Journal of Mining and Earth Sciences Vol.56 (2016) 49-57

Journal of Mining and Earth Sciences

Website: http://tapchi.humg.edu.vn

Geotechnical properties of soft clayey soil in the amQ_2^{2-3} formation in the coastal provinces of Mekong Delta for road construction

Nu Thi Nguyen*

Faculty of Geosciences and Geoengineering, Hanoi University of Mining and Geology, Vietnam

ARTICLE INFO

Article history:
Received 26 Oct. 2016
Accepted 05 Sep. 2016
Available online 20 Nov. 2016

Keywords:
Soft soil
Physico-mechanic
Properties
Shear strength
Consolidation

ABSTRACT

Based on the test results of a large number of samples and field tests in the Mekong Delta coastal provinces, the statistics and analysis about geotechnical properties of soft clayey soil of the middle - upper holocene, fluvio-marine deposits (amQ_2^{2-3}) are made. In four areas of the Mekong Delta coastal provinces, amQ_2^{2-3}deposits are large change of thickness from few meters to more than tens of meters. The dominant component of clay minerals in soft soil is illite or kaolinite due to the topography and natural conditions. Some characteristics which are disadvantage of stabilization of soil for road construction such us organic matter content is over 5%, the pH values is less than 4, the cation exchange capacity of soft soil is medium to high (from 16,9 to 25,86 me/100g of dry soil). These soils are generally associated with low dry unit weight, high moisture contents, high compressibility and low shear strength. They are disadvantage for construction of the road and soft ground treatment must be applied. The researching on the mechanical parameters may serve and improve the efficiency of ground improvement for road construction.

1. Introduction

The coastal provinces of Mekong Delta include Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang. The potential of this region is its strategic position in socio - economic development, especially in agriculture and aquaculture. However, the development of transport infrastructure in the region is weak, cannot meet the actual needs. Roads (except the new line was built in recent years) are often flooded in the rainy season, only route connecting the provinces are paved, the rest is mostly gravel roads. Thus, the Government of Viet Nam is investing in improving and upgrading the transport system in this region.

The construction of the road network in the coastal provinces of the Mekong Delta is

*Corresponding author
E-mail: nguyenthinu@humg.edu.vn

facing a lot of difficulties. Because this place is part of the delta low - lying terrain, dense hydrographic network and was covered by Holocene deposits with great thickness. Holocene deposits have different origin sediments, but the most common are amQ_2^{2-3} deposits. These deposits exposed in the surface, mostly classified very soft clayey soil. The thickness of deposits is relatively large, from a few meters to more than tens of meters. In amQ_2^{2-3} deposits, there are most commonly weak soils as soft - very soft clay soil, soft - very soft sandy clay soil. These are objects directly affected when we construct the road. Therefore, this article should clarify the geotechnical properties of amQ_2^{2-3} deposits for road construction.

