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THE RESEARCH OF GROUTING TECHNIC OF CONSOLIDATING SAND AND SEALING WATER BY A TEW CHEMICAL MATERIAL FOR WATER-DRAIN TUNNEL

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ABSTRACT

A circular fissure threaded together had happened in a water drain tunnel of tailing pond in a metal mine. A vast amount of tailings together with water into the tunnel from the outside and destroyed the circular system of water used for production in the ore-dressing plant. As a result, production of that metal mine had been help up for almost a month.

The size of the tailings is mainly 0.066-0.034 mm or below. The weight of the tailings of that size is about 60.5% of the total.

A New chemical material was used to consolidate sands and seal water for this tunnel.

This paper gives a detailed description of a great number of experiments on the properties of the new material done in the labs. Grouting parameters were determined by apparatus. A few strigent measures had been taken in order to guarantee the grouting successfully.

The paper also theoretically analysed several problems encountered in grouting process.

INTRODUCTION

A water-drain tunnel with lining 0.4m thickness, located at tailing pond in a metal mine, had been destroyed by the soil pressure. A circular fissure threaded together had been happened in this tunnel with a width of 25-180mm. The top of the tunnel is covered with tailings about 30m. A vast amount of tailings together with water poured into the tunnel and destroyed the circular system of water used for ore-dressing plant. As a result, production of that metal mine has been held up for more than 20 days. Economical losses were heavy.

Grain size compound of tailing is shown in list 1.

list 1. Grain size compound of tailing

size,mm	0.196	0.152	0.101	0.066	0.034	below0.034
content %	3.5	25.00	11.00	23.875	18.875	17.75

As shown in the list above, the content of grian size 0.066mm and below 0.066mm is compounded with a weight of 60.5% in total.

Groutability of the tailing is very poor, and the grouting site is still in the moving-water condition. In order to sealing water, a steel sheet had been supported against the lining in which the fissure had been happened. Between the steel sheet and lining, some quantity of rubber and hemp were filled, but it failed in sealing water and tailing. Later, for the same aim, a double shoot injection of cement slurry and sodium silicate was used, but it was failed again. In this condition, a new chemical material was applied with which a firm grouting layer was formed. For more than 2 years, neither the water nor the tailing pour into the drain tunnel any more. Since that time, production of this mine became normal. A high economic efficiency is achieved and the environment is kept from pollution.

THE EXPERIMENTAL PROPERTIES OF THE NEW CHEMICAL GROUTING MATERIAL

The new chemical grouting material is composed of 5 components, i.e. the main agent A, adding agents B,C,D, and diluting agent E.

1. Setting time

If the other components of the chemical material remain the same, the setting time of the material is varied with the changing weight of the agents D and E (their percentage to the main agent A). The relation is shown in Fig. 1 and Fig. 2.

As shown in Fig. 1 and Fig. 2, it is obviously that the setting time decreases as the content of the adding agent D and diluting agent E increases.

2. The relation between the material viscosity and the content of diluting agent E

As shown in Fig. 3, material viscosity decreases as the content of agent E increases. But, the strength of the consolidating tailing with chemical material decreases as the content of the agent E increases.

3. Mechanical properties of chemical grouting material

The test sample dimension of chemical material consolidated with tailing is 50(dia.)x50(height)mm. The data shown in list 2 is the average value of the 3 experiments.

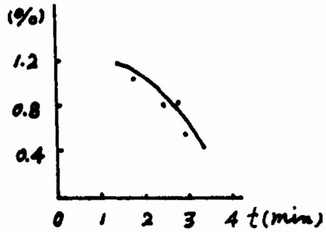


Fig. 1 The relation of setting time with the content of D.

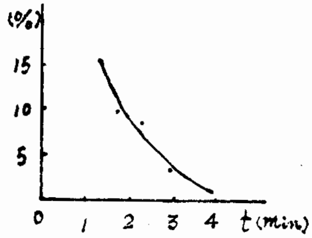


Fig. 2 the relation of setting time with the content of E.

