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Effects of Dosing and Mechanical Activation on the Performance of Reservoir Sediment-Cement Composite Cementitious Material

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To solve the problem of reservoir sediment accumulation, this paper intends to study the feasibility of preparing reservoir sediment-cement composite cementitious material by partially replacing cement with reservoir sediment. Using the single factor test method, the replacement rate of reservoir sediment and mechanical activation time were selected as variables to explore the effects of water requirement of normal consistency, setting time, mortar fluidity, and mechanical properties of mortar specimens. The results show that with the increase of sediment replacement rate, the water requirement of normal consistency of composite cementitious material paste increases, the setting time increases, the fluidity of mortar decreases, and the mechanical properties of mortar specimens decrease significantly. With the increase of mechanical activation time, the water requirement of normal consistency decreases, the setting time decreases, the fluidity of mortar increases, and the mechanical properties of the mortar specimen increase. The microcosmic results show that mechanical activation can promote the formation of C-S-H gel in reservoir sediment, and fill each other with unreacted reservoir sediment particles, resulting in a denser microstructure. The purpose of this paper is to provide theoretical support for the preparation of reservoir mud-cement composite cementitious material.

Keywords: reservoir sediment, mechanical activation, cementitious material, fluidity, water requirement of normal consistency, setting time.

1. INTRODUCTION

With the rapid economic development, dredging reservoir sediment projects are gradually carried out in various places, making the volume of reservoir sediment accumulation in China reach 400 million m^3 a year [1]. The dredging volume shows a trend of increasing year by year [2]. The effect of dredging is pronounced, but the water content of dredged reservoir sediment is high. Moreover, it contains more heavy metals and organic pollutants, so if it is dumped without proper disposal, it will easily pollute the environment and affect the resource utilization of reservoir sediment [3, 4]. Reservoir sediment is in a fluid and plastic state, and the bearing capacity is poor. So it must be dewatered and dried before use [5, 6]. Therefore, most of the reservoir sediment is disposed by stockpiling, which will occupy a large amount of land and produce secondary pollution to the environment [7, 8]. Therefore, resource utilization of dredged sediment has become essential for comprehensive environmental improvement [9].

With the promotion of ecological civilization construction and low-carbon green development concept in China, the resource utilization of reservoir sediment has become a hot issue [10 – 12]. Currently, the resource utilization of reservoir sediment in China mainly includes land use, calcination treatment, and landfill [13]. However, it does not fundamentally solve the problem of reservoir sediment polluting the environment and endangering human health. For example, after reservoir sediment is forged and burned, about 30 % of the ash will remain, and heavy metals are not removed. If used for reclamation, it will pollute the marine ecosystem, and heavy metals will accumulate in the food chain, endangering human health [14]. Reservoir sediment contains many toxic and harmful substances and heavy metals, and the environmental damage is not negligible when used as compost in the soil. For example, reservoir sediment that has not been harmlessly treated is used directly in the soil, which will lead to soil sludge, thus affecting soil fertility. Heavy metals can cause severe damage to the surrounding soil when disposed in landfills, and the infiltration of toxic substances can also contaminate groundwater. Therefore, there is an urgent need to develop new ways of utilizing reservoir sediment.

Reservoir sediment is mainly composed of SiO_2, Al_2O_3 and CaO, and the existence of these oxides is conducive to the formation of calcium silicate hydrate gel [15]. Moreover, relevant tests show that the leaching concentration of heavy metal elements in the sediment-cement solidified body decreases significantly, and with the extension of curing time, the degree of cement hydration increases, the internal structure of the solidified body becomes denser, and the curing stability effect on heavy metal elements becomes more obvious. Finally, the leaching concentrations of all elements were in line with the Class III water standard in the "Surface Water Environmental Quality Standard" (GB 3838-2002) [16 – 18]. Many domestic and foreign scholars have researched reservoir sediment instead of cement as a composite cementitious material. Chin et al. [19] studied the effect of calcination temperature on the activity of reservoir sediment, prepared mortar with

