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Experimental Research for Determination of Basic Parameters of Soil Improved By Cement

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Abstract
To ensure the stability of the construction works on soft soil, it is always required the measures to improve the soft soil foundation before construction. Compared with other types of foundation, cement-soil piles have been proved to be much more economical as they can use the local materials, thus redue the cost of construction. Although this has been widely studied and applied in the world, it is still limited in Vietnam constructions, especially it is required to be studied in detail in order to be suitable with Vietnam's conditions. Determination of the amount of cement used for each type of soil is very important task to ensure the quality of cement-soil piles . Therefore, the main objective of this study is to study of mechanical properties of cement-soil piles and the amount of cement used for a specific soil type in Vietnam's conditions.

Keywords: Soil-cement deep mixing method, cement-soil piles,cement content, soft soil improvement.

INTRODUCTION

In the world, the soil – cement deep mixing technology is used to treat soft soil for many different projects including the foundation for marine constructions such as sea dykes, embankments and seaports. It is considered as one of the advanced technology which has been applied widely andefficiency. In order to apply this technology in Viet Nam's constructions, the determination of physical and mechanical properties of cement-mixed soil under Vietnam's conditions is very necessary and useful. Many indicators that need to be researched to improve the properties of weak soils which depend on the properties and requirements of the projects. In this paper, we focus on the properties of shear strength, unconfined compressive strength and deformation modulus of soil improved by cement with different cement content at the sample age of 7 days and 28 days . For this, the data collected from Lang road area on the axis of Cat Linh - Ha Dong urban railway and the clay at Linh Dam lake are in Hanoi.

PHYSICAL AND MECHANICAL PROPERTIES OF STUDIED WEAK SOFT SOILS AND EXPERIMENTAL MATERIALS

Characteristics of weak soft soils

Two types of soft soil from two different areas in Ha Noi were selected in this study including sand and clay. Sandy samples were collected from the geological boring hole at the Cat Linh Urban Railway - Ha Dong section through the Lang road. The sand is black-grey and has physical and mechanical properties as shown in Table 1.

Table 1 Physical and mechanical properties of sand at Lang road, Ha Noi

Parameters		Unit	Value
Grain composition (Sieve content %)			
	From 1,0 ÷ 0,5 mm	%	2,40
	From 0,5 ÷ 0,25 mm	%	35,90
	From 0,25 ÷ 0,1 mm	%	38,10
Natural moisture (W, %)		%	18,16
Volumetric mass (ρ)		g/cm^3	1,893
Dry volumetric mass (ρ_k)		g/cm^3	1,602
Saturation (S)		%	73,19
Porosity (n)		%	39,76
Void ratio (e)			0,660
Compressibility coefficient (a_{1-2})		cm^2/kG	$5,2.10^{-4}$
Deformation modulus (E_{1-2})		kG/cm^2	1923
Angle of internal friction (φ)		degree	28,67
Unit cohesion (c)		kG/cm^2	11,4

Clay samples were collected from Linh Dam Lake, Hanoi. Gray clays with high plasticity are often removed before construction. The physical and mechanical properties of the clay are shown in Table 3. The sampling process and maintenance are careful to ensure the undisturbed samples, moisture is not changed to not affect the study process.

Cement

Cement used for the test in this study is Portland Cement VICEM Tam Diep PCB30 which is manufactured in accordance with current Vietnamese standards (TCVN 6260: 2009), the batch of cement is tested in 02-2014 lot, the main characteristics of the cement are shown in Table 3.

Water

Water used for the experiment is the normal water that is suitable to be used for concrete. The physical and chemical analyzing results of the water sample are shown in Table 4.

