Preservation of Natural Ground Water Flow for Underground Construction

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Abstract

This paper discusses the preservation methods of groundwater flow as countermeasures of solving various problems caused by the groundwater intercept when the underground structures such as the tunnel are constructed under the groundwater level. Firstly, the influences on the groundwater and the environment caused by underground construction are outlined. Secondly, case studies of underground construction concerning groundwater, such as open cut method, NATM method, and shield tunneling, and their countermeasures are described in detail.

Keywords: Groundwater, Underground structure, Groundwater flow obstruction, Groundwater preservation method, Case study

1. Introduction

When the underground structures such as tunnels are constructed under the water level regardless of in the mountains area or in the urban area, it will have some influences on natural groundwater flow. In the tunnel construction with drainage, it will induce (1) the drawdown of the groundwater level around the tunnel, (2) the decrease of the amount of water necessary for daily life such as the stream water and the groundwater, (3) the dried-up of the spring water and the well, and (4) the settlement due to the groundwater level decrease. The natural groundwater flow is intercepted by the underground structure beneath the groundwater level, causing the rise of the groundwater level at upstream side and drawdown at downstream side. Moreover, the chemical grouting, the ground improvement by jet column, or the injections of slurry and additive mud material might change the groundwater flow and pollute the groundwater.

On the other hand, the water leakage from underground structures, such as the lining, will cause a settlement of the tunnel for the long term. The development of various countermeasures and the improvements in the design and the construction are performed, so that such underground construction may reduce the impact on the environment as much as possible.

In current paper, the influence from underground construction to the groundwater flow and the case study of groundwater flow preservation measures in Japan will be introduced.

2. Influence on groundwater flow by construction work

2.1 Change in groundwater level by drainage of groundwater

In general, when constructing a NATM tunnel in a high groundwater level area, the engineers will attempt to draw down the groundwater level by drainage from the drain

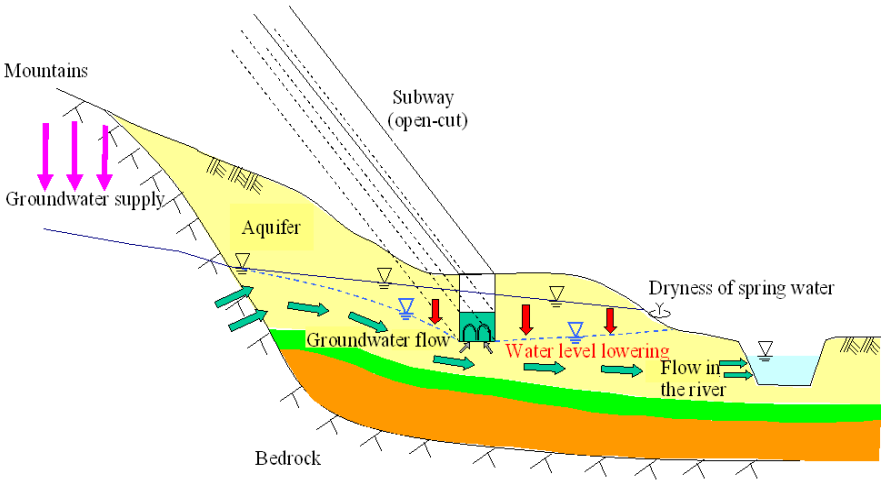

Fig. 1 Influence on groundwater flow by underground construction

boring and the cutting face to secure the face stability. In this case, the groundwater level around the underground structure will get lower. Consequently, the nearby stream, marsh, well and natural spring water, etc. may be dried-up or decrease. Fig. 1 shows the influence on groundwater flow by the underground construction.

At the open cut construction in the urban area, the groundwater level around the construction site often become lower because of not only the leakage from the cracks of the earth retaining wall but also the deep well drains for the heaving prevention and for the piping prevention. Moreover, leakage from the defective part of the earth retaining wall may be occurred uncommonly. As a result, the dried-up of the well and the settlement around the underground structure by the drawdown of the groundwater level might be generated.

