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Effect Evaluation of Bench Blasting Based on Unascertained Measurement Model

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Abstract. In order to resolve the uncertainty problem of influence factors in effect evaluation of bench blasting, the effect evaluation model of bench blasting based on uncertainty measurement theory was built, then this model was used to evaluate the bench blasting effect in Hongshuitai flat engineering. The evaluation results show that: the information entropy and confidence identifying criterion were respectively used to ascertain the evaluation index weight and identifying criterion, by these ways, the evaluation results of this model are more objective; and the evaluation index can be selected flexibly according to actual situation, the calculation of evaluation model is simple, so the evaluation results can offer decision basis for blasting workers to make timely adjustment of the blasting scheme.

Introduction

With the development of national economic construction, the bench blasting was increasingly applied in many areas such as mining, cutting shaping of rail and road and so on. So how to achieve optimum blasting effect has been a concern topic for the majority of blasting workers. However, in the actual project, for there are many factors influence the effect of bench blasting, it is difficult to give a reasonable evaluation of the blasting effect. Therefore, the study for effect evaluation of bench blasting is important significance for making optimal blasting scheme to improve the blasting effect and increase the economic efficiency of blasting engineering. For making accurate evaluation of bench blasting effect and providing a judging decision for improving the blasting scheme, the study of evaluation of bench blasting effect is needed. However, the present study about bench blasting effect is less, mainly because there are many influencing factors in evaluating the bench blasting effect, so it is difficult to make effect evaluation for bench blasting. The current evaluation method for blasting effect is mainly used AHP, fuzzy mathematics and gray correlation analysis. Such as Ma Li[1] established a comprehensive evaluation model of blasting effect based on the fuzzy mathematical theory; Hu Xinhua[2] established a comprehensive evaluation model of blasting effect based on the AHP and gray correlation analysis. However, for there are uncertainty in determining the influence factors of blasting effect, so the model based on fuzzy mathematic, AHP and gray correlation analysis often loss the information, and exist defects such exist subjective misjudgment in weight distribution and determine. In recent years, the uncertainty measurement theory was used by many scholars to make a comprehensive evaluation for multi-factor index, and obtained many achievement[2-4], and this article will use this theory to establish evaluation model of blasting effect and study its practical application .

Uncertainty Measurement Theory

Uncertain measure of a single index. Given a_1, a_2, …, a_i indicates n factors to be evaluated concerning the object, noting A={ a_1, a_2, …, a_i }; each single-factor evaluation index a_i has j evaluation grades b_1, b_2, …, b_j, then a_{ij} is used to indicate the observed value of single-factor a_i as an object to be evaluated on the jth evaluation grade b_j. The single-factor evaluation index a_i, when it

is in the jth grade of comment, is marked as a_{ij}. This paper adopts an expert grading method, providing that the sum of the value of points on the grade of all the comment about each evaluation factor is 100 points, the related experts will give 0~100 respectively to each grade b_j of the comment on each evaluation factor a_i, marking $\sum_{j=1}^{j} a_{ij} = 100$. The use of $u_{ij} = a_{ij}/100$ indicates that the observed value a_{ij} makes a_i stay at the uncertain measure angle of the grade b_j of the comment. u_{ij}, as the result of measure of 'degree', is the possibility measure. From this, we can obtain the measurement matrix of a single evaluation index as the evaluated object.

$$u_{ij} = \begin{bmatrix} u_{11}, u_{12}, \cdots, u_{1j} \\ u_{21}, u_{22}, \cdots, u_{2j} \\ \vdots \quad \vdots \quad \cdots \quad \vdots \\ u_{i1}, u_{i2}, , \cdots, u_{ij} \end{bmatrix} \quad (i = 1,2,\cdots,n) \tag{1}$$

