Numerical Analysis for Appropriate Buried Depth of Cold-Proof Drainage Hole of a Tunnel

Zhao Mao-long[1] and Zhu Wei[2]
[1]*Shaanxi Highway Group Co. LTD, Xi'an, Shanxi, China;*
[2]*Shaanxi Hengtai Highway Technology Co. LTD, Xi'an, Shanxi, China; 2511216271@qq.com*
E-mail: 2860381308@qq.com

ABSTRACT: Based on the MIDAS/GTS finite element analysis software, taking a tunnel in Qinghai province as an example, fixing the position of main tunnel and holing through, just adjusting the buried depth of the cold-proof drainage hole, the change rules of displacement, stress and plastic zone in different buried depths of cold-proof drainage hole are analyzed. The influence of different buried depths for cold-proof drainage hole on the structure of main tunnel is revealed. The result shows that (1) the influence between main tunnel and cold-proof drainage hole is mutuality; (2) from the point of displacement change rule, the optimal effective buried depth for the cold-proof drainage hole of a tunnel in Qinghai province is from 5 m to 6 m; (3) from the point of stress change rule, the optimal effective buried depth for the cold-proof drainage hole is also from 5 m to 6 m; (4) bases on the stress homogeneity of the support and the material, from the point of plastic zone change rule, the optimal effective buried depth for the cold-proof drainage hole is from 4 m to 6 m; (5) eventually, on the basis of comprehensive consideration of the largest frozen depth, requirements of safe and economy, and influencing factors of construction of tunneling engineering area, the proper effective buried depth of the cold-proof drainage hole is confirmed to be 5 m, i. e., the proper buried depth of the cold-proof drainage hole is confirmed to be 8 m.

KEYWORDS: Tunneling engineering, Buried depth, MIDAS/GTS, Cold-proof drainage hole, A tunnel in Qinghai province.

1. INTRODUCTION

The The region with the annual depth of frost penetration for soil layer greater than 80 cm is called as cold region. More than one half of the territorial areas belong to cold region in China and the tunnel engineering in cold region is special in infrastructure (Wu et al., 2003). With the rapid development of transportation infrastructure construction in China, more and more tunnels are built in cold region, and key technical problems in tunnel construction in cold region are accordingly paid more attention to by the engineering circle (Zhang et al., 2004; Gao et al., 2011; Wang and Xu 2013; Feng et al., 2014). Cold damage is one of the major problems affecting safe driving and operation management of tunnels in cold region in China (Lai et al., 1998; Lai et al., 1999; Zhang et al., 2002a; Zhang et al., 2002b; Lv, 2012).

Currently, there are three kinds of tunnel drainage systems in cold region, including bilateral thermal insulation ditch, central deeply-buried thermal insulation ditch, and cold-proof drainage hole (JTG D70-2004). In severe cold region, the average temperature in the coldest months is below -25 ℃. Cold-proof drainage hole can be set under the main tunnel when the depth of frost penetration of cohesive soil is more than 2.5 m, for instance, open-excavated central ditch is adopted with too big buried depth and difficult construction, and the stability of side wall and tunnel may be affected (JTG/T D70-2010). The application of cold-proof drainage hole in tunnels in cold region can trace to Dabanshan Tunnel in the northeast of Qinghai-Tibet Plateau, for which a cold-proof drainage hole was set at the place of 5.0 m below the main tunnel hole in order to ensure the operation of waterproof and drainage facilities in the hole (Zang et al., 1998; Wu et al., 2003). Cold-proof drainage hole and horizontal drainage hole play an important role in relieving and preventing the frost heave of surrounding rock and lining structure of Dabanshan Tunnel (Liu et al., 2011). At present, the studies on cold-proof drainage hole mainly focus on the following three aspects: (1) construction technology and cold-proof measures for cold-proof drainage hole (Shao and Yang 1998; Shao, 1999; Liu, 2001; Du, 2003; Liu, 2006; Hu et al., 2012); (2) field investigation on the cold-proof drainage hole of tunnels in service in cold region and evaluation on its effect; (3) simulation study for temperature field of cold-proof drainage hole (Lai, 2012; Xu, 2014; Liu, 2014; Li, 2014).

However, further study is required for the appropriate buried depth of cold-proof drainage hole under the main tunnel hole. The buried depth of cold-proof drainage hole means the depth from the bottom of main tunnel hole to the bottom of cold-proof drainage hole (Railways Second Survey and Design Institute, 1984). To determine the buried depth of cold-proof drainage hole, Guidelines for Design of Highway Tunnel (TG/T D70-2010) stipulates, " Water flows within the ditch shall be ensured to be non-freezing and the depth of frost penetration for the ditch shall be not less than the maximum depth of frost penetration for the surrounding rock in tunnel area; underground excavation shall not result in collapse of tunnel bottom; the buried depth shall not be too deep, thus avoiding unnecessary extension of cold-proof drainage hole and increase in engineering cost." Therefore, the maximum depth of frost penetration, safe and economical requirements as well as structural factors in tunnel area should be taken into consideration for the buried depth of cold-proof drainage hole for specific tunnel in cold region.

Taking a tunnel in Qinghai Province as an example, this paper adopts numerical simulation method to analyze the interaction between main tunnel hole and cold-proof drainage hole based on the finite element analysis software of MIDAS/GTS, and then constructs cold-proof drainage hole with the buried depth of 5-12 m after the run-through of main tunnel hole, so as to determine the appropriate buried depth of cold-proof drainage hole for a tunnel in Qinghai province.

