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Robotization of reinforced concrete building Construction in Japan

Construction de Bâtiments en Béton Armé au Japon

Résumé

L'accroissement de la production et l'amélioration des conditions de travail dans la construction de bâtiments béton armé sont des problèmes cruciaux dans l'industrie de construction. Depuis longtemps les efforts remarquables ont été faits dans ce domaine au Japon. Les recherches sur les robots et les activités développées par le gouvernement, les institutions académiques et des sociétés apparaissent dans ce rapport. L'auteur parle aussi du Projet de Recherches WASCOR (WASeda COnstruction Robot) fait à notre institut aussi que plusieurs thèmes qui seront developpés pour une introduction efficace des robots.

Robotization of Reinforced Concrete Building Construction in Japan

Abstracts

Increasing productivity and improving working conditions of reinforced concrete building construction are crucial issues in constructing industry. Very earnest efforts have been done in this field in our country since several years ago. In this paper, the robots research and development activities by government, academic institutions and companies are introduced. The author also introduces about WASCOR (WASeda COnstruction Robot) Research Project at our institute and some themes to be solved for successful introduction of the robots.

Robotization of Reinforced Concrete Building Construction in Japan

1. Introduction

A big wave of robotization is rapidly washing our industrial society. The historical trend of automation diffusion is consistently keeping the direction from simple to complicated operations. Objects of robotization have been progressed in such ways: consumers goods manufacturing (stationeries, cosmetics etc.) → durable consumers goods (home appliances, cars etc.) → productive goods (machine tools, equipments etc.). On further step of robotization, robots are spilt out from manufacturing industry and catching up construction industry, which is more complicated and less repetitive.

Until today majority of concrete building construction has been done manually because of its technical, managerial and structual obstruct reasons. The labor productivity of construction industry in many countries have not increased except only a few percent of increment in West Germany in the past ten years, in spite that the productivity of manufacturing industry accomplished 100% increment during the same period of time. But recent progress of robot technology is breaking through the thick wall of barriers against robotization in construction industry and managements and engineers of general constructors are going to be enthusiastic today. In this paper the author introduces many efforts for robotization of building construction in Japan and the research activities in our university.

2. Efforts for Developing Construction Use Robots

In Japan the kick-off of building construction robotization was almost ten years ago. At the beginning stage, Japan Industrial Robot Association took the role of the pioneering organization by sponsoring the following robot conceptual design projects.

1) Home use wooden panel wall assembly line automatization research project (1978)
2) Medium and tall building surface panel assembly automatization research project (1978)
3) Bridge painting operation automatization research project (1978)
4) Reinforce steel bar assembly operations automatization research project (1979)
5) Reinforced concrete mold assembly operations automatizatization research project (1980)
6) Large scale tank assembly operations automatization research project (1981)

The author participated in four of these research projects and was impressed that it was the right time to start the research and development of such sophisticated type of robots. Because the premises for starting the research such as serious needs for robots, accumulation level of robot and system engineering technology and so forth were going to reach some plateau.

The result of these research projects strongly stimulated robot research specialists, government officials and company executives, and urged to start more systematic research projects of construction. Today the following major research projects are being executed in our country.

2-1 Ministry of Construction Research Project
"Research on the Application of Electromics in the construction Technology"
The Ministry of Construction started a 5-year project in 1983. This is the biggest project in Japan concerning the research of new construction systems with robot development. The project is on the way by tight co-operation with the Building Contractors' Society, allied professional groups, universities, public research institutes and general constructors. Figure 1 shows the organization of the research project committees and teams.

2-2 Research and Development Project of Robots for Critical Environment
This national project was started in 1983 for 8 years' period of research time with 20 billion yen budget. The project is sponsored by MITI (Ministry of International Trade and Industry). The fundamental purpose is developing the new robot technology for meeting the sophisticated type of robots which are used in hostile environment such as in the deep sea, in the shield building of atomic power plant, in the emergency fire and so forth.
The project does not treat the research themes which directly connect to the construction robotization but it is understood that there are many related research themes to the construction robot development. Therefore we are to pay attention to the project.

2-3 Research and Development Project of a Decomissioning System for Nuclear Plant
The major theme of the project is developing a safe system to disassemble the used atomic power plant shield building by using robots. The project is being led by the Agency of Industrial Science and Technology, and robot manufactures, general contractors and nuclear engineering companies are participating as well. The concrete shield wall of the JPDR (the Japan Power Demonstration Reactor) will be dismantled during 1988-89 by using a cutting robot under research since 1981.

