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Research on Duration Estimation of Ling Shan Tunnel Engineering

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Abstract. The South-to-North Water Diversion is a tough and groundbreaking project of a province. Ling Shan tunnel is a key engineering which has many uncertain factors and complex problems in construction. In order to implement the project smoothly, is worth to research how to establish a scientific and reasonable construction schedule. The paper is based on the data of five similar tunnel engineerings, applying information diffusion theory to the construction progress network diagram so as to estimate main work time and determine the key circuit. Therefore, the project managers can calculate the total duration of Ling Shan tunnel engineering more accurately and offer reliable evidence for the follow-up engineerings.

Keywords: Tunnel; Information Diffusion Theory; Duration

1. Introduction

Located in north of Hanjiang river, Ling Shan tunnel lies low mountainous area of difficult terrain, along the gully development. The strata has Paleozoic metamorphic rocks and sedimentary rocks, and proterozoic intrusive rocks. Surrounding rockmasses have dark mica gneiss, mica schist, limestone, which is relatively complete.

The main structure of works area is fault, most of it is orthogonal with diversion of cavern hole and stable. The works areas are located in a narrow channel of Hanjiang River and its tributaries, which is illimitable steep mountains on both sides. Since the construction site is narrow, construction organization has a lot of difficulties.

2. Ling Shan Tunnel Construction

Ling Shan tunnel length is 16.94 km, and it is made up of three segments, which are the tunnel segments, export segments, and subsiding water tunnel. Tunnel longitudinal slope is i= 1/3000, transverse adopts round arches straight wall model, with the wide × height = 6.3×7.5 m. Concrete is a lining material that is usually sprayed and supported by, nets, anchor combined way according to surrounding rock types, and two lining concrete thickness is 0.40 ~0.50 m with a strength grade of C30.

2.1 Branch cavities construction

Branch cavity excavation method uses steps excavation, three arms hydraulic jumbo drilling, 3m3 wheel loader and 15ton dump trucks carriage to abandon slag field.

According to this geologic data stage, each branch cavity is given priority to V class surrounding rock. If severe weathered rock or fracture zone is encountered, short footage would be used, advance anchor bolt or advance grouting to strengthen, and necessary steel support.

2.2 The Main Hole Construction

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2.2.1. Excavation

Through the comprehensive comparison analysis of the drill-blasting method and TBM method, Ling Shan tunnel trunk adopts the drill-blasting method of construction. The holes are arranged in 5 construction branch cavities, including 3 right holes and 2 left holes. Tunnel trunk excavation utilizes three arms hydraulic jumbo drilling, 3m3 wheel loader and 15ton dump trucks carriage to abandon slag field. Excavation working faces are eight, including no. 2 and no.4 branch cavity double-faces excavation, the remaining 3 branch cavities and export of single -face. Tunnel trunk uses smooth blasting excavation, and Ⅲ class surrounding rocks use whole section excavation method, and Ⅳ, Ⅴ class surrounding rocks use steps excavation.

2.2.2. Support

Along with the tunnel ,the surrounding rocks are Ⅲ class primarily, and will need support after excavation. It should follow working face to a small amount of V class surrounding rocks. If it encountered severe weathered rock or fracture zone, it will need short footage, hang nets and shotcrete in time, adopt advance anchor bolt, advance grouting, steel for frame supporting, and shed support in a pinch.

After excavation support, primary support should be followed. If there is severe weathered rock or fracture zone encountered, then timely use short footage hanging nets shotcrete. If necessary, adopt advanced bolt, advance grouting, and steel pipe roof for frame supporting.

2.2.3. Construction Ventilation, Water Supply

Main hole drilling and blasting method construction section alone has a head tunneling maximum length of 2.37 km, These have a push-up type ventilation respectively from export and various construction branch cavities. Fans select GAL18-2000/2000 type axial flow fan, and duct use flexible pipe of 2.2 m diameter.

