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Expression and Treatment of Two Kinds of Contradictory Problems in Highway Slope Engineering

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Abstract:

In order to study the contradictory problems encountered in slope treatment in highway engineering, the basic theory of Extenics is introduced, and the expression and treatment methods of incompatible problems and opposite problems in highway slope engineering are put forward, including the definition of goals, conditions, problems, the generation method of extensible strategy to deal with incompatible problems, the transfer bridge method to deal with opposite problems, etc. These methods are descriptive, computable, extensible and easy to master. They can get rid of the excessive dependence on the experience, inspiration, insight and other individual abilities of engineering and technical personnel. Under the background of advocating the harmonious coexistence between man and nature, they are of great significance to guide the design and construction of highway slope engineering.

***Keywords**: Highway slope, Incompatible problem, Opposite problem, Extensible strategy, Transfer bridge.*

I. INTRODUCTION

Contradiction, transfer and unity run through the whole development process of human society, and highway slope engineering is no exception. These contradictions include the overall situation, such as the contradiction between slope construction and ecological environment, the contradiction between quality, construction period and cost; There are also local problems, such as how to realize ecological slope protection under the condition of extremely unstable slope, how to implement a certain support scheme when the existing conditions do not allow, and so on. Today, when advocating the harmonious coexistence between man and nature [1], it is required to innovate the design concept, improve the design quality, reduce the project cost, and achieve the harmonious unity of man, highway and nature

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[2-5]. The fact corresponding to the above requirements is that for a long time, these contradictions have been expressed in natural language, lack of effective expression, communication and calculation tools, and the solution to these problems can only rely on individual experience or ability to a great extent. In this context, a series of new topics have emerged, that is, is there a logical expression of the contradiction in highway slope engineering? Whether solving these problems can get rid of the excessive dependence on individual abilities such as experience, inspiration and insight, and whether there are ideas and laws to follow to solve these contradictory problems? The study of the above problems has very important methodological significance and practical value for the design and construction of highway slope.

Extenics is an original cross-sectional discipline across philosophy, mathematics and engineering proposed by Chinese scholar Cai Wen in 1983 [6, 7]. It has the characteristics of formalization, logic and mathematics. Its research object is contradiction, including the laws, theories and methods of dealing with contradiction. This paper introduces the basic theory of Extenics and combines the characteristics of highway slope engineering, and puts forward the expression and treatment methods of incompatible problems and opposite problems in highway slope engineering. This method is descriptive, computable, extensible and easy to master [8], which can be used as a reference for highway engineering technicians.

II. DEFINITION OF CONTRADICTORY PROBLEMS IN HIGHWAY SLOPE ENGINEERING

2.1 Definition of Goals

There are many kinds of goals in highway slope treatment. Common goals include ensuring slope stability, shortening construction time, reducing construction cost, realizing construction with a specific method, improving highway appearance and coordinating environment, etc. sometimes it is also required to achieve the above goals at the same time.

Setting goals is not only the premise of defining problems, but also the key to determining whether we can effectively find clues and ideas to solve problems. Goals can be abstract, specific, qualitative or quantitative, but they should be specific and digital as much as possible to facilitate processing and inspection. For example, the goal of "increasing the stability of slope as high as possible" is not clear enough. If it is changed to "increase the safety factor of slope stability by 30%", this goal can be formally expressed as follows:

$$g=\begin{bmatrix} \text{increase}, & \text{dominant object}, & \text{safety factor of slope stability} \\ & \text{range}, & 30\% \end{bmatrix} \tag{1}$$

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There can be only one goal or multiple goals. For example, while "increasing the safety factor of slope stability by 30%, it is also required to achieve" reducing the construction cost by 20% ", then this goal can be formally expressed as follows:

$$g = g_1 \wedge g_2 = \begin{bmatrix} \text{increase,} & \text{dominant object,} & \text{safe factor of slope stability} \\ & \text{range,} & 30\% \end{bmatrix} \wedge \begin{bmatrix} \text{reduce,} & \text{dominant object,} & \text{cost} \\ & \text{range,} & 20\% \end{bmatrix} \quad (2)$$

If there are multiple goals, in order to facilitate the definition and solution of the problem, the relationship between goals should also be analyzed. If the goal g_i is a component of g_j, g_i and g_j are subordinate ($g_j \Rightarrow g_i$), otherwise they are parallel; If goals g_i and g_j cannot be achieved at the same time under certain conditions, g_i and g_j are opposite, otherwise they are coexistence. For example, there are two sets of goal basic-elements g_3 and g_4, g_3 = (slope protection, ecological effect, good), g_4 = (slope vegetation coverage, numerical value, 100%), then g_3 and g_4 are subordinate ($g_4 \Rightarrow g_3$).

