Enhancement of filament winding fabrication capabilities for natural fibre composite facade construction

Researcher capacity enchancement – ITB research scheme, 2026

Rakhmat Fitranto Aditra [1], Anggera Bayuwindra[2], Andry Widyowijatnoko[1], Hafshah Salamah[1], Rizki Armanto Mangkuto[3].

[1]SAPPK, [2]STEI, [3]FTI

Abstract

This research explores the potential of fibre-filament wound composite as a customizable permeable façade system. The study investigates the relationship between winding syntax, façade porosity, and building performance through computer simulations. Two façade configurations were developed and evaluated, followed by iterative prototyping to develop human–robot collaborative fabrication setups. The results show that façade porosity can be customized through winding syntax alone, although the efficiency decreases at lower porosity levels. Energyplus simulations indicate that construction efficiency also influences the effectiveness of porosity control in improving UDI and building energy performance. Meanwhile, the prototyping process demonstrates that increasing automation does not necessarily improve fabrication efficiency, as unreliable automation can introduce additional errors and workload.

Keyword: fibre-filament wound composite, permeable façade, prototyping, simulation.

Introduction

Fibre-filament wound (FFW) composite can be an alternative for permeable façade. The precise fibre-filament winding fabrication can be employed has the potential for customization aimed for right balance between radiation and illumination.

This manuscript describes the development of fibre filament winding fabrication in Architecture program of Bandung Institute of Technology. The aim of the development is to propose a design and construction of fibre filament wound composite as permeable skin facade.

This manuscript also describes and discusses several fabrication setups used to construct and fabricate one of the proposed secondary skin components. The developed setups were all human and robot collaborative setups with increasing automation. The setups were developed incrementally since 2025 and in parallel with the porosity and building performance simulations.

Method

Consists of: design development, computer simulation and iterative prototyping. Two FFW permeable façade were proposed: Square and vertical panel. The correlation between design parameter of the façade to its porosity are tested through 3D modelling in Rhino3D and Grasshopper3D.

This research also employed case-study building performance simulation using Energy-plus to test the range of effect of FFW permeable facade to UDI and building energy.

Lastly, an iteration of prototyping session was done to test the constructability and to develop the fabrication setup. The prototyping evolved around an collaborative robotic arm with the aim of higher automation.

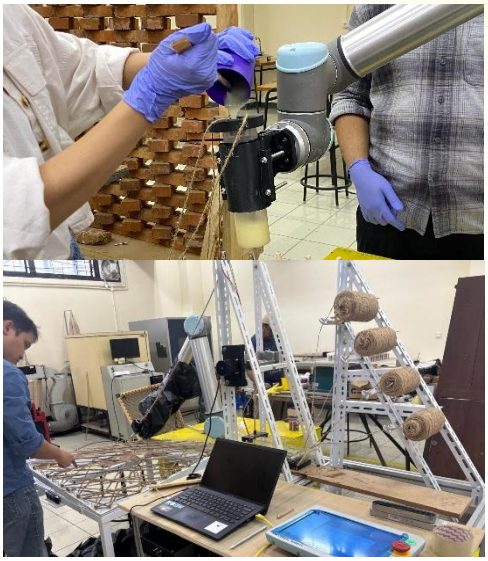


Fig 1. Development of collaborative human-robot fabrication setup



Fig 2. FFW composite panel demonstrator



Fig 3. Developed square panel prototypes

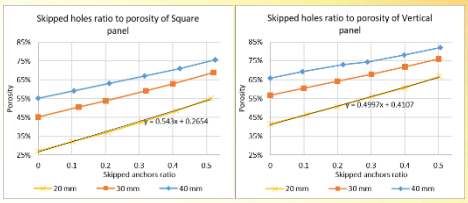


Fig. 4. Increased porosity by skipped anchors

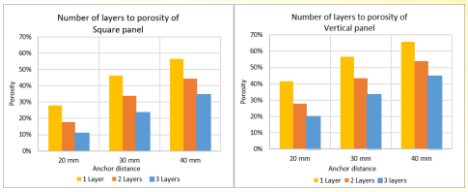


Fig 5. Reduced porosity by added layer

Table 3. Effect on UDI and building energy in Jakarta

			Avg of all orientation
Square panel			
	avg $\Delta E_{c,l}$/avg $E_{c,l}$	/Δskipped anchors ratio	9.85%
	avg ΔUDI		-17.23%
	avg $\Delta E_{c,l}$/avg $E_{c,l}$	/Δlayer number	-2.25%
	avg ΔUDI		2.04%
Vertical panel			
	avg $\Delta E_{c,l}$/avg $E_{c,l}$	/Δskipped anchors ratio	12.19%
	avg ΔUDI		-15.93%
	avg $\Delta E_{c,l}$/avg $E_{c,l}$	/Δlayer number	-3.59%
	avg ΔUDI		3.24%

Result

The porosity calculation shows the square panel is denser than the vertical panel due to its diagonal winding. The denser configuration makes its winding syntax more effective to change the building performance. However, the square panel less efficient construction still makes it less effective than the vertical panel to control UDI and building energy.

Over two year periods, the prototyping can be divided into two phases. The second prototyping session improved the precision and drying sequence. However, the added automation causes too many error that made the second prototyping more difficult to execute.

Conclusion

This research has demonstrate the potential of FFW composite as customizable façade construction.

The porosity calculation has shows that the porosity can be customized by its winding syntax only. However, at lower porosity, the efficiency of filament length to the change in porosity stagnates. The building energy simulation shows that the inefficient construction reduce the effectiveness of porosity control to the building performance.

The development of fabrication and prototyping setup shows that collaboration between human and automation require clear coordination and good reliability. Adding automation with low reliability results higher workload compared to less but more reliable automation setup.