Fig. 2 shows the change of the groundwater level in Osaka Plain. The groundwater level was drawn down nearby GL-30m in the 1960's, and has recovered almost by the pumping restriction afterwards. However, the lowering in the groundwater level that originates in the construction of the underground structure can be seen in the 1990's.

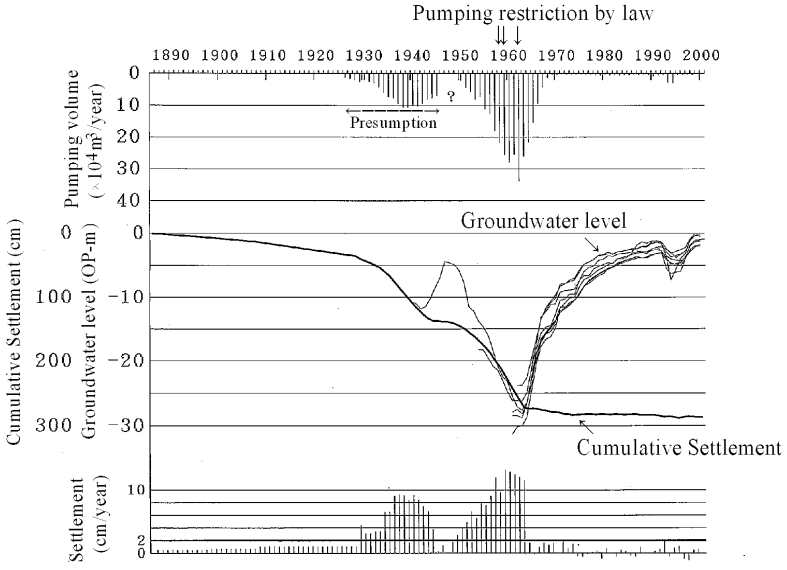

Fig. 2 Change of groundwater level in Osaka

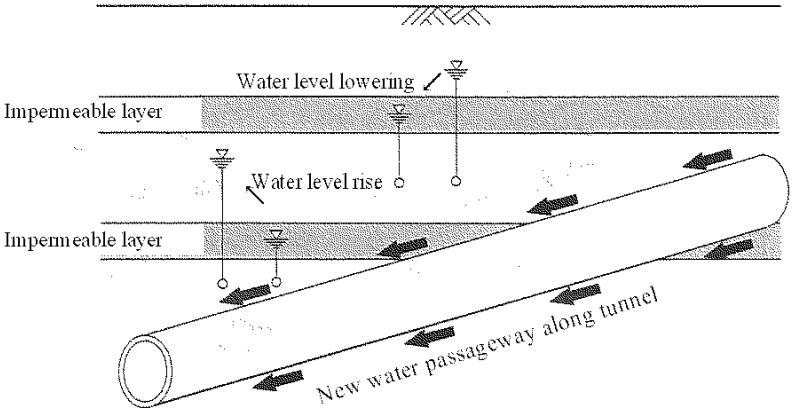

Fig. 3 Case of the tunnel crossing two or more aquifers

Moreover, at the tunneling work in the urban area, it causes the drawdown of the groundwater level around the underground construction by the spring water from the cutting face and the water leak from the tunnel lining, etc., and the settlement of the ground and the tunnel due to the drawdown of the groundwater level. When the tunnel crosses some aquifer, as shown in Fig. 3, groundwater flows from the layer where hydraulic pressure is high to a low layer. As a result, the water level and the water quality changes may occur.

2.2 Change of the groundwater flow due to groundwater flow obstruction

When the aquifer is intercepted by an earth retaining wall or a long linear underground structure such as the tunnel, the groundwater flow will be obstructed, and consequently the groundwater level rises on the upstream side, and falls on the downstream side.

