PROCEEDINGS OF THE 4th INTERNATIONAL CONFERENCE VIETGEO 2018

GEOLOGICAL AND GEOTECHNICAL ENGINEERING IN RESPONSE TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE

Quang Binh, 21&22 September 2018

INTERNATIONAL CONFERENCE

VIETGEO 2018

ORGANIZING COMMITTEE:

Assoc. Prof. Ta Duc Thinh	VAEGE, Vietnam
Assoc. Prof. Le Hai An	HUMG, Vietnam
Dr. Nguyen Duc Ly	Quang Binh Depart. of Science and Technology
Prof. Motoyuki Suzuki	Yamaguchi University, Japan
Assoc. Prof. Nguyen Huy Phuong	VAEGE, Vietnam
Assoc. Prof. Do Minh Duc	VAEGE, Vietnam
Prof. Nguyen Quoc Dung	Hydraulic Construction Institute, Vietnam
Prof. Suksun Horpibulsuk	Suranaree University of Technology, Thailand
Mr. Le Cao Minh	Technical World Co. Ltd, Vietnam
Assoc. Prof. Nguyen Van Vuong	VNU University of Science, Vietnam
Prof. Ding Wenqi	Tongji University, China
Assoc. Prof. Dau Van Ngo	Ho Chi Minh University of Technology, Vietnam
Assoc. Prof. Do Quang Thien	Hue University of Science, Vietnam
Assoc. Prof. Nguyen Quang Minh	HUMG, Vietnam

SCIENTIFIC COMMITTEE:

Prof. Tran Thanh Hai	HUMG, Vietnam
Prof. Motoyuki Suzuki	Yamaguchi University, Japan
Prof. Emeritus. Hiroshi Matsuda	Yamaguchi University, Japan
Prof. Suksun Horpibulsuk	Suranaree University of Technology, Thailand
Prof. Pham Van Ty	VAEGE, Vietnam
Prof. Nguyen Quoc Dung	Hydraulic Construction Institute, Vietnam
Prof. Faquan Wu	General Secretary of IAEG
Prof. Ding Wenqi	Tongji University, China
Dr. Kochi Yoshifumi	K's Lab - Geotechnical Consultant, Japan
Assoc. Prof. Tran Manh Lieu	VNU University of Science, Vietnam

CONFERENCE SECRETARIAT:

Dr. Bui Truong Son	HUMG, Vietnam
Dr. Bui Trong Vinh	HCMUT, Vietnam
Dr. Nguyen Chau Lan	UTC, Vietnam
Dr. Vu Ba Thao	HyCI, Vietnam
Dr. Tran Thanh Nhan	HUSC, Vietnam
Dr. Nguyen Van Phong	HUMG, Vietnam
Dr. Nguyen Thi Nu	HUMG, Vietnam
Dr. Nhu Viet Ha	HUMG, Vietnam
Msc.Nguyen Thanh Duong	HUMG, Vietnam
Msc. Duong Van Binh	HUMG, Vietnam
Msc. Nguyen Van Hung	HUMG, Vietnam
Msc. Vu Thai Linh	HUMG, Vietnam
Msc. Pham Thi Ngoc Ha	HUMG, Vietnam
Msc. Phung Huu Hai	HUMG, Vietnam

PROCEEDINGS OF THE 4th INTERNATIONAL CONFERENCE VIETGEO 2018

QUANG BINH, VIETNAM
21&22 September 2018

GEOLOGICAL AND GEOTECHNICAL ENGINEERING IN RESPONSE TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE

Editors:
TA DUC THINH
PHAM VAN TY
NGUYEN HUY PHUONG
DO MINH DUC
BUI TRUONG SON
TRAN MANH LIEU
VU BA THAO

SCIENCE AND TECHNICS PUBLISHING HOUSE

INTERNATIONAL CONFERENCE

VIETGEO 2018

GEOLOGICAL AND GEOTECHNICAL ENGINEERING IN RESPONSE TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE

21&22 September 2018

QUANG BINH, VIETNAM

Organized by

Vietnam Association of Engineering Geology and the Environment (VAEGE)
Hanoi University of Mining and Geology (HUMG)
Quang Binh Department of Science and Technology
Technical World Co. Ltd (TW)
FECON Corporation
Yamaguchi University, Japan
Suranaree University of Technology, Thailand
Tongji University, China
Ho Chi Minh University of Technology (HCMUT)
Hue University of Sciences - Hue University (HUSC)
VNU University of Science, Vietnam National University, Hanoi (VNU-HUS)
Hydraulic Construction Institute (HyCI)

With the supports of

Quang Binh Department of Science and Technology
Technical World Co. Ltd (TW)
FECON Corporation
GMC Investment and Development Co. Ltd.
Research Center for Technology and Industrial Equipment, HCMUT
Union of Survey and Construction J.S.C (USCO)
Geotechnical Research Cenre, HUMG
Nam Mien Trung Co. Ltd.
Hanoi Construction Design Investigation Consultants J.S.C
Power Engineering Consulting J.S.C 1 (PECC1)
Hydraulic Construction Institute (HyCI)

TABLE OF CONTENT

SESSION 2
GEOTECHNICS FOR SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE

SESSION 3
GEOTECHNICAL MONITORING AND MATERIALS

SESSION 4
GEOHAZARDS AND SLOPE STABILITY

SESSION 5
TECHNICAL NOTES

PREFACE

Infrastructure development towards the sustainability in Vietnam as well as in the world is facing with many challenges, especially in the context of global climate change. Smart responses to climate change for harmonious and sustainable development are a legitimate desire. This is also the responsibility in the hands of scientists in general and geological - geotechnical engineers in particular.

