Use of Sodium Silicate in Combination with Cement for Improving Peat Soil in Mekong River Delta - Vietnam

Vu Ngoc Binh, Do The Quynh

Abstract: ***Peat soil is formed from river-bog sediments (abQ232) are largely distributed in Mekong river Delta provinces-Vietnam such as Kien Giang, Hau Giang, Bạc Liêu and Ca Mau. The resuls of research to improve them with many kinds of cements showed that the unconfined compressive strength of soil samples reinforced by cements had increased within 28 days, from 28 to 56 days this strength was reduced. Research for improving the soil above by cement and sodium silicate to increase the strength and stability with curing time had been conducted. The results showed that the concent of 0.5% of sodium silicate in comparison with cement mass was added to soil samples, their strength increased significantly when compared to soil samples without sodium silicate and greater than that of the soil samples reinforced by contents of 1%, 1.5% and 2% of sodium silicate in comparison with cement mass and also the concent of 0.5% of sodium silicate in comparison with cement mass added to soil sample has solved the problem of reducing soil sample strength with curing time.***

Keywords: Curing time, Improve, Peat soil, sodium silicate, ,unconfined.

I. INTRODUCTION

Properties of peat soil are high natural water content and compression, low permeability and shear strength resistance. This soil is largely distributed in Mekong river delta provinces such as Kien Giang, Hau Giang, Bạc Liêu and Ca Mau. This soil is formed from young sediments (Holocen) originated from river-bog sediments ($abQ_2{}^3{}_2$) [1]. The soil with high content of organic substances belong to a kind of soft soil. It is difficult to use cement to improve the peat soil for building structure effectively because the peat soil has a high content of organic substances. In Mekong river delta, the peat soil with PH<4.5 is infected by salty of sulfate. The compressive strength of the peat soil samples reinforced by cement increase within 28 days; however this strength reduce within from 28 days to 56 days. It is meaningful and important to improve this soft soil so that the compressive strength of peat soil after reinforcing by adhesive substances are increased in comparision with the initial compressive strength not decreased in time. Sodium silicate is a kind of chemical, wich is used peretty popular in the process of producing glass, cermics, china, and dye.

It is safe and friendly with environment. Sodium plays a roll as a addition in making cement or mix or soil and cement hard faster, which is very usefull in the process of construction in flowing water condition and underground flowing water as well (Houlsby, 1990, Kazemian et al, 2010). Sodium silicate has ever been used to improve soil, prevent seepage flow and reinforce the fissured rock ground [4], [5], [6].

Hossein Moayedi and et all (2011) have ever used the sodium silicate dose of 1, 3, and 5 mol/l to improve clay in Serdang – Malaysia, the results show that it is not effective if only sodium silicate is used in despite of increasing the compressive strength corresponding to dose rise of from 1 mol/l to 3 mol/l.

The causes of the above results are because soil is saturated, the connections between the clay grains may be reduced, which made the compressive strength reduced. However, the sodium silicate makes PH concentration of the environment change, which activate the hydration between cement and soil [3].

Bujang B.K. Huat et al (2011) improve the peat soil by the sodium ratio of 0 %, 1 %, 2.5 %, and 5 %, the results show that the shear strength is maximum at the ratio of 2.5 %. The optimum sodium silicate made the undrained shear strength increase [7].

Sina Kazemian et al (2012) combined the sodium silicate of 3 %, Calcium Chloride of 0 %, 1 % , 2 % and 4 % and cement of 20 % in comparison with natural organic soil mass, the results show that the compressive strength was maximum at the calcium chloride ratio of 2 % [8].

In the study problem, sodium silicate is used as additive to improve the peat soil in Mekong river delta in Vietnam in order to make the compressive strength of stabilized soil increase and be constant in time.

II. MATERIALS

A. Peat soil

The peat soil sample is taken at the 2.5 m depth in Go Quao district in Kien Giang Province, the sample is taken in the undisturbed condition and tested to specify the properties, mineral components, chemical components, and ion exchanges according to ASTM and BS standard.

The experiment results are shown in the table from table I to table IV.