As a result, the groundwater infiltrates to the basement on the upstream side, and uplift acts on the underground structure. Moreover, the liquefaction resistance decreases by rising of the groundwater level. On the other hand, the drawdown of groundwater level is occurred on the downstream side, and it causes the dried-up of the well and the settlement of the ground. The influence due to the groundwater flow obstruction is shown in Fig. 4.

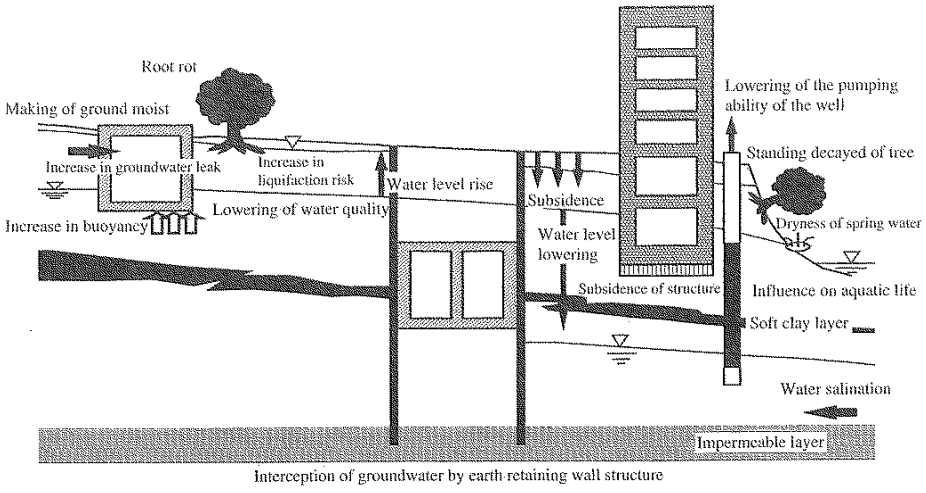

Fig. 4 Image of problems that occur by interception of groundwater

2.3 Change of the groundwater flow and water quality due to grouting

In the tunnel construction, the ground improvement by the grouting and the jet column, or the injections of slurry and additive mud material changes the groundwater flow and pollute the groundwater. When the gel time of grouting is long, the grouting will flow farther, and finally becomes a low permeability layer as a aquitard, then will change the groundwater flow.

When the tunnel is excavated using a slurry shield or an earth pressure balanced shield (EPB) in the high permeability ground, the groundwater are polluted by leak of the slurry and the additive mud material. Similarly, the backfill grouting also causes the leak of slurry and the mud pumping, and the groundwater and the stream water are polluted.

3. Open cut tunnels

3.1 Trouble case in open cut tunnel

At the subway Tozai Line construction in Osaka, when the station was excavated by open cut method, excavation pit was submerged due to the water leak from the defective part of the earth retaining wall, and many houses were damaged by a large settlement of the surrounding ground, as shown in Fig. 5.

On the other hand, when groundwater in the confined aquifer under the excavation level is decreased by pumping up for the heaving prevention, its influence will occur much farther than imagination. Fig. 6 is a field investigation on pumping up of aquifer in Osaka. The groundwater was drawdown 10m or less by pumping up 20m^3 per minute. The radius of influence area reached as far as 15km. In Osaka Plain, there is a soft clay layer of the thickness of about 10m in the upper part and the consolidation settlement about 2cm was generated.

The countermeasures to the open cut method are as follows.

