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The Development and Management of the ICT System for Dam Construction at Okukubi Dam

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ABSTRACT:
We developed and operated the ICT System for Dam Construction at Okukubi Dam (completed in March 2012), the world's first full-fledged trapezoidal cemented sand and gravel dam we constructed in Okinawa Prefecture. This system enables improvements in efficiency and assurance of the quality of construction by keeping track of three-dimensional positions and temporal information using construction machinery such as bulldozers, vibrating rollers, backhoes and dump trucks equipped with GPS, and by managing construction data in four dimensions (X,Y,Z,T) by units of elements, based on a database called 4D-DIS (4 Dimensions – Dam Information Service).

Keywords: Okukubi Dam, Trapezoid CSG Dam, ICT Construction, 4D-DIS, Traceability

1. INTRODUCTION

As indicated in Fig.1, this system centers on the 4 Dimensions-Dam Information Service and consists of individual subsystems such as the rolling compaction control system, material tracing system and the slope compaction control system. These subsystems enable improvements in efficiency and assurance of the quality of construction.

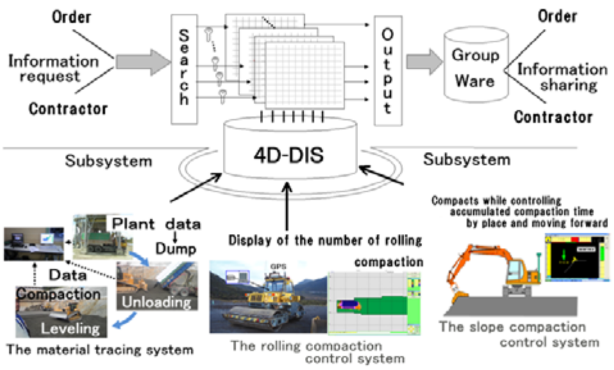

Figure 1. Summary of the Whole System

2. 4D-DIS DATABASE CORE

For the 4D-DIS core, we have adopted the Relational Database Management System. The characteristics of the core exist in that it manages accumulated data four-dimensionally with use of a coordinate and time .
As indicated in Fig.2, the interior of a construction is to be treated by element.

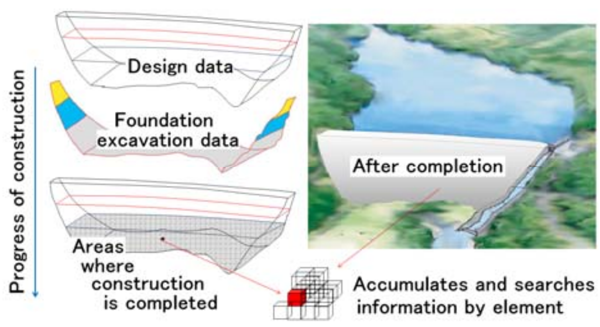

Figure 2. Data Concept

Once you designate an element or a scope of elements, a series of information on the relevant element/elements including compositions and manufacturing dates of materials, construction methods used and construction results will be searched and extracted. As indicated in Fig.3, you can designate items as follows:

・The scope of a search
  you can designate a subsystem, a portion of data, or target all.
・Place/the scope of places
・Time and date/the scope of times and dates

The function to add searching options as necessary is also installed.

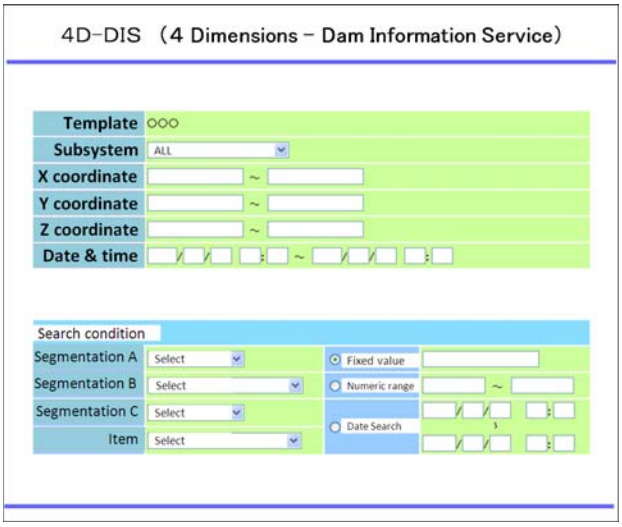

Figure 3. Search Data Screen

3. SUBSYSTEMS APPLIED TO THE OKUKUBI DAM

The Okukubi Dam, to which this system has been applied, is a trapezoidal CSG dam with the following specifications:

・Structural height: 39.0m
・Crest length: 400m
・Volume: 339,000 m^3
・Reservoir capacity: 8,560,000m^3
・Reservoir area: 0.61km^2
・Catchment area: 14.6km^2

The summary of the Dam is shown in Fig.4.

Figure 4. Construction Condition of the Okukubi Dam

In the management of CSG construction, in addition to attended inspection such as phased confirmation and the grasp of construction conditions by visual observation, we implement quantitative confirmation with use of Information and Communication Technologies regarding the following items:

・Leveled thickness 3 layers (25cm per layer)
・Compaction
 The number of rolling compaction in general areas. There are 2 non-vibrations and 6vibrations. And compaction time of slope edges are 30 seconds.
・Time Control
 The time limit from material manufacture to the start of rolling compaction within 6 hours.

The subsystems were applied to include the control systems for rolling compaction, slope edge compaction and compaction completion time. Also, from the viewpoint of data accumulation, the batcher plant and the weather station can be regarded as part of subsystems. Here, we focus on the followings as major functions of subsystems and report their utilization in field sites:

・Execution of informatization in management of transportation and extraction of base materials
・Compaction control (rolling compaction and slope edge compaction)
・Material tracing system for Control of compaction completion time
・Control system of leveled thickness of CSG materials

3.1. Execution of Informatization in Management of Transportation and Extraction of Base Materials

By utilizing Integrated Circuit tags in the management of extraction, transportation and temporary placement of base materials, the system prevents human errors, assures classification in temporary placement and grasps quantities (Fig.5). Moreover, we created a three-dimensional model of the borders between base materials and waste rocks from boring exploration and geological data. By revising this with the field survey data, we confirmed the possible extraction quantity of base materials (Fig.6).

This system writes the type of base materials on the IC tag mounted on a dump track when the operator in the backhoe presses the selecting switch corresponding to the material type in loading base materials on an individual dump truck. Then, when the dump truck leaves the loading area, the system reads the information on the IC tag and indicates the designation on the display board. The driver of the dump truck sees the display and drives to the stock yard. On arriving at the destination, the system reads the information on the IC tag at the entrance and indicates the unloading location corresponding to the type of base materials.

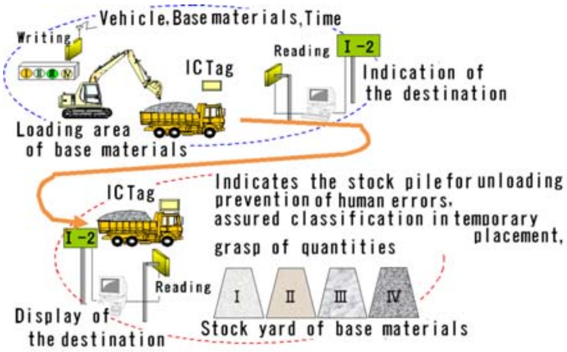

Figure 5. Image of Base Material Management

Because the driver of the dump truck can confirm the unloading location here, it becomes possible to assure classification in temporary placement and prevent human errors.

Furthermore, we created a three-dimensional model of the borders between base materials and waste rocks from boring exploration and geological data. By revising this with the field survey data, we enabled to confirm the possible extraction quantity of base materials (Fig.6).

