Comparative evaluation of the compressive behaviour of modular composite wall with and without sheathing

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Introduction

Modular building construction

- Pre-fabrication of structural members in a factory and then transported to the site for assembly to construct a building
- Quick construction process, better quality, low capital investment and less environmental impact

Holiday Inn Express, Manchester, UK
(Chapman 2017)

Material of construction

- Conventional materials such as Steel & light steel, concrete and timber

Steel containers modular building

(Howick 2020)

Timber concrete

(Ferdous et al. 2019)

Concrete core modular building

(Ferdous et al. 2019)

Drawbacks of conventional materials

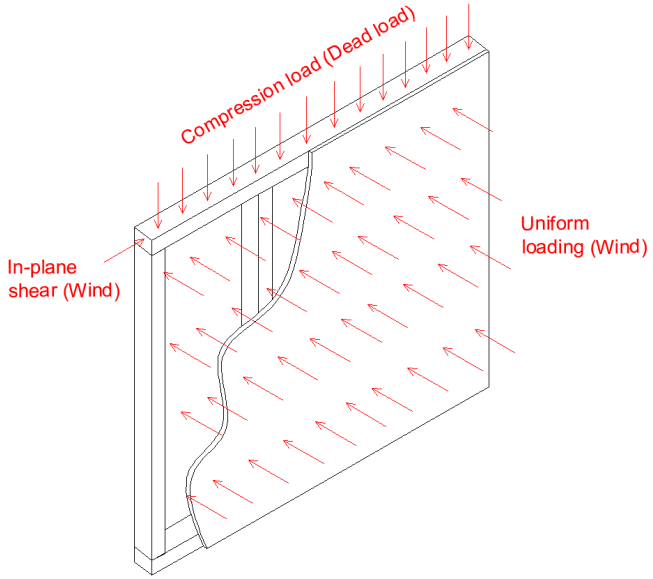
- Steel: Corrosion, heavy weight and high maintenance cost (Ferdous et al. 2019)
- Concrete: Prone to cracking during transportation, heavy weight (Lacey et al. 2018)
- Timber: Pest and biological decay (Ferdous & Manalo 2014)

Fibre Reinforced Polymers (FRP) as construction material

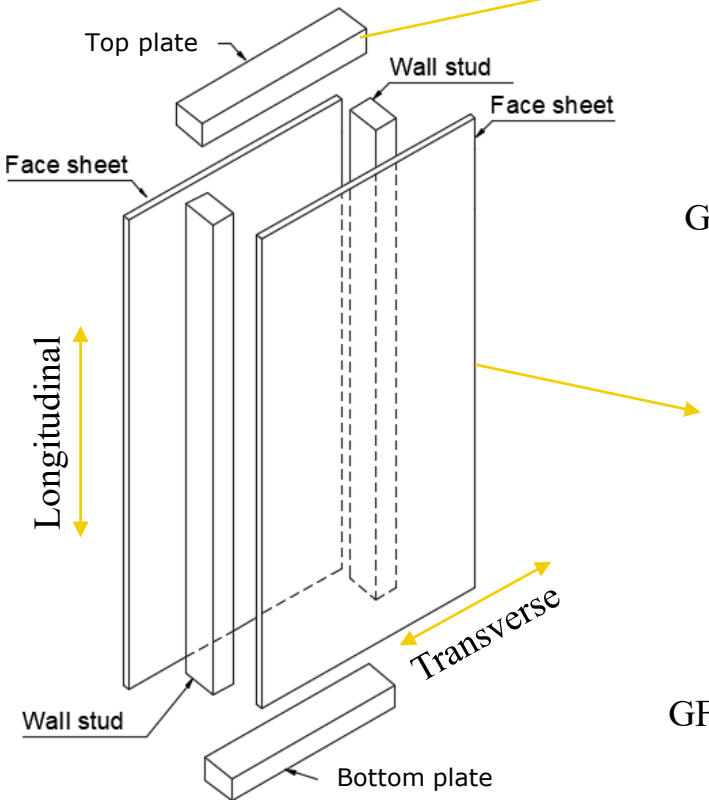
- High strength-to-weight ratio
- Design flexibility
- Zero corrosion
- Very less maintenance
- Immunity from pest and biological decay

