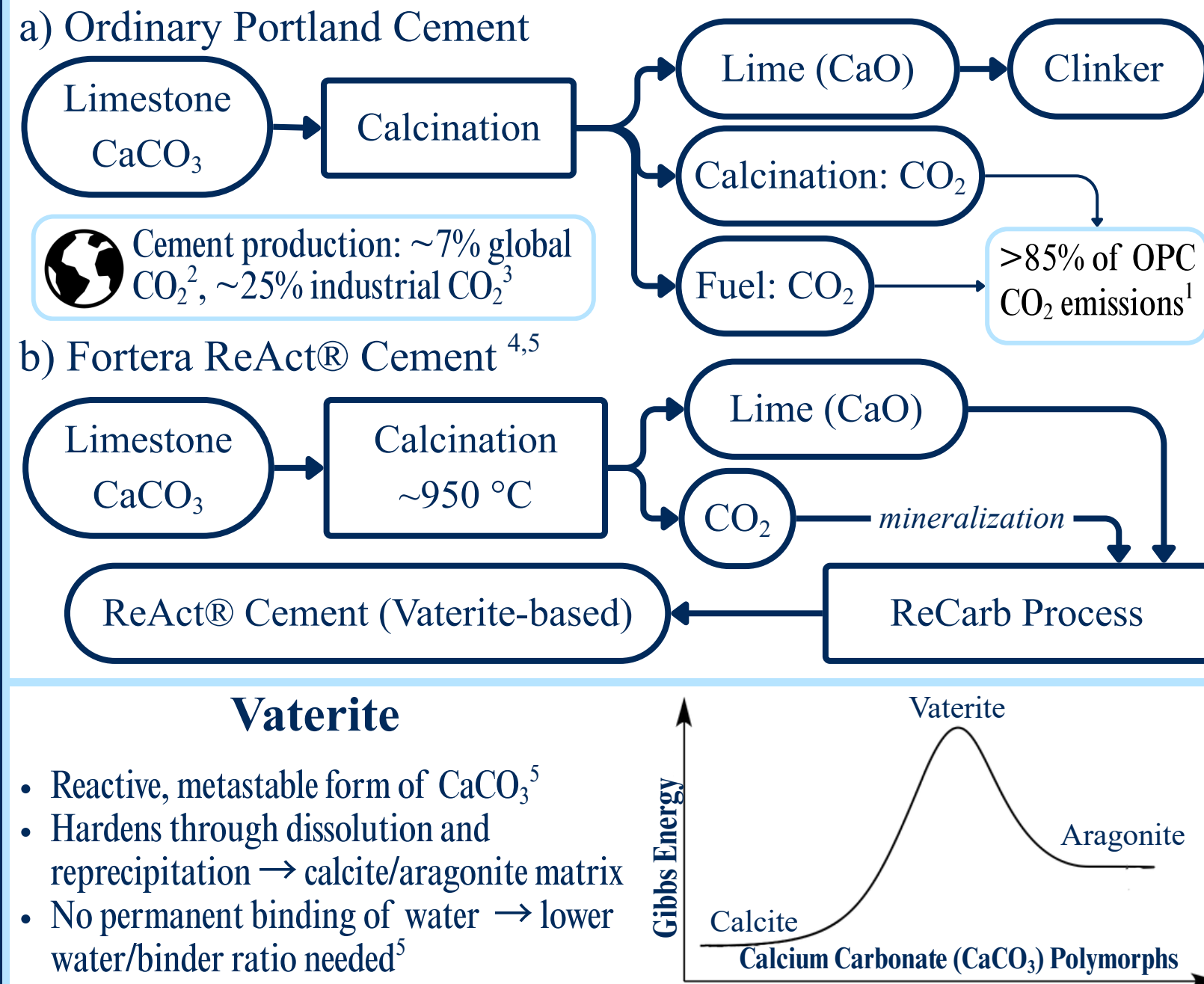


1. Background and Context

- Concrete is the most widely used manufactured material on Earth¹

Cement Processes



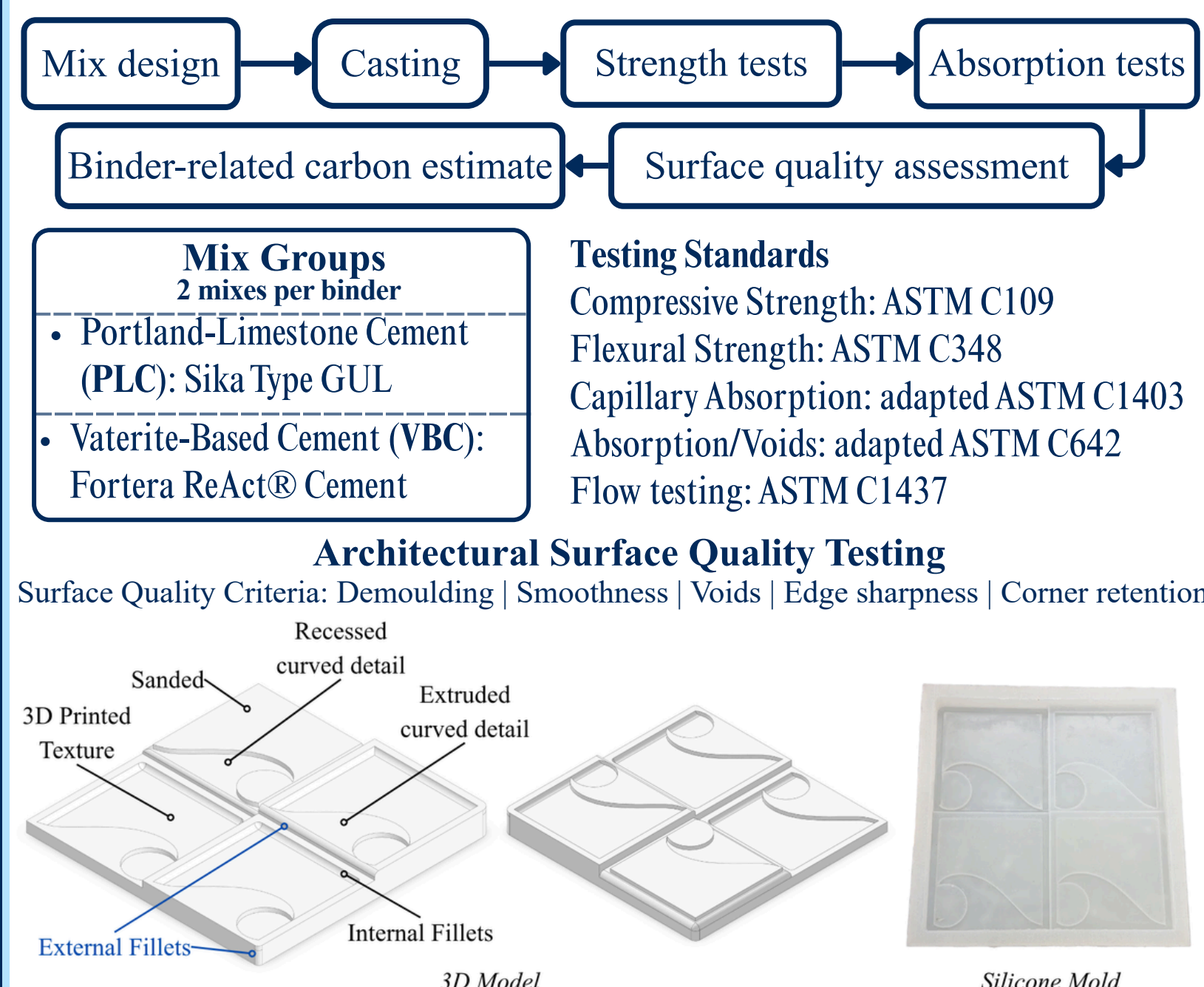
2. Objectives

Evaluate **workability** and **casting behaviour**, assess **mechanical strength** (compressive and flexural), measure **absorption/porosity/density**, evaluate **surface quality**, estimate binder-related **embodied carbon emissions**.

