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MULTISENSOR SHM OF A WOODEN CANOPY WITH MECHANICALLY CROSS-LAMINATED ROOF STRUCTURE

Authors: S. Shahsavar, I. Knoops, J. Henriques, B. Vandoren and E. Vereecken

Presenter: Sadra SHAHSAVAR - PhD Researcher, Hasselt University, Belgium

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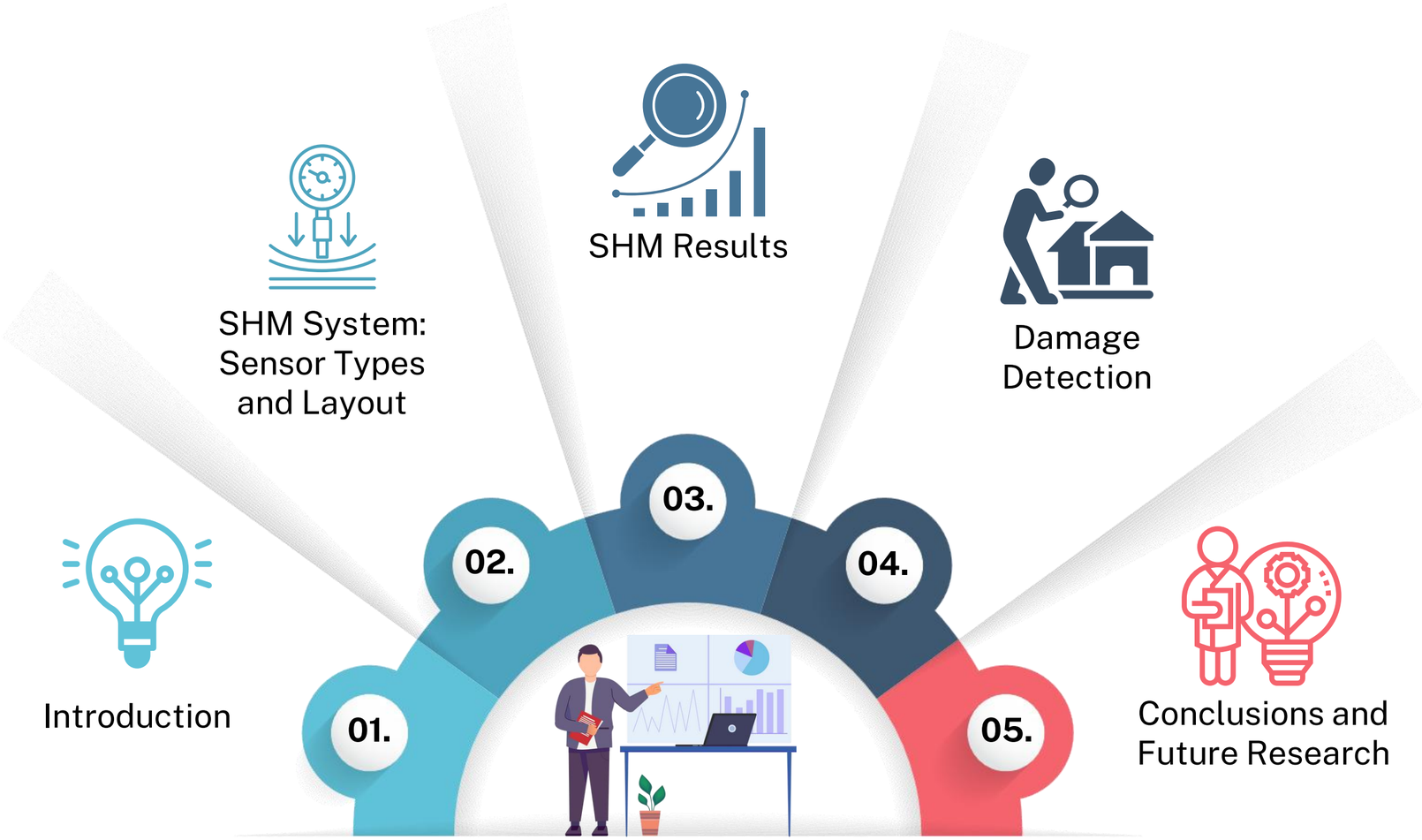


THE OVERVIEW OF THE PRESENTATION

Introduction

01

Role of Structural Health Monitoring for Life-Cycle Assessment

- With growing interest in circularity and life-cycle assessment, monitoring timber structures is crucial.
- Structural Health Monitoring (SHM) provides continuous data and serves as a proactive tool for maintaining the integrity of timber structures.

