New Application Method of Sprayed UHPFRC

By Satoru Kobayashi

The decline in the number of workers in the construction industry is a severe problem in Japan. Formwork is indispensable for concrete structures, but due to the shortage of carpenters, formwork assembly tends to be slow and can cause project delays. To deal with this problem, new workers are being hired and formwork carpenters are being trained, but the payoff is not immediate because the acquisition of the required skills takes several years of education and experience. The "formless construction method" that eschews formwork, might be a possible solution (Fig. 1), substituting an outer shell formed with sprayed mortar. The reinforced concrete structure is then created by placing reinforcing bar and casting self-compacting concrete (SCC) inside the outer shell.

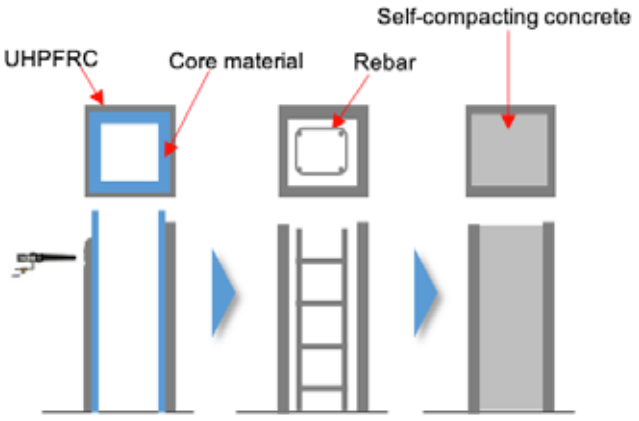

Fig. 1: Concept of formless construction method

In this approach, the lateral pressure of the fresh concrete stresses the outer shell during concrete casting, so the shell must have high tensile strength. Since Japan is an earthquake-prone country, structures are required to have strong deformation performance and must resist the large bending and compressive stresses generated during earthquakes. Furthermore, to reduce the life cycle cost of the structure and increase its sustainability, both high durability and maintenance-free design of the structure are required. Thus, the outer shell must have a high resistance to chloride ion penetration and other aggressive exposures.

To satisfy the performance requirements, we decided to use Ultra High Strength Fiber Reinforced Concrete (UHPFRC) as the sprayed material. UHPFRC is a high-strength and high-ductility material with compressive strength of 22,000 to 36,000 lb/in^2 (150 to 250 MPa) and tensile strength not lower than 1200 lb/in^2 (8 MPa). It is also characterized by a highly dense concrete matrix with very low water and air permeability and thus high chloride resistance. In Japan, UHPFRC has been used mainly for factory produced precast products. Recently, with the advent of mass manufacturing of precast members with large sections, the application of UHPFRC to civil engineering structures has been increasing. The largest such project to date is the application of UHPFRC for the floor slabs of Runway D at Tokyo International Airport with a UHPFRC volume of approx. 26,000 yd^3 (20,000 m^3).

Thus far, UHPFR has rarely been used with sprayed placement, and forming the outer shell of a structure with sprayed UHPFRC is a novel challenge. This article outlines the experimental method developed and used to form the outer shell of a structure with sprayed UHPFRC.

We focused on columns as the target structure. This formless construction method requires a core material that is easy to install and remove. Air tubes were adopted as the core material. Figure 2 shows the installation of the air tubes. The thickness of the member was 16 x 16 in. (400 × 400 mm), and the thickness of UHPFRC was 1.6 in. (40 mm). The height of the columns was 59 in. (1500 mm).

In this experiment, a mortar pump (squeeze type), maximum discharge rate 8 yd^3/hr (100 L/min) and a delivery hose with a diameter of 2 in. (55 mm) were used.

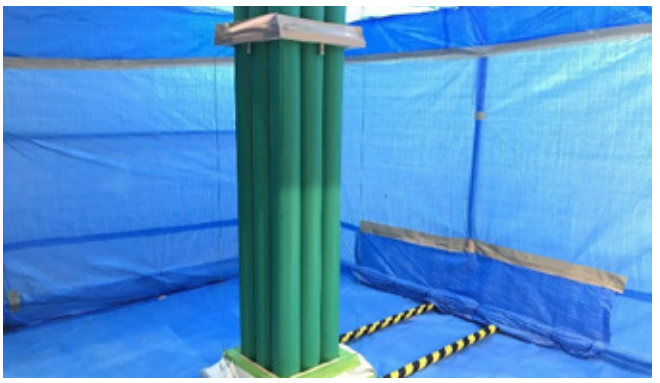

Fig. 2: Installation of air tubes

Fig. 3: Spraying of UHPFRC on air tubes

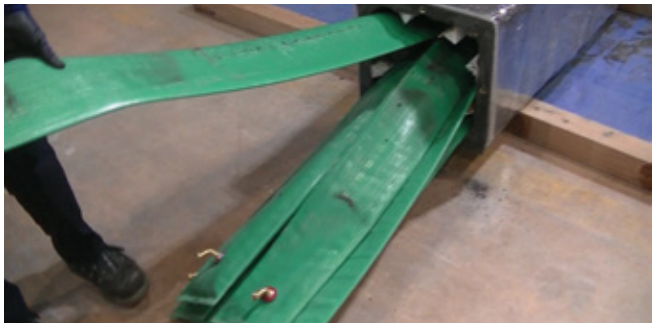

Fig. 4: Removal of the air tubes

The diameter of the tip nozzle was 0.6 in. (15 mm). The sprayed material was required to stick on vertical surfaces without sagging. To this end, a non-alkali hardening accelerator was added at the nozzle.

Figure 3 shows the spraying of UHPFRC. The material adhered to the vertical surfaces of the air tubes without sagging, and coverage of the sprayed material to the required thickness and height of 5 ft (1.5 m) was achieved without problem.

Figure 4 shows the removal of the air tubes that was easily accomplished.

As the next steps, reinforcing bars will be set and SCC will be cast inside the outer shell. The structural performance will be evaluated by flexural strength testing.

Satoru Kobayashi *is a senior researcher for Kajima Technical Research Institute based in Japan. He graduated from Hiroshima University where he studied the durability of concrete. He is highly skilled in concrete, for example, self-compacting concrete, anti-washout underwater concrete, dam concrete, and shotcrete. Recently his research project focuses on the new application method of UHPFRC and various ways to use it at the construction site effectively in order to improve the durability of the structure and the productivity of the construction process.*