MINISTRY OF EDUCATION AND TRAINING
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

VIETNAM ACADEMY FOR WATER RESOURSES

NGUYEN HUU NAM

INVESTIGATION OF USING POZZOLAN-CEMENT AND LIME FOR IMPROVING BASALT SOIL IN WATERPROOF TILTED WALL OF WEST HIGHLANDS

BRANCH : Geotechnical engineering

CODE : 9-58-02-11

SUMMARY OF THESIS

Hanoi – 2021

The project was completed at:

VIETNAM ACADEMY FOR WATER RESOURSES

SCIENTIFIC DIRECTOR

Supervisors:

1. **Dr Ngo Anh Quan**
2. **Assoc. Prof. Dr. Hoang Pho Uyen**

Review 1: Assoc. Prof. Dr. Nguyen Duc Manh

Review 2: Assoc. Prof. Dr. Ho Sy Tam

Reviewer 3: Assoc. Prof. Dr. Phung Vinh An

The thesis will be defended in front of the Institute-level Doctoral Thesis Judging Committee meeting at the Vietnam Academy For Water Resourses, at ....time ....day ...... month ....year 2021

Thesis can be found at the library:

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PREAMBLE

1. INTRODUCTION

Basalt backfill material derived from basalt belongs to an unfavorable group when used as a dam filling material, due to its special properties such as low dry weight, high optimum humidity, and natural humidity in the season. dry low so when construction needs more watering; high clay dust content is difficult to compact, these properties lead to difficulty in quality control during construction; The soil is disintegrating and wet, so when the reservoir is in operation, there is a risk of many potential problems. In fact, basalt-filled earth dams account for a large proportion of about 56%, these dams were built many years ago, construction technology and techniques have not yet developed, so most of these dams are currently under construction. phenomenon or has been permeable and dehydrated [33]. In order to ensure the economy and make full use of local materials, it is necessary to study on-site soil improvement with binders to improve dam embankment materials as well as to make waterproofing materials for sloped walls. set. The successful application of the solution of using pozzolan as a binder in soil improvement will bring economic efficiency in construction in general and in upgrading, repairing and building small and medium earth dams in particular. Therefore, the solution of using natural pozzolan materials to improve the soil in situ to make inclined walls to waterproof earth dams in the Central Highlands is a positive solution to overcome the above situation. Therefore, the author chooses the topic of the thesis: "*Investigation on improving basalt soil with a mixture of pozolan - cement - lime as a waterproof inclined wall for earth dams in the Central Highlands*" is very necessary.

2. PURPOSE OF THE RESEARCH

It is proposed to have a suitable mix of natural pozzolan in combination with cement and lime to improve basalt soil to make views to waterproof earth dams in the Central Highlands; The mixture has a permeability coefficient $K<10^{-5}$ cm/s, is stable with water (no swelling, no shrinkage and no disintegration).

3. OBJECT AND SCOPE OF THE RESEARCH

Research object: Using available natural pozzolan to improve the strength and improve the water repellency of basalt soil as a filling material for small and medium earth dams in the Central Highlands.

Research scope: Natural pozzolan obtained from the Central Highlands; Small and medium-sized earth dams in the Central Highlands region use basalt soil as fill material.

4. RESEARCH METHODS

The thesis used research methods such as: Document study; Inheritance method; Experimental research methods; Methods of mathematical modeling

5. SCIENTIFIC AND PRACTICAL MEANINGS

Scientific significance: Contributing to perfecting the theoretical basis for reclamation of basalt soil in the Central Highlands with natural pozzolan and cement and lime additives to make the inclined wall of the yard covered with soil dam waterproofing.

Practical significance: The thesis has found a reasonable level of economic - technical, including: basalt soil exploited in situ mixed with finely ground natural pozzolan, PC40 cement, finely ground lime and compacted at optimum moisture to make waterproof inclined wall for earth dam in the Central Highlands; The solution to improve basalt soil with natural pozzolan reduces the amount of cement used, utilizes local soil materials and utilizes an abundant natural source of pozzolan but lacks the direction of local consumption, contributing to reducing construction costs. building waterproof structures and promoting local economic development.

6. NEW CONTRIBUTIONS OF THE THESIS

- To quantitatively elucidate the formation of colloidal CSH, CASH increases the strength, cohesion and reduces the permeability coefficient of natural pozzolan-improved soil, cement and lime through thermodynamic modeling.

- It is proposed to be mixed with basalt soil improved with natural pozzolan, cement and lime P10C5L4 which meets the requirements to make inclined wall structure waterproofing earth dam in the Central Highlands.

7. CONTENTS AND STRUCTURE OF THE THESIS

The thesis has 4 chapters, in addition to the introduction and conclusion, illustrated by 44 tables, 82 figures and graphs, 7 related published studies, 142 references and appendices.

CHAPTER 1 OVERVIEW OF SOLUTIONS TO WATERPROOF AND IMPROVING SOIL USING CEMMENTITIOUS MATERIALS

1.1 Penetrating through earth dam in the Central Highlands

1.1.1 Dam in the Central Highlands

No	Province	Total	In which the reservoir has				Others
			Lake	$>3x10^6$ m^3	0,5-$3x10^6m^3$	$<0.5x10^6$ m^3	
1	Kon Tum	521	70	4	12	54	451
2	Gia lai	338	112	10	7	95	226
3	Đắk Lắk	766	600	22	44	534	166
4	Đắk Nông	231	186	3	16	167	45
5	Lâm Đồng	500	226	13	17	196	274
Total		2.356	1.194	52	96	1046	1.162

Table 1-1. Classification of Irrigation reservoirs in the Central Highlands

According to the general assessment of the safety of small and medium earth dams in the Central Highlands, out of a total of 732 dams, there are 118 dams that have failed, with seepage incidents accounting for nearly 29% [45]. Summary of reservoirs, dams and pumping stations in the Central Highlands is shown in Table 1-1 . [2].