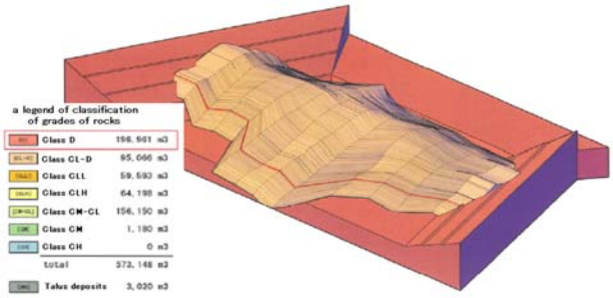

Figure 6. Management of Base Materials by Execution of Informatization

3.2. Compaction Control

This system, with the Global Positioning System, wireless LAN and an in-vehicle personal computer being mounted on the compaction roller, counts and records how many times and where in the working area compaction is conducted on a pre-determined mesh-by-mesh basis (Fig.7).

Because the numbers of rolling compaction by mesh are indicated in different colors at the monitor of the driver seat, the operator, based on this information, runs operation until all meshes reach specified numbers. In addition, economical construction is possible even when using multiple numbers of compaction rollers because the accumulated number of rolling compaction is indicated on each mesh. Figs. 8 and 9 indicate examples of display screen images of rolling compaction. The information was shared at the offices of the order and the contractor in real time.

Figure 7. Compaction Roller

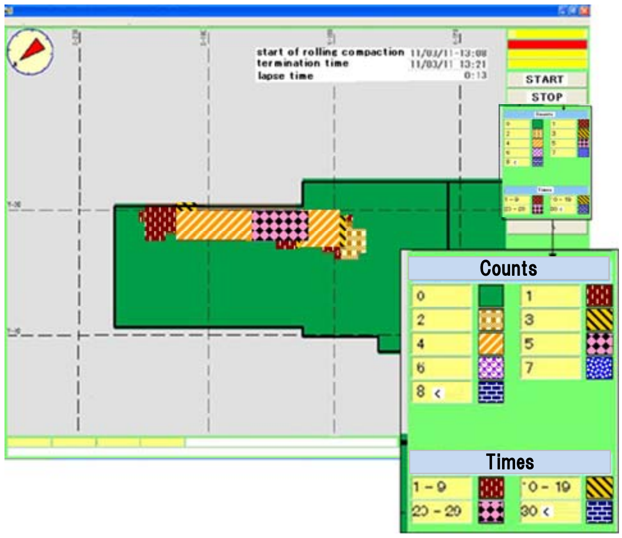

Figure 8. Example 1of the Screen to Share Display Information on Rolling Compaction

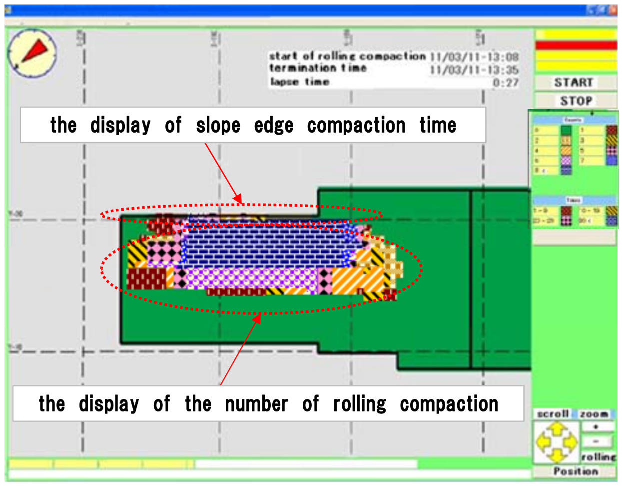

Figure 9. Example 2 of the Screen to Share Display Information on Rolling Compaction

In the display screen image of the number of compaction by a roller, non-compacted areas are displayed in green, and the color changes according to the number of the rolling compaction as follows: the areas compacted once are in brown, twice in pale brown, three times in yellow, four times in vermillion, five times in pink, six times in purple, seven times in blue and more than eight times in dark blue. (Figure is displayed in variable density. The same hereinafter.) The operator implements compaction of a specified number while referring to these colors. Next, Figs.10 and 11 indicate images of compacted slope edges. On slope edges, compaction is done by a special machine equipped with a vibration generator. On slope edges, differently from compaction by a roller, compaction control is based on the position and time and compaction is carried out until the accumulated compaction time on a certain position reaches the specified number of seconds.

