CHAPTER III

DISCUSSION

3.1 Shaft Construction Problems and Rectifying

3.1.1 Tilting

According to M.W.W.A. specification (11), the allowable deviation from the vertical axis of shaft is 1:200. When the shaft is sunk, it is necessary to check and record its position.. As soon as the tilt exceeds the tolerance, the following rectification methods will be used.

1. More dredging in area of the higher side of the shaft.
2. Bentonite slurry jetting at the external surface of the higher side of the shaft to add lubricant between the shaft wall and surrounding soil.
3. More load providing in the higher side is order to provide greater sinking.

3.1.2 Shaft Sinking in Loose and Soft Clay

When the shaft has been sunk in loose and soft clay, the sinking rate can be controlled by the following procedures:

1. Providing gradual reclamation by sand fill cause friction.

2. Providing temporary obstacles at the inside wall of cutting edge until a shaft reaches stiff clay stratum as shown in Fig. 66.

3.1.3 Shaft Sinking in Sand

When a shaft has been sunk in sand or water bearing granular soil, the methods of stopping the heave are as follows:

1. Filling water in the shaft up to the ground water level to provide force against the heaving stress.
2. Grouting the sand layer by chemical or others to improve the ground condition as shown in Fig. 67.

3.2 Tunnel Alignment Deviation and Correction

The most important in tunnel alignment control is to keep the actual tunnel alignment as close as the design alignment. It is necessary to find the deviation as soon as possible and correct the direction in both straight and curved lines.

3.2.1 Causes of Tunnel Driving Machine Deviation

The causes of tunnel driving machine deviation are as follows:

1. Due to unequal earth pressure.
2. Deviation of fixing location of jacks in tunnel driving machine.

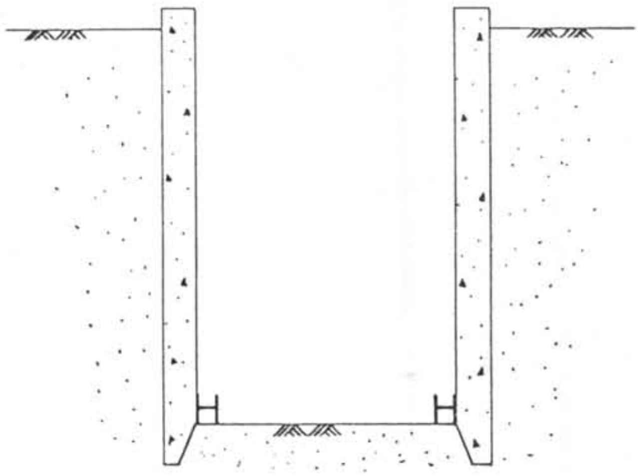

Fig. 66 Temporary obstruction to reduce rate of sinking of shaft in very soft clay.

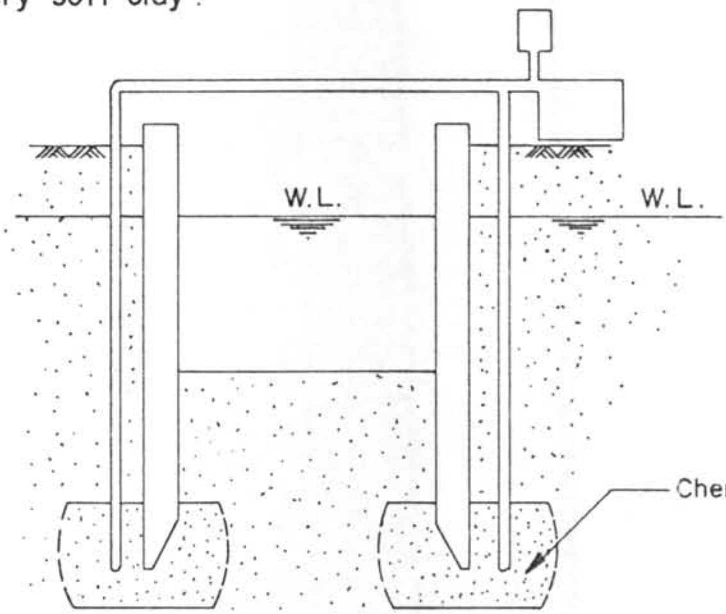

Fig. 67 Chemical grout in sand layer to reduce heaving.

3. Due to the deformation of primary lining segments from the thrusting of jacks (lack of strength of segments).

4. Due to the characteristic of tunnel driving machine itself (dislocation of center of gravity of the machine, error against exact circle).