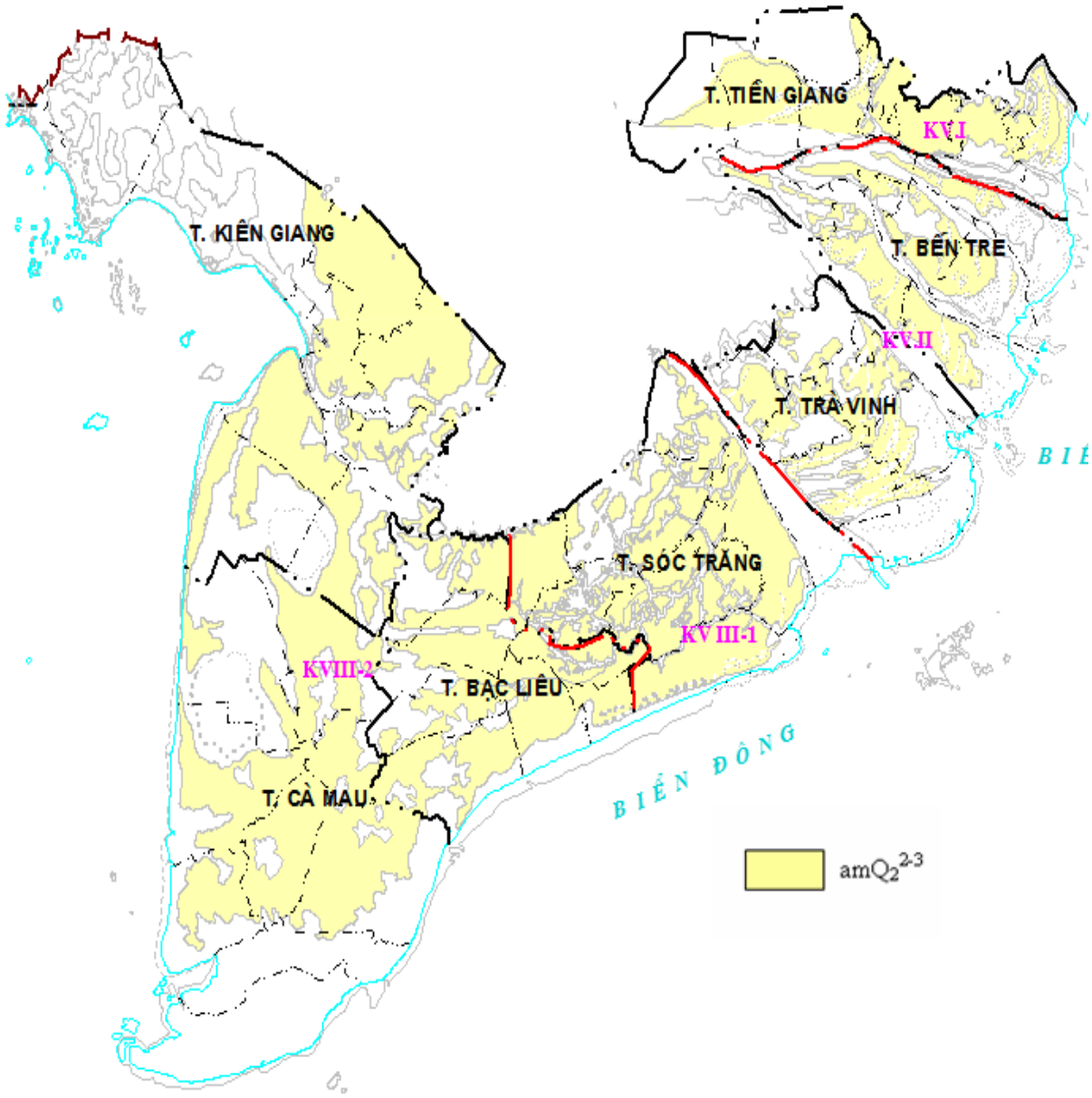

Figure 1. General map showing the distribution of amQ_2^{2-3} deposits in the coastal provinces, Mekong delta

2. Structural features of amQ_2^{2-3} deposits of the study area

According to the statigraphic sediments (Nguyen, 2004) and engineering geological conditions (Nguyen, 2014), the Mekong Delta coastal provinces can be divided into four areas: The North Tien River area (KV.I) – Tien Giang; In the between of Tien and Hau river area (KV.II) – Ben Tre, Tra Vinh; Soc Trang area (KV.III-1); Ca Mau Peninsula area (KV.III-2) – Bac Lieu, Ca Mau, Kien Giang. The structures of amQ_2^{2-3} deposits shown in figure 1, some component characteristics, and thickness of amQ_2^{2-3} deposits are:

- In the Northern of Tien river area (KV.I), the composition of deposits are homogeneous, include clay, clay silt with thickness from 5m to 15m, sometimes greyish brown, ash - grey, dark - grey clay, clay silt with thickness from 1m to 5m;

- In the between of Tien and Hau river area (KV.II), deposits consist of parts; in the lower part, composed of sand, clay, silt (sandy clay) intercalated with brown, greyish brown silty clay or grey clay bearing sand lenses; in the middle part, greyish brown silty clay, sometimes fine sand bearing mica flakes. In the upper part, greyish brown, bluish grey silty clay, clayey silt and fine sand lenses, shells. The thickness of deposits change from 2,0m to 10,0m ÷ 15,0m.

- In the Ca Mau peninsula area (KV.III-1, KV.III-II), relatively homogeneous deposits composed of grey, brown clay, silt bearing little organic matter and fragments of shells and snails. Thickness of deposit changes from 10 to 15m. The upper part is yellowish grey clay, silt bearing alum, salt; the thickness tends to increase gradually to the south, southwest. In Kien Giang provine, thickness of soil is thin, less than 5m.

