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

International Journal of High-Rise Buildings
June 2022, Vol 11, No 2, 87-102
https://doi.org/10.21022/IJHRB.2022.11.2.87

Toward the Future of Mechanized Construction Introduction and Future Prospects of Mechanized Constructions Using Digital Information

Makoto Kayashima[1] and Yuusuke Noguchi[1]

[1]*TAISEI DESIGN Planners Architects & Engineers, Design Division, Taisei Corporation, Tokyo 163-0606, Japan*

Abstract In Japan, the population progresses to the extreme aging society and it is entering the phase of the population decrease while the population increase is continuing in the world. The construction market is expected to shrink accordingly, however the situation of labor shortage is expected to continue at a faster rate, because the aging of construction workers is progressing and new younger labor force cannot be secured. In order to supplement the labor shortage, it is required to progress mechanization, automation, labor saving, and efficiency improvement by utilizing the information well in each stage in a series of flow of planning, design, construction, operation, and disassembly in one building. The measures to maintain and expand the construction market by the new efficiency improvement techniques which enhance the utilization degree of building information are required. Currently, the elemental technologies which utilized BIM (Building Information Modeling) are accumulated by advancing digitization in each phase. DX (Digital transformation) in the construction industry can be achieved by the technology maturing and having a series of continuities. It is anticipated that this will evolve to a new method which is unprecedented. Present status of BIM and mechanized constructions in Taisei Construction are introduced, and future prospect is described.

Keywords Labor Shortage, BIM, DX, Mechanized Construction, Automated Construction

†Corresponding author:
Makoto Kayashima
Tel: +81-80-8460-6831
E-mail:
kayasima@arch.taisei.co.jp

1. Introduction

1.1. Social background

In Japan, the population progresses to the extreme aging society and it is entering the phase of the population decrease while the population increase is continuing in the world.

The construction market is expected to shrink accordingly, however the situation of labor shortage is expected to continue at a faster rate, because the aging of construction workers is progressing and new younger labor force cannot be secured.

The number of construction workers aged over 55 is about 35%, and the number aged under 29 is about 12%, which is remarkable in comparison with other industries. In order to maintain the construction industry production system for the future, it is indispensable to promote and commit the employment of younger workers and to make a smooth generation change Figure 1. Progress in the aging of construction workers In order to supplement the labor shortage, it is required to progress mechanization, automation, labor saving, and efficiency improvement by utilizing the information well in each stage in a series of flow of planning, design, construction, operation, and disassembly in one building. Especially, the mechanized construction becomes a field which is greatly expected for efficiency improvement and development of future construction industry.

For the purpose of efficiency improvement, construction techniques utilizing digital information are also expected at the same time. and the introduction is rapidly advancing. Concretely, it is a technique to advance design, construction, and building operation based on a series of digital information by utilizing BIM (Building Information Modeling). Digital information and mechanized construction have good compatibility, and it can be anticipated that further fusion and development in the future will be possible.

1.2. Constructive background

Since the mid-1900s in Japan, population concentration in urban areas has continued to advance, and many large facilities and high-rise buildings have been required and

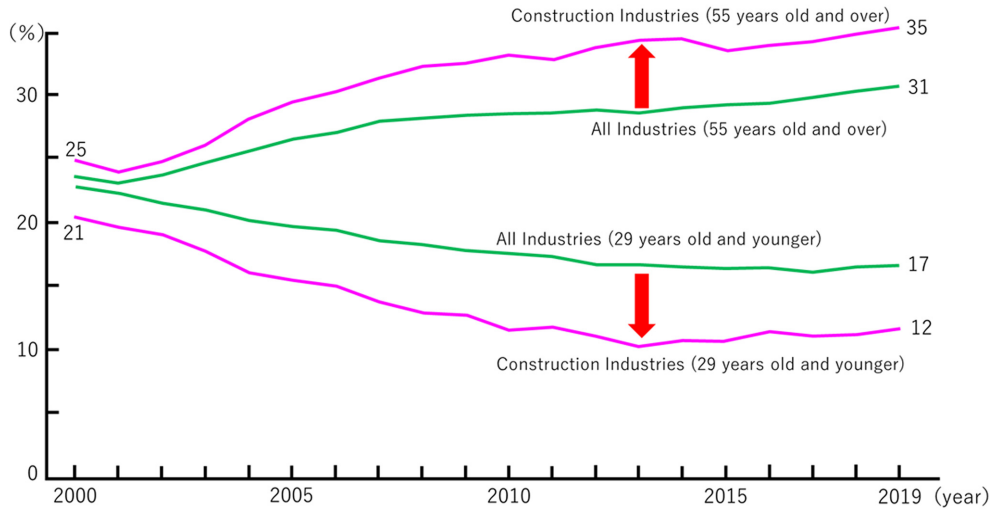


Figure 1. Progress in the aging of construction workers. (The number of construction workers aged over 55 is about 35%, and the number aged under 29 is about 12%, which is remarkable in comparison with other industries. In order to maintain the construction industry production system for the future, it is indispensable to promote and commit the employment of younger workers and to make a smooth generation change)

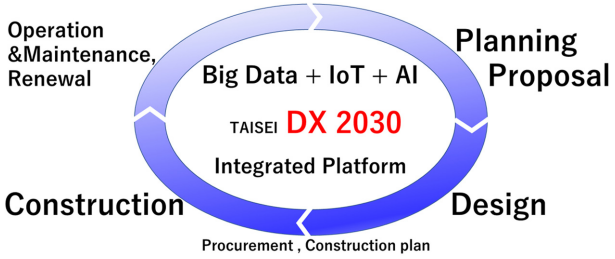


Figure 2. Schematic diagram of DX.

constructed. The factors that have supported the construction include the advancement of higher strength of materials such as steel and concrete, the development of precast members, the development of prestressing members, and the development of mechanical connecting systems that connect them, as well as the factory of building construction technologies employing industrialized products and semi-finished products manufactured in factories.

The merit of BIM is recognized, and widespread is advancing at a glance in the 2000's. Not only the structural but also the industrial commercialization of each building element progresses and matures, the good compatibility with the design utilizing the digital information is gradually penetrated. In addition, the concepts of efficient DX (Digital transformation) by a new series of building information-management techniques which have not been available until now are also being introduced.

2. Existing construction technologies for mechanized construction

2.1. Construction machinery

Selection and layout planning of jib crane type and capacity are one of the important items affecting process and cost in the construction plan of high?rise or large-scale buildings. There are several types of options, and typical ones are a tower crane which is arranged outside the building and rises from the ground, and a climbing crane which is arranged inside the building and rises from the middle floor and climbs according to the progress of the construction process. Generally, tower cranes can lift objects in the long distance though requires the large maximum lift capacity. Meanwhile, climbing cranes can shorten the distance to the object though, the lower layer of the arrangement part becomes post-construction. Each of these method has advantages and disadvantages and adopted on a case-by-case basis according to the site conditions and the planning of the building.

