

# Study on Rheological Properties of Whole-tailings Paste Backfilling Material Bases on L-pipe Experiments

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**Abstract.** Pipeline transportation of the backfilling material is an important part of the backfill mining method. The rheological property of the filling slurry is the cornerstone of pipe diameter selection and resistance calculation. Its research matters not only mining costs, but also the safety in production. In order to ensure the whole-tailings paste backfilling material of Shirengou iron mine can be achieved pipeline transportation, L-pipe experiment is designed in this paper to study the transport characteristics of the whole-tailings paste in the pipeline. The study results provided theoretical basis for determine the best transport concentration, cement/aggregate ratio and the pipeline self-flow transportation concentration limit.

## 1. Introduction

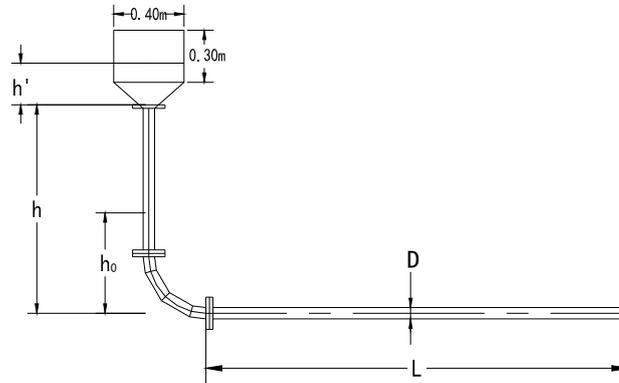
Over the past three decades, mine backfilling has become an integral part of mining operations used for overall support for stability of mine openings. [1] Underground mining of economic minerals creates voids in different shapes including stop, cave, room, goaf, and gob void forms.[2] Compared with other mining methods, filling method is characterized by simple process, low cost, high rate of recovery, secure operation and protection of the surface environment, etc.[3-6]

Whole-tailings paste backfilling material can be achieved pipeline transportation involves many factors. The main factors are: the rationality of composition of material, concentration, transport capacity, diameter and material of filling pipe, dip angle, pipe network layout parameters and so on.[7] The rheological property of highly concentrated whole-tailings filling material is usually described by the Bingham model,[8-9] whose arguments can be presented by shear stress  $\tau_0$  and viscosity coefficient  $\eta$ , in most cases, they are determined by loop-pipe experiment.[10] However, the design process of it is complex and cost is high. In order to research the rheological property of the filling material of Shirengou iron mine and study the transport characteristics of the whole-tailings paste in the pipeline, a simple and practical L-pipe experiment is designed. The shear stress  $\tau_0$  and viscosity coefficient  $\eta$  of the whole-tailings paste was determined during experiment, and then the resistance loss of the pipe was calculated by them. Using these data, the optimal transport concentration and cement/aggregate ratio can be determined.

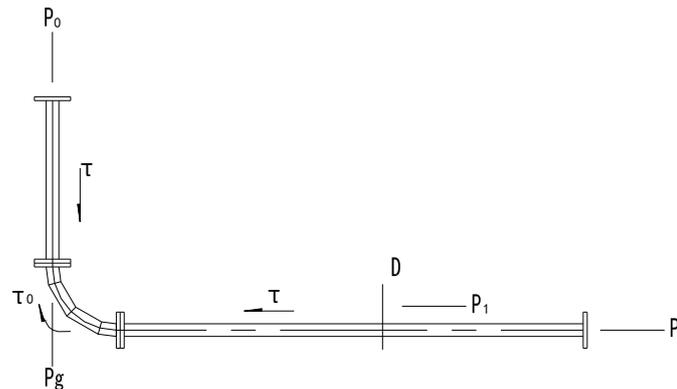
## 2. Principle of the L-pipe experiment



L-pipe experiment system mainly includes receiving hopper, two transparent PVC pipes, connecting elbow ( $90^\circ$ ) and iron bracket. The structure and dimension of the system are as shown in Figure 1. In the figure,  $h=1.2$  m,  $h'=0.24$  m,  $D=0.06$  m,  $L=2.4$  m.



