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Technical design of high temperature tunnel geothermal solution to frozen soil subgrade disaster and its comprehensive application

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Abstract

In order to solve the problem of frozen soil subgrade diseases, this paper analyzes the causes of frozen soil subgrade diseases. Based on the current frozen soil subgrade treatment technology, this paper analyzes the causes of the diseases of Tibet highland thermal tunnel and frozen soil subgrade, and proposes to build a ground heating system near the highland thermal tunnel with continuous highland thermal energy to solve the problem of frozen soil subgrade diseases in a certain range, and can reduce the temperature of highland thermal tunnel, Reducing the construction difficulty, cost and later maintenance cost of high and low heat tunnels can also be used to improve the lives of local residents and promote local economic development. In the long run, it will also be a starting point for the establishment of the ground heating system network in all levels of urban areas in Tibet.

Keywords

Highland thermal tunnel; Geothermal; Frozen soil subgrade; Diseases; Floor heating system.

1. hazards of highland thermal tunnel

1.1. formation causes and distribution of hazards in Highland thermal tunnel

The harm of highland thermal tunnel is due to the natural high and low thermal energy on the tunnel route, resulting in difficult tunnel construction, high construction cost and great damage to construction equipment and personnel [1].

Tibet is the region with the strongest geothermal activity in China, and its geothermal reserves rank first in China. There are more than 700 geothermal displays all over the region, of which 342 geothermal display areas can be developed, and the temperature of most surface water exceeds 80 degrees. A series of problems about highland thermal tunnels have been and will inevitably be encountered on the Qinghai Tibet railway, Sichuan Tibet railway and Sichuan Tibet Railway under construction. There are about 22 highland thermal tunnels on the Qinghai Tibet railway. The Sichuan Tibet Railway under construction passes through the Mediterranean Himalayan tropics, and hot springs (water) are mainly exposed along deep and large active fault zones (concentrated in Woka, Basu, Batang and Kangding). There are about 50 high-temperature hot springs affecting the line, about 26 tunnels may have high-temperature heat damage, and the maximum rock temperature of sangzhuling tunnel of Lalin line under construction is 89.9 ℃. And for all kinds of traffic routes built on the Qinghai Tibet Plateau now

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and in the future, it is inevitable to encounter some highland thermal tunnel construction. Most of the Qinghai Tibet Plateau is located in the permafrost area. As long as the subgrade meets the geological conditions of water, it is very prone to the disease of permafrost subgrade, so this technology has relatively large application space [2].

1.2. Specific hazards of highland thermal tunnel

(1) Many construction workers will suffer from dizziness and vomiting due to long operation time; (2) Due to the difficult heat dissipation of construction machinery, the failure rate increases gradually; (3) On the surface of surrounding rock in some sections, deliquescence occurs from time to time and turns into powder when encountering water, which makes it difficult to bond the shotcrete on the rock surface; (4) It causes the expansion of ordinary ammonium nitrate explosive, and some packaging paper expands and cracks; Some detonating tubes soften and lose elasticity, and cannot be restored to the original state after extrusion; (5) The strength of most mortar anchor bolts decreases; (6) In high altitude thermal environment, the accuracy of measuring instruments is greatly reduced; (7) In Highland thermal environment, sudden rock burst disaster may occur at any time in tunnel construction, which has a great impact on casualties and damage to mechanical equipment; (8) Temperature stress is easy to cause cracking and spalling of tunnel surrounding rock; (9) The additional temperature stress of concrete structure lining caused by high ground temperature for a long time will lead to cracking and uneven stress, which will reduce the safety and durability of the structure. It will also affect the stability of surrounding rock; (10) High temperature environment has high requirements for materials. Whether the explosives, blind drainage pipes and Waterstops used in tunnel construction are resistant to high temperature needs to be considered. Therefore, the cost of tunnel construction will increase; (11) Geothermal problems caused by heat radiation or rock temperature conduction will exist for a long time in the operation process and need to be maintained after the completion of the tunnel. Under the condition of high ambient temperature, the service life of the decoration materials used in the tunnel will be greatly reduced, which will have an adverse impact on the passing passengers and maintenance personnel. At the same time, it will cause difficulties in tunnel maintenance and repair, resulting in a significant increase in the operation cost; (12) In the highland thermal environment, the construction cost is very high [3] - [8].

