The Application of the Automated Transit System to Construction Sites

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ABSTRACT

We introduced the outline of the remote-control type automated transit system in a paper presented at the 11th International Symposium on Automation and Robotics in Construction, entitled "The Development of a remote-control transportation system for use in underground space". This system is used to convey excavated soil, materials and tools to the construction site of a subway in Tokyo, Japan. At this construction site, there were very difficult obstacles to construction work, such as soft ground, many buried structures, and severely restricted space for the construction work above ground. Very good results were achieved by the introduction of the underground tunnel-conveyance system to this subway construction site. Because this system which operates grab buckets and hoists of the suspended traveling type, automatically by a remote-control device, has been developed over a long period of time, it is applicable to very soft ground. It has still enough operation ability even in spite of some restrictions at the entrance to carry in and out. As it well maintains the safety and improves the working environment in a tunnel. It was operated smoothly even under severe construction conditions, and as a result, there was a drastic reduction of labor and the completion of the phase of the project was achieved. This paper reports the application example of the automated transit system to this construction site.

1 INTRODUCTION

Nowadays, information-oriented systems are rapidly developing in various industries; irrespective of production divisions and administration divisions, reduction of labor and high efficiency is strongly desired.

The Construction Industry is not an exception. Even on a construction site, not only the safety, security and the improvement of working environment is important, but also the reduction of labor, the release of the workers from hard work, the improvement of the efficiency of the operation and whole of the construction work, and the reduction of the term of work is strongly required.

In this paper, the example where the automated transit system that was developed to meet the above requirements was applied to the construction site is shown.

2 THE PROCESS OF THE DEVELOPMENT

2.1 The Background of the Development

When an underground excavation is executed with the cut and cover method in the cities where traffic, buildings and buried structures are concentrated, there are a lot of restrictions regarding the conveyance work of excavated soils and the materials and tools (See Photo. 1).

Photo. 1 The Condition of the Site

It is especially difficult to carry them in and out directly to the required spot from the ground. In many cases, the method to convey vertically at a restricted opening space and then to convey again horizontally in a tunnel is applied.
In this method, as a vertical conveying operation, the procedure to convey them by a crawler type instrument on the excavating surface has been used widely.
A horizontal tunnel conveying operation with a crawler type instrument, however, has the following problems:

(1) **In soft ground, it is impossible to run on a tunnel wall without an assisting construction method.**

(2) **It is impossible to convey astride the installing spots of the earth retaining structures.**

(3) **It is impossible to convey astride the construction work areas.**

(4) **A skillful technique is required to operate in a narrow tunnel.**

(5) **The working environment is bad because of exhausted gas, dusts and so on.**

Due to the above reasons, the development of the new conveying system to make horizontal tunnel conveying operation safe and efficient was begun.

2.2 The Purpose of the Development

At the start of this project, the purposes were clarified.

(1) **To secure sufficient operation ability**

1) To secure the operation ability of 90 ~ 100m3 per machine which is operated for 7 hours a day
2) To mechanize the various conveying operations in tunnels, and to standardize, simplify and automate their operating methods
3) To enable the operation with a stable cycle-time regardless of the level of skill of the workers

(2) **To improve the safety of the conveying operation in a narrow tunnel where the earth retaining materials mingle with one another**

(3) **To improve the working environment**

(4) To project high efficiency for the whole execution work

We became engaged in the development of this system with these purposes in mind.

2.3 The Study of Construction Methods

The following four plans were examined as new methods of conveying excavated soils to solve the problems of the traditional methods.

1st plan: Back hoes and bulldozers (traditional method)

2nd plan: Back hoes and travelling grab buckets

3rd plan: Back hoes and belt-conveyers

4th plan: Excavators with pumping instrument

After examination, because it does not put the excavated surface into disorder and has less exchange of steps and offers a good working environment and so on , as an optimized method for field work

the 2nd plan: Back hoes and traveling grab buckets

was selected.

