Identification of The Suitable Type of Waste Dumps for Open-Pit Coal Mines in Cam Pha, Quang Ninh, Vietnam

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Abstract - Mining waste disposal is recently an important work of open-pit coal mines in Cam Pha, Quang Ninh, Vietnam. According to the long-term development plan of the Vietnam National Coal - Mineral Industries Holding Corporation Limited (VINACOMIN). the mining waste volume of those coal mines is projected to be around 3.9 billion cube meters to 2030. However, the filled area and space are reducing over the years. With this in mind, the identification of the suitable type of waste dumps for open-pit coal mines in Cam Pha, Quang Ninh, Vietnam, where 80% of the total of Vinacomin's mining wastes are disposed, is essential. This paper studies different types of waste dump with associated equations used to estimate waste dump parameters. The results show that, with the same waste dump capacity and different height levels, the waste dumps with squared basements require the largest land area. In contrast, the least land area is required for those with ellipse basements. The maximum C parameter corresponds to the smallest land occupation area that is required.

Keywords - Waste Dump – Open-Pit Coal Mines – Mining Waste Disposal – Quang Ninh.

1. INTRODUCTION

Mining waste disposal is considered to be one of the most important works in open-pit mines, particularly in the case in which the mining scale and capacity are increasing recently. The research results in open-pit coal mines in Cam Pha, Quang Ninh, Vietnam indicate that mining waste disposal negatively influences people's lives and health, and environment, even many years after the mining has been finished. Therefore, the plan for mining waste disposal needs to be studied so that it is suitable for the mining scale and capacity as well as meets the standard for people's health and environment protection. The total waste disposal volume is projected to be 3.9 billion cube meters in 2030 of which 70% are disposed of in the waste dumps in Cam Pha, Quang Ninh [1].

The annual survey results reveal that the waste dumps in Cam Pha are overlapped in the area. With limited waste dump areas and the increase in mining capacity, the mining waste disposal in this area is recently complicated. This causes difficulty in management in the dumps and leads to the loss of safety to workers, residence, and equipment working in the dumps. This also results in instability for the adjacent areas [2]. Therefore, the identification of the suitable type of mining waste dumps for open-pit coal mines in Cam Pha, Quang Ninh, Vietnam is essential of which the study results are useful in practical applications.

In this study, the types of open-pit mining waste dump with the associated system of equations used to estimate the disposal parameters are studied. The objective is to derive the optimal design of the waste dump. The remainders of the study are organized as follows. Section 2 introduces the background of mining waste disposal in open-pit mines in Cam Pha, Quang Ninh, Vietnam. In Section 3, the suitable types of mining waste dump for Cam Pha, Quang Ninh are studied. Section 4 concludes the study.

2. MINING WASTE DISPOSAL IN OPEN-PIT COAL MINES IN CAM PHA, QUANG NINH, VIETNAM

2.1. Characteristics of Quarry Waste

Cam Pha, Quang Ninh, Vietnam (Fig. 1) is the area where many open-pit mines with large scales and high capacities are located, including Deo Nai, Cao Son, Coc Sau, and Khe Cham II [1]. Over 90% of the total exploration output of Vinacomin's open-pit mines are from this area. Different types of rock are included in the geological column in Cam Pha, including bibbley rock, gritstone, sandstone, siltstone, argillic rock, coal clay, and coal seams. The characteristics of these types are described as [3, 4, 5]:

- Bibbley rock: The color ranges from white to pinkish. The main mineral is quartz with less silica. The sample size ranges from 5 mm to 12 mm cemented by quartz sand. The quarries are of massive structures or thick layers with strong cracks.

- Gritstone: The color ranges from grey to grey-pinkish. The main mineral is quartz. The sample size ranges from 1 mm to 3 mm cemented by quartz sand, silica. The quarries are of massive structures or thick layers with strong cracks.

- Sandstone: This is a main quarry type in the mines. The color ranges from ash-gray to white-gray. The main mineral is quartz. The sample size is less than 1 mm. The quarries are of thick layers with fewer cracks.

- Siltstone: This is located in the coal seam pier. The color ranges from ash-gray to dark gray. The main mineral is clay and sand with the sample size ò 0.01 mm to 0.1 mm. 50-70% are contributed by cement. The quarries are of layers with fewer cracks.

- Argillic rock: The color ranges from gray to dark gray with a layer structure. This is compressed as slate and easily breakable.

The mechanical characteristics of the types of rock in open-pit mines in Cam Pha are summarized in Tab. 1.

Tab 1. The mechanical characteristics of mining waste rocks in open-pit mines in Cam Pha, Quang Ninh.

