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Study on geotechnical characteristics of Holocene soils with reference to geohazards in Kien An - Do Son, Hai Phong coastal zone

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Abstract. In recent years, after renovation policy launched by the Vietnamese government, the economy of Kien An - Do Son, Hai Phong coastal zone in the Northern Vietnam has quickly changed with high income and fast economical grow rate. With the economical development, the environment in many areas has been severely damaged. In addition, the so called "global change" has also strengthened the natural hazards especially torpedo, storms surges, salt intrusion due to the sea level change... increasing of the losses caused by natural hazards in this very sensitive zone. Based on the results obtained in site recent investigation some main geological hazards were recorded and studied in detail such as flooding, coastline and river bank erosion. The results of vulnerability assessment in this study will help in proposing suitable remedial measures for hazards prevention, and also will help in realizing effectively the implementation of the socio-economic plans for the sustainable development of this very sensitive coastal zone.

1. Introduction

Kien An - Do Son region is located in the Southwest of Hai Phong city - one of the most important seaports of Vietnam, about 100 km east of Hanoi city. Both Kien An and Do Son newly had become main districts of Hai Phong city instead of small towns of the suburban districts (Fig. 1).

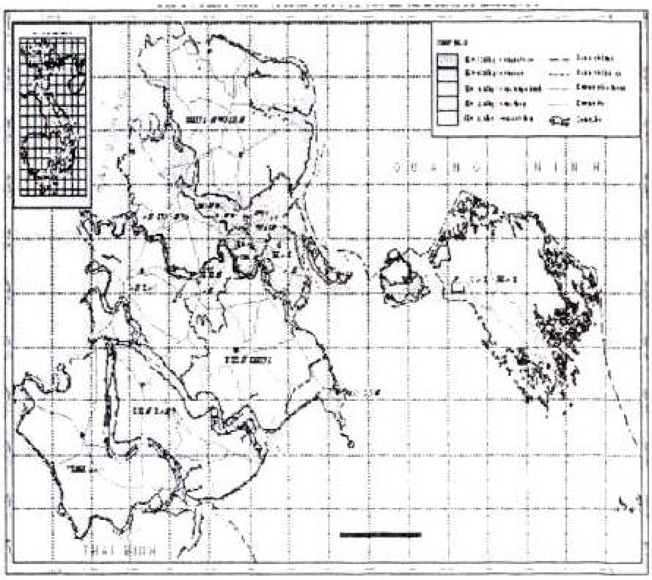

Fig. 1. Location of the study area.

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Do Son, Hai Phong is one of important doors attracting foreign investment in the Northern Vietnam having many industrial zones. Besides, it is also a dynamic center for tourism, aquaculture... so that this region has conflicts between socio-economical development and environmental protection. Each year it faces with about 4-5 typhoons causing great losses, even deadths for the habitants.

2. Background on natural & geological characteristics of the study area

2.1. Geographical condition

Locating in the NE of the Red River Delta (RRD), the study area is comprised of 4 main types of relief: karts, remained low hill, plain and coastal mangrove land with the area of about 500 km^2.

Terrain here is very differentiated with the gradual decrease in height in SE direction:

- Karts terrain: mainly distributed in Nui Voi with the elevation varying from 10 ÷ 300m, the plant cover is not regularly distributed.

- Remained low hill terrain is scattered distributed in Kien An in the NE-SW orientation and comprising terrigenous sediments. The elevation is varying from 15 ÷ 140m. In Do Son this type of terrain also developed in Van Hoa, Nui Thap and Choi Mong jointed in range with the NW-SE orientation.

- Plain terrain is widely distributed in the South and the Southeast parts with elevation varying from 0.8 ÷ 1.2m. Composition is mainly clayey sand, silty clay of alluvial origin.

2.2. Climatic condition

Climate in Hai Phong has tropical - humid characters with high influence of the sea. The climate is sharply divided into two seasons: summer and winter. Summer is usually hot and humid, many showers lasting from May to October (containing 80-90% of the annual rainfall). Winter is cold lasting from November to April of the next year. Annual rainfall is 1600-1800mm. High humidity (85-86%).

Hai Phong is located in the area of frequently occurred storms and cyclones. There are 45 days of strong wind or storms during a year. Besides, mild drizzles and frogs are frequently occurred.

2.3. Hydrological conditions

All big rivers in Hai Phong are distributaries of Thai Binh river system which are flowing NW-SE with high meandering and wide sandbars. Main rivers are Bach Dang, Cam, Lach Tray, Van Uc, Hoa, Han and Thai Binh. The distributaries are Tam Bac, Da Do, Da Bach. In average, at distance of 20 km along the coast there is an river mouth flowing into the sea.

