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AUSTRALIAN HEMP MASONRY

A STATE-OF-THE-ART REVIEW OF HEMPCRETE PERFORMANCE:

A CRITICAL EVALUATION OF THE PHYSICAL, STRUCTURAL AND FUNCTIONAL PROPERTIES

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ENERGY DEMANDS OF THE BUILT ENVIRONMENT

- 2050 forecast: cities account for 70% global population [1]
- one third global energy consumption [2]
- 37% global CO_2 production [2]
- Australian construction industry: 18% national carbon footprint [3]

1 United Nations (2023); **2** UN Environment Programme (2022); **3** Department of Climate Change, Energy, the Environment and Water (2022)

CONVENTIONAL CONCRETE

- most common material used globally [4]
- granular aggregate + water + cementitious binder
- 9% global greenhouse gas emissions [5]
- carbon intensive preparation of raw materials: calcination of limestone [6]
- reduce embodied/operational carbon - sustainable alternatives

4 Li (2011); **5** OECD (2018); **6** Ma *et al* (2016)

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HEMPCRETE

- bio-based aggregates: hemp shiv + fibres
- carbon-negative crop [7, 8]
- reduction in carbon-intensive lime-based binder [9]

Cast in Place | Brick | Prefab | Prefab + Greenwall

UTS TechLab (2023)

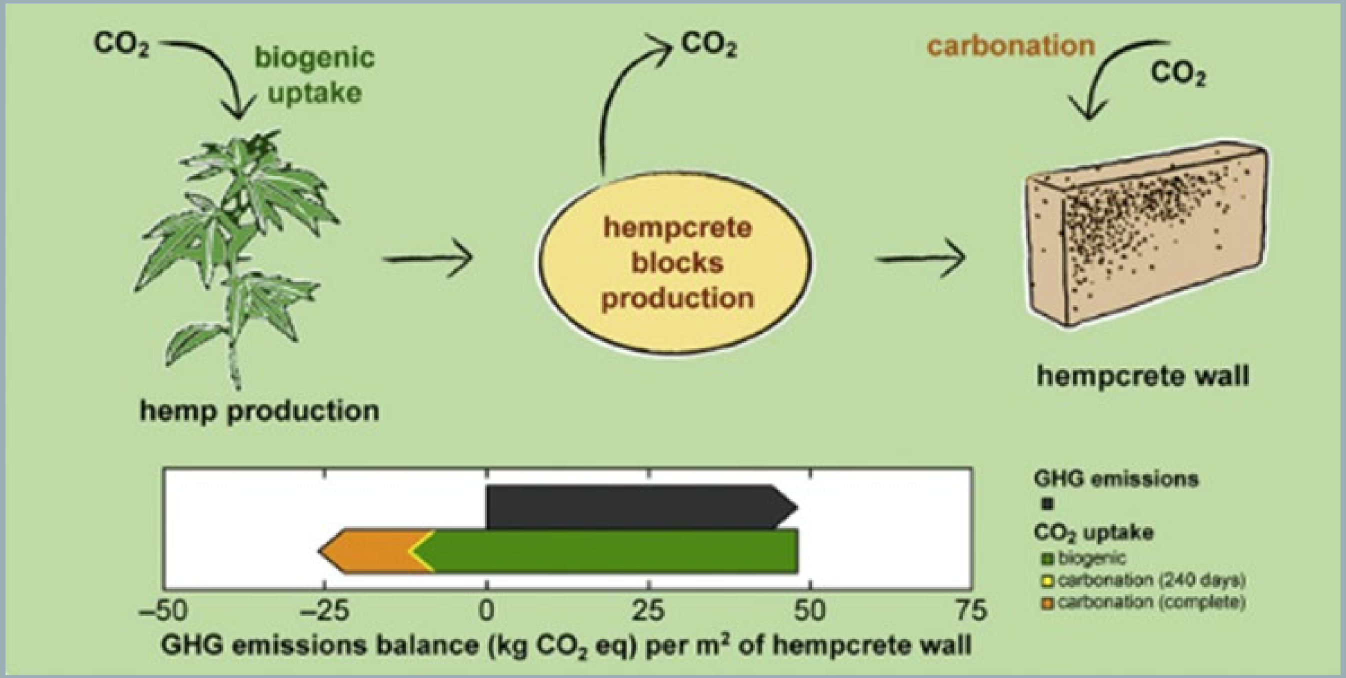
Prefabricated

Cast in place

Slurry (render)

