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Influence of Some Key Parameters on the Efficiency of Flocculation–Solidification–Filter Press Combined Method for Sustainable Treatment of Waste Mud Slurry

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Abstract: The flocculation–solidification–filter-press combined method is a new type of method for treating waste slurry that combines flocculation and chemical curing with a mechanical filter press. Among these processes, the mechanical filter-press process is key to the efficient disposal of waste engineering slurries by the flocculation–solidification–filter-press combined method. In the mechanical filter-press process, parameters including the initial thickness of filtration mud, the magnitude of filtration pressure, and the duration of press filtration have important impacts on the dewatering and strength after subsequent curing. In this work, a series of laboratory tests were conducted to study the influence of filter-press parameters on flocculated–solidified mud by measuring the properties of treated and cured mud. The test results showed that the initial mud bag thickness is an important factor in the mud treatment effect. As the initial mud bag thickness increases, the greater the water content of the mud at the end of the filter-press process after applying the same amount of time and the same amount of pressure, the lower the post-conservation strength will be. The increase in filtration pressure and filtration time within a certain range can reduce the water content of the mud brick after filtration and significantly improve its shear strength. In the actual process of filtering in the project, the thickness of the initial mud bag should be no more than 140 mm, the filtration pressure is about 0.35 MPa, and the filtration time is suitable for 2 min.

Keywords: engineering muds; filter presses; flocculation; solidification

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1. Introduction

Engineering mud, as a suspension system composed of water, bentonite particles, clay particles, and various additives, is often utilized as a material for lubrication and cooling, hole clearing and slag removal, and mud wall protection during the construction process of drilled pile foundation construction, diaphragm wall construction, mud–water shield construction, and so on [1]. However, a large number of drill cuttings and other debris will be mixed with the engineering mud during the construction process, resulting in a change in its nature after several periods of recycling, which means that it cannot be used. Thus, inevitably, a large amount of waste engineering mud is produced [2]. Waste engineering mud, as a typical construction waste, can pose a threat to the environment if not handled properly. Adopting safe and environmentally friendly methods to treat it can not only solve the waste disposal problems encountered in current engineering construction but also promote the healthy and sustainable development of the engineering field [3,4].

At present, the treatment methods of waste engineering muds mainly include external discharge, chemical curing, mechanical dewatering, and the flocculation–solidification combined method [5]. However, the existing treatment methods are each characterized by a certain number of shortcomings, and the results are not satisfactory. Traditional outbound emission treatment methods have high transportation costs, often cause environmental pollution throughout the process, and occupy considerable land resources and pollute the environment after outbound emission [6]. Chemical curing methods can enhance soil strength through curing cementation, but their efficiency decreases sharply with the increase in water content of engineering mud [7], leading to a significant increase in the consumption of curing agent, as well as affecting the environment. In comparison, mechanical dewatering is more environmentally friendly, but mechanical dewatering through vacuum pre-pressurization and other means is inefficient due to the low permeability of the mud [8]. The flocculation–solidification combined method has considerable advantages over traditional methods but still has certain shortcomings. Firstly, the flocculant is usually added in the form of solution, which improves the mud dewatering performance and also significantly increases the water content of the mud. Secondly, the solid particulate matter in the treated mud still relies only on self-weight to complete the deposition and solidification curing process, so it still has a relatively high water content and porosity itself.

In order to better solve the problem of engineering mud treatment, this research group proposes the treatment of a flocculation–solidification–filter-press combined method. This method improves the mud dewatering performance through flocculation and conditioning [9,10], and with the help of the mechanical filter-press process, it increases the speed of mud dewatering, reducing the water content after the mud is subjected to a lower dosage of curing agent to achieve increased strength [11–13]. The joint method of treating waste engineering mud technology is based on a combination of multiple actions of flocculation and conditioning, mechanical-press dewatering, and hydration and cementation of solidifying agents. In principle, the flocculation and conditioning effect enhances the mud dewatering performance, and the mechanical filter-press process ensures that the conditioned mud can be dewatered quickly and efficiently. After dewatering, the strength of the mud brick grows under the curing effect of the curing agent, so as to achieve the goal of dewatering and reducing the amount of waste mud treatment and resource utilization. Numerous studies have shown that the efficiency of mud dewatering using mechanical-press filtration depends on the dewatering properties of the mud [14,15]. The incorporation of various types of flocculants can significantly improve the dewatering efficiency, which is conducive to the rapid dewatering of mud in the process of mechanical press filtration [12].

In this method, the filter press is an important part of mud dewatering. Under pressure, the floc structure formed by the mud is compacted and the pore water is discharged, thus forming a mud brick with low water content. In the process of press filtration, the selection of filtration parameters such as filtration pressure and filtration time has a direct and important influence on the effect of press filtration and the curing effect in the later stage [16,17]. For the actual project, the selection of the appropriate geotechnical mud bag thickness, filtration pressure, and filtration time during the filtration process is key to improving the treatment efficiency. Therefore, this paper intends to investigate the effects of filtering mud thickness, filtration pressure, and filtration time on the characteristics of the flocculating and solidifying combined filtration method through a series of indoor geotechnical experiments, and to optimize the filtering parameters to provide a basis for the selection of filtering parameters in future engineering practice.