Resembling the building under construction as assembling factory, it is considered necessary to redefine the ideal way of the jib crane uses as a base as a platform for the method in which robots will take the leading role in proceeding the construction of the building in the future.

2.2. Pre-cast method

Pre-cast method produces and installs a product of a unit such as a concrete column of one story and a concrete beam of one span, or its semi-finished product in the factory, and carries and installs it to the workshop and connects it. It is natural to consider that the Pre-cast method is good in compatibility with mechanized construction and robotized construction. In addition, instead of the human reading the information for the product manufacture from the design drawing, if the input of the data from the design information (BIM) directly to the manufacturing machine is possible, the efficiency improvement will proceed at once.

The current problem is establishing the method and solution which smoothly cooperate the work which com-

plements the difference in the density between design drawing and construction drawing by automation.

2.3. Connection of members

In the case of steel frame structure, the technology of bolt joint and welding joint has been established. Problems to mechanized construction are common use of high strength bolts suitable for high strength members and automation of welding joints. Quality of welded joint is greatly affected by human technology. Hence, automation, robotization, and mechanization are urgently required to prepare for the future shortage of human resources.

In the reinforced concrete structure, it is necessary to carry out the approach by dividing into connection technology of reinforcement and connection technology of concrete. Connecting techniques of reinforcing bars include gas pressure welding, conventional welding joints, mechanical joints, lap joints. Since gas pressure welding and conventional welding are largely affected by human techniques, mechanical joints seem to be suitable for mechanized construction. Problems of mechanical joints are grouting work, and the human takes a good time to complete. Another challenge is to rely on people in terms of qualifications and technological capabilities to handle special materials.

A certain range of wet concrete volume is required for the joint part of Pre-cast concrete. The method of filling high-strength grout mortar by reducing the joint volume as much as possible to reduce construction period. It can be said that there is room for improvement, because the effect of the human also greatly intervenes in this work.

3. Basic and elemental technologies for digital construction

3.1. Standardized foundation integrating Wi-Fi conditions and AI/IoT

In conjunction with mechanized construction, digital technologies are used at construction worksites to improve productivity at construction sites.

Specifically, a standardized infrastructure at the construction site by integrating a mesh Wi-Fi system that covers a wide range of internet environments within the site and a system that captures the work status of employees are established.

This infrastructure foundation makes it possible to collect and analyze various data on the site from the start of construction to the completion, thereby improving productivity at the construction site in the future.

It had been difficult to use the Internet in places where portable radio waves do not reach, such as basement floors and high floors, at construction sites. Hence, it was necessary to install a large amount of receiving equipment for positioning when determining the location of materials and equipment located on each floor.

As a result, it took a lot of labor and costs to develop a wireless environment on-site, which posed problems in introducing advanced work robots on-site and implementing on-site management using digital information.

Therefore, by integrating meshed Wi-Fi access points with superior communication functions and receiving devices for positioning, it became possible to perform communication and locating on a small number of devices, thus reducing costs.

In addition, by linking these on-site wireless environments with the conventional "IoT-based visualization system", it has become possible to collect and analyze various on-site data and use them in a centralized manner.

In the future, we plan to improve safety management, quality control, and productivity, as well as to utilize these technologies for collaboration with customers and in-house remote support.

3.2 Remote patrol system for construction sites using a quadruped walking robot

A remote patrol management method for construction sites using a quadruped walking robot equipped with a

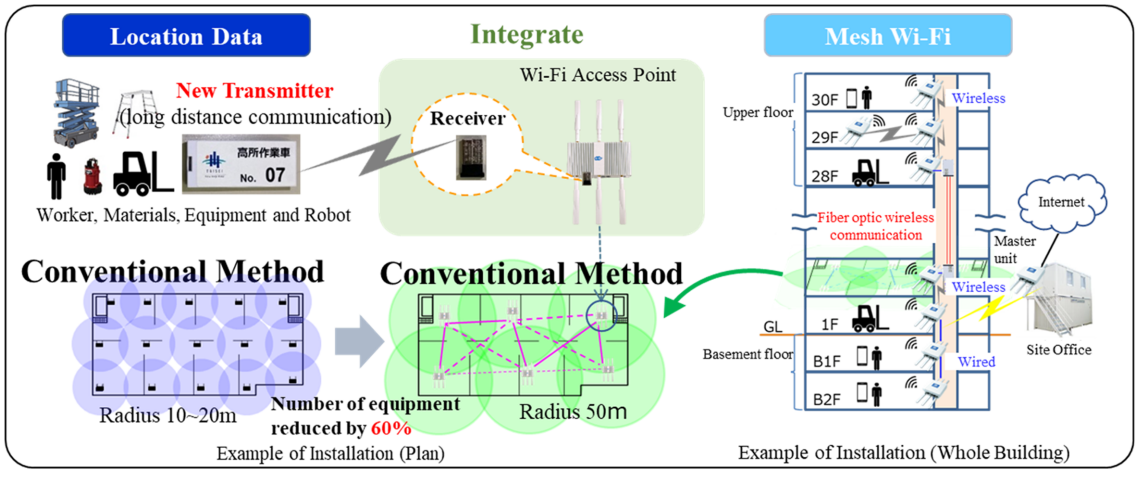


Figure 3. Equipment used to locate the standard base and example of installation at the site.

