ROBOTIZATION OF CONSTRUCTION WORK

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1 Introduction

The waves of automation have gradually been penetrating the operations, from simple to complicated, in the history of industry. The appearance of industrial robots is accelerating the speed of the automation diffusion and breaking through in many difficult fields. The most successful field of robot application today is mainly in mass and the medium scale of manufacturing operations in factories such as automobile, electric appliances, electronics and so forth.

But on the other hand, many types behind the operations remain in a poor situation without receiving any benefit of innovative robot technology even today. The productivity in the field of constructing industry and there exists a big gap between them, which we are discussing seriously today.

The author and the group of colleagues have been participating in a robotization research group of constructing work since several years, and the group was enforced under the name of WASCOR (Waseda Construction Robot) research project group since last year.

The Japanese government also started provisional activities to start the robotization research in this field recently. In this article the author introduces a methodology of the research, problems in constructing industry, conceptional design of construction robots and some robot development examples, also the problem to be solved for the successful robot introduction are discussed.

2 Problems in Construction Industry from the Standpoint of Robotization

Figure 1 shows a scene of manual constructing operations. Today most of the concrete building construction work is done manually. The reasons why robotization has not yet been done are considered as follows:

1. Products (buildings) differ by each piece.
2. Product size is big and the weight of components is heavy.

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3. The location of construction site changes each time.

4. A variety of operations is needed for completing a building and multi-function is also needed for the robots.

5. There are many complicated group operations.

6. The information feed-back from production people to product designers is not enough and they cannot improve the construction productivity because of many design restrictions.

7. The stability of operation is not yet sufficient.

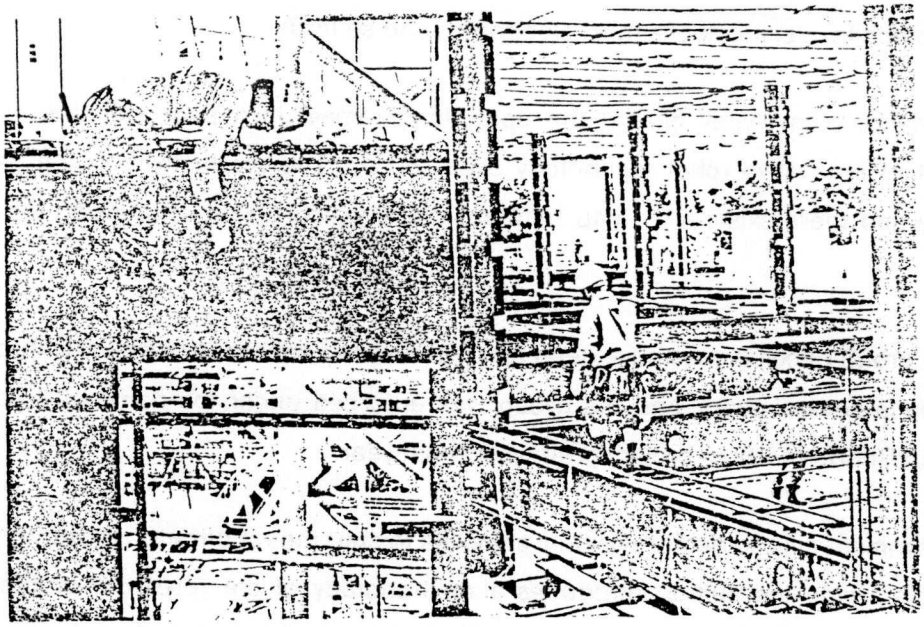

Figure 1: Manual constructing operations

Figure 2 shows the recent tendency of productivity increment in types of industry. It is very unusual that, in the construction industry, there was no increment of productivity in spite of rapid increase in manufacturing industry.

Figure 3 shows the trend of material, labour and total cost of wooden concrete form per square meter during fifteen years. In these years the labor cost has increased more than four times. Because of the lower productivity today, the construction industry in our country faces on one hand the cost increase and on the other hand the poor working conditions. For that reason people in this industry started to consider introducing robots and breaking through the thick wall of the serious low productivity problem.

