ANALYSIS OF CONSTRUCTION WORKS FOR ROBOTIZATION

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ABSTRACT

In order to develop a robot which can be applied for construction work, it is necessary to verify the actual needs of construction companies, construction machinery manufacturers, and subcontractors, as well as the seed technology. This report collects and analysis the opinions of subcontractors who will be in the position of operating robots at construction sites with respect to the introduction and the operation of robots. According to the results of research and analysis, it has been clarified that the subcontractors have a positive attitude toward the introduction of robots and that the robots will contribute particularly to solving the labor shortage and reduce the manual labor of workers at construction sites. As regards the technological level of robot, they hope that a robot which can handle more than one task of works when operated by a human worker. And, as a result of an analysis classified by types of works, the reasons for improving each type of work (for example, mold carpenters are liable to suffer injuries) and characteristics of works it was concluded that there is a strong possibility of introducing robots.

Introduction

The Building contractors Society (BCS), which is composed of 78 representative Japanese construction companies, has been researching and analyzing the keeping technologies and needs of the participants in construction works, since 1988 to accelerate the development and diffusion of construction
robots i.e. general contractors, subcontractors, and construction machinery manufacturers towards the construction robots.

In relation to subcontractors described in the research and the analysis mentioned above, this report expands on the research and analysis of subcontractors.

1. Objects and Method of Research Study

In Japan, a general contractor receives a construction order by lump sum contract from the owner and then the construction work is divided into pile work, frame work, and reinforcement work, etc., followed by placing orders with individual subcontractors. The general contractor plans and controls the construction work and supplies or lends the subcontractors staple materials and machinery. The subcontractors go forward with the construction work by directly operating the machinery supplied (there may be a case in which a self-owned or leased machinery is employed).

Therefore, in order to develop a robot which can be used for construction work, it is indispensable to accurately identify the needs of subcontractors. Accordingly, research was carried out on the job classifications listed in Table 1, which assume integral roles in construction work. The research was undertaken in the form of a questionnaire to 552 people in 6 types of job classification (reply rate: 44.4) followed up with interviews for several samples.

Table 1. Objects of Research Study

	Foreman	Asst foreman	Main worker	Others	Sub total	Ave age years
Concrete placers	32	4	3	9	48	46.0
Mold carpenters	23	2	1	9	35	45.2
Reinforcement bar placers	22	4	1	8	35	45.0
Steel frame workers	29	2	1	15	47	46.5
Plasterers	28	4	2	10	44	43.8
Painters	21	6	0	9	36	44.7

(TOTAL 245)

2. Research Results on Subcontractors' views on Construction Robots

In this report, the authors describe the research results for five questions with respect to the introduction, development, and operation of robots from the viewpoint of subcontractors.

2.1 Views on the Introduction of Robots

No feelings of resistance among subcontractors against the introduction of robots were discerned for all six job types. On the contrary, the opinion "We want to positively make use of the robots if they are introduced in the manner we want" occupied the overwhelming majority. (See Fig. 1.)

2.2 Results Expected from Introducing the Robots

Although there were some differences in the results expected among the types of jobs, the most common expectations of the introduction of robots was to "supplement the shortage of labor and reduce manual labor."

It has been clarified that the three items: reduction of cost, improvement in quality, and shortening construction period, which the authors regard as the ultimate purposes of introducing robots, do not to attract them very much. (See Fig. 2.)

