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Conception of Idealized New Construction Robot in Civil Engineering Work

Noboru Okazaki

Director of The Technical Research Division
The Zenitaka Corporation

31, Ichibancho 1-chome, Chiyoda-ku, Tokyo 102, Japan

Abstract

Recently, in Japan's civil engineering work, some automated construction robots are positively employed to sites to avoid having the dangerous and painful work.

Under such conditions, author introduces a dredging robot being able to prevent a muddiness of seabed-soil during excavation to be applied to offshore marine projects such as New Kansai International Airport and Trans-Tokyo Bay Highway, etc.

1. Introduction

Amid the rapidly changing international economic climate, the Japanese construction industry is forced to make a bitter, drastic turn in its course to cope with a variety of hardships, including the ongoing industrial reorganization mainly through the expansion of domestic demand and the recent sharp appreciation of the yen against the dollar.

Under these circumstances, many sectors of the Japanese industry have begun using industrial robots and other advanced systems for labor-saving and automation purposes, which help bring about higher productivity and a better working environment. It is generally said, however, that the civil engineering sector is lagging behind in introducing new robotization technology probably because of the peculiarities of the working process in this field. Despite such restraints, the automation technology is steadily permeating among members of the sector under a new concept of robotization.

This report studies on what concept civil engineering works should be robotized under the specials conditions of this industrial sector. Discussions here are focused on the basic ideas of such a concept as well as the specific subjects of study involved.

2. Major Considerations in Robotizing Construction Works

1) Leveling-off of Productivity

The Japanese construction industry faces an unusual business climate where the size of labor force is not linked with the trend of output. For instance, the number of construction employees or laborers sometimes increases even during a slump in public works,

resulting in a lower statistic figure for the industry's productivity. Also notable is the general view that the growth rate of the construction industry's productivity is appreciably lower than those of other sectors.

2) Trend toward a Shortage of Skilled Workers amid the Expansion of Total Work Force

The efficiency rating of workers is declining significantly, especially in reinforcing bar placement, mold carpentry, plastering and scaffolding, because the average age of workers in these fields tends to grow older.

3) High Occupational Hazards - the Construction Industry Represents 1/3 of the Total On-Duty Casualties and Nearly 1/2 of the Total Industrial Accidents Involving Deaths in Japan

To cope with this problem, studies are being made on how to introduce electronics-based technologies, particularly those for automation and robotization, into the construction industry.

3. Basic Concept of Robotization in Civil Engineering

The basic concept of robotization in the civil engineering sector comprises three essential elements: (1) Higher productivity; (2) Release of human workers from dangerous, unpleasant work; and (3) Improvement and stabilization of job quality.

However robotics is not expected to bring about productivity-improvement or cost-saving effects for at least some time to come because there are many drags on robotization in the civil engineering sector as primary emphasis is placed on the public aspect of activities in this field.

Use of innovative robot technology will probably fail to realize the desired results and sometimes it may only lead to confusion unless satisfactory arrangements are made at the job site to build up an integrated system of work suited for such new technology. We cannot expect that robotized systems will be successfully introduced into civil engineering in a short period of time. From the current state of things, use of these systems will have to be limited to certain purposes at the initial stage of their introduction.

Now let us look at drags on robotization from the performance of construction works. Many of these constraints can hardly be removed because they come from the peculiarities or structural qualities of the civil engineering industry, involving lots of social factors. From technical and managerial standpoints, these problems may be summarized as follows:

1) Technical Problems

(1) System designs vary with individual projects and are difficult to standardize.

(2) The job site moves from one place to another for each project.

(3) There are many different jobs at each site, few of which are repetitive.

(4) Civil engineering projects involve many complex jobs the details of which are variable.

(5) The feedback of information between the design and project performance units is inadequate.

2) Managerial Problems

(1) The installation of advanced systems is hardly feasible because civil engineering is a low value-added sector.

(2) Capacity utilization is kept low by rigorous restrictions on operating hours.

(3) Heavy reliance of major industry members on subcontractors hampers the development of their own techniques or expertise.

(4) The industry does not have sufficient arrangements for developing automation technology.

(5) Civil engineering firms are not very eager to increase their productivity; most of them are more interested in operations like a trading company rather than in technological development.

An analysis of the motives behind robot development activities now under way indicates that most of them are carried on in the hope of achieving such ends as: (1) Development and accumulation of robot engineering techniques for future purposes; and (2) Upgrading of corporate images.

In terms of the requirements for robotization of civil engineering works, none of the existing concepts of robotics application in this area has so far gone beyond the "replacement of human workers" by robots, specifically their "release from dangerous, unpleasant jobs," to make a definite contribution to the betterment of productivity or the strengthening of business management through the development of new robot systems that can successfully perform those jobs which are beyond human ability.

