

The Impact of Temperature on the Triaxial Compression Characteristics of Cemented Paste Backfill

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Abstract: In deep well mining, due to the influence of the surrounding environmental temperature, the mechanical properties of the cemented paste backfill (CPB) will change. Therefore, studying the effect of temperature on the mechanical characteristics of CPB is of great research significance for the safety and stability of the mining stope. This article conducted triaxial compression tests on CPB at different temperatures, studied the effect of temperature on the shear strength characteristics of CPB specimens, and investigated the failure mechanisms and characteristics of CPB. The results show that: (1) The cohesion and internal friction angle of CPB specimens increase with increasing temperature. (2) As the temperature increases, the failure mode of CPB specimens changes from single oblique section shear failure to Y-type failure.

Keywords: Cemented paste backfill; triaxial compression; temperature ; failure mode.

1. Introduction

As the global economy continues to develop, the demand for metallic resources is increasing, leading to the gradual depletion of easily accessible surface metallic resources. This phenomenon has forced global metal mining activities to continuously advance into deeper layers of the Earth. However, with increasing mining depths come numerous technical challenges, with elevated temperatures being particularly prominent. This poses a severe test to the performance of backfill materials. Therefore, conducting in-depth research on the influence of the temperatures on the mechanical properties of backfill materials is crucial.

Studying the mechanical properties of backfill materials can help optimize mine filling designs to ensure the quality meets mining safety requirements. Additionally, by thoroughly investigating the effects of high temperatures on the mechanical properties of backfill materials, it is possible to uncover the laws governing the variations in mechanical properties with temperature changes, providing more reliable theoretical support for deep metal mine extraction activities. Numerous scholars have conducted extensive research on the compression tests of cemented paste backfill (CPB). Fall M et al. [1] studied the influence of tailings particle size and density on the strength of backfill materials, providing important insights for material selection. Xu Wenbin [2] studied the influence of different fly ash-sand ratios and concentrations on the strength of backfill materials, providing experimental data for optimizing material ratios. Deng Xuejie [3] studied the strength requirements of cemented backfill based on the control of the filling rate in coal mining goaf, providing a new method for the strength design of coal mine backfill materials. Qiao et al. [4] and Sari Muhammet et al. [5] analyzed the influence of gradation and mineral admixtures on the strength of cemented paste backfill from the perspective of material physical and chemical properties. Nie Yalin [6] studied the strength and damage model analysis of pure tailings cemented backfill with different water contents, providing a scientific basis for adjusting water content. Men Ruiying [7] studied the thermal-mechanical-damage behavior simulation and experimental analysis of cemented backfill,

providing new ideas for the long-term stability evaluation of backfill. Zhihong Z and Jiacheng L [8] conducted a series of uniaxial compression and triaxial compression tests, studying the influence of CPB specimen strength characteristics on factors such as cement content, curing age, and curing temperature. Schutter G D et al. [9,10] 's experimental research on cement showed that curing temperature has a significant impact on the hydration process of cement. Li Kaibing [11] studied the relationship between temperature effects on backfill damage characteristics and mine pressure control. Nasir O's [12] research focused on the coupling effects of temperature and binder hydration reaction on CPB strength development. His research provided theoretical guidance for the design of backfill materials in high-temperature environments, revealing that the coupling effects between temperature and hydration reaction significantly influence the strength development of backfill materials. This implies that when designing and selecting backfill materials, the effects of temperature and hydration reaction need to be considered. Xiong Rui [13] studied the influence of high temperature on the strength and deformation characteristics of cemented backfill, conducting uniaxial compression experiments on cemented backfill cooled after high-temperature exposure. Experimental results showed that after high-temperature exposure and cooling, the strain of backfill increased with temperature, peaking at 200°C before decreasing. Fall [14] studied the influence of different temperatures (100°C, 200°C, 400°C, 600°C) on the uniaxial compressive strength of backfill materials, finding that the compressive strength of backfill materials was highest at 200°C. While these studies are valuable in mining engineering, it's worth noting that most of the research has focused on uniaxial compression, which does not align with the actual three-dimensional stress state.