Research Question

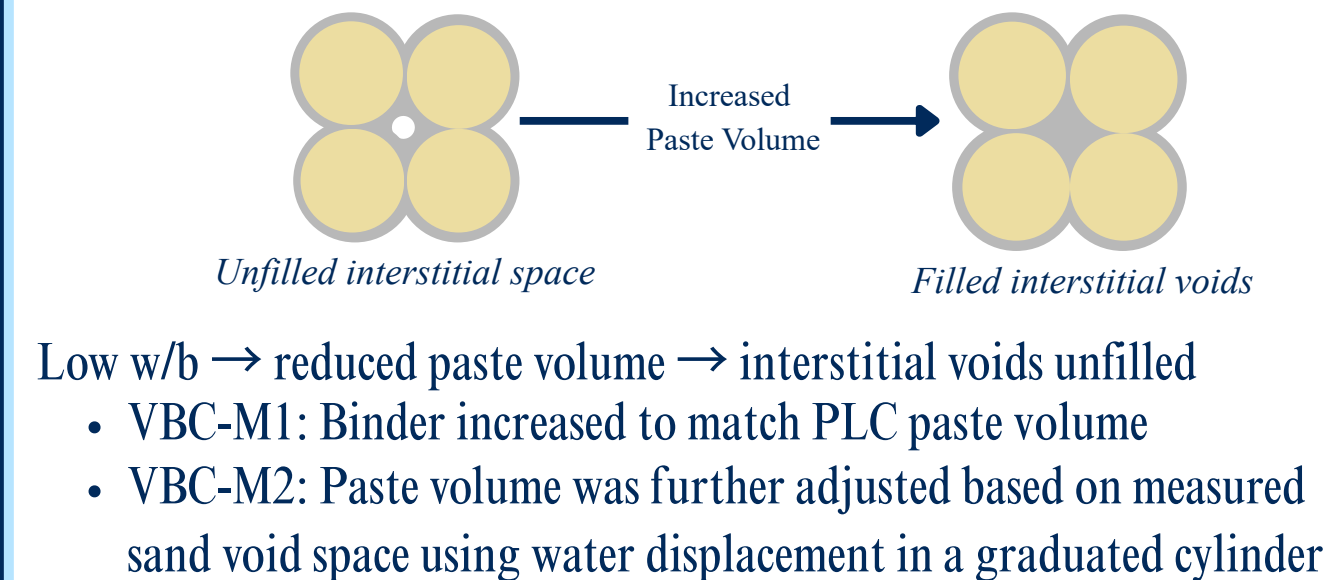
Can Vaterite-based Cement (VBC) provide a lower-carbon alternative to Portland Cement for precast architectural applications while maintaining acceptable mechanical performance and surface quality?