The river discharge is not equally distributed during the year round. The flooding season contains 75-85% of discharge volume (mainly in June, August and September) meanwhile the dry season contains only 15-25% (lowest discharge in March containing only 1%). The big mud and sand volume carried during flood season makes the quick siltation in the harbors and high turbidity of seawater in all Do Son beaches.

2.4. Geological conditions

The Quaternary sediments overlying uncomfortably the Neogene deposits are composed mainly of sand and gravels, sometime with lenses of silt and clay. The sediments are thicker towards the sea, reaching up to 200 m in thickness in the coastal area. The uppermost Quaternary sediments consist of four formations: Le Chi, Vinh Phuc, Hai Hung and Thai Binh.

The Le Chi formation consists of gravel, fine to medium sand and silty clay. Vinh Phuc formation is composed of an upward fining succession of gravel and clay; the Hai Hung formation composed mainly of sand. Finally, the Thai Binh formation is composed of an upward- fining unit of gravel, sand and clay. So that the coastal zone of the RRD is considered as propagating coastal system formed mainly as a result of river sediment supply.

The Holocene marine terraces are between 3 and 5m above mean sea level (MSL) and the coastal lowland area located seaward from that terrace is predominantly lower than 3m (Nghi et al., 2000). The coastline is a drowned coastline following the rise in mean sea level of some 80m over the last 10,000 years.

In this study, efforts are concentrated in geotechnical characteristics of two upper geological divisions: Hai Hung and Thai Binh formations.

2.5. General geotechnical characteristics

Geotechnical characteristics of typical soils in Holocene formations can be described as follows:

1. Fill material ***(an Q_2)***

The thickness of this type of sediments is 0.5-2.0 m comprising mainly sand, clayey sand, clay mixed with waste construction materials. Not suite for use as fill materials.

2. Alluvial-swamp sediments of Late Holocene, Upper Thai Binh formation ***(ab Q_2^3 tb_3)***

These sediments are not widely distributed along small rivers and usually submerged with the thickness of around 1-3m. Composition is mainly clayey mud, clayey mud containing organics of dark grey or li-grey in color.

3. Alluvial-marine-swamp sediments of Late Holocene, Upper Thai Binh formation ***(amb Q_2^3 tb_3)***

Composition is clayey mud, silty-sandy mud of brownish grey containing organics. It is distributed in Lach Tray, Van Uc river mouths. Consistency is very soft to medium (B= 0.54-1.4), Bearing capacity is varied from 0.5-0.7 Kg/cm^2. (top part) to 1.7-1.8 Kg/cm^2. (bottom part).

4. Marine sediments of Early-Middle Holocene, Upper Thai Binh formation ***(a Q_2^3 tb_3)***

It is distributed in narrow range from Do Son to Van Uc, around Thai Binh river mouths. Composition is silty sand of grey color. Consistency is medium stiff (B = 0.65), Bearing capacity is 2.2 Kg/cm^2.

5. Alluvial sediments of Late Holocene, Middle Thai Binh formation ***(a Q_2^3 tb_2)***

This type of sediment is widely distributed along Van Uc, Thai Binh, Hoa rivers. Composition is mainly silty sand, silty clay of brown color, very soft. Void ratio is about 1.02-1.43, high compressibility with coefficient of compression a = 0.078 -0.026 cm^2/kg.

6. Alluvial-marine sediments of Late Holocene, Lower Thai Binh formation ***(a m Q_2^3 tb_1)***

Sediment composition is silty clay, silty sand of brownish and dark grey. It is widely distributed in Thuy Nguyen, An Hai, Vinh Bao and inner Hai Phong. Thickness is around 17m

7. Marine sediments of Late Holocene, Lower Thai Binh formation ***(m Q_2^3 tb_1)***

Sediment composition is mainly sand, silty sand of yellow, brownish yellow and brownish grey containing shell fragments. Thickness is around 2.6 m.

8. Alluvial sediment of Early-Middle Holocene, Lower Thai Binh formation ***(mb Q_2^{1-2} hh_1)***

The sediment is not seen on the surface but can be observed in boreholes with maximum thickness of 24m. Composition muddy sand, sandy mud containing organics, low consistency. Bearing capacity is 0.5 kg/cm^2.

9. Marine sediments of Early-Middle Holocene, Upper Hai Hung formation (m Q_2^{1-2} hh_2)

Outcrop of these sediments were observed in An Hai, North of Thuy Nguyen, in the periphery of Phu Dien hill range and in boreholes at depths. Thickness is varied from 1-16.6m (2-2.5m in average). Sediment composition is silty sand, silty - clayey sand.