Rock type	Percentage [%]	Volume weight γ [g/cm^3]	Density ϱ [g/cm^3]	Compressive strength σ_n [MPa]	Tensile strength σ_k [MPa]	Adhesion C [MPa]	Angle of internal friction φ [degree]
Argillic rock	3.4	2.667	2.751	28.856	4.597	8.715	31.43
Siltstone	25.4	2.673	2.749	48.076	5.659	14.714	33.37
Sandstone	47.7	2.659	2.721	99.956	10.902	37.098	34.45
Bibbley rock	15.3	2.594	2.674	127.313	13.427	43.825	34.4

Tab. 1 indicates that the rock types of open-pit mines in Cam Pha, Quang Ninh have strengths from medium to hard or very hard. However, after ripping by drilling and blasting then disposal to the waste dump, the mechanical characteristics of the rocks, such as tensile strength, adhesion, and angle of internal friction, decrease. This negatively affects the stability of the waste dumps, particularly in climate change conditions.

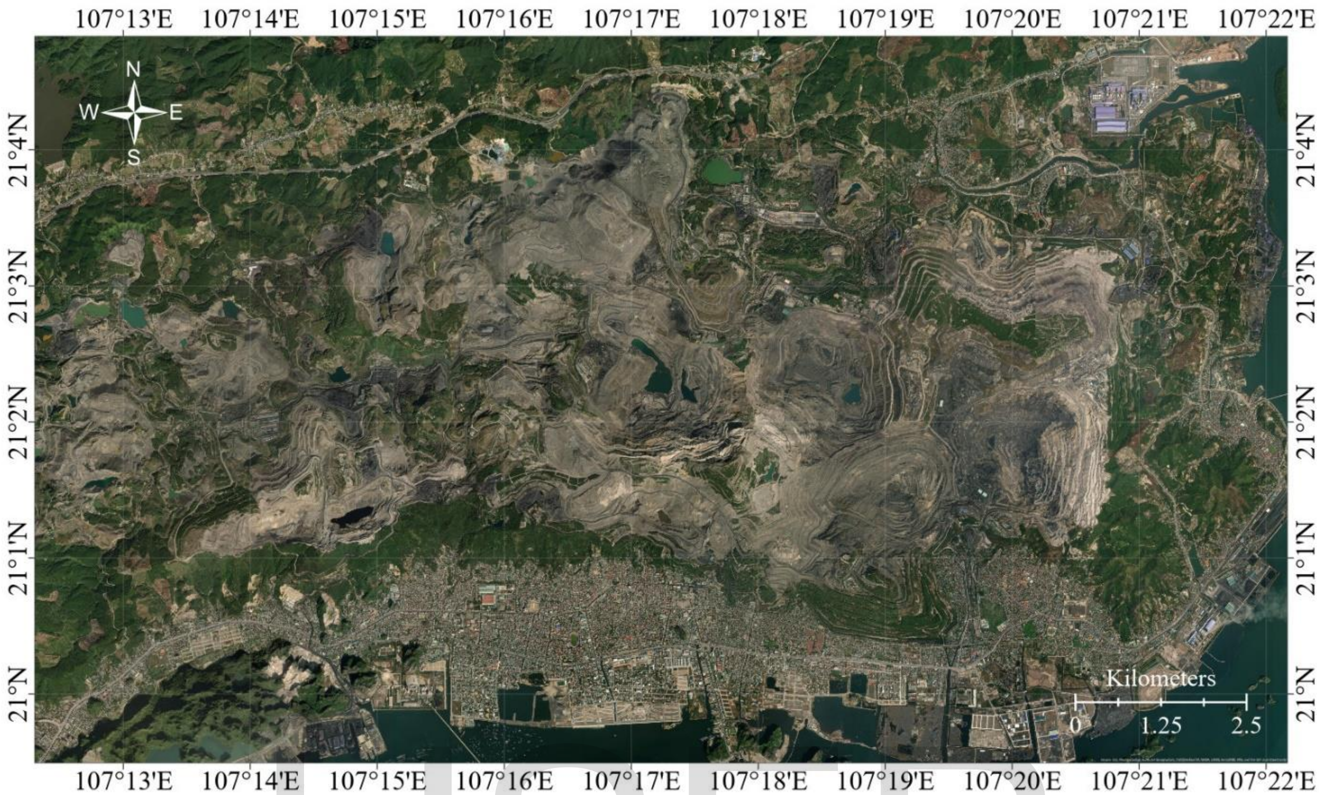

Fig 1. Open-pit mines in Cam Pha, Quang Ninh (from ArcGIS Pro)

2.2. Positions and Methods of Mining Waste Disposal

2.2.1. Positions of Waste Disposal

The mining waste of the open-pit mines of Deo Nai, Cao Son, Coc Sau, and Khe Cham II in Cam Pha, Quang Ninh is disposed of to the waste dumps of Dong Cao Son, Bang Nau, Dong Khe Sim, Lo Tri, and Ta Ngan. The main characteristics of these waste dumps are summarized in Tab. 2.

