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Development of a remote-control transportation system for use in underground spaces

Satoshi Iwaoka[a], Toshio Mori[a], Yasutaka Nakai[a], Kazuhiro Funatsu[a],Hiroyoshi Watabe[b]

[a]Mechanical Department, Civil Engineering Division, FUJITA Corporation, 4-6-15 Sendagaya, Shibuya-ku,Tokyo, Japan

[b]Sanken, Reserch & Development, FUJITA Corporation, K&K Bldg, 1-9-6, Sendagaya, Shibuya-ku,Tokyo, Japan

Abstract

Subway underground excavation work with cut-and cover method, particulaly the transportation of constraction material, equipment, and muck, is greatly affected by construction conditions aboveground. The appropriateness of the method used for this work is a major factor in the progressing of construction. Traffic in urban areas has become increasingly heavy, which makes it difficult to set up asystem for the direct transportation of things between the road surface and work sitesunderground. As a result, things are usually transported vertically along shafts at fixedacces points and then horizontally along levels to the work sites.

1. INTRODUCTION

The main problems with this type of transportation system are listed below.

(1) Space restrictions

Transportation of long or heavy objects through areas with complex steel shoring requires highly skilled machine operators.

(2) Characteristics of natural ground

In the case of weak natural ground, crawler-type transportation machines cannot be moved continuously over the subgrade. Work to stabilize the subgrade is often required.

(3) Transportation capacity

Concurrent transportation of muck and materials requires separate transportation systems, and there is often not enough space to install them. When only one system is installed, transportation of muck and materials must be done in turn, which greatly reduces transportation capacity.

(4) Work environment

The work environment is uncomfortable and unhealthy. Workers often have to breathe exhaust fumes emitted from heavy machinery and to work above and below in insufficient light.

(5) Safety

Confined and poorly lit work spaces do not afford workers sufficient visibility to see what they are doing. Such conditions greatly increase the likelihood of dangerous mistakes.

The remote-control transportation system has been developed to alleviate these problems by machanizing, standardizing, and simplifying transportation in the underground. The system does not require such highly skilled machine operators and stabilizes the time required to complete the transportation cycle.

2. OUTLINE OF THE SYSTEM

2.1. System Configuration

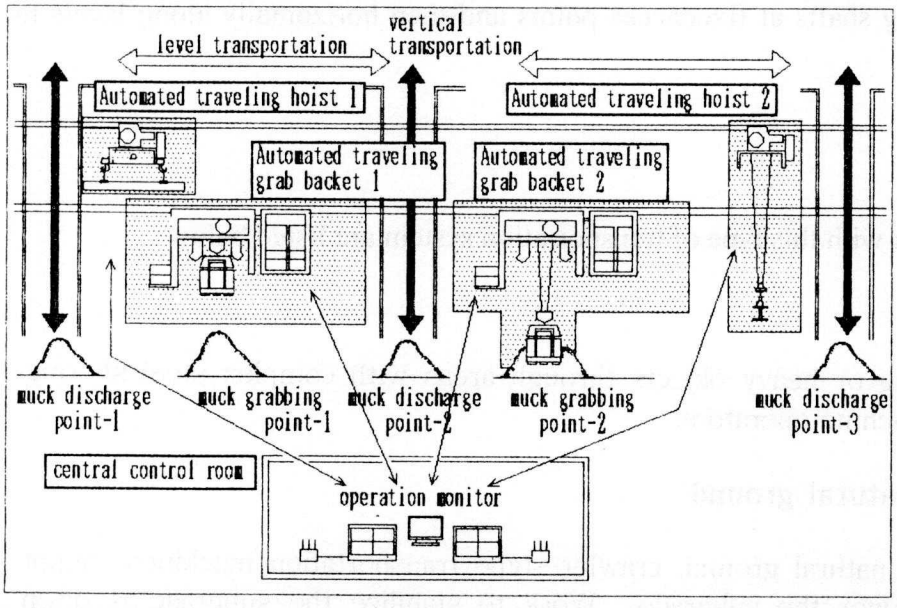

Figure 1. Conceptual Transportation System

The system consists of transportation machinery and a central control unit which controls the transportation machinery. Four machines comprise the transportation machinery: two automated traveling grab buckets for transporting muck an two automatic traveling hoists for transporting equipment and materials. The central control unit consists of an opera-

tion monitor, a function confirming monitor and a remote controller.

