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A NEW BREED OF SUSTANIABLE ULTRA-LIGHTWEIGHT AND ULTRASHALLOW STEEL-CONCRETE COMPOSITE FLOORING SYSTEM: LIFE CYCLE ANALYSIS

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OUTLINE

- INTORDUCTION
- AIM
- NEW FLOORING SYSTEM
- METHODOLOGY
- RESULTS
- CONCLUSIONS

INTRODUCTION

- Sustainability and the reduction of CO_2 emission have taken an important attention in all industries.
- The construction industry is influenced due to the extensive use of materials and the large amount of waste generated.
- Buildings account 40% from the global material flow (Dong et al., 2015).
- Concrete has been identified as a carbon intensive material (Meyer, 2009).
- The on-site construction process is another source of carbon emission.
- An enormous contribution to sustainable design can be made by changing the design of traditional members and systems and integrating new or under-developed materials from the initial stages.

Table 1:Summary of LCA of building sector

Building materials and construction process	Problems	Solutions	ultra-light ultra-shallow flooring system
Concrete	• Higher energy consumption from the production of cement • Higher CO_2 emissions from the production of cement	• Using alternative materials (lime mortars instead of cement mortars) • Using foamed concrete • Using green concrete • Using precast units	• Using foamed concrete
Steel	• Higher energy consumption from the production of steel • Higher CO_2 emissions from the production of steel	• Using optimized steel elements • Using lightweight steel elements • Manufacturing small metal components without any scraps • Re-use steel elements without recycling	• Using lightweight steel elements
On-site construction process	• Higher energy consumption from the fuel consumption in material transportation and heavy equipment, waste treatment management • Higher CO_2 emissions from the fuel consumed in material transportation and heavy equipment, waste treatment management	• Prefabrication construction process	• Fully fabricated flooring system
Building through its entire life	• Higher energy consumption for heating, cooling and lighting • Higher CO_2 emissions for heating, cooling and lighting	• An energy saving buildings by using insulation materials to obtain better thermal performance	• Using insulation material

AIM

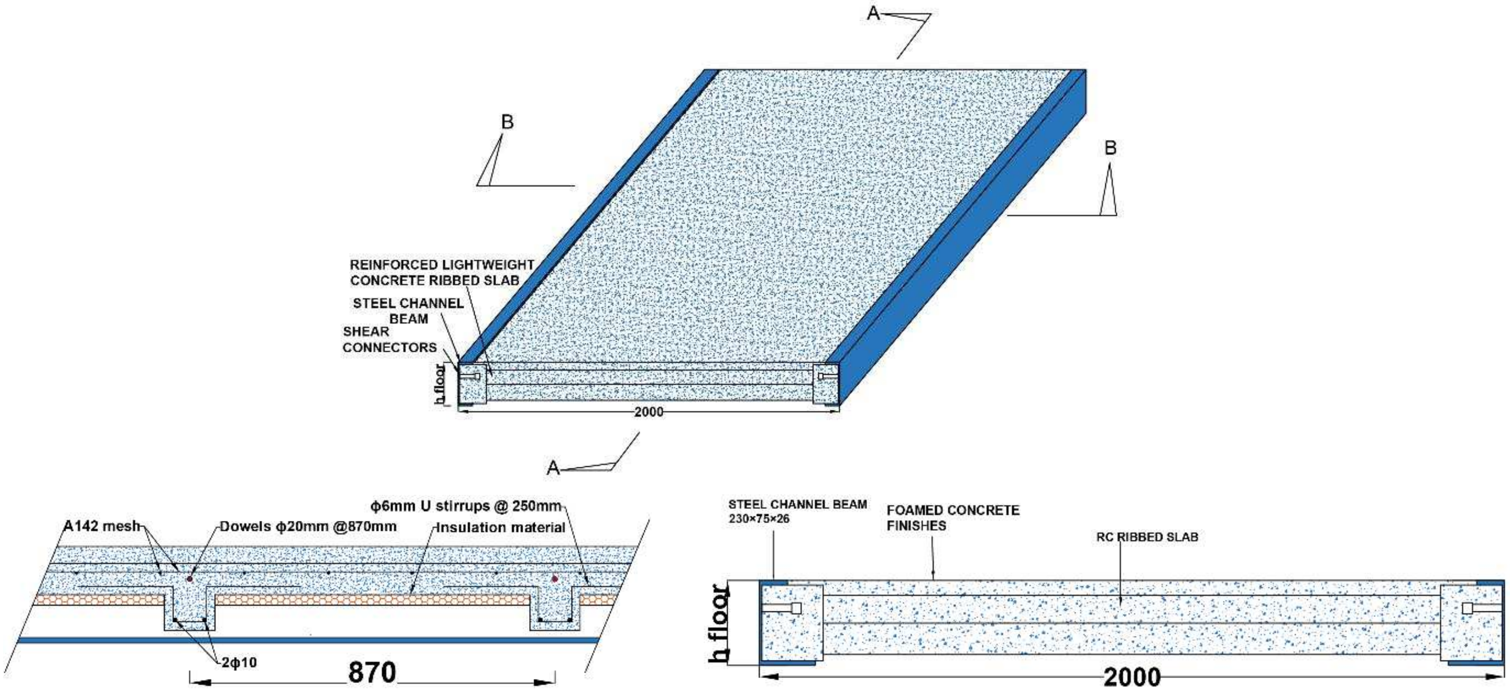
- Developing a new composite flooring system which exercises the sustainability approach in the selection of its components.

