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STUDY ON THE STRENGTH OF IRON AND STEEL SMELTING WASTE BLAST FURNACE SLAG

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The waste blast furnace slag generated during the steelmaking process is used as the basic material, and an appropriate amount of fly ash is added to conduct shear tests to obtain the shear mechanical indicators of the fly ash blast furnace slag mixture, thereby obtaining the strength mechanical properties of the mixture. The test results show that there are few fine particles in the mixture, which is not enough to affect its shear mechanical properties, so the water content has little effect on the shear strength of the mixture, and the mixture has good water stability; In the shear test, it can be found that the greater the normal stress, the greater the initial shear shrinkage, and the smaller the later shear expansion. After the normal stress exceeds 150 kPa, the shear expansion significantly decreases.

Keywords: blast furnace slag; shear test; shear strength; steel smelting

INTRODUCTION

Most steel smelting uses blast furnace smelting, which generates a large amount of blast furnace slag waste. Data studies have shown that refining 1 ton of steel produces 0,3 to 1 ton of blast furnace slag. At present, the treatment methods for these wastes include the production of insulation material mineral wool, the development of high-performance slag cement, the development of imitation basalt products, etc. or the application in the engineering field of processing into stone for the construction of facilities such as highways, railways, airports, etc. [1-3]. When using blast furnace slag to fill high fill sections of public railways, in order to control the stability of the roadbed, foundation, or slope filled with blast furnace slag, it is necessary to study its strength characteristics. In order to obtain good engineering mechanical properties, it is generally necessary to reprocess or add fine particle substances to improve it, such as adding fine particle substances such as fly ash and silty clay [4]. In this paper, the shear strength characteristics of blast furnace slag are verified by adding appropriate pulverized coal in the blast furnace slag for research and shear test, which provides a theoretical basis for practical application.

SAMPLE AND CONFIGURATON CHARACTERISTICS

During the steel smelting process, blast furnace slag floats on top of the molten iron, creating some pores inside its particles. This porosity is not a fixed value, and different iron ore raw materials will produce different values. This experiment uses blast furnace slag produced by Tangshan Iron and Steel Plant in Hebei as the experimental material. The average porosity measured by the average method is about 10,5 % and the density is 2,465 g/cm3.

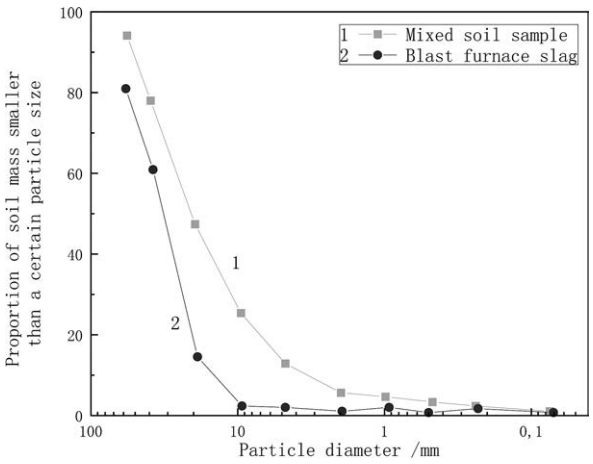

Figure 1 Curve of blast furnace slag and ingredient table

During the compaction process, blast furnace slag will produce particle breakage, and its coarse particles will be crushed to produce a certain amount of fine particles.

Based on the compaction effect analysis, the content of fly ash to be added in this experiment is 2 %. Then, particle analysis tests were conducted on pure blast furnace slag samples and fly ash modified blast furnace slag samples, and the grading curves of the two test samples were obtained as shown in Curve 1 in Figure 1. At the same time, the particle composition indicators of the two test samples were also obtained. Referring to

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Table 1 **Particle Composition Indicators of Test Soil Samples**

Source of soil sample	d≤0,075 mm %	d≥5 mm %	Cu	Cc	Grading
Blast furnace slag	0,16	97,47	2,46	0,93	Poor
Mixed soil sample	1,26	87,33	6,44	1,31	Good

the coarse soil particle analysis index, the coarse particle content P5 of blast furnace slag was 97,47. Its non-uniformity coefficient Cu=2,46 and curvature coefficient Cc=0,93. This type of blast furnace slag is a poorly graded mixed soil with large particles.

This experiment simulates the impact of actual construction process on blast furnace slag filler. In the laboratory, the blast furnace slag mixture that has been added with 2 % powdered coal is compacted, and then particle analysis experiments are conducted. Curve 2 in Figure 1 shows the grading curve of the fly ash blast furnace slag mixture sample. Through laboratory simulation, it was found that the coarse particle content P5 of the mixture is 87,33, the non-uniformity coefficient Cu is 6,44, and the curvature coefficient Cc is 1,31. Through literature review, it was found that the compacted test results in good gravel soil. The results indicate that after being compacted by heavy compaction equipment on the construction site, the grading composition of blast furnace slag also changes from poorly graded massive soil to well graded gravel soil. It can be well used to fill the roadbed or foundation of high-grade engineering projects such as highways, railways, airports, etc.

