SEISMIC - RETROFIT

An open air museum park integrated with brick buildings and new seismic retrofit system.
Content

Overview
Background & Problem statement ------- 4
Research Question ---------------------- 10
Project Description --------------------- 12

Research
Structure Concept --------------------- 16
Research with Design ------------------ 19
Structure Strategy --------------------- 33

Architecture Design
Site & Concept ------------------------- 35
Landscape Design ----------------------- 41
Program Design ------------------------- 45
Facade Fragment ------------------------ 51

Technical Design
Seismic Retrofit Strategy ------------- 55
Structure Design ---------------------- 58
On Site Restoration ------------------- 61
Joints Design ------------------------- 67
Climate Design ------------------------ 78

Interior Design
Concept ------------------------------- 81
Interior axonometric ------------------ 82
Materialization ----------------------- 83
01 OVERVIEW

Background & Problem statement
Research Question
Project Description
In total more than 1,000 earthquakes between M0.2 and M 3.6 have been recorded since the first earthquake occurred in 1986. Due to the drilling of gas out of the soil, the hypocentres lie at a depth of only 3 km, leading to a larger impact on a smaller scale.

Source: http://khanacha.blogspot.nl/2014/10/gas-group-nam-says-more-serious.html
OVERVIEW

Background & Problem

Research Question

Project Description

ARCHITECTURE DESIGN

TECHNICAL DESIGN

INTERIOR DESIGN
Unreinforced masonry is widely used in Groningen. According to an assessment by Arup, more than 250,000 buildings in this area are potentially needed strengthening.
OVERVIEW

Background & Problem

Research Question

Project Description

ARCHITECTURE DESIGN

TECHNICAL DESIGN

INTERIOR DESIGN

Source: "How Warffum was awakened"
Diagram by author, statistic from Wikipedia.
Increasing of damaged **vacant** masonry buildings, losing of **public facilities** and **population**.

The **building quality** need to be improved to call back people's confident of the area.

Source: <How Warffum was awakened>
A more architectural solution to reinforce earthquake damaged masonry buildings and improve the existing architecture quality by integrating existing damaged buildings with new spatial construction.
Research Question

A wood light-weight complementary construction system as an architectural solution to reinforce and reuse earthquake damaged masonry buildings.

Source: http://www.woodworks.org/design-with-wood/building-systems-clt/
Site selection -- Warffum

Source: https://www.google.nl/maps


Street view and backyard around Openluchtmuseum Het Hoogeland
Warffum, suffered two earthquakes in 2012 and 2013, measured 3.6M and 3.2M, about forty percent of homes damaged in this village,

The population has been decreased from 4000 after the war to current 2500, the increase of vacant buildings.

The public facilities begun to disappear, such as shops, decreased from 6 in 2007 to 4 in the 2013. Even the care center in Warffum was closed.

Source: <How Warffum was awakened>
Integrating existing brick buildings in Warffum into new Openluchtmuseum park with new wooden construction, which is used to improve the seismic behavior of existing buildings.
02 RESEARCH

Structure Concept
Research with Design
Structure Strategy
Basic Methods of seismic strengthen of brick buildings.

- **Strengthen of brick**
  - Strengthen of brick
  - Conflict of brick and wood

- **Extral support**
  - Light-weight structure.
  - Seismic optimization.

- **Indoor elements**
  - Light-weight construction.
  - Fixing problem
Structure Concept: How to improve? -- A more architectural solution
Structure Concept: How to improve? -- A more architectural solution

1. Folded light-weight structure to provide extra support.
2. Strengthen of brick work, solve the conflict of different structural behavior between brick and wood.
3. Light-weight structural elements replace of heavy brick work.
4. Light-weight function construction combine with structure elements.
1. How to deal with basic damage of brick structure

The brittle behavior of brick work, easy to get damaged in earthquakes, especially in Groningen, where the unreinforced brick is widely used.