- Evaluating this new ultra-light ultra-shallow flooring system through Life Cycle Assessment (LCA) methodology.

- Conducting a comparative LCA of the new ultra-light ultra-shallow flooring system and an existing state-of-the-art shallow flooring system (CoSFB with Cofradal 260 mm) (Braun et al., 2011), which is based on three stages:
  - (i) production of materials used in flooring systems,
  - (ii) transportation of materials, and
  - (iii) end of life of the materials of the flooring systems themselves.

NEW FLOORING SYSTEM

- The **ultra-light ultra-shallow flooring system** consists of two main structural components, which are lightweight concrete floor and lightweight steel beams.
- The concrete floor, which is in the form of T ribbed slab sections, has been constructed using reinforced lightweight concrete(foamed concrete).
- The lightweight steel edge beams encapsulate the floor slab in the middle and provide a clean and straight finish edges.
- This flooring system will be fully prefabricated in the shop.



Sec (A-A)

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Figure 1: ultra-light ultra shallow flooring

METHODOLOGY

- LCA is a method widely used to estimate the ecological impact of processes, products, and designs over the whole life cycle.
- This study focuses on two impact categories only: (a) embodied carbon, and (b) embodied energy impacts for the three stages.
- LCA has been applied to calculate the embodied energy and embodied carbon of the flooring systems for a typical grid of 8.10m×8.10m.

- **Production Stage:**

$$EE_{-P} = \sum_{i=1}^{n} \left(W_i \times EE_{(i)-LCI}\right) \quad (1)$$

$$EC_{-P} = \sum_{i=1}^{n} \left(W_i \times EC_{(i)-LCI}\right) \quad (2)$$

- **Transportation Stage:**

$$EE_{-T} = \sum_{i=1}^{n} \left(W_i \times D_i \times EE_{(i)-LCI(TR)}\right) \quad (3)$$

$$EE_{-T} = \sum_{i=1}^{n} \left(W_i \times D_i \times EC_{(i)-LCI(TR)}\right) \quad (4)$$

- **End of life Stage:**

$$EE_{-ST-EOL} = \sum_{i=1}^{n} \left(W_i \times RC \times EE_{(i)-LCI}\right) + \sum_{i=1}^{n} \left(W_i \times D_i \times EE_{(i)-LCI(TR)}\right) \quad (5)$$

$$EE_{-ST-EOL} = \sum_{i=1}^{n} \left(W_i \times RC \times EC_{(i)-LCI}\right) + \sum_{i=1}^{n} \left(W_i \times D_i \times EC_{(i)-\mathbf{LCI(TR)}}\right) \quad (6)$$

(Yang et al., 2013)

Table 2: Embodied carbon and embodied energy coefficients for the production of materials (Hammond et al., 2008)

