Correlative Analysis Method and Its Application in Highway Slope Engineering

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Abstract. Highway slope engineering is faced with a large number of information elements, and the complicated relationship between these information elements makes the slope stability evaluation very difficult. This paper introduces the correlative analysis method of Extenics, and puts forward the concept of “slope stability correlative chain”. Starting from matter-element $M=(\text{slope}, \text{stability}, v)$, the slope stability correlative network is established. The case analysis shows that the correlative analysis method can help to analyze the stability of highway slope, and has great engineering application value.

1. Extenics and Extensible Analysis Principles
Extenics is a subject founded by Chinese scholar Cai Wen in 1983[1]. Extenics uses formalized models to study the extension possibility of things and explore the laws and methods of innovation, so as to solve the contradictory problems (including incompatible problems and antithetical problems) in reality. Extenics method is helpful to get rid of the excessive dependence on experience, inspiration and other individual abilities when solving the contradictory problems [2,3].

The logical cell of Extenics is basic-element, including matter-element "M", affair-element "A" and correlation-element "R"[4]. Basic-element is formally expressed as $B=(O,C,V)$, where $O$ is the object, $C$ is the characteristic, and $V$ is the value about the characteristic. The value can be a quantitative number or a qualitative description. A basic-element can be one-dimensional or multi-dimensional, and it can also be a parametric basic-element. Extensible analysis principles include divergent analysis principle, correlative analysis principle, implicative analysis principle, expandable analysis principle and conjugate analysis principle.

2. Principle of Correlative Analysis
If there is a certain dependence between the value of a certain evaluation characteristics and other basic-elements, it is called correlation[5]. The principle of correlative analysis can be expressed as:
Given matter-element \( M(t) = (O_w(t), c_m, c_n(O_w(t))) \), there exists at least one matter-element \( M'_w(t) = (O_w(t), c_m, c_n(O_w(t))) \) with the same characteristics, or matter-element \( M'_c(t) = (O_c(t), c_m, c_n(O_c(t))) \) with the same object, or foreign matter-element \( M'(t) = (O_c(t), c', c_n(O_c(t))) \), so that \( M(t) \sim M'_w(t) \), or \( M(t) \sim M'_c(t) \), or \( M(t) \sim M'(t) \).

In the above principle, the symbol "\( \sim \)" means correlation. According to this principle, when a matter-element can not solve a problem, it can be considered to use the correlated matter-elements to solve it. The establishment of correlative network is also very beneficial to the analysis of the problem to be solved.

3. Application of Correlative Analysis in Highway Slope Engineering

Various objects involved in highway slope engineering are not isolated, they are inextricably linked with other matters. Due to the existence of these connections, when an object changes, it will cause changes in its correlated objects. The relationship between a matter-element and other matter-elements, such as network structure, is also called correlative network. The correlative network is dynamic, but at a certain time, it is uniquely determined for a given matter-element. Correlative network can be used to analyze the causes of problems, as an auxiliary means to solve slope engineering problems.

For example, a highway design institute plans to design a 21m high embankment. Is this plan feasible? What problems will be brought about by the implementation of this scheme? We can start from matter-element \( M = \) (embankment, height, 21m), carry out correlative analysis, and establish the correlative network of matter-element \( M \), as shown in Figure 1.

![Figure 1. Correlative network of high embankment](image)

The above correlative network can also be expressed as

\[
M \sim M'_w \sim M'_c \sim M' \sim M_1 \sim M_6 \\
M \sim M_7 \sim M_8 \sim M_9 \\
M \sim M_{10} \sim M_{11} \\
\cdots
\]
It can be seen from the correlative network that in order to fill this section of high embankment, it is necessary to check the stability of the embankment, formulate a special construction scheme for embankment filling, study the operation safety after the completion of high embankment, and analyze the economy of embankment construction. According to the results of embankment stability checking, the reinforcement or protection measures to be taken, the construction methods and economy of reinforcement or protection measures are determined. When making the filling scheme of high embankment, because of the large demand of filling material, the first thing to consider is whether the source of filling is reliable and whether it is economical. It is necessary to consider the safety of the embankment after its completion. It can be seen that the establishment of correlation network is very beneficial to the comprehensive analysis of slope engineering problems.

There are many factors affecting the stability of cutting slope, which can be summarized into four points, namely, the characteristics of rock mass discontinuity, the geometric shape of slope, the mechanical properties of rock and soil and the effect of external force. But these factors are not isolated, they are related to many other factors.

starting from matter-element $M = \{\text{slope, stability, } \nu\}$, a general correlative network of slope stability can be established, as shown in Figure 2.

Figure 2. Correlative network of slope stability

It should be pointed out that the geology, external load characteristics and construction methods of each slope are quite different. In slope engineering design, the correlative basic-elements should be further added or reduced based on the correlative network given in Figure 2 according to the specific situation.

For complex highway slope engineering, the possible failure mechanism of slope should be further studied. There are many information elements in practical slope engineering, so it is necessary to find an effective tool to sort out and summarize these information. By using the correlative analysis method, the factors related to the slope stability can be analyzed intuitively, carefully and systematically. Combined with professional knowledge, the possible failure mechanism of the slope can be analyzed. The same slope may have a variety of failure mechanisms. In the slope stability related network, we can start from one or several basic-elements that have a great impact on the slope stability, find the correlative chain of this basic-element (that is, the correlative chain that has the greatest impact on the slope stability), and then combine with professional knowledge to study and judge its possible failure mechanism. For example, the physical and mechanical indexes of a slope in its natural state can basically ensure the stability of the slope, but the rainfall in the area where the slope is located is very abundant. Before the support is carried out, that is, when the influence of the support measures on its stability is not considered, the correlation chain that has the greatest impact on the stability of the slope is shown in Figure 3 (the figure is taken from Figure 2).
4. Conclusions

Correlative analysis is an extensible analysis method. To sum up, the basic steps of the application of correlative analysis method in highway slope engineering are as follows:

1. Write out the basic-element $B$ of the object to be analyzed (usually, the slope construction method, the slope itself, some engineering geological characteristics, etc.);
2. Based on the principle of correlative analysis and the knowledge of slope engineering, the correlative network of element $B$ is listed;
3. The correlative network is analyzed to determine the element $B_i$ that causes the change of element $B$ or the element $B_j$ that changes due to the change of element $B$;
4. Analyze the conduction effect, select a basic-element $B_i$ in the correlative network to solve the problem; or find the correlative chain of $M = \{\text{slope, stability, } \nu\}$ to analyze the stability of the slope.

Appendix: Extenics symbols and their meanings in this paper

| Symbol | Implication | Symbol | Implication |
|--------|-------------|--------|-------------|
| $B$    | Basic-element| $M$    | Matter-element|
| $A$    | Affair-element| $R$    | Relation-element|
| $O$    | Object of basic-element| $C$    | Characteristic of basic-element|
| $\nu$  | Value about the Characteristic of basic-element| $\sim$ | Correlation|

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