Classification and Application of Surrounding Rock Stability of Straight Wall Semi-circular Arch Roadway

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Abstract: The stability of surrounding rock plays an important role in the safety of roadway, so the classification of roadway stability becomes an indispensable part in the safety analysis of coal roadway. Based on the statistical analysis of 25 relevant literatures and the principle of index selection, 12 classification indexes were determined by comprehensive analysis. A genetic neural network model was established. Data of 12 straight wall semi-circular arch roadways were investigated as training samples, and 4 roadways were selected for testing. The prediction accuracy of the model is 100%. Combining with the theory of strong support for coal roadway sidewall and angle, the stability classification model is applied to the classification of surrounding rock stability of straight wall semi-circular arch roadway, and reasonable supporting countermeasures and suggestions for different grades of surrounding rock are given. In order to verify the reliability of the model, the model has been applied in engineering, and achieved good results. It proves that the model has good fit and strong applicability.

1. Introduction
The stability of the surrounding rock of the roadway plays a vital role in the safety of the roadway. Therefore, classifying the stability of the roadway becomes an indispensable part in the safety analysis of the roadway. Currently, in the classification of rectangular coal roadway stability, many scholars have conducted in-depth research and proposed Fuzzy clustering analysis[1], Support vector machine[2], Neural network[3-4], Zhengtai cloud model[5], EW_UCA model[6], Bayes discriminant analysis[7], etc. Having achieved many results. However, there is still a lack of corresponding research on the stability analysis of surrounding rock in straight wall semi-circular arch roadway.

This paper conducts statistical analysis on 25 related documents and determines 12 classification indexes; establish a genetic neural network model, investigate 12 straight wall semi-circular arch roadway data as training samples, and select 4 roadways for testing; apply the stability classification model in the classification of surrounding rock stability of straight wall semi-circular arch roadway. Combining with the theory of strong support for coal roadway sidewall and angle, the reasonable supporting countermeasures and suggestions of different grade surrounding rock are given, and the engineering application is carried out.
2. Establish a genetic neural network model

2.1. Determine classification index
Determining the classification index is the premise and foundation of the classification analysis of the surrounding rock stability of the straight wall semi-circular arch roadway, and plays a vital role in the classification of stability.

This paper analyzes the frequency statistics of 25 related documents, as shown in Figure 1, and obtains the features of the indexes, combined with the principle of index selection (high impact, accuracy, quantification, non-correlation, etc.), after comprehensive analysis, determine 12 classification indexes: strength of roof(index1), strength of sidewall(index2), strength of bottom(index3), buried depth(index4), strata inclination(index5), roadway width(index6), straight wall height(index7), semi-circle arch height(index8), ratio of direct roof and mining height(index9), coal pillar width(index10), service life(index11), water inflow(index12).

![Index frequency cluster columnar section](image)

Figure 1 Index frequency cluster columnar section

2.2. Model design
Genetic algorithm is a method to obtain the optimal solution by simulating the genetic evolution process. Its characteristic is that for the parameter coding, the calculation of the adaptation value is completed by the objective function, so the dependence on the problem is small. Genetic algorithm can improve computation speed by parallel computing when solving spatial problems. The neural network is an abstract mathematical model that simulates the basic characteristics of the human brain, and is widely used in pattern recognition[8-10]. Genetic algorithm and neural network are very capable of dealing with problems, but each has its own shortcomings. Therefore, this paper applies genetic algorithm to optimize neural network method, and constructs a genetic neural network classification model for surrounding rock stability of straight wall semi-circular arch roadway.

The classification model of surrounding rock stability of genetic neural network roadway is composed of two parts: building a model network topology and acquiring high-precision analysis capability[11]. (1) According to the characteristics of the research problem, select the basic type of suitable artificial neural network. After determining the basic model of the neural network, design and optimize the specific structural parameters of the model. (2) The connection weight and threshold of the classification model are obtained by the optimization calculation, and the nonlinear relationship between the roadway classification index and the surrounding rock stability type of the roadway is obtained. As shown in Figure 2.
2.3. Sample design and training
The sample input information is the information providing source of the input layer of the genetic neural network classification model, and its function is to provide the actual input value of the model in the training learning phase and the application testing phase. The input information of the sample consists of 12 components, which correspond to 12 roadway stability classification indexes, and the output information consists of 5 indexes, corresponding to five types of surrounding rock stability classification of straight wall semi-circular arch roadway: Extremely stable type, stable type, more stable type, unstable type, and extremely unstable type. Therefore, the output vector of the network has a dimension of 5, as shown in Table 1.