2. Materials and Methods

2.1. Materials

The engineering mud used in the test was sourced from a yard in Shanghai, with an initial water content between 60% and 75% and a high content of coarse particles. After the engineering mud was filtered and sieved to remove coarse particles and remodeled, the plastic limit of the engineering mud was measured as 18.2% and the liquid limit was 28.7% by using a combined liquid–plastic limit tester. The relative specific gravity of the soil particles was 2.69. The particle size distribution curves of the mud samples are shown in Figure 1 and the XRD diffraction patterns are shown in Figure 2. From the figures, it can be seen that the main mineral present in the Shanghai abandoned project mud sample is quartz, accompanied by a small amount of illite and kaolinite, as well as a trace of mica.

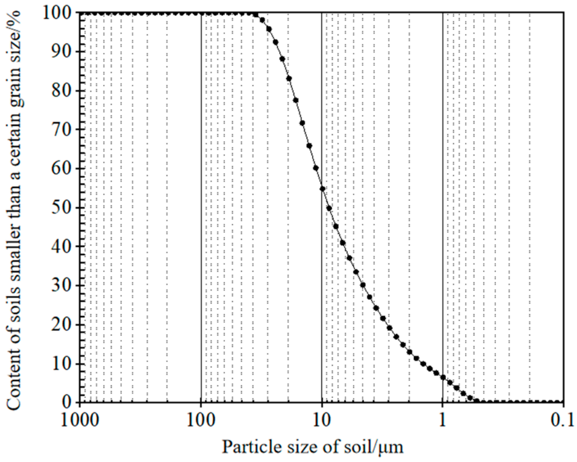


Figure 1. Engineering mud particle gradation for testing.

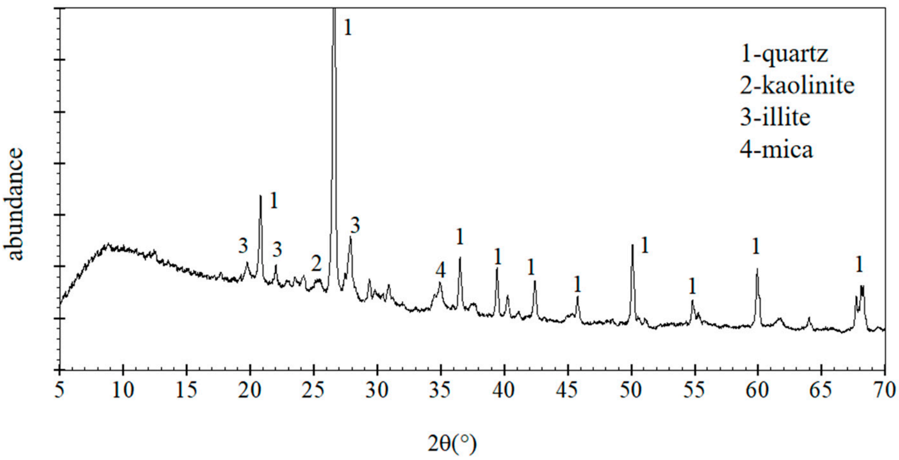


Figure 2. XRD diffraction patterns of engineering mud for testing.

Based on the results of previous research from this research group, cement (OPC) and slag powder (GGBS) were used as curing agents. The cement was 42.5 ordinary Portland cement, and the blast furnace slag was 500-mesh granulated ground blast-furnace slag powder. In order to obtain a better flocculation effect, inorganic flocculant and organic flocculant were used together in the test. We selected the organic flocculant anionic AN926 polyacrylamide (PAM) reagent of the aqueous solution, which had a PAM reagent to water mass ratio of 1:500. Calcium hydroxide ($Ca(OH)_2$) was used as the inorganic flocculant. The geotechnical filter bag used in the mechanical filter-press process is made of 300-mesh polypropylene, which can effectively isolate the seepage of mud particles and has good water permeability.

2.2. Test Conditions

In order to explore the influence of press filtration-related parameters, a total of three groups of tests were set up with a total of four types of working conditions. The settings of different working conditions are shown in Table 1.

Table 1. Data sheets for different operating conditions.

Working Condition	Quantity of Dry Mud (kg)	Filtration Pressure (MPa)	Filter-Press Time (min)	Initial Moisture Content	Dosage of Curing Agent	PAM Dosage	Slaked Lime $Ca(OH)_2$ Dosage	Equivalent Initial Moisture Content
A1	2							
A2	3							
A3	4							
A4	5	0.3	10					
A5	6							
A6	7							
A7	8							
B1		0.2						
B2		0.25						
B3		0.3						
B4	4	0.35	10	170%	4%	0.06%	1.50%	200%
B5		0.4						
B6		0.5						
C1			2					
C2	4	0.3	4					
C3			6					
C4			8					
D1			2					
D2	6	0.3	4					
D3			6					
D4			8					

Test one: setting seven working conditions, A1–A7. Different initial mud bag thicknesses were considered for each condition, and other filter-press parameters as well as admixture dosages were kept consistent. The amount of curing agent was 4% (2% each of OPC and GGBS). The flocculant was a combination of PAM and $Ca(OH)_2$, with $Ca(OH)_2$ dosed at 1.5% and PAM (solution prepared at 1:500) dosed at 0.06% (PAM dry powder mass as a percentage of dry soil mass). The project mud had an initial water content of 170%, and the equivalent initial water content obtained after the addition of flocculant was 200% (the exact amount of flocculant is calculated based on the amount of mud loaded). Considering that the mud obtained through flocculation and solidification treatment is in a fluid state, it is not possible to determine the initial mud bag thickness more accurately after filling the geotechnical filter bag. Therefore, by controlling the dry mud mass, the initial mud bag thickness for each condition was obtained from the density–volume relationship. The filtration pressure was about 0.3 MPa and the filtration time was 10 min.

