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Experimental study on the effect of quicklime on the strength characteristics of composite cured river bottom muds

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Abstract
To address the problem of river bottom mud accumulation, this paper proposes a method of composite curing river bottom mud with quicklime as alkali exciter. In this paper, by changing the lime dosage, the influence of lime dosage on the physicochemical and mechanical properties of composite cured river bottom mud under different curing ages was investigated. The results show that: quicklime can well improve the performance of cured mud, with the increase of quicklime doping and curing age, the unconfined compressive strength of cured mud is increasing, the water content is decreasing, and the pH value of cured mud with the increase of quicklime doping is on the rise, and when the curing age is shorter, the rate of its growth is faster..
Keywords: *River bottom mud curing,Quicklime, Unconfined compressive strength, Moisture content, pH.*

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I. INTRODUCTION

River bottom slurry is an important part of the ecology of the natural water system, but with the continuous development of the urban process and the continuous development of urban industrialisation, the problem of its treatment is becoming more and more prominent. At present, the treatment of river bottom slurry mainly adopts the accumulation treatment, which requires high requirements for the site and is more polluting to the surrounding environment, so it is crucial to find a more efficient and green and economical technology for river bottom slurry.

In recent years, mud curing technology has been proposed [1][2], where curing materials are added to river bottom mud to mix and change its physicochemical properties, thus reducing the leaching of its pollutants to reduce the impact on the surrounding environment, and at the same time, the strength of river bottom mud can be improved for use as backfill material in foundation excavation to achieve the purpose of resourcefulness.Ramzi A[3] used ordinary silicate cement with cement roadside dust and quarry fine aggregate as a curing agent combination to cure soft soil, yielding that the curing agent combination can be used as a building material for ordinary buildings, pavements, and landfills when it reaches a certain percentage. However, at present, the curing material application research technology of river bottom mud is mostly focused on adding cement as the main, supplemented by one or two other curing materials for curing the substrate, but there are very few studies on the effect of multiple auxiliary curing materials on the curing of substrate.

To address the above deficiencies, this paper uses cement, slag and zeolite as the curing agent and quicklime as the exciter to cure the river bottom mud of Huangpu River in Shanghai, to study the physicochemical properties and mechanical characteristics of the cured mud, and to provide support for the resourceful utilisation of the river bottom mud and the promotion of curing technology.

II. OVERVIEW OF THE TRIAL

2.1 Test Material

The river bottom mud used in the test was taken from the 0-10 cm sediment in the surface layer of the Huangpu River bottom in Shanghai, and the main chemical compositions are shown in Table 1.

Table 1:Main Chemical Composition of River Bottom Mud.

moisture content/%	pH	Cu (mg/L)	Zn (mg/L)	Ni (mg/L)	SiO2 (mg/L)	Al2O3(mg/L)	CaO	organic substance/%	CODCr (mg/L)
78	8.6	0.0145	0.0939	0.0198	63.23	11.25	8.21	33.15	65

Cement is 42.5 ordinary silicate cement produced by Shanghai Baoshan Cement Co., Ltd; Fly ash is taken from the fine ash of a thermal power plant in Shanghai, with a specific surface area of about 3900cm2/g; Slag powder is taken from a slag powder plant in Shanghai, with a CaO content of 44.8%; Lime is used in this test after being finely ground, and the pure quicklime is white, and it is light grey or yellowish when it contains impurities. Lime will absorb water and carbon dioxide in the air; zeolite powder is made from natural zeolite powder, specific gravity is 2.2-2.4.

2.1 Test Programme

In this experiment, the effects of quicklime dosing on the unconfined compressive strength, water content and pH value of river bottom mud were investigated. According to the previous research, the cement dosing was determined as 24% of the total mass of river bottom mud, the slag dosing was 16%, the zeolite dosing was 2%, and the lime dosing was selected as 2%, 4%, 6%, 8%, and 10%, respectively, to investigate the cured substrate's unconfined compressive strength, water content, and pH value under the different age of curing at 7d, 14d, 28d, 60d, and 90d. The specific test proportioning table is shown in Table 2.

Table 2: Test Ratio Design.

