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Study on Practical Application of the MMST Method

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Abstract

The MMST (Multi-Micro Shield Tunneling) method is a large-section tunneling method. Tunnel outer skin portions are excavated in advance by means of multiple small-section shields, followed by connection of excavated portions to make up external structures. Soil from inside the skin structure is then removed. Conventionally, large-section rectangular tunnels have been constructed according to the cut-and-cover method. The MMST method, on the other hand, enables construction of similar large-section rectangular tunnels without cut-and-cover, a singular advantage in projects requiring urban tunneling. This paper introduces the MMST method and reports on a construction test intended for future practical applications.

1. Introduction

Not a few expressway routes currently in service in city areas employ mainly tunnel structures. They are generally constructed according to a cut-and-cover method, but this method is not applicable to certain locations due to difficulties such as site, construction, and environmental assessment conditions. Moreover, restrictions including neighboring buildings and road alignment may make ordinary methods without cut-and-cover, such as shield method and NATM, inapplicable. In this background, a new method, not cut-and-cover, compatible with these severe conditions has come to be required.

A promising new method which can manage to achieve the target under the above restrictive conditions is the MMST method. However, no rational design and construction approaches have yet been developed and established at present, and this method is not yet been applied practically to tunneling up to now. Metropolitan Expressway Public Corporation in Tokyo has established a Research and Study Group Concerning Practical Application of the MMST Method to the Trans-Kawasaki Route (headed by Professor Konda of the Tokyo Metropolitan University). This group has conducted research concerning practical applications of the MMST method. Construction of the ventilation tunnel in the Daishi junction (temporary name) connecting the Trans-Kawasaki Route with the Yokohane Route has also been started as a construction test employing the MMST method(Fig.1) .

2. Outline of the MMST Method

2-1 Procedure and Features

The MMST method is implemented as described below (Fig. 2):

(1) Construction of individual small-section tunnel portions (shield excavation and arrangement of MMST steel shells)

(2) Connection of individual tunnel portions (excavation, reinforcing bar arrangement, and concrete placement between tunnel portions)
(3) Construction of the external structure (concrete placement in steel shells)
(4) Removal of soil from the inside of skin structure (mechanical removal with a back hoe)
(5) Internal construction work (intermediate slab, roadway surfaces)