Manuscript received on January 09, 2021.
Revised Manuscript received on January 28, 2021.
Manuscript published on February 28, 2021.
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Table –I: The properties of the peat soil

Properties	Values	Standard
Sand grain sizes (%)	36.5	D6913
Dust grain sizes (%)	45.2	D7928-17
Clay grain sizes (%)	18.3	D7928-17
Natural water content (%)	285.0	D2216
Natural unit weight, γ_w (kN/m^3)	11.3	D7263
Density, ρ (kN/m^3)	19	D854
Liquid limit, W_L (%)	235.8	D4318
Plastic limit, W_P (%)	171.6	D4318
Friction angle, φ (độ)	2°04'	BS 17892-10
Cohesive, c (kPa)	1.47	BS 17892-10
compression ratio, a_{1-2} (kPa^{-1})	$16.49*10^{-3}$	D2435
Su (kPa)	10.10	D2573
Su' (kPa)	3.24	D2573
Seepage coeffictient, k (cm/s)	$1,28x10^{-5}$	BS 17892-11
SPT, N_{30}	1	D1586

Table –II: The mineral components of the peat soil

Mineral components (%)	Values
Montmorillonite	5
$KAl_2[AlSi_3O_{10}](OH)_2$	13
$Al_2[Si_2O_5](OH)_4$	7
$Mg_2Al_3[AlSi_3O_{10}](OH)_8$	5
SiO_2	23-25
$K_{0.5}Na_{0.5}AlSi_3O_8$	3-5
$Fe_2O_3.H_2O$	14-16
Amhibol	Little
FeS_2	5-7
$Al[Si_2O_5](OH)$	4
$CaSO_4$	15
Other minerals	Gipxit

Table –III: The chemical components of the peat soil

Chemical components	Values (%)	Chemical components	Values (%)
SiO_2	27.87	FeO	0.15
TiO_2	0.37	MnO	0.12
Al_2O_3	9.23	CaO	1,30
Fe_2O_3	6.67	MgO	1,38
K_2O	1.75	SO_3	10.80
Na_2O	0.27	Loss on ignition (450°C)	44.28
P_2O_5	0.11	Loss on ignition (900°C)	50.05

Table –IV: The ion exchanges of the peat soil

Components	Unit	Values
pH	mg/100g	2.1
TSMT	mg/100g	292.5
Fe^{2+}	mg/100g	214.73
Fe^{3+}	mg/100g	19.52
Ca^{2+}	$m_{eq}/100g$	12.76
Mg^{2+}	$m_{eq}/100g$	10.59
Al^{3+}	mg/100g	1.30
Cl^-	mg/100g	38.99
SO_4^{2-}	mg/100g	397.2
Na^+	$m_{eq}/100g$	0.68
K^+	$m_{eq}/100g$	0.07
CEC	mg/100g	5.42
Total N	%	0.533
Humus	%	26.56
Mn	mg/kg	621.2

The test results from table I to table IV show the peat soil in this study reveal high water content and high compression ration, low bearing capacity, high organic content. The soil is much aluminous (SO_3 = 10.83 %) and contains Pyrit, Goethite and pyrophylit. Mineral components are not good to improve the peat soil by cement like …… The minerals such as montmorillonite, illite, chlorite và feldspathic are unfavourable for improving the peat soil by cement because the fiery structure of these minerals is grid àn these minerals are easy to absorb water, which make the peat soil be belied. The peat soil is much acidic because the value PH=2.1. According to authors Bezruk et al, the ratio Cl^-/SO_4^{2-} =38.99/397.2= 0.1 reveals the peat soil is infected by sulfate salt, the value Cl^- = 0.39 ‰ reveals the peat soil is not saline soil.

B. Cement

In order to study the influence of cement on the stablised peat soil, many peat soil samples were mixed by many kinds of portland cement that are popularly used in Mekong River Delta such as Tay Do PCB30 (TĐ30), Tay Do PCB40 (TĐ40), Kien Luong PCB40 (KL40), Nghi Son PCB40 (NS40), Ha Tien PCB40 (HT40). Before doing an experiment, cement samples were tested to find out the chemical components (see table V).

Basing on the facts in the table V, the content of oxides SiO2, TiO2, Al2O3, Fe2O3 of cements Tay đo PCB30 and Ha Tien PCB40 is higher than that of cements Kien Luong PCB40 and Nghi Son PCB40. The content of oxide CaO of cement Kien Luong PCB40 is the highest (60.42%), the content of oxide CaO of cement Tay đo PCB30 is 49.42 %, the content of oxide CaO of cement Tay đo PCB40 is 54.74 %. The total oxides of alkali (Na2O and K2O) of cement Tay đo PCB30 are the highest of 5 kinds of above cement.

C. Additive

The sodium silicate is used in this study. Its characteristic is that chemical formula is Na_2SiO_3, pH=11, the content of Na_2SiO_3 = 40.9 %, modular is 2.5, absolute density is 1.45.

