Sustainability Performance of Construction Materials and Building Products made from Secondary Materials

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# Resource flows in urbanised areas

<table>
<thead>
<tr>
<th>Energy related resources</th>
<th>Material related resources</th>
<th>Water, Land</th>
<th>Ecosystems</th>
<th>Human health</th>
<th>Resources</th>
</tr>
</thead>
</table>

- Energy related resources
- Material related resources
- Water, Land
- Ecosystems
- Human health
- Resources
Global Material Extraction & GDP

Source: Krausmann et al. 2009
Average Metabolic Rates

Metabolic rates [t/cap/yr]

- Ores and industrial minerals
- Fossil fuels
- Construction minerals
- Biomass

Source: Krausmann et al. 2008
Our «ecological rucksack»

Material needed per capita per year

50 tons = 100 %

<table>
<thead>
<tr>
<th>Category</th>
<th>Tons (per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>others</td>
<td>11</td>
</tr>
<tr>
<td>community</td>
<td>6</td>
</tr>
<tr>
<td>leisure</td>
<td>13</td>
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<tr>
<td>education</td>
<td>5</td>
</tr>
<tr>
<td>health</td>
<td>9</td>
</tr>
<tr>
<td>clothing</td>
<td>6</td>
</tr>
<tr>
<td>food</td>
<td>20</td>
</tr>
<tr>
<td>residence</td>
<td>29</td>
</tr>
</tbody>
</table>

The hidden material “rucksack”

- erosion
- earth displacement
- unconverted materials

The visible material load

- mineral raw materials
- fossil fuels
- biological raw materials

Our «ecological rucksack»
Construction and Demolition Waste in Europe

- Construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU.
- CDW accounts for approximately 25% - 30% of all waste generated in the EU and consists of concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled.
- Despite its potential, the level of recycling and material recovery of CDW varies greatly (between less than 10% and over 90%) across the Union.

EU target to divert 70% of construction and demolition waste from final disposal by 2020
EU Construction Products Regulation

New Basic Requirement No. 7: „Sustainable Use of Natural Resources“

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and ensures the following:

a. recyclability of the construction works, their materials and parts after demolition
b. durability of the construction works
c. use of environmentally compatible raw and secondary material in the
d. construction

→ all product standards have to be revised!
Recycling options of building construction material in Germany

• **Mineral construction waste**
  - Separation technology determines the quality of the recycling potential. Road construction is the most used recovery path > 50%
  - **Bricks** can be mechanically cleaned of plaster and mortar residues.
  - **Broken bricks**: aggregate for mortars, plasters, sand-lime bricks or as a natural bulk and substructure material for road construction. In addition, recycled bricks may be used as a lightweight aggregate in concrete or as an aggregate in tennis sand.

• **Timber**
  - Direct reuse of **untreated waste wood** as beams, formwork material or wooden paving is in principle possible
  - Less than a quarter of the resulting waste wood is recycled for the production of laminated wood mouldings and chipboard
  - The vast majority is incinerated for energy recovery
Recycling options of building construction material in Germany

- **Polyvinyl chloride**
  - For the recycling of PVC windows, doors and roller blinds a nationwide collection and transport system in Germany has been established
  - The *non-existent purity* of PVC composite materials is a problem for recycling

- **Glass**
  - The majority of *waste glass* is melted on as often as desired and used for the manufacture of new glass products
  - Insulating materials made of *glass wool* are made of recycled glass up to a limit of 70% and are melted with other ingredients
  - *Expanded glass granulate* (up to 95% recycled glass) is used as a lightweight aggregate for mineral plasters or lightweight concrete, as well as bulk insulation and sound absorbers
Recycling options of building construction material in Germany

• Metall
  – Structural **steel** nearly closed cycle of materials of 99%. 11% of it can be reused directly. The remaining portion is recycled to high quality new secondary building materials.
  – **Copper** can be recycled any number of times

• Insulating material
  – The majority of **mineral wool** consists of old carcinogenic KMF. Although a higher recycling rate of new KMF is generally possible, currently the majority is landfilled.
  – **EPS**: lack of economic efficiency of existing treatment processes

• Gypsum based materials
  – **Gypsum** can be recycled many times, because the starting material is chemically identical to the hardened end product.
  – The plaster must be sorted, which is hardly the case
Gravel extraction

Land fill

New construction

Deconstruction

Quelle: Amt für Umweltschutz, Kanton Zug
Recycling of construction materials – Life cycle assessment (1/2)

Assumptions for C30/37

• Concrete content for 1 m³ of concrete:

<table>
<thead>
<tr>
<th></th>
<th>C30/37 with natural aggregates</th>
<th>C30/37 with recycled aggregates (25 M.-%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregates</td>
<td>2'000 kg natural aggregates</td>
<td>1'400 kg natural aggregates 460 kg recycled aggregates</td>
</tr>
<tr>
<td>Cement</td>
<td>300 kg CEM II/A</td>
<td>320 kg CEM II/A</td>
</tr>
</tbody>
</table>

• Miscellaneous (examples):
  - No transportation between and treatment and concrete plant
  - 18 km transport distance for the supply of recycled aggregates to the treatment plant
  - Etc.