Geotechnical characteristics of some surface Holocene typical soils are shown in Table 1.

Table 1. Geotechnical characteristics of surface soils of Holocene formations in Hai Phong area

No.	Properties		Sym-bol	Unit	Holocene formations and their typical soils			
					Silty clay (mb Q_2^{1-2} hh_1)	Clay (m Q_2^{1-2} hh_2)	Clayey silt (am Q_2^3 tb_1)	Silty clay (amb Q_2^3 tb_2)
1	Component	Sand		%	26.79	16.62	13.2	19.3
2		Silt		%	50,.	49.65	52.2	56.3
3		Clay		%	22.8	33.73	34.6	24.4
4	Water content		W	%	43.6	33.7	50.7	39.0
5	Unit weight		γ	g/cm^3	1.74	1.85	1.65	1.8
6	Dry unit weight		γ_C	g/cm^3	1.22	1.38	1.0	1.3
7	Specific gravity		Δ	g/cm^3	2.7	2.7	2.73	2.75
8	Void ratio		e		0.9	0.95	1.5	0.95
9	Porosity		n	%	52.3	48.8	59.0	54.6
10	Degree of Saturation		S	%	93	95	95	92
11	Liquid limit		W_L	%	34.6	40.4	44.3	35.0
12	Plastic limit		W_P	%	22.1	22.0	25.0	20.0
13	Plasticity index		I_P	%	12.4	18.4	19.7	14.4
14	Liquidity index		B		1.8	0.64	1.3	1.3
15	Cohesion		c	Kg/cm^2	0.054	0.13	0.059	0.06
16	Internal friction angle		φ	Degree	9	9	3	8
17	Coef. of compression		a_{1-2}	cm^2/Kg	0.09	0.073	0.09	0.057
18	Bearing capacity		R_0	Kg/cm^2	0.45	0.55	0.40	0.60

2.6. Generalized soil profile

Soil profile with variation of index properties of the soils against depths at the site of Van Huong high-grade villa are shown in Figure 2. It is divided into 4 layers in a 18 m depth borehole:

Fill is characterized as sandy clay with gravel and broken brick. The layer is ranged from the ground surface to the depth of 2m.

Silty clay layer (CL), soft to medium extends from the depth 2m to 7.5m. It is li-grey to dark grey colour with low plasticity. The water content is in range between 34% and 40%. The liquid limit (LL) is between 23% and 41%. In this layer, some organic matters are found.

Clay layer (CH) of soft to medium consistency locates from the depth 7.5m to 12m. It is brownish gray colour to li-grey, grey colour with high plasticity. The water content is in the range of 40% to 52%, the LL is of 50% to 61%.

Clay layer (CH) of medium stiff consistency is found at the depth about 12m and extend to 18m until the end of borehole. The soil is grayish brown in colour and high plastic.

The water contend is in range of 40% to 50%, the LL is 55% to 65%. However there are some lenses of fine sand within this layer.

According to the authors, the age of the clay is estimated 20,000 - 40,000 years from the dating technique using carbon isotope, ^{14}C.

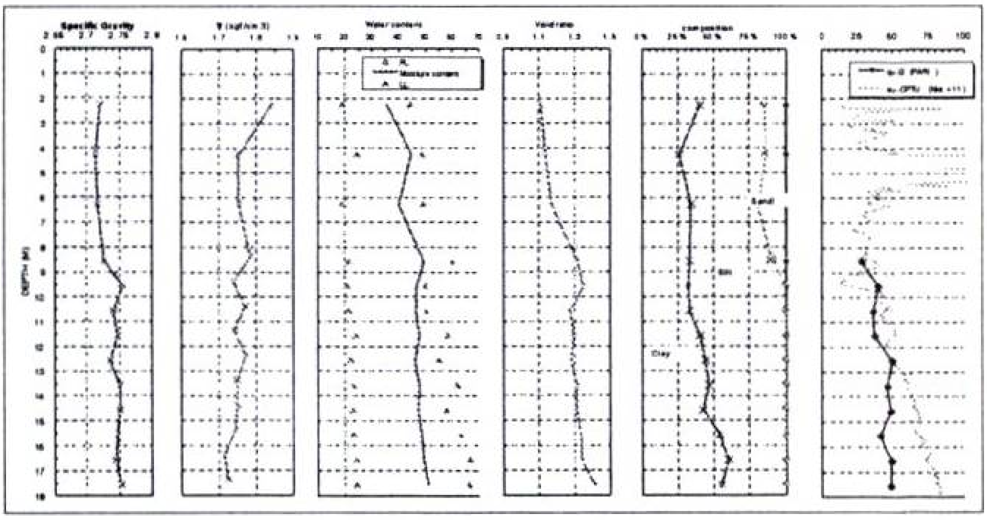

Fig. 2. Generalized soil profile and physical properties in Van Hương, Do Son, Hai Phong area.