Following the development and the success of the first conference in Hue 2012 (HueGeo 2012), the second in Hanoi in 2015 (HanoiGeo 2015), the third in Halong in 2016 (VietGeo 2016), the fourth international conference will be officially named VietGeo 2018. VietGeo 2018 is co-organized by the Vietnam Association of Engineering Geology and the Environment (VAEGE); Hanoi University of Mining and Geology (HUMG); Quang Binh Department of Science and Technology; Yamaguchi University, Japan; Suranaree University of Technology, Thailand; Tongji University, China; Ho Chi Minh University of Technology (HCMUT); VNU University of Science, Vietnam National University Hanoi (VNU-HUS); Hue University of Sciences - Hue University (HUSC); Hydraulic Construction Institute (HCI) and Technical World Co. Ltd (TW) on 21st and 22nd September 2018 in Dong Hoi city, Quang Binh province, Vietnam.

VietGeo 2018 will focus on the following themes:

- Slope stability and prediction,
- Coastal geotechnical engineering in response to climate change,
- Deep foundation and underground construction,
- Ground improvement method for infrastructure construction,
- Geotechnical instrumentation and materials.

VietGeo 2018 has received many kind supports from Quang Binh Department of Science and Technology, Technical World Co. Ltd (TW), FECON Corporation, GMC Investment and Development Co.Ltd. (GMC), Research Center for Technology and Industrial Equipment (RECTIE), Union of Survey and Construction J.S.C (USCO), Geotechnical Research Cenre - HUMG, Nam Mien Trung Co. Ltd, Hanoi Construction Design Investigation Consultants J.S.C, Power Engineering Consulting J.S.C 1 (PECC1), Hydraulic Construction Institute (HyCI).

The organizing committee would like to express our sincere thanks and appreciations to all of participants and supporting institutions. Special thanks to members of the advisory board, local volunteers and especially those of the secretariats who handle the daily hard work to make the conference successful.

We hope you will find this conference not only a chance to discuss, to share experience but also to explore cooperative opportunities.

Organizing Committee of VIETGEO 2018

EFFECTS OF CLIMATE CHANGE ON SLOPE STABILIZATION IN THE CAO SON COAL WASTE AREA, CAM PHA, QUANG NINH

To Xuan Vu, Nguyen Van Hung
Hanoi University of Mining and Geology, Vietnam
Corresponding author' Email: vudcct@yahoo.com.vn

Abstract: The quarry waste area from Cao Son coal mine is located on a terrigenous sedimentary basin with an area of over 100 ha. It is constructed by traditional dumping method (slurry dumping). The height of the quarry waste area is from 210 to 240m, the height of the discharge layer is from 30 to 70m, the slope angle of 32 to 45^0. In the discharge process, Cao Son waste disposal site is relatively stable. However, in floods late July / early August 2015, with the rainfall over 1500 mm, large erosion of the waste disposal sites in the dumping site, formed the debris flow on the bottom of the quarry waste area, seriously affecting the environment and economic activities, works. Based on the analysis of the effect of natural elements, especially the technical elements of discharge to stabilize and the stable situation of the quarry waste sites. identifying the reason is long, concentrated rain with great intensity, evaluating the impact of climate change to the process of weathering, increase the intensity of geological activities of rainwater falling on the surface and absorb into the waste discharge area the geological phenomenon of waste disposal sites. From that, propose solutions technology pouring thin layer, drainage to keep the slope of the floor, construction prevention of adverse effects of geological disaster sites.

Keywords: stability; quarry waste; site; Cao Son; coal mine.

1. Introduction

Cam Pha city is the largest coal mining center in Quang Ninh. Every year, millions of cubic meters of rock, soil are removed and dumped out of open pit mines. More and more coal mining sites are being built and the scale is expanding. Cao Son dumping ground is one of the largest

dumping ground for coal mining, which has long been established in the Cam Pha area. Over the years, scientists have been paying close attention to the safety of waste disposal sites in the discharge process with measures to enhance stability, preventing their adverse effects. However, in the context of complicated, unpredictable climate change, La Nina phenomenon causes unusual storms, which can seriously affect the stability of the quarry waste site. Therefore, it is necessary to deepen the clarification of elements influencing the status and impacts of climate change on the stability of the quarry waste site in coal mining sites, especially the Cao Son coal mine, and making the stability solution.

2. Affecting elements to stability of the quarry waste site in coal mine

The stability of the quarry waste area from coal mine depends on many elements, including natural elements and technical elements.

2.1. Nature elements

Natural elements such as climate, hydrology and geological conditions affect the stability of the quarry waste site.

- Climate is the source of the activity of exogenous elements that cause geological phenomena such as weathering, erosion, landslide, debris flow, etc., to alter the geological environment [3].

Among exogenous elements, rainwater plays an important role in the geological processes of waste dumps and has a great influence on the stability of the waste site.

