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PROSPECTS FOR APPLYING AUTOMATION / ROBOTIZATION IN CONCRETE DAM CONSTRUCTION

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ABSTRACT

There is a need to introduce the application of automation and robotization for excavation and concrete pouring to improve the working environment and to compensate for the labor shortage. Therefore, as an example, we have decided to study on concrete dam construction using the RCD (Roller Compacted concrete for Dam) method in order to investigate a future method for constructing concrete gravity dams.

This paper discusses the need for a highly-integrated robotic excavation system which consists of two robotic excavation systems, one for excavation/stockpiling and the other for transportation, and a support system. There is also a requirement for a highly-integrated concrete pouring robotic system for controlling successive processes of production, transportation, pouring and curing of concrete. The technical problems concerning the design and construction method that must be reviewed for the early realization of these systems are discussed in this paper as well.

1. INTRODUCTION

We have been conducting research to promote further application of automation and robotization to the RCD method, a rational construction method for concrete gravity dams, that has attracted the greatest attention from the industry. We have analyzed and evaluated the current technical level of each of operations included in the construction in order to present a future image of automation and robotic applications that can be considered today. We have also described the technologies and policies that are needed to realize new automation and robotic applications and their related problems. Assumed conditions for our study are as follows;

a) The proposed technical level must be possible to achieve within ten years early in the 21st century.

b) Appropriate alternate plans must be considered in light of current legislation covering regulations and standards.

c) Concrete volume for a dam should be seven hundred thousand cubic meters and the distance from the dam to the disposal place for the excavated material should be within 5 kilometers.

2. PRESENT STATE OF THE ART IN AUTOMATION / ROBOTIZATION

(1) Excavation of Bedrocks

One of the operations in contemporary dam construction where the introduction of automation and robotization is falling behind is excavation. Normally, excavation starts with clearing and then proceeds with surveying, excavation of both abutments, excavation of the riverbed, rock finishing, rock inspection, and finished work surveying. Concrete will be poured after the completion of these tasks.

At the time of the excavation of both abutments, slope protection is performed by spraying mortar or fixing slope nets. But the most common method of excavation is the bench cut method using explosives. Benches of various sizes are cut and then blasted with explosives. Muck produced by blasting is collected by ripper bulldozers and loaded into dump trucks with loading shovels and carried out to the disposal area or to the stock yard. (Fig.1)

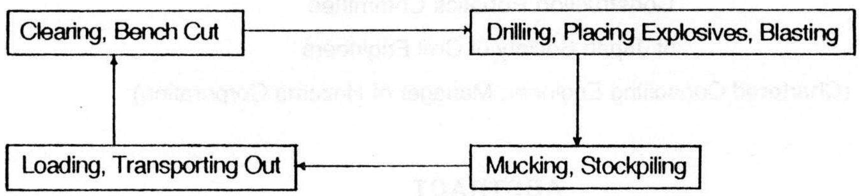

Fig.1 Flow of Excavation

(2) Concrete Pouring

Automation and robotic applications including experimental ones are being introduced into many fields of concrete operations performed in current RCD methods, namely, production, transportation, spreading, joint cutting, compaction, curing, surface treatment of concrete and transfer of forms. (Fig.2)

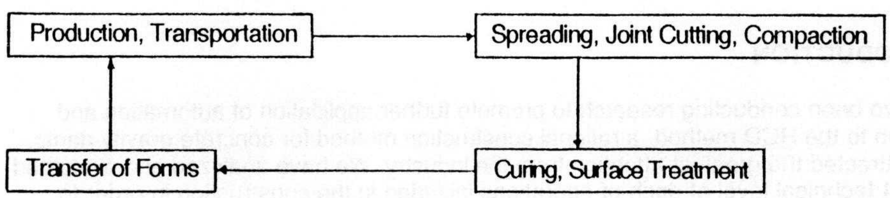

Fig.2 Flow of Concrete Pouring

3. PROPOSED SYSTEM

(1) Robotic Bedrock Excavation System

A series of operations from the drilling of the riverbed of the dam embankment and the slopes of both abutments to the disposal of muck would be performed by the robotic bedrock excavation system. This system would consist of two robotic systems, one for excavation/stockpiling and the other for transportation, and a support system (information processing system) that supports the robotic systems. (Fig.3)

a) Robotic Excavation/Stockpiling System

This system would consist of a drill, a ripper bulldozer, a belt conveyer, and a scraper. It would be used for the basic excavation and stockpiling of both abutments and also of the riverbed where the main part of the dam is to be constructed. (Table 1)