2. PROJECT PROFILE

Located at about 10 km away from the northeast of Xiewu Town of Chengduo County of Yushu Tibetan Autonomous Prefecture in Qinghai province, a tunnel in Qinghai province is a separated tunnel, with the left line length of 3966.0 m, designed pavement elevation of 4333.99 m ~ 4235.74 m at the exit and entrance, designed longitudinal gradient of -2.500%, with the right line length of 3950.0 m, designed pavement elevation of 4333.01 m ~ 4236.26 m at the exit and entrance, designed longitudinal gradient of -2.480%, axis azimuth of 228 °, designed clear width of 10.0 m and clear height of 8.0 m for a single hole (Bian, 2014). The buried depth of the cold-proof drainage hole is generally determined according to the maximum freezing depth of the tunnel site. Finally, the design of the cold-proof drainage hole buried depth of 6.0 m. (Li and Wei 2012).

The tunnel area is within the three rivers source region in Qinghai-Tibet Plateau and at the intersection of Tongtian River, Zhaqu River and Xiewu River, with the landform of low mountain and hill caused by tectonic denudation. Running from the northwest to the southeast, the terrain is of great variation. The tunnel area in the hinterland of inland plateau with high altitude is less affected by marine monsoon. It enjoys a typical plateau continental semi-arid climate. It is cold, windy, and snowy in the long winter, with the possibility of snow disaster; it is cool in the short summer with abundant rainfall. Middle and high mountains are covered with frost and snow all the year round and rainfall distribution shows obvious regional difference. With the increase of altitude, precipitation increases while air temperature and amount of evaporation decline and decrease relatively. The four seasons are not distinctive with large temperature difference between day and night. The air is thin with low pressure and less oxygen content. In the tunnel area, the annual average temperature is -1.7 ℃, extreme maximum temperature is 24.0 ℃, extreme minimum temperature is -33.0 ℃, annual average relative humidity is 81%, annual average amount of evaporation is 1649.2 mm, annual frost period lasts for seven months, maximum snow depth is 14 cm, and maximum depth of frost penetration is 3.08 m. There is abundant sunshine with annual average sunshine rate of 50% ~ 60%. In the project area, the winter is long and cold. In the tunnel construction process, severe weather environment such as cold and construction conditions have a great impact on personnel health. Construction water supply, ventilation, mechanical equipment, etc. also cannot run normally, while concrete construction will be frozen during low-temperature mixing, transportation, construction process and maintenance, so the durability of the structure cannot be guaranteed, which seriously affects the quality of the project (Li et al., 2018).

In the tunnel area, the average annual precipitation is about 615.2 mm, the number of average annual rainy days is about 170 d, and the maximum monthly rainfall is about 425 mm. Rain mainly comes between May and September, accounting for about 54% of annual rainfall. Atmospheric precipitation flows into the gully along slope and then feeds into Xiewu River. Water from Xiewu River runs throughout the year, with more water yield in rainy season and less water yield in dry season; Xiewu River has a narrow bed and gentle flood plain.

According to the storage conditions, groundwater in the tunnel area can be divided into quaternary unconsolidated rock pore water and bedrock fissure water. The quaternary unconsolidated rock pore water is distributed in slope and gully and stored in gravel soil and silty clay, and its recharge sources include atmospheric precipitation and groundwater by lateral recharge. Bedrock fissure water is mainly stored in the fissure of sandstone-shale interbed weathered zone in Bayan Har Mountains of Mesozoic Triassic series （T_3by） and controlled by the thickness variation of weathered layer, with good water permeability and water abundance. Its recharge source is atmospheric precipitation and the water yield varies greatly in different seasons. Groundwater is more developed, the construction process has water inrush, water surge, surface cracking, steel frame deformation, roof easy to collapse, falling block (Zhang and Guo 2014).

With Quaternary Holocene eluvial layer （Q_4^{el+dl}） overlying, the tunnel area is mainly made of silty clay including weathered clastic rock; Quaternary Holocene eluvial layer （Q_4^{el+dl}） mainly refers to silt and round gravel soil including gravel. Grayish black sandstone-shale interbed of Bayan Har Mountains of upper Mesozoic Triassic series （T_3by） lies underneath the tunnel area, and part of gully section is exposed. The tunnel area is mainly located in the head of Qinghai-Tibet-Yunnan-Burma zeta-type tectonic system and the peripheral folding belt, and reconnects complex Bayan Har-Songpan arcuate tectonic belt in the north. No large fracture structure is seen in the tunnel area and the area is of relatively stable structure. Influenced by the Xiewu Shiqu fault, F_1 fault is developed in k748 + 660 of tunnel barrel. Fault F_1 intersects the main line of the tunnel at a small angle, with strike of NE66 °, dip angle of 70-80 °, and fracture zone width of nearly 100 m, The stability of surrounding rock in this section is poor, and the rock mass is gravelly. When the cavern is excavated, the top of the cavern is prone to collapse and block fall. (Guo et al., 2012; Xuan, 2016).

3. MODELING AND PARAMETER DETERMINATION

3.1 Basic assumptions

The following assumptions are proposed based on the finite element analysis software MIDAS/GTS: The main tunnel hole has fixed location and it has been excavated and run through, and only the buried depth of cold-proof drainage hole needs to be adjusted; soil mass is set to be Mohr-Coulomb materials, and sprayed concrete is adopted for primary support; the weight stress field of surrounding rock instead of the structural stress is taken into account for initial stress field; the upper boundary of the model is defined to be a free surface, the left and right boundaries are defined to be normal constraint, and full constraint condition is employed for the lower boundary.