Source: <Handbook on Seismic Retrofit of Buildings> P27
Seismic response of brick structure, always have low shaking period due to the stiffness.
Earthquake damage on brick in Groningen.
In a more economical and practical way.
Prevent re-entrant corners

Regular Plan

Irregular Plan

Regular Plan
OVERVIEW

RESEARCH
- Structure Concept
- Research with Design
- Structure Strategy

ARCHITECTURE DESIGN

TECHNICAL DESIGN

INTERIOR DESIGN

Structure Concept
Research with Design
Structure Strategy

Disattach of brick wall
New Wall-Wall connection
Increase elasticity of connection

External structure to provide external support

Seismic Reaction
Weaken of brick wall to control seismic damage, and transfer the seismic motion to new constructions

Portal frame performance of the new construction attached with brick work

Hinge performance of weaken brick wall during earthquakes
2: A spatial proposal for extral support
A new shoring proposal.

Effect of folding on folded surface.

Source: https://commons.wikimedia.org/wiki/File:Iglesia_Atl%C3%A1ntida_Dieste.jpg
Source: http://calatrava.com/projects/oriente-station-lisboa.html?view_mode=gallery&image=1
Miura-ori Patterns
Consist of quadrilateral faces, benefit from boundary line, stable when made in plate, not stable when made in lattice.

Diamond Patterns
Consist of triangular faces, benefit from connections, both stable when made in plate and lattice.
Seismic force transition of traditional brick building

Seismic force transition of new construction system

Seismic force transition of new construction system when introduce folded structure
Conclusion of research:

*Improve the response period of brick structure:*

Disattach of brick connection, new damping wall-wall connection

*Weaken of brick wall, damage control and seismic motion transition, perform as hinge*

*Folded structure to provide extra support, perform as portal frame together*
3. Falling of interior elements during earthquake
A combined proposal for indoor elements.

A combined proposal, new indoor construction system.
OVERVIEW

RESEARCH

Structure Concept
Research with Design
Structure Strategy

ARCHITECTURE DESIGN

TECHNICAL DESIGN

INTERIOR DESIGN

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**Structure Concept**

**Research with Design**

**Structure Strategy**

**Original brick work**

**Divided into separate volume**

**Disattach brick walls and insert damping device to allow movement**

**Folded structure to provide external support of the brick work**

**Weaken brick wall to control damage and reduce brittle behavior**
03 ARCHITECTURE DESIGN

Site & Concept
Landscape Design
Program Design
Facade Fragment
3.6M and 3.2M earthquakes in 2012 and 2013

127 small earthquakes in 2013
Population: 2500 -- 1990
Shop: 6 -- 4
Restaurant: 2 closed
Library: closed
Bus Stop: disappear
Health center: closed
Seismic Retrofit -- Integrating existing brick buildings through extral support, and provide more public space with better quality.
More public space and function
West Street View
East Street View
Street View
new construction
OVERVIEW

RESEARCH

ARCHITECTURE DESIGN
- Site & Concept
- Landscape design
- Program Design
- Facade Fragment

TECHNICAL DESIGN

INTERIOR DESIGN
Open Floor for Loft
**Cross section A**
Cross section B
West Facade from courtyard
1. Wooden board 15mm
   - Woodenwool pressure resistant insulation 120mm
   - Water Proof layer 9m
   - Mechanical ventilator 150mm
   - Wood Film board 20mm
   - Floor heating system
   - Timber battens 30 x 30mm
   - Finishing Floor 20mm

2. Wooden board finishing 10 mm
   - 25 x 25 mm Wooden battens
   - 25 x 25 mm Wooden counter battens
   - Water Proof layer 9m
   - Insulation 60mm
   - Timber board 15mm
   - Insulation 80mm
   - Counter battens 80 x 80 mm
   - Steam proof layer
   - 10 mm Indoor wooden finishing

3. Wooden board finishing 10 mm
   - 25 x 25 mm Wooden battens
   - 25 x 25 mm Wooden counter battens
   - Water Proof layer 9m
   - Insulation 60mm
   - Timber board 15mm
   - Insulation 80mm
   - Counter battens 80 x 80 mm
   - Steam proof layer
   - 10 mm Indoor wooden finishing

