Original Article

Modification and in-place mechanical characteristics research on cement mortar with fly ash and lime compound admixture in high chlorine environment

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\textbf{A B S T R A C T}

As industrial waste, the comprehensive utilization of fly ash involves many fields, among which it is widely used in cement mortar and concrete. As brine water is used in the preparation of filling slurry of Sanshandao Gold Mine, the chloride ions in the slurry have a great negative effect on the strength of the backfill. Therefore, the effects of fly ash and lime on the transport performance and the mechanical properties of cement mortar test blocks were studied by experiment. Based on fly ash XRD analysis, cement mortar block scanning electron microscope test (SEM) and fly ash with various amount and different way of adding test, the mechanism of improving the strength of the cement mortar test block produced by the fly ash and the best mixing amount of the fly ash were determined under the condition of brine water through experiment and theoretical research. Application of fly ash in undersea metal mine is a major breakthrough in the application of filling materials of metal mine undersea metal filling, having great effect on reducing the adverse effects on the strength of the filling body of bittern ions and improving the strength of the filling body.

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\section{Introduction}

As industrial waste, the comprehensive utilization of fly ash involves many fields, among which it is widely used in cement mortar and concrete. Fly ash can be used as a supplement or partial replacement for cement in the preparation of cement mortar and concrete, and can play a certain role in gelling.
Because of the SiO$_2$ and Al$_2$O$_3$ in fly ash, fly ash has pozzolanic activity, which is an important reason for the cementing effect of fly ash [1]. However, the performance of fly ash is slow relatively, and the strength of cement mortar and concrete mixed with fly ash mainly reflects in the long term strength and durability [2], did not work well in the early age.

Because the content of calcium in fly ash plays an important role in its pozzolanic activity and cementing characteristics, lime is mixed in cement mortar in order to stimulate the cementing characteristics of fly ash. Brine water was used in the experiment, and the bittern ions in brine water also had some chemical reaction with cementitious materials in cement mortar.

Brine water was got from Sanshandao Gold Mine, and as the first mining of metal mines [3], most of the deposits are located under the Bohai Sea. The oceans, which cover 71% of the earth’s surface, provide important and abundant resources for mankind [4].

With the further expansion of mining depth, the requirement of the strength of the backfilling body is higher to ensure the safety in mining and after mining [5].

However, the strength of backfilling body in Sanshandao Gold Mine is obviously lower than the theoretical value because of the influence of brine water [6]. After relevant experimental and theoretical research, it is necessary to take measures to improve the long-term performance of the backfilling body [7]. Fly ash and lime were selected after comprehensive analysis, and the strength changes of cement mortar with different dosages and addition methods were studied [8,9].

2. Experimental details

2.1. Materials

2.1.1. Chemical composition of brine water

As shown in Table 1, the chemical composition of brine water from Sanshandao Gold Mine was got by water ion determinator, the main anions are Cl$^-$, SO$_4^{2-}$, and the main cations are Mg$^2+$, Na$^+$, Ca$^{2+}$. The content of Cl$^-$ in the brine water is so high that will cause corrosion to the cement mortar.

2.1.2. Classified tailings

Tailings were mainly got from Sanshandao Gold Mine, there are two kinds of tailings (classified tailings and full-tailings) used in backfilling system [10], the classified tailings were used in this experiment.

![Fig. 1 - Particle size distribution curve of classified tailings in Sanshandao Gold Mine.](image)

Table 1 - Chemical composition of brine water in Sanshandao Gold Mine.

