Present state of 3D printing method for construction towards practical applications

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Taisei Advanced Center of Technology

Structure and Material Research Section

Koji KINOMURA

Taisei Corporation – Group Company Profile

- Founded : October 1873
- Net Sales (FY2022): USD 12 Billion
- Approx. 14,500 Employees
- One of the Japan's Largest Contractor


Japan


Japan


Jimah Power Plant, Malaysia


Highway & Tunnels, Slovakia

Marmary MRT, Turkey


Dubai, UAE


East-west Speedway, Algeria


HAMAD Int. Airport, Qatar

New Tokyo Olympic Stadium, Japan


Outer Circular Highway, Sri Lanka

Recent major projects in Southeast Asia

As for 3D printing method with concrete, we have just implemented some trial applications in Japan but are evolving it step by step.

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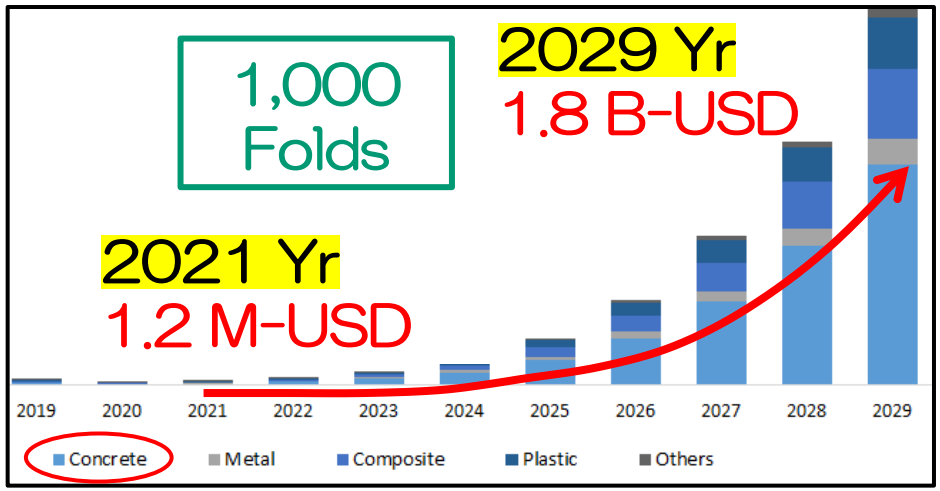
Expectations of 3D printing method

Expected advantages

1) **Enhancement of productivity & shortening period of construction** (thanks to skip of formworks, automated operation and rapid printing)
2) **Reduction of human involvement & enhancement of safety**
3) **Realization of complex shaped formation**
4) **Reduction of environmental loading**
5) **Providing new possibilities** (ex. weight reduction, heat or acoustic isolation, seismic resistance, etc…)

Market prospect over the world

The value will surge within 10 years regardless of some market predictions



(2021 Polaris Market Research; Marker Research Report)

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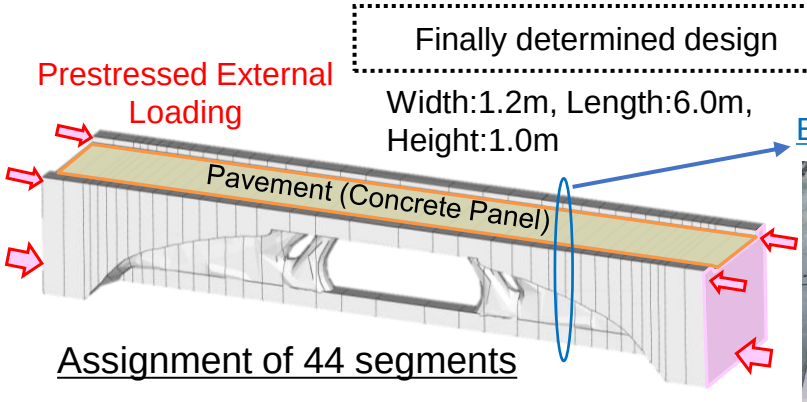
Prestressed Pedestrian Bridge Project (2020)

Critical Issue about 3D printing

- It is difficult to embed rebars and secure bonding in a layer during layered extrusion.
- As a result, the applicability is actually limited to non-structural members such as a bench and an ornament.