FRP composite wall system

- Modular wall system need to withstand sustained and operational loads.
- Type of loads acting on wall system (Compression, In-plane shear and uniform distributed load)

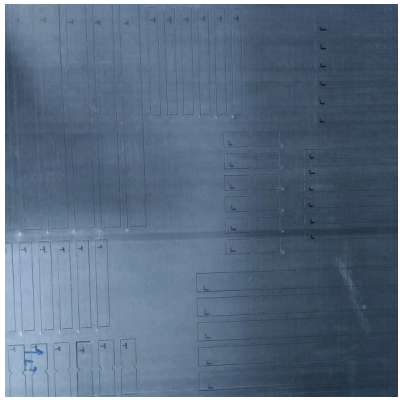


Composite wall system

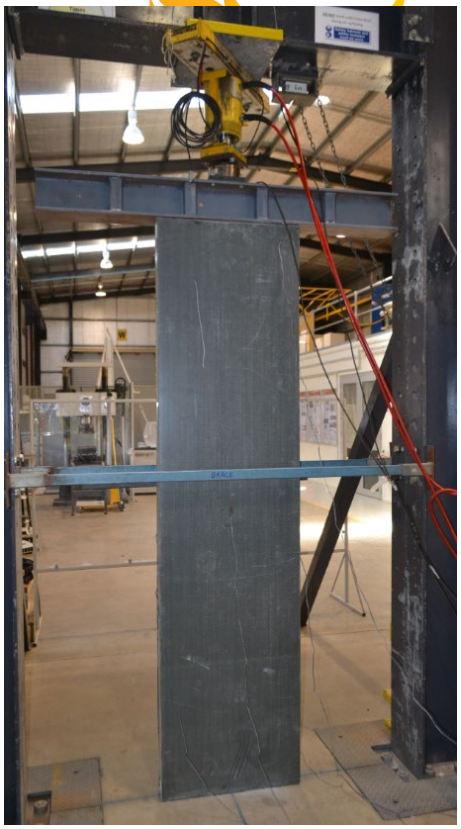


General configuration of wall system

GFRP RHS 100x75x5 (mm)

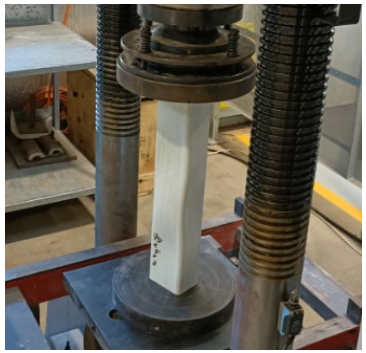


GFRP sheathing 2400x600x6.5(mm)



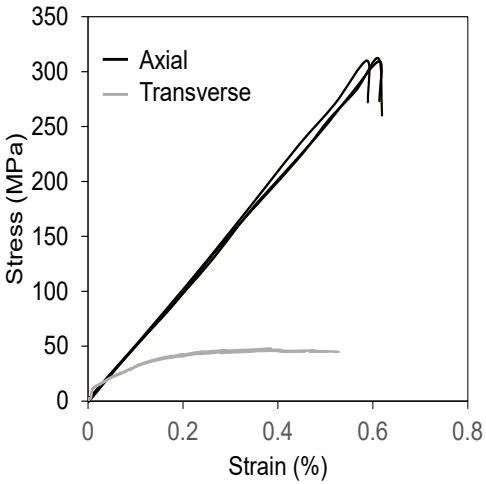
Full scale compression test (2400x600mm)