2.2 Definition of Conditions

After the goal is defined, it is necessary to analyze and define the existing conditions. Conditions include resource conditions and environmental conditions [9]. Resource conditions include internal resource conditions and external resource conditions. Environmental conditions are also divided into internal environmental conditions and external environmental conditions. The above conditions are divided into favorable conditions and unfavorable conditions (Table I). Most conditions exist objectively, but they can be created and changed.

The steps of defining conditions can be summarized as follows:

(1) Collect data related to slope engineering goals;

(2) Combined with the knowledge of slope engineering, analyze the conditions a required to achieve the goal;

(3) Determine the realistic condition l' corresponding to l_i and analyze the difference between l' and l_i;

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(4) l' is formally represented by basic-elements. Like the goal basic-element, the condition basic-element should be as specific and digital as possible.

TABLE I. Conditions' classification of highway slope engineering

CONDITIONS' CLASSIFICATION		COMMON CONDITIONS
Resource conditions	Internal resource conditions	Existing technical solutions; Existing slope engineering protection measures and construction conditions; The qualification, reputation, capital, technology, equipment and management level of all participating enterprises in slope engineering.
	External resource conditions	Cooperation with other enterprises; Support of all parties to the engineering, etc.
Environmental conditions	Internal environmental conditions	Slope geological structure; Lithology; Groundwater conditions; Shape features; Physical and mechanical indexes of rock and soil mass, etc.
	External environmental conditions	Regional rainfall; Earthquake; Slope erosion; External weathering; Cutting excavation method; Other loads, etc.

2.3 Definition of Problems

The contradictory problems in Extenics can be divided into two kinds [10]: one is the contradictory problem between subjective and objective, which is called incompatible problem; The second kind is the problem of subjective and subjective contradiction, which is called opposite problem.

The contradictory problem is formally expressed as: if the goal g cannot be achieved under conditions l, the problem $P = g*l$ is called incompatible problem and recorded as $g\uparrow l$; If the

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goals $g_1, g_2, ..., g_n$ cannot be achieved at the same time under certain conditions l, the problem P = $(g_1 \wedge g_2 \wedge ... \wedge g_n)$ *l is called an opposite problem, which is recorded as $(g_1 \wedge g_2 \wedge ... \wedge g_n) \uparrow l$.

Incompatibility and opposite problems exist widely in highway slope engineering. For examples, under certain conditions, some protection works cannot be constructed; Under certain conditions, the slope protection project cannot be completed on time; Construction according to a certain design scheme can not effectively improve the safety factor of slope stability; Under certain conditions, it can not guarantee to effectively improve the stability coefficient and realize ecological landscape slope protection; Under certain conditions, it is impossible to increase the quantity of protection works and reduce the cost.

For simple problems, we only need to judge whether they are incompatible problems or opposite problems subjectively. [11] In a strict mathematical sense, the types of problems should be defined by correlation function (compatibility function or coexistence function).