According to the point of the view of engineering geology, these deposits include a wide range of soils with different states. Soil types include very soft clay soil, very soft sandy clay soil and soft clay, sandy clay, very soft clayey sand. In particular, very soft clay soil, very soft sandy clay soil is more popular with large thickness which change from 10m to 20m, are unsuitable to building roads. Very soft clay soils distributed in the area between of two rivers have a higher heterogeneity, usually bear fine sand dunes or intercalated with sand. In Ca Mau Peninsula area, soft soils bear decomposed organic matter. The firm, stiff soils with thin thickness only distribute in areas with high terrain and good drainage conditions. Clayey sand, very soft clayey sand distributed narrowly in the area of between of Tien and Hau River, Soc Trang.

3. Methods

In order to determine the properties of soft clayey soil of amQ_2^{2-3} deposit, the in-situ test such as Vane shear test (VST), Piezocone penetration testing (CPTu) and test specimen were cut from piston sampler taken. According to the distribution of these soil, the locations of field test and boreholes were all in four areas (KV.I, KV.II, KV.III-1, KV.III-2), and shown in Figure 2. A lot of boreholes and CPTu test were carried out. The vane shear test was performed inside boreholes. The samples were taken at all depths from several meters to approximate 20 meters.

For determination of material composition of soil, all testing of mineral composition; chemistry; salt content and type of salt; pH value; organic matter content and cation exchange of soil were performed. Testing of mineral composition; chemistry of soil were conducted in the Center of Experimental Mining Research, Hanoi University of Mining and Geology and the Center of Analytical Geology, General department of Geology and Minerals of Viet Nam. The salt content and type of salt; pH value; organic matter content and cation exchange of soil tested in the laboratories of LAS - XD 928, LAS - XD 80, LAS - XD 442 and The Soils and Fertilizers Research Institute.

Testing of physico-mechanical properties of soil includes consolidation test in both horizontal and vertical direction, creep test of soil, UU test, CU test, CD test, unconfined compression test. Vertical consolidation of soil is determined by using Consolidation test (IL) and Constant rate of strain consolidation (CRS) test. The coefficient of consolidation in the horizontal direction (c_h) determined in the laboratory and in the field by various methods, such as Rowes radial compression type box, a constant rate of strain consolidometer with radial drainage developed at the Asian Institute of Technology (CRS- R; Seah, and Juirnarongrit, 2003); CPTu dissipation test (Lunne, Robertson and Powell, 1997); Back analysis from settlement data of the embankment during construction (Asaoka, 1978). These tests were conducted in the laboratories of LAS - XD928; LAS - XD 80; LAS - XD 442.

4. Results and discussion

4.1. Mineralogy and chemical compositions of soft clayey soil amQ22-3

The results of research on the material, chemical composition properties of soft soil amQ_2^{2-3} shown in Tables 1, 2, and 3. From these results, some discussions are drawn:

As seen in table 1, the clay minerals in four areas (KV.I, KV.II, KV.III-1, KV.III-II) are similar, also include illite, kaolinite, montmorillonite and chlorite, which is popular illite or kaolinite. The minerals dominated by kaolinite because of the pH of environment (pH<7, in the acid sulfate soils). It should be note that the amount of illite or montmorilonit affects plasticity,