1.1.2 Research on soil dam seepage

Earth dams are one of the types of structures that are considered to be durable and resistant to shocks. However, during the working process, due to the impact of natural and human factors, some earth dams have been damaged at different levels. The main cause is the phenomenon of water loss through the dam foundation, dam shoulder and dam body [69].

1.1.3 Physical and mechanical criteria, mineral and chemical composition of typical soils in the study area in the natural state

For basaltic soils in the study area, with permeability coefficient greater than 105 cm/s and some special mechanical properties such as swelling (shrinkage), disintegration, wet settlement...[13], [14], [33], [34], [37], [38], [39]. Therefore, in order to use this basalt soil material as a waterproofing structure for earth dams, such as structures of natural walls and covered yards, it is necessary to improve.

1.2 Waterproofing solutions for earth dams

1.2.1 Soil dam waterproofing solutions in design and construction of irrigation works

Homogeneous dam; Smash multiple blocks; Soft core wall; Soft inclined wall; Tilted wall and soft tray legs; Waterproofing membrane by grout drill; Hard waterproof wall.

1.2.2 Infiltration treatment solutions for existing earth dams

Drilling for waterproofing; Waterproof soil pile wall; Geomembrane waterproofing; Concrete carpet; Prestressed concrete piles; Plastic sheet pile; Bentonite - cement moat wall; Geotechnical waterproofing membrane trench wall; Inclined wall of geosynthetic clay carpet.

1.3 In situ soil improvement with binder

1.3.1 Research on soil improvement with inorganic binders in the world

1.3.1.1 Research on soil improvement with lime and cement

In Europe, studies on soil improvement with cement, cement - lime have been conducted since the 1960s and 1970s of the last century in Sweden and Finland. At the Conference on Soil and Foundation Mechanics (Stockholm, 1981), author Jim Mitchell presented a general report on the soil-lime-cement column for the treatment of cohesive and plastic soils and since then this method has been widely used. widely applied in the world. Studies on soil reinforced in situ with lime, cement and blast furnace slag are included: in Helsinki (1991), Kaltedt and Halkola (1993). In Finland, Kukko and Puohomaki (1995). Mitchell and Freitag (1959) studied for low plasticity soil, sandy soil with cement content (XM) used to reinforce soil from 5 đất14% by weight of soil; The amount of XM required depends on the type of soil, the state of the soil to be reinforced; [110]. Nguyen Duy Quang, Jin Chun Chai, Takenorihiho, Takehito Negami-SaGa University – Japan (2012) [114]studied dredged mud in the estuary of Ariake region of Japan to make backfill in situ. The soil is reinforced with lime and cement at the ratio of 2, 4, 6, 8% compared to the dry soil volume.

Table 1-2. The ratio of cement to different types of soil

No	Soil type	Cement/Soil ratio
1	Soil containing gravel, coarse sand, fine sand, with little or no trace of mud or clay	5% or less
2	Bad sandy soil with small amount of mud	9%
3	The remaining type of sandy soil	7%
4	Soil containing silt is not plastic or moderately plastic	10%
5	Flexible clay	13% or more

1.3.1.2 Research on soil improvement with pozzolan

Countries around the world with abundant natural sources of pozzolan have studied the use of this material in combination with some binders to improve soil in situ. Some authors have successfully studied using natural pozzolan in combination with lime to reinforce weak clay and cohesive soil such as Khelifa et al (2010); Khelifa et al (2011); Asson and Eugene (2014);Aref and nnk (2016). Mfinanga and Kamuhabwa (2008) conducted experiments to find out the mixing ratio of natural pozzolan and lime with soil; natural pozzolan, lime and gypsum with soil for the reinforced soil mix to achieve the strength required for road construction in Tanzania [107], [108], [76], [74], [117]. The research results found that the suitable mix is soil mixed with 10 to 30% pozzolan (by weight) and 2% lime.

Through research results abroad, natural pozzolan can be completely combined with lime and cement to improve the physical and mechanical properties of the soil in situ.

1.3.1.3 Soil improvement with lime combined with cement, pozzolan or fly ash:

Using lime or lime in combination with cement, artificial pozzolan (fly ash, slag), natural pozzolan, soil improvement has been studied and successfully applied by many foreign authors in practical works.

1.3.2 Research on soil improvement with inorganic binders in Vietnam

1.3.2.1 Research and application of soil improvement with cement and lime

In Vietnam, soft soil improvement with cement and lime has been studied and applied by many authors. Project "Research on solutions to strengthen soft soil by sand-cement-lime piles" [28]2002 was chaired by Ta Duc Thinh - University of Mining and Geology. The topic has suggested to use the amount of cement from 7.5 to 10% and the amount of lime from 7 to 9%. Pham Minh Tuan (2001) [49]studied the effect of organic content on the ability to improve soft soil with cement of both organic and soft clays of the Thai Binh and Hai Hung formations in Hanoi. The author has studied laboratory experiments with soil samples containing organic content with cement contents of 5, 10, 15, 20 and 25%. Nguyen Thi Thu Quynh (2010) [30], studied soil improvement in the southern region of Ca Mau province with cement with the content of 5, 7, 10, 13, 16% on the prepared soil with the salt content of 0.6; 1.0; 1.5 and 2%. Nguyen Thi Nu, Do Minh Toan (2010) [25], studied the effect of salt content on the reinforcing ability of clay soils in Tien Giang and Soc Trang. The sample was reinforced with cement contents of 9, 12 and 16%. Mai Thi Hong (2019) [ten], has studied the use of cement and lime to improve young alluvial soil for upgrading and building dams in the Central Highlands. Apply the method of mixing cement and lime at 2% and 3%. …etc

1.3.2.2 Research and use of natural pozzolan

In Vietnam, natural pozzolan has been researched and used a lot for cement production, unburnt bricks, construction of roller compacted concrete dams, large concrete blocks, etc. In soil reinforcement, author Vu Ba Thao et al (2019) [36]State-level project report. Research on using natural Pozzolan in construction and maintenance of rural traffic and irrigation works in Dak Nong province. Research has been conducted to use natural pozzolan, cement, and lime to make rural road structures with the ratio of pozzolan: cement: lime = 8%-10%: 4%-6%: 2%–3%, percent by weight of dry soil.

