PROSPECTS FOR AUTOMATION AND ROBOTICS REVOLUTIONIZING ORDINARY CONSTRUCTION SYSTEMS THROUGH ADVANCED INFORMATION TECHNOLOGY

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ABSTRACT

The wave of advanced information technology will drastically change the ordinary construction systems in the Japanese construction industry. The procurement and delivery systems of the Ministry of Land, Infrastructure and Transportation will also be computerized. Construction robots need to be regarded as a construction system in the context of the sophistication of information systems rather than simply as a machine with mechanical motions and automated functions.

This paper describes the current situations of Automation and Robotics in each field of earth work, foundation work, tunneling work, and offshore work, and provides their outlooks and challenges in the future.

Key words:
future vision of earthwork, unattended construction work , advanced information systems, Tunnel Boring Machine, future prospect for construction robots

1. INTRODUCTION

Japan's construction industry has begun to experience labor accidents, shortages of skilled workers, and other problems. Moreover, demand for cost cutting is intensifying, leading to higher expectations for new construction technologies and efficiencies. These trends will likely continue. To address these issues, the construction industry is closely examining the use of information technologies and robotics for construction.

This paper describes the current situation regarding construction robots in Japan and presents an idealized scenario for construction work based on a study of current challenges and future prospects.

2. INFORMATION TECHNOLOGY AND CONSTRUCTION ROBOTS

Rapid progress in information technology is beginning to have a dramatic effect on the daily construction management practices of contractors. This trend is being accelerated by the efforts of the Ministry of Land, Infrastructure and Transport to establish procurement and electronic delivery systems based on the 'Construction CALS/EC' concept and compliance with ISO standards.

Figure 1 shows the flow of information during a construction project. E-construction is a system by which a contractor can access information common to each trade and incorporate it into the construction work. Adding mechatronics (a controlling function) to this system creates robotics construction. In other words, advanced information technology, system sophistication, and mechatronics are keywords for construction robots.

The following sections shed light on Japan's current state of automation and the use of robotics for construction as well as describe future challenges and outlooks.

3. CURRENT STATE OF ROBOTICS CONSTRUCTION IN EACH TRADE

3.1 Automation and robotics in earthworks

The use of robotics in Japan for large-scale earthworks made a great leap forward in 1993 when unattended operations were carried out at Mt. Unzen Fugendake. Between 200-300 million m^3 of volcanic debris from an eruption was removed using remotely controlled breakers, backhoes, bulldozers, and dump trucks. This large-scale application of robotics was followed by the remotely controlled construction of an 870 m-long long debris barrier using the RCC (Roller Compacted Concrete) method, as shown in Photo 1 and Figure 2.