3. Methodology Overview



4. Results

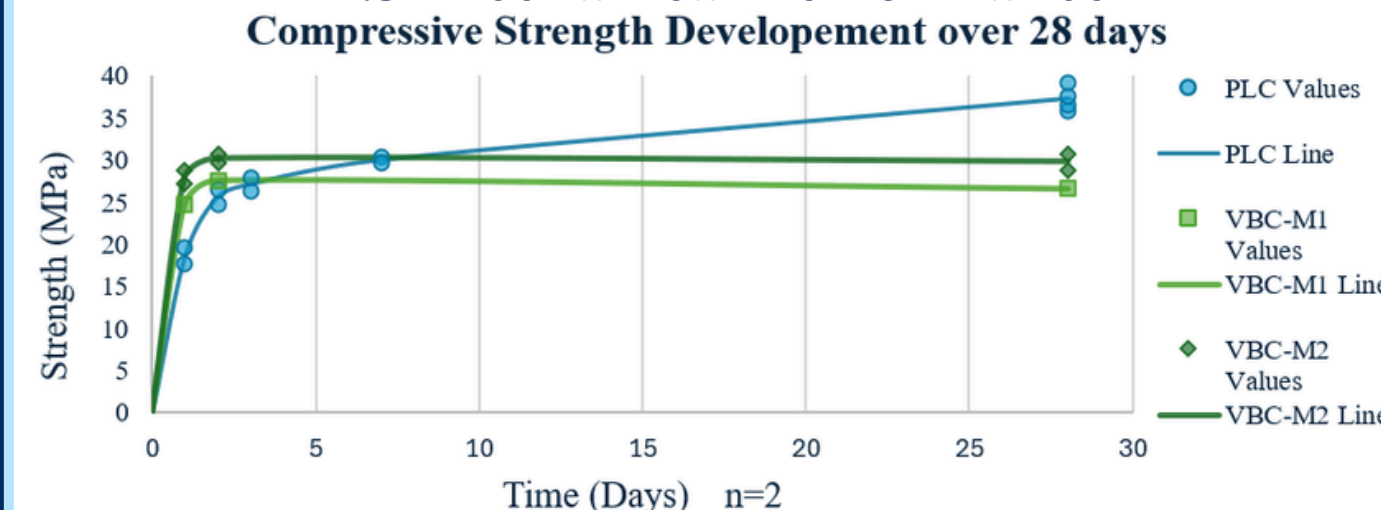
4.1 Mix Optimisation and Design



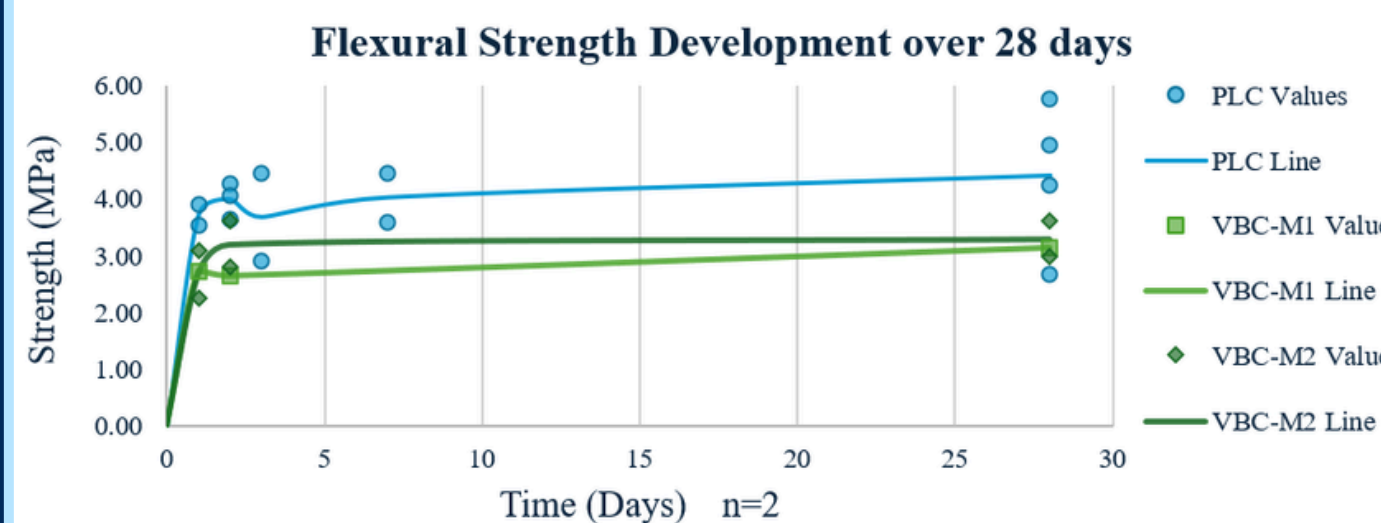
4.2 VBC Workability Observations

- Similar flow values did not produce identical casting behaviour
- Slid more readily across parchment and metal surfaces
- Showed a rate-dependent, elastic-like response under tamping
- In openings < 10 mm, paste could move ahead of the sand during vibration, making filling difficult