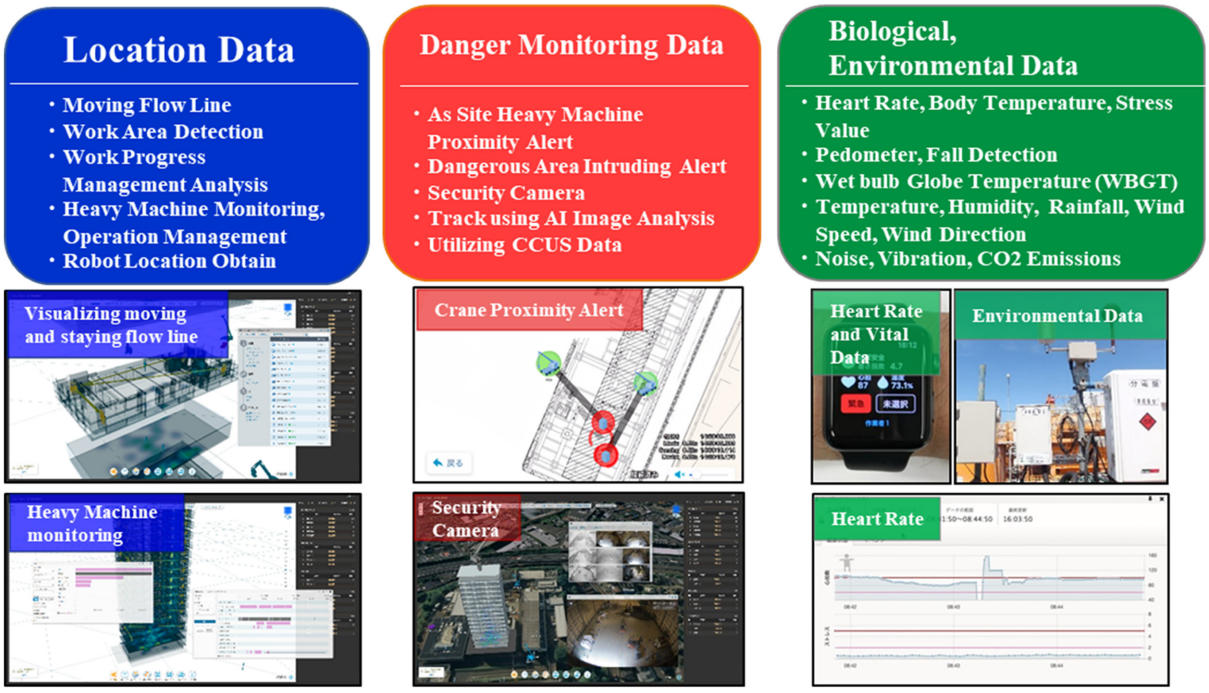


Figure 4. Examples of utilizing various digital data.

new remote management system is developed. Furthermore, more efficient on-site management using robots are under process.

In order to establish remote patrol at construction sites using robots, a system with multiple functions, such as remote control, video, and two-way voice calls have been developed. Using a quadruped walking robot equipped with the system, it has become possible to conduct on-site inspections, safety checks, and other patrols.

In addition, by linking this system with the separately developed wide-area Wi-Fi environment, even in basement floors and high floors where mobile phones cannot be connected, the system will be further utilized for site management through remote patrols, such as video recording on-site using 360° cameras mounted on robots, fixed-point photography, and process progress management.

The challenge for the robots to perform site patrols on behalf of people at construction sites, is to create simple controlling system for an operator without expertise steer the robot easily under different conditions for each building and a day-to-day changing field environment.

3.3. Welding robot

Here is an example of an automated method using a

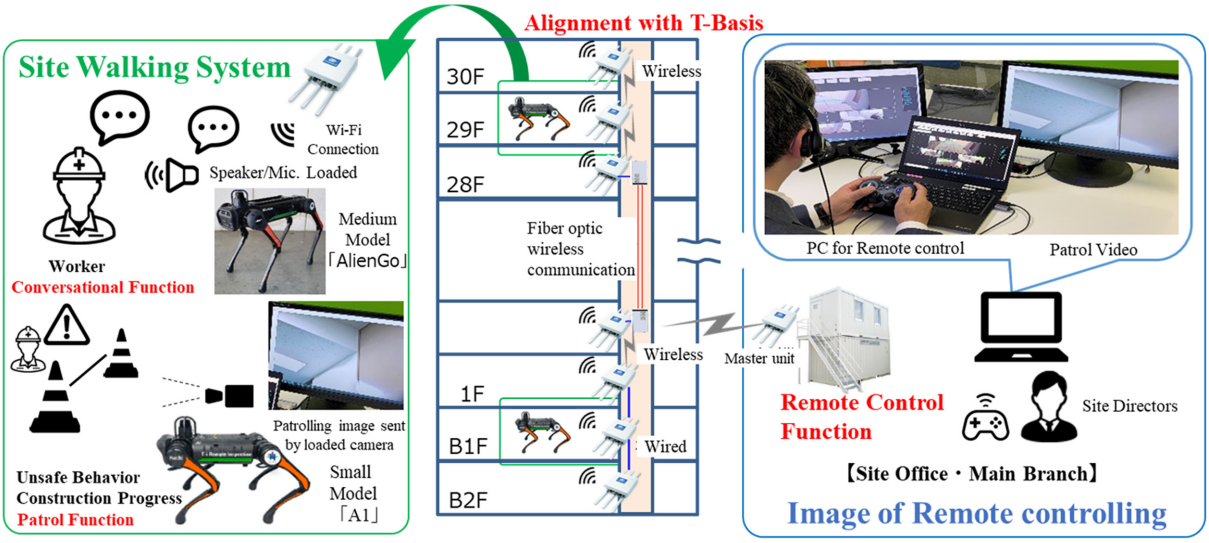


Figure 5. Remote System Overview.



Figure 6. Application Status of Welding Automation Method for Photographic Column.



Figure 7. Application Status of Welding Automation Method for Photographic Assembly BOX Columns.

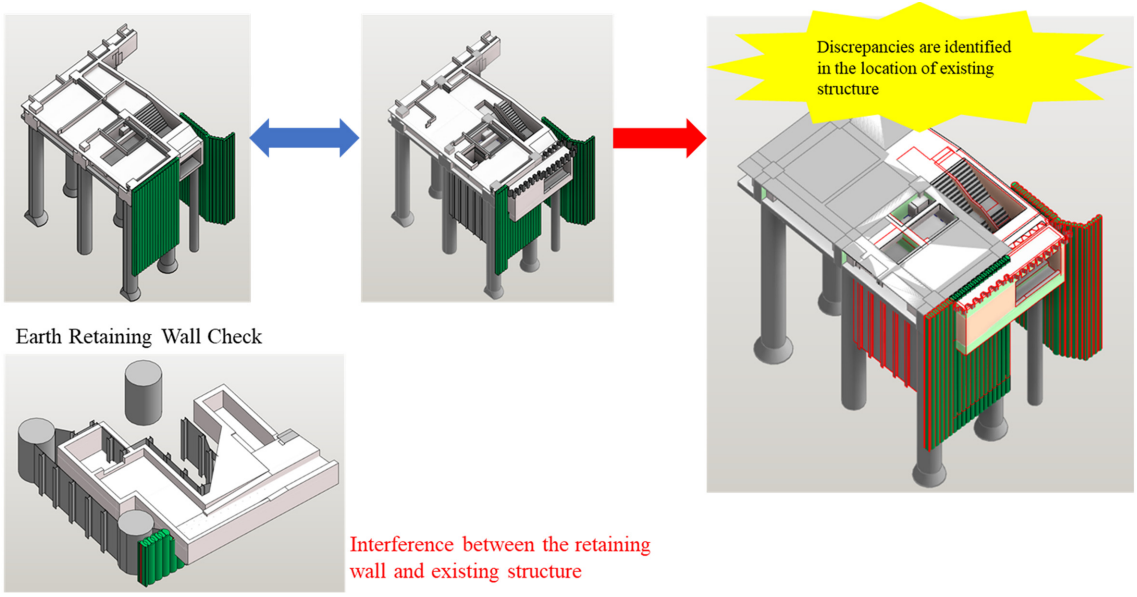


Figure 8. Check the relationship with the existing model to identify problems in the plan for early resolution.

