International Journal of High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

International Journal of High-Rise Buildings
September 2023, Vol 12, No 3, 241-249
https://doi.org/10.21022/IJHRB.2023.12.3.241

DX Challenges in Azabudai Hills

Ayako Yasutomi[1†] and Shinsuke Inoue[2]

[1]*Construction Technology Division, Shimizu Corporation, Japan*
[2]*Tokyo Branch, Shimizu Corporation, Japan*

Abstract Azabudai Hills is located in the area connecting Kamiyacho on the Hibiya Line and Roppongi 1-chome on the Nanboku Line, and was planned as a district with three skyscrapers arranged around a plaza. Based on the concept of a "Modern Urban Village", the project integrates a variety of urban functions, including offices, residences, a hotel, an international school, commercial and cultural facilities. The construction of the 64-story and 330-meter-high, "A block" was extremely difficult due to its large scale and diverse uses. This paper presents a case study of DX challenges to improve productivity and ensure quality, as well as the resulting benefits and future challenges.

Keywords High-rise buildings, DX challenge, Construction robots, Monitoring

†Corresponding author:
Ayako, Yasutomi
E-mail:
ayako.yasutomi@shimz.co.jp

1. Introduction

Issues surrounding the construction industry have been changing at an accelerated pace, including a shortage of construction workforce, an increase in unskilled workers, and changes in work styles in the recent past. In addition, projects are becoming more complicated, requiring adherence to construction delivery period and high quality.

Under these circumstances, in order to stay ahead of the competition, there is a need to transform work styles and improve productivity.

In this paper, introduce the "DX" initiative that applicable that IT tools and digital technologies at Azabudai Hills (A Block).

2. Building Outline

Location:1-Chome, Azabudai, Minato-ku, Tokyo

Building Type: Offices, Residences, Retail, Health Care, Education, Culture, e.g.



Figure 1. Perspective.

Developer: Toranomon-Azabudai District Urban Redevelopment Association

Designer: Mori Building Co. Ltd., Nihon Sekkei, Inc., Shimizu Corp.

Main Contractor: Shimizu Corporaion

Building Area: 5,300 m^2

Floor Area: 461,800 m^2

Floors: 5 basement floors, 64 floors above ground, 2 floors of penthouse

Building Height: 325 m

Steel frame weight: 130,000 tons

3. DX Strategy of Shimizu

The three pillars of our mid-term digital strategy, "Shimz Digital General Contractor", are "Digital Manufacturing", "Digital Support for Manufacturing", and "Provision of Digital Spaces and Services". Definition of a "Digital

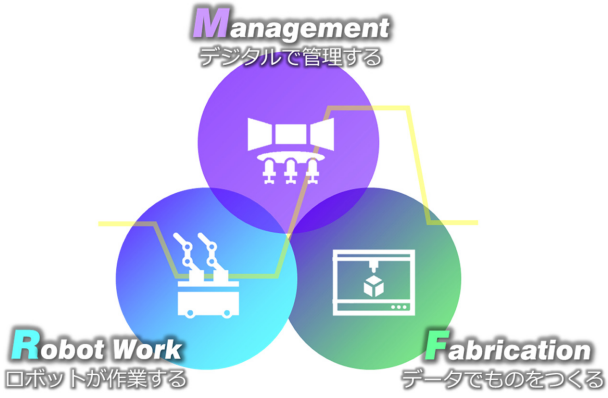


Figure 2. Shimizu Smart Site.



Figure 3. Smart Control Center (SCC).

general contractor", are construction company that digitally carries out manufacturing and provides both real and digital spaces and services, based on the knowledge of real manufacturing and cutting-edge digital technology.

In this project, deployed "Shimizu Smart Site", shown in Fig. 2, a next-generation production system in which AI-equipped autonomous construction robots and humans collaborate to carry out construction work, to promote the digitalization of construction management, and to operate the site with an eye toward the next generation.

4. Initiatives in Azabudai Hills

4.1. Smart Control Center (SCC)

The Smart Control Center, shown in Fig. 3, is a centralized monitoring room for the site. 36 units of 55-inch OLED displays were installed to collect and display all kinds of information on the site.

Images from surveillance cameras attached to tower cranes allow erection work 300 m above the ground to be viewed in this room, significantly reducing travel time within the site.

In addition, workers were aware that they are constantly being watched, and this has improved their safety awareness.

The Smart Control Center also provided other real-time status information, such as deflection of the retaining wall, vibration and noise, and weather conditions, all of which were digitized and stored.

