Applications of Trevi Forepiling Methods in Japan
(An Application of Micropiles)

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Abstract

The Trevi Methods are the Umbrella Forepiling methods developed in Italy. Since their introduction into Japan, the Trevi Methods have been applied and executed in 23 tunnels in Japan thanks to wide recognition and realization of their safety excavation an minimized settlement in tunneling with the Methods.

The execution shall be performed d by the specialized machines to be regarded as a total drilling and treatment system and applicable to every kind of geological conditions obtaining very high durable supports not only in forepiling but also in lengthy face bolts and for water drainage among others.

1. Introduction

Tunneling in urban area is increasing recently. In the urban area tunneling, many cases will be encountered with such difficult conditions as non-cohesive lose soil, thin overburden and existing buildings on the surface ground. Under such situation, the advance reinforcement and consolidation of the ground is very necessary for safety tunneling and excavation without adverse effects to ground surface.

The Trevi Methods are developed to give a solution for safety and controlled tunneling in such difficult conditions and situations as stated above.

This paper shows the outline & concept, the current applications tendency and future directions of the Trevi Methods in Japan.

2. Outline & Concept of Trevi Methods

In the Trevi Methods, there are two methods, i.e., "Trevi Tube Method" and "Trevi Jet Method".

2-1. Trevi Tube Method:

In advance to tunneling excavation, the arch shaped reinforced zone will be established through soil consolidation with long steel tubes with grouting holes and soil improvement with the grouting treatments.

The standard tubes' diameters are 114.3mm - 139.8mm and the length is 12m(Fig.1).

2-2. Trevi Jet Method:

This Method utilizes jet-grouting to produce shells shaped consolidated zone instead of normal grouting in the Trevi Tube method. The Method is effective in the soft clay and fine sand where improvement by normal grouting treatment is difficult. Also, the Method is effective for water cut-off.

The hole drilling and jet grouting are proceeded simultaneously and the steel tube is remained in the improved treated column center as an additional reinforcement material (Fig.2).

The reinforced treated columns with steel tube in the column center as shown in the Fig.3 will produce the continuous wall in the arch shape covering tunneling excavation area.