Purpose of this project

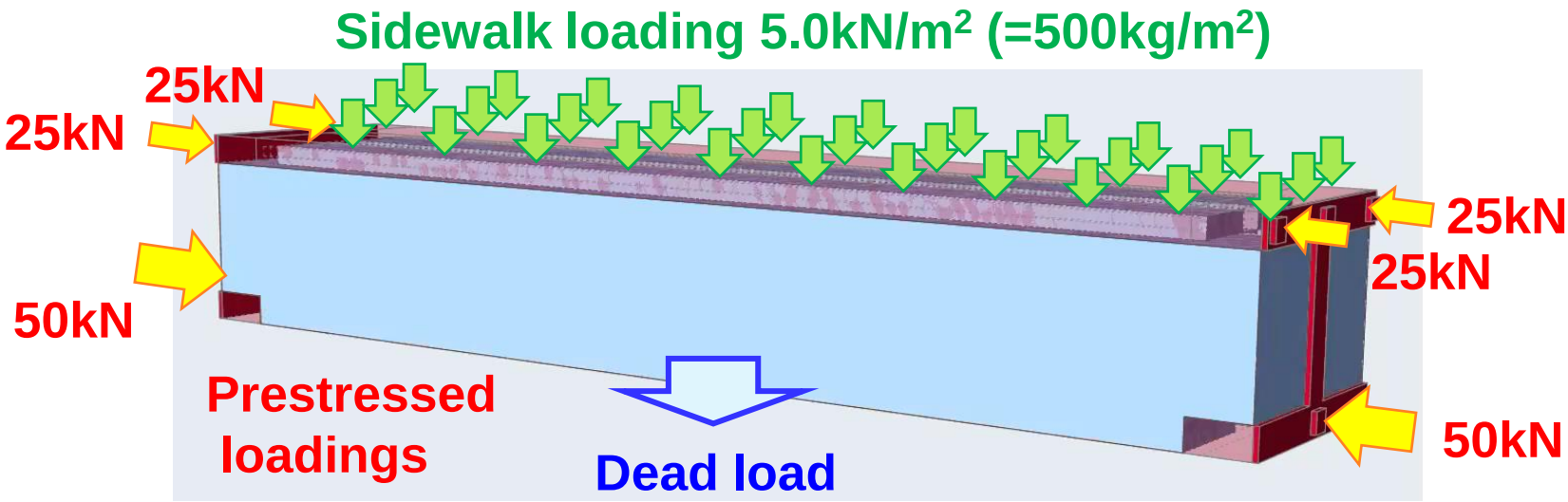
- A practical scale verification project in terms of structural performance is challenged as a feasibility study



Example of a segment

Execution of topology optimization

Software: *Altair, Insire Ver.2019.2 **



* Based on elastic model, not considering the tensile/compressive constitutive law independently

