SOME RESEARCH RESULTS USING THE CEMENT, FLY ASH, GROUND BLAST FURNACE SLAG AND MAGNESIUM OXIDE TO IMPROVE THE MECHANICAL CHARACTERISTICS OF THE DREDGING MUD IN CA MAU PROVINCE

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Abstract: *The article presents a study of stabilized dredged mud in brackish water in Ca Mau province. A method using a mixture of cement, finely crushed blast furnace slag, fly ash and magnesium oxide to improve the mechanical and physical properties of the dredged mud material. The dredged mud is used to replace sand leveling materials, embankment structures surrounding irrigation works. The results also show that using magnesium oxide in different proportions in the mixture of cement, finely crushed blast furnace slag and fly ash significantly improves the mechanical and mechanical properties of the hardened sludge, especially the compressive strength. This is a useful solution to reuse the dredged mud besides other solutions being used.*

Keywords: *Cement; Ground blast furnace slag; Fly ash; Magnesium oxide; Hardened mud soil.*

1. INTRODUCTION

Mekong River is a large river flowing through six countries, namely China, Myanmar, Laos, Cambodia, Thailand and Vietnam, located adjacent to the Mekong Delta. Southeast region, bordering Cambodia to the North, the South-West is the Gulf of Thailand and the Southeast-South is the East Sea. Mekong Delta is the lower delta of the With 13 administrative units including: One city directly under the government (Can Tho City) and 12 provinces (Long An, Dong Thap, An Giang, Tien Giang, Ben Tre, Vinh Long, Tra Vinh, Hau Giang, Kien Giang, Soc Trang, Bac Lieu and Ca Mau) account for about 12% of the country's area and 20% of the country's population

- Demand for dredging to clear large creeks and canals. Every year, with the assurance of waterway traffic and the demand for water drainage, the whole Mekong Delta has to spend hundreds of billions of VND on dredging to clear the flow. With the volume of mud to be dredged tens of millions of m3, the inevitable filling of storage yards has put pressure on local authorities.

In recent years, the scarcity of construction sand has occurred nationwide, especially in the first months of 2017 due to the sudden increase in sand prices. In order to contribute to ensuring the supply and demand for construction sand and stabilizing sand prices, the Ministry of Construction has proposed and

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recommended to the Prime Minister a number of solutions, including:

Therefore, the solution to harden the dredged mud to replace the leveling and filling sand of the Mekong Delta is a positive solution. This solution is evaluated as superior because the Mekong Delta has: (1) A large system of waterways and irrigation canals that must be dredged annually to ensure safety; (2) The reserve of leveling sand in the Mekong Delta is increasingly depleted. If the exploitation continues, it will lead to the erosion of riverbanks and coasts of the whole region. The implementation of research on hardening of dredged mud is not only of scientific value but also of great political significance. It contributes significantly to the prevention of erosion in the Mekong Delta.

2. MUD HARDENING SOLUTIONS

Mud is soil, humus, silt or clay mixed with water. It is usually formed after rain or near a water source. Ancient mud deposits hardened over geologic time to form sedimentary rocks such as shale or mudstone (commonly known as luthite). When geological deposits of mud are formed in estuaries, the resulting layers are known as mud.

2.1. Mud hardening by heating solution

The sludge is pressed into blocks, then heated at different temperatures to create products such as construction materials such as bricks, artificial gravel, lightweight aggregates [1], [2]. This technique has been exploited for nearly 20 years in Germany and the Netherlands.

2.2. Sludge hardening by mixing binder materials (Chemical method)

Using inorganic and polymer material in order to improve mechanical properties of soil

Use organic binders

Organic or polymeric binders have also been applied in many where of the world for soil stabilization.