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calcined reservoir sediment instead of some cement, and found that the mechanical strength of mortar was lower in the early stage, and the strength increased in the later stage. When the replacement rate of reservoir sediment was 10%, the temperature was 800 °C, and its strength was higher than that of pure cement, indicating that the calcination method can improve reservoir sediment activity. Chen et al. [20] pointed out that the chemical and mineral composition of reservoir sediment was similar to that of cement by compositional analysis. The mechanical strength of mortar specimens with different reservoir sediment replacement rates was tested. The results showed that the reservoir sediment partly replacing cement reduced the mortar's flexural and compressive strengths. When the replacement rate of reservoir sediment is 10 %, its strength was reduced by about 25 % compared to pure cement. Chang et al. [21] studied the influence of high-temperature activation on the pozzolanic activity of sediment and cement hydration. The results show that the calcination temperature from 600 °C to 900 °C increases the amorphous content of sediment, which is conducive to the strength development of mortar. In addition, heavy metals in the sediment can be fixed in the structure of hydration products during the calcination process, which ensures that the sediment will not pollute the surrounding environment during resource utilization. Although scholars at home and abroad have researched the reservoir sediment as cementitious material, the replacement rate of sediment for cement is low. The excitation of reservoir sediment activity is mainly focused on high-temperature activation. The activity of calcined reservoir sediment is improved; however, its energy consumption is high, which is not in line with the concept of green and sustainable development.

In this paper, the unmilled reservoir sediment was firstly substituted for P·O 42.5 cement at 0 %, 10 %, 20 %, 30 %, and 40 % by using the reservoir sediment of Yue Cheng reservoir in Handan City, Hebei Province, to study the effects of reservoir sediment on the water requirement of normal consistency, mortar fluidity, setting time and mechanical properties. Under the condition of not weakening cement performance and maximizing reservoir sediment usage, the replacement rate of reservoir sediment was determined. Then the reservoir sediment was mechanically activated at 15, 30, and 45 min based on a fixed amount of reservoir sediment. The effect of mechanical activation time on the water requirement of normal consistency, mortar fluidity, setting time, and mechanical properties were studied. This study can fully use reservoir sediment, save cement usage, reduce CO_2 emissions, and have a significant role in theoretical and practical aspects of mitigating climate change.

2. EXPERIMENTAL CONDITIONS

The reservoir sediment samples are obtained from Yue Cheng Reservoir, Ci County, Handan City, Hebei Province, China; their main chemical compositions are shown in Table 1. The XRD spectrum of the reservoir sediment is shown in Fig. 1, which shows that the main mineral compositions of the reservoir sediment are quartz, muscovite, albite, clinochlore, and calcite.

Table 1. Chemical composition of raw materials (mass fraction, %)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3	Others
Cement	18.09	5.88	3.90	64.39	1.94	1.22	–	0.35	3.38	1.66
Reservoir sediment	60.84	15.30	6.97	8.93	1.80	2.90	1.07	1.29	0.42	0.48

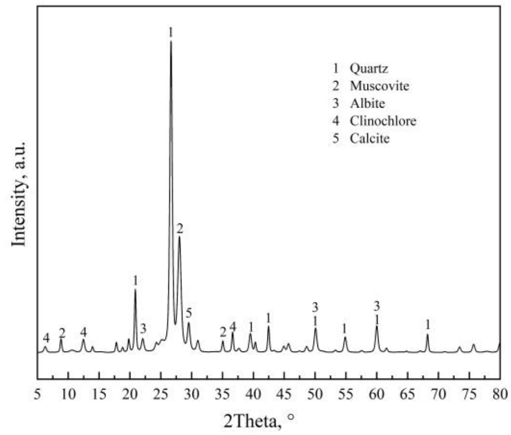


Fig. 1. XRD pattern of reservoir sediment

The main chemical composition of P·O 42.5 cement produced by Jiuqi Building Materials Co., Ltd. ISO standard sand produced by Xiamen Aisiou Standard Sand Co., Ltd and tap water were used (Handan, Hebei). The main equipment is shown in Table 2.

3. EXPERIMENTAL METHODS

3.1. Activation treatment of reservoir sediment

The reservoir sediment was dried in an oven at 100 °C until constant weight. Then the large pieces of reservoir sediment were cracked, passed through a 1.25 mm square-hole sieve, and activated on a planetary ball mill at 800 r/min using 2 mm diameter zirconia balls (mass about 1 g) as the activation medium and ethanol and polyethylene glycol as dispersants. After milling, the reservoir sediment was dried at 100 °C, passed through an 80-mesh square-hole sieve, and then used as material for the mechanical activation test of the reservoir sediment.

3.2. Mix ratio design of mortar test samples

Firstly, by designing different replacement rates of sediment mixture ratio, the performance of reservoir sediment partly replacing P·O 42.5 cement was explored. Reservoir sediment with a 1.25 mm square hole sieve was used to replace P·O 42.5 cement by 0 %, 10 %, 20 %, 30 %, and 40 % in mass to determine the optimal amount of reservoir sediment. Then, under the premise that the reservoir sediment replacement rate is specific, mechanical activation's effect on reservoir sediment's performance is further explored to determine the optimal activation time. Mortar is mixed according to cementing material – sand: water=1:3:0.5.

