Life Cycle Assessment of Tall Building Structural Systems

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LIFE CYCLE ASSESSMENT OF TALL BUILDING STRUCTURAL SYSTEMS

• Research Sponsored by ArcelorMittal

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OBJECTIVE OF THE STUDY

Assessment of the Environmental Impacts of Structural Materials/Systems through the Life Cycle of a Tall Building
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WHAT DOES LIFE CYCLE ASSESSMENT MEAN?

An LCA is the **quantification** and the **evaluation** of the environmental consequences on different **impact categories** of a product or a process through a scientifically accepted procedure.

The product/process has to be carefully **analyzed** and the **boundaries** of the analysis have to be clearly identified.
ENVIROMENTAL IMPACT CATEGORIES

The environmental consequences are assessed against two *impact categories* (Climate Change and Resource Depletion) by monitoring their impacts on two selected indicators: Global Warming Potential (GWP) and Embodied Energy (EE)

**LCA of the 60-story Scenarios**
- Embodied Energy
- Global Warming Potential
SCENARIO CONFIGURATION

• 2 different scenario: 60 and 120-story scenario
• 8 different structure configurations for each scenario
• 2 different structural firms studied each alternative

32 Different inventories of materials
CANDIDATES

Concrete core and Steel frame
All Concrete
All Steel
Composite
TWO ASPECTS HAVE TO BE CONSIDERED:

1- Recyclability is important, but there are different opinions on how to consider its benefits.

Each tall building scenario can benefit from the recyclability of some of the materials at the end of the life cycle.

**Steel** is a recycled and recyclable material.

It can be melted to produce new products, whose mechanical properties are identical to those of the previous product.

**Concrete** is reused too, but some down-cycling always occurs.

Recycled concrete cannot be used for structural purposes, but as ballast in road construction, with a significant loss value from its previous life.
RESEARCH RESULTS
60 Story Scenarios – Global Warming Potential, Whole Life Cycle
(including “module D”: information Beyond the System Boundaries)
RESEARCH RESULTS

60 Story Scenarios – Embodied Energy, Whole Life Cycle

(including “module D”: information Beyond the System Boundaries)
TWO ASPECTS HAVE TO BE CONSIDERED:

2 – Carbon emissions are not directly proportional with energy consumption

Steel can be produced with carbon neutral energy sources

Concrete emits carbon because of its production process

\[ \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \]
RESEARCH RESULTS

Environmental Optimized Scenario – Global Warming Potential

Significant benefits can be obtained by selecting a good material provider.
Environmental Optimized Scenario – Embodied energy

Significant benefits can be obtained by selecting a good material provider.
CONSIDERATIONS

Transportation of Construction and Demolition Waste
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The transportation of construction materials and demolition waste is not a very significant factor in a Tall Building LCA.

Most of the environmental impacts in this phase occur during the final delivery of the materials to the construction site, and not during the previous phases of their transportation process.

It is important to identify the “good” material producers, independently from their distance from the construction site.
CONSIDERATIONS

Use of Construction Materials
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Use of Construction Materials

The amount of material used in tall building is only marginally affected by the premium for height described by F. Khan.

Recycling material at the end of life can decrease significantly the environmental footprint of the building.

The examined case studies show that the Horizontal Components of structural frames are responsible for the greatest share of environmental emissions, independently from the building height.

It is important to optimize also the horizontal components of the frame (beams and secondary beams) and to use longer spans only when driven by economics for open space and more flexibility.
CONSIDERATIONS

The LCA is a still an evolving science, where seemingly small decisions on evaluation boundaries and source choices have significant impacts on the final results.

Life Cycle Analysis, as a research discipline, has been “invented” about 30 years ago, and it has been applied to the built environment only in the past 20 years.

Research can be developed and supported by the tall building industry.
• Explore the real needs of tenants in terms of column-free structural spans in buildings
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- Study on the optimal inter-story height may lead to significant savings in terms of materials
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- Investigate the possibilities for specific applications of modular, prefabricated steel elements on tall building, to speed-up construction and facilitate the building end-of-life.
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• Research on the demolition techniques for tall buildings, to reduce the impact of this phase.
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• Study the measurable influences of cements substitutes in the concrete mixes
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The Inventory of materials has been developed with the support of some of the leading firms in the tall building industry

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