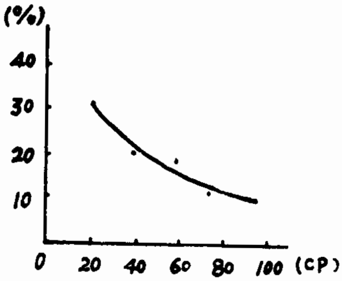


Fig. 3 The relation of material viscosity with the content of E.

As shown in list 2, it is obviously that the sample strength may be:

(1) Sample strength increases greatly with the increment of its age. For example, the compressive, tensile and shearing strength of prescription No. 1 for 28-day age are corresponding 133%, 138% and 152% to the strength of the same sample for 3-day age, the strength of prescription No.2 are corresponding 133%, 120% and 139% to the strength of the same sample for 3-day age.

(2) The consolidating tailing sample strength decreases as the content of diluting agent E increases. But the increasing

range is relatively small. For this reason, it is beneficial by injection with low viscosity material into fine sand and soil.

prescrip-tion	content of agent E %	compressive strength kgf/cm^2			tensile strength kgf/cm^2			shearing strength kgf/cm^2		
		3days	7days	28days	3days	7days	28days	3days	7days	28days
No.1	0	74.74	84.44	101.71	9.1	8.81	12.56	26.54	36.24	40.32
No.2	10	75.81	79.25	104.71	8.81	8.92	10.53	26.56	35.18	36.90
No.3	20		69.2	100.90	8.58	7.08		24.30	21.22	22.50
No.4	30		67.42*				6.66*			23.43*

List 2. Experimental mechanical strength of chemical material consolidated with tailing

* This strength was abtained from prescription No. 4 of 14days age.

4. Durability of the chemical consolidating tailing material

The 4 different samples of consolidating tailing material were immersed into solution with 25% acid and 25% alkali for 15 days. Then, these samples were taken from solution and inspected carefully, no erosion on exterior surface of samples was found, and exterior shape was not changed. Weight of samples is changed in the range between 0.8%-7% of its original. It is obviously that the corrosion resisting ability against acid and alkali is good. Water in tailing pond belongs to neuter.

5. Spreading radius of chemical grouts in trial apparatus

In order to determine the spreading radius of the chemical grout in tailing during injection, a trial apparatus is used for grouting as the same condition of tailing in pond. The trial apparatus is made of steel cylinder with 1m diameter and 1m height. On the 2/3 height of the cylinder a pair of short tubes is connected to it at the exteral surface for draining water in tailing during injection. The steel cylinder was fully filled with wet tailing and the tailing was pressed strictly with rod. In the center of cylinder a grouting tube is inserted. Chemical grout is injected into the cylinder along the grouting tube by grouting pump Model 2cy-1.1/14.5. Such an experiment was carried out for 3 times. After inspection the maximum spreading radius is 400-480mm and the minimum is 140-150mm. According to these trials such chemical grouts have good ability for injection in fine sand and soil.

6. Permeability of consolidating tailing samples in test

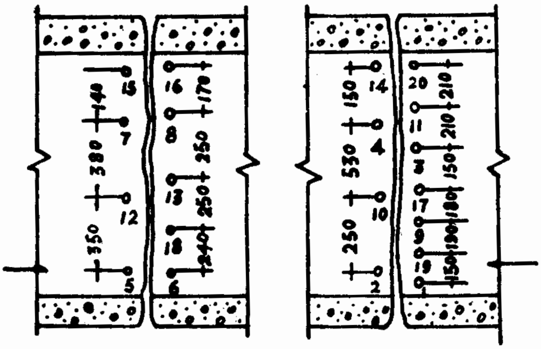
Take prescription No. 1 and 2 to determinate permeability of samples on permeameter. The permeable coefficients average are respectively 1.92×10^{-6} and 5.61×10^{-6} cm/s. These results belong to weak permeability. It is known that the consolidating tailing samples have a good anti-permeability.