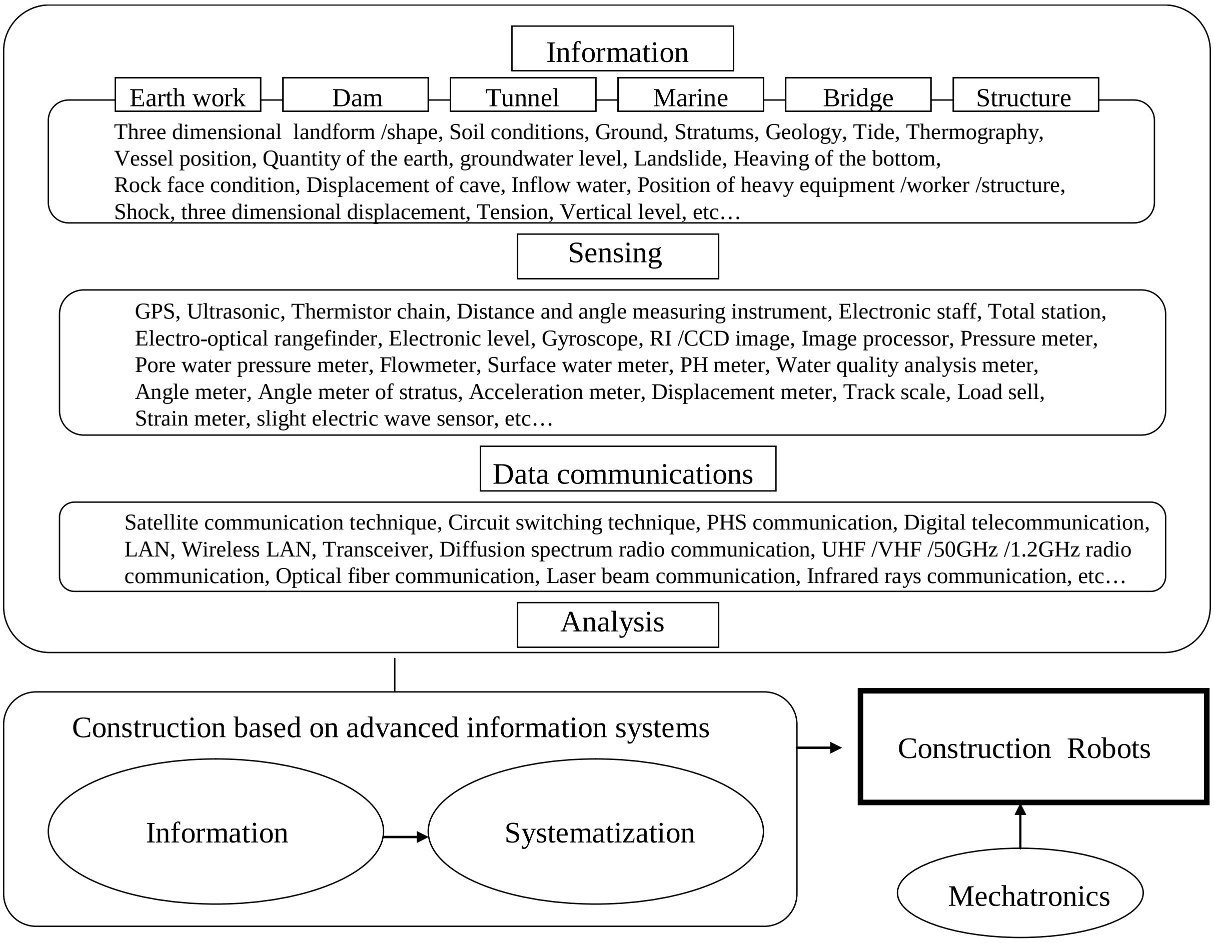
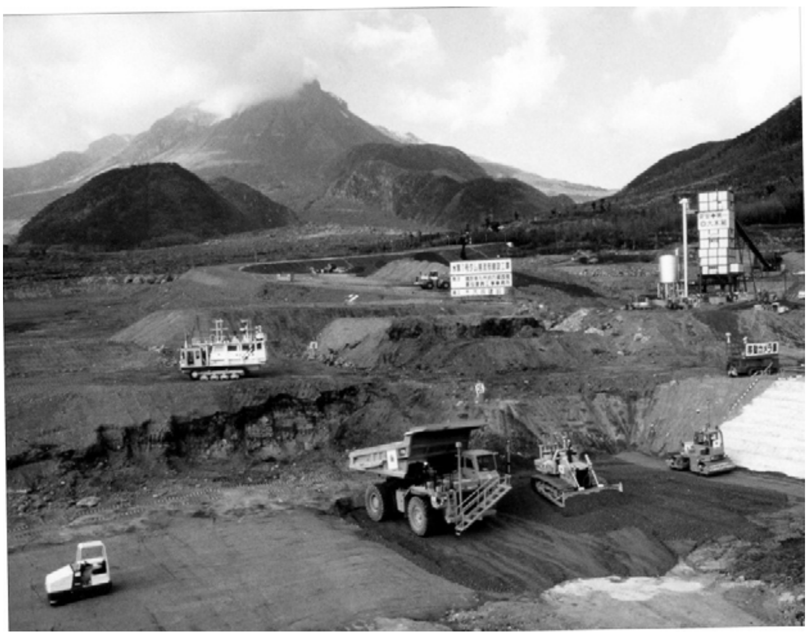


Figure 1 The flow of information during construction project

This was the first application of the GPS compaction control system to this type of work. It is now widely used in other earthworks projects. Information technologies that were developed during the work are now used by the construction industry to work out optimal heavy machinery plans and earth conveyance plans, substantially reducing construction time and costs.

Figure 3 shows a system for using laser control to automate measurements of a three-dimensional topography in an area specified on an image. This unattended measuring robot operates at night in order to avoid the numerous numbers of construction machinery that come and go on a site during the day.