2-4 Research Committee for Robotized Building Construction of Architectual Institute of Japan
The committee was started in 1985 with 15 members. As the first step of the activities they are surveying the problems which obstruct the introduction of robots into building construction sites. They they are going to select several themes to be studied at the institute.

2-5 WASCOR (WASeda COnstruction Robot) Research Project
It is a multiclient research project for developing building construction robots. The project is sponsored by System Science Institute of Waseda University, and 11 general contractors and construction machinery manufactures have been participating since 1982. The outline of the project is introduced in the next chapter.

2-6 Building Construction Use Robots Developed in Japan
Since several years ago the Japanese leading general contractors have done big efforts for developing building construction use robots. Table 1 shows the robots classified by operational functions.

3. Outline of WASCOR Research Project

3-1 Background and Purpose of the Project
Regarding the development of construction use robots, Waseda University has co-operated with the conceptual robot system design projects of Japan Industrial Robot Association since almost ten years ago as mentioned in the previous chapter. For executing the projects we organized a working group in System Science Institute of the University. The research task force is composed of university staffs and company engineers who were previous JIRA (Japan Industrial Robot Association) construction robot research project committee members. The university received research grants and spent it for running the working group. Professors of the university taught robotics to the members. They worked earnestly and have yielded good research result each year.

But cause of the association rule of the conceptual system design, the length of the research period was limited to within one year. After having completed a few themes, company working group members autonomously proposed to expand the project scale, period of time and research depth. The university accepted the proposal and the WASCOR research project was started in 1982 by several professors of robotics, civil engineering, industrial engineering and system science, and nine leading constructing and two constructing machinery manufacturing company members.

The purpose of the project was determined as the following items:

1) Education and training of construction robot engineers
2) Development of new technologies and equipments for research and development of the robots
3) Survey of the research needs and conditions
4) Determination of the research themes and execution of the research
5) Design robotized construction system for an imagined model building
6) Evaluation of the system alternatives
7) Building of a data bank for the research

3-2 Methodology of the Research
Figure 2 is a flow chart of the research, and the project team members are running the research following after the flow chart. In the research process we put emphasis on the following points.

1) To keep consistent system approach from the beginning to the end
2) To analize the structure of the issues and problems to be solved for developing the robot
3) To survey the environment of the industry, and forecast construction method and robot technology
4) To do field survey of the labor saving needs and its target
5) To determine the area of the research and imagine a model building construction project for the research
6) To make the conceptual model design of the total robotizwd reinforced concrete building construction system
7) To analyze parallelly the construction operations, modularize motions and develop the robot module concept
8) To apply the module concept to the model design and integrate both of design and analitical approach
9) To evaluate and select the model alternatives dynamically by applying a simulation model

3-3 Area of Research

Based on the policy to design totally robotized building construction system. We decided the area of research as shown in the figure 3. From the figure we can understand that there are many necessary supporting functions for successful operation of the robotized building construction system.

3-4 Selection of Construction Method

Fundamentally it is necessary to develop new construction methods for the sake of designing a successful robotized construction system. We selected two types of construction methods out of eleven alternatives. The one method is future oriented and put emphasis on the easiness of the robot introduction. The other method is more practical and put weight to wide diffusion of the method.

3-5 Conceptual Design of a Robotized Construction Site

Figure 4 shows an example of conceptual design of robotized construction system. In the figure the image of the construction robots are illustrated such as steel beam welding, reinforced steel bar assembly, concrete mold assembly, fresh concrete distributing and so forth. Regarding these robots we are studying each specification down to more detailed points.

3-6 Robot Engineering Technology Development for the Project

Through the process of the robot development we are facing the necessity to develop new robot engineering technology such as: new work study technology for robotization, new construction method evaluation technology for robotization, a simulator for inspecting relationship between a construction method and robot structure alternatives and so forth. We are concentrating the effort on this aspect.

4. Conclusion

In manufacturing industry, robot researchers and engineers spent about two decades starting from robot development to cropping the fruits. In the field of building construction robotization there are many particular difficult research and development themes which were not needed for introducing robots into manufacturing industry and will be needed for robotization of construction industry. The author anticipates that for accomplishing the R & D themes we need big amount of task force, financial support and lead time. If those themes are shared by countries under the tight co-operation, we shall be able to accomplish this difficult theme earlier than expected.