The following is an example to illustrate the definition process of contradictory problem: for the rock cutting slope of a highway, the stability factor is 1.70. In order to improve the appearance and ecology along the highway, it is proposed to plant grass for slope protection, and for the survival or growth of herbaceous plants, it is required to have at least 6cm to 10cm thick planting layer. Subjectively, there are no vegetation conditions on the rock slope, and the ecological protection goal can not be achieved. This problem is incompatible problem. The problem P is strictly defined below. Set the goal basic-element as:

$$G = \begin{bmatrix} \text{protect,} & \text{dominant object,} & (\text{rock slope, stability factor, } 1.70) \\ & \text{method,} & \text{planting grass} \\ & \text{location,} & \text{surface of slope} \end{bmatrix} \quad (3)$$

the condition basic-element is L = (slope surface, medium, rock), take the evaluation feature c0 = thickness of planting layer on the slope, the positive field is $X0 = <a, b> = <6, 10>$ cm, the value field is $X = <0, +\infty>$ cm, $X0 \subset X$, the optimal point is M=10, the quantity value that condition L can provide to characteristic c0 is 0, the compatibility function is established [12]:

$$k(x) = \begin{cases} \dfrac{x-a}{M-a}, x \le M \\ \dfrac{b-x}{b-M}, x \ge M \end{cases} \quad (4)$$

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the thickness of planting layer provided by slope is x=0<M, therefore, the value of the compatibility function is

$$k(x)=k(0)=\frac{0-6}{10-6}=-1.5<0 \tag{5}$$

Correctly defining contradictory problem is the premise of effectively studying and dealing with problems. The above example also shows that in the process of defining goals, conditions and problems, the knowledge related to highway slope engineering plays an important role, especially the determination of evaluation feature c0. In this problem, if you do not have professional knowledge and take c0 as other features, the problem will be wrongly defined and may become an unsolved problem. In other words, extension studies the expression and treatment strategies of contradictory problems, not only does not exclude the knowledge of specific professional fields, on the contrary, it needs extensive professional knowledge to support, so as to correctly and effectively deal with the contradictory problems in specific disciplines [13-15].

The steps to define the problem can be summarized as follows:

(1) Define the goals and existing conditions of slope engineering.

(2) Combined with the knowledge of highway slope engineering, it is first subjective to judge whether the problem belongs to incompatible problem or opposite problem.

(3) Combined with the knowledge of highway slope engineering, the appropriate evaluation features are selected.

(4) If the subjective judgment problem is incompatible, the compatibility value is calculated by the compatibility function. If the compatibility value is less than 0, the subjective judgment is correct; If the subjective judgment problem belongs to the opposite problem, the coexistence degree value calculated by the coexistence degree function. If the coexistence degree value is less than 0, it indicates that the subjective judgment is correct.

III. SOLUTION METHOD OF INCOMPATIBLE IN HIGHWAY SLOPE ENGINEERING

The Extenics model of incompatible problem is P = G*L. From the model expression, we can see that there are no more than three ideas to solve incompatible problem:

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(1) The incompatibility problem is solved through the transfer of conditions L (the goal remains unchanged);

(2) The incompatible problem is solved through the transfer of goals G (the conditions remain unchanged);

(3) The goals G and conditions L are changed to solve the incompatible problem.

No matter which way of idea, the key is to find the extension transfer T (solution transfer of incompatible problem, also known as extension strategy) to make the compatibility function value of the problem > 0, that is:

$$T_K K = K^{'}\left(P^{'}\right) > 0 \tag{6}$$

When solving incompatible problems, the process of generating solution transfer T is called extension strategy generation. When dealing with the incompatible of highway slope engineering, the idea of generating extension strategy is as follows:

(1) After defining the goals and conditions of the problem, express the goal G and the collected condition information L (resource conditions and environmental conditions) in the form of basic-elements. First, judge whether the problem belongs to incompatible problem subjectively according to the knowledge of highway slope engineering. If so, establish the extension model of incompatible problem P = G*L.

(2) Using the knowledge of highway slope engineering, analyze the value required about c0 when goal G is achieved and the value that the object element in condition L can provide about c0. According to the value field required by the objective and the value field provided by the conditions, the compatibility function K(P) of the problem is established. If K(P) < 0, the problem is an incompatible problem. The compatibility function can also be used to judge the contradictory degree of the problem.