Table 2. Main test equipment for experiment

Equipment	Model number	Manufacturer
Electronic balance	TC10KHB	Guangzhou Jingyang Instrument Equipment Co., Ltd
Vertical blast drying oven	DHG-9245AE	Shanghai Jiecheng experimental Instrument Co., Ltd
Planetary ball mill	XQM-0.4A	Changsha Tianchuang Powder Technology Co., Ltd
Automatic surface area tester	FBT-9	Zhejiang Extension Instrument Equipment Co., Ltd
Laser particle size analyzer	Mastersizer 2000	Shanghai Keheng Industrial Development Co., Ltd
Cement mixer	NJ-160	Wuxi Jiangong Test Instrument Manufacturing Co., Ltd
Cement mortar mixer	JJ-5	Wuxi Jiangong Test Instrument Manufacturing Co., Ltd
Vicar instrument	-	Shanghai Luda Experimental Instrument Co., Ltd
Cementitious sand fluidity tester	NLD-3	Wuxi Jiangong Test Instrument Manufacturing Co., Ltd
Colloidal sand test molding (ISO) vibrating table	ZT-96	Wuxi Jiangong Test Instrument Manufacturing Co., Ltd
Cement fully automatic flexural and compressive integrated machine	DYE-300S	Zhejiang Yingsong Instrument Equipment Manufacturing Co., Ltd
X-ray fluorescence spectrometer	PANalytical Axios	Panaco in the Netherlands
X-ray diffractometer	X´Pert Powder	Netherlands Panaco Co., Ltd
Scanning electron microscope	JSM-6700F	Japan Electronics Corporation
Transmission electron microscope	JEM-2100F	Japan Electronics Corporation

Table 3. Mix ratio of mortar samples

Number	Cement, g	Reservoir sediment, g	Mechanical activation time, min
1	450	0	0
2	405	45	0
3	360	90	0
4	315	135	0
5	270	180	0
6	315	135	15
7	315	135	30
8	315	135	45

3.3. Specimen preparation

Using an automatic mechanical mixer to stir, then the fresh mortar mixture was cast into a 40 mm × 40 mm × 160 mm steel mold, which was demoulded after 24 h and cured in a standard curing room for 3, 7, and 28 days.

3.4. Test methods

Measure the water requirement of normal consistency and setting time according to the "Test Method of Cement Water Requirement of Normal Consistency, Setting Time and Stability (ISO method)" (GB/T 1346-2011). According to the "Determination Method of Mortar Fluidity (ISO Method)" (GB/T 17671-2021) to measure the mortar fluidity. The mechanical properties were tested, according to the "Test Method of Mortar Specimen Strength (ISO Method)" (GB/T 17671-2021). Mortar specimens were cured to 3, 7, and 28 d. The flexural strength was tested in a universal testing machine at a loading rate of 50 N/s, and the compressive strength at a loading rate of 2.4 kN/s. Transmission electron microscopy (TEM) was used to observe the appearance and characteristics of the reservoir sediment after mechanical activation. Ethanol was added to the reservoir sediment powder for ultrasonic shock, and the shock time was about 10 – 30 min. The glass capillary was used to absorb the evenly mixed powder and ethanol, and 2 – 3 drops were placed on the microgrid, and the samples were observed after waiting for more than 15 min for the ethanol to completely evaporate. The composition of reservoir sediment was measured by an X-ray fluorescence spectrometer (XRF). Powders through a 200 mesh sieve were tested with the lamination method. Process parameters were 30 tons of pressure, PVC plastic ring, and pressure maintenance for 30 seconds. X-ray diffraction (XRD) was used to analyze the mineral composition of the paste of the reservoir sediment-cement composite cementitious material. The sample was powdered through a 200 mesh sieve, and the test target anode was copper coupled with Cu Kα radiation (1.5406 Å). The scanning angle range was 5 – 80°, and the scanning speed was 5°/min. The micromorphology of cementitious material was observed by scanning electron microscopy (SEM).

4. RESULTS AND DISCUSSION

4.1. Effect of mechanical activation time on the particle size distribution of reservoir sediment

Through mechanical activation, the particle size of reservoir sediment can be reduced, and its surface energy can be increased, thus improving its reaction activity. Table 4 shows the particle size parameters and specific surface area of reservoir sediment at different mechanical activation times, which shows that the specific surface area of reservoir sediment increases gradually with the extension of mechanical activation time. When the mechanical activation time increased from 0 min to 45 min, the specific surface area of reservoir sediment increased from 146.51 $m^2 \cdot kg^{-1}$ to 612.56 $m^2 \cdot kg^{-1}$, the proportion of particle size of 0 – 40 µm increased from 78.91 % to 97.98 %, and the proportion of 0~10 µm increased from 36.4 % to 63.23 %, the proportion of particle size less than 3 µm increased from 6.36 % to 10.23 %. This is due to the strong mechanical force and the mutual collision between the particles during the high energy mechanical force ball milling. The reservoir sediment vitreous body undergoes partial depolymerization, and the large particles are broken into smaller particles, thus increasing its specific surface area.