2.2.4. Construction Drainage

Surrounding rock ooze water and construction waste water flow in the integrating wells in excavation, The water is then taken out of the hole, every 200m there will be a set well.

2.2.5. Concrete Lining Construction

Hole body concrete lining construction contains eight working faces and it is respectively lined from No.1 to No.5 branch cavities. Exports, includes No. 2 and No.4 branch cavity excavation with double-faces, the remaining working face are with a single -face. The average monthly lining footage is 800m. Top arch and side-wall concrete casting adopt unitary steel trolley and concrete transportation adopts 6m3 concrete mixing truck. Concrete is put in storage by concrete pump, and vibration of concrete adopts immersion vibrator and floor concreting parts adopt plate concrete vibratory.

2.2.6. Tunnel Grouting

Tunnel grouting backfills grouting; then consolidates grouting. Grouting begin when three tunnel lining casting segments are completed. Then drilling using the embed grouting pipe can be carried out by hand pneumatic, and grouting use mobile builder’s staging, in addition, grouting equipment select the grouting pump of automatic recorder.

2.3 Discharge Sluices and Retreat Sluices Construction.

The tunnel discharges sluices and retreat sluices adopt concrete structures, and install the flat steel gate. Chamber concrete adopts 10ton autocrane with 3m3 concrete cans.

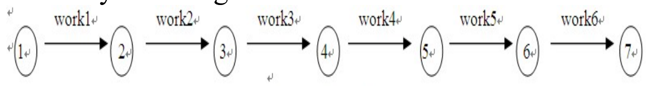
2.4 Metal Structure Installation.

Metal structure including discharge sluices, one flat steel gate, one retreat sluice work gate, one access door and one hoist.

Metal structure installation operate by labor primarily and mechanical operation as assistant. Door leaf installs on site, and sluice gate installation use 50ton wheel crane to gate slot. The brake room gate is hoist with pour chain hoisting.

3. Ling Shan tunnel construction schedule

Ling Shan tunnel construction Key route Fig 1



Key route figure 1

Note:
Work 1: Construction preparation
Work 2: Branch cavities construction
Work 3: Main hole excavation
Work 4: Main hole lining
Work 5: Grouting ending and branch cavities plugging
Work 6: Construction completion

4. Information diffusion

4.1 One-dimensional Information Diffusion

In a small sample problem, the no-diffusion estimate is to be considered coarse, and it need some kind of diffusion estimate to improve.

Order X is a sample; U is a subset of the domain. From X × U to [0, 1] as a mapping

μ : $X \times U \rightarrow [0, 1]$

$(x,u) \rightarrow \mu(x,u)$, $\forall (x,u) \in X \times U$

Called X as a information diffusion on U, if it is degressive, $\forall x \in X$, $\forall u'$, $u'' \in U$, if $\| u' - x \| \le \| u'' - x \|$,then $\mu(x,u') \ge \mu(x,u'')$. μ Called a diffusion function, U called a monitoring space.

Order $X = \{x_1, x_2, \cdots, x_n\}$ is a sample which is used to estimate the relation of R on the domain U, hypothesis γ is a reasonable operator, $\chi(x_i, u)$ is concomitant characteristic function, no-diffusion estimation is:

$$\hat{R}(\gamma, X) = \{\gamma(\chi(x_i, u)) | x_i \in X, u \in U\}$$

When X only is incomplete, there must be a reasonable diffusion function $\mu(x_i, u)$ and an corresponding operator, use $\mu(x_i, u)$ replace $\chi(x_i, u)$, γ' adjust γ, diffusion estimates:

$\tilde{R}(\gamma', D(X)) = \{\gamma'(\mu(x_i, u)) | x_i \in X, u \in U\}$

Make: $\| R - \tilde{R} \| < \| R - \hat{R} \|$

Among them, $\| \cdot \|$ is said the error between estimate relations and real relationships.