Note: layer 1 *(0-2m)*: fill,
layer 2 *(2-7.5m)*: soft to medium silty clay (cl),
layer 3 *(7.5-12m)*: soft to medium clay (ch),
layer 4 *(12-18m)*: medium stiff clay (ch) soil classification in brackets was made according to Vietnamese standards tcvn 5747:1993.

3. Geological hazards

3.1. Coastal erosion

The Northeast coast of Do Son had the average speed of erosion of 5-14 m/year (Dinh Vu-Bach Dang and along road No.14. At Bach Dang mouth area, during 60 years (1936-1996) an amount of 1055 ha of agriculture land with vegetation cover and 2844 ha without vegetation cover had been lost. The average erosion rate for three beaches in Do Son was varying from 0.36 - 0.45 m/year [1], causing lost to the infrastructure and sea dyke system (photos 1&2). This hazard could be particularly exaggerated by storm with high SWL rise (photos 4 & 5).

The average rate and width of erosion are shown in Table 2.

Table 2. Average rate and width of erosion at Bach Dang estuary and Do Son beaches

No.	Area	Average erosion rate (m/year)	The width of erosion area during 50 years (m)
1	Dinh Vu	0,8	40
2	Beach 1- Do Son	0,45	22.5
3	Beach 2- Do Son	0,36	18
4	Beach 3- Do Son	0,40	20

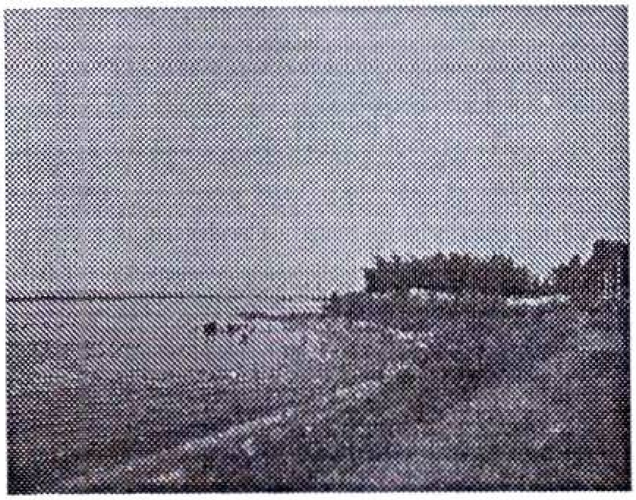

Photo 1. Sea dyke in Ward 2, Ngoc Hai Commune, Do Son - Hai Phong under erosion.

The Southwest part of the study area is highly productive in rice cultivation and with a high population density for a predominantly rural community. The human activities such as: shrimp and fish pond digging, sand exploitation, excavation with a large filling material volume, mangrove three cutting... not only influence geodynamic processes but also all natural conditions. At some places the shrimp ponds were dig very near to the dyke embankment. This could lead to severe damage to the dyke embankment.

This erosion situation will be particularly vulnerable in the event of accelerated sea level rise.

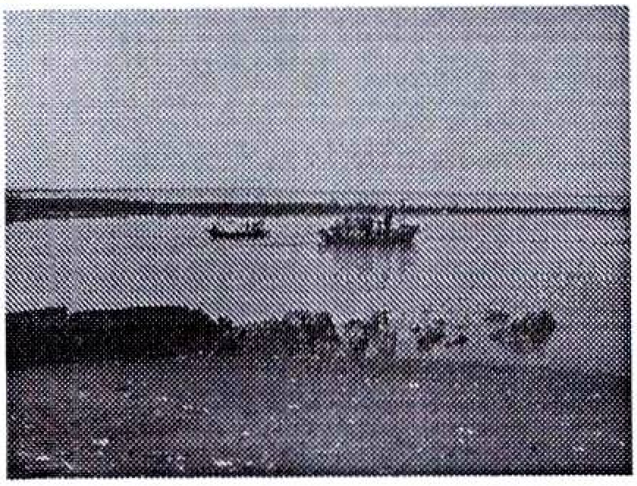

Photo 2. Dong Hai fishery port under threat of erosion.

3.2. Salinity intrusion

Salinity intrusion in the coastal zone is increasing due to fresh water extraction for irrigation and drinking water and due to the dam constructions in the catchments. Accelerated rate of the sea level rise also causes a higher penetration of saline water into rivers as well as into the ground water system.

