The popUP SUPERstructure
Introduction | Fascination

In nature...

Keukenhof, the Netherlands
Images: online source
In architecture...
In the world of events...

Montreal Olympic Stadium, Montreal, Canada
Images: online source
Linear Economy path:

construction → maintenance → renovation → demolition → waste
Four Principles for Circular Economy
Source: Ellen MacArthur Foundation

The Pure Cycle as the Key for Material Re-use & Less

Embodied Energy

Circular Economy path:

- Design for Disassembly
- Modular
- Lightweight
- Temporary
“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.”

Some causes that drive temporary architecture

<table>
<thead>
<tr>
<th>Cause:</th>
<th>Natural Disaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose:</td>
<td>Shelter</td>
</tr>
<tr>
<td>Typology:</td>
<td>Housing</td>
</tr>
</tbody>
</table>

Events

- Expo, Exhibit
- Games, Concerts
- Folly, Pavillion
- Arena
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 Zomer2015
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

Tourism for Tomorrow Award 2016
Top 100 Green Destinations
Context - Dutch nature as seen by Tourists

as seen by the Americans, British and Chinese

as seen by Belgians and Germans

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
popUP SUPERstructure responds to the needs of the present, while being able to gain new life in the future. SUPERstructure: capacity of structure to be flexible and adapt to various scales and programs.
Project Phasing

**PHASE 1**
Before IBA 2020

**PHASE 2**
IBA 2020

**PHASE 3 (future vision)**
After IBA 2020

- **Amsterdam**
- **Dusseldorf**
- **Brussels**

**Design Vision**

- **popUP URBANescapes**
- **popUP LANDescapes**
- **Folly/ Pavillion**
- **Flexibility**
- **Arena**
IBA 2020 - Meet IBA & Get Connected

02 Design Vision | Site Locations

IBA PARKSTAD
Heerlen (centre)
Brussum
Heerlen (Beaujean)
Schinveld
IBA 2020 - Meet IBA & Get Connected
Meet IBA
popUP URBANescapes
Welcome Centre
popUP LANDescapes
Follies to attract people to certain regions

Maastricht
THE NETHERLANDS
BELGIUM

Masterplan Strategy
Grunsvenplein - Welcome Centre

popUP URBANescapes
Welcome Centre
Grunsvleen - Welcome Centre
Beaujean Quarry - Folly (Floating Platform)

popUP LANDescapes
Follies to attract people to certain regions
Beaujean Quarry - Folly (Floating Platform)
**Schutterspark - Folly (Bridge)**

**popUP LANDescapes**

Follies to attract people to certain regions
Schutterspark - Folly (Bridge)
Schinveldse Bossen - Folly (Observatory)

popUP LANDescapes
Follies to attract people to certain regions
Schinveldse Bossen - Folly (Observatory)
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: 8%
- Wood: 2%

EMBODIED ENERGY IN BUILDING MATERIALS
- Steel: 51%
- Aluminum: 32%
- Other: 17%
- Concrete: 30%
- All other industries: 70%
Final results per material & possible scenarios

<table>
<thead>
<tr>
<th>Criteria I: Material Performance</th>
<th>Criteria II: Material Health</th>
<th>Criteria III: Cost</th>
</tr>
</thead>
<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>
Material choice influenced by transportation methods and span sizes

- **Span up to 6m**
  - S (3m) members
  - W 3m x H 3m x D 10m
  - 540 kg
  - 1674 €
  - 6588 MJ

- **Span up to 12m**
  - M (6m) members
  - W 6m x H 6m x D 10m
  - 2065 kg
  - 6385 €
  - 25200 MJ

- **Span up to 12m**
  - L (9m) members
  - W 9m x H 9m x D 10m
  - 2754 kg
  - 8514 €
  - 33600 MJ

- **Span up to 12m**
  - XL (12m) members
  - W 12m x H 12m x D 10m
  - 270 kg
  - 837 €
  - 3294 MJ

Material choice is influenced by transportation methods and span sizes.
Chosen scenario

Material Performance
ALUMINUM

BAMBOO

CARDBOARD

FRP

LAMINATED BAMBOO

LAMINATED WOOD

STEEL

WOOD

Material Health

Price

Good

Poor

Excellent

Excellent

Reasonable

Cheap

Expensive
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

Research X 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
Content

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Research x Design

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Toolbox Design
Structural Analysis
Advantages

05 Architecture
Use of Toolbox
Urban Study
Video
Toolbox Design

- Research
  Design Manual + Interviews
- Analyse
  Study
- Tool Box
- Experiment
  Prototypes
- Validate
- Test
  Calculations
- Implement
  Design needs
- Structural Analysis
  Feasibility
- Design
  Context + Program

04 Toolbox
Toolbox Goal

FLEXIBLE

EASY ASSEMBLE / DISASSEMBLE

LIGHTWEIGHT

MODULAR

TEMPORARY

Toolbox Design
Toolbox Parts

1. PRIMARY STRUCTURE
2. PRIMARY CONNECTION
3. EXPANDABLE BOLT
4. SECONDARY STRUCTURE
5. SECONDARY CONNECTION
6. FACADE
7. STACKABLE FOUNDATION
8. FLOORING
9. STAIRS
Primary Structure - Main members and connections