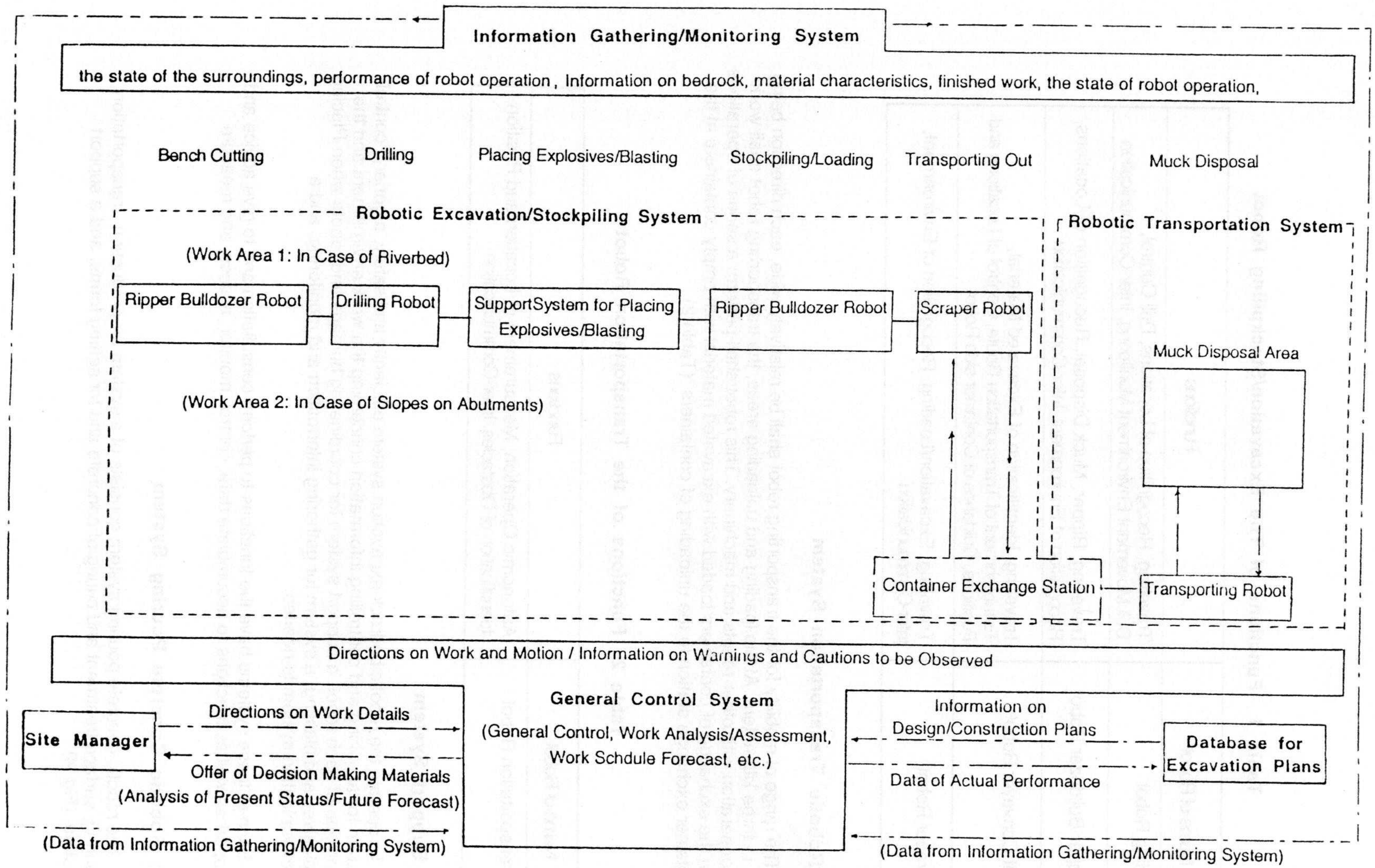

Fig. 3 Image of the Robotic Bedrock Excavation System

Table 1 Functions of The Excavation/Stockpiling Robot

Name of Robot	Functions
Drilling Robot	Travelling, Recognition of Locations, Drill Control, Drill Movement Environment Monitoring, Inter-Communication
Ripper Bulldozer Robot	Travelling, Ripper, Muck Disposal, Recognition of Locations, Recognition of Environment, Inter-Communication
Belt Conveyer Robot	Travelling, Identification of Excavated Material, Establishment of Transportation Route, Control of Locations and Positions, Guidance of Container-side Robot
Scraper Robot	Travelling, Excavation/Loading, Recognition of Environment, Inter-Communication

b) Robotic Transportation System

The range of mobility for the transporting robot shall be relatively wide, each direction being two to three kilometers. At the loading and unloading areas, the transporting robot shall work in cooperation with other robots and machinery. This robot shall perform a series of operations from the exchange of containers loaded with excavated material with empty containers at the container exchange station to the unloading of containers. (Table 2)

Table 2 Functions of the Transportation Robot

Name of Robot	Functions
Transportation Robot	Autonomic Operation, Measurement of Location and Position, Identification of Obstacles, Inter-Communication

c) Support System

To operate the robotic bedrock excavation system efficiently and safely, a general control system for acquiring and controlling information concerning the work environment and the operation of each robot, a support system for coordinating humans and robots when Placing explosives and blasting, a system for gathering information and monitoring, and a communication system is needed.

