Research Article

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Sustainable utilization of a converter slagging agent prepared by converter precipitator dust and oxide scale

Abstract: A converter slagging agent was prepared using converter precipitator dust and oxide scale as raw materials and bentonite, calcium oxide, and soluble glass as binders. The influence of different binders on the strength of the converter slagging agent was studied. The optimum ratio of bentonite, calcium oxide, and sodium silicate was determined by orthogonal experiments. The chemical composition, strength, moisture content, alkalinity, and other indicators of the prepared converter slagging agent met the requirements for converter smelting. The drop intensity of the green pellet was 3.7 times, and the compressive strength of the dry pellet could reach $988.72\,\text{N/m}^2$. Therefore, the sustainable utilization of converter precipitator dust and oxide scale could be realized by the preparation of a converter slagging agent.

Keywords: converter slagging agent, binder, converter precipitator dust, oxide scale

1 Introduction

A large amount of solid waste is generated in the production of iron and steel, and the waste also pollutes the environment while occupying land resources [1–5]. Therefore, recycling and reuse of these solid wastes are of great significance for reducing the amount of occupied land and resource utilization and protecting the environment [6,7]. The converter precipitator dust and oxide scale produced during metallurgical processes have a high iron content and few impurities. They are good secondary metallurgical resources and have great recycling value [8,9].

According to statistics, each ton of steel produced with converter steelmaking is accompanied by approximately 15–20 kg of precipitator dust [10–12]. The main components in converter precipitator dust are Fe, Ca, Mg, Zn, and other element oxides, and the average Fe oxide content is above 70% [13–16]. The particle size of most converter precipitator dust is approximately 50 μm, and the specific surface area can reach $4.336\,\text{m}^2/\text{g}$ [17]. The converter has a high total iron (TFe) content, fine particle size, and few impurities [18,19]. The scale is a layered iron oxide formed by the oxidation of the surface of the slab or billet during the production of continuous casting and steel rolling. It is approximately 1–2% of steel output. Its iron content is relatively high, and its composition contains only a very small amount of impurities [20].

In the process of converter steelmaking, slagging materials, such as fluorite, lime, and scale, should be added to promote the formation of slag [21,22]. The quality and output of steel can be improved by selecting a suitable slagging agent and controlling the composition and temperature of the slag [23,24]. According to the above process conditions and actual demands, the quality index of a converter slagging agent is as follows: the drop intensity is more than three times, the compressive strength is more than $800\,\text{N\,cm}^{-2}$, the alkalinity is greater than 3, the melting rate is less than 80 s, and the moisture content is controlled within 5%.

In the preparation of a converter slagging agent, the selection of the binder is directly related to the mechanical properties of the moulding samples [25,26]. Therefore, it is particularly important to study the influence of binder type and ratio on the strength of a converter slagging agent. At present, the common inorganic binders are bentonite, calcium oxide, sodium silicate, and cement [27–29].

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In this paper, the converter slagging agent was prepared by the cold pressing method with converter precipitator dust and oxide scale as raw materials, and bentonite, calcium oxide, and sodium silicate were used as binders. The performance of the prepared converter slagging agent was studied and analyzed. This research explored a suitable method for the sustainable utilization of converter precipitator dust and oxide scale.

2 Experimental methods

2.1 Performance analysis of the converter precipitator dust

The converter precipitator dust was a reddish black powder. The particle size distribution of the converter precipitator dust was relatively fine, as shown in Table 1.

The micromorphology of the converter precipitator dust (Figure 1) was detected by scanning electron microscopy. The particles in the converter precipitator dust showed no obvious agglomeration, some were spherical, and some had an irregular shape. For cold pressing moulding, particles with low sphericity have an improved contact area with other materials, improving the degree of mutual occlusion, increasing the number of anchor points adsorbed by the binder, improving the structure of the raw ball during moulding, and enhancing the strength of the raw ball after moulding.

The specific chemical composition and content are shown in Table 2. The converter precipitator dust is mainly composed of iron oxides and contains a small amount of other oxides.

