3D printed building envelopes with functionally graded materials for better insulation and engineering properties

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Contextualization

Traditional building envelopes and construction **processes** → **High CO_2** emissions → **Heat waves** and unpredictable **climate** → **Health** and **wellness** of building occupants

Extremely high summer temperatures

Sustainable Development Goals (SDGs)

- **Sustainable resource use**
- **CO_2 emission reduction**
- **Resilient cities**
- **Circularity**
- **Wellness**

→ **Urgent need** to develop **low-carbon** and **durable** buildings

- Smart manufacturing, such as **3D printing**
- **Circular economy** concept

Innovation and approach

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Development of 3D-printed building envelopes using low-carbon materials (shell) incorporating bio-based components (core)

Focusing on:

- **Low-carbon design**
- **3d printing** manufacturing
- Incorporation of **low-carbon** and **local resources** (geopolymers, LC3, soil, CDW, fibers…)
- **Climate-responsive** envelopes
- **Better hygro-thermal** performance
- **Adequate mechanical** properties
- **Higher durability**
- **Full-scale analysis** (specimen → wall)

Scientific objectives

1. To investigate the influence of **low-carbon materials** on the **rheological** properties, **green strength**, and **hydration kinetics** of **3D-printable envelopes**
2. To analyze the **mechanical** and **hygrothermal** performance of **lightweight infills** using **bio-based materials**
3. To assess the properties of the **3D printed composite elements** such as **strength**, **shrinkage** and **hygrothermal** properties at **material** and **structural scales**
4. To evaluate the **embodied carbon**, **hygrothermal** properties and **operational energy** in **3D printed full-scale wall** elements

Methodology

1 and 2 → Development of the low-carbon envelope (shell) and the lightweight bio-based (core)

Characterization of materials → Formulation and production → 3D printability → Mechanical strength → Hygrothermal performance → Durability properties

3 → Testing of the 3D-printed composite elements and interfacial bonding

Hygrothermal performance → Structural integrity → Durability properties

4 → Prototyping full-scale 3D-printed core-shell wall

Production of wall → Non-destructive monitoring → Embodied carbon and energy demand simulations

Expected impacts

Support the **de-carbonization goals** set by India, France, and other nations

- Improved **air quality** and public **health**
- Promotion of a **circular economy**
- Reduction in **embodied carbon**
- **Full-scale** evaluation of **mechanical, hygrothermal** and **durability** properties
- **Production** and **rheological characterization** of low-carbon **3d-printable** materials
- Improved building **resilience** and **climate** responsiveness

Acknowledgements

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LTDS Laboratoire de Tribologie et Dynamique des Systèmes

References

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