Research Summary on the Evaluation Methods of Tunnel Excavation Schemes in High Altitude Area

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Abstract: In recent years, with the rise of highway and high-speed railway construction, the construction of the tunnel has also made rapid development. The from high altitude tunnel construction status and common excavation methods summary to proceed, access to relevant literature, explore the excavation scheme research means. In this paper, the numerical analog AHP evaluation method, introduces the basic theory and operation process, the excavation method was evaluated.

Keywords: Tunnel construction; Excavation scheme; The numerical simulation-analytic hierarchy; Evaluation scheme

1. Introduction

1.1. Research background

With the continuous development of China's economic and social, the increasing demand of traffic, traffic tunnel construction scale of highway and railway in our country is increasing, of large-scale construction of the tunnel for the development of China's social economy and transportation make important contributions, has become our country to achieve the necessary conditions for Chinese dream. Tunnels in high altitude area not only to crossing fault fracture zone, frozen soil, containing ice formations Fu water layer of unfavorable geological section, but also facing the climate is cold and hypoxia harsh natural conditions, the plateau permafrost geology construction difficulty is great[1]. therefore, so it is extremely important to the tunnel excavation in high altitude area evaluation and selection scheme

1.2. The significance of research

High altitude perennial in low temperature, hypoxia, and even frozen soil environment, the face a particularly difficult environment in the process of construction, high construction difficulty, also on the excavation scheme, construction technology, construction process, construction management and other aspects of proposed higher requirements, and the current on high altitude tunnel excavation scheme selection is mostly a margin to grope for, can be used for reference in the similar tunnel is still relatively small, and tunnels in high altitude area excavation scheme evaluation and selection has important significance.

1.3. Research status

1) Research state in China

Tunnel of existing high altitudes only a few hundred seats, mainly in the northwest, because of the construction period of the lack of advanced construction technology and reasonable construction plan, so that the tunnel is located in permafrost regions emerging phenomenon of frost damage, some even run for several in scrapped. The face of high altitude alpine permafrost in the harsh environment, the more successful the Kunlun Mountains, Fenghuo Mountains railway tunnel and the Osaka Hill, Partridge Hill tunnel, built these tunnels only enrich the tunnel construction technology and high altitude also made a practice numerous construction programs. Our research for high altitude tunnel project related issues more attention, but also made a lot of achievements.

YANG Cheng[2] (2013) using the finite element software of frozen soil tunnel excavation process is simulated and analyzed the stability of surrounding rock and the optimization scheme is put forward; in situ test of frozen soil tunnel excavation in the rock temperature, clearance of tunnel deformation, internal displacement of surrounding rock, surface subsidence, anchor rod axis force research, obtained in the next method is more suitable in permafrost excavation of the conclusion. DONG Yuhui[3](2011) in accordance with the Osaka mountain tunnel engineering background by performing research on the anti-frost in tunnel construction technology, oxygen ventilation technology, mechanical construction, waterproof and drainage measures, explore deep supplement suitable for high altitude permafrost zone construction technique of high-speed railway tunnel.

SHEN lingjun[4] (2012) The soft ground surrounding rock large cross section Tunnel Construction Plan CRD method and three-step and seven-step method of the deformation force supporting structure numerical simulation, using a variety of methods to optimize the construction program selection, construction process and three-step method discussed CRD seven-step method, process, etc., and on-site evaluation of the feasibility of the implementation of the above-described construction program results. GONG Jianwu[5](2009)Choosing the optimize crane large cross section tunnel construction scheme use numerical simulation, simulation, respectively, next to France, up and down stairs law, the construction process by double side drift method, the establishment of a dynamic finite element analysis model of surrounding rock stability, vault subsidence, surface subsidence, middle rock pillar stress comparative analysis, a combination of mechanical construction, construction process and construction technology and other factors, and ultimately select the partition wall construction method.

Jiang Kun[6] (2012) established a discrete element modeling, optimization of jointed rock masses by two-way eight-lane tunnel construction program. DING Gaigai[7] (2014) analyzed mall spacing metro tunnel construction scheme optimization by non other large sections, the final line of small cross section of the left shield, the right line of large cross section CRD law or double side this pit method three kinds of construction program to simulate and comparison analysis, the results show that using the first through a large section CRD law and after a small section of the tunneling shield construction scheme for small disturbances surrounding rock, easier to control the surface deformation, reduce costs and speed up schedule.

