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Analysis of the Natural Characteristics of the Coastline of Tra Vinh Province, Vietnam - A Scientific Basis for Designing Sea Dike and Embankment Systems

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ABSTRACT: The coast of TraVinh province is located between two large river mouths of the Mekong River system, with a length of about 65 km, and has been eroding very quickly in recent years. Some areas are severely eroded, but there are also areas that are elevated due to the transport of mud and sand along the coast. The article has clearly analyzed the topographic and geological survey data in the area where erosion is taking place and proposed solutions for designing a sea dike system to stabilize the coast of TraVinh to serve current and future socio-economic development.

Keyword: TraVinh, coast, geology, meteorology, hydrology, dykes, seawalls, engineering

I. INTRODUCTION

The coastline of TraVinh Province, Vietnam, is located in the Southwest region, extending in a Northeast-Southwest direction within the Duyen Hai district, across four communes: HiepThanh, Truong Long Hoa, Dan Thanh, and Dong Hai. The coastline stretches approximately 65 kilometers, featuring a relatively flat beach terrain that is wide and characterized by its sandy-muddy nature.

Over the past few years, several locations along the TraVinh coastline have experienced coastal and beach erosion, with the speed and scope of erosion gradually increasing and becoming more complex. Additionally, along the TraVinh coastline, there are areas where erosion occurs interspersedly and changes with the Northeast and Southwest monsoons. The Northeast monsoon usually causes stronger coastal erosion than the Southwest monsoon. Furthermore, the beginning and end sections of the province's coastline are areas of significant accretion, such as the coastal stretch of My Long Nam commune adjacent to the CungHau estuary (Co Chien River) and Dong Hai commune adjacent to the DinhAn estuary (Hau River) on the left bank. To minimize erosion levels and protect residents, while fostering socio-economic development in the area, TraVinh province has approved a project to establish a sea dike and embankment system aimed at stabilizing the TraVinh coastline. However, given the unique characteristics of the TraVinh coastal area, where sediment primarily consists of mud-mixed particles, and sandy shores are typically gentle with changing coastlines affected by coastal hydrodynamic factors—the central coastal area of the province features the steepest seabed, allowing for easier access of currents and waves with greater intensity than other regions—designing and constructing the sea dike and embankment system that conforms to technical requirements and aligns with the natural characteristics and terrain of the coastline is crucial. Analyzing and surveying natural characteristics are essential steps in creating a scientific foundation for the design and construction of TraVinh's coastal dike and embankment system.

II. NATURAL CHARACTERISTICS

2.1 Morphological and Topographical Features

The coast of TraVinh Province, located in the Southwest region of Vietnam, stretches in a northeast-southwest direction across Duyen Hai District through four communes: HiepThanh, Truong Long Hoa, Dan Thanh, and Dong Hai. The coastline is approximately 65 kilometers long, characterized by a relatively gentle and wide beach with sandy-muddy shores that are subject to seasonal changes influenced by the Northeast and Southwest monsoons. The Northeast monsoon typically causes more severe coastal erosion than the Southwest monsoon. Additionally, the

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beginning and end parts of the coast experience significant sediment accumulation, notably in My Long Nam commune—adjacent to the CungHau estuary (Co Chien River)—and Dong Hai commune—adjacent to the DinhAn estuary (Hau River) on the left bank. The sandy beaches are generally gentle, with shorelines that often change due to coastal hydrodynamic factors. The central area of the coast has the steepest seabed topography, facilitating waves and currents to reach the shore more easily and with greater intensity compared to other regions.