Recycling of construction materials – Life cycle assessment (2/2)

C 30/37 with natural and recycled aggregates)

► Ambiguous result regarding the usage of recycled concrete aggregates for C 30/37 but different for lean concrete

Worldwide importance of the construction industry

- Jobs: 7%
- GDP: 10%
- Fresh water: 17%
- Energy / CO₂: 30-40%
- Raw materials: 50%
- Land harvesting: 60%
Sustainable development strategies

Resource decoupling refers to when fewer resources are used per unit of economic output, while impact decoupling is when negative impacts on the environment are reduced.

## Sustainability assessment of construction technologies

<table>
<thead>
<tr>
<th>Key challenges</th>
<th>Cost per m² (superstructure only)</th>
<th>Requirements building process, Skills</th>
<th>Time Schedule, Prefabrication</th>
<th>Degree</th>
<th>Economy of Scale, Mass Production</th>
<th>Modularization and Flexibility</th>
<th>Durability</th>
<th>Maintenance needs</th>
<th>Recycling Potential, Demolition Ability</th>
<th>Local value creation - labor, material</th>
<th>Interface infrastructure and housing techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scarcity of resources</td>
<td></td>
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<tr>
<td>Lack of sufficient funds</td>
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<tr>
<td>Shortage due to urgency of demand</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Shortage of skilled labour</td>
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<td></td>
<td></td>
<td></td>
<td>x</td>
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<tr>
<td>Quality control</td>
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<td>x</td>
<td>x</td>
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<td></td>
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<td>Wastage due to inefficiency</td>
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<td>x</td>
<td>x</td>
<td></td>
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<td></td>
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<tr>
<td>Lack of added value creation</td>
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<td></td>
<td></td>
<td>x</td>
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<tr>
<td>Quality and Location</td>
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<td>x</td>
<td></td>
<td>x</td>
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</tbody>
</table>

Examples of selected indicator values

<table>
<thead>
<tr>
<th>Initial Construction Costs [USD/m²]</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40 USD</td>
<td>10</td>
</tr>
<tr>
<td>&lt;60 USD</td>
<td>8</td>
</tr>
<tr>
<td>&lt;100 USD</td>
<td>6</td>
</tr>
<tr>
<td>&lt;140 USD</td>
<td>4</td>
</tr>
<tr>
<td>&gt;180 USD</td>
<td>2</td>
</tr>
<tr>
<td>N/A</td>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Requirements Production</th>
<th>Construction Process</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unskilled Labour with no training or local skills traditionally available, low-tech tools</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Unskilled Labour with short training (&lt; two week) or local skills available</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Unskilled Labour with intensive training (several weeks) or skilled workers</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Advanced skills or Tools required</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Very advanced Skill Level or Tools required</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Information not available</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Sustainability assessment of construction technologies

Average per construction technology category

Steps to obtain Sustainability Criteria from multi-perspective stakeholder data

# Summary of Sustainability Assessment Criteria

<table>
<thead>
<tr>
<th>No.</th>
<th>Pillar of Sustainability</th>
<th>Criteria</th>
<th>(1)</th>
<th>(2A)</th>
<th>(2B)</th>
<th>(3)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Society</td>
<td>Social Acceptance &amp; Advocacy</td>
<td>-</td>
<td>+/-</td>
<td>+</td>
<td>+</td>
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<tr>
<td>2</td>
<td></td>
<td>Participation &amp; Identification</td>
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<td></td>
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<td>3</td>
<td></td>
<td>Capacity Building</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>4</td>
<td></td>
<td>Income at local value chain</td>
<td>+</td>
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<tr>
<td>5</td>
<td></td>
<td>Maintenance &amp; Incremental Development</td>
<td>-</td>
<td></td>
<td></td>
<td>+</td>
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<tr>
<td>6</td>
<td></td>
<td>Health &amp; Comfort</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
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<tr>
<td>7</td>
<td></td>
<td>Enduring safety &amp; performance</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>8</td>
<td>Technology</td>
<td>Standardization, Quality Control, Pace of Construction</td>
<td>-</td>
<td></td>
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<td>+</td>
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<tr>
<td>9</td>
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<td>Continuous Innovation</td>
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<td>10</td>
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<td>Cost advantage of houses</td>
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<td>11</td>
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<td>Scalable business model</td>
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<td>12</td>
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<td>Supply accessibility</td>
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<td>+</td>
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<tr>
<td>13</td>
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<td>Supply availability &amp; sustainability</td>
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<td>14</td>
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<td>Environmental Impact</td>
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<tr>
<td>15</td>
<td></td>
<td>Compliance to policies &amp; regulations</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Modern bamboo-based housing built in Iloilo, Region IV in 2015

Systemic approach on research about building concept

Factors to design a construction material

Shall we choose EPS or stone wool here?

- Environmental impact
- Thermal conductivity
- Compression strength
- Fire resistance
- Water vapor transmission
- Water sorption capacity
- Density
- Thermal mass
- Sound absorption
- Bending strength
- Cost

Sustainable thermal insulation material
Conclusions

• Many set crews to optimise resource flows
  – Recycling economy approach (cradle-to-cradle)
  – Shift from non-renewables to renewables
  – Behaviour (sufficiency)

• Be aware of trade offs and sub-optimisation
  – Horizontally (energy, material resources, carbon emissions, …)
  – Vertically (Construction material, Product/component, Building, …)

• Holistic approaches and system thinking are needed
• Design for Sustainability
Correlation between material density and eco-efficiency - materials in GWP from multiple data sources

New concrete reinforcement technologies

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• Holistic approaches and system thinking are needed

• Design for Sustainability

• Design for Disassembly