PROPERTIES OF SOFT SOIL GROUND IN THE QUANG NINH COASTAL AREA AND PROPOSAL OF SOFT SOIL IMPROVEMENT IN THE CONTEXT OF THE CLIMATE CHANGE AND SEA LEVEL RISE

Nguyen Thi Nu[1], Nguyen Van Phong[1], Do Minh Toan[2], Nguyen Viet Tinh[1], Pham Thi Ngoc Ha[1]
[1]Hanoi University of Mining and Geology, Vietnam
[2]Vietnam Association of Engineering Geology and Environment
Coressponding author' Email: nguyenthinu@humg.edu.vn

Abtract: This paper presents the properties of soft ground structure in Quang Ninh coastal area. The basic of division of soft ground structure depends on the distribution and the thickness of soft soil. This result can be divided into 3 types (I, II, III) and 4 sub-types (I.a, II.a, III.a, III.b) of the soft ground structure. Each type of soft ground structure can be improved by many methods for construction in the condition of the climate change and sea level rise. Replacement partial or total excavation of soft soil, the embankment of berm or the friction pile will be used for sub-types I.a, II.a, III.a. Traditional sand piles, deep mixing technique and prefabricated vertical drains with preloading will be used for sub-type III.b.

Keywords: soft ground structure; soft soil; soft ground improvement.

1. Introduction

Quaternary geological structure of the coastal area of Quang Ninh has many ages and origins ranging from Pleistocene to Holocene with various lithological compositions, including the mbQ_2^3 lithological complex, characterized by soft soil - sensitive objects with the impact of the environment. This soft soil is a disadvantage for infrastructure construction. For building on the soft ground, ground improvement should be taken to ensure long-term stability of building under the impact of climate change and sea level rise.

Therefore, clarifying the soft soil distribution and the physico-chemical properties of soft soil to offering appropriate treatment solutions that play a very important role in contributing to the sustainable development of Quang Ninh coastal areas.

2. Soft ground structure in Quang Ninh coastal area

The purpose of the division of soft ground structure is the basis for the planning of economic exploitation territory, the orientation for the improvement of soft soil, serving the assessment of the impact of climate change and sea level rise. Dividing of soft ground structure is based on the properties of soft soil as well as the effectiveness of soft ground improvement. It also based on:

- The scale and characteristics of the buildings;
- The development plan of the Northern coastal region up to 2025 and vision to 2050; The socio-economic development plan of the economic development areas of the northern coastal region up to 2030 with a vision to 2050. The building is mainly planned for civil, industrial and infrastructure projects, transport, sea dykes with small and medium loading scale;
- The geology, hydrogeological feature.
- Technologies for soft ground improvement in Viet Nam.

The division of soft ground structure is mainly based on stratigraphic characteristics (presence and location of soft soil layers) and also based on hydrological and terrain factors.

Features of geological structures and properties of soft soil:

Due to researching on geology, geological engineering of the Quang Ninh coastal area shows that the types of soil in the quaternary sediments distributed from the surface to a depth of several meters or over ten meters, including types of marine origin (m), sea - marshland (mb) and river (a). Composed of cobbles, gravels, clayey sand (aQ_2^3); sandy cobbles and gravel in dense state, sandy clay and clayey sand in firm state (mQ_2^{1-2}); small grain sand, clayey sandy, sandy clay, clay in firm to soft state (mQ_2^3); Very soft clay and very soft sandy clay with organic matter and seashell (mbQ_2^3). So, only mbQ_2^3 formation is soft soil and widely distributed in the area.

The results of composition, physico-mechanical properties of mbQ_2^3 soft soil shown:

The amount of organic matter content varies from 2.35 to 6.31%

Soils have low bearing capacity (R_0 varies from 0.2 to 1.0kG/cm^2) and large deformation (E_0 varies from 3.0 to 35kG / cm

The characteristics of soft soil distribution in some places in Mong Cai, Cam Pha, Quang Ninh as follows:

Mong Cai district: composed of clay in very soft state (mbQ_2^3) distributed mainly in estuaries and streams to the sea from Tien Yen to Mong Cai through the territory of the communes of Quang Minh, Hai Dong, Hai Yen, Van Ninh, Hai Hoa, about one-third of the total area. Soft soil is distributed at the depth from surface to 5m and covered above eluvi and deluvi soils edQ.

Cam Pha district: Composed of very soft sandy clay (mbQ_2^3) distributed near the seaside, forming a narrow strip extending from Cam Binh, Cam Son, Cam Phu, Cam Trung, Cam Tay and Cua Ong to Mong Duong. Soft soil is distributed at the depth from surface to 5m and covered above eluvi and deluvi soils edQ or soils of mQ_2^3.

