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Prospects for Applying Automation/Robotization of Life-Line Piping Construction Work

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ABSTRACT

In this report, the present condition of life-line piping construction work has been analyzed. Life-line piping includes water supply, sewerage, electric power, city gas and communication and need of Automation and Robotization in construction work has also been studied. The group arranged the technical problems attended for automated construction system and proposed images of the system. The images are comprised with systems for advanced open cut method and trenchless piping method in which a vertical shaft is employed. This report includes the effects of the society accompany with automated construction system.

1. INTRODUCTION

Most of life-line services which indispensable to maintain city functions such as water supply, sewerage, electric power, city gas and communication are supplied by under ground pipelines or tunnels. Most of these life-lines are small scaled structures so it is likely that these facilities were mostly constructed by manpower. The ratio of construction done by machine is seemed low. This due to the small scaled work and spreaded site. Moreover in the city, it is not suitable for machine construction that existing utility lines are overcrowded and its locations are not always clear. The Committee, in which life-line concerned members are include has aimed the future and proposed new automated pipe-line construction systems. Though this report has not mentioned its detail, the Committee also studied issues such as organization images which will develop new systems, how to spread developed new system, and its effect to the society.

2. PRESENT SITUATION OF AUTOMATED/ROBOT SYSTEM FOR PIPING CONSTRUCTION WORK

Table 1 shows automated/robot system for small scaled familiar piping work. The technical level shown in the Table has been evaluated according to the following criterion.

A: The machine available sensor detected information and can make decision for next process.

B: Though the machine available sensor detected information, the decision for next step is done by operator.

C: The machine can not available sensor detected information and is operated by operator, this is only mechanization level or less.

In the Table, all items are resulted level C. The present situation is only mechanized level and large part of the work depends on manpower. When compared with other construction work, the piping work is lagging in application of automated/robot system.

Table 1 Work Items for Piping Construction Work and the Present Situation of Application of Automated/Robot System

Work items	Technical level	Content of work	Present application of automated/robot system	Problems
Setting of barricade	C	. Bringing in and setting of safety equipment.	——	. Car intrusion . Effect to the traffic and stores (ditto with folling column)
Pavement breaking	C	. Cut and peel pavement and load the debris into truck.	. Breaker	. Noise, vibration dust. . Hard work
Excavation, sheathing	C	. Excavate ground to the designed depth without damaging any existing structures . Setting sheathing.	. Trencher . Back-hoe . Crane attached truck	. Noise, vibration, stain . Hard work . Rupture of soil . Falling accident . Difficulty of soil disposal . Give damages to existing buried structure
Piping work	C	. Make level the excavated trench and connect pipe to pre-installed one.	. Joint setter (partially applied) . Crane attached truck	. Hard work . Rupture of soil . Falling accident . Work is not efficient.
Back-filling, removal of sheathing	C	. Backfill sand into trench and tamp it without giving damages to installed pipes. . Fill sand to indicated level and tamp it. Remove sheathing and backfill.	. Vibrating compactor . Tamper . Rammer . Bearing load testing machine	. Noise, vibration, stain . Hard work . Rupture of soil . Work is not efficient.
Restoration of roadbed	C	. Spread ballast and tamp it.		
Restoration of pavement	C	. Provide temporary pavement for traffic.	. Roller . Asphalt sprayer	. Noise, vibration, stain . Stink, get scalded . Work accident . Control of material temperature
Removal of barricade, cleaning	C	. After removal of safety equipment and cleaning, the traffic can be opened.	——	. Accident of car plunging into the construction site

3. PROPOSAL OF NEW AUTOMATED/ROBOT SYSTEM

The proposal of new automated/robot system for life-line piping construction work is composed of following two systems.

(1) Automated/robot system for open cut piping work.

(2) Automated/robot system for trenchless (small diameter propulsion method) piping work.