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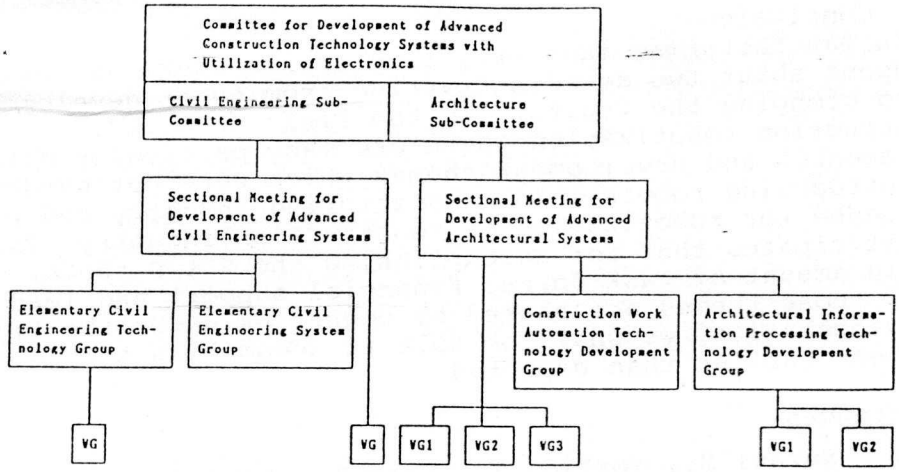