Until now, the construction industry has not captured data on the construction process, and its experience and

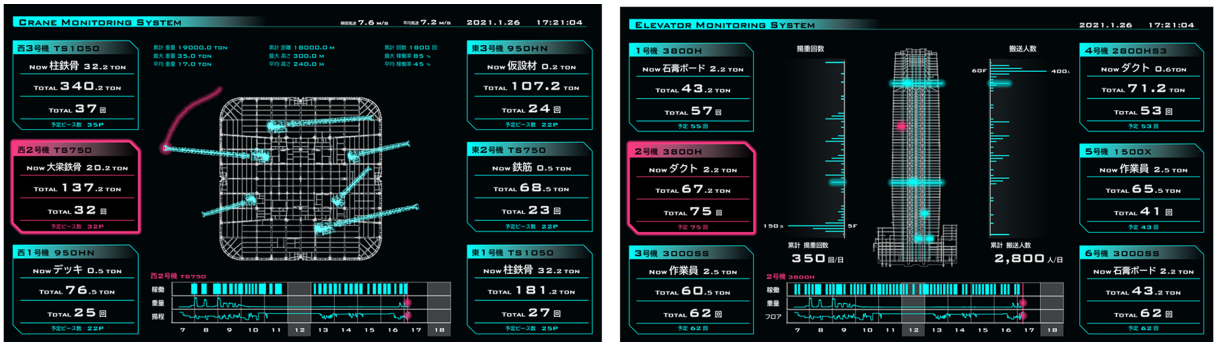


Figure 4. Monitoring system.

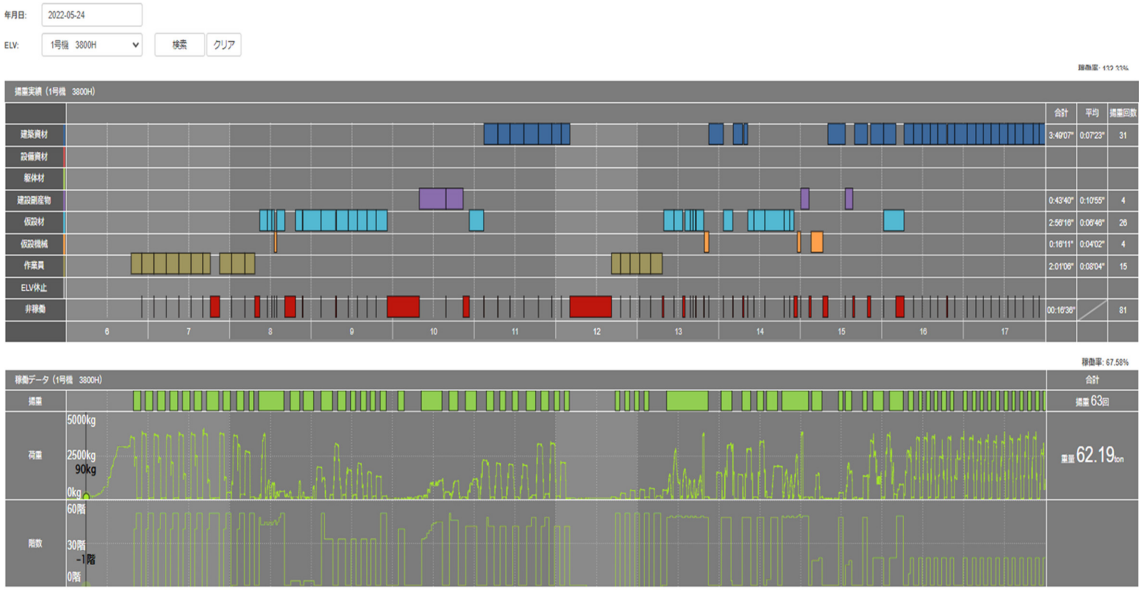


Figure 5. Lifting monitoring.

expertise have been gentrified and difficult to share. The challenge is to use AI to analyze these construction data in the future and utilize them to develop better plans for the next project.

4.2. Monitoring System

Fig. 4 provides an overview of the operational status of tower cranes and temporary lifts monitored by the Smart Control Center. Efficient lifting of people and materials is an important control point at a skyscraper construction site, and the operation status of six tower cranes and six temporary lifts are monitored.

