Sustainability and Service Life of Curtain Walls

Stick and unitised system for short-term and long-term use in curtain walls

Mentors: Dipl.ing. Tillmann Klein
Dr.ir. Fred Veer
Introduction


References

References
Sustainability and Service Life of Curtain Walls

Introduction

Product category business volume

- Introduction
- Growth
- Maturity
- Decline

Service life

- 0-2 years
  - production
  - storage
  - transport
  - construction

- x years
  - operation

- Demolition/disassembly

Growth Maturity Decline time

€
Sustainability and Service Life of Curtain Walls

Introduction

Product category business volume

0-2 years
• production
• storage
• transport
• construction

x years
• operation

Conclusions

service life

• demolition/disassembly
How long do you want your product to live?

- Design - decision making
- Program of maintenance
- Non-/durable materials
- Level of connectivity
- RELIABILITY

Factors:
- Cost
- Time
- Disturbance
- etc
How long do you want your product to live?

- Cost
- Time
- Disturbance etc

Design - decision making

Program of maintenance

Non-/durable materials

Level of connectivity

RELIABILITY
**Problem statement**

Proportion between *materialisation* and *operation* of a construction must be in balance for a sustainable life cycle.

- Low energy buildings have already reduced the operational energy demands.
- **Minimise** environmental impact of materialisation.
- Rethink the role of *product's expected life span*.
- Starting point: *curtain walls* (widely used in office and commercial buildings).

![Diagram](image)

**Design phase**  ➔ **Decision making**  ➔ **Sustainability & Environmental Impact**
Problem statement

Proportion between materialisation and operation of a construction must be in balance for a sustainable life cycle.

Low energy buildings have already reduced the operational energy demands.

Minimise environmental impact of materialisation.

Rethink the role of product’s expected life span.

Starting point: curtain walls (widely used in office and commercial buildings).
Research question

- How long should a curtain wall live to have minimum environmental impact?

- Does stick or unitised curtain wall provide the most sustainable materialisation and service life?

References
Research question

- How long should a curtain wall live to have minimum environmental impact?
- Does stick or unitised curtain wall provide the most sustainable materialisation and service life?
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

References

AFTER DESIGN FOR DIS-/ASSEMBLY
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Snap fit
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Reversible snap-fit
Sustainability and Service Life of Curtain Walls

Introduction

Snap fit

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Reversible snap-fit
Reversible snap-fit
10 steps to disassemble
• Architectural design
• Architectural design
• Visual comfort
• Architectural design
• Visual comfort
• Thermal insulation
• Architectural design
• Visual comfort
• Thermal insulation
• Ventilation
• Architectural design
• Visual comfort
• Thermal insulation
• Ventilation
• Protection from weather conditions
• Architectural design
• Visual comfort
• Thermal insulation
• Ventilation
• Protection from weather conditions
• Structural integrity
Curtain wall systems
Curtain wall systems

- Stick curtain wall
- Unitised facade
Curtain wall systems

Stick curtain wall
Curtain wall systems

Stick curtain wall

Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions
Introduction

Facade Design

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Curtain wall systems

Stick curtain wall
Curtain wall systems

Unitised facade
Curtain wall systems

Unitised facade
Curtain wall systems

Unitised facade
Design for easy dis-/assembly
Design for easy dis-/assembly
Design for easy dis-/assembly
Design for easy dis-/assembly
Design for easy dis-/assembly
Life span of materials

- 70+ years (Aluminium)
- 30 years (EPDM gasket)
- 30 years (Glass unit)
- 30 years (PE foam)
- 30 years (EPDM gasket)
Life span of materials

- 70+ years (Aluminium)
- 30 years (EPDM gaskets)
- 30 years (Glass unit)
- 30 years (PE foam)
- 30 years (EPDM gaskets)
Façade’s service life

- 30 years
- 60 years
- 120 years
Façade’s service life

![Graph showing the comparison between primary cost and environmental impact flexiblity against different service lives (30 years, 60 years, 120 years). The graph indicates that primary cost decreases with increasing service life, while environmental impact plus flexibility increases with increasing service life. The service life is measured from 30 years to 120 years, with 60 years being the point of intersection where primary cost equals environmental impact plus flexibility.]
Façade’s service life

![Graph showing the relationship between service life and primary cost](image)

- Primary cost:
  - 30 years
  - 60 years
  - 120 years

- Environmental impact:
  - Flexibility
Mechanical, Maritime and Materials Engineering Faculty (3mE)

- Use educational => regular changes
- Design 4 modular wings connected
Typical Dutch construction

(brick facade - insulation - concrete wall)
Scenarios of service life

15 years service life
Scenarios of service life

- 15 years service life
  - replace only the facade
  - building serv.life = 60 years
Scenarios of service life

15 years service life

- replace only the facade
  building serv.life = 60 years

- take apart the complete building
  building serv.life = 15 years
Scenarios of service life

15 years service life
- replace only the facade
  building serv.life = 60 years
- take apart the complete building
  building serv.life = 15 years

60 years service life
Scenarios of service life

15 years service life
- replace only the facade
  building serv.life = 60 years
- take apart the complete building
  building serv.life = 15 years

60 years service life
- refurbish once after 30 years
  building serv.life = 60 years
• Span of 60 years in total

• No material losses during disassembly and transportation to recycling shredder

• Highest percentages of material recovery through recycling

• Values acquired: average data (CES Edupack 2014)

• Façade’s performance: efficient

• Only triple glazing is evaluated for the long-term scenario

• Feasibility, experience, current equipment considered for the redesign
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Detailing