Specimen Group Number	Cement Admixture %	Slag Admixture %	Quicklime Admixture %	Zeolite Admixture %
Group1	24	16	2	2
Group2	24	16	4	2
Group3	24	16	6	2
Group4	24	16	8	2
Group5	24	16	10	2

2.3 Specimen Preparation and Test Methods

The river bottom mud after natural air drying sieve to remove impurities into a sealed barrel standby, and then according to the test of the proportion of sieved dry bottom mud, cement, slag, quicklime and zeolite (curing agent admixture according to the dry river bottom mud weighing), placed in the sample barrel, mixing to make a mixture of it, and then according to the moisture content of 50% to join the distilled water for mixing, mixing, after the three layers into the inner diameter of 45m, height of 100mm special mould (the inner wall coated with a layer of Vaseline to facilitate the release of the mould made of specimens. After mixing well, the sample was loaded into a special mould with an inner diameter of 45m and a height of 100mm in 3 layers (the inner wall was coated with a layer of petroleum jelly to facilitate the release of the mould). After demoulding, the specimens were wrapped with cling film and placed in a standard curing box at a temperature of 20°C and a humidity of 95% for standard curing until the required test age.

The unconfined compressive strength was tested in accordance with the Test Method for Strength of Cementitious Sand (ISO Method) (GB/T17671-1999) [4], and the load was applied uniformly at a loading rate of 5 mm/s throughout the loading process until the destruction of the cured body specimens. All test results were taken as the arithmetic mean of three parallel specimens.

The water content and pH determination were tested according to the Geotechnical Test Procedure for Highway (JTG 3430-2020) [5]. The test results were taken as the arithmetic mean of 3 parallel specimens as the final results.

III. RESULT AND DISCUSSION

3.1 Effect of Quicklime Dosing on Unconfined Compressive Strength

Table 3 shows the experimental results of the effect of different lime dosage on the unconfined compressive strength of cured mud.

Table 3: Effect of Quicklime dosing on compressive strength.

Specimen Group Number	7d Compressive Strength(MPa)	14d Compressive Strength(MPa)	28d Compressive Strength(MPa)	60d Compressive Strength(MPa)	90d Compressive Strength(MPa)
Group1	0.957	2.220	4.472	4.962	8.396
Group2	0.967	2.269	4.528	5.188	8.677
Group3	0.997	2.298	4.565	5.312	8.892
Group4	1.072	2.323	4.617	5.513	8.994
Group5	1.122	2.331	4.668	5.669	9.171

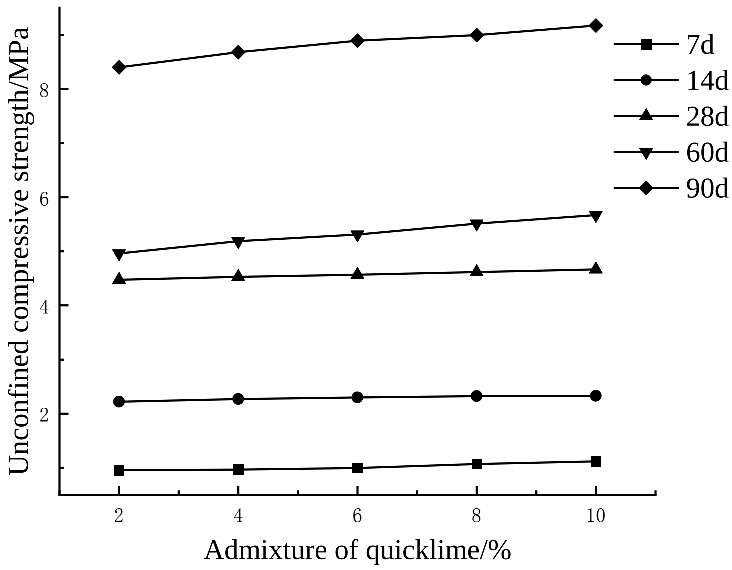

Figure 1: Effect of Quicklime Dosing on Unconfined Compressive Strength

Figure 1 shows the effect of different dosage of quicklime on the unconfined compressive strength of cured mud, from which it can be seen that the unconfined compressive strength of cured mud shows a gradual upward trend with the increase in the dosage of quicklime, and the longer the age of maintenance, the greater the overall unconfined compressive strength of the cured soil. Lime can promote the hardening speed of cement slurry, and react with water to generate $Ca(OH)_2$, which provides an alkaline environment for the hydration reaction of mineral powder, and at the same time, it can generate solid substances such as $CaCO_3$, which can fill the pore space of cured slurry and form a dense structure, which leads to the increase of strength of the cured slurry [6], therefore, with the increase of quicklime doping, the compressive strength of cured slurry increases continuously.