Fig. 5 provides an overview of the data from a temporary lift. The above part of the figure is the result of the temporary lift operator registering the name of the material, the number of floors to be delivered, the name of the contractor, etc. on an iPad, and the lower part is the automatic display of the load and the value of the floor to

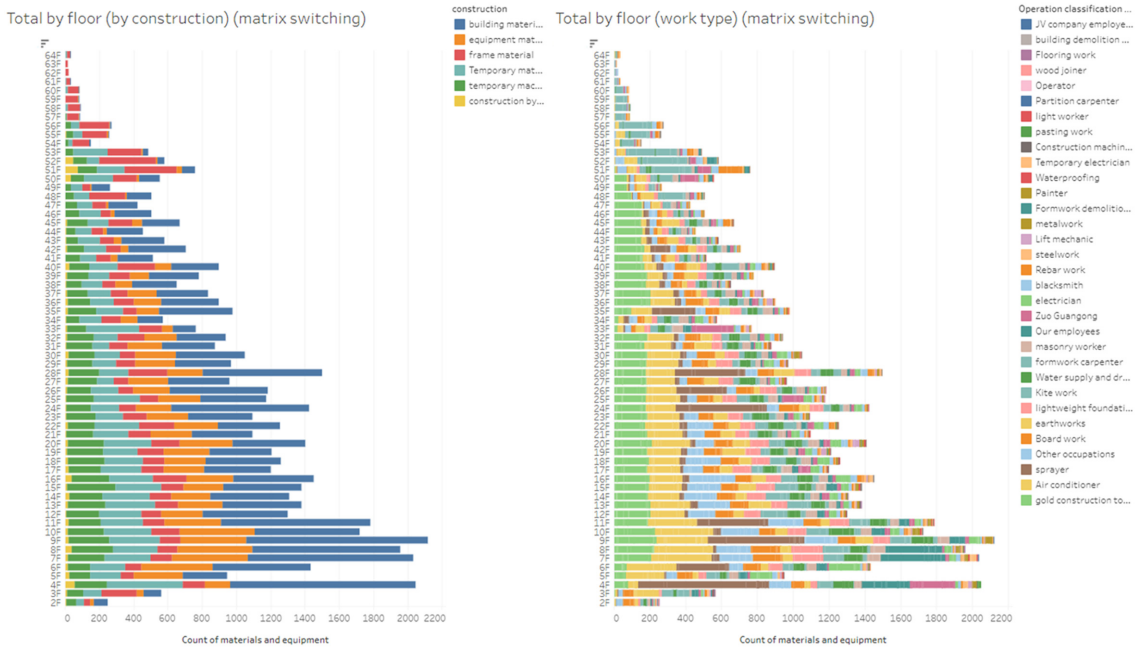


Figure 6. Lifting results by floor (number of lifts).

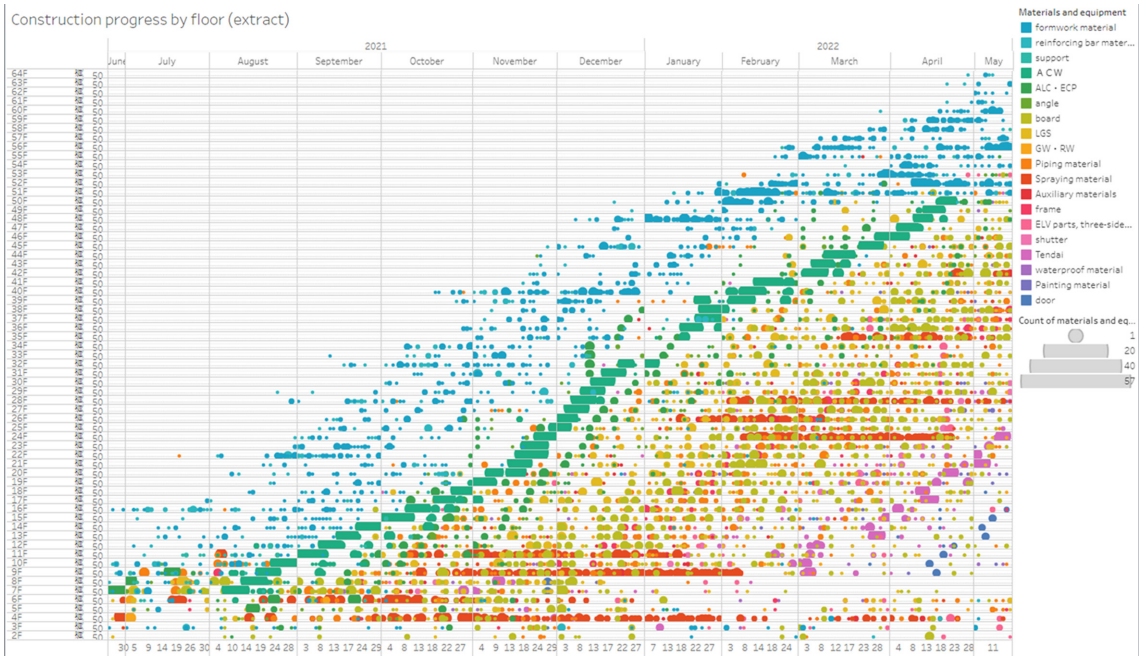


Figure 7. Lifting results by floor (lifting process).

be reached obtained from the temporary lift. In the future, we are considering using AI to automatically identify and record the number of workers and types of materials as well.

