BIM-Based Bridge Construction Productivity Improvement and Quality Control Enhancement

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In recent years, the introduction of BIM (Building Information Modeling) has been promoted for the purpose of improving productivity at construction sites and improving quality control. BIM is a digital representation of a 3D model that includes attribute information, and it is also possible to carry out pre-simulations such as construction plans with time axis and process progress management. A trial of quality support and remote management of field work has been reported that combines a BIM model and ICT (Information and Communication Technology). This time, the effects were confirmed on-site by using mixed reality, total station surveying, and image analysis technologies. In this paper, we report the details.

1. Introduction

In Japan, the construction industry is faced with a pressing need to address problems associated with declining the competence of construction site crew attributable to factors such as the decrease in the number and aging of skilled engineers at construction sites and the shortage of young workers who will bear the future of the construction industry. The Ministry of Land, Infrastructure, Transport and Tourism is working to implement the i-Construction scheme[(1)], which aims to improve the overall productivity of construction production systems and make construction sites more attractive places of work by introducing new approaches that utilize information and communication technology (ICT). The progress of projects tends to delay due to inadequate improvement in efficiency of overall construction process and poor working environment. This is believed to be a typical case where productivity at construction sites cannot be improved enough. In order to improve productivity and enhance quality control, efforts are underway to introduce building information modeling (BIM) to construction sites so that integrated models can be applied to all stages of construction project including planning, preliminary design, detailed design, construction and maintenance. **Figure 1** shows an example of a BIM model interoperability system[(2)].

In the coming years, it will also be necessary to introduce the latest technologies (e.g., utilizing ICT) into projects in order to achieve a higher level of efficiency. This report describes the BIM and ICT approaches adopted for the Koryo-Taki Road Taki PC bridge superstructure construction work (Shimane Prefecture) and the Ono-Aburasaka Road Kuzuryu River Bridge superstructure construction work (Fukui Prefecture). **Figure 2** shows the locations of these construction sites.

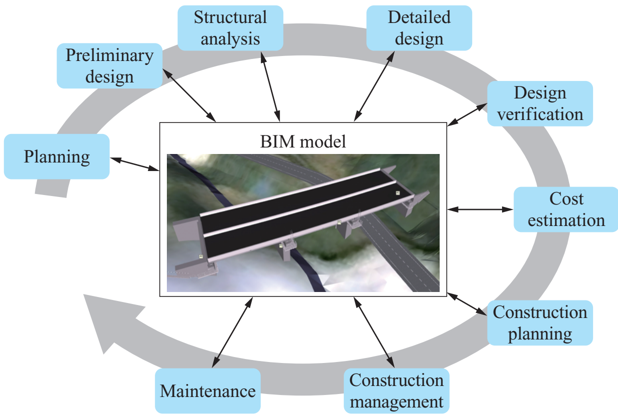


Fig. 1 Example of BIM model interoperability system[(2)]

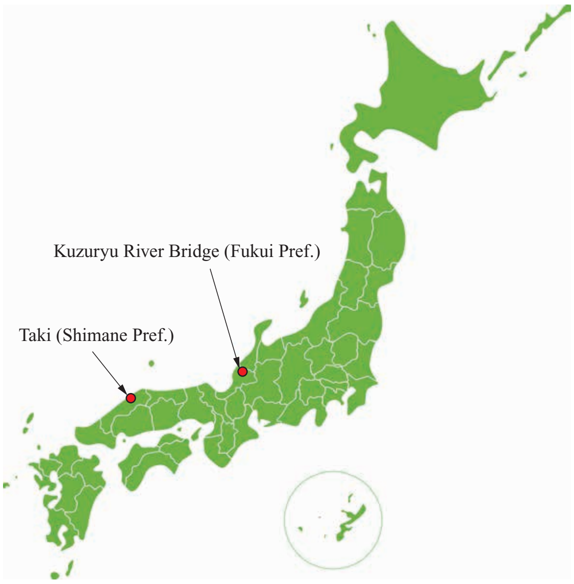


Fig. 2 Locations of the construction sites

2. Productivity Improvement Technologies for Taki PC Bridge Superstructure Construction Work

2.1 BIM-based front loading approach

The term “front loading” refers to the practice of investing much time early in a project in considering various arrangements so as to minimize possible rework at later stages and thereby make the project lead time as short as possible. The following sections explain the front loading approach carried out by using BIM.

2.1.1 BIM model preparation and interference check

Figure 3 shows condition in which a three-dimensional (3D) model image is obtained by conversion. The 3D model was obtained by converting the two-dimensional (2D) drawings of the structure issued when the contract was awarded by using a specialized BIM software. A four-dimensional (4D) BIM model was then prepared by adding information on the construction process (time axis) and attribute information on the bridge structure and its accessories. Because the 4D BIM model makes it possible to check the sequence of tasks such as assembly and disassembly of different types of work simultaneously, the model was used for interference checks of the bridge and accessory models. **Figure 4** is an example[3] of an interference check of accessories showing the interference between drainage piping and the inspection catwalk. As time and economic losses due to checks for inconsistency between drawings or redesign work were effectively prevented, construction efficiency was improved without interrupting on-site activities. Since the BIM model is visually easy to understand, the time spent on consultations and meetings can be reduced.