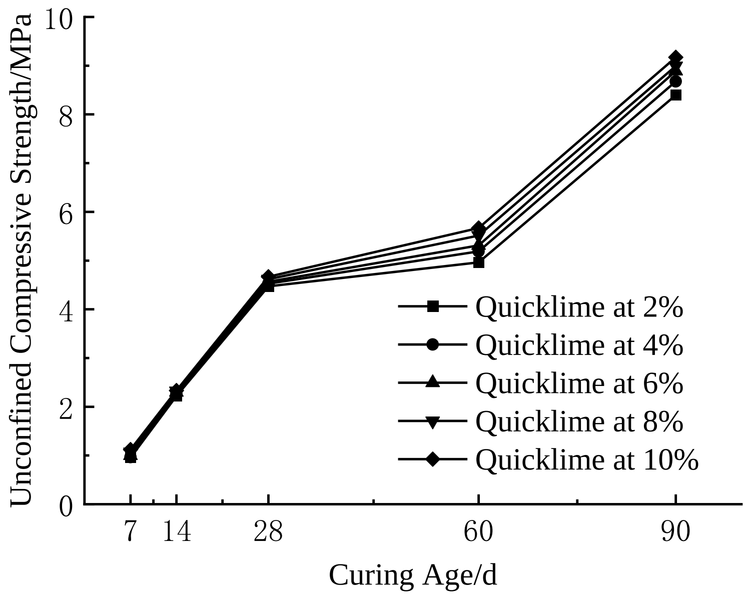

Figure 2: Effect of Curing Age on Unconfined Compressive Strength

Figure 2 shows the effect of different maintenance age on the unconfined compressive strength of cured mud, it can be seen from the figure that the compressive strength of cured mud with the growth of maintenance age is increasing trend, when the maintenance period of 7d, 14d, 28d, the compressive strength of cured mud with the increase of quicklime mixing growth rate is small, and when the maintenance period of 60d, 90d, the compressive strength of cured mud with the increase of lime mixing This is mainly because quicklime can accelerate the hardening speed of cement slurry and improve the overall strength of subsoil cured soil in the late stage of maintenance, thus the unconfined compressive strength of cured soil in the late stage of maintenance increases significantly with the increase of quicklime dosage.

3.2 Effect of Quicklime Dosing on Unconfined Moisture Content

Table 4 shows the experimental results of the effect of different lime dosage on the moisture content of cured mud.

Table 4:Effect of Quicklime Dosing on Moisture Content.

Specimen Group Number	7d Moisture Content(%)	14d Moisture Content(%)	28d Moisture Content(%)	60d Moisture Content(%)	90d Moisture Content(%)
Group1	20.130	19.110	18.700	17.110	16.890
Group2	19.920	18.830	18.590	16.990	16.710
Group3	19.740	18.710	18.250	16.730	16.520
Group4	19.530	18.550	17.910	16.600	16.360
Group5	19.230	18.250	17.690	16.500	16.160