7 Ahmed *et al* (2022); **8** Sudarsan *et al* (2022); **9** Chau *et al* (2023)

HEMPCRETE



- life cycles assessment: net carbon negative [10 11]
- carbonation: up to 300kg CO_2 /m^3 [12]
- higher capital outlay vs. higher operational savings [13]

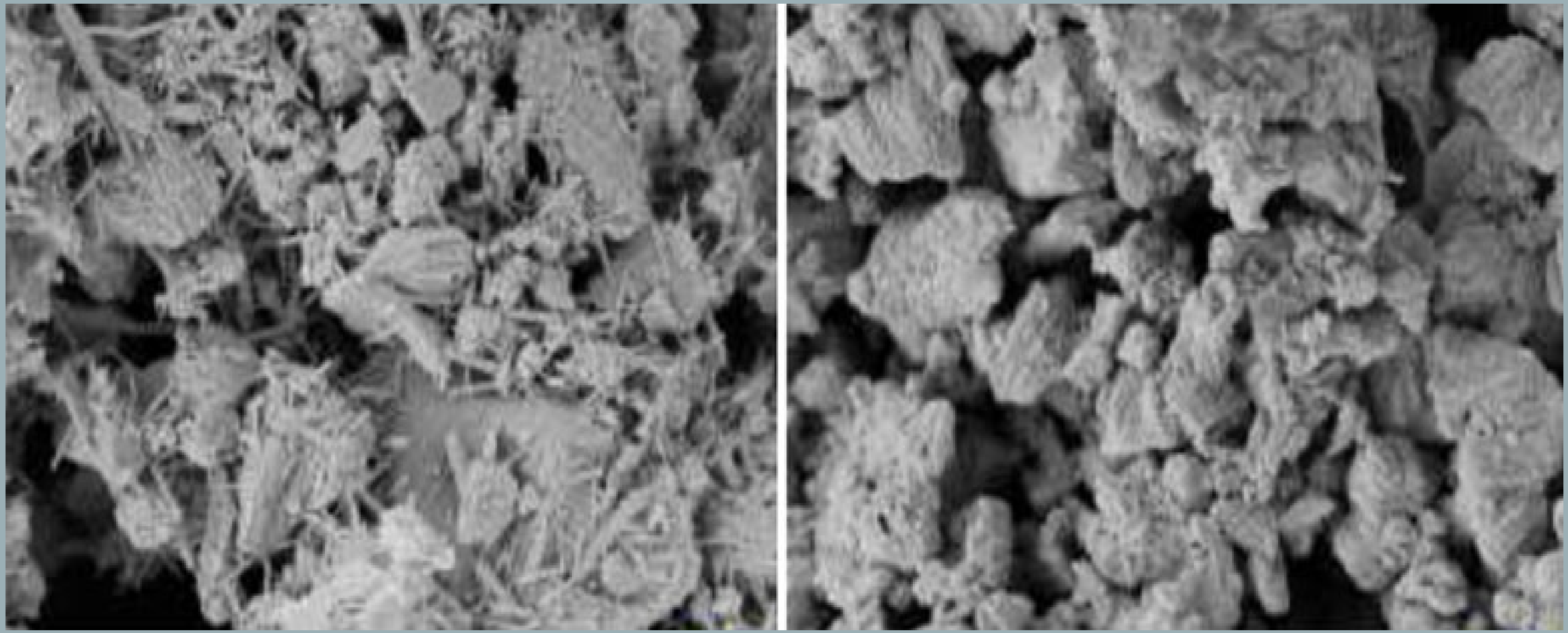
10 Le *et al* (2023); **11** Jami *et al* (2016); **12** Di Capua *et al* (2021): **13** Nordby & Shea (2013)

PHYSICAL PROPERTIES

- shiv : binder : water mix determines bulk density 182 – 1000 kg/m^3 [14]

- micropores (< 0.1mm);
  mesopores (0.1 – 1.0mm);
  macropores (> 1.00mm) [15]

