TRANSFORMATION IN NATURE

Integrating biomimetic design into New Pavilion Design in Seismic Groningen

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   2. Design Question
   3. Preliminary Design
1. Background

1.1 Reforestation Program

The Netherlands currently shares with Ireland the title of Europe’s least wooded country—trees currently cover just 11\% of its surface area.
1. Background

1.1 Reforestation Program

The Netherlands currently shares with Ireland the title of Europe's least wooded country—trees currently cover just 11 percent of its surface area.

1. Increasing the extent of woodlands, less-developed spaces in "Green Heart" area. (Rotterdam, Amsterdam, the Hague, and Utrecht)

2. Northern provinces (Drenthe, Groningen), poor agricultural productivity left it largely empty land.
2. Problem Statement

2.1 Earthquake:

The Groningen is facing a permanent danger of potential earthquake these years due to over extraction of the gas oil.

Although very few constructions are really collapse, buildings are in different extents of the damage.
2. Problem Statement

2.2 Population Shrinkage & Loss interest of rural life

Groningen has abundant landscape resource in farmland. People are not interested in the community life and rural lifestyle.
3. Diagram

- Unreinforced masonry structure in seismic area
- Lack of woodland
- Population Shrinkage
- Loss confidence of rural Landscape

Problem
3. Diagram

Problem

Current Solution

Limitation

1. Unreinforced masonry structure in seismic area
2. Reforestation Program
3. Population Shrinkage
4. Loss confidence of rural landscape

1. Engineering Technology to strengthen stability, such as adding braces and ring beam.
2. Less aesthetic value
3. Only retrofit the existing masonry buildings

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3. Diagram

- Problem
- Current Solution
- My idea

Limitation
- 1. Less aesthetic value
- 2. Only retrofit the existing masonry buildings

My idea
- 1. Learn seismic strategy from nature
- 2. Integrate natural construction with seismic challenge.

Current Solution
- 1. Engineering Technology to strengthen stability, such as adding braces and ring beam.

Problem
- 1. Unreinforced masonry structure in seismic area
- 2. Reforestation Program
- 3. Population Shrinkage
- 4. Loss confidence of rural Landscape
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3. Diagram

- **Problem**
  - Unreinforced masonry structure in seismic area
  - Reforestation Program
  - Population Shrinkage
  - Loss confidence of rural landscape

- **Current Solution**
  - Limitation
    - Less aesthetic value
    - Only retrofit the existing masonry buildings
  - Limitation
    - Engineering Technology to strengthen stability, such as adding braces and ring beam.

- **My idea**
  - Learn seismic strategy from nature
  - Integrate natural construction with seismic challenge.

- **My Solution**
  - Advantage
    - Biomimetic lightweight timber structure.
    - Responsive skin
    - More aesthetic value
    - A new construction way
    - Less energy consumption
    - More sustainable and recycled material
    - Close and intimate touch with nature environment

- **Conclusion**
  - Structural Proposals
Problem

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Current Solution

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My Solution

1. More aesthetic value
2. A new construction way
3. Less energy consumption
4. More sustainable and recycled material
5. Close and intimate touch with nature environment

Advantage

1. A new organic and biomimetic architecture
2. Reinterpret the farmland landscape regarding architecture morphology

OBJECT

B. Design
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4. Research Question

"How to adopt a biomimetic method for the seismic Groningen, taking the landscape, context, and technology into account?"

**seismic design research**
- 1. what Principles should architecture design comform to for the seismic resistance?

**Biomimetic structure research**
- 1. what kind of biology-inspired structure could better match with the anti-seismic principle?

