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NGUYEN TAM TINH

RESEARCH ON SUITABLE DUMPING TECHNIQUE TO ENSURE THE STABILITY OF WASTE DUMPS IN THE CONDITION OF TROPICAL RAINY SEASON FOR SURFACE COAL MINES AT CAM PHA AREA IN QUANG NINH

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Faculty of Mining, Hanoi University of Mining and Geology

Supervisors:
1. Prof. Dr. Bui Xuan Nam, Hanoi University of Mining and Geology
2. Assoc. Prof. Dr. Vu Dinh Hieu, Ministry of Natural Resources and Environment

Reviewer 1: Prof. Dr. Nhu Van Bach

Vietnam Association of Blasting Engineering

Phản biện 2: Dr. Mai The Toan

Ministry of Natural Resources and Environment

Phản biện 3: Assoc. Prof. Dr. Pham Van Hoa

Hanoi University of Mining and Geology

The thesis will be defended in front of the University's Thesis Evaluation Council at: Hanoi University of Mining and Geology, 18 Vien Street, Duc Thang Ward, Bac Tu Liem District, Hanoi at ………………………………………………………………………
date…………………………………………………………………………………..

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INTRODUCTION

1. IMOERATIVENESS OF THE THESIS

Waste rocks dumping is one of the main operations in surface mining. It has direct influence to mining effect, working safety and regional environmental issues. Negative impacts of the dumping works consists of occupying land, changing lanscapes, polluting water and air environments, landsliding, etc.

The main surface coal mines such as Deo Nai, Coc Sau, Cao Son of Vietnam are located mainly at Cam Pha area in Quang Ninh province, the largest coal field in Vietnam, with the applied dumping methods are inside and outside waste dumping. This area is influenced seriously by the tropical weather with dry and rainy season, especially under the global climate change.

The historial rains anf flood in 2015 at Cam Pha area had caused many serious impacts to people, property and the surrrounding environment from these waste dumps.

The stability of these waste dumps depends on the terrain, kind of mother rocks, geoengineering and hydrogeological conditions, shape of waste dumps, technical parameters of waste dumps, dumping equipment, rainfall and rainy time, etc. In which, the suitable dumping technique is very important for these waste dumps.

Therefore, the doctorate thesis "Research on suitable dumping technique to ensure the stability of waste dumps in the condition of tropical rainy season for surface coal mines at Cam Pha area in Quang Ninh" is really a scientific and practical problem.

2. AIMS

Enhance the stablity of waste dumps for the surface coal mines at Cam Pha area in Quang Ninh province, reduce the dumping cost and minimize hazardous impacts to environment.

3. OBJECT AND SCOPE

- The main objective of the thesis is the waste dumps of the surface coal mines at Cam Pha area in Quang Ninh province.
- The research scope of the thesis covers suitable dumping parameters and techniques for the waste dumps of the surface coal mines at Cam Pha area in Quang Ninh province in the tropical rainy condition.

4. CONTENT

The thesis focuss on the following contents

- Reviewing the dumping works in the world and Vietnam;
- Classifying the waste dumps for the surface coal mines at Cam Pha area in Quang Ninh province;
- Investigating the influence of rainfall and rainy time to the stability of the waste dumps;
- Assessing the relation of the between adhesiveness, internal friction angle, density of rock, and dumping bench height, dumping technology and equipment, in both dry and rainy seasons;
- Determining the suitable dumping parameters for the surface coal mines at Cam Pha area in Quang Ninh province;
- Building the dumping technological schemes to ensure the stability for the surface coal mines at Cam Pha area in Quang Ninh province in both dry and rainy seasons.

5. RESEARCH METHODOLOGY

The main methods were used in the thesis aiming to achieve the aims of the study include: field research; theory research; data collection; statistic and data analysis; mathematical model; IT application.

6. INNOVATIONS OF THE THESIS

- Proposed the acceptable safety criteria of waste dumps and the citeria for classifying waste dumps of surface coal mines at Cam Pha area in Quang Ninh.
- Determined the adhesive force, internal friction angle by the reverse calculation method from the deformed parameters of waste dumps combined the experiments.
- Proposed the shape of waste dump having the minimally land-occupied area with the maximal filled volume.
- Determined the suitable parameters for the stability of waste dumps in sunny and rainy seasons by digital modelling method.
- Proposed the suitable dumping technique to ensure the stability of waste dumps in the condition of tropical rainy season for surface coal mines at Cam Pha area in Quang Ninh.

7. DEFENDED STATEMENTS

Statement 1: The stability of waste dumps depends on geological condition of mother rock, kind of rocks, shape and geometric parameters of waste dump, technical parameters of waste dump, dumping technolgy and equipment, rainy season characteristics. Rainfall and rainy time increase, stability of waste dump will decrease, and reach the minimal value after 24 rainy hours.

Statement 2: Analyzing the stability of waste dump by changing the mechanic-physical properties of rocks in both natural and saturated conditions is the right way to determine the suitable dumping parameters for the waste dumps.

Statement 3: Applying the combined dumping technology with the internal and boundary dumping benches will ensure the stability and decrease the hauling and grading costs for waste dumps working on the moutainous side.

8. SCIENTIFIC AND PRACTICAL SIGNIFICANCE

- The research content of the thesis contributes the scientific basics for dumping technique to enhance the stability of waste dumps and minimize hazardous impacts to environment.
- The research results of the thesis contribute the increse of effect and safety for the waste dumping operation at surface coal mines at Cam Pha area in Quang Ninh, especially in the climate change condition.

9. THESIS STRUCTURE

Besides the introduction, conclusion, reference and apendix, the thesis structure includes 4 chapters:

- Chapter 1: Review of scientific works on dumping operation at surface mines in the world and Vietnam
- Chapter 2: Research on influenced factors to dumping operation of surafce coal mines at Cam Pha area in Quang Ninh province
- Chapter 3: Research on suitable dumping technology to ensure the stability in the condition of tropical rainy season for surface coal mines at Cam Pha area in Quang Ninh province
- Chapter 4: Application for the Cao Son mine at Cam Pha area in Quang Ninh province

CHAPTER 1
REVIEW OF SCIENTIFIC WORKS ON DUMPING OPERATION AT SURFACE MINES IN THE WORLD AND VIETNAM

1.1. REVIEW ON TYPES OF WASTE DUMPS AT SURFACE MINES IN THE WORLD

1.1.1. Review on surface mines

Surface mining method is the most oldest one in the world from the Ancient Age, and still use today. The role of surface mining method in the worldwide mining industry (solid) is more than 80%, 83% in USA and 70% in SNG countries. In Russia, 91% iron, >70% metals, >60% coal, nearly 100% building materials, are exploited by surface mining method [82].

1.1.2. Types of waste dump

Dumping operation at surface mine is total works: receiving and locating rocks at the specific area with a given order [3]. The properties for classifying the types of waste dump include: dumping area, number of dumping bench, terrain of dump, dumping equipment [11]. Besides that, there are more 3 properties as below:

1.1.2.1. Classification by location of waste dump

1.1.2.2. Classification by life time of waste dump

1.1.2.3. Classification by waste dumping technology

1.2. REVIEW ON WASTE DUMPING TECHNOLOGY

Presently, there are 3 used dumping methods: high wall dumping, dumping by flat grading, and dumping by layers [58]. In which, the high wall dumping method (other name: dumping method on inclined side) is the most popular one because of without requiremnets of technical parameters and qualitive criteria. However, this method causes a great distribution of rock sizes along the inclined side, and decreases the stability of slope. The dumping method by flat grading, requires grading equipment besides hauling equipment, and also causes unstable reason because of distribution of rock sizes along the inclined side. The dumping method by layers is the optimum one, however, the thickness of layer is not over 6 m. This increases the working time of dumping operation. Technical requirements are higher than two above-mentioned methods.

1.2.1. Dumping operation in Russia

1.2.2. Dumping operation in China

1.2.3. Dumping operation in Canada

1.3. REVIEW ON WASTE DUMPING OPERATION OF SURFACE COAL MINES AT CAM PHA AREA IN QUANG NINH PROVINCE

Main surface coal mines at Cam Pha area consist of Deo Nai, Coc Sau, Cao Son and Kha Cham II. Mining technology of these mines is drilling - blasting, loading, hauling, and dumping. Waste rocks are dumped at the inside and outside waste dumps, such as Dong Cao Son, Bang Nau, Dong Khe Sim, Lo Tri and Ta Ngan.

1.3.1. Waste rocks of surface coal mines at Cam Pha area

1.3.2. Size distribution at the waste dumps

1.3.3. Location of waste dump and dumping technology

1.3.3.1. Dong Cao Son waste dump

1.3.3.2. Bang Nua waste dump

1.3.3.3. Dong Khe Sim - Nam Khe Tam waste dump

1.3.3.4. Mong Giang waste dump

1.3.3.5. Lo Tri waste dump

1.3.3.6. Ta Ngan waste dump

1.3.4. Dumping technology

Most surface coal mines in Vietnam use the high wall dumping method with truck and bulldozer. The dumping operation is carried out as follow: trucks unloaded waste rocks directly down to the inclined side and on the dumping bench; bulldozer pushes waste rocks down to the inclined side or grades them by layers on the surface, then maintain the haul road for trucks between the dumping benches. The height of the waste dumps is 60÷150 m, some where to 270 m, the slope angle of the waste dumps is 30÷40°.

1.4. EVALUATION OF THE RESEARCHES ON THE DUMPING OPERATION

1.4.1. Overseas researches

Russian scientists have contributed to solve the slope stability management at the waste dumps, such as Фисенко Г.Л. [101], Ильин А.И., Гальперин А.М., Стрельцов В.И. [86], Попов И.И., Окатов Р.П. [96], Певзнер М.Е. [92], Демин А.М. [85], Сапожников В. Т. [98], Попов В.Н., Шпаков П.С., Юнаков Ю.Л. [95], Половов Б.Д. [94], Туринцев Ю.И., Половов Б.Д., Гордеев В.А. [100], Крячко О.Ю. [89], Козлов Ю.С. [88], Будков В.П. [84], and other foreign scientists as follow [33], [34], [56], [65], [71], etc.

1.4.2. National researches

Some Vietnamese scientists [3], [9], [11] have introduced types of waste dump, dumping methods and technical parameters of waste dumps on hard and soft foundation.

1.4.3. Evaluation of the researches on the dumping operation

The problems, that need to further research to ensure the stability of waste dumps in the tropical rainy condition, are the absorbed model of rain and unsaturated waste rocks, properties of waste rocks, optimum dumping parameters, and suitable dumping technology.

1.5. CONCLUSION OF CHAPTER 1

Dumping operation is an important chain in the mining activity, influences the mining effect and progress. Depending on specific natural condition, waaste dump can be located inside or outside the pit.

All most outsite waste dumps at Cam Pha area are dumped along the moutain side or on the surface with combination of truck and bulldozer. In recent years, Cao Son mine uses the dumping bridge and belt conveyor system to dump with high benches at the Bang Nau waste dump. The waste dump with high bench can be in unstable condition if rainy water is absorbed in the waste dump because of untight dumping layers.