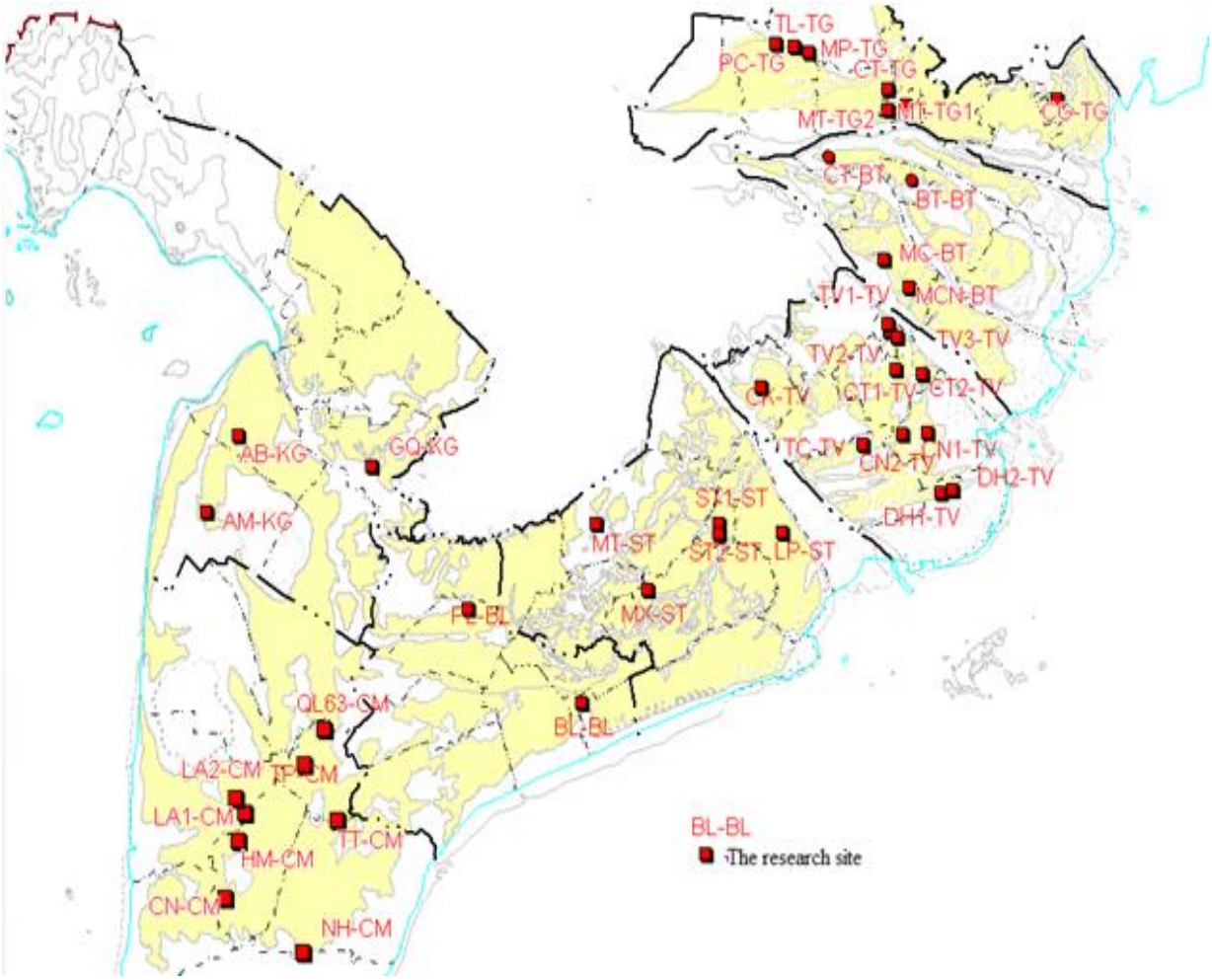

Figure 2. Sketch map showing the research sites in the Mekong Delta coastal provinces

swelling and deformation properties of soft soil as well as adversely affect the ability of improving soil with cement binders. Clay minerals of soft soil stated above reflect truly the formation condition of sediment in alluvial – marine environment. The presence of montmorilonite suggests that the soil was formed in modern environment. It is the same opinion with previous research (Le, 2005)

Table 2 shows the chemical composition in the very soft clay and very soft sandy clay soil in four areas. In very soft clay soil, SiO_2 changes from 58.83 to 66.97%, Al_2O_3 changes from 14.45 to 16,97%, Fe_2O_3 changes from 4.57 to 7.57%. Very soft sandy clay soil amQ_2^{2-3}, SiO_2 changes from 69.72 to 73.86%, Al_2O_3 changes from 11.01 to 13.10%, Fe_2O_3 changes from 3.82 to 4.44%. These results match the material composition of soil. It is clear that very soft clay soil has higher amount of Al_2O_3 and Fe_2O_3 and less amount of SiO_2 than very soft sandy clay soil due to the amount of clay particle.

From Table 3, it can be confirmed that the pH values changes from 3 to 7 - pore water is neutral and weak acid. Cation exchange capacity of very soft clay soil is medium to high, changes from 21.84 to 25,86 me/100 gram of dry soil, which is higher than the cation exchange capacity of very soft sandy clay soil. It is medium, changes from 16,9 to 20,74 me/100 gram of dry soil. The major exchangeable cations are Ca^{2+}, Mg^{2+} and minor amounts of Na^+, K^+, Al^{3+}; negligible amounts of Fe^{3+}, Fe^{2+}. These features reflect the alluvial - marine origin (depositional environment) and existing environment.