**Bioclimte technology research**
- 1. what kind of responsive skin technology could be integrated into the museum design?
5. Research Framework

- Seismic Research
  - Seismic Design Principle
  - Architectural Approaches
- Matching Process
- Bio-inspired Structure
  - Bio-inspired Structure
  - Frei Otto’s Precedent
  - Timber Construction
  - Responsive Skin
- Bio-climate Technology
  - Bio-climate Technology
- Structure Proposal
  - Structure Proposal
- Preliminary Design
  - Preliminary Design

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6.0 Seismic Design Principle

- lightweight mass
- Strength and Stiffness of structure, ductile material
- Prevention of torsion

The shear force can resist the bending moment, wall force and “Xy” directional force. The different ductility of structure responds to the seismic force.

a. deeper right-hand columns resist more force than left-hand columns.
b. Twisting at roof level about the CoR
6.0 Seismic Design Principle

- Building configuration: Regularity in plan and elevation
6.0 Seismic Design Principle

- Reasonable loadpath transfer
- Provide the building with second load paths and redundancy in structure

Two-way moment frame resisting inertia force whose structurally symmetrical layout integrate with gravity only columns.
6.0 Seismic Design Principle

- Reduce the demand by dissipating energy, or increasing the building period.
- Non-structure elements like triangular or hegxagonal windows and doors stabilize the structure.
6.1 Toolbox For Seismic Resistance

**STRENGTHEN THE HORIZONTAL STRUCTURE:**

- Consolidate the connection between horizontal diaphragm and vertical shear wall

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**Diagram 1:**
- Plan of inertial force in diaphragm
- Compression stress
- Wall
- Connection of diaphragm and wall

**Diagram 2:**
- Curve bond beam acting as arch

**Diagram 3:**
- Short wall in x direction as collector members would effectively resist the inertial force.
6.1 Toolbox For Seismic Resistance

**STRENGTHEN THE VERTICAL STRUCTURE:**
- X-brace to stabilize the loadbearing members
- Shearwall
- Moment frame

Moment frames  
shear walls  
Brace and chord
6.1 Toolbox For Seismic Resistance

- Add damping isolate member under the base to dissipate the earthquake energy.
- Add the building components with high ductile capacity like cable and strut.
6.2 Biomimetic Transformation

what is biomimetics? Biomimetics is not only about nature imitation, but by studying their mechanics and principles in order to transform and develop these principles into complicate technological and architectural solutions.

"Being an integral part of nature ourselves, we shall never be able to talk about it from the outside but only from the inside, uncertain whether to consider something created and produced by man as being 'outside' nature."

Paolo Portoghesi
6.2 Biomimetic Transformation

1. **Biomorphic structure**
The appearance of the building is similar to the natural shape as sculptures.

2. **Process and mechanism analogy**
bimimetic natural construction is building methods analogous to nature, like form finding, self-organization process.

3. **Interactive information**
Living skin performs the tasks of load distribution, substance exchange, information communication as well.... Mimic moisture control, acoustics and sound insulation, heat insulation and so on.

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Calatrava- Metropol Parasol  
Stadium in Munich  
Translucent facade
6.2 Biomimetic Transformation

Transferring Method:

The transfer of information from one discipline to the other disciplines is the most interesting part of the biomimetic process. The transfer of form, the application of morphological characteristics, information flow, construction process and material.

1. **Biology push approach**: Bottom up approach, Biomimetric technology is stimulated from insights of biological research.

2. **Technology pull approach**: Top down approach, driven by a technical scope, extracting the biological approach to improve an already mostly existing technological product.

3. **Pre-researched "Pool Research" approach**
   “Pool Research" ---- filling with the biological data reservoir, which are oriented to a quick generation of knowledge.
6.2 Biomimetic Transformation

- **Phrase 1: Screening**
  the laser confocal microscopy, a series of structure compare with the technical object

- **Phrase 2: Investigation of structure**
  The screened geometries of structure are modelled in cad

- **Phrase 3: Abstraction**
  structure principle is simplified and abstracted. Stress regions are identified in order to replicate the simplified structure.

- **Phrase 4: Optimization**
  the abstract models are parametric and tested

- **Phrase 5: Fabrication**
6.3 Biomimetic Structure

**Diatoms and radiolaria inspired structures:**

a lacy, mesh-like skeleton. open pores are filled with several mesh layers, which nested inside the one another.