Table 1. Classification index coding table.

| Type of stability | Output information |
|-------------------|--------------------|
| I      | 1 0 0 0 0 |
| II     | 0 1 0 0 0 |
| III    | 0 0 1 0 0 |
| IV     | 0 0 0 1 0 |
| V      | 0 0 0 0 1 |

According to the characteristics of the genetic neural network model and the range of output values (0~1), the transfer function of the model hidden layer is the Tansig Function, and the transfer function of the output layer is the Logsig Function.

Through the investigation, the data of 12 straight wall semi-circular arch roadway engineering data were collected and used as training samples. The training sample data after standardization processing is shown in Table 2. Then, the sample was used to train the genetic neural network model. Through continuous intelligent learning, the model grasps the nonlinear relationship between the classification index and the stability of the straight wall semi-circular arch roadway, and has the ability to judge and classify.
The stability of the surrounding rock in straight wall environments and different working conditions needs to be described, so as to provide support measures. To classify the stability of the roadway, the purpose is to be able to scientifically and quantitatively determine various types of roadways. The applicability of the model is very good and the network performance is excellent. The prediction accuracy of the model reaches 100%, and the visualization is clear.

### 2.4. Model test
In order to test the accuracy and fitting effect of the model, four straight wall semi-circular arch roadways were selected for testing. The results are shown in Table 3. The comparison shows that the prediction accuracy of the model reaches 100%, and the visible accuracy is very high, indicating that the applicability of the model is very good and the network performance is excellent.

#### Table 3. Model test data and results.

| Number | Input information | Output information | Type of stability |
|--------|-------------------|--------------------|-------------------|
|        | Index 1 | Index 2 | Index 3 | Index 4 | Index 5 | Index 6 | Index 7 | Index 8 | Index 9 | Index 10 | Index 11 | Index 12 |                        |
| 1      | 0.685   | 0.674   | 0.158   | 0.553   | 1.000   | 0.467   | 0.100   | 0.467   | 0.687   | 1.000   | 0.167   | 0.223   | 0 1 0 0 0 0 0 0 0 0 0 0 0 |
| 2      | 0.348   | 0.857   | 0.431   | 0.557   | 0.267   | 0.267   | 0.000   | 0.267   | 0.305   | 1.000   | 0.028   | 0.121   | 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| 3      | 0.366   | 0.343   | 0.434   | 0.300   | 0.133   | 0.200   | 0.100   | 0.200   | 0.614   | 0.000   | 0.010   | 0.162   | 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| 4      | 0.364   | 0.341   | 0.156   | 0.000   | 0.000   | 0.733   | 1.000   | 0.733   | 0.000   | 1.000   | 1.000   | 0.943   | 0 0 0 0 0 0 0 0 0 0 0 0 0 |

### 2.5. Support measures
The purpose of classifying the stability of the roadway is to be able to scientifically and quantitatively describe the stability of the surrounding rock, so as to provide support countermeasures under different environments and different working conditions. The stability of surrounding rock in straight wall semi-circular arch roadway is affected by many factors, and different grades of surrounding rock adopt different support schemes. In order to further link the classification of surrounding rock stability with support countermeasures, based on the above classification analysis, considering the stress conditions of surrounding rock, the surrounding rock strength conditions and support methods, etc. Combined with the theory of strong support for coal roadway sidewall and angle proposed by the author[12], the general support measures for determining various types of roadways are shown in Table 4.
### Table 4. Design table of support parameters for straight wall semi-circular arch roadway.