**Figure 1.** Schematic diagram of L-pipe experiment system



**Figure 2.** Stress analysis diagram of the flowing filling material in the L-pipe

The stress state of the flowing filling material is shown in Figure 2. According to the law of conservation of energy, we got following form:

$$P_0 + P_g = P_i + P' \quad (1)$$

Where,  $P_0$ —Inlet pressure of L-Pipe:

$$P_0 = \gamma h' \frac{\pi}{4} D^2 \quad (2)$$

$P_g$ —Self weight pressure of slurry:

$$P_g = \gamma \cdot h \frac{\pi}{4} D^2 \quad (3)$$

$P_i$ —Resistance loss of slurry:

$$P_i = \tau(h + L)\pi D + \sum_{i=1}^n \xi_i \gamma \frac{V^2}{2g} \quad (4)$$

$P'$  —Outlet pressure loss of L-pipe

$$P' = \gamma \frac{V^2}{2g} \cdot \frac{\pi}{4} D^2 \quad (5)$$

In these equations,  $\gamma$  —— Specific gravity of the slurry, N/m<sup>3</sup>;

$V$  —— Flow rate, m/s;

$\xi_i$  —— Local resistance loss coefficient,

Take 10% of the pressure loss in the straight pipe as the local loss, which includes bent tube loss, joint loss and so on. After simplifying the formula we obtained:

$$\frac{\gamma D}{4} (h + h') = 1.10\tau(h + L) + \gamma \frac{V^2 \cdot D}{8g} \quad (6)$$

As the experiment went on, the liquid level of the slurry dropped and the flow rate decreased gradually. When the flow stopped, the height of the liquid level is  $h_0$ . The gravity pressure of the slurry counterbalanced static friction force of the pipeline. The yield shear stress can be calculated according to the following equation:

$$\tau_0 = \frac{\gamma \cdot h_0 D}{4(h_0 + L)} \quad (7)$$

During the course of the experiment, we can calculate  $\tau$  According to the flow rate of slurry in pipeline ( $V$ ). The viscosity coefficient of the slurry  $\eta$  can be calculated by Bingham equation as follows:

$$\eta = \frac{(3\tau - 4\tau_0) \cdot D}{24V} \quad (8)$$

According to the rheological parameters calculated by equation 7-8 and pipe diameter of Shirengou iron mine (122 mm), the resistance loss of the pipe  $i$  can be obtained:

$$i = \frac{16\tau_0}{3D} + \frac{32\eta V}{D^2} \quad (9)$$

### 3. Results of the experiment

The filling material was prepared by whole-tailings of Shirengou iron mine and cementing material on site (Fig. 3). According to the principle of L-pipe experiment, we can determine the yield shear stress and viscosity coefficient of the slurry, then the resistance loss of the pipe can be obtained as shown in table 1.



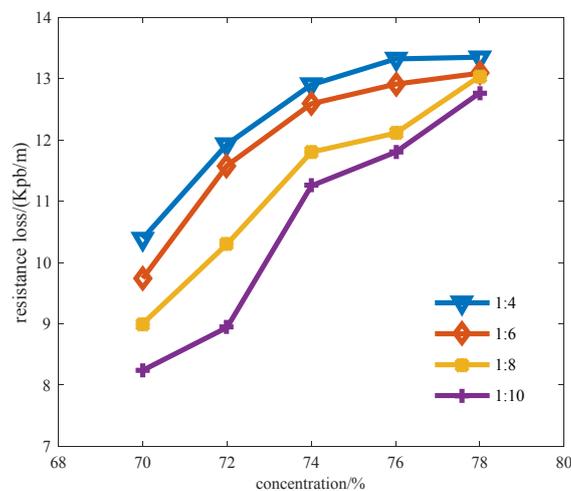
**Figure 3.** Whole-tailings paste backfilling material preparation system