2.2 Geology

Based on on-site geological descriptions and the results of laboratory tests on the physical and mechanical properties of the subsoil within the surveyed boreholes, each with a depth of 30 meters, the geological conditions of the project area consist of the following layers:

2.2.1. Layer labeled (1): This is a layer of fine sand, grayish-green in color (SP). It is in a loose state. The thickness ranges from 4.8 to 10.3 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index
1	Natural moisture content	W = 27.78 %
2	Natural density	γ_{tc}= 1.867 g/cm³ γ_{I}= 1.851 g/cm³ γ_{II}= 1.858 g/cm³
3	Dry density	γ_{C} = 1.45 g/cm³
4	Buoyant density	γ_{dn} = 0.90 g/cm³
5	Specific gravity	Δ = 2.66
6	Degree of saturation	G = 88.68 %
7	Porosity	n = 45.39 %
8	Internal friction angle	φ_{tc} = 31° 24' φ_{I} = 29° 14' φ_{II} = 30° 05'
9	Cohesion	C_{tc} = 0.097 kg/cm² C_{I} = 0.062 kg/cm² C_{II} = 0.053 kg/cm²
10	Modulus of deformation	E_{1-2} = 111.31 kg/cm²
11	Permeability coefficient	k = 2.32x10^{-4} cm/giây

2.2.2. Signatory Soil Layer (A): This is a gray-brown clayey sand lens layer (CL). It is in a liquid state with a thickness of 1.6 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index
1	Natural moisture content	W = 48.43 %
2	Natural density	γ_{W} =1.69 g/cm³
3	Dry density	γ_{C} = 1.14 g/cm³
4	Buoyant density	γ_{dn} = 0.71 g/cm³
5	Specific gravity	Δ = 2.68
6	Degree of saturation	G = 96.10 %
7	Porosity	n = 57.44 %
8	Void ratio	ε_{O} = 1.35
9	Plasticity index	W_{n} = 12.70 %
10	Consistency	B = 1.65
11	Internal friction angle	φ = 6.0°26'
12	Cohesion	F = 0.09 kg/cm²
13	Modulus of deformation	E_{1-2} = 14.63 kg/cm²
14	Permeability coefficient	k = 4.08x10^{-5}cm/giây

2.2.3. Signatory Soil Layer (2): This is a gray-brown sandy clay mud layer (CH1). It is in a plastic flowing state with a thickness ranging from 5.1 to 11.3 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index			
1	Natural moisture content	W	=	47.64	%
2	Natural density	γ_{tc} γ_I γ_{II}	= = =	1.712 1.703 1.706	g/cm^3 g/cm^3 g/cm^3
3	Dry density	γ_C	=	1.16	g/cm^3
4	Buoyant density	γ_{dn}	=	0.73	g/cm^3
5	Specific gravity	Δ	=	2.68	
6	Degree of saturation	G	=	97.44	%
7	Porosity	n	=	56.66	%
8	Void ratio	ε_O	=	1.31	
9	Plasticity index	W_n	=	20.44	%
10	Consistency	B	=	0.78	
11	Internal friction angle	φ_{tc} φ_I φ_{II}	= = =	5° 25' 3° 48' 4° 26'	
12	Cohesion	F_{tc} F_I F_{II}	= = =	0.150 0.130 0.138	kg/cm^2 kg/cm^2 kg/cm^2
13	Modulus of deformation	E_{1-2}	=	33.90	kg/cm^2
14	Permeability coefficient	k	=	$3.10x10^{-5}$	cm/giây

2.2.4. Signatory Soil Layer(3a):t is a grayish-blue clayey sand layer (SC). It is in a soft plastic state with a thickness ranging from 5.3 to 5.5 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index			
1	Natural moisture content	W	=	25.40	%
2	Natural density	γ_W	=	1.84	g/cm^3
3	Dry density	γ_C	=	1.47	g/cm^3
4	Buoyant density	γ_{dn}	=	0.92	g/cm^3
5	Specific gravity	Δ	=	2.68	
6	Degree of saturation	G	=	82.89	
7	Porosity	n	=	45.09	%
8	Void ratio	ε_O	=	0.82	
9	Plasticity index	W_n	=	6.41	%
10	Consistency	B	=	0.53	
11	Internal friction angle	φ	=	30.0°08'	
12	Cohesion	F	=	0.11	kg/cm^2
13	Modulus of deformation	E_{1-2}	=	112.51	kg/cm^2
14	Permeability coefficient	k	=	$2.55x10^{-4}$	cm/giây

