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CHOICE OF A RATIONAL TYPE OF EXPLOSIVE USING THE ANALYTIC HIERARCHY PROCESS

Обгрунтовано вибір раціонального типу вибухової речовини місцевого приготування за допомогою методу аналізу ієрархій з метою підвищення ефективності руйнування скельних порід на кар'єрах вибуховим способом. Результати дослідження можуть бути використані при проектуванні вибухових робіт на кар'єрах скельних порід

Ключові слова: метод аналізу ієрархій, вибухова речовина, підривні роботи, гірська порода, раціональний тип

Обоснован выбор рационального типа взрывчатого вещества местного приготовления с помощью метода анализа иерархий с целью повышения эффективности разрушения скальных пород на карьерах взрывным способом. Результаты исследования могут быть использованы при проектировании взрывных работ на карьерах скальных пород

Ключевые слова: метод анализа иерархий, взрывчатое вещество, взрывные работы, горная порода, рациональный тип

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1. Introduction

The explosives are used for the sand mining both open-cut and close-cut at present in the world. The demand for explosives increases from year to year. Most used explosives are the simplest (ANFO), igdanite-type, ammonium-saltpetrous and trinitrotoluene, water-filled charge and emulsion explosives [1].

From the choice of the rational type of explosives depends the quality of preparation of rock blasting (RB) and safety.

2. The literature review

The literature review [2-4] shows that the most important way to increase the efficiency and safety of RB is to extend the scope of a simple explosive composition. The comparison of the explosive materials was made by the means of the method of the analysis hierarchies. The materials: polymix ГР4-Т10, polymix ГР1/8, polymix ГР1/8 (85 %) + КРУК2 (15 %), polymix ГР1/8 (74 %) + КРУК2 (26 %) and compolight ГС6 contribute to capability enhancement for granites destruction. These explosives are characterized by the following criteria:

- the coefficient of the working capacity of explosive – e (H1);
- the specific discharge of explosive – q (H2);
- the cost of explosive in relation to grammonite 79/21 cost – S (H3);
- the CO volume in the explosion products – V_{co} (H4);
- the critical diameter of detonation – d_k (H5);
- the safe distance on effects of shock air wave on the constructions – r_c (H6) and people – r_h (H7).

The choice of rational type of explosive remains pending question. Therefore, one of the most important ways to increase the efficiency of the destruction of granite in the mining plant is the choice of an explosive with identifying the most effective option by ranking members of his criteria. A positive solution of this problem can be achieved by using the analytic hierarchy process (AHP) [5].

The work purpose is: to choose the explosive to increase granites destruction efficiency using the hierarchy analytical method. The research was carried out in accordance with the subject plan of scientific research of NTUU "KPI" № 0105U002292, which is carried out due to instructions of the Ministry of Education and Science of Ukraine.

3. Research results

This method is used to determine the weighting parameters of the process, product or service. The principle of method is as follows. We have a certain goal and a set of methods that can be used to achieve the goal. The selected objective is decomposed into a number of components of tasks or criteria (conditions). The implementation of these components is made the goal delivered. In accordance with the analysis hierarchy method the selected criteria are compared in pairs with each other. On the 9-th grade system the relative degree of importance of each criterion in pairs is determined. In the same way, through the paired comparison, the matrix of possible is received for every criterion. The coincidence degree is estimated for each criterion of the chosen method. Considering the degree of criteria importance, the weighting factor is determined for each method.

The hierarchy analysis method is effective when decision is made in a large number (more 5-7) of criterion and methods that may be used. This method can be successfully used when the number of criteria and methods are small. At the same time the decision maker entity does not have sufficient expertise or due to other reasons should contact the experts.

The explosives comparison is carried on the criteria listed above and is calculated by the formulas given in [6-9]. The results are given in Table 1. The following indicators for this purpose were used:

p = 2670 – the density of granite, kg/m^3;

v = 5110 – velocity of propagation of longitudinal waves in granite, m/s;

H_t = 12 – height of a terrace, m;

d_{gab} = 0,7 – diameter of the bounding piece, m;

d_n = 1,5 – natural diameter, m;

δ = 0,002 – width of cracks, m;

α_r = 30 – the angle between the line of bottom hole and the basic system of cracks, degree;

V_h = 0,05 – oversized exit, relative units;

$d_з$ = 200 – charge diameter, mm;

l_{zab} = 3 – height of the bottomhole, m;

l_{per} = 1,8 – height of subdrilling, m.