1/4 weight as much as the original shape

TAISEI

For a Lively World

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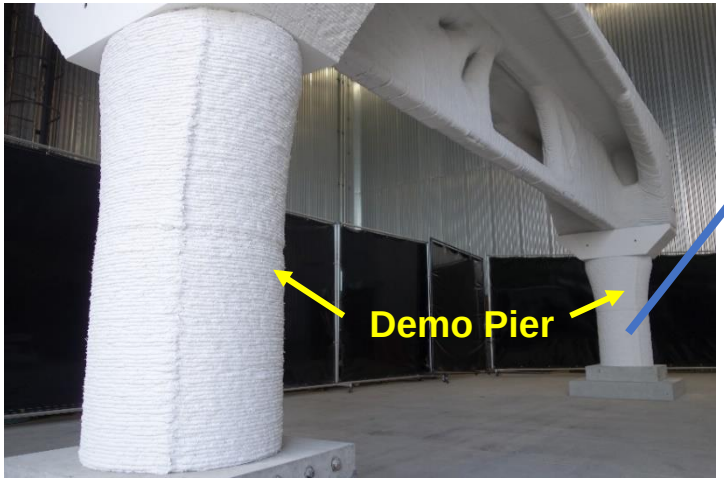
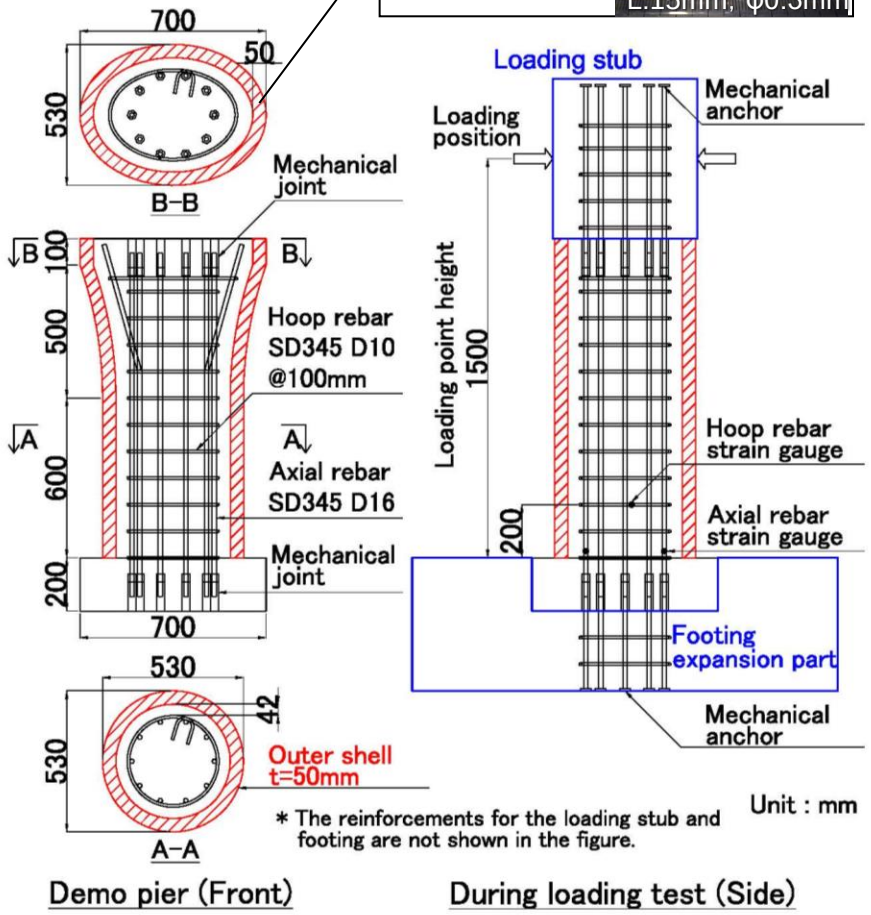
Summary of the Challenge (2021)