02

Focus on Wooden Canopy Prototype

A wooden canopy prototype has been instrumented with multiple sensors.

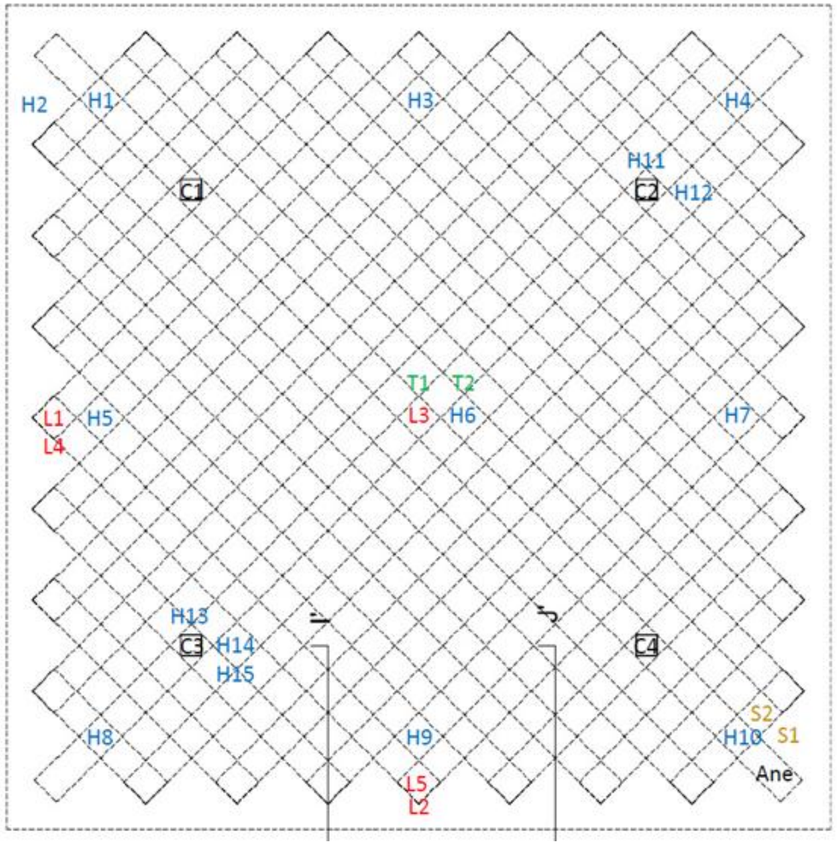
- **Roof structure:** 4 layers of timber beams in a waffle pattern
- **Connections:** Beams joined mechanically at each crossing
- **Covering:** Plywood sheathing + bitumen finish
- **Support:** 4 timber columns with ball-joint connections

SHM System: Sensor Types and Layout

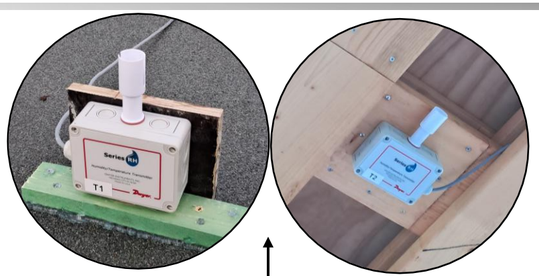
Moisture Content (H)

