Feasibility of Microtunnelling Method
by Water Jets Technology

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ABSTRACT

A microtunnelling (i.e. tunnel diameter less than 900mm) excavation process by water jets includes: (1) forming a working well; (2) boring a tunnel from the working well through water jets techniques which use at least one water jets cutter including a jets seat and a jets nozzle mounted rotatable. On the jets seat, the tunnel is being bored by moving progressively the jets seat along a circular path and by rotating the jets nozzle relative to the jets seat; (3) removing excavated cemented soil, rocks or gravel from the tunnel; and (4) advancing the water jets cutter along an axis of the circular path. In this study, we indicated that it is a very feasible method in boring by similar rock simulation.

1. Introduction

Conventional contact-type tunnel boring machines have their shortcomings in operation, such as the inability to provide sufficient friction and abutment force during cutting a hard rock structure or the problems of undesired attachment of cement onto the cutting head when cutting a cement structure. These disadvantages results a cutting efficiency decrease. So it will require additional manpower to bore the tunnel and to remove the attached cement on the cutting head. In microtunneling process, particularly in tunnel diameter less than 600mm, the aforesaid drawbacks become more seriously as an operation cost increase, a boring efficiency decrease, dust and noise pollution problems, safety concerns, insufficient emergent response space, etc…

So we make a mockup to simulate feasibility of microtunnelling method by water jets technology.

2. Mockup Model Property

(1) Conventional semi-contact type TBM

A conventional semi-contact type tunnel boring machine includes about eight parts. That includes a tubular tunnel support, a front end plate, a disc cutter mounted rotatably on the front end plate and provided with a drilling head, a motor for driving rotation of the disc cutter, a screw rod conveyor for removing excavated cemented soil, rocks or gravel from a collecting chamber, a main water jets unit with a plurality of first jet nozzles mounted on the front end plate, a secondary water jets unit with a plurality of secondary jet nozzles mounted on the drilling head (see Fig.1).

When working on a hard working surface of a cement structure, such as a gravel layer structure, a grouted soil, rocks or gravel structure, the traditional semi-contact type tunnel boring machine in a working
well to bore a tunnel into the ground, its main and secondary water jets units provide water through the main and secondary jet nozzles. So it can pre-weaken the structure of the hard working surface of the cement structure.

The water jets can be divided into the plain water jet and abrasive water jet. The disc cutter rotated by motor to cut the hard working surface through the weaken actions. After that it moves the excavated soil, rocks or gravel into the collecting chamber.

The screw rod conveyor extends into a bottom of the collecting chamber so as to remove the excavated soil, rocks or gravel therefrom. [1]

Fig.1 A conventional semi-contact type tunnel boring machine (Pin-tsung Cheng, et al., 2006)

(2) Microtunneling Apparatus

We present a fragmentary schematic view of the microtunneling equipment according researcher’ prior study in this section (see Fig.2). The operation processes and components of the microtunneling equipment operated as follows[2]:

(a) A microtunneling apparatus has a tubular tunnel support with a front slating barricade and a rear close barricade in it. Both barricades work at one close and another open condition. So the excavation chippings can move from the front barricade to rear barricade.

(b) A water jets cutter mounted in the front open end of the tubular tunnel support, rotatable relative to the tubular tunnel support about an axis of the tubular tunnel support, and including a jet seat and a jet nozzle that is mounted on the jet seat and that is movable relative to the jet seat;

(c) A hydraulic jack disposed externally and rearwardly of the rear open end of the tubular tunnel support and including a plurality of hydraulic cylinders abutting against the door;

(d) A pump disposed externally of the tubular tunnel support; a mud pipe line connected to the pump and extending into the tubular tunnel support;

(e) A water pipe line connected to the pump and extending into the tubular tunnel support.

The results of this study are according to the microtunneling apparatus(see Fig.2).

Fig.2 A fragmentary schematic view of the third preferred embodiment of the microtunneling apparatus (Pin-tsung Cheng, et al., 2007)

(3) Mockup model

We illustrate a mockup entity of full scale by fig.3. The composite properties of mockup are through three different water-to-binder ratios (0.4, 0.485, 0.6) which respectively mixed by 10, 20, 30, 40 and 50%
wasted liquid crystal glasses powder in order to replace part of cement produce mortar specimen. Other concrete specimen whose has design compressive strength of 210, 280 and 350 kg/cm² were added by 0, 20, 40, 60 and 80% wasted liquid crystal glasses powder. Compare with the Young’s modulus which ranged between 20–40 GPa, the results show that for all the proportion mixtures are higher than the control group. The sulfates resistance of wasted liquid crystal glasses powder with 20% specimen is below 0.7% . The result is more stable than control group. Ultrasonic pulse velocity for 28-day specimen is ranged from 4100 to 4400 m/sec which is good. [3]

3. Construction Process and Simulation results

To make improvement tunnel boring machines their disadvantages, such as the inability of providing sufficient friction and abutment force during cutting a hard rock structure or the problem of undesired attachment of cement onto the cutting head during cutting a cement structure, which results in a decrease in cutting efficiency. We operated through the microtunneling apparatus(see photo.1) to give suggestions about construction process of microtunneling method as below Fig.4 review.

![Flow Chart of Microtunneling Method](image)

**Fig. 4 A flow chart of consecutive steps of the microtunneling method**

Although the structure of the hard working surface of the cement structure can be pre-weakened before the actual cutting operation but a limited area of the hard working surface covered by the main and secondary jet nozzles is pre-weakened. The structure of the remainder area of the hard working surface remains relatively strong.

It is a fragmentary schematic view to illustrate a working well is formed according to the first preferred embodiment and where a microtunneling apparatus is installed in the working well by Fig.5.

By Fig.6, we explained that a fragmentary schematic view in a tunnel is boring using the microtunneling apparatus according to the first preferred embodiment.
Finally, We operated through ultr-high pressure (210~275 MPa) and mid-flow rate (40~45 letter/min) water jets to simulate the mockup model. Results show that it is a feasible microtunneling method. See below photos as a reference.

4. Conclusions

The objective of this study is to provide a microtunneling method that can overcome the aforesaid drawbacks. From our test, there is provided a microtunneling method that comprises: (1) forming a working well; (2) boring a tunnel from the working well through water jets techniques which use at least one water jets cutter including a jets seat and a jets nozzle mounted rotatably on the jets seat, the tunnel being bored by moving progressively the jets seat along a circular path and by rotating the jets nozzle relative to the jets seat; (3) removing excavated cemented soil, rocks or gravel from the tunnel; and (4) advancing the water jets cutter along an axis of the circular path. A high water pressure generator is connected to the first jet nozzles through a supply line for supplying high pressure water jets through the first jet nozzles. Finally, we showed that it is a very feasible method in boring by similar rock simulation.

References