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Technogenic Rock Dumps Physical Properties' Prognosis via Results of the Structure Numerical Modeling

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Abstract. Understanding of internal structure of the technogenic rock dumps (gob dumps) is required condition for estimation of using ones as filtration massifs for treatment of mine wastewater. Internal structure of gob piles greatly depends on dumping technology to applying restrictions for use them as filtration massifs. Numerical modelling of gob dumps allows adequately estimate them physical parameters, as a filtration coefficient, density, etc. The gob dumps numerical modelling results given in this article, in particular was examined grain size distribution of determined fractions depend on dump height. Shown, that filtration coefficient is in a nonlinear dependence on amount of several fractions of rock in gob dump. The numerical model adequacy both the gob structure and the dependence of filtration coefficient from gob height acknowledged equality of calculated and real filtration coefficient values. The results of this research can be apply to peripheral dumping technology.

1 Introduction

Using of gob dumps as filtration massifs for waste mine waters treatment is widespread at open pit mines in a major North Eurasia coal region Kuzbass. Nevertheless, frequent used peripheral dumping technology lead to the irregular ("stratisfied") structure of dump, as it shown at Fig. 1.

Therefore, unevenness of physical parameters (density, porosity, filtration coefficient etc.) to evolved from grain sizes segregation in dump height [1].

2 Material and Method

The research methods include photomapping, field observations, statistical analysis, and the discrete elements method (DEM, implemented in the algorithm of particles' packing for numerical counting filtration coefficient) [2-5].

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Fig. 1. Uneven structure of gob dump originate from peripheral technology.

3 Results and Discussion

The results of the photomapping analysis of the grain size distribution on dump height are presented in Fig. 2.

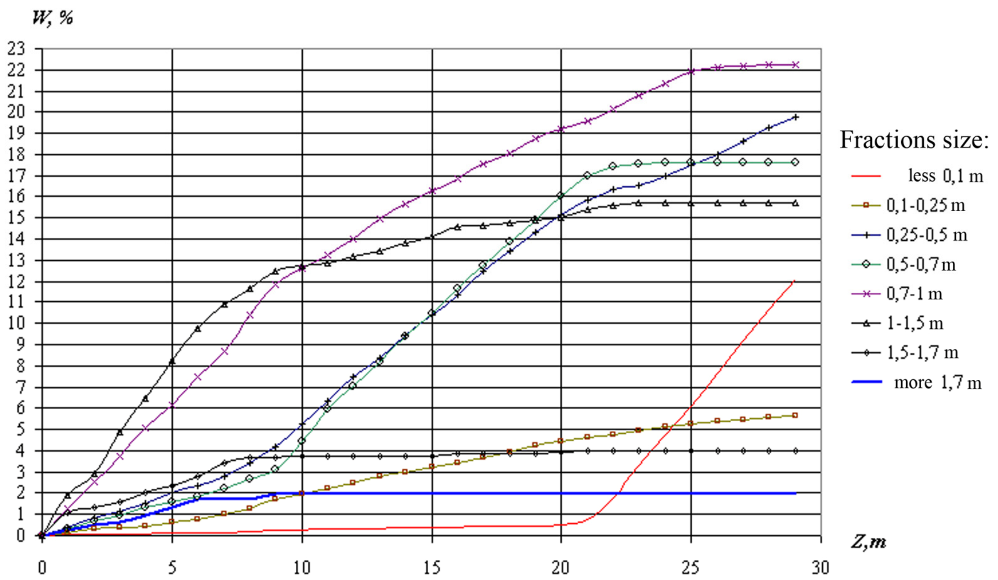

Fig. 2. Integral distribution of grain fractions *W* (%) depending on distance *Z* (meters) from base of gob pile.

To identify fractions have the most significant impact to filtration coefficient K_f was applied the folded Plackett-Burman design $2^8 \cdot 3/32$. Design initial data presented in Table 1. Based on the data of the variance analysis folded Plackett-Burman design $2^8 \cdot 3/32$ (see Table 2), fractions with grain sizes <0.1 m, 0.5-0.25 m and 0.7-1.0 m have a *p*-value less than 0.178, which correspond to it strong influence on filtration coefficient at a confidence level of 82,2%. Volumes of other fractions in gob dump have no significant effect on filtration coefficient.