| Type of stability | Three kinds of basic support of straight wall semi-circular arch roadway | The main support parameters of straight wall semi-circular arch roadway |
|-------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------|
| Extremely stable  | roof (sidewall): Simple Bolt Support                                    | Bolt: diameter 16~18mm, length1.6~1.8m; Row & Line Space 1.0~1.2m; one Anchor Solidifying Agent Resin, shotcrete |
| Stable            | roof (sidewall): Anchor Net Support or Anchor Beam Support              | (1) bolt:diameter16~20mm; length1.8~2.0 m; Row & Line Space 1.0~1.2m; one Anchor Solidifying Agent Resin; (2) beam: steel beam; (3) network: mesh reinforcement, (4) shotcrete |
| More stable       | roof: Anchor Beam (Belt)Net, Anchor Cable Support                       | 0.8~1.2m; two Anchor Solidifying Agent Resin (2) anchor cable: diameter17.8mm; length3~7m; Row & Line Space 1.0~4.0m; two Anchor Solidifying Agent Resin (3) beam: steel beam or the steel band of model W (4) network: mesh reinforcement; (5) shotcrete |
|                   | sidewall: Anchor Beam (Belt) Net Support                               | 0.8~1.2m; two Anchor Solidifying Agent Resin (2) beam: steel beam or the steel band of model W (3) network: mesh reinforcement; (4) shotcrete |
| Unstable          | roof (sidewall): Anchor Beam (Belt) Net, Anchor Cable Support           | (1) bolt: diameter 20~22mm; length 2~2.4m; Row & Line Space 0.8~1.0m; two Anchor Solidifying Agent Resin (2) anchor cable: diameter17.8mm or 21.6mm (17.8mm); length 8m (3~6m); Row & Line Space 1.0~3.0m; three Anchor Solidifying Agent Resin (3) beam: the steel band of model W or channel steel belt; (4) network: mesh reinforcement; (5) shotcrete; (6) shelf support |
| Extremely unstable| roof (sidewall): Anchor Beam (Belt) Net, Anchor cable support           | (1) bolt: diameter 22~25mm; length 22~2.6m; Row & Line Space 0.7~1.0m; two Anchor Solidifying Agent Resin (2) anchor cable: diameter17.8 or 21.6mm; length6~10mm; Row & Line Space 0.7~2.0m; three Anchor Solidifying Agent Resin (3) beam: the steel band of model W or channel steel belt; (4) network: mesh reinforcement; (5) shotcrete; (6) shelf support; (7) other special support |

3. **Engineering application**

This paper chooses the straight wall semi-circular arch roadway of the Shuiyu mine as the research object, and determines the stability type. Then the corresponding roadway support scheme is formulated and successfully applied to the underground support.

3.1. **Project Overview**

The buried depth of the roadway is 580m ~ 615m. The direct roof is sandy mudstone with a thickness of 1.6m. The direct bottom is mudstone with a thickness of 0.9m. The roadway width is 5m and the roadway height is 4m.

3.2. **Stability evaluation**

The relevant parameters of the roadway are input into the genetic neural network model. By analyzing and running the genetic neural network model established above, the output result is (0 0 0 1 0), thereby determining that the stability type of the roadway is unstable.

On this basis, look up Table 4, clarify the basic support parameters of the roadway, combined with the strong angle theory [12], support design.

3.3. **Support design**

According to the deformation and failure characteristics of the roadway, combined with the support parameters of Table 4, under the guidance of the strong support for coal roadway sidewall and angle theory, proposing five kinds of support schemes, and the five schemes are numerically simulated and analyzed. Considering the construction speed, construction cost and implementation, the optimal solution and scheme was determined as shown in Figure 3.
Compared with the original scheme, the optimal scheme not only reduces the support cost, but also effectively controls the deformation of the roadway. As shown in Figure 4, the convergence of the sidewall is 83.5mm, which is about 7% less than the original scheme; the maximum principal stress is also improved, to alleviate the degree of stress concentration, as shown in Figure 5.

3.4. Downhole application

Apply the optimal solution to downhole support. In order to verify the applicability and feasibility of implementing the new scheme, and to contrast with the original scheme, the monitoring section is arranged in the roadway to monitor the deformation amount under the original scheme and the new scheme. Figure 6 records the process of increasing the deformation of the roof and the two sidewalls over time.

It can be seen from Figure 6 that the displacement of the section of the new scheme is significantly smaller than that of the original scheme. Compared with the original scheme, the displacement of the sidewall is greatly reduced, indicating that the new scheme has good applicability, which further proves the applicability of the model and the rationality of the support scheme.

4. Conclusion

(1) Defining 12 classification indexes, establishing a genetic neural network model, investigating 12 straight wall semi-circular arch roadway data as training samples, and selecting 4 roadways for testing,
the accuracy of the model is 100%, indicating that the model is effect and good.

(2) Applying the genetic neural network model to the classification of surrounding rock stability of straight wall semi-circular arch roadway, combined with the theory of strong support for coal roadway sidewall and angle proposed by the author, the general support of each type of straight wall semi-circular arch roadway is determined.

(3) Taking the Shuiyu mine roadway as the research object, the genetic neural network model is applied to the actual underground support engineering, and the stability classification evaluation is carried out. The underground application is carried out according to the evaluation results, and good results are obtained, which proves that the model has strong applicability.

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