THE INTRODUCTION EFFECTS OF 3D INFORMATION MODELS IN KOISHIWARAGAWA DAM CONSTRUCTION PROJECT

T. MIYAZAKI
Asakura Management and Construction Office, Japan Water Agency, Fukuoka, Japan

T. YOSHIDA
Yachiyo Engineering Co., Ltd. ,Tokyo, Japan

ABSTRACT

The Construction Project of the Koishiwaragawa Dam, which is a rockfill dam and is to start operation from April 2020, is conducted by the Japan Water Agency. This project is a leading case of applying Three Dimensional (3D) information models to the design and construction process from the early stages of the owner's work. In Japan, the 3D information model in the civil engineering field is called Construction Information Modeling/Management (CIM).3D graphic models of the dam and surrounding structures were developed before starting construction of the dam body. Using Navisworks, an integrated application from Autodesk, the models incorporated a lot of construction-related information such as geological data on dam site and quarries, quality control data on embankment and monitoring data of the measuring devices installed in the embankment. This made it easier to recognize each data spatially and chronologically, to grasp the construction process, and to share the acquired information among relevant people, eventually streamlining the entire work process. Currently, we are planning to upgrade this system to make the record management around the dam and reservoir more efficient, by inputting monitoring data of the displacementdam body, surrounding slopes and patrolling record data into the 3D models after the initial impoundment.

1. INTRODUCTION

The Koishiwaragawa Dam is a multi-purpose dam for flood control, maintenance of the normal functions of water flow (including the replenishmen of emergency water at the time of an extraordinary drought) and new water utilization, and is under construction in the upper reach of the Koishiwara River in the Chikugo River system in Kyusyu Iland. It is a center core type rockfill dam with a dam height of 139 m. Construction work started in April 2016 and the embankment reached crown height in July 2019.

With the background of the conspicuous advancement of information and communication technologies in recent years, the Japan Water Agency (hereinafter referred to as "the Agency") has been working on improving productivity and work efficiency, from design and construction to operational management. In the Koishiwaragawa Dam Construction Project, the Agency has developed a CIM system for the first time to be operated by the owner at the design stage and has been examining the potential use of this CIM system at the construction stage and its further application at the operational management stage.

This paper reports the principal efforts made during the course of the development and application of the CIM system in question.

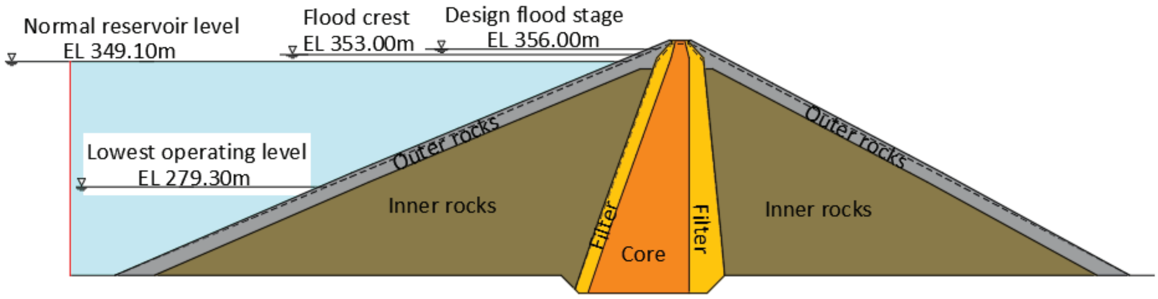


Figure 1 : The standard cross-section ofthe Koishiwaragawa Dam

2. CIM SYSTEM FOR THE KOISHIWARAGAWA DAM

2.1 3D modeling of design drawings

A CIM system for the construction stage was constructed as a system to convert a design drawing into a 3D model and add attribute information to it. The 3D modeling targets were topography, geological information, embankments, and surrounding structures such as flood spillways, inspection gallery, embankment roads. These models are shown in Figure from 2 to 5.These individually created models were integrated using Navisworks from Autodesk. Figure 6 shows an integrated model of the whole area around the dam and the reservoir.By presenting the completed image with the integrated model, consensus building among the relevant people proceeded smoothly.

