Construction, deconstruction, reuse of the structural elements:
the circular economy to reach zero carbon
RESOURCES CONTEXT

ECO DESIGN FOR SUSTAINABLE CITIES

BIM 6D ENVIRONMENTAL DATA

TRACEABILITY TO PRESERVE MATERIALS

CONCLUSION
RESOURCES

CONTEXT
Construction materials dominate total materials use in the world in 2017 and 2060

Reference: OECD Global Materiel Resources Outlook to 2060
Greenhouse gas emissions in France in million tons eq CO₂

- Construction and Non-metallic Minerals for construction: 20.7
- Other: 65.5
- Agriculture and forestry: 100.8
- Energy industry: 57.5
- Waste treatment: 12.6
- Manufacturing industry: 86.2
- Housing, tertiary, institutional and commercial: 96.5
- Other: 65.5

Reference: CITEPA, 2014
Greenhouse gas emissions in France in million tons eq CO₂

Being 33% of tons eq CO₂ for the construction and operation of buildings

Reference: CITEPA, 2014
Embodied energy contribution to the global balance

Reference: Peuportier Bruno, EIVP Summer University of September 6, 2018 (with logiciel EQUER, Mines ParisTech)
Embodied energy contribution to the global balance

**RT 2005 house**
- Embodied energy: 12%
- Consumption energy: 88%

**Passive house**
- Embodied energy: 30%
- Consumption energy: 70%

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**Graph**
- **Embodied energy**
- **Consumption energy**
- **RT 2005 house**
- **Passive house**

Reference: Peuportier Bruno, EIVP Summer University of September 6, 2018 (with logiciel EQUER, Mines ParisTech)
Greenhouse gas emissions in buildings

Reference: CTB n°349, March 2016
Waste reduction

- Household waste: 37.7 MT
- Buildings and Civil engineering works waste: 227.5 MT

Reference: Repar 2, from SOeS 2014
Waste reduction

- Household waste: 37.7 MT
- Buildings and Civil engineering works waste: 227.5 MT

Reference: Repar 2, from SOeS 2014
Impacts of reclamation

- New construction element
Impacts of reclamations

- New construction element
- Recycled construction element
Impacts of reclamations

New construction element  Recycled construction element  Reused construction element
ECO DESIGN FOR SUSTAINABLE CITIES
RESEARCH: STRUCTURAL SYSTEM

T1 Concrete tube

T2 Tubed mega frame + outriggers

T3 Outriggers + cross bracing

T4 Crosswall + cross bracing
RESEARCH: STRUCTURAL SYSTEM

T1 Concrete tube
T2 Tubed mega frame + outriggers
T3 Outriggers + cross bracing
T4 Crosswall + cross bracing
Comparative study of LCA impacts (NF EN 15804) scenario for the 1st cycle:

- Focused on incoming materials
- Until delivery on site (before construction)
- Variations of structural typologies in order to determine the most virtuous for the same load
- For a model, 4 variations of the number of hinged columns: none / only interior columns / only façade columns / all columns
### Comparative study of LCA impacts according to the structural typology (1st cycle)

<table>
<thead>
<tr>
<th>Acidification potential of land and water - kg SO2 eq.</th>
<th>Depletion potential of the stratospheric ozone layer - kg CFC-11 eq.</th>
<th>Eutrophication potential - kg P06 eq.</th>
<th>Formation potential of tropospheric ozone photochemical oxidants - kg ethylene eq.</th>
<th>Air pollution - m³</th>
<th>Water pollution - m³</th>
<th>Global warming potential - kg CO2 eq.</th>
<th>Abiotic depletion potential for fossil resources - MJ</th>
<th>Abiotic depletion potential for non-fossil resources - kg antimony eq.</th>
</tr>
</thead>
</table>

- T1: classic concrete tube typology
- T2: Tubed mega frame + outriggers
- T3 C: Outriggers + cross bracing (all hinged posts)
- T3 D: Outriggers + cross bracing (all built-in posts)
- T4 C: Cross wall + cross bracing (all hinged posts)
- T4 D: Cross wall + cross bracing (all built-in posts)
- T3 A: Outriggers + cross bracing (facade hinged posts)
- T3 B: Outriggers + cross bracing (interior hinged posts)
- T4 A: Crosswall + cross bracing (facade hinged posts)
- T4 B: Crosswall + cross bracing (interior hinged posts)

NF EN 15804
Comparative study of LCA impacts (NF EN 15804) scenario for the 2\textsuperscript{nd} cycle with reused columns:

- Focused on incoming materials
- Until delivery on site (before construction)
- Models and their variations with hinged columns (that will be considered as reused) > \textit{T3 & T4 variations}
Comparative study of LCA impacts according to the posts reuse and the structural typology (2nd cycle)

NF EN 15804
RESEARCH: GWP ZOOM

1st cycle of construction:
- T3 A: Outriggers + cross bracing (facade hinged posts)
- T3 B: Outriggers + cross bracing (interior hinged posts)
- T3 C: Outriggers + cross bracing (all hinged posts)
- T4 A: Crosswall + cross bracing (facade hinged posts)
- T4 B: Crosswall + cross bracing (interior hinged posts)
- T4 C: Crosswall + cross bracing (all hinged posts)

2nd cycle with reused columns:
- T3 A Reuse: Outriggers + cross bracing (facade reused hinged posts)
- T3 B Reuse: Outriggers + cross bracing (interior reused hinged posts)
- T3 C Reuse: Outriggers + cross bracing (all reused hinged posts)
- T4 A Reuse: Crosswall + cross bracing (facade reused hinged posts)
- T4 B Reuse: Crosswall + cross bracing (interior reused hinged posts)
- T4 C Reuse: Crosswall + cross bracing (all reused hinged posts)
BIM 6D
ENVIRONMENTAL DATA
The principal structural data for high-rise buildings can be divided into four categories:

- **the properties of the element (static):** geometry, composition, resistance class, relevant standard, etc.;
- **the behaviour of the element (mechanical):** position, type of loads, stress applied, connection conditions, creep, ageing characteristics, etc.;
- **the overall behaviour of the structure (mechanical):** exposure class, differential shortening, soil compaction, top displacement, top acceleration, differential displacements between floors, scaling criterion, useful life of structure, etc.;
- **information for the reuse process:** checks required, residual performance tests, deconstruction phasing, etc.
6D covers everything related to the sustainable development of a building, for example energy analysis and carbon footprint estimation for each phase. It will be possible to find the data for the calculation of BREEAM or LEED.
TRACEABILITY TO PRESERVE MATERIALS
Ensuring traceability involves keeping the information both digitally but also physically in the material, using various tools:

- **Digital traceability: BIM model**
- **Passive physical traceability: RFID chips**
- **Active physical traceability: sensors, IoT**
PASSIVE PHYSICAL TRACEABILITY: RFID CHIPS
ACTIVE PHYSICAL TRACEABILITY: SENSORS, IOT
CONCLUSION
The first results show that re-use allows a significant reduction of the embodied energy of a building element. Since the re-used element avoids the fabrication of an identical new element, it reduces GHGs and waste generation. All LCA impacts show an advantage in reuse.

- Embodied energy
- GWP – kg CO2 eq.
- LCA impacts
- Waste

Data on the implementation and analysis of a deconstruction process is needed to continue the research. Issues of removal, storage and re-use process must also be taken into account.
THANK YOU FOR YOUR ATTENTION

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