Phote 1 Remotely controlled construction of RCC Dam

The system can also perform kymographic observations, recording geographically distinctive points on the face of a cliff through image processing and automatically tracking the recorded points. The system is attracting attention for its potential use in disaster prevention systems as well as for its applications in earthworks projects. It is also considered a basic technology for robotics construction in the future.

3.2 Automation and robotics for foundation work

Foundation work has greatly benefited from robotics, which can carry out diaphragm wall work, caisson work, and other tasks, relieving human workers of hard and dangerous work and improving work efficiency and accuracy.

Using robotics, a large diaphragm wall was constructed as an earth retaining and water cut-off wall for an underground LNG tank. Robotics was also used to build a 119 m-deep, 2.8 m-thick wall for the “Kawasaki Man-made Island” on the Trans-Tokyo Bay Highway. As these cases show, as diaphragm walls grow larger, greater efforts are made to automate measurement management and other tasks in order to improve construction accuracy and work efficiency.

On the other hand, with the pneumatic caisson method, structures are submerged as they are constructed. Workers in these structures have long suffered from poor working environments and exposure to high atmospheric pressures. Figure 4 shows a chamber and a series of unattended operations, including excavation, loading, and earth discharge, that are remotely controlled from a room above ground. The system was recently made more sophisticated by the incorporation of a function that