4.3 Mechanical Performance

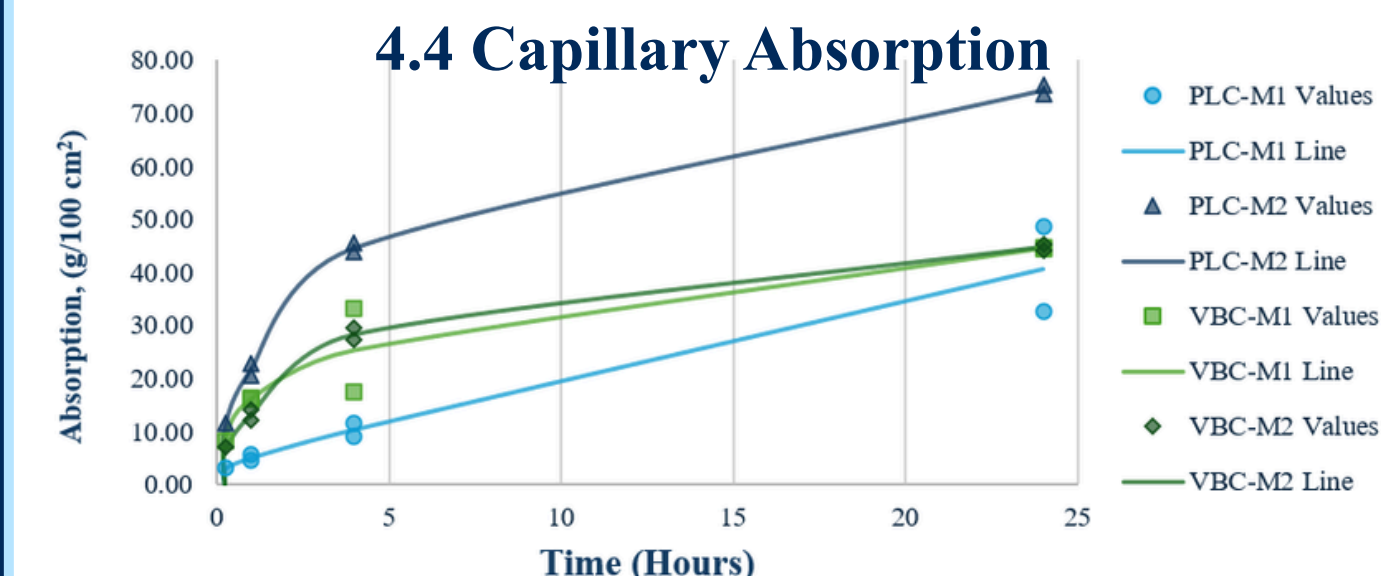


- VBC developed almost all of its strength within the first 48 h
 - Average strength was $\sim 42\%$ stronger than PLC-M2 at 1 d and $\sim 13\%$ stronger at 2 d, but $\sim 24\%$ weaker than PLC at 28 d



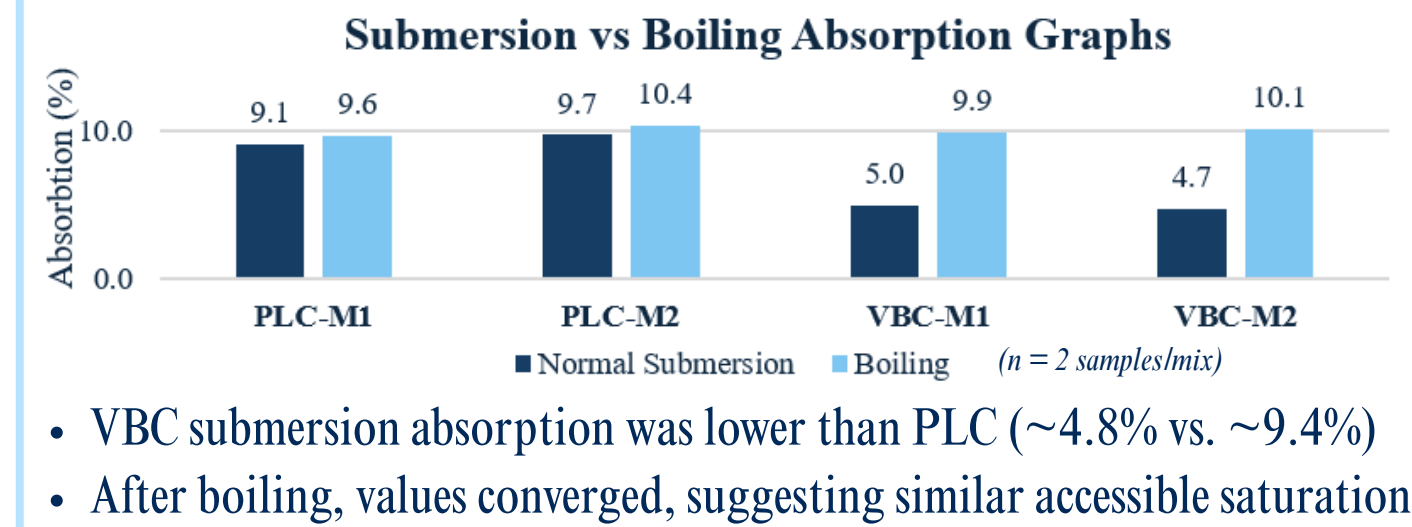
- VBC flexural strength remained below PLC at all ages
- Lower flexural/compressive ratio (10.6% vs. 14.4% for PLC) suggests VBC mixes had weaker relative bending performance
- At 28 d, VBC averaged 3.2 MPa vs. 4.4 MPa for PLC ($\sim 27\%$ lower)

Further mix optimisation is needed for bending-critical precast elements.