There are some researches on stability of waste dumps and dumping technology. However, a suitable dumping technology for sufarce coal mines at Cam Pha area in the tropical rainy condition to ensure the stability, is now a very necessary research.

CHAPTER 2
RESEARCH ON INFLUENCED FACTORS TO DUMPING OPERATION OF SURAFCE COAL MINES AT CAM PHA AREA IN QUANG NINH PROVINCE

2.1. CHARACTERISTICS OF TROPICAL RAINY SEASON AND MODEL OF WATER FLOWING INTO THE WASTE DUMP AT CAM PHA AREA IN QUANG NINH PROVINCE

2.1.1. Characteristics of tropical rainy season at Cam Pha area in Quang Ninh province

The surface coal mines in Cam Pha - Quang Ninh are located in a tropical monsoon climate with two distinct seasons. Rainy season from May to October, dry season from November to April next year. Rain is usually the heaviest in July and August every year, averaging in the range of 400÷600 mm.

Figure 2.1 shows that: in the years from 2011 to 2018, the annual rainfall did not change significantly; in 2015 the rainfall increased dramatically, the amount of rainwater flowing into the waste dump also increased a lot (from 2÷4 times) in previous years. After 2015, monthly rainfall tends to change unpredictably.

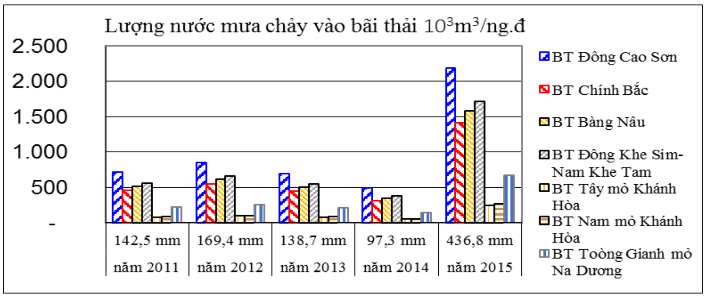

Figure 2.1. *The amount of water flowing into the external dumping site according to the largest annual rainfall data from 2011-2018 [5]*

2.1.2. Model of water flowing into the waste dump

Depending on the intensity of the precipitation (P), the initial water content of the rock near the surface, some of the precipitation will flow off the surface of the aquifer (Ro), part will evaporate from the surface (Es) and some will seep into the near-surface layer. Water infiltration causes a temporary increase in the amount of water stored in the near-surface layer of the waste dump (ΔSW). The water held in the near-surface layer is then reduced through evapotranspiration (ET) or by percolation below the waste dump (R), until a new equilibrium is reached or another seepage event occurs.

2.1.3. Deformations of waste dump

The deformation occurring on the discharge slope is the result of an internal imbalance of a mass of material throughout the slope. The deformations at the waste dump are often caused by the nature of the waste rocks, the conditions of the waste dump, causing changes in the waste dump parameters, and unstable waste dumps.

2.1.3.1. Types of landslides related to waste substrate properties

Landslides related to the properties of the landfill foundation include the following types [9]: a) Rotary mass landslides; b) Non-cyclic mass landslide; c) Wedge block slide; d) The phenomenon of displacement of the waste background; e) Liquefaction; f) Floor slip; g) Slip due to geological activity.

2.1.3.2. Landslide due to the nature of waste rock

Landslides due to the nature of waste rock include the following forms: a) Landslides at floor edges; b) Landslide along floor slopes; c) Landslide according to surface movement.

2.1.3.3. Landslide due to water flow

The landslides generated in this case are related to the sliding phenomenon of the rock mass in the slope area or the surface of the waste layer. The volume and speed of the material flow can increase the slip mass formation. The landslide may evolve in response to moisture gain and swelling, the growth of water layers, and the concentration of surface runoff.

2.2. INFLUENCED FACTORS TO DUMPING OPERATION

The work of dumping at open-pit mine dumps includes the following tasks: Selecting a dumping site, dumping parameters to ensure pre-order requirements, developing and implementing dumping technology and solutions to ensure stable at the end of discharge.

There are many different factors that affect the stability of a landfill. These factors are classified into: external factors and internal factors.

2.2.1. Influence of rainfall to stability of waste dump

Pore water pressure is not fixed over time in the landfill and can change due to environmental conditions. This affects the attraction and cohesion associated with waste rock, thereby affecting slope stability of unsaturated soil.

Geo-Studio 2018 software is used to analyze slope stability with two modules, SEEP/W and SLOPE/W. In which, the SEEP/W module is used to analyze the unstable permeability over time to determine the change of the saturation line in the slope when it rains.

From the above calculations it is shown that: in all cases, the coefficient of stability decreases during rain due to increasing pore water pressure. Although the reduction is small, from 0.2 to 2.9%. After 24 hours the coefficient of stability reached the minimum value. This is the basis for selecting the geometrical parameters of the landfill to ensure stability in the rainy season.

2.2.2. Influence of seismic

On the basis of using specialized software to analyze the impact of seismic and seismic shocks on the stability of the landfill. Based on the analysis results in the figure above, it shows that when the landfill is affected by seismic impacts, the stability coefficient is reduced by 8÷10% compared to when it is not.

2.2.3. Influence of landfill

The landfill ground is often destroyed in the form of soil or embankment that has slipped. The slip that occurs in a certain face in the soil mass is because the shear stress τ (caused by the load from the dump) at points on that face is too large, equal to the shear strength τo. When sliding, the large displacement of soil mass causes instability of the foundation or waste rock mass. Thus, the shear strength of the landfill foundation is a key factor determining the stability of the soil mass (base, waste soil) and the safety of the landfill.

2.2.4. Influence of waste dump parameters

2.2.4.1. Influence of height of dumping bench and waste dump

The height of the dumping bench (when the waste dump is one bench) and the waste dump Ht can affect the stability coefficient of the waste dump FoS. For a certain height, the larger the cohesive force, the larger the coefficient of stability. When the cohesive force is as large as C = 25 kPa, the FoS at the waste dump 11 decreases from 2.1 to 1.5 when the height of the waste dump increases from 20 m to 120 m.

2.2.4.2. Influence of slope angle of waste dump

The influence of slope angle of waste dump (α) on the safety factor FoS was investigated with one bench S_1 landfill (H_t = 20 m), two benches S_{11} landfill, each benh has a height of H_t= 20 m with different cohesive forces (C = 1, 5, 10 and 25 kPa). The dump slope angle varies from 26° to 37°. Calculation results show that for each type of rocks with the same value of cohesion force, the stability coefficient will decrease when increasing the slope angle of the waste dump. When the dump slope angle $\alpha = 30^o$, if increased when the cohesive force C is from 1 kPa to 25 kPa, FoS increases from 1.2 to 2.2.

2.2.5. Influence of cohesive force

The soil cohesion force (C) is one of the important parameters affecting the stability of the waste dump. To examine the influence of cohesion force on landfill stability [52], the author used the software SIGMA/W and then SLOPE/W for 4 cases of landfill S_1, S_{11}, S_{21} and S_{35} through evaluation. value $c/\gamma H_t$.

2.2.6. Influence of internal friction angle

SIGMA /W software was used to analyze the influence of fixed internal friction angle and variable internal friction angle in the waste dump on FoS. The results show that: FoS with φ unchanged is larger when changing the percentage of the reduction value of the safety factor depending on the depth of the slip surface. For deeper sliding surfaces, this decrease in FoS is more obvious.

2.2.7. Influence of dumping equipment

On the surface of the waste layer, there is often the movement of trucks and bulldozers, so the rock layer below the surface of the waste layer will be compacted under the direct effect of self-weight and the load of the equipment involved in the construction of waste dump. In terms of pressure on the platform, trucks usually payload from 55÷170 tons, 2÷8 times larger than bulldozers. Therefore, the automobile is the vehicle that plays a key role in creating a compaction layer with a thickness of h_0 (Figure 2.2).

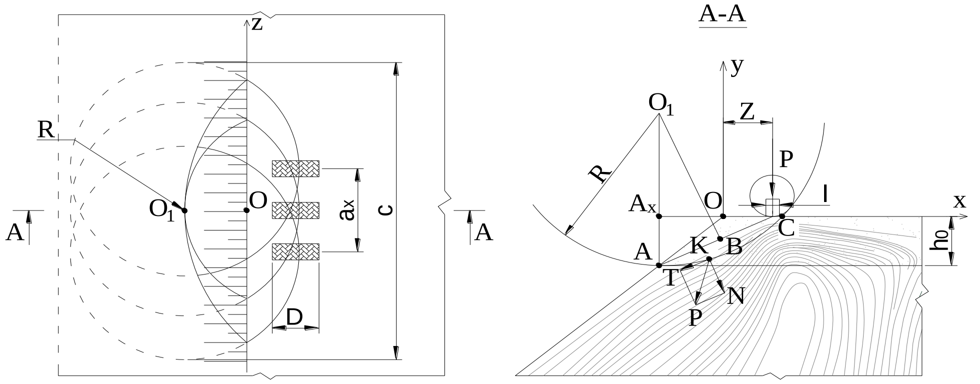

Figure 2.2. *Diagram of determining the thickness of the compaction layer under the effect of trucks loads*

2.3. RESEARCH ON ROCK CHARACTERISTICS OF WASTE DUMPS AT CAM PHA AREA IN QUANG NINH PROVINCE

2.3.1. Research on the distribution of particle size according to bench height

With circumferential dumping technology, when the truck unloads from the edge of the bench, soil particles of different sizes will fall at different speeds on the slopes of the dumping bench. Under the action of gravity, rocks will slide and roll on the slope of the waste layer. During the movement, the friction force between the rocks and the slope of the waste layer will appear and hinder the movement of the rocks. Due to the uneven distribution of particle size composition on the waste layer, leading to rocks physical and chemical parameters such as volumetric weight, coefficient of loose expansion, cohesion force, pore size, stability,... At each different height of the bench height will have different values. This is the basis for the proposed waste dump parameters.

2.3.2. Research on the change of soil cohesion force according to the dumping bench height

The soil cohesion force (C) is one of the important parameters affecting the stability of the waste dump. Similar to the volume of rocks, the cohesive force at different locations of the dumping bench also has different values. The cohesive force depends on the rock type, particle size, and water content in the aquifer. Based on the survey results at the waste dumps of TKV, it is shown that: in the condition that the waste dumps are saturated with water, the cohesive force decreases from 10÷15%.

2.3.3. Research on the change in volume of rocks volume on the dumping bench height

For each rock-grain size component, there are arrangement rules between rocks particles, pore size and density distribution. Therefore, according to the height of the rocks waste layer, the coefficient of separate expansion and the volume of rocks will be different (Figure 2.3).

In the presence of water, the rock becomes saturated, increasing the volume. According to the experimental results at the site of waste dumps of surface coal mines conducted by the Institute of Mining Science and Technology - Vinacomin during the period from November to December 2015 shows that: in the saturated state of water, the soil volume by volume stone increased from 5÷10%.

