Lean modeling proposal for recycling concrete application in civil engineering constructions

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1. Problem statement
   - Problem statement: Concrete waste

2. Background
   - State of the art
   - Lean thinking and lean modeling?

3. Lean modeling proposal
   - Lean modeling proposal framework
   - Short example of lean modeling application

4. Conclusion and Perspective
Problem statement

Problem statement: Concrete waste

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Conclusion and Perspective
Hotel demolition and concrete waste issues
A huge amount of concrete waste!

Paris subway extension program leads to the demolition of some buildings (Hotel and marketplace in Cachan)
Illustration of Life cycle of concrete
From natural resources to recycling platform for pavement work

Naturel ressource

Limestone, Clay, Shell...
Cement manufactory

Concrete plant

Work place
Building construction

Demolishment
Concrete waste

Recycling platfrome

Landing

Pavement road work

Aggregate and Sand

It's just impossible

Problem statement: Concrete waste
We should estimate the energy need for recycling concrete application process

- Not clear: What is the quality of the recycling concrete? *good or bad?*
- Not clear: How much money does it cost for the recycling concrete process? *expensive or cheap?*
- Not clear: How much does the CO2 footprint affect? *more than ordinary concrete or less?*
- Not clear: How strong energy efficient will we have for the buildings?

*Clear: we can reserve the natural resources!*
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Domestic project 'Recybéton' from 2012 to 2016

What have we done?

- Chemo-physical feature determination of crushed concrete (porosity, density, water absorption and etc),
- Determination of physico-mechanical features of recycling concrete,
- 30% of recycling concrete use for replacing of natural aggregates in the concrete mixing.

la maison des solidarités de Mitry-Mory (Saint-et Marne)

Parking (Chanopost69)

Bi-cycle bridge (Nimes)
Domestic project ’Recybéton’ from 2012 to 2016

What is it still missing?

- How can we handle various quality of recycling concrete as a random media?
- How big can ratio of the crushed concrete to natural aggregate be for the concrete manufacturing?
- How strong can the strength of structure be?
- How much money does it need for the recycling concrete manufacturing?
- What kind of energy efficiency building can we have during the service period?
- What can the customer and contractor obtain by the recycling concrete application?
Proposed classification of recycling concrete
Academic approach based on the materials science

⇒ Experimental test of density and water absorption for qualification of the crushed concrete
Proposed classification of recycling concrete

Academic approach based on materials sciences

⇒ Ordinary concrete is ≈ 45 MPa while recycling concrete is ≈ 39 MPa
M.F. Ashby’s methodology
There is no environmental impact in selection of materials

Ashby’s chart method for the selection of best materials

Young’s modulus versus Density
Strength versus Density
The X-development method
LCA and X development method proposal by Vareille in 2012

The general scheme is presented in following and the time is the horizontal axis.

The X-development method seen as twinned cycles
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Lean modeling/Lean construction approach
From car factory management to civil engineering

Starting from Toyota Motor Company in 1950s;

Toyota or Lean production
Just in Time Flow and Smart automation

It means the auto production **reducing all waste nature**;

1. Limited natural resource / Development of JIT / Limited space / Mass production practice / Lower demand / Quality Movement / Additional factors

'**TIME, MONEY, SPACE, AND WASTE...**'

→ Beginning of lean production
How about the construction industry?

- A new technology (Computer Aided Design) in 1980s can help the efficiency of drawing but it can reduce neither design error nor cost construction.

Lean construction was developed in the management of construction to eliminate the waste and increase the profit (UK in 1993):

Towards high productivity, high efficiency and cost effectiveness → Beginning of lean construction
Lean modeling/Lean construction approach

How about the construction industry?

Why does the recycling concrete use require to help the lean construction approach?

- *Reducing waste, main objective would be achieved by the lean thinking*
- *Reducing of the construction cost and increasing the benefit*
- *Lean thinking impact on the sustainability issue would be taken into account*

How can we apply the recycling concrete in the lean construction industry?

Making decision would be based on not only the performance issue but also the energy efficiency and sustainability issues.
Fantili proposal in 2014
The non-dimensional graph proposal using the environmental impact & mechanical performance

Ecological impact (CO2 footprint during manufacturing)

Ordinary concrete

Mechanical performance (strength of material and structure)
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Reliability number $R$ definition

Three functional parameters definitions

A general formulation of the design for the reliability number $R$ could be written as following:

$$ R = f(I_{mp}, I_{co2}, I_{en}) $$

- Index of strength of structure: $I_{mp}$
- Index of environmental impact: $I_{co2}$
- Index of economic impact: $I_{en}$

$\rightarrow$ If the material choice is the ordinary concrete, $R$ is always 1.
This index would be expressed by two non-dimensional numbers as following:

\[ I_{pf} = f(F, E); \quad F = \frac{F_{ch}}{F_{oc}}; \quad E = \frac{E_{ch}}{E_{oc}} \]

- \( F_{ch} \): compressive strength of material choice
- \( F_{oc} \): compressive strength of ordinary concrete
- \( E_{ch} \): Young’s modulus of material choice
- \( E_{oc} \): Young’s modulus of ordinary concrete
Index of Mechanical performance $I_{pf}$