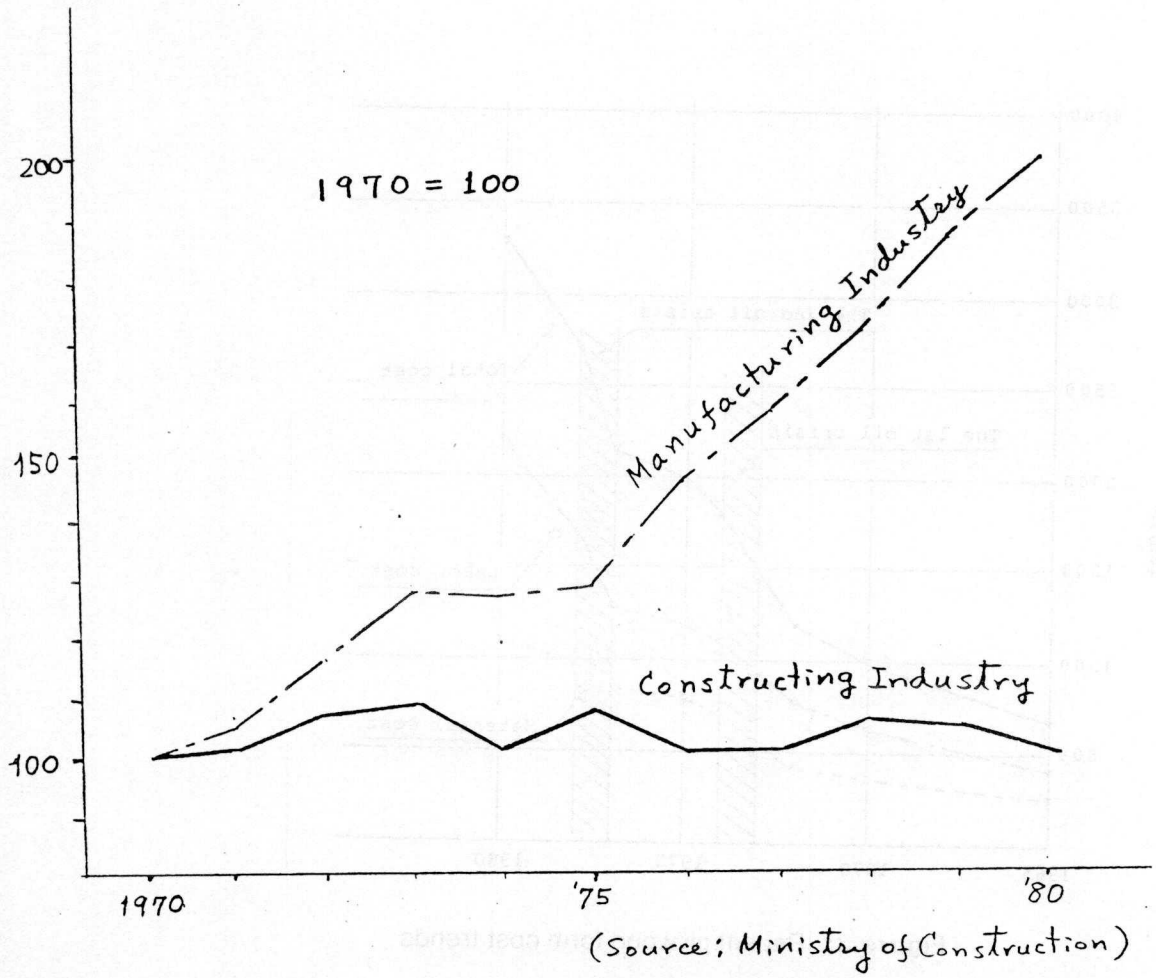

Figure 2: Productivity increment trends in types of industry in Japan

3 Conceptual Design of Construction Robots

3.1 Methodology to introduce industrial robots into the construction industry.

For conquering the difficulties of robotization in general construction, we finally developed a process chart as shown in Figure 4 and we executed the research by the following flow chart.

In the research, we put emphasis on the following points:

1. To keep a consistent system approach from the beginning to the end.
2. To make a survey about the flow of technology and its forecasting.
3. To decide the priority of future robotized operations based on the questionnaire survey and analysis of operations.
4. To select an appropriate method of construction for robotization.