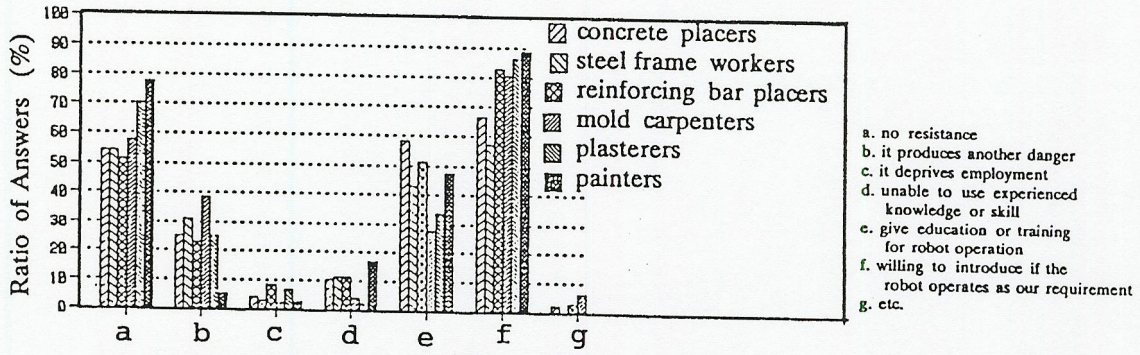


Fig.1 Answer to the introduction of Robot

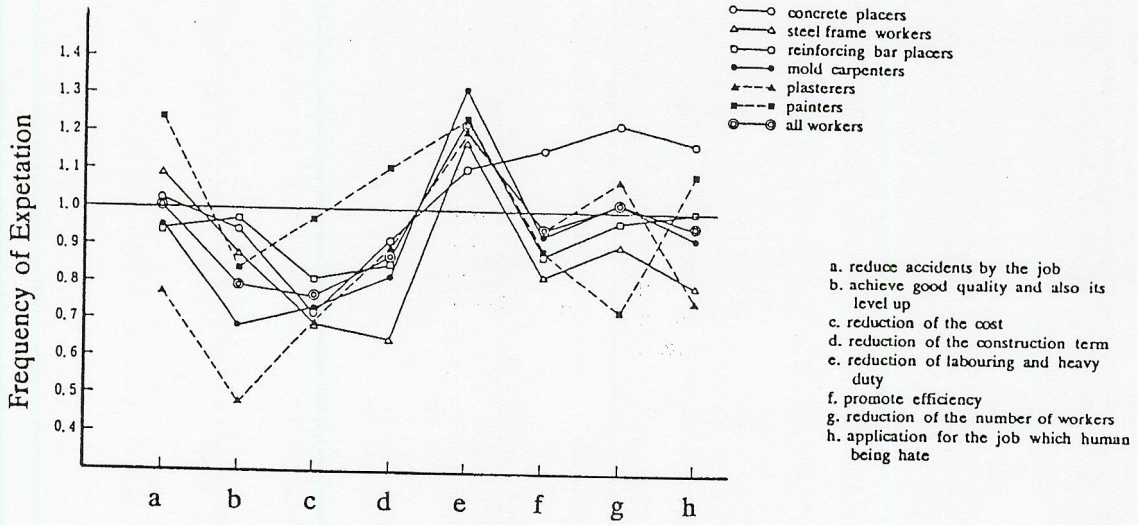


Fig.2 The expecting result by the introduction of Robot

2.3 The Level of Robots Required to be Developed

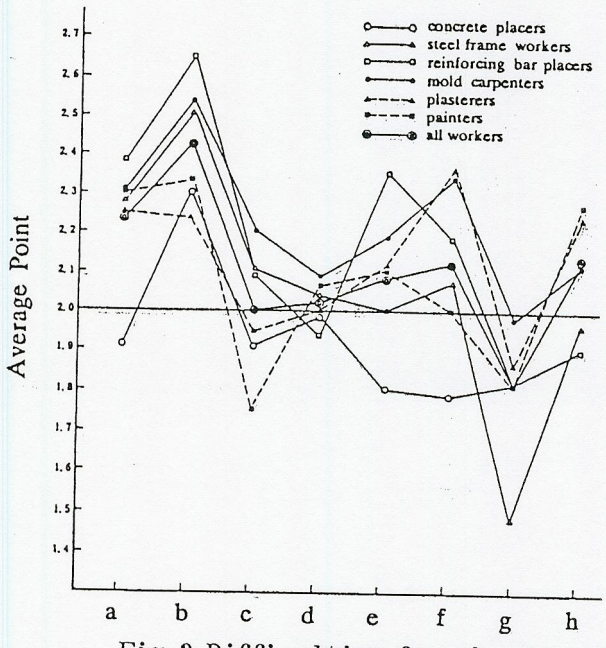
In general, the subcontractors want to introduce type of robots which mainly perform construction work and for human workers to operate and monitor them, and has been clarified that the subcontractors do not expect a highly developed robot such as an unmanned robot.