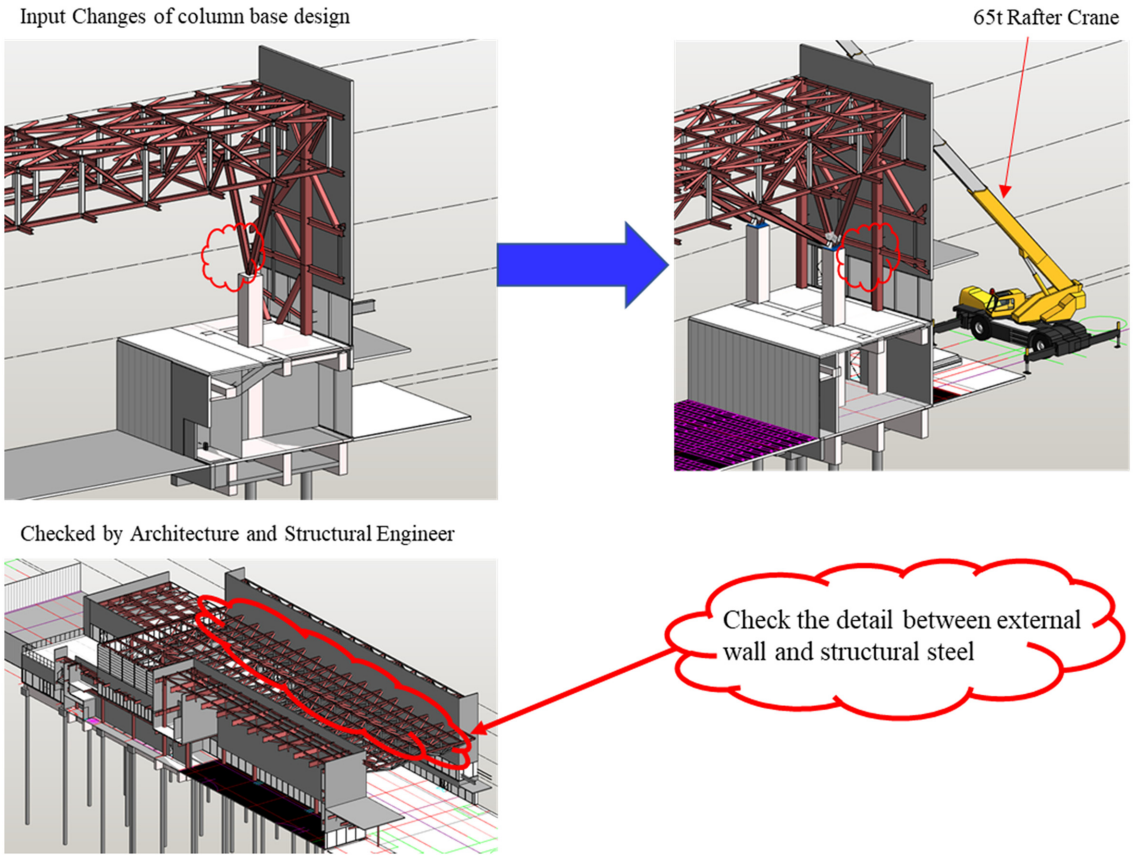


Figure 9. Implementation of the basic plan considering the erection plan.

welding robot for a column steel frame.

By continuing to improve the "teaching" work, in which welding operations are set in advance according to the shape of the column, automatic welding of columns, BOX columns, and other columns with different counts can now be performed smoothly.

Teaching means that the robot stores the groove shapes of the steel joints in each welding section prior to welding work. By improving this, the robot welding time has been reduced.

4. Spread of digital technology

4.1. Basic Design and Front-Loading Using BIM

When BIM is utilized in the basic design phase, speedup of decision making by accurate information transmission can

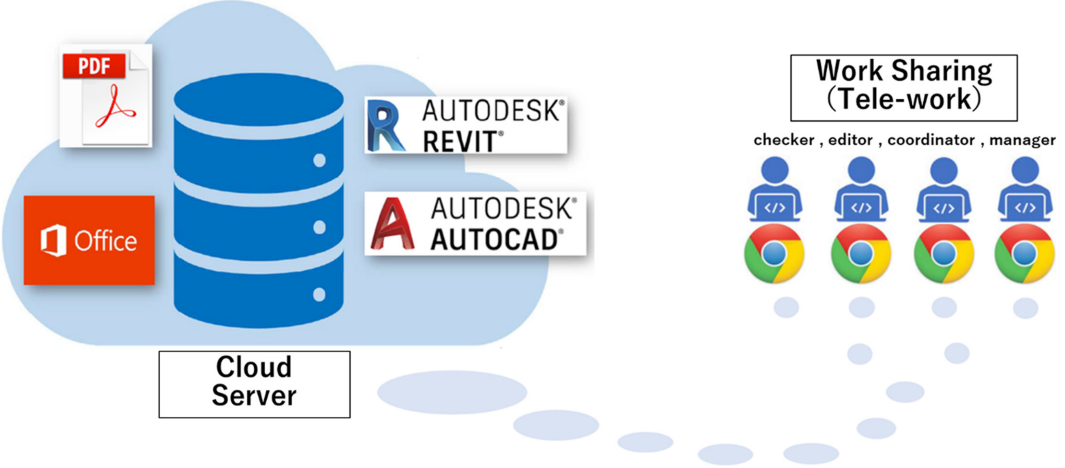


Figure 10. Image of Business Form Using Cloud Server.

be expected.

In addition, it is possible to select proposals such as automated design, computational design technique, and generative design technique, with large number of comparison cases in very short time which were not possible before.

The viewpoint of constructability, market information of materials, and cost information, which are knowledge of construction departments downstream from the initial

