The Pharma Innovation Journal 2018; 7(9): 187-191

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2018; 7(9): 187-191

www.thepharmajournal.com
Received: 07-07-2018
Accepted: 09-08-2018

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Improvement of suspension property and compressive strength of clay grouting materials by using various raw material

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Abstract
The aim of this research article is show how the suspension property and compressive strength of clay grouting materials of coal mine gob is improved by using various raw materials in correct composition and ratio. Based on the ratio of raw materials (water-solid ratio) effective results can be drawn which provides the increasing and decreasing property of drainage rate and concretion rate. The experimental result shows that when water-solid ratio is increased, the drainage rate of clay grout is increased but concretion rate is decreased. The drainage rate of clay and compressive strength both are increased by adding cement and lime. The concretion rate is also shortened by adding cement and lime. When lime dosage is 6% and cement dosage is 12%, compressive strength of clay- cement-lime grouts reaches the peak and the compressive strength is well developed.

Keywords: Compressive strength, concretion rate, drainage rate, grouting materials, water-solid ratio, raw materials

Introduction
China advanced the backfill technology which enhances remission control and other aspects of sustainable mining development. [1] Albeit, coal resource has finite extent. Coal is valued for its energy content and since the 1880s has been widely used to generated electricity. Present at hand, clay grouting, fly ash grouting and chemical grouting have been belonged to grouting materials of gob. Low-price clay grouting are good in heat absorbing, temperature lowering and coal wrapping as well as disregarded for limited coagul ability, poor stability and heavy land resources consumed. The main reason for the formation of activity of fly ash is high temperature, but have disadvantages of weak suspended and poor water retention [2]. For microscopic pore use of chemical grouting is known which has low-viscosity as advantage. Furthermore, the environmental pollution and high-price are continued still [3]. The characteristics of grouting materials of gob are wide range of sources, fluidity, minimum bleeding and segregation, low cost, good controllability and little pollution to nature [4]. For those characteristics, development of drainage rate and concreting rate with compressive strength by using perfect water-solid ratio for clay grouting material was researched. Appropriate cement and lime dosage enhance the quality of the clay-cement-lime grouts.

Experimental
Chemical composition of cement, clay and lime are described in Table 1.

Table 1: Chemical composition of cement, clay and lime (%)

Composition	SiO_2	Fe_2O_3	Al_2O_3	Ca O	Mg O	SO_3	K_2O	Na_2O
Cement	20.29	3.69	4.46	63.72	1.47	1.59	0.68	0.21
Clay	66.05	6.04	12.84	1.43	1.06	0.23	1.59	0.90
Lime	0.37	1.21	92.5	1.23	0.45	3.12	-	-

At first, the grout is prepared by mixing the raw materials and the provisional tests are done which are described below.

Suspension test: The prepared grout was poured into a graduated cylinder (250 ml), and wrote down the initial scale as H. Then started the timer and writing down the scale hx at the time of 3min, 5min, 10min, 20min, 30min, 40min, 50min and 1h. Then the volume of the concretion bodies was measured and wrote down the scale h_{24} after 24h. The drainage rate of grouts was calculated by the following formula------

$$D_x = \frac{H - h_x}{H} \times 100\% \text{ ------- (1)}$$

And the concretion rate of grout was calculated by the following formula-------

$$C_x = \frac{h_{24}}{H} \times 100\% \text{ -------- (2)}$$

Where D_x is the drainage rate of grouts, C_x is the concretion rate of grout

Strength test: This test is performed to check the compressive strength. In strength test 40mm×40mm×40mm specimens were prepared and the water-solid ratio is 0.55. Specimens were striped when they were conservation in the specified conditions (temperature- 20 ±5℃, 75%humidity) about 24h. Then compressive strength of specimens was determined by hydraulic testing machine at 2mm/min load rate in the prescribed age.