2.1.2 Construction planning using the 4D BIM model

The construction scheduling part of construction planning aims to complete construction work by a specified date by executing work within an appropriate number of days at an appropriate rate of progress while managing safety, quality and cost in an appropriate manner. Conventional time schedule charts using a spreadsheet software enable rough understanding of construction procedures, but there is no way to make sure that it is possible to carry out construction work as scheduled. Since the visualization using a construction simulation based on the construction conditions starting from the design stage is thought to be effective in improving construction site productivity, the following approach was taken. The BIM model to be used was prepared by superposing a bridge structure model on a topography model. For the purpose of construction process simulation, 3D models of hoisting equipment and construction equipment were prepared separately, and a 4D BIM model was prepared by adding construction process information. **Figure 5** shows a 4D BIM construction process simulation[2, 3]. **Figure 6** shows how the 4D BIM model can be used at a meeting with those involved in construction work and construction site workers. By visualizing the details of construction work in advance, work efficiency was improved, and the construction period was reduced by about 12%. The model was also utilized to ensure safety by, for example, making sure that the space required for hoisting equipment is made available and checking the clearance between the girder being constructed and the roadway. The model was also found to be effective in furthering the understanding of the construction work among the local residents who attend a briefing about the construction project.

Fig. 3 3D model conversion

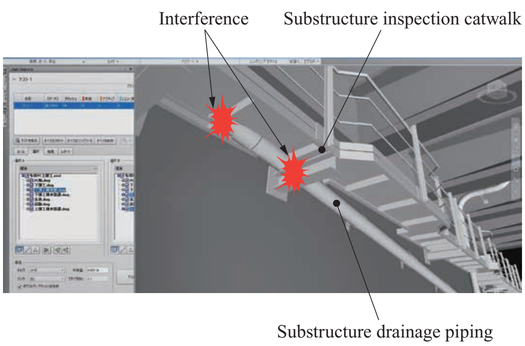


Fig. 4 Interference check of accessories[3]

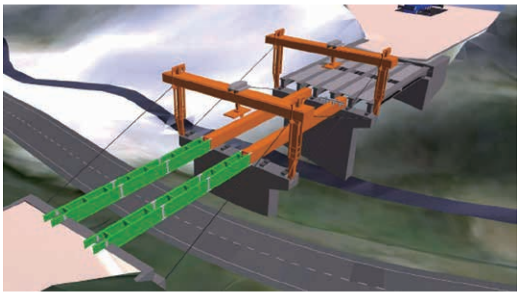


Fig. 5 4D BIM construction process simulation[2, 3]

Fig. 6 Meetings between the parties using 4D BIM

2.1.3 Progress management using the 4D BIM model

In construction management, the reduction in daily working hours is an important consideration, and rework at a construction can be a factor that causes delays in construction work. Since delays in nighttime construction work is a major factor affecting the local residents and those involved in the construction work, it is important to ensure steady progress of the construction. To this end, the 4D BIM model was utilized for construction progress management by providing the model with a daily progress management function so that the progress of construction work was visualized in the form of graphs. A drone was also used periodically to shoot aerial images of the construction work area to identify the differences between the planned schedule and the actual progress and reallocate resources such as workers and equipment to accelerate delayed activities as required. This made it possible to get the delayed construction activities back on schedule. **Figure 7** shows the progress management using the 4D BIM model[(2), (3)].

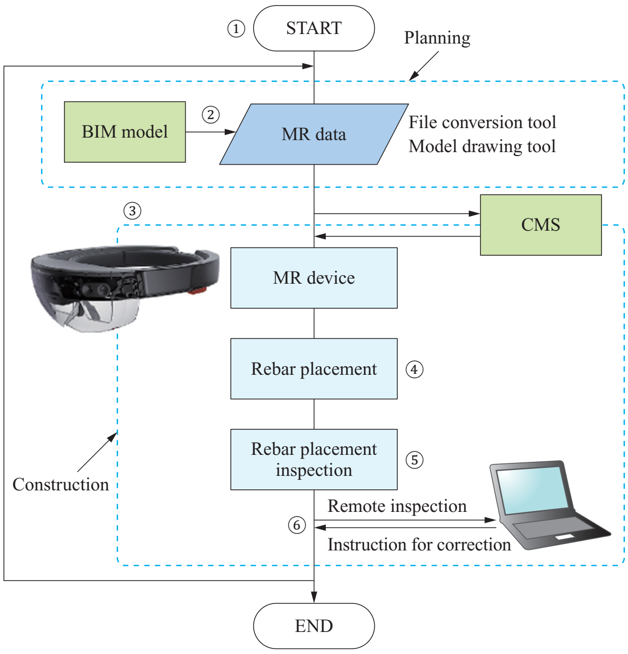
2.2 On-site utilization of BIM

2.2.1 Use of BIM and MR technologies for productivity improvement

An attempt was made to improve productivity by using a combination of BIM model and mixed reality (MR) technologies. MR refers to the technology that represents both the real world and virtual reality (VR) in the same space, for example, by superposing a VR model in real-world space. An important consideration in this attempt was to what extent construction work efficiency can be improved through labor saving and working time reduction. The attempt also involved trials to find a method of superposing a 3D model and work space at the construction site and a method of managing end-of-stage inspection for reinforcing bar (rebar) placement from a remote location.