3.2 Modeling

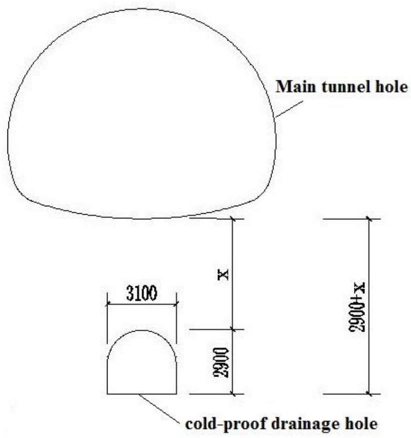
Three simplifications are made in the calculation model: (1) Mohr-Coulomb model is used to characterize the complex constitutive model of sand shale interbeds; (2) replace relatively flat strata at the tunnel site with horizontal strata; (3) the joints in the strata are ignored and the strata are regarded as isotropic. By comparing with the field measurement results, it is found that the simplified results of the calculation model are in good agreement with them. Therefore, we believe that the error of the simplified calculation model is within the acceptable range and can be used to study the problems concerned in this paper.

Considering the coverage of tunnel, the left and right boundaries of the model are 3-5 times of the tunnel diameter from the side of tunnel contour line, the lower boundary is 3-5 times of the tunnel height from the bottom of tunnel contour line, and the upper boundary is 25 m from the upper part of tunnel contour line, which is equal to the average buried depth. Hence, the model dimension is 110 m × 75 m. The setting of main tunnel hole and cold-proof drainage hole is shown in Figure 1 and the model meshing is indicated in Figure 2.

For a tunnel in Qinghai province, construction of cold-proof drainage hole is implemented after the excavation of main tunnel hole. See Table 1 for the construction stage division and stress release coefficient value. The scheme design of buried depth of cold-proof drainage hole is shown in Table 2.

3.3 Parameter determination

The mechanical parameters for surrounding rock materials selected are shown in Table 3.



Note: X means the effective buried depth of cold-proof drainage hole, and 2900+ X refers to the buried depth of cold-proof drainage hole

Figure 1 Sketch map of main tunnel hole and cold-proof drainage hole (unit: mm)

Table 1 Construction stage division and stress release coefficient value

Stage	Construction conditions	Stress release coefficient
1	Initial state (Excavation of main tunnel hole is completed, primary support has been provided, stress state is kept, and displacement is reset.)	0.4
2	Cold-proof drainage hole is excavated	0.3
3	The cold-proof drainage hole is supported	0.3

Note: Since stress release is not instantaneous during tunnel excavation, the concept of stress release coefficient is introduced to simulate the process. Stress release coefficient refers to the ratio of effective deformation modulus and initial deformation modulus of surrounding rock after excavation.

Table. 2 Scheme design of buried depth of cold-proof drainage hole

Scheme No.	Effective buried depth X/m	buried depth (2.9+X)/m	Scheme No.	Effective buried depth X/m	buried depth (2.9+X)/m
a	2.1	5	e	6.1	9
b	3.1	6	f	7.1	10
c	4.1	7	g	8.1	11
d	5.1	8	h	9.1	12

Table 3 Mechanical parameters of surrounding rock materials (Bian, 2014)

Type of materials	Weight /(kN·m^{-3})	Elasticity modulus /MPa	Poisson's ratio	Cohesion /kPa	Internal friction angle / (°)
Silty clay	18.7	200	0.35	80	23
Sandstone-shale interbed	19.5	1100	0.4	160	25
Primary support	25	25000	0.2	—	—

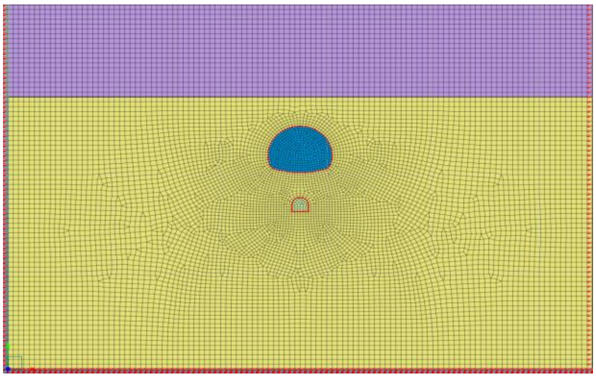


Figure 2 Model meshing map (unit: m)

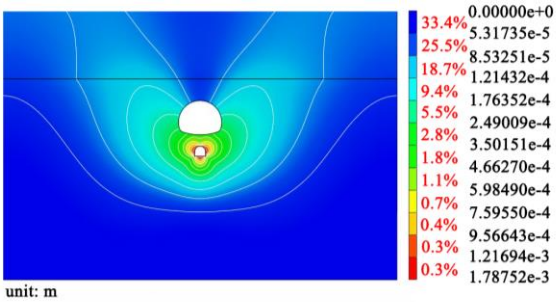
4. NUMERICAL MODELING CALCULATION

4.1 Variation law for displacement

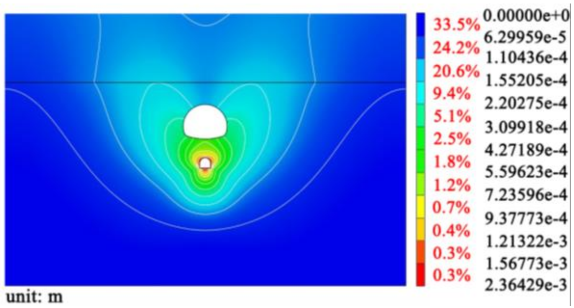
The excavation of cold-proof drainage hole has a certain influence on the main tunnel. When the cold-proof drainage hole is set under the main tunnel with different buried depths, it has different effects on the supporting structure of the main tunnel..In order to analyze the variation law for displacement of cold-proof drainage hole with different buried depth, the initial displacement is reset and the displacement nephogram of cold-proof drainage hole with different buried depth is shown in Figure 3. It can be seen from Figure 3 that the displacement distribution around the main tunnel after the cold-proof drainage hole is excavated. The displacement difference between the arch springing and the vault of the main tunnel is relatively large, while the displacement difference between the arch bottom of the main tunnel and the arch springing is relatively small. With the increase of the buried depth of cold-proof drainage hole, the displacement from the arch springing to the vault of the tunnel tends to be the same. When the effective buried depth of the cold-proof drainage hole is 5 ~ 6 m, that is, the buried depth is 8 ~ 9 m, the influence of the excavation of the cold-proof drainage hole on the displacement from the tunnel vault to the arch springing is basically the same. In the range of embedded depth of anti-cold drainage tunnel in this study, with the increase of embedded depth of cold-proof drainage hole, The influence of the excavation of anti-cold drainage tunnel on the displacement from the arch bottom to the arch springing is always small. and all of them are greater than the displacement from the vault to the arch springing.