Tab 2. The main characteristics of the waste dumps in Cam Pha, Quang Ninh

Basement altitude above the ground [m]	Waste dump height [m]	Waste dump width [m]	Slope angle [degree]	Slope of the waste dump surface [%]
+35−+300	20−30	20−50	30−37	3−5

2.2.2. Methods of waste disposal

Until now, the total waste volume that has been disposed to the waste dumps in Cam Pha, Quang Ninh, such as Dong Cao Son, Chinh Bac, Bang Nau, is hundreds of millions of cube meters. The height of the waste dumps is hundreds of meters with multiple dump levels. In the coming years, the waste volume is expected to increase by 10 to 60 million cube meters per year [1]. Most of the open-pit mines in Cam Pha, Quang Ninh apply the dumping method with the technology of high dump combing trucks and bulldozers. The waste disposal is conducted as: the trucks dispose of mining waste to the dump wall or the dump surface. Then, the mining waste is pushed to the dump wall or flattened on the surface and maintain the truck route (Fig. 2) [6, 7].

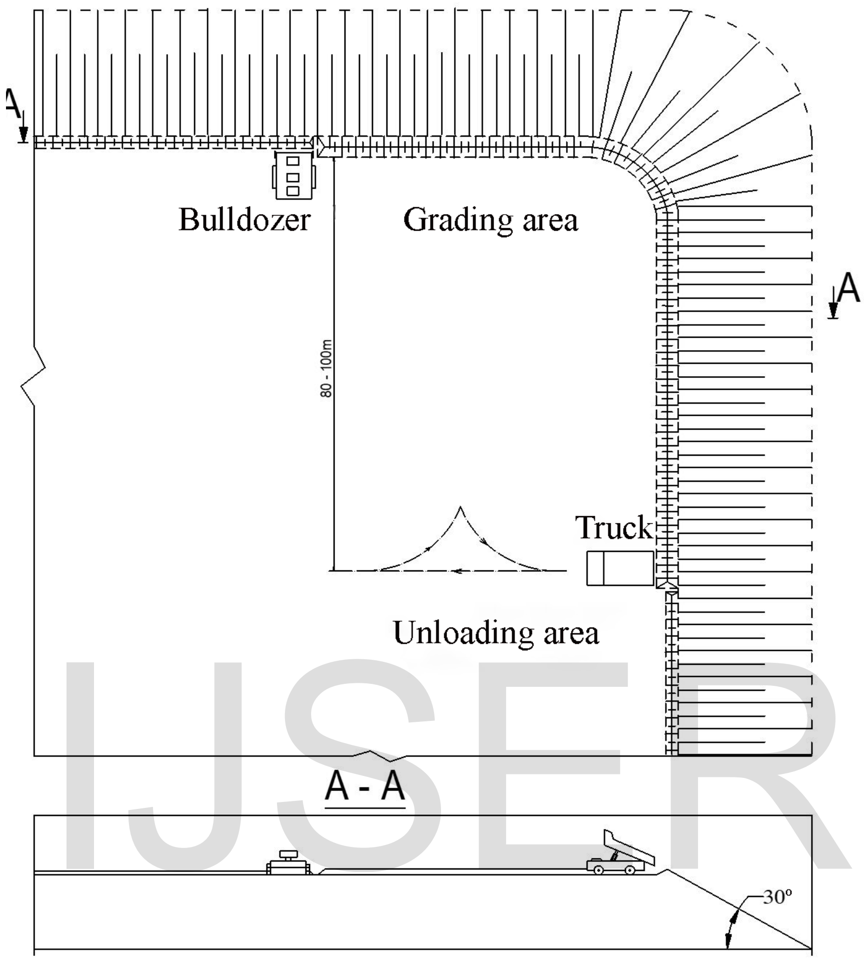

Fig. 2. High dump disposal technology combining trucks with bulldozers in waste dumps in Cam Pha, Quang Ninh.

3. Suitable waste dump types for open-pit mines in Cam Pha, Quang Ninh

Waste dumps suitable for open-pit mines in Cam Pha, Quang Ninh are those with parameters so that the land is used efficiently and the capacity of mining waste is the highest as possible. Actually, the basement of the waste dumps is of the rectangular, square, circle, or ellipse structure. To identify suitable parameters for a waste dump in which the dumping method combining trucks and bulldozers is utilized, the total volume of mining waste that can be disposed of (V) needs to be estimated. The area of the waste dump (S) can be estimated by:

$$S = \frac{V.k_r}{h.k_o} \quad [m2] \tag{1}$$

where h is the height of the waste dump, k_0 refers to a coefficient associating the slope and the irregularity of the waste dump (k_0=0.8 to 0.9 or 0.6 to 0.7 for the one-level or two-level waste dump).

The capacity (V) of a waste dump with a rectangular basement is estimated by:

$$V = L\ .\ R\ .\ h.\frac{k_o}{k_r} \quad , m3 \tag{2}$$

where L and R are the length and width of the waste dump.

The capacity of a one-level waste dump with a square basement is estimated by:

$$V = \frac{L_1^2 . h}{k_r} \quad , \text{m3} \tag{3}$$

where L_1 is the length of the basement.