Determination of the index weight. Entropy was first brought forward in thermo-dynamics by Clautheus and used to describe the state of a system, and in later years it was introduced to many domains. For a discrete random variable, its information entropy $S = -k\sum_{i=1}^{k} P_i \ln P_i$, where $P_i \geq 0$, where $\sum_{i=1}^{n} P_i = 1$. Entropy has such characteristics as symmetric, non-negative, additive and of extreme value. Given the space of natural state X=(x_1, x_2, …, x_n) is an uncontrollable factor. In the formula, x_i is the state that has occurred. Given the prior probability distribution of each state that occurred in X is $P(X) = \{P(x_1), P(x_2), ..., P(x_n)\}$. The uncertain extent of this state is defined as an entropy function:

$$H(x) = -\sum_{i=1}^{n} p(x_i) \ln p(x_i), \quad (0 \leq p(x_i) \leq 1, \sum_{i=1}^{n} p(x_i) = 1) \tag{2}$$

The observed value x_{ij} of the evaluated object of the quality of blasting regarding a_i makes the uncertain measure of the objects that stay at each grade b_i of comment become u_{i2}, …, u_{ij}. If the uncertain measure u_{ij} is regarded as p_i in H(x), then we have

$$H(u) = -\sum_{j=1}^{j} u_{ij} \ln u_{ij} \quad v_i = 1 - \frac{1}{\ln j} H(u) = 1 + \frac{1}{\ln j} \sum_{j=1}^{j} u_{ij} \bullet \ln u_{ij}, \quad w_i = \frac{v_i}{\sum_{i=1}^{i} v_i} \tag{3}$$

W_i ($0 \leq W_i \leq 1$, and $\sum_{i=1}^{i} W_i = 1$) is the weight of the evaluation index a_i.

Comprehensive evaluation system. If the measurement matrix of single evaluation index concerning the evaluated objects is known, then the classified weights of each index about the evaluated objects are obtained in Formula (3). Let

$$u_j = W \bullet u_{ij} = (w_1, w_2, ..., w_i) \bullet \begin{bmatrix} u_{11} & u_{12} & \ldots & u_{1j} \\ u_{21} & u_{22} & \ldots & u_{2j} \\ \ldots & \ldots & \ldots & \ldots \\ u_{i1} & u_{i2} & \ldots & u_{ij} \end{bmatrix} \tag{4}$$

Then u_i is a evaluation vector of the blasting as an evaluated object, describing the classification of uncertainty. In order to obtain the classifications of certainty, the difference of confidence needs to be marked. Because the grade division of comment is in order and because the grade b_j of the jth comment is 'better' than the grade b_{j+1} of the $j+1$ comment, the discrimination criterion for the maximum measure is not suitable to this case. We have to turn to use the discrimination criterion of confidence.

Given the confidence is $\lambda,(\lambda > 0.5)$, then 0.6 or 0.7 is usually adopted, let

$$j_0 = \min_j \left\{ j : \sum_{j=1}^{j} u_{ij} \geq \lambda, j = 1,2,...,j \right\} \quad (5)$$

Then it's judged that the evaluated object belongs with the j_0 th evaluation grade b_j.

Case Test

Establishment of the index evaluation system. By applying the theory and method of systematic engineering to set up an index system of a complete structure, a substantial content and convenient use for evaluating the quality of blasting, so as to provide a basis[5] for making accurate prediction of bench blasting effect and providing a judging decision for improving the blasting scheme. This paper in combination with one bench blasting in Hongshuitai flat engineering, established a pre-valuation index system of bench blasting effect based on the uncertainty measurement theory, the index system for evaluation of the bench blasting effect as shown in Table1.