Soils at four areas also include soluble salt, alum and organic matter, as shown in Table 2, 3. At KV.I, the soil is said to be slightly saline, in the high terrain soils non - infected salt, a dimple in the Dong Thap Muoi, the soil contaminated alum, sometimes with high organic matter content up to 9.08%. At KV.II, in the high terrain, the soils non - infected alum, salt and in the near sea area, the soil contaminated medium saline, organic matter content is less than 5%, some places soil contaminated slightly salt. At KV.III-1, the soil contaminated medium saline and slightly. At KV.III-2, the soil contaminated medium salt and slightly salt, some places are infected alum or salt - alum, organic matter content is up to 10.14%. Generally, the change of soluble salt, alum and organic matter in soils at four areas is different. The difference of salt content is due to terrain, the saltwater intrusion and the origin of soil. The presence of alum content or SO_3 is due to sulfur which is bioaccumulation of mangrove vegetation (trees tiger, parrot), after death, plant materials decomposed, and causing accumulation of alkaline (alum) elements.

Table 1. Mineralogy of soft clayey soil amQ_2^{2-3}

Areas		KV.I	KV.II		KV.III-1	KV.III-2	KV.I	KV.II	KV.III-1	KV.III-2
Minerals	Unit	Very soft clay soil amQ_2^{2-3}					Very soft sandy clay soil amQ_2^{2-3}			
Monmorillonite	%	5,1	3,6		3,3	5,7	1,8	2,5	4,3	2,5
Illite		17,3	14,6		19,5	19,5	18,8	11,7	19,3	17,5
Kaolinite		17,3	12,5		13,8	18,7	16,2	8,9	16,2	15,5
Chlorite		5,9	6,0		5,0	5,6	4,3	5,4	4,8	4,5
Quartz		35,7	54,2		40,5	30,7	47,8	60,0	44,7	40,5
Feldspar		5,0	3,2		4,3	4,1	3,5	7,3	4,5	4,5
Gotite		4,6	1,5		5,2	3,7	3,7	1,9	3,8	4,0
Calcite		0,2	1,0		0,0	0,2	2,0	1,2	0,3	0,0
Other Minerals		Zeo, Am, Vo, Gip	Vo		Am, Gip, Sid	Vo	He, gypsum	Vo	Vo, He, gypsum	Am
Note: Zeo – Zeolite, He – Hematite, Am – Amphibolite, Gip – Gypsite, Sid – Siderite, Vo – Amorphous mineral										

Table 2. Chemical composition of soft clayey soil amQ_2^{2-3}

Areas		KV.I	KV.II	KV.III-1	KV.III-2	KV.I	KV.II	KV.III-1	KV.III-2
Chemical composition	Unit	Very soft clay soil amQ_2^{2-3}				Very soft sandy clay soil amQ_2^{2-3}			
SiO_2	%	63,60	66,97	60,73	58,83	73,86	73,34	72,11	69,72
TiO_2		0,53	0,55	0,70	0,79	1,06	0,50	0,33	0,83
Al_2O_3		14,45	14,93	15,96	16,97	11,01	13,10	12,58	12,12
Fe_2O_3		6,16	4,57	7,57	5,79	3,92	3,82	3,98	4,44
FeO		0,18	0,16	0,25	0,69	0,73	0,28	0,23	0,33
MnO		0,03	0,00	0,11	0,00	0,00	0,00	0,00	0,00
CaO		0,45	0,08	0,49	0,24	0,40	0,08	0,23	0,94
MgO		1,69	0,99	1,00	1,51	0,96	0,93	1,41	1,85
Na_2O		1,29	2,50	0,94	1,39	0,89	1,69	1,65	1,76
K_2O		2,44	1,80	3,26	2,83	1,69	1,57	2,31	3,14
P_2O_5		0,11	0,17	0,34	0,25	0,26	0,61	0,00	0,02
SO_3		0,35	0,13	0,27	0,46	0,06	0,12	0,07	0,58
MKN		7,75	5,34	7,08	8,85	3,65	3,31	4,05	3,40