2.4 The Functions of Robots

As regards the functions of robots, a lot of responses expressed the hope that robot can be developed which can be utilized for more than one task in a specified job type. And were many answers concerning a robot which can be used for a specific task only, resulting in a small number of answers hoping for a robot capable of performing various tasks for more than one kind of job.

2.5 Factors Adversely Affecting the Introduction of Robots

On the whole, the prime factor consists of "differences in designs and specifications" followed by "The construction site changes every time" and "The contents of work are not obvious."



a. construction sites' condition is not always the same and each site has its own building area ground conditions etc.
b. the design or specification of the building is defferent one by one
c. no close contuct between designing and site construction
d. delay of prefabrication and muterial standerdization
e. many kinds of difference is required and all these are not repeated
f. the content of the work is not so clear and the working stage is not stable. The last quality depends on the worker's decision
g. draws causing the cost upward
h. applicable robotization technique are still in low level

Fig.3 Difficulties for the introduction of Robotization

3. Analysis of Construction Work from the Viewpoint of Robotization

In this chapter the authors discuss the results of an analysis of construction work as seen from the viewpoint of robotization based upon the research results described in Chapter 2. The purpose is to understand the real needs of construction workers who are in a position to operate and control the robots.

3.1 Research Method

3.1.1 Object tasks

The main tasks were identified individually with respect to the six types job clssification in the questionnaire, and research was conducted on each task. The respondents were in the foreman class and the number of samples was from 35 to 48 depending on the tasks.

3.1.2 Research items

Research was undertaken on four items concerning work objects: (1) difficulty of work, (2) need for improvement, (3) reason improvement needed, and (4) possibility of robotization. With respect to Items (1), (2), and (4), one choice was selected from out of three, and with respect to Item (3), the above three choices were selected out of eleven.

3.2 Research Results and Consideration

3.2.1 Relation between difficulty of work and need for improvement

In the case of the difficulty of work, in order to weigh the answers with points, 3 points were given to "difficult," 2 points to "intermediate," 1 point to "easy;" and moreover, with respect to the need for improvement, 3 points were given to "great necessity," 2 points to "some necessity," and 1 point to somewhat necessary," then these points were totaled for each task.

The average points for each type of job, although it varied depending on individual object of work, was highest for plastering work in terms of both difficulty of work and need for improvement. The points were 2.26 for the former and 2.11 for the latter. In addition, a positive correlation was found between the two for each type of job. In the case of plastering work, in particular, as Figure 4 shows, a high correlation was recognized. This means that the more the difficult work, the greater the necessity for improvement.