Table 1 Index system for evaluation of the bench blasting system

first-class	second-class	first-class	second-class
Quality of blasting A_1	Drilling cost a_1 Forward & backward strokes a_2 Cost of priming materials a_3 Unit consumption of explosives a_4 Coefficient of bulk increase a_5 Shoveling efficiency a_6 Boulder ratio a_7 Toe a_8	Safety of blasting A_2	Explosion gas a_9 Explosive shock wave a_{10} Flying rock a_{11} Blasting vibration a_{12} Slope Stability a_{13} Dangerous rock a_{14} Blind shot a_{15}

Evaluation of bench blasting effect. The evaluation grades of each single factor for judging the quality of blasting are classified as: fine, good, general, relatively poor and poor, so that the experts give 100 points respectively to each evaluation grade of single factors, shown as Table 2.

Table 2 Results of the points that the experts give

Pre-valuated factors	Evaluation grade				
	fine	Good	general	Relatively	poor
Drilling cost a_1	21	43	25	9	2
Forward & backward strokes a_2	16	32	23	16	13
Cost of priming materials a_3	23	36	15	16	10
Unit consumption of explosives a_4	18	33	14	21	14
Coefficient of bulk increase a_5	30	41	13	11	5
Shoveling efficiency a_6	22	42	17	11	8
Boulder ratio a_7	31	41	13	11	4
Toe a_8	32	43	13	9	3
Explosion gas a_9	20	44	15	16	5
Explosive shock wave a_{10}	35	41	15	6	3
Flying rock a_{11}	35	40	15	7	3
Blasting vibration a_{12}	32	41	12	10	5
Slope Stability a_{13}	23	47	17	8	5
Dangerous rock a_{14}	27	47	13	10	3
Blind shot a_{15}	26	46	16	8	4

According to table2, the matrix of single-index uncertain measure is obtained as formula(6). By Formula (3) to calculate the index weight of the evaluation factors, we can have: W=（0.084, 0.017, 0.029, 0.017, 0.068, 0.050, 0.074, 0.089, 0.060, 0.096, 0.090, 0.074, 0.0079, 0.091, 0.084）. By means of Formula (4) we determine the final result of evaluation: u=(0.278, 0.425, 0.154, 0.0989, 0.044).

Assuming the confidence $\lambda = 0.7$: both the discrimination criterion of confidence and Formula (5) are applied to judge that the grade of evaluation of the blasting effect in this bench blasting is the second, namely 'good'.

$$u_{ij} = \begin{bmatrix} 0.21 & 0.43 & 0.25 & 0.09 & 0.02 \\ 0.16 & 0.32 & 0.23 & 0.16 & 0.13 \\ 0.23 & 0.36 & 0.15 & 0.16 & 0.10 \\ 0.18 & 0.33 & 0.14 & 0.21 & 0.14 \\ 0.30 & 0.41 & 0.13 & 0.11 & 0.05 \\ 0.22 & 0.42 & 0.17 & 0.11 & 0.08 \\ 0.31 & 0.41 & 0.13 & 0.11 & 0.04 \\ 0.32 & 0.43 & 0.13 & 0.09 & 0.03 \\ 0.20 & 0.44 & 0.15 & 0.16 & 0.05 \\ 0.35 & 0.41 & 0.15 & 0.6 & 0.03 \\ 0.35 & 0.40 & 0.15 & 0.07 & 0.03 \\ 0.32 & 0.41 & 0.12 & 0.10 & 0.05 \\ 0.23 & 0.47 & 0.17 & 0.08 & 0.05 \\ 0.27 & 0.47 & 0.13 & 0.10 & 0.03 \\ 0.26 & 0.46 & 0.16 & 0.08 & 0.04 \end{bmatrix} \quad (6)$$

Summary

By applying the theory and method of systematic engineering, it conducts a evaluation factor index system of bench blasting effect was established. A criterion is adopted respectively for discrimination of the information entropy and creditability in determining the weight of each evaluation index and the discrimination criterion, therefore avoiding the defects of the fuzzy comprehensive judgment in these two aspects, making the result of evaluation more objective. A evaluation of bench blasting effect in the blasting field is realized by means of a programmed method, favorable to the improvement of the managerial level on the part of the construction project, promoting the safe, reliable and economical and effective operation of blasting construction.

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