The capacity of a one-level waste dump with a circle basement is estimated by:

$$V = \frac{\pi . R^2 . h}{k_r} \quad , \text{ m 3} \tag{4}$$

where R is the radius of the basement that can be estimated by:

$$R = \sqrt{\frac{V . k_r}{\pi . h}} \text{ , m} \tag{5}$$

The capacity of a one-level waste dump with an ellipse basement is estimated by:

$$V = \frac{\pi . h . (R1R2 + (R1 - hctg\beta)(R2 - hctg\beta)}{k_r} \quad , \quad \text{m 3} \tag{6}$$

where R_1 and R_2 are the semi-major and semi-minor axes.

3.1. One-level mining waste dump

Fig. 3 shows the structure of a one-level mining waste dump with parameters: the slope angle (β), and the height of the waste dump (h), the length of the basement (L), and the length of the top surface ($L_1 = h.cot\beta$).

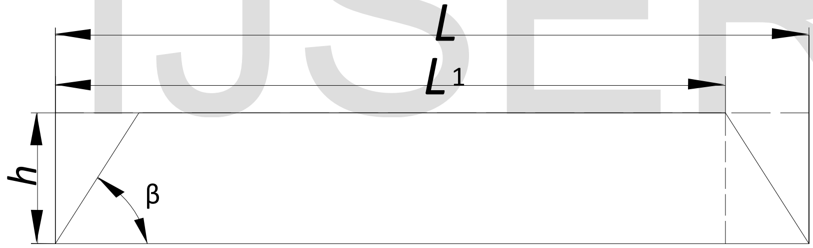

Fig. 3. Parameters of a one-level mining waste dump

The length of a square basement is estimated by:

$$L = L_1 + h.cot\beta = \sqrt{\frac{V.K_r}{h}} + h.cot\beta \;\; [\text{m}] \tag{7}$$

The area of a square basement is estimated by:

$$S = \left(h.cot\beta \;\; + \sqrt{\frac{V.k_r}{h}}\right)^2 [\text{m2}] \tag{8}$$

The area of a rectangular basement is estimated by:

$$\text{S} = S = \frac{\left(h.cot\beta \; + \sqrt{\frac{V.C.k_r}{h}}\right)^2}{C} [\text{m2}] \tag{9}$$

where C is the ratio between the length and the width of the basement, which represents the shape of the basement: $C = \frac{L}{R}$.

The area of a circle basement is estimated by:

$$S = \pi\left(\frac{1}{2}h.cot\beta + \sqrt{\frac{V.k_r}{\pi.h}}\right)^2 \text{ [m2]} \tag{10}$$

The area of a ellipse basement is estimated by:

$$S = \frac{\pi\left(\frac{1}{2}h.ctg\beta + \sqrt{\frac{V.k_r.C}{\pi.h}}\right)^2}{C} \text{ [m2]} \tag{11}$$

where C is the ratio of between the semi-major and semi-minor axes:

$$C = \frac{R_1}{R_2} \tag{12}$$

The computed areas of land occupation for a one-level waste dump with rectangular, square, circle, and ellipse basements are shown in Tab. 3, which are estimated with different parameters of the height and capacity of the waste dump and C.

Table 3. Estimated areas of land occupation of a one-level waste dump with rectangular, square, circle, and ellipse basements.

Height [m]	C	Area of land occupation S [10^3 m^2]					
		V = 10x10^6 [m^3]	V = 30x10^6 [m^3]	V = 60x10^6 [m^3]	V = 100x10^6 [m^3]	V = 200x10^6 [m^3]	V = 300x10^6 [m^3]
Square basement							
15	1	764	2253	4475	7430	14804	22168
20	1	586	1712	3387	5612	11158	16694
30	1	411	1176	2307	3805	7528	11238
Circle basement							
15	1	761	2247	4467	7419	14788	22149
20	1	582	1705	3377	5599	11140	16672
30	1	406	1167	2295	3789	7506	11211
Rectangular basement							
15	1.5	758	2243	4461	7412	14778	22137
20	1.5	579	1700	3371	5591	11129	16658
30	1.5	403	1162	2287	3779	7492	11194
15	2	755	2238	4453	7402	14763	22119
20	2	575	1693	3361	5579	11112	16637

30	2	398	1154	2275	3764	7471	11168
Ellipse basement							
15	1.5	756	2238	4454	7403	14766	22121
20	1.5	576	1695	3363	5581	11114	16640
30	1.5	399	1155	2277	3766	7474	11172
15	2	753	2233	4447	7394	14752	22105
20	2	572	1689	3354	5570	11099	16621
30	2	394	1147	2267	3753	7455	11149

3.2. Two-level mining waste dump

Fig. 4 shows the structure of a two-level mining waste dump with the parameters: the height of the dumping surface (h), the slope of the dumping wall (β), the width of the dumping surface (B), the slope of the waste dump (α), and the horizontal projection of the waste dump at the height H (L).