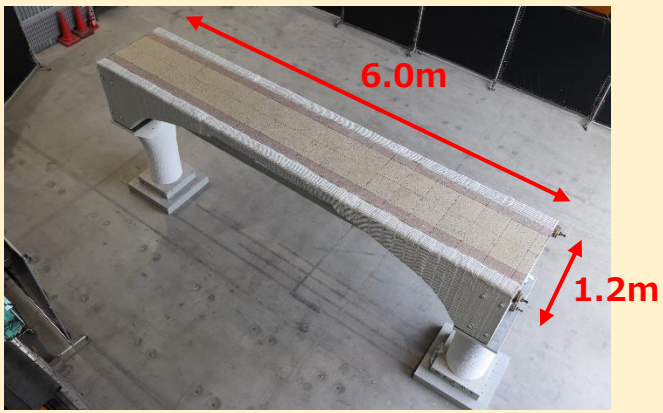
Including short fibers



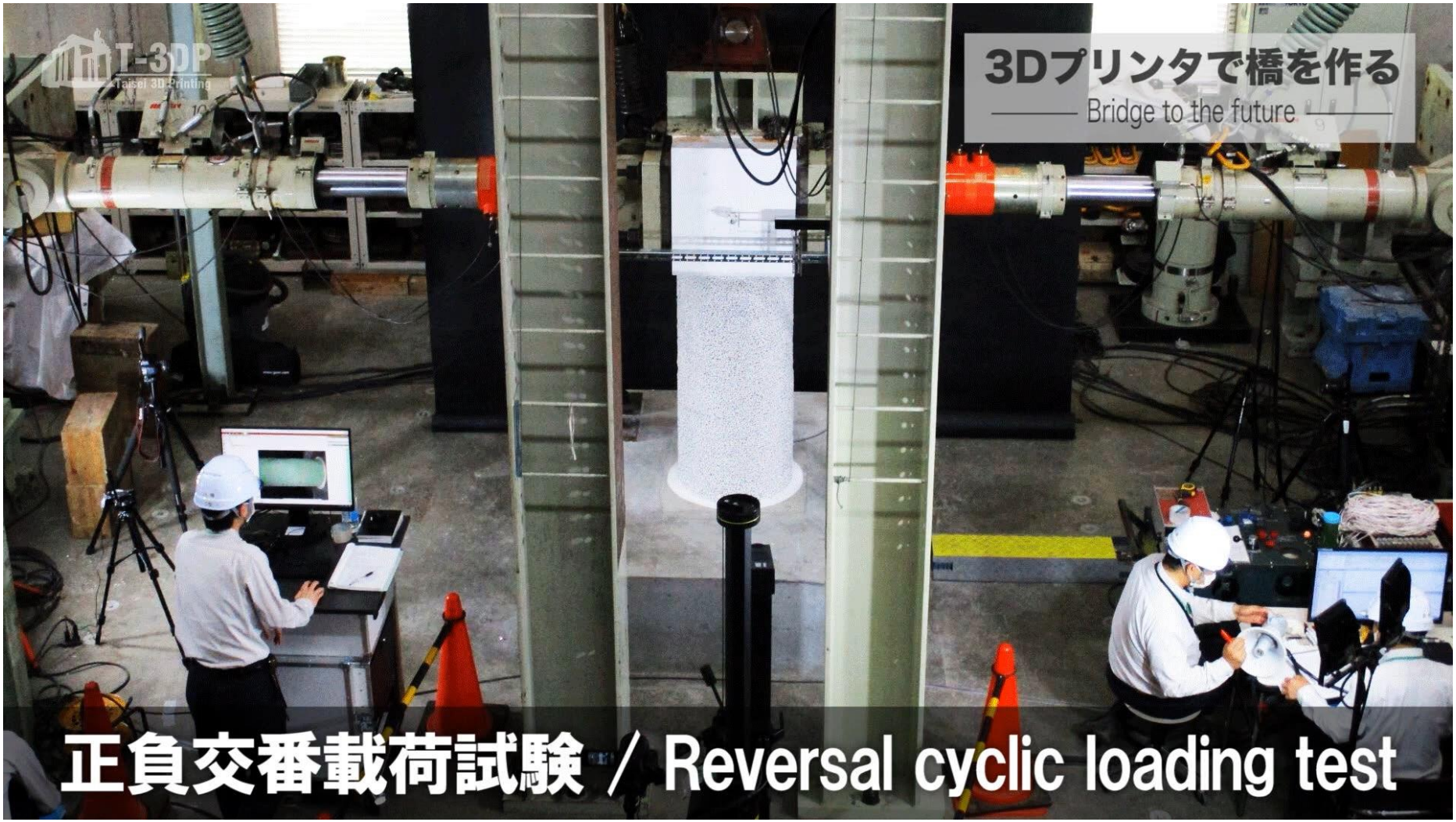
1)The outer shell illustrated as red stripes is formed by 3D printing with short-fiber reinforced mortar.

2)Pre-assembled rebars are placed and then high-fluidity concrete are cast into the outer shell, aiming at future automatization.