2.2.5. Signatory Soil Layer(4):It is a grayish-blue clay mixed with sand layer (CL). It is in a soft plastic state with a thickness ranging from 3.9 to 8.2 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index
1	Natural moisture content	W = 39.70 %
2	Natural density	γ_{tc} = 1.769 g/cm³ γ_I = 1.757 g/cm³ γ_{II} = 1.762 g/cm³
3	Dry density	γ_C = 1.27 g/cm³
4	Buoyant density	γ_{dn} = 0.79 g/cm³
5	Specific gravity	Δ = 2.68
6	Degree of saturation	G = 95.39 %
7	Porosity	n = 52.71 %
8	Void ratio	ε_O = 1.12
9	Plasticity index	W_n = 16.74 %
10	Consistency	B = 0.70
11	Internal friction angle	φ_{tc} = 7° 34' φ_I = 5° 59' φ_{II} = 6° 36'
12	Cohesion	F_{tc} = 0.092 kg/cm² F_I = 0.068 kg/cm² F_{II} = 0.077 kg/cm²
13	Modulus of deformation	E_{1-2} = 33.90 kg/cm²
14	Permeability coefficient	k = 3.10 x10^{-4}cm/giây

2.2.6. Signatory Soil Layer(5):It is a yellow-brown clay layer (CH2). It is in a semi-hard state, with a thickness to the bottom of the borehole ranging from 5.5 to 11.4 meters. This layer has the following physical and mechanical properties:

No.	Physical and mechanical properties	Index
1	Natural moisture content	W = 32.16 %
2	Natural density	γ_{tc} = 1.895 g/cm³ γ_I = 1.874 g/cm³ γ_{II} = 1.882 g/cm³
3	Dry density	γ_C = 1.43 g/cm³
4	Buoyant density	γ_{dn} = 0.90 g/cm³
5	Specific gravity	Δ =
6	Degree of saturation	G = 99.34 %
7	Porosity	n = 46.46 %
8	Void ratio	ε_O = 0.87
9	Plasticity index	W_n = 20.48 %
10	Consistency	B = 0.04
11	Internal friction angle	φ_{tc} = 13° 55' φ_I = 12° 24' φ_{II} = 12° 59'
12	Cohesion	F_{tc} = 0.418 kg/cm² F_I = 0.388 kg/cm² F_{II} = 0.399 kg/cm²
13	Modulus of deformation	E_{1-2} = 57.11 kg/cm²
14	Permeability coefficient	k = 9.01 x10^{-7}cm/giây

2.3. Meteorology and Hydrology

2.3.1. Meteorological Conditions

TraVinh is situated in a tropical monsoon sub-equatorial climate zone, characterized by year-round warmth and humidity, with two distinct seasons: the rainy season from May to November, and the dry season from December to April of the following year. The average annual rainfall ranges from 1400mm to 1600mm. Due to its low latitude position, TraVinh receives significant sunlight, averaging more than 2500 hours of sunshine annually. The average annual temperature is between 25°C and 27°C, with average humidity levels ranging from 80% to 85%.

The wind patterns throughout the year are typically as follows: From January to February, southeast winds at levels 3 to 4 are common, known locally as "gióchướng." In March and April, the winds shift more easterly. May and June are characterized by the southwest monsoon, marking the start of thunderstorms. From July to December, the monsoon gradually shifts southeast, bringing more rain, eventually turning to the northeast direction. TraVinh, while near the East Sea coast, is rarely affected by storms; the largest in the past century was Typhoon Linda in November 1997.

2.3.2. Temperature

The air temperature is relatively high and stable, with minimal variation between months.

- The average annual temperature is approximately 26.8°C.
- The highest monthly average temperature is 28.3°C (in April).
- The lowest monthly average temperature is 25.2°C (in January).
- The absolute highest temperature recorded is 36.8°C.
- The absolute lowest temperature recorded is 18.4°C.