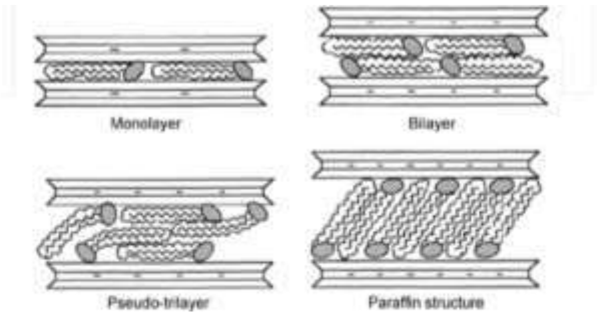

Figure 1: Structure rearrangement of soil particles under the influence of polymers [6]

Polymers stabilization soil through interactions with soil particles, here also called structural rearrangement of soil particles which tend to become tighter as polymer molecules (such as alkyl ammonium cations) are adsorbed between the soil layers in response to the intensity of charge density on the clay surface [3].

Use inorganic binders

Inorganic compounds capable of reinforcing soil and mud include cement, hydrated lime, fly ash, blast furnace slag, etc. [4], [5], [6], [7], [8], [9]. The main components of inorganic binders include SiO_2, Al_2O_3 and CaO in crystalline and amorphous form. Depending on the specific content of the above components, the positions of these binders expressed on triangular coordinates (with three sides being CaO, SiO_2 and Al_2O_3) will be different. Accordingly, the hydration activity of inorganic binders increased in the following order: Kaolin (metakaolin), Silica fume (silica fume), Organic matter ashes, natural pozzolan (volcanic rocks), Fly ash, Blast furnace slag, Portland cement. In general, the active inorganic additives mentioned above all contain amorphous SiO_2, Al_2O_3, so they can react with lime at normal temperature to become a solid mixed binder in water. In general, the active inorganic additives mentioned above all contain amorphous oxide SiO_2, Al_2O_3, so they can react with lime at normal temperature to become a solid mixed binder in water.

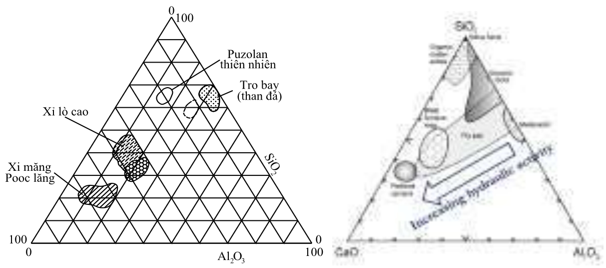

Figure 2: Representation of the composition of inorganic binders on equilateral triangle coordinates a) [10], b) [11]

In general, the use of lime, cement, fly ash, blast furnace slag and rice husk ash to reinforce soil for road construction has been widely applied in the world, in which lime, cement and fly ash are used. most commonly used.

2.3. Theoretical basis of reinforcing dredged mud soil by chemical method

In order to reinforce the mud, a variety of binders can be used such as Portland cement, lime, combined with additives such as fly ash, blast furnace slag, natural or artificial pozzolans. However, cement is still the most widely used and widely used binder. The mechanism of soil hardening, and reclamation is flocculation via cation exchange reactions and generation of C-S-H colloids through pozzolanic reactions in the mud soil medium:

$$nCaO + SiO_2^{vđh} + yH_2O \rightarrow C\text{-}S\text{-}H$$

After mixing with water, the mixed binders (such as lime - fly ash, lime - pozzolan...) will produce the following reaction:

$$xCa(OH)_2 + SiO_2^{vđh} + yH_2O \rightarrow xCaO.SiO_2.(y+1)H_2O$$

Thus, amorphous SiO_2 reacts with Ca $(OH)_2$ to form hydrated silicates. This substance, after a long time will turn into crystalline hydrated silicate. With lime-clay binder, when mixed with water, the following two reactions will produce stable hydration components:

$$Al_2O_3.2SiO_2 + CaO + yH_2O \rightarrow CaO.\ Al_2O_3.\ 2SiO_2.\ yH_2O$$

$$SiO_2 + CaO + yH_2O \rightarrow SiO_2.\ CaO.\ yH_2O$$

These stable hydration components will, after a while, become crystalline hydrate components.