3.1 Basic technical conditions of the system

Conditions to which the automated/robot system must be accorded are as follows.

(1) Functional conditions

* Grasp location of existing buried structures and do not give damage to these structures.
* Do not give unacceptable vibration and noise to the nearby environment.
* Take safety measures not only for workers but also for pedestrians and cars.
* Efficiency of the new system must be better than existing methods.

(2) Operational conditions

* The system must not requires expert operator.

(3) Conditions on standards

* A system must have multiple functions.

(4) Conditions of safety

* The system must have fail-safe mechanism which can prevent the machine from losing control.

3-2 Concrete study on the automated/robot system

(1) Automated/robot system for open cut method

It is assumed that the system is employed for one day restored life-line piping construction work. The work included the process of from pavement breaking to pavement restoration and must be finished within one day. The dimension of the site is from 3 to 4m wide and 50m long. Table 2 shows the required functions for the robot for each work process. The images of the work robot are illustrated in Figure 1 - Figure 4.

Table 2 Work Robot for Open Cut Method and Its Function (1/2)

Work process	Functions of robot		Name of robot
	Items	Details of function	
1. Survey before commencement of work (buried structures soil)	(1) Memory function for information of existing buried structures	. Memorize existing buried structures record transmitted from road management system within for the construction span.	Survey/ design robot (Figure 1)
	(2) Surveying function for buried structures (Trenchless method)	. Using data transmitted from road management system, survey buried structures from road surface.	
	(3) Automated design function	. Prepare work drawings according to data given by road management system and result of site survey . Transmit work drawings into construction machine or robot	
2. Pavement breaking	(1) Pavement breaking function	. Recognizing its location and according to drawings the robot must cut asphalt layer along instructed line. . Pavement block must be cut into smaller block.	Pavement cutting and breaking robot (Figure 2)
	(2) Small block loading function	. The robot loads small blocks into transportation machine.	
3. Excavation	(1) Function of excavation and soil disposal	. Recognizing its location and according to drawings, the robot must excavate ground avoiding buried structure and haul the soil out of trench. The image of this work is not that using machine and cutting natural ground, but is soft image which breaking soil using fluid material and the soil is sucked out.	Excavation, sheathing, pipe setting, backfill robot (Figure 3)
	(2) Function of prevent to damage to buried structures	. To prevent breaking unknown buried structures, the tip of cutting tool must be provided buried structure sensor and come to a immediate stop before the structure damaged.	

Table 2 Work Robot for Open Cut Method and Its Function (2/2)

Work process	Functions of robot		Name of robot
	Items	Details of function	
4. Setting sheathing	(1) Sheathing setting function	. According drawings the robot must excavate ground avoiding buried structures recognizing its location and buried structures. Then to prevent ground rupture, it will continuously set sheathing.	Excavation, sheathing, pipe setting, backfill robot (Figure 3)
5. Set piping	(1) Piping work function	. Lay pipe for piping into the trench avoiding buried structures and set pipe according to indicated location.	
	(2) Pipe connecting function	. A pipe set into trench must be connected with pre-installed pipe. To avoid complicated work, the joint must be simple mechanism such as insert type. Pipe holding arm must be developed which can avoid existing structures.	
6. Backfill and tamp, removal of sheathing	(1) Backfill function	. According to drawings and avoiding buried structures the robot must backfill the trench with appropriate soil.	
	(2) Tamping function	. Tamp the backfilled soil as hard as the natural ground.	
	(3) Work control function	. During the tamping, check the bearing capacity of backfilled soil and roadbed and record the data.	
7. Restoration of roadbed	(1) Paving function	. According to drawings and recognizing its location the robot will be restoring pavement along designed line.	. Pavement restoring robot (Figure 4)

