CL-C grouting technique development and its application in shaft sinking in China

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ABSTRACT

The paper discusses CL-C grouting development in China. The influence of CL-C components (clay slurry, cement and water glass) on the properties of CL-C grout is discussed. Examples of CL-C grouting, including the deepest grouting gproject are given in the paper. The future of this method in China is also discussed.

INTRODUCTION

Pre-grouting form the surface was applied in 64 shafts in China from 1958 to 1990. The grouting material was cement only or together with water glass. It costs much more in comparison with CL-C grouting which was developed by STG of the former Soviet Union. In order to decrease the cost, new technique developed by us can reduce cement by 80%, shorten grouting time by 55%, and decrease the cost by 40% in total, comparing to conventional cement grouting. The CL-C grouting technique has be applied in more than 28 shafts since its developmetn in 1990 in China. Improvement on CL-C is being carried out in grouting system.

CL-C GROUTING TECHNIQUE IN CHINA

CL-C grout properties

Components of CL-C grouting in China are mainly clay, cement and a a little amount of water glass. This kind of grout is a suspended substance. Its properties, such as plastic strength, rate of water separated out, viscosity, specific gravity and impermeability, are very important to sealing underground water. The plastic strength is the index of grout shear resistance, The specific gravity of clay slurry, the weight of cement per m^3 in suspended

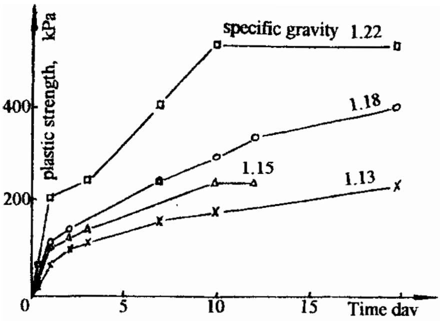

Fig 1. Influence of clay slurry specific gravity on CL-C plastic strength. (With cement 100kg/m³ and water glass 25l/m³)

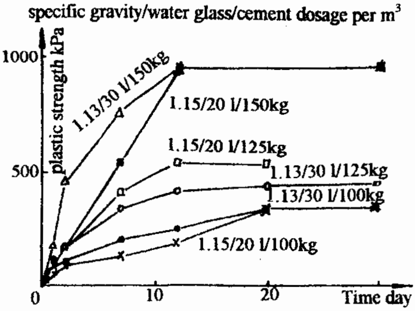

Fig 2. Influence of cement dosage on CL-C plastic strength

grout have great influences on the grout plastic strength. Test results are shown in figure 1, figure 2 and figure 3. From these figures one can find the following : the greater the specific gravity of clay slurry the greater the plastic strength; the more of cement per m³ in suspended grout the greater plastic strength; and the larger volume of water glass the greater the plastic strength. The influences of the three elements at different time on the plastic strength are different. The specific gravity of clay slurry and water glass volume have greater influence on plastic strength than cement dosage in grout in the initial 3 days. After this time, cement weight dosage in grout and the specific gravity of clay slurry have greater influence on plastic strength increase than water glass volume per m³ of grout. It can be found that time of the plastic strength increase can be divided into three stages: the initial stage in the first 1 or 2 days, the middle stage from 2nd day to around 10th day, and the final stage from 10th day to 20th day. The plastic strength increases faster at the initial stage than at the middle stage, and slowly at the final stage.

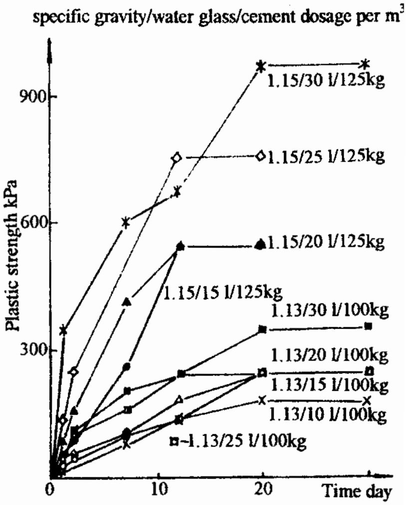

Fig 3. Influence of water glass dosage on CL-C grout plastic strength

Besides, clay properties, the make and the grade of cement and temperature have some influences on the plastic strength. The larger the clay slurry viscosity at the same specific gravity, the greater the plastic strength. The higher the grade of cement, the greater the plastic strength. The plastic strength of grout mixed with silicate cement is greater than that of mixed with slag cement. The higher temperature, the greater the plastic strength.

The rate of CL-C water separated out is a very important index of suspended grout stability and filling its capability in fissures. The rate of CL-C grout water separated out is about 0 ~ 5% (Table 1) and does not separate nor disperse when it meets water. Consequently it ensure grouting quality.

Table 1 : Rate of water separated out from CL-C grout

specific gravity of clay slurry	cement dosage kg/m^3	water glass mixed l/m^3	Rate of water separated out %
1.13	100	15	1.0
		25	1.0
		35	0
	125	20	1.0
		30	0
	150	15	2.0
		20	0
		35	0
1.15	100	20	1.0
		25	0
	125	15	0
		20	0
	150	10	0.2
		15	0
		30	0
1.18	100	10	0.5
		20	0
1.22		25	0

Note : clay with plastic index 36.5

The viscosity of CL-C grout increases with both the clay slurry specific gravity and cement and water glass content (see Fig 4 and Fig 5).