The inland extend of salinity intrusion (1 $^0/_{00}$ and 4 $^0/_{00}$) in the river system varies from Bach Dang to Thai Binh rivers (Tab. 3).

Table 3. Distance of salinity intrusion from river mount (km). (Ca V.T., 1989) [1].

River mouth (km)	Maximum ($1^0/_{00}$)	($4^0/_{00}$)	Average ($1^0/_{00}$)	($4^0/_{00}$)	Minimum
Bach Dang	35-40	30	25-30	20	-
Van Uc	28	20	18	8	1
Thai Binh	26	25	15	5	1

After the Hoa Binh reservoir operation, the 4 $^0/_{00}$ boundaries has retreated 5-10 km from the shore line. It is noted that for agriculture crop damage occurs above 1 g/l (or1 $^0/_{00}$) and beyond 4 g/l rice crops are not sustainable.

Salt intrusion is the main cause for soil degradation in Do Son area. This composes of two processes: the leaching of salt presented in the soils from their formation, not yet properly dissolved out because lying in lowland area and salt intrusion caused by infiltration in to coarse grain sandy layer widely distributed at the depths of 80-120 cm and sometimes fount even in the sub-surface (30-50 cm)layer.

3.3. Flooding

At present flooding is one of the hazards causing most negative influence in Vietnam development, especially in areas of the most economically active such as Red River Delta (RRD) and Mekong Delta. They have caused big human as well as economical losses.

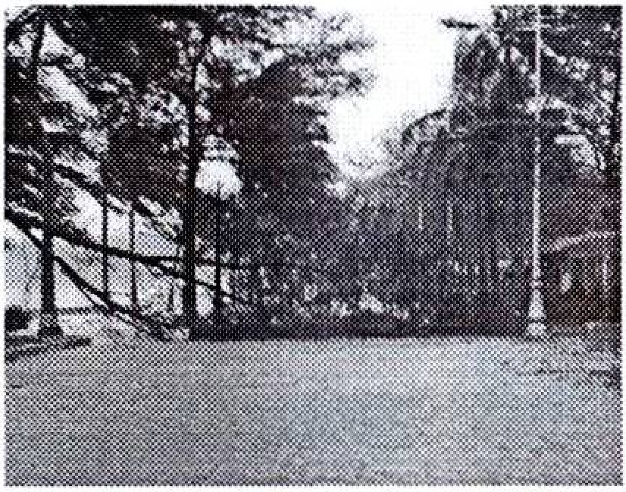

Photo 3. Road in Do Son city was flooded during the Storm No. 7, September 2005.

In the Red River (RR) Delta provinces the flooding at present is most severe during storm surges that happen rather often (around 4-5 times/year) in the areas of coastal zones. Recent extreme flood occurred in the RRD in 1971 (approx.1 in a hundred years) broke RR dyke system in tree locations and killed thousands of peoples and an area of 25000 ha was flooded, 2.7 mill. persons had suffered this severe flood hazard.

During the past 100 years, a number of 26 historical floods, predominantly rivers flooding were recorded in the RRD provinces. Most severe floods occur during occasions of high storm surges which lift the sea water level and inhibit the discharge of high run-off from heavy rains downpours in the catchments areas.

In addition, in many locations in the RRD the dykes are weaker and lower in the relation with their exceeding water levels. In the coastal zone in order to prevent flooding from the sea due to sea dyke failure, a second line of sea dyke is constricted behind the seaward dyke. Managed retreat strategies are applied for the most critical parts of the RRD coast. The estimation of the total annual budget for maintenance of sea and estuary dykes in the whole country is USD 1.54 millions.

3.4. Storm surges

From 1954 up to 1991 about 250 storm surges and cyclones landed or directly affected to Vietnam (Figs. 3). One fifth of these has arrived to the study area. Almost of the storms occurred during summer season (July-November) (Fig. 4).

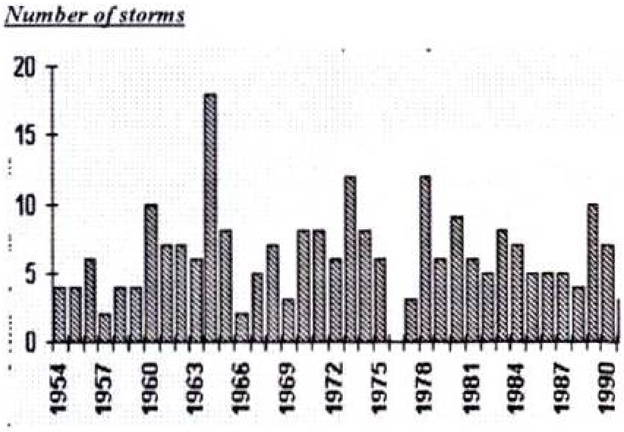

Fig. 3. Number of storms to Vietnam coast per year (1954 -1991).