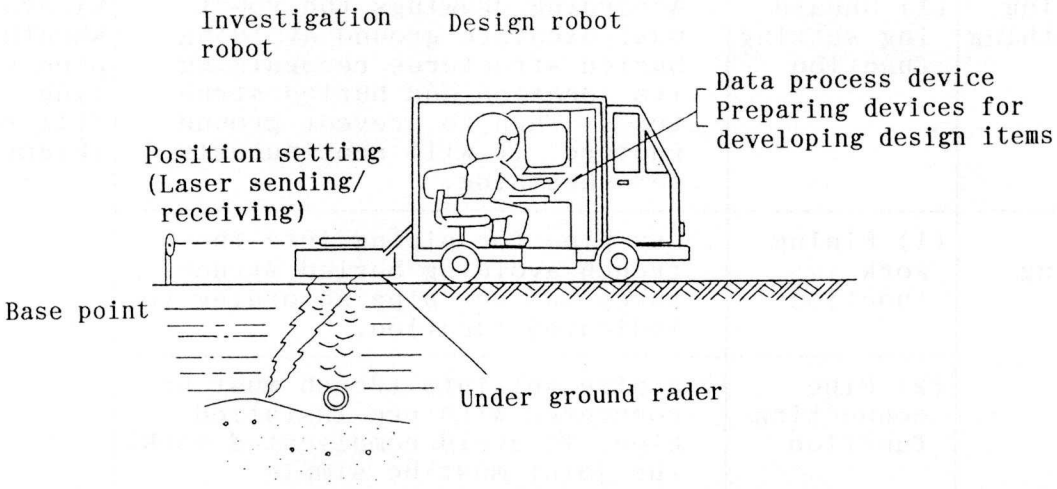

Figure 1 Survey/Design Robot

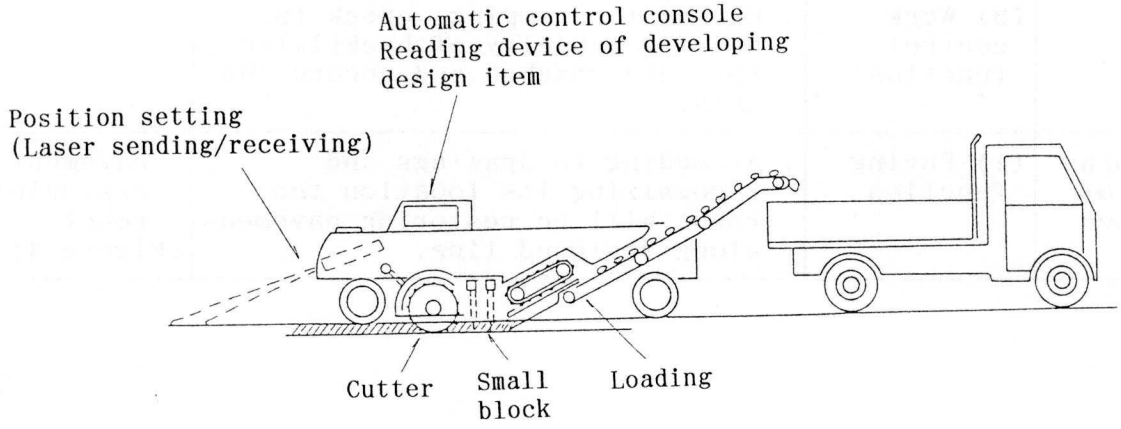

Figure 2 Pavement Cutting and Breaking Robot

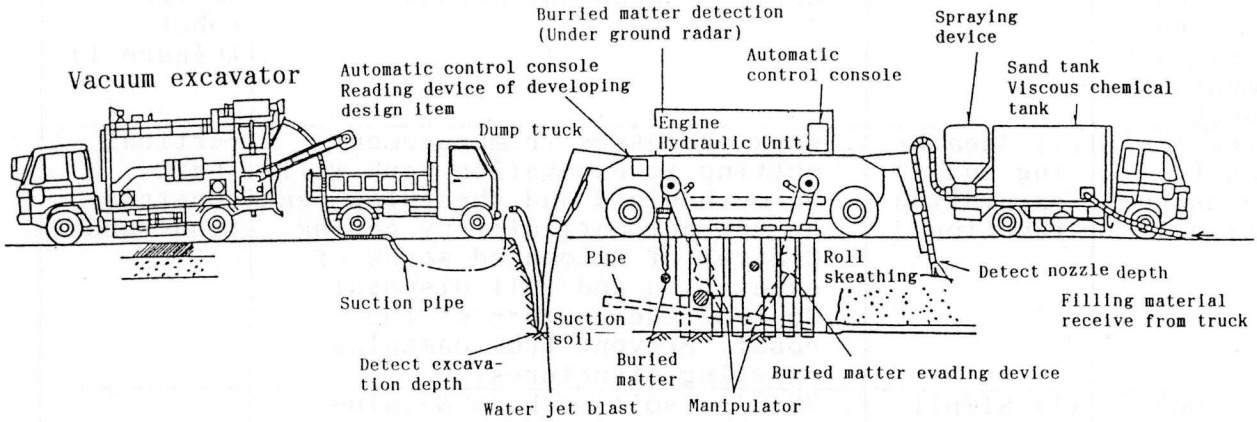

Figure 3 Excavation, Sheathing, Pipe Setting Backfill Robot

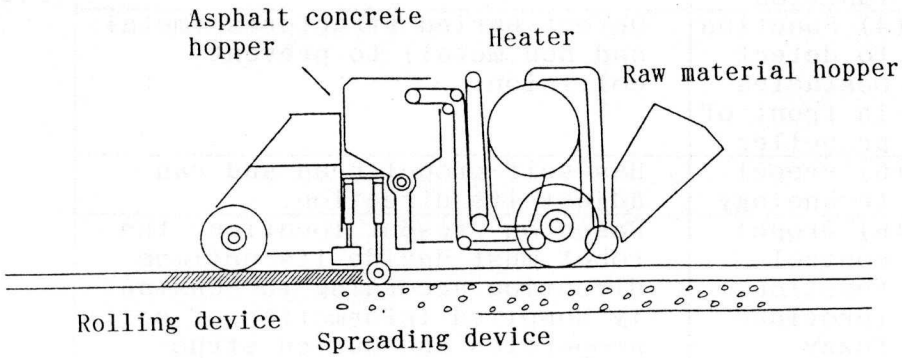

Figure 4 Pavement Restoring Robot

(2) Automated/robot system for trenchless piping work

In trenchless piping work, open cutting work is limited for vertical shaft only, and the system can be controlled by unified operation at the vertical shaft location, so this method may be the most suitable method for automated/robot system.

In this study, small diameter (less than 300mm) piping work, which is usually applied for a large part of life-line piping work, is considered. Table 3 shows the work process and corresponding robot function. Figure 5, 6 show images of robot which will send out propeller from ground surface, this system required no vertical shaft.

Table 3 Working Robot and Its Functions for Trenchless Method

Work process	Functions of robot		Name of robot
	Items	Details of function	
1. Survey ground before commencement of work		Refer to Open Cut Method.	Survey/ design robot (Figure 1)
2. Vertical shaft construction	(1) Sheathing and excavation function	. Work processes from pavement cutting to excavation work will be mechanized and sheathing can be set automatically by casing. Control of automated works of excavation and soil disposal. Control the posture of the robot. Prevent from damaging existing structures.	Vertical shaft construction robot
3. Propel	(1) Simplified soil survey function	. Examine soil such as N-value and soil properties which are needed for setting work conditions using bore hole.	Propel robot (Figure 5)
	(2) Function of setting locations for propel	. Make a total coordinates and put in covering and off set data then set location for propel.	
	(3) Location survey function	. Grasp propeller location correctly from road surface.	
	(4) Function to detect obstacles in front of propeller	. Detect buried structures (metal and non metal) to prevent collision.	
	(5) Propel technology	. Has self-propel head and can adjust its direction.	
	(6) Propel control function (provided fuzzy function)	. Based on present location, the robot must decide its optimum direction according to constantly supplied information of soil properties and buried structures.	
	(7) Signal transmitting function	. Transmit information supplied by propeller and detected location from road surface to the operation.	
4. Piping work	(1) Flexible pipe	. Can be applied for curve piping.	Piping robot for propel method (Figure 6)
	(2) Cast in place piping technology	. Cast in place piping which can applied for any curving piping work.	
	(3) Functions of automated pipe joint and setting work	. Pipes are automatically bring into shaft and connected except (1), (2) mentioned pipes.	
5. Restore vertical shaft		Refer to Open Cut Method.	Pavement restoring robot (Figure 4)