Material characterisation- GFRP RHS
Full profile test

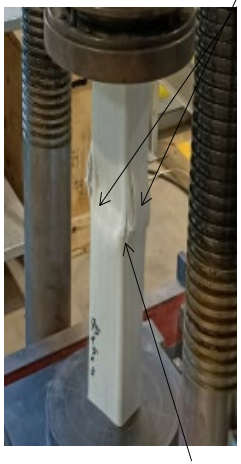


Axial compression

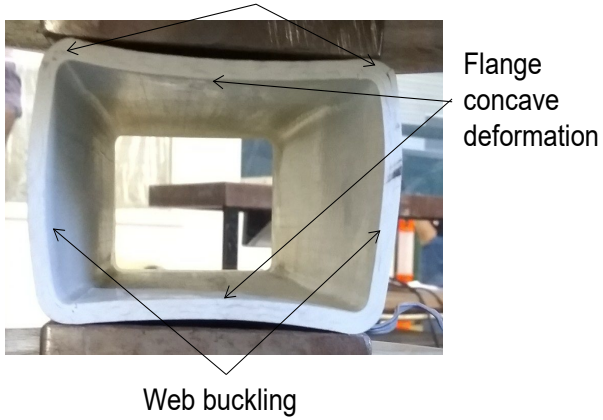
Transverse compression



(a) Stress vs strain



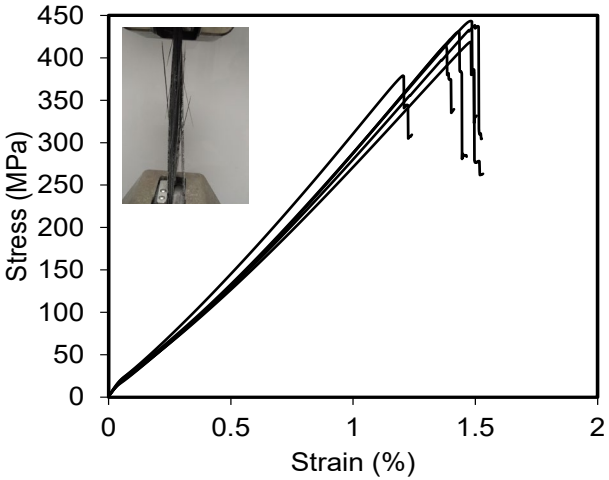
(b) Axial failure



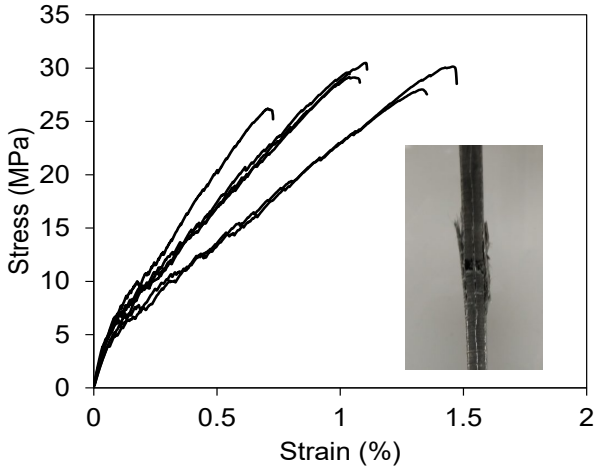
(c) Transverse failure

Source: (Sharda et al. 2021)

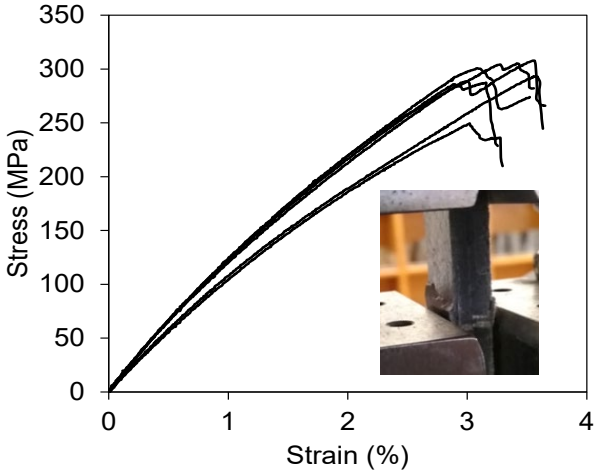
Material characterisation- GFRP Sheathing
Coupon testing