REN Jianxi[8],(2011) use the FLAC numerical analysis software for Reservation Core Soil and up and down stairs and French construction scheme bored tunnel shallow section was simulated with the model results to predict the surface deformation, a small catheter is recommended lead construction and steel grille jointly controlling surface subsidence.

ZHOU YiPeng[9](2012)use step method, full section method, side drift method, CRD excavation method numerical simulation method, from the beginning of lining internal force, displacement of surrounding rock, rock stress three respectively comparisons, the final step method to select the overall economic efficiency of construction. QU Shoucai[10](2012) by introduced the Mountain Tianheng tunnel construction method,such as micro-step method, CRD excavation and three-level seven-step method, and finally compare the effectiveness of its application.

2) Situation study abroad

High altitude tunnel frozen expansion technology development in foreign countries is very slow, Japan Railway Tunnel Leakage accounted for 56%, which produced the proportion of frost damage is 34%. Japan in 2006 statistics of the occurrence of frost damage of tunnel accounted for 28.9%, causing serious impact on traffic[3]. Foreign high altitude permafrost tunnel engineering 15.3 km north of the Mu Ya tunnel, 6.7 km tunnel Baikal, 2.5 kilometers keda'er tunnel, northern Hokkaido, Japan, Canada and Norway also built the a certain number of high altitude tunnel, accumulated some experience, for the excavation plan of the tunnel engineering of the high altitude area of our country, provide the corresponding reference [2].

2. Evaluation Method of Tunnel Excavation Scheme in High Altitude Area

According to the existing high altitude tunnel construction experience, initially identified (CD) method, to step down in order to, leave the nuclear subsoil arc heading method and cross diaphragm method (CRD) construction in high altitude area is feasible, mainly of the four excavation scheme is evaluated.

2.1. Four kinds of excavation overview of the program

1) CD method construction process

CD method is suitable for demanding land subsidence, formation is poor, unstable rock tunnel construction, it is divided into sections on the guide hole, and on the lower section of the main tunnel, excavation under section four parts [11].

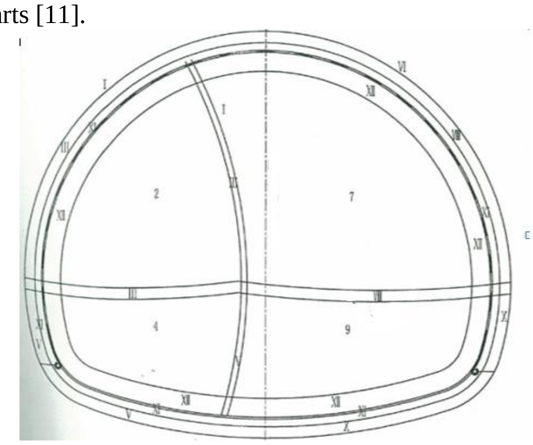

Figure 1. Schematic diagram of excavation by CD method

1) pilot hole and part of the main tunnel arch advanced small pipe advance guard.

2) the pilot tunnel excavation half section 2, the guide hole and a half portion of the main hole section shotcrete, installation of I-beam frame, hanging steel mesh.

3) Under section 4 semi-pilot tunnel excavation, under the guide hole and the hole half portion of the main section, invert concrete, install the I-beam frame, hanging steel mesh.

4) main tunnel arch advanced small pipe advance guard.

5) of section 7 of the main tunnel excavation half, half the guide hole and the main hole section shotcrete, installation of I-beam frame, hanging steel mesh.
6) main tunnel excavation of the lower half section 9, the main section of the hole and a half, invert shotcrete, installation beam frame, hanging steel mesh.
7) The excavation of four parts accumulated a certain length, the temporary removal of the wall, pouring a concrete invert lining, laying insulation, molded concrete to build the design thickness.
8) invert pouring concrete, laying waterproof board, using templates section trolley full-time secondary lining concrete pouring.

2) Step up and down stairs construction method

The section is divided into upper and lower step method on the steps, down the stairs two parts excavation, which stepped on the excavation after a certain distance ahead, up and down stairs can go hand in hand [11].