Results and Discussion

Drainage rate and concretion rate of clay grout are affected by lime dosage

When the lime dosage is increased, the drainage rate of clay grout is increased markedly; the concretion rate is increased and then decreased. The drainage rate of clay grout is increased with time. For 3% and 6% lime dosage, the drainage rate of clay grout is less than others. For 6% lime dosage, the concretion rate of clay grout is the highest. The effect of lime dosage on the drainage rate and concretion rate of clay grout is shown in the fig. 1 and 2

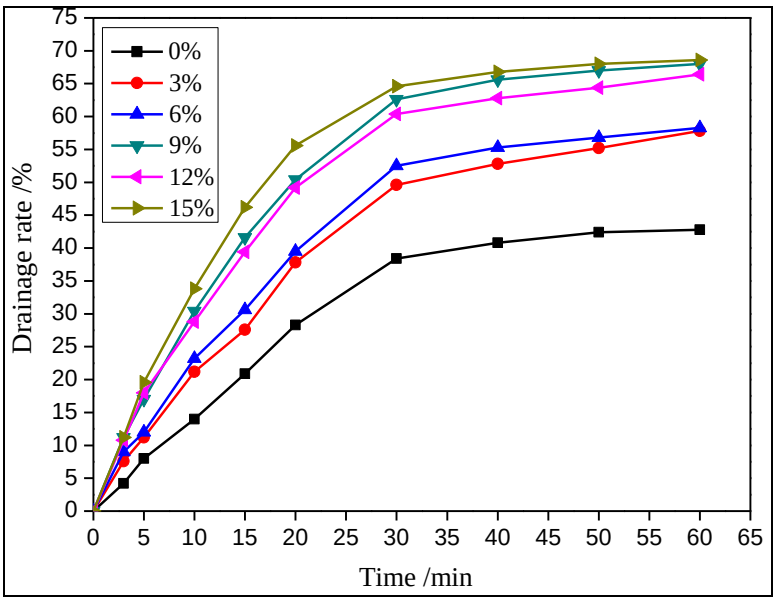

Fig 1: Influence of lime dosage on drainage rate of clay grout

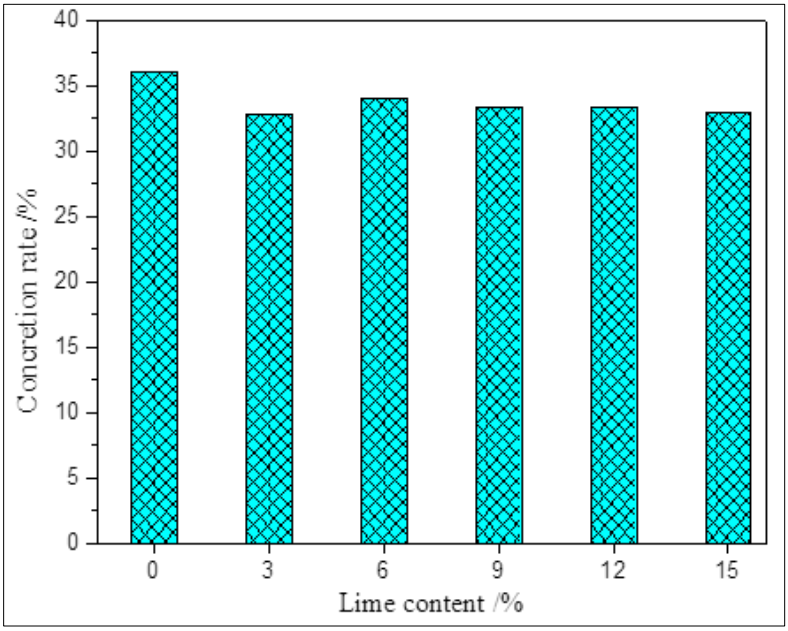

Fig 2: Influence of lime dosage on concretion rate of clay grout

Due to the ion-exchanges reaction (K^+ (Na^+) + Ca^{2+}→ (Ca^{2+}) + $2K^+$ (Na^+)) between the lime and clay, the drainage rate of clay grout is reduced. When the lime dosage is increased, the drainage rate of clay grout is also increased and the water film is ruptured. Due to the ion-exchanges reaction and the aggregation effect between the lime and clay the grouts becomes gel gradually and form "grid structure" [5]. At last, this "grid structure" is broken and the concretion rate of grouts is shortened with the lime dosage increasing. For 6% lime content, the drainage rate and concretion rate of clay grout are all good.

Drainage rate and concretion rate of clay grout affected by cement dosage

When the dosage of cement is increased, the drainage rate of clay grout is increased but concretion rate of clay grout is decreased. The drainage rate of clay grout is increased with time. The "Clay cement
ball" is formed due to the electric charge effect between the cement and clay [6]. The drainage rate and concretion rate of clay grout is changed by the ion-exchanges reaction and hydration. The effect of cement dosage on the drainage rate and concretion rate of clay grout is shown in the fig.3 and 4.