The impermeability of CL-C grout is much better than that of cement grout, the coefficient of the former permeability if about $10^{-5} \sim 10^{-6}$ cm/s, however that of the latter is about $10^{-1} \sim 10^{-3}$ cm/s.

Grout Technique

Both upward and combining upward and downward grouting methods are used in China. The latter is, generally speaking, used in deep shafts, or in geological folded strata. Grouting stage height is around 40 m ~ 75m, or even longer than 100m.

The grouting pressure is determined by the following :-

$$P=K\,p_0+a \qquad (1)$$

Where P_o - hydrostatic pressure, MPa;

K - condition coefficient, K=1.5 ~ 3;

a - depth influent coefficient, a=2 ~ 4 MPa.

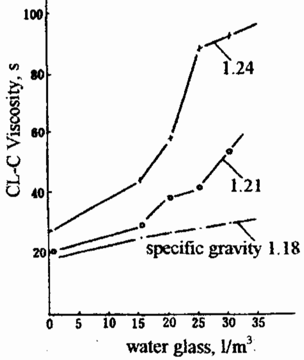

Fig 4. CL-C viscosity v.s. water glass with cement dosage 100kg/m³ in CL-C (after Su Jianshen ect. 1997)

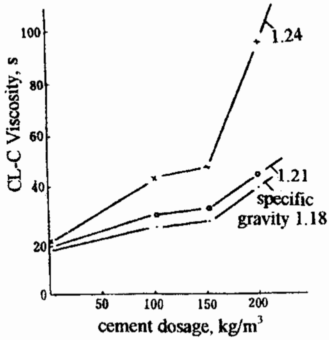

Fig 5. CL-C viscosity v.s. cement dosage mixed water glass by 15 l/m³ᴺ (after Su Jianshen etc. 1997)

The quantity of CL-C grouting (m³) is approximately calculated by the formula,

$$Q = \sum^{n} A\pi R^2 H_i \eta_i \beta \qquad (2)$$

Where A - consuming coefficient, A=1.2 ~ 1.5;

R - grout diffusion radius from shaft centre, m;

$R = \Phi / 2 + r$

Φ - diameter of grouting holes distribution circle, m;

r - effective diffusion radius, m;

H_i - grouting stage length, m;

η_i - stratum fissure rate;

β_i - grout filling coefficient, β_i=0.95;

n - grouting stage number.

Grouting can be finished when grouting pressure and grouted quantity meet the requirement calculated, and the final grouted quantity is stable for 20 min under 250 l/min.

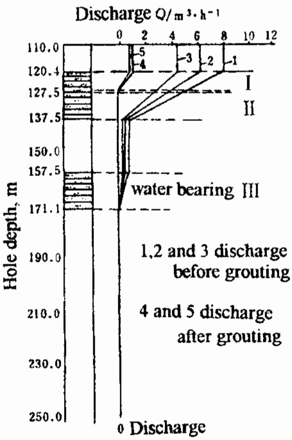

Fig 6. Discharge measurement (after Zheng Jun, 1997)

Grouting fluid/discharge data logging

According to fluid data logging results before grouting (Fig 6), the designed 5 stage were reduced to 3 stages, which speeded up grouting. The grouting efficiency can be checked by examining the fluid (discharge) data logging results.

APPLICATION OF CL-C GROUTING TECHNOLOGY

CL-C grouting has been used in more than 28 shaft in China since its development in 1990.

Compared with cement grout, cement dosage has been reduced by 80% and grouting time has been shortened by 55% by using CL-C grouting technique.

The shafts grouted by using CL-C were sunk with little water (water discharge was less than $3m^3/h$). Table 2 gives an example of CL-C grouting.

Table 2 : Engineering and Grouting Feature in Weichun Mine

	Main shaft	Service shaft
Net diameter, m	5.0	6.0
Depth, m	729	746.5
Freezing depth (ice wall), m	257	250
Grout initial and end depth, m	245 ~ 743	238 ~ 754
Water discharge before grouting, m^3/h	250	270
Grouting holes distributing circle diameter, m	10	10
Grouting hole number	6	6
Max. grouting pressure, MPa	16.5 ~ 19.0	16.5 ~ 19.0
Total grouting volume, m^3	6375.82	6835.71
Final water discharge, m^3/h	2.7	1.9
Total time, month	7.4	8.3

About 6458.9t cement and 26.4 months of time were saved comparing with conventional cement grouting.

Recently two shafts, the deepest grouting one is 859m, in Xuandong Mine were grouted by using CL-C grouting with results of final eater discharge $1.1m^3/h$ in main shaft and $0.8m^3/h$ in service shaft respectively. These results ensured the two shafts were sunk at advance speed of 117m/month on average and the construction was finished in 7 months only, which has been the highest speed in shaft sinking in such a deep shaft in China.

CONCLUSION

CL-C grout development has brought China great efficiency in shaft construction. A new CL-C grout system, will be developed with high grout pressure (30 ~ 40MPa), large grouting flow capacity (250 ~ 400l/min) and continuously grouting for at least 8h.

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