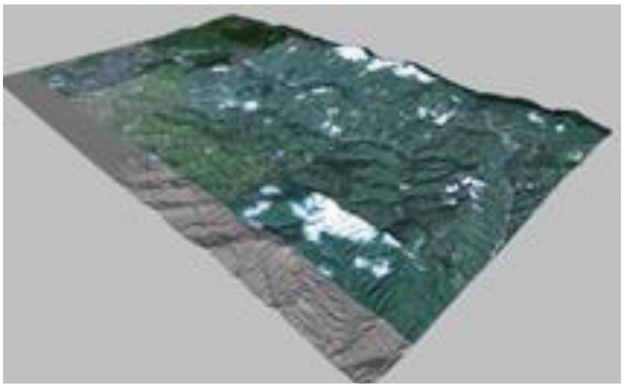


Figure 2 : Topography of Koishiwara River basin

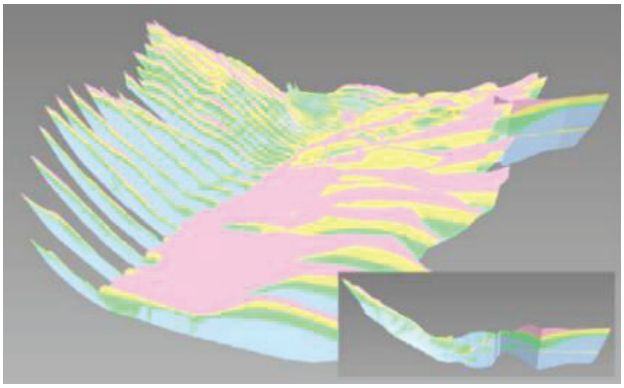


Figure 3 : Geological information
(Rock mass class :Panel diagram)

Figure 4 : Embankment

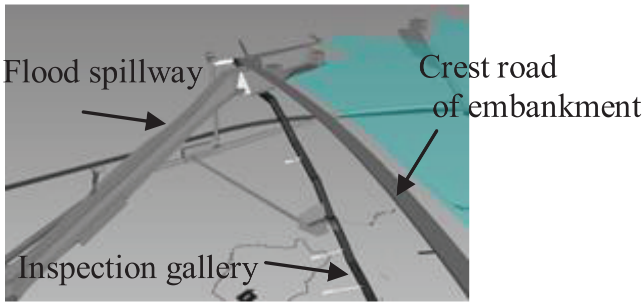


Figure 5 : Surrounding structures

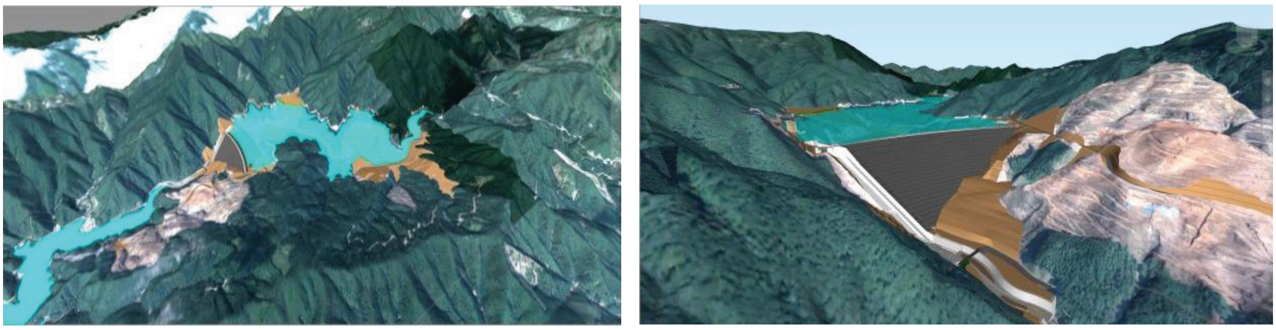


Figure 6 : Integrated forthe Koishiwaragawa Dam
(Left : Reservoir andits surrounding area; Right: View from the downstream of the dam body)

The creation of a 3D model has made it easier to capture three-dimensional structures that were difficult to understand with conventional design drawings alone. Mutual interference was confirmed from the waterway intersection shown in Figure 7 and the positional relationship between the conduits and cable racks in the inspection gallery shown in Figure 8, and this was reflected in the design review and construction plan.

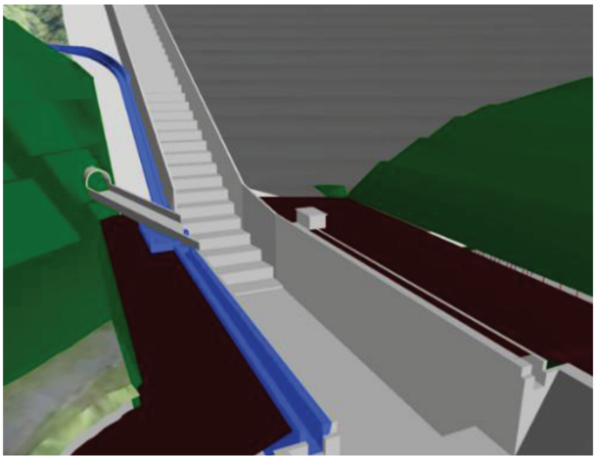


Figure 7 : Waterway intersection

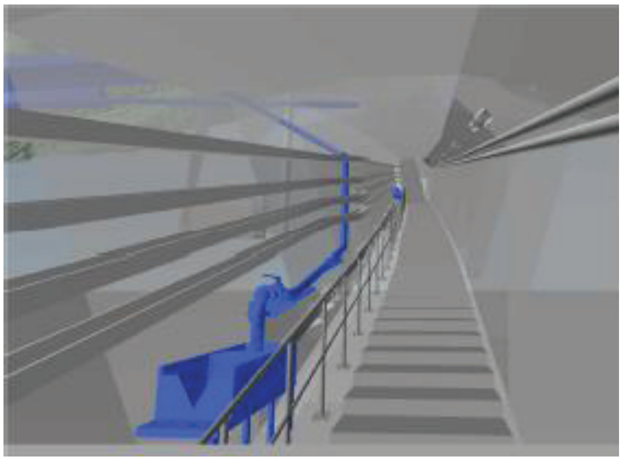


Figure 8 : Conduits and cable racks on the side of the spillway in the inspection gallery

A CIM system for the maintenance stage primarily focuses on its use for continual verification of dam safety, etc. by means of integrating patrol, inspection and measuringresults on a time-series basis to the post-completion model.

