CS-212

# DEVELOPMENT OF RECTANGULAR TUNNNEL STRUCTURING METHOD APPLYING WAGGING CUTTER SHIELD MACHINE

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## 1.INTRODUCTION

When a rectangular underground structure, for common use trenches, underground passageways, etc., is to be structured at a rather shallow layer of soil covering, the open trenching method is often used. However, in recent years there is an increase in cases where the open trenching method cannot be applied due to spatial restrictions from underground-embedded objects or adverse effect to surface traffic.

As a typical non-open trenching way, there is the shield tunnel method. However, in order to maintain the necessary inner space the diameter of the tunnel becomes large which not only increases the cost, but problems may arise, such as, difficulty in keeping it within the given property boundary, or due to lack of soil covering the alignment must be changed (see Fig. 1).

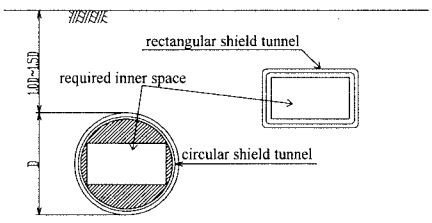


Fig.1 Comparison of Shield Tunnel Cross Section

With the aforementioned in the background, a structural method of a rectangular tunnel, having the prerequisite of a reduced cross-sectional dimension, and with the conditions of non-open excavation, as well as, a shallow soil covering has been developed, which summary is reported herein. Furthermore, with main objective in reducing machine cost, for digging with this shield machine applies a wagging cutter type shield mechanism that adopts a cutter-head which functions in a wiper type motion.

## 2.WAGGING CUTTER TYPE SHIELD MACHINE

The general illustration of the wagging cutter type shield machine is shown in Fig.2. The concept of the wagging cutter type shield machine is, a shield machine that possesses a driving mechanism which can excavate by wagging the cutter-head in a wiper motion (the wagging angle hereto is 100 degrees), by the expansion and contraction of hydraulic jacks (see Fig.2 and 3). The characteristics of the wagging cutter type shield machine are shown below.

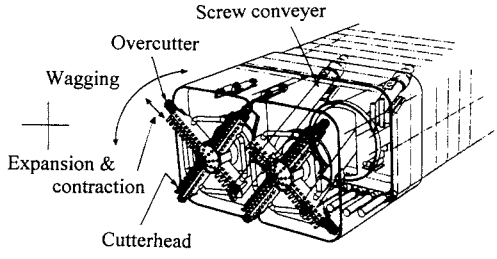


Fig.2　Rectangular Shield Machine

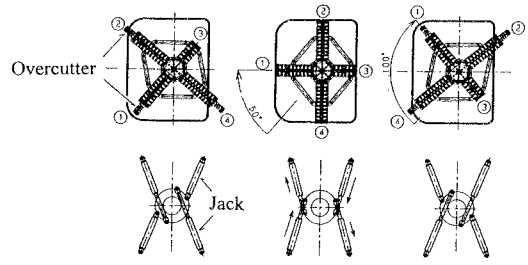


Fig.3　Hydraulic Jack Movements

1) The wagging torque of the cutter is the same as the rotating torque of an ordinary motor driven shield machine that excavate by rotating the cutter head in 360 degrees, only, the driving system of the wagging type is simpler. Moreover, the overall length of the machine can be shortened and the light weight adoption of the driving part becomes possible, which result in reducing costs, especially advantageous when the construction extension is a short distance.
2) The corner portions, which cannot be excavated by using just the wagging of the cutter-head, are cut by profiling with an overcut device (see Fig.3). Special bits (all direction cutting bits) are attached to the overcut device of which arrangement is made by taking into consideration the accumulation of dirt and gravel.
3) The forward body of the shield machine is divided into right and left portions to maintain the horizontal level of the machine. A middle bending device, which enables the individual portions to move up or down, is equipped to correct the rolling motions.
4) The erector, which assembles the steel shell, is equipped to work by separate right and left erector because there is a temporary middle column at the center of the steel shell. Also, at the time of assembling the middle column, a system is provided in which a shape maintaining device, that is equipped at the rear part of the machine, expands vertically towards the outside of the tunnel in order to prevent the deformation of the tunnel, and the middle column is inserted while maintaining the column height.