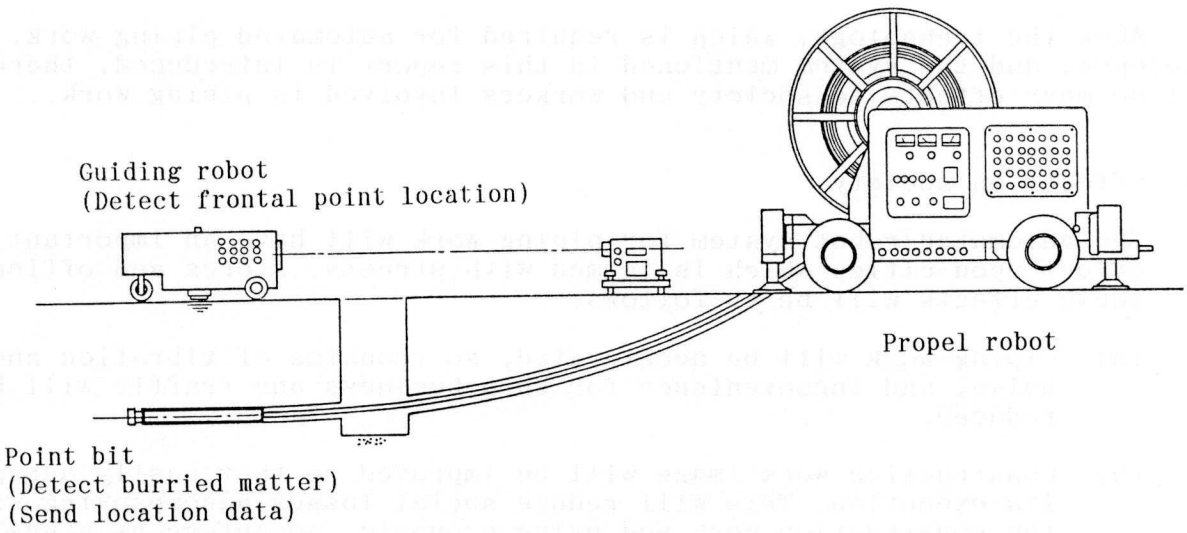

Figure 5 Propel Robot

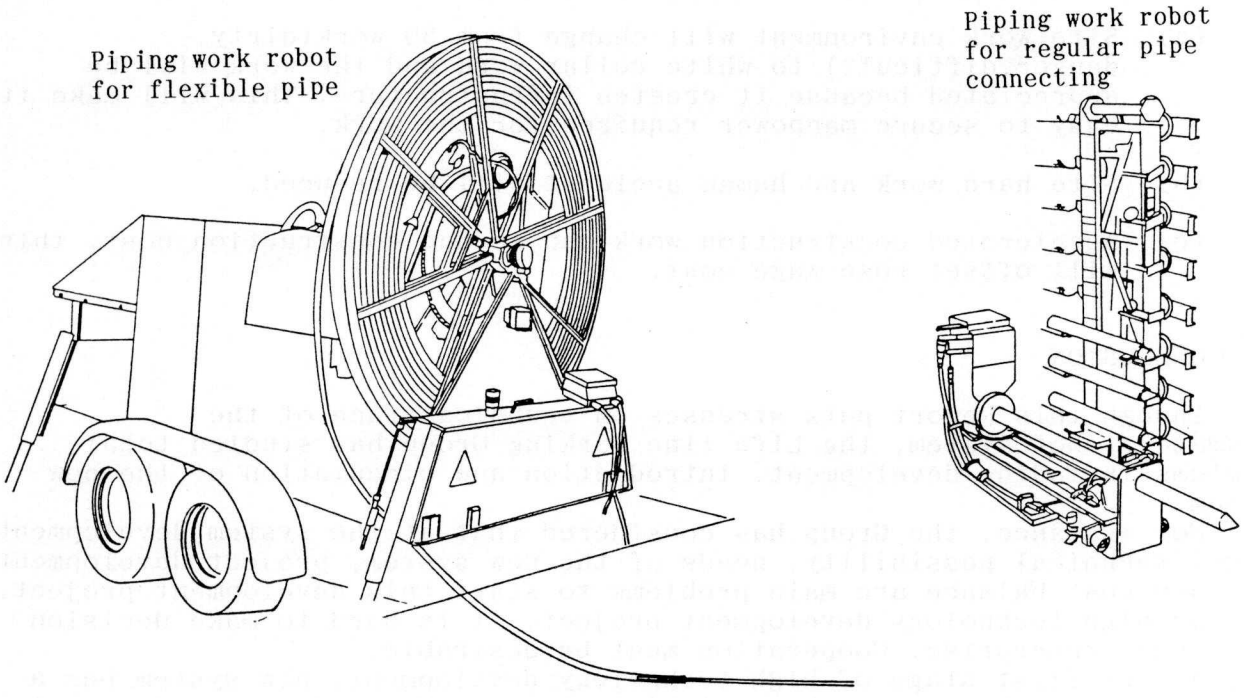

Figure 6 Piping Robot for Propel Method (flexible pipe and standard size pipe)

4. THE EFFECT OF INTRODUCING AUTOMATED/ROBOT TECHNOLOGY

When the technology, which is required for automated piping work, is developed, and the system mentioned in this report is introduced, there will be many effects to society and workers involved in piping work.

(1) Effects on society

The automated/robot system for piping work will have an important effect upon cities which is jammed with streets, stores and offices, these effects will be as follows.

(a) Piping work will be accelerated, so troubles of vibration and noise, and inconvenience for shop business and traffic will be reduced.

(b) Construction work image will be improved so they easily accept its execution. This will reduce social losses accompanying with the construction work and bring economic advantage as a whole.

(c) Accelerated construction work will achieve economical construction then costs for infrastructure can be reduced.

(2) Effects upon piping work concerned person

The automated/robot system for piping work will have following effects upon owners, contractors and workers.

(a) Site work environment will change from 3D work(dirty, danger,difficult) to white collar work and the work will be appreciated because it creates infrastructure. This will make it easy to secure manpower required for the work.

(b) Site hard work and human accident will be reduced.

(c) Accelerated construction work can reduce construction cost, this will offset rose wage cost.

5. CONCLUSION

Though this Report puts stresses on technical face of the automated/robot system, the Life-line Working Group has studied total problems including development, introduction and circulation of the new system.

For instance, the Group has considered that at the system development stage, technical possibility, needs of the new system, project development cost and cost balance are main problems to start this development project, but for high technology development project, it is hard to make decision for single enterprise. Cooperation must be desirable.

At the first stage of high technology development, new system has a disadvantage of high cost than existing systems. We must view and accept this disadvantage at technological development standpoint, but if the period when the first cost can be recovered is unknown, it is hard to make the decision. The Working Group will appreciate if its activity can be any help for future high technology development.