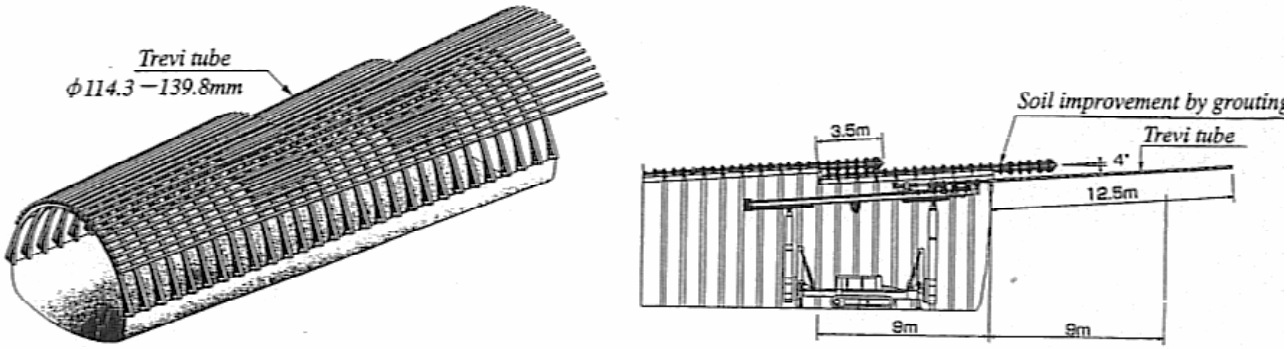


Fig.1: Trevi Tube Method

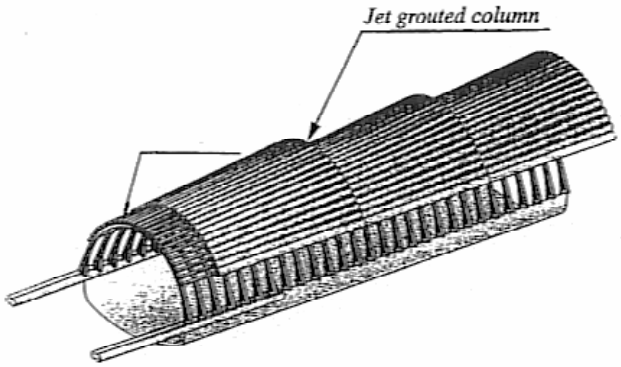


Fig.2: Trevi Jet Method

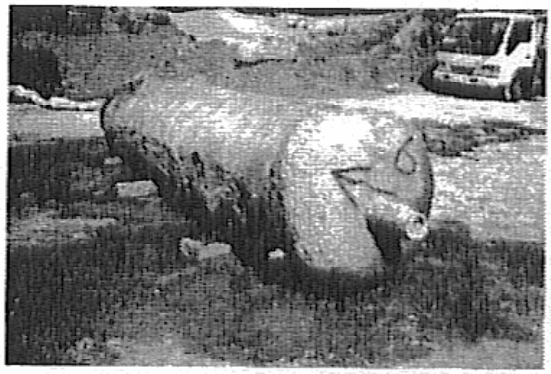


Fig.3: Jet-grouted column

2-3. Drilling Machine:

For execution, 18m-20m special long boom machine shall be used for installation of 12m-15m steel tube (Fig.4).

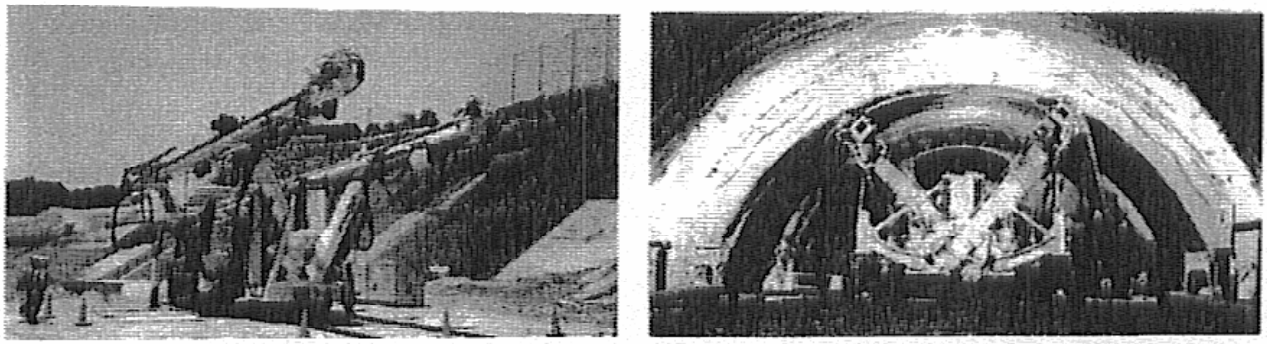


Fig.4: Drilling Machine

2-4. Drilling System and Their Applicability:

Drilling system, improved to apply for very complicated and variable geological conditions in Japan, is Double Head System consisting of front rotary and rear rotary percussion system. The drilling will be executed mainly by the following two ways ; one is top hammer, the other is down the hole hammer (Fig.5).

According to geology, we use either top hammer or DTH, as shown in Table 1.