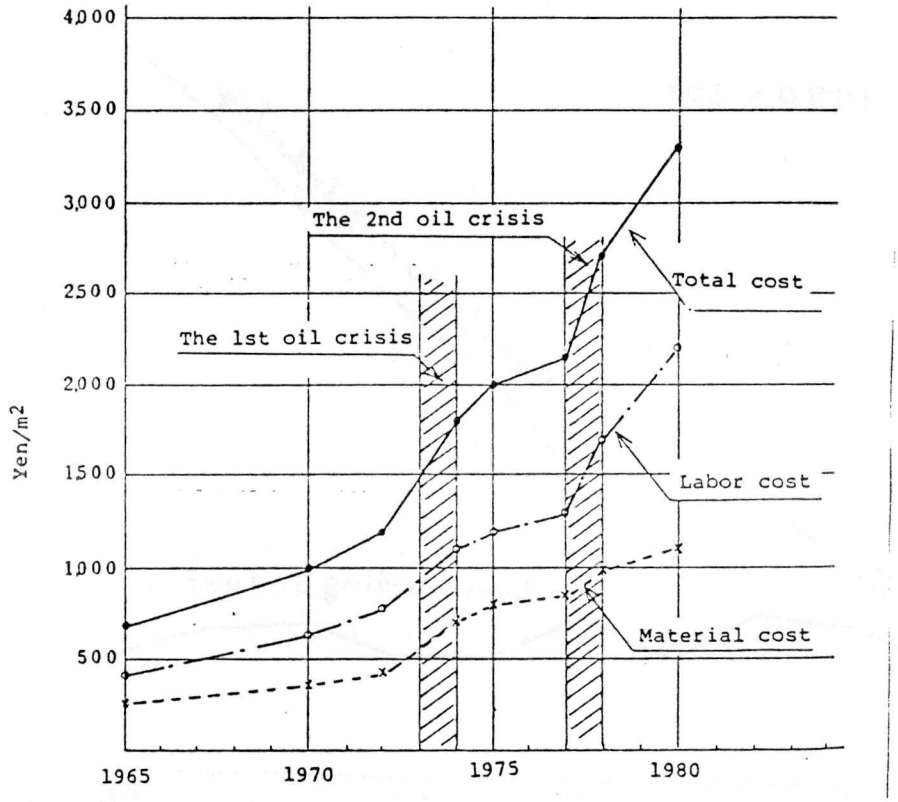

Figure 3: Recent plywood form cost trends

5. To decide the robotized system targets to be accomplished as the result of the research.

6. To imagine a model building as a foundation of the research.

7. To determine the restrictions as a premise of conceptual design of the new robotized system.

8. To make the conceptual model design of the robotized building construction system.

9. To make expecting specification of robots and other components.

10. To make evaluation of the model alternatives.

11. To make feasibility study of models.

12. To determine the problems for materializing model plans and future themes to be solved.

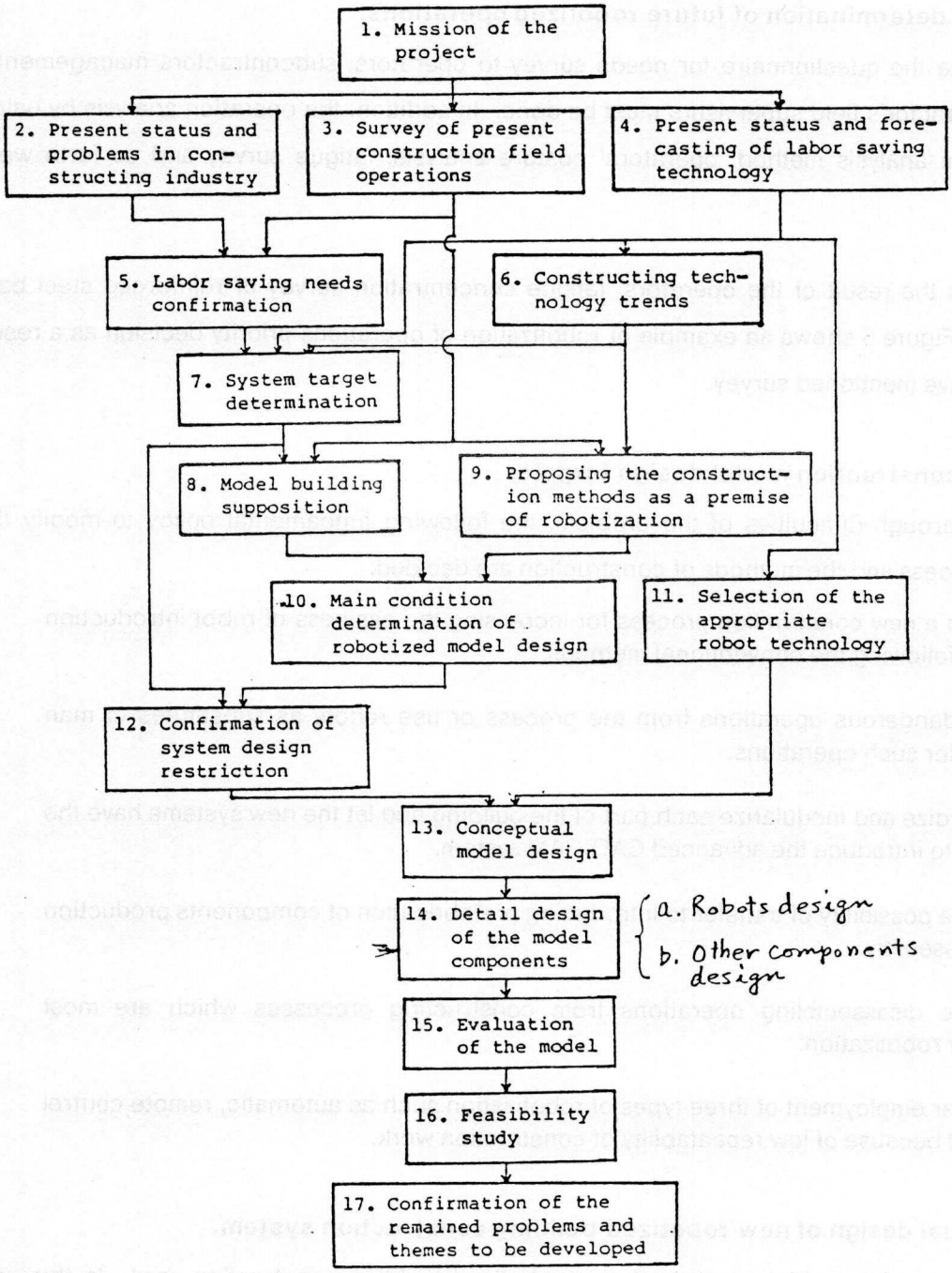

Figure 4: Flow process chart of the research

3.2 The priority determination of future robotized operations.

For this purpose the questionnaire for needs survey to operators, subcontractors managements, and general contractor's field supervisors must be done. In addition, the operation analysis by using memo-motion film analysis method, operators' posture analysis, fatigue survey and so forth were introduced.

Figure 5 shows the result of the operators' fatigue concentration survey of reinforced steel bars assembly work. Figure 6 shows an example of robotization of operations priority decision as a result based on the above mentioned survey.

3.3 Robotized construction model design targets.

For breaking through difficulties of the problem, the following fundamental policy to modify the conventional process and the methods of construction are decided:

1. To develop a new construction process for increasing the easiness of robot introduction instead of following the conventional methods.

2. To reject dangerous operations from the process or use robots as substitutes of man operators for such operations.

3. To standardize and modularize each part of the building and let the new systems have the possibility to introduce the advanced CAD-CAM system.

4. To seek the possibility of transfer to introducing prefabrication of components production and sub-assembly.

5. To remove disassembling operations from constructing processes which are most difficult for robotization.

6. To consider employment of three types of robotization such as automatic, remote control and hybrid because of low repeatability of construction work.

3.4 A conceptual design of new robotized building construction system.

Figure 7 shows an image picture of the future robotized building construction yard. In this year many types of robots will be used such as ground digging, soil handling, steel beam assembling, form assembling, reinforced bars assembling, concrete pouring, painting, measuring and so forth.

Building construction operations are composed of dozens of types of complicated operations. Therefore, giving wide versatility of functions of each robot is a very important issue in construction robot design.