When rain falls on the waste disposal site, part of it is absorbed, overflowing and some evaporation. Water absorbs in the soil makes the moisture of it increases, increasing the volume of soil and reduces the cohesion and friction of soil between particles, reducing the ability to resist the slope of the quarry waste layer. In case of heavy rainfall, saturated soil, the infiltration currents cause the hydrodynamic force toward the quarry waste site. In this process, erosion can occur. Small particles, fine particles are swept away, deposited in the gap between large particles of rock and partly can escape. The effect of this process is to increase the sliding force, increasing the porosity of the soil, creating favorable conditions for the formation of weak areas. From there, accelerate the sliding of the sloping floor.

Water overflows downstream of the waste floor can cause erosion (Figure 1). The eroded part, creating weak areas, loose material is brought down and deposited into the strip along the foot of the quarry waste site coal mine (Figure 1). This is a favorable condition, supporting the sliding of waste bed slides development. This process depends on the dynamics of overflow on the surface in which the supply of rainwater plays a decisive role. The heavier the rain, the longer the flow over the face of the strong.

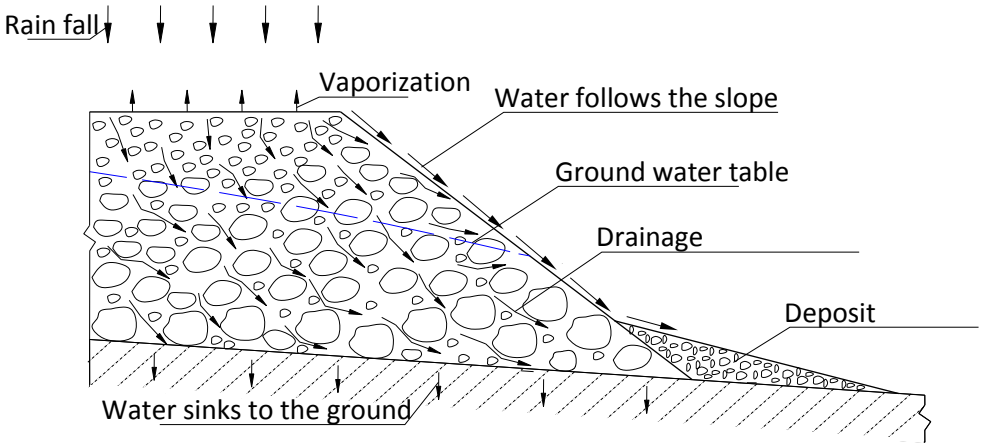


Fig. 1. Schematic diagrams and geological effects ò rainwater in the discharge layer

The geological conditions of the dump site determine the interaction between the waste rock and the natural foundation. Actual coal mining shows that waste disposal sites can be formed from the inside (internal waste dumps) or outside (external dumping sites) coal mines. As a result, geological conditions of the dump site may be very different. The stability of waste disposal sites depends not only on the composition, mechanical properties, substrate of the underground foundation but also on the slope of the substrate surface. If the surface of the landfill has a large slope, the friction between the waste rock and the natural foundation, the dump site can slip. According to research results of Do Ngoc Tuoc et al. [8], on the rock foundation with high stability, the stability of waste disposal sites depends mainly on the angle of inclination of the substrate. Occurs when the angle of inclination of the substrate is greater than 15^0.

2.2. Technical elements

Technical elements include: construction methods of waste disposal; Geological parameters of dump site (height of waste dump site, height, width of waste pavement surface, slope angle, cascade shape); loading equipment, ... have a great influence on the stability of waste disposal.

Currently, in the process of coal mining, often used two methods of dumping: pouring waste from the slope from the inside out and pouring out thin layer from the outside. Each method of dumping has its advantages and disadvantages. Technically, with the method of pouring down the slope, waste materials often have high heterogeneity in grain composition according to gravity differential law; lower tightness and shear strength, especially below the compacted impact range from discharge equipment, and the stability of the discharge site decreases. Thin layer deposition method significantly increases the degree of homogeneity, tightness, and durability of the waste materials due to the small discharge layer thickness along with the compaction effect of the discharge equipment. Therefore, waste disposal sites are generally more stable.

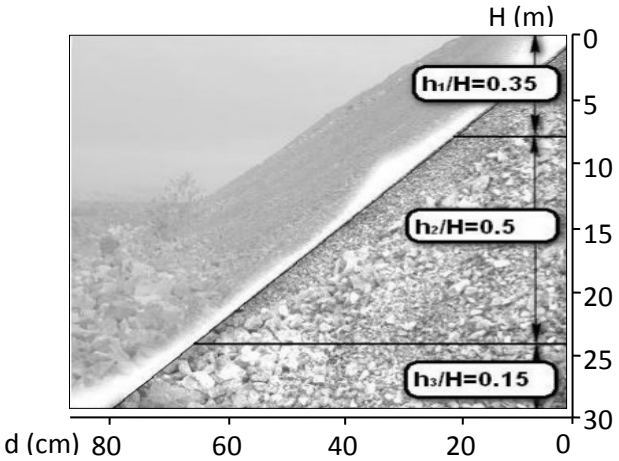


Fig. 2. The distribution of materials on the quarry waste site

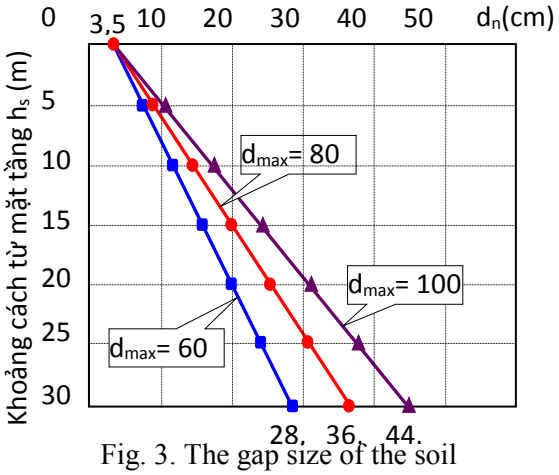


Fig. 3. The gap size of the soil particles following the height of the discharge layer