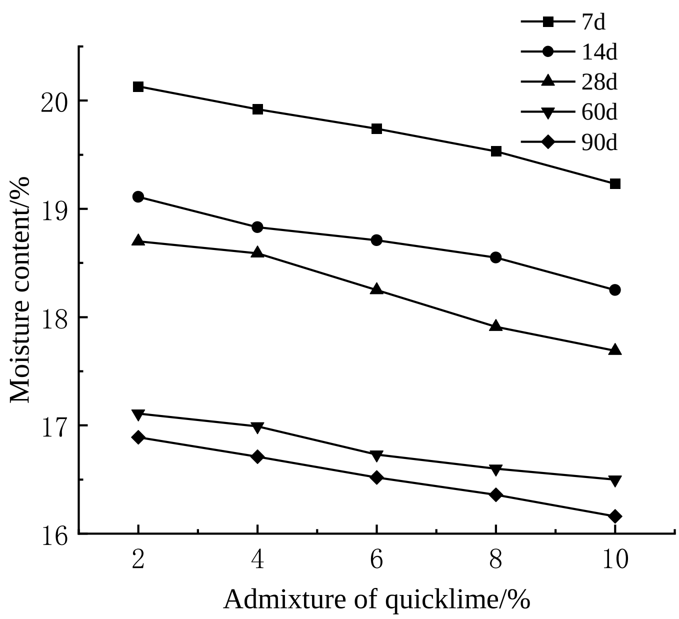

Figure 3: Effect of Quicklime Dosing on Moisture Content

Figure 3 shows the effect of different lime dosage on the moisture content of cured mud. From the figure, it can be seen that with the increase of quicklime doping, the moisture content of cured mud decreases continuously, and when the doping of quicklime is 10%, the moisture content of cured mud is the lowest, and the moisture content decreases with the increase of the age of maintenance. Lime can react with the water in the river bottom mud to generate $Ca(OH)_2$, thus reducing the moisture content of the cured mud and increasing the strength of the cured mud. However, the decrease is small, mainly due to the low content of quicklime added to the bottom mud and the small increase in quicklime.

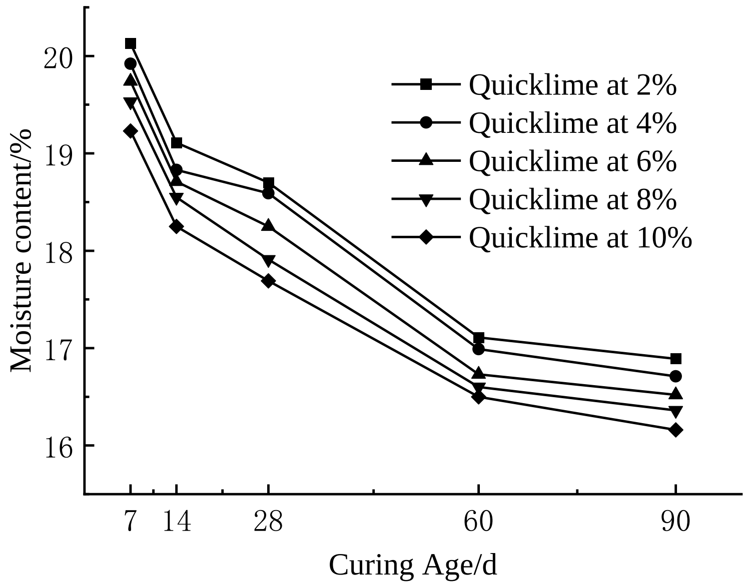

Figure 4: Effect of Curing Age on Moisture Content

Figure 4 shows the effect of different maintenance age on themoisture content of cured mud, from the figure it can be seen that with the increase of maintenance age, the moisture content of cured mud has an overall decreasing trend, and when the maintenance age is 90d, its moisture content is the smallest. When the maintenance age is 28-60d, the moisture content of cured mud decreases the fastest. When the maintenance age is shorter, the moisture content of cured slurry decreases significantly, and when the maintenance age is longer, the decrease of its moisture content tends to stabilise, which indicates that quicklime needs a large amount of water to carry out the hydration reaction at the early stage of the maintenance period, and at the later stage, its chemical reaction tends to stabilise.

3.3 Effect of Quicklime Dosing on pH

Table 5 shows the experimental results of the effect of different lime dosage on the pH of cured mud.

Table 5:Effect of Quicklime Dosing on pH.

Specimen Group Number	7d pH	14d pH	28d pH	60d pH	90d pH
Group1	11.938	11.943	11.943	11.948	11.955
Group2	11.940	11.946	11.955	11.952	11.958
Group3	11.945	11.951	11.958	11.960	11.961
Group4	11.948	11.957	11.959	11.962	11.962
Group5	11.952	11.963	11.966	11.965	11.969

Figure 5 shows the effect of different lime dosage on the pH value of curing slurry. From the figure, it can be seen that the cured slurry pH value overall between 11-12, and with the increase of quicklime doping overall upward trend, in the quicklime doping of 10% when the cured slurry pH value is the largest. And the pH value of cured slurry increases gradually with the growth of maintenance age. CaO, the main component of quicklime, can react with the water in the river bottom slurry to form Ca(OH)2, which is alkaline, so the pH value of the cured slurry increases with the increase of quicklime dosage. This property also makes quicklime often used as an alkaline stimulant to stimulate the mineral powder, so as to achieve the effect of curing slurry.