Test two: setting six working conditions, B1–B6. Different filter pressures were considered for each condition, and other filter-press parameters and admixture dosages were kept consistent. The effect of filtration under different working conditions was analyzed by measuring the water content, thickness, and strength of the mud brick after filtration. The mass of dry mud in each condition was 4 kg, keeping the initial mud bag thickness constant, and fixing the filter-press time at 10 min.

Test three: setting a total of eight working conditions for two groups, C1–C4 and D1–D4. The dry mud mass of group C and group D conditions were 4 kg and 6 kg, respectively, the pressure of filtration was 0.3 MPa, and the filtration tests were carried out with different filtration times. The effect of filtration under different working conditions was analyzed by measuring the water content, thickness, and strength of the mud brick after filtration. In addition, the B3 condition in Test 2 could be analyzed together with the Group C condition, and the A5 condition in Test 1 could be analyzed together with the Group D condition. Considering the short dewatering time after flocculation and conditioning of the engineering mud used in the test, the filtration time was set to 2 min, with a gradient difference of 2 min, and was defined as the time from the start of pressurization to the time of pressure release.

2.3. Test Procedure

The main instruments used in this experiment were a customized filter press (Figure 3), a straight-shear instrument, a B10 three-function mixer, a 101-series digital-display blower-drying oven, and a pneumatic soil extraction apparatus, supplemented with a number of aluminum boxes, beakers, spatulas, ring knives, and disposable plastic-scale strips with an accuracy of 1 mm.

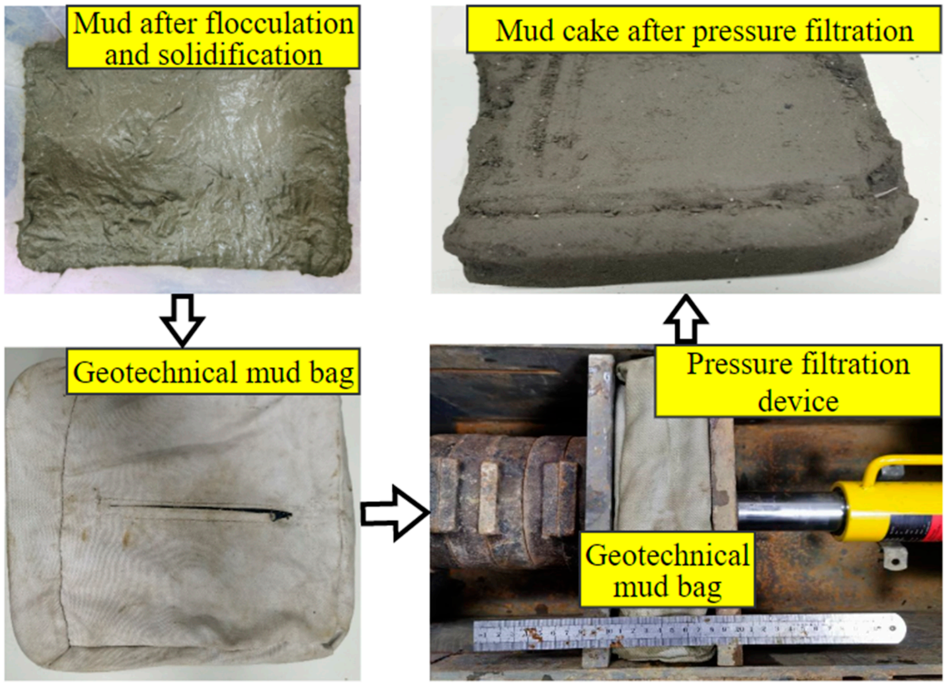


Figure 3. Press-filtration test.

1. The mud sample was prepared by using a B10 three-function mixer (10 L capacity), setting the initial water content of the mud to 200%, adding the original engineering mud and water to the mixer proportionally, and mixing to obtain the mud sample for standby.
2. Cement–slag powder composite curing agent was added to the mud in proportion to the mixing, and we continued to mix thoroughly to obtain a homogeneous mud mixed with curing agent.
3. The weighed PAM reagent was added to a predetermined amount of water and stirred to prepare a solution, noting that the solution should be stirred to a homogeneous state, next, it was added to the mud-consolidator mixing slurry, and the mixer was set to stir at a uniform speed of 90 r/min [18]. When flocculating agglomerates began to appear, we gradually slowed the mixing rate to avoid destroying the floc structure, and stopped mixing when the flocs were large and stable. The mixing process should not exceed 10 min.
4. The filter press (Figure 3) consists mainly of a filter chamber and a hydraulic jack. The hydraulic jack is a pressurized system that provides filter pressure to the filter bag, filling the bag with mud under the pressure of filtration. The filter chamber was equipped with drainage holes through which filtered water was discharged. The mixture was slowly poured into a customized geotechnical filter bag (Figure 3), which was then placed into the filter-press tank of the customized filter press. The hydraulic jack began to apply pressure to the filter bag; the jack hydraulic pressure meter readings remained at about 15 MPa for 10 min, at which time the pressure acting on the geotechnical filter bag was about 0.3 MPa.