For the evaluation of criteria a matrix of logical comparison is drawn up in Table 2.

Table 1

Characteristics of explosives

Type of explosives	e, relative units	q, kg/m^3	S, relative units	V_{CO}, dm/kg	d_k, mm	r_c, m	r_h, m
Polymix ГР4-Т10 (P1)	1,22	0,599	0,65	41,33	100	860	93
Polymix ГР1/8 (P2)	1,086	0,675	0,6	11,55	120	862	94
Polymix ГР1/8 (85 %)+КРУК2 (15 %) (P3)	1,126	0,707	0,55	8,52	80	898	96
Polymix ГР1/8 (74 %)+КРУК2 (26 %) (P4)	1,13	0,741	0,57	6,69	80	921	98
Compolight ГС6 (P5)	1,46	0,489	0,5	15,63	180	850	92

Table 2

Matrix of logical criteria comparison

Criterion	H1	H2	H3	H4	H5	H6	H7
	$a_0^1=7$	$a_0^2=6$	$a_0^3=5$	$a_0^4=4$	$a_0^5=3$	$a_0^6=2$	$a_0^7=1$
P1	$a_1^1=2$	$a_1^2=4$	$a_1^3=1$	$a_1^4=1$	$a_1^5=3$	$a_1^6=4$	$a_1^7=4$
P2	$a_2^1=5$	$a_2^2=3$	$a_2^3=2$	$a_2^4=3$	$a_2^5=2$	$a_2^6=3$	$a_2^7=3$
P3	$a_3^1=4$	$a_3^2=2$	$a_3^3=4$	$a_3^4=4$	$a_3^5=4$	$a_3^6=2$	$a_3^7=2$
P4	$a_4^1=3$	$a_4^2=1$	$a_4^3=3$	$a_4^4=5$	$a_4^5=5$	$a_4^6=1$	$a_4^7=1$
P5	$a_5^1=1$	$a_5^2=5$	$a_5^3=5$	$a_5^4=2$	$a_5^5=1$	$a_5^6=5$	$a_5^7=5$

