Attitude to the Use of Construction Robots in Japan
— Centered on Engineers of Committioning party —

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ABSTRUCT

This paper reports the results of the attitude survey carried out on the parties commissioning construction work in Japan to the introduction of construction robots.

The results of study show the attitudes of engineers from parties commissioning construction work at construction sites in Japan today where systemization of construction procedures and the use of robots is making rapid advance.

The study was carried out by the Robotics Committee in Construction of the Japan Society of Engineers. and is the first attitude survey on commissioning parties.

The study consists of the following contents.

(1)Level of awareness analyzed by nine facters.
(2)Image of desired construction robots categorized from four standpoints.
(3)Requests to constructors and manufacturers.
(4)Future trends.

1.Forword

Owing to a recent development of an allied technologies related with electronics, government and public offices, construction companies, manufacturers and so on, have eagerly proceeded the research and development of robotics in construction industries. A good result may be seen in some departments. However, different from industrial robots, construction robots have many subjects to be conquered technically and economically, because of its sever conditions and complicated construction technologies. Therefore, under the common recognition that it is indespensable that the orderer and manufacturer as one body should grapple with automization and robotization in construction work, substantial amount of research and development have been recently proceeded. Under such circumstances, Robotics Comittee in Construction made a market research for manufacturers to grasp the current condition of robotization in construction in 1988, to make these tendencies and problems clear and reported the result of the research at 5th ISRC.

Then, in 1989, the comittee continue to make a research for engineers for their recognition of development and introducion of robotics in construction.

This report shows the questionary and its analysis. As the target of this questionaries for wide and accurate reflection of all orderer's intensions, we selected as many organizations which have ordered construction works constantly in Japan as we can, but not covering all organizations. However, we expect that the intentions of orderers are fully grasped. Most of the results of analysis could be estimated . And extremely interesting results have been obtained which engineers regarding the orderer side hold the appraisal, expectation and future for robotics in construction and matters considering the receivers of an order and manufacturers.

2.Scope and object of the questionary

Regarding to the definition of robotics in Japanese construction, various kinds of discussions have been deployed. It has not been settled yet. In this thesis we made the investigation under the interpretation of safety in the constructing fields, labor-saving and systematization constructing methods as the difinition of "robotics in construction".

As regards the contents of this questionary, a wide range questions,which robotics in construction are adopted in works or not, what they think about advantage and disadvantage for adoption of robotics in construction, what they expect from construction robots in future, as given. Regarding to the works which adopt robotics in construction, it is selected in eight methods which classified and adjusted beforehand as shown in Table-1.

On the other hand, as the target of this questionary we selected governments

as well as the Ministry of Construction and the Ministry of Transport, public organizations, self-governing bodies and in private companies, electric companies, gas companies, railroad companies and communication companies which order construction works constantly. To collect accurate information in fields as much as we can, we asked directly this investigation to the people in charge of spuaring, planning, design, execution and management in each party. The number of people who participated with this questionary are the Ministry of Construction and the Ministry of Transport, Hokkaido Development Agency and Oki-nawa Development Agency: 401(143 sections), self-governingt bodies:166 (45 sections), public organizations :174 (67 sections), private companies:121 (29 sections), and 862 in total. Though the number of answerers may not be sufficient, this shows the intents of the whole industries which order construcion works in Japan The most of 862 participators have not only business in his charge but also concurrent business. As we counted it in each business, total is more than 862. Concretely, spuaring:26%, maintenance and management:25%, takes a high ratio. From the point of age, a ratio of the thirties and the fourties is high. This shows that many number of experienced engineers participated in this investigation. From this point of view, the questionary reflects the current status of constructing fields.