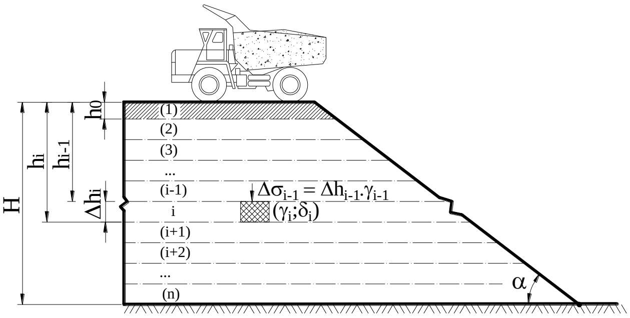

Figure 2.3. *Diagram to determine the volume and weight of rocks layers at different locations in the dumping bench; (1), (2), (3)…I - waste rock layers*

2.3.4. Synthetic research of rocks properties at waste dumps of the Cam Pha area

2.3.4.1. Experiment to determine the properties of waste rock

Rocks samples were taken on the surface of the aquifer at locations on the waste dumps. Experimental samples of manual digging have average size (length × width × depth) = 1m × 1m × 1m. Sample size (length × width × depth) = 3m × 3m × 3m was constructed by mechanical means. The rocks properties at the waste dumps are determined by field and laboratory experiments, including: volumetric mass, internal friction angle, cohesion force according to natural and saturated sample states.

2.3.4.2. Research on the properties of waste rock by reverse calculation method

Inverse analysis method based on trial and error concept focuses on failure geometry and it is carried out by varying the adhesive force and friction angle until the factor of safety is less than 1.0 [71].

For rocks of waste dumps at Cam Pha area, it is possible to use the reverse analysis method from the deformations that have occurred and the dump parameters: slope angle of strata, geometrical dimensions to determine the parameters c, φ.

Calculation results show that: at the waste dumps of the Cam Pha area, when C changes from 6÷10 t/m^2; φ varies from 19÷28^o; volumetric weight varies from 2.0÷2.4 t/m^3.

2.4. CONCLUSION OF CHAPTER 2

The rocks waste dumps of the surface coal mines at Cam Pha area are tropical, hot and humid, with a lot of rain, and a year is divided into two distinct seasons. The rainy season lasts from April to October with the largest rainfall in 1 rain in 2015 is 1,411 mm and in 5 months in the rainy season in 2015 is 2,916 mm. The dry season lasts from November of the previous year to March of the following year.

Rocks at the waste dumps at Cam Pha area are unsaturated. Tropical monsoon rains create intrusive flows into the waste dumps, causing the following parameters: density to increase, cohesion force and internal friction angle to decrease, pore water pressure increases, causing shear stress to increase.

The factors affecting the dumping operation include: physical and mechanical properties of waste soil, hydrogeological conditions (rainfall, amount of groundwater); dumping site parameters (height, width of the dumping bench, slope angle of the bench,...), dumping technology and equipment, and seismic conditions.

According to the height of the dumping bench from the floor down, small particles are distributed near the surface, in the middle are large particles, and boulders are distributed at the foot of the waste dump. The coefficient of expansion of rocks in the waste layer increases gradually from the surface to the bottom of the waste dump. When the rock is saturated with water, the density of the rock increases, the cohesion force and the internal friction angle decrease. When the entire rocks in the waste dump is saturated with water, the waste dump is in the most dangerous state.

The reverse calculation method to find the parameters c, φ typical for the entire waste dump has values closer to reality than the experimental method on the surface. Values of c, φ found enough basis to calculate waste dump stability.

CHAPTER 3
RESEARCH ON SUITABLE DUMPING TECHNOLOGY TO ENSURE THE STABILITY IN THE CONDITION OF TROPICAL RAINY SEASON FOR SURFACE COAL MINES AT CAM PHA AREA IN QUANG NINH PROVINCE

3.1. CLASSIFICATION OF WASTE DUMP

Depending on the following parameters: waste dump height, waste dump capacity, waset dump slope angle, dumping ground slope, dumping ground surface, bearing capacity of dumping ground, quality of dumping materials, waste dump construction method, dumping rate, seismic capacity, a classification system of waste dump stability can be used (Table 3.1).

Table 3.1. *Classification of waste dump according to stable conditions*

Total rating points	Stable classification	Risk of landslides	Level of survey, design and construction
< 300	I	Almost insignificant	There is a survey of the dumping area; minimal testing in the laboratory; regularly check the stability, can use the histogram.
300÷600	II	Low	Thorough site survey, with test pits, sampling may be required; laboratory testing is limited; stability may or may not affect the design, requiring a baseline stability analysis; regular visual and instrumental monitoring.
600÷1200	III	Medium	Survey the area in detail, in phases; require test pits, which may require drilling or conducting landfill site surveys; An intact sample may be requested; Detailed laboratory testing, including index of properties, shear strength and strength testing may be required; design influence stability and design controllable; require detailed stability analysis, which may include parametric studies.

> 1200		High	Detailed, phased investigation; requires test pits, and possibly grooves; drilling and landfill surveys may be required; intact samples may be required; Detailed laboratory tests, including indicators: shear strength and strength tests may be required; Detailed stability analysis, which may include parametric studies and a full evaluation of alternatives, may be required; Detailed design report phase II may be needed for approval/permission; Detailed equipment monitoring required for design validation.

3.2. BUILDING CRITERIA FOR ASSESSING STABILITY OF WASTE DUMP

3.2.1. Evolutionary history of stability acceptance criteria

Among the first to propose minimum stability acceptance criteria for rock dumps was the United States Mine Safety and Enforcement Agency (MESA) [54].

In the 1977 Open Mine Slope Manual, the Canadian Center for Mining and Metallurgy (CANMET) recommended minimum FoS guidelines for embankment works.

The stability acceptance criteria for rock dumps were published by the Rock Waste Land Research Committee (BCMWRPRC) in 1991 in the Handbook of Investigation and Design - Interim Guidance [17].

3.2.2. Recommend stability acceptance criteria

a. Reliability Index (RI)

b. Probability of landslide (PoF)

3.2.2.1. Possible risk

Low; Medium; High.

3.2.2.2. Reliability

3.3. RESEARCH ON SUITABLE WASTE DUMP PARAMETERS FOR SURFACE COAL MINES AT CAM PHA AREA IN QUANG NINH PROVINCE

3.3.1. Selecting the shape of the waste dump with minimal land use

Assuming the required volume of waste rock is V, the height of each duming bench is h, the width of the dumping bench is B, and the slope angle of the dumping bench is β. The author calculates waste dumps in the shape of square, rectangle, round, ellipse with the number of dumping bench of 1, 2 and 3 to choose the shape of the waste dump with the smallest land-occupying area.

3.3.1.1. One-bench waste dump

Consider a one-bench waste dump with the parameters shown in Figure 3.1.

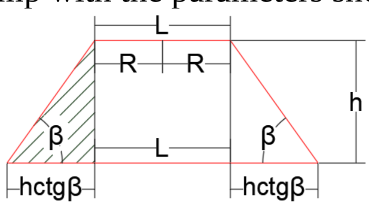

***Figure 3.1**. Section of a one-bench waste dump*

It is clear that the required capacity V of square and rectangular dumps is determined by the formula:

$$V = hS_m + C_m\frac{1}{2}h^2 ctg\beta + \frac{\pi}{3}h^3 ctg^2\beta, \text{ m}^3 \quad (3.1)$$

- For circular and elliptical dumps:

$$V = hS_m + C_m\frac{1}{2}h^2 ctg\beta, \text{ m}^3 \quad (3.2)$$

- For waste dumps with square and rectangular shape, S_m and C_m are determined according to formulas 3.3 and 3.4.:

$$S_m = kL^2, \text{ m}^2 \quad (3.3)$$

$$C_m = 2L(1+k), \text{ m} \quad (3.4)$$

- For waste dumps with circular and elliptical shapes, S_m and C_m are determined according to formulas 3.5 and 3.6:

$$S_m = \pi kR^2, \text{ m}^2 \quad (3.5)$$

$$C_m = 2\pi\sqrt{\frac{R1^2+R2^2}{2}} = 2\pi R\sqrt{\frac{1+k^2}{2}}, \text{ m} \quad (3.6)$$

From there, formula (3.1) of square and rectangular dumps is written as follows:

$$V = hkL^2 + (1+k)(h^2 ctg\beta)L + \frac{\pi}{3}h^3 ctg^2\beta, \text{ m}^3 \quad (3.7)$$

$$\text{Or } hkL^2 + (1+k)(h^2 ctg\beta)L + \frac{\pi}{3}h^3 ctg^2\beta - V = 0 \quad (3.8)$$

- For waste dumps with circular and elliptical shapes:

$$V = \pi khR^2 + \pi R\sqrt{\frac{1+k^2}{2}}h^2 ctg\beta \quad (3.9)$$

$$\text{Or } \pi khR^2 + \pi R\sqrt{\frac{1+k^2}{2}}h^2 ctg\beta - V = 0 \quad (3.10)$$

Solving quadratic equations (3.8 and 3.10) with unknowns L, R we have:

- For square and rectangular waste dumps:

$$L_c = \frac{\left(-(1+k)h^2 ctg\beta + \sqrt{((1+k)\,h^2 ctg\beta)^2 - 4kh(\frac{\pi}{3}h^3 ctg^2\beta - V)}\right)}{2hk}, \text{m} \quad (3.11)$$

- For waste dumps with circular and elliptical shapes:

$$R_e = \frac{\left(-(\pi h^2 ctg\alpha)\sqrt{0,5(1+k^2)} + \sqrt{(\pi h^2 ctg\alpha)^2 0,5(1+k^2) + 4\pi khV}\right)}{2\pi kh}, \text{ m} \quad (3.12)$$

From there, with a circular, elliptical waste dump, the radius (semi-axis) of the bottom is calculated by the formula:

$$R_{de} = \frac{\left(-(\pi h^2 ctg\beta)\sqrt{0,5(1+k^2)} + \sqrt{(\pi h^2 ctg\beta)^2 0,5(1+k^2) + 4\pi khV}\right)}{2\pi kh} + hctg\alpha, \text{ m} \quad (3.13)$$

- Land occupied area of square and rectangular waste dumps is calculated by the formula:

$$S_{dc} = kL_c^2 + 2hL_c(1+k)ctg\beta + \pi(hctg\beta)^2, \text{ m}^2 \quad (3.14)$$

- Land occupied area of circular and elliptical landfills is calculated by the formula:

$$S_{de} = \pi k\left(\frac{\left(-(\pi h^2 ctg\beta)\sqrt{0,5(1+k^2)} + \sqrt{(\pi h^2 ctg\beta)^2 0,5(1+k^2) + 4\pi khV}\right)}{2\pi kh}\right)^2, \text{ m}^2 \quad (3.15)$$

3.3.1.2. Two-bench waste dump

Consider a two-bench waste dump with the parameters shown in Figure 3.2.

Capacity V requires square, rectangular dumps determined by the formula:

$$V = 2hS_m + C_m(2h^2 ctg\beta + Bh) + \frac{\pi}{3}h^3 ctg^2\beta + \pi h(B+hctg\beta)^2 + \pi h^2(B+hctg\beta)\,ctg\beta, \text{ m}^3 \quad (3.16)$$

The volume V required for the circle and the ellipse is determined by the formula:

$$V = 2hS_m + C_m(2h^2 ctg\beta + Bh), \text{m}^3 \quad (3.17)$$

Where: S_m, C_m are the area and perimeter of the top dumping bench.