1. Earth retaining wall with intake and recharge facilities
2. Ground water recharge method
3. Ground improvement
4. Remote control pneumatic caisson

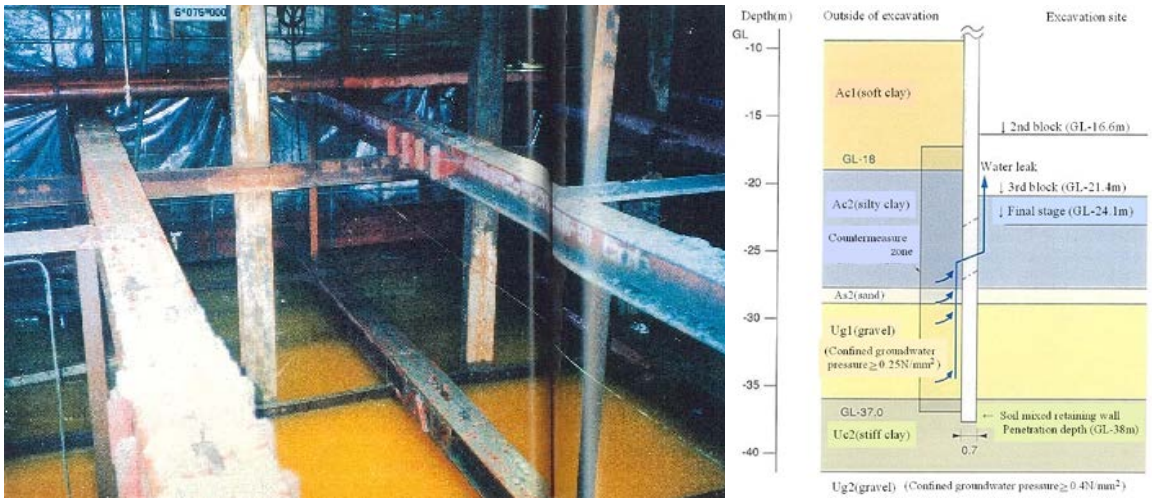

Fig. 5 Trouble case of water leak in open cut construction

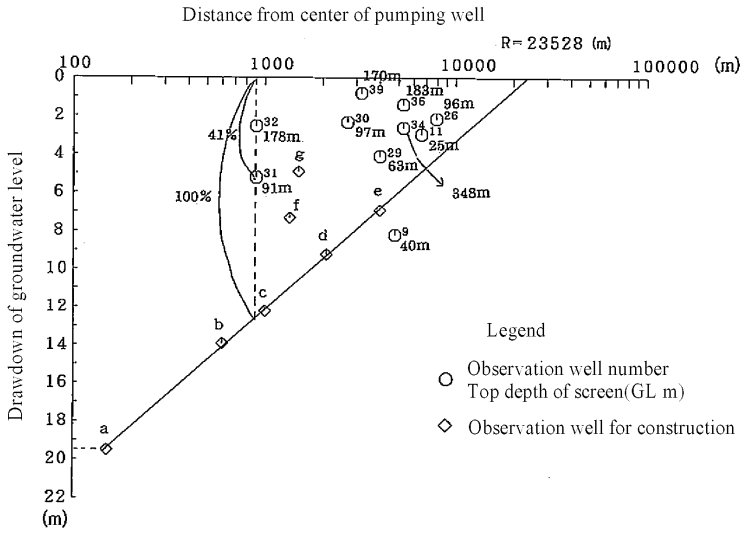

Fig. 6 Example of groundwater level drawdown by pumping up

3.2 Interception of groundwater flow and preservation method of groundwater flow at open cut tunnel

In the open cut method, the groundwater flow is obstructed when the underground structure is completely sealed, and the problem described in session 2 will occur. Then, groundwater flow preservation countermeasures are necessary. Fig. 7 ~ Fig. 9 show the conceptual diagram of the groundwater flow preservation countermeasures.

The case study with the groundwater flow preservation countermeasures adopted in the Kyoto subway, the Sannomiya station, and the Shoji tunnel is shown in Fig.10.