To introduce MR technology, an MR device, which is a specialized computer for graphics capable of running a commercially available operating system, was used. The position within a place and the direction of the field of view are detected with an infrared ray sensor called "a depth sensor" built into the MR device, and the workplace location is identified in real time with a 3D scanner. In the trial, software developed specifically for the trial was used to project BIM model data in a real-world space by adjusting location and scale details. The location of the 3D model is adjusted with an augmented reality (AR) marker placed on-site as an origin. To share 3D data from a remote location, a content management system (CMS) that can be managed on the cloud was used. **Figure 8** shows the flow of the MR technology trial.

Figure 9 shows an example how the MR device can be used to support rebar placement work[(3)]. On-site working time measurement showed that compared with conventional marking work, the time required for rebar placement and



Trial procedure
① Plan model information to be displayed on the MR device screen.
② Prepare a 3D model and import it into the MR device via the cloud by using software developed for that purpose.
③ Teach supervisors and technicians who actually perform construction activities how to put on and operate the MR device.
④ Position the 3D model on-site by using the origin (AR marker).
⑤ Display the 3D model screen with the MR device and use it to support rebar placement and drainage device and inspection catwalk positioning work.
⑥ Connect the MR device to the computer at the work office for the end-of-stage inspection and conduct a quality inspection in real time.

Fig. 8 MR technology trial flow

(a) Enter the actual progress of work at the office
(b) Manage the progress at the site
(c) Check on the difference between the planned and actual progress

Fig. 7 Process management using 4D BIM in the field[(2), (3)]

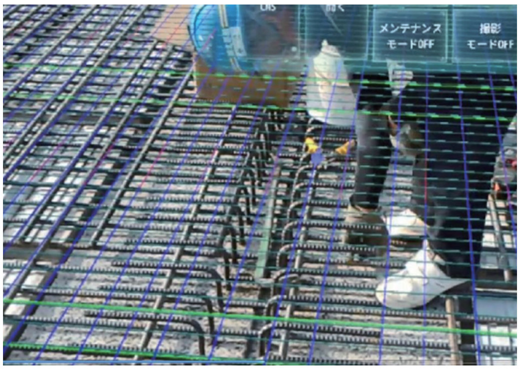


Fig. 9 Support for rebar placement work[3]

bridge accessory anchor positioning work was reduced by about 20%. **Figure 10** shows how rebar placement work can be managed from a remote location[3]. By visualizing rebar spacing and the number of rebars for end-of-stage inspection and sharing the site condition in real time with the work office, the time required for inspection by supervising and quality certification personnel was reduced.

2.2.2 Use of BIM and TS surveying technologies for productivity improvement

For the utilization of total station (TS) surveying technology, a system consisting of a TS linked with a tablet terminal was used. **Figure 11** shows the flow of the TS surveying technology trial. **Figure 12** shows the configuration of the surveying technology system. The coordinates are measured in real time while automatically tracking prism XYZ reference points with laser beams. The data thus acquired are transmitted via wireless LAN to the tablet at a frequency of 20 times per second. This TS-tablet system allows the user to directly specify measurement points in the BIM model and is capable of displaying BIM model and TS data in an integrated manner. Keeping track of the locations of the prism reference points in the BIM model, the system smoothly guides the person who is conducting measurement to the next measurement point by showing XYZ coordinates. **Figure 13** shows a TS surveying conducted at a construction site. Use of the system eliminates the need for on-site positioning work. The system made it possible for one person to conduct measurement instead of two as is normally required.

