UNB | Off-site Construction Research Centre

EST. 1785 UNIVERSITY OF NEW BRUNSWICK

PROJECT PROFILE

Preliminary Testing of a UHPC Cladding Technology

Nunafab Corp. is a prefabricated home manufacturing company based in Cambridge Bay, Nunavut. They specialize in structural components made of Ultra-High-Performance-Concrete (UHPC) that are high in strength and durability. The high-performance of their concrete allows for an overall reduction in the size of their fabricated components without sacrificing the integrity of their structures. This reduction in size results in lower transportation costs that would typically be associated to the high construction costs of housing in the region. Their mission is to make housing more affordable through precast construction methods. The goal of this project was for the OCRC to support Nunafab Corp. in the testing and development of an ultra-high-performance cladding technology.

PROJECT BACKGROUND

Currently, UHPC panels as thin as 25.4 mm are being incorporated in the design of panelized buildings; however, attempts to create thinner panels have been unsuccessful due to unwanted cracking. The goal of this research was to support Nunafab Corp. on their initiative in the development of a UHPC cladding technology for residential buildings in the arctic. Various mixes were cast, containing different levels of fibre and mesh reinforcements. Small 12.7 mm-thick test panels were cast vertically (Figure 1) and horizontally (Figure 2) to determine the best casting methods to obtain a smooth finish.

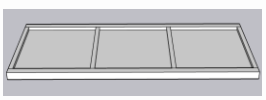

Figure 1: Horizontal Forms

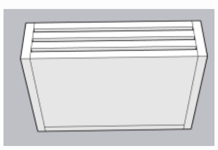

Figure 2: Vertical Forms

The mixes were then tested in compression, stiffness and bending to determine the optimal level of reinforcements (see Figures 3 to 5). Panels were also tested to determine the best methods for drilling holes to facilitate construction and the attachment of fasteners. A final mix design and casting process was then selected for Phase II of the project: large-scale prototyping.

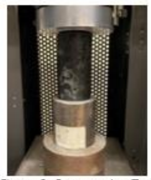

Figure 3: Compression Test

Figure 4: Modulus of Elasticity Test

Figure 5: Flexural Strength Test

RESULTS

Casting Methods and Finishes

The horizontal casting technique was faster, but it relied on the self-leveling abilities of the UHPC and did not always yield panels that were smooth on both sides. Casting vertically was the best way to add the mesh scrims and ensured that the panels had a smooth finish on both sides 100% of the time; however, careful attention had to be given during the de-molding process to avoid cracks forming from prying the panels off of the forms.

Mechanical Properties

There were no significant changes in stiffness between the mixes; however, changes in compressive strength and flexural strength were apparent between mixes with chopped fibre strands. Going from 2% to 3% PVA fibres resulted in increased compressive strength from 117.9 to 140.9 MPa and 10.0 to 11.2 for flexural strength. For the glass fibre mixes, going from 2% to 3% ranged from 146.0 to 119.8 MPa in compression and 12.0 to 16.1 MPa in flexure. Although the glass fibre mixes had the highest strengths, their failure mechanisms were very brittle compared to that of the PVA mixes (see Figure 6). The PVA-3% mix performed very similar to the mix containing the glass fibre mesh scrim in terms of bending strength, but the PVA-3% mix exhibited strain hardening behaviour and superior crack control.

Table 1: Mechanical Properties of Test Mixes

Mix	Compressive Strength (MPa)	Modulus of Elasticity (GPa)	Flexural Strength (MPa)
Glass Fibers-2%	146.0	45.9	12.0
Glass Fibres-3%	119.8	39.9	16.1
PVA Fibres-2%	117.9	44.2	10.0
PVA Fibres-3%	140.9	41.4	11.2
Glass Fibre Mesh Scrim	146.7	46.3	11.4
Polyethylene Mesh Scrim	144.5	45.6	8.9

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a) PVA Fibres-3% b) Glass Fibres-3%

Figure 6: Panels After Failure

Drilling and Constructability

Comparing drilling methods, it was apparent that the hammer drill was too rough, causing the concrete around the holes to crack. Results from the drill tests indicated that the best way to bore holes in the material was with the use of a carbide or diamond tipped drill bit with a regular drill.

a) Hammer Drill and Concrete Bit b) Regular Drill and Carbide Bit

Figure 7: Drill Test Results

RECOMMENDATIONS

It is recommended that the vertical casting method is used for the production of the large-scale panels because it will result in the best finish. The PVA fibres at a dosage higher than 2% should be selected for the large-scale prototypes moving forward. Using the PVA fibres at a higher dosage will ensure that the panels are lightweight, while offering some benefits to fire resistance and crack control. Furthermore, using the PVA fibres will ensure that the concrete will be workable enough during casting. If increasing the capacity of the PVA reinforced mix is required, there is potential that combining the PVA fibres with the glass fibres could increase its overall strength while maintaining its strain hardening behaviour. Casting with the mesh scrims posed to be very challenging for this thickness of panels. If there is still interest in the implementation of mesh scrims, additional research is needed towards the design of forms and the types of scrims to use. Attention should be paid to the de-molding process of the panels. To reduce the risks of cracking, samples should be given more than 24 hours before de-molding and should be carefully removed, sliding them out of the forms.