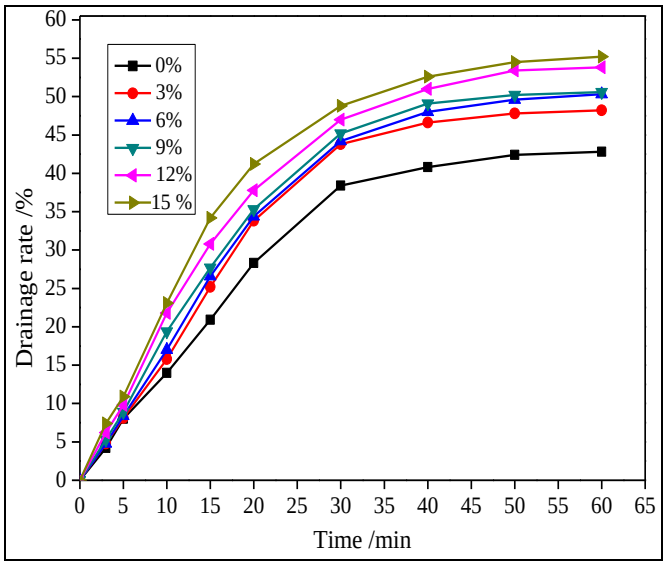

Fig 3: Influence of cement dosage on drainage rate of clay grout

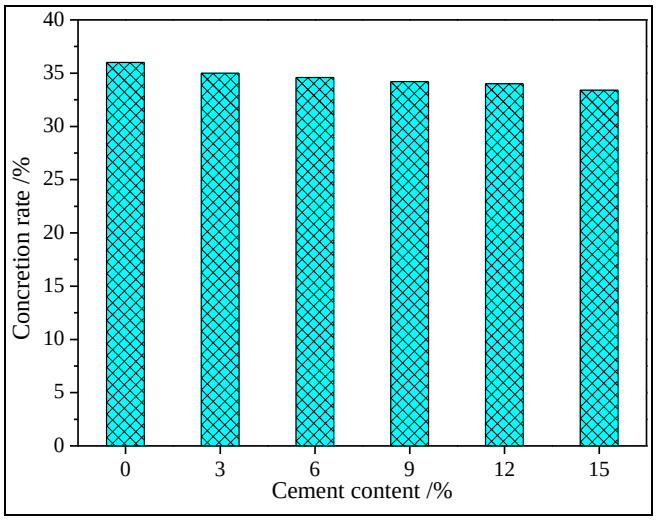

Fig 4: Influence of cement dosage on concretion rate of clay grout

Effect of water-solid ratio on the drainage rate and concretion rate of clay grout

It is seen in Figures 5 and 6, that when the water-solid ratio is increased, the drainage rate of clay grout is improved but the concretion rate is decreased. The drainage rate of clay grout is improved with time. In conclusion, water-solid ratio has a great influence of drainage rate and concretion rate for clay grouting material.

Compressive strength of clay grout affected by cement dosage

Fig. 7 shows that, when dosage of the cement is increased, the compressive strength of clay grout is improved. It shows that dosage of cement has a great effect on strength of clay grout. Hydration reaction occurs after the cement is added to the clay grout and produces hydrated calcium silicate(C-S-H), hydrated calcium aluminates (C-A-H), amorphous gel, and Ca (OH) $_2$. The grouts becomes gel gradually until it will be hardened [6-8]. The possible chemical reactions are the following

$$SiO_2 + 3Ca(OH)_2 + nH_2O_y \rightarrow 3CaO \cdot SiO_2 \cdot (n+3)H_2O_y \quad \text{---------- (3)}$$

$$3Ca(OH)_2 + Al_2O_3 + nH_2O_y \rightarrow 3CaO \cdot Al_2O_3 \cdot (n+3)H_2O_y \quad \text{---------- (4)}$$

