UNB EST. 1785 UNIVERSITY OF NEW BRUNSWICK | Off-site Construction Research Centre

PROJECT PROFILE

NUNAFAB MODULAR BUILDINGS

LITERATURE REVIEW OF CONCRETE MIX DESIGNS FOR COLD CLIMATES

Nunafab is a corporation based out of Nunavut that provides 3D, precast concrete modules and element fabrication for residential applications.

PROJECT BACKGROUND

The objective of this study was to determine the optimum type of concrete to produce prefabricated volumetric modules for affordable housing in Nunavut and across the Arctic. Specifically, the review is focused on the performance of concrete in very cold climates (down to -65°C) and the application of concrete technology to reduce the weight of the modules (by increasing the strength- to-weight ratio of the concrete) to aid in transportation and construction. Two specific technologies were examined: the use of ultra-high-performance concrete (UHPC) and lightweight aggregate concrete (LWAC).

RESULTS

UHPC provides the best opportunity for increasing structural efficiency. UHPC has a significantly increased cementitious material content compared to conventional concrete and typically contains a relatively high proportion of silica fume and quartz powder (silica flour). UHPC also has a very low water-to-cementing-materials ratio (w/cm ≤ 0.20), and only utilizes fine aggregate. The gradation and proportions of the main constituents are optimized to maximize the particle packing density. As a result, the mechanical properties of UHPC are enhanced.

The specific gravity of UHPC (2.4 to 2.5) is similar to conventional air-entrained concrete (2.25 to 2.35) but the strength-to-weight ratio is much higher. This allows for significant weight reductions by reducing the size of load-bearing components.

A recent development in Canada has been the use of UHPC to produce precast concrete insulated wall panels. Concrete sandwich panels consist of two outer wythes of concrete with a layer of insulation in between. The UHPC sandwich panels developed by Sylaj (2021) consists of two wythes just 25 mm thick, which reduces the self-weight of the panel significantly. Due to the dense microstructure, the durability of UHPC is considered to be superior to that of conventional concrete. UHPC has a greater resistance to cyclic freezing and thawing than conventional air-entrained concrete, even though UHPC is not air entrained. The high resistance to freezing and thawing probably results from UHPC's very low porosity and the fact that there are very few to no capillary pores.

RECOMMENDATIONS

The use of "normal" very high strength concrete should not be disregarded. It is possible to achieve strengths in the range of 120 MPa to 140 MPa without the special (and usually proprietary) formulations used in the production of UHPC. Such strengths have been used for cast-in-place concrete columns in high-rise buildings. Although such concrete still has strength below that achievable with UHPC, cost considerations may favour its use.