2.2 Performance analysis of the oxide scale

The oxide scale is a black flaky iron-containing oxide produced during the steel rolling process. The length and width of the scale used in the experiment were
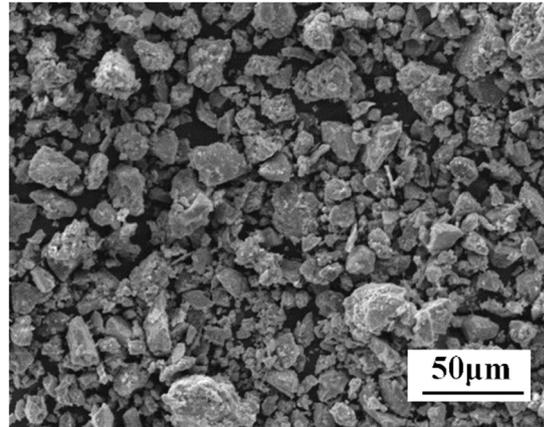

Figure 1: The micromorphology of converter precipitator dust.

distributed between 3 and 8 mm. The microstructure of the oxide scale is shown in Figure 2. The surface of the oxide scale skin itself was uneven, with irregular undulations and granular protrusions formed by rapid cooling. In addition, the oxide skin contained a distribution of cracks and was prone to fracture. Therefore, the binder readily adsorbed onto the surface of the material, and the fracture of the material can improve the particle size ratio of the material to a certain extent and increase the strength after moulding.

The chemical composition analysis shows that the iron content of the oxide scale was very high, as shown in Table 3.

High oxide content in a converter slagging agent can promote the melting of lime and rapid slag formation at the early stage of converter steelmaking. In addition, the content of TFe in the converter precipitator dust and oxide scale was high, which can increase the metal yield during steelmaking in the converter.

2.3 Performance analysis of the binder

The particle size of the lime used in the experiments was smaller than 75 µm. The chemical composition of the lime is shown in Table 4. The content of calcium oxide in lime was more than 98%.

The bentonite used in the experiment was industrial-grade bentonite and a yellow powder, whereas its particle size was smaller than 75 µm. The chemical composition of bentonite is shown in Table 5. The bentonite contained 57.25% SiO_2 and 19.36% Al_2O_3.

Industrial-grade sodium silicate, which is a transparent viscous liquid, was used herein. The specific chemical composition is shown in Table 6.

Table 1: The particle size distribution of the converter precipitator dust

Particle size distribution (µm)	≥82	75–82	≤75
Content (wt%)	2.6	95.6	1.8

Table 2: Chemical composition of the converter precipitator dust

Composition	TFe	FeO	SiO$_2$	CaO	MgO	S	P	Fe$_2$O$_3$
Content (%)	59.35	36.23	11.40	1.23	3.36	0.68	0.017	23.12
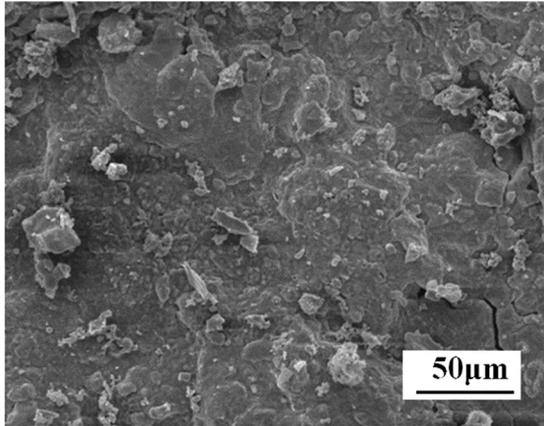
Figure 2: Microstructure of the oxide scale.

Table 3: Chemical composition of the oxide scale

Composition	TFe	FeO	Fe$_2$O$_3$	S	P
Content (%)	69.81	45.26	23.74	0.044	0.024

Because of the slow curing speed of liquid sodium silicate in normal temperature air, sodium fluorosilicate was used as a curing agent to accelerate the curing process; 15 wt% sodium fluorosilicate was added.

