popUP SUPERstructure
Content

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- Fascination
- Design Goal
- Research Question

02 Research
- Design Guide
- Research x Design
- Structural Analysis

03 Design
- Toolbox Design
- Architectural Design

04 Prototyping
- Video

05 Towards P5
- Next Steps
Introduction | Fascination

In nature...

Keukenhof, the Netherlands
Images: online source
In architecture...

Modern Pentathlon Park, Toronto
Images: by author
### Some causes that drive temporary architecture

<table>
<thead>
<tr>
<th>Cause:</th>
<th>Purpose:</th>
<th>Typology:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Disaster</td>
<td>Shelter</td>
<td>Housing</td>
</tr>
<tr>
<td>Events</td>
<td>Expo, Exhibit</td>
<td>Folly, Pavillon</td>
</tr>
<tr>
<td>Games, Concerts</td>
<td></td>
<td>Arena</td>
</tr>
</tbody>
</table>
Types of temporary architecture

According to Robert Kronenburg, mobile and temporary building systems can be divided into three specific types:

1) Portable buildings/structures

2) Relocatable buildings/structures

3) Demountable buildings/structures
Introduction | Fascination

Temporary architecture as addition to existing context

Paper Bridge by Shigeru Ban, France
Images: online source

Temporary architecture as addition to existing building

The stairs to Kriterion by MVRDV, Rotterdam

Temporary architecture as the building

London 2012 Basketball Arena by Sinclair Knight Merz
“However, portable (moveable) buildings, though temporary in location, are not temporary in use. Their portability is precisely what makes them not disposable. The fact that they can be re-used means that they can represent an efficient use of materials and resources, and should therefore be designed with care. They are high-quality products tuned to a specific need if not a specific location.”


Design Goal: Folly/ Pavilion → Arena

Temporary architecture is not disposable, but rather it can mean flexible & re-usable
Overall Design Question

How can temporary architecture used in events be designed to be easily assembled and disassembled in order to adapt to different programmatic needs and project scales when its temporary need has ceased to exist?
Technical Research Question
Which techniques will allow for the creation of a more sustainable and flexible temporary architecture?

Sub-questions
What materials will be most suitable for the creation of lightweight and demountable structures that have low environmental impact?

What would be the optimal sizes for ease of handling and transportation?

What assembly/disassembly methods and connections will be most suitable?
Problem statement concerning building materials

MOST COMMON BUILDING MATERIALS
- concrete: 90%
- aggregates: 8%
- brick: 2%
- other materials: 51%
- wood: 32%
- steel: 30%
- aluminum: 70%
- other: 8%
- concrete: 2%

EMBODIED ENERGY IN BUILDING MATERIALS
- steel: 51%
- aluminum: 32%
- other: 17%
- concrete: 30%
- all other industries: 70%
Problem statement concerning building materials

Embodied Energy of Materials as a Rising Issue

The Pure Cicle as the Key for Material Re-use & Less Embodied Energy

Four Principles for Circular Economy

Source: Ellen MacArthur Foundation
Researched materials

CATEGORY 1: METALS & ALLOYS

CATEGORY 2: COMPOSITES

CATEGORY 3: NATURAL MATERIALS

CATEGORY 4: ENGINEERED MATERIALS
Final results per material & possible scenarios

<table>
<thead>
<tr>
<th>Material Performance</th>
<th>Material Health</th>
<th>Price</th>
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<tbody>
<tr>
<td>Poor: 1 – 18 points</td>
<td>Poor: 1 – 18 points</td>
<td>Expensive: 1 – 18 points</td>
</tr>
<tr>
<td>Good: 19 – 36 points</td>
<td>Good: 19 – 36 points</td>
<td>Reasonable: 19–36 points</td>
</tr>
<tr>
<td>Excellent: 37 – 56 points</td>
<td>Excellent: 37 – 56 points</td>
<td>Cheap: 37 – 56 points</td>
</tr>
</tbody>
</table>

Criteria I: Material Performance
- ALUMINUM
- BAMBOO
- CARDBOARD
- FRP
- LAMINATED BAMBOO
- LAMINATED WOOD
- STEEL
- WOOD

Criteria II: Material Health
- Poor
- Good
- Excellent

Criteria III: Cost
- Expensive
- Reasonable
- Cheap
Material choice influenced by transportation methods and span sizes