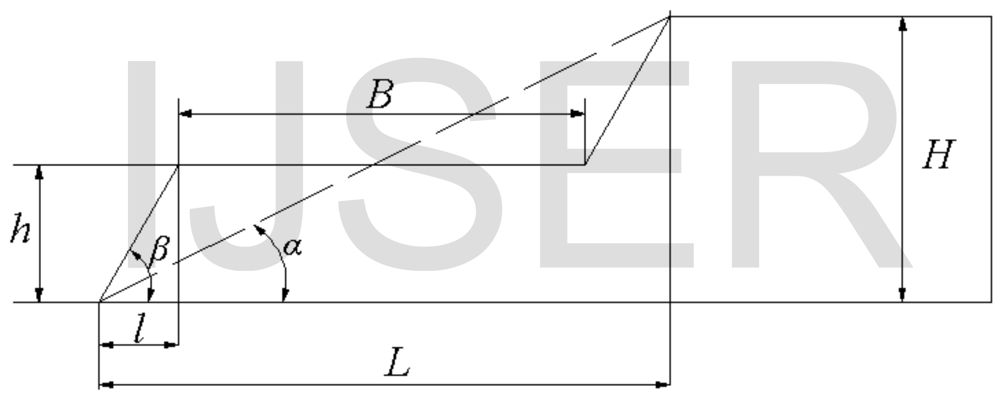

Fig. 4. Structure of a two-level mining waste dump

The horizontal projection of the waste dump at the height H is estimated by:

$$L = H.cot\alpha \text{ [m]} \qquad (13)$$

The width of the dumping surface of the first level is estimated by:

$$B = H(cot\alpha - cot\beta) \text{ [m]} \qquad (14)$$

The slope of the two-level waste dump is estimated by:

$$\alpha = atan\left(\frac{H.tg\beta}{H+B.tg\beta}\right) \qquad (15)$$

The capacity of a multi-level mining waste dump is the sum of the capacities of all levels, which is estimated by:

$$V = \sum_{i=1}^{N} V_i \text{ [m3]} \qquad (16)$$

As a result, the capacity of a two-level mining waste dump is estimated by:

$$V = V_1 + V_2 = \frac{L_1^2.h_1}{k_r} + \frac{L_2^2.h_2}{k_r} \quad [m3] \qquad (17)$$

or

$$V = \frac{L_1^2.h_1}{k_r} + \frac{(L_1 - 2B - 2.h_2 .ctg\beta)^2.h_2}{k_r} \quad [m3] \qquad (18)$$

where h_1 and h_2 are the heights of the two dumping levels, β is the slope of the dumping levels, B is the width of the dumping surface, L_1 and L_2 are the widths of the basements of the two dumping levels.

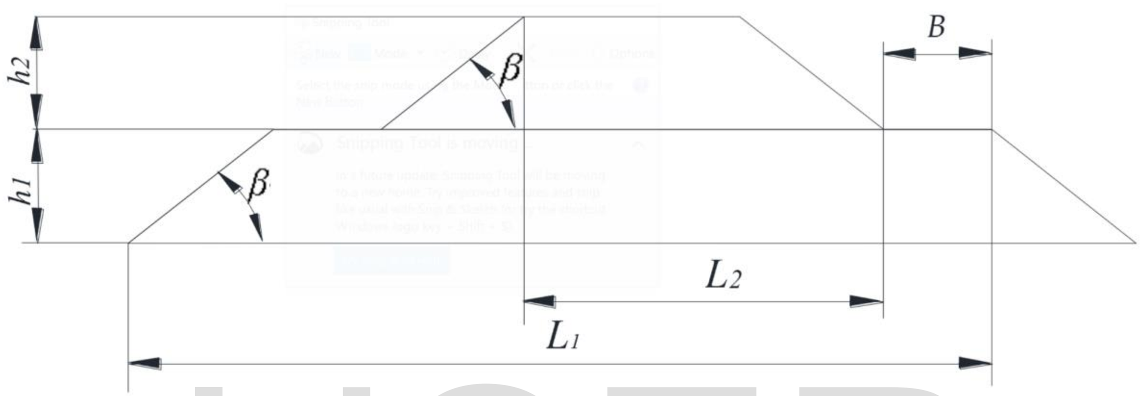

Fig. 5. Parameters of a two-level mining waste dump

The capacity of a two-level waste dump in which the two levels have the same height is estimated by:

$$V=\frac{h}{k_r}[L_1^2 + (L_1 - 2B - 2hcot\beta)^2] \ [m3] \qquad (19)$$

or

$$V = \frac{4h}{k_r}\left[\frac{L_1^2}{2} - L_1(B + hcot\beta) + (B + hcot\beta)^2\right] [m3] \qquad (20)$$

The width of the basement of the first level is estimated by:

$$L = B + 2hcot\beta + \sqrt{\frac{V.k_r}{2h} - (B + h.cot\beta)^2} \quad [m] \qquad (21)$$