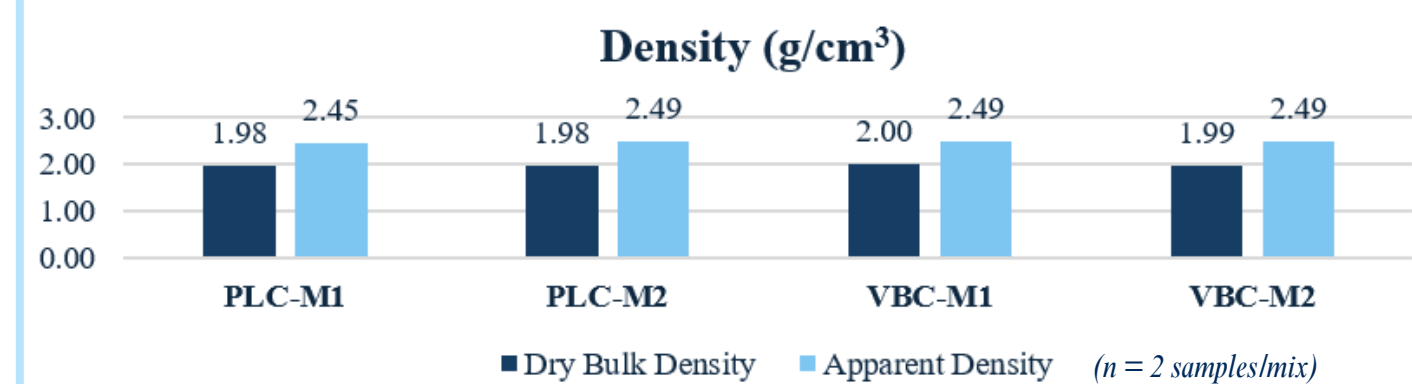


- VBC showed early uptake followed by a slower absorption rate
- VBC-M1 and VBC-M2 reached similar 24-h absorption values
- PLC results differed strongly between controls possibly influenced by different curing ages; repeat testing is needed

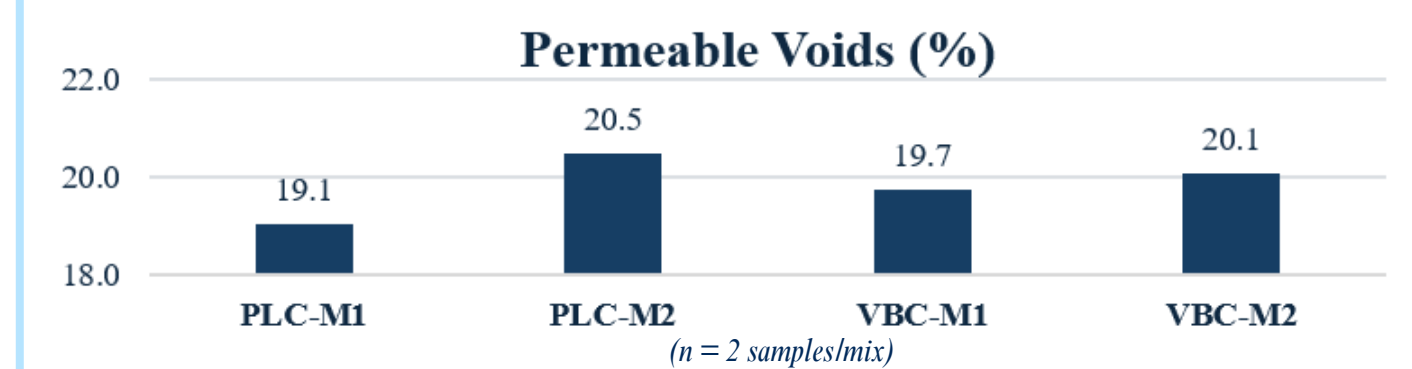
4.5 Absorption/Density/Permeable Voids



- VBC submersion absorption was lower than PLC ($\sim 4.8\%$ vs. $\sim 9.4\%$)
- After boiling, values converged, suggesting similar accessible saturation