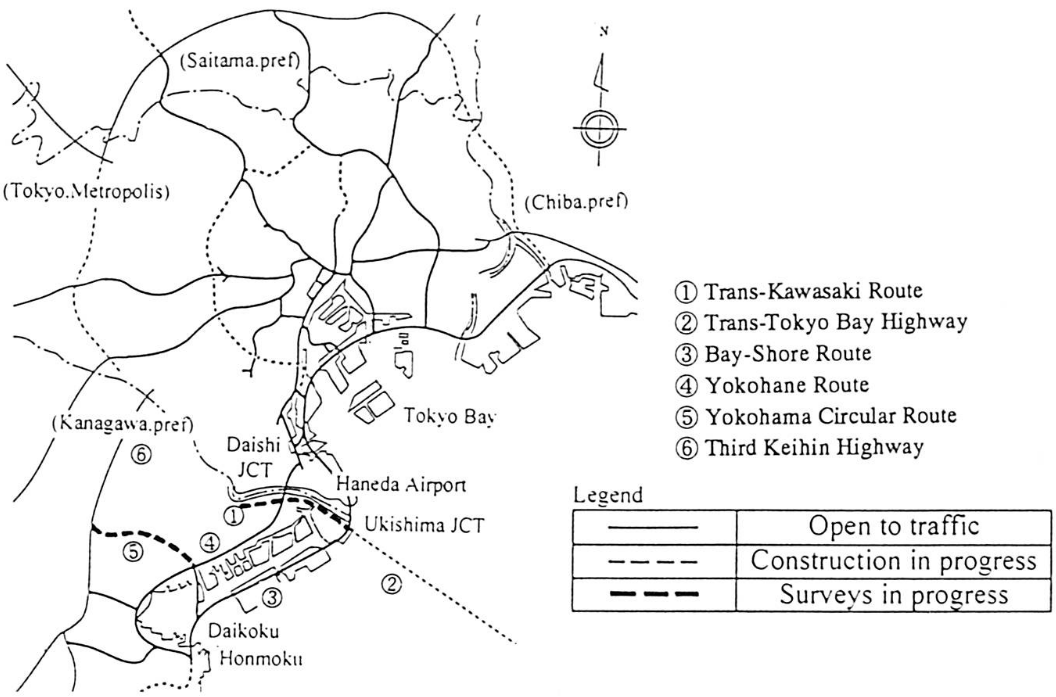


Fig. 1 Location map of Trans-Kawasaki Route

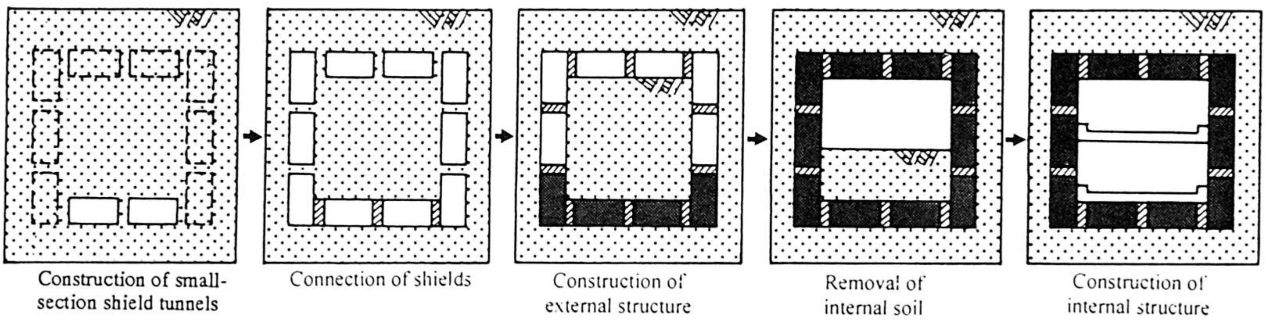


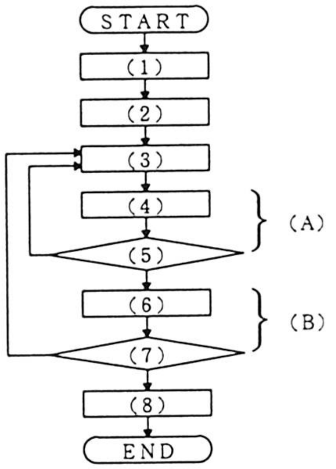
Fig. 2 Construction procedure according to the MMST method

Features and subjects of this MMST method are listed below:

- The MMST method can cope with changes in the tunnel section to a certain extent, which is favorable for matching to the road alignment.
- The use of small-section shields, which enables reduction of the size of shaft facilities while proving highly compatible with changes produced in the surrounding ground.
- Soil can be removed from the inside using an ordinary excavation machine, resulting in a decrease in industrial wastes from shield excavation.
- The shield is of a rectangular shape, long in a longitudinal or transverse direction, working in the extreme proximity of a neighboring shield.
- The external structure is of a construction in which SC and RC are combined. Besides, the force acting on members differs from one construction phase to another.
- The connection is made after removal of a part of steel shells from the tunnel inside, presenting considerable problems in terms of safety and workability. It is also necessary to take appropriate measures to adjust for errors during shield excavation.

2-2 Designing the MMST section

Fig. 3 shows the basic design flow of an MMST section.



(1) Individual tunnel portion arrangement plan
(2) Setup of design conditions
(3) Assumptions regarding the section
(4) Plane framed analysis of individual tunnel portions
(5) Verification of the stress
(6) Plane framed analysis of the MMST as a whole
(7) Verification of the stress
(8) Determination of the section
(A) The design of individual tunnel portions
(B) The design of the MMST as a whole

Fig. 3 MMST design flow

A structural system can vary greatly for each construction step. The design based on MMST is roughly classified into a design of individual tunnel portions during construction of an external structure and design of box culverts after its completion. The design of individual tunnel portions consists of designing MMST steel shells as individual shield linings on the basis of a plane framed model. In the design, four load cases shown in Fig. 4 are used. These are based on consideration of the effects of the neighboring shield according to the shield construction sequence. The design of the MMST as a whole includes the structural design of ordinary structures, which are steel-concrete composite members with concrete poured in steel shells, and connecting structures or RC members, according to the ordinary cut-and-cover tunnel design technique. Analysis is made using an overall frame model that takes the ground spring into account, as shown in Fig. 5, except that MMST steel shells are converted to reinforcing bars and designed as RC sections. The difference from the cut-and-cover tunnel is that the outer skin portions are completed first in the ground, followed by removal of internal soil. Therefore, the effect of unloading by removal of the soil, in other words, rebound expected during temporary construction of an ordinary cut-and-cover tunnel, is introduced as a load active on the tunnel invert. This effect is considered separately as a stress released effect during removal of internal soil.