Besides, with the application of this plan, a travelling hoist was selected for conveying the materials and tools.

The objectives mentioned above are intended to be achieved through making these machines electrically-powered and by centrally controlling several machines thereby making the operation automatic.

3 THE OUTLINE OF THE SYSTEM

The system roughly consists of a machine unit and a central control unit. The machine unit is made up of two automated travelling grab buckets and two automated travelling hoists, four machines in total. The central control unit is made up of an operation observing unit, an operation verificating monitor, a remote-control unit and so on. The outline of the system is shown in Figure 1.

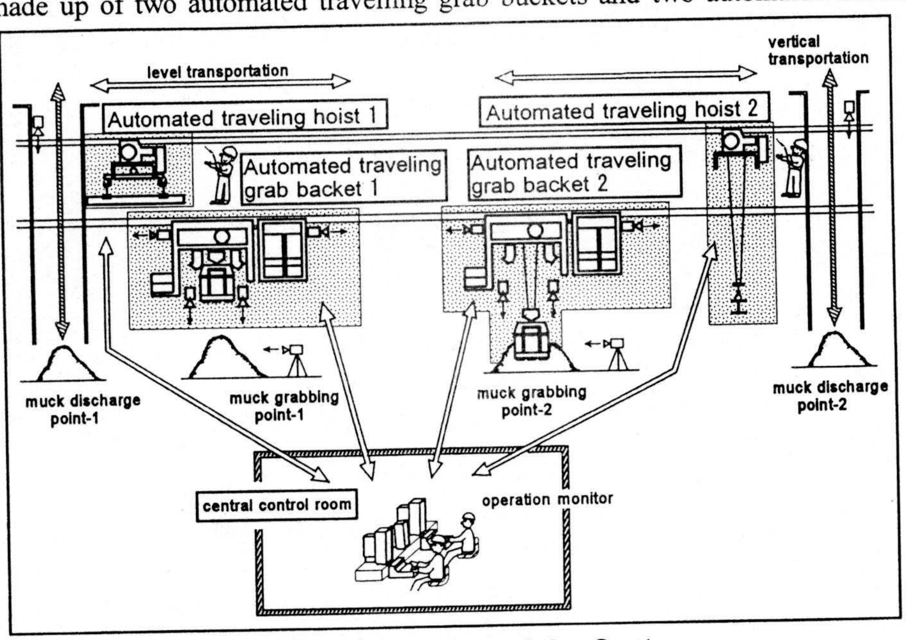


Fig. 1 The Outline of the System

3.1 The machine unit

This unit is operated under the condition that two automated travelling grab buckets are suspended on one railway of the two parallel rail system and two automated travelling hoists are suspended on the other one. Although these two railways are close to each other, the meeting and parting of the automated travelling grab buckets and the automated travelling hoists can be operated. The condition in which these units are erected on the construction site is shown in Photo. 2.

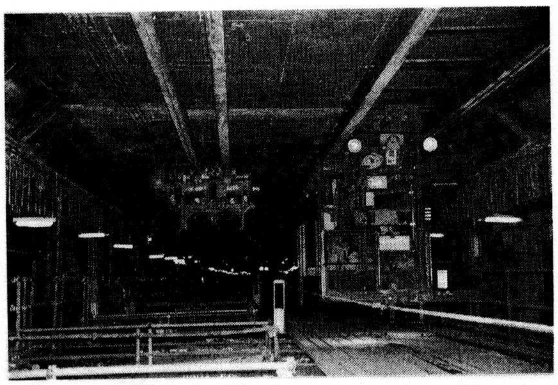


Photo. 2 The Units on the site

The item of the automated travelling grab bucket is shown in Table 1 and Figure 2. The automated travelling grab bucket repeats the automatic operation, "to move forward from the specified work base close to a excavating spot to the excavating place that progresses every day, to grab excavated and piled soils, and then to move backward to the specified work base to throw them out" The item of the automated travelling hoist is shown in Table 2 and Figure 3. The automated travelling hoist conveys materials and tools such as earth retaining materials from any place to another place in a tunnel.