As the contents of the information to be updated and frequency of updating differ between the construction stage and maintenance stage, two CIM systems have been developed to serve the construction and maintenance stages.

2.2 CIM operating system

The construction CIM is required to make the model reflect the design (revised) drawings and to sort out the reference materials, such as construction records, etc., for accumulation in the system. For the purpose of the smooth operation of the CIM, a system has been developed to make the Agency, design consultant and the contractor cooperate with one another. Construction management data obtained through the progress of the work is swiftly shared using a cloud storage service to modify the 3D model and to attach attribute information.

In the case of the maintenance CIM, a system to be operated by the Agency has been developed to input and output patrol records, etc. and more details are given later.

2.3 Construction CIM

Civil engineering structures, such as road and dam body, etc., are affected by the initial form of the ground and their shapes have their own characteristics. As it is difficult for a single 3D- Computer Aided Design (CAD) software to conduct the modelling of all types of civil engineering structures, it is necessary to select the best software to match the characteristics of civil engineering structure from a number of 3D-CAD software programs to conduct the necessary modelling. The data formats of these software programs may not be compatible. Navisworks of Autodesk was used to create the construction CIM system for the integrated management of CIM as this software is capable of loading various data formats, making the model lighter and enabling the attachment of attribute information.Figure 9 shows the composition of the construction CIM software.

As far as topographical data is concerned, a model solely for the area around the Koishiwaragawa Dam Reservoir has been developed usingLeaser Profiler(LP) data which is based on aerial surveying. For the outlying basin, 10m mesh data published by Geospatial Information Authority of Japan was used.

OS	Windows 10（64bit）
Memory	16GB
Graphics	AMD, NVIDIA 2GB
Storage	SSD: 256GB

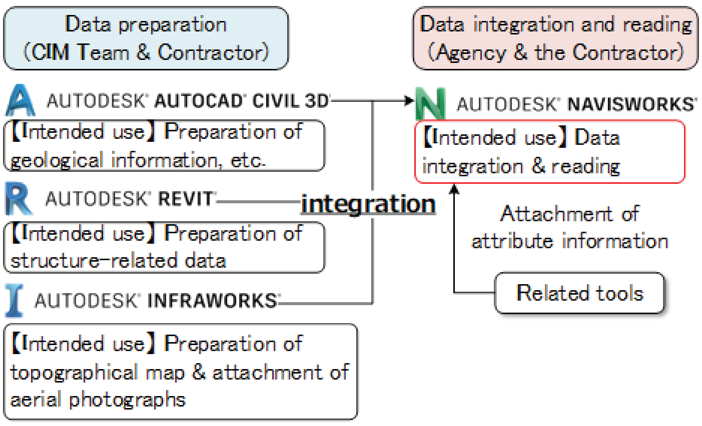


Figure 9 : Composition of the construction CIM software

2.4 Maintenance CIM

At the maintenance stage, the aim was to efficiently grasp the situation of the dam and area around the reservoir by means of spatiotemporally summarizing and arranging various types of monitoring information using the CIM. For this reason, a Web-based maintenance CIM system was created, bringing linkage with various monitoring systems, including the measuring instruments, into perspective.Figure 10 shows the composition of the maintenance CIM system.

The 3D model uses the "Three.js" of Web Graphics Library (WebGL) and has a user interface which is capable of integrally managing the CIM models for the design and construction stages as in the case of the construction CIM system.

With the models developed by the construction CIM system and externally referenced attribute information, a tree structure to arbitrarily select structures and a "ledger management" function were installed to the system for data storage. Moreover, the system was also given a "history management" function to store and chronologically arrange patrol, inspection and check data acquired at the maintenance stage and recorded on a table, etc. in relation to the relevant models. Furthermore, a graph function was added so that the measured and observation values automatically acquired by various monitoring systems could be made into graphs in connection with the CIM models.

It is believed that the developed system is capable of establishing the situation of various facilities and quickly responding to abnormalities at the operation and maintenance stage by means of combining measured data, etc. on the reservoir water level, dam body deformation, etc. with the patrol and inspection records which are managed in a three-dimensional space.