Ha Long district: Composed of very soft sandy clay, very soft clay, soft clay (mbQ_2^3). Soils narrowly distributed near the seaside, forming a continuous strip stretching from Yen Cu to Bai Chay. Soils reveal on the surface of the terrain. These soils distributed in low lying terrain, often flooded and only exposed at low tide. Soft soil is distributed at the depth from surface to over 5m and covered above eluvi and deluvi soils edQ or soils of mQ_2^3 and mQ_2^{2-3}.

Features of hydrogeology:

In Quang Ninh area, construction of medium and small buildings related to the Holocene aquifer. Groundwater level is influenced by tidal flows and caused changes in properties of soil. The water level is shallow, ranges from 0.2 to 2 meters.

Principles of the division of soft ground structure:

From the feature of geology, properties of soft soil and hydrogeology, the division of soft ground structure divided into types and sub-types. The depth of the division of soft ground structure is up to the thickness of soft soil layers, to the layers with capable of loading for buildings (sandy clay soils, stiff and very stiff soil edQ; mQ_2^{1-2}).

Type: Based on the distribution properties of soft soil and the soils distributed under soft soil. The style is denoted by Roman numerals. In Quang Ninh coastal area is divided into 3 types:

- Type I: Soft soil distributed on the surface and covered on eluvi and deluvi soils edQ (stiff and very stiff sandy clay soil with gravel);
- Type II: Soft soil distributed on the surface and covered on sand or gravel;
- Type III: Soft soil distributed on the surface and covered on stiff clay (mQ_2^{1-2}).

Types I and II have a thickness of less than 5m. Type III has a soft soil layer complexity. Therefore, due to the effectiveness of soft ground improvement, it will divide the type III into sub-types based on the thickness of soft soil.

Sub-type a: the thickness of soft soil less than 5 meters;

Sub-type b: the thickness of soft soil greater than 5 meters;

So, in Quang Ninh coastal area, there are 3 types (I, II, III) and 4 sub-types (I.a, II.a, IIIa, IIIb).

Tab. 1. The properties of type, sub-type of soft ground structure in the Quang Ninh coastal area

Types	Areas	Properties of soft ground structure
I.a	Mong Cai, Cam Pha	- Topography is smaller than 4m; it is an accumulation delta. - Soft soil distributed on the surface ; - Under the soft soil is eluvi and deluvi soils edQ (stiff and very stiff sandy clay soil with gravel); - The thickness of soft soil is smaller than 5m; - Composed of very soft sandy clay, very soft clay, soft clay; - The groundwater level is less than 2m, fresh ground water. - R_o<0.5 kG/cm^2; E_o<20kG/cm^2; e_0>1,000; γ<1,72g/cm^3 (Mong Cai); γ<1,64g/cm^3 (Cam Pha). Cv=0.45.10^{-3}-0.85.10^{-3} cm^2/s; C_c=0.270-0.383; Pc=0.16-0.65kG/cm^2; C_{uu} =0.06 -0.120kG/cm^2; φ_{uu} = 0^{0}36'-1^{0}59'.
II.b	Ha Long	- Topography is smaller than 4m; it is an accumulation delta. - Soft soil distributed on the surface ; - Composed of very soft sandy clay, very soft clay - Under the soft soil is sand or gravel in dense state (mQ$_2^{1-2}$); - The thickness of soft soil is smaller than 5m; - R_o<1,0 kG/cm^2; E_o<35kG/cm^2; e_0>0,850; γ<1,84g/cm^3. Cv=0.20.10^{-3}-0.66.10^{-3} cm^2/s; C_c=0.250-0.383; Pc=0.17-0.65kG/cm^2; C_{uu} =0.04-0.130kG/cm^2; φ_{uu} = 0^{0}26'-1^{0}58'. - The groundwater level is less than 2m, fresh ground water.
III.a	Ha Long	- Topography is smaller than 4m; it is an accumulation delta - Soft soil distributed on the surface ; - Composed of very soft sandy clay, very soft clay - Under the soft soil is stiff sandy clayey (mQ$_2^{1-2}$); - The thickness of soft soil is smaller than 5m; - R_o<1,0 kG/cm^2; E_o<25kG/cm^2; e_0>0,850; γ<1,84g/cm^3. Cv=0.20.10^{-3}-0.66.10^{-3} cm^2/s; C_c=0.300-0.423; Pc=0.13-0.55kG/cm^2; C_{uu} =0.05 -0.100kG/cm^2; φ_{uu} = 0^{0}36'-1^{0}52'. - The groundwater level is less than 2m, fresh ground water.
III.b	Ha Long	-Topography is smaller than 4m; it is an accumulation delta - Soft soil distributed on the surface ; - Composed of very soft sandy clay, very soft clay - Under the soft soil is stiff sandy clayey (mQ$_2^{1-2}$); - The thickness of soft soil is greater than 5m; - R_o<0,5 kG/cm^2; E_o<20kG/cm^2; e_0>0,950; γ<1,74g/cm^3; Cv=0.25.10^{-3}- 0.38.10^{-3} cm^2/s; C_c=0.306-0.581; Pc=0.23-0.85kG/cm^2; C_{uu} =0.08 - 0.150kG/cm^2; φ_{uu} = 0^{0}56'-3^{0}56'. - The groundwater level is less than 2m, fresh ground water.