Manufacturing Process



Reversal cyclic loading test



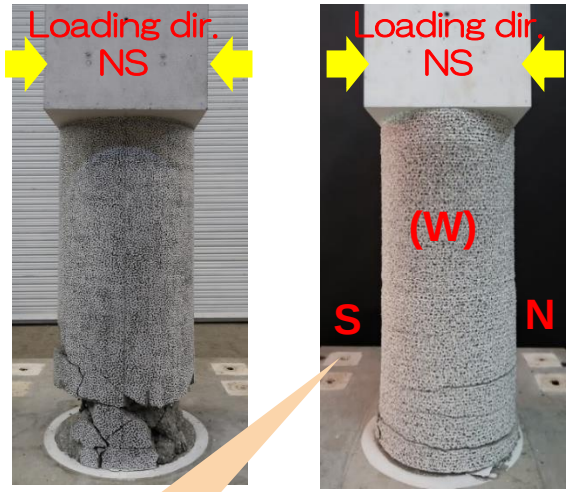
Result of the Experiment

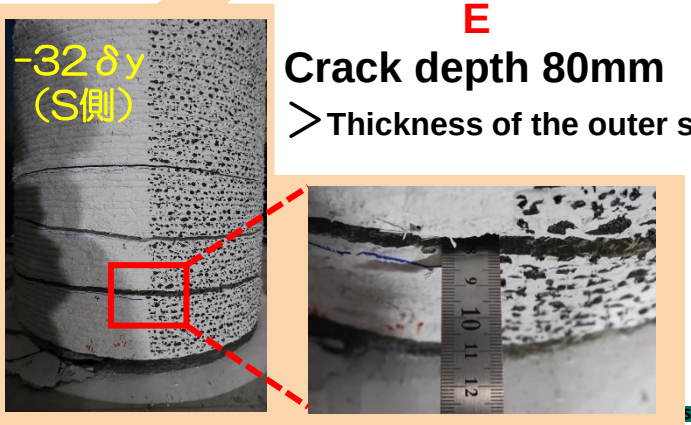
- **Cyclic loading tests were performed to evaluate the structural performances**

1)Conventional 2)3D-printed Pier（Each Size : Φ530mm, H1200mm）

After loading

Conv. 3DP



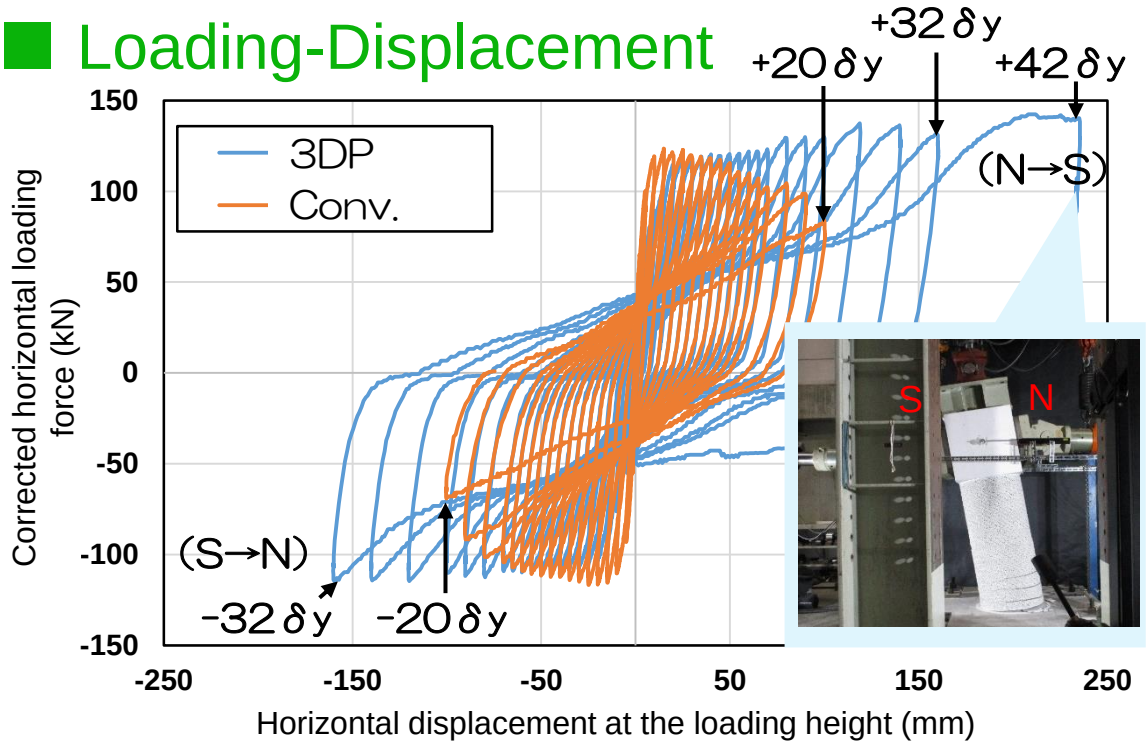


E

Crack depth 80mm

＞Thickness of the outer shell

Loading-Displacement



- The outer shell and inner concrete behaved as a unity
- It is suggested that the uniaxial distribution of short fibers in the outer shell enhances the reinforcement for shear force and confines the effect of cover concrete, producing higher ductility in case of 3DP.