2.2. Machinery

Prior to excavation, structural concrete slab is placed on the subgrade along which the machinery travels. I-beams for two parallel tracks are installed below the concrete slab. The tow grab bukcets run along one line and the two hoists run along the other. The two lines are close to each other, but the distance between them expands when a grab bucket and a hoist run concurrently along the tracks.

(1) Automated traveling grab bucket

The hydraulic grab buckets are raised and lowered by winches mounted on automatic suspended traveling carriages. The grab buckets continuously transport muck from excavation sites, which frequently change, and dump them at specified dumping sites. There are three machine operation systems: (1)the automatic remote system; (2)the remote lever system; and (3)the control system with the operator in the cab. The remote automatic system is the most common.

With the remote automatic system, the machines are operated by operators in the central control room. To operate a machine, the operator first views the function confirming monitor to conduct a safety check of the machine and its operating space, and then presses the safety confirmation button on the remote controller. The machine receives the signal and, through the operation program in its computer, automatically carries out four operations in the following order: (1)moving forward; (2)winching down and grabbing muck; (3)winching up and moving backward; and (4)discharging muck.

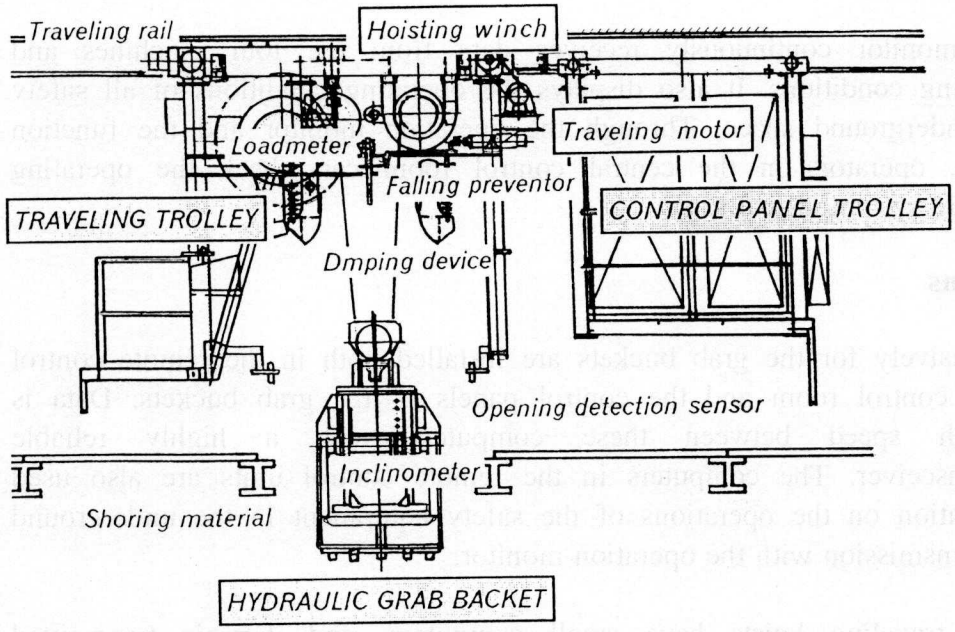

Figure 2. Automated Traveling grab backet

With the remote lever system, the machines are also operated by operators in the central control room. To operate a machine, the operator manipulates levers and switches on the operation panel while watching the function confirming monitor.