(3) In general, the existing conditions in slope engineering, especially the environmental conditions are difficult to change. Therefore, when the required goal G is only related to these conditions that are difficult to change, we can first consider expanding and analyzing the goal G of the problem. Because goal G is the final object that must be achieved, the implicative

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analysis method in the extension analysis should be generally selected (divergent analysis and correlation analysis can also be used in the analysis process), and the knowledge of slope engineering should be used to find the lower goal of G and establish the goal implication system, as shown in Fig 1. If the lower goal can be achieved under the existing conditions L, goal G is achieved.

$$G \Leftarrow \begin{cases} G_1 \Leftarrow \begin{cases} G_{11} \Leftarrow \cdots \\ G_{12} \Leftarrow \cdots \\ \vdots \\ G_{1m} \Leftarrow \cdots \end{cases} \\ G_2 \Leftarrow \cdots \\ \vdots \\ G_n \Leftarrow \begin{cases} G_{n1} \Leftarrow \cdots \\ G_{n2} \Leftarrow \cdots \\ \vdots \\ G_{nl} \Leftarrow \cdots \end{cases} \end{cases}$$

Fig 1: implication system of the goal

(4) If the goal G cannot be achieved according to the method in the previous steps, the extension analysis of the condition L of the slope engineering problem can be considered. In order to extend the condition information as much as possible, the following steps can be carried out in sequence:

a. Carry out correlative analysis on the existing conditions L and establish its correlation network or correlation tree (Fig 2):

$$L \sim \begin{cases} L_1 \sim \begin{cases} L_{11} \sim \cdots \\ \vdots \\ L_{1h} \sim \cdots \end{cases} \\ L_2 \sim \cdots \\ \vdots \\ L_n \sim \begin{cases} L_{n1} \sim \cdots \\ \vdots \\ L_{nm} \sim \cdots \end{cases} \end{cases}$$

Fig 2: correlation tree about conditions

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b. Through the divergent analysis of the leaves of the correlation tree in Fig 2, the divergent trees under various conditions can be obtained (Fig 3). If the leaves are matter-elements, the conjugate analysis of virtual reality, soft and hard, positive and negative, latent and obvious can also be carried out, so as to obtain a variety of ideas to solve the problem.

$$L_{11}-\left|\begin{cases}L_{111}\\L_{112}\\\vdots\\L_{11j}\end{cases},\cdots,L_{1h}-\right|\begin{cases}L_{1h1}\\L_{1h2}\\\vdots\\L_{1hs}\end{cases};\cdots;L_{n1}-\left|\begin{cases}L_{n11}\\L_{n12}\\\vdots\\L_{n1f}\end{cases},\cdots,L_{nm}-\right|\begin{cases}L_{nm1}\\L_{nm2}\\\vdots\\L_{nmd}\end{cases};\cdots$$

Fig 3: tree of divergent conditions

c. It is possible to get more ways to solve the problem by performing expandable analysis (combination or decomposition) on the leaves of the correlation tree about conditions after divergence in Fig 2.

(5) If the goal G still cannot be achieved according to the method in the previous step, analyze both goal G and condition L, establish the correlation tree and implication system of problem P, and then conduct divergent analysis or conjugate analysis on each element in the correlation tree and implication system.

(6) After implementing the above steps, if the method to solve the problem is found, the extension transfer or the operation of extension transfer is implemented, as shown in Fig 4 (taking the transfer of conditions in Fig 2 as an example), and then the compatibility function value of the original problem is changed through conduction transfer, so that $T_K K(T_L L)=K'(L') > 0$, the extension transfer of $K'(L') > 0$ or the operation formula of extension transfer, that is, the extension strategy to solve the incompatible problem.

$$\mathop{\wedge}_{i=1}^{n} {}_{L_i}T_L \Leftarrow \begin{cases}T_{L_1}\\T_{L_2}\\\vdots\\\mathop{\wedge}_{i=1}^{m} {}_{L_{mi}}T_{L_m} \Leftarrow \begin{cases}T_{L_{m1}}\\\vdots\\T_{L_{nm}}\end{cases}\end{cases}$$

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Fig 4: extension transfer implication system of conditions

(7) There are many strategies to solve the incompatible problem in slope engineering. If necessary, multiple strategies can be evaluated and optimized by superiority evaluation method.