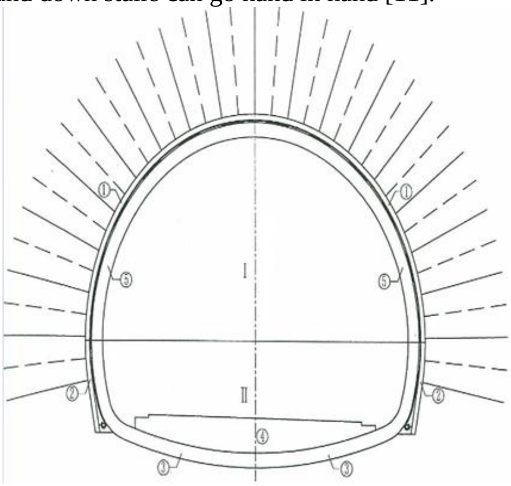

Figure 2. Schematic diagram of the excavation of the upper step down method

1) advance support;
2) Excavation on the stage I;
3) as the initial support①, the first jet concrete, hanging steel mesh and anchor bolt installation, I-shaped steel frame, and then to design the thickness of sprayed concrete.
4) Excavation hopping down the steps II;
5) facilities for the appropriate initial support ②, materials and order with ①;
6) After the initial support and stability, the overall mold built secondary lining ③.

3) Leaving the core territories arc Heading Method step

Leave the nuclear subsoil arc heading method also called annular excavation with the core of indigenous methods. This method is first in the upper part of the tunnel section excavated arc heading and re excavation of the central core of the soil, the excavation section half on both sides of the, each separate dug through respectively initial support, finally closed in time into the ring.Core soil construction process see below[11]:

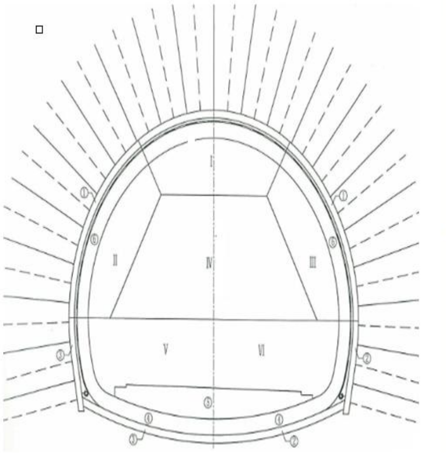

Figure 3. Reserved core soil excavation on the arc heading diagram

1) the use of advanced arch support.
2) an annular excavation section I, II, III; facilities for the initial section support ①, namely shotcrete, concrete mold building (including steel mesh and anchor), install the I-beam frame.
3) the core soil excavation section IV
4) switched excavation under section V; facilities for under Section initial support ②, namely shotcrete, concrete mold building (including steel mesh and anchor), install the I-beam frame.
5) quit excavation under section VI; facilities for under Section initial support ③;
6) construct the inverted arch ④.
7) invert backfill ⑤;
8) Full Section built secondary lining integrally molded to the design of reinforced concrete thickness ⑥.

4) Cross the wall (CRD) method construction process

CRD method is suitable for soft ground tunnel, control surface subsidence effect is obvious, mainly for urban subway construction. It is divided into sections on the left side, under the section on the right side of the upper section and the lower middle, six parts under section excavation[11].Because of its many processes, disturbance of surrounding rock more often, high cost, less used in the tunnel in the mountain.
1) left the excavation of the cross section ①, facilities for initial support and temporary horizontal, vertical support;
2) on the right side of the excavation section ②, facilities for initial support and temporary horizontal, vertical support;
3) Excavation men left section ③, facilities for initial support and temporary horizontal, vertical support;
4) the right men excavation section ④, facilities for initial support and temporary horizontal, vertical support;

5) Remove the temporary support of excavation on the middle section ⑤, facilities for initial support;
6) the remainder of the excavation ⑥, facilities for initial support;
7) invert excavation, backfilling;
8) facilities for secondary lining.

