CONCEPTUAL DESIGN USING BIM OF ULTRA-HIGH-SPEED CONSTRUCTION SYSTEM ASSUMING EMERGENCY SITUATIONS

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Abstract
The Japanese construction production system has aimed to achieve a high degree of balance between high Q: quality, low C: cost, appropriate construction D: duration, S: safety assurance, and reduction of E: environmental impact in project results. Against the background of low economic growth and low interest rates after the bursting of the bubble economy, the Japanese client did not strongly demand "UHSCS: ultra-high-speed construction system," which is the purpose of this research theme. However, if the QCSE satisfies the required standard, it is obvious that the introduction of UHSCS that realizes early recovery of funds will increase the value of the project. In addition, it goes without saying that reducing time, which is a parameter for amount of labor, material, and indirect costs, is effective in improving productivity, which the Japanese construction industry is currently working on. During the recent spread of COVID-19, those of us involved in construction watched helplessly as lives and health were lost due to the lack of medical facilities. In Wuhan city, China, a medical facility with 1,000 beds is said to have started operating 10 days after the site was prepared. In China, which is undergoing economic growth and has high financing costs, there was a strong need for UHSCS for hotels and offices. Based on the current situation, it is necessary to review UHSCS as another form of building production. The international architectural society has a social mission to prepare for the occurrence of similar pandemics and disasters such as earthquakes directly hitting the Tokyo metropolitan area that are predicted to occur in the future. This research utilizes the excellent construction elemental technology of Japanese industry, BIM, IoT, SCM and robotics, and presents a conceptual design of an UHSCS based on thorough standardization and labor-saving construction.

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1. Research background

1-1. Acceleration of construction production workflow

In construction production in Japan, we have aimed for a balance of high Q: quality, low C: cost, appropriate construction D: duration, S: safety assurance, and reduction of E: environmental impact in project results. During the recent spread of COVID-19, those of us involved in construction watched helplessly as lives and health were lost due to the lack of medical facilities in Japan. Meanwhile, according to reports, a 1,000-bed medical facility in Wuhan, China, began operations 10 days after site preparation. In China, which is undergoing economic growth and has high financing costs, there was a strong need for "UHSCS: ultra-high-speed construction system," for hotels and offices. Against the background of low economic growth and low interest rates after the bursting of the bubble economy, the Japanese client did not strongly demand UHSCS which is the purpose of this research theme. Based on the current situation, it is necessary to review UHSCS as another form of building production. The international architectural society has a social mission to prepare for the occurrence of similar pandemics and disasters such as earthquakes directly hitting the Tokyo metropolitan area that are predicted to occur in the future. However, it goes without saying that even in normal times, "speeding up" is a major factor in improving business feasibility.


1-2. Previous research

This research team has focused on the "group" function as a structural characteristic of BIM. BIM has two environments: a so-called "factory" environment where objects are created and a "site" where building models are created. In the "factory" environment, it is possible to create nested "groups" that are the very structure of the supply chain. Preparing the "factory" product in advance shortens the construction period compared to making a single part, but the same can be said for BIM. As pointed out in previous research, in digital space BIM, for example, it is possible to create a "group" that does not stand on its own in reality, taking out only the space and surface finishing materials. This "imaginary group", which the research team calls a "design study unit", can also be made ready-made in advance, contributing to shortening the study period at the time of study. When using the "design study unit", it is also possible to simplify the category classification once, improve the operability during study, and replace it with the BIM native category again using programming after the study is completed. [1]

2. Purpose of research

The purpose of this research is to show the procedure for speeding up the construction production workflow, using the structural characteristics of BIM, using the hospital facility production under emergency situations as a specific subject.

3. Research method

Autodesk Revit 2022 (hereinafter referred to as Revit) was used as the BIM core software, and the visual programming tool Dynamo and data integration software Navisworks were used together.

The examination method is based on the following steps.

- Consideration of workflow
- Consideration of classification of hospital functions and unit method
- Creation of BIM model and unit cataloging
- Development of zoning study method and unit automatic placement method
- Replacement with design study unit and examination of parts
- Consideration of the above method

4. Research content

4.1. Consideration of Workflow

While comparing it with the general workflow, we considered speeding up at each stage of design, production design, and construction.

- Speeding up the design stage
  Unit models of typical functional units are prepared in advance and organized as a "Catalogue" to expedite consideration.
- Speeding up the production design stage
  Accelerate the study of unitization and parts by using the "design study unit" that makes it easy to adjust design, structure, and equipment at the same time.
At the construction stage

Accelerate on-site work by utilizing prefabricated units that integrate design, structure, and equipment.