The results of the study on the slope discharge method of the scientists [11] have shown the high dissatisfaction of soil particles in the waste layer. According to this study, the size of the particle group, composition and extent of their distribution varies, depending on the distance from the surface to the bottom of the discharge layer; It is possible to distinguish three types of particle size (d) and their distribution range (h_i) according to the height of the discharge layer (H) (Figure 2).

- *Small size particles (d <20cm)* have the lowest kinetic energy, slow movement should exist mainly at the top, near the surface of waste layer (corresponding to unit height h_1/H=35%), along with the slope layer and fill in the gap of large particles;

- *Medium grain (d = 20 - 60cm)* moves sliding and rolling on the lower side of the gravity effect. During movement, at moment kinematic forces produce less shear force than frictional force, they stop moving and lie in the middle of the stratum (corresponding to unit height h_2/H = 50%). Each particle has different diameters, different weights, and their distribution positions are also different on the waste bed slope (the lower, the larger the grain size);

Large particles (d> 60cm) move at the bottom of the discharge layer with the highest speed, distributed mainly at the bottom and bottom of the discharge layer (corresponding to unit height h_3/H = 15%).

The gap between rock particles is closely related to the particle size distribution in the discharge layer. According to scientists, the diameter of the gap d_n at any depth below the surface of the discharge layer can be approximated by the formula: $d_n = d_0 + 0{,}415\frac{h_s}{H}d_{max}$

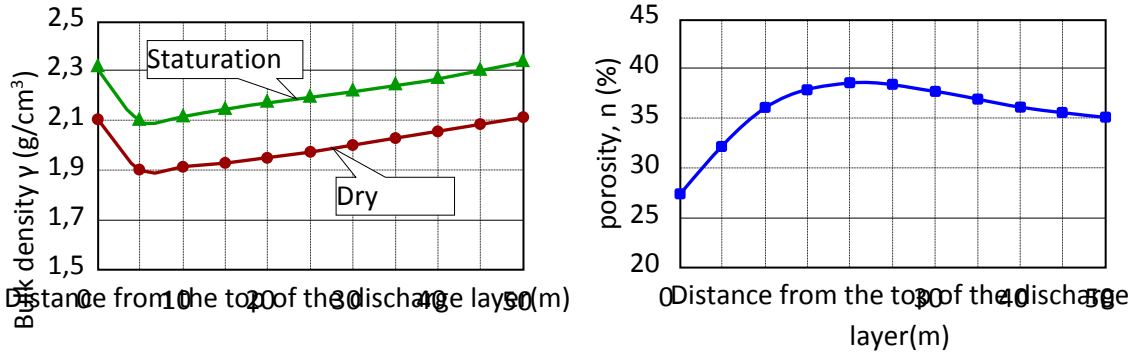
Where: d_0 - Gap diameter at the top of the slope;

d_{max} – Maximum diameter

The results of calculating the gap between the soil particles (Figure 3) show that, from the surface to the bottom of the discharge layer, the gap size increases dramatically and the waste materials have the largest particle diameter, The stronger the increase: from 3.5cm to 28.2cm (d_{max} = 60cm), 36.5cm (d_{max} = 80cm), 44.8cm (d_{max} = 100cm).

The law of distribution of grain composition in the depth of the waste layer and the compacting

effect of the waste disposal equipment also significantly affect the density of the waste materials layer. From the results of calculating the bulk density (γ) and the porosity (n) of the waste materials stratum [10], it can be seen that these characteristics also change with the height of the waste materials layer. The bulk density increases from the surface to the bottom of the discharge layer (except the top layer is directly compressed), while the porosity is highest in the middle of the effluent (Figure 4a, 4b).). Thus, the lowest density is the middle of the waste layer.



(a) (b)

Fig. 4. Bulk density (a) and porosity (b) of the waste materials layer following the height

- Geometric parameters of waste disposal sites not only play an important role in the relationship between the holding force and the sliding force of the discharge layer but also significantly affect the level of physical and chemical properties of waste materials. The results show that the higher the height of the discharge layer, the higher the level of particle separation. In general, the higher the height of the dumping site, the higher the slope of the discharge layer, the narrower the surface of the waste layer, the less disposable land.

3. The situation of the quarry waste site Cao Son coal mine

3.1. The characteristic of the quarry waste site Cao Son coal mine

The quarry waste site Cao Son coal mine is planned to be a dumping ground for Cao Son, Cau Sau and Deo Nai coal mines. The size of the dumping site: 3118m long; 1650m wide; from 210 to 240m high, divided into 4 to 6 layers. The layer height is from 30 to 70m, average 45m, width of 30 to 50m, slope angle of 32^0 to 45^0, average 40^0.