Figure 4 shows the vertical displacement variation for various control points of main tunnel hole with different buried depth. According to the figure, when cold-proof drainage hole has different buried depth, the vertical displacement variation for various control points of main tunnel hole indicates the same trend, but in terms of influence extent, arch bottom has the largest settlement, followed by the arch springing and vault. When the effective buried depth of cold-proof drainage hole is less than 4 m, excavation of cold-proof drainage hole exerts larger influence on the structure of main tunnel hole; when the effective buried depth is between 4 m ~ 7 m, the rate of variation becomes smaller and gentle, indicating less influence.

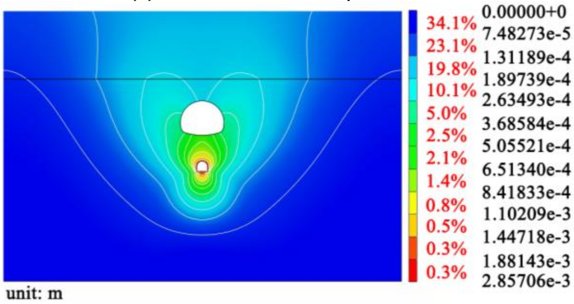
Figure 5 shows the vertical displacement variation for various control points of cold-proof drainage hole with different buried depth below the main tunnel hole. According to the figure, when the effective buried depth of cold-proof drainage hole is less than 4 m, the settlement of various control points is less and settlement has a big rate of variation, because the primary support on the arch bottom of main tunnel hole serves as a lintel for the structure of cold-proof drainage hole. When the effective buried depth is between 4 m ~7 m, the settlement of various control points varies at a small rate and becomes gentle due to the smaller influence of lintel at the arch bottom of main tunnel hole; when the effective buried depth of cold-proof drainage hole is more than 7 m, the settlement of various control points varies at a big rate due to the bigger burial depth of stratum, and the influence of lintel at the arch bottom of main tunnel hole has disappeared basically.



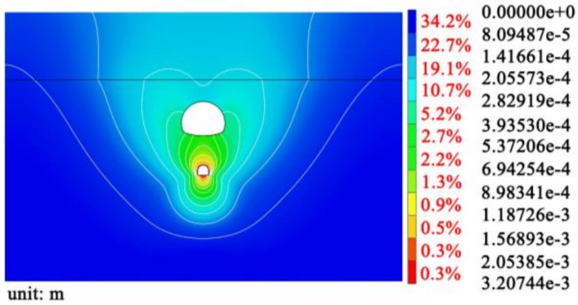
(a) Effective buried depth: 2.1 m



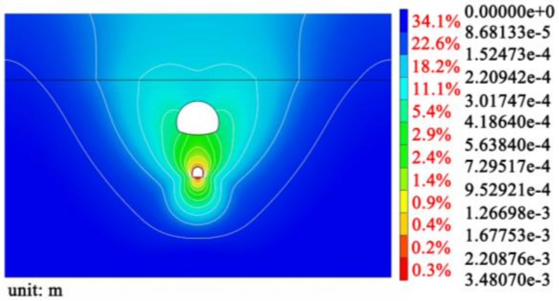
(b) Effective buried depth: 3.1 m



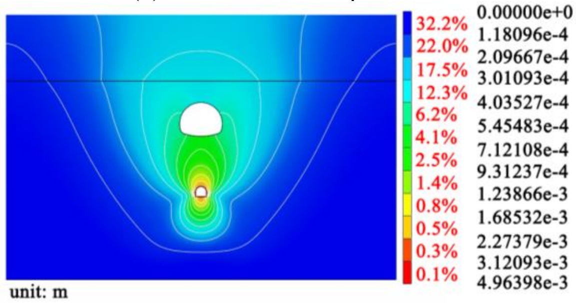
(c) Effective buried depth: 4.1 m



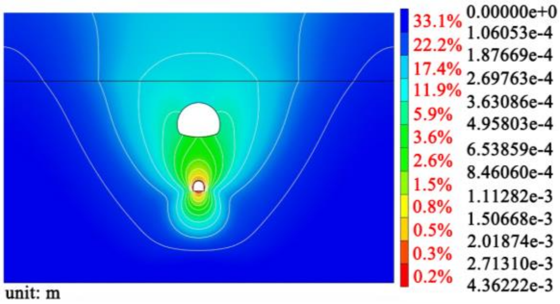
(d) Effective buried depth: 5.1 m



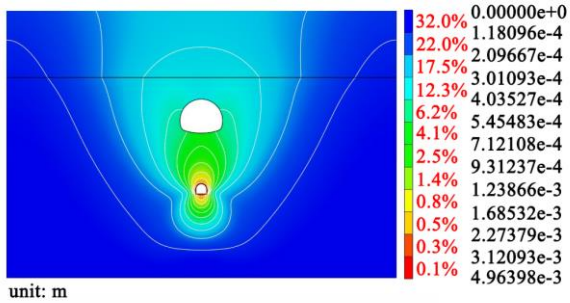
(e) Effective buried depth: 6.1 m



(f) Effective buried depth: 7.1 m



(g) Effective buried depth: 8.1 m



(h) Effective buried depth: 9.1 m

Figure 3 Displacement nephogram of cold-proof drainage hole with different buried depth (unit: mm)