Taxonomy for aggregate based on the dimensionless number is proposed:

<table>
<thead>
<tr>
<th>Type of aggregate</th>
<th>Quality A</th>
<th>Quality B</th>
<th>Quality C</th>
<th>Quality D</th>
<th>Quality E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>(2600kg/m$^3$)/ (2600kg/m$^3$)</td>
<td>(2200kg/m$^3$)/ (2600kg/m$^3$)</td>
<td>(1900kg/m$^3$)/ (2600kg/m$^3$)</td>
<td>(1600kg/m$^3$)/ (2600kg/m$^3$)</td>
<td>(1300kg/m$^3$)/ (2600kg/m$^3$)</td>
</tr>
<tr>
<td>Dimensionless numbers</td>
<td>1</td>
<td>&gt; 0.85</td>
<td>&gt; 0.73</td>
<td>&gt; 0.61</td>
<td>&lt; 0.50</td>
</tr>
<tr>
<td>Requirements and specifications</td>
<td>Ordinary concrete structure</td>
<td>Low quality structures usable for housings of limited lifespan and reduced high</td>
<td>Low quality structures usable for housings of limited lifespan and reduced high</td>
<td>Low quality structures usable for housings of short lifespan (refugees camp, temporary housings)</td>
<td>Non reliable structures, totally uncertain Roads, embankments</td>
</tr>
</tbody>
</table>

That value is assumed to be linked to the mechanical performance!
Index of environmental impact $I_{co2}$

This index would be expressed by two non-dimensional numbers as following:

$$I_{co2} = f(T, M) ; \quad T = \frac{T_{ch}}{T_{oc}} ; \quad M = \frac{M_{ch}}{M_{oc}}$$

- $T_{ch}$: carbon footprint of material choice during the transportation
- $T_{oc}$: carbon footprint of ordinary concrete during the transportation
- $M_{ch}$: carbon footprint of material choice during the manufacturing
- $M_{oc}$: carbon footprint of ordinary concrete during the manufacturing

→ It is necessary to estimate CO2 footprint for crushing the concrete building!
This index would be expressed by two non-dimensional numbers as following:

\[ I_{ec} = f(C, N) \]

\[ C = \frac{C_{ch}}{C_{oc}} \]

\[ N = \frac{N_{ch}}{N_{oc}} \]

- \( C_{ch} \): cost of construction using material choice
- \( C_{oc} \): cost of construction using ordinary concrete
- \( N_{ch} \): energy efficiency (thermal resistance) using material choice
- \( N_{oc} \): energy efficiency using ordinary concrete

Energy efficiency and sustainability issues should be included in mechanical design!
Various possible solution and decision
Mechanical performance solution, eco-friendly solution, economic based solution

- Mechanical performance solution
- Eco-friendly solution
- Economic based solution

Best solution all the way

worst solution to be avoided

Special solution for particular situation

A vnir-Lille November 8-9, 2016 Jena JEONG
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**Conclusion and Perspective**
let us consider the hotel ’Kyriad’ in Cachan, having 3 floors with 300 m$^2$ but without opening for our example. Here are some steps to be followed before the modeling:

1. **First step (pre-construction)**: demolishment of old hotel and then carried on the recycling platform.


3. **Third step (after construction)**: Energy efficiency matter during the service period.
A new hotel construction in Cachan, Paris

Infrastructure analysis

Localization of the hotel in Cachan in south Paris and nearest concrete plant on the east and recycling platform on the south Cachan
Three steps to be followed

Pre-construction (demolishment), Construction, Post-construction

1. First step: Demolishment of ancient hotel and then carried on the recycling platform
   - Quantity of crushed concrete from demolition should be estimated
   - Estimation of energy need and CO2 footprint during transportation from work place to recycling platform are considered

2. Second step: Preparation of concrete/recycling concrete
   - The price of construction could be estimated both natural and recycling concrete using cases.
   - CO2 footprint can be calculated (Natural aggregate must come from natural resource/ recycling concrete comes from the recycling platform.)

3. Third step: Energy efficiency issues during a period of service
   - In our modeling of study case, we consider the thermal conductivity parameter and the size of wall
R reliability number determination

Which solution...

• : Ordinary concrete

• : Recycling concrete
Which solution does it take into account using the ordinary or recycling concrete?

What do we need?

Based on our modeling, $R$ value for recycling concrete use provides following results:

- Mechanical performance is slightly less than the ordinary concrete,
- CO2 footprint is much higher and becomes greater than 1,
- Recycling concrete materials have less than 1. Therefore it could be provided the long term economical solution.

Consequently, the use of these materials does not provide any eco-friendly solution but it gives rise the economical solution.
So, it is required to improve the process of recycling concrete application by

1. Do not use new cement for manufacturing of recycling concrete
2. Do not even crush concrete
3. Do not carry on the crushed concrete

work place → recycling platform → concrete plant → work place

Consequently, we would suggest ’recycling masonry building’ using the ’concrete brick-cutting’ from the concrete buildings.
Thank you for your attentions!