IV. SOLUTION METHOD OF OPPOSITE PROBLEMS IN HIGHWAY SLOPE ENGINEERING

The Extenics model of the opposite problem is $P = (G_1 \wedge G_2) * L$, the solution of the opposite problem requires multiple goals that could not coexist under certain conditions. In Extenics, this solution transfer that can "go its own way and get its place" in dealing with opposite problems is called transfer bridge, which is defined as follows:

Given the opposite problem $P=(G_1 \wedge G_2) * L$, $(G_1 \wedge G_2) \uparrow L$, if there is transfer $T = (T_{G1}, T_{G2}, T_L)$, so that $(T_{G1}G_1 \wedge T_{G2}G_2) \downarrow T_L L$, T is called the solution transfer of problem P, which makes G_1 and G_2 coexist. The transfer object of solution transfer T is called transfer bridge and is recorded as B (G_1, G_2).

The process of solving the opposite problem is essentially the process of constructing the transfer bridge. However, the construction of transfer bridge is still inseparable from extension analysis (matter-element also includes conjugate analysis). Next, the solving steps of opposite problems in highway slope engineering are analyzed.

(1) After defining the goals and conditions of the problem, express the goal (G_1, G_2) and the collected condition information L (resource conditions and environmental conditions) in the form of basic-elements. First, judge whether the problem belongs to opposite problem subjectively according to the knowledge of highway slope engineering. If so, establish the extension model $P = (G_1 \wedge G_2) * L$ of opposite problem.

(2) Using the knowledge of highway slope engineering, the coexistence degree function $K_l(g_1, g_2)$ of the problem is established according to the value field required by the goal and the value field provided by the conditions. If $K_l(g_1, g_2) < 0$, the problem is an opposite problem.

(3) In general, the existing conditions in slope engineering, especially the environmental conditions, are difficult to change, so the extension analysis and transfer of the goals (G_1, G_2) of the problem can be considered first. Because goals (G_1, G_2) is the final objects that must be achieved, we should choose the implicative analysis method in the extension analysis (divergent analysis and correlative analysis can also be used in the analysis process), use slope

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engineering knowledge to find the lower goals of goals G_1 and G_2, and establish the goals' implicative system. If the lower goals of G_1 and G_2 can be achieved simultaneously under the existing condition L, the existing condition itself can be used as a turning part or transfer bridge, $K_L(G'_1, G'_2) > 0$.

When analyzing multiple goals, attention should also be paid to the use of slope engineering knowledge to distinguish the priority of goals. For example, among the many goals of highway slope protection, if one of the goals is to "ensure slope stability", this goal undoubtedly has priority, because once the slope is unstable, other goals will lose their significance. At this time, it should be considered to achieve the stable slope first, and then construct the transfer bridge on this basis to achieve other goals together.

(4) If the opposite problem cannot be solved in the previous step, consider extend and analyzing the condition L and implementing transfer to form a turning part or conversion channel so that $K_L'(G_1, G_2) > 0$.

(5) If the opposite problem has not been solved in the previous step, the extension analysis and transfer of condition L and target (G_1, G_2) are implemented at the same time. If $K_L'(G_1, G_2) >0$, the opposite problem is transformed into coexistence problem.

V. CONCLUSION

From the perspective of Extenics, this paper studies the classification and definition methods of contradiction problems in highway slope protection and the idea of solving contradictory problems. Contradictory problems are divided into incompatible problems and opposite problems. The mathematical basis for judging the category of contradictory problems is the compatibility function and coexistence function value of the problem. Defining contradictory problem includes three steps: defining goals, defining conditions and defining problems. According to the characteristics of highway slope engineering, an extension strategy generation method for solving incompatible problems and a transfer bridge method for solving opposite problems are proposed. These methods can be described, calculated, extensible and easy to master, and can get rid of the excessive dependence on the experience, inspiration, insight and other individual abilities of engineering and technical personnel. Under the background of advocating the harmonious coexistence between man and nature, it is of great significance to guide the design and construction of highway slope engineering.

When using these methods, it should also be noted that highway slope engineering is a complex system engineering, there are many influencing factors, and there are countless connections between various factors. Therefore, when dealing with the contradictory problems in highway slope engineering, we should pay attention to analyze the possible conduction contradictory problems, so as to determine whether to implement the solution transfer to solve the original contradictory problems.

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