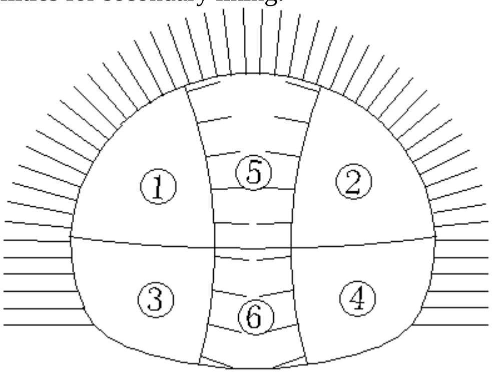

Figure 4. Schematic diagram of excavation by CRD method

2.2. Evaluation method of excavation scheme

1) Excavation program evaluation standards

Based on current experience and existing research results construction, it is concluded that the evaluation criteria of tunnel excavation scheme in high altitude area are as follows:

① the construction safety first, to develop appropriate measures to deal with risk factors for a variety of different construction schemes.

② from the field environment, engineering geological conditions, the size of the cross section form, construction difficulty, duration and other cost factors fully into account, than select the most suitable construction program.

After ③ surrounding rock excavation within the fast auto-time closed into a ring to complete the primary support.

④ when other conditions permit, priority section Division fewer construction program, to achieve large-scale mechanized construction, improve construction efficiency.

⑤ under other conditions permit, prioritize and easy conversion back to back construction plan for ease of geology, the mutated region surrounding rock construction method conversion and reduce cost.

2) Evaluation method of excavation scheme

FEM simulation capability is very strong, it can be considered non-uniformity of the rock mass, discontinuities and material, geometric nonlinearity and other characteristics, can be adapted to a variety of practical boundary conditions[12]. Analytic Hierarchy Process to establish a clear hierarchy to break down complex problems, measure theory using pairwise comparison, layer by layer construct judgment matrix, and then seek a normalization of each judgment matrix eigenvectors and weights, and finally calculates each alternative comprehensive programs right weight, and get the order of importance of each scheme. Prior to the establishment of AHP model, numerical simulation analysis during construction of different construction methods, the indicators can be obtained variation values of surrounding rock, has become an important basis for subsequent AHP judgment matrix.

In order to more accurately compare later judgment matrix is formed, for more efficient construction program evaluation, qualitative indicators will be quantified by means of numerical simulation. Using numerical simulation method of construction quality of the four construction scheme for numerical analysis.

Select the finite element method for modeling using finite element software Midas establish numerical model plane, dome Evaluation of different construction schemes under the settlement, changes in the level of convergence and initial support stress[12].

① model size

This model is mainly on the partition wall (CD) method, the method up and down stairs, leaving the core soil arc drift method, cross the wall (CRD) model of Four construction program, to obtain crown settlement, convergence and the level of early support Numerical simulation of stress.

② meshing

Numerical simulation of plane strain unit using soil, soil constitutive model is taken to be the ideal mole Coulomb model; the initial simulation using sprayed concrete beam elements; anchor implantation truss unit; secondary lining concrete plane strain unit. To increase the accuracy of the analysis, finite element mesh density of the surrounding rock tunnel section and make the appropriate increase. Far from the cross-section of the tunnel where the mesh density can be adjusted to reduce the number of units and reduce the amount of computation, improve processing speed [12].

③ model parameters

Model parameters include parameters of surrounding rock and supporting arguments, supporting arguments using single and composite lining structure calculations.

④ boundary conditions

When using the finite element model to calculate the impact on the results of the boundary conditions is relatively large. Thus, to reduce the impact on the boundary limits of the model, i.e. the model to take the given boundary conditions: the model can not be the right and left horizontal displacement in the x direction, Ux = 0; fixed bottom boundary of the model; bottom vertical boundary points and horizontal straight direction displacement are zero, Uy = 0 and Uz = 0; on the model surface is a free surface, it is not binding.

⑤ constitutive model

Granular rock mass determines its compressive yield strength than the tensile yield strength a lot, of rock and soil shear expanding the particles, so common mole Coulomb yield criterion (Mohr-coulomb) guidelines. Because it is the traditional mechanical elastoplastic constitutive model, but with rocks strikingly similar results, which reflects the failure characteristics in line with the actual situation, is widely used in engineering[12].

Soil ultimate shear strength of each side of the force can use Coulomb's law, said:

$$\tau_n = C + \sigma_n tg\varphi$$

Which τ_n represents the ultimate shear strength; σ_n represents a positive stress force plane; φ represents the internal friction angle of rock or cohesion. You can also use a graph showing the mutual relation between τ_n values and σ_n value between the hydrostatic pressure is small representation of available lines, as shown above, so the formula is also called mole Coulomb yield condition.