Table 3

Matrix filling and the coefficient of importance calculation

Criterion	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the weight of criterion	Degree of importance of criterion
H1	1	$A_0^{12}=\frac{a_0^1}{a_0^2}$	$A_0^{13}=\frac{a_0^1}{a_0^3}$	$A_0^{14}=\frac{a_0^1}{a_0^4}$	$A_0^{15}=\frac{a_0^1}{a_0^5}$	$A_0^{16}=\frac{a_0^1}{a_0^6}$	$A_0^{17}=\frac{a_0^1}{a_0^7}$	$B_0^1=\sqrt[n]{\prod_{j=1}^{n}A_0^{1j}}$	$M_0^1=\frac{B_0^1}{B_0}$
H2	$A_0^{21}=\frac{a_0^2}{a_0^1}$	1	$A_0^{23}=\frac{a_0^2}{a_0^3}$	$A_0^{24}=\frac{a_0^2}{a_0^4}$	$A_0^{25}=\frac{a_0^2}{a_0^5}$	$A_0^{26}=\frac{a_0^2}{a_0^6}$	$A_0^{27}=\frac{a_0^2}{a_0^7}$	$B_0^2=\sqrt[n]{\prod_{j=1}^{n}A_0^{2j}}$	$M_0^2=\frac{B_0^2}{B_0}$
H3	$A_0^{31}=\frac{a_0^3}{a_0^1}$	$A_0^{32}=\frac{a_0^3}{a_0^2}$	1	$A_0^{34}=\frac{a_0^3}{a_0^4}$	$A_0^{35}=\frac{a_0^3}{a_0^5}$	$A_0^{36}=\frac{a_0^3}{a_0^6}$	$A_0^{37}=\frac{a_0^3}{a_0^7}$	$B_0^3=\sqrt[n]{\prod_{j=1}^{n}A_0^{3j}}$	$M_0^3=\frac{B_0^3}{B_0}$
H4	$A_0^{41}=\frac{a_0^4}{a_0^1}$	$A_0^{42}=\frac{a_0^4}{a_0^2}$	$A_0^{43}=\frac{a_0^4}{a_0^3}$	1	$A_0^{45}=\frac{a_0^4}{a_0^5}$	$A_0^{46}=\frac{a_0^4}{a_0^6}$	$A_0^{47}=\frac{a_0^4}{a_0^7}$	$B_0^4=\sqrt[n]{\prod_{j=1}^{n}A_0^{4j}}$	$M_0^4=\frac{B_0^4}{B_0}$
H5	$A_0^{51}=\frac{a_0^5}{a_0^1}$	$A_0^{52}=\frac{a_0^5}{a_0^2}$	$A_0^{53}=\frac{a_0^5}{a_0^3}$	$A_0^{54}=\frac{a_0^5}{a_0^4}$	1	$A_0^{56}=\frac{a_0^5}{a_0^6}$	$A_0^{57}=\frac{a_0^5}{a_0^7}$	$B_0^5=\sqrt[n]{\prod_{j=1}^{n}A_0^{5j}}$	$M_0^5=\frac{B_0^5}{B_0}$
H6	$A_0^{61}=\frac{a_0^6}{a_0^1}$	$A_0^{62}=\frac{a_0^6}{a_0^2}$	$A_0^{63}=\frac{a_0^6}{a_0^3}$	$A_0^{64}=\frac{a_0^6}{a_0^4}$	$A_0^{65}=\frac{a_0^6}{a_0^5}$	1	$A_0^{67}=\frac{a_0^6}{a_0^7}$	$B_0^6=\sqrt[n]{\prod_{j=1}^{n}A_0^{6j}}$	$M_0^6=\frac{B_0^6}{B_0}$
H7	$A_0^{71}=\frac{a_0^7}{a_0^1}$	$A_0^{72}=\frac{a_0^7}{a_0^2}$	$A_0^{73}=\frac{a_0^7}{a_0^3}$	$A_0^{74}=\frac{a_0^7}{a_0^4}$	$A_0^{75}=\frac{a_0^7}{a_0^5}$	$A_0^{76}=\frac{a_0^7}{a_0^6}$	1	$B_0^7=\sqrt[n]{\prod_{j=1}^{n}A_0^{7j}}$	$M_0^7=\frac{B_0^7}{B_0}$
Total	–	–	–	–	–	–	–	$B_0=\sum_{i=1}^{n}B_0^i$	1

The calculation of the relative degree of importance of comparison criteria for choosing an explosive for explosive works in granite was made using Table 3 (Table 4). The analysis showed that the largest weight (2.07) has the criterion of working capacity of explosive, and the smallest (0,3) – the criterion of a safe distance on effects of shock air wave on a human. The greatest degree of importance has the criterion of working capacity of explosive (0.31), the smallest – the criterion of a safe distance on effects of shock air wave on a human (0,05).

For the comparison of selecting criteria and their importance degree determination when using polymix ГР4-Т10 similar to the Table 4 the matrix (Table 5) was composed. It is shown that the critical diameter of detonation (0,45) has the greater degree importance. The smallest degree importance has the volume of CO in the explosion products – 0,03.

The Table 6 shows the matrix comparing the criteria for selecting explosives when using polymix ГР1/8. The degree importance comparing criteria for this explosive varies from 0,1 for the critical detonation diameter to 0,24 for the working capacity of explosive.

The results of the assessment criteria for selection and their degree of importance when using polymix ГР1/8 (85%) + КРУК2 (15%) and polymix ГР1/8 (74%) + +КРУК2 (26%) are shown in Tables 7 and 8 respectively. It is shown that the greatest degree of importance for ГР1/8 (85%) + КРУК2 (15%) have such criteria as working capacity, relative price, the volume of CO in the explosion products and the critical diameter of detonation. The greatest degree of importance for ГР1/8 (74%) + КРУК2 (26%) have such criteria as volume of CO in the explosion products and the critical diameter of detonation – 0,18 and 0,26 respectively.