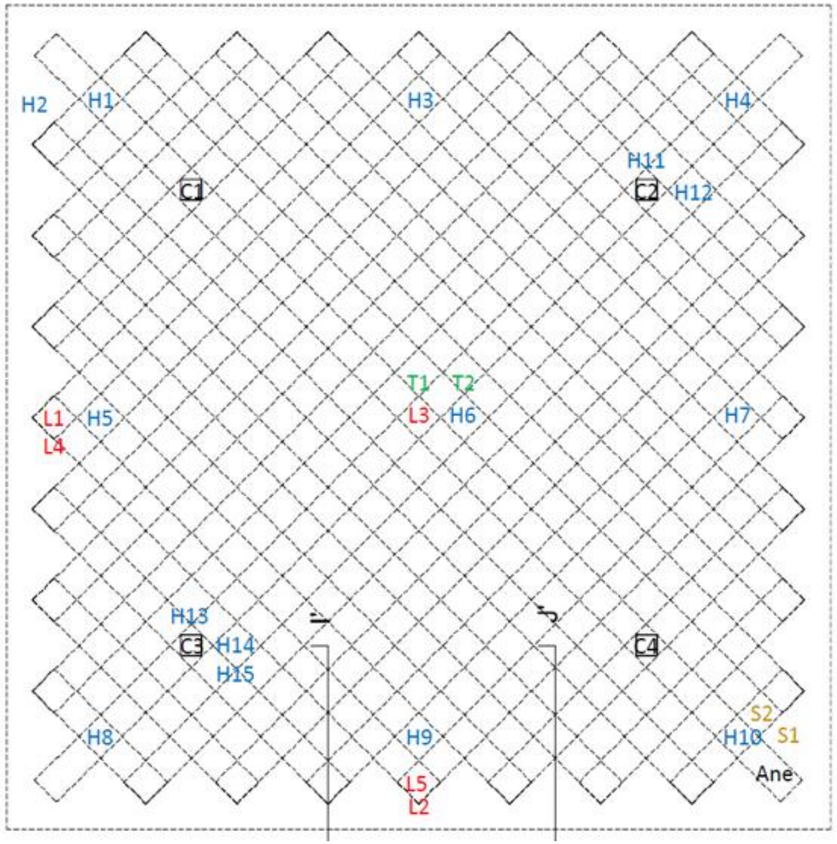
- Evikon E2353 sensors measure wood moisture content via conductivity.
- Humidity sensors were mostly placed in the lowest roof layer.
- One sensor (H2) was installed in the ply sheathing at a mold-contaminated spot.
- Columns C2 and C3 were equipped with humidity sensors.
- C2 is more exposed to driving rain, while C3 is less exposed.