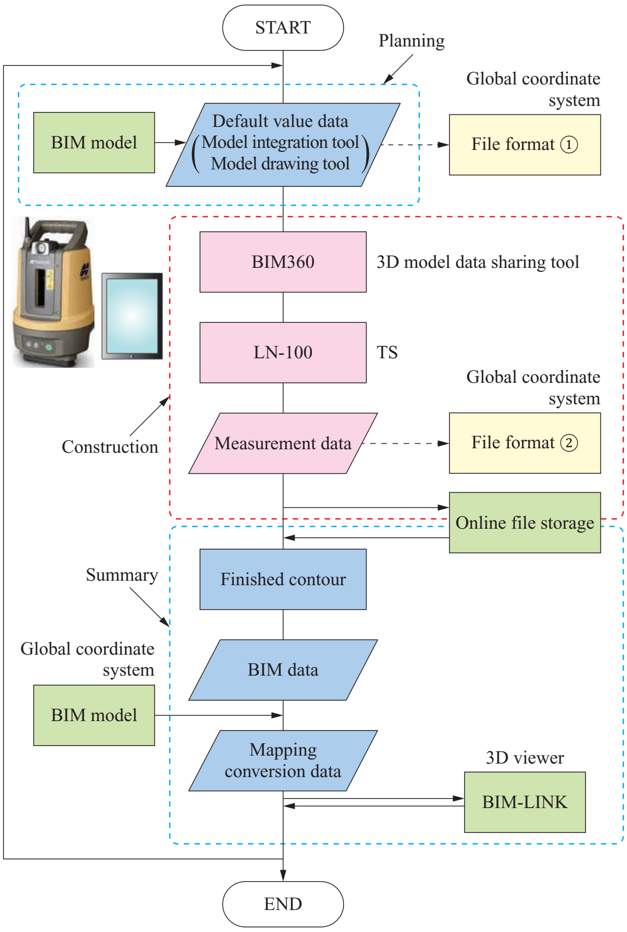


Fig. 11 Flow of TS surveying technology trial

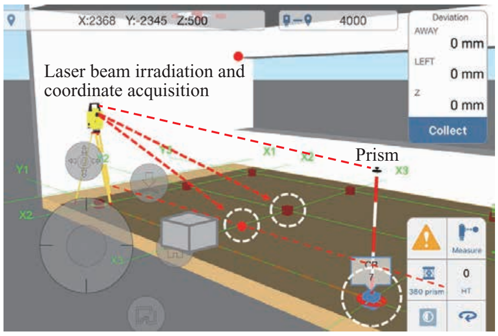


Fig. 12 TS surveying technology system

(a) Rebar placement inspection using the MR device

(b) Remote management from the work office

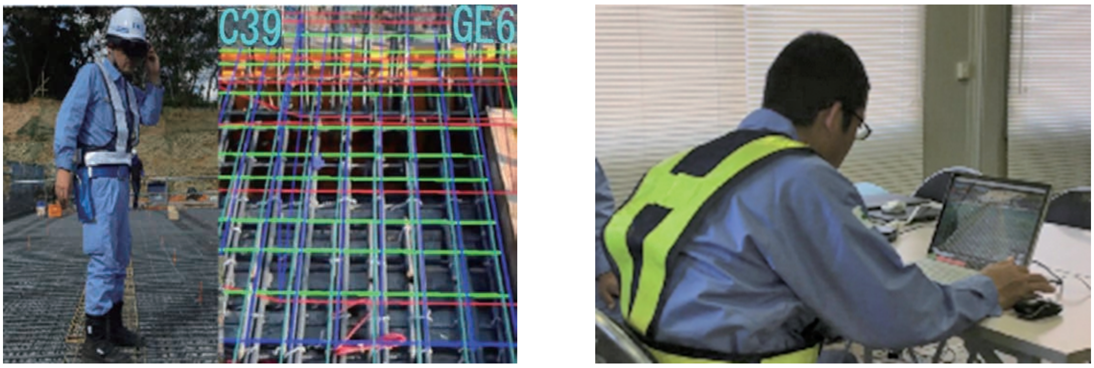


Fig. 10 Remote management of rebar placement work in field and office[3]

(a) TS surveying of parapet formwork (b) TS surveying of finished flooring (c) Example of position information on the tablet screen

Fig. 13 On-site TS surveying technology

The trial has confirmed the following effects:

(1) Manpower and time required for measurement conducted with the newly developed TS surveying technology were found to be about 60% smaller and shorter than with the conventional technology.

(2) Measuring accuracy is nearly as good as that achievable by conventional measurement, and the objectives of labor saving, working time reduction and comparable measurement accuracy have been achieved.

(3) Finished flooring contour software was used for the management of the finished parts of the bridge floor. By showing different levels of error from the design values in different colors, the height of the finished bridge floor was confirmed to be within tolerance. **Figure 14** shows an example of the contours of finished flooring.

2.3 Use of BIM for quality control enhancement technology

2.3.1 Work planning using the BIM model

A 3D model of rebar placement was used at a meeting with site workers about rebar placement work. **Figure 15** shows an example of the utilization of 3D model. The 3D visualization of the work to be performed from various angles made it possible to gain prior knowledge of details such as rebar placement sequence and rebar interference locations. The visualization also contributed to a deeper understanding of assembly work so as to meet rebar placement accuracy and concrete cover requirements without necessitating rework. Thus, it has been confirmed that the BIM model approach contributes to efficiency improvement. In the trial, the BIM model was used for rebar placement work, which does not require highly skilled workers. The BIM model approach, therefore, is thought to be even more effective when applied to construction work involving a complex structure or a densely reinforced concrete structure.