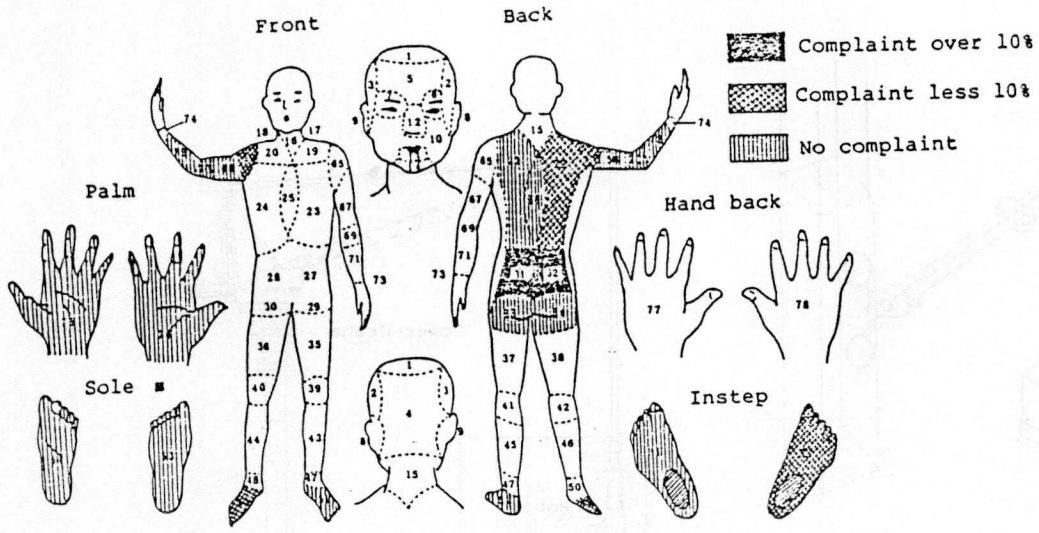

Figure 5: Operators fatigue concentration

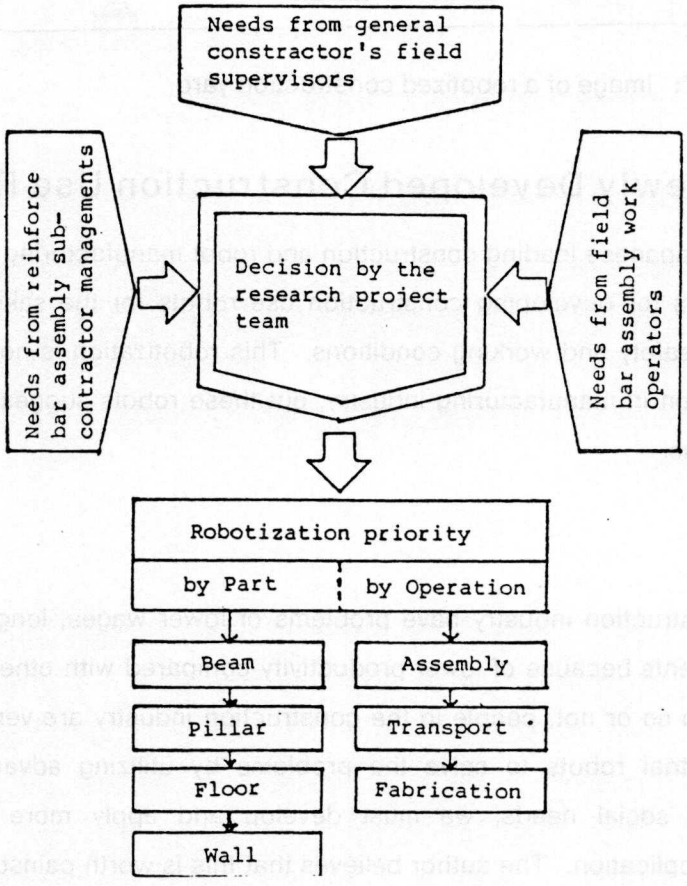

Figure 6: Robotization priority decision process and the result

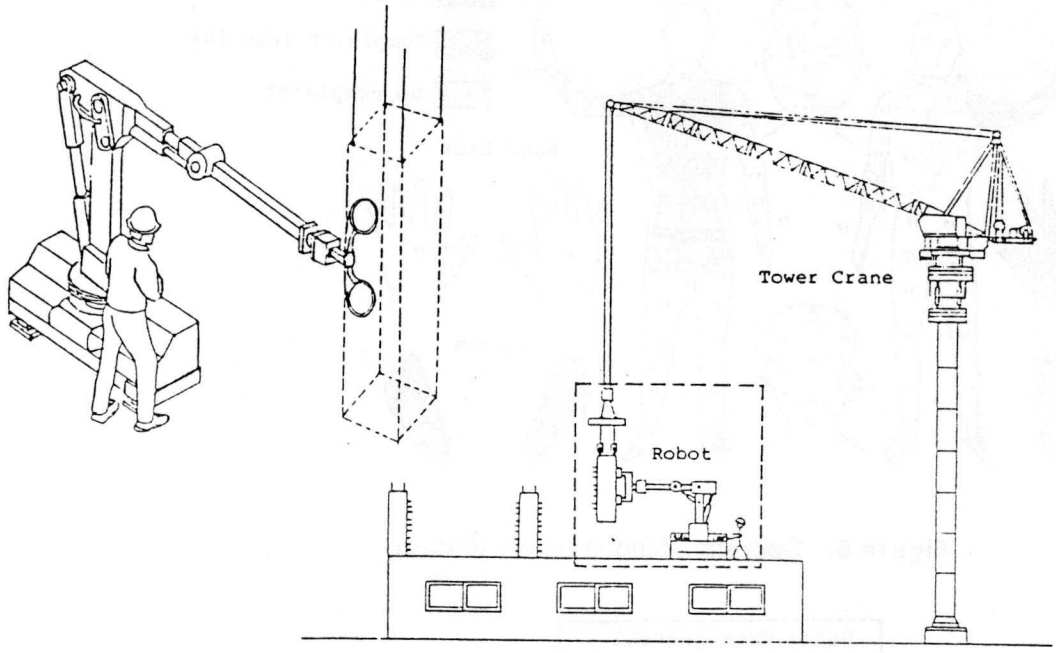

Figure 7: Image of a robotized construction yard

4 Some Examples of Newly Developed Construction Use Robots

Since several years ago, many Japanese leading construction and robot manufacturing companies have been continuing their efforts for developing construction use robots for the sake of saving construction cost and improving safety and working conditions. This robotization is not yet totally synthesized, like factory automation in manufacturing industry, but these robots suggest the future direction of construction operations.

5 Conclusion

Even today workers in the construction industry have problems of lower wages, longer working time, and poor working environments because of lower productivity compared with other advanced industries. Whether we like to do so or not, people in the construction industry are very earnestly expecting the invasion of industrial robots to solve the problems by utilizing advanced robot technology. For fulfilling such social needs, we must develop and apply more systematic methodology of industrial robot application. The author believes that this is worth painstaking effort in robot research and development.

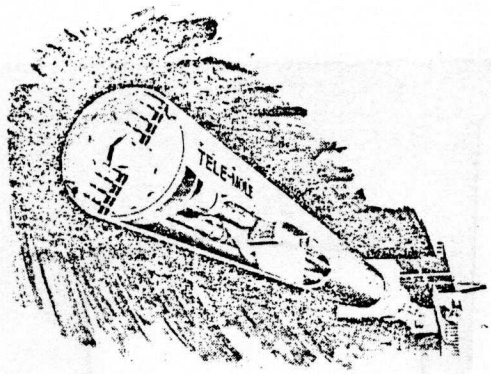

Figure 8: Earth pressure balancing remote control shield system
(courtesy of Taisei Corporation Ltd.)