2.3.3. Humidity

- The average humidity is 83%.
- The maximum humidity reaches 90% during the rainy months (August, September, October).
- The minimum humidity drops to 37% during the dry months (April).

2.3.4. Rainfall

The total annual rainfall in the project area is approximately 1672mm. There are two distinct seasons: the rainy season and the dry season. The rainy season lasts from May to November, accounting for over 90% of the total annual rainfall. The dry season extends from December to April of the following year, contributing less than 10% of the annual rainfall. Some months, such as January and February, experience little to no rainfall. October is the month with the highest rainfall, totaling 283mm, with the maximum daily rainfall reaching up to 102.9mm.

2.3.5. Wind

Wind is a highly variable factor daily and across different locations in the region. In the Mekong Delta, there are two distinct wind seasons: the Southwest and the Northeast, corresponding to the two pronounced climate seasons: the rainy season and the dry season.

Due to the topographical conditions, the wind pattern is generally quite consistent with the seasons: the Southwest winds prevail in summer, and the Northeast winds dominate in the winter. There is a transitional period between these two seasons, typically around October, characterized by weakening winds or calm weather. During this transition, the wind shifts from Southwest to Southeast and Northeast, and by March-April, the reverse occurs, switching from Northeast-Southeast to Southwest winds.

On average, monthly wind speeds during the Northeast monsoon months are generally higher than during the Southwest monsoon months, except in Rach Gia and PhuQuoc, where the opposite is true. The highest average monthly wind speed during the Northeast monsoon is 4.7 m/s in March in Vung Tau, whereas during the Southwest monsoon, it can reach 4.8 m/s in August in PhuQuoc. The lowest monthly average wind speed occurs during the transitional months, such as 0.8 m/s in May in Ca Mau and in October in SocTrang.

The strongest winds during the Northeast monsoon typically come from the East, while during the Southwest monsoon, they come from the Southwest. However, contrary to average speeds, the peak wind speeds during the Southwest monsoon are higher than those during the Northeast monsoon. Thus, the strongest winds throughout the year along the coastal region are from the Southwest monsoon, with the highest being 40 m/s from the Northwest, occurring in October in PhuQuoc.

For daily winds (observed at 01:00, 07:00, 13:00, and 19:00 daily), from October to April of the following year (during the Northeast monsoon and transition), the high-frequency wind directions are North (N), Northeast (NE), East (E), and Southeast (SE). The predominant direction is East, with frequency increasing from October to February and then gradually decreasing, all above 15%. During January to April, Southeast winds also show considerable frequency (over 10%). The early season and the northeastern regions have higher calm frequencies than the late season and southwestern areas. From May to September (during the Southwest monsoon), predominant directions are South (S), Southwest (SW), and West (W), with the peak in August reaching 55% in PhuQuoc.

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For extreme daily winds, during the Northeast monsoon, from November to April, winds mainly from the Northeast and East increase in frequency from November to January or February, then decrease until April. In the northeastern coastal area, the East direction has a higher frequency than Northeast throughout the monsoon. In the South and Southwest, during November and December, Northeast has a higher frequency, but from January to the end of the season, East dominates. During the Southwest monsoon, from May to October (from April in PhuQuoc), Southwest and West directions prevail. In the northeastern coast, these two directions have similar frequencies or West dominates, while in the South, Southwest prevails.

Regarding wind speed, during the Northeast monsoon, winds range mainly from 1 m/s to 5 m/s, with frequencies above 90% throughout the monsoon and along the entire coastal area. In northern areas (Vung Tau and Ba Tri), during January-April, wind speeds from 6 m/s to 10 m/s occur at a frequency of 25%, concentrated from the Northeast and North directions. The northeastern areas and southwestern islands experience winds of 11 m/s to 15 m/s in February and March, though at very low frequencies. During the Southwest monsoon, in the northeast region, wind speeds from 1 m/s to 5 m/s also dominate with high frequencies of 90% or more, but in the southwestern coastal region, wind speeds are noticeably higher, with frequencies of speeds from 6-10 m/s exceeding 22%; for July, August, and September, exceeding 30% with predominant Southwesterly and Westerly directions.