<table>
<thead>
<tr>
<th>Component</th>
<th>Na$^+$</th>
<th>Mg$^{2+}$</th>
<th>Ca$^{2+}$</th>
<th>K$^+$</th>
<th>Cl$^-$</th>
<th>SO$_4^{2-}$</th>
<th>HCO$_3^-$</th>
<th>CO$_3^{2-}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content (mg/L)</td>
<td>14,118</td>
<td>1440</td>
<td>4275</td>
<td>263</td>
<td>31,392</td>
<td>1981</td>
<td>62.8</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 2 - Particle size parameters and specific surface areas of classified tailings.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$d_{10}$ ($\mu$m)</th>
<th>$d_{50}$ ($\mu$m)</th>
<th>$d_{90}$ ($\mu$m)</th>
<th>$d_{ave}$ ($\mu$m)</th>
<th>Specific surface area ($m^2/cm^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classified tailings</td>
<td>12.119</td>
<td>84.590</td>
<td>173.408</td>
<td>83.44</td>
<td>0.246</td>
</tr>
</tbody>
</table>

The LMS-30 laser particle size distribution tester (measuring the particle size range from 0.1 to 1000 $\mu$m) was used to determine the particle size of the classified tailings got from Sanshandao Gold Mine. The particle size data and specific surface areas of classified tailings is shown in Table 2. In Table 2, $d_{10}$, $d_{50}$ and $d_{90}$ represent the particle size corresponding to the accumulated content (volume fraction) of the particle size curve at 10%, 50% and 90%, and $d_{ave}$ represents the weighted average particle size.

The particle size distribution curve was drawn according to the test data, as shown in Fig. 1.

2.1.3. Cement and fly ash

Portland cement in the experiment was also got from Sanshandao Gold Mine which used in backfilling slurry preparation process.

Fly ash is fine powder from the coal-fired power plant, which is the artificial material, has good activity, the powdery particles are mainly like ball in micro shape, either solid or hollow. The specific gravity of fly ash usually ranges from 2.1 to 3.0.

Chemical composition of fly ash was studied by Energy-dispersive X-ray spectroscopy (EDX) as shown in Table 3.

The EDX set-up was mainly used to analysis the elemental composition of the samples, the chemical composition of fly
ash was identified by the EDX set-up analysis in the SEM experiment. FEI Quanta 250 scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to analyze the cement mortar specimen.

The EDX system is an analysis tool to get the chemical characteristics by analyzing the X-ray wavelength and intensity of the element characteristic emitted by the sample. The element contained in the sample is determined according to the wavelength, and the relative content of the element is determined according to the intensity.

Composition of fly ash by X-ray diffraction: analysis results of test fly ash (Fig. 2) showed that the composition of fly ash with mullite, quartz, calcite and amorphous, it be summed up in two parts:

1. Amorphous phase (amorphous phase). Vitreous body was mainly composed of silicon aluminum, etc. The vitreous body stored high chemical energy through high-temperature calcination, which is the source of the activity of fly ash [11].

2. Crystalline phase. The crystalline phase was mainly composed of mullite, quartz, calcite, etc. [12,13]. Mullite in fly ash was not independent of the particle composition, larger size of mullite existed on surface of hollow micro beads and symbiosis with vitreous body, but smaller size of mullite existed in posterior wall beads and on the surface of porous bead glass, the activity of mullite was smaller compared with vitreous body.

The TTRIII multifunctional X-ray diffractometer (shown in Fig. 3) is the latest flagship X-ray analysis device in Japanese company, which integrates powder diffraction, stress and polar diagram analysis, small angle scattering, and thin film analysis. It can carry out phase identification and quantitative analysis of materials and atomic arrangement and occupancy analysis.

### Table 3 – Chemical composition of fly ash.

<table>
<thead>
<tr>
<th>Composition</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>Fe$_2$O$_3$</th>
<th>CaO</th>
<th>MgO</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
<th>SO$_3$</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content (%)</td>
<td>49.13</td>
<td>20.34</td>
<td>11.30</td>
<td>10.04</td>
<td>1.34</td>
<td>1.07</td>
<td>1.28</td>
<td>0.98</td>
<td>2.97</td>
</tr>
</tbody>
</table>

![Fig. 2 – X-ray diffraction pattern for fly ash.](image1)

![Fig. 3 – TTRIII multifunctional X-ray diffractometer.](image2)

#### 2.2. Method

##### 2.2.1. Test sample preparing and maintenance

In the test process, with reference of the GB/T17671-1999 “cement mortar strength test method” [14,15], the test samples were produced like this, putting cement mortar slurry into the mold after stirring, forming test pieces of 7.07 cm $\times$ 7.07 cm $\times$ 7.07 cm.