SAMPLE PREPARATION METHOD EXPERIMENTAL PLAN

Sample preparation method Sample preparation method: This experiment uses a large structural plane shear apparatus, which can be used for shear testing of coarser grained soil samples. This shear test adopts a strain control formula, with a direct shear rate of 2 mm/min. The cutting box is rectangular in shape and its size is: high × wide × length=200 × 400 × 600 mm (the height of the lower shear box is 100 mm, the height of the upper shear box is 110 mm, and approximately 10 mm is reserved for placing the normal loading plate during sample loading). This direct shear apparatus is suitable for specimens with a maximum particle size of 60 mm. The large direct shear instrument has a vertical displacement sensor on the normal loading plate. During the test, the vertical displacement data of the vertical displacement sensor is read to analyze the shear shrinkage and shear expansion in the shear test.

As an industrial waste, the particle distribution of blast furnace slag itself has uncertainty (disturbance) during the dumping process. Therefore, when using a large direct shear apparatus for direct shear, the disturbance method is used for sampling. When preparing the sample, in order to avoid uneven or even certain degree of segregation of coarse and fine particles when directly pouring the sample into the shear box, the experiment adopts three times of loading the sample according to the height of the shear box of the direct shear instrument. Each time, one-third of the coarse particles of blast furnace slag are first loaded, followed by fine particles, and then compacted. Repeat three times until the shear box is filled. When the loading sample is close to the top of the shear box, A 1 cm height space should be reserved for placing the upper cover plate of the cutting box. By adding and compacting coarse and fine particles in layers, segregation of coarse and fine particles can be effectively avoided, ensuring a uniform shear surface and making the experimental data more realistic and effective.

Test plan: The main purpose of this experiment is to understand the shear strength index and water stability of the compacted fly ash modified blast furnace slag mixture. During the experiment, shear tests were conducted on both dry and wet materials. The loading method and compaction process were the same for each test, and there were two situations during the experiment. One was dry material, where the filler was subjected to shear tests in a dry state; One type is wet material, which has a moisture content of about 8 %. The dry density of both dry and wet materials during the shear test is approximately 1,66 g/cm^3.

RESULT ANALYSIS

Analysis of shear strength parameter characteristics

The results of the shear test are shown in Table 2, Figure 2 and Figure 3. From the results, it can be seen that the influence of water on shear strength can be almost ignored, so it can be seen that the mixed material has good water stability. The reason is that the coarse particles in the mixture play a major role in the shear strength, and the friction and bite force between the coarse particles are large.

The shear strength of the mixture with different water content will be tested, and its shear strength and vertical pressure are shown in Figure 2 and Figure 3. It can be seen that the normal stress of 150 kPa is the boundary point. When it is less than 150 kPa, the slope of the curve is larger, while when it is less than 150 kPa, the slope of the curve is smaller. By extending the curves of the two slopes separately, it can be seen that when the normal stress is less than 150 kPa, the cohesion c value in the shear strength is negative. When the normal stress is greater than 150 kPa, the value of c is positive. However, we know that the mixture has almost no viscosity, and the cohesive force that occurs must be caused by some approximate force. Due to the large number of coarse particles in the mixture, it can be determined that the cohesion is caused by the bite force between the coarse particles, indicating a high bite force. Therefore, it can be concluded that the critical normal stress value

Table 2 **Shear test results**

Dry material		Wet material	
Normal stress /kPa	Maximum shear force /kN	Normal stress /kPa	Maximum shear force /kN
50	103,25	50	101,34
100	235,20	75	184,52
150	342,67	150	344,96
200	420,37	250	458,29
275	500,28	375	417,66
400	648,26	500	764,38