Each of these systems have the functions to perform consultation and to give advice and support as well as functions to accumulate data, control, monitor, assess, and measure.

(2) Robotic Concrete Pouring System

The robotic concrete pouring system consists of a system for production, transportation, pouring, surface treatment and curing of concrete and for setting forms, and a support system. (Fig. 4)

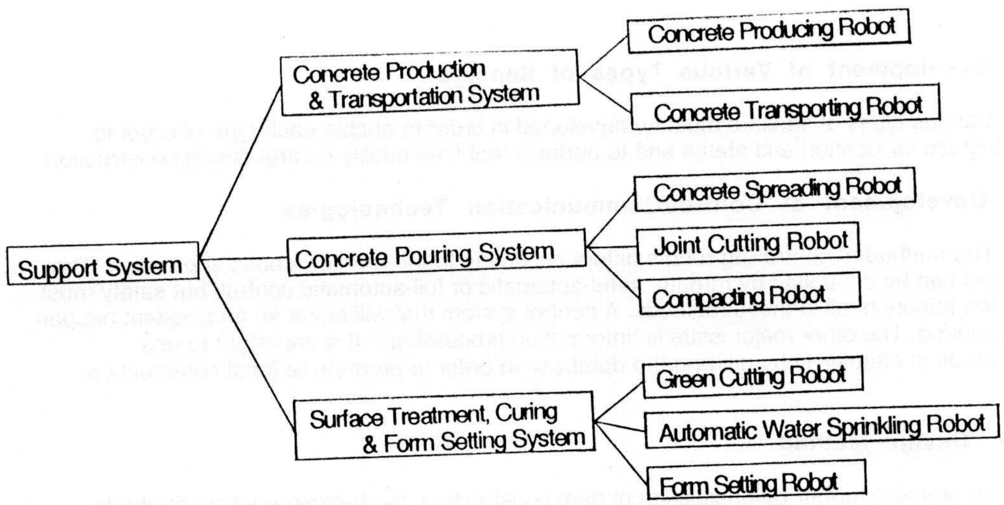

Fig.4 Formation of the Robotic Concrete Pouring System

Use of each of the robots (including the prototypes) is currently being promoted in many fields. From now on, systems for controlling each of these groups of robots will be needed. These robots will also be required to have functions for identifying locations, detecting obstacles, communicating with each other, and observing the quality of concrete.

4. TECHNICAL ISSUES AND POLICIES FOR REALIZATION OF NEW SYSTEM

(1) Construction System

The items to be reviewed concerning the construction system are listed below. Reconsideration and improvement will be necessary in terms of the institutional aspect and applicability during the R & D phase, and furthermore new rules will be required.

a) New construction method appropriate for robotic applications.

b) Construction cycle appropriate for robotic applications.

c) The optimal combination of robotic systems that has taken work performance, cycle time and other elements into consideration.

d) The optimal arrangement of robotic systems that has taken work performance, cycle time and other elements into consideration.

e) Methods for information transfer between the conventional works and the robotic systems and for information processing.

f) Methods for information transfer between the robotic systems and for information processing.

(2) Element Technologies

a) Development of Integrated Control Technology

Even if the robotic systems were actually introduced into construction sites, it does not mean that unmanned construction becomes possible. There are still considerable amounts of work that must be performed with the cooperation of workmen. Therefore, an integrated control system which enables efficient and safe operation of each of the robots needs to be developed.

b) Development of Various Types of Sensors

Various types of sensors must be developed in order to enable each type of robot to recognize its location and status and to perform real-time quality control during construction.

c) Development of Control/Communication Technologies

The method of controlling robots differs according to the level of robotic application. The robots can be controlled by remote, semi-automatic or full-automatic control, but safety must be the priority of all in these methods. A control system that will never let an accident happen is required. The other major issue is "information processing." It is important to use information effectively by utilizing the database in order to promote rational construction.

(3) Design Method

To promote further rationalization of dam construction, the following design methods should be used as long as they do not reduce the strength, safety and functions required of a dam structure. It is also important that these design methods be reviewed, taking into account the robotic application in dam construction and also the deduction or simplification of work related to the maintenance and repair of dams.

a) Review of the embankment shapes appropriate for robotic applications (outlet, gallery, etc.)

b) Standardization of design (structure, dimensions, etc.)

c) Simplification of construction procedures (Adoption of formwork, unification of internal and external concrete, etc.)

d) Application of materials that can be handled easily (Adoption of new fabric, new materials for concrete, etc.)

5. POSTFACE

We are proposing the introduction of automation and robotic applications for the construction of concrete gravity dams using the RCD method at the beginning of the 21st century, taking into consideration the current circumstances mainly of related technologies.

Of course, we must develop the necessary technologies, review other systems and structures which correspond to such development of technologies, and also create new rules in order to realize our proposal. A drastic but reasonable measure will be a key to the realization of the proposed matters.

The proposals made in this paper are the results of the study performed by the Subcommittee of the Construction Robotics Committee, Japan Society of Civil Engineers. The names of the people who participated in this study are as follows:

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