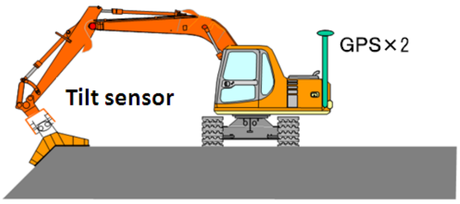

Figure 10. Image of Slope Edge Compaction (Transverse Direction)

Figure 11. Operational Situation of Slope Edge Compaction

This is because continuous compaction in a specific area may cause gaps and other problems on slope edges, and we take the method to repeat compaction while moving around different areas. And the display is designed to indicate whether the accumulated compaction time in each area reached the specified time. Here, time is indicated in brown for 1-9 seconds, in yellow for 10-19 seconds, in pink for 20-29 seconds and in dark blue for 30 seconds and over. As these conditions of slope edge compaction are displayed together on the screen of rolling compaction (Figs. 8 and 9), the operator conducts compaction while watching this display along with the screen indicating the induced position of the vibration generator (Fig. 12).Because the operators of both work machines conduct operations while watching this display on the monitors of their driver seats, they can prevent shortage in compaction. In addition, because these pieces of information are accumulated and saved, it is also possible to track back situations in the past and playback continuously. This feature is utilized at both offices of the order and the contractor.

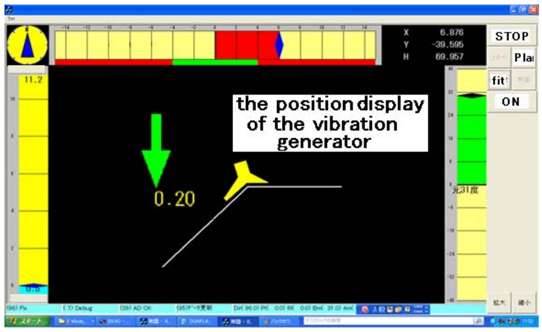

Figure 12. Screen Display Image of Slope Edge Compaction

3.3. Material tracing system for Control of compaction completion time

This system controls the time from CSG manufacture in plants, transportation of materials and leveling operation to the start of compaction by a roller and other equipment as well as the completion time of compaction. This should be done within 6 hours after CSG manufacture. The functions of the system include the followings (Fig. 13):

・Transmission of information on CSG manufacture in CSG plants to vehicles

・Measurement of installation positions by vehicles and information transmission

・Displaying the starting and completion time of CSG compaction

These pieces of information are also shared at offices of the order and the contractor.

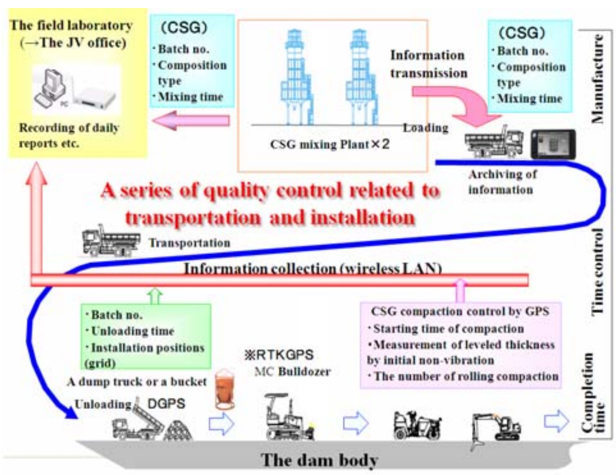

Figure 13. Material Tracing System

First, batch information on materials is sent to the personal computer installed on the dump truck, simultaneously with throwing CSG materials manufactured in the CSG mixing plant into a dump truck. Because this dump truck is equipped with a Differential GPS, the position where the truck transports and unloads the materials can be tracked. Then, the information both on the unloading position and batch is send to the field monitoring room via wireless LAN. Next, at the stage where leveling operation by a bulldozer and compaction by a roller including slope edge compaction are carried out, the information on lapse time after material manufacture on each position enables the operator of the roller including slope edge compaction to know the priority of locations to conduct compaction. Fig. 14 indicates the time control screen shown at this time.