humidity. T1 is on top of the roof and T2 is under the roof



SHM System: Sensor Types and Layout

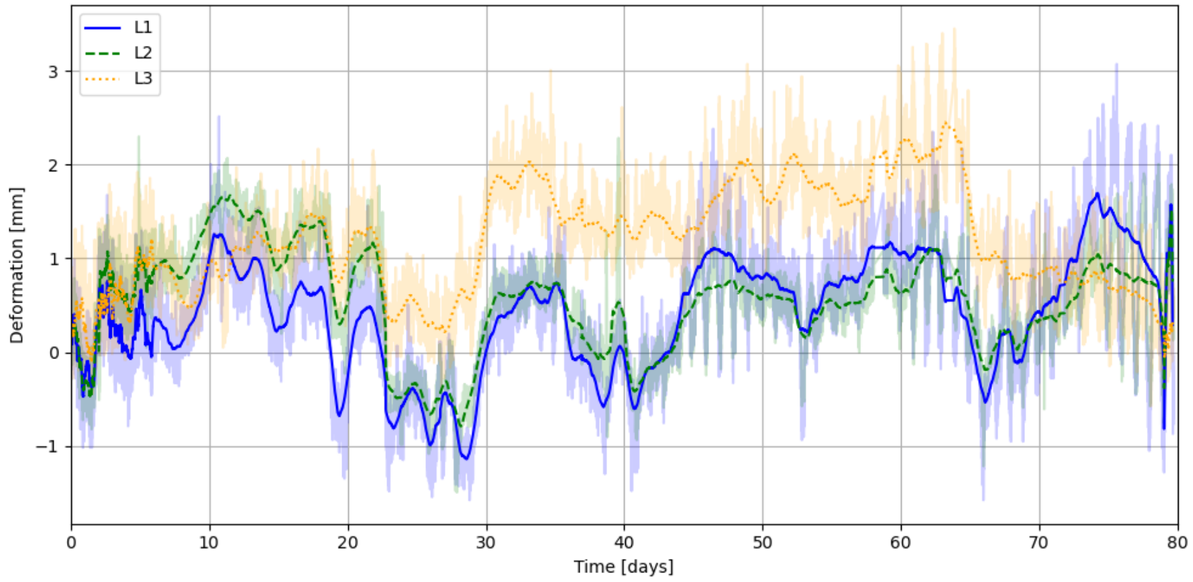




SHM Results: Deformation Analysis

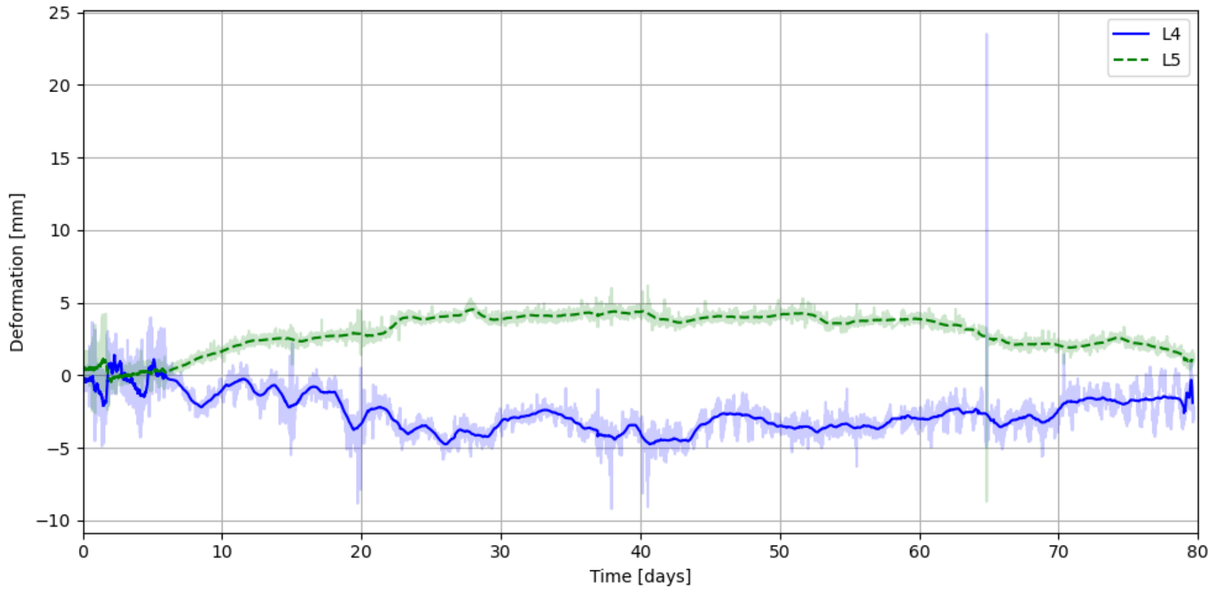
Vertical Deformations

- Vertical deformations measured at three points
- Middle of the roof (L3) shows higher overall change than the sides
- L1 and L2 deformations are closely aligned
- All measurements fluctuate with daily temperature and humidity cycles



