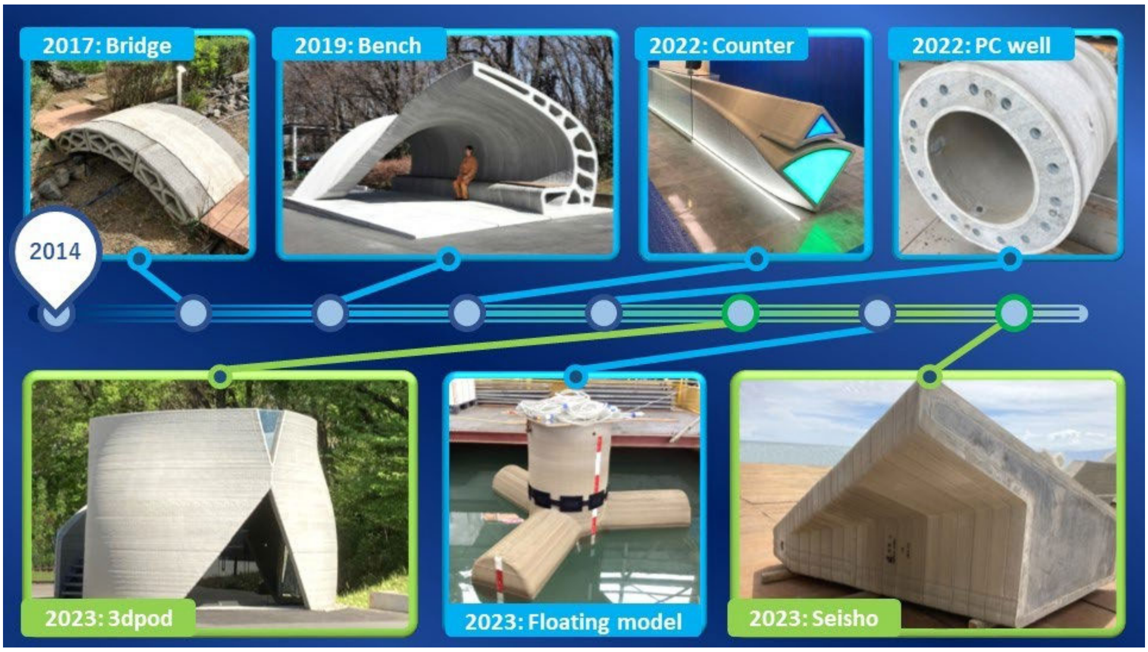
Progress and Latest Research Endeavors in 3D-Printing at Obayashi Corporation

OKAWA Haruna, SAKAGAMI Hajime, KITAMURA Yuto, ISHIZEKI Yoshikazu

(Obayashi Corporation, Technology Research Institute)

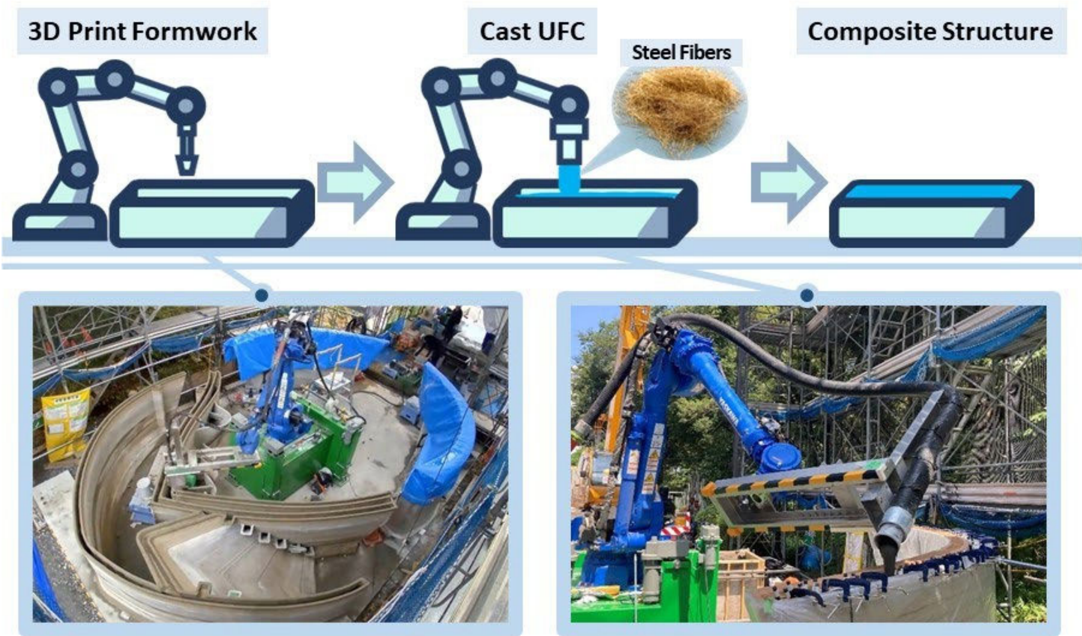
Research Development Timeline and Versatile Applications