5. Lack of skill of the machine operator or mistake of surveying

3.2.2 Sorts of Tunnel Alignment Error

The sorts of tunnel alignment error can be summarized as follows:

1. Deviation between centerline of the tunnel lining and the design centerline (Fig. 68).
2. Difference of direction between the center of tunnel lining and the design centerline (Fig. 69)
3. Difference of direction between the centerline of tunnel lining and the tunnel driving machine (Fig. 70).

3.2.3 Correction of Tunnel Alignment Error

Above stated sorts of deviation will occur singularly or in compound cases. For correction, both centerline of tunnel driving machine and tunnel lining must be tried to meet as close as possible, and after that make close these centerline to the designed center line. In general, about 1.5 times of the machine length is required to take the effect of correction. That error happens in direction, the

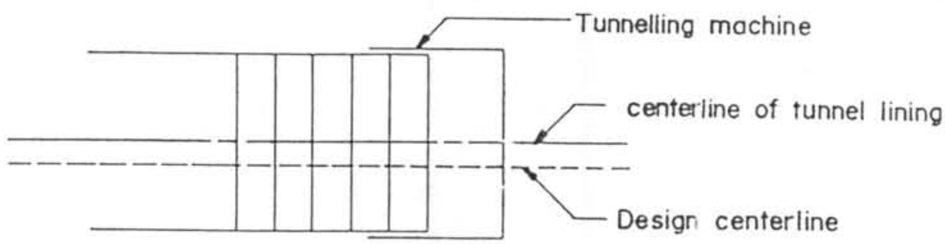

Fig. 68 Deviation between the centerline of tunnel lining and the design centerline.

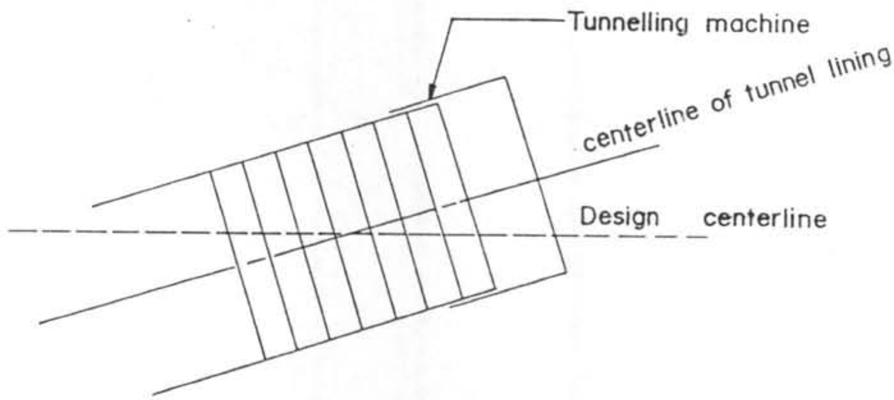

Fig. 69 Difference of direction between the centerline of tunnel lining and the design centerline.

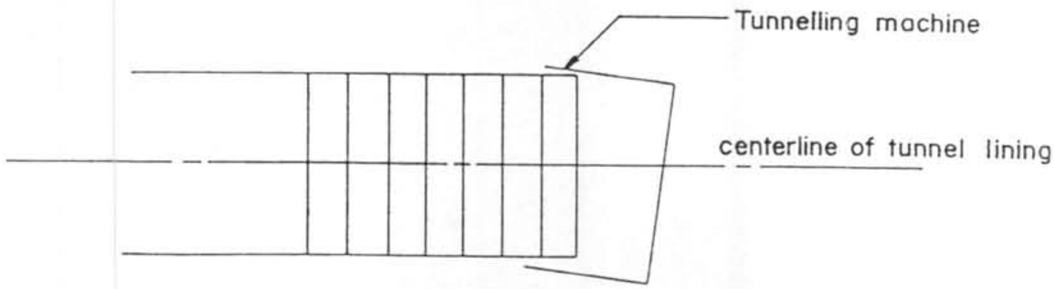

Fig. 70 Difference of direction between the centerline of tunnel lining and the shield machine

machine will proceed in the same direction for a distance and after that it will be close to the design centerline to curved line. If the correction is taken in short distance, the error between a tunnel driving machine and the tunnel lining will become large causing the difficulty in adjusting the segment and it will deviate to the opposite direction. Therefore the correction should be made gradually in long distance.

3.2.4 Alignment Control Development

Although the tunnel alignment control has been developed to high level of accuracy in Europe and America, the Japaneses contractors apparently still rely on manual methods, which restrict progress and lead to human error and delays. On M.W.W.A. project, lasers have been used by Japanese contractors, with some improvement in performance.