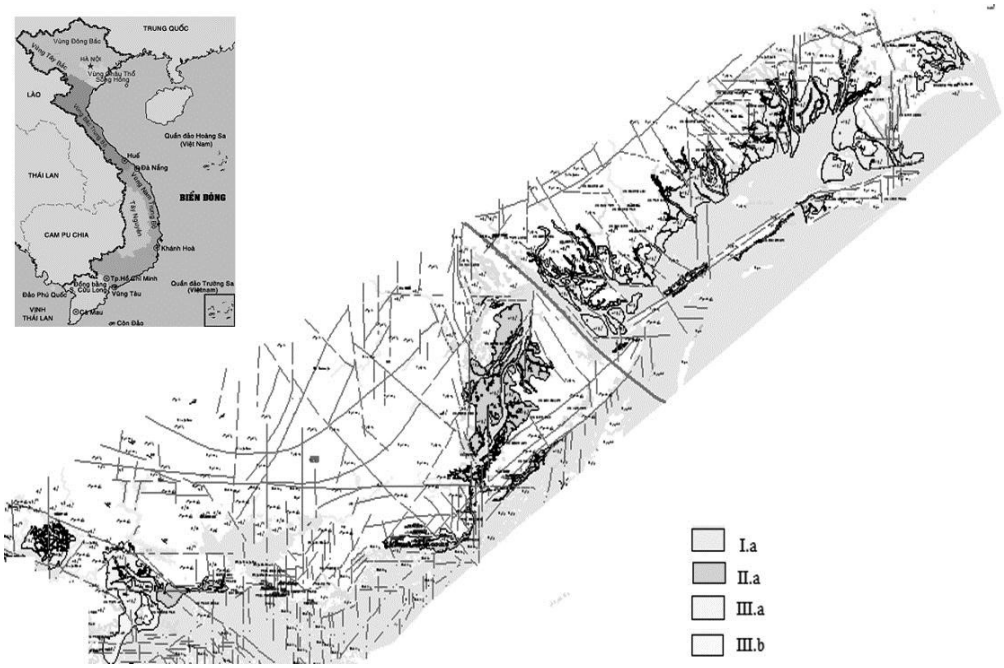

Fig. 1. The located of sub-types of soft ground structures in Quang Ninh coastal area

3. Proposing the soft soil improvement in the condition of the climate change and sea level rise.

The selection of soft ground improvement essentially investigates the interactions between geological environment and project construction or interactions between components of the natural – technique system. The result of this interaction is the development of geological processes and geological phenomena. When construction works under the soft ground, it makes the process of deformation and sliding instability. Therefore, the selection of suitable soft soil treatment methods is to control the deformation of the soft ground and sliding of soft ground to ensure with economic and technical requirements. The characteristics, intensity of these processes depends on the physico – mechanical properties of soft soil, the type of soft ground structure, or control of the optimal interaction and movement of the natural – technique system depends on the type of structure and the physico – mechanical properties of soft soil. No soft ground improvement is optimal for all types of soft ground structure. Therefore, when proposing the soft soil improvement, it is necessary to base and consider the following factors:

- The soft soil ground structure together with the composition and physical-mechanical properties of soft soil. In the research area, there are types I; II; III.a, III.b, with different distribution, thickness, composition and mechanical properties. Based on the study of the composition and physicochemical properties of soft soils, the distribution and characteristic of soft ground structure in Quang Ninh coastal area show that the stratigraphic and mechanical properties of soft soil are relatively complex, the thickness of soil changes in a relatively large range. This greatly affects soft ground improvement.

- The types and characteristics of buildings. In the study area, the buildings are of small-scale and medium size.

- Requirements for settlement and stability of the buildings;

- Economic efficiency and construction conditions;

- Effective protection of land resources against the effects of climate change.

In the condition of changing in climate and sea level, it makes many effects to properties of soft soil, the stable of buildings and the soft ground improvement (Table 2).