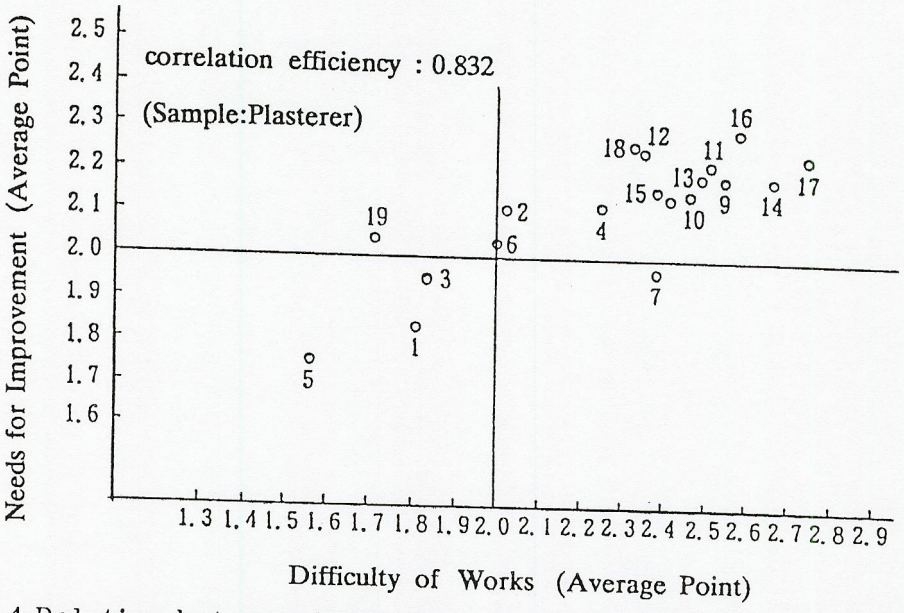


Fig.4 Relation between difficulty of work and need for improvement

3.2.2 Reason Improvement Needed

Table 2 shows the result of data processing for the answered ratios classified by types of jobs for the 11 reasons related to improvement. To analyze this table, the following are needed to achieve the greatest improvement for each work: "Getting dirty" was stated by concrete placers; "Liable to get injured" was stated by mold carpenters' "Much a attention is needed due to complicated work procedure" was stated by reinforcement bar placers; "Liable to get injured" was stated by steel frame workers; "Getting dirty" was stated by plasterers; and "Getting dirty" was stated by painters.

Accordingly, they point out the factors of "getting dirty," "danger," "heavy labor," and repetition of simple work as the reasons improvement was needed.

3.2.3 Possibility of Robotization

Table 3 shows the ratios of responses classified by choices concerning the possibility of robotization using the average values for general jobs. An analysis of this result shows that, excluding the mold carpenters, all of the workers engaged in every type of job gave an equally high answered ratio of answers foreseeing a strong possibility of robotization. In particular, it was clarified that this tendency was higher among painters and concrete placers.

3.2.4 Discriminant Analysis

The authors divided the workers into two groups; Group 1: the answer "There is a possibility of robotization" given by more than 60 of workers

Table 2. Ratio of Answers Reasons to Research Improvement needed

(Unit: %)

Reason needed	Concrete placers	Mold carpenters	Reinforcement bar placers	Steel frame workers	Plasterers	Painters
Fatique due to heavy work	26.5	9.5	22.5	33.3	44.1	18.0
Getting dirty	50.5	4.7	13.9	18.4	47.6	44.9
Bad environment for the health	5.4	0.7	0.9	4.9	5.8	30.1
Liable to get injured	9.5	40.4	17.9	36.4	8.3	11.3
Small working space and unstable	28.4	21.8	32.9	26.5	37.1	16.7
Difficult to handle materials (large and heavy)	5.1	43.3	28.8	22.8	7.5	6.7
Impossible with one laborer	31.6	36.4	37.8	30.0	20.5	10.9
Complicated work demanding careful attention	8.4	22.2	40.6	29.2	19.2	19.5
Repetition of simple work	33.8	24.0	29.7	31.2	27.1	42.7
Contents and procedure of work are not determined	9.7	11.3	16.2	16.8	18.1	22.3
Working time is irregular (early time and overtime work)	25.9	5.8	9.7	9.0	13.6	6.3

Table 3. Ratio of Replies on the Posssibility of Robotization (Unit: %)