**SYSTEM I:**
- Sectional profile 300x150mm

**SYSTEM II:**
- Sectional profile 400x150mm

**SYSTEM II STEEL PLATES CONNECTION**

**SYSTEM I STEEL PLATES CONNECTION**
Secondary Structure - Bracing

BRACING TYPE I

BRACING TYPE II

BRACING TYPE III

TOP VIEW

TOP VIEW

TOP VIEW

CONNECTION PRINCIPLE

HOLLOW ALUMINUM PROFILE

MAIN STRUCTURE

PIN

BRACING
Facade - Concept

- MODULAR PANELS W/ ETFE MEMBRANE
- RAIL SYSTEM EMBEDDED INTO WOOD
- ETFE MEMBRANE PANELS SLIDES DOWN
- CREATION OF DOUBLE FACADE SYSTEM ON KEDER RAIL PROFILES
Advantages of Facade system:

ETFE MEMBRANE
* 20x lighter than glass
* 100% recyclable
* high tensile strength
* flexible shapes
* low maintenance
* high light transmission
* high thermal performance
  up to U-Value 2.6W/m2K

PVC FABRIC
* only 1% recyclable
* toxic components
* flexible shapes
* low thermal performance
  U-Value 4.4W/m2K

GLASS
* not as light
* recyclable
* not flexible shapes
* high thermal performance
  up to U-Value 0.25W/m2K
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

Advantages of the system:
Flooring

SYSTEM I 400mm member
SYSTEM I 300mm member
BRACING TYPE I

SIMILAR TO FACADE SYSTEM
WOOD PURLINS
WOOD DECK

1. 2. 3. 4.

Toolbox Design
Stairs

1. TOP STRINGER

2. BRACING TYPE I

3. TREAD

4. RISER

5. STEPS (BLOCKS)
VIDEO
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

Load Combinations:

<table>
<thead>
<tr>
<th>Eurocode 1</th>
<th>Canadian Building Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 1kN/m²</td>
<td>Roofs 1.0 kN/m²</td>
</tr>
<tr>
<td>C1 3kN/m²</td>
<td>Assembly areas (class b) 2.4 kN/m²</td>
</tr>
<tr>
<td>C5 5kN/m²</td>
<td>Balconies and Footbridges 4.0 kN/m²</td>
</tr>
</tbody>
</table>

EUROCODE 5
COMBINATIONS OF ACTIONS (LOADS)

* Characteristic Actions according to EN 1991

Gₖ  PERMANENT  e.g.: Self-weight
Qₖ  VARIABLE  e.g.: wind, snow, traffic, imposed loads
Aₖ  ACCIDENTAL  e.g.: Impact, fire

<table>
<thead>
<tr>
<th>DESIGN SITUATION</th>
<th>Y₀</th>
<th>Y₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Design Calculation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>favourable effect</td>
<td>1.0</td>
<td></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 Y₀, Y₁ and Y₂ used to factor load reducing it depending on duration exposure)

ULS  structural design  1.35*Gₖ + 1.5*Qₖ  vertical axis for self weight and imposed load

  horizontal axis for wind load

SLS  serviceability  1.0*Gₖ + 1.0*Qₖ  vertical axis for self weight and imposed load

  horizontal axis for wind load
04 Toolbox | Structural Analysis

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Roofs

3m members

Footbridges  Usable Roofs

Canopies

3m members  hybrid members  6m members

Hybrid members
Most critical frames for System I

ROOFS - 3m members

ROOFS - 6m members

Legend System I:
- Fixed support connection: Failed "SLIP" check
- Hinged support connection: Passed "SLIP" check

Legend System II:
- Hinged support connection: Failed "SLIP" check
- Hinged support connection: Passed "SLIP" check
Most critical frames for System II

ROOFS - 3m members

LEGEND SYSTEM I
- Fixed support connection failed "SLE" check
- Hinged support connection passed "SLE" check

LEGEND SYSTEM II
- Hinged support connection failed "SLE" check
- Hinged support connection passed "SLE" check

ROOFS - 6m members

System I
System II
1. TEMPERATE CLIMATE: Single Facade
   1- open to allow for natural ventilation
   2- ventilators to enhance air flow
   3- removal of modules for cross ventilation

2. TEMPERATE CLIMATE: Double Facade
   1- open to allow for natural ventilation
   2- ventilators to enhance air flow
   3- outer layer: rain protection
   4- inner layer: shading
   5- air gap between layers to prevent from overheating
3. SUMER or WINTER

1- single or double facade
2 - fully enclosed building
2- AHU to control temperature
3- fabric air duct to distribute air
4- floor insulation added

4. WINTER (no heating needed)

1- fully enclosed building
2- no heating needed (ex: ice skate rink)
Existing Systems:

Proposed System:
05 Architecture | Program

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
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
Massing and Urban Study

Module 1

Module 3

Module 2 + 3

Module 1+ 2 + 3
VIDEO
Possible Future Uses

Outdoor Performances
SEATING CAPACITY: 500

Amphitheatre
SEATING CAPACITY: 1500

Arena
SEATING CAPACITY: 3000

Small Stadium
SEATING CAPACITY: 1600

Medium Stadium
SEATING CAPACITY: 3200

Arena
SEATING CAPACITY: 6200
Thank you!