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PROJECT PROFILE

Large-scale Prototyping of 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

Phase II: Large-Scale Prototyping was focused on scaling the work that had been done to develop the panels from Phase I into larger prototypes. The purpose of the work was to outline any challenges that would arise for the large-scale production of these panels and to provide recommendations moving forward. After the optimal reinforcement composition and casting procedures were selected, three 1000 x 2000 x 12.7 mm panels were prototyped. The full-sized prototype panels were cast, documenting the issues related to their production such as the mixing process, construction of the forms, casting and the finish of the panels. In addition, fresh and mechanical properties were recorded as a means to assess the quality of the final mixes.

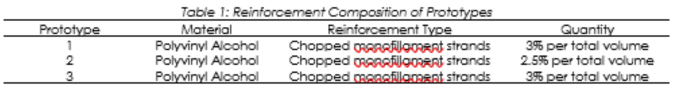

Table 1: Reinforcement Composition of Prototypes

Prototype	Material	Reinforcement Type	Quantity
1	Polyvinyl Alcohol	Chopped monofillament strands	3% per total volume
2	Polyvinyl Alcohol	Chopped monofillament strands	2.5% per total volume
3	Polyvinyl Alcohol	Chopped monofillament strands	3% per total volume

RESULTS

Production

It was shown that making the small change of replacing water with ice goes a long way in improving the flow and extending the working time of fresh UHPC. The concrete was so high in flow, every imperfection that was present on the forms was transferred to the final finish of the panels; some of which were cracks or variations in materials. These surface defects were especially prevalent in Prototype 1 (Figure 1).

a) Form b) UHPC Panel

Figure 1: Surface Material Defect

The majority of the challenges that arose were related to the choice of material that was selected for the formwork. The first being that the melamine was not capable of resisting the lateral pressure imparted by the concrete. Although additional reinforcements were put in place to prevent the melamine from bowing out, this resulted in holes needing to be drilled through the material for all of the prototypes (Figure 2). The second major issue with the melamine was its ability to absorb moisture from the concrete, which resulted in plastic shrinkage cracks for Prototype 3.

Figure 2: Prototype 1 Panel

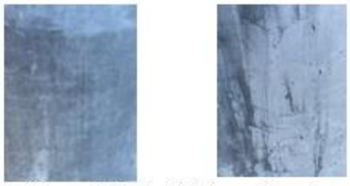

Figure 3: Plastic Shrinkage Cracks

The final issue that was observed during the production of the panels was the loss of entrapped air during the consolidation and setting process. This resulted in Prototype 2 being shorter than desired. To address this concern, monitoring holes at the base of the form should be incorporated to improve flow and allow air to escape during the casting process. Additionally, the panels can be made taller, then cut down to size once completely hardened.

If you are interested in getting involved in this initiative or other research and development projects, please contact the Off-site Construction Research Centre at: **offsiteconstruction@unb.ca**

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PROJECT PROFILE

Preliminary Testing of a UHPC Cladding Technology

Testing

The test results for the compressive strength and moduli of elasticity of the mixes were very consistent for all prototypes. The compressive strengths ranged from 131.3 MPa to 132.0 MPa and the stiffnesses ranged from 43.8 to 45.2 GPa.

The highest variations between mixes were seen in the flow test and flexural strength test results. The flow test results for Prototypes 1, 2 and 3 were 175, 240 and 213 mm, which were directly related to the fiber dosage and amount of ice that was used. Prototype 2 had the highest flow because it had the lowest fiber dosage and because it had more ice. Prototype 1 had the lowest flow because of its high fiber dosage and because it used the least amount of ice.

The flexural strength of Prototype 2 was the lowest at 12.9 MPa because it had a lower dosage of fibres. Prototypes 1 and 3 had flexural strengths of 14.4 and 16.0. The variation between these mixes was attributed to the panels' high sensitivity to the uneven distribution of fibers as a result of their low thicknesses.

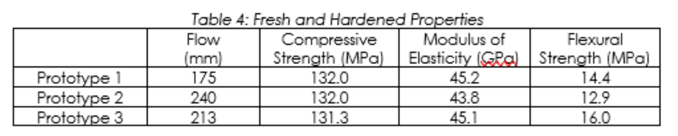

Table 4: Fresh and Hardened Properties

	Flow (mm)	Compressive Strength (MPa)	Modulus of Elasticity (GPa)	Flexural Strength (MPa)
Prototype 1	175	132.0	45.2	14.4
Prototype 2	240	132.0	43.8	12.9
Prototype 3	213	131.3	45.1	16.0

RECOMMENDATIONS

Moving forward, several recommendations were outlined for upscaling the production of these panels. Special attention should be given to the design of the forms. They should be made of a sturdy material that will not easily absorb moisture. A good design in the formwork will accelerate the preparation and de-molding process for each cast and will ensure a nice final finish for the panels. Furthermore, to address shrinkage cracking concerns, plastic sheeting should be used to cover concrete and can also be used to line forms. Shrinkage reducing admixtures and slow setting cements should also be considered.