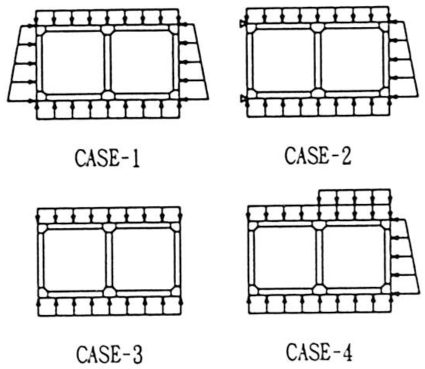


Fig. 4: MMST steel shell design model

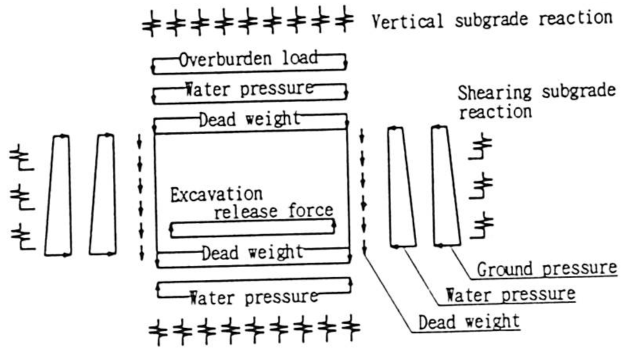


Fig. 5: MMST external structure design model

Figs. 6 and 7 show the construction of MMST steel shells and connections. MMST steel shells are made from main beams (angle steels) and skin plates (shell plates). To connect individual tunnel portions, part of steel shells is removed, and the RC structural member is constructed through excavation, a reinforcing bar arrangement, and placement of concrete between individual tunnel portions. Changing the length of connecting members can change the tunnel section.

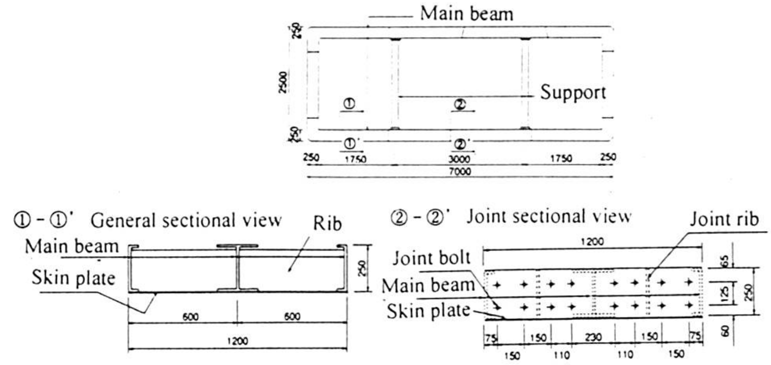


Fig. 6: Basic construction drawing of MMST steel shell

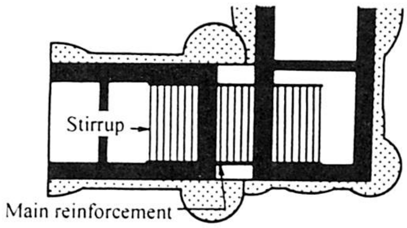


Fig. 7: Basic construction of the connection

3. Construction Test with the MMST Method

3-1 Objectives of the construction test

There are many problems to be solved before practical application of the MMST method is possible. These can be classified as follows : (1) Problems related to individual tunnel portions, (2) Problems related to connections between individual tunnel portions, (3) Problems related to the MMST structure as a whole, and (4) Other problems.

To solve these problems, the construction test was planned in parallel with numerical analysis and various experiments. Approaches including implementation of the construction test to address the above problems were classified into four kinds as shown in Table 1. Each approach plan was drafted: (1) Study through numerical analysis, (2) Study through elemental experiment, (3) Study through monitoring of construction test, and (4) Study based on the construction test state.