5. After the completion of filtration, the pressure was removed, and the mud brick obtained after filtration was removed from the filter tank (Figure 3), and a number of ring-knife samples were taken with a sampler for constant-temperature water-bath maintenance at 20 °C. At the same time, the water content of the mud brick after filtration was determined by the use of a blast oven after the completion of sampling.
6. A consolidation fast-shear test (shear rate 0.8 mm/min) was carried out using a straight-shear apparatus at the time of maintenance to the set maintenance age (7 d, 14 d, 21 d, 28 d). According to the provisions in the Standard for Geotechnical Test Methods (GBT 50123-2019) [19], the shear strength of each batch of specimens was determined under the positive pressure of 100 kPa, 200 kPa, 300 kPa, and 400 kPa, respectively, and the cohesion and internal friction angle of the mud brick were derived by fitting the curvilinear relationship between the positive pressure and the shear strength.
7. Steps 1–6 were repeated until the test was completed for all working conditions.

3. Results

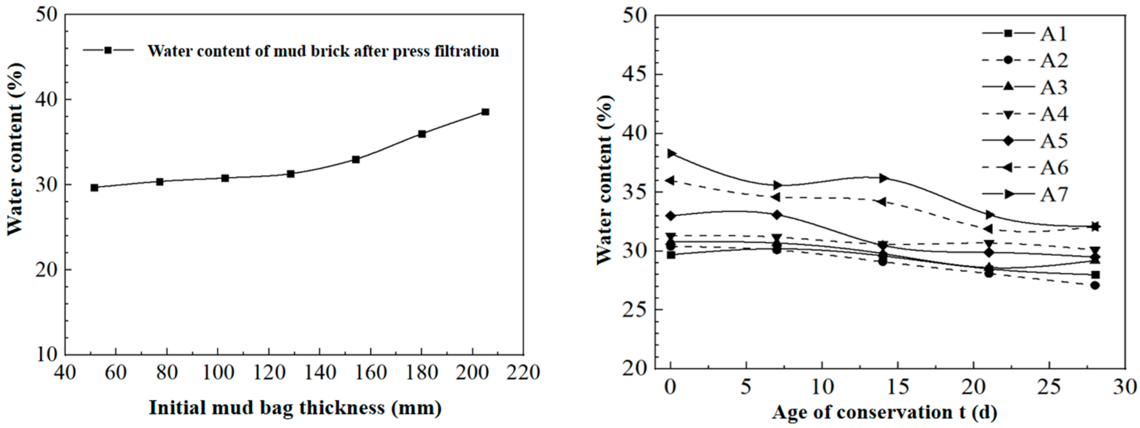
3.1. Analysis of the Influence of Initial Mud Bag Thickness on Filter-Press Effectiveness

According to the design data for the working conditions given in Table 1, the initial calculated thickness of the mud bag for Condition A is shown in Table 2.

Table 2. Calculated initial thickness values for Condition A.

Working Condition	Quantity of Dry Mud (kg)	Calculate Initial Weight (kg)	Calculate Initial Thickness (mm)
A1	2	6.11	51
A2	3	9.17	77
A3	4	12.2	103
A4	5	15.28	128
A5	6	18.33	154
A6	7	21.38	180
A7	8	24.44	205

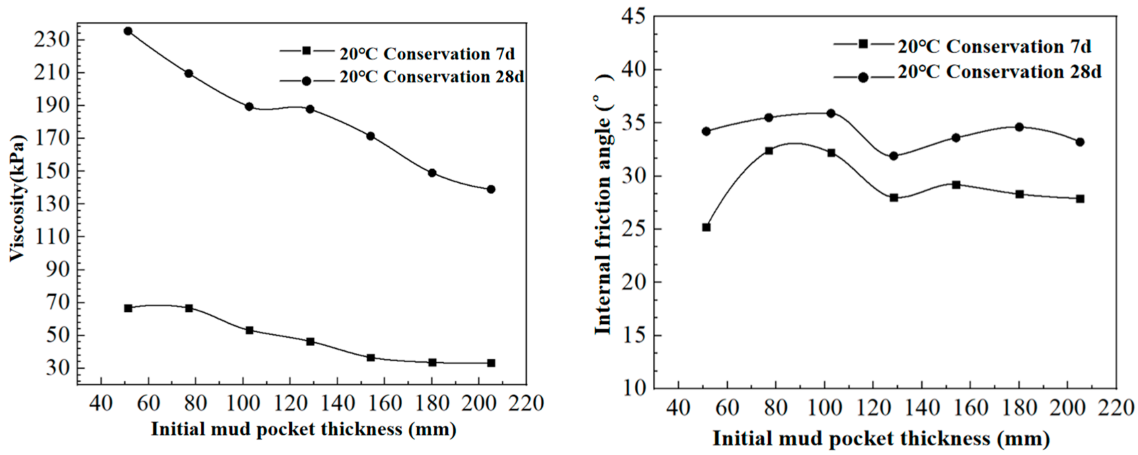
Figure 4a shows the variation in water content of mud brick obtained by diafiltration of mud at different initial thicknesses. Theoretically, as the thickness of the mud brick increases, the floc pore water drainage path becomes longer during the filter-press process, and dewatering becomes more difficult. At the same time, the inner wall of the geobag will be dehydrated by the mud to form a layer of denser mud skin at an early stage, which is characterized by a low permeability coefficient and difficulty in discharging pore water. This leads to difficulties in dewatering the internal mud at a later stage, which is especially detrimental to the dewatering of thicker mud bricks. From the figure, it can be seen that with the increase in the initial mud bag thickness, the water content of the mud brick obtained after the press filtration also increases, and the growth trend is more obvious after the initial mud bag thickness exceeds 140 mm. When the initial mud bag thickness reaches 200 mm, the water content of the mud brick after the filter-press process is close to 40%, but overall, the increase in the water content of the mud brick afterward is not more than 10%, which indicates that the dewatering performance of the mud is better under Condition A. From Figure 4b, it can be seen that the water content of the mud brick fluctuated during the maintenance process, but with the increase in age, the hydration reaction of the curing agent continues, and the water content generally shows a decreasing trend. The water content during the curing process was significantly higher than the other conditions when the mass of dry mud was 7 kg and 8 kg, i.e., when the thickness of the mud bag was greater.



