It is a reinforcement project applying anti-slide piles combined with bottom slurry-injection and reinforced concrete slate as shown in Figure 4.

The length of anti-slide piles can be worked out according to Figure.4 and formula (2), while the pile's anchoring depth is decided by the pile's top constraints. Generally speaking, the anchoring depth is about 0.6 to 0.8 times of load's length. Therefore, we used two rail piles in this project, 2.4 meters long each, they were placed symmetrically with the space between them is 1 meter.

5. *Conclusion.*

5.1 The main reason of the roadway floor heave is that the floor gets into plasticflow state. Therefore, the theory of slippageline can describe the stress state and the distortion property of the rock mass effectively.

5.2 The analysis of the roadway floor heave in theory is significant in choosing the appropriate method to control the roadway floor heave, at the same time, it can provide theory referrence in choosing reinforcement parameters correctly.

5.3 By referring to the theory of anti-slide piles in slope reinforcement, the anti-slide piles is used to control the roadway floor heave here. It is a reinforcement method of the roadway floor by utilizing the theory of plastic slippage line. This method has its many strongpoints, such as: great anti-slide force、credible effect、convenient construction process、good adaptability and low cost, etc.

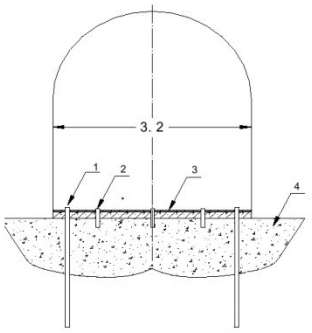

Figure 4. An example of rail stake to control tunnel bottom swelling. 1- rail stake, 2—slurry-injection pipe, 3—reinforced concrete slate, 4—slurry-injected mass

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NON-LINEAR DYNAMICAL FEATURES FOR STRATA MOTION

1. Introduction

China is the country that is abundant in coal resource. However, because of the limitation of embedding depth and geological conditions, underground excavation is the main method of coal mining in China. One of the drawbacks this method brings about is the failure of strata and catastrophe movement, such as roof fall abruptly , rock burst , bump of coal and mash gas etc. , which can result in casualties. Further more, with the development of excavation towards the depth, the disaster will be more severe, and even can affect the safety of excavation. So in the view of the predicting mechanism for strata motion, it is needed to break through the definite theory of Newton , and to find out a new predicting method for strata motion.

2. Self-organization for strata motion

Order variable is used to describe the degree of ordering of system. If the self-organization process for strata motion is studied by synergetic theory, then first of all we must determine the order variables describing the evolving process of the system and parameters of the related subsystem. According to the references [1, 2], AE can be selected as the variable describing the failure process of rock.

Assume the order variable of the system is ***N***, and it means the total number of AE events in unit time. N_L, the parameter of subsystem, is sign as the total number of AE large events in unit time. The change of AE rate, which shows the variation of cracking extension of roof system, is composed of increase and decrease.

Studies show order variable equation is given by

$$\frac{dN}{dt} = -\lambda_N N + \alpha_N N_L^2 + b_N N \quad (1)$$

Then the change of the subsystem parameter formed by large events N_L is given by the following equation

$$\frac{dN_L}{dt} = -\lambda_{NL} N_L + \alpha_{NL} N + b_{NL} N_L \quad (2)$$

Thus the main equation describing the evolution of the control system

$$\frac{dN}{dt} = -\eta N + \xi N^2 \quad , \quad (3)$$

where

$$\eta = \lambda_N - b_N, \ \xi = \frac{\alpha_N \alpha_{NL}^2}{(\lambda_{NL} - b_{NL})^2}.$$

The main equation that order variable N satisfies is equation (3), and obviously it is a non-linear ordinary differential equation of first order. From the

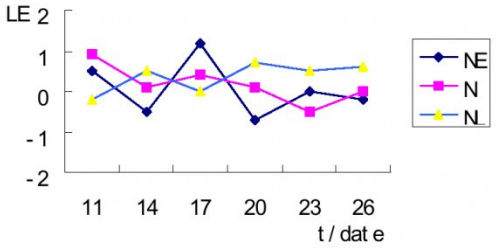

Fig. 1. Lyapunov Exponent of strata motion

equation, it can be concluded that the change of order variable is also be restricted and related by the coupling reaction between the system and its subsystem which is realized by feedback and inverse feedback between the system and its subsystem, i.e.

$\alpha_N<0$, $\xi<0$ → inverse feedback

$\alpha_N>0$, $\xi>0$ → feedback

During different phases of once roof movement, because the roof suffers different applied forces, the parameter η equals different values. For example,

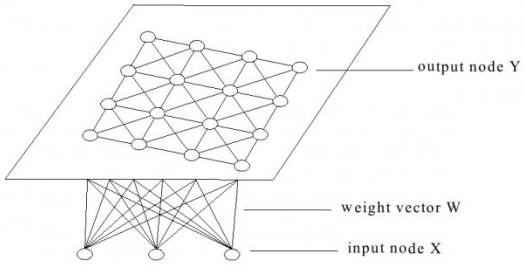

Fig.2. Structure figure of self-organization mapping of NN

during the phase of cracking and accumulation ahead of the remarkable movements of roof, the activities of AE raise mainly according to increase of the stress, i.e. $\eta < 0$; After the activity of roof weighing, the stresses relax and AE mainly decline, and so $\eta > 0$; When the roof experiences the process of relative stabilization → weighing → returning relative stabilization, the system is abound to go through the critical condition $\eta = 0$.

