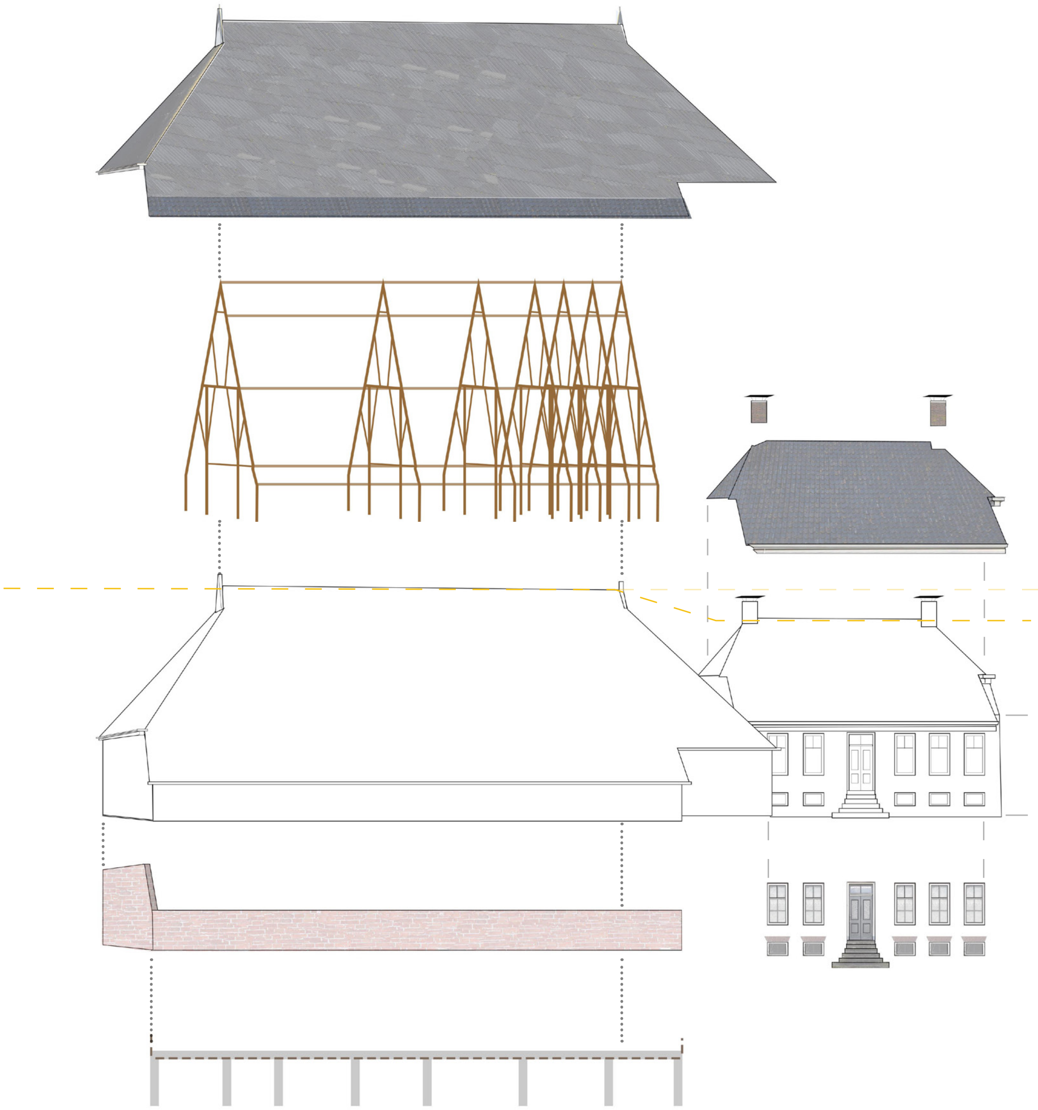



Figure 43: Exploded view

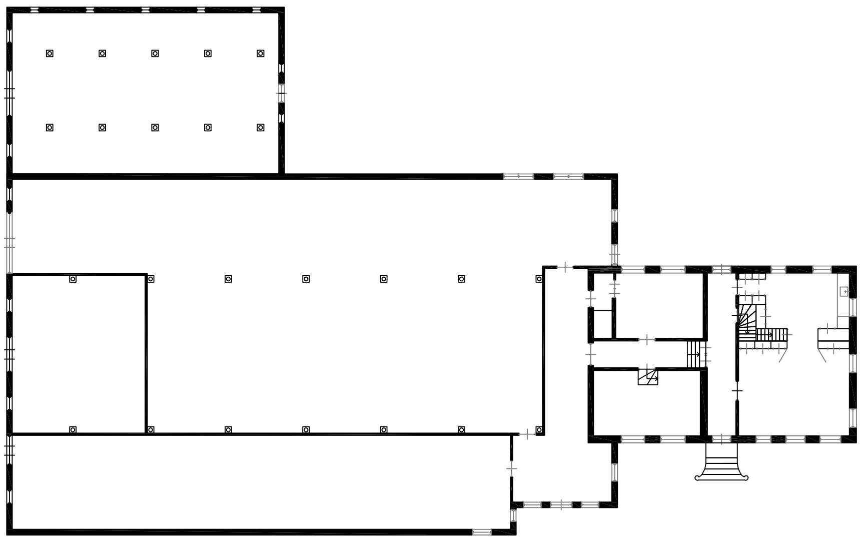


Figure 44: Floorplan ground floor

Figure 45

Figure 46

Figure 47

Figure 48

Figure 49

4.2.5 Masonry

All the façades are made of brickwork. This is done in the cross bond. It closely resembles the English bond. The difference between the two bonds is visible in figures 50 - 53. Here you can see that they both have a layer of headers, than a layer of stretchers and so on. The exact difference lays is the layer of stretchers. Where the English bond always starts with a full stretcher, the cross bond alternates a full stretcher with a not full stretcher.[26]

The area's where the brickwork ends sloping, is fixed via a 'boerenvlecht' See figure 46. Above the windows it ends as you can see in figure 45. The surface shows layering. The windows are placed not in the surface itself, but slightly back. See figure 47. The joints are made out of lime cement mortar and are quite thin. On most places the joints are still traditional, but on the south facade of the 'voorhuis' the joints are replaced. The farmer told me that it is a lime cement mortar, but that they made the original joint wider. See figure 48

The farm is damaged by earthquakes. The damages are visible in the masonry. As discussed in Chapter 3.4 'Unreinforced masonry buildings', mostly the masonry suffers the most during earthquakes. The damages in this farm confirm this. See figure 49

4.2.6 Masonry and earthquakes