Table 2 Physical and mechanical properties of the clay at Linh Đam Lake, Ha Noi

Parameter		**Unit**	**Value**
Grain composition (Sieve content %)			
	From 0,25 ÷ 0,1 mm	%	0,10
	From 0,1 ÷ 0,05 mm	%	33,6
	From 0,05 ÷ 0,01 mm	%	33,0
	From 0,01 ÷ 0,005 mm	%	10,0
	< 0,005 mm	%	23,3
Natural moisture (W, %)		%	31,68
Volumetric mass (ρ)		g/cm^3	1,789
Dry volumetric mass (ρ_d)		g/cm^3	1,359
Saturation (S)		%	94,56
Porosity (n)		%	48,53
Void ratio (e)			0,943
Liquid Limit (LL)		%	48,86
Plastic Limit (PL)		%	28,62
Plastic index (PI)			20,24
Liquid index (LI)			0,151
Compressibility coefficient (a_{1-2})		cm^2/kG	0,027
Deformation modulus (E_{1-2})		kG/cm^2	29,6
Angle of internal friction (φ)		degree	12,14
Unit cohesion ©		kG/cm^2	0,167

Table 3 Characteristics of cement used in this study

No.	**Experimental items**	**Unit**	**Test method**	**Standard**	**Results**
1	Fineness: - The rest on the sieve 0,09 mm - Private surface, Blaine method	 % cm^2/g	TCVN 4030:2003	 ≤ 10 ≥ 2800	 1,8 4570
2	Standard plasticity	%	TCVN 6017:1995	-	30,2
3	Hardening time: - Start - Finish	 minute minute	TCVN 6017:1995	 ≥ 45 ≤ 420	 155 215
4	Volume stability, determined by the Le Chatelier method (Soundness)	mm	TCVN 6017:1995	≤ 10	0,0
5	Compressive resistance: - 3 days - 28 days	N/mm^2 N/mm^2	TCVN 6016:1995	≥ 14 ≥ 30	16,3 -
6	Content of SO_3	%	TCVN 141:2008	≤ 3,5	1,31

Table 4 The physical and chemical analysis of water samples

No.	Parameters	Unit	Results	Standard	TCVN 302:2004 Permitted levels		
					Purpose 1	Purpose 2	Purpose 3
1	Color	-	No	22TCN 61:1984	No	/	/
2	PH	Concentration	7	6636:2000	4 ÷12,5	4÷12,5	4÷12,5
3	Ionic content Cl^-	mg/l	10,53	6194:1996	< 350	< 1000	< 3500
4	Ionic content SO_4^{2-}	mg/l	7,39	6200:1996	< 600	< 2000	< 2700
5	Total dissolved salt	mg/l	107,4	4506:1987	< 2000	< 5000	< 10000
6	Total insoluble salt	mg/l	0,74	4506:1987	< 200	< 200	< 300
7	Organic content	mg/l	0,55	4506:1987	< 15	< 15	< 15

Note: Purpose 1 is for water mixed with concrete and water mixed with mortar for the protection of steel in reinforced concrete structures; purpose 2 is for water mixed with concrete and water mixed with mortar at joints of reinforced concrete structures; purpose 3 is for water mixed with concrete for non-reinforced concrete structures andwater mixed with mortar.

RESULTS AND DICUSSION

In this study, experiments were conducted on the samples at the age of 7 days and 28 days with the ratio N/X = 0.6 corresponding to the different cement content

Sand

Results of the unit cohesion and the internal friction angle of the sandy soil correspond to the different proportions of cement additives are shown in Figure 1.

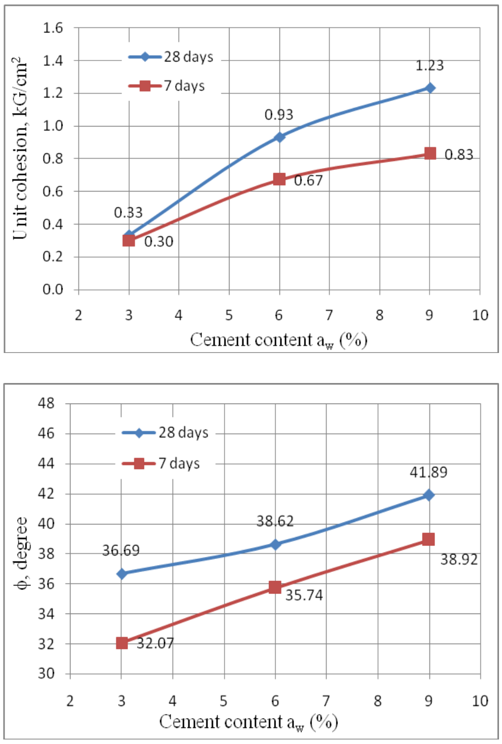


Figure 1: Relationship between cement content with the unit cohesion and internal friction angle