1.4 Conclusion of Chapter 1

Basalt soil in the Central Highlands is abundant but has special properties such as difficult to compact, magnetic, high content of dust particles, so it has a large permeability coefficient, disintegration, unstable in water, easy to lose water. reservoir, cannot be used directly to make inclined wall, covered yard or center wall to waterproof earth dam. Besides, the local clay source in the area is scarce. Therefore, it is necessary to study and select solutions to improve and strengthen basalt soil to make fill materials and waterproof structures for earth dams. Research to simultaneously improve the strength, stability in water and waterproofing ability of the embankment soil in the Central Highlands with locally available natural pozzolan combined with cement and lime to meet the requirements of anti-rust structure. soil dam permeability, is a new research direction in Vietnam. Using natural pozzolan available at low cost in reducing the amount of cement and lime used in soil reinforcement, it will reduce the cost of materials and promote the use of abundant natural resources of pozzolan in the Central Highlands. From the waterproofing solutions that have been reviewed, the author chooses the inclined wall waterproofing structural solution to focus on research.

CHAPTER 2 SCIENTIFIC BASIS AND POSSIBILITY OF USING NATURAL POZZOLAN FOR SOIL REGULATION

2.1 Scientific basis for soil improvement with pozzolan combined with binder

The synthesis of these mechanisms has been [101] summarized through the general scheme:

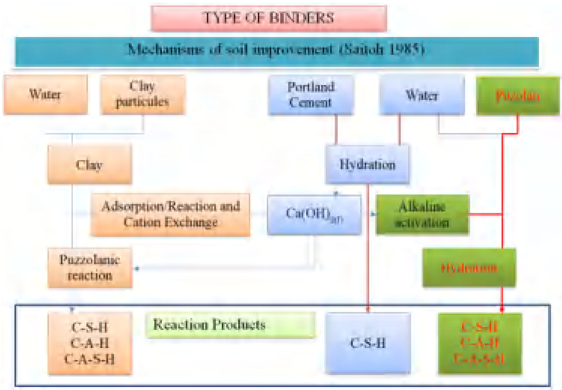

Figure 1. Mechanism of physico-chemical reaction between soil particles and inorganic binder [101]

2.1.1 The process of calcification in the soil

The process of hydration when mixing lime with soil occurs as follows:

$$CaO + H_2O \longrightarrow Ca(OH)_2 + 15{,}3\ kcal \qquad (2.1)$$

According to KB Egorov, the increase in soil strength in the early period is due to the formation of hydroxide-silicates when $Ca(OH)_2$ is applied to SiO particles.2 secondary:

$$SiO_2 + xCa(OH)_2 + nH_2O \longrightarrow xCaO.SiO_2.(n+1)H_2O \qquad (2.2)$$

2.1.2 The process of cement hydration in the soil

Features of each phase:

* Alit (C_3S): includes $3CaO.SiO_2$ accounting for 45-60% in clinker.

*Belit (C_2S): includes $2CaO.SiO_2$ accounting for 20-30% in clinker.

*Celite (C_4AF): is a mineral that makes up 5-15% of clinker;

*Calcium aluminate (C_3A): $3CaO.Al_2O_3$ accounting for 4-13%.

When mixing cement with water, the phases C_3S, C_2S, C_3A, C_4AF carry out the hydration reaction.

* Hydration of the mineral Alit (C3S)

* Hydration of Belite Minerals (C2S)

*The hydration of the mineral Calcium aluminate (C_3A)

*Celite Mineral Hydration (C_4AF)

2.1.3 Improve the soil with binders

Currently, there are many solutions to improve the soil with binders to increase the strength as well as the waterproofing ability of the mixture. After mixing with water, the mixed binders (such as lime - fly ash, lime - pozzolan, etc.) will produce the following reaction:

$$xCa(OH)_2 + SiO_2 + aq \rightarrow xCaO.SiO_2.aq \qquad (2.3)$$

2.1.4 The behavior of cement with soil

When mixing cement into the soil, the cement acts as a binder and the particlessoil is aggregate. To explain the solidification process, people often use the Baikov-Rebinder theory, this process is divided into 3 stages: *The dissolution phase; Colloidal stage; Crystallization stage*

2.1.5 The behavior of the binder with soil and natural pozzolan

Natural pozzolan is a material containing amorphous SiO_2 or containing amorphous SiO_2 and Al_2O_3 with little or no cohesive properties, but when finely ground and in a humid environment chemically reacts with $Ca(OH)_2$ at room temperature to form cohesive compounds.

2.1.6 Hydrolysis products of natural pozzolan and artificial pozzolan

Both natural and artificial pozzolan have similar reaction mechanisms to produce mechanically mineralized components such as CSH, CAH and CASH. The solid products of cement hydration are Portlandite $Ca(OH)_2$, colloidal CSH, aluminum combined with water, calcium and sulphate to form the main minerals AFt (ettringite) and AFm, and some minerals. hydrogrossular groups (CAH and CASH).

2.2 The basis of work and requirements of soil materials for waterproofing inclined wall structures for earth dams.

2.2.1 Standards for testing

Standard compaction test; Test to determine the permeability coefficient; Compressive strength test; etc…

2.2.2 Some requirements of soil materials for waterproofing inclined wall structures for earth dams

Requirements on permeability coefficient: less than 10^{-5}cm/s for soil material as waterproofing structure for earth dam; Requirements for resistance in water: no disintegration, no shrinkage, no swelling

2.3 Soil materials for embankment in the Central Highlands.

On the basis of formation origin and typical structure of weathered crust on basalt rock, the thesis has divided basalt soil Figure 2.2, Figure 2.3 into main soil types such as: dQ is the product of the ridge, the main component. weak is phase lightning; eQ is the in situ weathering product of basalt; HW is a strongly weathered bedrock zone, partly transformed into soil and rock.