4. Concept of Robot Systems for Automating Civil Engineering Works

To relieve human workers from dangerous, unpleasant jobs in civil engineering, efforts are needed to carry out two basic concepts: (1) Integrated geological survey access control system for tunneling; and (2) Offshore turbidity-free digging and concrete-casting robot system.

1) Concept of Integrated Geological Survey Access Control System for Tunneling

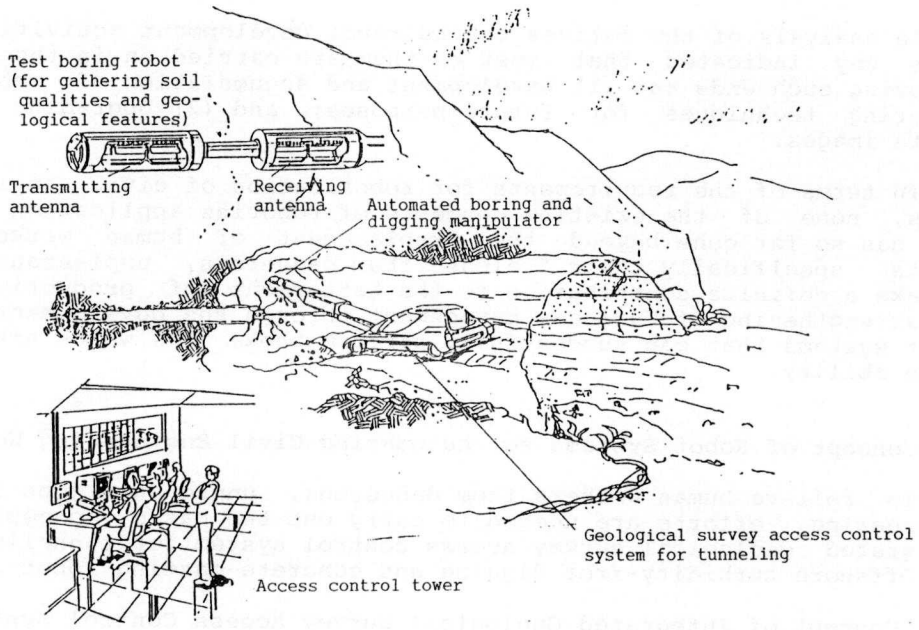
There is an urgent need to develop a feasible scheme for ensuring safety in tunneling works by making the most of a large-scale value-added network (VAN) system covering all processes of such engineering works from a geological survey - an important job providing a proper access to the works - to digging, removal of earth from the tunnel, and wall-surfacing.

The plan is to develop an integrated control system for managing information on soil qualities and geological features for

projects to cut tunnels through mountains. With this system, an attempt will be made to build an access control center that receives and sends off a variety of information on the tunneling works as well as predictions on likely changes in the rock mass on the further side of the tunnel. The control center will always be connected with the VAN by an on-line system to gather and offer information on tunnel excavation, predicted changes in the affected rock mass, and security. It will also control and monitor the excavator unit, performing all jobs involved from the feedback of information on design and execution techniques to prearrangements and support for daily works.

For instances, the integrated access control system can quickly map out a timesaving schedule for efficiently coping with such tough working faces as faults and spring water. Another feature of the system is its capability to make an exchange of important information on display screens through the control center. These are the major details of the basic concept of the integrated geological survey access control system.

Total Concept of the Integrated Geological Survey Access Control System for Tunneling



Note: This concept was presented at an expert group meeting of the Japan Industrial Robot Association

2) Concept of Offshore Turbidity-Free Digging and Concrete-Casting Robot System

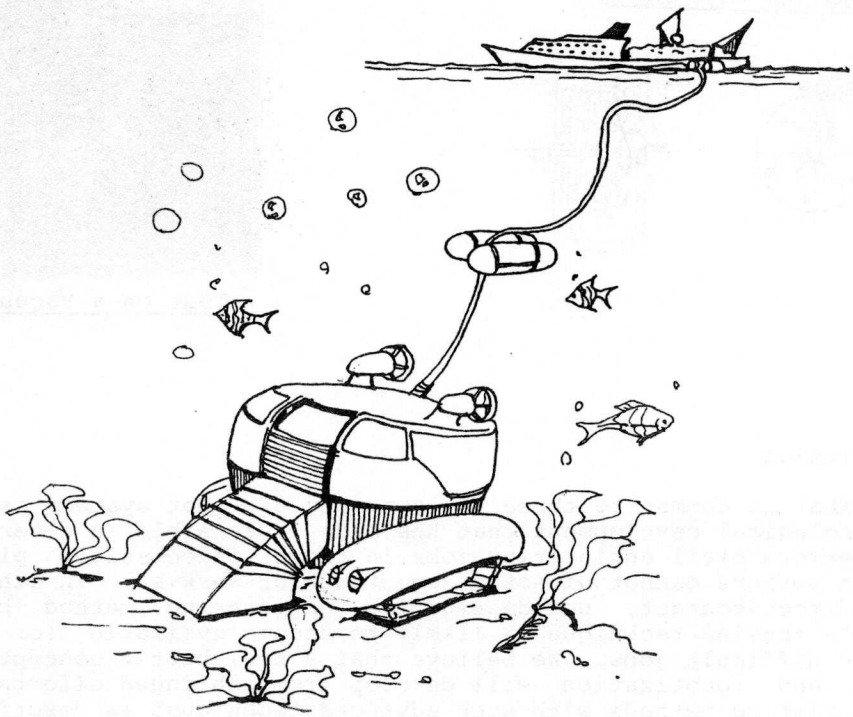
There days when a series of major projects, including the New Kansai International Airport and the Trans-Tokyo-Bay Highway, are