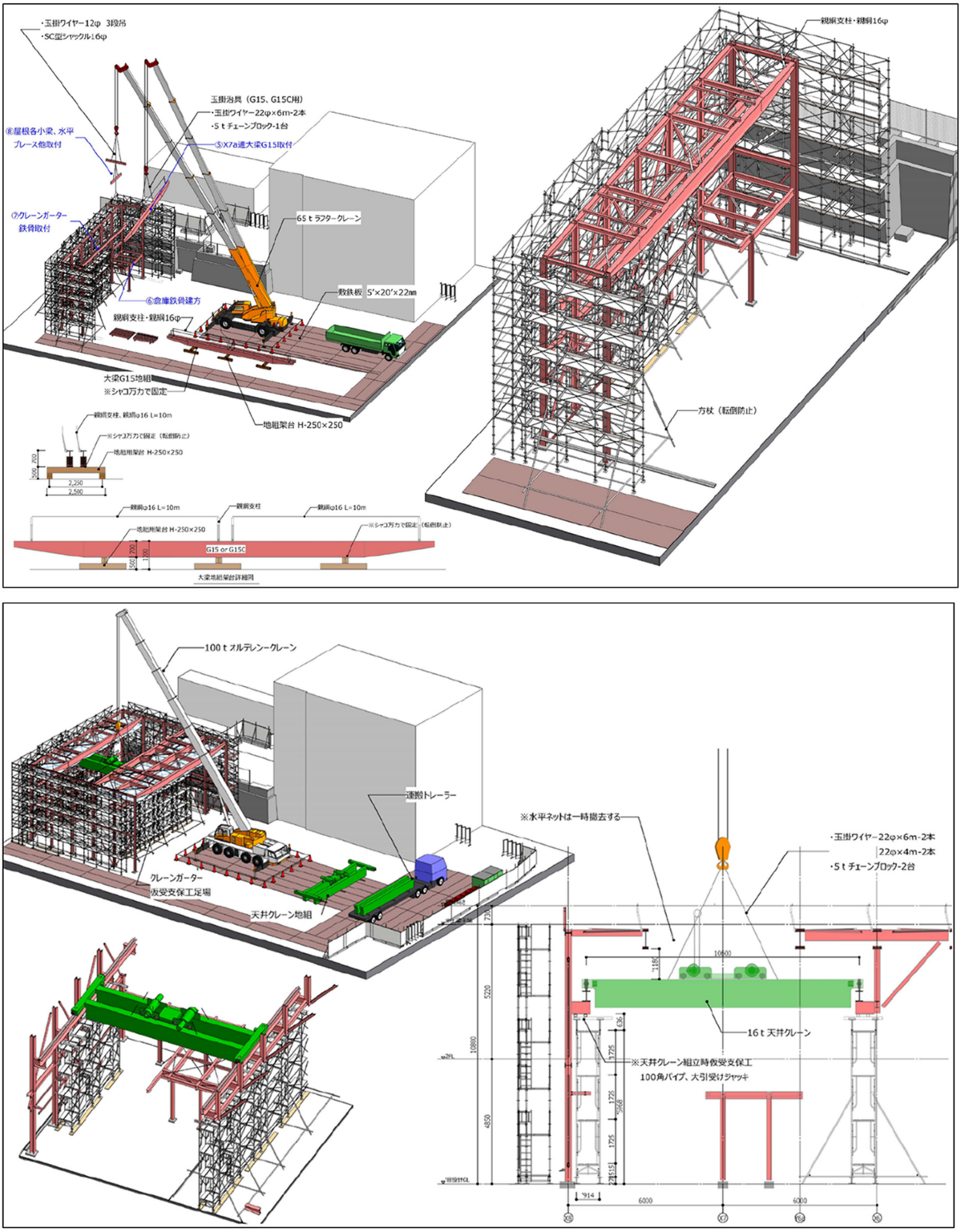


Figure 11. Construction plan using BIM model.

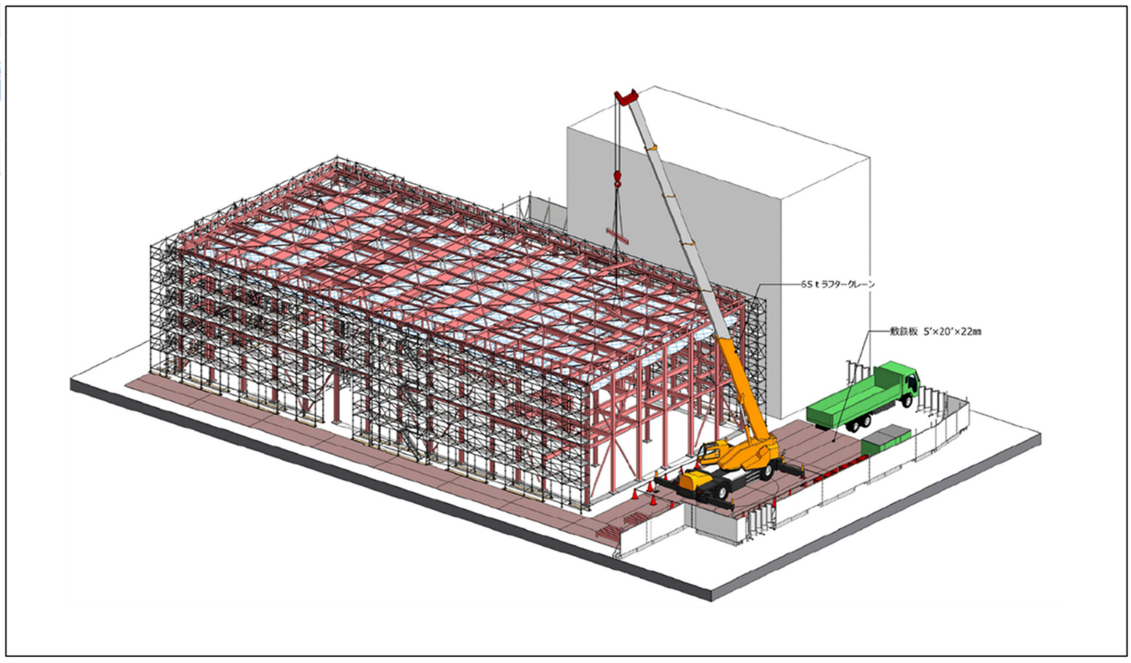


Figure 11. Continued.

stage of design, are introduced at the time of basic design. Resulting in reducing the number of retreat and retreat of design, and efficiency improvement will be possible in total.

In the case of redevelopment, the relevance of the position with the existing frame becomes a problem in many cases. By utilizing a model generated from existing drawings and point cloud information by field survey, it is possible to check the interference part, to extract problems, and to solve them at an early stage by repeating it with a planning model.