The molecular formula for sodium fluorosilicate is Na$_2$SiF$_6$, and it appears as white powdery particles or crystalline powder. The specific chemical composition is shown in Table 7. As shown in Table 7, the main component in the sodium fluorosilicate was 99 wt% Na$_2$SiF$_6$, whereas the impurity content was very small.

2.4 Experimental apparatus

The models of the equipment used in the experiment are shown in Table 8, including the digital display hydraulic

Table 4: Chemical composition of the lime

Composition	CaO	Chloride	Nitrate	Sulfate	Fe	Heavy metals	Alkali metal and magnesium
Content (wt%)	≥98	≤0.003	≤0.004	≤0.1	≤0.015	≤0.005	≤0.5

Table 5: Chemical composition of the bentonite

Composition	SiO$_2$	Al$_2$O$_3$	CaO	MgO	K$_2$O	Na$_2$O
Content (wt%)	57.25	19.36	0.81	2.34	0.71	0.45

press, electric blast constant temperature drying oven, blender, and scanning electron microscope.

2.5 Research methods

2.5.1 Raw material ratio

The converter precipitator dust was powder-like, which was easier to press in the mould than the oxide scale in patches. Because of the fine particles in the converter precipitator dust, the gas in the raw material was not easily discharged during the compression moulding process. When the moulding pressure was removed, it was easy to produce elastic aftereffects that caused internal cracks in the sample and affected the strength of the sample. Only when the ratio of the converter precipitator dust to the oxide scale in the raw materials was similar did the prepared samples have the highest strength herein. At this time, the converter precipitator dust with a fine particle size filled the gaps formed by the oxide scale, and it was easier to achieve a tightly packed state of the raw materials. Therefore, the raw material quality ratio of converter precipitator dust to the oxide scale was set to 1:1 in the experiment.

2.5.2 The added amount of water

During the preparation of a converter slagging agent, the added amount of water has a great influence on the

Table 6: Chemical indicators of the sodium silicate

Composition	Na$_2$O	SiO$_2$	Modulus	Density	Fe	Water insoluble matter
Content (wt%)	≥8.2	≥26.0	3.1–3.4	1.382	≤0.02	≤0.05

Table 7: Chemical composition of the sodium fluorosilicate

Composition	Na$_2$SiF$_6$	Free acid	Oxide	Sulfate	Carbonate	Fe	Heavy metals
Content (wt%)	≥99.0	≤0.25	≤0.005	≤0.01	≤0.01	≤0.005	≤0.005

Table 8: Experimental instruments

Device name	Model	Application
Electronic balance	BSA224S	Weighing experimental materials
Digital display hydraulic press	YES-600	Sample forming; compressive strength measurement
Electric blast constant temperature drying oven	101-5A	Sample drying
Blender	MSA-0420	Material mixing
Scanning electron microscope	VEGA3 LMH	Observation of micro-morphologies

uniformity of the mixture and the forming performance. If the amount of water added is small, the water forms a lump with the raw materials that are first contacted during the mixing process, and then subsequent agglomeration leads to the formation of a ball that makes the raw material dry and wet unevenly. As a result, the slagging agent cannot be mixed uniformly, and the moulding effect is poor. If the amount of added water is very high, the excessive water is squeezed out of the sample because of the pressure during the compression moulding process, and it is mixed with the converter precipitator dust on the outer surface of the sample and forms a muddy state. Between the outer surface of the sample and the inner surface of the mould, the muddy slagging agent makes it difficult to demould. Therefore, the amount of water added during the preparation of the slagging agent should be moderate.

Based on the outcomes from the previous studies [30] and multiple verifications during this experiment, when the amount of water added was 6 wt% of the raw material, the requirement of uniform mixing of the raw materials was met. Moreover, the mixed raw materials were loose and not agglomerated, the moulding strength was the highest herein, and the demoulding process was easy. Thus, the amount of water added in the experiment was set at 6 wt% of the raw material.