The test samples were maintaining in the environment of temperature of 20 °C and the relative humidity of 90%, released after 24 h, and continued maintain to the appropriate age, then tested the strength of the samples.

Determination of strength: take three identical specimens, test the compressive strength of 3 days, 7 days and 28 days, and take the average value as the test results.

In engineering application and laboratory experiment, slump test is the common method to determine slurry fluidity. The slump will fall due to self-weight, and the distance from the top of the slump cone to the top of the slump slurry is called slump. The slurry after uniform stirring is put into an inverted conical slump cone, the top is scraped flat after filling, and then the slump cone is lifted vertically upward. The slurry will expand around because of self-weight, the slump can be calculated by measuring the slurry height after slump. Slump is an important parameter to characterize the fluidity of cement mortar. The slump level directly reflects the flow state and frictional resistance of cement mortar, and the larger the slump, the greater the fluidity of the slurry. However, if the slump is too large, the pipe will be blocked because of water segregation, if the slump is too small, the pipe resistance will be large. When slump is in the range of 23–27.5 cm, it can basically satisfy the requirement of self-flow transportation in mine backfilling.

##### 2.2.2. Test scheme design

Different specimens were making according to the design of test, respectively for various fly ash content, activator of lime
dosage, different concentration of slurry, and various cement sand ratios.

The content of fly ash is defined as the mass ratio of fly ash, and cementitious material:

\[ \text{Fly ash content} = \frac{F}{C + F} \times 100\% \]

C – cement content in each m³ concrete (kg); F – fly ash content per m³ concrete (kg).

According to the design quality, the filling materials were taken in the mixer, and then the mixture was put into the standard triple steel test mold of 7.07 cm × 7.07 cm × 7.07 cm. In order to facilitate the removal, it has been in the mold with oil [14,15]. The mold filled with slurry was dehydrated and then scraped. The mold was released after 24 h as shown in Fig. 4.

Cement mortar samples were put in the YH-40B type standard constant temperature curing box, and then using digital hydraulic pressure testing machine for uniaxial compressive strength test after maintain to the appropriate age, as is shown in Fig. 5. The experimental results were obtained the data obtained after the conversion process.

Calculation of the compressive strength of cement mortar samples (accurate to 0.01 MPa):

\[ \sigma_c = \frac{P}{S} \]

\( \sigma_c \) – compressive strength of cubic specimen (MPa); \( P \) – destructive load (N); \( S \) – pressure area (mm²).

In the experiment, the commonly used slump cone was selected as the main measuring instrument. The selected slump cone was as shown in Fig. 6, high 300 mm, the upper section diameter of 100 mm, the lower section diameter of 200 mm without roof, no lid tin slump cone.

2.3. Testing program

Making cement mortar samples respectively with Sanshandao brine water and pure water, sand ratio is 1:6 and 1:10, slurry concentration is 72%, the raw materials was used in the experiment. The curing age was 60d, 120d, 210d, respectively.

Making cement mortar samples respectively with Sanshandao brine water and tap water, sand ratios were 1:5, 1:10 and 1:16, the contents of fly ash were 5%, 10%, 15% and 20% respectively, the contents of lime were 1.5%, 3%, 4% and 5%, respectively, the slurry concentrations were 65%, 70%, 72%, orthogonal combination, weighing different components corresponding to the quality, putting into the standard triple steel test mold of 7.07 cm × 7.07 cm × 7.07 cm through stirring.