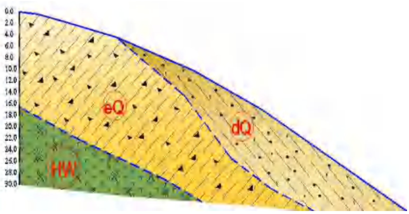

Figure 1.2: Typical section of weathered crust of basalt KVNC

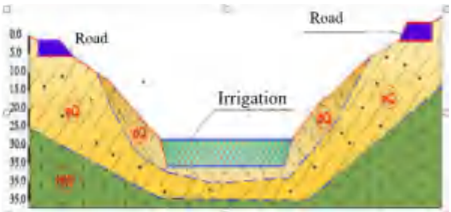

Figure 2.2: Distribution of works on the cross-section of the basalt weathering crust

2.3.1 Mineralization composition of basalt soil in KVNC

Basalt soil samples were taken at Dak Noh lake, Dak Nia commune, Gia Nghia, Dak Nong. Image of digging to take soil samples at the site, Figure 2.4.

Figure 2.4. Digging soil samples at Dak Noh lake, Dak Nia commune, Gia Nghia town, Dak Nong (Photo taken by PhD student)

The results of analysis of the mineral composition of the soil showed that the mineral composition of kaolinite accounts for 23%, this is a mineral that will increase the efficiency of the pozzolanic reaction of GH Hilt, DT Davidson [eighty seven]. Experimental results show that the content of soluble salts of the studied soil (Cl^-, SO_4^{2-}, etc...) are all less than 5%; soil pH 5,05 > 4%; Organic content < 5%, according to TCVN 10379:2014, the research soil can be reinforced with cement.

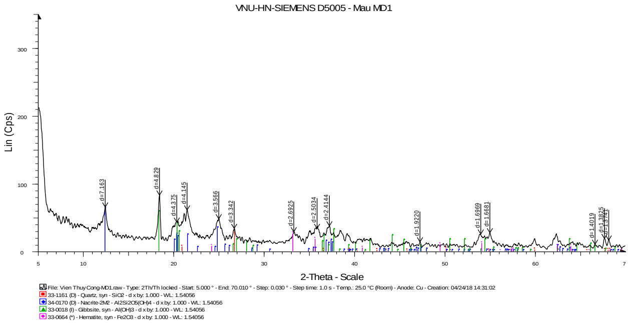

Figure 2.5. Mineral analysis results of soil samples by means of diffraction

2.3.2 Mechanical properties of basalt soil samples KVNC

Basalt soil samples were taken at Dak Noh lake, Dak Nia commune, Gia Nghia town, Dak Nong. Experiments on mechanical and mechanical components were carried out at the Geotechnical Research Department - Institute of Hydraulics (Las-xd 268). Conduct compaction and preparation test at compaction, K = 0,98 to determine the mechanical-mechanical properties. The experimental criteria and applicable standards are presented in Table 2-5.

2.4 Natural source of pozzolan in Vietnam and the Central Highlands

Investigation agencies have found sources of pozzolan in many regions of our country, but after evaluating according to ASTM C618-2003 standard, it was found that: only a few sources of additives meet the requirements of chemical composition are presented in Table 2-7. For Pozzolan mineral resources in the Central Highlands, Kieu Quy Nam et al of the Institute of Geology [15], [16], [17], [18], [19]has studied the distribution and reserves of pozzolan for many years. Research results show that the source of pozzolan in the Central Highlands is relatively abundant, convenient and cheap to exploit, and meets the technical requirements. [15].

2.5 Evaluation of the possibility of using natural pozzolan selected for research to improve soil

2.5.1 Distribution characteristics

Research results over the years (from 1960-2000) by the Institute of Geology together with a number of other agencies have shown that our country has a great potential for pozzolan, rich in genres and quality.

2.5.2 Quality assessment of natural pozzolan studied

Chooseselected basalt from natural pozzolan mine located in Quang Phu and Buon Choah communes, Krong No district, Dak Nong province for research. Soil samples were taken at different locations (foot, hillside).

2.5.3 Experimenting the properties of natural pozzolan

2.5.3.1 Mechanical and physical parameters of natural pozolan samples

The author used this experimental result of the project "Research on the use of natural Pozzolan in the construction and maintenance of rural transport and irrigation works in Dak Nong province").

2.5.3.2 *Specialpointpetrology* - mineralogy

Initial assessment shows that natural pozzolan has a dense structure, relatively solid, color varies from dark gray to light gray, rash architecture, dolerite background. The petrographic composition (Table 2-9),Mineral composition by Ronghen, Table 2-10.

2.5.3.3 Chemical composition characteristics

Sampling pozzolan at the study site in Dak Nong province to test the chemical composition, we have the results as in Table 2-12. Thereby, the total content (Si_2O + Al_2O_3 + Fe_2O_3) of the samples with an average value of 73,60% is higher than the required value according to ASTM C618-03 which is 70% [139],Contains no organic content. The [SO3-]

content is all less than 1%. The content of glass components is quite high, so it can be assumed that the basalt samples tested have pozzolan properties. The powdered pozzolan sample reacts with alkali as well as with lime, the test results show that the hardening ability is very obvious. Initial analysis results show that the quality of natural pozzolan is good enough for soil improvement.

2.5.3.4 Pozzolan activity

The activity of natural pozzolan samples was evaluated through the lime absorption and strength activity index for cement. The results of the lime absorption test of the samples showed that the lime absorption of the natural pozzolan samples reached the average lime absorption of 78,37 mg CaO/g > 30 mg CaO/g [53], strength activity index for cement reached 81,44% > [75%], [70]. The analysis results show that the natural pozzolan in the study area ensures the activity level.

2.6 Basis for selection of experimental distribution phối

2.6.1 Cement content

The proportion of cement used for soil improvement mainly depends on the soil group (soil classification). According to the American engineer document [126] soil classification according to AASHTO M 145 standard and the American Association of Cement Association (Portlan Cement Association) [114] The recommended minimum amount of cement required for soil improvement is shown in Table 2-14.