(**a**) **Change in water content of mud brick after press filtration** (**b**) **Change in moisture content during conservation**

Figure 4. Variation in mud brick moisture content.

From Figure 5, it can be seen that as the initial mud bag thickness increases (from A1 to A7 conditions), the mud brick cohesion shows an overall decreasing trend, while the angle of internal friction fluctuates within a certain range. At 7 d of maintenance, the mud brick cohesion for the initial mud bag thicknesses of 51 and 77 mm conditions are closer to each other at about 66 kPa. However, when the initial mud bag thickness is 205 mm, the cohesive force is only 30 kPa. At 28 d of maintenance, the difference in the cohesion of mud brick with different initial mud bag thicknesses increases significantly, with a maximum cohesion of 230 kPa for 51 mm thickness and only 140 kPa under for 205 mm thickness. In addition, the internal friction angle of the mud brick changes less at both maintenance ages and also increases slightly after maintenance, indicating that the frictional properties between soil particles in the mud brick are only affected by the maintenance age.



(**a**) **Changing law of cohesion with initial mud bag thickness** (**b**) **Change rule of internal friction angle with initial mud bag thickness**

Figure 5. Variation in mud brick strength index.

The reduction in the water content of the mud during diafiltration is also reflected in the reduction in the thickness of the geosynthetic mud bags. As can be seen in Figure 6, as the dry mud mass increases, the initial mud bag thickness also increases linearly according to the conversion relationship, while the thickness of the mud brick after press filtration is also roughly linear. The ratio of mud brick thickness before and after press filtration of mud bags with different initial thicknesses is basically the same, around 40%. Thus, in this respect, the difference in dewatering effect of different initial thicknesses of mud bags is not significant, probably due to the sufficiently long duration of the filter-press process.

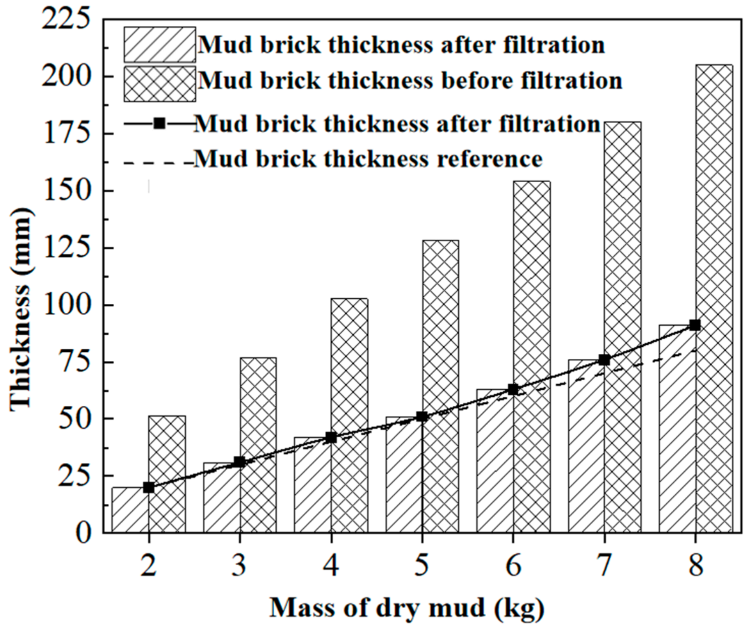
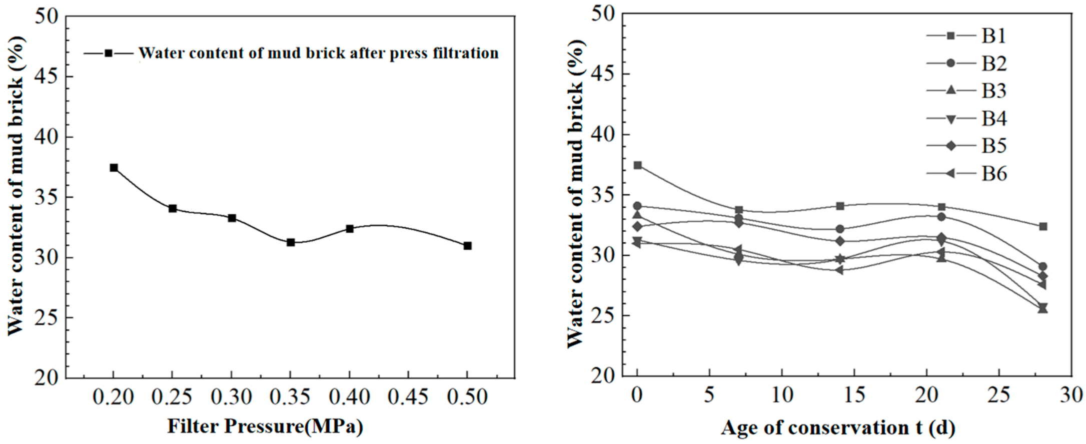


Figure 6. Variation in mud brick thickness.