Fig. 6 provides of the number of counts for the times of lifting the each floor by construction and job type. Six temporary lifts are monitored, and all the lifting data is stored in a cloud server, on which AI is used to automatically calculate the lifting frequency and analyze the lifting data. The data is then used to improve daily lifting management and as reference data for other projects, throughout the company.

The construction of the typical floor of a high-rise building proceeds to the upper floors, repeating the same procedure for each floor. Building materials of each construction type must be lifted in a timely manner in accordance with this cycle. By overlaying this data with the actual weight lifted to each floor and the process, it is possible to determine whether the construction progress is on schedule.

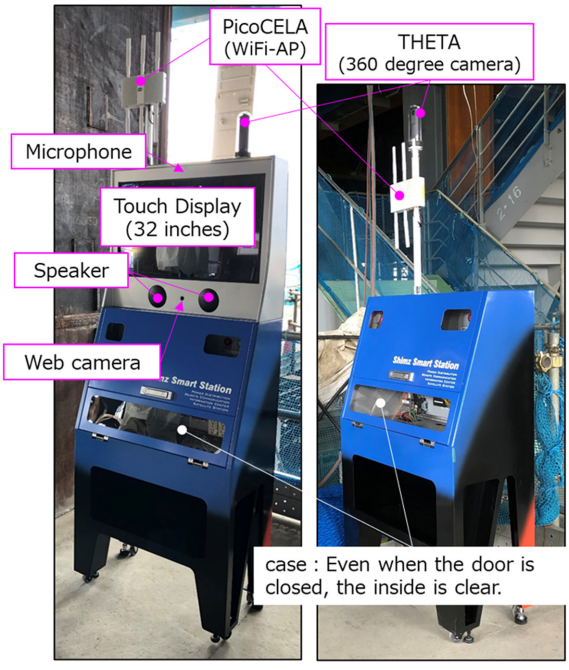


Figure 8. Smart Station.

4.3. Smart Station

Fig. 8 is a Smart Station developed as a next-generation distribution board. It is a distribution board with a 32-inch touch display and has the following three features.

1) Ionization of IoT of distribution boards enables breaker monitoring and remote operation.

2) Serves as a platform for on-site communication infrastructure with Wi-Fi functionalities.

3) On-site communication tool

The IoT system for the distribution boards has made it possible to remotely operate that with the system shown in Fig. 9. As such no longer necessary to patrol on site to turn off the lights. In addition, the 360-degree camera installed on the distribution board stores images, allowing the operator to check not only the current status but also the past status (Fig. 10). In the future, the company is considering using the system to check the progress.

Fig. 11 provides of the morning meeting at the job site. As a communication tool, the day's site layout and process chart can be displayed and viewed with a single click on a touch monitor. In this project, as a Covid-19 measure, morning meetings were held in each work area. Workers gather at the Smart station in each area, confirm the instructions for the entire site, and then hold a morning meeting for each area. And became improvement productivity by them.