Based on this, this paper focuses on the fully tailings cemented backfill at Boao Iron Mine as the research object, conducting a series of triaxial compression tests to analyze the strength characteristics and failure modes of backfill materials at different temperatures.

2. Materials and Methods

2.1. Materials

Using the full tailings of the Boao Iron Mine as aggregate, the basic physical properties of the tailings were determined in accordance with the "Rock Test Procedures for Water Resources and Hydropower Engineering" (SL/T 264-2020). The density and moisture content of the test materials were measured using the ring knife method and the drying method, respectively. The natural density of the tailings was 1.638 g/cm³, and the dry density was 1.652 g/cm³. The moisture content was 0.825%.

2.2. Specimen Preparations

To prepare the cemented filling material slurry, P. O 42.5

silicate cement, tailings, and water were mixed, and it was poured into a cylindrical mold with an inner diameter of 50mm and a height of 100mm. The slurry concentration was 74%, and the cement-to-sand ratio was 1:4. The sample was cured in a BSYH-90 standard constant temperature and humidity curing box at 20°C and 95% humidity for 7 days.

The well-cured CPB (cemented paste backfill) specimen was placed into the BF1200-544 box furnace, as depicted in Figure 1. It was then heated at a rate of 2°C per minute to the temperatures of 40°C, 60°C, and 80°C. To ensure uniform heating throughout the CPB, the specimen was maintained at each peak temperature for 2 hours. After the heating process, the specimen was allowed to cool down to room temperature inside the furnace. The specimen that was cooled to room temperature is shown in Figure 2.



Figure 1. BF1200-544 box furnace

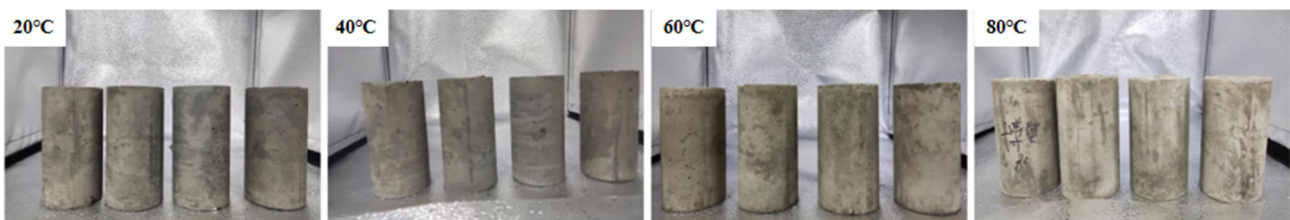


Figure 2. Samples after cooling from high temperature

2.3. Testing of CPB Specimens

Compression tests were carried out using the TruePath automated stress path triaxial apparatus under confining pressures of 100, 200, 300, and 400 kPa, as well as at four temperature gradients (20°C, 40°C, 60°C, 80°C). The Mohr's

circles of stress for different temperatures and CPB were plotted for each confining pressure. The shear failure lines for each CPB sample were then fitted using the Mohr-Coulomb criterion, which allowed for the determination of the cohesion and internal friction angle corresponding to each sample, as shown in Figure 3.