So the formula is also called mole Coulomb yield condition. Moore Coulomb yield condition can also make use of the plane principal stresses σ_1, σ_3 represents

$$\frac{1}{2}(\sigma_1 - \sigma_3) - \frac{1}{2}(\sigma_1 + \sigma_3)\sin\phi - C\cos\phi = 0$$

On the φ plane, Moore Coulomb yield criterion condition is not exactly equal to the angle of the equilateral hexagon, as shown above, in the principal stress space, Moore Coulomb yield condition is pyramid surface, a central axis and Isoclines overlap. Moore Coulomb yield condition in three-dimensional space is expressed as follows:

$$\frac{1}{3}I_1\sin\phi + \sqrt{J_z}\sin\left(\theta + \frac{\pi}{3}\right) + \frac{\sqrt{J_z}}{3}\cos\left(\theta + \frac{\pi}{3}\right)$$
$$\sin\phi - C\cos\phi = 0$$

After comprehensive consideration, this paper numerical simulation of soil constitutive relation taking molar Coulomb guidelines.

Analytic Hierarchy Process is by the famous American professor T.L.Saaty in the 20th century put forward, is an effective system analysis methods, especially for multi-program, multi-factor and multi-standard comprehensive evaluation[13]. Characteristics of the Analytic Hierarchy Process is a combination of qualitative and quantitative analysis to policy-making, the advantage is flexible, simple system, we were able to quickly and widely applied in the social sciences. Essence of AHP is to establish a clear hierarchy to break down complex problems, measure theory using pairwise comparison, layer by layer construct judgment matrix, and then obtain a normalized feature vector and matrix determine the weight of each weight, and finally calculated each comprehensive options right weight, and get the order of importance of the programs. Level configuration simplifies complex problems from the "program level, factors that layer, the target layer" analysis of the problem, given a complete calculation methods and processes. The biggest advantage of AHP is to policymakers quantification of subjective judgment, it became a scientific way of thinking[14]. It has the following characteristics:

1) First, the complex issues of hierarchy layer decomposition, become multiple single evaluation criterion, and then evaluated by one single issue guidelines to its synthesis.

2) The use of the various factors 1-9 scale method according to the degree of "importance" of the reunification of the quantization scale.

3) Consistency Inspection judgment matrix, prevent the use of judgment matrix 1-9 scale method to give the appearance of paradox.

4) the use of methods for solving linear algebra to calculate the process for each of the plurality of level judgment matrix, the right to obtain the required weight and ordering information as a decision-making support.

Numerical simulation to have quantifiable, AHP taking into account the factors of high altitude, thus constructed a tunnel excavation program evaluation model for high altitude, by combining these two methods, numerical simulation constructed - level evaluation methods combining excavation scheme for the evaluation of high altitude provides a comprehensive evaluation method.

3. Conclusion and Prospect

In this paper, preliminary numerical analysis method and analytic hierarchy process (AHP) assessment in conjunction with excavation scheme. In this paper, the numerical analysis method can observe the construction of the tunnel surrounding rock deformation and various parts of the stress situation and output corresponding numerical advantages from on high altitude tunnel excavation scheme analysis, scheme evaluation method for excavation and so on, the level analysis method combining excavation scheme evaluation. In the concrete operation, some qualitative evaluation indexes are used to quantify the method of numerical simulation of tunnel construction, which greatly reduces the fuzzy nature of analytic hierarchy process, and makes the decision maker to judge more accurately when the excavation scheme is selected.

The evaluation model of different excavation methods in high altitude area was constructed, and the optimal excavation scheme of IV grade surrounding rock in high altitude area was obtained by numerical simulation and tomography analysis. This paper has achieved the research objectives, but further research will find that there are still the following shortcomings:

①The selection of excavation scheme evaluation index from the construction quality, construction safety and construction schedule and construction cost, decrease of

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quantity efficiency without considering the construction of high altitude area caused by the future research should be more comprehensive consideration in the selection of evaluation index.

②For the numerical simulation and the analytic hierarchy process method model itself, there are still some problems, such as related to expert scoring, with a certain degree of subjectivity and fuzziness and because there is no test case, so the next step to test case, optimizing the evaluation methods or to explore the other more accurate evaluation method is still very necessary.

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