## 3.CONSTRUCTION PROCEDURE OF RECTANGULAR SHIELD TUNNEL

The construction procedure of the rectangular shield tunnel is shown in Fig.4

KEY WORDS: Wagging cutter type shield machine, rectangular tunnel, steel shell, friction type connection
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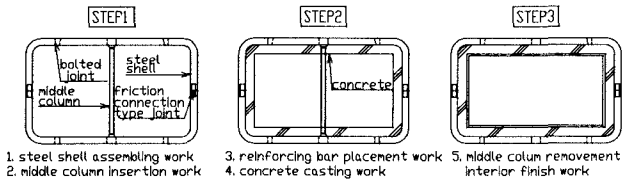



Fig.4 Construction Procedure

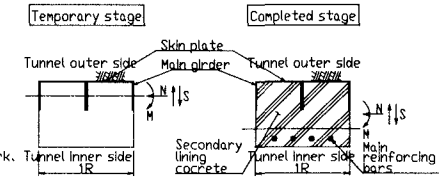



Fig.5 Lining Cross Section

## 4. LINING STRUCTURE OF RECTANGULAR SHIELD TUNNEL

The characteristics of the lining structure of the rectangular shield tunnel are described below.

1) The tunnel lining consists, on the outer side, of a steel concrete (SC) structure, and on the inside a reinforced concrete (RC) structure. The steel shell consists of a steel flat plate, and a skin plate of steel sheet. During temporary stage it is used as the tunnel lining, and at the time of completion it is unified with the RC member and functions as the main tensile material of the tunnel lining (see Fig.5). In this manner, by utilizing the steel shell for permanent use the tunnel excavation cross section can be made smaller by just about the height of the steel shell which enables to economize on the construction costs when compared with the normal tunnel that builds the permanent RC structure inside the steel shell which had been used for temporary works.
2) Of the joints between preassembled pieces of the steel shell, friction connection type joints that possess high tensile rigidity are employed for the joints those are stationary tensile upon completion (see Fig.6). Friction connection type joint is a joint mechanism that transmits the strength of the main girder through the splice plate by means of friction between the main girder and the splice plate.
3) As the shear reinforcing material of the lining member, steel bars are placed. The ends of the steel bars are welded to the plates, and by the high tension bolts the plates are anchored to the main girder for the steel bars to function as the shear reinforcing material.

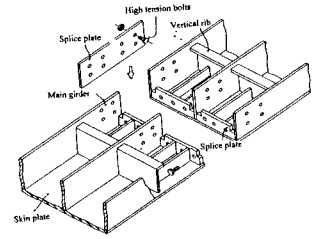



Fig.6 Friction Connection Type Joint

## 5.MEASURMENT OUTLINE

Regarding the steel shell measurement, the objective is placed in comprehending the stress condition of the tunnel lining. The measurement items are the stress of the main girder and the middle column, the measuring point was the 25th ring from the starting shaft, and the instruments were arranged on one side of the entire tunnel cross section (see Figs.7).

## 6.MEASUREMENT RESULTS

From the comparison of the measured and the design cross sectional strength during temporary stage, as shown in Fig.8, it can be seen that the cross sectional strength is in good agreement qualitatively. The calculation of the design cross sectional strength was conducted by a frame analysis. The model composed of the steel shell and the middle column was assumed as having uniform stiffness, the load is full overburden pressure in the vertical direction and the soil pressure and water pressure of Ks=0.5 in the horizontal direction.

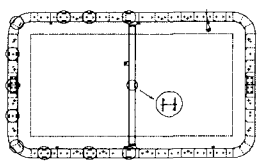
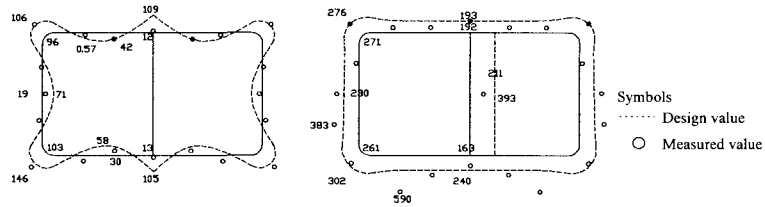


Fig.7 Instruments Arrangement




Bending moment (kN·m) Axial Strength(kN)

Fig.8 Cross Section Strength

## 7.CONCLUSION

As to the issues requiring further attention henceforth, it is thought that the workability should be improved on the tunnel lining structure. Especially, regarding the shear reinforcing steel bars, which interfere with the main reinforcing bars and those in axial direction, it requires extra time for bolts tightening. It is necessary to improve the anchorage structure of the shear reinforcing steel bars. Also, when the top slab concrete is being poured a possibility exists of air accumulating inside the steel shell, therefore it is necessary to arrange air extraction pipes or innovate a simple structure for the steel shell itself so that air will not accumulate easily.

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