3-2 Outline of the construction test

The construction test using the MMST method was planned for a part of a ventilation tunnel connecting a ventilation station planned within a junction of the Trans-Kawasaki Route and the expressway tunnel. (Fig. 8)Three routes were decided upon as shown in Table 2. The following points were considered ;

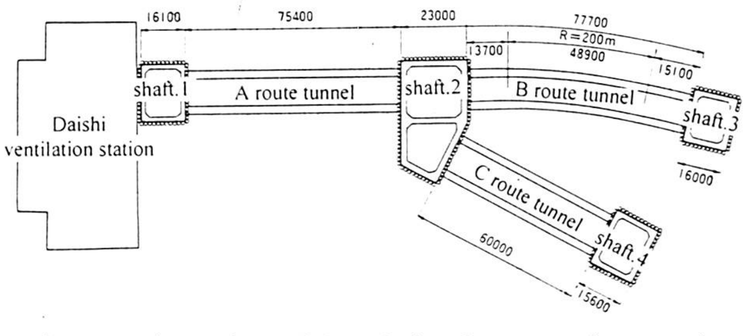


Fig. 8: Plane view of the whole of construction test plan

(1) Connection pattern of individual tunnel portions (a total of four types including longitudinal and transverse connections, and two types of corner connections),
(2) Change in the length of connection (1.6 – 0.5 m),
(3) Connector construction types (RC and PC constructions), and
(4) Linear and 200R curved sections of the plane alignment.

3-3 Specifications of MMST shield machine

The sectional shape of the tunnel being a super flat rectangle(aspect ratio approx. 1/3), the shield machines to be used for excavation of individual tunnel portions according to the MMST method had to ensure highly accurate position control, more than in the case of ordinary circular tunnel construction. This may be due to the extremely narrow distance between individual shields, and the fact that excavation errors may grow too much to offset errors in the joint and other structures.

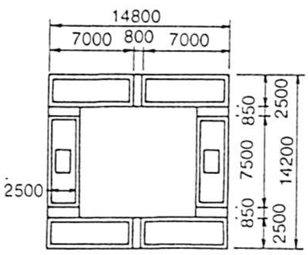
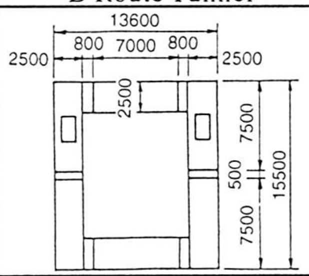
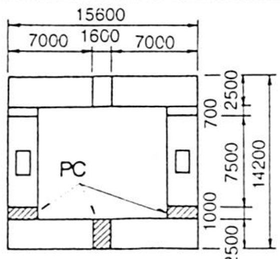
Shield machines prepared for the construction test included longitudinal and transverse shield machines for each tunnel. A drum cutter type slurry shield machine was prepared for the tunnel route A, a slurry earth-pressure type shield machine for the route B, and a slurry shield machine

Table 1: MMST Method Problem Factors and Countermeasures

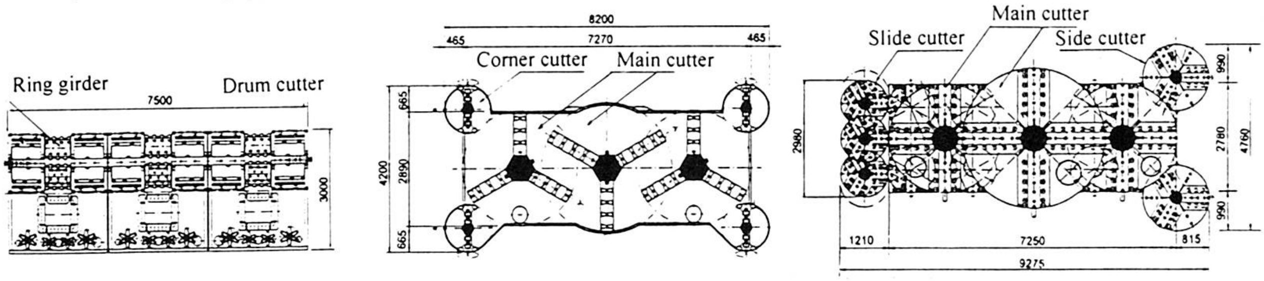
Problem factors			Countermeasures: Analysis	Countermeasures: Elementary experiment	Construction test: Monitoring test	Construction test: Construction state
Individual tunnel porting	D	Confirmation of MMST steel shell joint performance		O	O	
		Confirmation of active load during proximity construction of individual tunnel portions	O		O	
	C	Understanding of behavior of individual tunnel portions	O		O	
		Confirmation of position control of shield machine				O
Connection between individual tunnel portion	D	Confirmation of joint construction design method for linear connection	O	O	O	
		Confirmation of joint construction design method for corner connection	O	O	O	
		Confirmation of effects of individual tunnel portion construction error on proof stress	O	O		
	C	Confirmation of workability of connection		O		O
MMST tunnel	D	Confirmation of design method as a steel-concrete composite construction		O	O	
		Confirmation of effect of removal of internal soil	O		O	
		Confirmation of the stress of general members in each construction stage	O		O	
		Confirmation of opening construction design method in each construction stage	O	O	O	
		Confirmation of the effect of thermal stress generated after placement of structural concrete	O		O	
		Confirmation of the effect on overall system of advance stress occurring in steel shell during construction of individual tunnel portions	O	O	O	
		Confirmation of anti-seismic safety of overall system	O			
	C	Confirmation of workability as a whole				O
Others		Understanding of how ground deformation occurs in each construction stage	O		O	
		Confirmation of workability of ground and tunnel internal facilities				O
		Construction cost and process				O