Table –V: The chemical components of cements

Chemical components (%)	Kinds of cement				
	TĐ30	TĐ40	KL40	NS40	HT40
SiO_2	25.41	21.71	16.97	20.78	23,77
TiO_2	0.66	0.46	0.26	0.30	0,52
Al_2O_3	6.20	5.27	4.70	4.94	5,83
Fe_2O_3	3.91	3.43	3.23	2.81	3,94
FeO	1.01	0.56	0.12	0.45	0,22
MnO	0.06	0.07	0.05	0.11	2,53
CaO	49.42	54.74	60.42	56.53	51,66
MgO	2.53	2.91	1.81	2.41	2,53
K_2O	1.25	1.23	0.89	1.44	0,88
Na_2O	1.24	0.79	0.26	0.57	1,04
P_2O_5	0.20	0.15	0.11	0.14	0,33
SO_3	1.93	2.25	1.40	2.05	2,25
Cr_2O_3	0.010	0.01	0.006	0.007	0,016
fineness	0.95	0.83	1.65	0.94	-
Loss on ignition (at 900°C)	6.29	6.85	9.63	7.74	8,26

III. METHODOLOGY

The undisturbed peat soil were mixed with the contents of cement of 250 kg/m^3, 300 kg/m^3, 350 kg/m^3 and 400 kg/m^3 by machine. After mixing, the stabilised peat soil samples were made by hand of d=50 mm diameter and h=100 mm height. The stabilised soil samples were cured for 6 hours to maintain suitable water content. After that The stabilised soil samples are submerged in the pure water to make them saturated before compressing them at the curing time of 7 days, 14 days, 28 days, 56 days, 91 days and 180 days. We compressed 3 stabilised soil samples to find out one value of unconfined compressive strength. The works during testing time were conducted according to ASTM D2166 [2].

IV. RESULT AND DISCUSSION

B. The peat soil is stabilised by kinds of cement

Table –VI: The value of unconfined compressive strength according to curing time

Kinds of cement	Content of cement (kg/m^3)	unconfined compressive strength (q_u, kPa) according to curing time (day)					
		7	14	28	56	91	180
TĐ30	250	117,8	135,7	131,2	108,7	102,7	82,7
TĐ30	300	122,6	164,7	184,1	144,1	127,4	126,4
TĐ30	350	123,4	175,0	191,7	152,6	145,9	150,3
TĐ30	400	124,5	179,8	200,1	190,0	158,8	145,7
TĐ40	250	93,2	229,4	188,0	173,0	164,8	153,2
TĐ40	300	154,9	267,4	236,2	152,5	148,3	101,6
TĐ40	350	186,8	227,5	244,5	206,3	201,0	150,9
TĐ40	400	204,6	236,0	271,3	254,7	169,9	162,1
KL40	250	70,7	93,9	87,0	87,9	78,4	75,0
KL40	300	174,3	208,3	202,9	138,6	116,7	107,6
KL40	350	183,3	207,9	214,2	137,1	129,7	119,8
KL40	400	224,8	233,8	240,0	227,5	210,6	163,0
NS40	375	152,1	190,9	197,3	216,2	212,3	181,8
NS40	400	150,7	221,2	225,4	256,8	236,2	215,0
NS40	425	202,5	228,8	227,3	301,6	271,9	231,8

Relation between unconfined compressive strength and the curing time of the stabilised peat soil with kinds of cement, the content of cement were shown in Figures from Fig.1 to Fig.4.

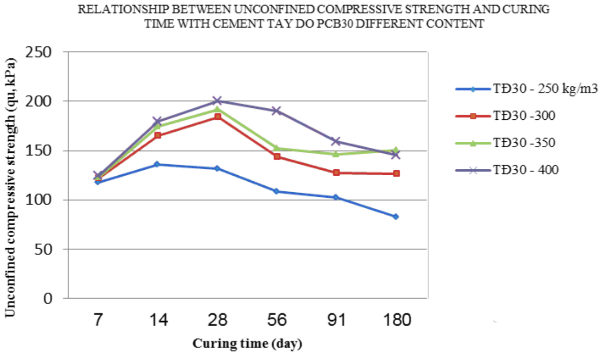

Fig.1. Relation between unconfined compressive strength and curing time with cement Tay Do PCB30.