2.5.3 Moulding pressure

The forming pressure directly affects the degree of compaction between the raw materials and determines the strength of green pellets. If the moulding pressure is very low, the moulding strength of the sample is very low. In this case, the moulded sample shatters under a small force. In contrast, if the moulding pressure is very high, part of the moisture is mixed with the slurry of the converter dust removal ash and is squeezed out, resulting in a reduction in the bonding effect of the moisture and difficulty during demoulding. Therefore, the moulding strength of the sample decreases instead. The experiment measured the drop intensity of green pellets prepared under different forming pressures. The results show that when the moulding pressure was 60 kN, the drop intensity of the sample was the largest herein, and no moisture was extruded. From this, the moulding pressure was selected to be 60 kN in this experiment.

2.5.4 Experimental processes

First, the converter precipitator dust and oxide scale were mixed without adding water. During the mixing process, large-sized oxide scale was broken under various stresses

and actions and formed a particle gradation with the converter dust to promote close packing of the raw materials. Then, the binder was added according to the proportion, and secondary mixing was carried out without adding water. Finally, 6 wt% water was added to the raw material for even stirring and mixing.

After the mixing was completed, 55 g of well-mixed raw materials was weighed and moulded by a digital display hydraulic press. Under a moulding pressure of 60 kN, it was pressed into a cylindrical sample with a size of Φ 36 × 18 mm. Ten samples were randomly selected as a group from the press-formed samples. A total of five sets of samples were tested for the drop intensity. The remaining samples were dried in a constant temperature oven for 0.5 h, and then the compressive strengths of the dry pellets were tested. The specific experimental process is shown in Figure 3.

2.6 Performance testing of the converter slagging agent

The drop intensity of the green pellets and compressive strength of the dry pellets were used to measure the performance of the converter slagging agent. The drop intensity of the green pellets was used to characterize the forming strength of the sample. The test method involves dropping a single sample from a height of 0.5 m onto a 10 mm thick steel plate. The drop intensity of the green pellet was the number of times that it could be dropped until it broke. The compressive strength of the dry pellet was used to characterize the strength of the sample after drying. The test method involves applying pressure to the sample with a hydraulic press. The compressive strength of dry pellets can be obtained by calculating the corresponding pressure value when the sample is broken.

Considering the actual production process, the strength of the converter slagging agent should meet the requirement that the drop intensity of green pellets should be more than two times, and the compressive strength of dry pellets should be greater than 800 N cm^{-2}.

3 Results and discussion

3.1 Effect of the binder on the strength of the converter slagging agent

3.1.1 Effect of bentonite on the strength of the converter slagging agent

The trend for the converter slagging agent strength was studied when bentonite was used alone as a binder. After mixing the converter dust and oxide scale with a mass ratio of 1:1, 1, 2, 3, 4, and 5 wt% of the bentonite and 6 wt% of the water were added. The prepared converter slagging agents were tested for their strength.

As shown in Figure 4, with an increase in the added bentonite amount, the drop intensity of the green pellets and the compressive strength of the dry pellets changed in the same way, and both increased at first and then decreased.

This is because bentonite is a very fine-grained montmorillonite aggregate. Bentonite easily absorbs water, swells during mixing, and decomposes into flake components. It has good adhesion and helps to form a stable structure. Therefore, the drop intensity of a green pellet can be improved by adding bentonite. After drying, the compressive strength of the dry pellet correspondingly increased.
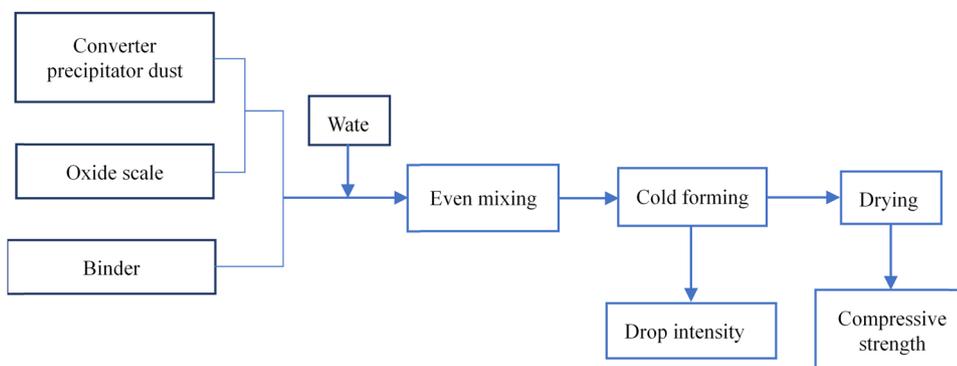