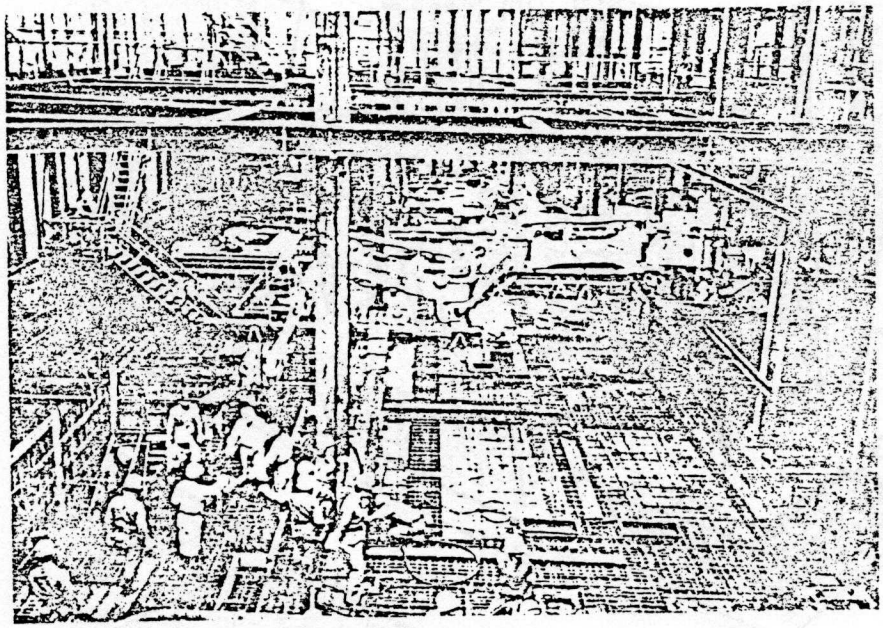

Figure 9: A concrete distributing robot
(courtesy of Takenaka Komuten Co., Ltd.)

