Design of Geopolymer Panels

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Introduction

Ceramic and cement production are energy-intensive processes, therefore they emit significant amounts of CO_2 annually.

Ceramic
19 million tonnes CO_2 [1]

Cement
110 million tonnes CO_2 [2]

Geopolymers can cut emissions by up to **80%** [3], offering a more **sustainable alternative**. The project aims to **replace ceramic shower tiles** with geopolymer using only local materials. This part of the research explores the **performance** and **optimal dimensions** of geopolymer panels.

Methodology

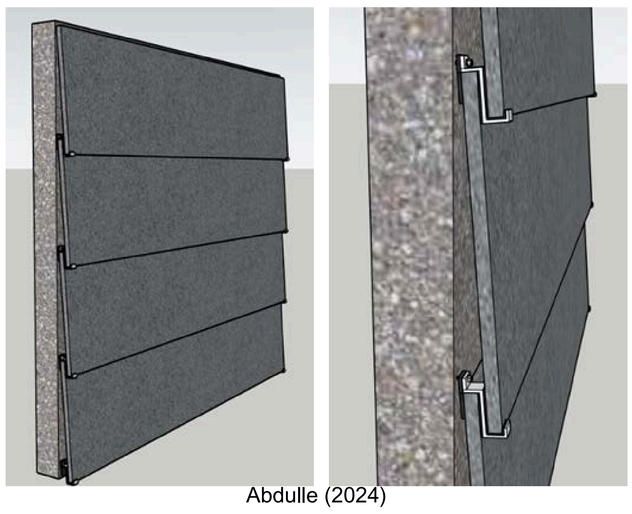
Main Research Question

What are the optimal dimensions for modular, durable geopolymer panels in wet areas like showers, toilets, and kitchens?

Initial Design	Forces Analysis	Sample Production and Testing	Final Design
Brainstorm ways to **enhance the connections** between the panels made last semester.	Analyse **permanent and accidental forces** and minimum mechanical requirements.	Conduct **aging test**, **3-point bending**, **water absorption**, and produce **large samples**.	Production of the **final detailed drawings** ready for the **prototype construction**.

Results

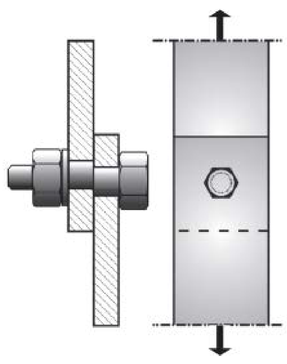
Initial Design



Abdulle (2024)

Forces Analysis

Shear on the screw

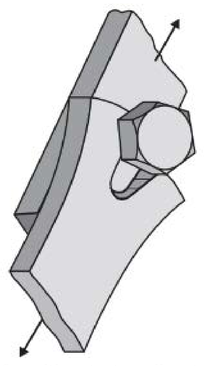


$$F_{v,Rd} = \frac{\alpha_b A_b f_{ub}}{\gamma_{a2}}$$

- M3 screws
- Stainless
- fub > 45 MPa

fub: ultimate tensile strength of a bolt
Fakury et al. (2016)

Tearing on the aluminium profile

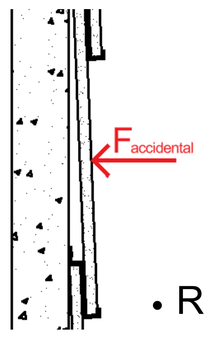


$$F_{c,Rd} \leq \begin{cases} \frac{1,2\,\ell_f t f_u}{\gamma_{a2}} \\ \frac{2,4\,d_b t f_u}{\gamma_{a2}} \end{cases}$$

- Stainless
- fu > 12,4 MPa

fu: ultimate tensile strength
Fakury et al. (2016)

Bending stress on the panels



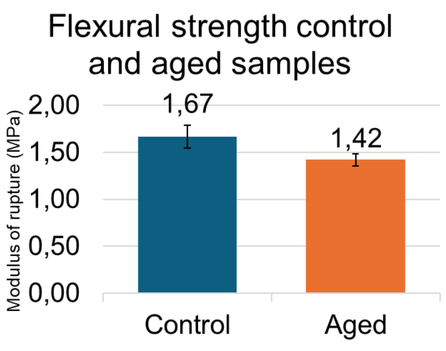
$$R = \frac{3Fl_2}{2Bh^2}$$

- R > 2,07 MPa

R: Modulus of rupture

Sample Production and Testing

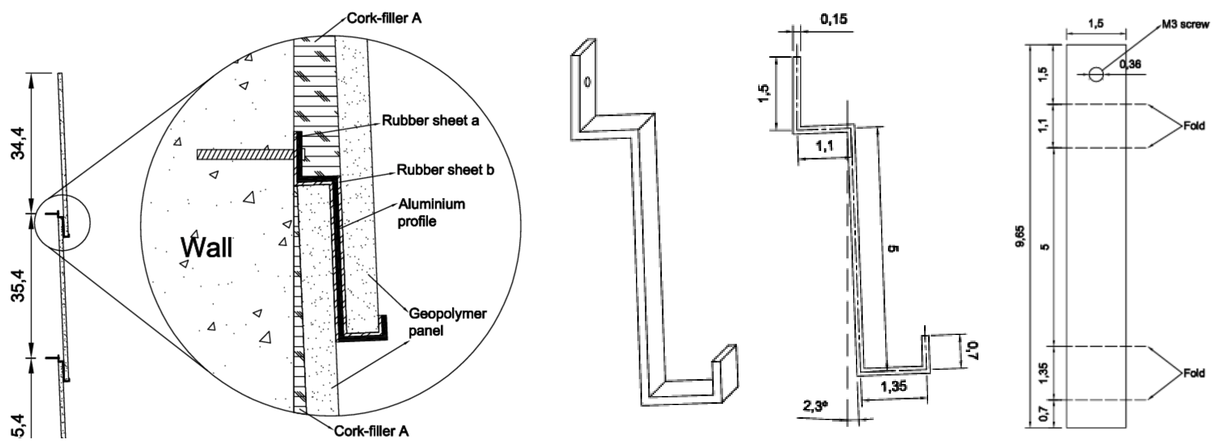
Aging test, 3-point bending, and water absorption



Initial water absorption: 10,68 %w/w

Highest water absorption: 11,88 %w/w

Final Design



Discussion

Optimal dimensions

- It was decided to be **40x80x1 (cm)**, as long as the material attends all mechanical requirements.

Aging test

- Water absorption **increased** throughout the cycles;
- Flexural strength **decreased by only 15%** in 25 cycles.

Scaling up to large samples

- Maintain curing humidity at **70–85% RH** to avoid surface cracks;
- Add 5% (%v/v) **flax fibers** to **improve flexural strength** and prevent cracking.

References

[1] The European Ceramic Industry Association, “Ceramic Roadmap to 2050 – Continuing Our Path Towards Climate Neutrality”, November 2021.
[2] A. Marmier, “Decarbonisation options for the cement industry”, 2023.
[3] M. Nawaz, A. Heitor, M. Sivakumar, “Geopolymers in construction - recent developments”, November 2020.