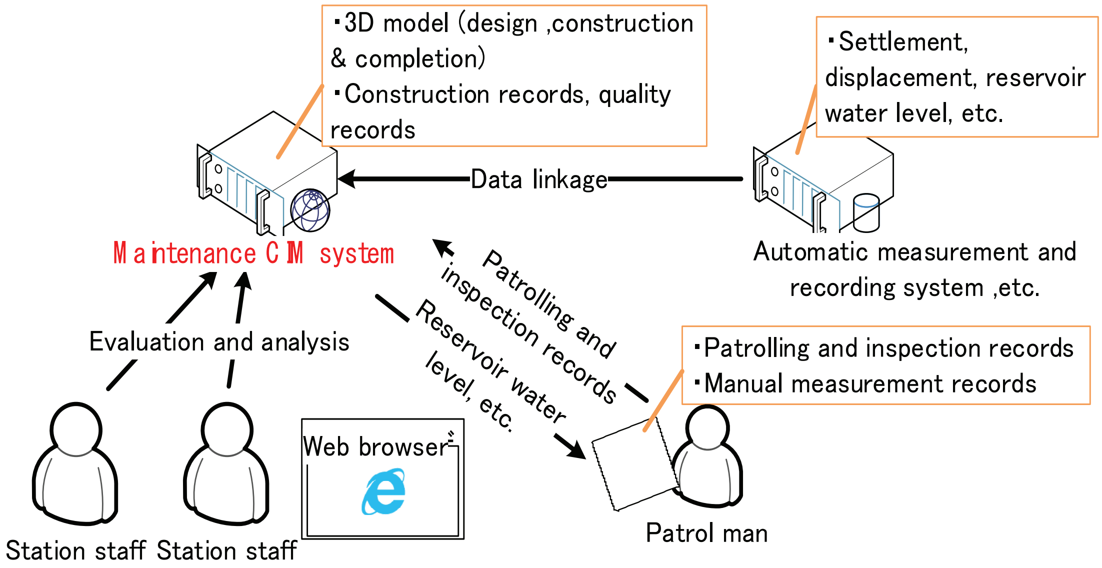


Figure 10 : Composition of the maintenance CIM system

3. UTILIZATION OF CONSTRUCTION CIM

Here, the case of examining the appearance of the dam administration building is reported along with the utilization situation of the construction CIM system regarding such representative types of dam body work as "embankment work", "interior instruments" and "foundation treatment".

3.1 Embankment work

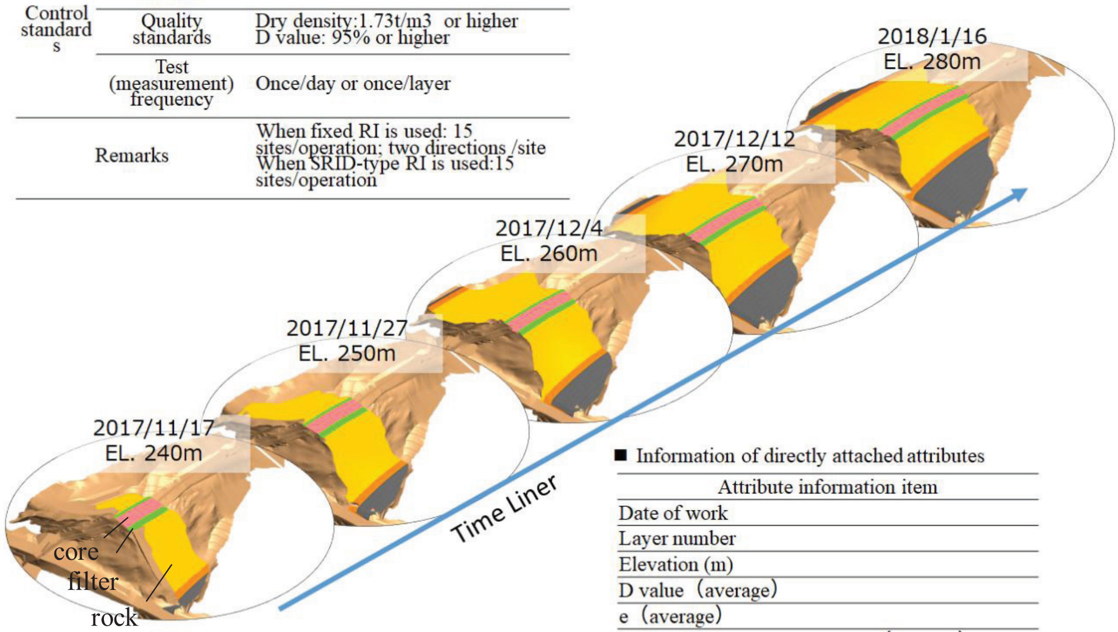
For the embankment work, the completed amounts of work per day and per month are modelled along with the design models corresponding to the core, filter and rock zones.

Figure 11 shows the progress of embankment work in chronological order. Quality control of the embankment surface involves regular management tests (in-situ permeability test and in-situ density test, etc.), and routine control tests (dry density (Radio Isotope (RI) method), moisture content, etc.) conducted for each work layer along with whole area measurement of the number of compactions and Compaction Control Value (CCV) for all construction layers.

Figure 12 is a graph showing the measurement results of the compaction degree in elevation or time series.These measurement results are stored as attribute information of the model, and necessary information can be efficiently extracted.