3.3 Defeciency of Tunnel Driving Machine and Rectifying

The shield tunnelling machines are selected in accordance with the soil condition, the sufficient geological survey is indispensable, Fig. 71 shows the failure of tunnel face from the unsuitable shield machine:

The selection of type of tunnel driving machine is affected by the length or section of tunnel and geological conditions. It is shown in Table 6.

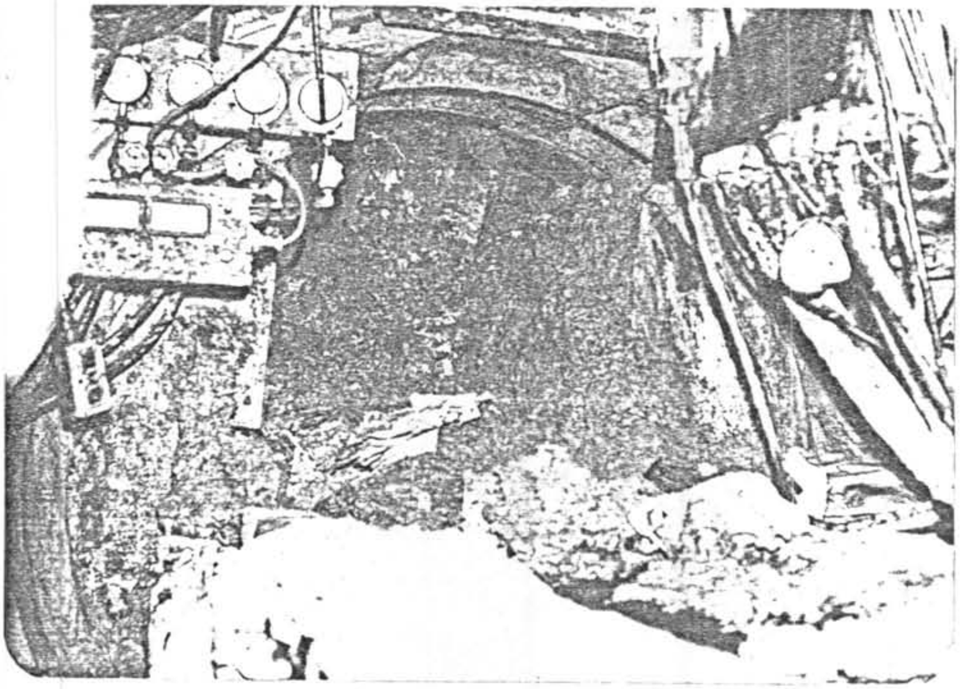

Fig. 71 The failure of tunnel face from the unsuitable tunnelling machine

Fig. 72 The unforseen obstruction in tunnel alignment

Table 6.

Geological condition	Selection of type
Very stiff to medium clay	Open face semimechanized excavation machine.
Soft to very soft clay, silt.	Blind face machanized excavation machine.
Water bearing sand, granular soil.	Slurry machine.

3.3.1 The Tunnel Driving Machine Modification

It is known that the soil profile investigation is taken from the random bore holes, so the problems in expectation are sometimes inaccessibility. By facing the unexpected problems, it is necessary to modify the tunnelling instrument and improve the workability system for appropriate condition.

Obstruction such as pile as shown in Fig. 72 must be eliminated from the tunnel alignment.

3.3.2 Problem in Alignment Control

The center of gravity of the machine is located on the front side, therefore there is tendency to go down during excavation.

In order to keep the tunnel alignment in the designed line, the machine operator has to know its characteristics.

3.3.3 Problem of Inflow Water in Tunnel

Water entering the tunnel is a serious problem, the sufficient predrainage equipment is installed to control the flow of water. Compressed air system and properly grouting are used to reduce the inflow water.

3.4 Primary Lining Damage and Prevention

The causes of primary lining damage are excessive load and unexpected bearing condition.

Cracks of the edges and ribs of primary lining segments during transporting, handling and placing are hardly avoidable even with the greatest care. Owing to the great propulsion thrust in axial direction, hair cracks and fissure will frequently appear. These cracks do not only impair watertightness, but also promote corrosion of the reinforcing steels. Impact effects under the surface and underground traffic in the tunnel may also contribute to the decay of the lining, not as a primary cause, but as an accelerating factor. It is particularly determental in widening the crack.

Before the erection of primary lining, all segments have to be checked carefully and repaired. The serious damaged segments will not be used. In order to reduce the dangers of rib fissure during shield propulsion, the more uniform distribution of jacks pressures on the contact faces will be taken by tightening bolts in all axial joints contact faces will be taken by tightening bolts in all axial joints and the circumferential connections.