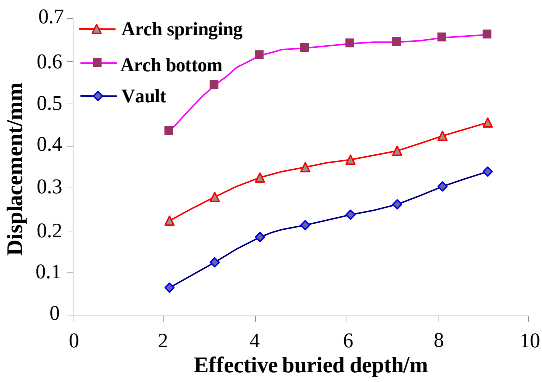


Figure 4 Displacement of various control points for main tunnel hole with different buried depth

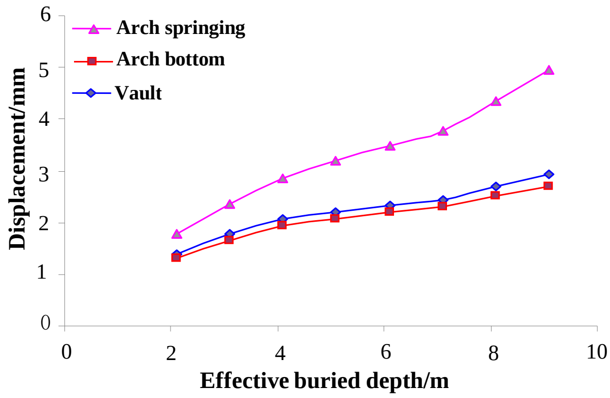


Figure 5 Displacement of various control points for cold-proof drainage hole with different buried depth

According to the analysis of variation law for the displacement of cold-proof drainage hole with different buried depth, the structure of main tunnel hole is interplayed with that of cold-proof drainage hole; when the effective buried depth of cold-proof drainage hole is between 5 m ~ 6 m, it is the best period to control the main tunnel hole and cold-proof drainage hole.

4.2 Variation law for stress

Figure 6 shows the stress of various control points for main tunnel hole with different buried depth. According to the figure, the first principal stress for vault of main tunnel hole remains the same because the excavation of cold-proof drainage hole exerts less influence on it due to the primary support of main tunnel hole; excavation of cold-proof drainage hole has bigger influence on the first principal stress for arch bottom and arch springing of main tunnel hole compared with the vault, and with the increase in buried depth of cold-proof drainage hole, the first principal stress shows valley value when the valid buried depth of cold-proof drainage hole is 5 m ~ 6 m. Besides, Figure 6 indicates that the third principal stress for arch springing of main tunnel hole increases with the increase in buried depth of cold-proof drainage hole, but it becomes gentle when the effective buried depth is about 4 m ~ 7 m; the vault and arch bottom of main tunnel hole show obvious regular variation, and with the increase in buried depth of cold-proof drainage hole, the third principal stress shows valley value when the valid buried depth is 4 m ~ 7 m.

Figure 7 shows the stress for various control points of cold-proof drainage hole with different buried depth below the main tunnel hole. According to the figure, the first principal of vault of cold-proof drainage hole shows great variation when the effective buried depth is 4 m, and it becomes stable when the effective buried depth is 5 m ～8 m; when the effective buried depth is 4 m～7 m, the first principal stress of arch springing of cold-proof drainage hole shows valley value; when the effective buried depth is 4 m～6 m, the first principal stress of arch springing of cold-proof drainage hole is stable. Moreover, based on Figure 7, the third principal stress of vault and arch bottom of cold-proof drainage hole show variation when the effective buried depth is 4 m, and it becomes stable when the effective buried depth is 4 m～8 m; the third principal stress of arch springing of cold-proof drainage hole increases with the increase in buried depth of cold-proof drainage hole; and the third principal stress of arch springing of cold-proof drainage hole shows fluctuation when the effective buried depth is 4 m～7 m.

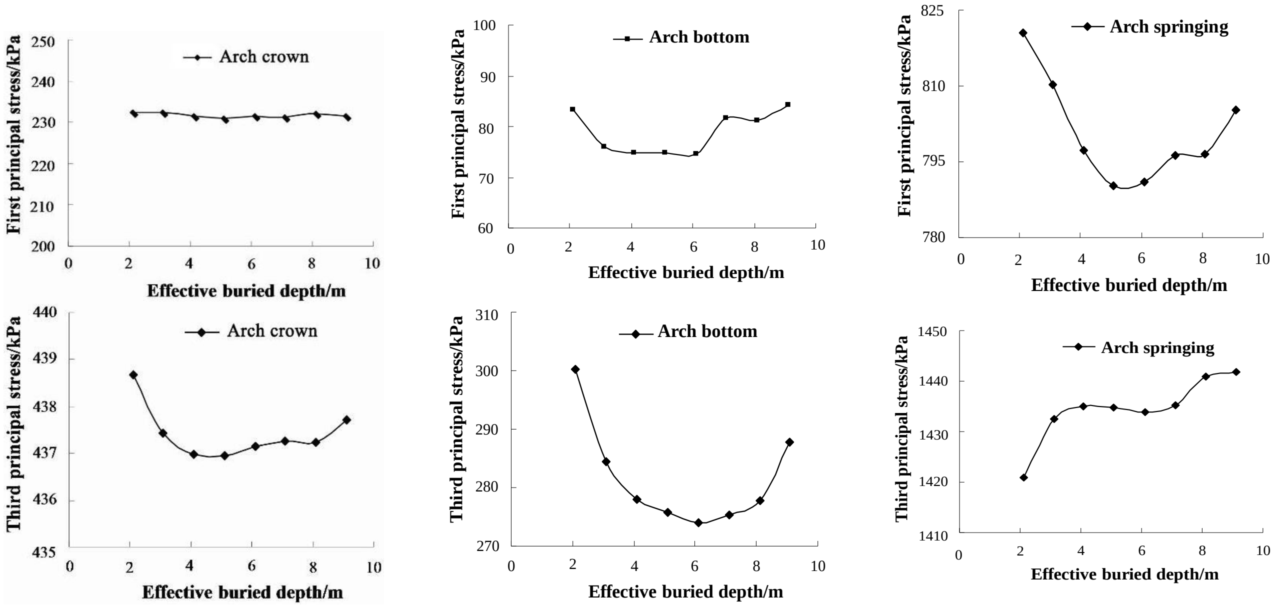


Figure 6 Stress for various control points of main tunnel hole with different buried depth