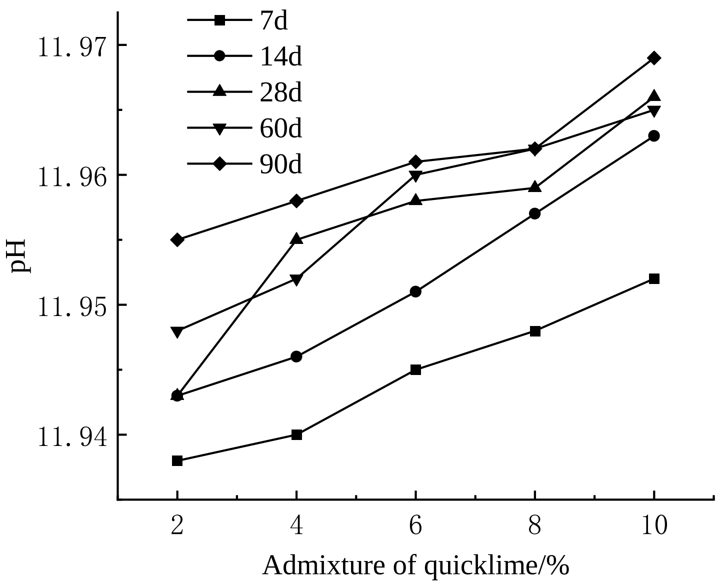

Figure 5: Effect of Quicklime Dosing on pH

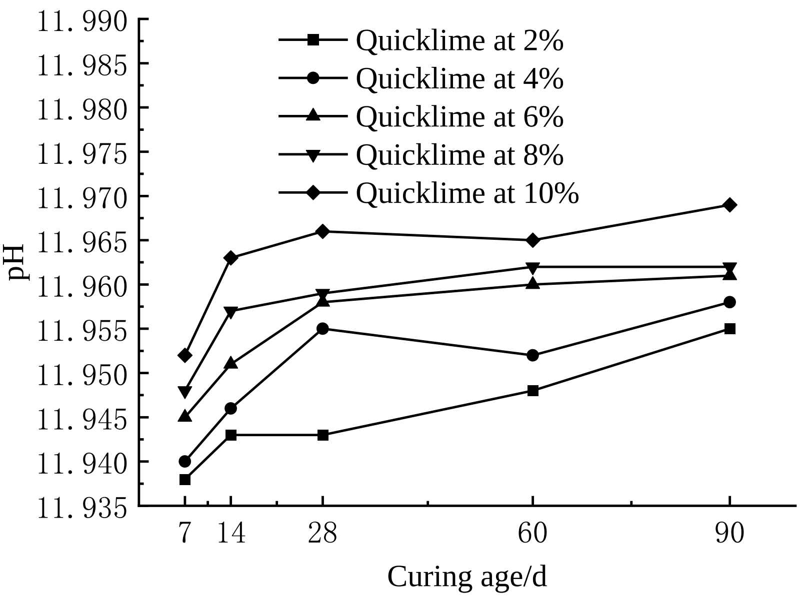

Figure 6: Effect of Curing Age on pH

Figure 6 shows the effect of maintenance age on the pH value of cured mud, from the figure can be seen with the increase of maintenance age, the pH value of cured mud is increasing. When the maintenance age is shorter, the curing mud pH value growth rate is faster, this time the curing reaction has not occurred completely, the addition of quicklime can quickly improve the pH value of the curing mud, when the maintenance age is longer, the curing mud pH value growth rate decreases and tends to stabilise, mainly due to the curing agent and the subsoil of the hydration reaction of alkaline substances generated by the mud tends to stabilise.

IV. CONCLUSION

In this paper, the effect of lime doping on the physicochemical and mechanical properties of composite cured river bottom mud under different maintenance ages was investigated by changing the lime doping, and it was concluded that quicklime can well improve and enhance the performance of cured mud, and provide a good alkaline environment for the subsequent hydration reaction of mineral powder and other materials. With the increase of quicklime dosage and maintenance age, the unconfined compressive strength of cured mud increased continuously, and the compressive strength of cured mud reached the maximum value when the dosage of quicklime was 10%. Because CaO in quicklime can react with the water in the river bottom slurry, the water content of the cured slurry shows a decreasing trend with the increasing of quicklime dosing and maintenance age. The pH value of the cured slurry increases with the lime dosage and maintenance age, and when the maintenance age is longer, the pH value increases at a lower rate and tends to stabilise, providing a sufficiently alkaline environment for the hydration reaction of the remaining curing agents to take place.

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