Making cement mortar samples with tap water, sand ratios were 1:10, the contents of fly ash was 5%, the contents of lime was 1%, the slurry concentrations were 65%, 70%, and the prepared slurry is put into the slump cone according to the prescribed method, tamped and scraped flat. The slump cone is lifted vertically and moved to the side. And the shovel is smoothed, and the tube is lifted up to the side vertically, and the slurry mixture is slumped due to self-weight. The height between the upper section of the slump cone and the highest point of the slump, and the spread diameter of the slurry are expressed in centimeters and are indicated in sequence.

First, well-stirred cement mortar slurry is filled in the slump cone to remove the air inside the slump cone, avoid air bubble inclusion in the slurry. And if necessary, hit the steel plate of the slump cone bottom when necessary, let the slurry
3. Results and discussion

3.1. Test results and analysis of slump of cement mortar

The slump state pictures of cement mortar were obtained by experiment as shown in Fig. 7.

The slump state pictures of cement mortar show that the slurry with fly ash and lime has better water retention and workability, while the slurry without fly ash and lime has slight segregation and bleeding.

Table 4 shows the test results for the slump of cement mortars with different slurry concentrations, with and without the addition of fly ash and lime.

The slump of the slurry without the addition of fly ash and lime was larger as shown in Table 3, but the slurry had segregation phenomenon from Fig. 3. So the cohesiveness and water retention of the cement mortar slurry was also important even though the slump meets the requirements. The slump of cement mortar slurry with fly ash and lime was slightly smaller than that without fly ash and lime. Fly ash and lime have good water retention due to finer particles, which reduces the flow of free water in the slurry. When the slump is 23–27.5 cm, it can basically meet the requirement of self-flow transportation in the filling process of mine. Therefore, the fly ash and lime has no adverse effect on the self-flow transportation of slurry. The greater the slump, the better the fluidity of the slurry, but the slump was too large and the workability would be poor, and it was easy to cause segregation and bleeding.

3.2. Analysis of test data of the compressive strength of cement mortar test samples with fly ash

3.2.1. Influence of fly ash content on strength of cement mortar test samples

In the preparation process of cement mortar, the fly ash content used in each experiment was 0%, 5%, 10%, 15%, 20%, respectively. The cement sand ratio was 1:5, and the slurry
concentration of cement mortar was 70%. Brine water and tap water were used to make cement mortar of different groups. The relationship between the uniaxial compressive strength and the fly ash content of the cement mortar was shown in Fig. 8.

![Diagram](image)

**Fig. 8 - The curve diagram of relationship between the compressive strength of the specimen and the amount of fly ash content.**

However, when the fly ash content continued to increase, the uniaxial compressive strength of cement mortar showed a decreasing trend with the increase of fly ash content. The analysis suggests that the reason is that the activity of fly ash under the excitation of lime and brine was limited and the excessive use of fly ash had a certain influence on the strength growth and cementing characteristics of cement.

**Fig. 9** shows the relationship of the uniaxial compressive strength of cement mortar prepared with brine water or tap water over different curing ages as the fly ash content increases. The uniaxial compressive strength of cement mortar with fly ash prepared by brine water was significantly higher than that of cement mortar with fly ash prepared with tap water. It can be concluded that sulfate and chloride salts in brine water can be used to stimulate the pozzolanic activity of fly ash.

The reaction of CaO in cement mortar materials and water form Ca(OH)$_2$, SO$_4^{2-}$ and Na$^+$ in the brine water react with Ca(OH)$_2$ to form NaOH and CaSO$_4$, the fly ash has been destroyed in this period. And SO$_4^{2-}$ reacted with the related components of fly ash in the presence of Ca$^{2+}$ to produce calcium hydration sulfoaluminate, the reaction of Ca$^{2+}$ with SiO$_2$, Al$_2$O$_3$ played the gelling properties of fly ash further. NaCl and CaCl$_2$ in brine water also had a positive effect on activating fly ash, which Na(OH) formed by NaCl increased ability of vitreous body structure, and Ca$^{2+}$ and Cl$^-$ reacted with the activity of Al$_2$O$_3$ in fly ash to produce hydration chloroytite aluminite. However, the strength of the cement mortar test block with 20% fly ash after three days and seven days had a defect error with this rule. The uniaxial compressive strength of cement mortar blocks prepared by brine water and tap water increased with the increase of curing age.