- microstructure and mixing ratios
  determine insulative performance

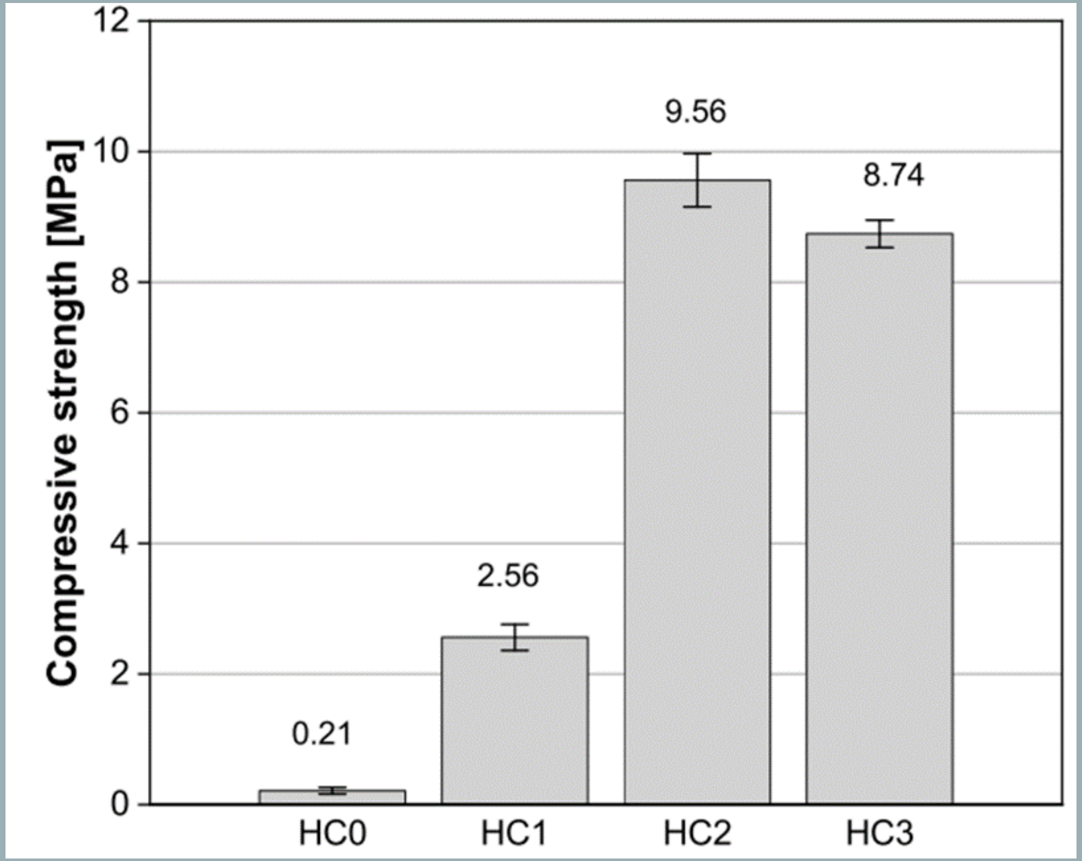


Scanning Electron Microscope Imagery of Microstructure [16]

14 Delhomme *et al* (2020); **15** Demir & Doğan (2020): **16** Walker & Pavia (2014)

MECHANICAL PERFORMANCE

- load bearing structural concrete: 32 MPa [17]
- hemp concrete composites: 0.5 – 10 Mpa [18]
- higher binder/shiv ratio + higher compaction
  → bulk density → compressive strength