According to the results in Figure 1, it can be observed that as cement content in sandy soil increases, the corresponding unit cohesion and internal friction angle also increase. Particularly, as the cement content increases from 3% to 6%, the unit adhesion force and the friction angle increase rapidly. As the cement content increases from 6% to 9%, the unit cohesion and internal friction angle of the sand - cement sample increase more slowly.

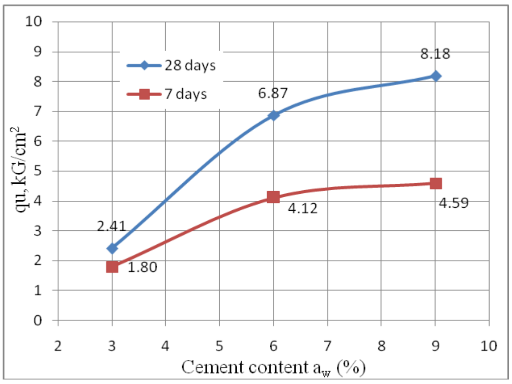


Figure 2: Relationship between cement content and unconfined compressive strength

Figure 2 shows the relationship between the cement additive content and the unconfined compressive strengths on the sand-cement samples. It can be seen that the unconfined compressive strength of specimens also increases with the same rule of the unit cohesion and internal friction angle while the content of cement increases. As the cement content increases from 3% ÷ 6%, the unconfined compressive strength increases hastily and then increases slowly.

Deformation modulus and compressibility coefficient varies with the change of cement content. Relationship between the cement additive content and the deformation modulus and the compressibility coefficient is shown in Figure 3. It shows that deformation modulus of the specimens increases in proportion to the increment of the additive. Cement content increases from 3% to 6% of the deformation modulus of sand - cement samples increases rapidly, and the rate of increase slows down when the cement content increases to 9%. Relationship between the cement ratio and the defomation modulus is consistent with the increase of the unit force, the internal friction angle and the unconfined compressive strength (Figure 3).

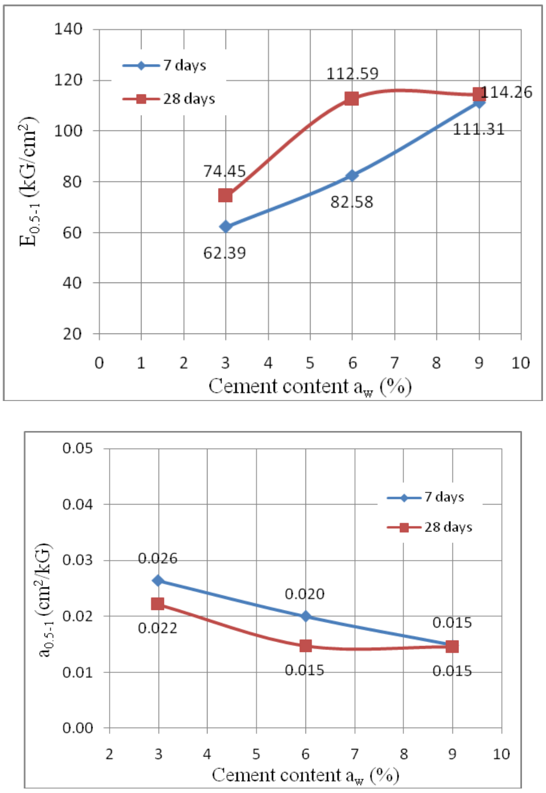
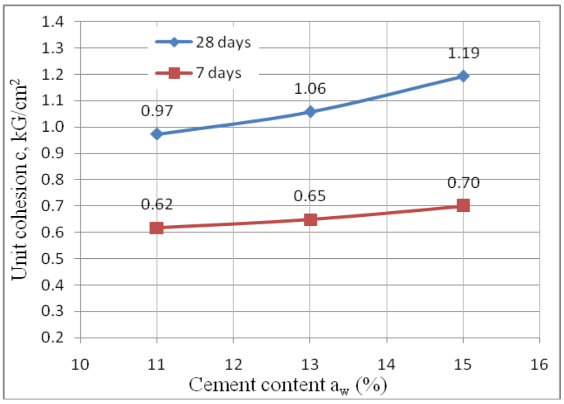