2.6.2 Lime content

Summary of the design method of soil mix for lime improvement by the National Lime Association (National Lime Association) [97], the lime content selected depending on the particle composition and the plasticity index is shown in Figure 2.14. Recommendations for lime content (Coach) to improve coarse-grained soil based on total dust and clay content (BS) are as follows: Coach from 2%, 3%, to 5% if BS is less than 50%; Coach from 5%, 7%, to 10% if BS is greater than 50%.

2.6.3 Natural pozolan content

According to research by Nader Abbasi (2018) [122], when researching for silt sand soil in Jandagh - Garmar area, Iran, the author studied and mixed 4 concentrations of Pozzolan (0, 5%, 10% and 15%) with 4 ratios of lime (0, 1%, 3%, 5% and 7%). The results of compressive strength at 14 natural days showed that the sample reached the maximum compressive strength when the ratio of pozzolan/lime was 3-5 times.

2.7 Conclusion Chapter 2

From research on the scientific basis of using inorganic binders to improve soil in situ such as: improving soil with lime; improve the soil with lime combined with binders. It is found that pozzolan can strengthen the soil to increase its strength and reduce permeability, swelling, shrinkage, and disintegration. Natural pozzolan in the Central Highlands is abundant and has not been used commensurate with available resources. The quality of pozzolan in the study area is mainly in the basalt weathering shell with the total chemical content required for the binder being more than 70% in accordance with ASTM C618-03

CHAPTER 3 ANALYSIS OF THE MECHANISM OF IMPROVEMENT OF LAND WITH NATURAL POZZOLAN, CEMENT AND LIME USING THERMODYNAMIC MODEL

3.1 Using thermodynamic model to study soil improvement in situ by binder

3.1.1 Introduction to thermodynamic model and its applications

The "thermodynamic" model is a model that can simulate well and support the analysis of chemical reactions in the process of research, analysis and evaluation related to chemistry and thermodynamics.

3.1.2 Application of thermodynamic models to the study of cement hydration

Applications of thermodynamic models such as the study of hydration of cement: Study of cement hydration under the influence of CaCO3; Research on cement hydration under the action of pozzolan; Effect of temperature on hydration of sulphate resistant cement; Effect of mineral content CSH on permeability coefficient of materials.

3.2 Selection of simulation software

There are many reaction databases that have been built to serve thermodynamic equilibrium simulations such as Phreeqc, Cemdata and Nagra-psi Kernel [eighty six]... GEMS-PSI software is written on the C^{++} programming language. It is the most popular software with high confidence in the thermodynamic simulation community [eighty seven]. Therefore, the author uses GEM-PSI software to study.

3.3 Fundamentals of thermodynamic modeling

3.3.1 Activity and ionic strength

In a solution, the activity of a solute A is expressed by the following equation {A} [136]:

$$\{A\} = \frac{\gamma_A [A]}{[A_0]} \quad (3.1)$$

To be able to determine the activity coefficient, it is necessary to determine the ionic strength of the solution, symbol I (mol/kg water):γ_A

$$I = \frac{1}{2}\sum_i z_i^2 [A_i] \quad (3.2)$$

There are many approaches to calculating the activity coefficient, but in general these approaches are developed from the Debye-Huckel equation [116], this equation applies only to dilute solutions with ionic strength (mol/kg water): $I < 0{,}005$

$$\log(\gamma_i) = -\xi z_i^2 I^{0,5} \quad (3.3)$$

3.3.2 Thermodynamic equilibrium

The interaction of ions with minerals leads to dissolution of the old mineral and theprecipitation of new minerals. The saturation of mineral m is represented by the equation below: Ω_m

$$\Omega_m = K_{s,m}^{-1} \prod (\gamma_i C_j)^{\upsilon_{mj}} \qquad m = 1, \ldots, N_p \qquad (3.9)$$

3.4 Mineralization composition of input materials for thermodynamic model

The hydration reactions of cement take place between highly active components such as SiO_2, CaO which are the main components of cement. [2], [127].The reaction mechanism of many different systems of equations requires the use of a computational model. The author uses thermodynamic models to simulate these reaction equations through GEMS-PSI software.

3.5 Preliminary design of distribution by thermodynamic model

Specifically, Pozzolan has 7 concentrations: 0%, 5%, 10%, 15%, 20%, 30% and 40% (marginal addition with the rate of 30%, 40% compared to the proposal in chapter 2); cement has 6 concentrations of 0%, 2%, 3%, 5%, 8% and 10%; Lime has 3 concentrations of 0%, 4% and 8% by weight of the material mixture.

When lime and cement are not used, the CS-H+CASH improved soil mixture with colloidal CS-H+CASH is negligible (almost zero) despite the presence of natural pozzolan. When not using cement in the reinforcement mix, the CS-H+CASH content increases gradually in proportion to the natural pozzolan content, but is quite small. At the same time, the results also show that if natural lime and pozzolan are used as the sole materials for soil improvement, the CS-H+CASH content is relatively small at 4% lime or 8% lime compared to when using lime. cement use. Therefore, if only lime is used as an activator of pozzolan reactions, the colloidal content of the improved soil will not develop strongly even if a lot of lime is used, which is consistent with the soil reclamation design of the Center. Indiana State Geotechnics, USA [140].