From **Fig. 10**, it can be seen from the figure that the amount of hydrated calcium silicate (C–S–H) and part of ettringite (AFt) in the cement mortar sample with brine water was slightly different from that of tap water, and ettringite (AFt) was not found in the hydration product of the sample with brine water. However, the main products of cement hydration calcium silicate (C–S–H) difference are obvious. Therefore, the cement hydration products that affect the compressive strength are mainly hydrated calcium silicate (C–S–H).

The high content of sulfate and magnesium salt of brine water were harmful to the uniaxial compressive strength ascension of the cement mortar blocks. The reaction product of SO$_4^{2-}$ and the chemical composition of cement have
crystallization expansion ability, so that the increasing of cement mortar block stress was harmful to cement mortar strength. Ettringite was harmful for long-term strength development of the cement mortar blocks, which was formed easily in the presence of sulfate. And $\text{Mg}^{2+}$ would break down the cementations’ materials which had the characteristics in gel material, $\text{Mg(OH)}_2$ and $\text{SiO}_2\cdot\text{H}_2\text{O}$ and other substances without gel characteristics were produced. But it could be seen from the results of the chemical analysis of the brine water, the concentrations of $\text{SO}_4^{2-}$ and $\text{Mg}^{2+}$ were 1981 mg/L and 1440 mg/L respectively, and the content was relatively low. $\text{NaCl}$ and $\text{CaCl}_2$ in the brine water are the main components of chloride early strength agent of Portland cement concrete. The concentrations of $\text{Na}^+$, $\text{Ca}^{2+}$ and $\text{Cl}^-$ in the brine water were as high as 14118 mg/L, 4275 mg/L and 31392 mg/L, which improved early strength of the cement mortar block from the test results definitely.

### 3.2.2. Effect of lime dosage of fly ash activator on the strength of the cement mortar test block

In order to study the effect of lime on uniaxial compressive strength of cement mortar, the experiment was designed to add 1.5%, 3%, 4% and 5% lime, the cement sand ratio was 1:5, the amount of fly ash was 15%, the slurry concentration of cement mortar was 70%, and the mixing water for cement mortar was brine water or tap water, respectively. Based on the experimental data, the relationship between compressive strength and lime content of cement mortar test block is drawn as shown in Fig. 7.

Fig. 11 shows that the uniaxial compressive strength of the cement mortar increased with the increase of the lime content. It can be concluded that the addition of lime can play a good “crystal nucleation effect” and accelerate the hydration reaction of cement. The hydration reaction of cement, when $C_3S$ in cement begins to hydrate, released a large amount of $\text{Ca}^{2+}$. Due to the adsorption of $\text{CaCO}_3$ on $\text{Ca}^{2+}$, the concentration of $\text{Ca}^{2+}$ around $C_3S$ decreases, which accelerates the hydration of $C_3S$.

Due to the addition of fly ash in the preparation of cement mortar, under the stimulation of lime, $\text{Ca(OH)}_2$ can produced by the reaction of water and lime which was the volcano activity of fly ash activator, and Si–O and Al–O of the surface of fly ash particles bond was broken in the alkaline environment, then the free unsaturated chemical bonds was formed and the active $\text{SiO}_2$, $\text{Al}_2\text{O}_3$ was stripped. The reaction of $\text{Ca(OH)}_2$ and active substances $\text{SiO}_2$, $\text{Al}_2\text{O}_3$ of fly ash produced calcium silicate hydrate formation (C–S–H) and calcium aluminate hydrate formation (C–A–H) with a certain intensity, thus uniaxial compressive strength of cement mortar specimen increased.