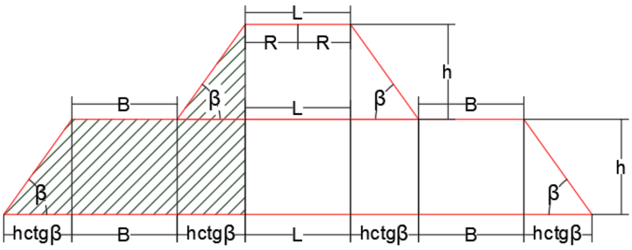

***Figure 3.2**. Section of a two-bench waste dump*

The formula (3.16) for waste dumps in the form of squares and rectangles is written as follows:

$$2hS_m+C_m(2h^2ctg\alpha + Bh)+\pi h[\frac{1}{3}h^2ctg^2\alpha + (B+hctg\alpha)^2 + h(B+hctg\alpha)ctg\alpha]-V=0 \quad (3.18)$$

Or

$$2hkL^2+2(1+k)h(2hctg\beta + B)L+\pi h[\frac{1}{3}h^2ctg^2\beta + (B+hctg\beta)^2+h(B+hctg\beta)ctg\beta]-V=0 \quad (3.19)$$

- For waste dumps with circular and elliptical shapes:

$$V= 2\pi khR^2+ 2\pi R\sqrt{\frac{1+k^2}{2}}(2h^2ctg\beta + Bh)\ , m^3 \quad (3.20)$$

$$\text{Or}: 2\pi khR^2+ 2\pi R\sqrt{\frac{1+k^2}{2}}(2h^2ctg\beta + Bh) - V = 0 \quad (3.21)$$

Solving quadratic equations (3.19) and (3.21) with unknowns L, R we have:

$$Lc = \frac{-2(1+k)h(2hctg\beta+B)+\sqrt{(2(1+k)h(2hctg\beta+B)^2-8kh(\pi h[\frac{1}{3}h^2ctg^2\alpha+(B+hctg\beta)^2+h(B+hctg\beta)ctg\beta]-V)}}{4kh},\ m \quad (3.22)$$

$$Re = \frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(2h^2ctg\beta+Bh)\right)+\sqrt{4\pi^2\frac{1+k^2}{2}(2h^2ctg\beta+Bh)^2+8kh\pi V}}{4kh\pi},\ m \quad (3.23)$$

- For two-bench circular and elliptical dumps, the length of the bottom edges is calculated by the formula:

$$Rde = \frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(2h^2ctg\beta+Bh)\right)+\sqrt{4\pi^2\frac{1+k^2}{2}(2h^2ctg\beta+Bh)^2+8kh\pi V}}{4kh\pi}+(2hctg\beta + B), m \quad (3.24)$$

The area of the bottom of the two-bench square and rectangular waste dumps is calculated by the formula:

$$Sdc = kL^2c + 2Lc(k + 1)(B + 2hctg\beta) + \pi(B + 2hctg\beta)^2, m^2 \quad (3.25)$$

The area of the bottom of the two-bench circular and elliptical waste dumps is calculated by the formula:

$$Sde = \pi k\left(\frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(2h^2ctg\beta+Bh)\right)+\sqrt{4\pi^2\frac{1+k^2}{2}(2h^2ctg\beta+Bh)^2+8kh\pi V}}{4kh\pi} + (2hctg\beta + B)\right)^2 \quad (3.26)$$

3.3.1.3. Three-bench waste dump

Consider a three-bench waste dump with the parameters shown in Figure 3.6.

Capacity V required square, rectangular waste dumps is determined by the formula:

$$V=3hkL^2+2(1+k)(4{,}5h^2ctg\beta + 3Bh)L+\pi h[\frac{1}{3}h^2ctg^2\beta + 5(B+hctg\beta)^2+3h(B+hctg\beta)ctg\beta], m^3\ , m^3 \quad (3.27)$$

Or:

$$3hkL^2 + 2(1+k)(4{,}5h^2ctg\beta + 3Bh)L + \pi h[\tfrac{1}{3}h^2ctg^2\beta + 5(B+hctg\beta)^2 + 3h(B+hctg\beta)ctg\beta] - V = 0 \qquad (3.28)$$

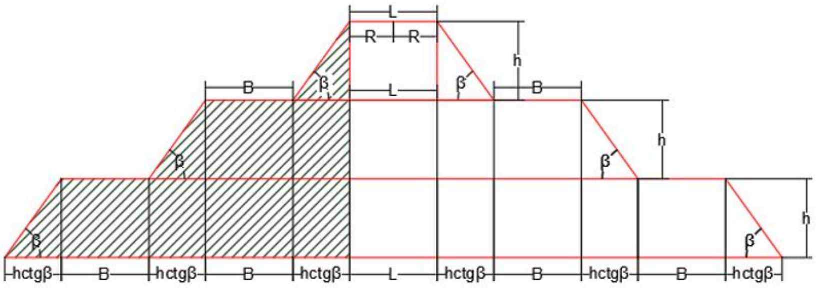

***Figure 3.3**. Section of a three-bench waste dump*

The capacity V requires a circular and elliptical waste dumps to be determined below:

$$V = 3\pi khR^2 + 2\pi R\sqrt{\frac{1+k^2}{2}}(4{,}5h^2ctg\beta + 3Bh),\ m^3 \qquad (3.29)$$

$$\text{Or: } 3\pi khR^2 + 2\pi R\sqrt{\frac{1+k^2}{2}}(4{,}5h^2ctg\beta + 3Bh) - V = 0 \qquad (3.30)$$

Solving quadratic equations (3.28) and (3.30) unknowns L, R we have :

$$Lc = \frac{-\left(2(k+1)(4{,}5h^2ctg\beta+3Bh)\right)+\sqrt{4(k+1)^2(4{,}5h^2ctg\beta+3Bh)^2-12kh(\pi h[\frac{1}{3}h^2ctg^2\beta+5(B+hctg\beta)^2+3h(B+hctg\beta)ctg\beta]-V)}}{6kh},\ m \qquad (3.31)$$

$$Re = \frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(4{,}5h^2ctg\beta+3Bh)\right)+\sqrt{2\pi^2(1+k^2)(4{,}5h^2ctg\beta+3Bh)^2+12kh\pi V}}{6kh\pi},\ m \qquad (3.32)$$

- For three-bench circular, ellipse waste dumps, the length of the bottom edges is calculated by the formula:

$$Rde = \frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(4{,}5h^2ctg\beta+3Bh)\right)+\sqrt{2\pi^2(1+k^2)(4{,}5h^2ctg\beta+3Bh)^2+12kh\pi V}}{6kh\pi}+(3hctg\beta + 2B),\ m \qquad (3.33)$$

The area of the bottom of the three-bench square and rectangular waste dumps is calculated by the formula:

$$Sdc = kL^2c + 2Lc(k+1)(2B + 3hctg\beta) + \pi(2B + 3hctg\beta)^2,\ m^2 \qquad (3.34)$$

The area of the bottom of the three-bench circular and elliptical waste dumps is calculated by the formula:

$$Sde = \pi k\left(\frac{-\left(2\pi\sqrt{\frac{1+k^2}{2}}(4{,}5h^2ctg\beta+3Bh)\right)+\sqrt{2\pi^2(1+k^2)(4{,}5h^2ctg\beta+3Bh)^2+12kh\pi V}}{6kh\pi} + (3hctg\beta + 2B)\right)^2,\ m^2 \qquad (3.35)$$

Calculation results show that: with the same required capacity V, waste dump height H, width of dumping bench B, and height h at different dumps, the waste dump has a large area of land occupied by H and h. Small S_d when V requires large S_d. The square waste dump has the largest land area. The smallest land-occupying area is an elliptical waste dump with the ratio of semi-axis (small/large) $k \to 0.5$.

3.3.2. Research on selection of waste dump parameters for surafce coal mines at Cam Pha area

3.3.2.1. Research on selection of suitable dumping bench height

The height of the dumping bench is an important waste dump parameter that affects the volume and stability of the waste dump. The height of the dumping bench is related to the distribution of the size composition of rocks particles in the dumping bench. The height of the dumping bench is proportional to the potential energy (E_t = m.g.H) of the rocks when dumping, affecting the falling speed and the arrangement of the rock components of different sizes on the slope of the dumping bench.

The reasonable height of the dumping bench H_{hl} (or a one-bench waste dump) is selected according to the following principles: ensuring the stability (FoS) of the waste dump as required in the rainy season and the total cost of creating a waste dump (truck + bulldozer) (C_t) smallest.

FoS = f(H) with FoS >1,3 ; H_{hl} = min ; C_t = f (H)→ min

a) Research on selecting the height of the dumping bench according to the rocks mechanical properties

a1) When the rocks are in a homogeneous natural state

a2) With homogeneous rocks, saturated with water

a3) When rocks properties change

b) Research on selecting the height of the dumping bench according to the minimum transportation and leveling costs

b.1) Transport costs

b.2) Cost of clearing the waste dump

3.3.2.2. Research to choose the appropriate slope angle of the dumping bench

3.3.2.3. Research to choose a reasonable width of dumping bench

3.3.2.4. Selecting the waste dump height

3.3.2.5. Choosing the suitable slope angle of waste dump

3.3.2.6. Sensitivity analysis of waste dump stability coefficient according to input parameters

3.4. PROPOSAL OF SUITABLE DUMPING TECHNOLOGY TO ENSURE THE STABILITY IN THE CONDITION OF TROPICAL RAINY SEASON FOR SURFACE COAL MINES AT CAM PHA AREA IN QUANG NINH PROVINCE

3.4.1. Principal for building the suitable dumping technology to ensure the stability of waste dump in the condition of tropical rainy season

Tropical monsoon rains directly affect the waste dump through the amount of rainwater entering the waste dump, causing pore pressure, causing the cohesion force, the internal friction angle to decrease, and the density of rocks to increase. On the other hand, heavy rains make it difficult for equipment to operate on the waste dump. With specific dumping requirements, the stability factor has been approved, the parameters: the height of the dumping bench, the width of the safety belt, the slope angle of the dumping bench, and the waste dump are also clearly defined. Since then, when choosing the dumping technology and equipment, it is necessary to follow the following principles:

- Ensure the selected waste dump parameters;
- Ensure the required dumping volume (m^3/day, m^3/month, m^3/year);
- Ensure safety for people and equipment; the smallest land-occupying area, with little impact on civil and industrial works and the surrounding environment of the area;
- Ensure favorable conditions for environmental rehabilitation and restoration of waste dumps;
- Stability in climate change conditions (extraordinarily heavy and prolonged floods);
- Ensure the cost and cost of dumping operation is minimal.