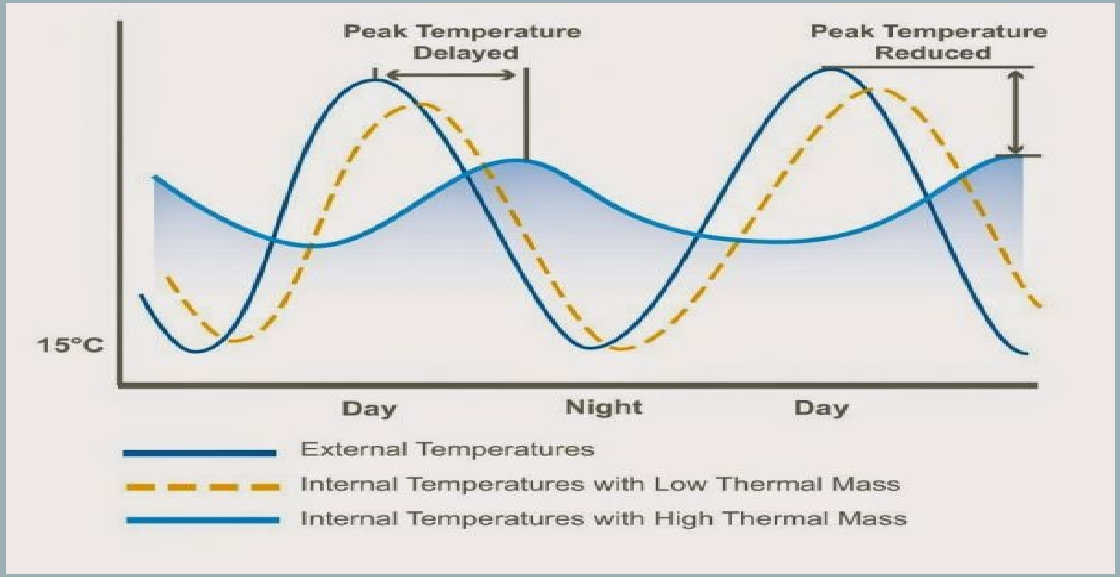


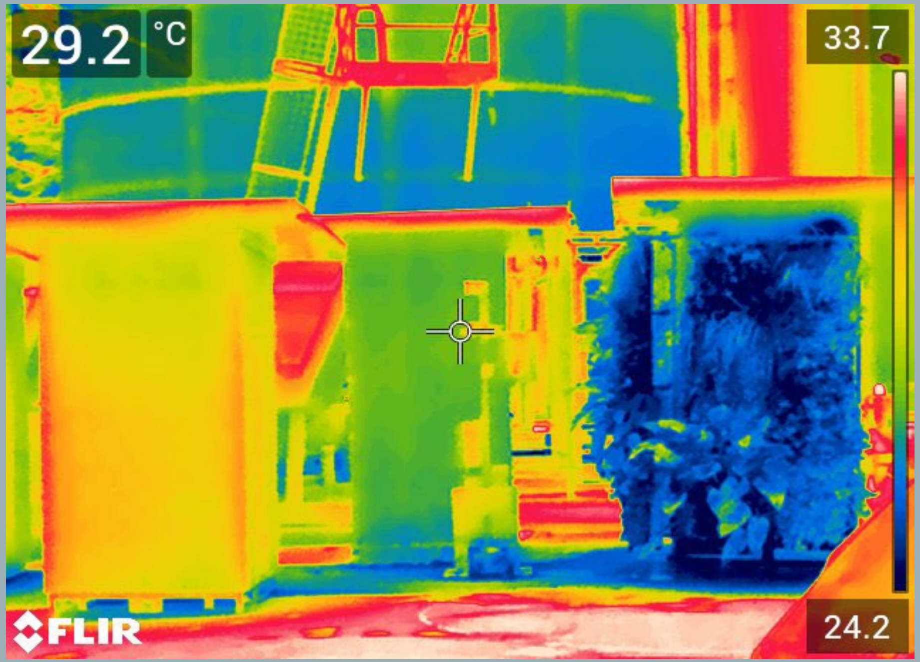
Compressive strength of hempcrete at varying binder ratios [19]

17 Department for Infrastructure and Transport (2022); **18** Wadi *et al* (2019); **19** Horszczaruk *et al* (2023)

THERMAL PROPERTIES

- defined by thermal conductivity, specific heat/thermal mass and thermal diffusivity [20]
- standard density concrete at room temp (1.33 - 1.95 W/m.K) [21]
  hempcrete (90 - 160mW/m.K) [22] [23]
- thermal performance optimised by higher hemp shiv mixing ratios [24]