Table 3. Cation exchange capacity of soft clayey soil amQ_2^{2-3}

Areas		KV.I	KV.II	KV.III-1	KV.III-2	KV.I	KV.II	KV.III-1	KV.III-2
Cation exchange capacity	Unit								
Types of soil		Very soft clay soil amQ_2^{2-3}				Very soft sandy clay soil amQ_2^{2-3}			
pH		5,49	6,01	6,75	5,78	5,98	5,75	5,99	5,65
EC	mmho/cm	1,02	1,25	3,65	4,76	2,36	1,10	2,48	2,54
Cl^-	%	0,08	0,09	0,18	0,61	0,29	0,09	0,17	0,31
SO_4^{2-}		0,10	0,05	0,09	0,79	0,08	0,12	0,07	0,14
Ca^{2+}	me/100g	6,89	5,02	11,27	8,49	3,74	4,12	10,85	6,73
Mg^{2+}		9,33	3,77	8,13	8,96	7,26	3,01	8,68	4,57
Na^+		3,25	2,42	9,69	6,51	2,32	1,73	10,70	5,42
K^+		0,82	0,58	1,28	1,23	0,85	0,41	1,53	1,03
Mn^{2+}	ppm	71,08	68,48	75,33	121,70	99,83	81,93	84,00	99,50
Ni	%	0,00	0,08	0,00	0,00	0,00	0,07	0,07	0,08
Fe^{2+}, Fe^{3+}	ppm	0,43	3,98	0,68	139,15	0,73	8,58	0,48	5,05
Al^{3+}	me/100g	0,06	0,49	0,16	0,42	0,01	10,53	0,02	0,01
CEC (Cation exchange capacity)	me/100g	22,65	25,86	21,84	25,55	16,90	20,74	19,44	19,38
Organic content	%	4,09	2,33	3,18	4,73	3,27	1,07	2,52	0,98
Salt content	%	0,29	0,33	1,42	1,27	0,55	0,33	0,71	0,65
Alkali exchange coefficient, Kt		0,23	0,34	0,57	0,52	0,29	0,30	0,63	0,57

4.2. Physio - mechanical properties of amQ22-3 soft clayey soil

The physico - mechanical properties of soft soil: a lot of research for characteristics of consolidation, deformation, load history, shear strength of soft clayey soil amQ_2^{2-3} shown in Tables 4, 5, and 6. Some characteristics are shown. These soils are high compression. Compressibility index (Cc) is one of the most important soil parameters for calculating the settlement. In this study, the very soft clay soil amQ_2^{2-3} is larger compression with varying C_c from 0.464 to 0.777. For soft sandy clay soil amQ_2^{2-3} is less compression, C_c changes from 0.253 to 0.396. It can be seen that the compressibility of clay soil is extraordinarily large, is quite high compared with that of sandy clay soil. The reason for high compressibility of very soft clay soil is the high of clay content and the high of cation exchange capacity.

Table 4. The consolidation properties of soft clayey soil amQ_2^{2-3}

Soil types		Very soft clay soil					Very soft sandy clay soil	
Areas		KV. I	KV. II	KV. III-1	KV. III-2			
						(1)		(2)
The coefficient vertical of consolidation of soil, c_v, m^2/year	Average	1,29	2,00	1,33	1,06	0,55	2,75	1,19
	Max	2,57	6,52	3,65	2,93	0,79	8,82	2,79
	Min	0,42	0,74	0,41	0,33	0,37	0,73	0,63
The coefficient horizontal of consolidation of soil, c_h, m^2/year	Average	2,92	5,60	5,09	3,52	2,40	3,98	4,84
	Max	4,04	12,55	9,41	5,98	3,19	17,90	10,85
	Min	2,00	1,58	2,46	2,37	1,28	3,09	2,34
The ratio of c_h/c_v	Average	2,87	3,01	3,72	3,87	4,35	2,52	4,26
	Max	4,05	6,32	6,09	5,98	5,96	3,12	5,91
	Min	1,64	1,47	1,35	2,02	2,46	1,35	3,13
Note: (1) Very soft clay soil has poorly decomposed organic matter; (2) Very soft sandy clay soil sometimes has sandwiched sand, and organic								

Table 5. The parameters of deformation and load history of soft clayey soil amQ_2^{2-3}

Soil types	Very soft clay soil				Very soft sandy clay soil
Areas	KV. I	KV. II	KV. III -1	KV. III-2	
Unit weight, γ, g/cm^3	1,55 1,43÷1,66	1,60 1,51÷1,65	1,59 1,51÷1,67	1,54 1,43÷1,67	1,74 1,62÷1,82
Void ration, e	1,952 1,548÷2,727	1,724 1,509÷2,143	1,775 1,509÷2,154	2,015 1,502÷2,704	1,201 1,008÷1,515
Preconsolidation pressure (σ_c), kPa	51 30÷72	54 20÷80	50 31÷96	49 16÷99	56 26÷85
Compression index, C_c	0,714 0,402÷1,505	0,587 0,355÷0,811	0,619 0,339÷0,897	0,753 0,320÷1,140	0,308 0,159÷0,508
Swell index, C_r	0,091 0,020÷0,143	0,082 0,027÷0,209	0,113 0,050÷0,260	0,144 0,044÷0,299	0,050 0,017÷0,113
The ratio of C_α/C_c	0,0362		0,0383	0,0354	0,034
Note: The value is respectively Average, Min, Max					