- **Span up to 6m**
  - S (3m)
  - M (6m)
  - **GROUND:** Road Class I: 7.82m
  - **SEA:** 20ft (6.1m) shipping container

- **Span up to 12m**
  - L (9m)
  - XL (12m)
  - **ROAD CLASS I:** 13.6m
  - **ROAD CLASS II:** 13.6m
  - **ROAD CLASS III:** 7.82m to 13.6m
  - **SEA:** 40ft (12.2m) shipping container

Research | Design Guide
Material choice influenced by transportation methods and span sizes

Span up to 6m
- S (3m)
- M (6m)

Span up to 12m
- L (9m)
- XL (12m)

Material choice influenced by the needs of the project, transportation methods, and span sizes.
Shortlisted Materials

<table>
<thead>
<tr>
<th>Material Performance</th>
<th>Material Health</th>
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</thead>
<tbody>
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<tr>
<td>Excellent</td>
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- ALUMINUM
- BAMBOO
- CARDBOARD
- FRP
- LAMINATED BAMBOO
- LAMINATED WOOD
- STEEL
- WOOD
Research

Research X Design

Methodology

Tool Box

Analyse
Study

Experiment
Prototypes

Test
Calculations

Structural Analysis
Feasibility

Implement
Design needs

Validate

Design
Context
+ Program

Research
Design Manual
+ Interviews

+
Design Principles

01
- Lightweight
- Durable
- Sustainable
- Affordable

02
- Flexible
- Modular
- Easy to transport
- Easy to handle on site

03
- Easy to Assemble
- Easy to Disassemble
- Few parts
- Simplified design

FLEXIBLE AND REUSABLE TEMPORARY STRUCTURES
Modularity
Modular sizes for different project scales

Flexibility
Curved connection members for different shapes

Bracing of different sizes to add curvature to designs
Preliminary Toolbox Design

Span up to 6m
System I:
sectional profile 300x150mm

Span up to 12m
System II:
sectional profile 500x250mm

Primary Structure
Secondary Structure (Bracing)

1m 1.5m 3m 6m
3m 6m 9m 12m
90° 105° 120° 135° 150°
90° 105° 120° 135° 150°

Type I
Type II
Type III
First Model to test idea

- Modular sizes - main structure
- Curved connection members
- Bracing of different types for design customization

Before Assembly

NO GLUE

After Assembly
First Model main findings

1) Wood on wood connections offered weak points with concentrated stresses in small wooden sections.

2) Primary structure had reduced sectional profile at connection, which reduced structural instability.

3) Linking primary and secondary structures (the bacing) created moment on the primary structure due to structural instability.

SOLUTION:

a) Use much bigger wooden members
b) Adopt to steel connections and do some structural analysis
Structural challenge:

1) Determine the limits of toolbox design in terms of possible and structurally sound structures.

2) Design connections according to stress loads.

Possible typologies

**ROOFS**

**FOOTBRIDGES**

**CANOPIES**

**ROOF DECKS**

<table>
<thead>
<tr>
<th>Load Combinations:</th>
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</thead>
<tbody>
<tr>
<td>![Diagram of Load Combinations]</td>
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</table>

<table>
<thead>
<tr>
<th>Eurocode 1</th>
<th>Canadian Building Code</th>
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</thead>
<tbody>
<tr>
<td>H</td>
<td>1 KN/m²</td>
</tr>
<tr>
<td>C1</td>
<td>3 KN/m²</td>
</tr>
<tr>
<td>C5</td>
<td>5 KN/m²</td>
</tr>
<tr>
<td>H</td>
<td>1.0 KN/m²</td>
</tr>
<tr>
<td>C1</td>
<td>2.4 KN/m²</td>
</tr>
<tr>
<td>C5</td>
<td>4.8 KN/m²</td>
</tr>
</tbody>
</table>

**EUROCODE 5**

**COMBINATIONS OF ACTIONS (LOADS)**

* Characteristic Actions according to EN 1991

<table>
<thead>
<tr>
<th>Q_s</th>
<th>PERMANENT</th>
<th>e.g.: Self-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q_v</td>
<td>VARIABLE</td>
<td>e.g.: wind, snow, traffic, imposed loads</td>
</tr>
<tr>
<td>A_s</td>
<td>ACCIDENTAL</td>
<td>e.g.: Impact, fire</td>
</tr>
</tbody>
</table>