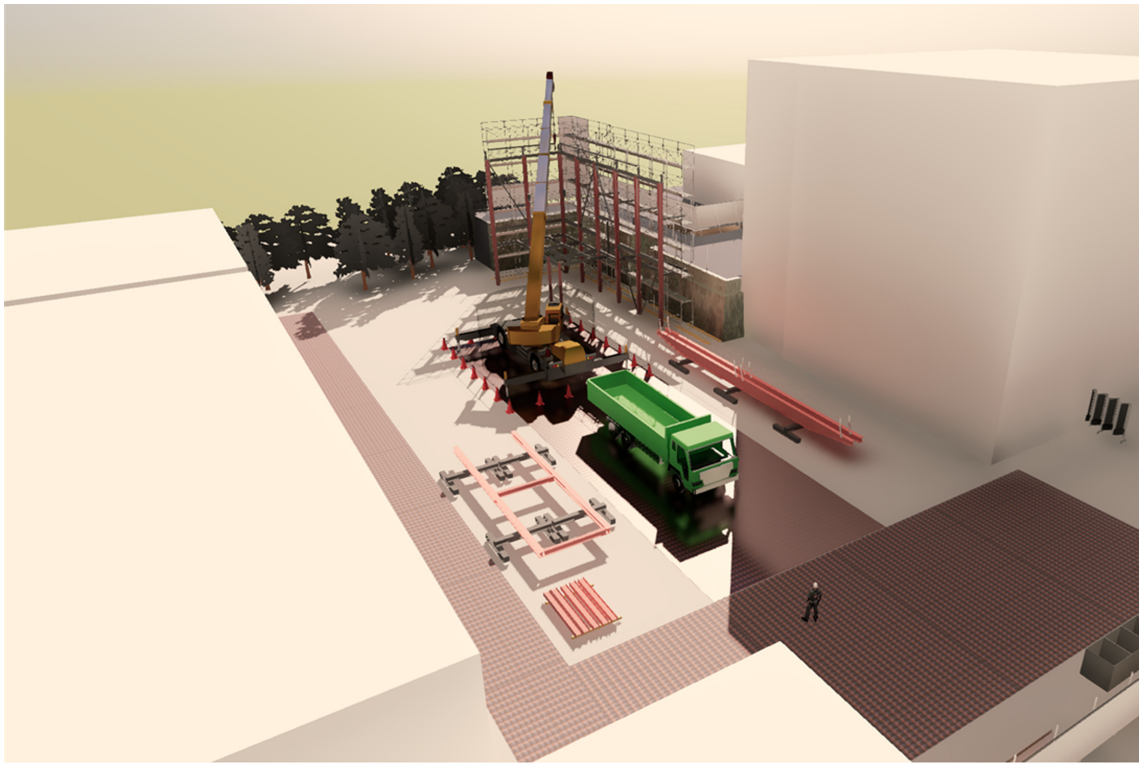


Figure 12. Construction plan utilizing BIM. (rendered video can be distributed for better understanding)

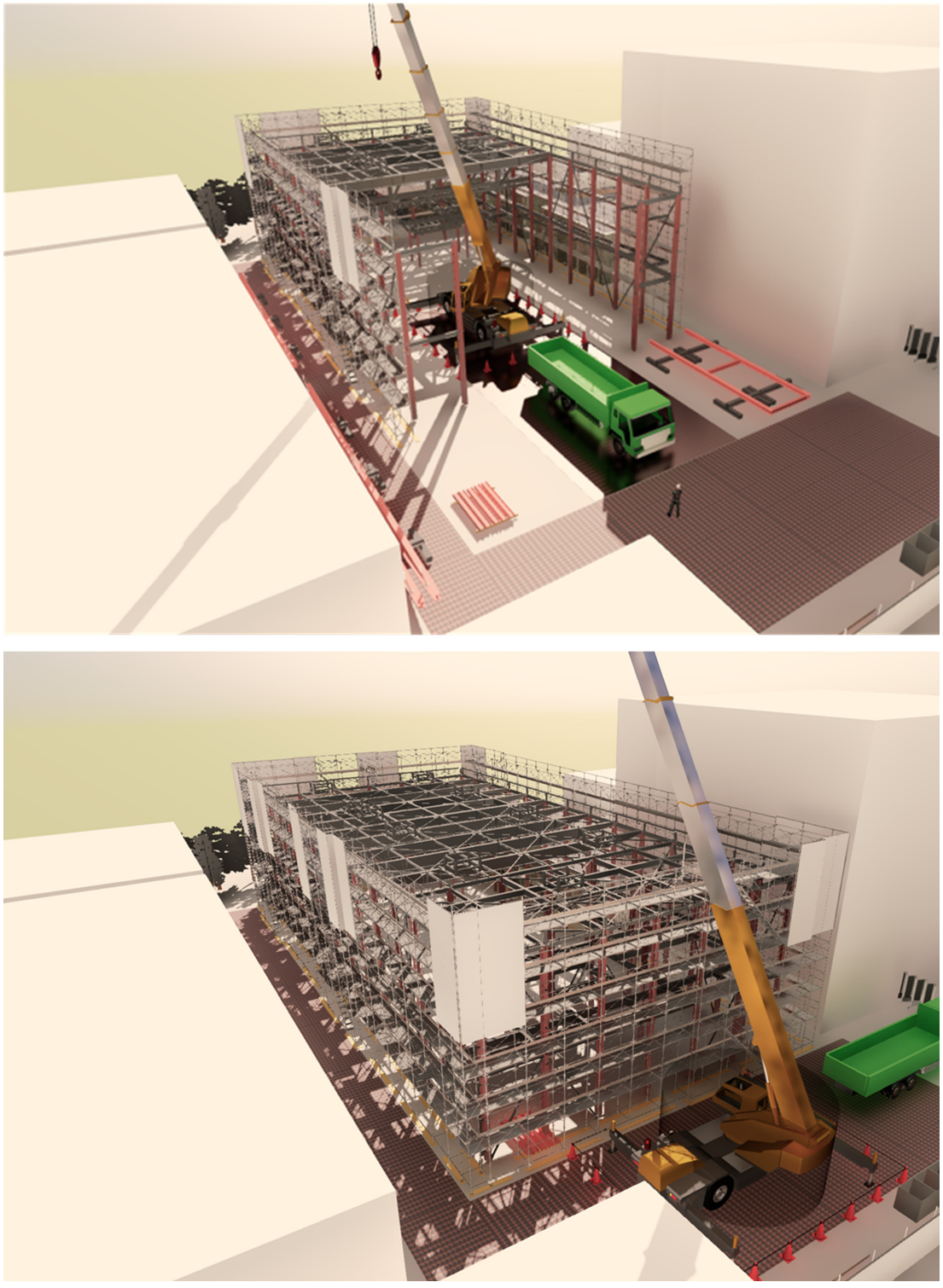


Figure 12. Continued.

4.2. Implementation design using BIM

In the implementation design, the details of BIM will also increase, and the number of involved people and field will also increase.

Recently, a different way to proceed with BIM, which is different from the conventional method, by utilizing cloud servers has been adopted.

Concretely, this method integrates design information on a BIM360 which is a cloud server, and the person in charge accesses the information to progress the design. The Taisei Corporation Design Division has prepared more than 1000 licenses to rapidly improve its operations.



Grand Prince Hotel Akasaka
Location: Kioi-cho Chiyoda-ku Tokyo
Use: Hotel
Structure:Substructure : Steel Framed Reinforced Concrete Superstructure : Steel
No. of Story: Substructure: 2-story Superstructure: 39-story , Penthouse:1-story
Max. Height: 138.9m
Building Area: 3,098m^2
Total Floor Area:67,750m^2
Completed: November 1982
Designer : Architect : TANGE ASSOCIATES : Structural Engineer : KAJIMA CORPORATION
Contractors: KAJIMA CORPORATION,
SEIBU CONSTRUCTION Co., Ltd.
Demolishing Period: November 2011-June 2013
Demolition Contractor: TAISEI CORPORATION

Figure 13. Outline of the building demolished by the TECOREP System.



Figure 14. View of the Demolition Progress.

It becomes operable by setting management of each access range and management of action restrictions (such as viewing only and editing permission).