Table 6. The parameters of shear strength of soft clayey soil amQ_2^{2-3}

Soil types		Very soft clay soil				Very soft sandy clay soil
Areas		KV. I	KV. II	KV. III-1	KV. III-2	
Undrained shear strength (UU test)	C_u, kPa	12,9	14,5	11,2	10,7	16,1
		6,9÷24,4	7,5÷26,7	4,7÷20,3	5,0÷22,8	8,9÷28,0
	φ_u, degree	0°30′	1°21′	1°11′	0°55′	1°43′
		0°01′÷°59′	0°04′÷3°13′	0°02′÷1°59′	0°18′÷1°46′	0°39′÷3°38′
CU test	C_{cu}, kPa	17,1	12,7	13,2	11,8	14,6
		8,4÷27,8	5,9÷21,5	5,0÷20,0	4,7÷28,6	4,6÷22,3
	φ_{cu}, degree	11°12'	13°25'	13°43'	13°08'	15°18'
		8°00'÷16°21'	8°11'÷16°40'	9°26'÷17°46'	7°59'÷17°52'	8°32'÷25°38'
	C', kPa	15,6	0,096	0,114	0,101	0,117
		4,5÷25,6	2,9÷14,0	3,0÷18,0	3,9÷25,2	4,5÷21,6
	φ', degree	21°29'	23°42'	22°41'	22°57'	26°01'
		13°10'÷28°41'	13°07'÷31°11'	17°04'÷29°14'	11°20'÷29°56'	16°29'÷33°15'
Note: The value is respectively Average, Min, Max						

The vertical coefficient of consolidation of very soft clay soil amQ_2^{2-3} at KV.I is greater 1,34 times at KV.II is greater 2,01 times and at KV.III-1 is greater 1,51 times than it of KV.III-2. These results may be due to the difference of soft soil structure and the amount of clay content in soft soil. This is shown that the permeability of very soft clay soil amQ_2^{2-3} at KV.III-2 is lowest, soft ground treatment has lower efficiency

The coefficient horizontal of consolidation of very soft clay soil is higher than the coefficient vertical of consolidation, the ratio of c_h/c_v is the range of 1.35 to 6.32 due to the type of soil and the distribution of soft soil in four areas. Thus, this is the special characteristics of sediment which deposited in a quiet, unstable environment of coastal estuaries, alternating the thin sand layer. The research result show that the difference of ratio of c_h/c_v in other areas which were studied by other authors such as $c_h = 1{,}5c_v$ in soft soil in Ha Phong (Suzuki et al., 2008); $c_h = (2 \div 2{,}5)c_v$ in soft soil in Ho Chi Minh city and Vung Tau city (Koji Suzuki et al., 2011); $c_h = (1{,}5 \div 3)c_v$ in soft soil in Singapore and Sweden (Tan, Chew, 1996); $c_h = c_v$ in soft soil in Japan (Tan, Chew, 1996).

The ratio of C_α/C_c of very soft clay soil amQ_2^{2-3} in KV.I, KV.II, KV.III-1, KV. III-2 is 0,0362; 0,0364; 0,0383; 0,0354 in respective. For very soft sandy clay soil, the ratio of C_α/C_c is 0,0340. This ratio of C_α/C_c is lower than the ratio of C_α/C_c of organic soil in other area in the world (Matsuo, K., et al., 1986).

For undrained shear test, the undrained shear strength of very soft clay soil is from 10,4 to 15,0 kPa for UU test; from 8,8 to 11,4 kPa for unconfined compression test and from 12,7 to 21,0kPa for VST. For very soft sandy clay soil, the figure is respective: 13,0 to 19,2kPa; 15,6 to 20,5kPa and from 23,4 to 25,3kPa. These clarify soil in soft to very soft state. The test result reflects that in soft soil is not good to use the unconfined compression test to determined undrained shear strength of soil.