**DESIGN SITUATION**

<table>
<thead>
<tr>
<th></th>
<th>ψ_s</th>
<th>ψ_v</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Design Calculation</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>unfavourable effect</td>
<td>1.35</td>
<td>1.5</td>
</tr>
<tr>
<td>Check at serviceability limit state</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**FORMULAS USED:**

(not considering reduction factors ψ0, ψ1 and ψ2 used to factor load reducing it depending on duration exposure)

<table>
<thead>
<tr>
<th>ULS</th>
<th>structural design</th>
<th>vertical axis for self weight and imposed load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.35 * Q_s + 1.5 * Q_v</td>
<td>horizontal axis for wind load</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLS</th>
<th>serviceability</th>
<th>vertical axis for self weight and imposed load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0 * Q_s + 1.0 * Q_v</td>
<td>horizontal axis for wind load</td>
</tr>
</tbody>
</table>
Roofs

3m members

Footbridges

Usable Roofs

Canopies

3m members

hybrid members

6m members

Hybrid members
Most critical frames

Research | Structural Analysis

- System I
- System II

Roofs

Footbridges

Usable Roofs

Canopies

3m members

hybrid members

6m members

Hybrid members
**Research | Structural Analysis**

Most critical roof frames that passed SLS analysis for System I

![Diagram showing roof frames A4-1, A5-3, and A6-3]

**Table of maximum stresses at connections**

**Pinned Base Connection - System I**

<table>
<thead>
<tr>
<th>FRAME TYPE</th>
<th>Vertical Connection</th>
<th>Inclined Connection</th>
<th>Horizontal Connection</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>SLS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4-1</td>
<td>-10.8</td>
<td>-9.3</td>
<td>-27.81</td>
</tr>
<tr>
<td>A5-3</td>
<td>-13.4</td>
<td>-12.8</td>
<td>-31.38</td>
</tr>
<tr>
<td>A6-3</td>
<td>-17.7</td>
<td>-16.3</td>
<td>-40.55</td>
</tr>
<tr>
<td></td>
<td>5.7</td>
<td>5.8</td>
<td>-41.68</td>
</tr>
<tr>
<td></td>
<td>17.1</td>
<td>17.4</td>
<td>-51.94</td>
</tr>
<tr>
<td>A6-3</td>
<td>-19.8</td>
<td>-19.1</td>
<td>-46.78</td>
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<tr>
<td>A6-3</td>
<td>-26.2</td>
<td>-24.6</td>
<td>-60.41</td>
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<td>-</td>
<td>-</td>
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</table>

**Legend**

- Compression (N)
- Shear (N/m)
- Bending Moment (N/m)

**Diagrams**

- Vertical connections

  - Compression
  - Shear
  - Bending Moment

- Inclined connections

  - Compression
  - Shear
  - Bending Moment

- Horizontal connections

  - Compression
  - Shear
  - Bending Moment
Inclined Connection

**Results:**
2 steel plates of 8mm
8 bolts of 20mm diam. (on each side of connection)

**Observation**
Calculations done based on Eurocode. Model is for illustration using a similar system with steel plates and bolts inserted into Glulam wood.

Inclined connections presented significant stresses due to moment and axial forces as well as relatively moderate shear forces.

Horizontal Connection

**Results:**
2 steel plates of 8mm
4 bolts of 16mm diam. (on each side of connection)

**Observation**
Calculations done based on Eurocode. Model is for illustration using a similar system with steel plates and bolts inserted into Glulam wood.