3.2. Influence of Filter Press Pressure Magnitude on Filter Press Effectiveness

As can be seen from Figure 7, the water content of the mud brick first decreases and then remains basically unchanged with the increase in filtration pressure for a certain filtration pressure time. When the mud water content decreases to a certain level and mud brick forms, the pore ratio is also rapidly reduced, the permeability coefficient is gradually reduced, and close to the inner wall of the geobag, mud dewatering occurs and forms a mud skin, resulting in pore water discharge being subject to greater resistance. When the filtration pressure is low, the pore water struggles to overcome the resistance to discharge, resulting in a higher water content of the mud brick. When the filtration pressure increases, the pressure of super pore water generated in the mud brick also increases, which helps the pore water to overcome the resistance to discharge. When the pressure increases to a certain extent, the super pore water pressure in the mud brick is already enough to overcome the resistance, continuing to increase only to accelerate the discharge of pore water, so the water content of the mud brick demonstrates the abovementioned rule. Tests of the water content of the press-filtered mud brick during 28 d of post-filtering maintenance reveals that, in general, the water content of the brick decreased with age due to the hydration reaction. From Figure 7b, it can be seen that the water content develops in different patterns with time during the specimen-curing process after pressure filtration of different sizes.

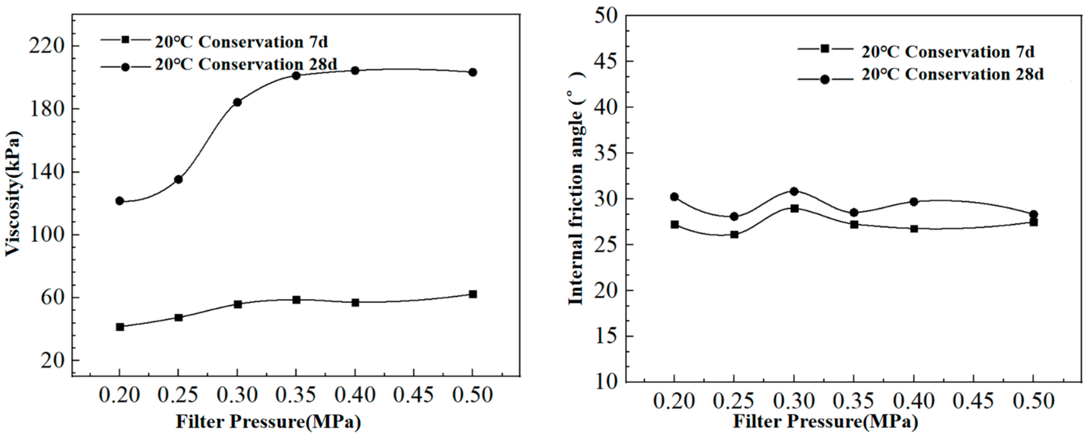
As can be seen from Figure 8, the cohesion increased with the increase in filter press pressure, and the cohesion increased substantially after 28 d of maintenance compared with that at 7 d of maintenance. The higher the pressure of the filter press, the greater the increment of cohesion and the greater the strength. When the pressure of filtration is greater than 0.35 MPa, the cohesion before and after maintenance does not change much with the pressure of filtration. When the filtration pressure is greater than 0.35 MPa, the internal friction angle with the change in filtration pressure similarly exists with a small change in magnitude. According to the above results, it can be seen that the strength properties of the treated sludge are more sensitive to a change in pressure when the pressure is below a certain value, while when the pressure is greater than a certain value, the effect of continuing to increase the pressure on the strength properties of the specimen can be ignored. This also indicates that there is a strong correlation between the shear strength of the mud brick and the water content. On the other hand, a higher filtration pressure can bring the soil particles closer to each other, which is manifested as a denser mud brick, thus improving the shear strength of the mud brick to a certain extent.



(**a**) **Changes in water content of mud brick after press filtration**

(**b**) **Changes in moisture content during conservation**

Figure 7. Variation in mud brick moisture content.



(**a**) **Change rule of cohesion with filtration pressure**

(**b**) **Change rule of internal friction angle with filtration pressure**

Figure 8. Variation pattern of mud brick strength index.

3.3. Influence of Filter Press Time on the Effectiveness of Filter Press

The time factor in the filtration press process is an important factor affecting the effectiveness of the filter press, and an increase in the filtration press time theoretically allows more pore water to seep out of the mud. However, as the water content of the mud brick decreases, later dewatering becomes more difficult. Therefore, for practical engineering applications, selecting the appropriate filtering time can improve the efficiency of filtering treatment under the premise of ensuring the filtering effect.