Horizontal Deformations

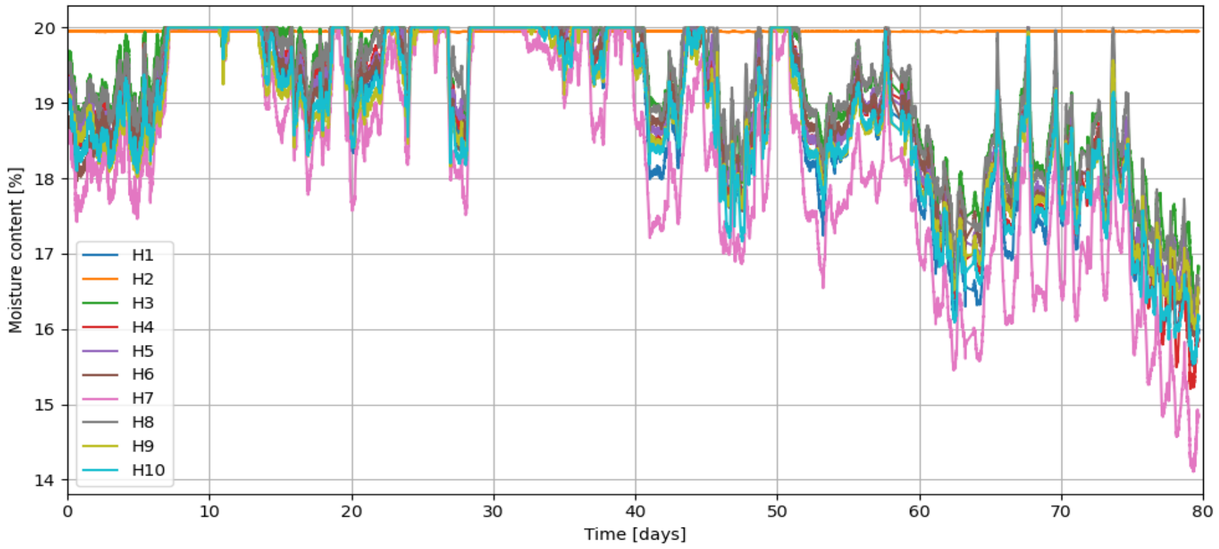
- Horizontal deformations show daily fluctuations and seasonal trends
- L4 and L5 follow similar trends but in opposite directions
- L5 shows smaller short-term fluctuations than L4
- L4 appears more sensitive to environmental changes



SHM Results: Moisture Content Insights

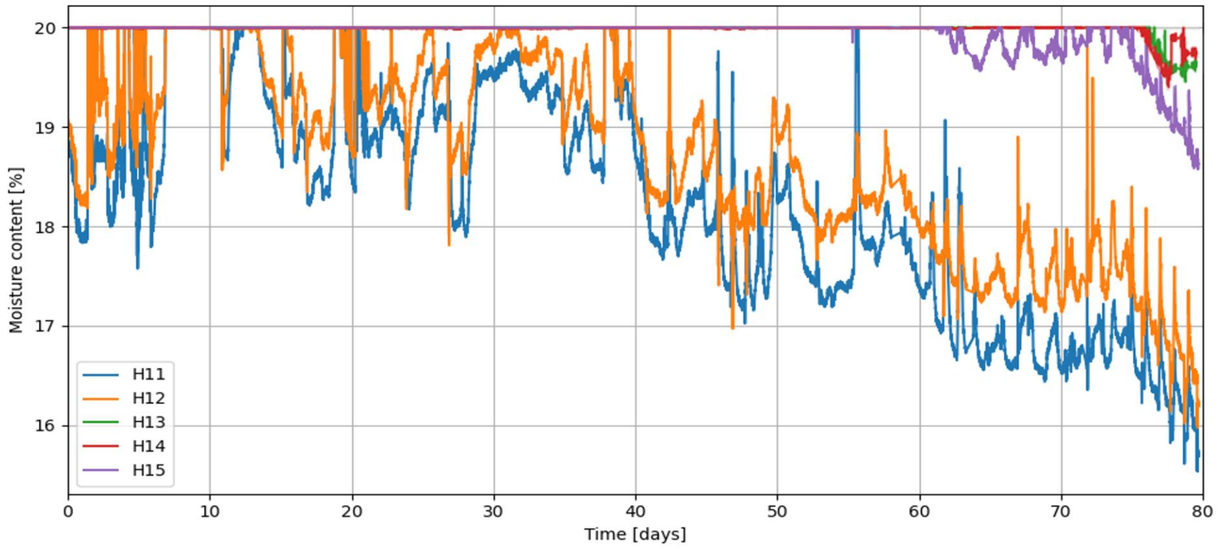
Roof Moisture Content

- Moisture content measured at 10 roof locations
- H2 (in mould) constant at 20% (sensor limit)
- Other sensors reach 20% during wet conditions (snow/rain)
- As spring approached: overall drying trend with local fluctuations linked to daily temperature changes is shown.