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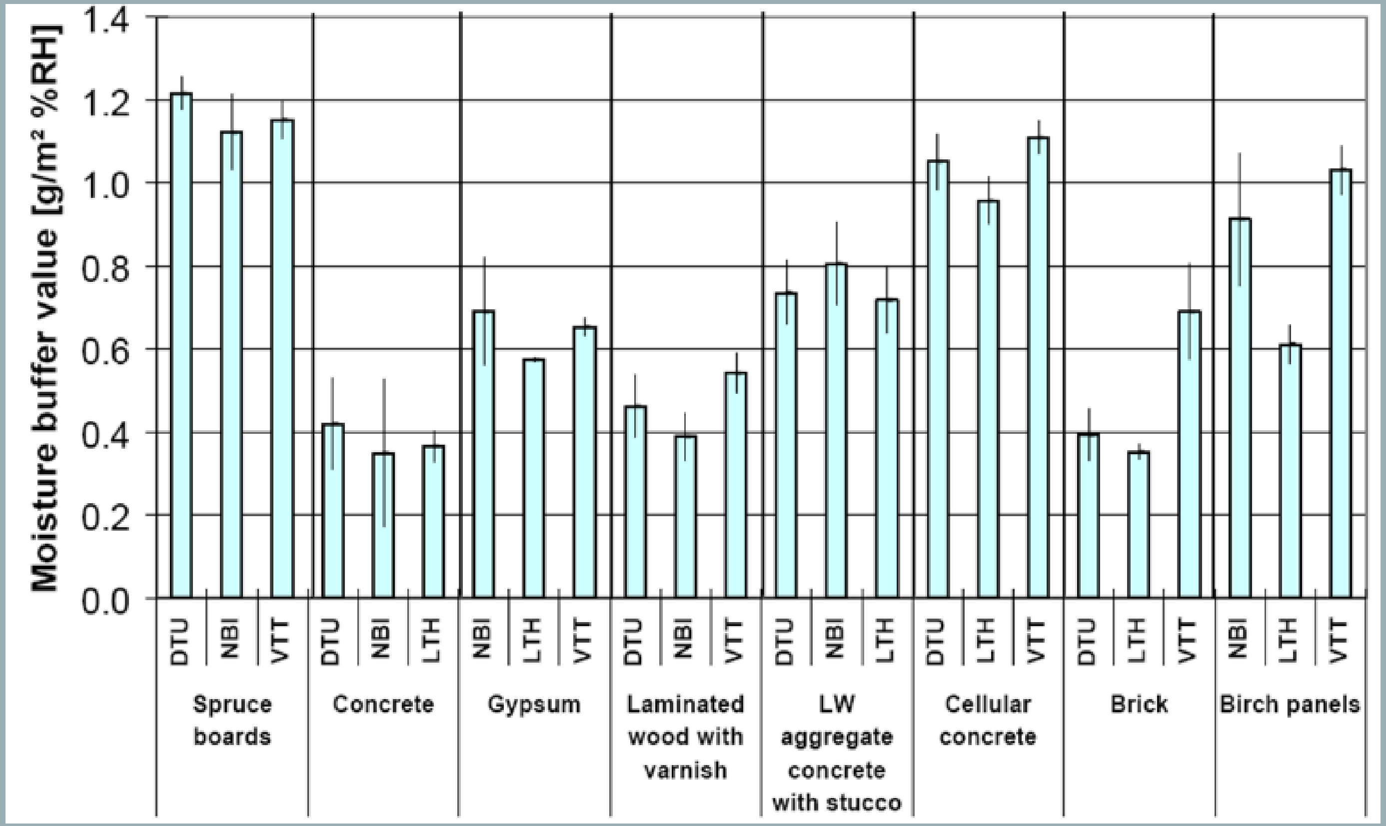
20 Haik *et al* (2020); **21** Asadi *et al* (2018); **22** Collet & Pretot (2014); **23** Bruijn & Johansson (2013); **24** Sassoni *et al* (2014)

HYGRIC PROPERTIES

- moisture buffering capacity: stabilises RH [25]
- hempcrete: > 2 g/(m2·% RH) [26]
- significant reduction in risk of condensation [27]

Hempcrete	M B V
Sprayed	2.15
Moulded	2.14
Precast	1.94



Moisture buffer values of common building materials [28]

25 Bennai *et al* (2022): **26** Collet *et al* (2013); **27** Shang & Tariku(2021); **28** Rode *et al* (2007)

ACOUSTIC PERFORMANCE

- noise reduction coefficient (NCR) [29] :
  - wood, steel, concrete blocks (0.05 – 0.25)
  - hempcrete (> 0.44)

- acoustic insulation directly relates to bulk density [14] [30]