Figure 3: Relationship between cement content with defomation modulus and compressibility coefficient for sand

Clay

For the clay-cement sample, the results of unit cohesion and internal friction angle for different cement additive ratios are shown in Figure 4. the results show that the unit cohesion and internal friction angle with the cement content of 11%, 13% and 15% increase moderatelyas the cement content of the samples is relatively close.



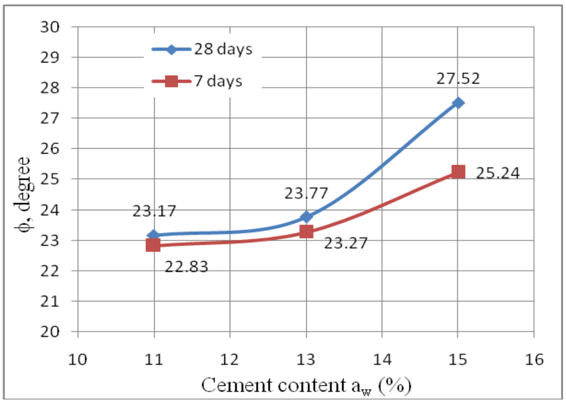


Figure 4: Relationship between cement content with unit cohesion and internal friction angle

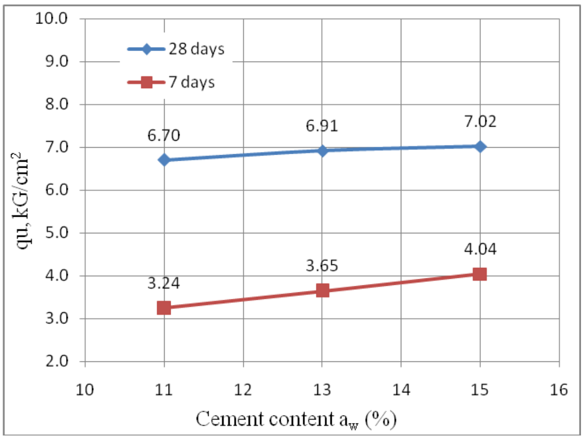


Figure 5: Relationship between cement content and unconfined compressive strength

Figure 5 shows that the unconfined compressive strength on the clay-cement samples increases with the same rule with slow increase and is shown in Figure 5. The difference is not much in terms of cement content makes the value of q_u not much fluctuations. From the figure, the rate of increase in the cement content increases from 11% to 13% faster than from 13% to 15%.

The results of deformation modulus and compressibility coefficient determined by one-dimensional laboratory consolidation test on clay - cement samples at the age of 7 days and 28 days are shown in Figure 6. It shows that the increasing rule of deformation modulus is also in accordance with the principle of unit cohesion, internal friction angle, and unconfined compressive strength.