4.4. Utilization of construction robots

4.4.1. Robo-Carrier

The transfer robot shown in the Fig. 12 was used to

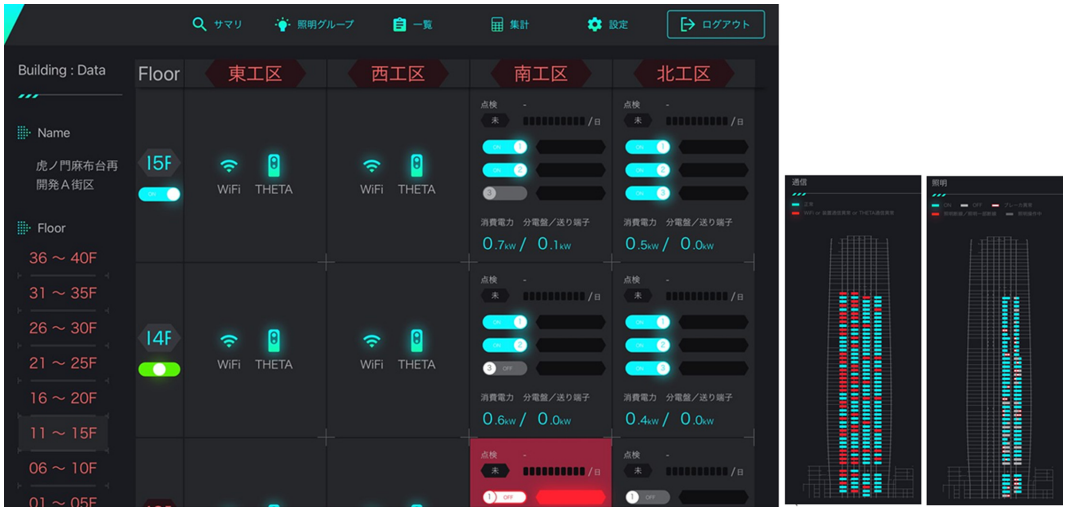


Figure 9. Remote monitoring and operation system.

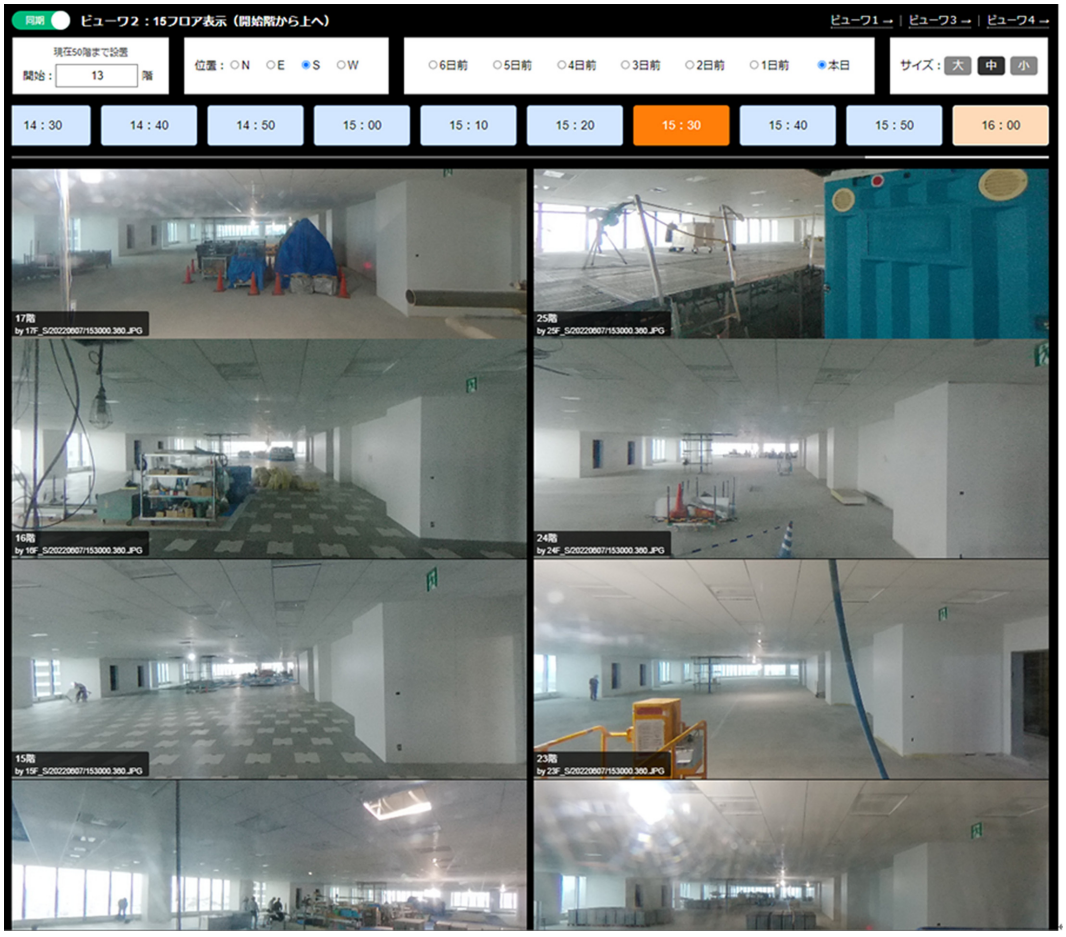


Figure 10. Fixed point 360 degree camera viewing app.