- NCR sensitive to binder type: pozzolan outperform hydraulic lime-based binders [31]

29 Fediuk *et al* (2021); **30** Gourley *et al* (2016); **31** Kinnane *et al* (2016)

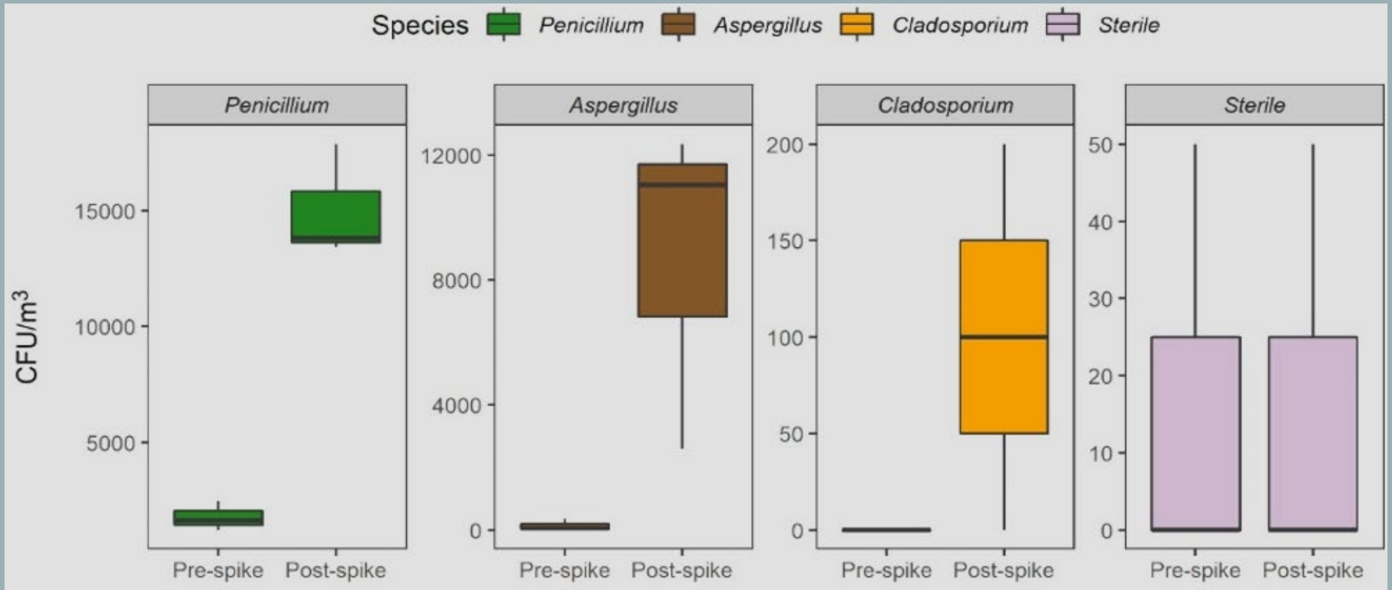
MICROBIAL GROWTH POTENTIAL

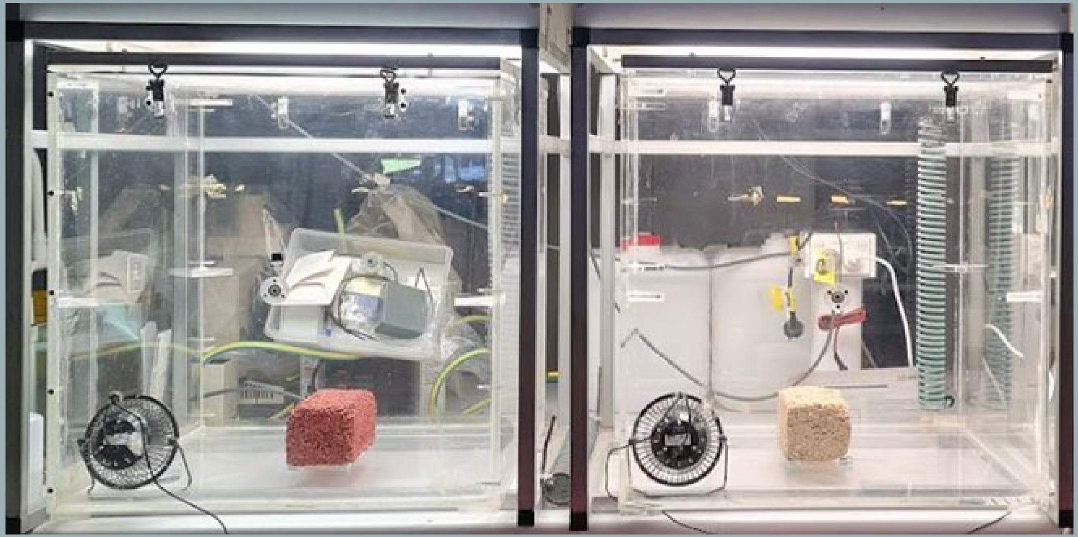
- inert nature of hempcrete → robust to biodegradation [35]
- hemp concrete has antimicrobial properties [18] :
  - alkalinity of lime → generally resistant to mould/insects [36]
  - no available nutrients to support bacterial/fungal growth [35]
- paucity of research within extreme conditions [9]