■ Quality control standards for core materials (excerpt)

Test (measurement) item		In-situ density test
Control standards	Test (measurement) method	RI method
	Quality standards	Dry density:1.73t/m3 or higher D value: 95% or higher
	Test (measurement) frequency	Once/day or once/layer
Remarks		When fixed RI is used: 15 sites/operation; two directions /site When SRID-type RI is used:15 sites/operation



■ Information of directly attached attributes

Attribute information item
Date of work
Layer number
Elevation (m)
D value （average）
e （average）
Field permeability coefficient （average）
Compacted sand dry density （average）
Compacted sand D value （average）

Figure 11 : Embankment work model

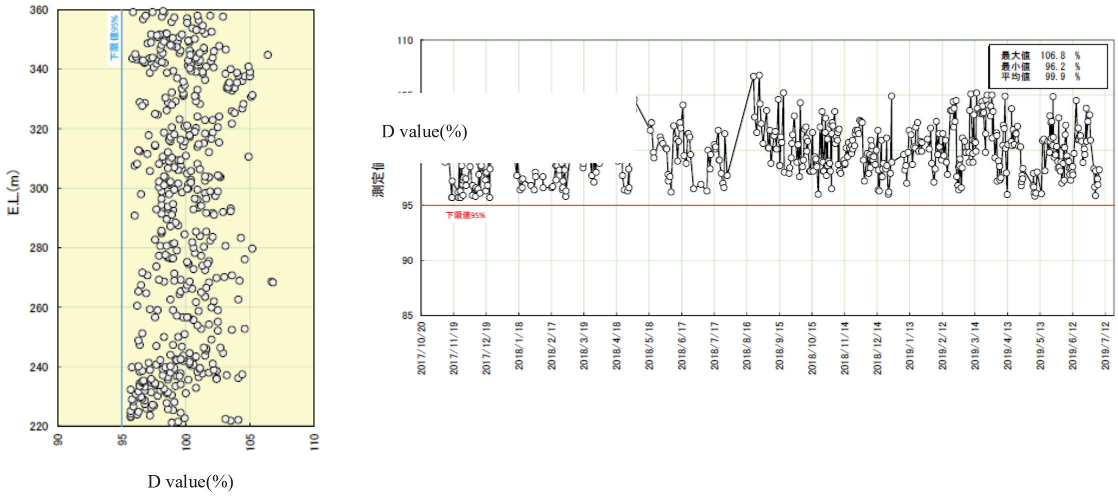


Figure 12 : The measurement results of the Compaction degree (D value)
(Left: Graph in elevation; Right: Graph in time series)

3.2 Embedded instruments

Various instruments are installed inside the dam body and have been conducting various observations since the construction stage.

With the construction of CIM system, plotting of the installation sites of these interior instruments on the relevant models has been attempted to store observation data as attribute information while making graphs into 3D models in the CIM space.

Figure 13 show the modelling of the measured values of differential settlement. Although the graphs are semi-3D models where projection is made to specific traverse lines corresponding to the direction of the upstream and downstream of the dam, they can assist understanding of three-dimensional behavior, such as a change of the settlement volume corresponding to the progress of the embankment work. More detailed numerical data can be checked using attribute information.

As mentioned earlier, access to quality control data around the instruments at the time of the embankment work means that it is possible to grasp the relationship among the obtained observation results using the CIM as the starting point.