Table-1 Classification of works

Works	Description
1.Earthwork and Rock works	Excavation works, Haul works, Banking, etc.
2.Earth retaining works	Continuous underground wall method, Peristylar continuous underground wall nethod, Earth anchor method, Horizontal sheet-pile with perpendicular steak method, Sheet-pile earth retaining method, etc.
3.Foundation works	Soft ground improvement method, Pile foundation method, Caisson foundationmethod, etc.
4.Concrete works	Mixing, Haul works, Placing, Compaction, Curing, Finishing, joint works, Rainforcement works, Form works, Timbering, Repairing and rain forcement, etc.
5.Tunnel works	Mountain tunnel, Shield tunnel, Propelling, Under ground cave, Trench method, etc.
6.Surveying and measuring	
7.Under water works	Surveying, Dredging, Reclamation, Foundation works, Ground improvement, Structure, etc.
8.The other works	Pavement works, Scrap works, Cofferdam works, Temporary works, Welding, Cutting, etc.

Table-2 Business paticipators in charge

A business in charge	The number of replies	Percentage
Spuaring	312	26.0
Planning	202	16.8
Design	237	19.7
Construction management	301	25.0
Others	150	12.5
Total	1202	100.0

Table-3 The constitution of ages of participators

An age bracket	The number of replies	Percentage
20～29	105	12.2
30～39	313	36.3
40～49	328	38.1
50～59	102	11.8
Others	14	1.6
Total	826	100.0

3.Current condition of the introduction of robotics in construction

3.1 Results of adoption of robotics in construction

As mentioned above, participators who adopted robotics in constructing fields actually are 111 of 862 (12.9%). Under present conditions, participators who have not experienced adoption of construction robots take a majority.
As the reason why they have not adopted it, ① no chance of adoption, ② safety, ③cost up, ④delay of construction period, ⑤accuracy of construction, are stated. Above all, ① occupied an overwhelming majority (92%). This brought an inevitable result from the pervasion of constructing robots. Items of adoption

of robotics in construction according to companies and organizations are shown in Figure-1.

3.2 Works in which robotics in construction have been adopted

From the foregoing paragraph, participators who have experienced adoption of robotics in construction are 111(139 items). 139 items of works are shown in Figure-2. Three types of works; Tunnel works, Concrete works and Underwater works occupy 2/3 (69 %). In case of Tunnel works, spraying robots classified occupy a majority. It shows the current state of construction industries in Japan, which are labor shortage and improvement of severe working conditions. This coincided with the result of investigated research for engineers who belong to private companies, and works proceeded for the research and development reflected the results of adoption.