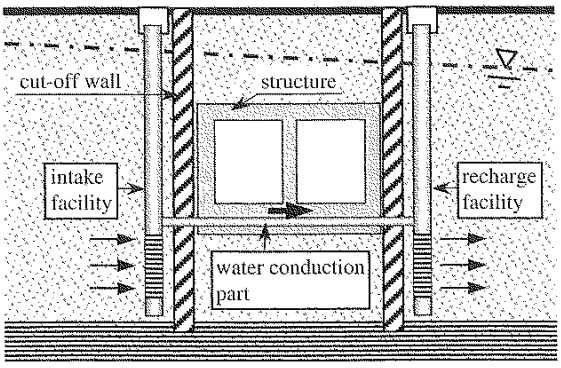

Fig. 7 Conceptual diagram of a groundwater flow preservation measure

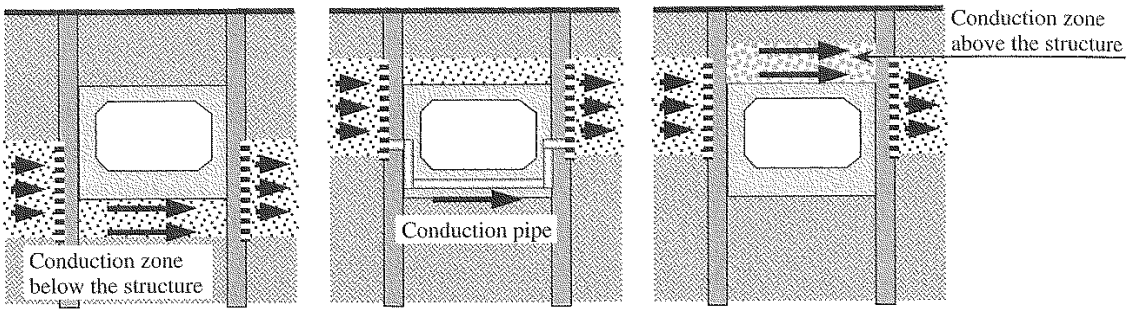

Fig. 8 Water conduction method

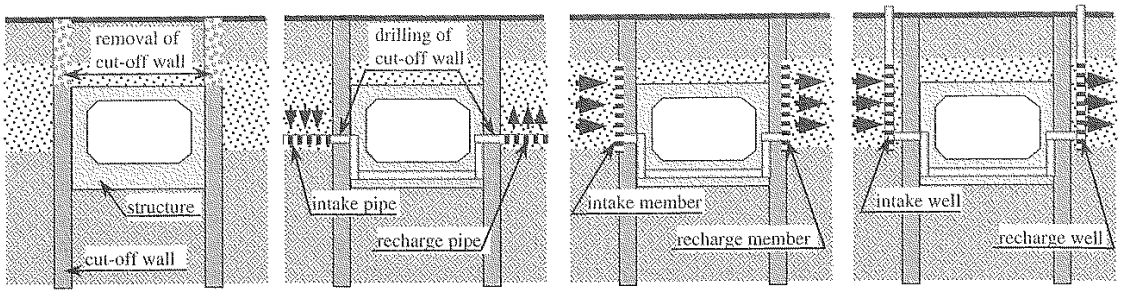

Fig. 9 Intake and recharge methods

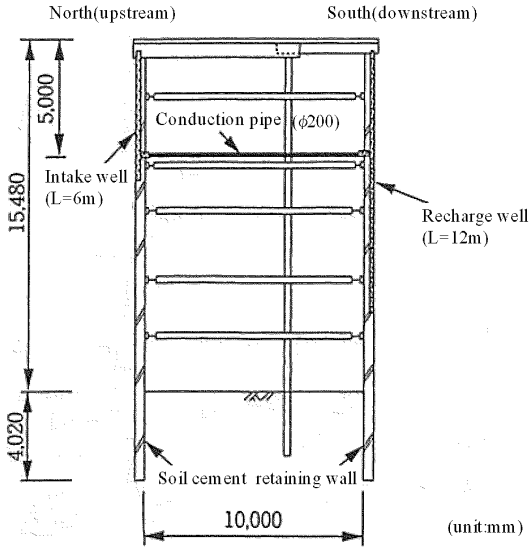

Fig. 10(a) Case of Kyoto subway

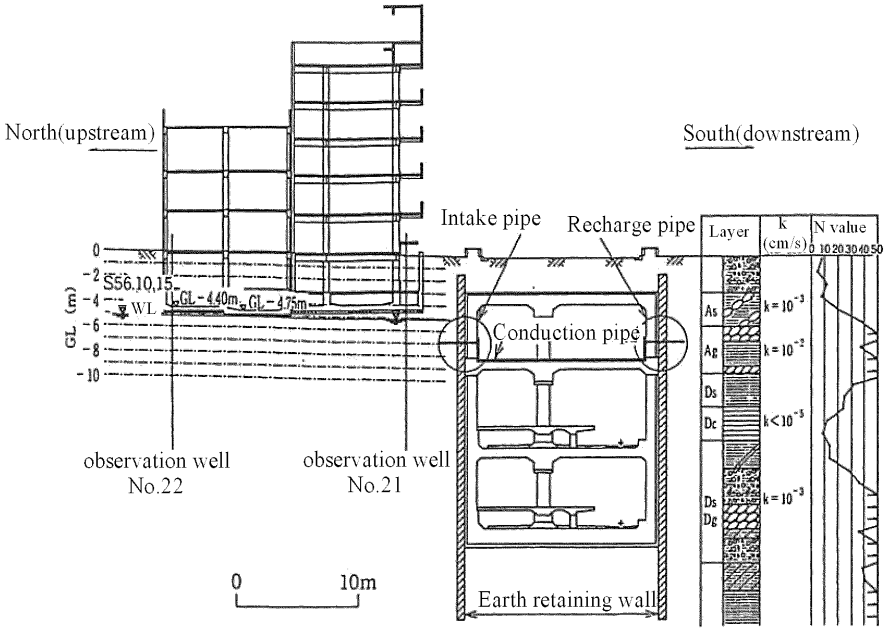

Fig. 10(b) Case of Sannomiya station

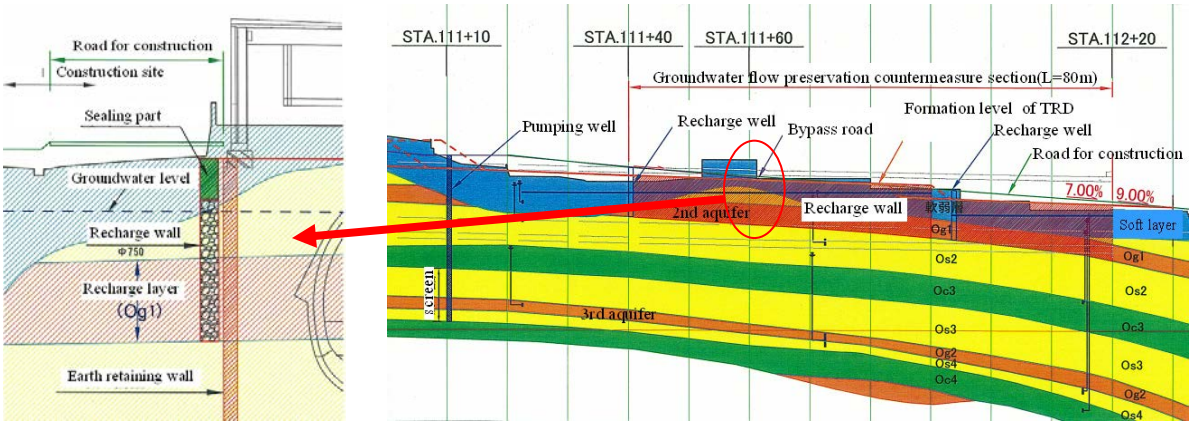

Fig. 10(c) Case of Shoji tunnel

4. NATM tunnels

In general, when a mountains tunnel is constructed in a high natural groundwater level, the engineers are attempting to the drawdown the water level by drainage boring to secure the face stability. In this case, the groundwater level around tunnel becomes lower, and nearby stream, marsh, rice field, well, and natural spring water will be dried up or the amount of water decreases. As a countermeasure, there are a rock and soil hybrid type TBM shown in Fig. 11, a grouting method for dewatering shown in Fig. 12, and a recharge method after the tunnel is completed.