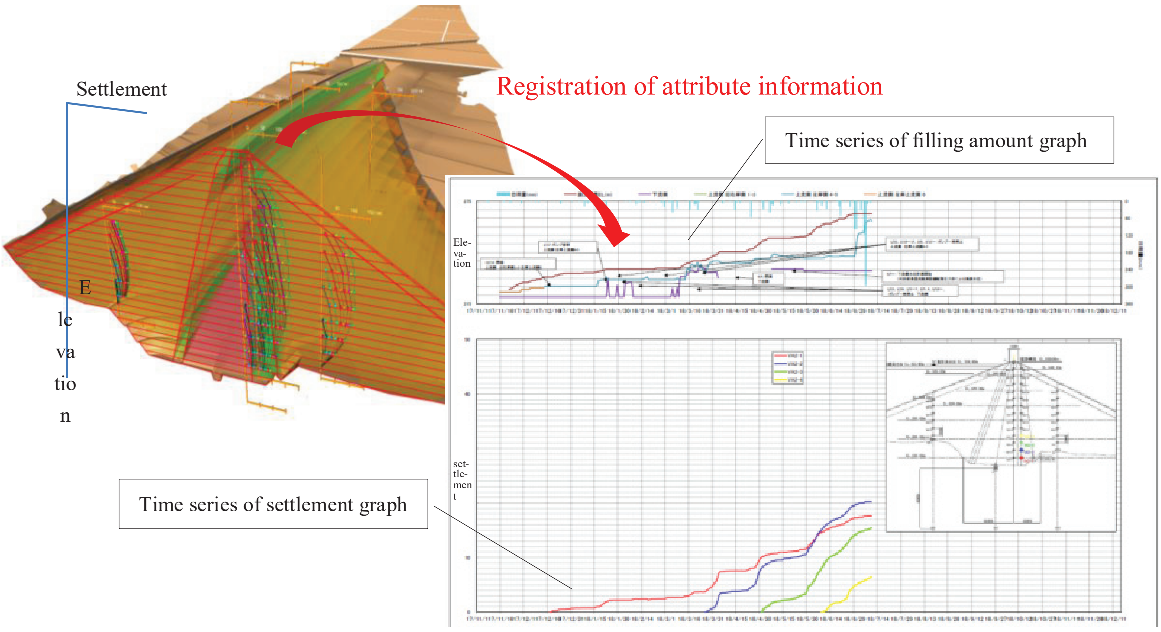


Figure 13 : Modeling of the differential settlement gage graph

3.3 Foundation treatment

For the 3D model for foundation treatment, the lugeonvalue and injected cement volume, etc. as grouting data (see Table 3) are directly attached as attribute information while photographs of the core, cement injection chart and permeability test results, etc. are provided as linked attribute information. The results of foundation treatment were created as a cylindrical model shown as Figure14. The lugeon value is classified by color, with red being high water permeability and blue being low water permeability. (Table 1) The cement injection amount is classified by diameter, and the larger the diameter, the larger the injection amount. (Table 2)

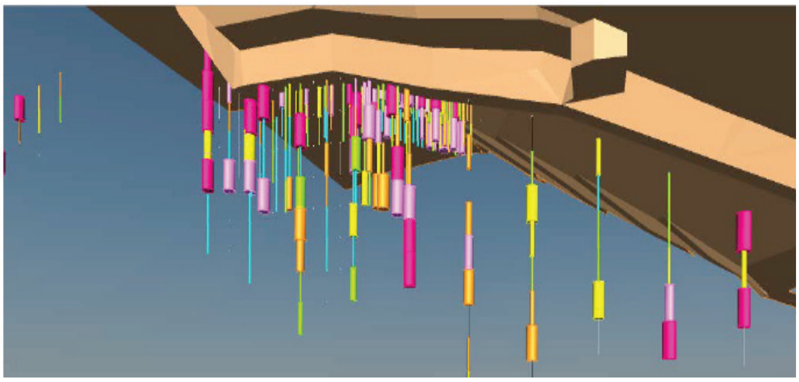


Figure 14 : Grouting model

Table 1 : Coloring by lugeon value

Lugeon Value	RGB
50 < Lu	255.0.122
20 < Lu ≦ 50	255.122.255
10 < Lu ≦ 20	255.142.30
5 < Lu ≦ 10	255.255.0
2 < Lu ≦ 5	127.255.255
Lu ≦ 2	0.255.255

Table 2 : Cement unit injection volumeand diameter

Unit Cement Injection Amount (kg/m)	Cylinder Diameter (m)
400 ≦	2.4
300 < ~ ≦ 400	2.0
200 < ~ ≦ 300	1.6
100 < ~ ≦ 200	1.2
50 < ~ ≦ 100	0.8
< 50	0.4

Table 3 : Directly attached attribute information

Attribute		Unit	Example
Date of work			2017/4/1
BL			B15
Line number			UG
Hole number			2250
Degree			1
Stage			0.1
Drilling depth	Upper end	m	0
	Bottom end	m	0.5
Drilling length	Concrete	m	0.05
	Bedrock	m	0.45
	Total	m	0.5
Drilling method			P/NC
Bore diameter		mm	66
Tilt angle		θx	0
		θz	0
Borehole elevation		m	230.46
Spring water			
Drilling time	Starting time	h:min	13:55
	Ending time	h:min	14:00
	Duration	h:min	0:05
Cement unit injection volume			200
Lugeon value			20
Drilling situation			Drilling completed

Grouting data was imported into CIM as the construction progressed and used as a database. It was used to evaluate the hydrogeological structure and contributed to the efficiency of operations.

The use of directly attached information makes classification by degree and limited display of those stages where a higher permeability than the set value is detected possible. Figure 15 shows an extraction result based on number of operations. From 1st operation to 4th operation, it is easy to confirm that the ground has been improved by the foundation treatment and the area with high water permeability has been reduced.