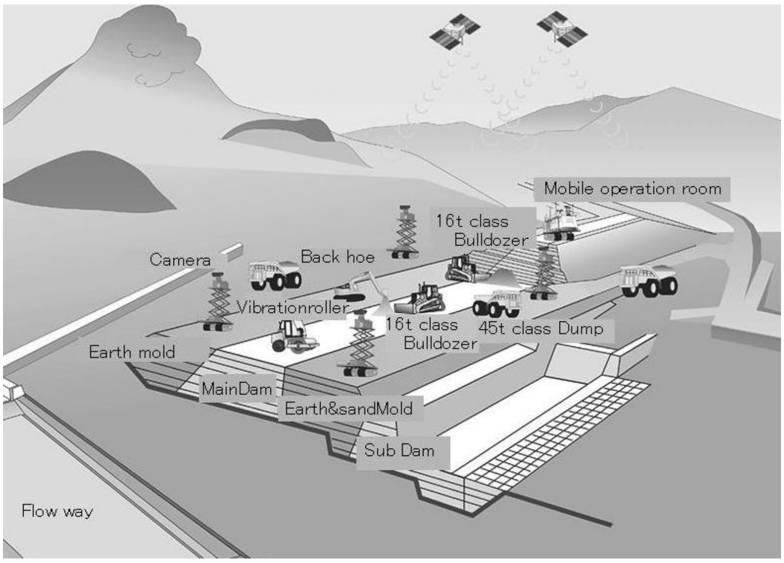


Figure 2 Unattended remotely controlled construction system

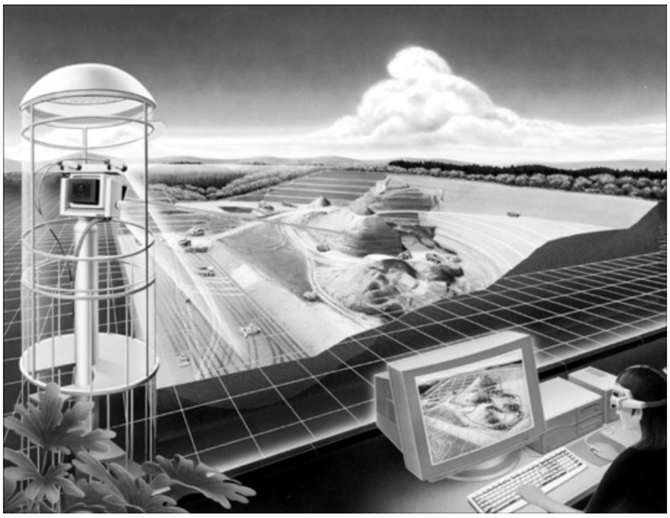


Figure 3 Survey robot using laser and image control

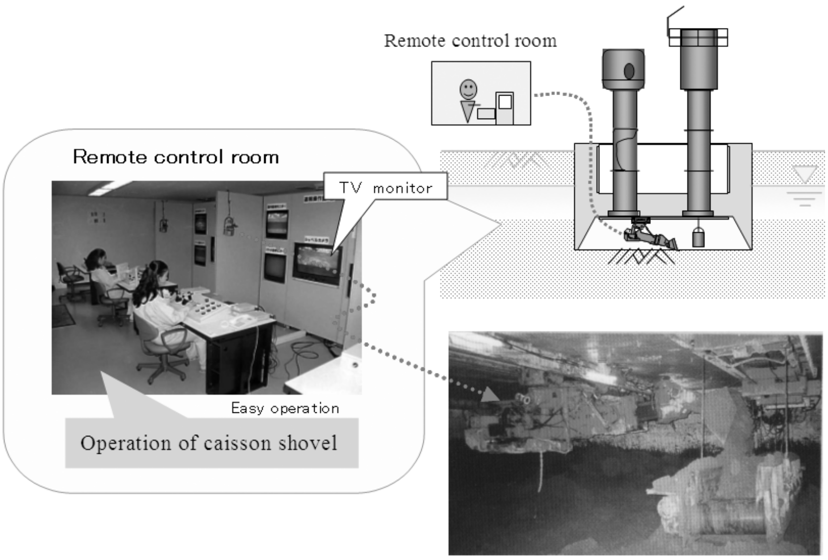


Figure 4 Remotely controlled pneumatic caisson system

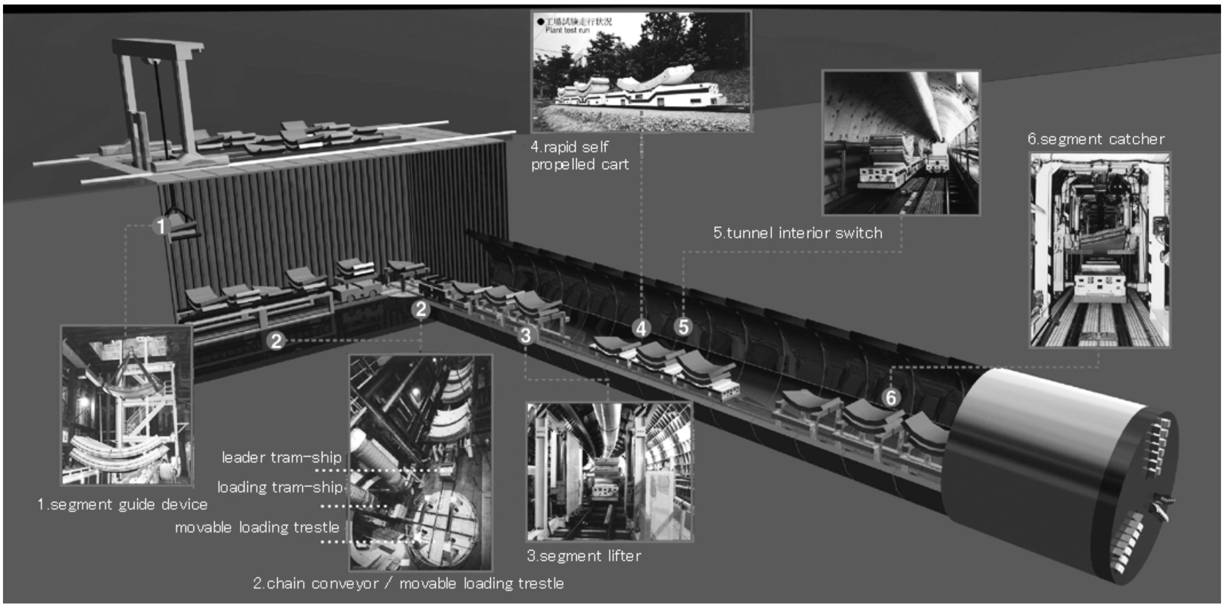


Photo 2　Segment conveyance Robot

automatically measures the track of a boring machine and the shape of the excavation ground.

3.3　Automation and robotics in tunneling work

Shield tunneling is drawing great attention as a way to reconstruct urban infrastructure without causing congestion.

The shield tunneling excavation process has been fully automated, with robotics controlling the launching speed of the machine, the rotation speed of the cutter, the location, position, and orientation of the machine, the water pressure at the tunnel face, pumping operations, etc. The segment assembly process has also been fully automated, with robotics

Photo 3 Tunnel Boring Machine

Photo 4　Hard-rock free-section excavator robot

being used for in-tunnel conveyance, assembly, and other tasks. Photo 2 shows a segment conveyance robot. Managed from a central control room, this fully automated system controls a variety of tasks, from the arrival and storage of segments, to their retrieval and conveyance to a tunnel face by means of automated guided vehicles.

