THE DEVELOPMENT OF THE AUTOMATIC SEGMENT ERECTION SYSTEM

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ABSTRACT

A automatic segment erection system for a medium and a small diameter shield has been developed. The erection system consists of a segment automatic conveyance device, a flatcar for temporary storage of a segment and an automatic erector device. This system has an automated a series of events until rough positioning of a segment has been achieved. It effectively utilizes a narrow working space, improves the working environment, makes rapid progress in the area of maneuverability, it is labor saving and safe. It also realizes a higher speed of execution compared to the conventional segment erection operation system. This report describes a synopsis of the system and the results of an in-situ verification experiment.

1. INTRODUCTION

Since segment erection work requires the difficult operation of handling heavy objects in a narrow working space in the tunnel and necessitates a complicated working schedule, a highly skilled operation is demanded where the automation is the most desirable. The automated segment erection system for medium and small diameter shields with the exception of a large section shield has been left behind particularly because of the restrictions on the effective work space. On such a basis, the segment automatic erection system for medium and small diameter shields has been developed jointly with Hitachi Zosen Corporation, and was practically applied to the execution of Subway No. 7 Work for Osaka city.

1) The objectives of the development

In developing the segment automatic erection system, the objectives were, as follows:

(1) The system was to be operable using conventional standard segments.
(2) Labor saving
The erection was to be made possible by using less than two workers.

(3) Improvement of safety

The system was to have better safety than a manual erection.

(4) Coping with complete automation in the future

The system was to be interlinked with the unmanned segment conveyance system from aboveground.

(5) Scope of automation

After gripping a segment from a flatcar which was used for temporary storage of a segment (manual operation) , a series of operations , from the conveyance of a segment ~ supplying it ~ gripping it by the erector ~ to a partial segment erection (rough positioning of a segment) was to be automated.

2 . SYSTEM SUMMARY

This system stores segments for one ring (6 pieces) by lifting them manually from the segment flatcar stopped at a designated position , for temporary storage of segment. It automatically grips segments that are temporary stored after the advance of the shield conveying them automatically to the position of supply. Delivery to and receipt from the erector are automatically made in the air. The erector device makes confirmation after receipt of the segments separation of conveyance device and then turns automatically to the rough position of erection. For the tightening operation of the bolts that fix segments, manual operation (using motor driven impact wrench), which is quick and accurate, was adopted.

Fig. 1 shows the summary drawing of the segment automatic erection system.

Summary of "The Automatic Segment Erection System"

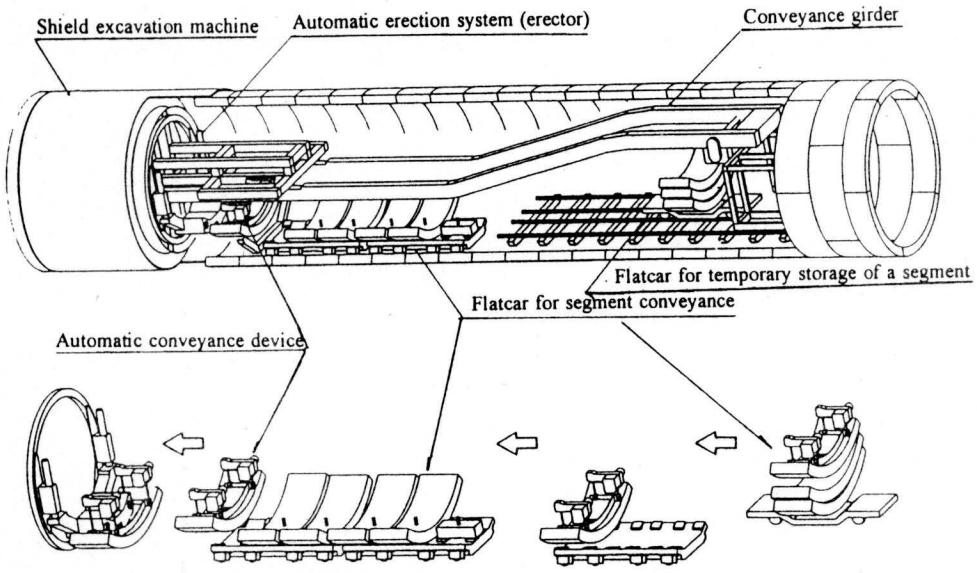

Fig. 1. Summary Drawing of Automatic Segment Erection System.