The rocks waste dumps at Cam Pha area in Quang Ninh are mainly external dumps dumped on the mountain side by truck and bulldozer technology. Currently, Cao Son coal mine uses conveyors and bulldozers and Coc Sau coal mine uses waste dumps inside. Generally, the current dumping technology of waste dumps at Cam Pha area in Quang Ninh province includes:

+ Technology of using bulldozers;

+ Technology using belt conveyors and bulldozers;

+ Technology of using trucks and bulldozers to dump waste inside.

3.4.2. Dumping technology for outside waste dump

3.4.2.1. For new waste dump

The peculiarity of the waste dump is that it is built on the mountainside when dumping the waste rocks at the top of the bench, that is, the trucks transporting rocks move downhill, so they can dump the waste rocks with the maximum height of the dumping bench but still ensure the stability coefficient of the waste dump FoS > 1.3. According to calculations, when the height H = 90 m, the stability coefficient FoS > 1.0 can choose the maximum height of the one-bench waste dump PE < 90 m. For each type of truck, B_{min} has different values. Assume that the waste dump is designed with an ending bench width of B_t. Depending on the value of B_{min}, the author proposes the following dumping schemes:

a) Dumping scheme by block in turn from bottom to top

* If $B_t > B_{min}$: Dumping sequence by block in turn from bottom to top (Figure 3.4).

* If $B_{min} > B_t$: Dumping sequence by block in turn from bottom to top (Figure 3.5).

b) Dumping scheme by layer in turn from bottom to top

Pour from the bottom bench to the top bench in turn within the waste dump height H. With a height equal to the height of the dumping bench h (Figure 3.6).

c) Combined dumping scheme

In the combined dumping scheme, the dumping sequence is shown in Figure 3.7.

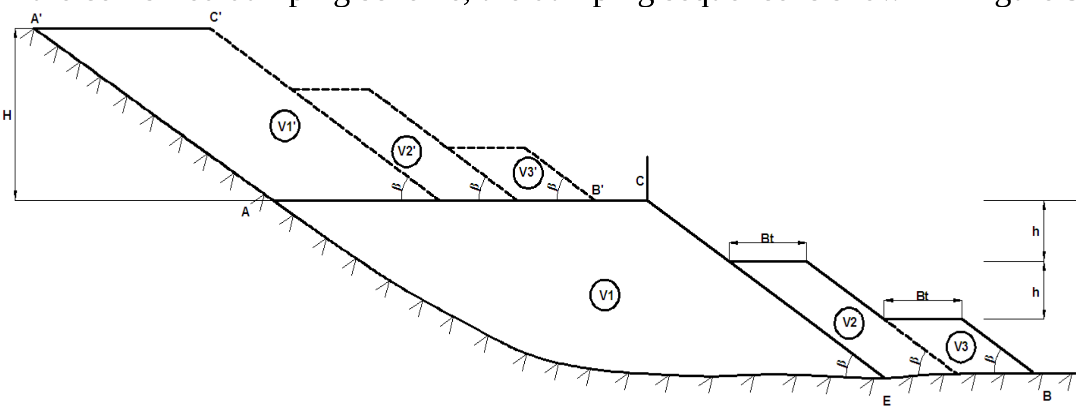

Figure 3.4. *Dumping sequence in blocks when $B_{min} < B_t$*

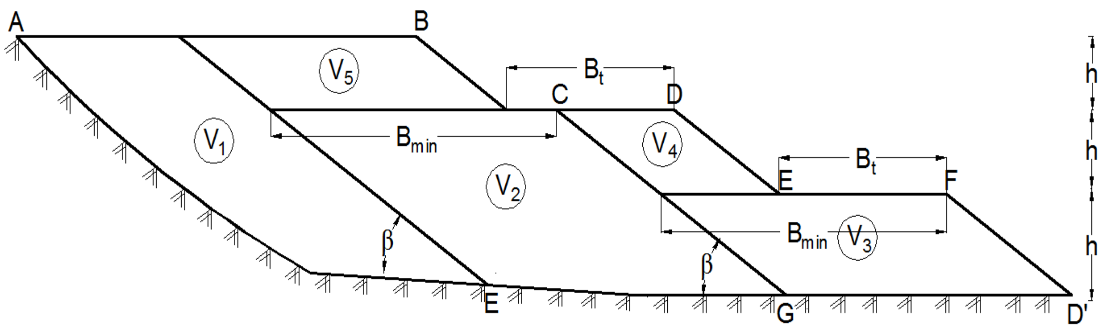

Figure 3.5. *Dumping sequence in blocks when $B_{min} > B_t$*

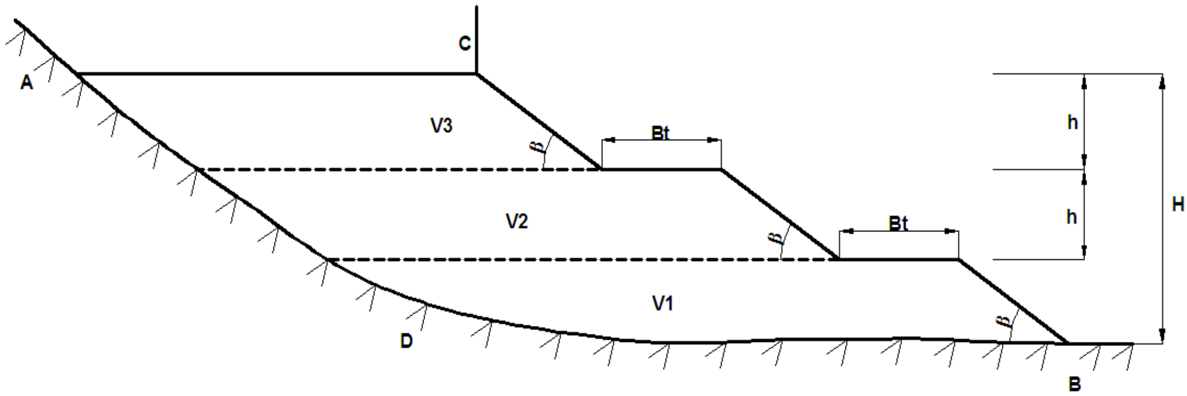

Figure 3.6. *Dumping sequence in layers*

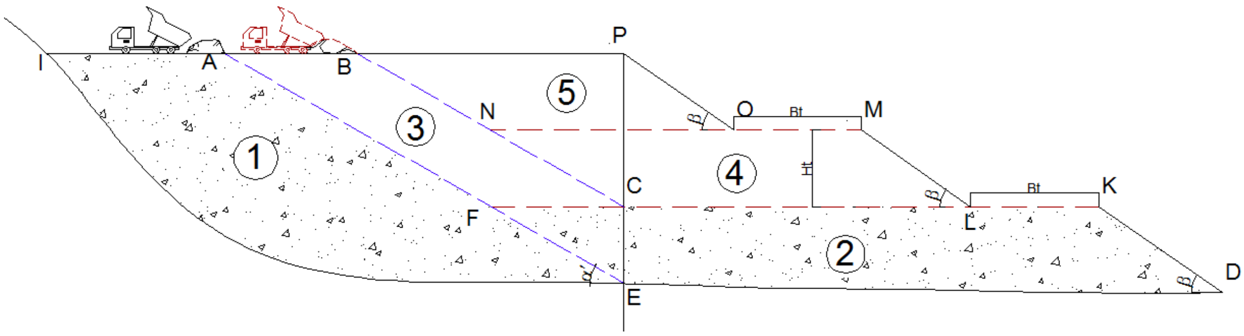

Figure 3.7. *Combined dumping sequence in period 1*

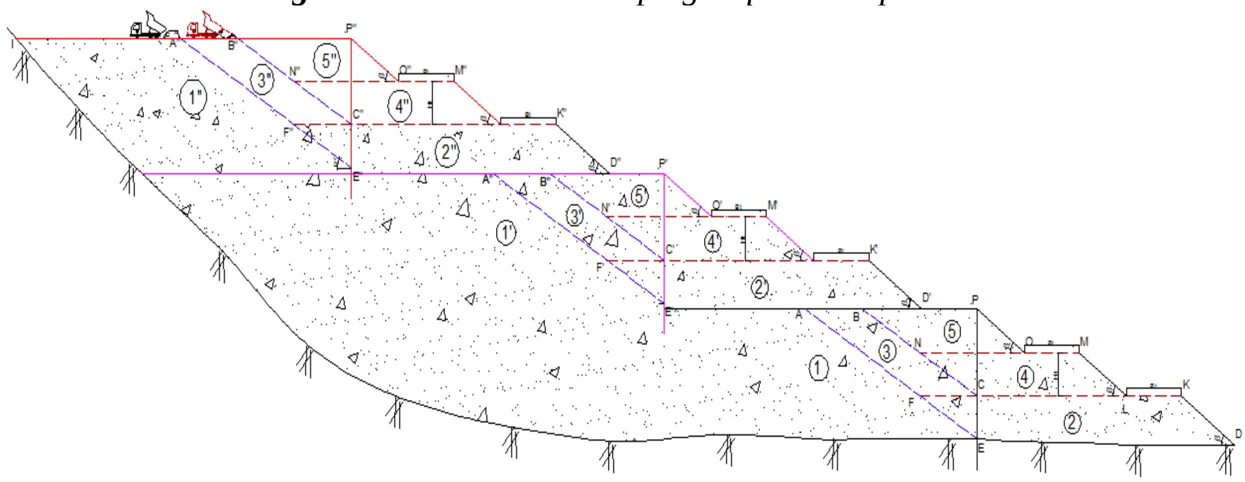

Figure 3.7. *Combined dumping sequence in periods 2,3…*

Analyzing the considered dumping sequence schemes, the author proposed to choose a combined dumping scheme to apply to the conditions of surface coal mines at Cam Pha area, with the following parameters: height of dumping bench h = 30 m; slope angle of the end dumping bench $\beta = 35^0$, width of the end bench surface B = 50 m, height of the waste dump H = 90 m.

3.4.2.2. For working waste dumps

At the working waste dumps, depending on the distance from the toe of the bottom bench and the boundary of the end of dumping process (point D), waste rocks can be dumped in the following order:

a) When $ED > 2B_{tmax} + 3H_t\, ctg\beta$

- Stage 1: continue pouring high bench AE to position A'E' where $E'D = 2B_{tmax} + 3H_t ctg\beta$ (Figure 3.9) then pour blocks 2, 3, 4 and 5 similar to the combined dumping scheme in period 1 of new waste dumps.

- Stage 2: dump the upper benches similar to stage 1. The dumping sequence is shown in Figure 3.9.

