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Geological conditions and key rock mechanics issues in the Western Route of South-to-North Water Transfer Project

Xuechao Wang*

Yellow River Engineering Consulting Co., Ltd., Zhengzhou, 450003, China

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Abstract: In terms of special geological conditions of the Western Route of South-to-North Water Transfer Project, the classification method for surrounding rocks is discussed by combining with the construction method of tunnel boring machine (TBM). The classification standard of surrounding rocks is put forward on the basis of physical simulations and engineering practices. Damage, deformation and evolution of surrounding rocks induced by TBM excavation are discussed. Meanwhile, the long-term deformation mechanisms and stability of surrounding rocks are also studied. On this basis, a three-dimensional constitutive model for interbedded sandstone slate and a flat shell-joint element-foundation system for calculating internal forces of segment lining are established. The deformation features of surrounding rocks of deep and steep interbedded sandstone slate and their influences on internal forces of segment lining are presented. Finally, the design methods of segment lining constructed in deep and steep flysch are proposed.

Key words: the Western Route of South-to-North Water Transfer Project; rock mechanics issues; classification of surrounding rocks; stability of surrounding rocks; excavation-induced damage; lining design

1 Introduction

The first stage construction of the Western Route of South-to-North Water Transfer Project (Western Route for short) was designed to divert water from the upper reaches of Yalong River and Dadu River to the upper reaches of the Yellow River. It was planned to be constructed on the Tibetan Plateau. The diversion work consists of diversion junction and long tunnels at large overburden depth. The suggested scheme for water diversion with a volume of 8×10^9 m^3 is composed of 7 dams and 14 tunnels (Fig.1). The overall length of the Western Route is 325.6 km, with 321.1 km of tunnels. The Reba concrete faced rockfill dam (CFRD) in the Yalong River is the highest dam with a height of 192 m. The diversion tunnel plays a very important role in the Western Route. The minimum and maximum diameters of the main diversion tunnel are 7.34 and 9.60 m, respectively. The minimum and maximum natural segment lengths of the tunnel are 3.7 and 72.4 km, respectively. The maximum overburden depth of tunnel is 1 150 m, and the average is approximately 500 m.

The Western Route is located on the first terrace of landform in West China. The natural condition is relatively tough with complicated land surface topography, lithology and regional geological structures. The geological conditions are complicated while the lithology of rocks is rather uniform. The rocks are mainly composed of epizonal metamorphic sandstone and slate of Triassic, which are comparatively uniform layers with large thickness. The rocks are intensively compacted, and the folds are fully developed. The dips of most of strata are relatively large [1–5]. The long tunnel with large overburden depth goes through many engineering geological units, and hydrogeological conditions are complicated, which brings many unexpected difficulties to the tunnel construction. In future construction and operation of the project, numerous difficulties in rock mechanics issues will be encountered.

The geological conditions in the Western Route are suitable for construction using TBM. The advantages of high speed and efficiency of TBM can be well reflected in the construction of long tunnels with large overburden depth. Meanwhile, TBM, which is highly

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*Corresponding author. Tel: +86-13607667660; E-mail: wangxchao@263.net
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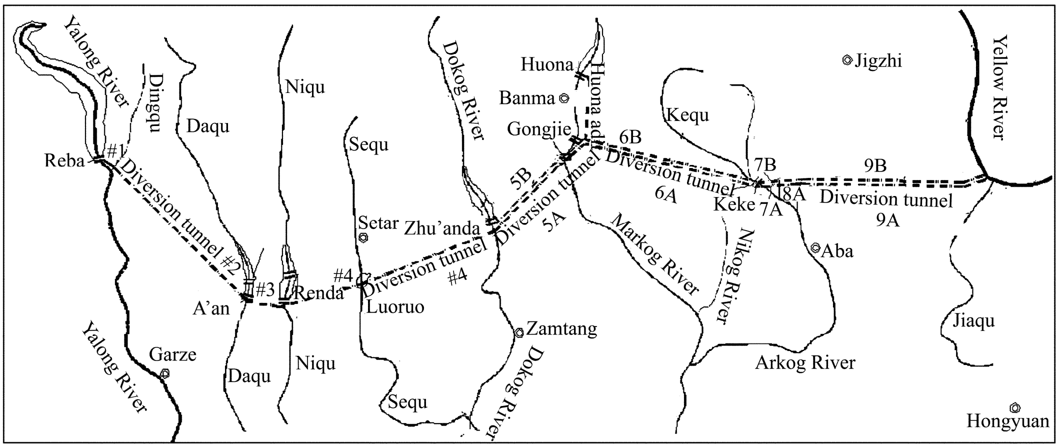

Fig.1 Layout of the first stage in the Western Route of South-to-North Water Transfer Project.

mechanized, may be adopted in the Western Route due to the special climate conditions such as coldness and oxygen deficit at the Tibetan Plateau. Therefore, TBM was considered for the main diversion tunnels, and the adits would be constructed by drilling and blasting method according to geological conditions and investment benefits. 24 TBMs with different diameters were selected for the first stage tunnel excavation. The past experiences of tunneling show that, except support, ventilation and drainage techniques that control the construction of long and deep tunnels, various potential geological hazards also should be prevented or treated. Although TBM has the advantages of high speed, high quality, economic merits and security, it is not suitable in unfavorable geological conditions such as tunnel failures, rockbursts, weak rock units, water inrush and swelling rocks. It could impede the process of tunneling if not handled properly.

The issues that may be encountered in the Western Route in terms of rock mechanics, environmental geology and engineering geology have been extensively discussed [6–12]. As for this project, the rock mechanics issues observed in the dam sites (junctions) are usually conventional. But those observed in tunnels are important factors, which may affect the success of the project. The key rock mechanics issues in the Western Route can be approximately reflected in the following 3 aspects. Firstly, the issues considered before TBM operation were preliminary investigations of surrounding rocks. Secondly, the issues concerned during TBM construction were concentrated on the excavated damage and deformation features of surrounding rocks, the interaction of surrounding rocks and segment lining, and the optimized support design. Finally, the issues occurring during project operation concerned mainly the deformation mechanism and long-term stability of diversion tunnels under complicated environments. This paper will discuss the above key rock mechanics issues.

2 Description of geological conditions

2.1 The issues of fault activity

The NW faults are mostly observed in the Western Route, and faults of other directions are few and at a small scale. The fault activities have obvious characteristics of inheritance and small-amplitude, with no active fault developed. The regional active faults are primarily reactivation of faults along the boundaries of tectonic units. The active faults were developed frequently in early and medium Quaternary period, and the range was reduced in the late Pleistocene period. Some faults are not active or only local faults are active. The active faults have an obvious controlling effect on occurrence and magnitude of earthquakes. The earthquakes with magnitudes larger than 6.0 all happened along the Holocene active faults.

According to field investigations and laboratory tests, most of the faults in the vicinity of the project region are not active. Also, there is no distribution of active faults or epicenter at the dam site. No active fault traverses the tunnels. Active faults like Garze-Yushu fault, Sangrima fault and Gande fault, which are 70, 120 and 200 km away from the tunnel, respectively, are distributed within the range of 300 km from the project.