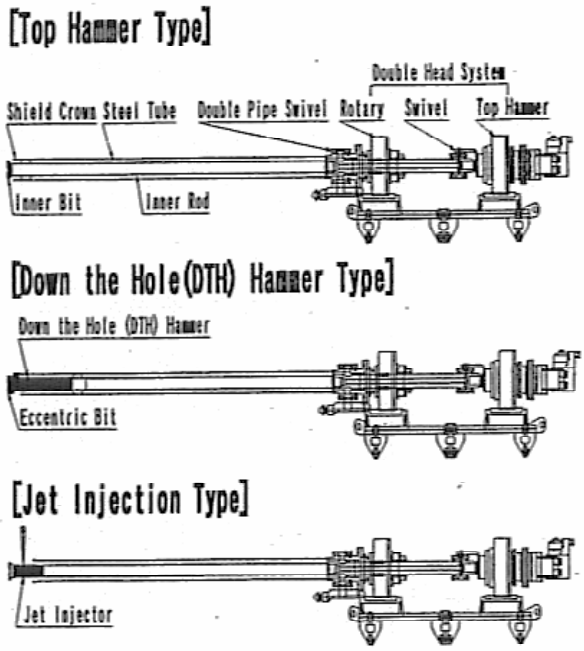


Fig.5: Drilling System in Trevi Method

Table 1: Drilling Method and Their Applicability

Trevi Tube Method

Drilling Methods	Clayey	Sand Layer	Gravel Layer	Cobble Layer	Boulder with Soil	Soft Rock
Top Hammer	O.K.	O.K.	O.K.	Can be applied	NA	O.K.
Down the Hole	NA	Can be applied	O.K.	O.K.	O.K.	O.K.

NA = Can not be used

Trevi Jet Method

Jet injection type; Soft Clayey, Fine-sand Layer

3. Case History

The Trevi Methods have been introduced into Japan in 1993 and applied in 23 tunnel projects. The many of them are in urban area such as Kobe, Nagoya and Tokyo as shown in the Fig.6. And some examples are shown below;

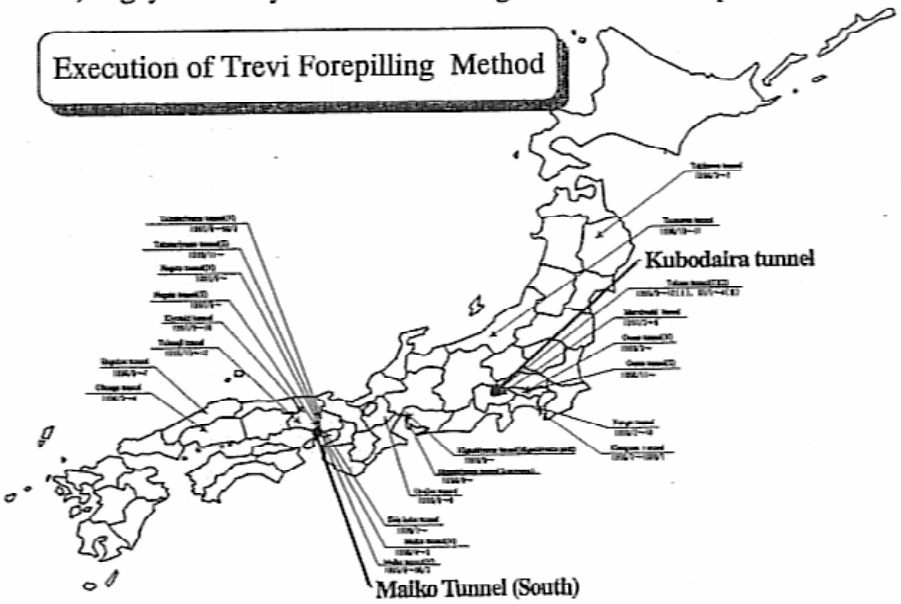


Fig.6: Trevi Methods tunneling sites location

3-1. Maiko Tunnel (South) in Kobe

The Maiko tunnel is three lanes road tunnel with 8m radius.

The Tunnel has been executed under residential area with multi-storied buildings and service pipes for city gas and water supply (Fig.7).

The geology of the tunnel is a soil composed of gravel and sand. The overburden ranged from 9 to 30 meters.

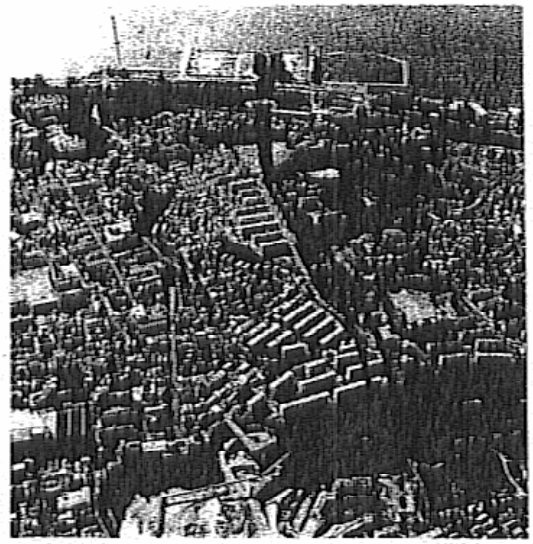
Trevi Tube Method was adopted for the entire tunnel length of about 330 meters.