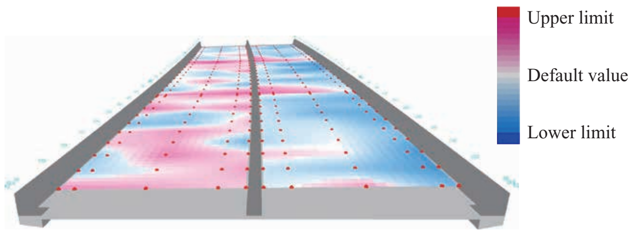


Fig. 14 Contours of finished flooring

2.3.2 Use of BIM and TS surveying technologies for quality control enhancement

In order to ensure the quality of a concrete structure, if concrete is placed in multiple layers, it is necessary to carry out concrete placement within the specified period of time. The future durability of a bridge may be greatly affected by the accuracy of the finished parts of the bridge floor slab. **Figure 16** shows an example of floor slab quality control using a TS[(2), (3)]. In the Taki PC bridge superstructure construction work, an attempt was made to address those problems by linking together the 4D BIM model and survey data obtained during concrete placement. Since direct prism collimation during concrete placement is difficult because the work area is crowded with construction workers, a TS that does not require a prism (non-prism TS) was used. The quality control involved the following procedures:

(1) By using a non-prism auto-tracking TS, the finished flooring constructed was measured and recorded for each alignment line, and placement interval was

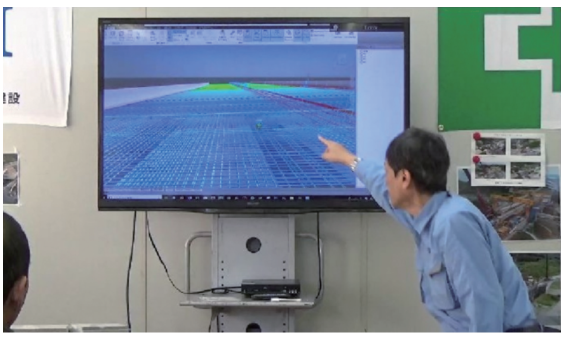


Fig. 15 Utilization of local quality BIM

Fig. 16 Floor slab quality control using TS[(2), (3)]

measured and recorded for each predetermined placement area.

(2) The results of floor slab height and placement interval were transmitted in real time to the tablet terminal carried by the measurement personnel.

(3) Concrete placement work was carried out while keeping track of the difference between the planned value and the measured value throughout the process from concrete placement to completion of the work. In cases where the measured height of the finished surface deviated substantially from the planned value, the construction crew was instructed to refinish the surface.

Figure 17 shows the real-time management of finished contours indicating the differences between the actual heights of the finished floor slab surface and the planned values and the times of placement displayed on the BIM model[(2), (3)]. Positive differences relative to the direction of design height of the floor slab are shown with red contours, and negative differences with blue contours, and placement intervals are also shown. By managing the finished flooring and placement interval (time) in real time, finished floor height and placement interval requirements were successfully met.

3. Productivity Improvement Technologies for Kuzuryu River Bridge Superstructure Construction Work

A digital twin refers to a reproduction in cyber space of a real-world object, such as a site or a building, created by transmitting physical space information to cyber space by use of such means as IoT (Internet of Things) technology. A cyber space reproduction thus created is called a "twin" because all physical world information is reproduced in cyber space. Digital twin technology, therefore, makes it possible to reproduce acquired data on a computer and utilize the data for various construction- and maintenance-related applications while performing tasks such as planning, design and analysis. **Figure 18** illustrates the digital twin workflow. The reason why digital twin technology began to draw attention is that it enables automatic continuous real-time data acquisition thanks to the widespread use of IoT technology. It can be said that a digital twin is a system that reproduces real-world activities or construction processes in cyber space. With digital twin technology, it is possible to

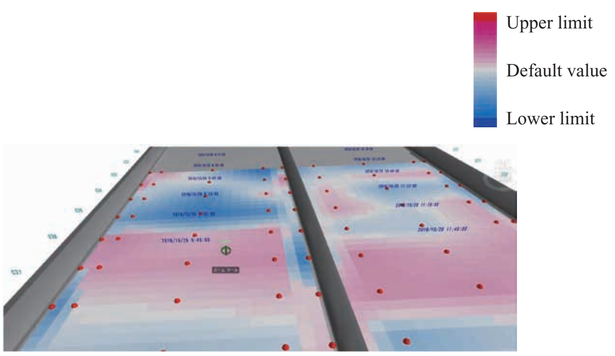


Fig. 17 Real-time management of finished contours [(2), (3)]

