Computer Dynamic and Intelligent Prediction Model for Surrounding Rock Deformation Grade using Numerical Simulation Method

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Abstract. Risk assessment is an effective means to identify and prevent deformation of tunnel surrounding rock during construction. The comprehensive prediction system is established by selecting the burial depth, groundwater, surrounding rock grade, the uniaxial compressive strength, and the integrity of the rock. The weight of each index is calculated based on the entropy weight method. Finally, the risk level of each tunnel section is determined by the extension theory.

1. Introduction
As an underground project, tunnels inevitably pass through unfavourable geological bodies, such as soft rocks, faults [1], fracture zone [2], and then surrounding rock deformation [3, 4].

Many scholars have studied the problem of large deformation of soft rock and achieved good results. Teng et al. [5] used the numerical simulation method to study the change law of each physical field of the tunnel under the action of surrounding rock pressure and underground water and pointed out that the low rock strength and underground water were the main reasons for the tunnel deformation. Zhong et al. [6] deduced the deformation of tunnel based on the continuum theory, and the theoretical value was in good agreement with the actual value. Xue et al. [7] analyzed the influencing factors of the deformation of the loess tunnel and established an evaluation and prediction model.

In this article, two mathematical methods are used to evaluate the index weight, and then the risk evaluation model is built. Finally, the assessment model is applied to Xiamen Haicang undersea tunnel for risk evaluation.

2. Methods

2.1. Entropy weight method
Entropy is a measure of the uncertainty of a system, and the higher the entropy, the greater the uncertainty of the system. The advantage of the entropy weight method lies in that it gives weight based on objective data and is not disturbed by subjective reasons. The data of each risk assessment index in this paper are all from the actual tunnel. As an objective data set, it is appropriate to use the entropy weight method to calculate the weight of each risk assessment index. However, if there is a large deviation in the original data, the evaluation effect will be seriously affected, and the weight obtained may not match the actual importance of the index.
2.2. Extension method
Extensions [8] is an interdisciplinary subject with basic element theory, extension set theory and extension logic as the core. It was founded by Cai Wen and other professors in 1983 to solve incompatible, contradictory problems in real life. The matter-element model of a multi-index comprehensive evaluation is established by using multi-index extension comprehensive evaluation method, and the multi-objective evaluation is transformed into single objective decision making, and the evaluation results are expressed simply and clearly by quantitative numerical value, which is suitable for the multi-objective complex decision making problem such as tunnel deformation risk assessment.

2.3. The entropy weight-extension method
Entropy-extension theory is a new kind of evaluation method, evaluate the risk of tunnel surrounding rock deformation by the method, can expand on the concept of distance in real variables function as the "distance", expand the scope of the correlation function domain, will be transformed from a single value of clear evaluation indexes for the interval value, implements the comprehensive judging the degree of evaluation objects belonging to the collection. Using the entropy weight method to calculate the weight coefficient of the evaluation index can overcome the subjectivity of determining the weight coefficient and avoid human interference. At present, the entropy weight-extension evaluation method has been widely used in geotechnical engineering. Huang et al. [9] used the entropy weight method to evaluate the quality grade of surrounding rock in the Pingzitou Tunnel. Xie et al. [10] used this method to evaluate the dangerous accident of coal and gas outburst in the coal seam. Huang et al. [11] used this method to evaluate the risk of water inrush accidents in coal mines. Shen et al. [12] applied this method to evaluate the blasting quality of jointed rock mass tunnels. From the comparison between the evaluation results of the above scholars and the actual situation on the site, the consistency is strong, and a good evaluation effect has been achieved.

3. Deformation risk evaluation index system and evaluation model

3.1. Risk evaluation index system of tunnel surrounding rock deformation
The risk assessment is a multi-objective and complex decision-making problem. In addition to hydrogeological factors, the influence of construction, rock properties and other factors should be considered. Based on the existing design and construction data, this paper comprehensively evaluates the deformation of tunnel surrounding rock from five aspects: the surrounding rock grade Y1, the burial depth Y2, groundwater Y3 [13], the uniaxial compressive strength Y4 [14] and the integrity of the rock Y5. The evaluation system is shown in Figure 1.

![Figure 1. Evaluation index system.](image)

3.2. Comprehensive prediction system
Based on careful consideration of domestic and foreign surrounding rock classification standards, codes and relevant literature, tunnel surrounding rock deformation risks are divided into four grades I–IV, as shown in Table 1.
Table 1. Standard for risk assessment of surrounding rock deformation.

| Level | Y1(m) | Y2                  | Y3 | Y4(MPa) | Y5(%)  |
|-------|-------|---------------------|----|---------|--------|
| I     | <50   | No water            | II | >30     | 75~100 |
| II    | 50~100| Water seepage       | III| 15~30   | 50~75  |
| III   | 100~200| Drip water         | IV | 5~15    | 25~50  |
| IV    | >200  | Linear drop         | V  | <5      | 0~25   |

4. Engineering examples and applications

4.1. Research Area
This study focused on twelve tunnel sections of the Haicang subsea tunnel in Xiamen City, Fujian Province, China.

Table 2. Measured value of evaluation index.

| Section | Y1(m) | Y2                  | Y3 | Y4(MPa) | Y5(%)  |
|---------|-------|---------------------|----|---------|--------|
| 1       | 32    | No water            | III| 65      | 80     |
| 2       | 45    | Water seepage       | III| 70      | 77     |
| 3       | 35    | No water            | II | 75      | 86     |
| 4       | 54    | No water            | III| 55      | 65     |
| 5       | 101   | Linear drop         | V  | 35      | 32     |
| 6       | 95    | Drip water          | IV | 40      | 55     |
| 7       | 67    | No water            | IV | 50      | 68     |
| 8       | 88    | Water seepage       | IV | 40      | 45     |
| 9       | 87    | No water            | III| 60      | 72     |
| 10      | 121   | Linear drop         | V  | 27      | 19     |
| 11      | 82    | Water seepage       | III| 55      | 84     |
| 12      | 76    | No water            | III| 70      | 79     |

4.2. Calculation of the weight
Calculating the weight of each influencing factor is shown in Table 3.

Table 3. Weight of influence factors.

| The weight | Y1     | Y2     | Y3     | Y4     | Y5     |
|------------|--------|--------|--------|--------|--------|
| ω          | 0.207  | 0.262  | 0.224  | 0.146  | 0.161  |

4.3. Establishment of risk assessment model
First-grade division, the evaluation indexes for the front shows that the risk grades are divided into 4, respectively, in the low risk, risk, high risk and very high risk, and then determine the classical domain and domain, then proposed evaluation of the deformation of tunnel surrounding rock evaluation indexes into, and the single index correlation functions, indicators and a certain level of correlation, the greater, the more closely it correlates with that level. The established model was used for risk assessment, and the results were shown in Table 4.

Table 4. Deformation risk rating assessment.

| Section | Grade | Section | Grade |
|---------|-------|---------|-------|
| 1       | II    | 7       | II    |
| 2       | II    | 8       | II    |
| 3       | I     | 9       | IV    |
| 4       | II    | 10      | II    |
| 5       | III   | 11      | II    |
| 6       | III   | 12      | II    |
5. Conclusion

According to the weight comparison, the influence of groundwater is the largest, so the tunnel deformation risk can be reduced by controlling the underground water quantity. For example, groundwater drainage, advanced grouting and other measures can be taken. Then, the tunnel deformation risk assessment model was used to evaluate Haicang undersea tunnel. According to the results, the deformation risk level of the 5th, 6th and 9th tunnel sections were high, and the site workers were required to reinforce them in time, which provided guidance for the construction of the project.

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