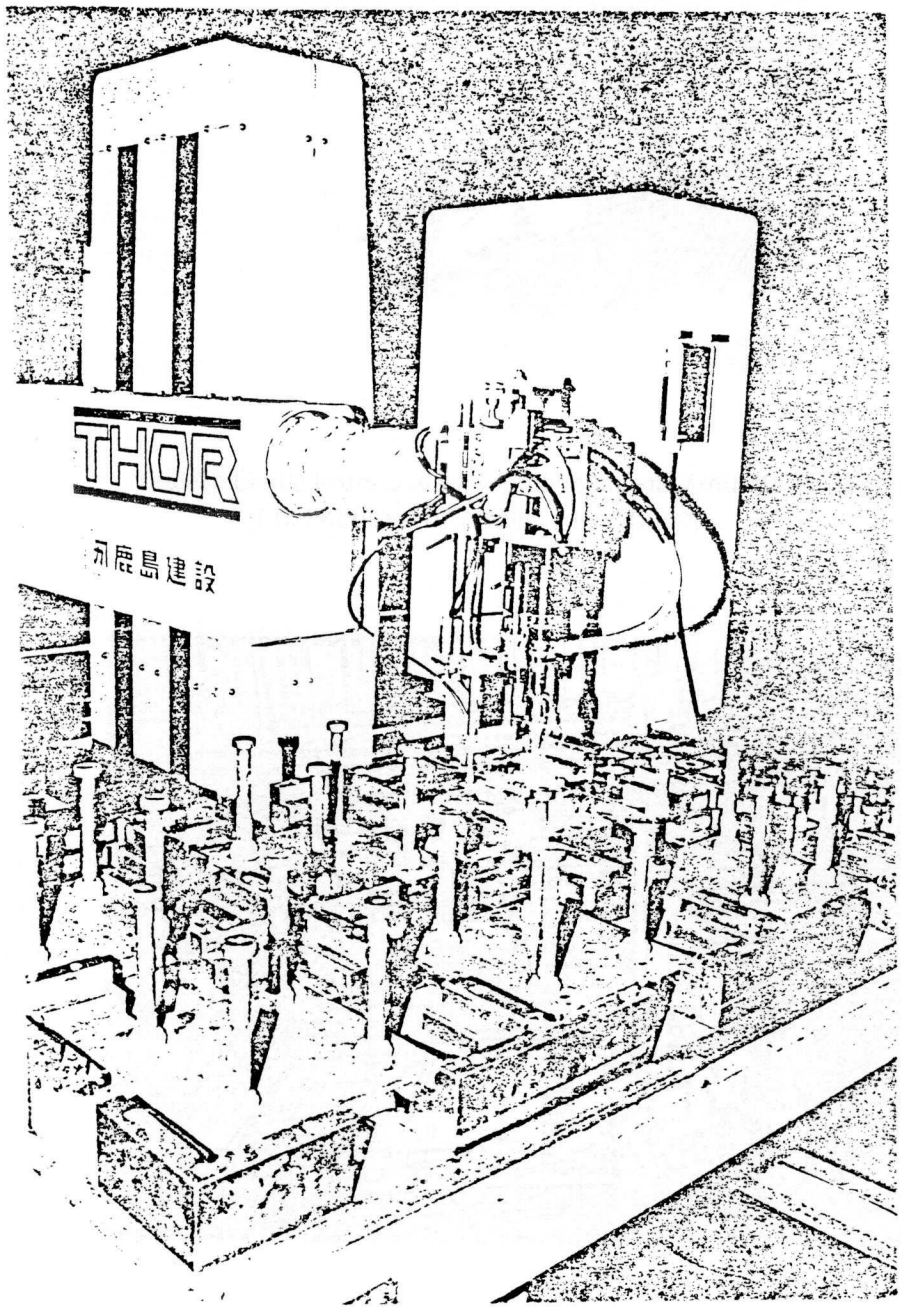

Figure 10: A stud bolds setting robot for atomic power plant building construction (courtesy of Kajima Corporation)

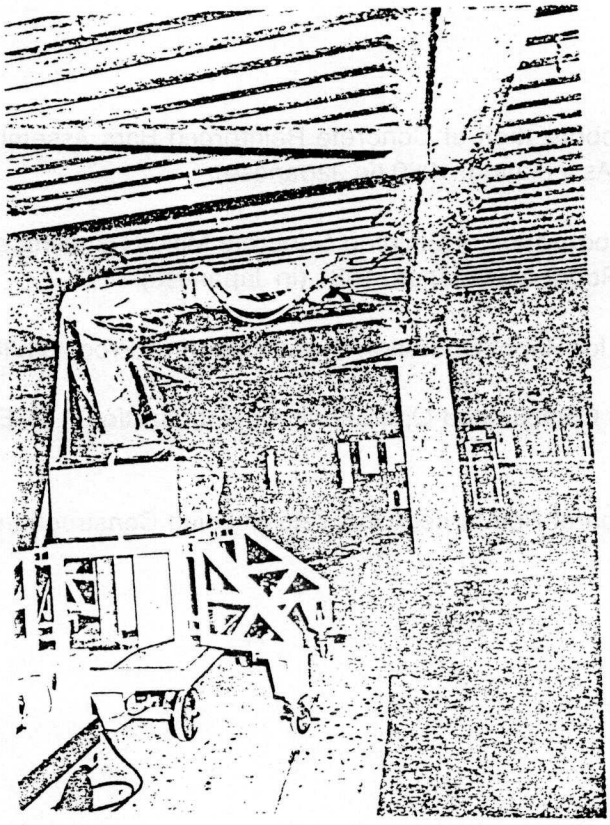

Figure 11: An fireproof insulating coat on steel beam robot
(courtesy of Shimizu Construction Co., Ltd.)

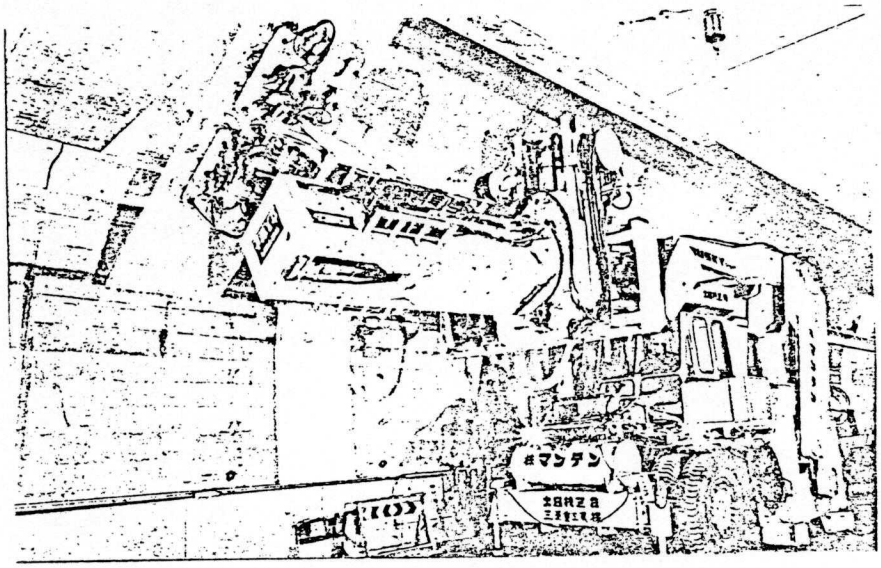

Figure 12: A large concrete panel handling robot
(courtesy of Obayashigumi Co., Ltd.)

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