Namely: assume X is a given sample. If X is not complete, there must be a diffusion function $\mu(x_i, u)$, it can turn X into a fuzzy samples $D(X)$, diffusion estimate is closer the diffusion estimates $\tilde{R}$ than the real relationships R.

4.2 Information diffusion distribution function

Information diffusion has the function of information expletive, and fill along the decreases direction of concentration. In diffusion process it has not increase or decrease phenomenon of information of the total. In other words, the information diffusion discussed is working in the closed system, and the total in value of formation fixed in the system , and there is no information loss phenomenon. This ensures that the information didn't appear distortion phenomenon in the transfer process, and it largely avoid uncertainty issues.

Assume $F(u, x)$ is information diffusion distribution function, $f(u,x)$ is information diffusion density function.

Then $F(u, x) = \int_{-\infty}^{+\infty} f(u,x)\,dx$

d is defined the distance between the observation x_i and decentralizing u , namely $d = \| x_i - u \|$, d is the smaller, $F(u, x)$ is bigger, and decentralizing u can obtain more information.

Fig 2, the sum of the acreage integral below the curve is the sum of information sum[1].

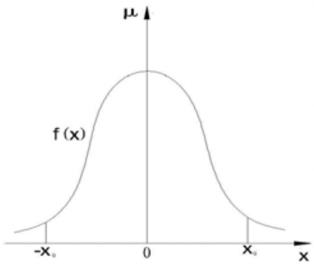


Fig 2 information diffusion density function diagram

4.3 Information Diffusion Scope, Decentralizing and Step Length Determined

If diffusion scope, diffusion coefficient and decentralizing setting method are different, the diffusion results are different.

4.3.1. Confirm the range of information diffusion

For normal distribution function, the closer variable to the center position , the bigger the concentration of its information. Therefore, there must be a range of making the information of outside the scope little, so it have little effect to the whole [2].

Because,

$$P(|X-\mu|\le k\sigma)=P\left|\frac{X-\mu}{\sigma}\right|\le k$$

Make, $\frac{X-\mu}{\sigma}=X^*$, then:

$$P(|X^*|\le k)=\phi(k)-\phi(-k)=2\phi(k)-1$$

Among them, $\phi(k)$ is normal distribution probability value when k is the samples , σ is standard deviation.

Check the normal distribution list:

$$P(|X^*|\le 3)=2\phi(3)-1=0.9974$$

Probability is more than 99.74%, when the distance between variables and the center position in the normal distribution function. It is less than 3 millimeters, when the distance is out of 3σ . So choosing 3σ as normal information diffusion range ω is more reasonable. But in practical application incomplete samples, we can hardly know material variance, so we usually adopt sample unbiased estimation S to replace σ , and the information diffusion area formula :

$$\omega=\bar{x}\pm 3S$$

Among them, $\bar{x}$ is the sample mean, $\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i$

S is variance of samples . $S=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}$

4.3.2. Confirm Information Diffusion Monitory Point

In information diffusion, the monitory point is more, step length is smaller, and diffusion results are more precise. So, it is a difficult problem faced to choose either from a scientific or reasonable monitory point. We usually take subjective determine method; because its subjectivity, is too big. The diffusion results and the precision of diffusion information get effected greatly. In order to solve the problem, we use calculation formula of information diffusion monitory point after as a result of research and experiments,

$u_j=x_i\pm S'$

Among them, u_j is the information diffusion monitory point of j; S' is the value of the integer of S , according to the principle of rounding. x_i is the sample value.

It need to notice that the monitory point determined is not necessarily completely satisfy 3σ rule to its boundary point, namely monitory point of maximum and minimum. Therefore we need to supply for information diffusion monitory points, and combine information diffusion the information diffusion coverage. The method is as follows:

Compare $\omega_{\min} = \bar{x} - 3S$ and $u_{j\min}$. If $u_{j\min} < \omega_{\min}$, does not need to replenish the lower limit of monitory points. Conversely, take less than $\omega_{\min}$ and the maximum integer as a first monitory point, and $u_{j\min}$ serves as a second monitory point.