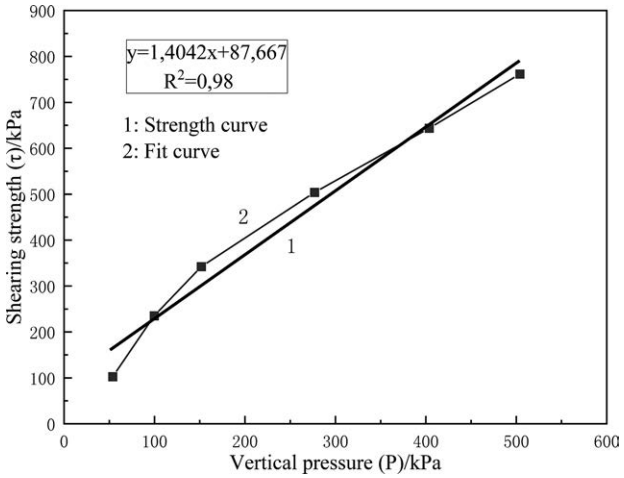

Figure 2 Relationship between shear strength and normal stress of dry materials

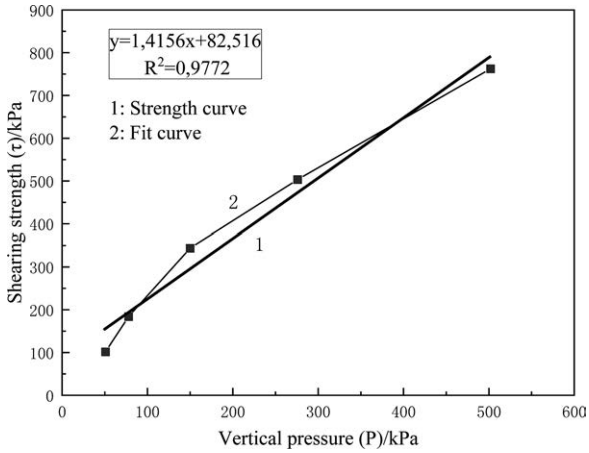

Figure 3 Relationship between shear strength and normal stress of wet materials

for the cohesive force of fly ash modified blast furnace slag mixture is 150 kPa.

Shear expansion analysis

During the shear test, shear dilation phenomenon occurs, which is manifested as the opening of the front opening of the shear box. This phenomenon occurs after a shear displacement of about 2 cm. In order to understand the shear dilation of the mixture in the shear test, the vertical displacement of the vertical pressure loading plate was measured, and the test results are shown in Figure 6. It can be seen that before the shear displacement is about 2 cm, the vertical pressure loading plate undergoes downward displacement. The higher the normal stress, the greater the downward displacement. When the normal stress reaches 500 kPa, its downward displacement can reach about 1mm. When the shear displacement exceeds 2 cm, the vertically loaded plate begins to experience upward displacement, manifested as the smaller the normal stress, the greater the upward displacement. This indicates that the shear test of improving blast furnace slag with fly ash first undergoes shrinkage reduction, followed by shear expansion. The higher the normal stress, the greater the shrinkage reduction. The lower the normal stress, the greater the shear expansion.

The reason for the shrinkage phenomenon is due to the mutual squeezing effect of coarse particles, while the shear expansion phenomenon is caused by the rolling and overtaking effect of coarse particles on the shear surface. The shear surface of the shear test is a complex particle interaction surface. This interaction is manifested by the occurrence of squeezing, crushing, dislocation, rolling, shearing, etc. between coarse particles, among which the embedding and crushing of particles can be considered as leading to a decrease in sample volume; The dislocation and rolling of particles can be considered as causing an increase in sample volume; Particle shearing can be considered as the sample volume remains basically unchanged.

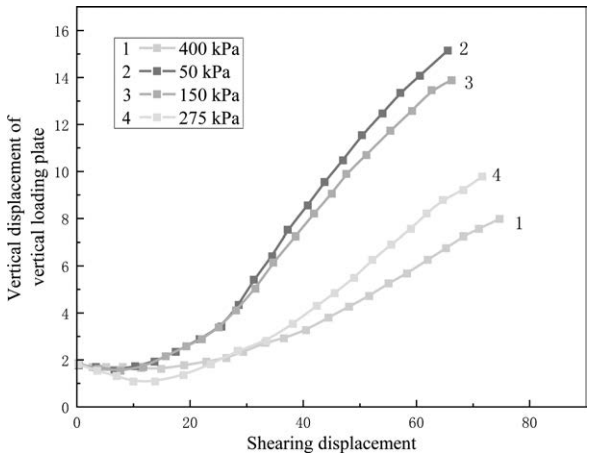

Figure 4 The relationship between vertical displacement and shear displacement of vertically loaded plates

During the shear test process, the main forms of action of particles vary under different normal stress and shear displacement stages, with particle shear being the main form of action generally occurring under large vertical pressure and large shear displacement. From Figure 4, it can be seen that when the normal stress is above 150 kPa, the vertical displacement of the vertically loaded plate is much smaller than when the normal stress is 150 kPa, and the vertical displacement is closer when the normal stress is 50 kPa and 150 kPa. It can be concluded that when the normal stress is above 150 kPa, the volume of the mixture changes less, and the

shear plane is mainly dominated by coarse particle shear, accompanied by a relatively small amount of shear expansion.

CONCLUSION

The shear test results of fly ash improved blast furnace slag mixture show that the mixture has good water stability; When the normal stress value of the mixture is greater than 150 kPa, a biting force will occur; During the shear test, shrinkage first occurs, followed by shear expansion. The greater the normal stress, the greater the reduction. The smaller the normal stress, the greater the shear expansion; When the normal stress is higher than 150 kPa, the volume of the mixture slightly changes, and the shear plane is mainly dominated by coarse particle shear, accompanied by a relatively small amount of shear expansion.

Acknowledgments

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Note: The responsible for English language is H. Z. Yang.