At the same time, the fine particles of lime can fill in the cement hydration products and play a filling role to improve its compactness. However, lime cannot produce C–S–H with gelling characteristics after hydration at the later stage of cement hydration, so it has little beneficial effect at the later stage of hydration reaction.

In the early stage of cement hydration, fly ash has little promotion effect, but its pozzolanic activity has certain contribution to the later strength of cement mortar. Therefore, the complex mixing of lime and fly ash can achieve the “superimposition effect” and promote the increase of compressive strength of cement mortar.

A series of chemical reactions take place in water between lime and fly ash with pozzolanic activity ingredients $\text{SiO}_2$, $\text{Al}_2\text{O}_3$ and $\text{Fe}_2\text{O}_3$, forming a series of materials such as calcium silicate hydrate and calcium aluminate hydrate with gelling properties. The chemical reaction formula is as follows:

$$\text{Ca(OH)}_2 + \text{SiO}_2 + \text{H}_2\text{O} \rightarrow \text{CaO} \cdot \text{SiO}_2 \cdot n\text{H}_2\text{O} (\text{C–S–H, Gel})$$

Fig. 10 – SEM image cement mortar test samples of the fly ash produced with brine water (a) and which with tap water (b).

Fig. 11 – Diagram of the uniaxial compressive strength of the test block with the lime content.
Ca(OH)$_2$ + Al$_2$O$_3$ + H$_2$O $\rightarrow$ CaO·Al$_2$O$_3$·nH$_2$O(C–A–H, Fibrous)

But the uniaxial compressive strength of cement mortar with lime prepared by brine water had decreasing trend, because of the certain free Ca$^{2+}$ and Cl$^-$ in the brine water, calcium chloride hydration reacted with C$_2$A of cement with lime like is: CaCl$_2$ + C$_2$A + 16H$_2$O = C$_3$A - CaCl$_2$ - 16H$_2$O. Therefore, fly ash activator content was not too much for cement mortar test block produced with brine water, could be around 1%.

3.2.3. Analysis of other factors influencing the uniaxial compressive strength of cement mortar test block

The concentration of cement mortar slurry had certain effect on uniaxial compressive strength of the cement mortar test block, in order to the analysis on variation of cement mortar blocks uniaxial compressive strength increased with the concentration of slurry with fly ash, test scheme of preparing cement mortar test samples with slurry concentration of 65%, 70%, 72%, cement sand ratio 1:5, 5% of fly ash content and lime content, test water of tap water and brine water respectively, the uniaxial compressive strength block histogram of cement mortar test samples with different slurry concentrations was plotted as Fig. 9.

As can be seen from Fig. 12, the uniaxial compressive strength of the cement mortar test block using tap water and brine water relatively change consistently by the concentration of the slurry, the uniaxial compressive strength was higher with the higher concentration of the slurry. However, it could be found through comparative analyses that the single axial compressive strength increasing of the cement mortar specimen with tap water were smaller than that of the brine water. With the slurry concentration prepared with brine water varied from 65% to 70%, the compressive strength of cement mortar test blocks was doubled in every curing period. Therefore, the concentration of cement mortar slurry did not less than 70% in Sanshandao Gold Mine, field filling stations to the gob area of, and it was necessary to further enhance the strength of cement mortar slurry concentration in order to improve the cement mortar body of each stage.

![Fig. 12 – Uniaxial compressive strength block histogram of cement mortar test samples with different slurry concentrations.](image1)

![Fig. 13 – Uniaxial compressive strength comparison chart of cement mortar test samples with different cement sand ratio.](image2)

In order to the change rule analysis of uniaxial compressive strength of fly ash cement mortar test specimens with different cement sand ratio, the cement mortar test blocks were produced with slurry concentration 70%, of fly ash and lime dosage was 5%, cement sand ratio were 1:5, 1:10, 1:16, respectively, and testing test blocks with water tap water and brine water.

According to the experimental data, uniaxial compressive strength comparison chart of cement mortar test samples with different cement sand ratio curing different period was shown in Fig. 10.