Due to little moment on the horizontal connection, 4 bolts instead of 8 were sufficient and bolts needed to address mainly shear forces.
System I: Connection design

- **OPTION A**: INSERTED CONCEALED BARS
- **OPTION B**: INSERTED CONCEALED PLATES
- **OPTION C**: INSERTED CONCEALED BARS
- **OPTION D**: INSERTED VISIBLE PLATES
- **OPTION E**: INSERTED VISIBLE PLATES
- **OPTION F**: INSERTED VISIBLE PLATES
Most critical roof frames that passed SLS analysis for System II

### Table of maximum stresses at connections

**PINNED BASE CONNECTION - SYSTEM II**

<table>
<thead>
<tr>
<th>FRAME TYPE</th>
<th>VERTICAL CONNECTION</th>
<th>INCLINED CONNECTION</th>
<th>HORIZONTAL CONNECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AxialForceN (KN)</td>
<td>ShearForceF (KN)</td>
<td>Bending Moment (KN.m)</td>
</tr>
<tr>
<td>SLS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS2</td>
<td>-20.2</td>
<td>8.3</td>
<td>50.1</td>
</tr>
<tr>
<td>BS4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BS3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UL5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Compression
- Shear
- Bending moment
Most critical roof deck frames that passed SLS analysis for System I

Table of maximum stresses at connections

<table>
<thead>
<tr>
<th>FRAME TYPE</th>
<th>PINNED BASE CONNECTION</th>
<th>INCLINED CONNECTION</th>
<th>HORIZONTAL CONNECTION</th>
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<tbody>
<tr>
<td></td>
<td>VERTICAL CONNECTION</td>
<td>INCLINED CONNECTION</td>
<td>HORIZONTAL CONNECTION</td>
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<tr>
<td>SLS</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>RD2</td>
<td>-18.7</td>
<td>4.4</td>
<td>19.7</td>
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<tr>
<td>RD1 beam=300</td>
<td>-13.6</td>
<td>2.5</td>
<td>11.8</td>
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<tr>
<td>RD1 beam=400</td>
<td>-14.0</td>
<td>2.4</td>
<td>10.7</td>
</tr>
<tr>
<td>RD1 beam=400 and cable=30°</td>
<td>-8.5</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>RD1 beam=400 and cable=45°</td>
<td>-8</td>
<td>2.4</td>
<td>1.9</td>
</tr>
<tr>
<td>ULS</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>RD2</td>
<td>-27.9</td>
<td>6.5</td>
<td>29.4</td>
</tr>
</tbody>
</table>

Vertical portion of connection

Horizontal portion of connection

+ compression
- shear
+ bending moment

- compression
+ shear
+ bending moment
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Next Steps
Primary Structure - Main members and connections

SYSTEM I:
- sectional profile 300x150mm

SYSTEM II:
- sectional profile 500x250mm
Secondary Structure - Bracing

BRACING TYPE I

BRACING TYPE II

BRACING TYPE III
Secondary Structure - Connections

**Connection for Bracing Type I or Type II**

**Connection for Bracing Type III**

[Diagrams showing different types of connections for bracing.]
Modular Panels w/ ETFE Membrane

Rail System Embedded into Wood

ETFE Membrane Panels Slides Down

ETFE Membrane
Different types to attend various building performances

Keder Rail Aluminum Profile (various types exist)
Facade - Study of sliding system

STUDY 1

STUDY 2

STUDY 4

STUDY 4
Facade - possible arrangements

FACADE WITH BRACING TYPE I OR TYPE II
FACADE WITH BRACING TYPE I OR TYPE II
FACADE WITH BRACING TYPE III
Stackable Foundation

SYSTEM I
Lightweight concrete footing (700 x 700mm)

SYSTEM II
Lightweight concrete footing (1200 x 1200mm)

Possible Configurations
Flooring

1. SYSTEM I 400mm member
2. SYSTEM I 300mm member
3. BRACING TYPE I
4. SIMILAR TO FACADE SYSTEM

WOOD PURLINS
WOOD DECK
Stairs

1. TOP STRINGER
2. BRACING TYPE I
3. TREAD
4. RISER
5. RAILING

BOTTOM STRINGER

30°
International Event/Expo to be held in 2020 in order to showcase future-proof, innovative and experimental projects that will draw attention to the region and help boost its economy and restore the pride of its citizens.
Context - The Parkstad Region Challenge

Population Density

-875
birth surplus in 2013

9%
unemployment

2,05
average household size

1,180
population density inhabitant per km²

Shrinking Region

Data Source: Handboek IBA Zomer 2015
Context - The Parkstad Region Challenge

Population Density

Tourism for Tomorrow Award 2016

Top 100 Green Destinations

-875 birth surplus in 2013
9% unemployment
2.05 household size
1.180 population density inhabitant per km²

Shrinking Region
Context - Dutch nature as seen by Tourists

Data Source:
(source: https://www.mooistenatuurgebied.nl/over-de-natuur)
Images: online source
Context - What makes the Parkstad Region unique?