* D: Design C: Construction

Table 2: Outline of the plan for each route

Sectional view / Outline of the plan	A Route Tunnel	B Route Tunnel	C Route Tunnel
			
Tunnel length	L=75.4m	L=77.7 m	L=60.0m
Tunnel outside dimensions	Height : 14.2m Width : 14.8m	Height : 15.5m Width : 13.6m	Height : 14.2m Width : 15.6m
Internal excavation sectional area	90m2	90m2	98m2
Excavation sectional area	210m2	211m2	222m2
Connection type	RC	RC	RCandPC
Overburden	4.7〜6.9m	7.3〜7.4m	5.1〜6.0m
Horizontal alignment	Linear R=∞	Curved R=200m	Linear R=∞
Vertical alignment	3.0% down-grade	1.0% upgrade	3.0% upgrade

for route C (Fig. 9). Important investigation items for this construction test were the workability confirmation in terms of position control because this shield has to manage the super-flat rectangular section as well as confirmation of construction accuracy. Accordingly, each shield machine has various position control mechanisms for pitching, yawing, and rolling, which include a copy cutter, over cutter, slanting jack, articulation system, and movable flap.



(1) A route tunnel (2) B route tunnel (3) C route tunnel

Fig. 9: Horizontal shield machine

3-4 Monitoring plan

During the construction test, problems classified below were monitored:
(1) Understanding the load
(2) Understanding the behavior and structural characteristics
(3) Understanding of effects on the surrounding ground

For these problems, two monitoring sections were set for each tunnel. Measuring equipment shown in Fig. 10 were arranged for measurement for analysis and review as the work progressed.

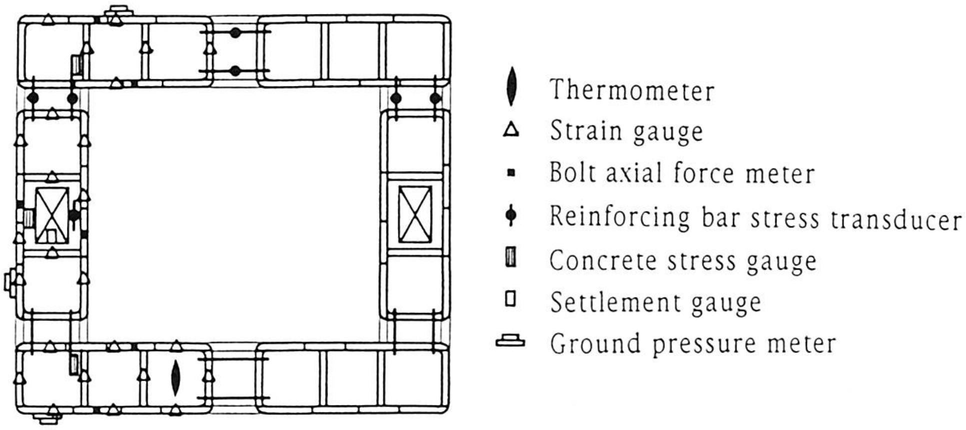


Fig. 10: Instrument arrangement plan

4. Summary

The MMST method is a new large-section tunneling method with superior features for urban areas with severe restrictions. Because of lack of a practical application record, and due to the complicated procedure, this method faces problems in terms of design and construction. This report briefly described various reviews and tests used to clarify these elements. As regards the construction test progress, the shaft was nearly completed in July 1997, and the shield machine, whose launch is scheduled for the earliest time, will be launched in September. The connections between small-section tunnel portions are planned for February 1998. In line with the construction test, various elemental experiments and FEM analysis are in progress. We plan to summarize these results to establish an economical MMST design and a construction method and practical application for the construction of Trans-Kawasaki Route.