GROUTING TECHNOLOGY

Before grouting along the destroyed tunnel lining, we made a cement mat which cuts the flow out of chemical grouts during injection. After that, we drilled 20 grouting and inspection holes. The arrangement of holes is shown in Fig. 4. Holes were arranged at both sides of the fissure on the tunnel lining. Grouting tubes were inserted 0.35m into tailing across the lining and in radial direction relative to tunnel. Tube diameter is 1 inch. There are 120 apertures on the tube for efflux of chemical grout.

There were 5 batches for grouting 20 holes. Grouting time for each hole was about 3-6 min.. Distances between holes were 150-180mm, individual 530 mm. Total grout quantity is 884.5 liters.

In order to avoid collaboration of chemical grouts in holes each other and flow backwards across apertures on grouting tubes into transport tubes and grouting pump by hydrostatical pressure downwards, some measures had been adopted strictly as follows.



tunnel left tunnel right

Fig. 4. Arrangement of holes and grouting order. (water flow direction)

1. Holes arrangement were maintained in a definite order. It is aimed at that the distances between holes all are larger than the spread distances of chemical grout. Holes were grouted in such order, the first batch has 6 holes, No. 1,2,3,4,5,8, the 2nd batch has 5 holes, No. 6,7,9,10,11, etc.. There were 5 batches to be grouted (as shown in Fig. 4).

2. Holes were grouted immediately after drilling each batch of them. Grouting pressure and quantity for each hole was detailed record in note books.

3. Injection with low pressure.

In order to obtain the design thickness of cutflow layer and to avoid the chemical grout spreading too far by aim of saving material, low grouting pressure was adopted.

4. Chemical grout spreaded with definite quantity.

In accordance with design each hole was grouted only 60 liters, and increased or decreased quantity appropriately in the light of actual condition. It means that the grouting quantity for each hole could formed a desired layer thickness and controlled the grout-flow spreading not too far so as to save material.

5. Painting on perforation holes (apertures) of grouting tube with loess for preventing tailing from pouring into them.

Based on these measures grouting went on smothly. It is belived after drilling inspection that a layer of consolidated tailing is formed on the outer side of tunnel.

A FEW PROBLEM IN GROUTING TECHNOLOGY

1. Primary and last grouting pressure.

The hydrostatic pressure at grouting site was about 2.3kgf/cm^2. The primary grouting pressure was adopted 3 kgf/cm^2. The last pressure was the same 3 kgf/cm^2, with some exception of 3.5 3.5kgf/cm^2 when grouting completed standard reached for each hole. It is known that the last grout pressure was equal essentially to the primary pressure. The causes would be analyzed that the desired spread diameter was not large and viscosity of chemical grout was low, even if the grain size was very fine and its groutability was very poor. The attenuate grouting pressure might be calculated as follows when the chemical grout flowed in radial direction (as a plane radial flow).

Owing to the adopted low grouting pressure and small rate of flow, lineal permeable law might be applied.

$$V = \frac{Q}{F} = -\frac{K}{\mu}\frac{dp}{dr} \qquad (1)$$

$$\frac{Q}{2\pi hr} = -\frac{K}{\mu}\,\frac{dp}{dr} \qquad (2)$$

$$dp = -\frac{Q}{2\pi h}\cdot\frac{\mu}{k}\,\frac{dr}{r}$$

$$\int_{P_0}^{P} dp = -\frac{Q}{2\pi hk}\int_{r_0}^{r}\frac{dr}{r} \qquad (3)$$

$$p = P_0 - \frac{Q\mu}{2\pi hk}\,\ln\frac{r}{r_0} \qquad (4)$$

Here: V --- grout permeable velocity, cm/s,

Q --- grout rate of flow by pump, 10l/min,

F --- cylinder surface of grouted tailing, cm^2,

r --- radius of grouting tubes, r = 1.3 cm,

r --- changing radius when grout spreaded, cm,

P --- grouting pressure in hole, 3 kgf/cm^2,

k --- grout permeable coefficient, k = 6.8 x 10^{-6}cm^2,

--- grout viscosity, = 21.5 cp.;

h --- grouting length, h = 35 cm.