The cultural and historic heritage of the Parkstad Region

Images: by author
popUP SUPERstructure: capacity of structure to be flexible and adapt to various scales and programs.

popUP responds to the needs of the present, while being able to gain new life in the future.

series of interventions
promote the region
showcase innovation
showcase sustainability
increase tourism
create jobs
restore pride of citizens
Design | Architectural Design

Project Phasing

PHASE 1
Before IBA 2020

Amsterdam
Dusseldorf
Brussels

IBA

PHASE 2
IBA 2020

PopUP LANDescapes

Folly/ Pavilion

PHASE 3 (future vision)
After IBA 2020

PopUP URBANescapes

Arena

FLEXIBILITY
IBA 2020 - Meet IBA & Get Connected

Meet IBA
Welcome Centre

Get connected

popUP URBANescapes
Follies to attract people to certain regions
Design | Architectural Design

Grunsvenplein - Welcome Centre

Heerlen
Heerlen is considered the Heart of the Parkstad Region. Rich Roman heritage at Via Belgica. City is situated strategically between main roads leading to Belgium and Germany.

Image: Google Earth
Grunsvenplein - Welcome Centre
Vision

**FLEXIBLE INDOOR SPACES**
- Cultural: Mining & Industrial Heritage EXHIBITIONS
- Social & Sustainable: Local Produce MARKET

**FLEXIBLE OUTDOOR SPACES**
- Leisure: Recreational Gatherings FESTIVAL & CONCERT
- Nature: Interaction with Landscape BARE NATURE
- Historic: Interaction with Site History INSTALLATION

Heerlen
Toolbox use for modules creation

Frame A4-1 + Bracing Type III
Frame C3-2 + Bracing Type I
Frame C3-2 + Stairs + Bracing Type I

Module 1
Module 2
Module 3
Combined single module into a long shape.
Not a strong presence on site.
Blocking view of the main theatre.
Module 3

Combined single module type. Strong presence on site. Blocking view of the main theatre. Street as backdrop.
Combined different module types for different programs.
Strong presence on site.
Partial blocking view of the main theatre
Massing and Urban Study

Module 1+ 2 + 3

Combined different module types for different programs.
Strong presence on site. Street approach guided by fluid form.
Direct access to main theatre.
Aerial View

Heerlen
Design | Architectural Design

Program Diagram

Heerlen
Building Sections

Section B

EXHIBITION
IBA PARKSTAD REGION

EXHIBITION
IBA PARKSTAD PROJECTS

IBA PARKSTAD REGION MODEL

Section C

INFO DESK

SOUVENIR SHOP (behind)
Exploded Axonometric

- MODULAR FACADE SLIDING SYSTEM
- BRACING (TYPE III)
- LAMINATED AND ACETYLATED WOOD FRAME
- WOOD DECKING (TONGE AND GROOVE CONNECTION)
- WOOD PURLINS
- BRACING (TYPE I)
- LAMINATED AND ACETYLATED WOOD BEAM
- LIGHTWEIGHT CONCRETE FOOTING
Crystal (or silver) sand used for the manufacture of glass since 1914. The sand is known for its mineral and chemical purity. The quarry landscape was closed to the public and is now being transformed into a public park.

Image: Image: online
Beaujean Quarry - Folly (Floating Platform)
“From Black to Green”: project at the intersection between the Park and the waste left behind by the mining industry now aims to bring back to surface the Rode Beek stream and create a green corridor.

Image: by author
Schutterspark - Folly (Bridge)
03 Design | Architectural Design
Clay pits excavated during Roman times for production of pottery. Elevated pond location is a viewing point for surrounding landscape.

Image: Image: online
Schinveldse Bossen - Folly (Observatory)
VIDEO
<table>
<thead>
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<th>03</th>
<th>04</th>
<th>05</th>
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<td>Structural Analysis</td>
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</table>
Next Steps

* Compile all structural analysis information into a booklet
* Showcase 3 additional design better
* Produce 1:20 Sectional model of Heerlen design
* Adjust details to incorporate more tolerances when needed
Thank you!