The area of the square basement of the second duping level is estimated by:

$$S = (B + 2h.cot\beta + \sqrt{\frac{V.k_r}{2h} - (B + h.cot\beta)^2}\ )^2 \quad [m2] \qquad (22)$$

or

$$S = (H.cot\beta + \sqrt{\frac{V.k_r}{H}})^2 \quad [m2] \qquad (23)$$

The area of the square basement of the first dumping level is estimated by:

$$S = \frac{(B + 2h.ctg\beta + \sqrt{\frac{V.k_r.C}{2h} - (B + h.ctg\beta)^2}\ )^2}{C} \quad [m2] \qquad (24)$$

or

$$S = \frac{(H.ctg\beta + \sqrt{\frac{V.C.k_r}{H}})^2}{C} \quad [m2] \tag{25}$$

The radius of the circle basement of a two-level waste dump is estimated by:

$$R = \frac{1}{2}B + hcot\beta + \frac{1}{2}\sqrt{\frac{2V.kr}{\pi h} - (B + h.cot\beta)^2} \quad [m] \tag{26}$$

or

$$R = \sqrt{\frac{V.k_r}{\pi h} + \frac{H.ctg\alpha}{2}} \quad [m] \tag{27}$$

The area of the circle basement of a two-level waste dump is estimated by:

$$S = \frac{1}{4}\pi\left(B + 2hcot\beta + \sqrt{\frac{2V.k_r}{\pi h} - (B + h.ctg\beta)^2}\right) [m2] \tag{28}$$

or

S= π($S = \pi\left(\sqrt{\frac{V.k_r}{\pi H}} + \frac{H.ctg\alpha}{2}\right)^2$ [m2] (29)

The area of the ellipse basement of a two-level waste dump is estimated by:

$$S = \frac{\pi.(B + 2h\ ctg\beta + \sqrt{\frac{2V.k_r.C}{\pi.h} - (B+h.ctg\beta)^2})2}{4C} \quad [m2] \tag{30}$$

or

$$S = \frac{\pi(\sqrt{\frac{V.k_r.C}{\pi H}} + \frac{H.ctg\alpha}{2})2}{C} \quad [m2] \tag{31}$$

The computed areas of a two-level mining waste dump with rectangular, square, circle, and ellipse basements are shown in Tab. 4, which are computed with different parameters of the height of the dumping level, the capacity of the waste dump, and C.

Tab. 4. Estimated areas of land occupation of a two-level waste dump with rectangular, square, circle, and ellipse basements.

Height [m]	C	Area of land occupation S [10^3 m^2]					
		V = 10x10^6 [m^3]	V = 30x10^6 [m^3]	V = 60x10^6 [m^3]	V = 100x10^6 [m^3]	V = 200x10^6 [m^3]	V = 300x10^6 [m^3]
Square basement							
15	1	460	1261	2427	3959	7745	11504
20	1	370	987	1878	3044	5914	8756
30	1	284	721	1340	2141	4099	6029
Circle basement							

15	1	449	1242	2401	3925	7698	11447
20	1	359	968	1852	3010	5867	8698
30	1	272	701	1312	2105	4049	5968
Rectangular basement							
15	1.5	443	1231	2385	3905	7669	11411
20	1.5	352	957	1836	2989	5838	8663
30	1.5	265	689	1295	2084	4019	5931
15	2	433	1213	2360	3873	7624	11356
20	2	341	939	1811	2957	5792	8607
30	2	254	670	1268	2050	3971	5873
Ellipse basement							
15	1.5	434	1216	2364	3878	7631	11364
20	1.5	343	942	1815	2962	5799	8616
30	1.5	255	673	1272	2055	3978	5881
15	2	425	1200	2342	3849	7591	11315
20	2	334	926	1792	2933	5759	8567
30	2	245	656	1249	2025	3936	5830

3.3. Three-level mining waste dump

Fig. 6 shows the structure of a three-level waste dump with the parameters: the height of the dumping level (h), the slope of the dumping wall (β), the width of the dumping surface (B), the slope of the waste dump (α).