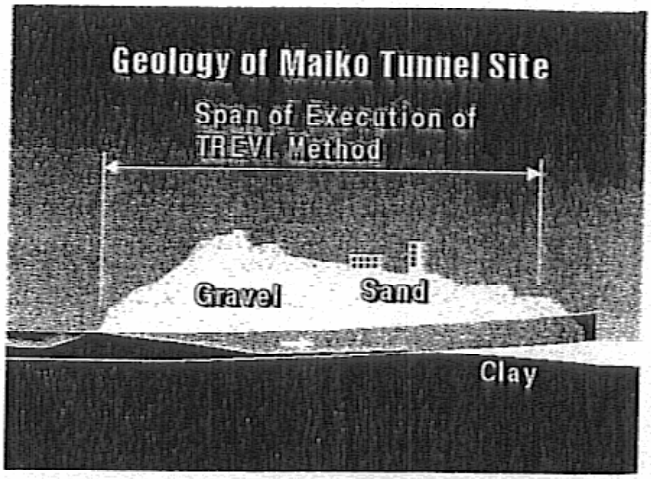
The main problem was ground settlement. Thus, the aim of this project was to secure stability during tunnel excavation and to suppress land-subsidence .

In this tunnel, 45 forepilings with 114mm diameter steel pipes, the forepiling pitch 400mm, cement grouting at low pressure 5kg/cm^2 were applied.

The execution was completed within a contractual ground settlement limitation 20mm.

No damage was given to the tunnel by the Great Hanshin-Awaji Earthquake occurred during the execution.





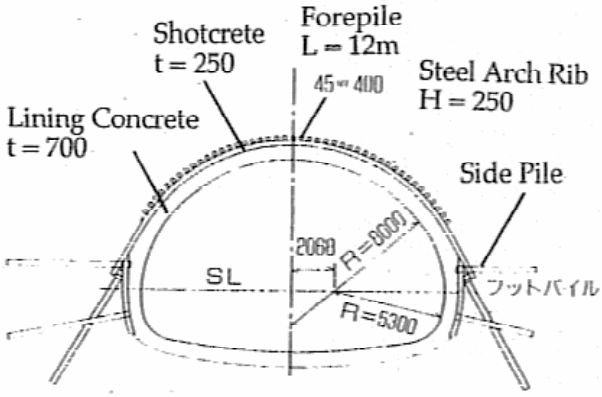


Fig.7: Maiko Tunnel (South)

3-2. Kubodaira tunnel (Yamanasi Pref.)

Kubodaira tunnel is a two-lane road tunnel with a diameter of about 12 meters. The tunnel had to be constructed under a channel, roads and residential buildings. Overburden was a mere 5 meters (Fig.8).

The site geological conditions are very lose matrix soil with boulders and cobbles. Boulders diameter was 50 cm to 1m and their hardness were 1,500 to 2,000kg/cm^2.

31 Trevi Tube forepiles with 114 mm diameter steel pipe reinforcement were executed. Usually 12 meters long Trevi Tube forepilings are performed with an overlap of 3 meters between two successive sections, allowing 9 meters of excavation. However, in this case of lose soil, it was necessary to increase the length of overlap sometimes.

DTH was selected as a drilling system because of the presence of boulders with a hardness up to 2,000kg/cm^2.

Due to the porous soil conditions, polyuretan resign type grouting material was used.

The graph on Fig.9 displays the amount of settlement as measured in Kubodaira tunnel during the execution. Before using Trevi Tube Method, the settlement increases as the overburden decreases, whereas applying Trevi Tube Method resulted in a sharp decrease of settlement even under 5 m of overburden.