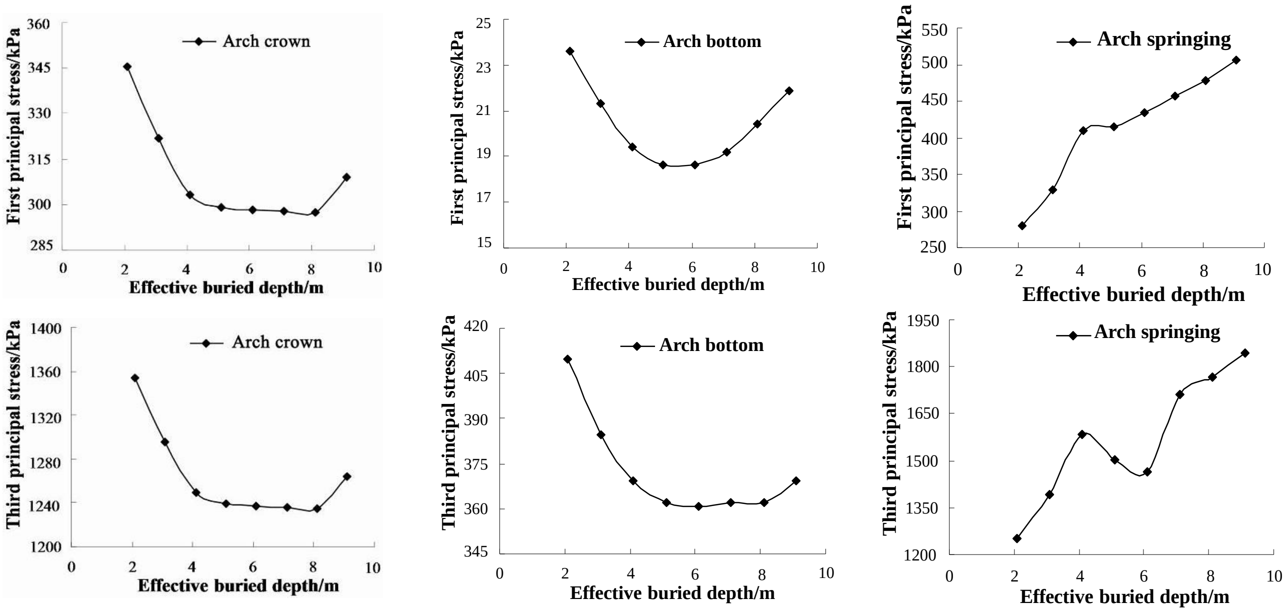
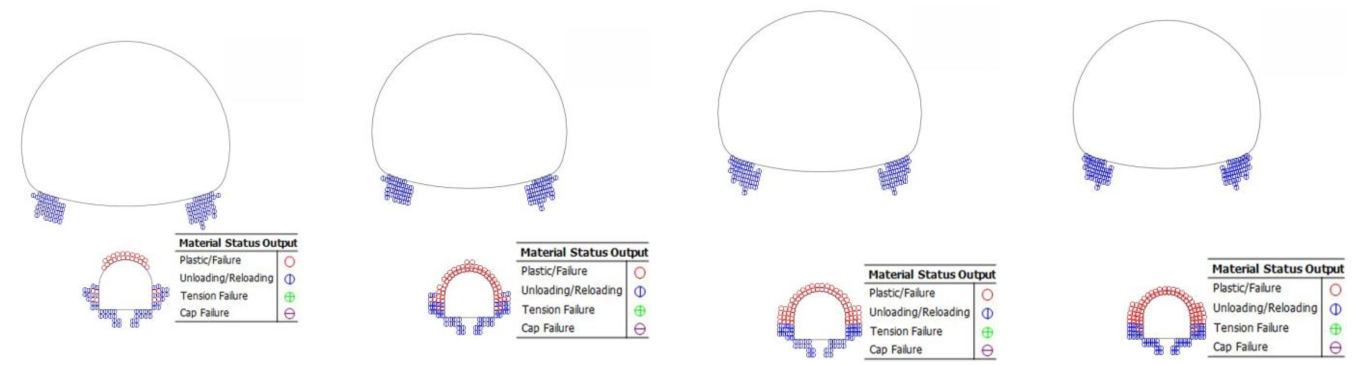
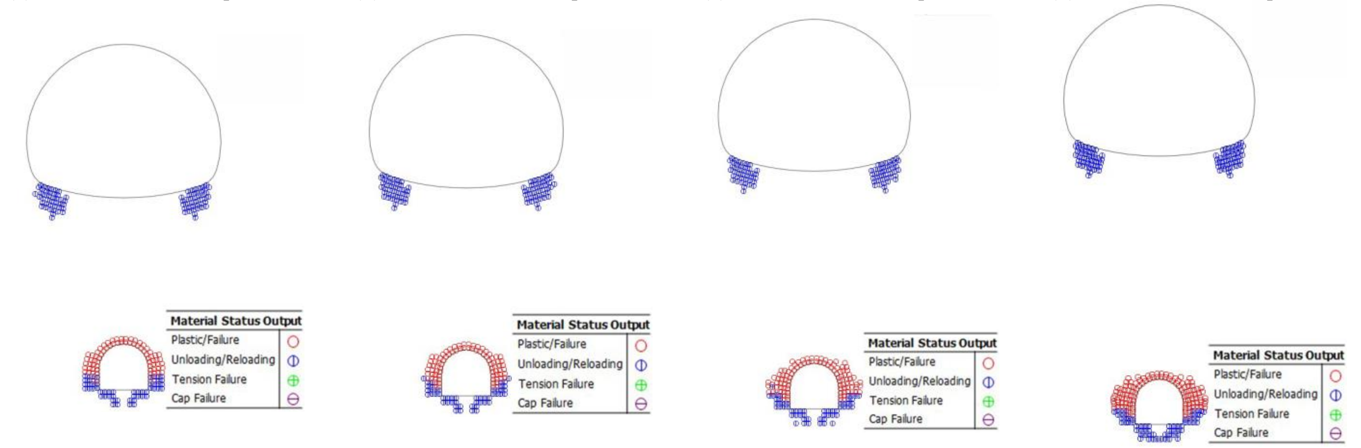