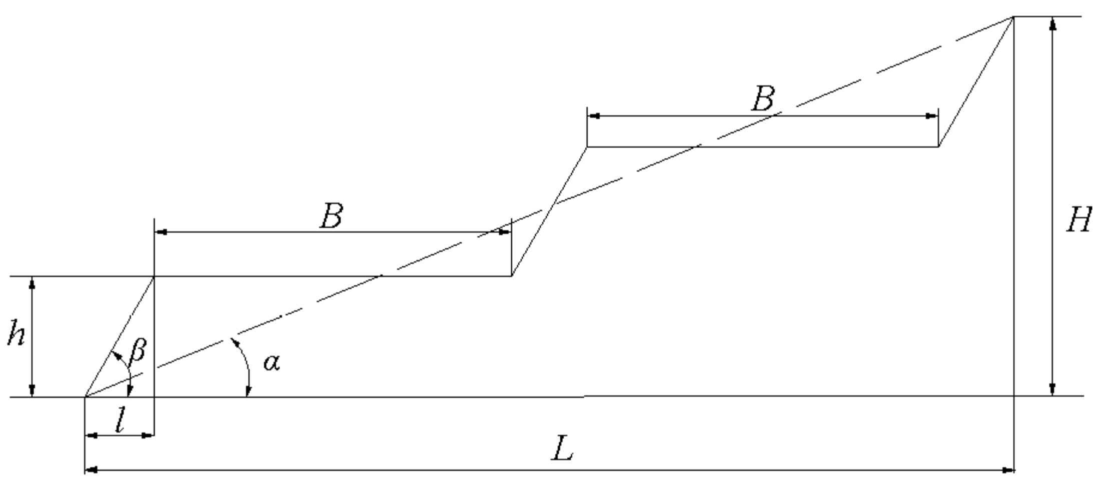

Fig. 6. The structure of a three-level mining waste dump

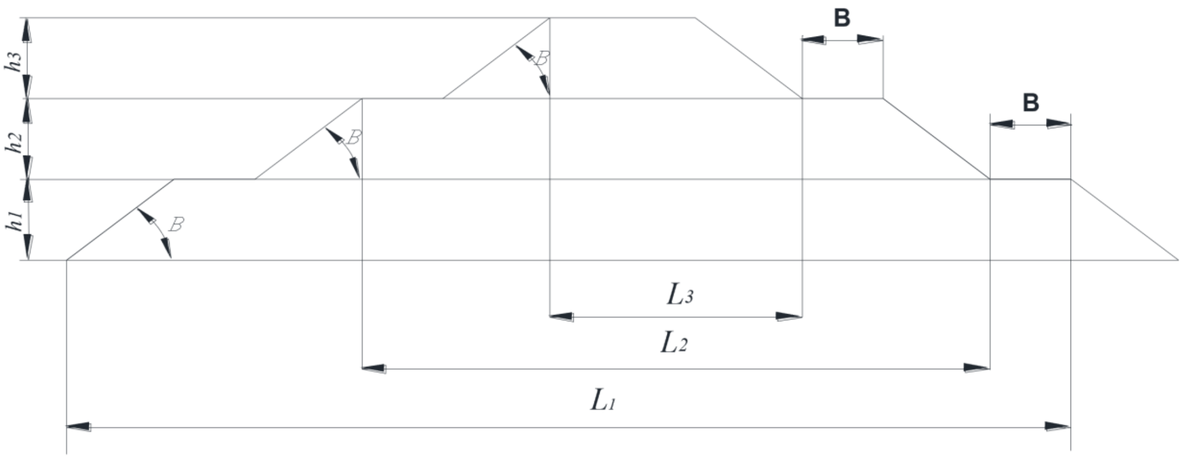

Fig. 7. The parameters of a three-level waste dump

The horizontal projection of a dumping level (L) at the height H is estimated by:

$$L = Hcot\alpha \text{ [m]} \tag{32}$$

The capacity of a three-level waste dump is estimated by:

$$V = V_1 + V_2 + V_3 = \frac{L_1^2.h_1}{k_r} + \frac{L_2^2.h_2}{k_r} + \frac{L_3^2.h_3}{k_r} \quad \text{[m3]} \tag{33}$$

or

$$V = \frac{L_1^2.h_1}{k_r} + \frac{(L_1 - 2B - 2.h_2\ .ctg\beta)^2.h_2}{k_r} + \frac{(L_1 - 4B - 4.h_3\ .ctg\beta)^2.h_3}{k_r} \text{ [m3]} \tag{34}$$

If all the dumping levels are of the same height, the capacity is estimated by:

$$V = \frac{h}{k_r}(3L_1^2 \text{ -12L1 } (B+h.ctg\beta) + 20(B+h.ctg\beta)2) \text{ [m3]} \tag{35}$$

The width of the first basement is estimated by:

$$L = \frac{1}{3}(6B + 9h.\ ctg\beta + \sqrt{\frac{3V.k_r}{h} - 24(B + h.ctg\beta)^2} \text{ [m]} \tag{36}$$

The area of the square basement of a three-level waste dump is estimated by:

$$S = \frac{1}{9}(6B + 9h.ctg\beta + \sqrt{\frac{3V.k_r}{2h} - 24(B + h.ctg\beta)^2}\ )^2 \text{ [m2]} \tag{37}$$

or

$$S = (H.ctg\beta + \sqrt{\frac{V.k_p}{H}})^2 \quad \text{[m2]} \tag{38}$$

The area of the rectangular basement of a three-level waste dump is estimated by:

$$S = \frac{(6B + 9h.ctg\beta + \sqrt{\frac{3V.k_r.C}{h} - 24(B + h.ctg\beta)^2}\ )^2}{9C} \quad \text{[m2]} \tag{39}$$

or

$$S = \frac{(H.ctg\beta + \sqrt{\frac{V.C.k_r}{H}})^2}{C} \quad [m2] \qquad (40)$$

The ratio between the length and the width of the waste dump C is estimated by:

$$C = \frac{L_1}{R_1} = \frac{L_2}{R_2} \qquad (41)$$

In the above equations, h_1, h_2 and h_3 are the heights of the levels of the waste dump, β is the slope of the dumping level, B is the width of the dumping top surface, L_1, L_2, and L_3 are the widths of the basements.