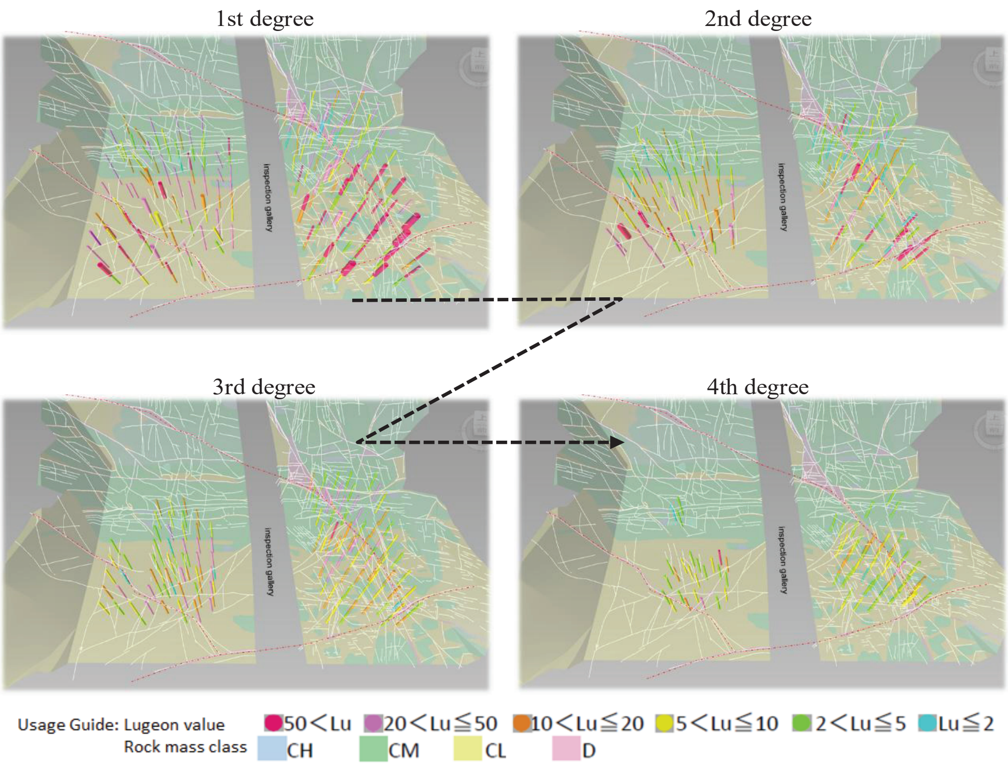
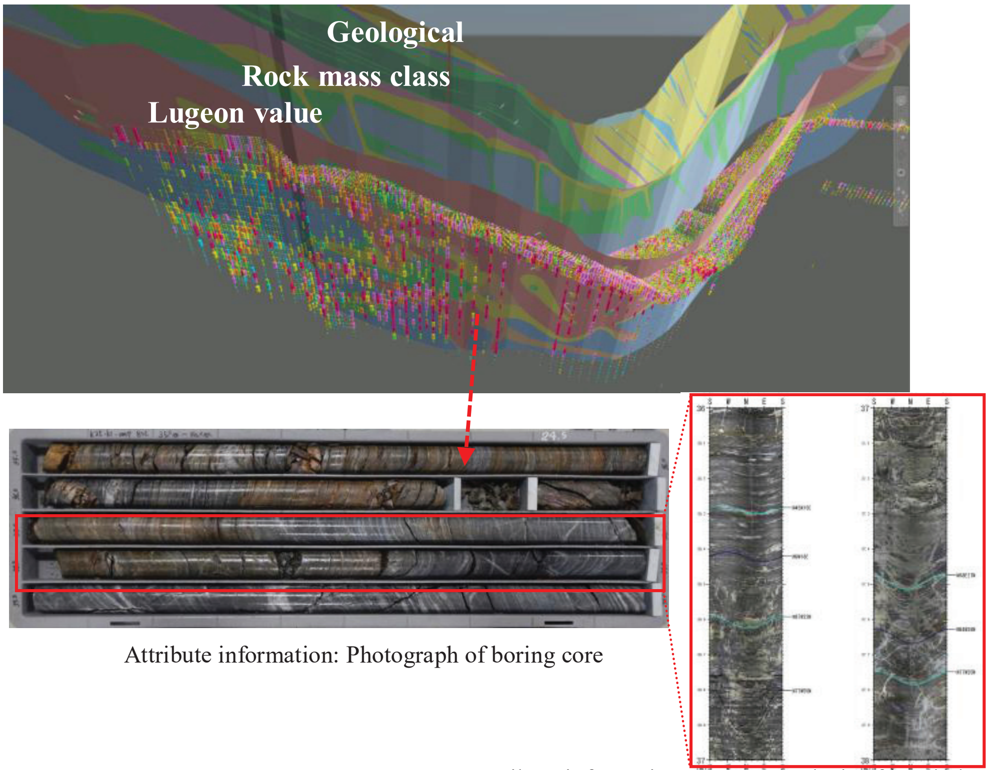


Figure 15 : Extraction of grouting results by degree

Figure 16 superimposes the curtain grouting results on the geological cross-section. The information on local geology, etc. at the design stage consists of the geological class, rock class and lugeon value. They can be easily switched on the model or shown in parallel by sliding their positions. These figures can be used as tools for information sharing and discussionsamongrelevant people.



Attribute information: Scanner analysis of borehole

Figure 16 : Results of curtaingrouting and geological information
(In the cross-section, lugeon value, rock mass class and geological from the fore to the back)
(Photographs of core, etc. are stored as the attribute information at each stage.)