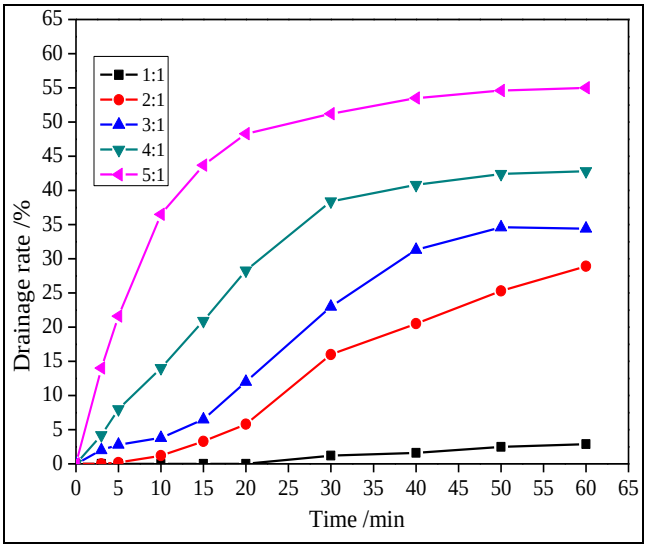

Fig 5: Influence of water-solid ratio on the drainage rate of clay grout

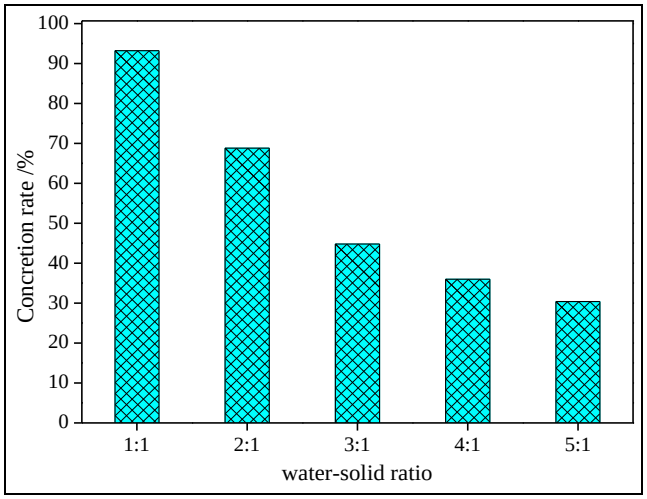

Fig 6: Influence of water-solid ratio on the concretion rate of clay grout

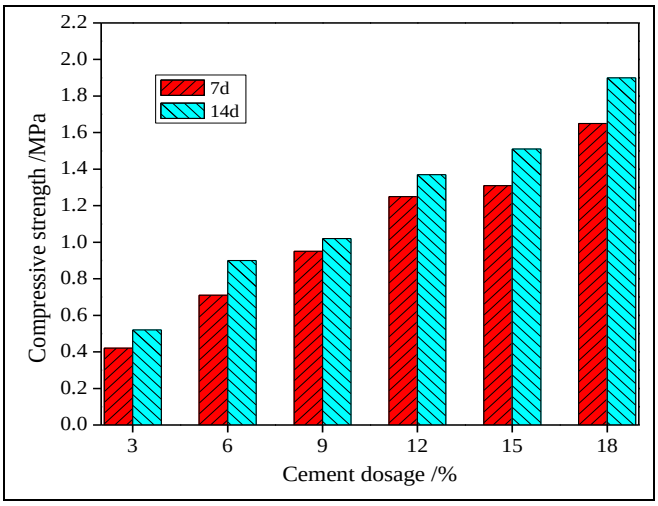

Fig 7: Influence of cement dosage on the compressive strength of clay grouts

Compressive strength of clay-cement grouts affected by lime dosage

Fig. 8 shows that, maintaining cement dosage (12%) unchanged when the lime is added; the compressive strength of clay-cement grouts is improved. The compressive strength of grouts is increased and then decreased with the lime dosage increasing. Meanwhile the compressive strength of grouts reaches to the peak when the lime dosage is 6%. The physical and chemical reactions between lime and grout are happened, such as hydration, ion-exchange and aggregation effect, hard coagulation reaction and carbonation. The possible chemical reactions are the following;

$$CaO + H_2O \rightarrow Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^- \text{-------- (5)}$$

$$SiO_2 + 3Ca(OH)_2 + nH_2O_y \rightarrow 3CaO \cdot SiO_2 \cdot (n+3)H_2O_y \text{-------- (6)}$$

$$3Ca(OH)_2 + Al_2O_3 + nH_2O_y \rightarrow 3CaO \cdot Al_2O_3 \cdot (n+3)H_2O_y \text{ ------- (7)}$$

$$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + mCa(OH)_2 + nH_2O \rightarrow mCaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot (n+2)H_2O \text{------ (8)}$$