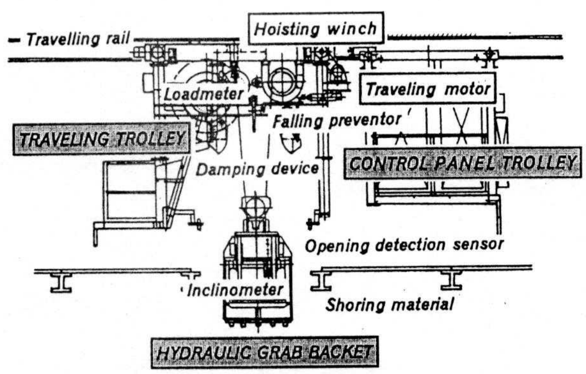


Fig. 2 Automated Travelling Grab Bucket

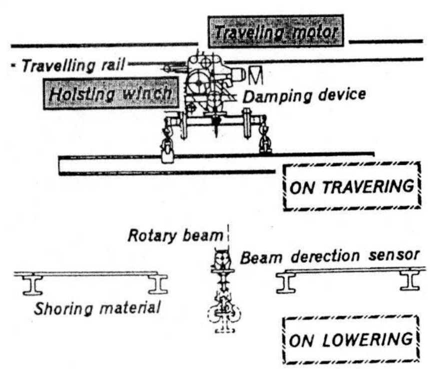


Fig. 3 Automated Travelling Hoist

Table 1 The Item of Unit(A.T.G.)

ITEM		UNIT	AUTOMATED TRAVELLING GRAB BUCKET
Rated load		Ton	1.44 (0.8m ³)
Hoisting load		Ton	2.94
Hoisting device	Electric motor	Kw	15 (2/4p)
	Speed	m/min.	Loaded : 20 Unloaded : 40
	Speed control	——	Pole change (lowering)
	Lift	m	15
Travelling device	Electric motor	Kw	5.5 (4P)
	Speed	m/min.	6 ~ 120
	Speed control	——	Inverter (set for 4 notches)
Hook hanger	Mounted device	——	Hydraulic grab bucket
	Electric motor	Kw	5.5 (4P)
	Speed	sec.	Shell open : 8.0 Shell closed : 10.0

Table 2 The Item of Unit(A.T.H.)

ITEM		UNIT	AUTOMATED TRAVELLING HOIST
Rated load		Ton	2.65
Hoisting load		Ton	2.95
Hoisting device	Electric motor	Kw	4.1 (2/4P)
	Speed	m/min.	8.4
	Speed control	——	Constant speed (on/off)
	Lift	m	13
Travelling device	Electric motor	Kw	0.5 (4P)
	Speed	m/min.	21
	Speed control	——	Constant speed (on/off)
Hook hanger	Mounted device	——	Rotary beam
	Electric motor	Kw	0.1 (4P)
	Speed	rpm	1.0

3.2 The central control unit

The operation observing unit installed in the central control room always communicates with the four machines mentioned above, by radio and centrally controls the operation conditions of all of the machines and the safety of the working space.
The operator of the automated travelling grab buckets automatically operates them with a remote control device while checking the surrounding conditions of the affected machines with an operation verificating monitor. On the other hand, the tasks regarding the evasion from the collision of four machines including automated travelling hoists and from the contact and bump with the invaders in railways are operated automatically by the operation observing unit.
To improve the safety level further, the central control room was located at the place where the working conditions of the machines can be checked directly.

4 A TEST EXECUTION

Through the process of the development, the experiments on an actual scale and the adjustment work during the introduction of this system to the execution site as well as any discrepant conditions were improved. Then a test execution was begun in January of 1995.