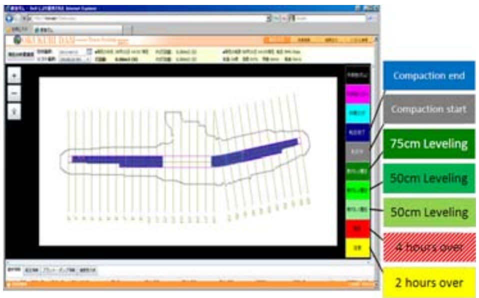

Figure 14. Screen to Control Compaction Time

By the way, the numbers of hours after material manufacture are indicated by color on the screen. Fig. 15 indicates this changing situation.

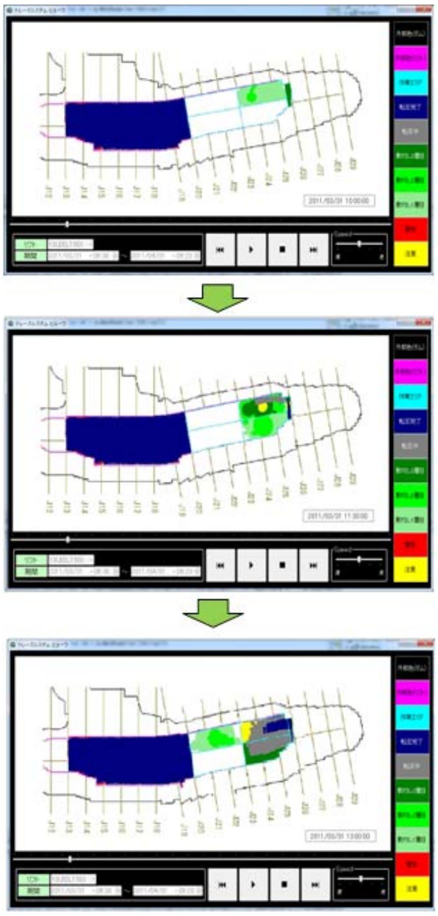

Figure 15. Example of a Replayed Screen Image of Compaction Time Control

White indicates places where no leveling operation has been implemented. Pale green indicates that the 1st layer has been leveled, green for the 2nd layer and dark green for the 3rd layer. Moreover, the materials older than 2 hours are indicated in yellow and the color turns red when 4 hours has passed. Therefore, the operator conducting rolling compaction or slope edge compaction, while watching this display, operates on locations of priority. When rolling compaction or compaction is carried out, the area turns into gray. On completion of the operation, the area is indicated in dark blue.

Because the data on this compaction completion time control by the tracing system is also accumulated and saved, one can track back to a past point and play back at offices of the order and the contractor. Fig. 16 indicates the operational cycle of the tracing system.

Figure 16. Operational Cycle of the Tracing System

3.4. Control of Leveled Thickness of CSG Materials

Although we first planned to control leveled thickness by rotary laser levels, we finally adopted the work method using bulldozers equipped with machine-controlling functions (hereinafter MC bulldozers), taking account of workability and motion path recording. A MC bulldozer is to enable to level designed heights by utilizing GPS and automatically controlling the bulldozer blade (Fig. 17).