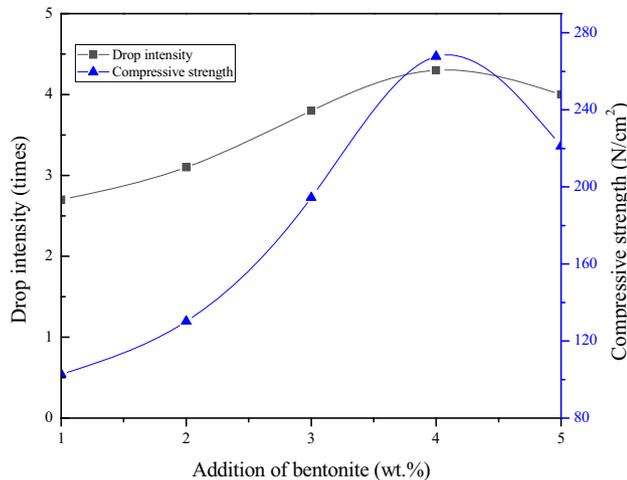**Figure 3:** Preparation process of the converter slagging agent.

Figure 4: Effect of bentonite addition on the sample strength.

Figure 5: Effect of calcium oxide addition on the sample strength.

With the addition of bentonite, the strength of the converter slagging agent increased and reaches the maximum value when the amount of bentonite was 4 wt%. When the addition amount exceeded 4 wt%, additional moisture was absorbed by the bentonite because bentonite has a strong water absorption property. Particle agglomeration occurred in the raw materials during mixing, which led to inhomogeneous mixing. The strength decreased because of defects in the sample.

When the addition of bentonite was 1 wt%, the drop intensity of the green pellet met the production index. However, the compressive strength of the dry pellet was low. When the addition amount of bentonite was 4 wt%, the compressive strength of the dry pellet reached the maximum value of $267.65 \, N \, cm^{-2}$, which still did not meet the index. Subsequently, the compressive strength of the dry pellet showed a downward trend.

3.1.2 Effect of calcium oxide on the strength of the converter slagging agent

The trend for the strength of the converter slagging agent was studied when calcium oxide was used alone as a binder. The converter slagging agent was prepared by mixing the converter dust ash and oxide scale with a mass ratio of 1:1; in addition, 1–9 wt% calcium oxide and 6 wt% water were added. Then, their strengths were tested.

As shown in Figure 5, with an increase in the calcium oxide dose, the decreasing trends of the green pellet and dry pellet compressive strength were consistent. When the added amount of calcium oxide was less than 7 wt% of the raw material, the strength of the sample increased with
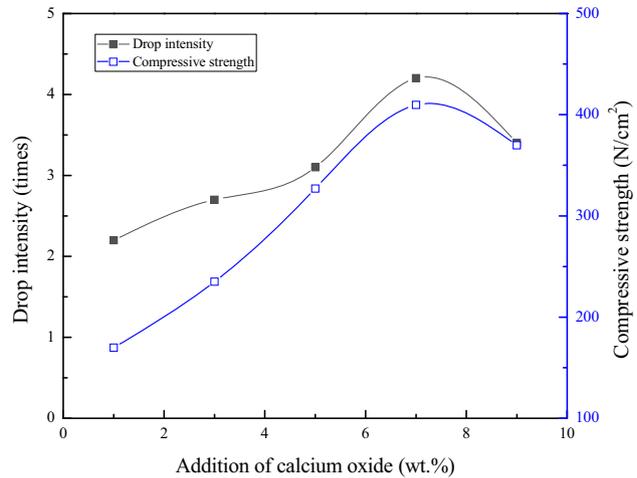
increasing added amount. When the added amount was 7 wt% of the raw material, it reached its maximum value. When the added amount exceeded 7 wt% of the raw material, similar to bentonite, the lack of moisture led to the inability to mix the raw materials, and the strength tended to decrease.