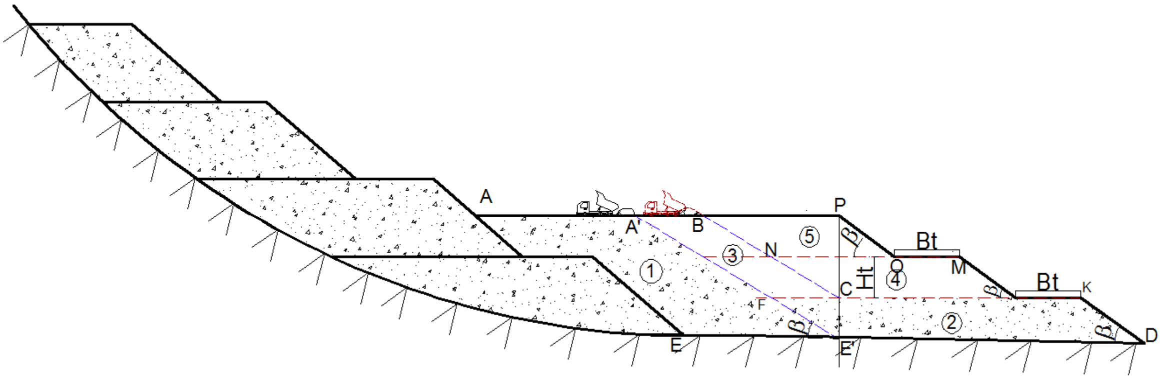

Figure 3.9. *Dumping scheme at the working waste dump*

3.4.3. Dumping technology for inside waste dump

Dispose of waste rocks in accordance with the top-floor dumping scheme for areas where there is no underground furnace line to reduce waste disposal costs. When there are furnace lines below, the waste will be poured in layers to reduce porosity, reduce the pressure of soil, rock and water on the top of the furnace.

3.4.3.1. When there are no furnace lines below

When there are no furnace lines under and around the inner dumping site, dump the waste at the top of the *bench* with a large *bench* height (Figure 3.10).

The dumping scheme in Figure 3.10 has a small disposal cost. However, with a large bench height, it is necessary to regularly monitor the surface of the waste dump to have a solution to ensure that trucks and bulldozers work on the surface of the dumping bench.

3.4.3.2. When there are furnace lines below

The dumping process is carried out layer by layer from bottom to top and must be well compacted and compacted to ensure the compaction of waste K ≥ 0.85. From the bottom of the pit to the level of self-flowing drainage, dumping waste in layers with a height of h_{cl} = 5÷10 m, above the level of self-flowing water dumping waste in layers with a height of each layer ⩾ 10 m [4].

To ensure good drainage, the surface of the waste dump must have a slope of i ⩾ 2%, directing the surface flow from the waste dump to the self-flowing drainage ditch system. The dumping technology scheme by layers with furnace lines below is shown in Figure 3.11.

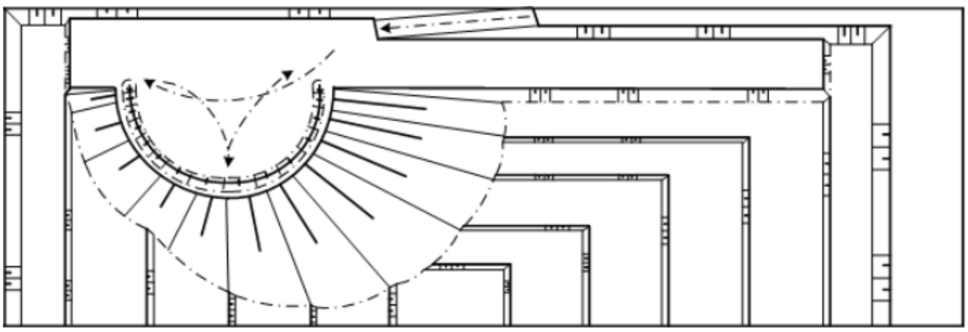

Figure 3.10. *Dumping technology for inside waste dump without furnace lines below*

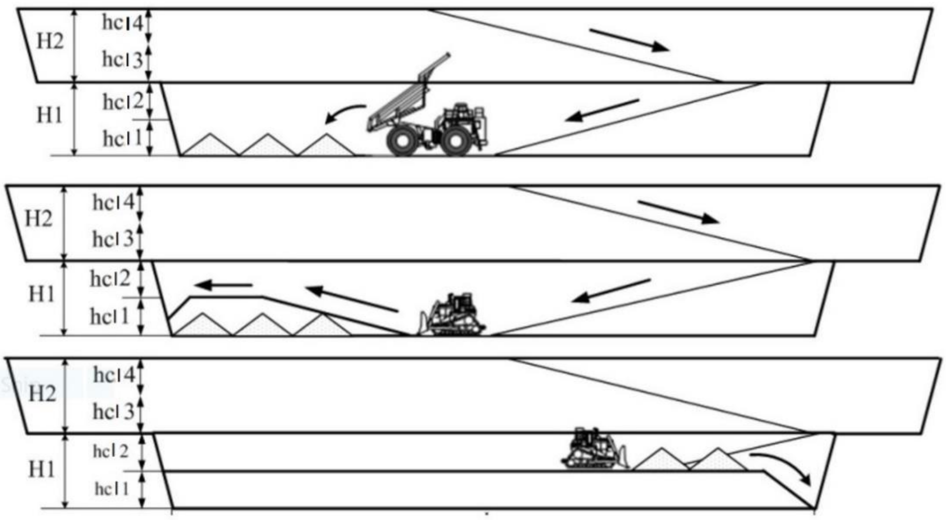

Figure 3.11. *Dumping technology for inside waste dump with furnace lines below*

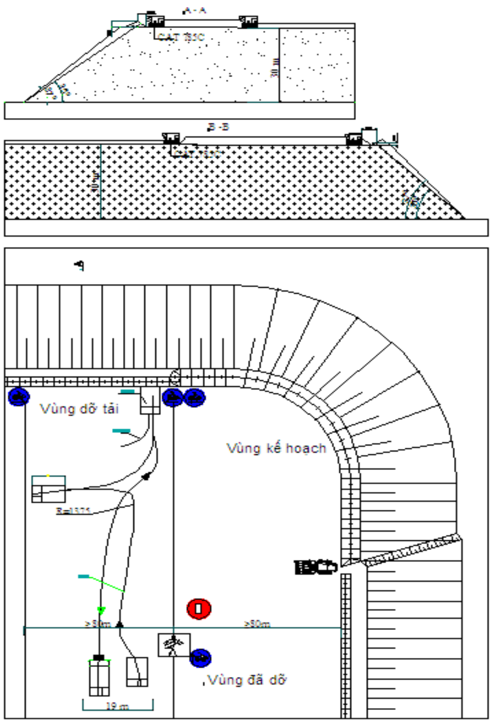

Figure 3.12. *Perimeter dumping technology*

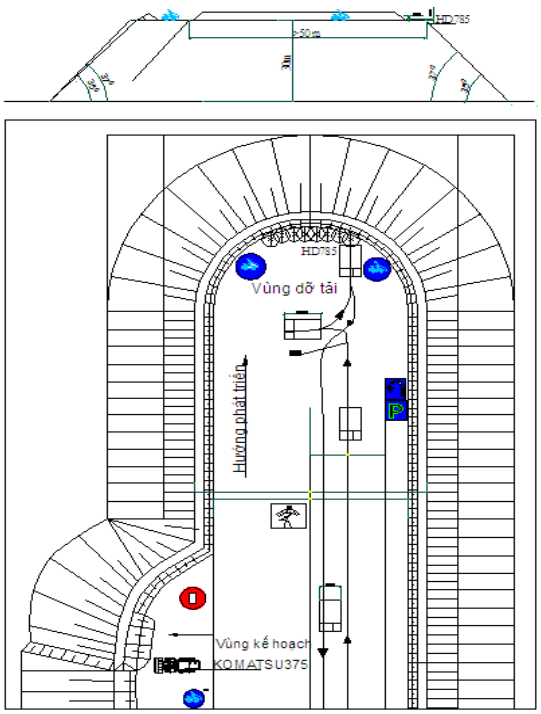

Figure 3.13. *Area dumping technology with truck and bulldozer*

3.4.4. Dumping technology with equipment

3.4.4.1. Dumping technology with truck and bulldozer

This technology is divided into 2 dumping methods, specifically as follows [4]:

a) Perimeter dumping method

When discharging by this method, the waste rocks are unloaded directly to the slope of dumping bench or slope of waste dump, then using a bulldozer to push the remaining soil and rock on the dumping bench to the side of the waste dump (Figure 3.12).

b) Area dumping method (disposal by surface)

When discharging along the surface of waste dump, it is completely unloaded on the surface of the waste dump, then leveling with bulldozers is carried out. The distance of rock leveling in this case is up to 5÷15 m. This method is often applied to discharge soft, unstable rock or in areas where there is a high demand for rock compaction (Figure 3.13).

3.4.4.2. Dumping technology with belt conveyor system

When transporting by belt conveyor system, the removal works in combination with the waste disposal machine. Waste dumps are dumped in the form of two layers, both unloading and unloading, or can be dumped in one-bench from bottom to top.

On the waste dump, bulldozers are used to create a route that gradually extends the belt conveyor system for each dumping stage. Dumping technology scheme by belt conveyor system is shown in Figure 3.14.

Given the actual topographical conditions of the waste dumps at Cam Pha area, using the unloader on the slope of the dumping bench by the dumping bridge with the parameters as shown in Figure 3.15: a = 25 m; H_t = 90 m; β = 30÷32°; L_{tb} = 434 m. When the minimum area at an unloading machine location is 6,000 m^2, the unloading volume there is V = 740,149 m^3.