under way in different parts of Japan, there is an urgent need for developing an underwater robot system that can dig bottom sludge and cast concrete without making the water turbid. The requirements and constraints to be considered in working out a basic concept of such a system are summed up below:

(1) Requirements
   a. Specification of the digging mechanism;
   b. Operability, weight capacity and sturdiness;
   c. Capability to visually indicate water turbidity;
   d. Position-recognizing ability for digging, ground-raising and concreting;
   e. Image-processing ability for describing the job site;
   f. Selection of robot suppliers for partners in joint technological research and development projects; and
   g. Costing and financing for system production and maintenance.

(2) Constraints
   a. Shapes and soil qualities of the structures for which the system is intended;
   b. Surrounding conditions (e.g., the depth of water, the state of sludge and tides);
   c. Digging rate in m^3/h;
   d. Simplification and modularization of the system;
   e. Restraints from engineering methods (including statutory regulations); and
   f. Establishment of standards for system construction.

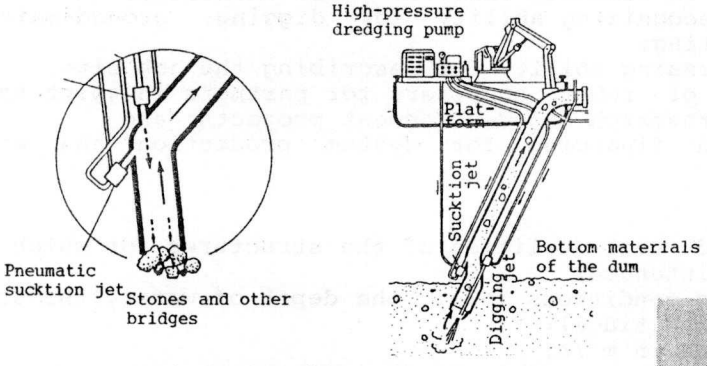
Concept of a Turbidity-Free Dredging Robot



New Idea

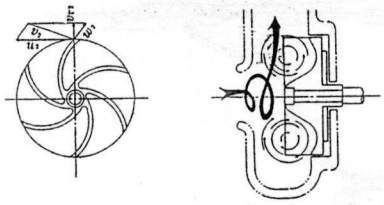
The centrifugal torque pump is an advanced swage pump developed from a new idea and a new theory based on a combination of the advantages of the centrifugal and torque flow pumps.

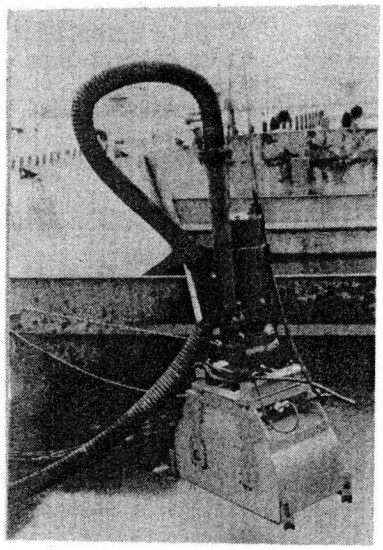
Concept of the Turbidity-Free Robot System



Water Jet System

Saction Valve System





Test on a Vacuum

Conclusion

What is common to these two concepts of robot systems is the recent technological development that has made it feasible in a certain degree to perform civil engineering jobs in those inaccessible places which human workers cannot directly see, touch or work at. In other words, a non-direct-contact, non-destructive engineering method based on the remote sensing technique is likely to become available for performing these difficult jobs. We believe that a new, better concept of automation and robotization will develop from continued efforts to replace the existing methods with such advanced techniques as described above.

Acknowledgments

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