It seems to be a good compatibility with business form by telework which penetrated at once by social situation caused by the viruses. Moreover, it is effective information management and information transfer means in future mechanization construction age.

The cloud server is shared not only within the design division, but also with the construction division, the estimation division, the construction management division, and even more external organizations, application organizations, consulting companies, and customers. If this information sharing progresses can progress further, more effective efficiency improvement of a series of works can be made.

It is a powerful weapon for achieving the construction DX, which is exactly the way the business is proceeding in the new era.



Figure 15. Demolition Site (interior view): All-weather demolishing space created at the top of the building Repeat the work of demolishing two layers inside the building and jacking down the roof at the top.



Figure 16. Demolition Site (interior view): Application example of rectangular plan building Floor opening for unloading at the front and a heavy machine for demolition at the back.

4.3 Construction plan utilizing BIM

An example of construction plan utilizing BIM model is introduced. Accurate examination is possible by reflecting design information, and it is possible to inform workers very easily of the situation of temporary construction in each construction step, positions of heavy machines, and detailed contents of construction.

4.4 Construction diagram utilizing BIM

Conventional construction drawings are also used in conjunction with BIM.

Consistency check work can be omitted by taking over information from design BIM and linking to BIM construction drawing and resulting in eliminating human error.

By taking out necessary information from commonly shared building model information by a wide variety of specialist constructors, it can reduce adjustment time and items among contractors, and it is possible to approach to construction of high-quality buildings.

In addition, if the environment can utilize the cloud, management of the latest model information and change information during construction can also be shared in real time.

4.5 Problem

As a problem, effects of utilizing BIM are limited, since transmission and approval methods of construction information using BIM to every member of specialist constructor are not completely shared.

However, it is a situation that can be said to be a matter of time.

Generalization of the technique utilizing BIM is expected to spread rapidly in near future.

5. Examples of new mechanized construction methods

5.1 Example of mechanized construction in demolishing project ①

Japan's high-rise buildings are also increasingly being demolished from the viewpoint of aging and economical efficiency. There has also been a demand for demolishing high-rise buildings with a height of more than 100 meters, which cannot be demolished by conventional demolishing methods, since around 2010.

TAISEI Corporation has developed and applied a new environmentally conscious demolishing method "TECOREP SYSTEM" for high-rise building. This system had continued to improve and expanded its application range to buildings with a small site area and middle-rise buildings with important facilities (such as rail ways and embassies) in the neighborhood.

The basic concept of "covering" cultivated from the prevention of scattering and noise of demolished materials is well suited as a base for all weathered type mechanized construction and robotized construction of new construction

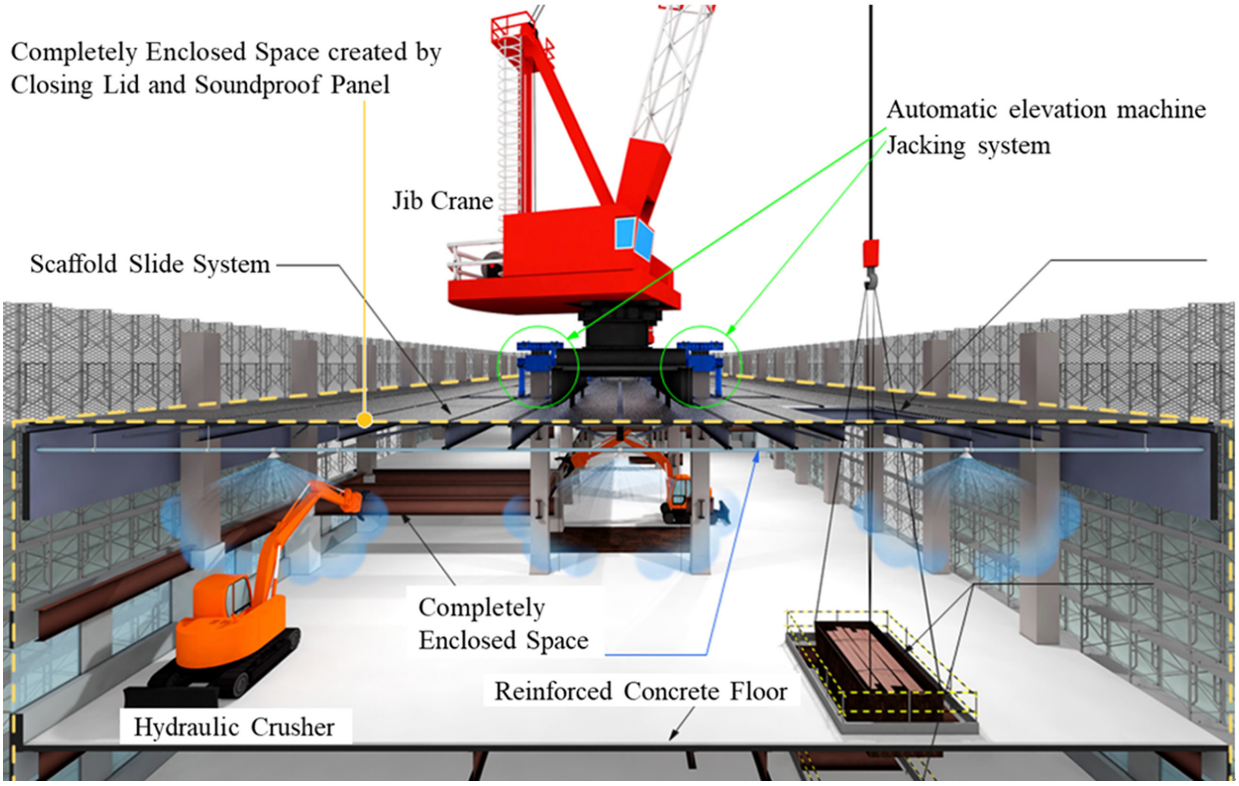


Figure 17. Conceptual Diagram of TECOREP-Light System.



Figure 18. Demolition Site. (Exterior view)



Figure 19. Demolition Site (interior view): Use of existing RC columns and lightweight frames The steel beams are demolished, and the cross section of the end is exposed.

and future development is also expected.

This system is an environmentally conscious demolishing method contributing to a recycling-oriented society utilizing a new crane which also generates power by utilizing falling energy, and here is introduced a demolishing case of a skyscraper about 140m in height.

5.2 Example of mechanized construction in dismantling project ②

This paper presents an example of an environmentally conscious mechanical demolition method "TECOREP-Light" developed to demolish middle and high-rise buildings while considering the surrounding environment.

This method constructs an enclosed space for environmental consideration simply by combining existing columns of buildings with a light weight roof frame unit to make a suspension structure.

The jib crane is installed at the top of the system to improve work efficiency.