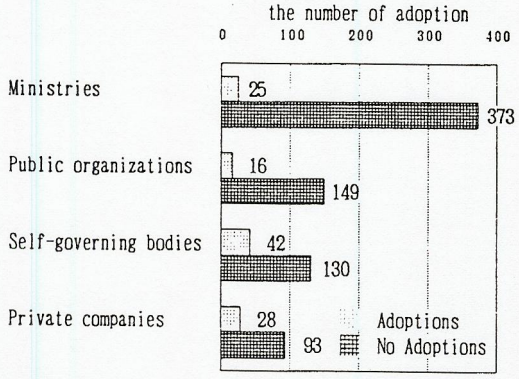

Figure-1 Items of adoption

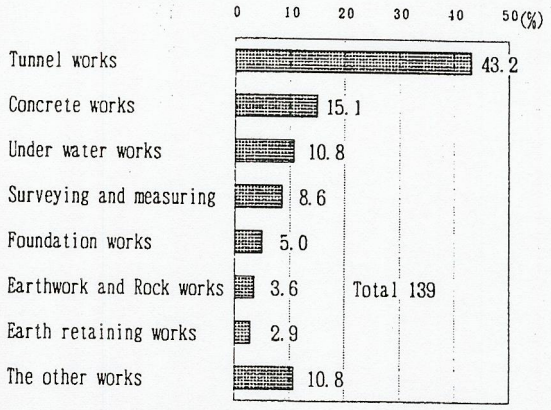

Figure-2 Items of adoption by works

3.3 Determination of adoption for robotics in construction

It is obtained from the result of other research that the research and development of robotics in construction has been lead by private construction industries at present. For the expense to be invested in the research and development a ratio of construction industries is extremely high. From these background this research shows the interesting results about determination of adoption for robotics in construction. That is to say, for the adoption of robotics in construction, contents of the orderers:50.4%, self-adoption of the manufucturers:42.4 % and others:7.2%. Items according to section of the orderers are shown in Figure-3. It shows that the introduction of high-technologies in constructing fields in Japan has been advancing in keeping the balance between the orderers and the manufacturers. Figure-4 shows a ratio according to works.

In concrete work when it is ordered the designation of constructing methods is comparatively few, a ratio of adoption by the intent of the orderers decline :25%. On the contrary, in other works occupy 60%:high percentage.

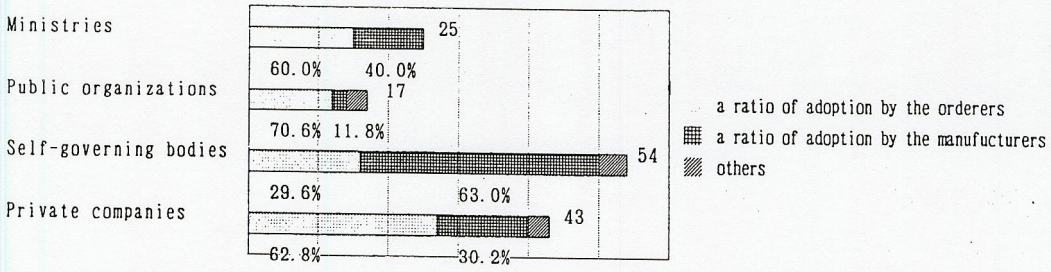

Figure-3 A ratio of adoption according to the orderers

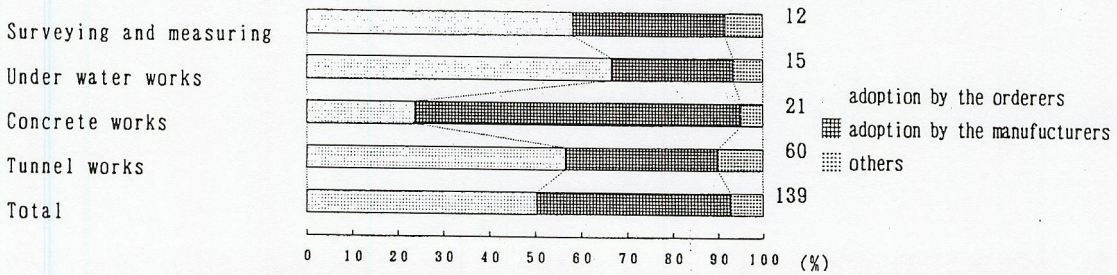

Figure-4 A ratio according to works

3.4 The expence of construction which adopted robotics in construction

Regarding to the expense of constructions which adopted robotics in construction, adoption in large constructions over 2,000,000,000 yen makes 31,7%. The rest is 10,000,000 to 50,000,000 yen :22,3%, below 10,000,000 yen:17,3%, 50,000,000 to 100,000,000 yen:15,8%, 100,000,000 to 200,000,000 yen:11,5%, in that order. In comparatively small constructions below 50,000,000 yen it makes 40%. Between the expense and adoptions of robotics in construction, there is no mutual relation.

3.5 Level of automatization of robotics which have been adopted in construction

As mentioned before, at present the definition of robotics in construction has not precised yet. It is important to know the level of automatization of robotics handled in constructing fields. This reserch brought the results that 2/3 (61,9%) of entire robotics adopted in construction are remote controlling.