Figure 7 Stress for various control points of cold-proof drainage hole with different buried depth



(a) Effective buried depth 2.1 m (b) Effective buried depth 3.1 m (c) Effective buried depth 4.1 m (d) Effective buried depth 5.1 m



(e) Effective buried depth 6.1 m (f) Effective buried depth 7.1 m (g) Effective buried depth 8.1 m (h) Effective buried depth 9.1 m

Figure 8 Nephogram of plastic zone for cold-proof drainage hole with different buried depth

According to the analysis of variation law for the displacement of cold-proof drainage hole with different buried depth, the structure of main tunnel hole is interplayed with that of cold-proof drainage hole; when the effective buried depth of cold-proof drainage hole is between 5 m ~ 6 m, it is the best period to control the main tunnel hole and cold-proof drainage hole.

4.2 Variation law for plastic zone

Figure 8 shows the nephogram of plastic zone for cold-proof drainage hole with different buried depth. According to the figure, when cold-proof drainage hole with different buried depth is excavated, the arch springing of main tunnel hole is unloaded because the excavation of cold-proof drainage hole with different depth leads to stress redistribution at the bottom of main tunnel hole. Besides, according to Figure 8, the area of plastic zone increases with the increase in buried depth when the buried depth of cold-proof drainage hole is different, and plastic zone extends symmetrically along two sides to the arch springing; the arch springing and arch bottom of cold-proof drainage hole are unloaded because surrounding rock stress is released due to the excavation of cold-proof drainage hole.

According to the analysis of variation law of plastic zone for cold-proof drainage hole with different buried depth, the structure of main tunnel hole is interplayed with that of cold-proof drainage hole. Considering the stress uniformity of support and material for cold-proof drainage hole, buried depth scheme with uniform distribution of plastic zone is selected. In other words, when the effective buried depth of cold-proof drainage hole is 4 m ~ 6 m, it is the best period to control the main tunnel hole and cold-proof drainage hole.

5. CONCLUSION

1) In the area of a tunnel in Qinghai province, it is cold in the long winter, the annual average temperature is -1.7 ℃, extreme maximum temperature is 24.0 ℃, extreme minimum temperature is -33.0 ℃, annual frost period lasts for seven months, maximum snow depth is 14 cm, and maximum depth of frost penetration is 3.08 m. Cold-proof drainage hole is an effective measure to prevent a tunnel in Qinghai province from cold damage that may destabilize tunnel lining structure, reduce the security and reliability of lining structure, and affect its safe operation and good running.
2) Based on the MIDAS/GTS finite element analysis software, fixing the location of main tunnel and run through, just adjusting the buried depth of the cold-proof drainage hole, the change rules of displacement, stress and plastic zone in different buried depths of cold-proof drainage hole are analyzed. The influence of different buried depths for cold-proof drainage hole on the structure of the main tunnel is revealed. The result shows that the structure of main tunnel hole is interplayed with that of cold-proof drainage hole; from the point of displacement change rule, the optimal effective buried depth for cold-proof drainage hole of a tunnel in Qinghai Province is from 5 m to 6 m; from the point of stress change rule, the optimal effective buried depth for cold-proof drainage hole is also from 5 m to 6 m; considering the stress uniformity of support and material for cold-proof drainage hole, from the point of plastic zone change rule, the optimal effective buried depth for the cold-proof drainage hole is from 4 m to 6 m.
3) Eventually, on the basis of comprehensive consideration of the largest frozen depth, requirements of safe and economy, and influencing factors of construction of tunneling engineering area, the proper effective buried depth of the cold-proof drainage hole is confirmed to be 5 m, i. e., the proper buried depth of cold-proof drainage hole is confirmed to be 8 m.

6. REFERENCES

Bian, B. (2014) “Yan Kou Shan Tunnel Construction Method of Comprehensive Technical Research”, PhD thesis, Shijiazhuang Tiedao University. (in Chinese)

Du, B. (2003) "Construction Technique Research for High Elevtion Tunnel in Cold Weather", Chinese Journal of Rock Mechanics and Engineering, 22, Issues Z1, pp2453-2456.

Feng, Q., Jiang, B. S., Zhang, Q., and Wang, L. P. (2014) "Analytical Elasto-plastic Solution for Stress and Deformation of Surrounding Rock in Cold Region Tunnels". Cold Regions Science and Technology, 108, pp59-68.

Gao, G. Y., Chen, Q. S., Zhang, Q. S., and Chen, G. Q. (2011) "Analytical Elasto-plastic Solution for Stress and Plastic Zone of Surrounding Rock in Cold Region Tunnels", Cold Regions Science and Technology, 72, pp50-57.