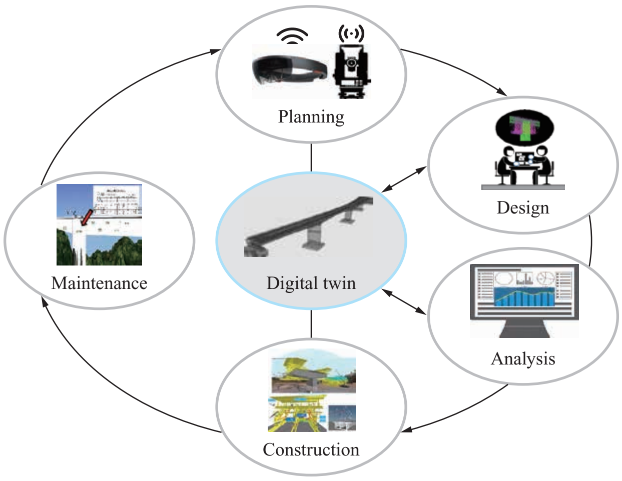


Fig. 18 Digital twin workflow

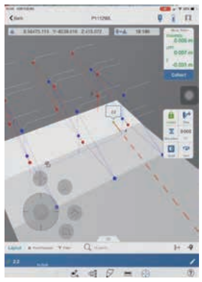
not only perform conventional static simulations but also create a virtual representation of the real world because each of the construction processes is reproduced in real time on a computer. A digital twin system differs from conventional simulation systems in that digital data can be acquired in real time, and teaching data, which can be used in the future for purposes such as the development of an artificial intelligence (AI) system for construction automation, can be accumulated. The following sections explain how the digital twin technology was utilized for the Kuzuryu River Bridge superstructure construction work.

3.1 4D labor saving technologies for construction equipment

The following approach was taken with the aim of improving labor productivity associated with the handling and setup of construction equipment. **Figure 19** shows construction equipment management using TS technology[(4)]. As the first step, a 3D model of the traveling platform was prepared; the model was linked up with the TS instrumentation system capable of automatically tracking prism XYZ reference points with laser beams; and equipment location and motion information was read into the tablet terminal from the cloud. Then, as shown in **Fig. 19-(a)**, the TS and the prism for auto tracking were installed on the traveling platform, and the crew leader managed the traveling platform setup, as shown in **-(c)**, while acquiring high-accuracy position information, such as traveling distance and height of the 3D model, from the tablet terminal shown in **-(b)**. **Figure 20** shows the safety monitoring method[(4)]. As a means of ensuring safety, access control areas were monitored by setting up a digital camera system at the construction site and using AI technology to detect humans, and the displacement of the traveling platform was acquired in real time from the marker installed on the platform by using image analysis technology (coordinates). Through these measures, the work area was monitored for anomalies such as falling from a high place and unauthorized entry, and a warning system consisting of devices such as sound alarms and rotating beacon lights was constructed so that a warning is issued if preset limits are exceeded. **Figure 21** shows the warning devices. Although

(a) Install a position information acquisition device

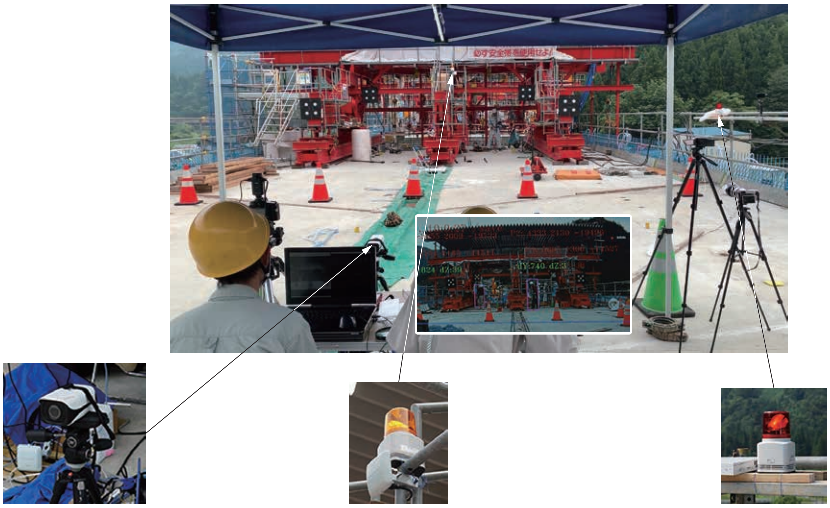
(b) 3D model's position information



(c) Set up the traveling platform according to the position information shown on the tablet terminal

Fig. 19 Machine management using TS technology(4)

(a) Install the digital camera system and the warning devices



(b) Acquire displacement coordinate information

Fig. 20 Safety monitoring using AI and image analysis technology(4)

(a) Rotating beacon light for movement monitoring during construction activities

(b) Rotating beacon light for access control during construction activities

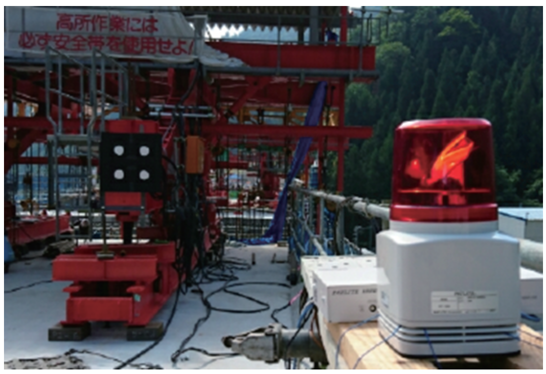


Fig. 21 Warning devices

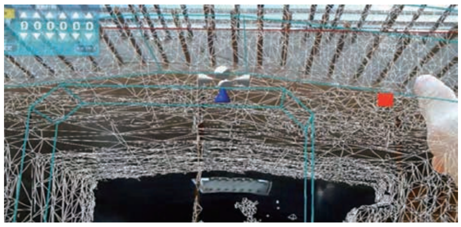
conventional technologies require personnel for tasks such as positioning marking, height measurement using levels, and looking out for safety, the newly developed system enabled automatic acquisition of traveling platform position and motion data in millimeters and eliminated manual tasks requiring more than one person such as marking and height measurement. With the new system, it is also possible to monitor the displacement of the traveling platform on a computer and therefore early detection of anomalies and labor saving are possible while manual observation was required when using conventional systems. Furthermore, the obtained data can be used for safety management, VR- and AR-aided training and it can also be used to extract girder deflection data usable as teaching data for AI-assisted deep learning.