4. OPERATING PLAN OF CIM FOR MAINTENANCE

4.1 Loading of monitoring data

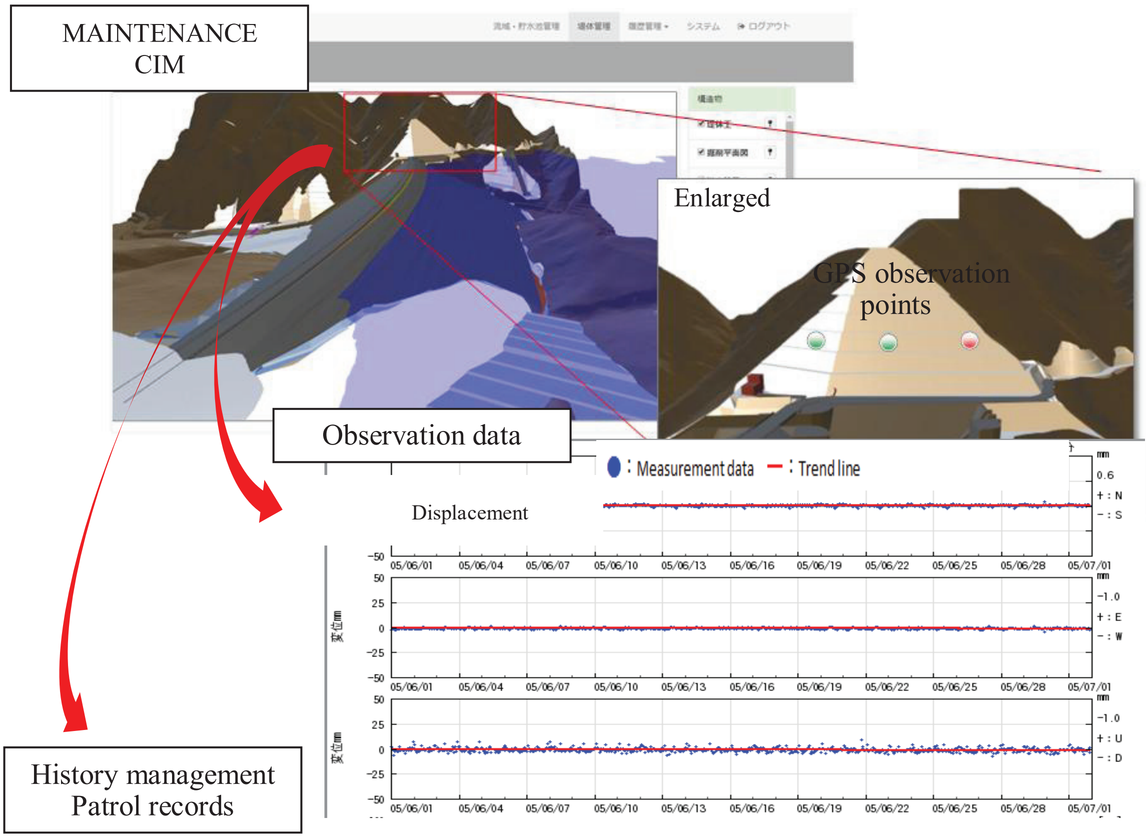
It is planned that the maintenance CIM system will accumulate newly measured data and patrol records, etc. at the operation and management stage in addition to the models and attribute information established by the construction CIM system so that information on the dam and reservoir can be managed in an integrated manner.

At the Koishiwaragawa Dam, a system capable of delivering data is developed by attaching an automatic measuring instrument and communication equipment to the GPS system to measure the deformation of the dam body as well as the borehole inclinometer, ground extensometer and ground water level gauge, etc. to measure the landslide behavior of the reservoir.

The maintenance CIM system developed is capable of integrating the measured data and displaying it in the form of graphs. Confirmation of the position of each equipment using the 3D model and mutual checking of the graphs for various measuring instruments make it easier to understand the three-dimensional behavior and relationship among various sets of data.

Figure 17 shows the GPS observation points on the slope of the dam site. In addition to the graph display, information on history management can be obtained from the maintenance CIM system, so that this information can be easily compared with patrol records.

It can be expected that the entire picture of the phenomena obtained from the measured and monitoring data can be efficiently evaluated by means of utilizing and combining the various functions described above.



Inspection Date	Location information		Content	Status	Artilcle
2019/6/1	dam site	slope	Are there any cracks?	No abnormality	
2019/6/1	dam site	slope	Are there any spring water?	No abnormality	
2019/6/1	dam site	slope	Are there any other abnormalities?	No abnormality	

Figure 17 : Verification of monitoring data and work records

5. CONCLUSIONS

In the Koishiwaragawa dam construction project, the introduction effects of CIM were as follows.

1. By creating a 3Dmodel of the design drawing, it was possible to easily grasp the interference of structures that was understood with difficulty in the past, and it was possible to review the design and reflect it in the construction plan.
2. By presenting the completed image in a 3D model, consensus building among the relevant people proceeded smoothly.
3. By saving the attribute information at the time of construction as an external reference linked to the model, the extraction of necessary data was made more efficient. In addition, in the basic processing, specific conditions can be selected by directly adding attribute information to the construction performance model, which has been useful for evaluating construction results.
4. At the maintenance stage, the history of dam and slope measurements and patrol records were consolidated into a CIM-based system to make it easier to grasp the condition of the dam.

The Koishiwaragawa Dam is under initial impoundment, and we will continue to improve the CIM in the maintenance stage.