Put spread radius r = 5,10,15, 20, 25 cm into formula (4) might **obtain** grouting attenuate pressure P (see list 3).

List. 3 Grouting attenuate pressure P

spread radius m	0	0.05	0.10	0.15	0.20	0.25
pressure kgf/cm^2	3	2.7	2.52	2.41	2.34	2.30
attenuate coefficient	100	90	84	80	78	76

As shown in list 3, during injection in very fine tailing, grouting pressure would be attenuated as increase of the spread radius, but attenuate velocity was small. The adopted last pressure essentially equal primary. This primary pressure would be satisfied engineering demands and avoided chemical grout to flow farther on.

2. The relation between grouting time and discharge.

In general, in homogeneous sand and soil, grouting discharge basically equals in unit time. But in this practice, the condition was not so as description above. For example, in holes No. 8, 14, 15, 20, the grouting time and discharge, by practical survey was shown in Fig. 5.

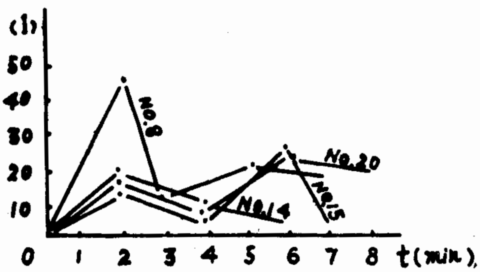


Fig. 5 Relation between grouting time and discharge

It is shown in Fig. 5, even though the tailing is homogeneous and total grouting time for each hole is more or less the same (6–8 min.), but the following differences are existent.

(1) The differential discharges of holes in unit time are large, the maximum discharge is 48 1 per 2 min., the minimum is 4 1. The range of discharge is great.

(2) Under such condition that the grouting pressure is similar (3 kgf/cm^2), but the total discharge in each hole is different. For example, discharges in holes No.. 8, 14, 15, 20 are corresponding to 101. 5, 35, 46, 70 liters. The differences of discharge in holes are great. Hence:

(1) In chemical grouting technology, discharge decreases suddenly, it does not signify that injection in this hole would be finished. If discharge increases suddenly, it means that the chemical grout makes a break through some primary consolidated tailing and goes on to spread forwards at the begining. Hence, in grouting process if discharge in any hole decreases suddenly, it may be persisted by last pressure to continue injection in period 3-4 min. If it is not discharge again, then, injection of this hole may be finished.

(2) According to aviod chemical grout spreading too far so as to save material, injection might be stoped when discharge in each hole reaches the quantity of design. On this condition discharge for each hole is not more related to the continued grouting time.

3. The relation between grouting layer thickness and spread radius.

By inference of fissure location (fissure located behind the steel sheet support) grouting holes were arranged at both side of the fissure in 2 rows. Distance between rows is 300 mm. Distance between holes in each row is 0.14-0.38 m (individual 0.53 m. See Fig. 4).

Spread radius was about 0.159-0.533 m by judge of grouting quantity in each hole.

Spread radius was 0.14-0.48 m, which was obtained by practical survey from testing spread apparatus.

Total grouting holes 14, and total discharge 840 liters in design. Total grouted holes 20 and total discharge 884.5 liters in practice. The latter was larger 5.3% than the former.

In view of the above, it is believed after drilling inspection and analysis that a firm layer of consolidated tailing is formed on the outer side of the tunnel. In practice, up to date in the period of more than 2 years, water and tailings all were not poured into tunnel. Production of ore-dressing plant goes on normally.

CONCLUSION

1. For grain size of tailing below 0.066 mm, this new chemical grout has better groutability, higher mechanical strength of consolidating tailing, beter ability against acid or alkali and permeability than other chemical grout. It may be considerable and adoptable for grouting project on the same conditions.

2. Before injection it is important to pay attention to basic work. The essential prerequisite for successful grouting project are detailed investigation of medium which would be grouted and ample achievement of experimental data.

3. It is an important aspect to quarantee successful grouting project, when strict technologic measures are adopted which can remove different influences of unfavourable factors.

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