This quarry waste site located on terrigenous sediment, with stratification is medium to thick, age $T_{3n\text{-}r}hg$. The main lithological components of this dumping ground include: conglomerate; sandstone; siltstone; claystone and clay with coal. The surface in this are is weathered with different degrees to create thin weathering crust (thickness from 1 - 2m to 5 - 6m). The terrain is quite smooth with a slope of less than 10^0, including slopes, valleys and small slits. Underground water is deep. Physical and mechanical properties of soil as in Table 1.

Tab. 1. The soil properties from the quarry waste site Cao Son coal mine

Soil and rock type	Moisture content, W (%)	Bulk density, γ_w (g/cm^3)	Press strength, σ_n (kG/cm^2)	Cohesion, C (kG/cm^2)	Angel of friction, φ (độ)	Compression factor, a (cm^2/kG)
Clay, sandy clay	9,05	1,82		0,5	26,51	0,012
Claystone		2,67	289	87	31,43	
Siltstone		2,67	481	147	33,37	
Sandstone		2,66	999	371	34,45	
Conglomerate		2,59	1273	438	34,40	

In general, the quarry waste site in Cao Son coal mine is considered to be favorable for the existence of the waste site, the stability of this waste site depends on the characteristics of the waste site as well as the impact of the natural factors affecting.

The process of forming this quarry waste site is closely related to the method of mining and dumping in coal mines. With blasting technology exploiting open-pit coal has created loose waste rock with very different particle size, ranging from very granular to very small granules such as silt, clay. In particular, the composition of coarse grain is very large, fine grain account for a negligible proportion. Research results show that the size of grain size under 50mm is only over 10%, from 50 - 800mm is about 80%, the rest is coarse grain with the size is more than 800mm. After blasting, the waste rock from the mining site is transported by car to the dumping site and dumped at the edge of the slope of the disposal site, with the assistance of a leveling shredder.

Slope dumping method at this quarry waste site also created high heterogeneity in the composition and physical and mechanical properties of waste materials. The study of Information Technology and Environment Company (VITE) [7] at waste disposal sites, it is quite clear that the rules of distributing granules on the side of the dumping ground as follows:

- From the surface of the dumping ground to the depth of about 1.5m, mainly concentrated particles of small size (sand, silt). Particle size less than 15mm is 40-50%;

- From the surface of this quarry waste site, the lower the proportion of small groups, the larger the group of large particles increases. In the middle of the quarry waste site, the grain size is larger than 500mm, accounting for over 60%;

Large particles group (600 - 800mm) are concentrated at the bottom of the quarry waste site. They usually roll down to the foot of the dump to a certain extent, causing the trough to concave.

For stopped waste dumping sites, the proportion of groups distributed on the stratosphere has changed considerably. Small particles group of less than 15mm at the top are reduced to only 30-40%, while at the bottom, including the foot of the dumping site, the composition of the particle changes insignificantly. The change in particle size showed the effect of top-down seepage, which transported and deposited in the large group at the bottom, on the side of this quarry waste site and partly at the bottom of the foot. This shows that erosion has formed and developed after dumping.

3.2. Situation of the quarry waste site in Cao Son coal mine

The quarry waste site Cao Son coal mine is the one of the biggest quarry waste site and is extending more and more. Discharge is underway in the eastern, northeast and southeastern sections, and the western and northwestern sections have stopped pouring out.

The data at two monitoring points in this discharge sites in 2015 showed that the maximum transfer velocity was 0.71 mm/day and 0.89 mm/day. This results show that, in general, the quarry waste site in Cao Son coal mine is relatively stable (the maximum transfer rate is less than 1.00 mm/day). However, according to the survey results for many years in waste dumps, during heavy rains, the rainfall was over 200mm as in August 2008, November 2013, July 2016 and August 2017, local erosion still occurs on the slopes, most notably at the pouring layers. Particularly, the rainy season occurs between at the end of July and early August 2015, with the total rainfall of up to 1500 mm (over 400 mm/day), has eroded and slid locally on the eastern side of the waste dumping site on a large scale: from + 200m to + 60m (altitude of waste dump); approximately 800 m length. Discarded material is concentrated from dumping processes and erosion activity in the disposal site provides the run off at the foot of the dumping site, resulting in streams of mud flowing into the surface of One member limited liability company 790, at the altitude of + 58m with the area of about 5 hectares, overflowing coal transport street down to the bottom, seriously affecting the population of Mong Duong ward (Figure 5).

This fact has shown that the cause of geological hazards in Cao Son waste dump is that the rainfall on the discharge site is too large, creating a strong driving force to generate and develop geological processes. waste disposal site.