2.1 System Composition

This system is composed of three devices, as follows:

- Segment conveyance device
- Erector device
- Flatcar for temporary storage of a segment

The summary of these devices is as shown below.

1) Segment Conveyance Device

This device lifts up segments and conveys them from a flatcar for segment to a flatcar for temporary storage of segment and from a flatcar for temporary storage of a segmen t to the erector device, which consists of the following:

(1) Two-row parallel travelling girders

This is for the travelling of the hoisting device, which consists of two girders with the length of about 20.2m. As it has a slope of 15 ° a roller chain is wound round between the driving sprocket in rear and the tension sprocket in front to make the hoisting device travel.

An electric geared motor is used as driving source and by applying an inverter control it makes it possible to travel at a high speed.

(2) Motor-driven chain block

This is a device which is used to hoist the conveyance gripping device. It consists of two units of motor-driven chain blocks with two-point suspension. They are installed separately on the right and the left guarder, and are suspended from the frame at four points in total. An inverter control is applied and by using an encoder for detecting the hoisting position it is possible to perform fine control.

(3) Conveyance gripping frame

The frame is constructed so that even if an erroneous operation should be made the gripping frame would not come off under the condition that the lifting ring on a segment is clamped and the segment is lifted. For an actuator for a clamp, a motor cylinder with a brake is used. For the purpose of confirmation of the lifting ring, the clamp and adherence of a segment, a switch is installed.

2) Erector Device

The erector device has a clamp device for gripping a segment in the air in addition to a general manual erector device. The erector is driven by a hydraulic cylinder and a lock mechanism is provided for safety. The support jacks are separately laid out for A and B segments and K segment. As the turning motion from gripping, segment support and to position of erection is automatically made, an absolute encoder for the detection of the turning position and various switches for confirmation of the operating condition of each cylinder, are installed.

3) Flatcar for the Temporary Storage of a Segment

It is a two-flatcar coupled type, which is pulled by the working platform in the rear of

the shield machine body. Three pieces of the segments can be loaded on one flatcar and therefore 6 pieces of a segment for one ring can be stored on two coupled flatcars. The flatcar is supported on urethane wheels so as not to damage the segment. As well, the traction portion adopts the floating mechanism so as to cope with posture of the machine, dislocation of segment, etc. Also, a switch for confirmation of the temporary storage of a segment is installed at each position of the piece of the segment.

2.2 Summary of the Operation of Automatic Segment Erection System and Scope of Auto mation

Fig. 2 shows the summary of operation of automatic segment erection system and scope of automation.

The automatic segment erection system can be divided largely into the conveyance portion and the erection portion. The conveyance portion is further composed of an automatic conveyance (hereinafter to be referred to as "backward conveyance") between the segment conveyance flatcar and the flatcar for temporary storage of the segment and the automatic conveyance from the flatcar for temporary storage of and to docking point to erector (hereinafter to be referred to as "forward conveyance").

The erection portion receives segments from the conveyance device by means of an erector device and automatically turns and moves the erector device until rough positioning of segment to designated position of each piece of segments is achieved. After minute positioning has been made, the bolts are tightened manually.