4.2. Consideration of classification of hospital functions and unit method

Based on the organization of hospital zoning and traffic line plans, a "center corridor" was established to consolidate the main traffic lines and main equipment routes in order to simplify the functional configuration of the building. The center corridor becomes the "trunk" and each functional zone becomes the "branch and leaf", making the hospital structure extremely clear as a tree-like organization.

4.2.1. Center Corridor

The center corridor has the following three functions,

- Line of flow as a “trunk”

Hospital functions can be broadly divided into outpatient flow lines and back flow lines. The traffic line of foreigners is set as the center corridor. Through this arrangement, it is possible to realize a universal design that makes it easy for even first-time visitors to intuitively grasp the flow line. Zones are also clearly demarcated, contributing to security planning.

- Equipment route as a “trunk”

The main trunk line for electrical equipment and the main trunk line for water supply and drainage were consolidated in the center corridor. In general building plans, water supply and drainage routes are not necessarily connected to a single main trunk, but water is often supplied for each zone and sent to an
underground pit through vertical pipes for each zone, but the piping and wiring are network-like. It becomes a plan, and the number of design adjustments increases. The tree-like organization greatly reduces the number of items to be coordinated between buildings and facilities. Although there is a disadvantage that the wiring and piping length increases slightly, the advantage of speeding up was given top priority.

- Seismic element as a trunk

In the center corridor, earthquake-resistant braces (X direction Y direction braces and horizontal braces) are installed to provide sufficient strength against rolling, and the center corridor partially bears the horizontal force of each functional zone during an earthquake. As a result, the degree of freedom in planning for each functional zone can be increased, and the speed of structural design can be increased. Although there is a disadvantage that the frame of the center corridor is slightly excessive, the advantage of speeding up is given top priority here as well.

![Fig. 3 Center corridor and functional zones as "trunk"

With the above arrangement, for example, it is possible to partially complete the construction of the center corridor and patient rooms first and then start using them. Furthermore, it is also possible to extend the center corridor in the future and expand the function. It can be said that it is a horizontal development of the old concept of "metabolism".

4.2.2. Plan variations

In actual planning, if the center corridor is set in a straight line, depending on the scale, there will be an adverse effect of lengthening the back flow line of doctors and nurses. By considering the following plan variations, it is possible to shorten the back flow line.

4.3. Creation of BIM model and unit cataloging

Unitization of zones requires a unit that can be unitized into a container for each room like a hospital room, and a complex functional linkage like an operating room. Unitization on BIM that cannot be done as a unit was divided and organized. Design, structure, and equipment BIM models were created based on the standard plan, and grouped using the group function. I also entered the specification information such as performance. In order to make it easier to refer to, the created "group" was arranged in the project space of BIM and made a "catalog". When designing, copy from this catalog and use it while transforming, supplementing and correcting information according to the project. In addition to the zone catalog, we also prepared a study model using a spatial object called a Revit "mass". At the initial stage of design, the volume model is used to expedite zoning studies, and once the zoning plan has been finalized, it is replaced with the zone model. It is automated using programming, and multi-objective optimization is also utilized for site layout studies.

4.4. Development of zoning study method and unit automatic placement method

The design study unit was used in the study of unit construction and prefabrication. By temporarily replacing models with a single category, it becomes easier to divide and integrate design, structure, and equipment models, and it also speeds up the examination of parts. The attribute information necessary for construction is once extracted to Excel, and after converting it into parts, it is put back into the native
data. The BIM model created in this way was linked to Navisworks, and the on-site process was examined using the 4D simulation function. Fig. 7 shows the process of the study. In Fig. 8, the model created this time was visualized by linking it with the landscape software Lumion.

Fig. 5 Maintained zone model catalog

Fig. 6 Initial study model and model replacement

5. Discussion

In this paper, assuming "emergency situations" such as disasters and pandemics, we focus on medical facilities with high priority on functionality, and use the concept and function of BIM to construct buildings such as spaces, members, and units. The concept of UHSCS with simplified elements is presented. Specifically, it showed a rational design using BIM, the introduction of prefabrication that is compatible with the concept of BIM, and the procedure for speeding up the workflow by saving labour at the construction site. I would like to think about the effect of compensating for the construction production system, which is understaffed even in normal times, by thoroughly standardizing and labour-saving construction trials by further utilizing BIM, IoT, SCM, robotics, etc., which are building elemental technologies of the Japanese industry.
References