Concept for a BIM-based Material Passport for buildings

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BI(Material

• Research project „BI(Material: Process-Design for a BIM-based Material Passport“
• Project duration: 01/2016 – 05/2018
• Funded by the Austrian Ministry for Transport, Innovation and Technology
• Project partners from TU Vienna and industry
Point of departure

- Buildings in the EU are responsible for 50% of all extracted materials and for 35% of greenhouse gas emissions \(^1\)
- The construction sector is the largest consumer of raw materials \(^2\)
- Aim of the EU: reducing waste, using less virgin materials and increasing recycling rates \(^3\)

\[\downarrow\]

Consumption of raw materials needs to be reduced in the building industry

- Information about the material composition of buildings is required!

\(^1\) European Commission, Roadmap to a Resource Efficient Europe, Brussels, 2011
\(^2\) WEF, World Economic Forum, Shaping the Future of Construction: A Breakthrough in Mindset and Technology, 2016
\(^3\) European Commission, Commission Decision, 2011
What is a Material Passport (MP)?

A qualitative and quantitative documentation of the material composition of a building showing the material distribution within a building

• Allocation of materials
• Amount of materials (masses)
• Share of recyclable and waste materials
• Environmental impact of materials
• Separability of materials
Aim of this research

- Process-Design for a BIM-based Material Passport
- Is a BIM-based and automated generation of a Material Passport possible?
Framework for the BIM-based MP

- Mix of bottom-up and top-down approach, starting at element-level
- Based on Markova and Rechberger (2011)
Scope of the BIM-based MP throughout the life-cycle

- **MPa**: Rough analysis and optimization tool, variant studies (timber vs. concrete)
- **MPb**: optimization of the selected variant (thickness of layers, material)
- **MPc**: documentation of the exact material composition
- **MPd**: basis for a secondary raw materials cadastre
Method and data

IBO database

Consistent data!

Eco-data (eco2soft)
- Global Warming Potential (GWP)
- Acidification Potential (AP)
- Primary Energy Intensity

Recycling-data (eco2soft)

<table>
<thead>
<tr>
<th>Recycling grade</th>
<th>Recycling</th>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>2</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>3</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>4</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>0%</td>
<td>125%</td>
</tr>
</tbody>
</table>

Building elements (baubook)
- Concrete outside wall
- Cross laminated timber outside wall etc.

IBO, Austrian Institute for Building and Ecology
http://www.ibo.at/de/oekokennzahlen.htm

Eco2soft: https://www.baubook.info/eco2soft/
Baubook: http://www.baubook.info/index.php
Method and data

• Assessing the share of recycling for a specific material (concrete) in a wall of $1\,m^2$ (based on the IBO method):

\[
\text{density (eco2soft)} \times \text{thickness (baubook/BIM)} \times \text{area (BIM)} \times \text{recycling grade (eco2soft)}
\]

\[
2300 \,[kg/m^3] \times 0,18 \,[m] \times 1 \,[m^2] \times 50\% \,[\text{grade 2}] = 207 \,kg
\]

Separability is not considered in the IBO method – partly manual process necessary (pre-defined elements)
Workflow for generating the MP

1. **Modeling Guide**
   - Pre-defined building elements (without properties)

2. **BIM**
   - Layers of building elements
   - Single elements: doors/windows
   - Building services: pipes

3. **Control Tool**

4. **Material Inventory and Analysis Tool**
   - Eco-inventory database
   - Recyclability potential and LCA-data
   - Pre-defined building elements (with properties)

**Results:**
- Material composition of a building and the mass of recyclable and waste materials;
- Environmental Impact (GWP, AP, PEI);
- Material Passport
Modelling methodology for MPa

**BIM**
Mono-layered elements without properties

**Material inventory and analysis tool**
Multi-layered elements with properties (MP- and LCA-data)

Possibility to carry out variant studies
Modelling methodology for MPb

BIM
Multi-layered elements without properties

Material inventory and analysis tool
Multi-layered elements with properties (MP- and LCA-data)

Possibility to make small changes in the thickness or a specific material
Case study: office building

- Existing model of the building
- 3 storeys
- Concrete construction

Mono-layered elements (for Mpa)

Mono-layered elements replaced by multi-layered elements from the catalogue (for MPb)
**MP-results**

### Recycling Potential of the Building

<table>
<thead>
<tr>
<th>Grade</th>
<th>Recycling Grade</th>
<th>Share of Recycling (t)</th>
<th>Share of Waste (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>86-100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>64-72%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>44-56%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>31-44%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>17-31%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3-17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>&lt;=11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&lt;=11%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Disposal Indicator of the Building *

<table>
<thead>
<tr>
<th>Grade</th>
<th>Disposal Indicator (FI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*Disposal indicator is element-based and area weighted, it considers the volume, disposal- and recycling-grade.*
MP-results on building level

Waste vs. Recyclable mass

LCA
MP-results on building level

Material composition in %

Accruing masses throughout the life-cycle (t)
MP-results on component level

Waste vs. Recyclable mass

LCA
MP-results on material level

Waste vs. Recyclable mass

LCA
Conclusions

Main obstacles:

• **Inconsistent nomenclature** in different eco-databases

• In early design stages the **material composition is not defined** yet, therefore the use of pre-defined elements is necessary – restriction for planners

• **Parametrization** of materials in BIM is **not possible** in a consistent way, therefore the Material Inventory and Analysis Tool was used - requires specific know-how

• Knowledge regarding materials and sustainability necessary - „MP-consultant“
Conclusions

• Semi-automated generation of the BIM-based MP is possible
• MP enables optimizations in early design-stages
• MP represents a vital contribution to implement circular solutions within the AEC industry
• Basic method (from IBO) could be improved and enriched with data
• New construction rate across Europe is 2% - generation of MPs for existing buildings necessary (research project SCI_BIM)
Publications

• Publications to BIMaterial:

• Information and final report of BIMaterial:
  • https://www.industriebau.tuwien.ac.at/forschung/forschungsprojekte-ip/bimaterial/
New research project

• SCI_BIM – Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling

• Information to SCI_BIM:
  • https://www.industriebau.tuwien.ac.at/forschung/forschungsprojekte-i-p/sci-bim/

• Contact:
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Thank you for your attention!

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