Figure 9 gives the relationship between the variation in water content of mud brick with filtration press time for the two groups of conditions, C and D. With C, D group conditions using the same mud for filtration, the water content of the mud brick with the change rule of filtration time is also similar, that is, the longer the filtration time is, the smaller the water content of the mud brick. However, the magnitude of the change is smaller, and the trend of reduction gradually slows down. As can be seen from the figure, the water content of the mud brick of groups C and D has been reduced to less than 40% when the filter-press time is 2 min, which corresponds to a large amount of dewatering of the mud in the first 2 min of the filter-press process, i.e., a large amount of free water seeps out of the filter chamber during the filter press test. On this basis, with the increase in filter press time, both the pore ratio and permeability coefficient of the mud brick decrease because the water content of the brick itself is already low and because the mud soil particles are squeezed and densified, thus leading to a rapid decrease in the dewatering rate. In addition, it can be seen that the water content of mud brick under the same filtering time in group D is always smaller than that in group C, and the difference is more obvious when the filtering time is shorter, which indicates that the thickness of the initial mud bag will have a more prominent effect on the filtering when the filtering time is shorter.

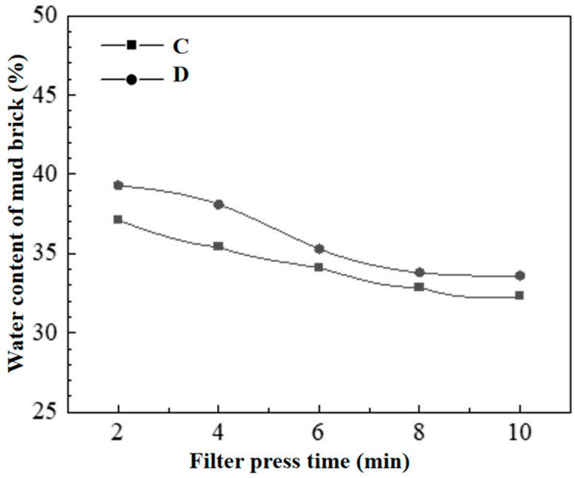
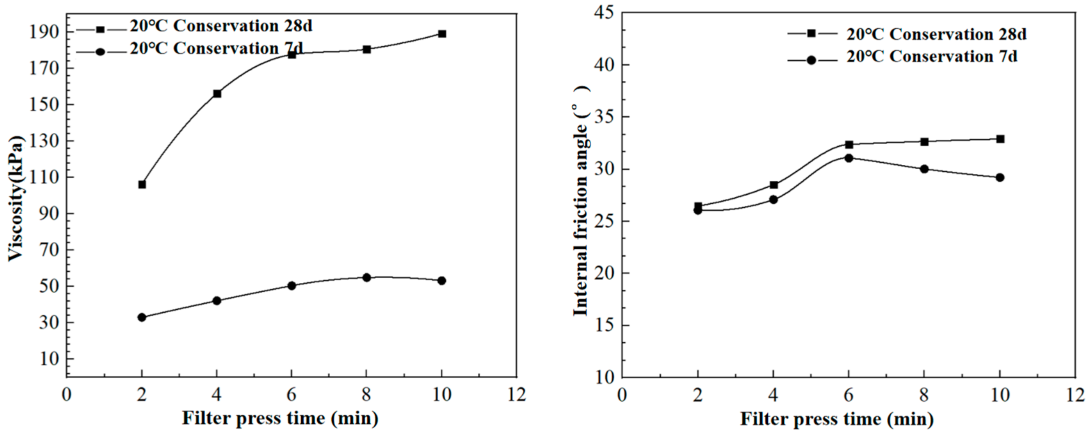


Figure 9. Variation in water content of filter-press mud brick.

From Figures 10 and 11, it can be seen that the thickness of the initial mud bag only has a certain effect on the size of the cohesive force, while the overall rule of change is basically consistent with the changes in the angle of internal friction mentioned above. At 7 days of maintenance, the increase in cohesion of the mud brick is not significant with the increase in filter press time. The effect of filter press time on the strength of the mud brick is better illustrated by the cohesion of the mud brick after 28 days of maintenance. The cohesion of the mud brick after 28 days of maintenance has a rapid increase phase with the increase in filter press time, and then remains basically unchanged. When the filtration time is short, increasing the filtration time can effectively improve the shear strength of the mud brick, but after increasing it to a certain time, it has little effect on the shear strength of the mud brick. It is assumed that under prolonged pressure, the soil particles tend to be more densely packed, the pore water is sufficiently transferred, the water content inside the mud brick is more uniformly distributed along the thickness direction, and the overall strength is improved. With a short filtering time, the water content inside the mud brick is unevenly distributed along the thickness direction, and there is a weak surface of strength, which affects the macroscopic strength of the mud brick and is reflected in the relatively small cohesive force of the specimen.