2. Harm of frozen soil to Subgrade

2.1. Freezing damage mechanism and influencing factors of foundation soil

Frozen soil refers to all kinds of soil with temperature equal to or lower than zero degrees Celsius and containing ice. Frozen soil can be divided into seasonal frozen soil and perennial frozen soil according to the freezing time. Permafrost is widely distributed in China, accounting for about 75% of the land area, including the Qinghai Tibet Plateau, the north of the big and small Xing'an Mountains in the northeast, and about 22% of the permafrost in Tianshan and other areas "[9].

The temperature of soil at a certain depth below the ground changes with the change of atmospheric temperature. When the air temperature is lower than zero degrees Celsius, the water in the soil forms frozen soil due to freezing, and frost heaving occurs with the volume expansion of the soil. When the surrounding temperature of the soil is lower than zero degrees Celsius, the negative air temperature is introduced into the soil, and the water in the unfrozen soil is dispersed and migrated to the frozen area, and then frozen to form ice crystals. The volume increases, which is manifested in the volume expansion of the soil. When the soil layer thaws, the ice crystals gathered in the soil melt, the volume becomes smaller, and the soil particles also sink, which is manifested as the phenomenon of thawing [10]. This characteristic of soil with seasonal frost heave and thaw settlement is also called the frost heave day of soil. The factors affecting the frost heaving of foundation soil include air temperature, water content, groundwater level and soil type. The primary factor is the air temperature around the soil, which is also the decisive factor for the frost heaving of soil.

(1) Liquid water in soil can be divided into bound water and non bound water. Non bound water can be divided into capillary water and gravity water. Non bound water is also a direct factor affecting the frost heaving of foundation soil. When the temperature is lower than the melting point of water and the moisture content of soil exceeds a certain limit, frost heaving occurs in the soil, which is called frost heaving moisture content. With the increase of water content, the frost heaving rate of soil increases, and the frost heaving performance is stronger.

(2) Groundwater level and subgrade height are directly related to the degree of frost heave of subgrade soil. When the groundwater level is lower than a certain depth, only the influence of the internal water content of the soil on frost heave needs to be considered; When the groundwater level is higher than a certain depth, due to the action of capillary water, the groundwater will continue to migrate to the frozen area, greatly enhancing the frost heaving of soil. At this time, we should not only consider the water content of soil itself, but also pay attention to the impact of groundwater recharge.

(3) Different soils have different sensitivity to frost heaving, which is related to soil particle size, mineral composition and other factors. It is found that within the particle size range of frost heaving, the frost heaving of soil increases with the decrease of particle size and the increase of dispersion. At the same time, when the content of hydrophilic mineral components in the soil is high, the soil particles absorb more water, resulting in the frost heaving of the soil will also be significantly enhanced.

2.2. Main hazards of subgrade frozen soil

2.2.1. Collapse

Thawing usually occurs in the cohesive soil section with large water content and low temperature all year round. When the embankment base or cutting slope is covered with a thick layer of frozen soil, due to various effects of the construction and operation process, the overlying frozen soil will subside under the action of self weight after local melting, resulting in serious deformation of subgrade and pavement [11] - [13].

2.2.2. Frost heaving

Frost heaving is the effect of soil expansion and uneven uplift of the ground surface caused by the freezing of water in the soil and the formation of ice body. There are two necessary conditions for frost heaving: sufficient water supply and supply channel, which makes the water in the lower unfrozen soil migrate and gather to the freezing surface while the original water in the soil freezes.

2.2.3. Churning

When the spring thawing temperature rises, the upper soil mass of the subgrade melts first, while the lower soil mass has not been thawed, so the water cannot penetrate downward and accumulate in the upper part of the subgrade soil mass to form free water. When the moisture content exceeds the liquid limit moisture content of subgrade soil, the subgrade strength decreases, and it will be destroyed rapidly under the action of driving load to form churning.