Next to remote controlling, semi-automatization(25,9%), complete automatization (10,8%). On the other hand, another report brought a result about a development of robotics in construction which aims at complete automatization:37%, semi-automatization:36%, remote controlling:27%. This shows the gap from development side and practical side, and in practical use robotics in construction are moving from the stage of remote-controlling to complete automatization. Figure-5 is comparison of automatization in four works which adopt robotics in construction substantially.In Surveying and Measureing and Tunnel works automatization is high, and low in Underwater works and Concrete works. This shows the difficulty of robotization and automatization by works. It coincides with the technological difficulty of development in Japan.

3.6 Change of design by adoption of robotics in construction

Present constructing methods have been established from the experience of many years, not necessarily procedure suitable for automatic construction as represented by robotics in construction. Therefore, from the circumstances that depending on the kind of works constructing methods have been determined by a specification when ordered, it is a serious problem whether to change the design or not in adoption of robotics in construction.

The results brought : changed the design ; 15(10.8%),did not change the design ; 120(86,3%) in entire 135 adoptions. This shows that design change has been scarceley made at present in spite of intent of adoption of robotics in construction by manufacturers or by the orderers.It contains a lot of problems which are design method, constructing method, a form of ordering, a form of receiving the orders, rule and prescription and so on, and it is important to spend many yesrs to make researches.

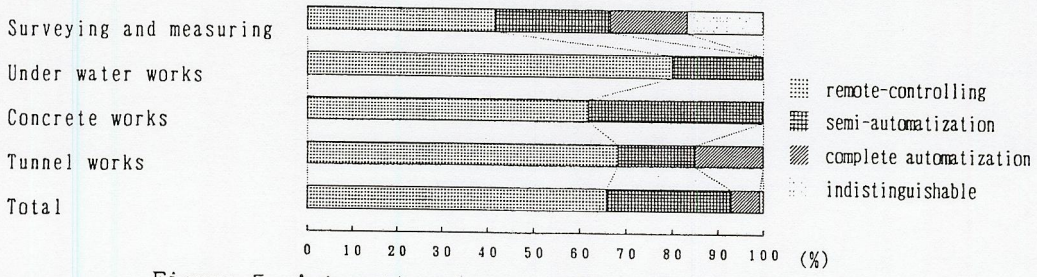

Figure-5 Automatization according to works

3.7 Advantages and disadvantages of introduction of robots for construction

It is a great aid for the research and development in the future to know the engineers and managers in the construction field regard advantage and disadvantage of introduction of robots for construction. Here, the aspects that advantages and disadvantsges mean are as follows: improvement of safety, improvement of working condition, progress of lavour-saving, reduction of management work, curtailment of the completion for construction, effect of advertizement, improvement of constructive precisement, improvement of quality, improvement of productivity, and cutdown. We believe that we have obtained the results which shows the actual conditions by these investigations though it is rather difficult to reffer to the whole construction fields as the general tendency because the robots are not introduced throughout the constructing field at present. Over 50% of the engineers regard introduction of robots as an advantage in every aspect except for cutdown, and that exactly shows that now is the transitional period into in-

troduction. Results of the researches in each aspects:
(1)The aspects which over 75% of the engineers regard effective are improvement of safety, improvement of working conditions and progress of lavour-saving. On these aspects, we can easily see advantages as robots can work instead of men.
(2)The aspects which they generally regard better than the present conditions are reduction of management, curtailment of the completion for construction, and effect of advertizement. They didi not find out either strong advantages or disadvantages but regard it as more effective than the present circumstances, and so we believe that introduction of construction robots and improvement of automization make them positively regard it as advantages.
(3)The aspects in which they found both advantages and disadvantages are improvement of constructive precisement, quality and productivity. That is because the present technical level of construction robots are not high enough.
(4)Most of them regard cutdown as disadvantage. It is quite natural because the development of robots costs much and the present robots can only work for one kind of work. It means that introduction of robots at present does not cause cutdown of the whole construction. This will be the most important matter in the future.