The research and development efforts at Obayashi Corporation towards the application of 3D printing technology in the construction industry were initiated in 2014. Subsequently, from 2017 onwards, a series of printing experiments using robotic arms have been conducted. In various fields in buildings and infrastructure, the potential applications of 3D printing have been explored based on extensive demonstration experiments. These endeavors have enabled the production of complex shapes that were until now challenging to manufacture and the acquisition of the capability to perform printing in both on-site construction environments and controlled factory settings.



Composite Structure: 3D-Printed Formwork Filled with UFC (Ultra-high-strength Fiber-reinforced Concrete)

The construction methodology has been developed for fabricating composite structures by pouring ultra-high-strength fiber-reinforced concrete (UFC) into 3D-printed formwork based on the series of the above experimental studies. This innovative approach overcomes the inherent weakness of cement-based materials in handling tensile forces and enables the construction of structures that exhibit enhanced strength and durability.



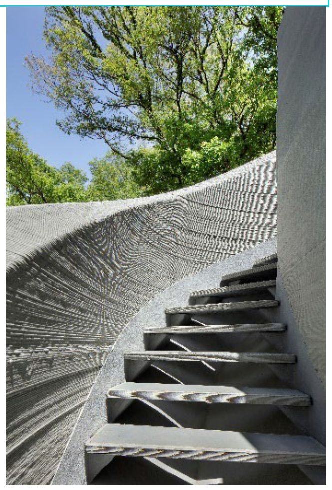
3dpod

Project Overview

3dpod is a certified building in Japan, granted approval by the Minister of Land, Infrastructure, Transport and Tourism under Article 20 of the Building Standards Act. The overall shape was designed to achieve a spacious area with minimal material usage. The thickness of the rooftop slab is also reduced by the vein-like ribs.

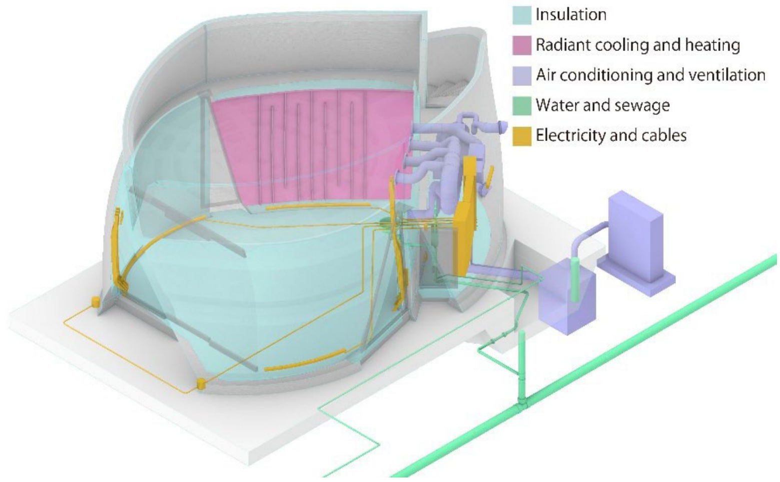
Profile:

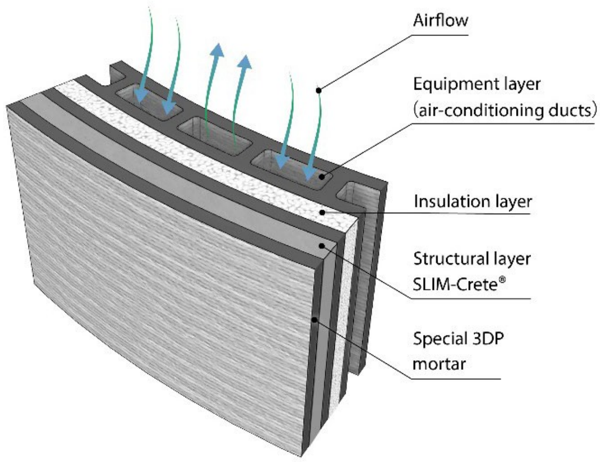
Building area:	34.49m^2	Maximum height:	4,040mm	Main structure:	UFC
Floor area:	27.09m^2	Eave height:	2,800mm	Foundation:	RC Slab foundation