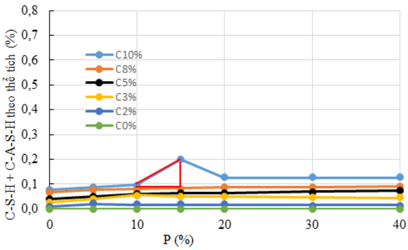

Figure 3.7. Composition CSH + CASH, with L=0%

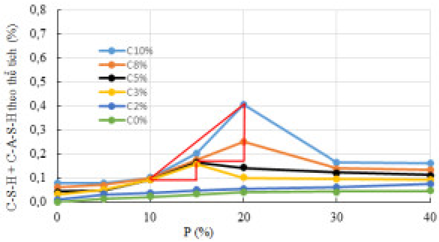

Figure 3.8. Composition of CSH + CASH, with L=4%

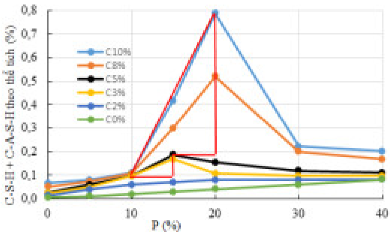

Figure 3.9. Composition of CSH + CASH, with L=8%

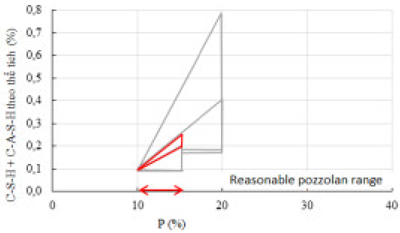

Figure 3.10. Approximate use of pozzolan

3.6 Analysis of soil improvement mechanism of natural pozzolan, cement and lime mixture by thermodynamic model

The content of CSH and CASH glue in 100 g of the improved soil mixture is shown in Figure 3.7, Figure 3.8, Figure 3.9 and Figure 3.10. This content depends on the mass percent composition of natural pozzolan, cement and lime. The distribution for the maximum amount of CS-H+CASH glue for each amount of lime used 0%, 4% and 8% respectively is “cement/natural pozzolan = 10/15; 10/20 and 10/20”.

3.6.1 Reaction soil- natural pozolan-cement-lime

In the distribution system included in the study in the model, a random distribution is selected for analysis. Specifically, the grade is selected corresponding to the cement and lime content of 3% and 4%, respectively, of the volume of improved soil for simulation.

3.6.2 Natural pozolan-cement-soil reaction

In this part, thermodynamic model will be used to study the activation ability of cement to natural pozzolan Dak Nong in the process of soil improvement without lime. Two matrices were used for the study: P0C10L0 and P10C10L0.

Table 3-7. Mineral content CSH and CASH

No	Mix design	P0C10L0	P10C10L0
1	C-S-H (volume content)	0,0725	0,0735
2	C-A-S-H (volume content)	0,0239	0,0239
3	C-S-H+C-A-S-H (volume content)	0,0964	0,0973

3.6.3 Comparing the activity of natural pozzolan Dak Nong with natural pozzolan Bigadiç-Turkey by thermodynamic model

In order to more accurately evaluate the activity of natural pozzolan mined in Dak Nong, in this section the author uses a thermodynamic model to simulate the equilibrium system of soil/natural pozolan/cement mix. /lime, corresponding to cement 5% and lime 4%. The results are relatively similar and consistent.

3.7 Conclusion of chapter 3

Calculation results from the proposed model show a reasonable range in the envelope with the proportion of natural pozzolan from 10% to 20%, cement from 5% to 10% and lime from 4% to 8%. However, considering economic conditions, materials are available locally and with the goal of using limited cement and lime content. Through the results of the model, it is proposed to choose a reasonable level of coordination P10C5L4.

CHAPTER 4 RESEARCH TO REPRODUCE THE WEST PLANTS OF BAZANIA WITH NATURAL POZZOLAN, CEMENT & LIME – TRIAL APPLICATION ON SPECIFIC WORKS MODEL

4.1 Experimental content and comparison with thermodynamic model

4.1.1 Experimental content

The content of selected binders for testing in the laboratory was built as follows: Natural Pozzolan: 0, 5, 10, 15, 20%; Cement: 0, 3, 5, 10%; Lime: 0, 4, 8%.

4.1.2 Experiment results

4.1.2.1 *Standard compaction (K=0.95)*

Lime-improved soil has a reduced dry volume and increased optimum moisture content compared to natural soil. Because lime has a lighter density (2,07 g/cm3) than soil (2,78 g/cm3) and the water absorption capacity of lime is higher than that of soil; Soils with the addition of pozzolan and cement mixtures increase the dry bulk weight and reduce the optimum moisture content of the mixture compared with unreinforced soils;

4.1.2.2 Compressive strength at 14 days of age (K=0,95; OMC=28%)

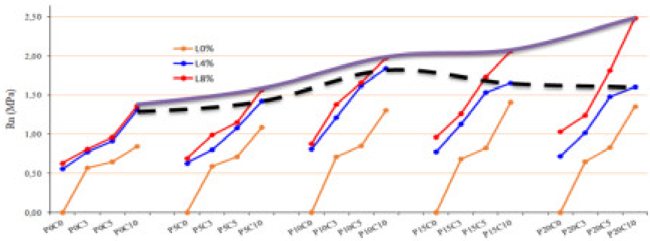

Figure 4.23. Sample compressive strength of improved soil at 14 days old (BH)

To use natural pozzolan as a binder for soil improvement, lime must be added. When reinforcing 8% lime, or 10% cement is not effective.

4.2 Study on the influence of pozzolan, cement and lime on the permeability coefficient

4.2.1 Permeation test for soil samples: The constant water column method, the variable water column method and the method of calculating the permeability coefficient based on the particle composition

4.2.2 Experiment results:

CP1: Natural soil is compacted;

CP2: P10C5L4 (reasonable level);

CP3: P10C10L4;

CP4: P15C5L4;

CP5: P15C10L4 .