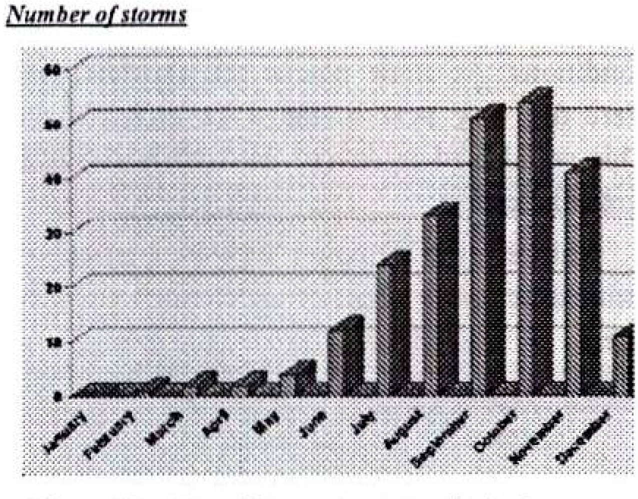

Fig. 4. Number of storms vs. months in the years.

During storm surges the sea water level (SWL) raised more than 1m, among them 30% of storms raised the SWL more than 1,5 m and 11% of them raised the SWL more than 2,5 m. The area of 40 km in width from the seacoast could be severely affected. These kinds of storms also caused flooding and destruction to sea dyke system and infrastructure (Photos 3 to 6).

3.5. Sea level rise (SLR)

The increased green house effect is making the earth is warmer, with melting ice in two poles in addition of this the over-exploitation of underground water in urban areas make rising sea levels.

According to scenario 1 (ASLRT1) of Vietnam Coastal Zone Vulnerability Assessment (CVCZVA, 1996) with 1m sea level rise and no additional protection measures about 40.000 km^2 of coastal zone of Vietnam will be subject to annual flooding [11]. About 10% of lands in the Kien An – Do Son, Hai Phong coastal zone could be partially or almost completely affected.

Photo 4. Sea dyke Do Son I during the storm No. 7, September 2005.

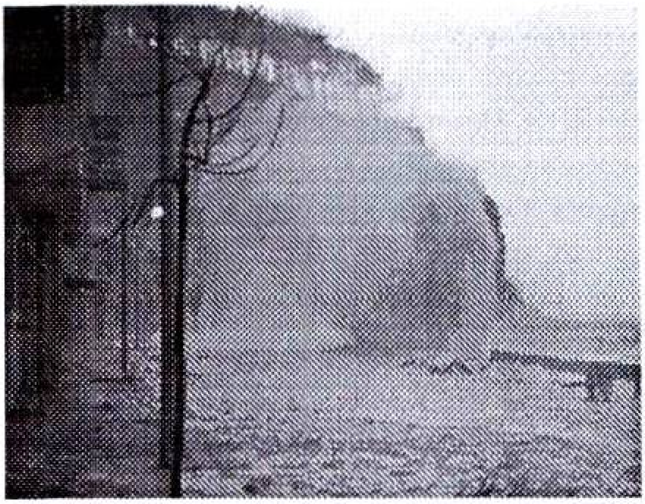

Photo 5. Tourism facilities and houses under threat during the storm No. 7, September 2005.

Photo 6. The destroyed infrastructure by Storm No. 7, September 2005.

According to the research of scientists announced recently in the Workshop on "Climate change issues and management of tourism development of urban coastal areas" organized in Do Son from 4-6 January 2008, speed of climate change in our country increasing. In 40 years, average temperature in Vietnam has increased 0.6^0 C in 20 years and sea level has to rise in 6cm more; storms more powerful and strength, rain becomes stronger with more water, the cycle of drought and heat longer than in the last decades.

Forecast to the year 2070, temperatures in the North will increase 2-4^{0}C, in the South will increase 2-3^{0}C. By the year 2050 the sea level will rise 33cm more and in 2070 will increase more than 50cm. This is a great risk for the coastal provinces of Vietnam.

However, SLR is not the sudden change but a gradual process lasting over time and space. Therefore the approach should be gradual and in asymptote of ecological environment, adapting to cope with the changes of nature. Engineering and non-engineering solutions to the changes must be built flexibility in accordance with the gradual increase of the rising in sea water level. It is necessary for basic research of hydraulic, physical, environmental conditions, climate, promoting the research and development of sloping land... to reduce the negative impact if any.