Figure 11. Morning meeting with Smart station.

efficiently transfer the large number of materials brought in daily to the construction floor. Automated transfer systems are generally operated by linking an automatically operated temporary lift with a robot for loading and unloading. In this case, the waiting time for the temporary lift would be long, so in this project, the loading was done by workers, two robots were used for loading and unloading on the construction floor, and horizontal transportation of temporarily placed materials was done



Figure 12. Robo-Carrier.



Figure 13. Robo-Welder.



Figure 14. Welding Procedure.

during free time, prioritizing the operating efficiency of the temporary lift.

4.4.2. Robo-Welder

Fig. 13 provides of the welding robot and Fig. 14 provides of the welding procedure by the robot. Welding is one of the most difficult tasks at construction sites. The welding robot, which performs this task in place of workers, can detect each weld line, recognize its shape, calculate the target position of the next weld line, and weld. By recognizing the shape of the weld line, even thick plates of 40 mm or more can be welded without defects. In addition, the system was designed to accommodate taper gaps from 5 mm to 11 mm, reflecting actual field conditions. Various tests were conducted on site, and after passing the tests, the columns were welded.



Figure 15. Robo-Spray.

4.4.3. Robo-Spray

Fig. 15 is a fireproof coating spraying robot. The robot arm performs the spraying and is programmed to handle



Figure 16. Robo- Buddy.

the duct holes and ribs of large beams. The back side of the beam's bottom flange can be installed without sprayed material falling off, just like a human.

There was tried on two floors of 325 m^2 apply to 45 mm spraying thickness.

4.4.4. Robo-Buddy OA Floor

Figure 16 provides of the OA floor installation robot. The robot that transports the panels and the robot that installs them work together to proceed with the installation. First, the arm on the left side sees the floor markings and sets the support legs. At this time, it receives the laser beam and automatically sets the height. Next, the right arm places the panels. Because of the robot's size, workers set up the panels near walls and other inaccessible areas, but the robot set up most of the floor.

The daily installation capacity was approximately 40 m^2, and approximately 420 m^2 of installation was attempted.

4.5. BIM Utilization

4.5.1. BIM linkage between building frame works and equipment

Fig.17 provides an overview of Revit was used to draw the building frame drawings for the structure, and Rebro was used to coordinate with the equipment, such as route verification of underground equipment works and close inspection of steel sleeves, to establish a rational relationship.



Figure 18. Steel Frame 3D Model by KAP.

KAP is a specialized CAD system for steel frame

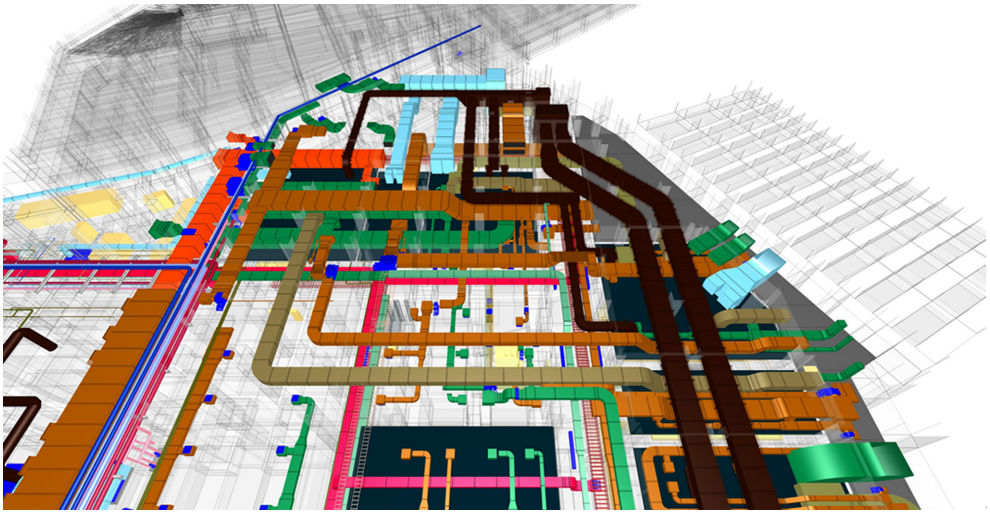


Figure 17. Verification of rational routes for underground facilities by Rebro.