4. Wooden Column 80 x 120 mm, 80 x 80 bracing
   - 15 mm air space
   - 140mm Wooden sandwich panel
   - Steel plate
   - 60mm air space
   - 10 mm insulation
   - Water proof layer
   - 100 mm Ream pipe
   - 10 mm wooden board
   - 15 x 10 mm counter battens
   - 10 mm wooden board finishing
Courtyard View
04 TECHNICAL DESIGN

Seismic Retrofit Strategy
Structure Design
On Site Restoration
Joints Design
Climate Design
Original brick plan
Division of volume
Disattach of brick work
OVERVIEW

RESEARCH

ARCHITECTURE DESIGN

TECHNICAL DESIGN

Seismic Retrofit Strategy

Structure Design

On Site Restoration

Joints Design

Climate Design

INTERIOR DESIGN

Extra construction
Folded plate roof construction, with skylight towards north.

Folded timber roof structure

Horizontal gframes integrated with interior

Timber frame with curved bracing

Light-weight sandwich panel facade
OVERVIEW

RESEARCH

ARCHITECTURE DESIGN

TECHNICAL DESIGN

Seismic Retrofit Strategy

Structure Design

On Site Restoration

Joints Design

Climate Design

INTERIOR DESIGN

Old roof with opening for skylight

Original roof construction

Opening floor of loft, integrated with interior

Timber frame with transparent envelope, new entrance

Old brick work with new Wall-Wall connection, integrated with interior
On site restoration

New wall-wall connection
Opening to communicate two sides

External timber frame with curved bracing
63

**OVERVIEW**

**RESEARCH**

**ARCHITECTURE DESIGN**

**TECHNICAL DESIGN**

- Seismic Retrofit Strategy
- Structure Design
- On Site Restoration
- Joints Design
- Climate Design

**INTERIOR DESIGN**

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*External timber frame with curved bracing*

*Folded plate roof construction*

*Horizontal frame to strength structure and facade installation*
**Seismic Retrofit Strategy**

- Weaken brick work to control the damage
- Secondary beam to strength old wall-beam connection
- Insert lighting box and maintenance device
Shelves, tables and chairs attached to the timber frame

Generated interior attached to the old building and fixed with each other
Open floor for loft and interior attached to old building

Folded roof and facade attached to the timber frame, opening towards north
Joint A
1. Glass lighting box
2. Steel plate to fix elastomeric device
3. Steel rubber mat
4. 15 X 15 mm rubber pattern
5. Light
6. Steel screw

Detail B Column - Foundation connection
Joint B Column - Foundation connection
Seismic Reaction
Detail C  Beam - Wall connection

1. Wooden panel
2. Tapestry brick cover
3. Steel Plate : wall-beam connection
4. Screw
5. Steel rubber mat
6. 60 X 140 mm Wooden beam X 2
7. Skylight framing with gutter
8. 40mm Glazing
Detail D Wall - Wall connection

1. Wooden panel
2. Tapestry brick cover
3. Steel Plate : wall-beam connection
4. Screw
5. Steel rubber mat
6. 60 x 140 mm Wooden beam x 2
7. Skylight framing with gutter
8. 40mm Glazing
Joint D Wall - Wall connection
Seismic Reaction
Detail E

1. Glass lighting box
2. Steel plate to fix elastomeric device
3. Steel rubber mat
4. 15 X 15 mm rubber battens
5. Light
6. Steel screw
Joint E
Seismic Reaction
Summer condition
Winter condition
04  INTERIOR DESIGN

Concept
Interior axonometric
Materialization
**Concept: A combined proposal for indoor elements**

A combined proposal, new indoor construction system.
Interior axonometric
<table>
<thead>
<tr>
<th>OVERVIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESEARCH</td>
</tr>
<tr>
<td>ARCHITECTURE DESIGN</td>
</tr>
<tr>
<td>TECHNICAL DESIGN</td>
</tr>
<tr>
<td>INTERIOR DESIGN</td>
</tr>
</tbody>
</table>

- **Concept**
- **Interior axonometric**
- **Materialization**
THANK YOU !