Table 4. Particle size parameters and specific surface area of reservoir sediment at different mechanical activation time

Time, min	Volume, %				Specific surface area, $m^2 \cdot kg^{-1}$
	< 3 μm	0 – 10 μm	0 – 40 μm	> 40 μm	
0	6.36	36.40	78.91	21.09	146.51
15	7.61	42.20	90.45	9.55	449.79
30	8.58	44.87	92.42	7.58	511.28
45	10.23	63.23	97.98	2.02	612.56

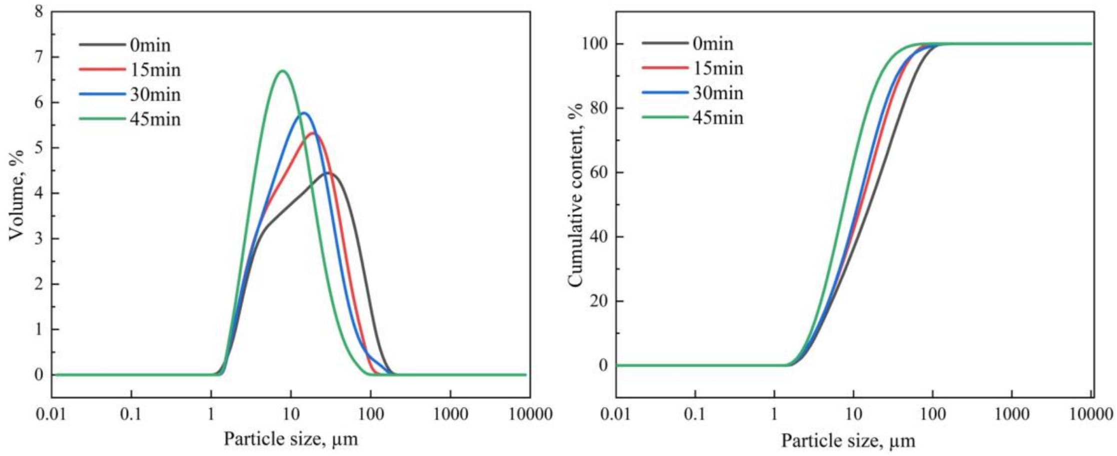


Fig. 2. Effect of mechanical activation time on particle distribution(a) and cumulative distribution(b) of reservoir sediment

Fig. 2 shows the effect of mechanical activation time on the particle size distribution and cumulative distribution of reservoir sediment. Fig. 2 a shows the particle size distribution of reservoir sediment at different mechanical activation time. It can also be found that the overall curve shifts to the left with the increase in grinding time, indicating that the particle size of reservoir sediment gradually moves in the direction of small particle size, and the proportion of fine particles gradually increases. Fig. 2 b shows the cumulative distribution of reservoir sediment particle size at different mechanical activation time. It can also be found that with the increase in grinding time, the curve as a whole also moves to the left, and the maximum particle size of reservoir sediment decreases.

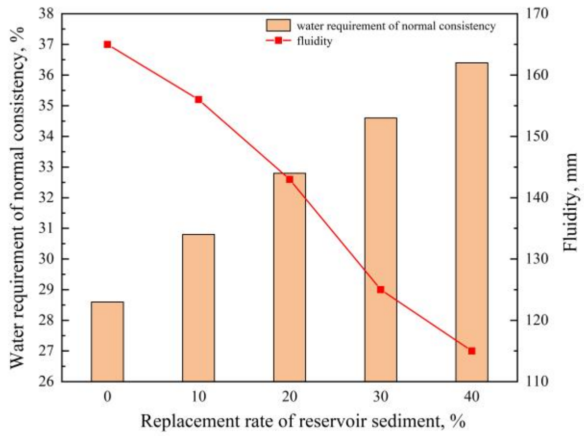


Fig. 3. Water requirement of normal consistency and fluidity of different reservoir sediment replacement rates

4.2. Performance analysis of reservoir sediment with different replacement rates

Fig. 3 shows fluidity and water requirement of normal consistency with different replacement rates of unmilled reservoir sediment. It shows that water requirement of normal consistency of 10 %, 20 %, 30 %, and 40 % reservoir sediment replacement rate increase by 2.2 %, 4.2 %, 6 %, and 7.8 %, respectively, compared with pure cement. As the replacement rate of unmilled reservoir sediment increases, its water requirement of normal consistency increases continuously. Because the mixing water has the following characteristics: 1) filling the interstices of cement particles, which is related to the particle gradation and particle shape of cement; 2) wetting the surface of cement particles, which is related to the particle shape and size of cement, i.e., the specific surface area of cement; 3) meeting the initial hydration of cement, which is mainly related to the mineral composition of cement; 4) the cement contains loose porous structure, it will absorb water into the pores inside [22].