Magnesium oxide (MgO): Magnesium oxide binder is usually in the form of a fine powder consisting mainly of magnesium oxide (MgO), produced by heating magnesium oxide $MgCO_3$ or Dolomite rock ($CaCO_3.MgCO_3$) at the temperature of 750 - 850 ^{0}C.

$$MgCO_3 \xrightarrow{750-850^\circ C} MgO + CO_2$$

When mix a magnesium binder with water, hardening occurs very slowly, but if mixing with a solution of magnesium chloride or other magnesium salts, hardening occurs more rapidly and increases the strength considerably of the binder, because the hydration product in addition to $Mg(OH)_2$ also contains a hydrated double salt $3MgO.MgCl_2.6H_2O$. The bearing strength of the magnesium binder is relatively high, depending on its mineral composition, the compressive strength at the age of 28 days can reach 100 ÷ 600 kG/cm^2.

3. MATERIAL USED IN THE STUDY

3.1. Dredged Mud

The dredged mud used for the study is brackish water mud typical of the Mekong Delta. Mud samples were taken at Ong Doc River, near Khanh An bridge, in Ca Mau province. The physical and chemical parameters of the mud soil are summarized in Table 1 and 2.

Table 1: Chemical proportion of brackish water dredged mud

Sample type	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Na_2O	Fe_2O_3
	%	%	%	%	%	%	%	%	%	%	%
Brackish water mud	0.679	12.683	52.048	0.978	0.760	5.054	1.343	1.804	0.394	0.143	21.290

Table 2: Physical properties of brackish water mud

Sample mark	Organic content	pH	Moisture content	Natural density	Specific gravity	Atterberg limit			Force parameter	
						Liquid limit	Plastic limit	Consistency	Friction angle	Cohesive strength
			W	g_w	D	W_l	W_p	I_s	J_u	C_u
	%		%	g/cm^3	g/cm^3	%	%		độ	kPa
Brackish water mud	1.70	6.76	82.2	1.47	2.53	72.0	41.8	1.38	$2^0 39'$	14.0

3.2. Cement

The study uses Ha Tien PCB40 cement to design, test results of some physical properties of cement as presented in Table 3. Cement meets technical requirements according to TCVN 6260:2009 [12]

Table 3: Physical properties of Ha Tien PCB40 cement

No.	Test items	Unit	Test results
1	Specific gravity	g/cm^3	3.10
2	Fineness (remaining on 0,09 mm sieve)	%	3.65
3	Mixing water requirement	%	27.5
4	Time of setting (start)	minute	119
	Time of finished setting	minute	185
5	Soundness	mm	3.0
6	Compressive strength 3 days	N/mm^2	23
	Compressive strength 28 days	N/mm^2	44

3.3. Fly ash

The fly ash mineral admixture of Duyen Hai 1 thermal power plant was used in the study. The test results of some physical and chemical properties of fly ash met the requirements according to TCVN1032:2014 [13].

3.4. Blast furnace slag

In the study using Hoa Phat finely ground activated blast furnace slag with the density of 2.90 g/cm^3, specific surface area of 5020 cm^2/g, strength activity index at the age of 28 days reached 96%. The basic chemical composition is presented in Table 5 below. Activated blast furnace slag has mechanical and physical criteria satisfying TCVN 11586:2016 [14] and BS EN 15167-1:2006 standard [15].

Table 4: Physical properties and chemical composition of fly ash Duyen Hai 1

No.	Test items	Unit	Test results
1	Moisture content	%	0.28
2	Natural unit weight	kg/m^3	944
3	Specific gravity	g/cm^3	2.24
4	Loss on ignition	%	6.48
5	SiO_2 content	%	56.02
6	Hàm lượng Fe_2O_3 content	%	6.61
7	Hàm lượng Al_2O_3 content	%	22.47
8	Hàm lượng SO_3 content	%	0.22
9	Strength activity index at the age of 28 days	%	82.0

Table 5: Chemical composition of Hoa Phat blast furnace slag

Composition	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	K_2O	Na_2O	MKN
% by mass	35.18	16.26	0.25	0.15	39.95	5.95	0.31	0.18	0.01

3.5. Magnesium oxide

The magnesium oxide (MgO) used in the study has the mechanical and physical parameters as presented in Table 6.