(2) Automated traveling hoist

The motor-driven rotary hooks of the hoists are raised and lowered by winches mounted on automatic suspended traveling carriages. The hoists transport materials and equipment from place to place in the underground space. There are two systems for operating the machines: (1)a transceiver system with a remote control and (2)a wire relay system with pendant switches. The transceiver system is the most common To operate a machine, the operator stands beside it, which is different from the operation of an automated traveling grab bucket.

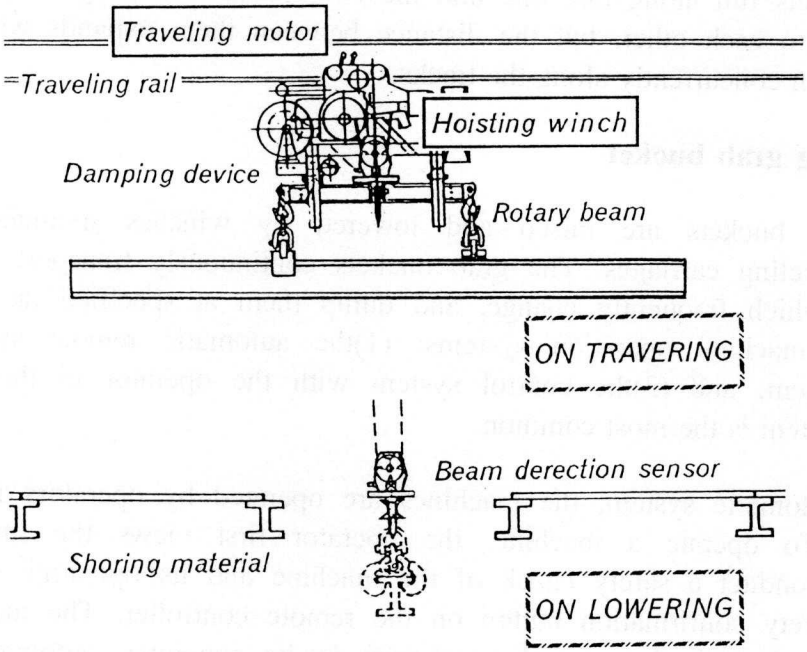

Figure 3. Automated Traveling hoist

2.3. Central Control Unit

The operation monitor continuously receives data from the four machines and displays their operating conditions. It also displays the operating conditions of all safety equipment in the underground space. Through the operation monitor and the function confirming monitors, operators in the central control room can check the operating conditions of the entire system in real time.

2.4. Control Systems

Computers exclusively for the grab buckets are installed both in the remote control units in the central control room and the control panels of the grab buckets. Data is transmitted at high speed between these computers with a highly reliable millimeter-wave transceiver. The computers in the remote control units are also used for inputting information on the operations of the safety equipment in the underground space and for data transmission with the operation monitor.

The automated traveling hoists have small computers, and data is transmitted between these computers and the operation monitor with transceivers. A workstation simultaneously transmits data between the operation monitor and the four machines.