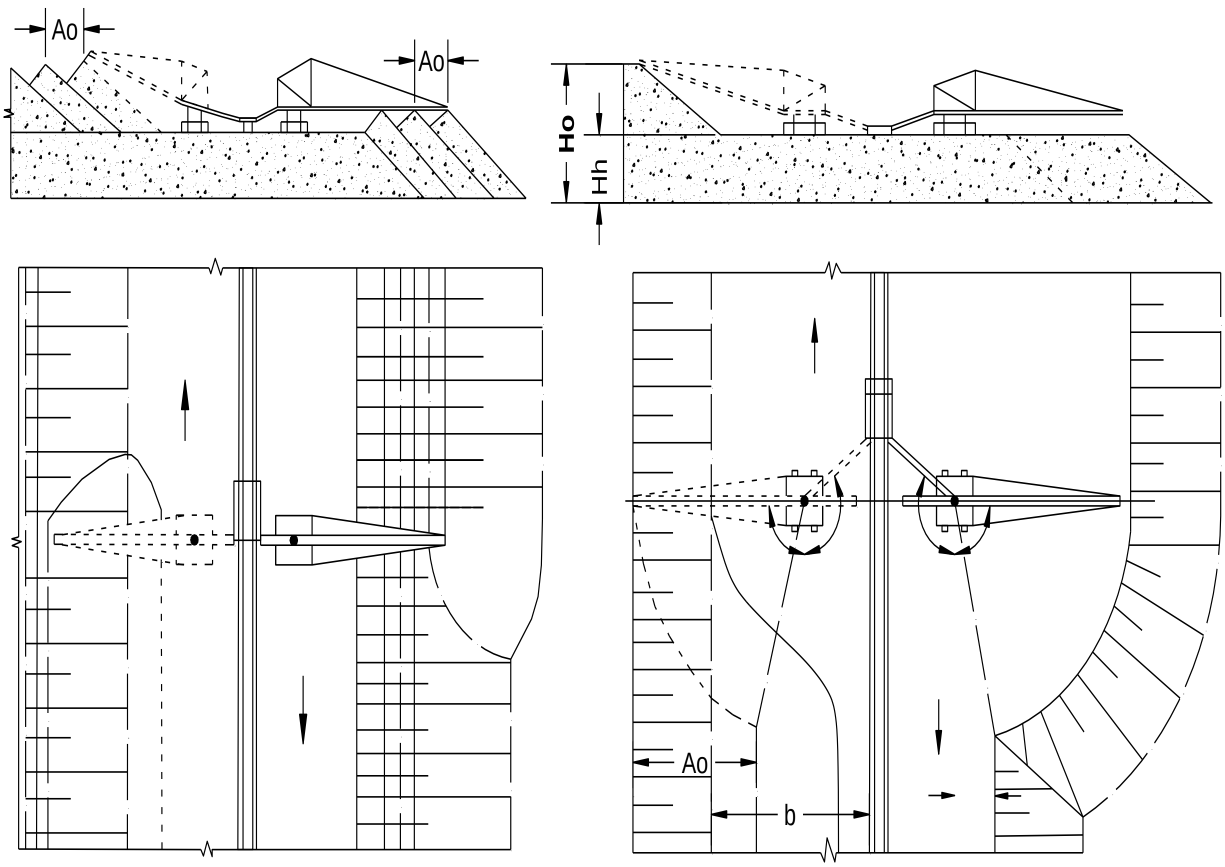

Figure 3.14. *Dumping technology with the belt conveyor system*

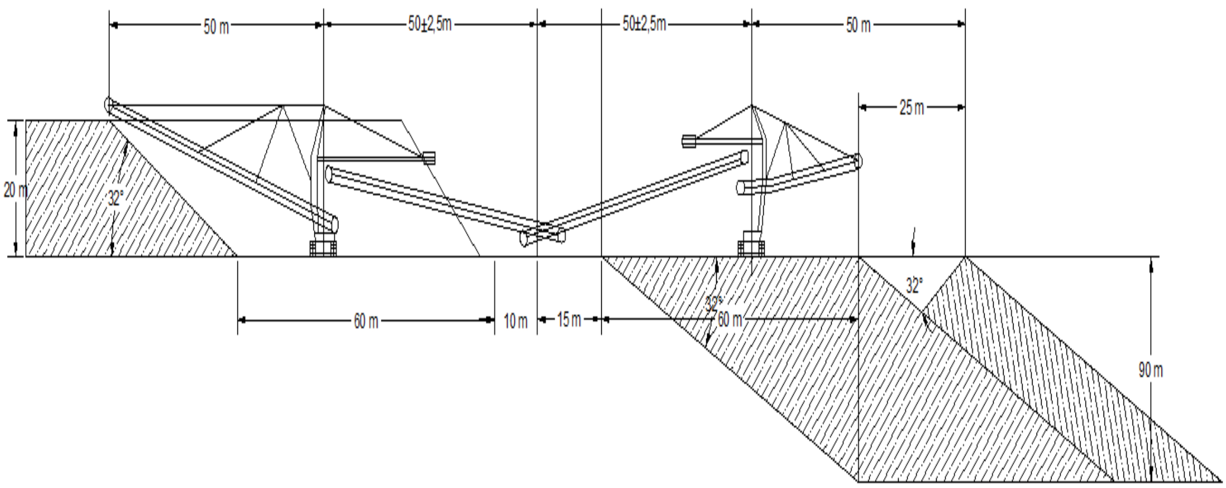

Figure 3.15. *Dumping technology with the dumping bridge*

3.5. CONCLUSION OF CHAPTER 3

The outside waste dumps at Cam Pha area are classified as dumping on hard and semi-solid foundation, according to classification criteria, they are classified as Class III with low to moderate risk of instability. The waste dump stability parameters are determined through the finite element model with the stability acceptance coefficient FoS = 1.3÷1.4 with the probability of waste dump < 5 ÷10%; when the FoS coefficient > 1.5, the probability of waste dump is less than 5%.

Analysis of the change in area of the bottoms of one-, two- and three-bench dumps at constant values for the height and capacity of the waste dump shows the value of the minimum occupied area ($S \rightarrow min$) is performed provided that the waste dump is formed as an ellipse, proportional to the lengths of the semi-axes ($C \rightarrow 0.5$),...

The height of the dumping bench depends on the properties of the waste rocks, the stability coefficient of the waste dump, the degree of water saturation of the waste rocks, and the transportation and disposal costs. When using trucks with payload of q= 36÷58 tons, the selected dumping bench height is 15 m lower; for trucks of 91÷96 tons, choose a lower dumping bench height of 30 m.

The width of the protective bench depends on the height of the dumping bench and the stability of the waste dump. The width of the protective belt ensures that it can accommodate the volume of waste dumps in the upper bench and the safe space.

The waste dump height is from 120÷460 m; slope angle of dumping bench from 30÷35^0; waste dump slope angle from 14÷29^0; stability coefficient when in dry state n_k = 1.373÷1.794, and in water saturated state n_{bh} = 1.311÷1.598. The waste dumps on the mountainside are dumped with a height of < 90 m inside and dumped outside the dumping benches with a height of 30 m, with a slope angle of 35°.

Working waste dumps, depending on the distance from the toe to the border of the end of dumping process, can dump <90 m high inside and dump outside 30 m high. When the width of the bottom of the dumping bench to the border is small, it is necessary to dump the waste from the bottom to the top with benches of 30 m high, with a slope angle of 35°. Dumping technology scheme according to the method of circumference for the dry season and the area for the rainy season.

At the waste dumps in or in the valley area, the top bench can be dumped with the maximum height. When there is underground construction, it is necessary to dump waste rocks in layers with a layer height of 5÷10 m in order from bottom to top. For mines, the truckand belt conveyor combination is used to transport rocks and discharge the dumping bench height when using the belt conveyor from < 90 m. In the end, use a combination of truck and bulldozer to pour tiles around to create a bench with a height of 30 m.

CHAPTER 4
APPLICATION FOR THE CAO SON MINE AT CAM PHA AREA IN QUANG NINH PROVINCE

4.1. INTRODUCTION TO CAO SON SURAFCE COAL MINE

Cao Son coal mine is one of the largest surface coal mines in our country today. The coal is of good quality, however, the mine has a high average stripping ratio and a rather long length of rock transportation. In recent years, the average coal production has reached 2.7÷3.25 million tons/year, equivalent to 25.66÷33.37 million m^3/year of peeled waste rocks output.

4.1.1. Natural and rock characteristics of the mine

4.1.2. Weather characteristics of the mine area

Cao Son coal mine area is in the tropics, hot and humid with lots of rain, a year is divided into two distinct seasons. The rainy season lasts from April to October with the largest rainfall in 1 rain in 2015 is 1,411 mm and in 5 months in the rainy season in 2015 is 2,916 mm. The dry season lasts from November of the previous year to March of the following year. The temperature varies according to the season, the summer temperature is up to 37÷38^{0}C (July, August every year), the winter low temperature is usually from 8÷15^{0}C, sometimes down to 2÷3^{0}C. Average humidity in dry season is 65÷80%, rainy season is 81÷91%. On heavy rainy days, not only transportation but also drilling, blasting, loading and unloading work must be temporarily suspended to prevent occupational accidents that are easy to happen during this time.

4.1.3. Mining work at Cao Son coal mine

Currently, Cao Son Coal Company is exploiting 3 coal seams: 14-5, 14-2 and 13-1, distributed in 3 areas southwest of Cao Son, Southeast of Cao Son and Central.

The technology of rock removal applied is the vertical layer cutting technology. The technology of deep excavation of the mine bottom is the application of a ladder mine bottom with a inclined pit bottom with the use of a hydraulic excavator with a bucket capacity E = 3.3÷4.7 m^3.

4.1.4. Dumping work at Cao Son coal mine

Rocks from Cao Son coal mine is currently mainly dumped into 2 waste dumps, namely Nam Khe Tam and Bang Nau waste dumps, of which Bang Nau is the main waste dump. According to design, Bang Nau waste dump has a length of 2920 m, a width of 1955 m and the height of the waste dump is +300 m.

Rocks from benches +290 m ÷ +395 m in Nam Cao Son area are dumped at Nam Khe Tam waste dump, the rest are dumped at Bang Nau waste dump by trucks at levels of +70 m, +120 m, +170 m and by the belt conveyor system at levels of +290 m ÷ +300 m.

Bang Nau dumping site is a high waste dump. Previously, the mine used trucks to dump waste along the mountainside. The dumping ground is not flat in the forward direction of the dumping site, the foot of the dumping ground is above the self-flowing drainage level. There is no water supply around the waste dump. At present, about 20 million m^3 of rocks are dumped annually at Bang Nau waste dump by means of a belt conveyor system and dumping bridge.

4.2. PROPOSE DUMPING TECHNOLOGY TO ENSURE THE STABILITY FOR BANG NAU WASTE DUMP AT CAO SON COAL MINE

To propose a reasonable dumping technology, the following steps should be taken:

- Check the stability according to the current status of the waste dumps;
- Propose the waste dump parameters to ensure safety in tropical monsoon rains;
- Develop the technical solutions to bring the waste dump to the proposed parameters.

4.2.1. Check the stability according to the current state of the waste dumps

Calculation results of Bang Nau waste dump with natural and saturated soil and rock parameters are shown in Figures 4.2 and 4.3. From the calculations, it is shown that with the current state of high bench dumping, the Bang Nau waste dump is in a limited equilibrium. If the rock is saturated, landslides may occur. The above calculations are consistent with the current subsidence in the dumping area by the belt conveyor system and dumping bridge at Bang Nau waste dump.

4.2.2. Recommend dumping parameters to ensure safety in tropical monsoon rains

According to the waste dump evaluation criteria presented in chapter 3, the waste dump stability coefficient when dumping FoS > 1.3. Therefore, it is necessary to select the waste dump parameters to ensure the required stability coefficient even in the most unfavorable case; that is when the soil is rocky in the rainy season with the same time and intensity of rain as the July 2015 rainy season and when saturated with water. From that, the author proposed the parameters of Bang Nau waste dump as follows: height of dumping bench h = 30 m; slope angle of dumping bench $\alpha = 35^o$; width of dumping bench surface when operating B = 30 m; at the end of B_T = 40 m; slope angle of waste dump when operating $\alpha = 26 \div 27^o$, at the end $\alpha_T = 20 \div 22^o$.

4.2.2.1. Assessment of waste dump stability according to proposed parameters

a. Assessment of waste dump stability in natural state

The results of the audit of the Bang Nau waste dump model using the proposed methods show that: the Bang Nau waste dump is stable with a FoS of 1.43÷1.44.

b. Assessment of waste dump stability in the saturated state

Evaluation of the stability of Bang Nau waste dump according to the proposed parameters when the soil and rock is in a state of saturation by the following methods: Morgenstern-Price's limit equilibrium method; the finite element method (SSR); the finite elements method is combined with Morgenstern's limit equilibrium method.

c. Assessment of waste dump stability when it comes to earthquakes

Calculation results show that: In the natural state, the waste dump is stable with FoS > 1.44. When it rains with an intensity of 437 mm in a 24-hour period FoS drops to 1%. At full saturation, FoS decreases by 10%. When taking into account the 6.5-magnitude earthquake, if in the dry state, FoS decreases to a value of 1.27, equivalent to a decrease of 11.2%; if the waste dump is in a saturated state, the FoS = 1,146 is reduced by nearly 20% compared to that in the natural state. Thus, this waste dump is completely stable.