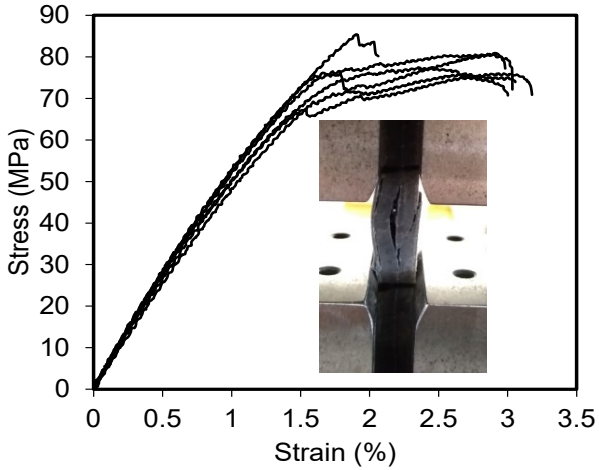
(a) Tension- Longitudinal
(Instant delamination)



(b) Tension- Transverse
(Resin cracking)



(c) Compression- Longitudinal
(Crushing failure)



(d) Compression- Transverse
(Interfibre fracture failure)

Source: (Sharda et al. 2021)

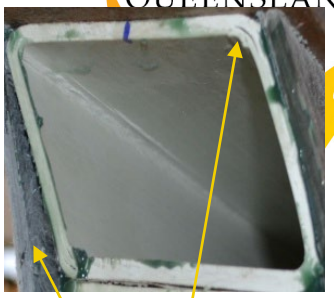
Full scale compression test

GFRP wall panel
without sheathing

Horizontal cracking

Junction failure

GFRP wall panel with
GFRP sheathing



Inter-laminar delamination
& Junction failure

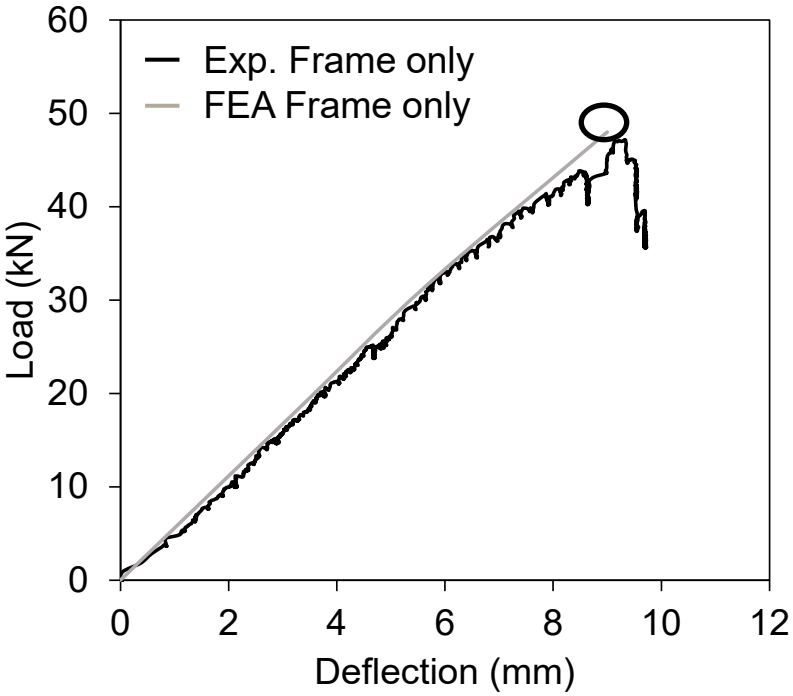
Debonding

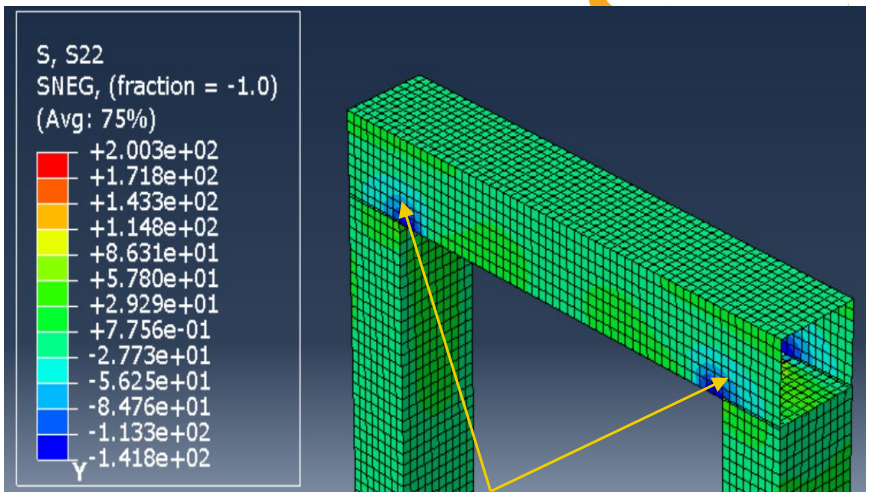
Frame only

Sheathed frame

Source: (Sharda et al. 2021)