3.8 Intension for introduction of construction robots now and in the near future

84% of all answerers intends to introduce construction robots in a specified field or construction and 9% of them positively wants to introduce robots in every fields, but 4,9% of them does not want robots in any field at all. We can see that most of them intend to introduce robots but they think that there are still various kinds of problems at this time and therefore hesitate to adopt robots in all the construction field.

3.9 The reasons for rejecting robots

The reasons why they do not want to introduce construction robots are as follows: ocurrance of new danger, decline of constructive precisement, satisfaction with the present condition, and decline of quality. On the other hand, there is no one who points out that introduction of robots causes decline of productivity and working conditions. It shows that they regard construction robots as safe, precise, and good in quality, and so it will make us believe the prospect of our future technical development is bright.

4.Concrete elements of construction robots

4.1 Condition for introduction of construction robots

The aspects that they think important to introduction of construction robots are shown in Figure-6. Over 80% of them regard "improvement of safety" as important and high-percentage of them regard "labour-saving" and "cutdown" as well. That shows that orderers expect that robotization and autmization will solve the problems such as: accidents during the work, low productivity, aging of workers, and decline of skilled workers. In another investigation, the engineers of constructing field regard "labor-saving","improvement of constructive precisement", and "improvement of quality" as important but they do not regard "improvement of labor safety", "cutdown" and "curtilment of completion for construction" as important. It is quite interesting to see the distinct difference between the orderes and construction companies and manufacturers.

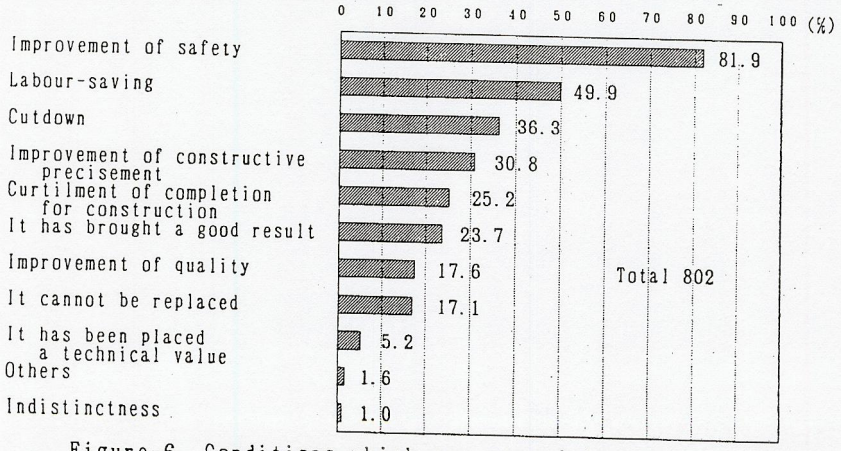

Figure-6 Conditions which are regarded as important for adoption of construction robots

4.2 The kinds of construction works where construction robots are required

Construction works where construction robots are required are as follows:(Higher percentage works come;prior) ①concrete works ②under water works ③tunnel works ④foundation works ⑤earth work and rock work ⑥surveying and measuring ⑦earth retaining works ⑧others. There is no obvious difference between each respective work.

Also, the matters of works where construction robots are required are as follows: ①excavation works ②surveying and measuring ③caisson foundation works ④shield tunnel ⑤dredging ⑥propelling ⑦welding ⑧under water foundation works ⑨mountain tunnel ⑩compaction. We believe that this is the result quite faithfully reflects the present situation of Japan.

4.3 Respective works where construction robots are required

The matters of constructing works where introduce construction robots are required are as follows:①building ②surveying and measuring ③measurement ④maintenance ⑤transport.

We can easily imagine that building work takes the highest percentage but we find it rather surprising that they want to introduce construction robots in surveying and measuring works have become more important in these years, and so they expect to avoid mistakes and to save labor in collecting and arranging the data by using robots.