The effective shear strength of very soft clay soil is determined by CU test as follows: effective friction angle (φ') is range from $19^0 26'$ to $24^0 00'$ and effective cohesion (C') is range from 9,1 to 15, and 6 kPa. Similarly, for very soft sandy clay soil, φ' is range from $24^0 27'$ to $31^0 48'$ and C' is range from 5,6 to 14,5kPa. The effective friction angle of very soft clay soil is smaller than the value in very soft sandy clay soil. It clarifies the higher clay content in very soft clay soil.

5. Conclusion

From the research results of the geotechnical characteristics of amQ_2^{2-3} soft

clayey soil distributed in the coastal provinces of the Mekong Delta for road construction, can make some conclusions:

The amQ_2^{2-3} soft clayey soil distributed widely accounts for a large area in the coastal provinces of the Mekong Delta. The thickness varies from a few meters to almost 20 meters, and exposed in the surface of topography. So it is very difficult for road construction.

In amQ_2^{2-3} soft clayey soil, there are soluble salt, alum and organic matter. If the amQ_2^{2-3} very soft clayey soil contains more than 5% organic matter, the pH values of less than 5 or contains more than 1% soluble salt, they are unsuitable for economic stabilization (Bel, 1993; Nguyen, 2014).

The geotechnical characteristics of amQ_2^{2-3} soft clay soil are disadvantage for construction of the road. Therefore, soft ground treatment must be applied. So far, these engineering geological characteristics of amQ_2^{2-3} soft clayey soil will serve and improve the efficiency of ground improvement for road construction.

To guide the research, designing the ground improvement method recommend to use the ratio of ch/cv of very soft clay amQ_2^{2-3} at KV.I, KV.II, KV.III-1, KV.III-2 respectively is the range of 1.64÷4.05; 1.47÷6.32; 1.35÷6.09; 2.02÷5.98 and the ratio of ch /cv of very soft sandy soil amQ_2^{2-3} is the range of 1.35 to 3.12; the soft sandy clay soil with sand mixed, organic matter, the ratio is the range of 3.13 to 5.91.

Acknowledgements

The author is grateful to Assoc. Prof. Do Minh Toan and Dr. Nguyen Viet Tinh for constructive comments on this manuscript.

References

Asaoka, A., 1978. Observational procedure of settlement predictions, *Soils and Foundations* 18 (4), 87-101.

Bel, F.G., 2005. *Engineering treatment of soil*. Taylor & Francis e-Library.

Http://www.idm.gov.vn/Nguon_luc/Xuat_ban/2006/A295/a51.htm

Lunne, T., Robertson, P.K., and Powell, J.J.M., 1977. Cone Penetration Testing in Geotechnical Practice. *Soil mechanics and foundation engineering* 44(6), 15-16.

Le, X.T., 2005. Some characteristics of clay mineral distribution in the Mekong Delta. *Journal of Geology*, Series A**,** 295.

Matsuo, K., Yamaguchi, H., and Ohira Y., 1986. Coefficient of Secondary consolidation of peat. *Soils and Foundations* 26(1), 139-150.

Nguyen, D.Q., Giao, P.H., Seah, T., 2010. Settlement calculation and back - analysis of soil properties for a test embankment on a soft clay ground improved by PVD and vacuum - assisted preloading at a site in Vung Tau, Vietnam. *Viet Nam Geotechnical Journal,* 14.

Nguyen, H.D., Pham, H.L, Trinh, N.T., Le, D., and Tran, V.K., 2004. Dividing the stratigraphic and structural characteristics of N-Q sediments of the southern delta. *Report*, South-Vietnam geological mapping division.

Nguyen, T.N., 2014. *Researching of engineering geological properties of amQ_2^{2-3} soft clayey soil distribution in the coastal provinces of Mekong delta for ground improvement for road construction*. Unpublished Dortoral Thesis, Hanoi University of Mining and Geology, Vietnam.

Seah, T.H. and Juirnarongrit, T., 2003. Constant rate of stain consolidation with radial drainage. *Geotechnical Testing Journal, 26(4).*

Suzuki, K. and Takeuchi, H., 2008. Performance of band shaped vertical drain for soft Hai Phong Clay. *Soils and Foundations* 48(4), 577-585.

Suzuki, K. and Nguyen, C.O., 2010. Apparent Value of ch Determined from Field Bahavior of Two Soft Clay Deposits in Southern Vietnam. *Geotechnical Engineering*, 47, 171-188.