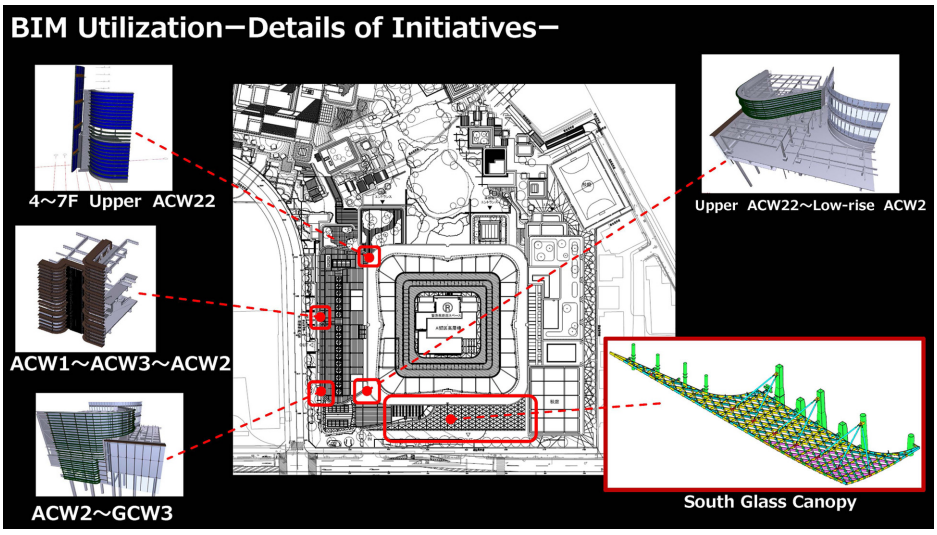


Figure 19. BIM Utilization.

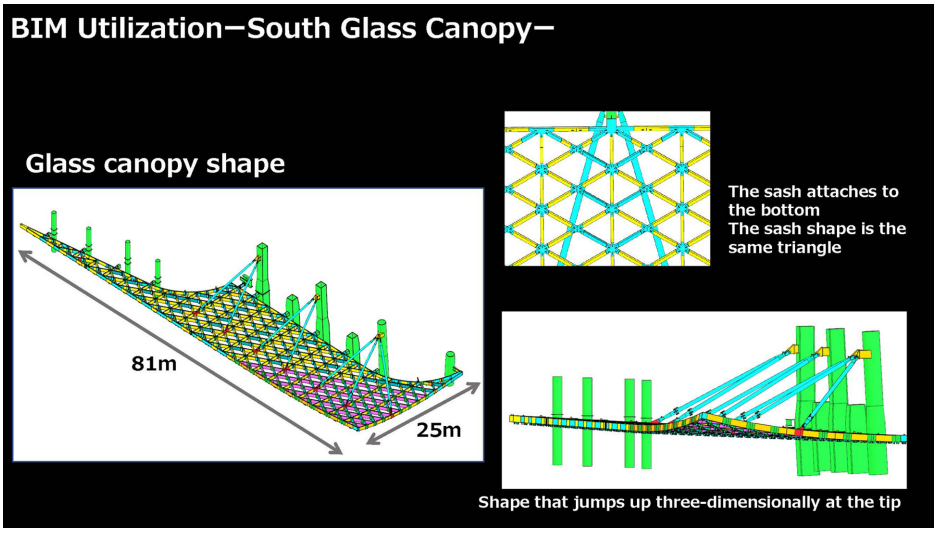


Figure 20. South glass canopy.

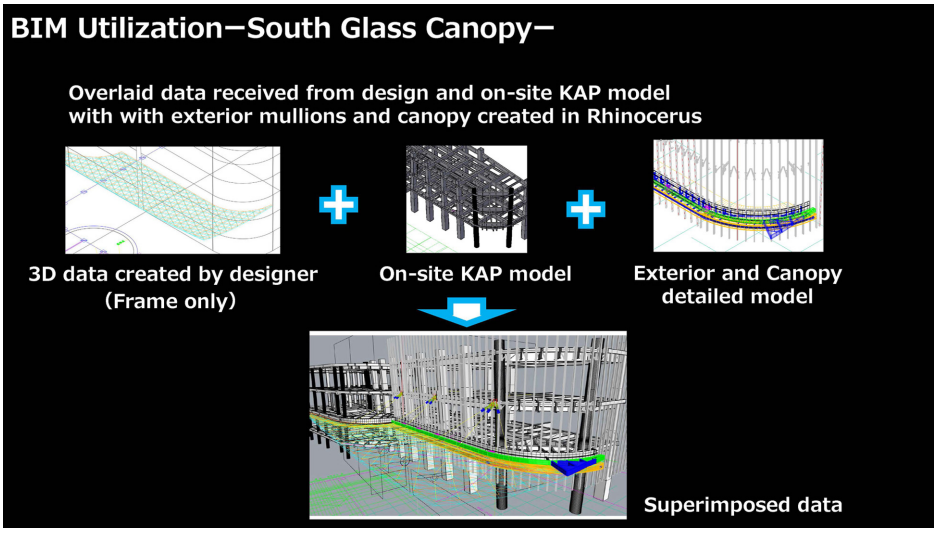


Figure 21. Superimposed data.