From "General Silicate Cement" (GB/175-2020), it is known that the specific surface area of silicate cement is 300 – 400 $m^2 \cdot kg^{-1}$, while the specific surface area of unmilled reservoir sediment is 146.51 $m^2 \cdot kg^{-1}$. So the particle size of unmilled reservoir sediment is more significant than that of cement when it is mixed with cement, the pores become more prominent, resulting in the increase of water wrapped between the particles. Furthermore, the reservoir sediment is loose and porous, which will absorb water to the inside of the pores, increasing the water requirement of normal consistency. From the fluidity in Fig. 3, it can be seen that the fluidity is 156, 143, 125, and 115 mm when the replacement rate of unmilled reservoir sediment is 10 %, 20 %, 30 %, and 40 % respectively, which is 5.5 %, 13.3 %, 24.5 %, and 30.6 % lower than the fluidity of pure cement mortar. The fluidity of mortar decreases with the increase of reservoir sediment replacement rate. Because of the increase in unmilled reservoir sediment replacement rate, the water requirement of normal consistency is increasing. All the mortar is mixed according to the water-cement ratio of 0.5. So in the case of the water-cement ratio remaining unchanged, with the increase of reservoir sediment replacement rate, the mixed mortar will become more and more dry and thick, which leads to a decrease in its fluidity.

According to the water requirement of normal consistency that has been measured, the initial and final setting time of reservoir sediment replacement rate at 0 %, 10 %, 20 %, 30 %, and 40 % were measured. The test results are shown in Fig. 4 a. The initial and final setting time of pure cement were 271 and 345 min. The reservoir sediment-cement system's initial and final setting time were 446 and 519 min, respectively, when the reservoir sediment replacement rate is 40 %. As the proportion of unmilled reservoir sediment replacing cement increased, the reservoir sediment-cement system's initial and final setting time increased. Because of the low activity of unmilled reservoir sediment, the overall activity of cementitious material decreases with the increase of reservoir sediment replacement rate, which leads to slower hydration and hardening rate, so the setting time increases.

Fig. 4 b and c show the flexural and compressive strengths of unmilled reservoir sediment at various ages for different replacement rates. The 28 d flexural strength of unmilled reservoir sediment specimens decreased by 14.7 %, 26.71 %, 36.3 %, and 42.7 % when the replacement rate of unmilled reservoir sediment is 10 %, 20 %, 30 %, and 40 % compared with that of pure cement specimens. The 28d compressive strengths of the specimens were 38.46, 31.25, 24.3, and 20.62 MPa when the replacement rate of unmilled reservoir sediment is 10%, 20 %, 30 %, and 40 %, which were 14.7 %, 30.7 %, 46.1 %, and 54.3 % lower than those of the pure cement specimens. Compared with those pure cement specimens, the mechanical strength of all samples with reservoir sediment decreased at all curing ages. The flexural and compressive strengths continuously decreased, with the increased reservoir sediment replacement rate. Because the XRD spectrum of reservoir sediment in Fig. 1 shows that the main mineral component of reservoir sediment is quartz, a very stable crystal in terms of physical and chemical properties. Under the total amount of cementitious material remaining unchanged, the reservoir sediment is continuously mixed in. The cement is replaced by part of the non-reactive or slightly reactive reservoir sediment and diluted. The hydration products produced during the hydration reaction are decreasing, so the flexural and compressive strength is decreasing. To ensure that the performance of cement is not weakened as much as possible, more reservoir sediment can be substituted for cement, so the reservoir sediment replacement rate is fixed at 30 %.

4.3. Mechanical activation on reservoir sediment performance analysis

The effect of mechanical activation on reservoir sediment was further investigated based on a fixed replacement rate. Fig. 5 shows the effect of different mechanical activation time of reservoir sediment on mortar fluidity and water requirement of normal consistency.