Material	Embodied Energy Coefficient (MJ/kg)	Embodied Carbon Coefficient ($kgCO_2e/kg$)
Cement	5.5	0.93
Sand	0.081	0.0048
Gravel	0.083	0.0052
Water	0.01	0.001
Fly ash	0.1	0.008
Silica fume	0.1	0.014
Super-plasticizer	9.0	0.25
Reinforcing steel bar	17.4	1.31
Metal Deck	22.6	1.54
Steel Section	21.50	1.42
Rock wool Insulation	16.8	1.12
Expanded Polystyrene	88.6	3.29

Table 3: Embodied carbon and embodied energy coefficients for end of life of materials (Hammond et al., 2008)

Material	Embodied Energy Coefficient (MJ/kg)	Embodied Carbon Coefficient ($kgCO_2e/kg$)
Steel recycling	13.1	0.75
Reinforcing steel bar recycling	11	0.74
Concrete demolition	0.007	0.00054
Rock wool Insulation	N.D.A	N.D.A
Expanded Polystyrene	N.D.A	N.D.A

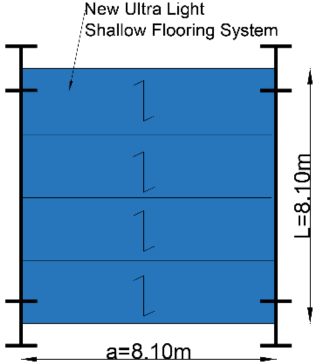

Figure 2: Grid 8.10×8.10

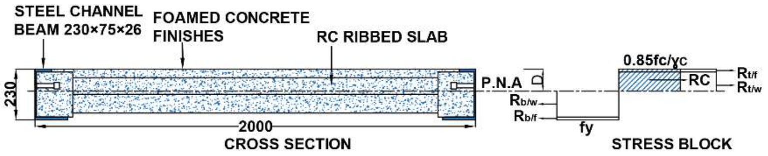

Figure 3: ultra-light ultra shallow flooring

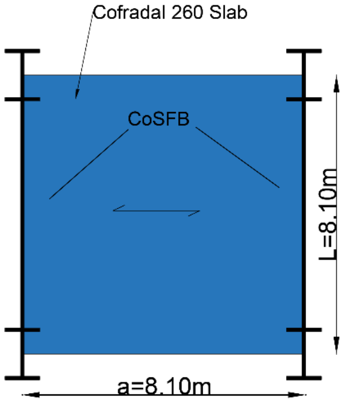

Figure 4: Grid 8.10×8.10

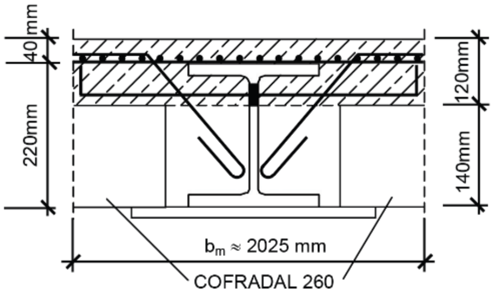

Figure 5:CoSFB Section (Braun et al., 2011)

RESULTS

Table 4:Embodied Carbon and Embodied Energy of flooring systems

Stage	Embodied Energy (GJ)	Embodied Carbon (tonne CO_2e)	Embodied Energy (GJ)	Embodied Carbon (tonne CO_2e)	% Reduction in Embodied Energy	% Reduction in Embodied Carbon
	CoSFB with Cofradal 260mm flooring system		Ultra-light ultra shallow flooring system			
Production	106.25	8.69	90.19	8.67	**15**	**0.23**
Transport	5.24	0.32	3.01	0.19	**42**	**40**
End of Life	46.63	3.10	36.54	2.12	**21**	**31**

CONCLUSIONS

- The results from the LCA study revealed that **lower embodied energy and embodied carbon values of the new ultra-light ultra-shallow flooring system** from production, transportation, and end of the life stages compared with the results of CoSFB with Cofradal 260 mm.

- The results indicated that the new ultra-light ultra-shallow flooring system is an ideal solution towards the right direction.

- The ultra-light and ultra-shallow flooring system has proved an effective, a sustainable, and a valuable alternative solution for the construction industry in terms of both <u>environmental performance</u> and <u>speed of construction</u> while <u>reducing site work and site risks</u>.

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Thank you for your attention
Questions?

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