Though we have another datailed data of questionary, we cannot show it because of the shortage of pages. It is interesting that these results of investigation show how the engineers feel about the recent construction field that is growing larger and more complicated.

4.4 What kind of robots do they expect to be developed?

According to the questionary, construction robots are expected to be developed for specific works. There are total of 370 answers: tunnel works(50), underwater works(50), foundation works(31), earth retaining works(11), and other works(60). There is not distinct difference in numbers from concrete works to foundation works and other works are 60, which means development of construction robots is requested in all kinds of works. The orderers require construction robots in these respective works which gain many numbers, and they seem to wish to use construction robots when they are well developed. The aim for development of construction robots has been made clear.

Moreover, altogether as many as 237 opinions on the period needed for development are collected as follows: 0～3 years:139(59,4%), 3 ～5 years:67(28,6%), 5 ～10 years:26(11,1%) and more than 10 years:2(0,9%). That means 88% of all answers want the robots to be developed within 5 years.

5.What the orderers expect from manufacturers and construction companies?

We asked orderers how they feel about and what they expect from the construction companies and makers regarding automization, uninhabitization, and robotization. We collected their opinions on 8 factors which were earlier set up from the aspects; technical level, orgainization of development, and attitude to development.

5.1 Technical level

The technical level required from the construction companies and manufacturers are shown in the Figure-7.

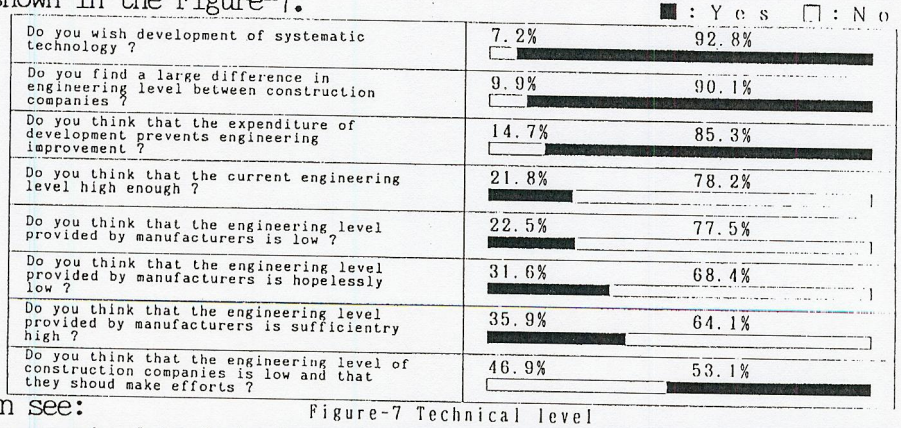

Figure-7 Technical level

We can see:

①The organized technical develoment will be necessary in the future but the expendure will be very high and it will be difficult for makers and companies to

proceed it by themselves.
②The technical level of makers can meet the requirements of constructing field but majority of the companies cannot manage these technics successfully. Moreover there is a large gap between each company.

5.2 Organization of development

The requirements for the construction companies and makers from orderers are shown in Figure-8, and the following are concluded.
①Co-operation not only by the companies and makers but also by the government and universities is indispensable to systematize the development.
②Development solely by companies and makers cannot be proceeded successfully, because the expenditures are quite high and there is differense in quality between each company.

■ : Yes □ : No

	Yes	No
Do you think that manufacturers should perticipate with the development system ?	2.0%	98.0%
Do you think that nation,civil,and study should work on the development system together ?	4.7%	95.3%
Do you think that the quality is different in the development system between costruction companies ?	9.1%	90.9%
Do you think that the expenditure prevents establishment of development system ?	15.0%	85.0%
Do you think that manufacturers adopt the development system required by construction field ?	16.8%	83.2%
Do you think that the construction companies adopt the development system that is required ?	20.2%	79.8%
Do you think that the orderes need development system of their own ?	30.7%	69.3%
Do you think that it is difficult to retain the current development system ?	39.8%	60.2%

Figure-8 Organization of development

5.3 Attitude to development

The views for attitude of the makers and companies to development are shown in Figure-9. We can conclude:
①Co-operation by makers is regarded necessary but most of the companies do not make any effort on co-operation and suggestions. Even in the case of the companies which make some effort, there is a large gap between each company.
②It is necessary for the companies, government and universities to co-operate, because the expenditures of development are high.