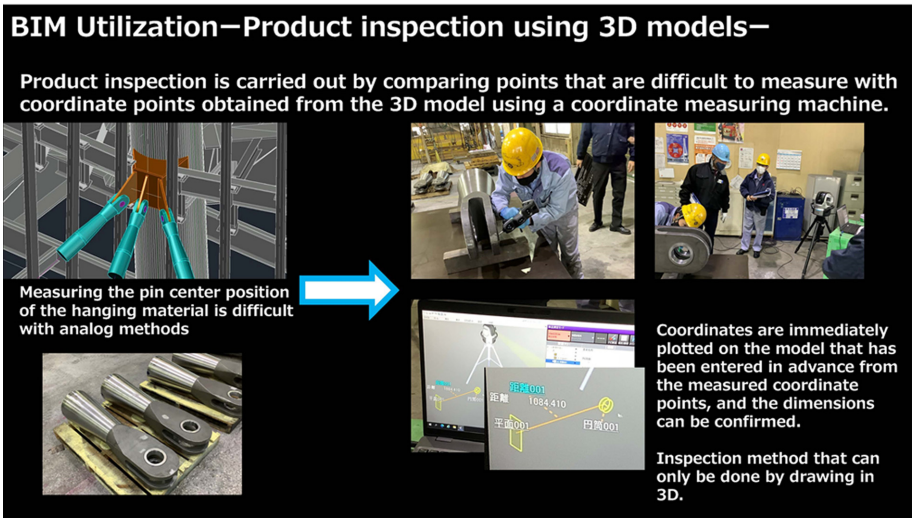


Figure 22. Product inspection using 3D models.

works and used to estimate the weight of steel frames and draw general drawings of steel frames. While see as Fig. 18, The 3D model generated at the same time as the drawings could also be used for building equipment studies.

4.5.2. BIM as a "common language" in complicated geometry

In this project, it was necessary to discuss complex shapes with a wide variety of curved surfaces with many parties, including overseas designers. In this situation, we utilized BIM as a communication tool to convey visual information to all parties. This was particularly effective in the discussion of the exterior and steel-frame attachments, as shown in Fig. 19.

Fig. 20 provides of the large glass canopy penetrated exterior curtain wall. Canopy size are 81 m wide and 25 m depth, with a three-dimensional raised tip, and the steel frame of canopy suspended from three pillars.

BIM model shown in Fig. 21 was created by superimposing KAP, facade and canopy data on the skeleton model issued by designer. That was effectively used by design meetings.

As shown in the Fig 22, this 3D model was also used for product inspection. Until now, only steel tape and inserts had been used for measurement, but by using a 3D measuring device to measure the actual coordinates of the parts and automatically plotting them on the pre-input model using a PC, the model was generated on the PC in a few seconds and the dimensions could be checked, making the inspection very quickly and accurately.

5. Conclusions

This paper describes the DX challenges in Azabudai Hills.

As the global situation becomes increasingly severe, with climate change, pandemics, conflicts and prices escalation, Japanese construction industry is also under pressure to make major changes.

The DX challenge in this project is just the first step, but we must continue to take on the challenge to solve the issues listed below and meet further demands.

(1) Standardization of tools as well as standardization of working procedure is needed.

(2) Advanced analysis and next actions are needed for big data obtained through improved sensing technology and advances in communications and software.

(3) Rather than aiming for full automation, it is important for engineers to use robots to improve productivity, and developers need to fully understand the work in the field and aim for optimal work sharing between humans and robots.

(4) Standardization of tools and drawing work is needed for further utilization of BIM.

(5) In order to deploy DX to many sites, it is necessary to reduce costs and lower the hurdles to trial.

(6) Even if the results of a new initiative do not reach the desired level, the data obtained from it should be used for the next development and continue to grow.

Acknowledgments

Construction of the A block was completed in June 2023.

We would like to express our sincere appreciation to all parties involved in this project.

References

Okabe, Toyama, Furuta, Yamashita, Mukai, Goseki, Masuda, Shimazaki, Miyagi, Ozawa (2022).
Structural Design of High-Rise Building in Toranomon-Azabudai Project (A Block).
International Journal of High-Rise Buildings, pp.157-170