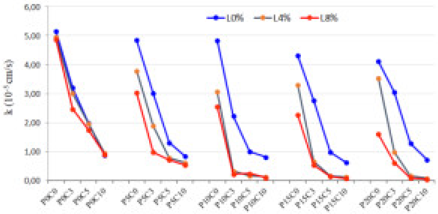

Figure 4.25. Permeability coefficient, K=0,95

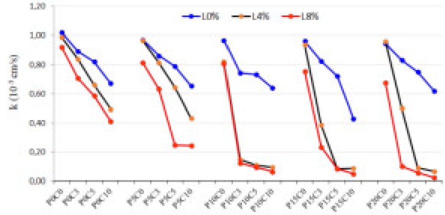

Figure 4.28. Permeability coefficient, K=0,98

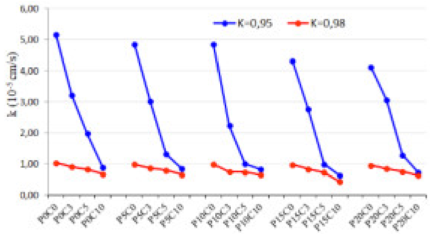

Figure 4.28. Effect of compaction coefficient (K) on permeability coefficient (L 0%)

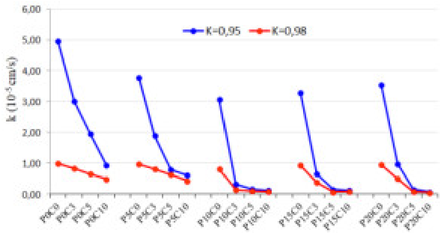

Figure 4.29. Effect of compaction coefficient (K) on permeability coefficient (L 4%)

4.2.3 Permeation test for concrete samples

4.2.3.1 Experimental methods

Determination of permeability coefficient according to the method of maintaining a stable flow (Constant Flow Method) according to Vietnamese Standard TCVN 8219-2009; USA CRD-C48-92; China SL48-94.

4.2.3.2 Result of permeability test

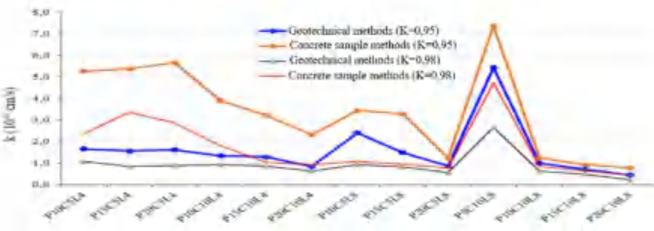

Figure 4.30. Permeability coefficient of the geotextile method and the BT . sample

Figure 4.31. Permeation test images.

4.3 Compare the experimental results with the results of the thermodynamic model

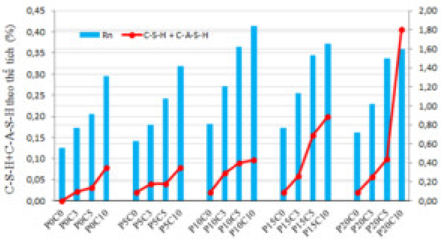

Figure 4.33. Relationship between CSH + CASH and Rn, with L4%

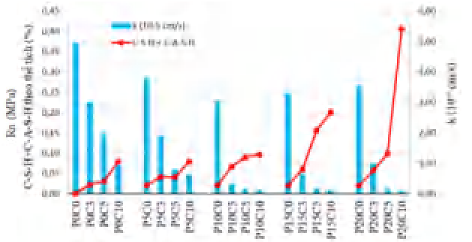

Figure 4.36. Relationship between CSH + CASH and permeability coefficient (k), with L4%

4.4 Evaluation of the mechanical properties of the rational grade

4.4.1 Choose a reasonable level of coordination

Based on experimental results in the room with different proportions and reasonable selection criteria, the author chooses a reasonable combination of 10% pozzolan, 5% cement and 4% lime. .

4.4.2 Compressive strength at different age days

The compressive strength increased rapidly in the first 28 days (Rn at 28 days old increased by 27% compared to Rn at 7 days old), tended to develop slowly from 28-90 days old, only about 7%;

4.4.3 Tensile strength when pressing split at different age days

Tensile strength increased rapidly in the first 28 days (Rech at 28 days increased by 79% compared to Rech at 7 days), tended to develop slowly from 28-90 days of age, only about 29%. This is consistent with the test results of compressive strength;

4.4.4 Elastic modulus at different ages

Elastic modulus increases rapidly in the first 28 days (E at 28 days increases by 90% compared to E at 7 days), tends to grow slowly from 28-90 days of age, only about 10%.

4.4.5 The disintegration of the improved soil

Disintegration is one of the root causes of water loss through the dam body. The sample of the P10C5L4 mix does not disintegrate

4.4.6 The swelling properties of the soil have been improved

With the mixing ratio of 10% pozzolan, 5% cement and 4% lime as selected, after 7 days of curing, the swelling of the mixture will decrease from 7,27% to 0%. Sample does not swell

4.5 Study on field experiments to evaluate waterproofing of pozzolan-improved soil and binders

4.5.1 Experimental methods

Darcy's seepage experiment laid the foundation for the theoretical basis of the study of seepage problems in geotechnical engineering. The narrow gap seepage model is suitable for 2-dimensional problems and the model width is limited to a few mm, so it is difficult to carry out seepage tests for earth dams with waterproofing structures.

4.5.2 Experiment scenario

Step 1. Site preparation; Step 2. Dig a test hole of size 1×1×1m at Dak Noh Lake, Dak Nia commune, Gia Nghia town, Dak Nong; Step 3. Mixing and compacting. Each test grade is carried out in a pit with compaction coefficient K = 0,95; Step 4. 28-day-old curing; Step 5. Water pouring experiment.

4.5.3 Results of the field seepage test

No	Mix design	K = 0,95 (cm/s)
1	CP0: Initial soil	$2,45\times10^{-4}$
2	CP1-Natural soil, K = 0,95	$2,77\times10^{-5}$
3	CP2-P10C5L4	$2,25\times10^{-6}$
4	CP3-P10C10L4	$1,44\times10^{-6}$
5	CP4-P15C5L4	$2,16\times10^{-6}$
6	CP5-P15C10L4	$1,35\times10^{-6}$

Board 4-11. Result seepage test by field method

4.6 Applying the research results of seepage treatment to specific construction models.

4.6.1 Model introduction

Experimental grades to compare waterproofing include: CP0: Current soil; CP1: Compacted natural soil K = 0,95; CP2: P10C5L4;

CP3: P10C10L4; CP4: P15C5L4; CP5: P15C10L4.