The watertightness of segments concrete lining may be improved by reducing the number of joint (by increasing the length of singular element). This necessitates the application of more powerful erection machinery. Watertightness between the segments is ensured by the insertion of plastic sheets or a seal of artificial rubber and occasionally by caulking between the joints of segments.

3.5 Compressed Air Problems and Prevention

The work may have to be performed under air pressure greater than atmospheric pressure, when tunnelling is carried out in water bearing strata.

The unavoidable problems are the high cost of installation of a special plant of machinery, the slow down of the progress of the work and the condition, that may be injurious to health. The most important problems are as followings:

1. Compressed Air Sickness

Compressed air sickness, also referred to as caisson disease and decompression sickness, is known generally as bend. Every care will be taken to keep the incidence of decompression sickness as low as possible by ensuring that the decompression procedures are carried out accurately.

Every person exposed to pressure over 1 ksc. must undergo a radiagraphic examination of his major joints as soon as possible after his engagement and every 6 months.

2. Blow-out Problems

The serious problem of pneumatic dewatering in tunnel construction is the danger of blow-out. If the cover-strata depth is insufficient, compressed air will burst out to the ground surface. The escape of air will be traced by a sudden drop in the pressure, which rapidly enlarges and causes the fog and a recognizable hissing noise. When the air pressure will not longer be able to keep the outside water pressure in balance, the water will rush in from the face, washing surrounding soils into the working chamber. The bigger the shield machine diameter, the greater the blow-out hazard.

Therefore, it is always essential to check the thickness and specific air-sealing capacity of earth covering. The rate of expectable escape must be comparable with the supply capacity of compressed air and if an ample safety margin can not be assured, an artificial increase of the air insulating capacity of the cover (by raising the air-tight on the original cover or by various grouting processes) must be carried out.

3.6 Grouting Control Problem and Rectifying

3.6.1 The Pressure Control and The Quantity of Grouting Material

Grouting material enters to the space between the tail of the shield machine and the tunnel lining and flows into the head around the cutting edge of the shield machine, when filling the primary lining back space.

The estimation of necessary grout pressure and total grout volume are based on the void volume of the soil, it is necessary to fill to a maximum degree all voids volume. However, the radius of grout flow is very irregular and usually involves a great loss of grout into neighbouring zone.

3.6.2 Unsuccessful Grouting of Cement Grout

Cement grout may be selected, by the lower cost compatible with adequate travelling capacity for the dimension of pore to be filled. But in case of sand type the diluted cement grout will lose its water while in contact with sand, because the water in water bearing sand is expelled by compressed air.

3.7 Surface Settlement and Long Term Distortion Problems

3.7.1 Surface Settlement and Rectifying

The unexpected ground surface settlement due to the tunnel construction will occur singularly or by compound causes as followings:

1. Imcomplete grouting.
2. Compressed air release.
3. Dynamic compaction effect.

After the compressed air has been released, further invasion of the incomplete grout space behind the tunnel lining occurs. The latter effects are the recompaction of the disturbed soil and gradual consolidation of clay due to drainage toward the tunnel.

Dynamic compaction effect of surface traffic on the loosen ground layers is an aggravating effect to the remoulding soil and accelerate the settlement rate. The increase of overburden pressure due to the settlement effect is disturbance and disruption of the equilibrium around the tunnel.

All of these causes may result in pressure superposition and in further extension of the loosened zones.

For rectification, the back space filling will be immediately taken by the most suitable method. Before compressed air release, the secondary grouting is also taken for sealing the incomplete back space fill.

3.7.2 Excessive and long-term distortion

Excessive distortion of primary lining is caused by the changes in external load. The present secondary lining designed is very sensitive to the amount of excessive distortion. This would lead to higher reinforcement stresses in secondary lining and the construction must be deferred until the effect of long-term distortion to secondary lining is neglilible.

3.8 Secondary Lining Deficiency and Rectifying

Because of the difficulties on quality control and repairing the deficiency, the reinforced concrete secondary lining are seldom satisfied in water transmission tunnel works. Due to a great deal of concrete in narrow section of monolithic pouring, the deficiency in concrete always appeared.

3.8.1 Causes and Sorts of Deficiency in Reinforced Concrete Secondary Lining

Table 7

Causes of deficiency	Sorts of deficiency
1. Moving of forms when pouring concrete.	1. Steel exposed or insufficient clear cover.
2. Insufficient of vibration.	2. Air bubbles.
3. Separation of concrete.	3. Honey-combs.
4. Too long period in concrete pouring.	4. Cold joint.
5. Construction joint in concrete.	5. Fin and projection.

3.8.2 Repairing the Deficiency

After the defective concrete has been removed to sound concrete, epoxy will be brushed over the chipping area and patching by mortar.