Column Moisture Content

- C2 (more exposed to wind/rain) → dried significantly faster than C3
- C3 showed unexpectedly high moisture → indicated local roof leakages. Leakages later visually confirmed
- Demonstrates SHM system's ability to detect critical design flaws (e.g., roof/column connections prone to leakage)



Damage Detection via Robust Principal Component Analysis

Challenges:

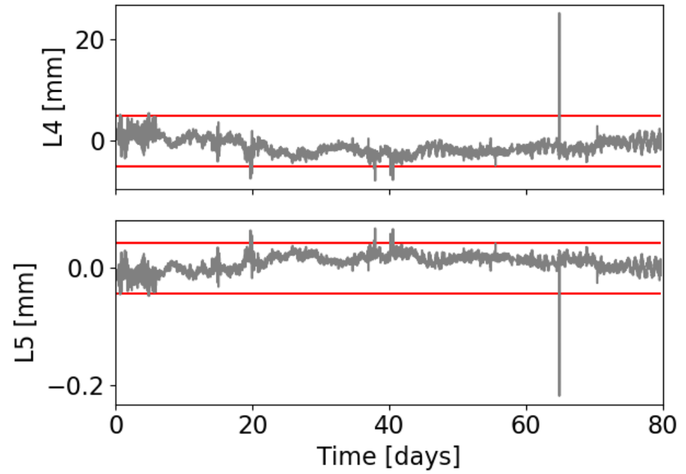
- Daily temperature/humidity cycles cause natural fluctuations → makes abnormal deformation detection difficult.
- No strong correlation can be found between environmental parameters & humidity

Solution:

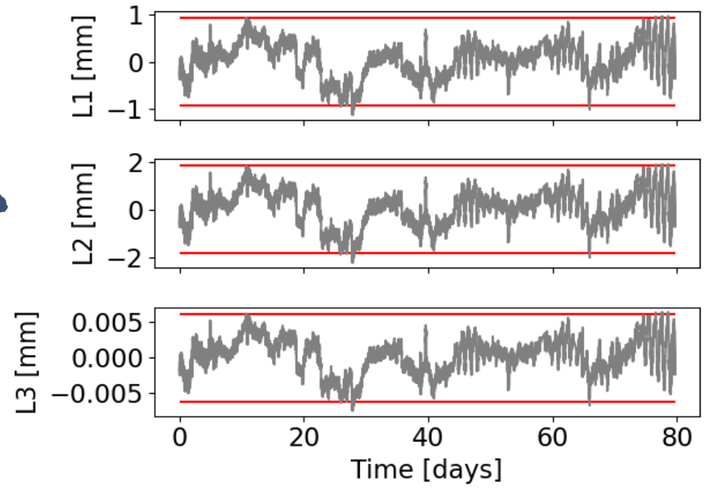
- Robust PCA
- Learns “normal” multi-sensor behavior.
- No need for environmental variables as inputs.

- This method is purely data-driven, which means it only detects deviations from the observed behavior
- The thresholds indicate when the system detects unusual patterns.
- Our dataset only covers one season, not the full year, so some outliers may simply reflect extreme weather conditions rather than actual damage
- It makes damage detection more difficult, as these deviations must be verified on-site. So, this approach should be combined with a model-based method, which can simulate data.

Horizontal deformation measurements



Vertical deformation measurements



Conclusions and Future Research Directions

Conclusions

1. SHM successfully detected severe moisture conditions and local leakage
2. Spatial correlation between roof sensors is low despite high temporal correlation
3. Sensor locations should be based on structural changes and environmental exposure
4. No simple relationship between deflections and moisture/humidity could be established
5. Robust PCA provides effective damage detection without requiring environmental correction

Future Research

1. Incorporate wind speed and surface temperature measurements
2. Investigate relationships between horizontal deformations and wind speed
3. Analyze seasonal variations with longer-term data
4. Develop 3D model of the structure and generate FEM model to simulate deformations
5. Investigate influence of local E-modulus and joint stiffness

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THANK YOU

For your attention

Email: sadra.shahsavar@uhasselt.be
LinkedIn: Sadra SHAHSAVAR