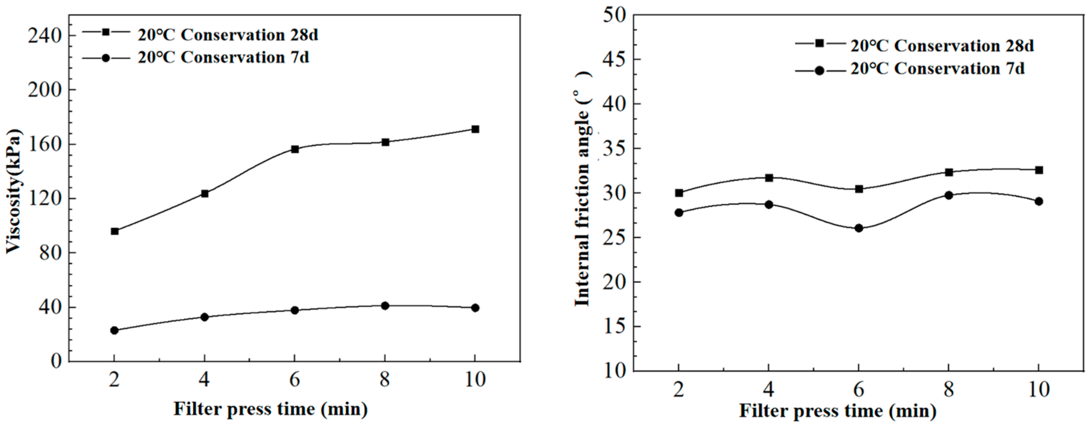
Comparing brick water content and strength, for mud with good dewatering performance, a large amount of dewatering can be formed in a short period of time, and the filtration effect is not much affected by the increase in filtration time to a certain value. For mud with poor dewatering performance, good dewatering results can still be achieved by increasing the filter press time.



(**a**) **Change rule of cohesion with filter press time**

(**b**) **Change rule of internal friction angle with filter press time**

Figure 10. Variation in shear strength index dry clay with mass of 4 kg.



(**a**) **Change rule of cohesion with Filter press time**

(**b**) **Change rule of internal friction angle with filter press time**

Figure 11. Variation in shear strength index for dry clay with mass of 6 kg.

3.4. Effect of Water–Cement Ratio on Cohesion

Cohesion is a force formed by a combination of gravitational forces between the molecules of the soil particles and the cementation of the compounds in the soil, and the water–cement ratio is the ratio by weight of the amount of water to the amount of cement in the soil [20]. The relationship between the variation in water–cement ratio and cohesion for different working conditions at 7 d and 28 d curing time is shown in Figure 11. For the mud brick obtained after the flocculation–solidification–filter-press combined method in this study, the initial water content in the water–cement ratio is defined as the water content w_{ed} of the mud brick at the end of the preloading, due to the differences in the formation process with the conventional consolidated soil. According to the empirical equations for water–cement ratio parameters based on indoor tests proposed by Zheng Shaohui et al. [21],

$$C_{\Phi} = K(w_{\mathrm{ed}}/w_{\mathrm{c}})^{-a} \quad (1)$$

where K, a are the fitting parameters, $w_{\mathrm{ed}}/w_{\mathrm{c}}$ is the water–cement ratio, and C_{Φ} is the cohesive force.

The relationship function fitted by Equation (1) is shown as the curve in Figure 12. Overall, the cohesion of the mud brick after 7 d and 28 d of maintenance decreases with the increase in water–cement ratio in a power function trend. In addition, the fitted parameters *K* and a increase significantly with increasing conservation age, and the form of the fitted curve development is steeper in general. It is hypothesized that there is a significant correlation between the magnitude of mud brick cohesion and the age of maintenance and initial water–cement ratio of the mud brick. When carrying out the practical application of the project, the construction quality of the mud brick formed by the flocculation–solidification–filter-press combined method can be controlled in advance according to the fitting relationship function obtained from the indoor test.

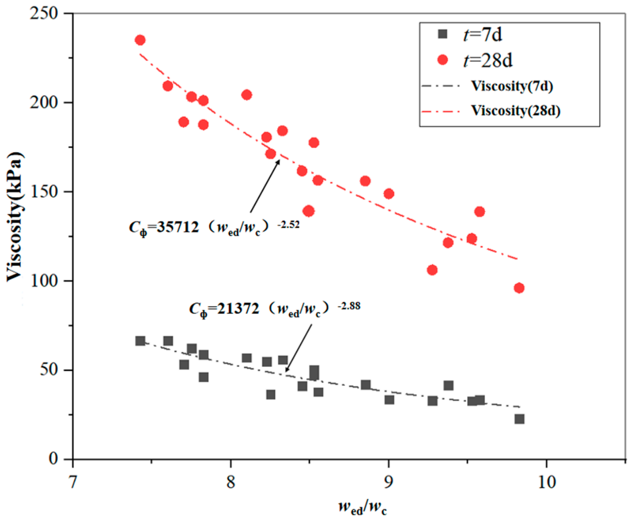


Figure 12. Relationship curve between cohesion and water–cement ratio.

4. Conclusions

In this paper, by carrying out a press filtration test of flocculating and solidifying silt, and conducting post-conservation property tests on the mud samples after filtration to investigate the influence of the thickness of the filtered mud samples, the size of the filtration pressure, and the time of filtration on the characteristics of the flocculating and solidifying combined filtration method, and analyzing the results of this study, we can draw the following conclusions:

(1) The initial mud bag thickness is an important factor affecting the mud treatment: with the increase in the initial mud bag thickness, the greater the water content of the mud after the end of the same application time and the same size of pressure filtration, the lower the strength after maintenance. The greater the mass of dry soil, the greater the effect of filtration time.

(2) The increase in filtration pressure within a certain range can reduce the water content of the mud brick after filtration and significantly improve the shear strength of the mud brick. However, when the pressure exceeds a certain value, the mud filtration effect caused by the continued increase in pressure is not significant. And the longer the filtration time within a certain range, the lower the water content of the mud brick after the filter-press process, and the higher the shear strength of the mud brick at the same time.

(3) In the actual process of filtering in the project, the recommended initial thickness of the mud bag is not more than 140 mm, the filtration pressure is about 0.35 MPa, and the filtration time is 2 min.

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