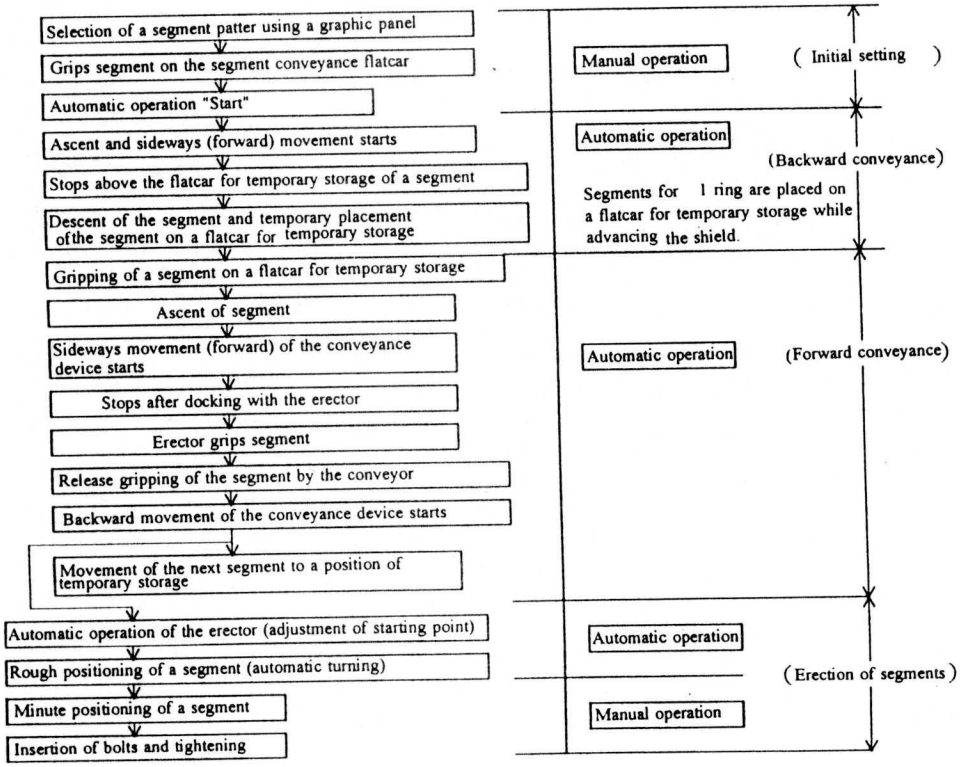

Fig. 2. Summary of automatic segment erection operation and scope of automation.

3. SUMMARY OF SITE OF VERIFICATION EXPERIMENT

This system was practically applied to a medium diameter shield for which the introduction of automation was delayed and verification was made of the operation cycle, maneuverability , safety , etc. The following shows the summary of the site where the verification work was performed:

3.1 Summary of the Work

1) The Owner : Transportation Bureau of Osaka City

2) Title of the Work : Rapid Electric Railway Line No. 7 Nagahoribashi Station Section 1 and underground Line Work (Section 8)

3) Location : Minami Senba 2-chome - Matsuya-machi, Chuo-ku, Osaka-shi

4) Construction Period : February 8, 1992 - September 30, 1995

5) Description

(1) Underground Line Section

① Construction method : Pressurized slurry shield

② Extension of the work : L = 806.947m

③ Outside diameter : ϕ 5,440mm

④ Segment : Reinforced concrete segment, globular graphite cast iron segment

Outside diameter	: ϕ 5,300mm	Outside diameter	: ϕ 5,300m
Inside diameter	: ϕ 4,740mm	Inside diameter	: ϕ 4,800mm
Length	: 1,000mm.	Length	: 1,000mm

⑤ Curve radius :

West bound: 3,000, 3, 000, 310m
East bound: 2,600, 2,600, 210m

⑥ Grading : Longitudinal curve at 2 locations (per one line)
-2‰～ +2‰, -2‰～ +2‰

⑦ Earth coverage: 16 ～ 18m

4. RESULTS OF THE VERIFICATION EXPERIMENT

The automatic segment erection system was introduced from the actual advance of the west bound section. During the initial period of introduction , problems concerning the software and hardware problems , such as erroneous movement of a sensor and cumbersome maneuverability , etc. , occurred. Therefore large scale alterations were made. As a result, shortening of the cycle time and rapid improvement of the reliability, maneuverability , safety , etc . , were able to be realized . It was confirmed that it is possible for this system to be applied to medium and small diameter shields , the details of which will be reported in the following section. Photo. 1 shows the situation of a segment conveyance and Photo. 2 shows the situation of erection of a segment.