It could be indicated from Fig. 13 that the uniaxial compressive strength of cement mortar test blocks around 20% higher with various of the curing period for all cement mortar test blocks with different cement sand ratio, but the uniaxial compressive strength of cement mortar test blocks was three times with the various cement content. Therefore, experimental research could be further designed about the relationship of compressive strength between cement mortar test blocks of high cement sand ratio with fly ash and which of low cement sand ratio without fly ash. For the field cement mortar, the increase of the amount of cementing material was obvious, increased the cementing material content improve the compressive strength of cement mortar body largely, and the use of fly ash was beneficial to the control of cement mortar cost.

3.2.4. Effect of fly ash on the compressive strength of cement mortar test block by the method of equivalent substitution and addition of fly ash

There were three kinds of ash fly adding in the process of cement mortar blocks making, equivalent replacement method, excessive replacement method and external additive, respectively. The design schemes in this paper were mainly equivalent replacement method and external additive. The former indicated that the fly ash replace the cementations' material, the latter indicated that the fly ash replace the tailings.

Excessive substitution for use of fly ash to replace the cementations’ material of cement mortar cement and tailings, replacing part of cement to decrease cost, another part to
replace the tailings to improve the effect of the cement mortar block strength for cementations’ material and brine water.

In order to analyze the effect of fly ash and external cementations’ material on the uniaxial compressive strength of cement mortar block, the design of the slurry concentration was 70%, cement sand ratio was 1:5 and 1:10 respectively for the production of two groups’ tests, using tap water and brine water, fly ash and lime substitute and external additive for curing period three days. According to the uniaxial compressive strength test results of cement mortar specimen, the comparison diagram of the uniaxial compressive strength of the fly ash equivalent replacement of cement and fly ash with the and fly ash external additive is shown in Fig. 10.

From Fig. 14, fly ash addition method had obvious effect on uniaxial compressive strength of cement mortar specimen. The uniaxial compressive strength of cement mortar specimen with fly ash and lime external additive was higher than which with fly ash and lime equivalent replacement. And the former cement mortar specimen with the cement sand ratio was 1:10, the cement mortar compressive strength growth was 2.5 times.

4. Conclusion

(1) The amount of fly ash added was 5% and the amount of lime added was 1% in mass, the slump of different concentrations of slurry had a certain decrease. But the slump meets the requirements of mine self-flow transportation based on the slump data. The addition of fly ash and lime improved the water retention and workability of the slurry from the test pictures, and was beneficial for preventing the separation and bleeding of the slurry. (2) The uniaxial compressive strength of tailings cement mortar test blocks of different curing period produced with brine water or tap water was improved to some extent when the amount of fly ash was 5%. From the experiment, it was concluded that the uniaxial compressive strength of the filled specimens with different content of fly ash was significantly higher than that of the tap water.

(3) For the cement mortar test block produced with brine water, lime activator of fly ash dosage of 1% was appropriate, it’s useless for the long-term growth of uniaxial compressive strength of cement mortar specimen produced with high content of lime. But for the cement mortar test specimen prepared with tap water, the higher the content, the higher the uniaxial compressive strength of the cement mortar test block within a reasonable range of 5% in the amount of lime content.

(4) For the uniaxial compressive strength of cement mortar specimen produced with fly ash replacing cement or additive, the compressive strength showed not much different when the cement sand ratio was high, but the latter compressive strength was two times higher than the cement mortar blocks produced with fly ash replacing cement when the cement sand ratio was low.

(5) The uniaxial compressive strength of cement mortar specimen produced with brine water increased significantly greater than which made of tap water when fly ash was added. The sulfate and chloride in brine water had a certain role for the excitation of fly ash volcano ash activity. At the same time, the concentration of Cl− decreased after the chemical reaction of the fly ash and the chloride, and it was effect for the long-term strength of the cement mortar body was reduced.

Conflicts of interest
The authors report no conflicts of interest.

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