Due to the fact that I want to use masonry in my new design I should look for new solutions. A system that is still in development got my attention. This system is called: H-block. H-block is invented by manufacturer 'Blom' and the owner of the masonry company 'Deen'. It is originally not designed as a system to be earthquake proof. H-block needs reinforced polymer H-profiles and a sawing process that involves post-cutting double parallel channels into the top and bottom surfaces of brick. This turns common brick into a precisely dimensioned block suitable for a dry stacking system.

The benefits I see in this system is the re-use of the bricks of the farm. Not all of the bricks could be re-used because they could be damaged by aging or earthquakes. Still I think I should have enough bricks. This has to do to the fact that this new system is a aesthetic outer leaf. The original walls are bearing. For the bearing wall you need two layers of bricks next to each other. The H-block only requires one layer of bricks. Imagine 1/3 of the bricks is damaged, I still have enough bricks to make the same amount surface. See figure 54

The system still needs development, but I think it is a very interesting system for me to continue with. To make the system more stable out of plane, extra measures are necessary. For example this could be done with cables trough the system, or attach the joint elements to the rails for stiffness.

26. Mulder, K. (2016) Het Zinderend Oppervlak; Metselwerkverband als patroonkunst en compositiegereedschap. [Delft, Nederland] Uitgave in eigen beheer. (P. 21-23)

Figure 50: bond used in farm

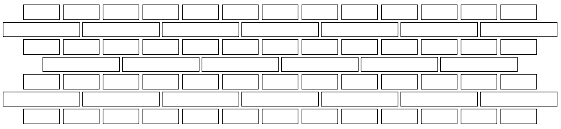


Figure 51: Cross bond

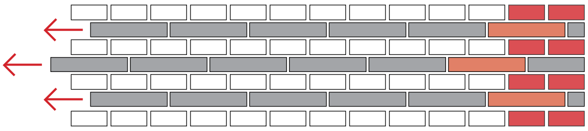


Figure 52: Cross bond

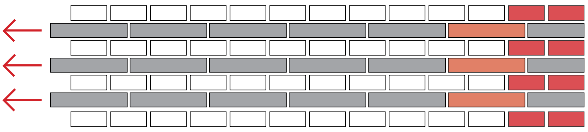


Figure 53: English bond

RE-USE BRICKS:

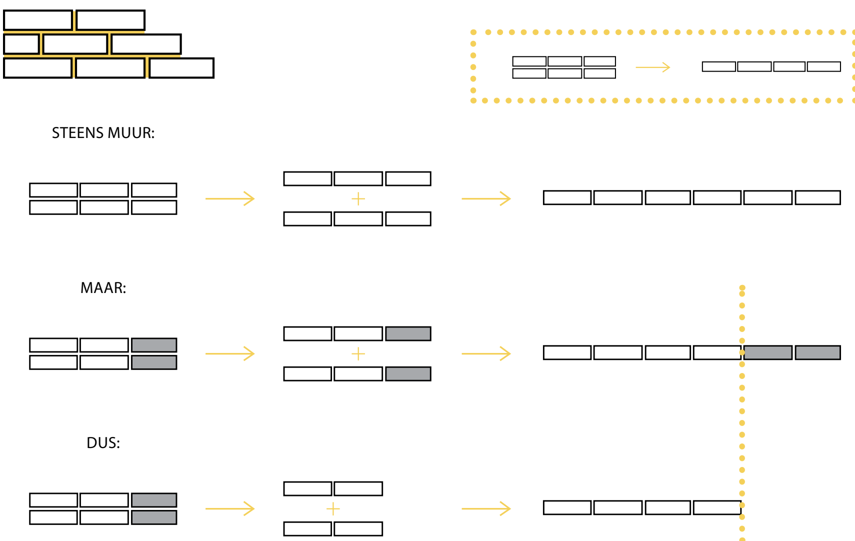
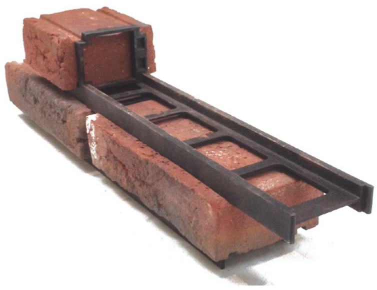
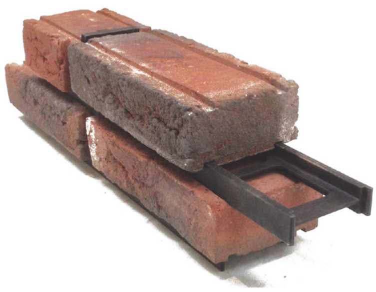


Figure 54: re-use bricks

H:block





5. Conclusion

To give answer to the research question: 'How to bring back value to damaged buildings and make sure the new design will be earthquake-resistant as well?' I will answer the subquestions one by one.

What is the identity of Groningen?

The identity lays in the history and development of the land. There is too much information to take into account to use everything from history till now. This is why I discussed what makes the identity of Groningen to me. This lays in some specific typologies like: the Oldambtster farm with its elogated floorplan and perticular roof. Symmetry you will find not only in farms, but also in houses and many other buildings. Also the mustar yellow colour stands for the identity. But the strongest segment for the identity is for me the brickwork.

What kind of earthquakes do we deal with in Groningen?

The earthquakes in Groningen are not natural. They are a result of gas extraction. Compared to other countries where earthquakes are natural, it doesn't sound that bad because in the Netherlands they are way smaller. But still the buildings of Groningen are not build against earthquakes and thus there is the risk of losing identity because more and more buildings will be damaged.

What are the damages?

As I just said, the damages in Groningen are smaller than in other countries. This doesn't say that there is no problem. The physical damages is not the only one counting. The earthquakes lead to material and emotional damage and, indirectly to depreciation of property and damage of the identity of Groningen.

How to build earthquake-resistant?

There are many possibilies to build earthquake resistant. The things that stood out were the cracks in the masony and the undesirable shape of the bulding itself(elogated floorplan) during earthquakes. To reinforce masonry there are some solutions, but they do not fit in the idea of my design task were I want to use the Japanse proverb; repair with gold. For this reason I will continue searching for solutions.

Design assignment:

- How to fit a new design into the identity of Groningen?

To be able to make a good design, the case study of farm 'Alma' was necessary. The farm is special because its build on top of the foundation of a 'borg'. Also the long driveway, the channel and the placing of the trees show the remains of a 'borg'.

The location of the farm lays in a shrinking area. For the new design I should give it another function in order to attract more people to the area.

The new design should embrace the qualities of the current farm. These qualities lay in the identity of this farm. A large share of the identity lays in the masonry, but you can also find this in the typology, structure, roofs and symmetry of the building. To me, the quality of the design lays mostly in the detail.

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