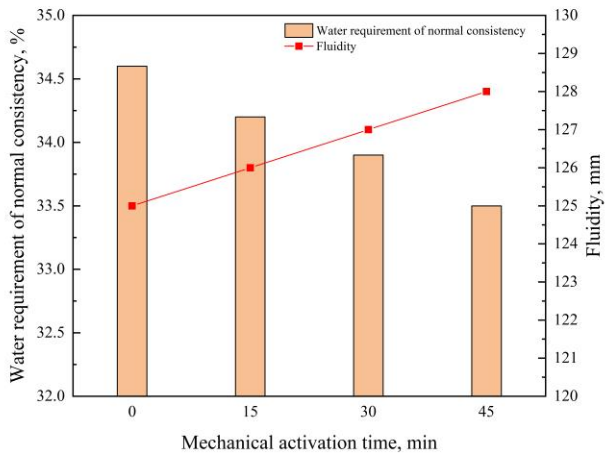


Fig. 5. Water requirement of normal consistency and fluidity of reservoir sediment at different mechanical activation time

It can be found that the water requirement of normal consistency of composite cementitious material decreased by 1.2 %, 2 %, and 3.2 % compared to pure cement for 15, 30, and 45 min mechanical activation time of reservoir sediment. Xie et al. [23] considered that when two types of cement of different finenesses are mixed, the blended cement is considered a binary system. This system has the closest packed volume, and its value depends on the diameter ratio of fine particle cement to coarse particle cement. The smaller the ratio, the greater the value of the system's compactness and the less water fills the interparticle spaces in its freshly mixed slurry.

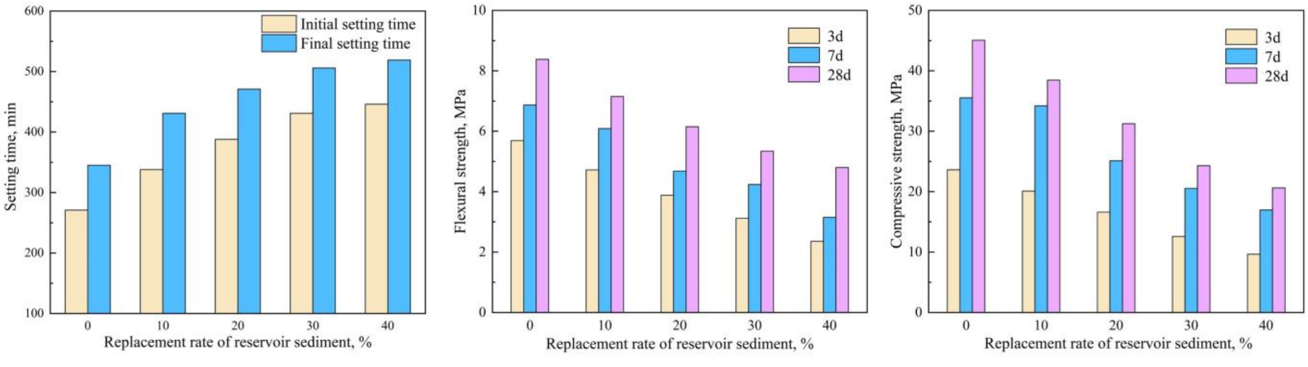


Fig. 4. a – setting time; b – flexural strength; c – compressive strength of reservoir sediment with different replacement rates of reservoir sediment

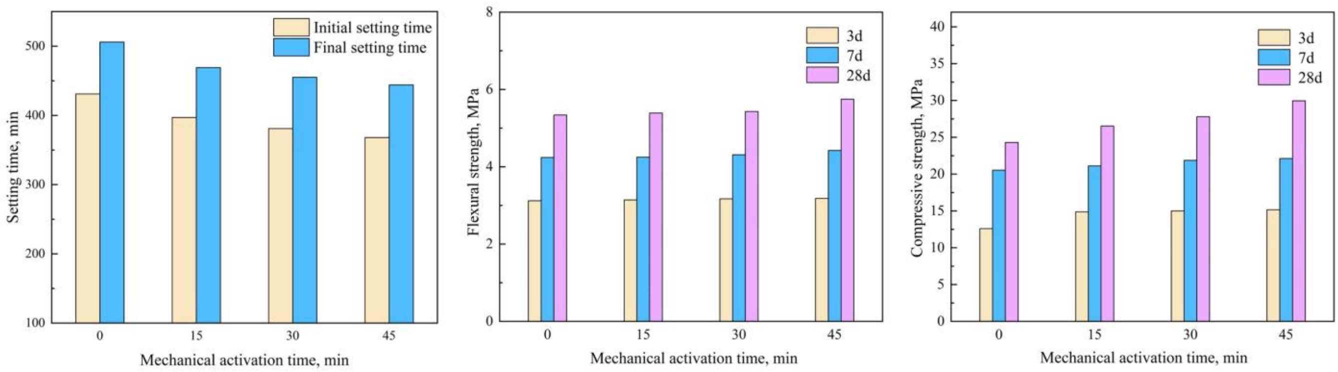
With the prolongation of mechanical activation time, the particle size of reservoir sediment becomes smaller and smaller, which acts as the space between large cement particles, the cement particle gradation is improved, and the space between cement particles is reduced. Thus, the water requirement of normal consistency is reduced. From the fluidity rate in Fig. 5, it can be seen that when the mechanical activation time of reservoir sediment is 15, 30, and 45 min, the fluidity of mortar is 125.5, 126, and 126.5 mm. The fluidity of mortar with mechanical activation of reservoir sediment for 45 min is 1.6 % higher than that without mechanical activation. With the increase of mechanical activation time, the fluidity is slowly increasing because the corresponding water requirement of normal consistency is slowly decreasing with the extension of mechanical activation time, and the fluidity of mortar increases under the same water-cement ratio.