1. elongated oval shape, radially symmetric; The radial ribs run from center outwards supporting the fine mesh layer in between

2. **hollowed hexagonal frame form**
6.3 Biomimetic Structure

Panel structures:

1. The **hexagonal panels roof** and the hexagonal **concrete building blocks** are connected covering the hollow hexagonal frame, which are easily to be produced and assembled.

2. six pieces of diatom-shaped **steel reinforced concrete shells** for water reservoir is arranged together.

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6.3 Biomimetic Structure

Nods and rods framework

Siliceous sponges, the nodal points are more dissolved and forming a network of branching struts. The entire structure is oriented on the trajectories of forces.

1. grow with the accumulation standardized elements. basis, large, long-spanning

2. Fossilized sea sponge, spatial nod-and-rod framework, high torsion-resistant capacity, force trajectory
6.3 Biomimetic Structure

shell structure

1. wide-stretched, thin-walled form, building material like pre-stressed concrete. self-supporting network found by hanging chains

2. the ratio between the diameters and shell thicknesses, 1/1000
6.3 Biomimetic Structure

**Hierarchical Structure**

1. The diatom exhibits **rigid ribs** and secondary **branching structures**. The large ribs are supported by smaller substructures.

2. **Hexagonal** structure unit, **modularly** constructed with the **same size, pressure-resistant shell structure**, efficient.
6.3 Biomimetic Structure

Bone Brace structure

1. interior bone correspond to the stress trajectories of compression and tension.
light.

2. bone strut is base on the existing available prefabricated products (T profiles), optimize the structure stability.
6.3 Biomimetic Structure

**Folding system**

increasing the rigidity of surfaces and surface area

Around X-shape vertex, the direct transformation, difficult. One panel can be best coordinated with the neighboring panel automatically resisting the deformation and movement, and lastly forming a very rigid frame.
6.3 Biomimetic Structure

**Autonomous Movements**

Triger: chemonastict, seismonastic, thermonastic, photonastic
Natural apparatuses that open and close themselves without mechanical elements
based on the *elastic deformation property* in material, sun shading facade is changeable.
6.3 Biomimetic Structure

**Structure Optimization**

1. **Optimize form**: Branch is superior than perpendicular shape

2. **Reduce mass**:

3. **SKO methods**: "Soft kill option": adaptive bone mineralization, which is that heavily burdened region have increased rigidity while less burden regions are reduced in mass.
6.4 Frei Otto's Precedents

cable net system

- Simple saddle membrane
- Arch-type membrane
- Ridge-type membrane
- High-point-type membrane
  (Mast and cable supported membrane)

- **Pre-stressed** cable
- **The loops "eye"** is introduced in the web structure to ease the excessive point load
  also found in spider web
- **Extra mass** in the severely stressed nodal structure. Spiders strengthen these
  regions by adding more silk threads or thickening the individual threads.
- **Large span** can be bridged by tensile structure.
6.4 Frei Otto's Precedent

Retractable roof & Umbrellar structure

Cable, pulley, cloth roof, minimum material, minimum intervention

The major load-bearing is concentrated into the central column
6.4 Frei Otto's Precedent

**Tree Structure**

A flat roof is supported by the **a few point** column, load is distributed into **many point tree-branched column**.

Each column bears **less force** than the former one, evitably with **less material**.

**Structure optimization process**
6.4 Frei Otto's Precedent

**Spine structure**

The human spine is a system of ligaments, tendons, muscles and bones, connecting the extremities in body.