4.6.2 Permeable safety evaluation

The calculation results of the saturation line for the dam body when using the inclined wall is a mixture of improved soil with two different permeability coefficients shown in Figure 4.45, showing that the saturation line is in the infiltration safety zone.

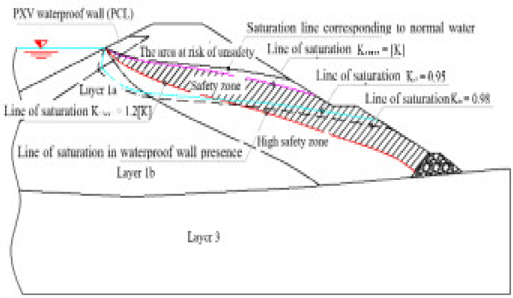

Figure 4.45. Saturated line when there is a waterproof wall

4.7 Conclusion of Chapter 4

Evaluation of mechanical properties of the appropriate combination P10C5L4 at different ages: Rn; Rech; E, swelling and disintegration showed a reasonable level of coordination to ensure bearing capacity and resistance to disintegration when met with water. Experimental results in the room and results calculated by mathematical model are similar; Through laboratory and field penetration tests, it is shown that a reasonable reinforcing agent mixture P10C5L4 has a coefficient of variation from about 5×10^{-6} cm/s to 1×10^{-6} cm/s, meeting the requirements of waterproofing structures for small and medium earth dams in the Central Highlands; Applying slanted wall structure using improved soil mixture to waterproof the earth dam that is being seeped, the calculation results show that the saturation line is in the safe zone of seepage, proving the effective waterproofing.

CONCLUSIONS AND RECOMMENDATIONS

I. CONCLUSION

- The thesis has selected a reasonable combination of 10% natural pozzolan, 5% cement and 4% lime (P10C5L4).
- Evaluate the mechanical properties of the appropriate grade P10C5L4

at different ages: Rn; Rech; E, swelling and disintegration showed a reasonable level of coordination to ensure bearing capacity and resistance to disintegration and swelling when meeting water. The experimental results in the room and the results calculated by the mathematical model are similar.

- Reasonable reinforcement mix P10C5L4 with coefficients varying from about 5×10^{-6} cm/s to 1×10^{-6} cm/s, meeting the requirements of waterproofing structures for small and medium earth dams in the Central Highlands. Applying slanted wall structure using improved soil mixture to waterproof the soil dam being permeable, the calculation results show that the saturation line is in the safe zone of seepage, proving the waterproofing effect of the improved soil mixture. create.
- With this mixed-use inclined wall structure, the advantages of locally available materials have been maximized, the construction solution is not complicated, the construction progress is fast, the quality is guaranteed to meet the technical requirements. .

II. RECOMMENDATIONS

- To study more mixtures of improved soil with different soil types in the Central Highlands;
- Experimental application in practice as a waterproofing structure for an earth dam in the Central Highlands;
- Studying the influence of pH, ambient temperature on the development of CS-H+CASH minerals as well as the strength of the soil mixture improved by thermodynamic model in the following studies.

LIST OF DISCLOSED SCIENTIFIC WORKS

1. Ba Thao Vu, Van Quan Tran, Quoc Dung Nguyen, Anh Quan Ngo, **Huu Nam Nguyen**, Huy Vuong Nguyen và Hehua Zhu (2018). "A Geochemical Model for analyzing the mechanism of stabilized soil incorporating natural puzolan, cement and lime". Proceedings of China-Europe Conference on Geotechnical Engineering. Springer Series in Geomechanics and Geoengineering. Springer, Cham. ISSN: 1866 - 8755 (1), pp 852-857, (**Scopus**).
2. Ba Thao Vu, **Huu Nam Nguyen**, Van Minh Pham, Huy Vuong Nguyen, Van Thuc Dinh, Van Quan Tran (2018), "Study on potential of using natural puzolan in Đak Nong to stabilize soils". Proceedings of the 4th International Conference VietGeo 2018: Geological and Geotechnical Engineering in Response to Climate Change and Sustainable Development of Infrastructure, Quang Binh 21-22th September, Science and Technics Publishing House. ISBN: 978-604-67-1141-4, pp 312-319.
3. **Nguyễn Hữu Năm**, Phạm Văn Minh, Vũ Bá Thao, Nguyễn Huy Vượng, Đinh Văn Thức (2018). "Phân tích hoạt tính và khả năng cải tạo đất của Puzolan tự nhiên tỉnh Đăk Nông". Tạp chí Khoa học & Công nghệ Thủy lợi. ISSN: 1859-4255, Số 47, tr 98-107.
4. **Huu Nam Nguyen**, Van Quan Tran, Anh Quan Ngo, Quang Hung Nguyen (2019), "Using Numerical Model To Evaluate Puzolanic Activity Of Natural Puzolan In The Soil Stabilization Process". International Journal of Engineering and Advanced Technology (IJEAT). ISSN: 2249 – 8958 (8), pp 142-145.
5. **Huu Nam Nguyen**, Van Quan Tran, Anh Quan Ngo, Canh Tung Nguyen (2019), "Application of thermodynamic model to mix design of stabilized soils". International Journal of Engineering and Advanced Technology (IJEAT). ISSN: 2249 – 8958 (8), pp 1295-1300.
6. **Huu Nam Nguyen**, Van Quan Tran, Anh Quan Ngo, Quang Hung Nguyen (2019), "Using Natural Pozzolan, Cement and Lime for Stabilizing Soil in Earth Dams". International Journal of Engineering and Advanced Technology (IJEAT). ISSN: 2249 – 8958 (8), pp 2809-2814.
7. **Nguyễn Hữu Năm** (2020). "Mô hình nhiệt động lực học và ứng dụng trong nghiên cứu sử dụng các chất kết dính vô cơ". *Tạp chí Khoa học & Công nghệ Thủy lợi*. ISSN: 1859-4255, Số 58 - 2020, tr 63-70.