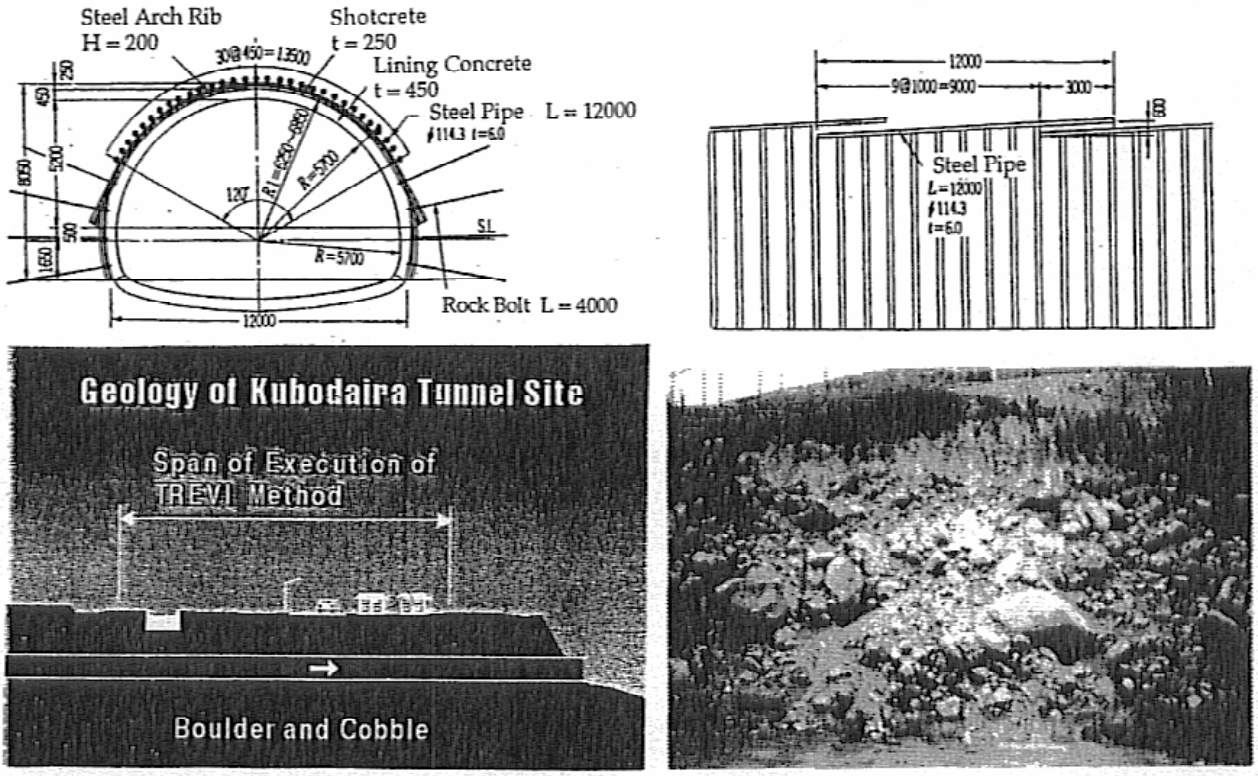


Fig.8: Kubodaira Tunnel

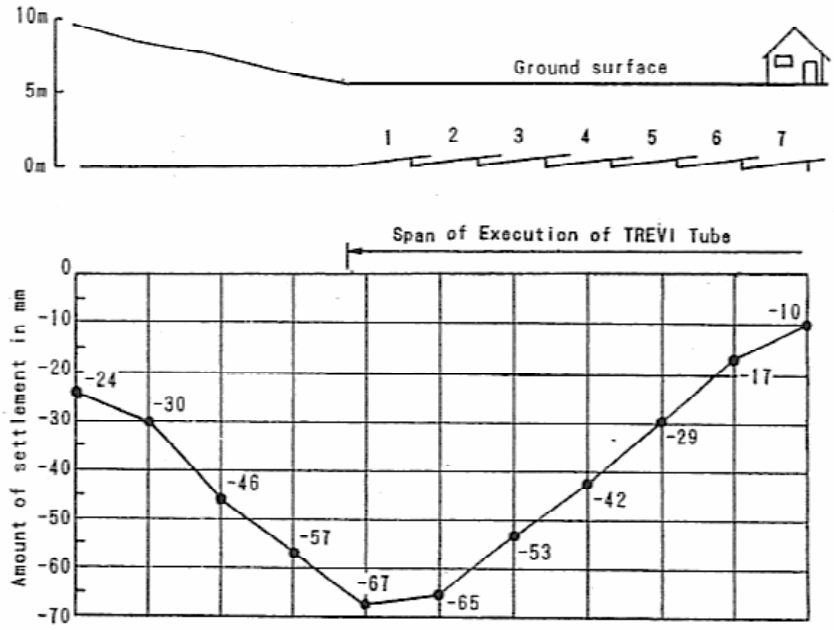


Fig.9: Amount of settlement of ground surface on completion of excavation of the upper half of tunnel.