35 Walker *et al* (2014); **36** Picandet (2013); **18** Horszczaruk *et al* (2023);

MICROBIAL GROWTH POTENTIAL

- hempcrete exposed to extreme conditions
- common fungal genera found to proliferate
- sensitive to common household disinfectants





Chamber studies assessing mould growth on hempcrete blocks at 100% RH [9]

9 Chau *et al* (2023)

GAPS IN KNOWLEDGE

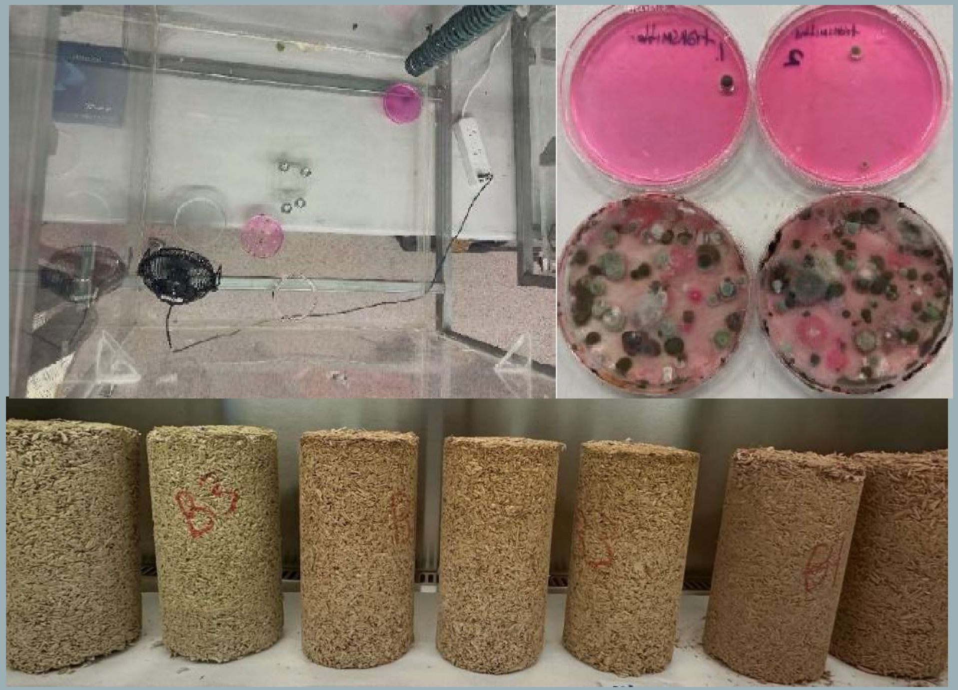
- paucity of local Australian studies assessing hempcrete at the building scale.
- extreme weather conditions – high heat exposure, flood and drought conditions.
- potential of alternative binders – how to reduce lime demand, how to optimise mechanical strength, durability and insulative performance.

UTS Techlab 2024

THE FUTURE OF HEMPCRETE

- contribution of novel binders
  - crushed brick (better mechanical strength)
  - reducing lime content, maintaining performance
  - calcinated clay, geopolymers

- integration of other biobased building material
  - green wall technology to further remediate air quality



UTS Laboratory - chamber studies (Duani, 2024)

UTS Techlab - hempcrete and green walls in concert

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