The calcium oxide generated calcium hydroxide with water during the mixing process, and the calcium hydroxide colloidal particles had a strong binding ability, thereby improving the strength of the sample after moulding. During the drying process of the sample, it combined with CO_2 in the air to form calcium carbonate. After losing water, it formed a network of whiskers on the surface of the sample, which improved the compressive strength of the dry pellet.

When calcium oxide was used as a binder alone and the addition amount was 1%, the drop intensity of the green pellet met the production index. However, the compressive strength of the dry pellet increased with increasing addition amount. It reached a maximum value of $407.71 \, N/cm^2$ when the addition amount was 7 wt% and then exhibited a downward trend. Therefore, the compressive strength of the converter slagging agent did not meet the production index when calcium oxide was used alone as a binder.

3.1.3 Effect of sodium silicate on the strength of the converter slagging agent

The trend for the converter slagging agent strength was studied when sodium silicate was used alone as a binder. After mixing the converter dust and oxide scale with a mass ratio of 1:1, the converter slagging agent was
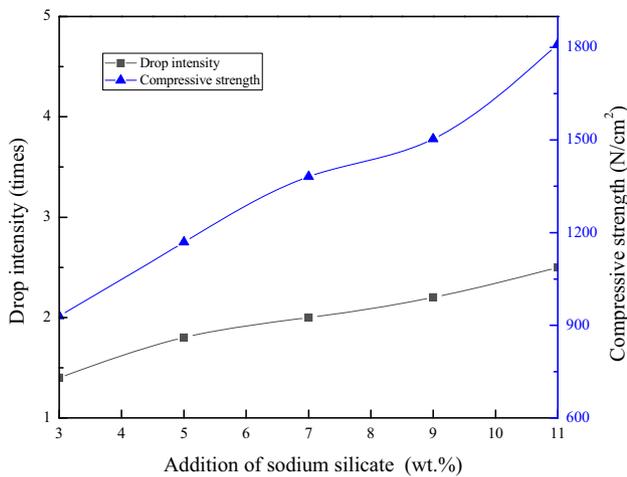
Figure 6: Effect of sodium silicate addition on the sample strength.

prepared by adding different amounts of sodium silicate and 6 wt% water. Then, its strength was tested. To speed up the curing speed of the sodium silicate, sodium fluorosilicate was added as a curing agent during the mixing process. The addition amount of sodium fluorosilicate was always 15 wt%.

As shown in Figure 6, compared with that for bentonite and calcium oxide, the drop intensity of the green pellet prepared with sodium silicate as the binder was low. Moreover, with an increase in the amount of water glass, the drop intensity of the green pellet did not improve substantially. However, the compressive strength of the dry pellet was significantly increased. During the drying process of the sample, the sodium silicate between the voids hardened and consolidated to form a three-dimensional network structure, which wrapped and supported the material. Therefore, with an increase in the amount of added sodium silicate, the compressive strength of the dry pellet also increased.

When the added amount of sodium silicate was higher than 3 wt%, the compressive strength of the sample met the production index. However, its drop intensity only reached 2.1 times when the addition of sodium silicate was 7 wt%. It just met the production index.

3.2 Effect of the composite binder on the strength of the converter slagging agent

According to the analysis, it can be observed that the drop intensity of the green pellet met the production index when the addition amount of bentonite and calcium oxide was 1 wt% as a single-component binder, but the compressive

strength of the dry pellet was low. In contrast, the compressive strength of the dry pellet met the production index when the content of sodium silicate was low, and the drop intensity of the green pellet was always low at the same time.

To improve the drop intensity of the green pellet and compressive strength of the dry pellet at the same time, three kinds of binders were designed in combination. Because the price of sodium silicate is higher than that of bentonite and calcium oxide, too much of sodium silicate also affects the alkalinity of the slagging agent. Therefore, under the premise of meeting the production index, the amount of sodium silicate should be reduced as much as possible in the experimental design.