Frei Otto experiments with structure system of spine, **pre-tensioned steel cable** to imitate the ligament and muscle.
6.5 Timber Construction

-Transform tensile stress to compressive stress

81. St Martin’s Church

Three-pin frame with raised tie
6.5 Timber Construction

-Transform tensile stress to compressive stress

Multiple-purpose hall in primary school

Trussed beam with tie in middle or steel
6.5 Timber Construction

Fish belly truss with steel tie
6.6 Responsive Skin

-Active Light Control and Collection

The orange puffball sponge (Tethya aurantia) lives in deeper waters. The speciality of this living thing lies in its ability to transfer, distribute light through the bio-fiber bundles. (See figure 93) the light havesting fibers is showing a form of bundles. The ending part of the silicate shreads absorb sun light from the environment and emit it into the interior of the body.
6.6 Responsive Skin

- HUMIDITY REACTIVE SKIN

Cones of conifers is sensitive to the environment of "humidity" and "airdity". The exterior skin process hygroscopic changing abilities, which are evoked by anisotropic behavior of the wood fibers. The wood changes with absorption or desorption of water, the cones open in dry conditions and close in moist conditions.
6.6 Responsive Skin

- ACTIVE SUNSHADING FACADE SYSTEM

A double-layer skin is made with the outer layer as "guard cells" controlling light and heat transmission, the inner layer consisting of louvers to redirect or prevent the light into the interior space.
7. Comparison & Assessment

**Seismic design Principles & Toolbox**

**DESIGN PRINCIPLES**
- lightweight mass
- Strength and Stiffness of structure, ductile material
- Prevention of torsion
- Building configuration: Regularity in plan and elevation
- Reasonable loadpath transfer
- Provide the building with second load paths and redundancy in structure
- Provide Adequate connection between the members
- Reduce the demand by dissipating energy, or increasing the building period
- Non-structure elements like windows and doors stabilize the structure.

**TOOLBOX FOR SEISMIC RESISTANCE**
- Strengthen the connection between horizontal diaphragm and vertical shear wall
- X-brace to stabilize the loadbearing members
- Add the building components with high ductile capacity like cable and strut.
- Add triangular or hexagonal non-structure members like window

**Biomimetic structure application**

**STRUCTURE SYSTEM**
- Diatoms and radiolaria-inspired structures
- Nods and rods framework
- Shell structures
- Hierarchical structure
- Bone braces
- Folding system
- Tensiile structure -- cable net system
- Tensegrity system -- retractable roof
- Umbrella structure
- Tree column system
- Spine structure
- Parabolic arch system

**CONSTRUCTION STABILIZATION ELEMENTS**
- umbrella brace support
- Fish belly Truss
- K-brace Truss
- Post-trussing connection

**TECHNOLOGY OF SKIN**
- Active light control system
- Addaptive sunshading facade

**Structure Member**
- roof structure, column
- roof, frame structure
- roof
- column, arch and vault
- arch frame
- roof and facade
- tensile cable member
- roof
- column and roof
- column
- arch and vault
- arch
- truss & beam
- cable truss & beam
- truss & beam
- cable truss & beam
- roof glazing, facade
- facade

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Matching Process
## 7. Comparison & Assessment

### Seismic design Principles & Toolbox

#### DESIGN PRINCIPLES
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### Matching Process

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8. Structural Proposal

Fish belly beam replicates itself one by one, transforming the tension of cable into the supporting force.
The spine-arch is an integral structure system consisting of both tension and compression of members.
8. Structural Proposal

The hierarchical tree columns form into a bunch structure to support the roof. The branches of support stand in a circle.
The site is located in the south of the Menkenma garden in Uithuizen, surrounded with high trees.

The Menkenma garden is designed by Allert Meijer in 16th century. "The gardens are marked by a clear cut, orderly and symmetrical layout with principal axis and a transverse axis which intersect at the center of the house. The style proclaims "man, the master of nature."
1. Site & Context
2. Design Question

"Can I design a bio-inspired additional museum in Seismic Groningen, with reinterpreting the local landscape?"

-1. How to create a new inspirational structure with the knowledge of biomimetic research and timber construction?

-2. How to integrate the responsive skin technology into the museum design creating a charming space atmosphere?
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**CONTEXT**
- Seismic Groningen
- Reforestation Program

**PROGRAM**
- Menkema Garden
- Seismic Museum
- Menkema Additional Pavilion
- New Landscape

**TECHNOLOGY**
- Biomimetic Structure
- Earthquake Resistance Technology
- Responsive skin
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Thank you for your Attention, Time for questions!