Table 1. Initial data for design

Distance from bottom of dump, m	Grain size distribution, % of overall volume								Filtration rate K_f, mps
	≤0,1 m	0,1–0,25 m	0,25–0,5 m	0,5–0,7 m	0,7–1,0 m	1,0–1,5 m	1,5–1,7 m	>1,7 m	
0–1	0.033	0.155	0.378	0.311	1.27	1.905	1.049	0.242	0.017
1–2	0.017	0.138	0.469	0.356	1.24	1.021	0.262	0.242	0.017
2–3	0.018	0.076	0.295	0.311	1.24	1.974	0.262	0.121	0.016
3–4	0.018	0.098	0.401	0.341	1.331	1.565	0.437	0.363	0.016
4–5	0.015	0.136	0.454	0.267	1.089	1.769	0.35	0.363	0.015
5–6	0.02	0.174	0.34	0.282	1.301	1.497	0.437	0.363	0.015
6–7	0.026	0.219	0.476	0.341	1.24	1.157	0.612	0	0.014
7–8	0.04	0.242	0.59	0.43	1.664	0.749	0.262	0	0.014
8–9	0.058	0.444	0.771	0.445	1.452	0.817	0	0.242	0.013
9–10	0.018	0.272	1.074	1.334	0.786	0.272	0.087	0	0.012
10–11	0.029	0.261	1.074	1.512	0.605	0.136	0	0	0.008
11–12	0.022	0.28	1.149	1.112	0.756	0.34	0	0	0.008
12–13	0.02	0.263	0.877	1.112	0.968	0.204	0	0	0.008
13–14	0.021	0.212	1.089	1.215	0.696	0.408	0	0	0.008
14–15	0.017	0.236	0.96	1.112	0.635	0.34	0	0	0.008
15–16	0.02	0.225	0.945	1.171	0.605	0.408	0.087	0	0.008
16–17	0.022	0.261	1.112	1.067	0.696	0.068	0	0	0.008
17–18	0.028	0.261	0.975	1.171	0.454	0.136	0	0	0.008
18–19	0.021	0.278	0.915	0.993	0.726	0.136	0	0	0.008
19–20	0.025	0.219	0.817	1.156	0.454	0.136	0.087	0	0.008
20–21	0.253	0.197	0.711	0.963	0.393	0.34	0.087	0	0.0023
21–22	1.04	0.132	0.446	0.415	0.575	0.204	0	0	0.0023
22–23	1.497	0.178	0.242	0.163	0.605	0.136	0	0	0.0023
23–24	1.493	0.163	0.439	0.015	0.544	0	0	0	0.0023
24–25	1.325	0.136	0.491	0	0.575	0	0	0	0.0023
25–26	1.582	0.112	0.484	0	0.242	0	0	0	0.0023
26–27	1.506	0.095	0.658	0	0.03	0	0	0	0.0023
27–28	1.462	0.085	0.628	0	0.06	0	0	0	0.0023
28–29	1.439	0.106	0.507	0	0	0	0	0	0.0023

Table 2. Data of the variance analysis folded Plackett-Burman design

Source fraction (grain size)	*P*-value	Sum of squares	Df	Mean square	F-ratio
<0.1 m	0.1742	0.0000046957	1	0.0000046957	2.03
0.1-0.25 m	0.5162	0.00000102028	1	0.00000102028	0.44
0.25-0.5 m	0.0963	0.00000726736	1	0.00000726736	3.15
0.5-0.7 m	0.2417	0.0000034287	1	0.0000034287	1.49
0.7-1 m	0.0447	0.0000110785	1	0.0000110785	4.80
1-1.5 m	0.3365	0.00000227591	1	0.00000227591	0.99
1.5-1.7 m	0.4301	0.0000015178	1	0.0000015178	0.66
>1.7 m	0.4569	0.000001346	1	0.000001346	0.58
Total error		0.0000346204		0.00000230803	

If differential percent amount of gob dump fraction with particles diameter less 0.1 m is as W_1 (or $W_{<0.1}$), particles diameter 0.25–0.5 m is as W_2 (or $W_{0.25–0.5}$), and particles diameter 0.7–1 m is as W_3 (or $W_{0.7–1}$), then response function as nonlinear multifactor regression model $K_f = f(W_1, W_2, W_3)$ will be:

$$\begin{aligned}K_f &= 0.011 \cdot W_1 \cdot W_3^2 + 0.062 \cdot W_2 \cdot W_3^2 + 4.786 \cdot 10^{-3} \cdot W_3^3 - 0.056 \cdot W_3^2 - \\ &-0.025 \cdot W_1 \cdot W_2 \cdot W_3 + 0.071 \cdot W_2^2 \cdot W_3 - 0.21 \cdot W_2 \cdot W_3 + 0.127 \cdot W_3 + \\ &+3.624 \cdot 10^{-3} \cdot W_1 \cdot W_3 - 0.012 \cdot W_1^2 \cdot W_3 - 0.072 \cdot W_1 \cdot W_2^2 + 0.054 \cdot W_2^3 - \\ &-0.172 \cdot W_2^2 + 0.202 \cdot W_2 + 0.079 \cdot W_1 \cdot W_2 - 0.022 \cdot W_1^2 \cdot W_2 - \\ &-0.052 \cdot W_1 + 0.056 \cdot W_1^2 - 0.014 \cdot W_1^3 - 0.071\end{aligned} \quad (1)$$

Correlation coefficient of this model is 0.98, which confirms the adequacy of the model (1).

4 Conclusions

The proposed high reliability prognosis model establishes a dependence of filtration coefficient from differential amount of gob dump fraction with particles diameter less 0.1 m is as W_1 (or $W_{<0.1}$), particles diameter 0.25–0.5 m is as W_2 (or $W_{0.25–0.5}$), and particles diameter 0.7–1 m is as W_3 (or $W_{0.7–1}$). It can be used for estimate gob dump as filtration massif for purifying of quarry wastewater [6-8].

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