Fig. 6 a shows the effect of different mechanical activation time on the setting time of reservoir sediment-cement slurry. It can be seen that the initial and final setting time of reservoir sediment-cement slurry decreases from 431 and 506 min to 368 and 444 min, respectively, when the reservoir sediment is 0 min to 45 min of mechanical activation. With the extension of mechanical activation time, reservoir sediment-cement slurry's initial and final setting time decreases. Because fineness is an essential factor affecting the setting time, the finer the particles, the larger the specific surface area, the larger the contact area with water, and the faster the rate of hydration and hardening. With the extension of mechanical activation time, the finer the particles of reservoir sediment, the larger the specific surface area, so the setting time of reservoir sediment-cement slurry is reduced.

Fig. 6 b and c show the effect of mechanical activation on the flexural and compressive strength of the reservoir sediment at various ages. It can be found that the 28 d flexural strength and compressive strength of 45 min of mechanical activation time were 5.75 and 29.96 MPa, respectively, which increased by 7.7 % and 23.3 % compared with those without mechanical activation. The flexural and compressive strengths of the specimens increased slowly with the extension of the mechanical activation time. From Table 3, it can be seen that the specific surface area of reservoir sediment increased with the increase of mechanical activation time. The finer the particle size, the larger the surface energy, the correspondingly larger the area of action providing chemical reactions, and the stronger the reaction capacity [24]. Fu et al. [25] showed that the particles with particle size less than 40 μm of the mixed material promote the improvement of cement strength, among which the particles with particle size less than 10 μm have the most significant promotion effect on cement strength, and the particles with particle size greater than 40 μm inhibit the improvement of cement strength. Mechanical activation can stimulate the activity of some SiO_2 and Al_2O_3 to participate in the hydration reaction, which leads to increased mechanical activation time. The increase in the mechanical activation time increased the mechanical properties of the specimens.

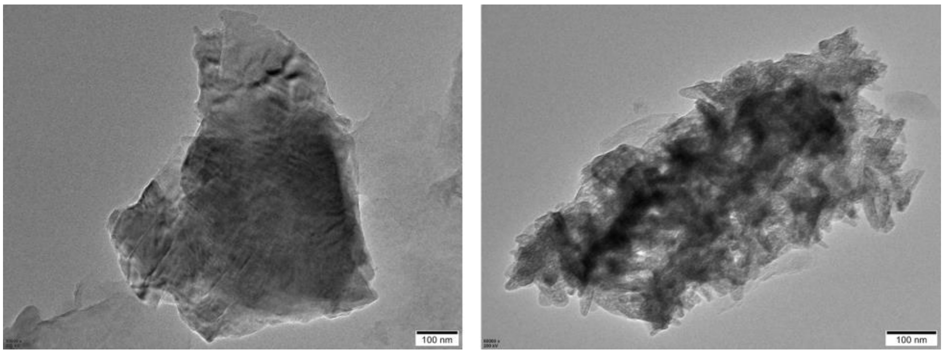
4.4. Microstructure analysis

Fig. 7 shows the TEM images of reservoir sediment powder. In Fig. 7 a, the unmilled reservoir sediment powder is dense and hard.



a b c

Fig. 6. a – setting time; b – flexural strength; c – compressive strength of reservoir sediment under different mechanical activation time



a b

Fig. 7. TEM images of reservoir sediment powder ((a) no mechanical activation, (b) mechanical activation for 45min)

In Fig. 7 b, after milling, the periphery of the reservoir sediment powder becomes transparent, which indicates that the powder becomes looser and cracks occur on the surface, which improves the activity of the reservoir sediment powder. Fig. 8 shows the X-ray diffraction pattern of the reservoir sediment-cement paste. The peak intensity can be used to indicate the relative content of the major crystalline phases in the sample. Fig. 8 shows that after 45 min of mechanical activation of the reservoir sediment, some of the SiO_2 activity is activated. The activated SiO_2 reacts with CH ($Ca(OH)_2$) to produce C-S-H(Calcium Silicate Hydrate), which increases the specimen's mechanical strength. It thus also leads to a decrease in the intensity of the peak of CH. The appearance of the $CaCO_3$ phase is due to the carbonation of calcium hydroxide and calcite in the raw material.