3.2 Use of MR technology for inspection labor saving

The following approach was taken with the aim of improving the productivity of formwork assembly inspection and finished parts management. BIM models (formwork and finished parts 3D models) were loaded into an MR device via the cloud, and dimensions were measured on the screen. This measurement was made by using the MR device's spatial mapping capability for recognizing the surrounding space from recorded image data as 3D geometry data. The measurement of spatial dimensions has been made possible because 3D mesh data can be generated within the MR device in real time, by use of an infrared sensor, from image data acquired on-site. **Figure 22** shows measurements which can be made by linking up the motion of the MR device with the TS so that auto tracking can be performed[4]. **Figure 23** shows an example of a trial measurement procedure. As the first step, map the BIM data for the object to be measured onto the structure. Then, point the pointer on the screen to a point on the formwork or the object to be measured displayed on the MR device and air tap. After a cone representing a direction (forward, backward, rightward, leftward, upward or downward) appears, air tap the direction of measurement. This air tapping activates the automatic measurement of the distance between the two points of interest. The measurement results are automatically recorded in inspection record forms via the Internet. In a conventional inspection using a tape

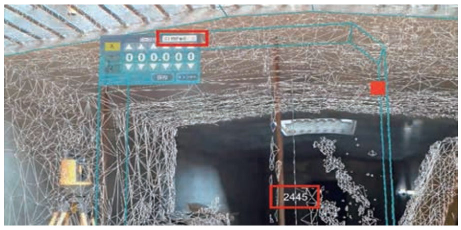
(a) Pointing and air tapping

- Accurately map formwork BIM data onto the structure.
- Point the pointer on the screen to a point to be measured on the formwork displayed on the MR device screen and air tap (i.e., touch your thumb to your index finger).



(b) Automatic measurement of the distance between two points

After the cones representing the forward, backward, rightward, leftward, upward and downward directions appear on the screen, air tap the cone representing the direction of measurement to execute automatic measurement of the distance between the two points.



(c) Automatic recording of measurement results in record forms

Measurement results are automatically transmitted via the Internet and recorded in inspection record forms.

Fig. 23 Example procedure of measurement trial

(a) MR device and TS instrument

(b) Prism

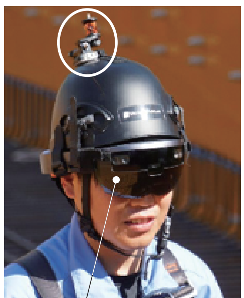


Fig. 22 Measurement using MR-TS integration[4]

measure or scale at unstable places such as elevated platforms, measurements need to be taken by two or more persons, and it is necessary to spend a significant amount of time carefully taking dimensional measurements while paying attention to safety. In a conventional inspection, it is also necessary to take inspection records back to the work office and prepare inspection record documents. In the measurement trial, the use of the MR device made it possible for one person to measure the formwork and finished parts by mapping the dimensions of the formwork and bridge girder cross sections onto the BIM data. The trial also solved another problem: In past measurement sessions in summer, the temperature of the MR device rose so high that the measurement system failed. In this measurement trial, the measurement system successfully performed continuous measurement without failing because a cooler device equipped with a miniature motor pump to circulate water through resin piping was used.

4. Use of BIM for Maintenance

Since the BIM models are supposed to be used for maintenance purposes over a long period of time, they are likely to be shared and utilized among different companies, organizations and other related institutions. In order to enhance maintenance technology in a feasible manner, it is necessary to make effective and efficient use of quality information in the future. **Figure 24** shows the BIM model management system. This system was used to add attribute information such as as-built geometry (finished parts) data and quality control record data to the 3D models, and the system packages thus prepared were delivered to the owners. It is expected that the quality control record and BIM digital data can be utilized to improve the efficiency of maintenance activities and conduct disaster prevention and mitigation simulations in the future.

5. Discussion

In the Koryo-Taki Road Taki PC bridge superstructure construction work, BIM was introduced on a trial basis to improve on-site productivity and enhance quality control technology. A series of experiments on the superposition of real-world space and a BIM model focusing mainly on MR technology revealed the following:

(1) In the superposition of a 3D model and work space, measurement error increases as the distance from the origin (AR marker) is longer.