15 years service life

60 years service life
Sustainability and Service Life of Curtain Walls

Introduction
Industrial Design
Facade Design
Design Proposal
Evaluations
Conclusions

Detailing

15 years service life

60 years service life

Stick curtain wall
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Detailing

15 years service life

60 years service life

Stick curtain wall

reduced tolerance for adjustments in glazing

TU Delft
Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Detailing

15 years service life

60 years service life

Stick curtain wall
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Detailing

Stick curtain wall

15 years service life

60 years service life

cover cap reversible connection
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Detailing

15 years service life

60 years service life

Stick curtain wall

replace with Nylon polyamide
**Introduction**

**Industrial Design**

**Facade Design**

**Design Proposal**

**Evaluations**

**Conclusions**

### Detailing

- **15 years service life**
- **60 years service life**

**Stick curtain wall**
Energy evaluation

Primary Embodied Energy
+ Refurbishment/Replacement Embodied Energy
+ End-of-life Energy = Total Embodied Energy of evaluated energy
(Refurbishment E.E = x % recycling E.E. + y % primary E.E.)

*Respectively for the CO₂ emissions.
Energy evaluation

Embodied energy
&
$\text{CO}_2$ emissions
Energy evaluation

Embodied energy & CO\textsubscript{2} emissions

- Stick curtain wall
- Unitised facade
Energy evaluation

Embodied energy & CO₂ emissions

Stick curtain wall

- 15 years service life
- 60 years service life

Unitised facade

- 15 years service life
- 60 years service life
Sustainability and Service Life of Curtain Walls

Introduction

Industrial Design

Facade Design

Design Proposal

Evaluations

Conclusions

Energy evaluation

Embodied energy & CO₂ emissions

Stick curtain wall

Unitised facade

Outcome

Stick Vs Unitised

15 years service life

60 years service life

15 years service life

60 years service life
Energy evaluation

Embodied energy & CO₂ emissions

Stick curtain wall

Unitised facade

Outcome

Stick Vs Unitised

Short Vs Long-term

15 years service life

60 years service life

15 years service life

60 years service life

Energy evaluation
Comparison of Results

Glazing: double
Refurbishments: 2
Comparison of Results

Glazing: double
Refurbishments: 2

Emb. Energy (MJ)

CO₂ emissions (kg)

Emb. Energy (MJ)

CO₂ emissions (kg)

STICK

UNITISED

+ 21%

+ 27%
Comparison of Results

Glazing: triple
Refurbishments: 2
Comparison of Results

Glazing: triple
Refurbishments: 2

![Graphs showing comparison of Emb. Energy and CO₂ emissions for STICK and UNITISED configurations.](image)
Comparison of Results

Glazing: triple
Refurbishments: 2
Comparison of Results

Glazing: triple
Refurbishments: 2
Comparison of Results

Glazing: triple
Refurbishments: 2

Emb. Energy (MJ)

CO₂ emissions (kg)

~ 17%
Comparison of Results

Glazing: triple
Refurbishments: 2
Comparison of Results

Glazing: triple
Refurbishments: 2
Cost - Time

Primary Cost

<table>
<thead>
<tr>
<th>Facade system / Primary cost (€)</th>
<th>Double glazing</th>
<th>Triple glazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stick 15 years Service Life</td>
<td>279.30</td>
<td>392.46</td>
</tr>
<tr>
<td>Stick 60 years Service Life</td>
<td>-</td>
<td>404.59</td>
</tr>
<tr>
<td>Unitised</td>
<td>288.25</td>
<td>401.41</td>
</tr>
</tbody>
</table>
Cost - Time

Primary Cost

<table>
<thead>
<tr>
<th>Facade system / Primary cost (€)</th>
<th>Double glazing</th>
<th>Triple glazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stick 15 years Service Life</td>
<td>279.30</td>
<td>392.46</td>
</tr>
<tr>
<td>Stick 60 years Service Life</td>
<td>-</td>
<td>404.59</td>
</tr>
<tr>
<td>Unitised</td>
<td>288.25</td>
<td>401.41</td>
</tr>
</tbody>
</table>

![Cost-Time Diagram]

- **Time of labour (hours)**
  - Stick: 210 hours (On Site: 150, In Factory: 60)
  - Unitised: 120 hours (On Site: 100, In Factory: 20)
Cost - Time

Primary Cost

<table>
<thead>
<tr>
<th>Facade system / Primary cost (€)</th>
<th>Double glazing</th>
<th>Triple glazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stick 15 years Service Life</td>
<td>279.30</td>
<td>392.46</td>
</tr>
<tr>
<td>Stick 60 years Service Life</td>
<td>-</td>
<td>404.59</td>
</tr>
<tr>
<td>Unitised</td>
<td>288.25</td>
<td>401.41</td>
</tr>
</tbody>
</table>

TIME = MONEY

UNITISED → + 40 h in factory
- 130 h on site
- 90 h in total

less labour
better conditions
better quality
less expenses
Design matters...
• Both stick and unitised facade have approximately the same environmental impact
• Both stick and unitised facade have approximately the same environmental impact

• Unitised system provides better working conditions and saves a lot of time and expenses
• Stick system requires more time and costs and daily transportation, as most of the work is done on site
• Both stick and unitised facade have approximately the same environmental impact

• Unitised system provides better working conditions and saves a lot of time and expenses
• Stick system requires more time and costs and daily transportation, as most of the work is done on site
• Both stick and unitised facade have approximately the same environmental impact

• Unitised system provides better working conditions and saves a lot of time and expenses
• Stick system requires more time and costs and daily transportation, as most of the work is done on site

• **Long-term service life** should be applied on façades, and refurbish when needed (currently not applied)
Thank you for your attention!

Questions?