Table 6: Physical properties of MgO

No.	Technical parameter	Unit	Test result	TCXDVN 383:2007
1	MgO content	%	85,26	≥80
2	Color		White podwer	
3	Particle size passing through 0.5 mm sieve	%	100	100
4	Particle size passing through 0.075 mm sieve	%	62	≥50

4. TEST RESULTS

Trial mix designs: The cement content selected to carry out experiments with fly ash, blast furnace slag and magnesium oxide was 6% by weight of 1 m^3 natural mud with density of 1.42 g/cm^3. The blast furnace slag content changes were 2%, 4% and 6% and the fly ash content was 6%, 4% and 2% respectively. MgO is 0.5%, 1.0% and 2.0%, respectively. The material composition of the mixes and the test results of the physico-mechanical properties of the mixture of mud, cement, fly ash, blast furnace slag and MgO are presented in Table 7.

Table 7: Test result of mud, cement, fly ash, blast furnace slag and MgO mixture

Sample mark	Cement	Blast furnace slag	Fly ash	MgO	Moisture content	Liquid limit	Plastic limit	Consistency	Friction angle	Cohesive strength	Compressive strength
					W	W_L	W_P	Is	Ju	Cu	Qu
	%/kg	*%/kg*	*%/kg*	*%/kg*	*%*	*%*	*%*		*độ*	*kPa*	*kPa*
L_X6X2TB6Mg0.5	6/85.2	2/28.4	6	0.5	71.48	78.75	66.28	0.42	14.40	31.66	328.53
L_X6X4TB4Mg0.5	6/85.2	4/56.8	4	0.5	70.30	75.88	66.87	0.38	14.51	33.61	348.66
L_X6X6TB2Mg0.5	6/85.2	6/85.2	2	0.5	69.80	77.17	65.30	0.38	17.39	37.60	373.68
L_X6X2TB6Mg1.0	6/85.2	2/28.4	6	1.0	64.80	81.22	58.48	0.28	17.15	37.99	383.29
L_X6X4TB4Mg1.0	6/85.2	4/56.8	4	1.0	64.10	73.83	60.79	0.25	16.49	42.02	406.77
L_X6X6TB2Mg1.0	6/85.2	6/85.2	2	1.0	66.00	93.01	55.97	0.27	18.90	45.12	423.51
L_X6X2TB6Mg2.0	6/85.2	2/28.4	6	2.0	51.80	54.87	51.30	0.14	19.48	47.48	447.17
L_X6X4TB4Mg2.0	6/85.2	4/56.8	4	2.0	53.48	70.65	50.66	0.14	17.18	50.42	474.56
L_X6X6TB2Mg2.0	6/85.2	6/85.2	2	2.0	52.46	66.86	50.20	0.14	22.50	56.39	479.98

Table 8: Permeability coefficient and Density of hardening mud mixture have best strength

Sample ID	**Permeability coefficient**	**Density**
	K $\times 10^{-8}$ m/s	g_w (g/cm^3)
L_X6X6TB2Mg2.0	3.20	**1.49**/1.42