Guo, Y. P., Hu, J. Y., and Wang, Y. L. (2012) "Yankou mountain tunnel collapse treatment measures", Highway Tunnel, 2012, Issues 3, pp54-55.

Hu, J. B., Qiao, C. J., Chu, Y. D., Ren, Y. B., and Zou, Z. L. (2012) "The Galongla Long tunnel waterproofing and drainage program design of Tibet Medog Highway", Highway, Issues 3, pp242-246.

"JTG D70-2004. Highway Tunnel Design Specifications", China Communications Press, Beijing. (in Chinese)

"JTG/T D70-2010. Highway Tunnel Design Detailed Regulations", China Communications Press, Beijing. (in Chinese)

Liu, G. Y. (2001) "Tunnel Construction Technology for the High Altitude and the High and Cold Area", China Railway Science, 22, Issues 4, pp50-55.

Liu, G. Y. (2006) "The Frozen Soil Problems and Related Prevention Countermeasures of Dabanshan Highway Tunnel", Journal of Glaciology and Geocryology, 28, Issues 6, pp833-837.

Lai, J. X. (2012) "Experimental Study on Air Temperature Field for Cold-region Tunnel in Qinghai-tibet Plateau: a Case Study", Advances in Computational Environment Science, 142, pp265-271.

Lv, K. C. (2012) "Tunnel and Underground Engineering Waterproofing and Drainage Guide (Second Edition)". China Communications Press, Beijing.

Liu, R. Q. (2014) "Research of Setting Technology for Winter Protection Drainage Hole of Highway Tunnel in High Altitude and Cold Regions", PhD thesis, Chongqing Jiaotong University, (in Chinese)

Li, Y. (2014) "Study on Distribution of Temperature Field and Cold Insulation Technology on Tunnel in High Attitude and Cold Zones", PhD thesis, Chongqing Jiaotong University. (in Chinese)

Li, G. P., and Wei, Q. (2012) "Waterproof and drainage design of highway tunnel in alpine region", Highway Tunnel, 2012, Issues 3, pp43-45.

Li, G. P., Yang, S. Z., and Xi, W. Z. (2018) "Safety Risk Assessment Technology of Yankou Mountain Tunnel in High Altitude and Cold Area", Journal of Catastrophology, 44, Issues s1, pp69-74.

Lai, Y. M., Wu, Z. W., Zhu, Y. L., and Zhu, L. N. (1998) "Nonlinear Analysis for the Coupled Problem of Temperature, Seepage and Stress Fields in Cold-region Tunnels", Tunnelling and Underground Space Technology, 13, Issues 4, pp435-440.

Lai, Y. M., Wu, Z. W., Zhu, Y. L., and Zhu, L. (1999) "Nonlinear Analysis for the Coupled Problem of Temperature and Seepage Fields in Cold Regions Tunnels", Cold Regions Science and Technology, 21, Issues 1, pp89-96.

Liu, H. J., Zheng, J. Y., Cheng, C. G., and Huang, L. H. (2011) "Rehabilitation project of the Dabanshan highland road tunnel", Journal of Chongqing University, 34, Issues 12, pp138-143+150.

Railways Second Survey and Design Institute. (1984) "Tunnel (Revised Edition)", China Railway Publishing House, Beijing.

Shao, F. Y, and Yang, Z. Y. (1998) "Anti-frost System and Construction of Dabanshan Tunnel", Railway Construction Technology, 1998, Issues 3, pp40-42.

Shao, F. Y. (1999) "Construction Technology of Dabanshan Tunnel Cold Insulation Systems", Railway Construction, Issues 10, pp27-29.

Wu, Z. W., Lai, Y. M., Zang, E. M., et al. (2003), "Cold Regions Tunnel Engineering", Ocean Press. Beijing.

Wang, X. Y., and Xu, X. T. (2013) "Exploration and Discussion of Cold-proof Spillway Tunnel in Cold Region", Journal of Water Resources and Architectural Engineering, 11, Issues 3, pp127-130.

Xu, X. T. (2014) "Study on Frostance, Anti-freezing and Drainage Technology of the Elashan Tunnel", PhD thesis, Chongqing Jiaotong University. (in Chinese)

Xuan, M. H. (2016) "Research on the Thickness of Shotcrete Layer in the Initial Support of the Shallow Buried Section of the Yan Kou mountain tunnel", Value Engineering, 35, Issues 27, pp79-82.

Zhang, X. Q., and Guo, Y. P. (2014) "Treatment technique of cave-in caused by deformation of the first branch of surrounding rock and replacement of arch in yankoushan tunnel", Highway Tunnel, 2014, Issues 2, pp36-38.

Zhang, X. F., Lai, Y. M., Yu, W. B., and Zhang, S. J. (2002a) "Non-linear Analysis for the Freezing-thawing Situation of the Rock Surrounding the Tunnel in Cold Regions Under the Conditions of Different Construction Seasons, Initial Temperatures and Insulations", Tunnelling and Underground Space Technology, 17, Issues 3, pp315-325.

Zhang, X. F., Lai, Y. M., Yu, W. B., and Zhang, S. J. (2002b) "Nonlinear Analysis for the Three-dimensional Temperature Fields in Cold Region Tunnels", Cold Regions Science and Technology, 35, Issues 3, pp207-219.

Zhang, X. F., Lai, Y. M., Yu, W. B., Zhang, S. J., and Xiao, J. Z. (2004) "Forecast Analysis of The Refreezing of Kunlun Mountain Permafrost Tunnel on Qing-Tibet Railway in China", Cold Regions Science and Technology, 39, Issues 1, pp19-31.

Zang, E. M., Ma, Z. Y., and Feng, Y. (1998) "Waterproofing and Drainage System in Dabanshan Highway Tunnel", Highway, Issues 3, pp1-6.