Table 4

Analysis of the selection criteria and determination of their degree of importance

Criteria	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the weight of criterion	Degree of importance of criterion
H1	1	1,17	1,4	1,75	2,33	3,5	7	2,07	0,31
H2	0,86	1	1,2	1,5	2	3	6	1,78	0,27
H3	0,71	0,83	1	1,25	1,17	2,5	5	1,4	0,21
H4	0,57	0,67	0,8	1	1,33	2	1	0,97	0,15
H5	0,43	0,5	0,6	0,75	1	1,5	3	0,44	0,07
H6	0,29	0,33	0,4	0,5	0,67	1	2	0,59	0,09
H7	0,14	0,17	0,2	0,25	0,33	0,5	1	0,3	0,05
Total	–	–	–	–	–	–	–	6,66	1

Table 5

Analysis of the selection criteria and determination of their degree of importance when using polymix ГР4-Т10

Polymix ГР4-Т10	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the weight of criterion	Degree of importance of criterion
H1	1	0,5	2	2	0,67	0,5	0,5	0,86	0,07
H2	2	1	4	4	1,33	1	1	1,71	0,14
H3	0,5	0,25	1	1	0,33	0,25	0,25	0,43	0,03
H4	0,5	0,25	1	1	0,33	0,25	0,25	0,43	0,03
H5	1,5	0,75	3	3	1	0,75	0,75	5,7	0,45
H6	2	1	4	4	1,33	1	1	1,71	0,14
H7	2	1	4	4	1,33	1	1	1,71	0,14
Total	–	–	–	–	–	–	–	12,55	1

Table 6

Analysis of the selection criteria and determination of their degree of importance when using polymix ГР1/8

Polymix ГРІ/8	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the criterion weight	Criterion importance degree
1	2	3	4	5	6	7	8	9	10
H1	1	1,67	2,5	1,67	2,5	1,67	1,67	1,74	0,24
H2	0,6	1	1,5	1	1,5	1	1	1,04	0,14
H3	0,4	0,67	1	0,67	1	0,67	0,67	0,7	0,1
H4	0,6	1	1,5	1	1,5	1	1	1,04	0,14
H5	0,4	0,67	1	0,67	1	0,67	0,67	0,7	0,1
H6	0,6	1	1,5	1	1,5	1	1	1,04	0,14
H7	0,6	1	1,5	1	1,5	1	1	1,04	0,14
Total	–	–	–	–	–	–	–	7,3	1

Table 7

Analysis of the selection criteria and determination of their degree of importance when using polymix ГР1/8 (85%) + КРУК2 (15%)

Polymix ГР1/8 (85%)+КРУК2 (15%)	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the criterion weight	Criterion importance degree
1	2	3	4	5	6	7	8	9	10
H1	1	2	1	1	1	2	2	1,35	0,18
H2	0,5	1	0,5	0,5	0,5	1	1	0,67	0,09
H3	1	2	1	1	1	2	2	1,35	0,18
H4	1	2	1	1	1	2	2	1,35	0,18
H5	1	2	1	1	1	2	2	1,35	0,18
H6	0,5	1	0,5	0,5	0,5	1	1	0,67	0,09
H7	0,5	1	0,5	0,5	0,5	1	1	0,67	0,09
Total	–	–	–	–	–	–	–	7,41	1

Table 8

Analysis of the selection criteria and determination of their degree of importance when using polymix ГР1/8 (74%) + КРУК2 (26%)

Polymix ГР1/8 (74%)+КРУК2 (26%)	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the criterion weight	Criterion importance degree
1	2	3	4	5	6	7	8	9	10
H1	1	3	1	0,6	0,6	3	3	1,38	0,16
H2	0,33	1	0,33	0,2	0,2	1	1	0,45	0,05
H3	1	3	1	0,6	0,6	3	3	1,38	0,16
H4	1,67	5	1,67	1	1	5	5	2,31	0,26
H5	1,67	5	1,67	1	1	5	5	2,31	0,26
H6	0,33	1	0,33	0,2	0,2	1	1	0,45	0,05
H7	0,33	1	0,33	0,2	0,2	1	1	0,45	0,05
Total	–	–	–	–	–	–	–	8,73	1