Figure 1 Organization of Ministry of Construction Resarch Project

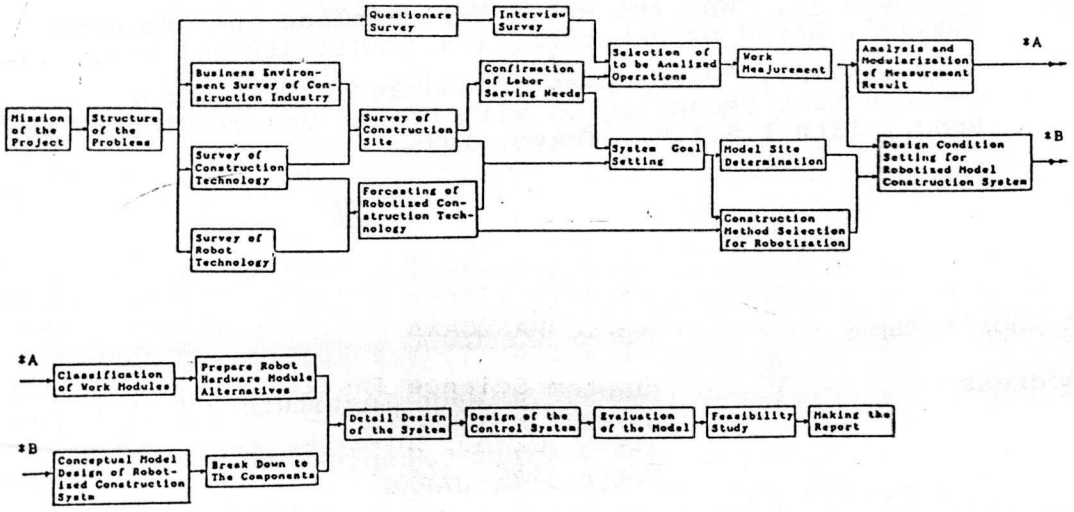

Figure 2 Procedure of WASCOR Research Project

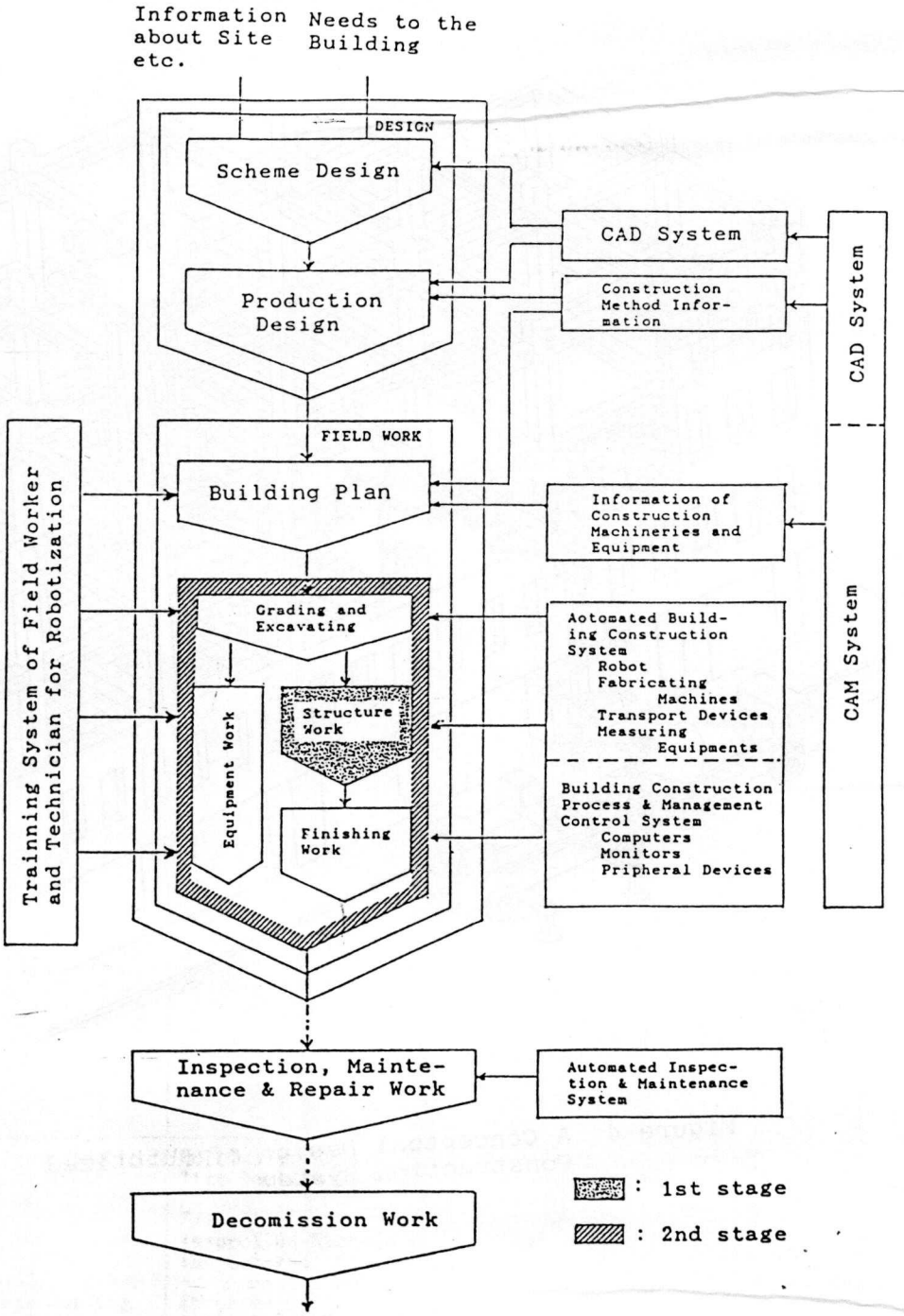

Figure 3 Area of WASCOR Research

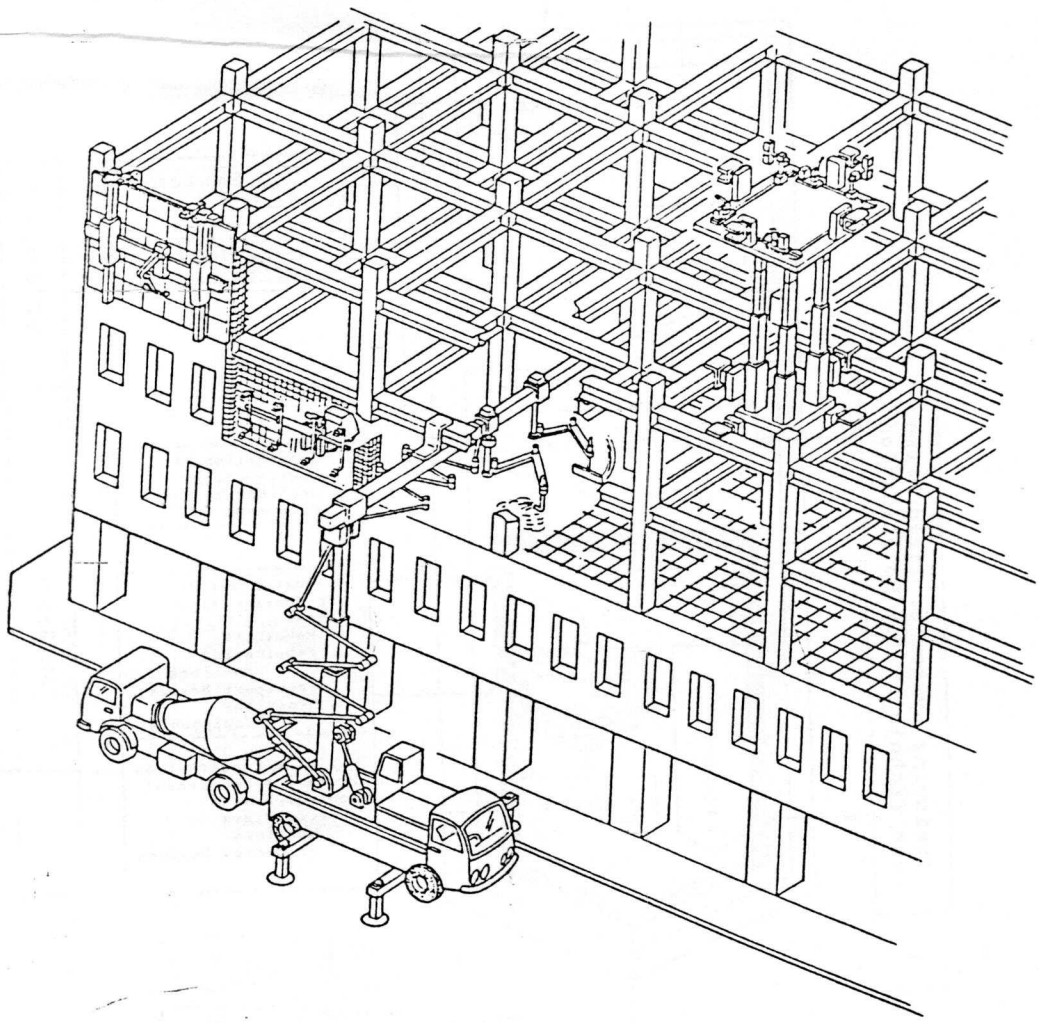

Figure 4 A Conceptual Design of Robotized Construction System

Table 1 Building Construction Robots Developed in Japan

	Task	Name	Features	Developer(s)	Note
1	Steel beam positioning for election	Mighty Jack	Fixed on column head with two grippers	Shimizu	
		Auto Setter	Fixed on column head with two grippers	Taisei	
2	Clamp work for structual steel column erection	Auto Clamp	Suspended and radio control	Ohbayashi	
3	Fire proofing for steel structures	SSR-1,2,3	Self positioning and moving play back robot	Shimizu + Kobe	
4	Stud dowell welding	Stud Welding Robot	Teaching play back robot	Kajima	
5	Reinforcing bar arranging	Automatic Heavy Reinforcing Bar Arranging Robot	Handles staggered or radial arrangements	TEPCO + Kajima	
		Automatic Crame	Intelligent and psitioning	TEPCO + Shimizu	
6	Fresh cocrete ditribution	Horizontal Concrete Distributing Robot	Hrizontal folding type	Takenaka	
		Concrete Placing Crane	Vertical type 5 degree of freedom	Ohbayashi	
7	Slab Concrete finishing	Concrete Slab Finishing Robot	Travel on wet concrete	Kajima	
		Concrete Slab Finishing Robot	Travel on wet concrete	Takenaka	
8	Clearing grinding etc. of concrete slab surface	Multi Purpse Traveling Vehicle	Traveling and multi function	Shimizu	
9	Painting	Pillar Coating Robot	Move along pillars and sensor equipped	Taisei	
		OSR-1	Suspend from corridor or balcony and move vertically and horizontally	Shimizu	
10	Detecting tile exfolation	Exfoliated Wall Tile Dectator	Suspended traveling	Kajima	
		Self Climing Inspection Machine for External Wall	Suspended traveling	Takenaka	
11	Concrete Cutting	Abrasive Jet Cutting Robot	Remote control with tactile sensors	Kajima	
		A.W.J Cutting System	Moving X,Y direction	Taisei	