Figure 20. Completed drawing Location: Sapporo City, Hokkaido. Total floor area: Approx. 98,400 m^2 Max. height :175 m (48-story)

5.3 New Construction Project: Mechanized Construction in Ultra-High Rise RC Buildings

This paper presents a case of application of an ultra-high rise RC building by developing a "TECOREP system". Mechanized construction technology of temporary erection frame lifting and lowering used for an environment-conscious demolition method "TECOUP" of ultra-high rise buildings is applied to new construction works, and a steel frame mounted with a tower crane is constructed by raising it.

The merits of this method are that it can be constructed by a crane smaller than that of a tower crane, because the degree of freedom of the crane arrangement position is improved, and that the exclusive use strut of tower crane can be omitted.

And, construction efficiency is improved by not providing a floor opening (post-construction range) of floors below, compared with a floor climbing method.

This is a mechanism to support a jib crane for construction by a newly constructed pole, and the construction progresses by a method to lift a crane and a floor frame using a jack with a pole as a support mechanism.

It has the advantage of continuing construction without stopping, because it can complete the climb of 3.3 meters per floor in one hour.



Figure 21. The new system was adopted in the left side crane of the two cranes.

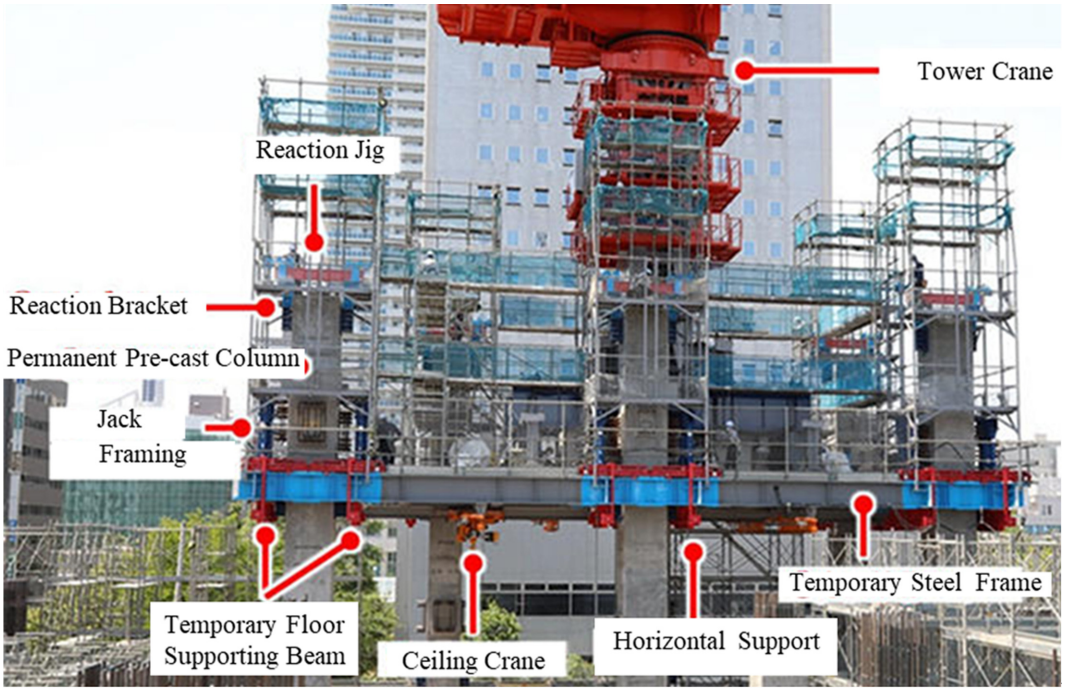


Figure 22. Each part of TECOUP system

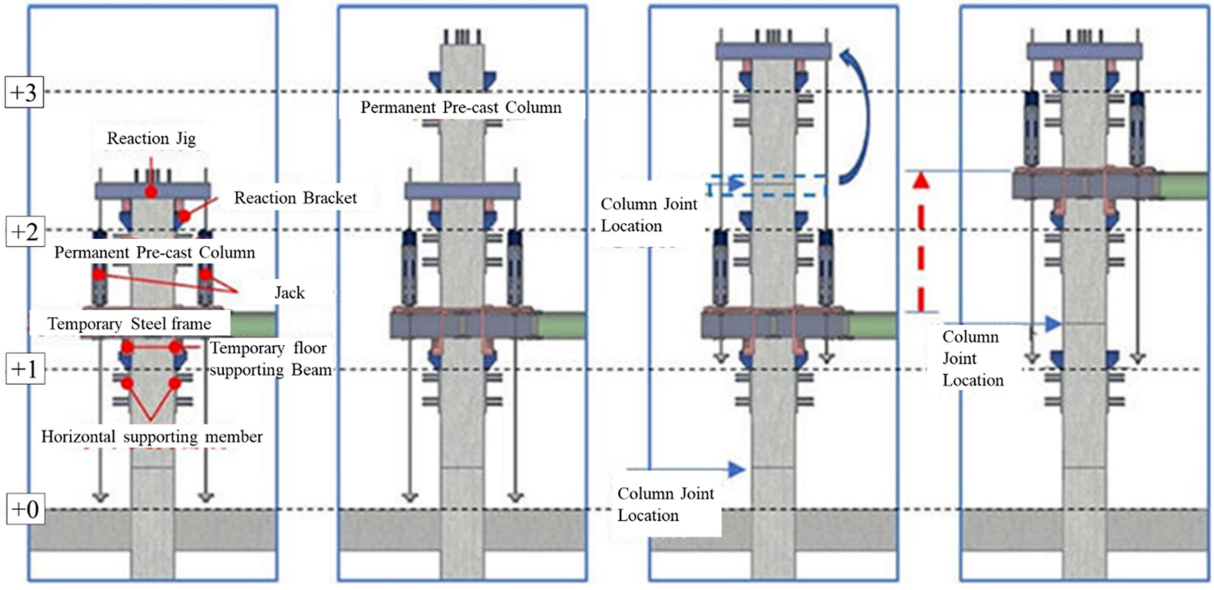


Figure 23. Chart implementation status

It is applied to the construction of a new high-rise RC building in Sapporo, Hokkaido.

6. Future Outlook

6.1 Integration of Digital Technology, Robot Construction, and Mechanized Construction

At present, for the full-scale mechanization construction and robot construction age, improvement of each digital technology, development and execution of construction robot, and all-weather enclosed type construction system in which they can work most efficiently are individually raised to the next level.

They have already been blushed up to the application level steadily, rather than desktop planning.

The challenges are also clear, and the phase is to integrate and implement continually and quietly.

In the future, we will create a new, clean building site

where automated machinery and robots can provide high-quality buildings while ensuring safety in collaboration with people, using an enclosed space as a digital construction plant.

7. Conclusions

This paper presents the present state and prospect to the construction method in the new age considered by Taisei Corporation.

We will continue to implement "For a Lively World" and "To Create a Vibrant Environment for All Member of Society" by constantly challenging and realizing technologies that lead the times.