4.2.2.2. Propose dumping technology

Belt conveyor system is dumping at Bang Nau waste dump from level of +300 m down to natural terrain with a very large height of dumping bench > 250 m; the level of +300 m is also the end height according to the design, the dumping bridge has a limited length, so to partially overcome the above difficulties and be suitable for the weather and climate, it is proposed to use 2 dumping technology schemes in the dry and rainy seasons as follows:

1. In the dry season: using the loading and unloading scheme on the slope of the dump site in combination with the bulldozer and excavator to level and shovel to create a gradually higher plane with a slope of 7÷10% to compensate for settlement, when the waste dump stability has a slope of 1÷2% (Figure 4.1).

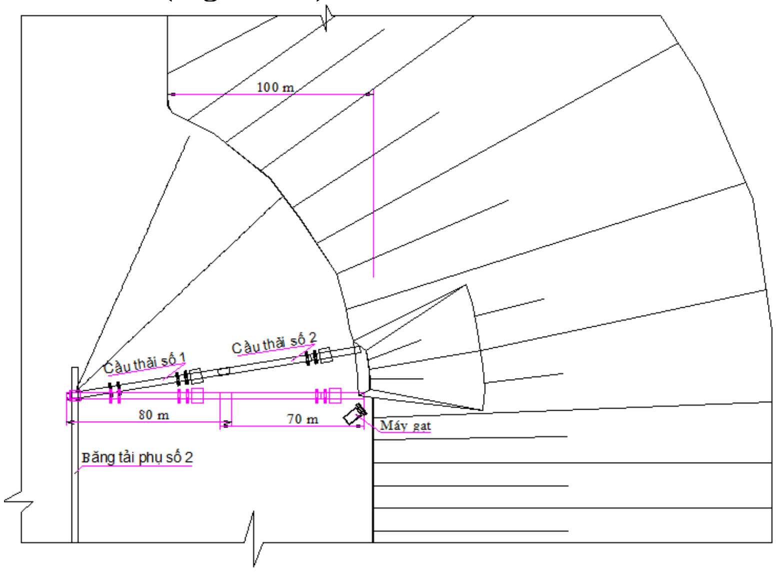

Figure 4.1. *Dumping scheme in the dry season*

2. In the rainy season: use the dumping scheme on the surface of the waste dump in combination with the bulldozer and excavator to grade and shovel the rocks down the slope of the waste dump, and create a gradually higher plane with a slope of 7÷10 % to compensate for settlement, when the waste dump is stable, the slope is from 1÷2% (Figure 4.2).

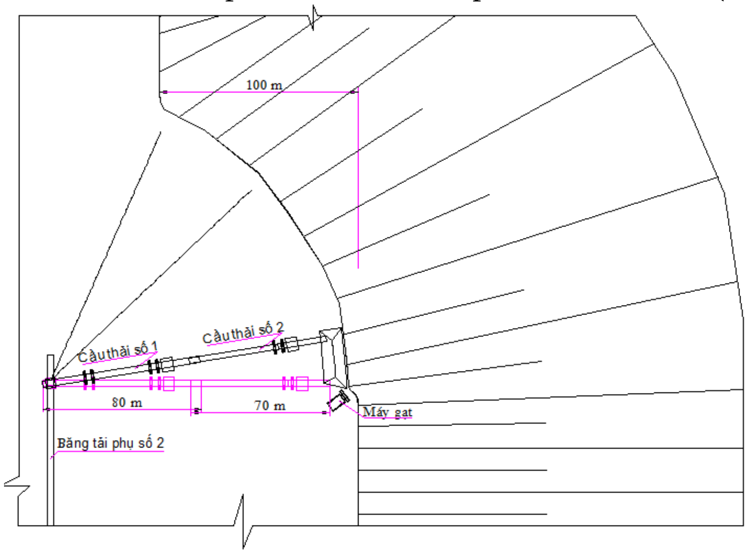

Figure 4.2. *Dumping scheme in the rainy season*

After the belt conveyor system empties the waste to the final border of the waste dump, renovate the slope of the dumping bench into benches with basic parameters as presented according to the design parameters in Table 4.1.

Table 4.1. *Parameters of Bang Nau waste dump at the end*

No.	Parameters	Unit	Values
1	The height of the waste dump surface	m	+300
2	Height of dumping bench at the end (H)	m	30
3	Width of dumping bench at the end (B_{min})	m	40
4	Longitudinal slope of waste dump surface during operation	%	7÷10
5	Longitudinal slope of the waste dump surface at the end towards the drainage position	%	1÷2
6	The horizontal slope of the dumping bench surface inwards for the renovated area	%	1÷2
7	Slope angle of dumping bench	degree	35
8	Slope angle of waste dump	degree	20÷24

4.3. CONCLUSION OF CHAPTER 4

Bang Nau waste dump is the main dumping site of Cao Son coal mine. Here, two technologies are being used: dumping by belt conveyor with a large height >250 m; dispose of waste by trucks in combination with bulldozers in the areas below the waste dump.

The current stability check calculation model at the belt conveyor discharge area shows that the conveyor waste dump is in a limited steady state. To ensure the safety of the waste dump, it is necessary to improve the waste dump parameters according to the stability criterion n > 1.3.

With the soil and rock parameters of the waste dump in the rainy and dry seasons, it is necessary to choose the parameters of Bang Nau waste dump as follows: height of the dumping bench h = 30 m; slope angle of dumping bench $\alpha = 35^o$; protective belt width B = 40 m. Calculation and comparison of the waste dump stability coefficient with the proposed parameters by means of limit balance methods, numerical methods, combined methods according to natural states, rain intensity 437 mm/day and dynamic 6.5 richter land. Stable dump results. Using dumping technology to pour directly onto the side of the waste dump in the dry season and on the surface in the rainy season and improve the dumping bench at the end of dumping according to the proposed parameters to ensure a safe and effective waste dump.

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

The thesis has analyzed the overview of the current situation and researched on the stability of waste dumps at surface mines in the world and in Vietnam. The study also specifies methods to calculate the stability of waste dumps in rainy season conditions in countries around the world. Since then, the urgency of the topic has been raised, the issues that the thesis needs to focus on solving in order to apply specifically to the dumping work at surface coal mines at Cam Pha area in Quang Ninh province.

Through waste dump models, the thesis uses specialized software to investigate the influence of parameters on waste dump stability: intensity and duration of rain, seismicity caused by earthquakes and blasting, properties of waste dump substrate, geometrical parameters, physical and mechanical properties of waste rock, technology and equipment for disposal. From that, it can be seen that: rainwater forms flows that infiltrate the waste dump, causing the following parameters: density to increase, cohesion force and internal friction angle to decrease, pore water pressure increases causing shear stress to increase, stability number decreases gradually and reaches the minimum value after 24 hours of rain. Based on the current deformation status, waste dump parameters, the thesis uses the inverse calculation method to determine the parameters C, φ of the waste dump in a dangerous state as the limiting condition for parameter selection calculations of waste dump geometry.

With experience in mines in the world, the current status of waste dumps at surface coal mines in Quang Ninh, the thesis has classified the waste dumps according to the criteria of risk of instability, and proposed criteria for calculating the stability of the waste dump.

With the same capacity, height, and required stability coefficient, the thesis has used a calculated geometric model and determined an elliptical waste dump with a half-axis ratio of 2 that will occupy the smallest usable area.

Based on the characteristics of waste rocks, equipment involved in dumping operation, stability requirements in rainy season and seismic scenarios by specialized software and analysis of the sensitivity of waste dump stability when changing. By changing the input parameters, the thesis has determined the optimal parameters for the waste dumps of surface coal mines in Quang Ninh such as: the height of the dumping bench, the slope angle of the dumping bench, the width of the dumping bench, the limited height of the waste dump.

The thesis has proposed the dumping technique to ensure a stable coefficient, using the maximum storage capacity with small costs: pouring high bench inside <90 m and emptying the outside of the waste layers with a height of 30 m. When the width of the bottom of the waste dump to the border is small, it is necessary to dump the waste from the bottom to the top with benches of 30 m high, with a slope angle of 35°. Dumping technology scheme according to the micro-method for the dry season and the area method for the rainy season. At the dumps in or in the valley area, the top bench can be dumped with the maximum height. When there is underground construction, it is necessary to dump waste in layers with a layer height of 5÷10 m in order from bottom to top. For mines, the truck and belt conveyor combination is used to transport rocks and discharge the waste layer height when using the belt conveyor from < 90 m. In the end, use truck and bulldozer to pour tiles around to create a bench with a height of 30 m. The thesis has also applied the research results to analyze and propose the parameters and dumping techniques at Bang Nau waste dump of Cao Son mine to ensure the required coefficient of stability in the rainy season, taking into account the influence of seismic effects.

2. RECOMMENDATIONS

- Continue to research and develop theoretical and experimental models of the amount of rainwater flowing into the waste dump according to the intensity and duration of rain in order to determine the rule of water infiltration into the waste dump, the change of soil physico-mechanical parameters waste rock.
- Using the finite element method for the waste dump stability calculation model gives the most accurate results compared to the existing methods when the input parameters are reliable enough. Therefore, it is necessary to continue using the finite element method to calculate the stability for mine banks and waste dumps in other surface mines.

LIST OF PUBLICATIONS RELATED TO THE THESIS

1. **Nguyen Tam Tinh**, Bui Xuan Nam (2016), *Artificial neural networks and the ability to determine the time variation of the waste dump surface*, Mining Industry, No. 2/2016, 46-52.

2. **Nguyen Tam Tinh** (2019), *Assess the current status of some waste dumps of open-pit mines in Cam Pha and Quang Ninh areas and propose some solutions to improve their stability*, Journal of Mining and Earth Sciences, Episode 60, Part 2 (2019), 121-130.

3. Hoang Nguyen, **Nguyen Tam Tinh**, Dinh Tien (2021), *Utilizing a bagging model based on decision trees and k-nearest neighbors for predicting slope stability in open pit mines*, International Conference on Geotechnical challenges in Mining, Tunneling & Underground structures (ICGMTU 2021), 20-21 December 2021, Malaysia.

4. **Nguyen Tam Tinh**, Xuan-Nam Bui (2021), *Identification of The Suitable Type of Waste Dumps for Open-Pit Coal Mines in Cam Pha, Quang Ninh*, International Journal of Scientific & Engineering Research, Volume 12, Issue 12, Nov-2021.

5. **Nguyen Tam Tinh**, Pham Duy Thanh (2022), *Assessing the applicability of unmanned aerial vehicles in monitoring and evaluating the stability of open-pit mine dumps*, Mining Industry, No. 1/2022, 40-45.

6. **Nguyen Tam Tinh** (2022), *Research on solutions to ensure stability of Bang Nau waste dump - Cao Son coal mine*, Natural Resources and Environment, Part 2, 4/2022, 47-49.