■ : Yes □ : No

	Yes	No
Do you think that it is inquired that the construction companies should make some effort on technology introduction and development ?	3.9%	96.1%
Do you think that nation,civil,and study should be more united ?	4.5%	95.5%
Do you want active proposal and perticipation of manufacturers ?	7.7%	92.3%
Do you think that the attitude for development is different between construction companies ?	10.8%	89.2%
Do you think that you have obtained active proposal from manufacturers ?	13.9%	86.1%
Do you think that the expenditure is obstructive reason ?	14.8%	85.2%
Do you think that the construction companies and manufacturers have positive intention for development ?	25.2%	74.8%
Do you think that construction companies proceed development though not very actively ?	29.9%	70.1%

Figure-9 Attitude to development

6. What to be resolved?

We made a questionary to engineers and managers who belong to the orderer companies how they think about the future of robotics in construction. The analysis of the questionary is shown in Figure-10 and 11.

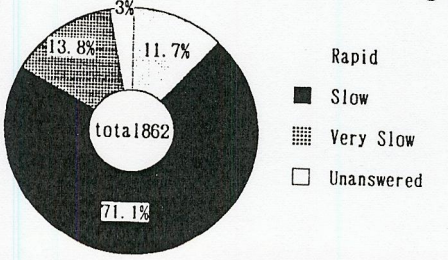

Figure-10 Prospected Progressing Speed of the Introduction of Robotics in Construction

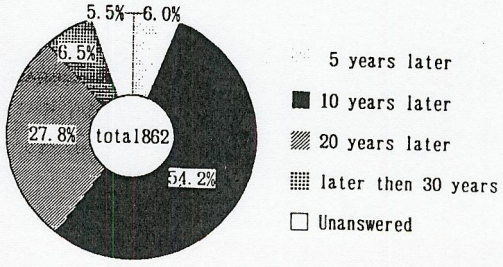

Figure-11 Prospected Times of Robotics in Construction Commonly used

The following can be pointed out:
①Regarding the speed of the development for construction robots, majorities think "slowly develop". Ther is no large difference between the orderer companies, works, or ages. The same tendency can be seen concerning prospective time of robotics in construction to be commonly used. Also, there is no difference between companies which have experience in robots and which have not. It shows that robotization is indispensable in the construction field even though some factors to be resolved regarding technical level, development organization, and how to link the past engineering method to robotization.
②On the prospective time of robotics in construction to be commonly used, 82.0% of all answers "10～20 years later". On the other hand, as for "period neede for development", 88% answered "3 ～5 years", as formaly mentioned. This result shows that there is still much to be resolved concernig current technical level, technology development system, and environments of construction field for robotization although instruction of robotics in construction is hastely required.

7. Conclusion

This is the first investigation in Japan, made on what the orderers of the construction think of automization, uninhabitization and robotization. The analysis of the questionary shows no special result utterly unexpected. If the individual answers are studied in detail, there are many interesting points found. Our future subject is how to effectively use the result. Even higher result can be obtained by reffering to "The Existing State and Future Problems of Robotization in Construction" reported before. We intend to make the best use of this investigation for "the research on further systematization of construction technology " which has been inquired by the Robotics Commitee in Construction.
We have already oresented several reports of robotization on the other factors such as promotion means, and obstructive factors. We expect that development of construction robots will positively progress studying these reports together with this investigation.

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