One of the projects in the strengthening, protection and upgrading of the sea dyke systems available from Quang Ninh to Quang Nam is "Strengthening, protecting and upgrading the Sea Dyke Line No. II in Kien Thuy and Do Son districts, Hai Phong with total investment over 104 billion VND, invested by the Department of Agriculture and Rural Development. The project was implemented with the goal of strengthening and upgrade more than 10km in the sea dyke line No. II to prevent salt intrusion, high tides and ensure ring the dyke will be safe at the designed level. This project is under progress during 2008-2010.

3.6. Earthquake disaster

The study area is situated in Red river deep fault zone stretching along Red River from Vietnam-China border to the East Sea with total length of more than 600km. According to geophysical studies, the Red river zone is still activated in the period of Quaternary- present with the right sliding movement of 4.5-5m in velocity and the NE part of RRD in still subsiding of average rate 2.mm/ year that's why Red River tectonic zone has the average stress-released equivalent with of magnitude earthquake Ms= 4.5.

Although the study area is situated far from the most seismic activated region (Son La, Lai Chau) with Ms = 6-8 but it is situated in a large basin filled with weak zone deposit (sand, silt, clay). Under this special condition earthquake can occur at distance of 500-600km from the source (epicenter region).

Then much of the destruction can be occurred due to significant amplification of earthquake ground motions by this thick soft soil deposits. The subsoil of Thai Binh formation with varying composition from silty sand to sandy-clayey silt also easily to get into liquidified condition under earthquake's vibrations.

The most effective measure to mitigate seismic risk in the urban area to be taken into account is introducing the suitable design requirements for new, especially economically important construction such as high rise buildings, ports and sea dyke... It is needed to adopt in Vietnam the seismic design requirements (codes and standards) as most quickly as possible.

4. VUlnerability assessment of the Kien An - Do Son, Hai Phong coastal zone

For evaluating the vulnerable level of socio-natural system of coastal zone, a series of investigations and calculations in the site have been established in a grid with area of 1 km^2 and 4km^2 equivalent to 1: 50.000 and 1: 100.000 topographic maps covering different regions with different characteristics of geological formation, topography, hydro-geology, and human activities, ...

The information from field study combining with collected data can be gathered in groups such as: Type or category, history of appearance, intensity, scale, signs and impact of the hazard with vulnerable socio- natural character. Hazard prevention activities that have been and are applied study the current state and predict the potential of loss caused by the human activity in the area (irrigation, transportation, sea, and mining, tourism activities...) [10].

The determination of risk caused by hazard to marine and coastal regions can be carried out with following steps:

+ Define the hazard types and calculate grade of risk level caused by each hazard basing on different criteria such as type, intensity, frequency of its occurrence by the following equation:

$$G = (F + A) \times M$$

while: G = Total score,

F = Frequency,

A = Impacted area, and

M = Potential damage magnitude.

The result calculated are shown in table 4. The relative priority of the principal hazards is as follow sequent: coastal erosion, salt intrusion, storm surge flood, earthquake and sea level change...

Table 4. Calculation of the relative priority of the principal hazards [10]

Type of hazards	Frequency +	Impacted area x	Magnitude =	Total score
Coastal erosion	5	4	4	36
Salinity intrusion	3	5	4	32
Storm surge	3	4	4	28
Flood	4	4	3	24
Earthquake	1	5	3	18
Sea level change	2	4	2	12

+ Recognize the hazard type and calculate total point of risk level for each square:

$$DI_i = SH_i / SH_{tb}$$

while: DI_i : dangerous level for each square,

SH_i: total points of the i square, and

SH_{tb}: average dangerous density for the whole region.

Then the next step is filling in the result in this square. Zoning of risk level for the coastal zone can be made on the map basing on the total point of each square together with some other criteria established from site investigation for the coastal zone.

Basing on the points of single and integrated potential hazards, the zoning of risk caused by hazards along the Kien An - Do Son coastal zone can be divided into 4 zones according DI_i value:

$DI_i < 1$ - Low risk potential

$1 < DI_i < 2$ - Intermediate risk potential

$1.7 < DI_i < 3.4$ - High risk potential

$DI_i > 3.4$ - Very high risk potential

4.1. Zoning of potential hazards

Zone of very high risk potential hazards is containing at least 4-6 types of disasters (erosion, salinity intrusion, storms, flood and the effect of sea level rise (SLR))... with DI value > 3.4 is not presented in the study area.

The high risk hazard potential zone distributed widely in the study area including lowland areas situated both side of Ngoc Xuyen and Yen Son hill range and stretching to Kien An , where the rocks mainly are composed of siltstones sandstone belong to the intermediate risk potential zone.