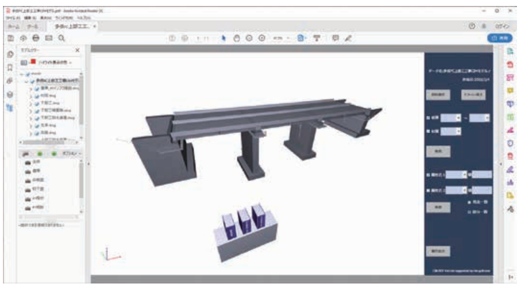


Fig. 24 BIM model management system

(2) In remote management, 3D model image resolution deteriorates as the amount of data increases to the extent that measurement locations and rebar placement details cannot be checked.

In the Ono-Aburasaka Road Kuzuryu River Bridge superstructure construction work, a new approach taken to improve labor productivity proved effective in improving efficiency. Concern still remains, however, about possible negative impacts on quality owing to the digitalization of construction and inspection. Examination of possible causes of such risks revealed the following:

(1) In the construction work using a 4D system for construction equipment, a coordinated system consisting of a network camera system and a recorder was used for analysis and recognition. During preliminary trial sessions, the safety management system for image analysis temporarily failed to recognize coordinate values in some cases when a person obstructed the view of a marker while the traveling platform was in motion. In order to prevent monitoring interruption even in such cases, the motion sensing capability was improved by using a high-resolution camera system capable of reading information faster. Attention was paid to the location of an object within the image frame, the method of capturing and the size of an object in the image frame. The accuracy of object sensing was found to be higher when an object is sensed in the central area of an image instead of the peripheral area because the object can be captured in its entirety. As a sensing parameter, the size of an object to be sensed (human detection) was also taken into consideration. For the purpose of coordinate information verification, the accuracy of the network camera system used was evaluated by repeating an experiment in which coordinate values were acquired at two-second intervals with a high-performance digital camera and comparing the results of both cameras. The experiments confirmed that similar levels of accuracy can be achieved.

(2) In the inspection in which MR technology was utilized, the combination of the MR device and a TS instrument resulted in high-accuracy measurement. Verification results indicate, however, that measurement errors occurred in areas where the 3D mesh data and edges of the structure overlapped on the MR device screen to the extent that measurement points were difficult to identify. There is a need, therefore, to make measurement points easier to identify on the MR device screen and further improve measurement methods. System research is currently underway on the stability and accuracy of measurements. Remote presence technology using an MR device requires that a large amount of data, such as video and image data obtainable during inspection, be acquired in real time. At construction sites where a satisfactory telecommunication environment is not available, the current practice is to use long-range Wi-Fi devices designed for industrial telecommunication applications, until 5G coverage

expand, to meet telecommunication environment requirements.

It is believed that the next step is to accumulate data through measurements conducted by using a combination of BIM data and ICT and verify the accuracy thus attained, in order to develop a highly efficient construction quality management system.

6. Conclusion

Through field testing, BIM-based front loading has proved to be effective in reducing the time required for construction work. It has also been confirmed that measurement accuracy achievable with the front loading approach in combination with TS surveying technology is comparable to that achievable with conventional technology, and that the approach can also be used for labor saving and working time reduction. The utilization of BIM is a promising means which might provide solutions to the problem of the decreasing number of skilled civil engineers attributable to the declining birthrate and aging of society. The number of BIM utilization attempts remains limited, and there are some problems yet to be addressed such as the shortage of engineers capable of making effective use of BIM. There is a need to develop BIM software that does not require experts capable of making image analyses and system refinements involving AI and other technologies on-site when utilizing construction quality management systems at construction sites in future projects. The Koryo-Taki Road Taki PC bridge superstructure construction work was completed in January 2019 as scheduled. **Figure 25** shows the completed bridge superstructure[(2)]. The Ono-Aburasaka Road Kuzuryu River Bridge superstructure construction work was completed in December 2019. **Figure 26** shows the completed bridge superstructure[(2)].

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Fig. 25 Completion of construction of Taki PC upper bridge[(2)]

Fig. 26 Completed bridge superstructure of Kuzuryu River Bridge[(2)]

REFERENCES

(1) Ministry of Land, Infrastructure, Transport and Tourism : the i-Construction Promotion Consortium, < http://www.mlit.go.jp/tec/i-construction/index.html >, accessed 2019-12-3

(2) H. Atarashi, K. Yamashita, M. Watanabe and Y. Wakabayashi : Efforts for utilization of 4DCIM and quality management in bridge superstructure construction: Koryo Taki road PC bridge superstructure construction, Journal of Civil Engineering, Vol. 60, No. 5, 2019, pp. 67-70

(3) Y. Wakabayashi, S. Nakamura, K. Yasuda, Y. Hirahara and H. Atarashi : Improvement in efficiency of bridge superstructure construction with CIM, PROCEEDINGS OF ANNUAL CONFERENCE OF THE JAPAN SOCIETY OF CIVIL ENGINEERS, No. 74, VI-933, 2019

(4) Y. Wakabayashi, K. Mitani, T. Akamatsu and K. Yasuda : BIM/CIM-Based Prestressed Concrete Box Girder Bridge, Construction Productivity Improvement, Proceedings of The 29th Symposium on Development in Prestressed Concrete, 2020, pp. 481-484

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