FEA- Frame only



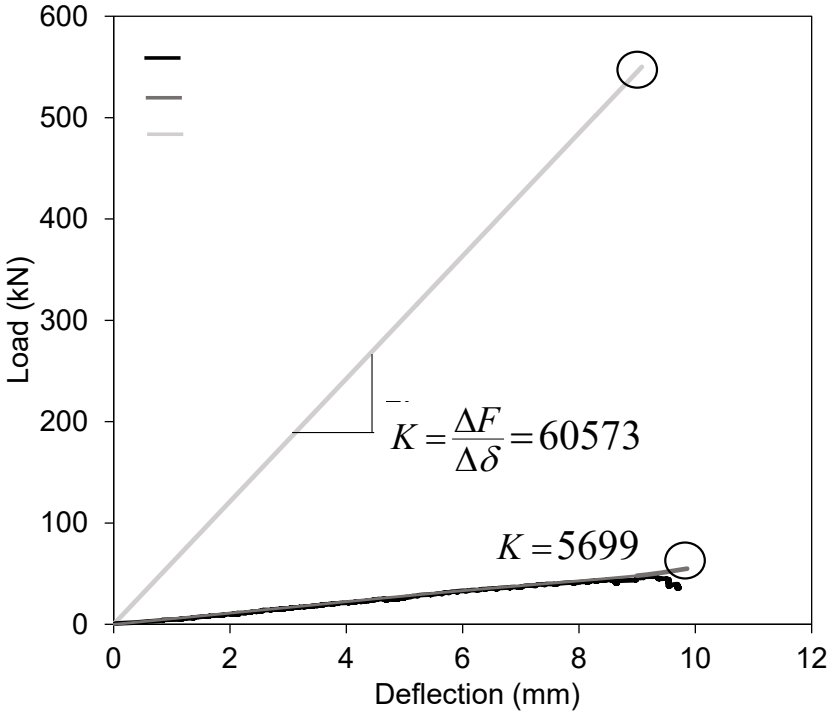


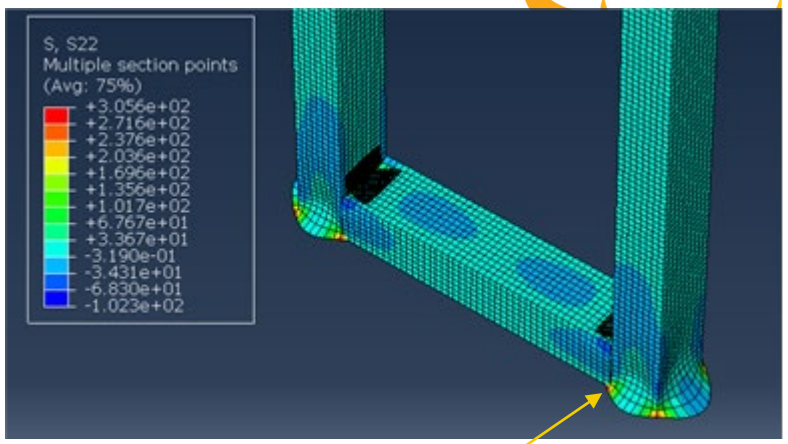
Ultimate compression stress limit

Horizontal cracking

Source: (Sharda et al. 2021)

Full scale FEA for extended studs frame only





End crushing

1. 10.63 times higher overall stiffness
2. 11.91 times loading capacity

Source: (Sharda et al. 2021)

Conclusion

- Material characterisation of full profile is quick, repeatable and helps is understanding constituent material's failure behaviour.
- Linear finite element analysis provides agreement with the experimental results.
- Significant increment in axial stiffness and loading capacity can be achieved by altering frame configuration.
- Finite element analysis of combined loading conditions such as compression and flexural load or compression and shear load should be conducted to understand the behaviour of wall system under combined loading conditions.

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Chapman 2017, Offsite construction, viewed 04/04/2023, <https://www.chapmantaylor.com/news/holiday-inn-express-wins-retail-leisure-project-of-the-year-at-the-2018-offsite-construction-awards>

Ferdous, W & Manalo, A 2014, 'Failures of mainline railway sleepers and suggested remedies–review of current practice', Engineering Failure Analysis, vol. 44, pp. 17-35.