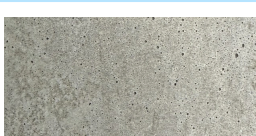
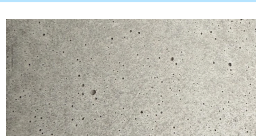
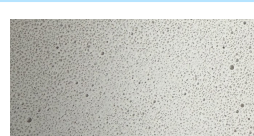
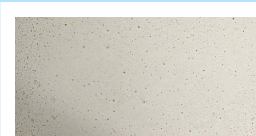


- VBC showed slightly higher dry bulk and apparent density than PLC

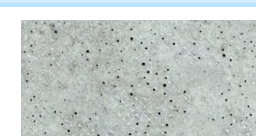
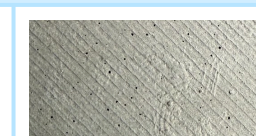
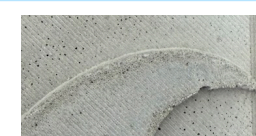
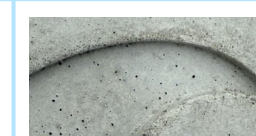


- VBC and PLC had similar permeable void content
- Lower VBC absorption suggests differences in pore accessibility and connectivity rather than total accessible pore volume

4.6 Surface Quality

Mix	PLC-M1	PLC-M2	VBC-M1	VBC-M2
				
Scores (1-5)	3.0	3.4	4.4	4.4
Mould residue				

- VBC mixes achieved higher overall surface-quality scores than PLC
- Showed easier demoulding, less mould residue, less surface tearing

Feature	PLC	VBC
Flat/ texture		
Curved detail		
Corner		
Inner edge		

- VBC produced smoother, glossier, brighter-white surfaces with strong edge/detail reproduction
 - Vibration appeared to create a paste-rich mould surface, which may have improved smoothness and fine-detail reproduction

4. Results

4.7 Embodied Carbon

Emission factors: PLC = 0.798 kg CO₂e/kg⁶; VBC = 0.221 kg CO₂e/kg
VBC estimated from Fortera-provided 76% reduction relative to OPC = 0.919 kg CO₂e/kg⁷

Mix	Sand/binder	Binder (CO ₂ e kg/m ³)	28-d Strength (MPa)	normalised (kg CO ₂ e/ (m ³ ·MPa))
PLC-M1	2.75	415.4	36.2	11.5
PLC-M2	2.75	416.9	38.4	10.9
VBC-M1	2.32	141.7	26.6	5.3
VBC-M2	2.22	146.7	29.8	4.9

- $\sim 65\%$ lower binder-related CO₂e per volume than PLC
- $\sim 54\%$ lower after normalising by 28-d compressive strength
- Further strength and mix optimisation could reduce normalised emissions even further

4.8 Applications

- Architectural precast: decorative panels, cladding, tiles and pavers requiring smooth finish, white colour, fine detail and easy demoulding.
 - Concrete masonry units (CMUs): promising for low-/zero-slump, vibration-compacted production and immediate mould release.
- Production advantage:** rapid early strength could enable earlier handling and faster manufacturing cycles.

5. Conclusions

- VBC developed most of its strength within 48 h, exceeding PLC at early ages but remaining $\sim 24\%$ lower in 28-d compressive strength.
- Flexural performance remained lower than PLC and requires further optimisation
- VBC had lower submersion absorption, with similar density and void content to PLC.
- VBC provided easier demoulding and smoother, brighter-white architectural surfaces with strong detail reproduction.
- Binder-related CO₂e was $\sim 65\%$ lower and strength-normalised CO₂e $\sim 54\%$ lower.
- Further mix optimisation and concrete-scale testing are needed before implementation.

6. Future Work

- Develop a broader **VBC mix-design database** for varied performance targets
- Test **0-12 h strength development** to identify the earliest safe demoulding time
- Investigate **low-/zero-slump applications**, especially concrete masonry units
- Expand to more detailed architectural panels and **concrete-scale testing**
- Compare consolidation methods, timing, and sequence** for surface quality

Study limitations: mortar-scale testing; n = 2; unequal capillary curing ages; qualitative surface scoring; binder-only carbon estimate

7. Acknowledgements

I would like to thank the Laidlaw Foundation, the University of Toronto Laidlaw Scholars Programme, Dr. Scott Ramsay, and the Fortera team—Dr. Craig Hargis, Dr. Ryan Gilliam, and Andrew Sleugh—for their invaluable support and guidance throughout.



8. References and Paper