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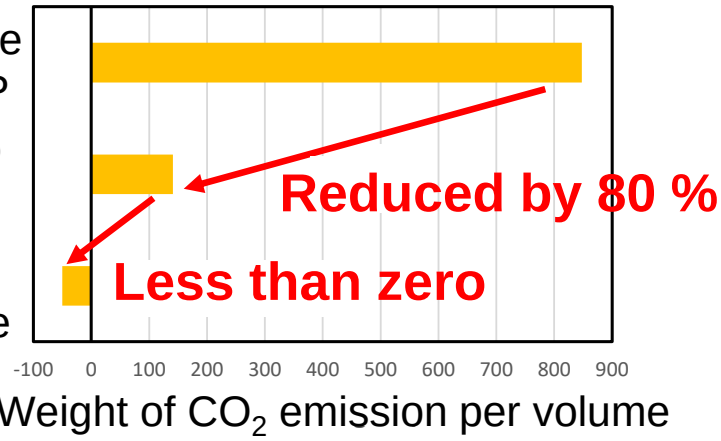
Latest R&D

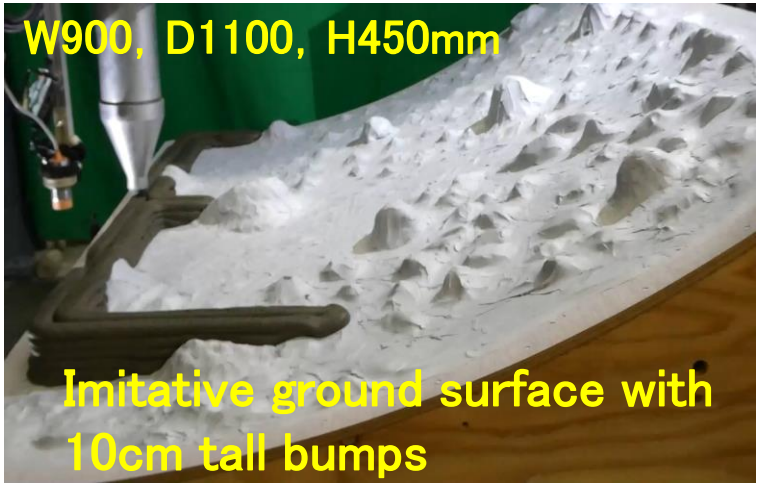
2022 Development of low-carbon 3D printing mixture

1) Standard type mix. for 3DCP
2) Cement zero type mix.
3) Carbon Recycled type mix.



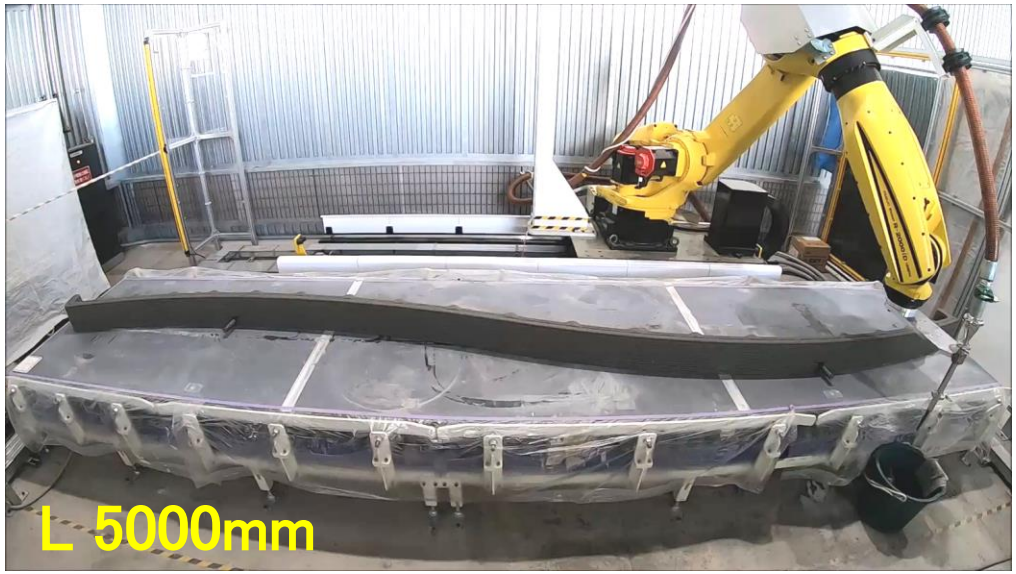
Achievement of net-zero CO_2 emission included in CMs production