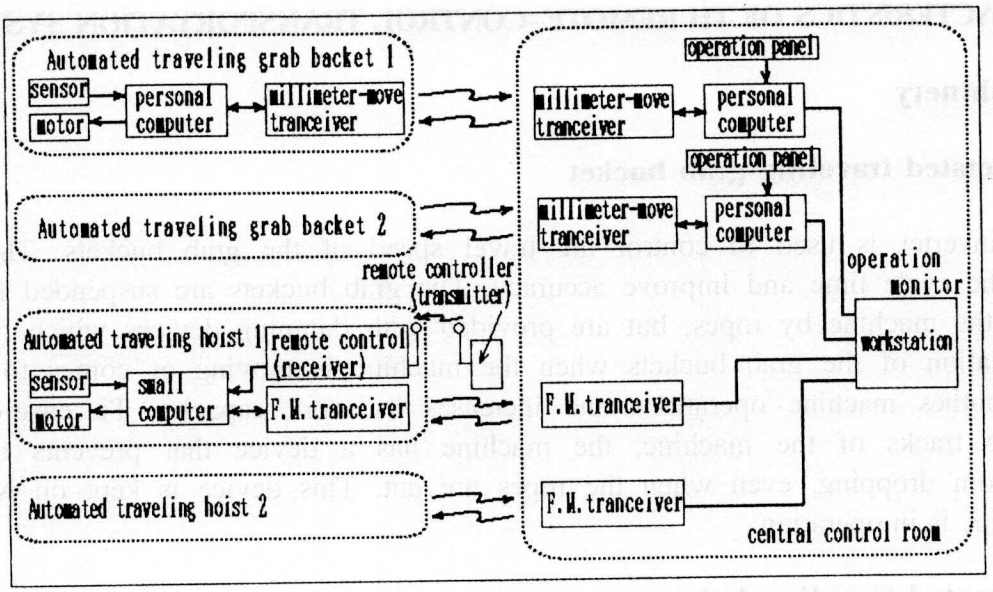

Figure 4. Conceptual Visual System

2.5. Site Monitoring System

A site monitoring system is incorporated into the remote-control transportation system. Cameras are installed at key places in the underground space, which makes it possible to observe, in the central control room, conditions around the grab buckets while they are in operation. Both grab buckets each have three cameras: (1)a camera for monitoring forward; (2)a camera for monitoring backward; and (3)a camera for monitoring beneath the machine where muck is grabbed up. To minimize blind spots, auxiliary cameras are installed where muck is grabbed up and where muck is discharged. Small CCD cameras, which are more sensitive to light than humans are, are used in low-light areas. All visual information from the cameras is transmitted by dedicated devices to the central control room where information from specified locations is automatically combined and displayed on the function confirming monitors.

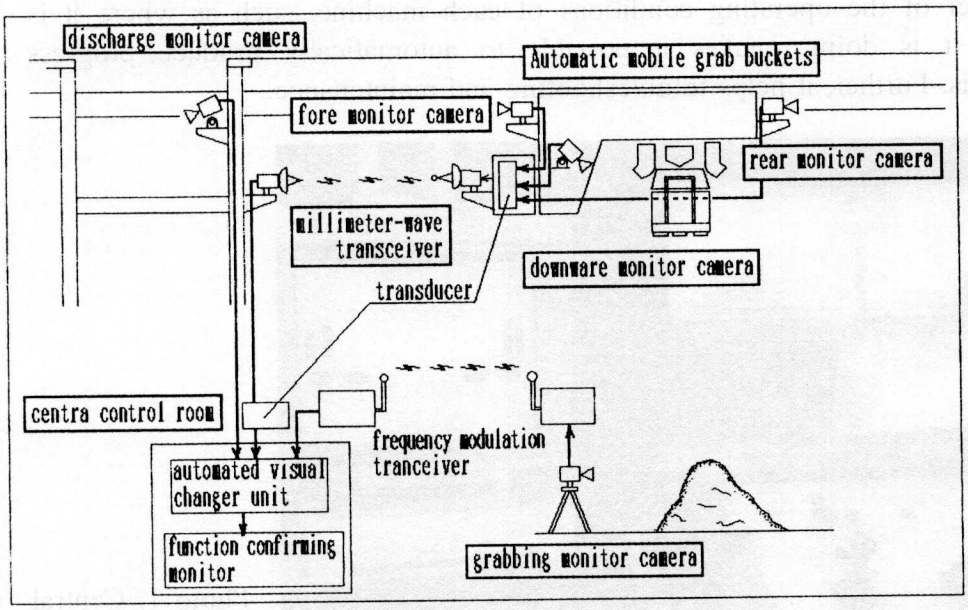

Figure 5. Conceptual Control System

3.CHARACTERISTICS OF TH REMOTE-CONTROL TRANSPORTATION SYSTEM

3.1. Machinery

(1) Automated traveling grab bucket

An inverter is used to control the travel speed of the grab buckets. This helps shorten the cycle time and improve accuracy. The grab buckets are suspended from the body of the machine by ropes, but are provided with damping devices which minimize the oscillation of the grab buckets when the machine is moving or comes to a stop. This smoothes machine operations and increases its work capacity. To ensure safety along the tracks of the machine, the machine has a device that prevents the grab bucket from dropping, even when the ropes are cut. This device is kept on whenever the machine is in operation.