A number of problems have surfaced regarding the New Austrian Tunneling Method (NATM), which is widely used to construct mountain tunnels. These problems include difficulties in automating blasting, a poor tunnel environment due to dust, and labor accidents. This situation has accelerated the introduction of robots, including TBMs (Tunnel Boring Machines) and free-section excavators.

Modern TBMs offer safe and rapid excavation in the complex or soft ground conditions characteristic of Japan. TBMs are being used in a rapidly increasing number of tunnel projects. Photo 3shows the world’s largest TBM. With a diameter of 12.84 m, it has been used to excavate two-lane road tunnels and other large tunnels. It is an example of the remarkable technological progress being made in the development of TBMs, particularly in the application of IT to such sophisticated tasks as probing the ground ahead. This has helped to achieve high-performance robotics construction.

In contrast, hard-rock free-section excavators are environmental-friendly, hard-rock boring machines that eliminate the need for blasting. These excavators are gaining attention not only for their environmental friendliness but also as a blast-free method that has little effect on adjoining structures, does not harm the ground, and can excavate watertight spaces having any desired cross-section. As Photo 4 shows, this type of excavator is designed to use reaction forces. It has four grippers and supports the ground at two points. The disc cutter moves vertically and horizontally, creating pressure that breaks the rocks. Automated operation reduces energy needs, increases excavation efficiency, and improves the quality of the construction work.

3.4 Automation and robotics in offshore work

By moving offshore, Japan has found a means of expanding the urban infrastructure of its congested cities. Current projects include extending Haneda Airport out to sea and constructing artificial islands near the Kansai and Chubu Airports. As these cases indicate, offshore work is being carried out in soft ground and at increasingly greater depths, which creates difficult working conditions. A shortage of qualified divers is also a serious problem. As a result, the industry is optimistic about the use of robotics in offshore work.

Photo 5 shows a walking dredging robot. Through onshore control, it walks on eight legs along the sea bottom, performing automatic dredging operations in a safe and efficient manner.

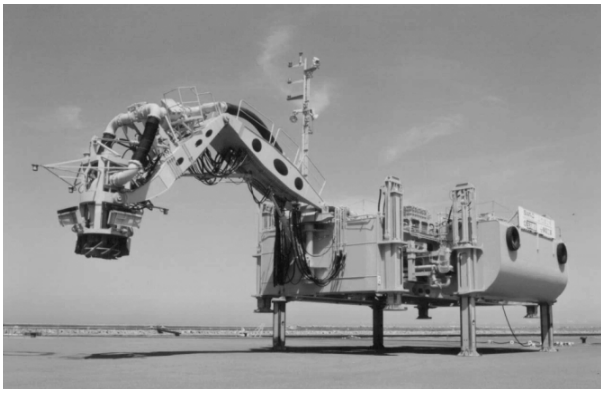


Photo 5 Walking dredging robot

4. CHALLENGES AND PROSPECTS FOR ROBOTICS CONSTRUCTION

4.1 Current state and challenges of robotics construction

The Japan Society of Civil Engineers Committee on Automation and Robotics in Construction conducted a survey on the current use and technical level of robotics in each work task. The results were categorized into levels from A to C. In Level A, the robots operate automatically according to the decisions is makes on its own. In Level B, the robots operate according to decisions made by human operators. Level C means basic mechanization of construction work.

The study revealed that Level A is the most commonly seen level in shielding work. Many work tasks are using robots on a trial basis, however, and a range of problems must be solved before they can be used more widely.

Level C is also quite visible in shielding work, indicating that many operations require human involvement and judgments even in shielding work, which seems to be ahead of the other trades in the introduction of automation and robotics. The committee noted that robots working alongside humans must also be considered for certain cases.

The committee found that Levels B and C predominated in gravity dam and offshore construction. Few projects were at Level A. The report pointed out that B- and C-level projects incorporate many types of activities and these are different in nature from shielding and other types of construction work, which are characterized by continuous streams of work. To promote automation and robotics in various fields, the study suggests using IT to automate operations in each trade as well as creating more sophisticated systems as a whole.