Integration of Various Facilities

The building incorporates various essential systems such as electricity, air conditioning, and plumbing, along with insulation and waterproofing measures. The walls consist of maximum of 3 layers; structural, insulation, and equipment layers.





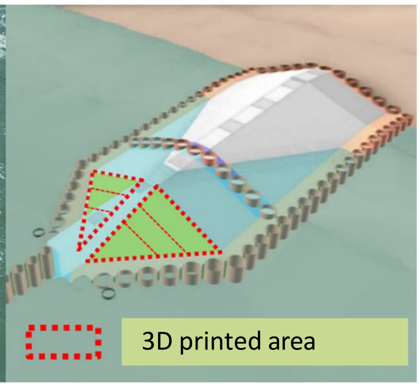
Construction Process and Accuracy

3dpod embraces the innovative use of 3D printers for constructing all the above-ground structures. The walls were printed on-site relocating the 3D printer between two locations, north and south. The rooftop slab was constructed by laying precast deck pieces, fabricated by the 3D printer, after the construction of the walls on the first floor. Afterward, UFC was poured to complete the slab, and further printing of the parapet and pouring of UFC were done on top of the slab. The total printing time amounted to approximately 138 hours (33 days in total). The average construction error of the structural wall thickness relative to its designed value was -0.28mm, with a standard deviation of 1.46mm. The construction was successfully carried out within the allowable construction error, ±5mm, as determined by the preliminary experiments.

Seisho: Large Seashore Structures

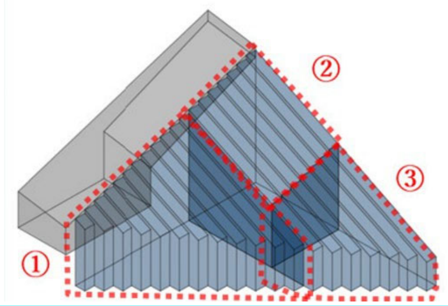
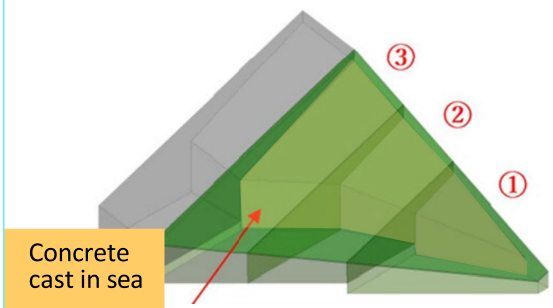
Project Overview

3D-printed precast components were used for the construction of the Seisho Coast Breakwater in Kanagawa Prefecture. The Six pieces of the tip of the breakwater were manufactured by the composite structure with 3D-printed formwork and UFC fillings. This project marks the first application of 3D printing to large-scale structures commissioned by the Ministry of Land, Infrastructure, Transport and Tourism in Japan.



Design Modifications for 3D Printing

The original design aimed to connect a total of 26 PCa panels per side to create three larger blocks using steel bars at the construction site. However, there were challenges regarding weight, construction feasibility, and safety. The new plan involved manufacturing three PCa blocks using a 3D printer at the factory. To reduce the blocks' weight, hollow sections were incorporated, and concrete was later poured into these sections to structurally integrate them.

	Original Deign	Design modified for 3D Printing
Structure		
Weight (3 blocks)	85.5t (16.8~35.5t for each)	37.6t (8.5~17.6t for each)

Productivity Improvement

The following reduction was achieved by employing 3D printing technology; 1) production of the components (excluding curing): from 55 days to 28 days, 2) the block installation process: from 15 days to 6 days, and 3) the number of workers: from 96 to 42. The lightweight blocks reduced the possibility of damage derived from collisions with adjacent blocks during installation, resulting in improved safety. The application of 3D printing technology to large-scale structures contributed to the reduction of construction timelines and labor with improved safety on site.