2023 3D printing technology applicable to non-flat surfaces



Latest R&D

2023 **Widely movable 3D printing technology with a robotic arm**



1) To print a large structure at one time

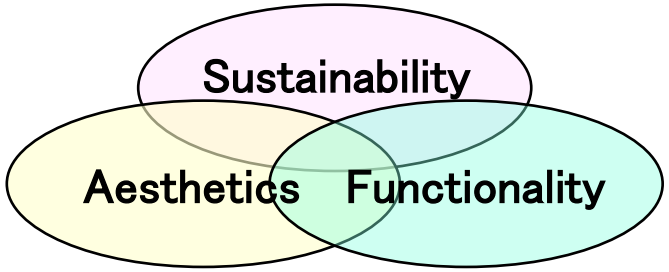
2) To get close to rebars by inclined approaching of a nozzle

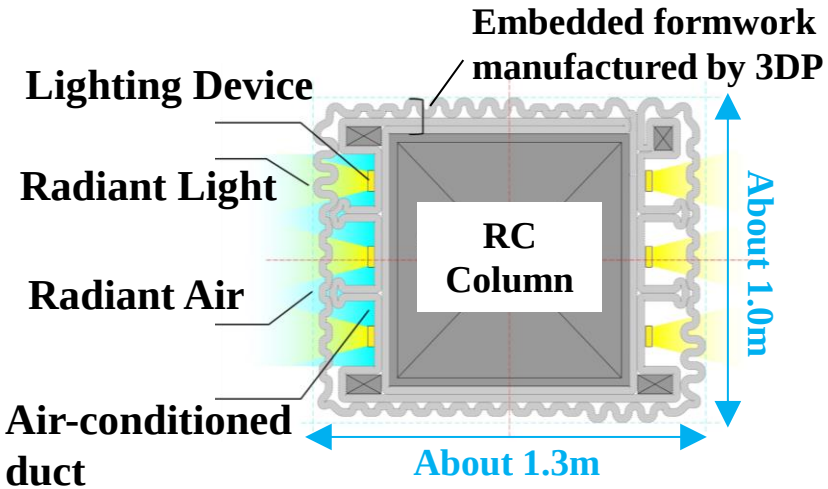
Latest our R&D

2024 Cross-ministerial Strategic Innovation Promotion Program

National R&D project called “Smart Infrastructure Management System”

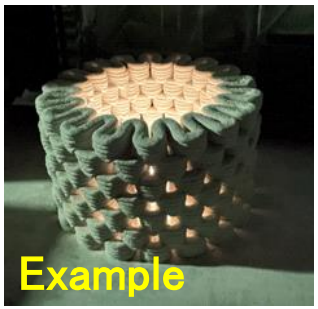
Design Concept of the ZCB application



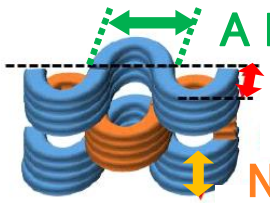


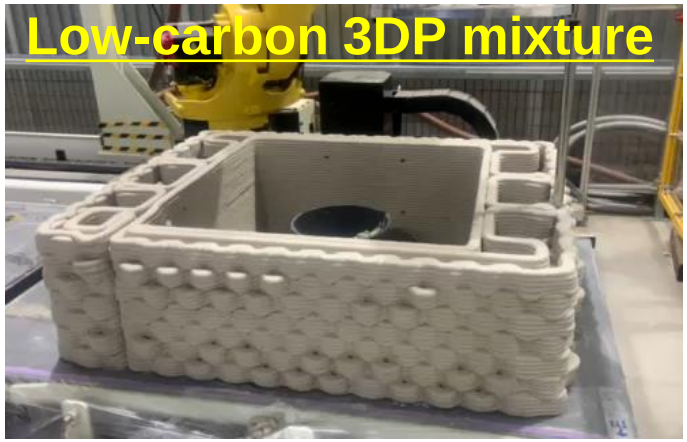
- Aesthetics : Similar to a cherry tree
- Functionality : Radiant features