Zone of low risk hazard potential is presented in Xuan Son & Nui Voi hills, where Kien An Formation containing the sandstone of quartzite types or limestones is mainly distributed.

4.2. Zoning of density of vulnerable socio-natural objects

Based on Cutter's criteria (1996, 2000) and NOAA (1999) with the analysis results of the social object in the study area, 10 objects socio-natural vulnerable can be determined concluding: 1- tourist sites, 2- port, 3- boat parking area, 4- petrol station, 5- salt field, 6- agricultural pond, 7-amount of boats and ships (in port, coastal and offshore), 9- national reserve park and 10) historical & cultural place of interests...

For the zoning of vulnerable socio-natural objects the following works need to be done:

+ The socio - natural objects that are vulnerable should be recognized and classified into different vulnerability level in a certain area. These vulnerable objects are closely related with impact and participation of the human such as tour places, ports, aquaculture ponds, factories...

+ Counting points for vulnerable socio-natural object in each square combining with expert's knowledge on the study area.

Average density of vulnerable socio-natural objects ($SOD_{(tb)}$) can be calculated for the whole area with formula:

$$SOD_{tb} = \sum SODi \;/\; N_{(i = 1,2,,3....n)}$$

while: SOD_i - point of vulnerable objects belonging to the square;

n-the number of square in the topographical map of the study area.

Basing on the density of vulnerable objects SODi (max) and SODi (average) could be identified and then the vulnerability of social objects was classified in 4 classes according to vulnerable social factors (VSF):

low density of VSF: ≤ 2.5

rather high density of VSF: 2.5 - 4.0

high density of VSF: 4..0 - 6.0

very high density of VSF.: ≥ 6.0

Zoning and evaluation of vulnerable level for the socio-natural system can be conducted basing on the overlying combination and analysis of the above two component maps.

The results of VA analyses show that in the Kien An - Do Son coastal zone there are 3 sub-zones of different vulnerable degree (VD) such as: sub-zone of high VD, sub-zone of intermediate VD and sub-zone of low VD.

The most highly vulnerable degree of VA sub-zone is bordered Ngoc Xuyen, Yen Son communes which includes areas behind the sea dyke Do Son I in the Northwest and Bang La dyke in the Southwest of Do Son peninsular stretching from Lach Tray mouth to Van Uc mouth with about 10-15 km wide.

The next sub-zone of intermediate vulnerable areas locked by 1st highly VA sub-zone to Kien An town. The last sub-zone with low degree of VA is Xuan Son & Nui Voi hills, mostly low hill areas with rather durable sandstone of quartzite type or limestone of Kien An formation..

5. Discussions and recommendations

1. The Holocene soils in Kien An-Do Son area is comprising 4 formations as Hanoi, Vinh Phuc, Hai Hung and Thai Binh with maximum thickness of 25-30m. Two upper layers are deposits of swamp, shallow marine or alluvial origins with mainly clay, silty clay or silty /clayey sand of grey or grayish brown of medium to high consistency with fine grain components varying from 73-87%.

2. The result of the investigation and the analysis show that the study region is mainly influenced by 6 types of geological hazards namely: 1- coastal erosion, 2- salt intrusion 3- storm surge & torpedo, 4- flood, 5- earthquake and 6- sea level rise... which are ranged in decreasing priority order.

3. Upgrading sea dyke and river dyke systems by raising them in 50 cm more in height towards 2020 to cope with rising sea levels is an remedial but not effective solution. It is needed to note that upgrading 1 km of sea dyke costs about 10 billions VND, while construction of one km newly built sea dyke costs 10 time more - about 100 billion VND.

The coast in the study area has the advantage in good adaptation for the formation and development of mangrove forests. It was recognized that, during the Storm No. 7 in 2005 landing to RRD with level of 12 all sea dykes with mangrove forests protected are not broken, meanwhile solidified concrete dyke in Hai Hau facing direct wave is completely destroyed.

According Phan Nguyen Hong, a researcher from Hanoi Teachers Training College, the wave energy caused by storm No. 7 going through mangrove areas in Bang La, Do Son (Hai Phong) decreased from 85 to 87% and that though cork forest at Vinh Quang (Hai Phong) has reduced from 77 to 83%.

A strategy for the development of forest and mangrove forests in coastal areas is a wise, important and sustainable one to minimize the effects of SLR.

4. Zoning of risk caused by hazards is rather correspondent with the zoning of social vulnerability factors. The use of VA as a first step towards Integrated Coastal Zone Management (ICZM) is necessary, valuable and important part in the building of Strategy and Action Plan for sustainable development in this sensitive coastal zone.

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