Similarly, compare $\omega_{\max} = \bar{x} + 3S$ and $u_{j\max}$. If $u_{j\max} < \omega_{\max}$, take more than $\omega_{\max}$ and the smallest integer as the last monitory point, and $u_{j\max}$ serve as a penultimate monitory point. Conversely, there is no need to add upper limit of monitory point.

4.3.3. Confirm Information Diffusion Step-Length.

Information diffusion step-length $\Delta = u_{j+1} - u_j$, namely the spacing between two adjacent monitory points. Due to the monitory point determination method, monitory point may appear to jump, so Δ may be equal to the step-length, and may be the variable step length.

5. Ling Shan Tunnel Total Duration Estimate

For example, because of finite condition, this project data base refer to five similar tunnel engineering, the working time of work 1 are calculated, and the unit is week, A = {10,11,10,12,12} as a sample set, according to the information diffusion theory.

$\bar{x}$ is the sample mean, $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = 11$,

S is sample variance,

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$= \sqrt{\frac{1}{5-1}\left[(10-11)^2 + (11-11)^2 + (10-11)^2 + (12-11)^2 + (12-11)^2\right]} = 1$$

S '= 1

According to, $u_j = x_i \pm S'$

When the sample point is 10, monitory points to 9,10,11;

When the sample point is 11, monitory points to 10,11,12;

When the sample point is 12, monitory points to 11,12,13;

Then, $u_{j\min} = 9$, $u_{j\max} = 13$.

Again, $\omega_{\min} = \bar{x} - 3S = 8$, $\omega_{\min} < u_{j\min}$, and need to replenish lower limit 8,

$\omega_{\max} = \bar{x} + 3S = 14$, $\omega_{\max} > u_{j\max}$, and need to replenish upper limit 14,

Sample A monitoring discrete domain UA = {8,9,10,11,12,13,14}. According to traditional normal distribution information diffusion coefficient, n = 5, h = 0.8146 (12-10) = 1.6292. Diffusion equation is:

$$\tilde{p}(a) = \frac{1}{nh\sqrt{2\pi}}\sum_i \exp\left(-\frac{(a_i - u_j)^2}{2h^2}\right)$$

Table 1 the spread matrix

Table 1 diffusion matrix of work 1 time

$\mu(a_j,u_j)$	8	9	10	11	12	13	14
10	0.0231	0.0406	0.0490	0.0406	0.0231	0.0090	0.0024
11	0.0090	0.0231	0.0406	0.0490	0.0406	0.0231	0.0090
10	0.0231	0.0406	0.0490	0.0406	0.0231	0.0090	0.0024
12	0.0024	0.0090	0.0231	0.0406	0.0490	0.0406	0.0231
12	0.0024	0.0090	0.0231	0.0406	0.0490	0.0406	0.0231
$\tilde{p}(a)$	0.06	0.1223	0.1848	0.2114	0.1848	0.1223	0.06
%	6.3452	12.9336	19.5431	22.3562	19.5431	12.9336	6.3452

The weighted average working time of work 1 is $\overline{a}$ = 11.

Similarly, branch cavities construction completion need 28 weeks, the main hole excavate completion need 64 weeks, and the main hole lining completion need 88 weeks, Grouting ending and branch cavities plugging need 4 weeks, and project completion need eight weeks. So Ling Shan Tunnel total duration need 203 weeks.

6. Conclusion

This paper focuses on more precise measurements of Ling Shan Tunnel engineering of total duration, and the bases of the Ling Shan Tunnel construction key work with information diffusion principle. This method has a lot of room for improvement. Key work can improve the accuracy of measuring through refinement process. Key work and non-critical work can be transformed into a dynamic process, and will need further study. In addition, with the arrival of information age, computer aided measuring software development is the future development trends.

7. References

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