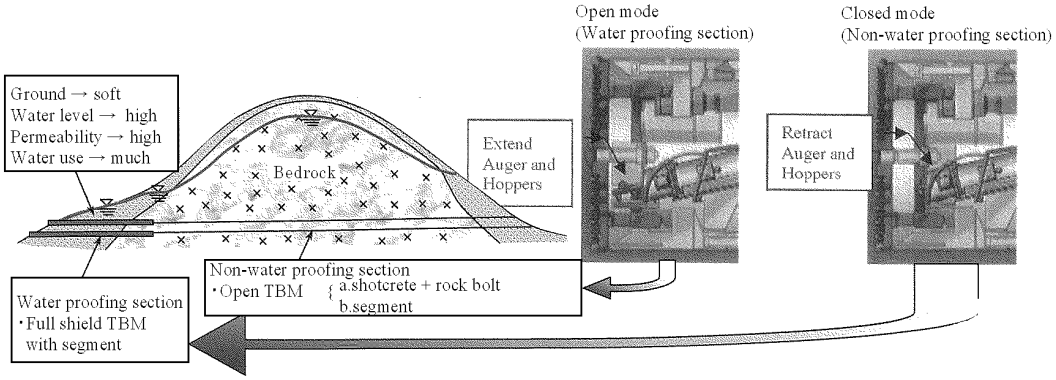

Fig. 11 Hybrid type TBM

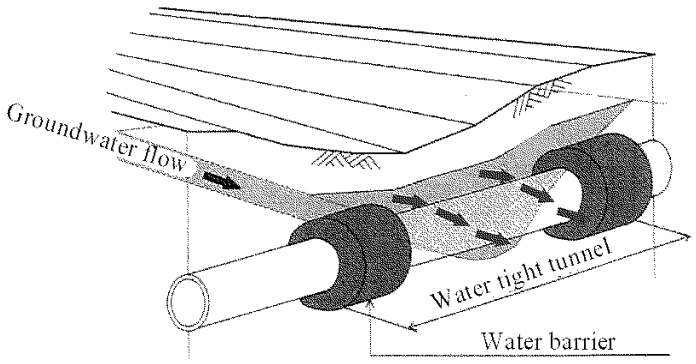

Fig. 12 Grouting method for dewatering

5. TBM tunnels (Shield tunnels)

In the open type shield and the earth pressure balanced shield (EPB), leakage water from the cutting face often occurs. There are the adoption of closed face shield, sealing facility, pressure feeding pipe, and the use of additive mud material, etc. as a countermeasure.

On the other hand, the water leak from the tunnel lining causes the consolidation settlement due to the decrease of pore water pressure in the clay ground (Komiya et. al, 2006, Mair, 2008). There are the grouting methods for dewatering backfill material and the waterproof method as a countermeasure.

6. Conclusion

When the underground structures such as tunnel is constructed under the groundwater level regardless of in the mountains area or in the urban area, it will have some influences on natural groundwater. The development of various countermeasures and the improvement in the design and the construction methods are performed in Japan, so that the underground construction may reduce the groundwater impact on the environment as much as possible.

This paper introduced the influence from the underground construction to the groundwater, and the preservation countermeasures of groundwater flow in Japan. It is great if this paper becomes some references when the problem concerning groundwater will be faced in the future at the tunnel construction in China.

References

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