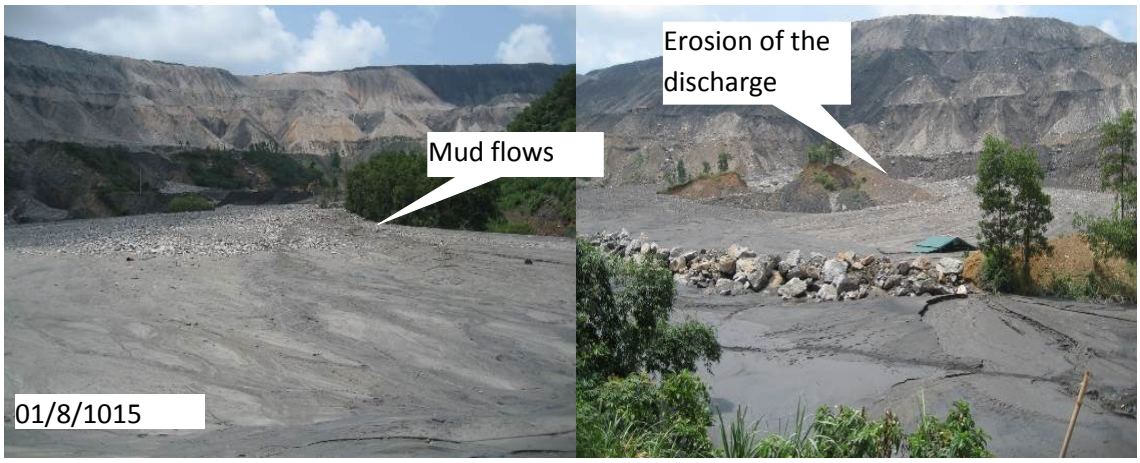


Fig. 5. Erosion, mud flows at the east of Cao Son dumping site after rain

4. Effect of climate change on stabilization of the quarry waste site in Cao Son coal mine

4.1. Characteristics of climate change

In recent years, climate change has become a major concern in the world as well as in Vietnam. According to the Institute of Science Meteorology, Hydrology and Environment [5], there are three scenarios of climate change: low emissions (B1); Medium emissions (B2) and High emissions (A2). It shows that, in the future, Quang Ninh in particular, Vietnam in general will face the severe effects of climate change.

- *High average temperature*: According to the high emission scenarios, in the northern coastal area, by 2100, the annual average temperature will

increase by 3.6^{0}C compared to the last decades of the 20th century. Following by the medium emissions, the annual average of temperature increase is about 2.3^{0}C, in Quang Ninh is 2.5^{0}C. The increase in temperature will be clearly felt in the North zones. The number of hot days increase. Increasing average temperatures will increase the number of hot time and reduce the number of cold time. The hot summer, which tends to come early and end late.

- *The rainfall*: Climate change will increase total annual rainfall in all regions. In particular, the rainfall will only increase in the rainy season, even more than in recent times, while in the dry season is the opposite. The probability of occurrence of heavy rains (over 200 mm), extreme (over 500 mm, 1000 mm) causing floods, landslides will also increase, especially in the mountainous area in the north. Reducing rainfall, prolonging the freezing time in dry months will result in increased evaporation due to high temperatures, low humidity.

- The storm, extreme weather: Due to the increase in temperature, accelerating atmospheric pressure accumulation, thunderstorms, tropical depression appear more and intensity of extreme weather types also lead to heavy rain. The change of the storm is more complicated, does not appear according to the normal rule and becomes unexpected, unpredictable.

4.2. Effect of climate change on stabilization of the quarry waste site in Cao Son coal mine

As discussed above, there are many factors that affect the stabilization of waste disposal sites. For coal mining quarry waste sites in Quang Ninh in general, the quarry waste site in Cao Son coal mine in particular, climate factor plays an important role in the geological processes of waste dumping sites.

- Climate change promotes the intensity of weathering

Weathering is an exogenous geological phenomenon that occurs due to the effects of weathering agents (temperature, water, oxygen, carbon dioxide, etc.). The process of weathering changes the soil in terms of composition, architecture, structure, state, physico-mechanical properties, etc., which are disadvantageous to their stability such as decreasing durability, density, increasing moisture content, water permeability, subsidence compression. The weathering not only adversely affect the geological environment but also enabling other geological phenomena such as slides, erosion ditches,mud flows; ....

According to V.D. Lomtadze [2], temperature and water are major factors to rock weathering. High temperatures and sudden changes cause strong physiological weathering, accelerating the activity of chemical weathering. Water is not only the cause of weathering but also it is the environment for chemical reactions occurring during weathering such as solubilization, hydration, hydrolysis, oxidation, carbonation, etc. Thus, in the context of climate change, the average temperature rises in both hot and cold seasons, prolonged periods of hot sunshine, increased rainfall in rainy months, abundant water supply and increased moisture content, increase the ability to exchange water, chemical weathering will develop stronger. For rocks and soil in the quarry waste from the coal mine, the conditions for weathering develops in high depth that are very favorable, as most of the waste rock is composed of terrigenous sediments (sandstone, siltstone, claystone and coal clay), excavated from the depths up by blasting method, exist mainly in the form of scattered granules, often with large porosity that easy to changes in the new environment (due to the effects of exogenous factors), especially in the context of the effects of climate change.

- Climate change increases the intensity of geological activity of water on the surface and in the waste site

The movement of rainwater on the waste disposal site depends not only on the characteristics of waste disposal site (water recovery area, waste stream height, slope of layer surface, water storage capacity,...) but also on rainfall, rainy duration. According to the survey results at the waste dump site, the flow of rainwater into the dumping ground and the overflowing water (Q) on the surface of the dumping site cause geological phenomena, destabilize the waste site is closely related to the amount of rainfalls on waste land.