Ferdous, W, Bai, Y, Ngo, TD, Manalo, A & Mendis, P 2019, 'New advancements, challenges and opportunities of multi-storey modular buildings – A state-of-the-art review', Engineering Structures, vol. 183, pp. 883-93.

Howick 2020, Volumetric modules, viewed 04/04/2023, <https://www.howickltd.com/applications/modular-construction/volumetric-modules?gclid=EAIaIQobChMIiOPak7LT6AIViTUrCh3DXgA-EAAYASAAEgJHsfD_BwE>.

Lacey, AW, Chen, W, Hao, H & Bi, K 2018, 'Structural response of modular buildings – An overview', Journal of Building Engineering, vol. 16, pp. 45-56.

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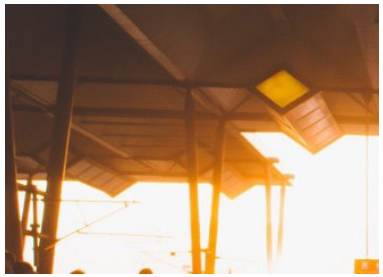
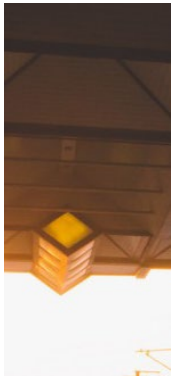
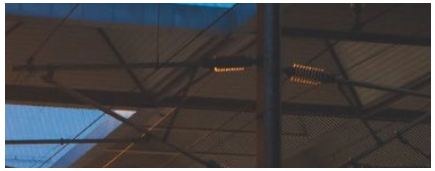
Thank you for your kind attention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Research papers

1. Axial compression behaviour of all-composite modular wall system

https://www.sciencedirect.com/science/article/abs/pii/S0263822321004463

2. Flexural behaviour of composite modular wall systems under uniformly distributed and concentrated loads

https://www.sciencedirect.com/science/article/pii/S0263822322010789

3. In-plane shear behaviour of prefabricated modular wall system assembled of fibre reinforced polymer composites

https://www.sciencedirect.com/science/article/pii/S2214509522009512