Trial work



Parameters for the hole geometry





In-situ construction

Short movie

Construction Procedure

Placements of embedded formworks
+
Casting inner concrete

Completed within a day with 3 workers as actual workload

Critical point of the procedure

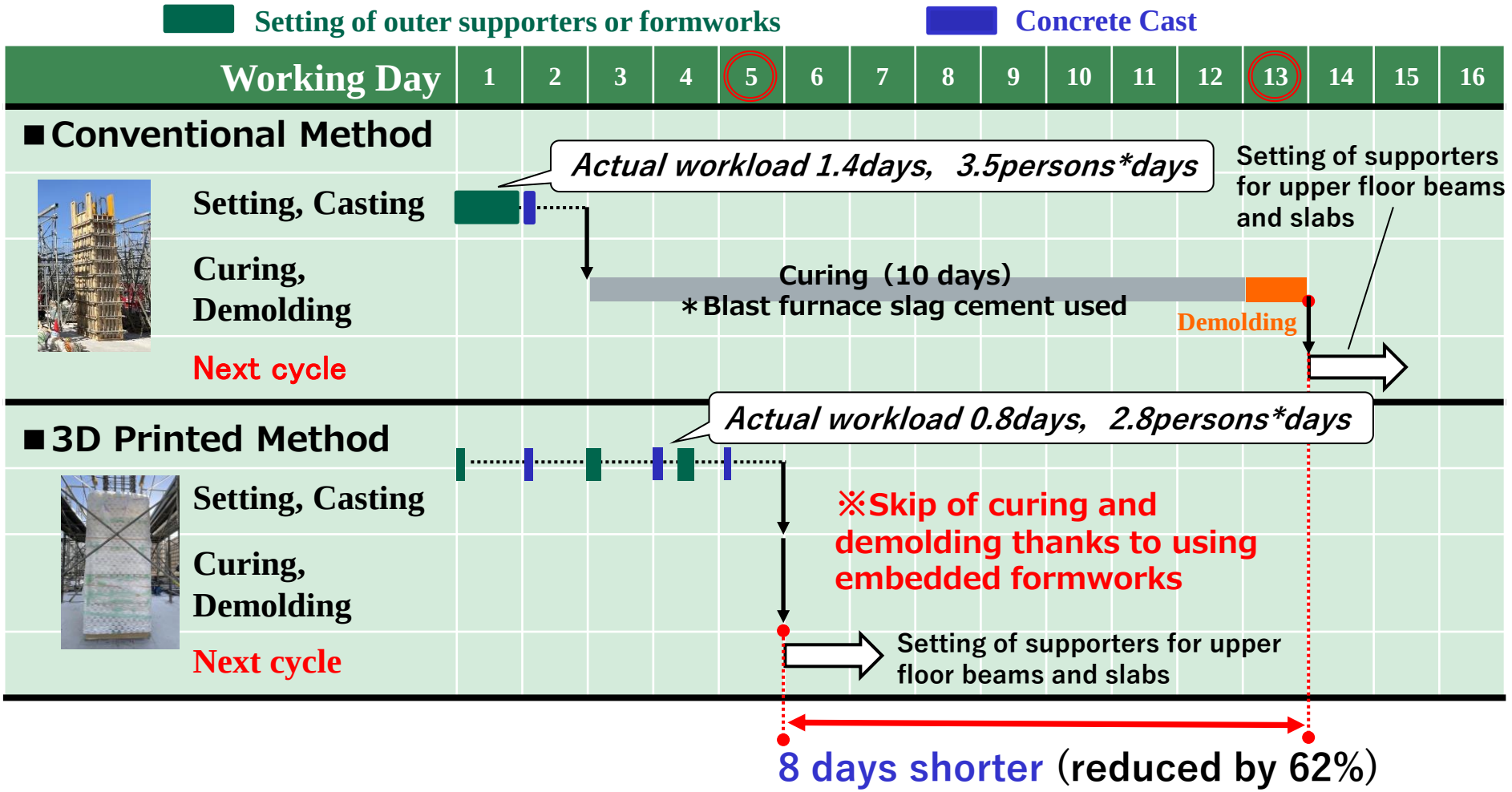
Conventional formwork

Outer supporters are required to resist the pressure induced by concrete casting

3D printed embedded formwork

The embedded formwork with high strength enables to omit the outer supporters, leading to time saving.

Effect of time saving



Less in-situ workload and skip of curing period can lead to much time saving per column

Future Prospect

- **The guideline of the construction method with 3D printed formworks will be published by Japan Society of Civil Engineers next spring.**

- **This method is still applied to non-structural members mainly, but further applications to structural members will be implemented as the durability and structural performances are identified clearly.**

- **The basic development has been addressed considerably.**
  As a result, the R&D phase is being shifted from aesthetic design to practical and technical issues in Japan.

- **This method enables to combine aesthetics, sustainability and functionality flexibly with less additional cost. This attractive feature may bring innovative applications in the near future.**

Thank you very much for your attention