On small and moderate rainfall (less than 20 mm/day), all rainwater falls on waste dumping sites and seepage in the dumping ground, no water on the ground waste, on the side of the layer of the dumping ground cannot see water flow or expose water. In this case, the rainfall is less than or equal to the infiltration flow (Figure 6a).

On heavy rainy days (rainfall is from 20 to 50 mm/day), the rainfall is absorbed to saturate the soil, the infiltration flow occurs and escapes to the lower layer of the waterway, the part that is not immediately filled up to surface water on the ground. Only the surface water on the ground of the discharge layer (the water that does not get to the waste ground) flows down to the foot of the dumping site with small, very small flow, which indicates the flow of rain water falls beyond the infiltration flow (Figure 6b).

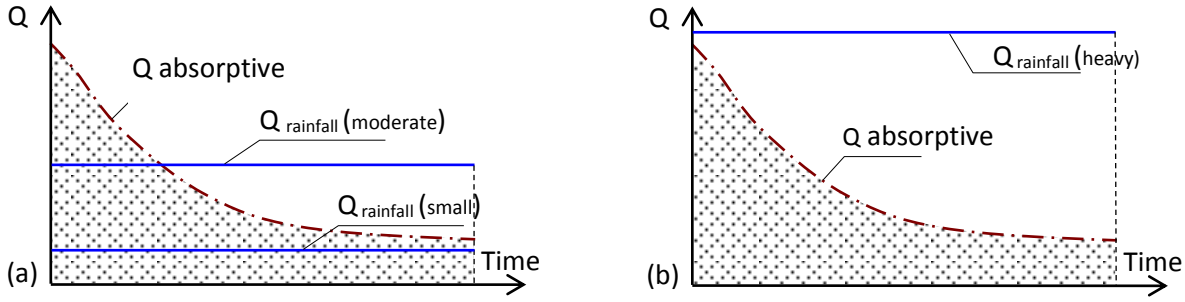


Fig. 6. Diagram of rainfall flow and spillage on the dumping site

Extremely heavy rainfall (50 – 100 mm/day and more), the more rainwater is not absorbed (usually large amounts of rain) accumulate on the dumping ground, break or spill over the shore. At the bottom of the dumping ground, the discharge flow is quite large, causing local erosion of the discharge layer at different levels. According to Cua Ong meteorological observation station [1], there are about 10 heavy rainy days per year, that makes the flow water to the bottom of the dumping ground.

According to the results of the survey at the waste dump site, the soil has low compression, large porosity, high water holding capacity, rapidly absorb speed and permeability. So rainwater was mostly absorbed in the dumping site, surface water and spill water on the surface of the waste layer only appear when the rainfall on the dumping site over 100 mm/day.

The role of rainwater for geological processes inside or outside the disposal site is very different. In the dump site, the activity of the infiltration flow is always directed toward the middle of the discharge layer due to the heterogeneous characteristics of the particle size. However, the permeability of the infiltration flow reaches only a certain limit, because the hydrodynamic force is the greatest and most stable as the surface water remaining on the discharge layer begins to flow downward. On the discharge side, the intensity of the run-off of the surface water depends on the amount of rainwater supplied. The larger the rainfall, the greater the erosion. The erosion process increases the slope of the dumping size and

hence, the intensity of activity of the water overflows on the face increasingly stronger. This process only slows down and stops when the slope of the dumping size decreases and reaches the equilibrium value.

In fact, the stability of the quarry waste from Cao Son coal mine site depends on the amount of rainfall on the site. In general, if there are no significant changes in the meteorological factors, the quarry waste from Cao Son coal mine site will generally stable and geosynthetic discharges can occur but only on a small scale, with no significant impact to surrounding environment. However, in the case of climate change like the past years and forecasting in the future with abnormal disturbances, not follow the rules of extreme weather phenomena that result in heavy rain, prolonged with the amount heavy rain, the stability of the quarry waste from Cao Son coal mine site will be broken by the sudden increase in activity of the geological discharges. The flood in 2015 caused the geological catastrophe in the quarry waste from Cao Son coal mine site proved for these assessments.

5. Solutions to stabilize the quarry waste from Cao Son coal mine site

In order to ensure the stability of the quarry waste from Cao Son coal mine site in the context of climate change impacts, the solutions applied need to come from the supporting causes and conditions, the develop of the geological processes inside, on the surface, in the waste disposal sites and have to use multiple solutions simultaneously.

5.1. Stable solutions to the waste yards are forming

- *Change of dumping method*: Apply thin layer (from 3 m to 5 m depending on the weight of discharge equipment and size of waste material) in each waste layer. This method has many advantages compared to slope discharge methods such as minimizing the distribution of particles, porosity to the height of the discharge layer, increasing the density of waste materials and thus increasing the quarry waste site stability. The results of the study [11] showed that the method of thin layer deposition might increase the Bulk density by 8 - 10% and the density is not changed. After that, the settlement of the discharge is reduced to very small compared to the method of slope discharge.

- *Reducing the slope of the quarry waste site, increasing the width of the dumping ground:* In the condition of climate change, heavy and prolonged rain, the waste material is always saturated and under the maximum hydraulic pressure of the magnetic permeability in the dumping site and become unstable, it is necessary to reduce the slope angle of the quarry waste site, increase the width of the the dumping ground. According to calculations [12], under the above conditions, if the height of the waste layer is 50m, the maximum angle of the slope is 19 - 22^0 and the smallest width of the waste layer to be able to store the amount of slurry the slope of the top discharge layer is 52 m. If the height of the discharge layer is 30m, the smallest width of the discharge layer is 36m.