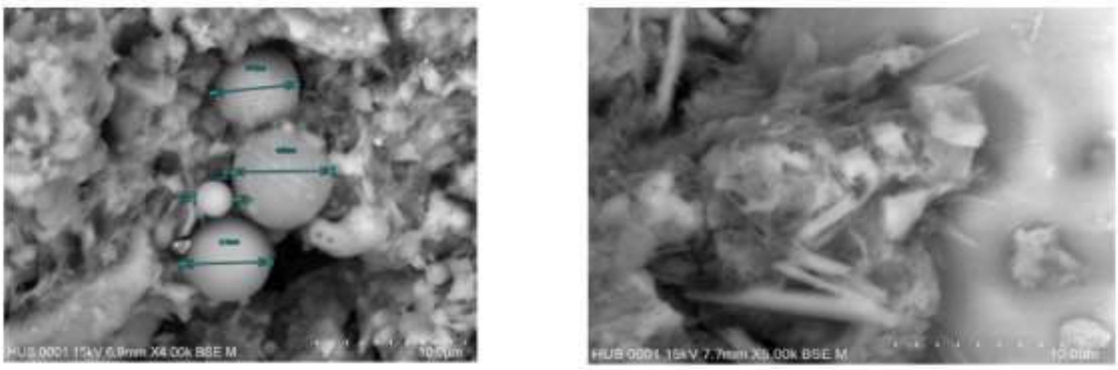

Figure 3: Scanning electron microscope (SEM) image of hardened mud sample at 28 days (Mud + XM + fly ash + XLC + MgO)

The research results show that the use of MgO has a clear effect in improving some mechanical and physical properties of the hardened mud, the physical and mechanical parameters of the hardened mud satisfy the design requirements, especially hardened mud soil with small permeability, suitable for replacing natural sand for embankment work in the Mekong Delta.

From figure 3, it can be seen that C-S-H, C-A-H and MgOH crystals appear on the surface and voids.

The results of XRD analysis (X-ray diffraction) of hardened samples (mud+ cement +fly ash+blast urnace slag+MgO) are presented in Figure 4.

The XRD analysis results showed the presence of Bavenite compounds which is a calcium beryllium aluminosilicate and Clintonite compounds which are calcium, magnesium, aluminum, iron and silicon minerals.

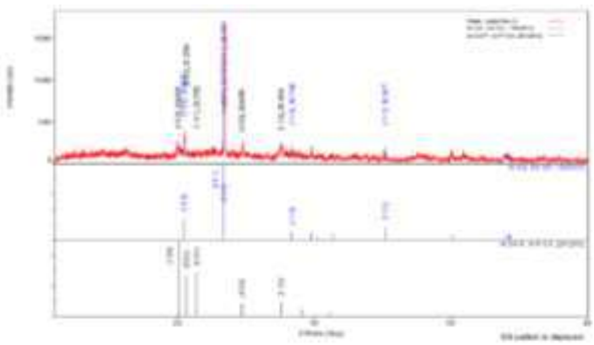

Figure 4: XRD differential thermal analysis results of hardened mud samples (Mud + Cement + fly ash + Blast furnace slag + MgO)

5. CONCLUSION

The test results of mixtures of brackish water mud with cement, fly ash, blast furnace slag combined with MgO showed that the physico-mechanical parameters of the sludge were significantly improved compared to untreated sludge samples. The test results of hardened mud samples showed that:

+ When hardening dredged mud with 6% cement content, combined with blast furnace slag, fly ash and MgO, the viscosity, internal friction angle, adhesion force, and strength of the mud mixture are improved. Specifically, the higher the MgO content, the lower the viscosity, the larger the friction angle, the greater the adhesive force, the strength of the hardened mud increases proportionally to the MgO content.

+ The use of MgO in combination with the traditional binder of cement and active mineral additives showed a marked improvement in the physico-mechanical parameters of the mud, especially the strength of the mud after hardening increased. This is one of the solutions that can be considered to harden the soil in general and harden the mud in particular. Therefore, this is a solution that should be studied and applied widely to all types of mud soil not only in Ca Mau province but should be applied to other provinces in the Mekong Delta.

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[12] TCVN 6260: 2009 Portland blended cement – Specifications

[13] TCVN1032:2014 Activity admixture – Fly ash for concrete, mortar and cement

[14] TCVN 11586:2016 Ground granulated blast furnace slag for cement and mortar

[15] BS EN 15167-1:2006 Ground granulated blast furnace slag for use in concrete, mortar and grout Definitions, specifications and conformity criteria