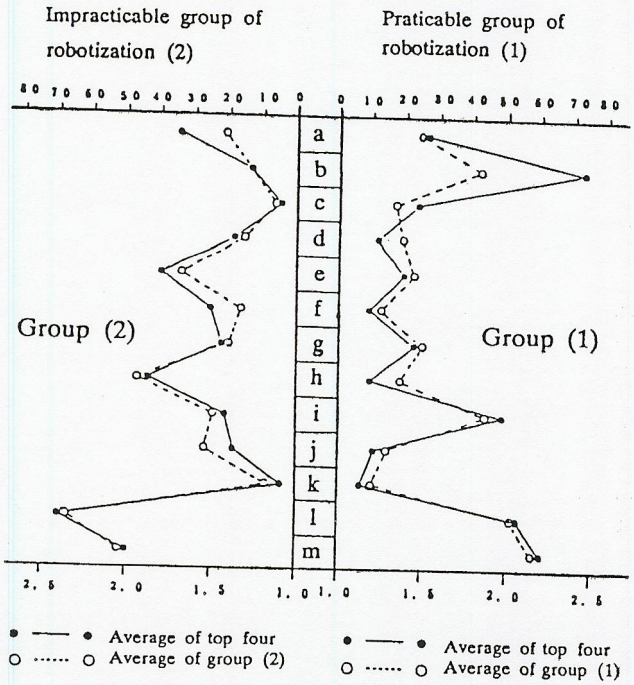
	Robot cannot go beyond human capability	Possible	Engineering method other than robot is preferable
Concrete placers	32.2	53.6	14.2
Mold carpenters	42.2	35.6	22.1
Reinforcing bar placers	38.4	43.1	18.5
Steel frame workers	35.1	49.7	15.2
Plasterers	39.8	42.8	17.5
Painters	37.9	53.8	8.3

combined with the answer of "Impossible to improve the task by robotization" given by less than 25 of workers, as well as Group 2: the response "Impossible to improve the task by robotization" given by more than 50 of workers combined with the response "There is a possibility of robotization" by less than 25 of workers.

The division revealed that 23 types of work come under the former, and 11 types of work under the latter. With regard to this total of 34 types of work, a discriminant analysis was conducted by choosing the ratios of answers to the reasons improvement is necessary, as well as the difficulty of the work, and the needs for improvement as the parameters. Figure 5 shows the average values of the top four jobs in the discriminant as well as the average of all the jobs belonging to each group.

In examining the results of analysis, it was clarified that the points given for improvement needed became higher for the work involving the possibility of robotization (Group 1) than work for which robotization is difficult.

Conversely, in the case of tasks that are impossible for robots to do (Group 2), the tasks that need much attention due to the complicated procedures involved, need a lot of space and more stability to perform the tasks; moreover, the contents and procedures of the tasks change with every job and accordingly the points for difficulty became higher in comparison with the need for improvement.



a.fatique due to heavy work
b.getting dirty
c.bad environment for the health
d.liable to get injured
e.small working space and unstable
f.difficult to handle materials (large and heavy)
g.impossible with one laborer
h.complicated work demanding careful attention
i.repetation of simple work
j.contents and prodcedure of work are not determined
k.working time is irregular (early time and overtime work)
l.difficulty of works (average point)
m.needs for improvement (average point)

Fig.5 Results of Discriminantion Analysis

Conclusion

As a result of a survey on the feelings towards robots in construction work, it was clarified that construction workers have a positive attitude towards introducing robots for all kinds of job classifications. In addition, the purpose of introduction, performance of robots to be introduced, and expectations of subcontractors concerning the development system have been made clarified. Moreover, as a result of an analysis of construction work from the viewpoint of robotization, the relationship between the difficulties of tasks for each job and the need for improvement, reasons for the improvement, characteristics of work with a strong possibility of robotization have been clarified. Thus, the needs of subcontractors have been clarified. The authors are going to integrate these results with the research results of manufacturers and general contractors to establish the conditions for developing practical robots.

To this end, the authors would like to mention that the research stated in this report were carried out by the following members.

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