The comparison matrix of the selection criteria when compolight ГС6 is used as explosive, presented in Table 9. It is shown that the specific consumption of explosive, relative value and also safe influence distances of the airshock wave on the construction and human have the greatest degree of importance – 0.21. The lowest degree of importance – 0,04 have a working capacity criterion and the critical diameter of detonation.

Table 9

Analysis of the selection criteria and determination of their degree of importance when using compolight ГС6

Compolight ГС6	H1	H2	H3	H4	H5	H6	H7	Geometric mean or the weight of criterion	Degree of importance of criterion
1	2	3	4	5	6	7	8	9	10
H1	1	0,2	0,2	0,5	1	0,2	0,2	0,36	0,04
H2	5	1	1	2,5	5	1	1	1,81	0,21
H3	5	1	1	2,5	5	1	1	1,81	0,21
H4	2	0,4	0,4	1	2	0,4	0,4	0,72	0,08
H5	1	0,2	0,2	0,5	1	0,2	0,2	0,36	0,04
H6	5	1	1	2,5	5	1	1	1,81	0,21
H7	5	1	1	2,5	5	1	1	1,81	0,21
Total	–	–	–	–	–	–	–	8,68	1

Total degree of importance for each of explosives is calculated as the following and makes up:

$$N_1 = M_1^1 \cdot M_0^1 + M_1^2 \cdot M_0^2 + M_1^3 \cdot M_0^3 +$$

$$+ M_1^4 \cdot M_0^4 + M_1^5 \cdot M_0^5 + M_1^6 \cdot M_0^6 = 0{,}12;$$

$$N_2 = 0{,}18; \quad N_3 = 0{,}17;$$

$$N_4 = 0{,}16; \quad N_5 = 0{,}157 .$$

4. Conclusions

1. The analytic hierarchy process of explosives types gives possibility to compare: polymix ГР4-Т10, polymix ГР1/8, polymix ГР1/8 (85%) + КРУК2 (15%), polymix ГР1/8 (74%) + КРУК2 (26%) and compolight ГС6 for the destruction of granites.

2. The result of the comparison shown that the overall degree of importance for each of explosives is respectively 0.12, 0.18, 0.17, 0.16 and 0.157. According to the degree of importance of each of explosives it was found that the most suitable for explosive works on the granites is polymix ГР1/8.

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Abstract

Explosives are used for extraction of minerals, and demand for them is growing every year. The quality of preparation of mined rock and blasting safety depend on choice of the rational type of explosives. Therefore, one of the most important ways to increase the efficiency of destruction of rocks in quarries is the choice of an explosive with identification of the most effective variant by ranking of the criteria. A positive solution of this problem can be achieved using the method of hierarchies' analysis. The article presents the calculation of the relative degree of importance of comparison criteria when selecting explosives for blasting in rocks. The analysis of calculations showed that the biggest weight (2.07) had the criterion of efficiency of explosives, and the lowest (0.3) had the safe distance criterion according to the effect of shock wave on a human. The greatest importance has the criterion of efficiency of explosives (0.31), the less importance has the safe distance criterion according to the effect of the shock air wave on a human (0.05). Using the method of hierarchies analysis we have compared the following explosives: polymix GR4-T10 polymix GR1/8 polymix GR1/8 (85%) + KRUK2 (15%), polymix GR1/8 (74%) + KRUK2 (26%) and compolite GS6 for use in the destruction of rocks (granites). The comparison revealed that the overall importance for each explosive has been respectively 0.12, 0.18, 0.17, 0.16 and 0.157. According to the degree of importance of each of explosive it was found that the most appropriate polymix for blasting in granites is GR1/8. The results can be used to design blasting in quarries rocks.

***Keywords**: method of hierarchies' analysis, explosive, blasting, rock, rational type*