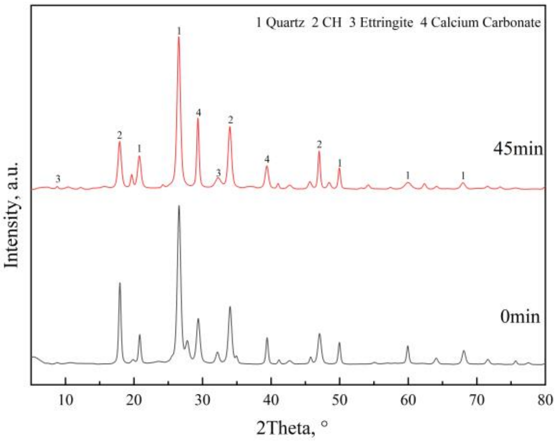


Fig. 8. X-ray diffraction pattern of reservoir sediment-cement paste

Fig. 9 shows the SEM images of 28 d of the reservoir sediment-cement cementitious material net slurry specimens; it can be found that the microstructure of the hydration products generated by the mechanically activated reservoir sediment net slurry is dense. Because mechanical activation can activate the activity of reservoir sediment, and then participate in the hydration reaction, promoting the formation of C-S-H gel and AFt (Ettringite). At the same time, it can be found that more C-S-H gel and unreacted reservoir sediment particles fill each other, reducing the porosity of the sample, which also contributes to the increase of the strength of the samples.

5. CONCLUSIONS

To make resource utilization of reservoir sediment, reservoir sediment was partially substituted for cement to prepare reservoir sediment-cement composite cementitious material. The effects of sediment replacement rate and mechanical activation time on the water requirement of normal consistency, setting time, mortar fluidity and mechanical properties of mortar specimens were analyzed. This study is helpful to determine the relationship between the mechanical strength of reservoir sediment-cement composite cementitious material and the test variables, provides theoretical guidance and technical support for the preparation of reservoir sediment-cement composite cementitious material by partially replacing cement with reservoir sediment. The main conclusions of this study are as follows:

1. Due to the low activity of reservoir sediment, with the increase of reservoir sediment replacement rate, the water requirement of normal consistency of composite cementitious material increases, the setting time prolongates, the mortar fluidity decreases, and the mechanical strength of mortar specimen decreases significantly.
2. After mechanical activation, the reservoir sediment activation increases, the water requirement of normal consistency of composite cementitious material decreases, the setting time is shortened, the setting time is shortened, the mortar fluidity increases, and the mechanical strength of the mortar specimen increases.
3. Microcosmic analysis showed that mechanical activation promoted the formation of C-S-H gel and AFt in reservoir sediment, and it was also found that more C-S-H gel and unreacted reservoir sediment particles filled each other, resulting in a denser microstructure.

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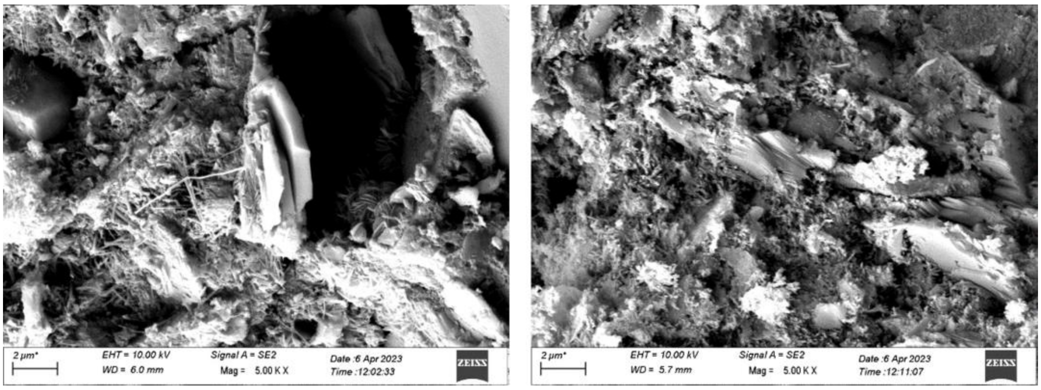

a b

Fig. 9. SEM images of the reservoir sediment-cement cementitious material net slurry sample for 28 d: a – mechanical activation for 0 min; b – mechanical activation for 45 min

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