**Table 1.** Rheological parameters and resistance loss of whole-tailings paste backfilling material

No.	Cement-sand Ratio	Concentration/%	Yield Stress $\tau_0$ (Pa)	Viscosity Coefficient $\eta$	Resistance Loss $i$ (Pa/m)
1	1:4	70	0	0.670	10.39
2	1:4	72	12.83	0.730	11.93
3	1:4	74	21.12	0.750	12.9
4	1:4	76	25.37	0.950	13.32
5	1:4	78	26.06	1.500	13.35
6	1:6	70	0	0.382	9.74
7	1:6	72	11.503	0.542	11.58
8	1:6	74	16.033	0.600	12.59
9	1:6	76	21.40	0.677	12.91
10	1:6	78	25.52	1.377	13.09
11	1:8	70	0	0.410	9
12	1:8	72	6.00	0.480	10.3
13	1:8	74	11.83	0.542	11.8
14	1:8	76	17.22	0.700	12.11
15	1:8	78	23.48	1.120	13.04
16	1:10	70	0	0.265	8.24
17	1:10	72	5.87	0.410	8.94
18	1:10	74	6.021	0.526	11.25
19	1:10	76	12.17	0.69	11.8
20	1:10	78	18.01	0.954	12.77

### 3.1. Influence of Transport Concentration on Resistance Loss

Under different cement-sand ratio conditions, the change curve of the resistance loss of the pipe over the slurry concentration is shown in Figure 4. From the fig we can discover the variable laws as follows:



**Figure 4.** Change curve of the resistance loss over the slurry concentration

(1) In any cement-sand ratio, the resistance loss of the pipe was increased with the increase of concentration;

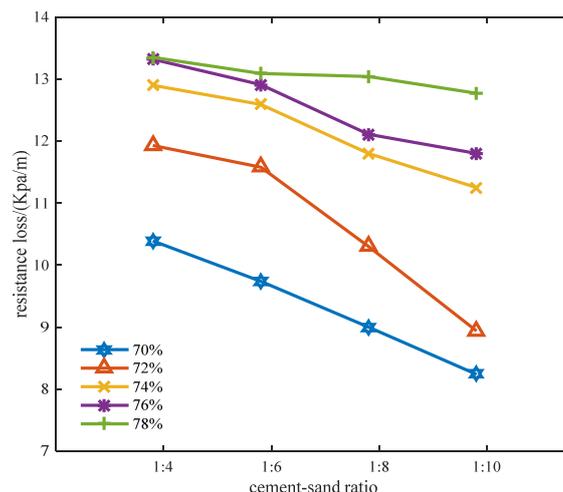
(2) When the concentration of the slurry is low (<74%), resistance loss was strongly affected by concentration, the resistance curve was showing a linear upward trend;

(3) Concentration has a little influence on the resistance loss when it is relatively high (>74%), the curve became flat gradually;

(4) When the concentration reached to 78%, the resistance loss of the pipe closed to a fixed value (13 KPa/m), which stands for the pipeline self-flow transportation concentration limit.

### 3.2. Influence of Cement-sand Ratio on Resistance Loss

Under different slurry concentration, the change curve of the resistance loss of the pipe over the cement-sand ratio is shown in Figure 5.



**Figure 5.** Change curve of the resistance loss over the cement-sand ratio

This figure shows that, in any slurry concentration, the resistance loss of the pipe was increased with the increase of cement-sand ratio. Accordingly, smaller cement-sand ratio filling material should be used under the precondition of the required strength in order to reduce transportation resistance loss.

#### 4. Conclusions

In this paper, L-pipe experiment system has been designed for deducing the calculation method of the rheological parameters of highly concentrated whole-tailings filling material based on the theory of fluid mechanics. The rheological property of the filling material of Shirengou iron mine is studied through this experiment. The study results provided theoretical basis for determine the best transport concentration, cement/aggregate ratio and the pipeline self-flow transportation concentration limit.

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