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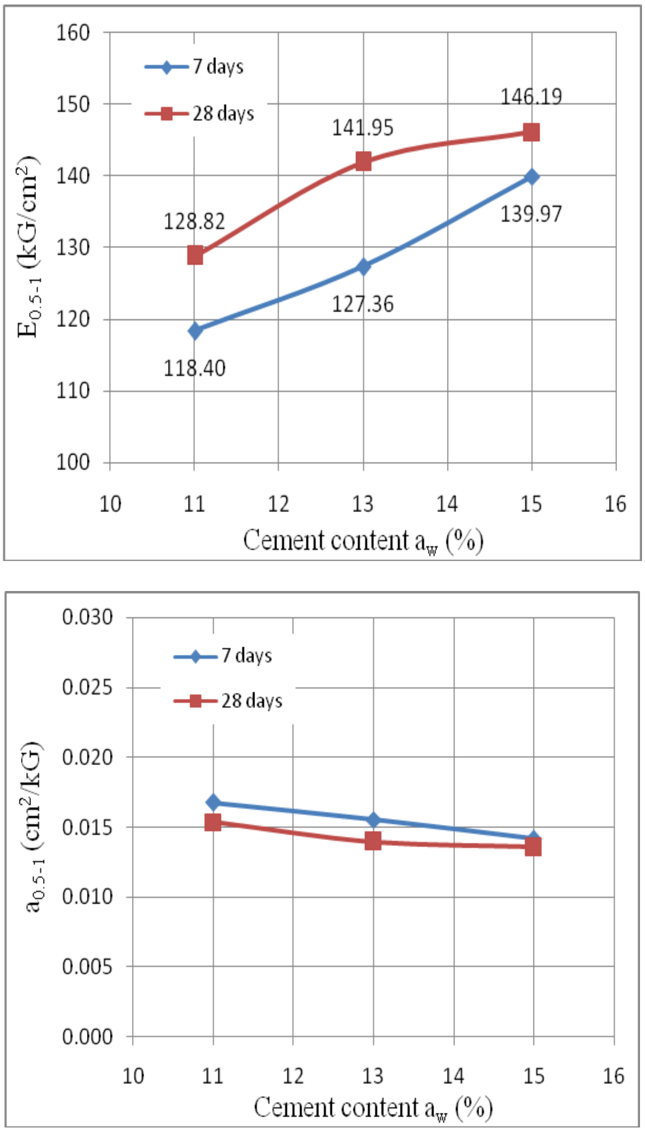
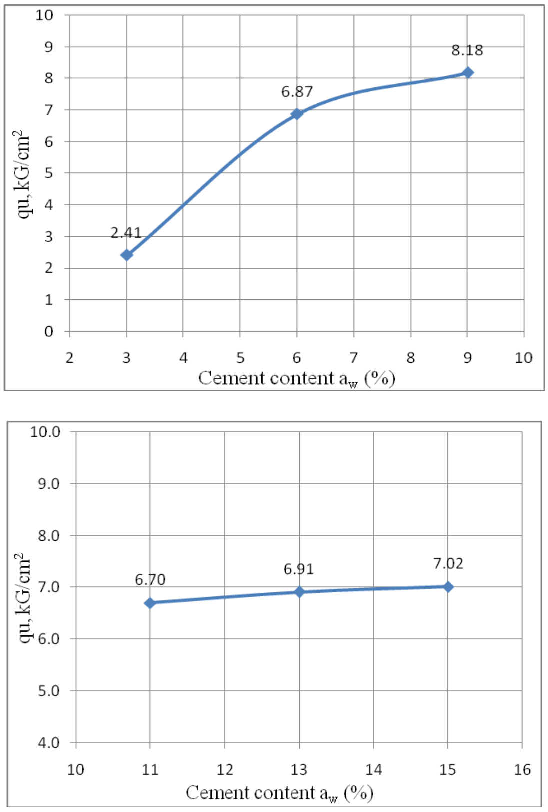