About the "Chướng" winds: During the Northeast monsoon, the prevailing surface winds are not in the direct Northeast direction but shift to East or East-Southeast, almost perpendicular to the eastern coastline of the Mekong Delta. These winds are locally referred to as "Chướng" winds. The average speed of "Chướng" winds is 5 m/s, while offshore in the east, they can average up to 10 m/s and during strong periods, can range from 15-20 m/s.

2.4. Hydrological Conditions

The hydrological regime is strongly influenced by the semi-diurnal tidal pattern of the East Sea, which affects the Co Chien River estuary and the DinhAn sea mouth. Each day, there are two high tides and two low tides. Every month, there are two spring tides (typically occurring around the 1st and 15th days of the lunar calendar) and two neap tides (usually happening around the 7th and 23rd days of the lunar calendar).

2.4.1. **Water Level**: The area is influenced by an irregular semi-diurnal tidal pattern, with a tidal range of 3.5-4.0 meters. Annually, more than 90% of the coastal land and river mouths are affected by salinity. The average high tide peak is 1.1-1.2 meters, with the maximum reaching up to 1.3-1.4 meters. The average low tide trough ranges from -2.8 to -3.0 meters, with the lowest reaching down to -3.2 meters. The highest water levels typically occur around November and December, while the lowest levels are around June and July. The tidal fluctuation amplitude is nearly 4 meters.

2.4.2. **Flow**: Flow velocity is greater during the northeast monsoon season compared to the southwest monsoon season when the tide rises. During the southwest monsoon, when floodwaters from upstream flow in, the velocity is greater than during the northeast monsoon when the tide falls. The flow velocity is higher during the ebb tide than during the flood tide in both seasons.

During the northeast monsoon season, the flow velocity ranges from 0.01 to 0.95 m/s. In the southwest monsoon season, the velocity ranges from 0.01 to 0.6 m/s. The predominant flow direction is northwest and west-northwest during the flood tide, and southeast and east-southeast during the ebb tide.

2.4.3. **Wave Characteristics**: Waves during the northeast monsoon season are much larger than those during the southwest monsoon season. During the northeast monsoon, wave heights range from 0.01 to 1.4 meters, while in the southwest monsoon, they range from 0.01 to 0.45 meters. The predominant wave direction during the northeast monsoon is east-northeast; in the southwest monsoon, due to the area's natural shielding, the wave direction towards the shore remains east-northeast at points near the coast.

2.4.4.

III. CONCLUSION

The study of the natural characteristics of the TraVinh coastline has provided important information, contributing to the scientific basis for designing effective seawall and breakwater systems for this area. Analyses show that the TraVinh coast has noteworthy features: a gentle slope sensitive to the impacts of wind and waves, and sand–mud morphologies that change with seasonal winds. Notably, the northeast monsoon causes more significant erosion, while accretion occurs robustly at the mouths of major rivers.

Identified geological layers from fine sand to clay-sand with clearly defined physical properties reflect varying load-bearing capacities and stability across layers, necessitating careful engineering consideration for safety and sustainability in dike and breakwater design. Meteorological and hydrological elements like rainfall, humidity, and seasonal wind speed impact such designs significantly. Structures should endure large waves from the Northeast Monsoon and incorporate effective anti-erosion measures in the rainy season. Based on these results, the integration of technical solutions with ecological measures, such as planting mangrove forests, can enhance coastal protection capabilities. The analyzed data will support designers and engineers in optimizing coastal defense solutions for TraVinh, contributing to environmental stability and sustainable regional development. Lastly, regular monitoring and further research on marine dynamics, along with updates to new methodologies, are essential to improve the quality and accuracy of coastal protection projects.

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