4.2 Future prospects for robotics in construction

In the future, advanced information technology will become more tightly integrated with construction machinery, creating highly sophisticated robotic construction systems that can provide greater efficiency, productivity, and safety.

Figure 5 depicts mountain tunnel construction in the future using an advanced, smart TBM. The machine operates according to a tunneling plan developed from a variety of information sources. The plan is constantly updated during the course of excavation with data from the machine's current position.

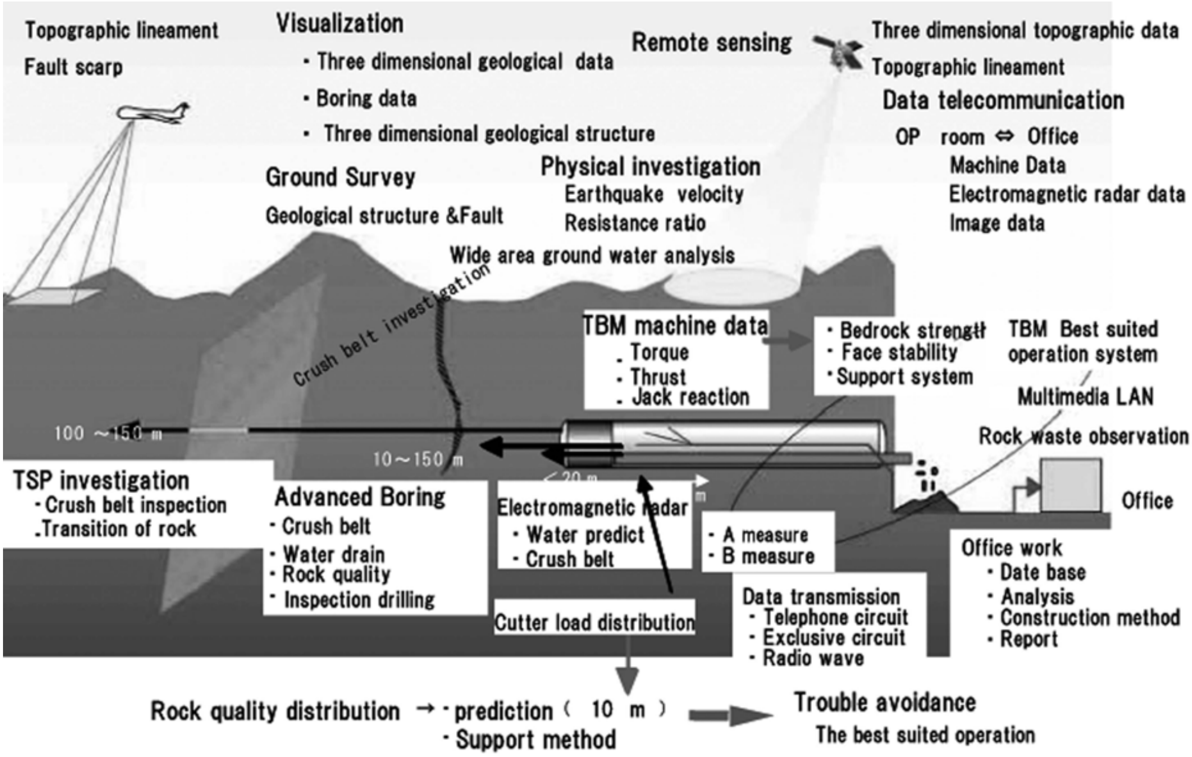


Figure 5 Future prospect of smart TBM in tunnel construction

As seen above, construction robots in the 21st century will likely be equipped with advanced information technologies and designed as sophisticated systems that operate alongside human workers.

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Since its foundation in 1985, the Committee on Automation and Robotics in Construction of the Japan Society of Civil Engineers has been active in a variety of fields relating to automation and robotics in the construction industry. This paper presents some of the results of those activities. I would like to express my sincere thanks to the colleagues with whom I have worked.

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REFERENCES

[1] The Committee on Automation and Robotics in Construction of the Japan Society of Civil Engineers , ” Prospects for automation and robotics in construction ”, Jun.1992

[2] The Committee on Automation and Robotics in Construction of the Japan Society of Civil Engineers, ” A view of automation and robotics in construction for the 21st century ” Dec.1996

[3] The Committee on Automation and Robotics in Construction of the Japan Society of Civil Engineers, ”Prospects for automation and robotics in construction on the 21st century ”,Jun.2001