3-3. Others

The Trevi Methods will also be applied together with micropiles and face bolts as shown in the Fig.10.

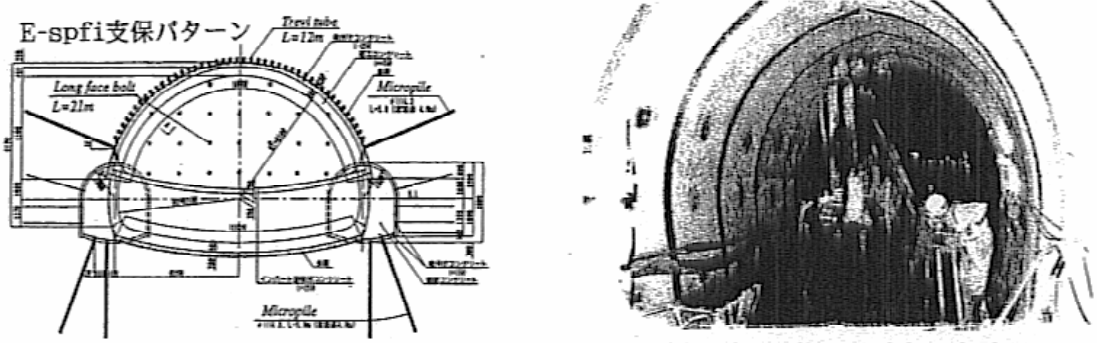


Fig.10: Trevi Methods with combinations with micropiles and face bolts

4. General Measures and Directions

In addition to the availability of the strong drilling capacity and large diameter & thicker steel tube applications, the recent combined applications as the general measures, such as forepiling, face bolts, jet-grouting for base of tunnel support as shown in the Fig.11, makes main reason for adoption of the Trevi Methods.

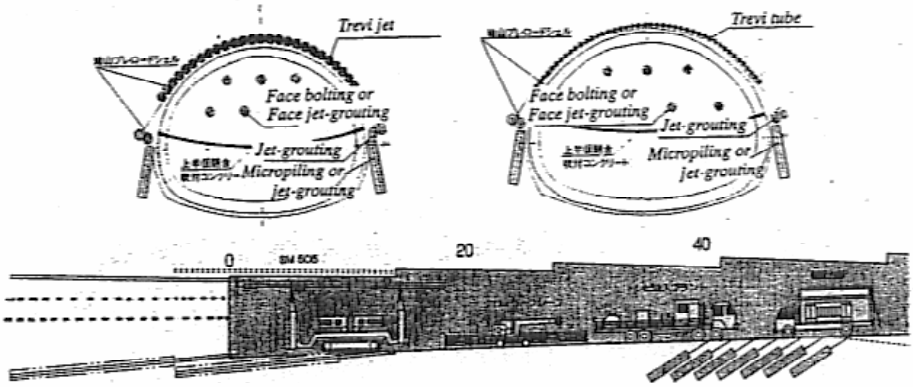


Fig.11: General Measures

5. Conclusion

In country like Japan with complicated geology, the Trevi Methods are of utmost importance.

The following salient features of the Methods were established through the execution work at various tunnel projects in Japan.

- Settlement suppression
- Stabilization during the excavation
- Improvement of work environment
- Prediction of bedrock ahead of heading

The applications of Trevi Methods are heading for two general directions;

- Expand each forepile length in order to achieve lower cost of and shorten the period of construction
- General measures with the combination of forepiling, longer face bolting, water draining and antecedent soil improvement for base tunnel support

6. References

1) Amamiya et al. :"Execution of tunnel by using Trevi Tube Method through a loose soil with boulders and cobbles "(in Japanese),Tunnels and Underground of JTA, Vol.27, No.8, 1996