4.1 The Outline of the Construction Site where this System was Introduced

The construction site where this system was introduced is located at almost in the center of Tokyo, Japan, and the road traffic and existing buildings are very concentrated. Therefore, for any kind of construction work a lot of difficulties were expected. The condition of the execution site is shown in Photo. 1.
In this project, a two-story subterranean tunnel for a subway, 205 m long by 10 m wide by 19 m deep, is going to be constructed in such a place with a cut and cover method. The upper floor slabs of this tunnel are going to be pre-executed before the excavation of the space deeper than the affected slab.
An explanation of the existing specially severe conditions are the following.

(1) Restricted piling site of the soils

Piling sites of the soils are restricted to only two areas at the both edges of the construction area because of the following two reasons: the construction site is located at the 11m-wide-road surrounded by lots of offices and shops and traffic congestion is severe night and day; the upper floor slabs must be pre-executed.

(2) Soft ground

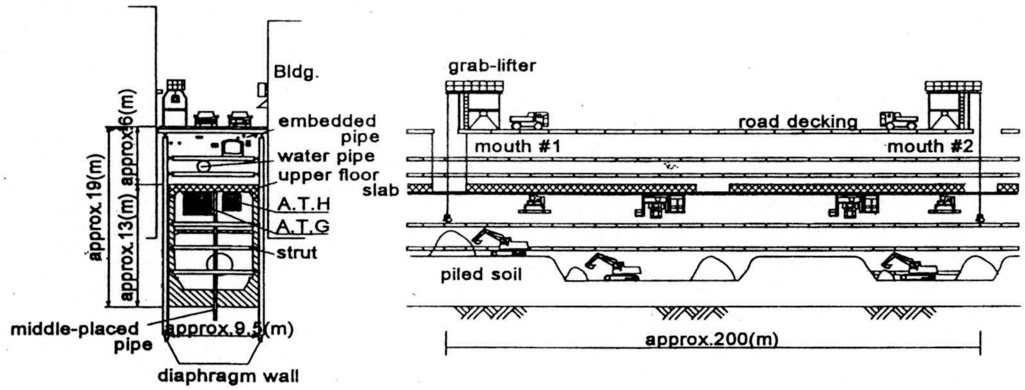
There was a pond at the construction site before and it was filled in approximately 1870. Therefore, the ground of this area is very soft.

(3) Narrow tunnels

Because the excavation site is narrow, around 10 m wide and earth retaining supports are concentrated, it is difficult to keep a safe travelling lane.
The system mentioned in this paper has been developed from the beginning to cope with soft ground, to keep sufficient execution ability even with the restricted entrances for carrying in and out and to be operated safely and highly efficiently. Therefore, this system was the very best one for this construction site.

4.2 The Condition of the Execution

The condition of the execution in the site is shown in Figure 4.



CROSS-SECTIONAL VIEW LONGITUDINAL SECTION

Fig. 4 The Condition of the Execution in the Site

4.3 A Test Execution

In a test execution, the operation ability, durability, operability and cooperation with other heavy machines of the machine and system were checked by operating the machines as the construction work proceeds. The condition of the operations is shown in Photo. 3 ~ 5.

Photo. 3 The Operation (1)

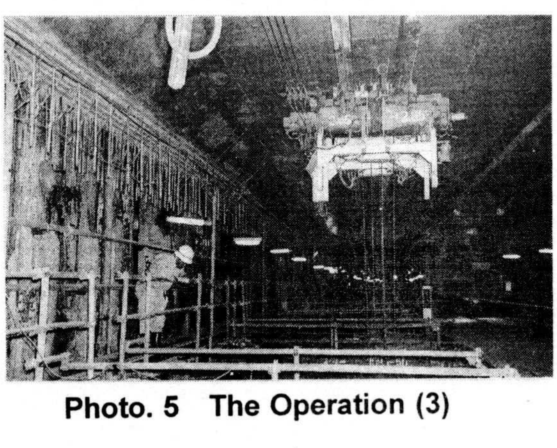


Photo. 5 The Operation (3)