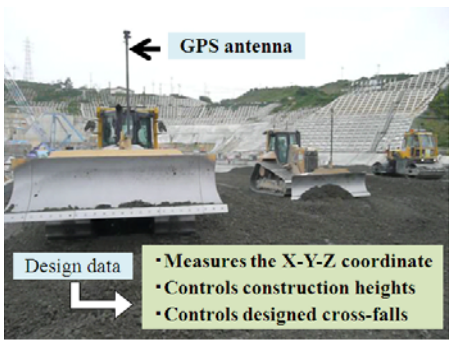

Figure 17. MC Bulldozer

Because the GPS data during construction is stored in the internal memory at this time, it is possible to use the information as electronic data after construction.
Fig. 18 indicates an example of the display of the motion path of a MC bulldozer on each layer. This displays the

motion path within a frame and the part outside the lane is uncovered and not counted. In addition, we have also conducted a conversion analysis of the average number of rolling compaction within a lane by setting the width of a caterpillar and multiplying this by the mileage on each layer within the lane (Fig. 19). Fig. 20 indicates an example of an output form of these motion paths.

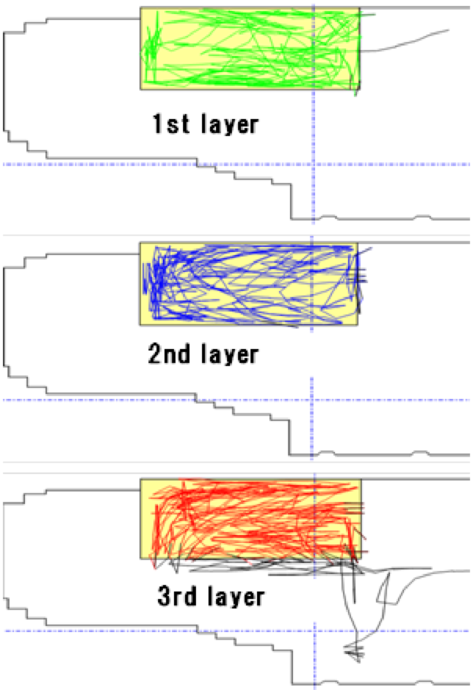

Figure 18. Motion Path

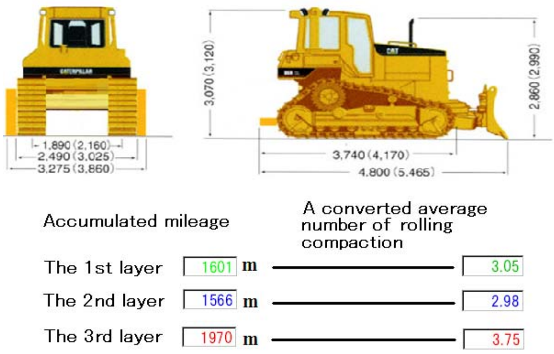

Figure 19. Conversion to an Average Number of Rolling Compaction

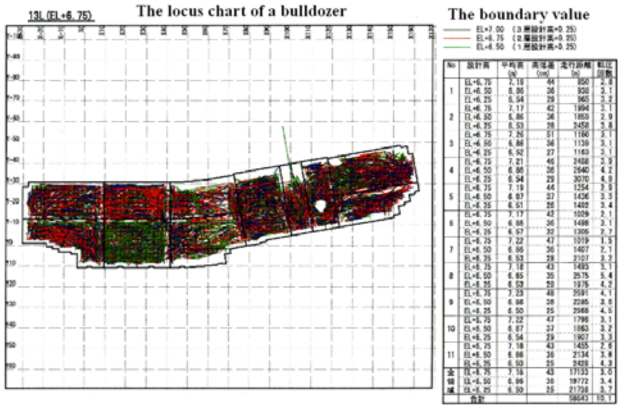

Figure 20. Example of an Output Form of Motion Paths

4. CLOSING

By applying the 4D-DIS database core and the individual control systems for temporary placement, compaction, compaction completion time and leveled thickness of CSG materials to the Okukubi Dam, we were able to utilize them for accumulation of quality certification and work histories as well as for sharing of these pieces of information.

Because the comprehensive Dam ICT work management system “4D-DIS” is applicable other than to CSG materials, we intend to apply and develop this technology and utilize it for quality improvement targeting roads and site preparation in the future.

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