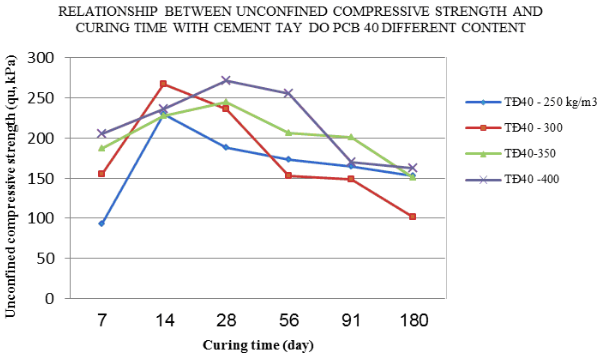

Fig.2. Relation between unconfined compressive strength and curing time with cement Tay Do PCB40.

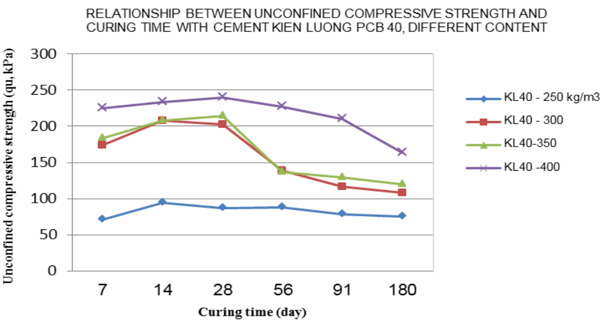

Fig.3. Relation between unconfined compressive strength and curing time with cement Kien Luong PCB40.

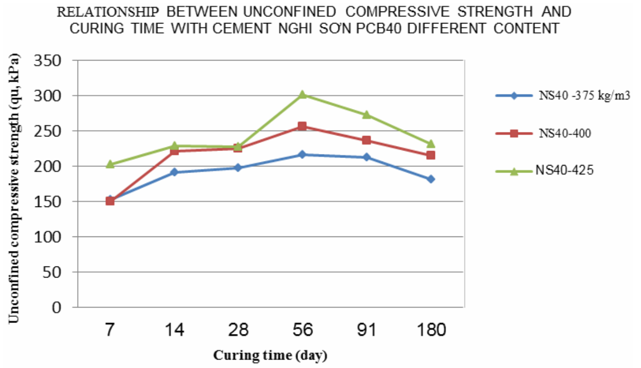

Fig.4. Relation between unconfined compressive strength and curing time with cement Nghi Son PCB40.

The results in the Table V and from Fig.1 to Fig.4 show that the unconfined compressive strength increases when the content of cement increases. The unconfined compressive strength increases when the curing time increases from 7 days to 56 days.

After 56 days, the unconfined compressive strength reduces. The causes to the decrease of the unconfined compressive strength after 56 days are that the organic substance of the peat soil is high, the value pH is low, the peat soil contains pyrite, pyrophyllite. When the peat soil is mixed with cement, the hydrolysis process of the organic substance continue happening, which makes pH continue reducing leading to the disadvantages of hydration process of cement and also connection of cement. According to B. Huat et al (2005), D.-H. Chen et al (2009), W. Zhu et al (2009), the peat soil contains much organic substance, which make the pH of it low. The value of pH is so low to the level that it is not able to dissolve the clay mineral with time [13], [14], [15]. According to the findings of Mohd Yunus. N. Z et al (2012), when the content of humic acid increases from 0.5 % to 3 %, the unconfined compressive strength of the stabilised soil sample reduces more than that of the stabilised soil sample which contains the content of humic acid of 0 % [12]. Therefore, the value of pH continues ruducing more, which prevents the hydration of the portland cement. The calcium, the substance makes the unconfined compressive strength increase, appears from the hydration process of cement. However, the hydration process of cement is prevented by humic acid (Chen et al., 2006, Moayedi et al., 2011a). All in all, using the cement to stabilise the peat soil is not effective, the unconfined compressive strength is reduced with curing time.

B. Findings of improving the peat soil by combining the cement and sodium silicate

In order to study the influence of sodium silicate on the unconfined compressive strength of the stabilised soil sample, we used cement Hà Tiên PCB40 (HT40) with the content of 350 kg/m3 and the content of sodiume silicate in comparison with cement mass are 0.5 %; 1.0 %; 1.5 %; 2 % respectively. The sample name of the stabilised soil sample HC350 stand for the content of cement of 350 kg/m3 and the content of sodiume silicate of 0 %. The sample name HC350NS0.5 stand for the content of cement of 350 kg/m3 and the content of sodiume silicate of 0.5 %. The sample name HC350NS1.0 stand for the content of cement of 350 kg/m3 and the content of sodiume silicate of 1.0 %. The sample name HC350NS1.5 stand for the content of cement of 350 kg/m3 and the content of sodiume silicate of 1.5 %. The sample name HC350NS2.0 stand for the content of cement of 350 kg/m3 and the content of sodiume silicate of 2.0 %. The fidings of the unconfined compressive strength of the stabilised soil sample with the of the other days are shown in table 7.