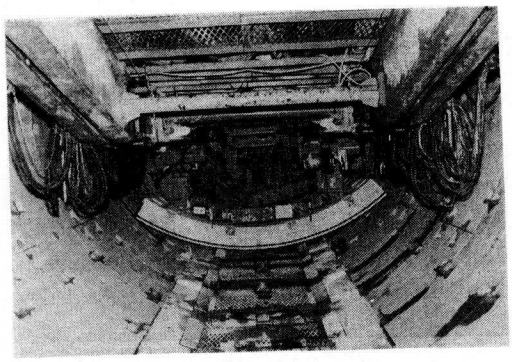

Photo .1. Situation of a segument conveyance (Forward conveyance)

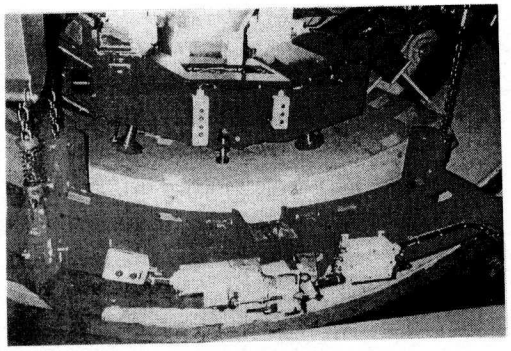

Photo. 2. Situation of a separation of the conveyance frame after completion of the gripping by erector.

4.1 Operation Cycle

By shortening the time of each operation in the process, speeding up of operation cycle was realized.

1) Backward conveyance
Up to 5 rings on one line, conveyance of 6 pieces of segments is possible while the shield is advancing. (Including time for installation of sleepers)

2) Forward conveyance
The job was completed within 25 minutes.

Table 1. Cycle time.

Operation process	Development target	Record of automation	Record of manual operation
Backward conveyance	35 minutes	15 minutes and 35 seconds	12 minutes and 59 seconds
Forward conveyance ～ completion of erection	40 minutes	23 minutes and 46 seconds	17 minutes and 29 seconds

4.2 Improvement of Maneuverability

① The maneuverability was improved by changing the segment erection pattern freely in addition to the basic pattern.

Pattern of segment:

RC segment (A pattern·B pattern)
PC segment (A pattern·B pattern)
Deformed segment (A pattern·B pattern)
→ 6 patterns + optional setting

② The status of the operation is indicated on a touch panel so as to be able to judge erroneous operations and abnormalities readily.

③ Operations done by the operator were simplified.

4.3 It is possible to cope with construction on a curve

Gripping was made possible even though the grip position becomes slippery more or less because the grip portion is tapered.

4.4 Safety

Safety was improved due to the fact that work could be carried out without entering into the scope of movement of the system during the conveyance of segment , monitoring could be done thoroughly and in addition, a towline switch for emergency stoppage was installed along the girder and emergency stop switches were installed at some locations.

5. THEMES IN THE FUTURE

In order to be able to practically apply the system to medium and small diameter shields in the future, the following themes must be overcome:

1) Problems due to slippage of the gripping position

Although the system was able to cope with the slippage of the gripping position that had occurred at the time of construction of a 210m curve on this occasion, it is necessary to have a system which will be able to cope with the construction of sharper curves and to cope promptly with others including the slippage of the gripping position of rolling, etc.

2) Prevention of swinging of the K segment

Since the tendency was observed that K segment tended to swing obliquely at the time of separation after docking with erector the support mechanism would have to be improved.

3) Securing of the reliability and increasing the durability of various sensors

Although reliability and durability were considerably improved as a result of large scale alterations, it is necessary to secure complete reliability as the operation is undertaken in an inferior environment.

6. CONCLUSIONS

Although the automatic segment erection system is composed largely of "Segment gripping device", "Segment conveyance and supply device", "Positioning device" and "Bolt tightening device", the system developed this time was automated upto and including a part of the positioning device (determing of rough position). This system was not complete automation since some manual operations were necessary. Future aims are miniaturizing of the device, increasing the efficiency of the operation cycle and reduction of the costs. As a result, the system was confirmed to be sufficient for practical application to medium and small diameter shields.

In the future, more alterations and improvements had better be made based on the results of verification experiment, so that we will be able to have a system that can be readily used with high reliability.