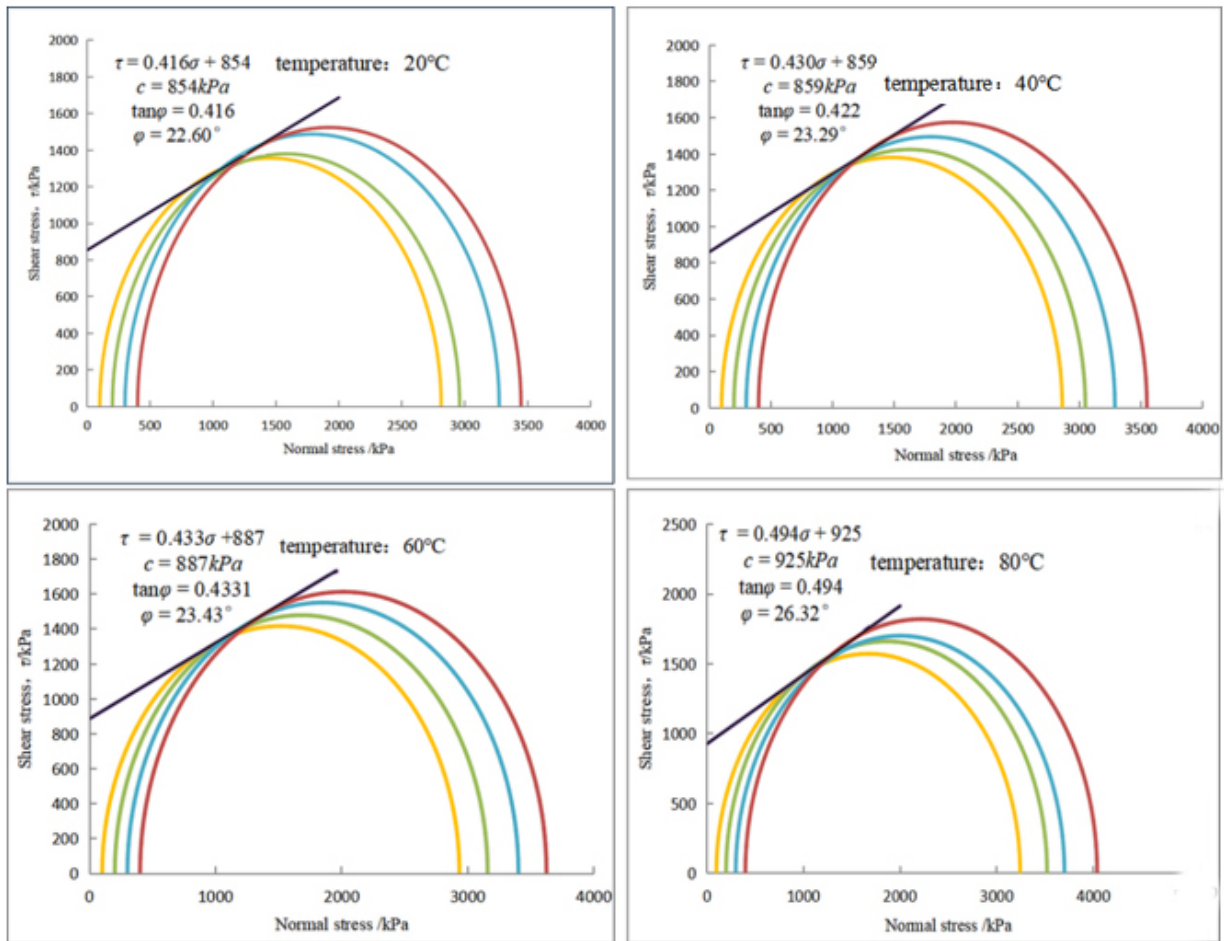


Figure 3. Fitting schematic diagram of triaxial compression test results for the CPB

3. Results and Discussion

3.1. Influence of Temperature on Shear Strength Indexes

The relationship curve between cohesion, internal friction

angle, and temperature of CPB specimens is shown in the following graph:

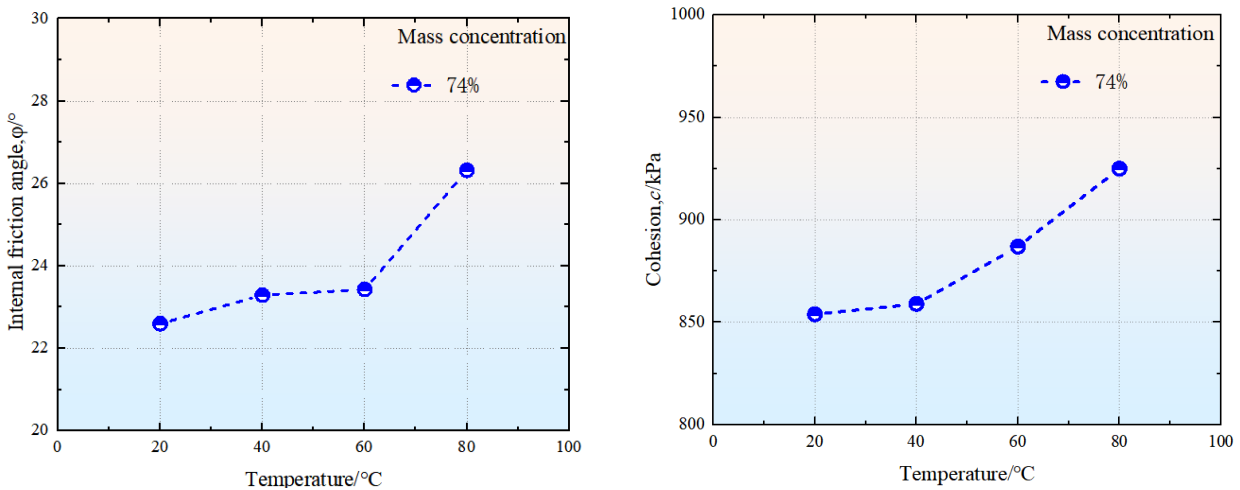


Figure 4. Relationship curve between shear strength indexes and temperature

As shown in Figure 4, with the increase of temperature, the cohesion of the CPB specimen increased rapidly and significantly, from 854 kPa at 20°C to 925 kPa at 80°C. This is because the higher temperature promotes the hydration of cement, producing more hydration products that gradually fill

the pores, reduce the porosity, strengthen the structure, and thus enhance the cohesion of the CPB.

The internal friction angle of the CPB specimen also increased slightly with the rise in temperature, by approximately 3.72°. This is due to the fact that as the

temperature increases, more hydration products are formed, progressively coating the surface of the tailing particles, enhancing the inter-particle connections, and improving the particles' resistance to sliding, thereby increasing the internal friction angle.

Overall, the increase in temperature enhances the cohesion and internal friction angle of the CPB by promoting the hydration reaction of the cement, thereby strengthening the overall mechanical properties of the CPB. These findings are of significant practical value for understanding and predicting the mechanical behavior of CPB under different temperature conditions, as well as for support design and safety assessments in underground mining operations.

3.2. Failure Characteristics of CPB Specimens

Figure 5 shows the physical image of CPB failure after

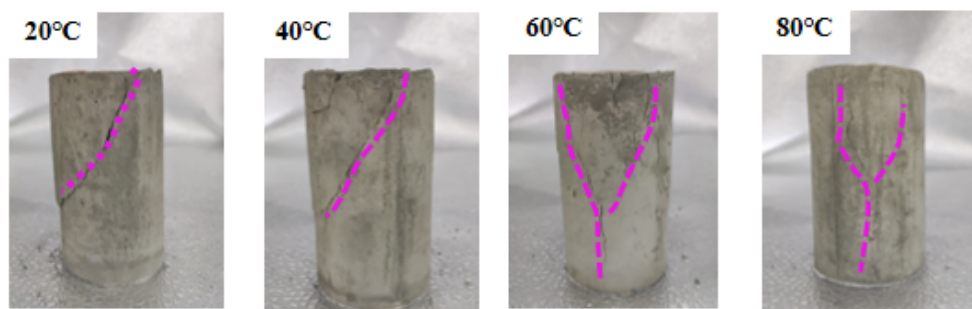


Figure 5. CPB Failures under triaxial compression

4. Conclusions

In this article, we conducted triaxial compression tests on CPB to investigate the variation in triaxial compressive strength of the filler under different temperature conditions. Through mechanical testing, we revealed the impact mechanism of temperature on the performance of the filler and summarized the failure patterns and characteristics of the filler.

(1) The test results indicate that with the increase in temperature, both the cohesion and the internal friction angle of the filler show an increasing trend. This enhancement is due to the acceleration of the cement hydration reaction, leading to an increase in the amount of hydration products. These products fill the gaps between particles, enhancing the bonding effect among them, which in turn improves the shear strength of the filler.

(2) At temperatures of 20°C and 40°C, the failure mode of CPB manifests as continuous inclined tensile-shear fracture surfaces. However, when the temperature rises to 60°C and 80°C, the failure mode of the full tail sand filler from the Boao iron mine changes to a Y-shaped pattern.

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