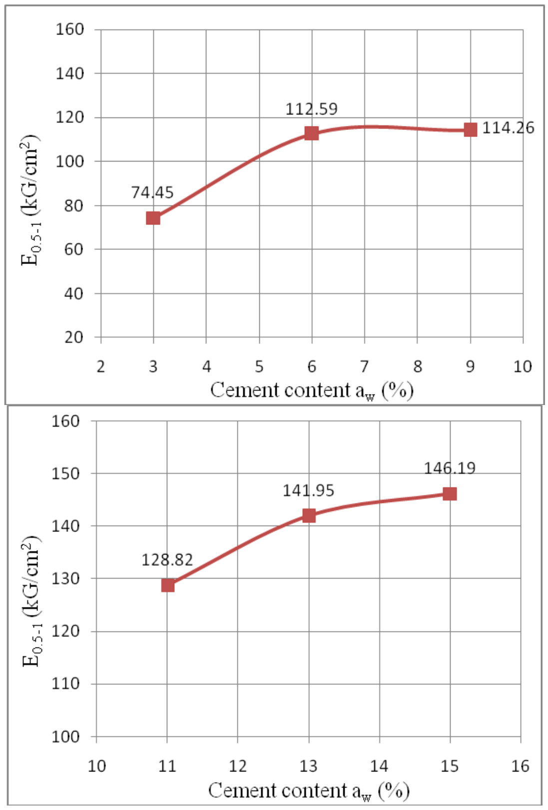
Figure 6: Relationship between cement content with defomation modulus and compressibility coefficient for clay

Selection of suitable parameters for each type of soil

According to the above results, it can be seen that as the same ratio of water - cement, the content of cement (a_w) increase, the unit cohesion, internal friction angle, unconfined compressive strength, deformation modulus of reinforcing soil also increase for both sandy and clay soil. Thus, the increased cement content brings significant treatment effects if the ratio of water - cement remains constant.



a. Sand



b. Clay

Figure 7: Relationship between cement content and unconfined compressive strength and deformation modulus

Relationships between cement content and unconfined compressive strength and deformation modulus of the sand and clay samples mixed with the cement additive are shown in Figure 7.

For sandy soil, it is found that cement content of a_w = 6% is the most suitable ratio for sand-cement formulation. For this ratio, the relationship line of the unit cohesion, the internal friction angle, the unconfined compressive strength, and the defomation modulus has a change in gradient from very fast to slow. As the percentage of cement increases, these parameters increase negligible. Thus, cement ratio of 6% for sandy soil is the optimal ratio. For clay, the same is also based on the slope angle of the relationships of unit cohesion, internal friction angle, deformation modulus, we found the most appropriate cement content is a_w = 13%. Results of this study are consistent with the results of Mitchell and Freitag (1959) which showed that the optimum cement content for sandy soils is between 5% and 9% and the low to hard plastic clay is from 10% ÷ 14%. For each type of soil, the relationships shown in Figure 7 will be the basis for the selection of the suitable cement content for the treatment of weak soil for each type of site.

CONCLUSION

This paper investigated the physical and mechanical properties of soil cement reinforcement for two types of soils: sandy soil and clay. Selection of the cement content in weak reinforcement by soil-cement technology is an important task affecting the strength of reinforced soil. In fact, the investigation of the effect of cement content on the physical and mechanical properties of soil is still limitted, especially parameters such as unconfined compressive strength and deformation modulus for soil types in Vietnam. In this study, the results showed that the most suitable cement content for sandy soil is 6% and for clay is 13%. This study is the a basis for selecting the appropriate cement content for the weak soil treatment by the soil - cement pile method for construction in Vietnam.

REFERENCES

[1] Trung Viet Nguyen, Tuan Vu Minh, “Soil cement pile - methods of reinforcing soft ground”.

[2] National publisher Ho Chi Minh City, “Technology of producing Portland cement and inorganic adhesives”.

[3] R. Whitlow, Longman Scienticfic and Technical, “Basic soil mechanic”, the second edition.

[4] Braja M.Das, Nagaratnam Sivakugan, 2015, “Fundamentals of Geotachnical Engineering”, the fifth edition.

[5] Braja M.Das, “Principles of Foundation Engineering”, Sixth Edition.

[6] Arnold Verruijt, Delft University of Technology, 2001, 2004 “Soil mechanics”.