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3. Technical design of geothermal solution to frozen soil subgrade disaster and its comprehensive application in Highland thermal tunnel

3.1. Action mechanism

In order to solve the problem of frozen soil subgrade diseases, the causes of frozen soil subgrade diseases are analyzed. Based on the current treatment technology of frozen soil subgrade and the analysis of the causes of frozen soil subgrade diseases, it is proposed to build a ground heating system near the highland thermal tunnel by using the continuous highland thermal energy to solve the problem of frozen soil subgrade diseases in a certain range. On the one hand, it can reduce the temperature of highland thermal tunnel, reduce the construction difficulty, cost and later maintenance cost of high and low thermal tunnel, and reduce various hazards of highland thermal tunnel; On the other hand, a ground heating system is constructed by using the continuous high land thermal energy near the high land thermal tunnel, so that the temperature of frozen soil subgrade within a certain range of the high land thermal tunnel is always maintained above 0 ℃, that is to ensure that the original frozen soil subgrade within this range will not produce frost heaving and thawing after ablation [14]. At the same time, it can also be used to improve local residents' living heating, vegetable greenhouse, medical treatment, bathing and other aspects, and promote local economic development. In the long run, it will also lay a starting point for the establishment of the ground heating system network at all levels of urban areas in Tibet in the future.

3.2. Technological innovation

(1) This project is the first to take measures to continuously provide heat to keep the frozen soil subgrade in the melting state and keep the subgrade temperature above 0 ℃, that is, to ensure that the frozen soil subgrade will not suffer from frost heave and thawing settlement [15].

(2) With the global warming, the technical difficulty of frozen soil subgrade treatment at this stage will be higher and higher, and it may fail one by one in the future, and this project has its corresponding advantages.

(3) It can not only greatly reduce the temperature of highland thermal tunnel, reduce the construction difficulty and maintenance cost of highland thermal tunnel, but also solve the diseases of frozen soil subgrade in a certain range. At the same time, it will also use the ground heating system for the life of local residents and promote the development of local economy, that is, the built ground heating system can locally solve three problems.

(4) The highland thermal energy of the highland thermal tunnel is used in the best way, instead of the large discharge and loss of geothermal energy in the previous highland thermal tunnel construction, which makes efficient use of the highland thermal resources, because the highland thermal energy is also an extremely precious resource for each country.

(5) The constructed ground heating system network locally increases the temperature in some permafrost areas in a certain range, which can promote the reconstruction of the local ecosystem in permafrost areas to a certain extent.

(6) To a certain extent, promoting local economic development will lay a starting point for the establishment of the ground heating system network in all levels of urban areas in Tibet in the future.

3.3. Technical feasibility

(1) As for its applicable conditions, for all kinds of traffic routes built on the Qinghai Tibet Plateau now and in the future, it is inevitable to encounter some highland thermal tunnel construction, and most of the Qinghai Tibet Plateau is in the range of permafrost area. As long

as the subgrade meets the geological conditions of water, it is very easy to have the problem of frozen subgrade disease, so this technology has relatively large application space.

(2) As the energy source of the whole ground heating system, the high ground thermal energy near the high ground thermal tunnel can continuously provide huge heat energy to the ground heating system, ensuring that the energy of the pipeline of the whole ground heating system is enough to make the subgrade temperature above 0 ℃ [16].

(3) Its cost is lower than that of rubble subgrade, ventilation subgrade, hot rod, bridge instead of road and other subgrade; Its service life is higher than that of sunshade, insulation board and other subgrade.

(4) In terms of its economic benefits, it can greatly reduce the construction cost of highland thermal tunnel. At the same time, the constructed floor heating system can improve the life of local residents and promote local economic development [17].

(5) In terms of its unique advantages, with the global warming, the global permafrost is also accelerating to melt, and the melting speed and trend of permafrost are also gradually increasing. Therefore, it will be more and more difficult to keep the temperature of permafrost subgrade below 0 ℃ at home and abroad, that is, keep the permafrost subgrade frozen all the time. Maybe one day, such measures will fail one by one due to global warming.

4. Conclusion: problems that need to be demonstrated through outdoor experiments and field experiments

Through a large number of field experimental data, carry out multi-directional and multi angle outdoor experiments and field experiments, and finally get the practical feasibility of this project.

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