Table-VII: The unconfined compressive strength of the stabilised soil sample with the of the other days

Sample name	unconfined compressive strength (q_u, kPa) according to curing time (day)					
	7	14	28	56	91	180
HC350	64,7	66,0	69,5	64,9	51,8	49,0
HC350NS0.5	285,3	299,2	315,4	331,5	363,3	393,2
HC350NS1.0	194,1	231,9	245,7	251,2	276,2	322,6
HC350NS1.5	189,3	209,4	241,4	239,3	269,8	283,4
HC350NS2.0	176,4	198,9	234,4	237,3	259,4	267,7

The relation of the unconfined compressive strength and sample name and curing time are shown in Fig. 5.

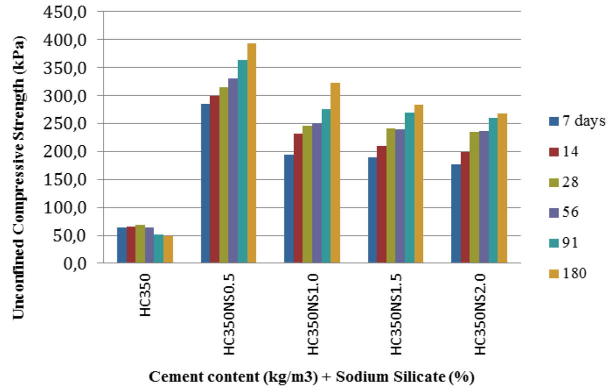

Fig.5. The relation of the unconfined compressive strength and sample name and curing time

The findings of the unconfined compressive strength in the Table VII and Fig.5 show that the unconfined compressive strength of the sample HC350NS0.5 is highest. When comparing with then sample HC350, the unconfined compressive strength of the sample HC350NS0.5 is 4.4 times higher at the curing time of 7 days, 8 times higher at the curing time of 180 days. Moreover, the sodium silicate has prevented the reduction of the unconfined compressive strength with the curing time. The explanation to the these findings are that the silicate sodium added to the stabilised peat soil react calcium salt in the water to form the calcium silicate gel, the process of hydration of silicate calcium is the good factor to form cement. Moreover, the addition of 2 ions Ca^{+2} and Mg^{+2} replaces Na^{+} by these 2 ions with divalence and the addition of 2 ions Ca^{+2} and Mg^{+2} allows them to mix together to form the connection structure gel that is not dissolved [9]. A part from that the silicate sodium changes the acid environment into the basic environment, which is usefull for the hydration process of cement. According to Sina Kazemian et al (2011), the value pH=10-12 is good for the hardening and hydration in the stabilised organic soil by cement [10]. The findings from our testing showed that when the small amount of silicate sodium is added to the water with pH=7, the value of pH of the water changes sharply.

When the ratio of silicate sodium of 0,5 %; 1,0 %; 1,5 % and 2 % in comparison with the water were used to add to the water, the value of pH of the corresponding solvent are 10,3; 10,5; 10,6 và 10,6 respectively. When the silicate sodium is added to the peat soil stabilised by the cement, which changes the hydration environment and activates the reaction of ions exchange of monovalence and divalence to form the setting for the cement.

V. CONCLUSION

In Mekong river deltta –Vietnam, the peat soil has high organic content, high water content, low bearing capacity and the high infection of alum. The improvement of this soil by the cement shows that the unconfined compressive strength increases with the time; however, after 28 days or after 56 days the unconfined compressive strength reduces.

The silicate sodium makes the hydration environment of the cement change in the peat soil after the stabilisation and makes the unconfined compressive strength not reduce with the curing time. The silicate sodium content of 0.5 % in comparison with the cement shows the highest value of the unconfined compressive strength of the silicate contents of 0.5 %; 1.0 %, 1.5 % and 2.0 %. At the curing time of 180 days, the highest value of the unconfined compressive strength is 8 times higher than the value of the unconfined compressive strength of the stabilised peat soil with no silicate sodium.

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