Recycled and bio-based materials for sustainable constructions

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Ascertainment

We need materials
Ascertainment

We need materials

construction consumes between 40 and 50% of natural resources (materials),
construction consumes 40% of energy and produces 40% of CO$_2$
We need materials for improving the energy performance of buildings

Increasing relative weight of building materials vs environmental impacts

Needs for new materials

Source: G. Escadeillas, Métamorphoses, Liège, 2011)
Ascertainment

We produce a lot of wastes

Between 3.4 and 4 billions tons/year, (80 to 126 tons/sec! )
Each day, human activity produces more than 10 billions kg wastes
Wastes produced in 2010 in EU: 2.5 billions tons
According to Pike Research, we produced 74 millions tons/year electrical and electronical wastes in 2014 (2,346 kg/sec)!

Construction produces more or less 50% of all the wastes

http://www.planetoscope.com/dechets/363-production-de-dechets-dans-le-monde.html
We produce a lot of wastes
Wastes (different shapes and conditioning)
  83% solid wastes
  10% « paste »
  7% liquids
Industrial by-products
  inorganic wastes (70%)
  organic wastes (25%)
  not classified

Direction générale Statistique et Information économique (DGSIE) [www.ccfee.be](http://www.ccfee.be) (2012)
Ascertainment

We are living in a **limited world**
- energy
- natural resources
- space (urban development)
- nature’s resilience

Ascertainment → behaviour
- Consuming
- Architecture
- Civil engineering

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Bio-based materials

Coming home
Bio-based materials

materials from biomass of plant or animal origin. They now cover a wide range of products and found many applications in the field of building and construction, as:

- insulation (wool plant or animal fibers, recycled textiles, cellulose wadding, straw bales, etc.),
- mortar and concrete (hemp, wood, miscanthus, etc.),
- panels (particles or vegetal fibers, compressed straw, etc.),
- fibers reinforced plastics (matrix, reinforcement, fillers),
- building chemistry (glues, admixtures, paints, etc.).
Bio-based materials

**Wooden concrete**: wooden chips « mineralized » for light aggregate production

*Wooden concrete* $\lambda = 0.09 \text{ W/m.}^\circ\text{K}$

Cellular concrete $\lambda = 0.12 \text{ W/m.}^\circ\text{K}$

Silicate brick $\lambda = 0.27 \text{ W/m.}^\circ\text{K}$
Bio-based materials

*Constructive system CEMWOOD, ATG 13/2932*
Bio-based materials

**Raw clay (earthern construction)**

Increasing thermal inerty of wooden structure for building by using bio-based materials (ArgiMob product)
Technique

- External panel
- Wood structure
- Insulation
- Internal panel
- Wood support
- Technical space fulfilled with inertia material
- Finishing internal panel
Space for fluid transfer elements
Bio-based materials

Straw bales

Better knowledge of straw bales for using as insulation material in construction

aPROpaille (2012-2014) Research program Erable (UCL/ICEDD/PailleTech/GbxAgroBioTech) - Wallonie
Bio-based materials

Bio-based products

Straw bales
Analysis of a precast solution
Measurement of hygro-thermal parameters
Monitoring devices
Monitoring of buildings
Heat Balance
\[ \frac{\partial H}{\partial T} = \nabla (\lambda T) + h \nabla (\delta p \nabla (\phi_{sat})) \]

Moisture Balance
\[ \frac{\partial v}{\partial \phi} = \nabla (D \nabla \phi + \delta \nabla (\phi_{sat})) \]

Numerical simulations with WUFI
Numerical simulations (WUFI Pro) and monitoring
Numerical simulations (WUFI Pro) and monitoring
Bio-based materials

« Mineralized » miscanthus constructions blocks
Bio-based materials

CO₂ captation

Manufacturing concrete blocks with mineralized miscanthus aggregates + CO₂ injection

Bio-based materials

Effect of carbonation on mineralized miscanthus concrete blocks

Compressive strength after 7 hours
Secondary raw materials

Recycling and durability
Urban waste recycling

Municipal solid wastes
Burning at 900-1000°C
Post-combustion treatment

Approvisionnement → Cribling → Magnetic separation → Maturation (10 – 20 weeks)
Urban waste recycling

Precast concrete pavements

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splitting resistance (N/mm²)</td>
<td>4.05 ± 0.53</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>6.61 - 6.29</td>
</tr>
<tr>
<td>Abrasion (mm)</td>
<td>0.98 - 1.36</td>
</tr>
</tbody>
</table>

Urban waste recycling

APPEROUT (2013-2015): Increasing properties of recycled materials for roads by means of treatment units optimization (Wallonia grant - BRRC, CTP, ULg)

CONREPAD (2014-2016): Concrete design with recycled aggregates by means of Particle Packing Density concept (Wallonia/EU grant – PREFER company, ULg)

ECOLISER (2016-2021): Development of eco-binders for soils treatment and public works (FEDER – CTP, Inisma, Materia nova, BRRC, ULg)

VALDEM (2016-2021): Integrated solutions for the valorization of raw materials from demolition wastes: border approach towards a circular economy (INTERREG V A – CTP, Mines Douai, ULg)
Conclusions and prospect

Tomorrow, materials
Conclusions

Materials for future ..... 

Free of “toxic products”, ...
From alternative resources
Urban mining (reuse, recycling)
Appropriate selecting criteria and requirements
Adaptative and evolutive materials and structures

Nature did it …, why not human?
Thank you