3. Chaos features for strata motion

A. Wolf [3] [ever presented the method that computing Lyapunov Exponent from the measured values, which is now used to calculate Lyapunov Exponents of the number of AE major events, the total number and average energy rate during three typical periodic time of the April, June and October from the literature [4]. The results show that the dimension of saturate phase space $m = 9$, and the minimum delay time of the phase space elements $\tau = 3$.

In order to analyze the features of change on Lyapunov Exponent of the number of AE major events N_L, the total number N and average energy rate N_E, observed datum are computed every nine times to get the Lyapunov Exponent. Fig. 1 is the calculation results of the April.

From Fig.1, we can see that during roof movement, the Lyapunov Exponent curves of N_E and N show the following laws.

(1) The Lyapunov Exponent is usually negative or the curve is in the area of dropping at the period of main roof weighing. On April 17, the Lyapunov Exponents of N_E 、 N are 1.2、 0.4.The weighing started on April 19 and on April 20, the Lyapunov Exponents of N_E 、 N are –0.7 、 0.1. The analysis

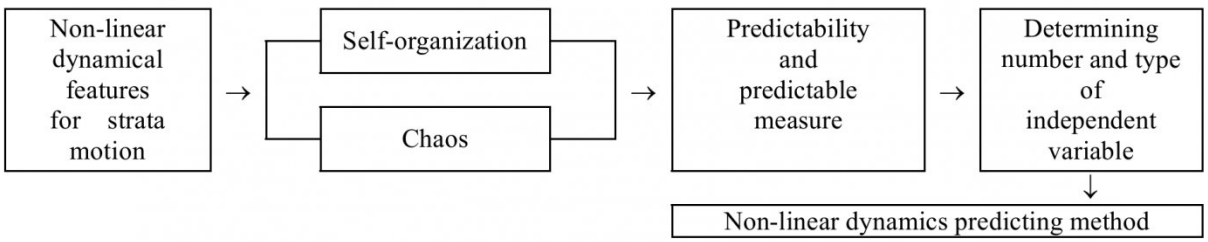

Fig. 3. Elementary frames of non-linear dynamic features and predictions for strata motion

illustrates that the degrees of disordering increase during the process of extension and transfixion between macro-crack and micro-crack ahead of remarkable roof movement, which behaves the increase of chaos features of AE. However, once main roof weighing begins, namely after the transfixion of macro-crack, the roof evolves in the direction of ordering through rotating weighing to reach a new balanced mode.

(2) During the movement of roof, the Lyapunov Exponents show the features of alternation of "+" and "-", which indicates that roof motion experiences complex dynamic states including the alternation of periodic motion, quasi-periodic motion and chaos motion. At the period of chaos of roof motion, it is usually difficult to predict the evolution of roof movement because of the sensitivity to disturbance, so careful evaluation on the predictability is the problem to be further considered.

4. Back prediction of non-linear dynamics for strata motion

4.1. A basic non-linear back analysis predicting method for strata motion

Strata motion is expressed by a non-linear differential equation of high order, and is further described by state space. Assume the evolution of state variable χ_i describing strata motion system with time

$$\frac{dx_i}{dt} = \varphi_i(\chi_1, \chi_2, \Lambda, \chi_n), i = 1,2,..,n \quad (4)$$

The equation (4) may be written in the form of difference, and the minimum two-solution can be gotten by extracting generalized inverse matrix of coefficient matrix through decomposition of rare value from measured datum.

4.2. The method determining independent variables for strata motion

4.2.1.The method determining the number of variables for strata motion

The numerical results [5-6] from computer experiments show that those points gotten by ordinary differential equation or the evolution of mapping with time form a rare set of self-similar results, and the following equation is used to describe the relation between its fractal dimension D_C and the independent variable n_v of dynamical process is

$$n_v \geq |D_c| + 1 \quad (5)$$

As to a dynamical system, however, there are at least three variables to express complicated dynamical features like chaos, so a criterion, determining the number of system variables for the evolution of strata motion, is presented

$$n_v = \max\{\text{int}|D_C| + 1, 3\} \quad (6)$$

4.2.2. The method determining the type of variables for strata motion

There are plenty of variables describing the evolution process of strata motion. For example, deformation quantity of wall rock, deformation velocity of wall rock, load of support, number of AE event, average energy rate etc. It is essential to identify that which ones of these variables are correlative, which ones show identical or similar properties of the system, otherwise it's by no mean to select independent variables describing the features of evolution of system.

Self-organization characteristic mapping is a kind of clustering analysis method of NN (Neural Network) without teachers' supervision, clustering center formed by which can map onto a plane or curved surface while keeping the topology fixed. Assume $X \in R^K$ is input mode vector, W is weighting vector matrix, and $Y \in R^K$ is output node vector (see Fig. 2).

Studies show that the above method can cluster Exponents and variables of identical or similar properties together, so it offers an effective tool for selection of the type of independent variables correctly.

3. Conclusion

Non-linear dynamical features and predictions for strata motion is a new problem on the leading edge of the subject. Through the studies, an elementary frame is put out (see Fig 3). Certainly, the frame is primary and needs to be further perfected and deepened

Acknowledgement

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