- *Creating slope of the surface layer, drainage surface, not to overflow the floor*: These solutions are aimed at drainage left on the surface of waste discharge to the foot of waste disposal. During discharge, the ground surface is kept relatively flat and tilted to the inside of the dumping site, the minimum slope of 3 - 5%, the size of the drainage trough on the discharge layer depends on the area of rainwater surface that ensure the collection of surface water .

- Consolidating the ground of dumping site, building the drainage ditches along the top of the waste site, protecting the edge of the riparian layer and plant cover: This solution shall apply to exhausted waste layers. Improving the surface of the waste layer by using the rolling equipment that increases the density, durability of waste materials

on the surface, reducing the permeability of rain water. Making the drainage system along the foot of the upper waste stream to collect and transport surface water down to the waste disposal site. On the edge of the waste ground, embankment is used to prevent water from flowing down the ground. The dike size must be stable and prevent rainwater in the condition of precipitation corresponding to the rainfall caused by geological hazards in 2015 (frequency of 1-2%). Plant cover on the surface will enhance the stability of the stratum, reducing the surface and underground flow potential to cause erosion of the bed slides.

5.2. Stable solution for waste dumping sites

The density and the degree of homogeneity of soil particles in the disposal sites has been significantly increased due to the self-compacting process. The rainfall flow process in the discharge layer, carrying small particles, accumulating in the gap of large particles. In order to stabilize waste dumping sites, waste disposal sites can be used in the same waste disposal sites as for fully discharged wastes (in the case of waste disposal sites are forming). However, it is necessary to solidify the works to prevent surface water drainage to ensure long-term waste disposal.

5.3. Total defenses at the foot of the waste disposal sites

The formation and existence of coal mining sites in general, Cao Son dumping ground in particular has shown that the deposition of fine particles at the bottom of the dumping ground due to discharge from the discharge site is not possible avoid. Only heavy rains are too large to surface flow from the surface down or the infiltration flow on the side of the ground, fine particles were transported and accumulated again. These accumulation materials can be transferred far or near, large or small particle size which depends on the water kinetic energy in the waste disposal site and at the foot of the dumping site, greatly affecting the environment around the site. In order to solve this problem, there must be a comprehensive countermeasuresolution for waste disposal sites such as the construction of waste landfills along the waste dumps and dams to create reservoirs on streams and streams around waste dumps to accumulate water flow from waste disposal site. These works must ensure the stability of the dumping ground, control of the amount of solids deposited, the water level in the reservoir and the discharge flow outside the waste disposal area in the extreme rainfall equivalent to the flood.

6. Conclusion

From the results, the following conclusions can be drawn:

- The stability of the quarry waste from Cao Son coal mine site depends on many factors. In particular, the construction method of slope dumping has a great influence and is considered as a condition to support (promote) the geological process that makes the instability of dumping site.

- The quarry waste from Cao Son coal mine site is unstable due to heavy and long-lasting climate change, with a large amount of rainfall, destroying drainage works, creating flow of wastewater layers with large speed and flow, making erosion, sliding layer discharge on a large scale.

- In order to ensure stability for the quarry waste from Cao Son coal mine site, it is necessary to use a number of solutions, including technical solutions during the construction of waste dumps and measures to prevent adverse impacts of rainwater in the climate change.

References

[1] General Department of Hydro-Meteorology (1978 - 2017), Meteorological Yearbook of coastal monitoring stations in the North, Hanoi.

[2]V.D. Lyttelton (1978), Project Interpretation, College and Professional Publishing House, Hanoi.
[3] V.D. Loremtze (1983), Geomagnetic Engineering, College and Professional Publishing House, Hanoi.
[4] Tran Mien (2006), Some Initial Orientations in Improving, Reverting the Environment of Coal Mine Sites, Proceedings of the 17th Vietnam Mining Science and Technology Conference, Hanoi
[5] Institute of Meteorology, Hydrology and Environment (2012), Scenarios of climate change in the provinces and coastal areas of Vietnam, Hanoi.
[6] Luu Van Thuc et al. (2011), Causes of distortion of open-pit mine discharge and recommendations for stabilization measures, Institute of Mining Science and Technology, Hanoi.
[7] VITE Information Technology and Environment Company (2012), waste dump improvement ... - Technical documents of some projects in Cam Pha area, Quang Ninh.
[8] Do Ngoc Tuoc et al. (2013), Study on the selection of appropriate technologies for discharge of coal in coal mines - Final Report on Science and Technology, Ministry of Science and Technology, Ha Noi Cabinet.
[9] Tran Manh Xuan (2010), Stabilization of Cascades and Dumps, Hanoi University of Mining and Geology, Hanoi.
[10] Robert Lucas (2014), Optimization of Waste-Dump Lift Heights for Prestrip Operations
[11] Mr. Marcus Fuchsschwanz, Mr. Shakeel Ahmad, Dr. José B. Pateiro Fernández (2010), *Definition of height of layers for test dumping at Chinh Bac waste dump*.
[12] Ю.Г. Полкунов, Силкин, Р.Ш. Наимова, Расчёт устойчивости откоса отвала под действием сосредоточенной нагрузки.