Tab. 2. Some impacts of changing in climate and sea level rise

Types	Mainly impacts	Effect of impacts
Changing in climate: - Give and increase the dynamic load by storm and sea waves move on coastal buildings; - Flooding local, raises more pore water pressure. ***The sea level rise:*** - Extend area of influent of the tide - Increase salty area and salty groundwater.	Increase the level saturation and infiltrate salty	- It is an insignificant change in properties of soil. - Salt content increased from 0.10 to 0.51% depending on types of soil and salinity of water; - Reduce the effectiveness of the ground improvement by cement: intensity and modulus of deformation down from 5% to 10%.
	Increase dynamic load	Reduce the coefficient of stability of the buildings, increase the risk of liquefaction ground (clayey sand, fine - grained sand)
	Increase pore water pressure in soil	- Reduce shear strength of soil 2% to 8% - Reduce the efficiency of ground improvement by vertical drainage; - Reduce the stability of the wall barriers and underground construction;
	Extend the range of oscillation of groundwater	- The impact of moving, erosion dikes and embankments made of sand; - Erosion for underground excavation and soft ground treatment with sand, sand piles, sand drain;

Thus, based on the results of studies on soil structure and composition, the combination of experience and soft ground improvement in Vietnam and in the world, there will analyze and propose solutions for the following types and types of soft ground structure adaption to change in climate and sea level as follows:

Types of soft ground structure (I.a, II.a, III.a) with the thickness of soft soil are less than 5m. Type I is only distributed in Mong Cai, Cam Pha - Quang Ninh, soft soil distributed on the surface and covered on eluvi and deluvi soils edQ (stiff and very stiff sandy clay soil with gravel). Type II.a is only distributed in Ha Long - Quang Ninh, soft soil distributed on the surface and covered on sand or gravel in dense state (mQ_2^{1-2}). Type III.a is only distributed in Ha Long - Quang Ninh, soft soil distributed on the surface and covered on stiff sandy clayey (mQ_2^{1-2}). The soils of the formations distributed under soft soil are generally for the construction of buildings. In the studied areas, the natural building materials such as sand, gravel or soils are abundant. Therefore, it is possible to use ground treatment such as replacement partial or total excavation of soft soil, embankment of berm, buffering sand layer, buffering soil layer, buffering gravel layer, partial replacement of geotextile, deep mixing method.

Types III.b with the thickness of soft soil is higher than 5m. Type III.b is distributed in Ha Long – Quang Ninh. It can be used ground improvements such as granular piles (traditional sand piles) or deep mixing method, Prefabricated Vertical Drains with Preloading. For deep mixing method, it can be used for no salt or little salt soils or small organic soils more than 5%. In the case using deep mixing method for salt soil or soil with organic matter content, there must be considered and analyzed the factors affecting such organic matter, salt content to the ability of soil improvement, add additives (lime, ...). To vercome the impact of sea level rise, it is possible increase the cement content and adds the additives.

All soft ground improvement used for each sub-types of soft ground structure shown in Table 3.

Tab. 3. Soft ground improvement method

Types of soft ground structure	Thickness of soft soil, m	Areas	Soft ground improvement in climate change and sea level rise
I	<5	Mong Cai, Cam Pha - Quang Ninh	Replacement partial or total excavation of soft soil, embankment of berm, buffering sand layer, buffering soil layer, buffering gravel layer; partial replacement of geotextiles; the friction pile.
II	<5	Ha Long - Quang Ninh	
III.a	<5	Ha Long - Quang Ninh	
III.b	5-10	Ha Long - Quang Ninh	- Traditional sand piles. - Deep mixing cement method for soil with little or no salt. Increase the cement content and add additives. - Friction piles close to stiff sandy clay soil of Pleistocene formation. The safety factor is higher than that of the normal case. - Prefabricated Vertical Drains with Preloading.

In the condition of climate change and sea level rise:

- For soft ground improvement by sand (sand drain, sand piles, buffering sand layer, buffering gravel layer: Sand must have well – graded sand for no erosion and buffering sand layer, the density of sand should be K≥0.9 (standard compaction). It should be researched for the liquefaction of sand.
- For deep mixing method for salt soil or soil with organic matter content, it should be considered and analyzed the factors affecting such organic matter, salt content to the ability of soil – cement mixing.
- For prefabricated vertical drains with preloading, it should be increased the high of preloading or increased the time of treatment.
- For friction piles, it should be increased the safety factor of building and pay attention to the negative friction of soft soil.

4. Conclusion

From the research results, there are drawn the following conclusions:

In Quang Ninh coastal area can be divided into three types (I, II, III) and 4 sub–types (I.a, II.a, III.a, III.b) of ground structure.

Proposing soft ground improvement for each type and sub–type. In the condition of climate change and sea level rise as follows:

- Replacement partial or total excavation of soft soil, the embankment of berm or the friction pile will be used for sub- types I.a, II.a, III.a.

-Traditional sand piles, deep mixing technique and prefabricated vertical drains with preloading with some notes in table 3 will be used for sub-type III.b.

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