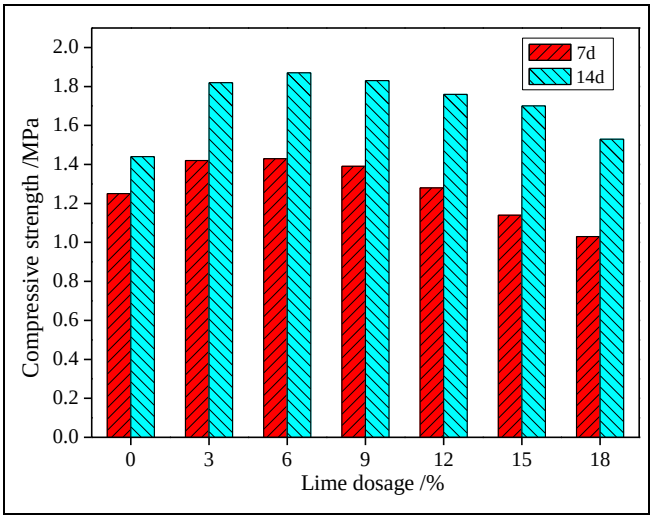

Fig 8: Influence of lime dosage on the compressive strength of clay-cement grouts

Compressive strength of clay-lime grouts affected by cement dosage

It is seen in Fig 9 and 10 that maintaining lime dosage (6% and 12%) unchanged when the cement is added, the compressive strength of clay-lime grouts is improved markedly.

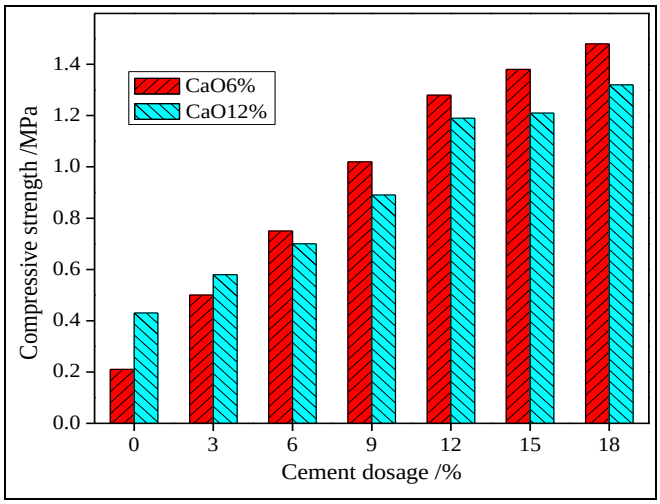

Fig 9: Influence of cement dosage on the compressive strength of clay-lime grouts (7d)

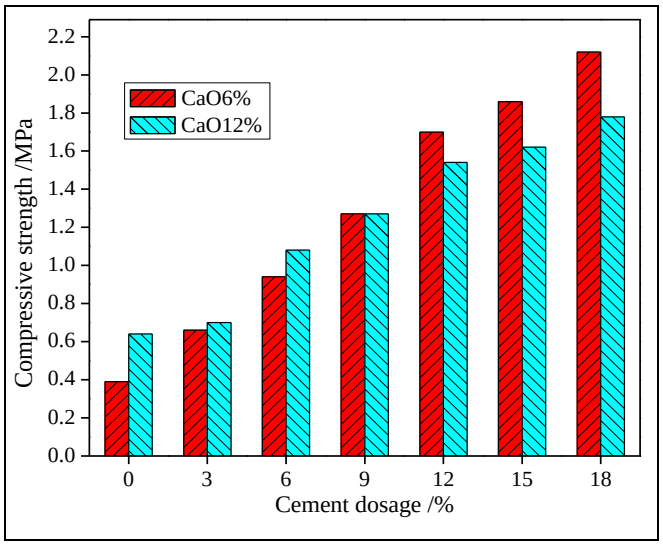

Fig 10: Influence of cement dosage on the compressive strength of clay-lime grouts (14d)

When the dosage of cement is 12%, the dosage of 6% lime dosage has higher compressive strength all the time and the degree of increase for compressive strength is the largest whatever lime dosage and ages.

Conclusions

From the above results of the experiment, it can be concluded that Increasing the water-solid ratio the drainage rate of clay grout will be increased and the concretion rate will be decreased that improve the grout characteristics.

Adding the lime, the drainage rate of clay grout will be increased; the concretion rate of clay grout will be shortened; the compressive strength of clay-cement grouts will be improved. The strength of clay-cement grouts is increased and then decreased with the lime dosage increasing. Extra, the compressive strength of clay-cement-lime grouts reaches to the peak when the lime dosage is 6%. Adding the cement, the drainage rate and the compressive strength of clay grout will be increased; the concretion rate of clay grout will be shortened. The compressive strength of clay-lime grouts is increased with the cement dosage increasing. When the cement dosage is 12%, the degree of increase is the largest for compressive strength of clay-cement-lime grouts and the strength is well-developed.

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