(2) Automated traveling hoist

The automated traveling hoists have motor-driven rotary hooks and a damping device, and together they serve to keep long loads stable and pointed in the right direction. Space in the underground is limited so this feature makes the hoists safer and easier to operate.

3.2. Central Control Unit

(1) Operation monitor

The centralized control of the operation of the four machines and the safety devices with computers improves safety by preventing accidents caused by human error. The recording on computer of the operating conditions of each machine, such as where it is operating and what it is doing, makes it possible to automatically produce progress reports on a daily basis. Further, it helps troubleshooting and maintenance.

Photo 1. Central control unit

(2) Function confirming monitors and the remote controller

The work environment of the operators is greatly improved since they can operate the machines in the central control room while watching monitors.

4. MACHINE TESTING

To ensure that the machines could perform basic functions properly and to adapt the machines to construction conditions, Fujita Corporation built two testing apparatus at its testing center. For simulating work during the installation of shoring materials, one apparatus was used to test the movenent of a hoist and grab bucket along tracks and the other apparatus was used to test the lowering and raising of a grab bucket and its scooping of muck. Through these tests, the basic performance; suitability for the work site, transportation capacity, and safety of the machinery and the control system, was determined.

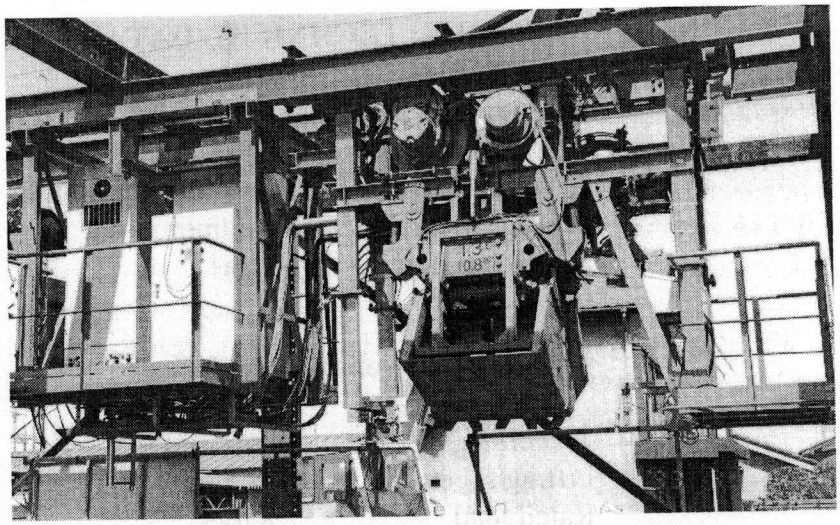

Photo 2. The view of testing automated traveling grab backet

Photo 3. The view of testing automated traveling hoist

5. CONCLUSION

The testing of the machinery and the control system has been completed, and preparations for the introducrion of the system into construction sites are underway. The system will be set up at a subway construction site this fall. The goal is to expand (1)the use of the remote-control transportation system beyond cut-and-cover construction to a variety of construction projects such as underground excavation work for building construction, and (2)a perfect centralized control system by applying it to other construction systems.

APPENDIX: TECHNICAL DATA

Automatic travelling grab bucket

Travelling speed:	maximum 120 m/min
Lifting speed:	40 m/min
Bucket capacity:	0.8 m^3

Automatic travelling hoist

Travelling speed:	20 m/min
Lifting speed:	8 m/min
Rated load:	2.8 tons

Provisional maximum transportation capacities

Automatic travelling grab bucket:	14.2 m^3/hr
Automatic travelling hoist:	13.5 tons/hr