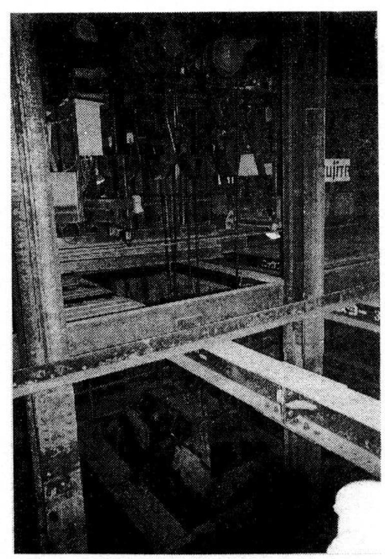


Photo. 4 The Operation (2)

4.3.1 The Automated Traveling Grab bucket

This machine is, at first, designed so that it can carry 90 to 100m3 of soil in 7-hour-operation a day assuming that the carrying distance is 50 to 60m.

(1) The object of the tests

About 8,000m3 of soil under the slabs were the object of the test as the construction work proceeds.

* They are different from the object of the operation.

(2) The results of the tests

The conveying records in this test execution are shown in Table 3.

Table 3 The Conveying Records

CLASSIFICATION	ITEM	UNIT	AS PLANNED	MACHINE #1	MACHINE #2	TOTAL
Operating hours	Actual work day	Days	——	50	54	104
	Total operating hours	h	——	274	307	581
Conveying distance	Total conveying distadce	m	——	212,594	270,288	482,882
	Average conveying distance	m	50 ~ 60	62	60	61
Soil amount	Total conveyed soil	m^3	——	3,443	4,548	7,991
	Conveyed soil per hour	m^3/h	12.9 ~ 14.2	12.6	14.8	13.8
	Conveyed soil per day (seven hours)	m^3/d	90 ~ 100	89	104	97

1)The averaged carrying distance is approx. 60m and conveying record is 13.8m3/h per machine during the whole period of the test. Therefore, in case the machine works 7 hours a day, it can carry approximately 97m3 of soil.

2)This grab bucket has sufficient ability as was expected. It also has sufficient ability for excavating procedure.

4.3.2 The Automated Travelling Hoist

(1) The object of the tests

The conveying tests were applied to all of the materials such as construction material, tools and general materials (including scraped materials).

(2) The results of the tests

The conveying records in this test execution are shown in Table 4.

Table 4 The Conveying Records

No	OBJECT MATERIAL	RESULTS	REMARKS
1	Shoring material	○	
2	Form material	○	
3	Reinforcing bar	△	Long and deflect material
4	Miscellaneous material	△	Heavy material with unfixed form

1) Generally, the results were good. The space of the travelling area, however, was severely restricted. Therefore, some device is necessary for long and deflective materials such as reinforcing steel, and the slinging work with large scrapped materials.

5 CONCLUSION

A test execution regarding a whole automatic travelling system was successful. The objective set at the beginning of this development was attained and the target of operation ability was passed. Furthermore, this system proved to be effective to improve the efficiency, safety and working environment for execution on the construction site.

(1) Sufficient operation ability

1)The operation ability was achieved as was planned, which was also sufficient for the process on the site.

2)The various conveying operations in the tunnels were mechanized and automated. Their operation ability turned out to be just as planned.

3)A stabilized operation was accomplished regardless of the skill of the operators.

(2) The improvement of the safety in conveying operation

1)Due to the central control of several machines, safety was improved.

(3) The improvement of the working environment

1)The exhausted gas and dusts from the heavy machines were rarely detected.

2)The excavating disk was seldom damaged.

(4) The improvement of the excavation efficiency

1)It turned out to be possible for it to be operated astride the work areas such as the earth retaining structures, which caused a drastic improvement in the excavation efficiency and a reduced a term of work.

Finally the authors would like to express their appreciation to all persons concerned for their advice and cooperation in the development and test execution of this system. We also have renewed determination to improve this system further.