The capacity of a three-level waste dump with circle basements is:

$$V = \frac{\pi R_1^2.h_1}{k_r} + \frac{\pi R_2^2.h_2}{k_r} + \frac{\pi R_3^2.h_3}{k_r} \quad [m3] \qquad (42)$$

With a waste dump in which all levels are of the same height, the capacity is:

$$V = \frac{\pi R_1^2.h}{k_r} + \frac{\pi(R_1 - B - h.ctg\beta)^2.h}{k_p} + \frac{\pi(R_1 - 2B - 2h.ctg\beta)^2.h}{k_p} \quad [m3] \qquad (43)$$

or

$$V = \frac{\pi h}{k_p}(3R_1^2 - 6R1\ (B+h.ctg\beta) + 5(B+h.ctg\beta)2) \quad [m3] \qquad (44)$$

The radius of a circle basement of a three-level waste dump is:

$$R = \frac{1}{3}(4{,}5\ h.\ ctg\beta + 3B + \sqrt{\frac{3V.k_r}{\pi h} - 6(B + h.ctg\beta)^2} \quad [m] \qquad (45)$$

The area of a three-level waste dump with a circle basement is estimated by:

$$S = \frac{1}{9}(4{,}5h.ctg\beta + 3B + \sqrt{\frac{3V.k_r.C}{\pi h} - 6(B + h.ctg\beta)^2})^2 \quad [m2] \qquad (46)$$

or

$$S = \pi(\sqrt{\frac{V.k_r}{\pi H}} + \frac{H.ctg\alpha}{2})^2 \quad [m2] \qquad (47)$$

The area of a three-level waste dump with a ellipse basement is estimated by:

$$S = \frac{\pi(4{,}5h.ctg\beta + 3B + \sqrt{\frac{3V.k_r.C}{\pi h} - 6(B + h.ctg\beta)^2})^2}{9C} \quad [m2] \qquad (48)$$

or

$$S = \frac{\pi(\sqrt{\frac{V.k_r.C}{\pi H}} + \frac{H.ctg\alpha}{2})^2}{C} \quad [m2] \qquad (49)$$

The ratio between semi-major and semi-minor axes is

$$C = \frac{R_1}{R_2} = \frac{R_2}{R_3} \qquad (50)$$

The computed areas of land occupation of three-level waste dumps with square, rectangular, circle, and ellipse basements are shown in Tab. 5, which are estimated with different parameter.

Tab. 5. Areas of land occupation estimated for a three-level waste dumps with square, rectangular, circle, and ellipse basements.

Height [m]	C	Area of land occupation S [10^3 m^2]					
		V = 10x10^6 [m^3]	V = 30x10^6 [m^3]	V = 60x10^6 [m^3]	V = 100x10^6 [m^3]	V = 200x10^6 [m^3]	V = 300x10^6 [m^3]
Square basement							
15	1	383	969	1798	2870	5488	8065
20	1	321	784	1428	2254	4257	6221
30	1	264	608	1070	1653	3047	4401
Circle basement							
15	1	367	942	1759	2821	5419	7981
20	1	305	757	1390	2205	4189	6138
30	1	248	579	1030	1602	2977	4316
Rectangular basement							
15	1.5	357	925	1736	2791	5377	7929
20	1.5	295	740	1366	2175	4147	6087
30	1.5	238	562	1006	1572	2934	4264
15	2	341	899	1699	2744	5311	7849
20	2	280	714	1330	2129	4082	6008
30	2	222	535	968	1524	2867	4182
Ellipse basement							
15	1.5	344	903	1705	2751	5320	7861
20	1.5	282	718	1335	2136	4092	6020
30	1.5	224	539	974	1531	2877	4195
15	2	330	880	1673	2709	5262	7790
20	2	268	695	1303	2095	4034	5949
30	2	210	515	941	1488	2818	4123

The results shown in Tab. 3−5 indicate that, with the same required capacity with different dumping levels, the square basement waste dumps require the largest land occupation. In contrast, the ellipse basement waste dumps occupy the smallest land area. With the maximum coefficient C, the land occupation is the smallest.

4. CONCLUSIONS

The waste disposal is one of the important activities in open-pit coal mines in Cam Pha, Quang Ninh, Vietnam. Based on the development plan of Vinacomin, the disposal capacity of those mines continues increasing in coming years. In the condition that the area and space of the waste dump are limited, the study of the suitable type of waste dump for coal mines in Cam Pha, Quang Ninh is necessary.

The study results indicated that, with the same required capacity of the waste dump and with different dumping levels, the square basement waste dumps occupy the largest land area. In contrast, the ellipse basement waste dumps require the smallest area. The maximum C results in the smallest land area that is required.

The experimental results in this study is useful for Vinacomin as well as coal mines in Cam Pha, Quang Ninh to make a plan to optimize the waste disposal so that the disposal capacity is increased with the smallest land occupation as possible.

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