3.2.1 Design of the orthogonal experiment

To improve the experimental efficiency and obtain an optimal performance, an orthogonal test was designed to determine the optimal ratio of the three single-component binders to meet the production index. In the orthogonal experiment, the amount of added water was 6 wt%, the pressure during moulding was 60 kN, and the addition of sodium silicate, bentonite, and calcium oxide were selected as the three factors, each of which had three levels. The addition of sodium silicate was 3%, 5%, and 7%; the addition of bentonite was 2, 3, and 4 wt%; and the addition of calcium oxide was 3, 5, and 7 wt%. The above factors and levels were filled into an L9 (3^4) orthogonal table. The specific orthogonal experimental design is shown in Table 9.

3.2.2 Results from the orthogonal experiment

The orthogonal experiment was carried out according to the determined experimental parameters, and the experimental data were recorded and calculated. The calculation results and analysis of the orthogonal experiment are shown in Table 10. It can be observed from Table 10 that when bentonite, calcium oxide, and sodium silicate were used as binders in combination, the experimental results of the ratio in the orthogonal experiment table all met the production indicators. For the drop intensity of the green pellet, when the addition of sodium silicate and bentonite was at the third level, the results were the best. However, the best value was obtained when the amount of added calcium oxide was that in the first level. Therefore, the best experimental condition for the drop intensity was A3B3C1; that is, the addition of sodium silicate, bentonite, and calcium oxide was 7, 4, and 7 wt%, respectively.

Table 9: Orthogonal experiment table

Level	Factor		
	Sodium silicate (wt%) A	Bentonite (wt%) B	Calcium oxide (wt%) C
1	3	2	3
2	5	3	5
3	7	4	7

Similarly, for the compressive strength of the dry pellet, the best test condition was A1B3C3. That is, the additions of sodium silicate, bentonite, and calcium oxide were 3, 4, and 7 wt%, respectively.

According to the previous consideration, the price of sodium silicate is relatively high, and the increase in sodium silicate content reduces the basicity of the converter slagging agent, which is not conducive to rapid slag formation. Therefore, the formula with less sodium silicate, namely, orthogonal formula A1B3C3, was the third experimental proportion in the orthogonal table. There was no need to carry out other comparative experiments for verification. At this time, the average drop intensity was 3.7 times, and the average compressive strength was 988.72 N/cm². The experimental results showed that the slagging agent met the production requirements.

3.3 Performance analysis of the converter slagging agent

3.3.1 Quality index of the converter slagging agent

The converter steelmaking temperature during blowing is generally greater than 1,450°C. A large amount of slagging agent should be added in the early stage of blowing. It is usually required that the melting point of the converter slagging agent be lower than the blowing temperature. The dephosphorization conditions during steelmaking include a high basicity, high ferrous oxide content, large slag content, and low temperature. If the alkalinity of the converter slagging agent is very low, it is not conducive to the rapid improvement of the alkalinity, and it increases the consumption of lime. If the content of ferrous oxide is low, the iron in the molten metal is substantially oxidized. The converter steelmaking process is approximately 12–16 min. In the initial stage of converter smelting, the slag making speed is required to be fast. The water in the slagging agent evaporates when heated, which can easily cause the converter to splash. Therefore, the moisture content of the converter slagging agent should be less than 5%.

According to the above process conditions and actual demands, the quality index of the converter slagging agent is shown in Table 11. The melting temperature is lower than 1,450°C, alkalinity is greater than 3, melting rate is less than 80 s, and moisture content is controlled within 5%.

Table 10: Orthogonal test design and results

Level	Factor			Results	
	Sodium silicate (wt%) A	Bentonite (wt%) B	Calcium oxide (wt%) C	Drop intensity D (times)	Compressive strength P (N cm^{-2})
1	3	2	3	2.3	819.12
2	3	3	5	2.9	813.35
3	3	4	7	3.7	988.72
4	5	2	5	3.5	924.37
5	5	3	7	3.2	826.46
6	5	4	3	4.1	827.08
7	7	2	7	3.6	839.62
8	7	3	3	4.3	878.73
9	7	4	5	3.9	835.41
K_1/D	3.0	3.1	3.6		
K_2/D	3.6	3.5	3.4		
K_3/D	3.9	3.9	3.5		
R/D	1.0	0.8	0.1		
K_1/P	873.73	861.04	841.64		
K_2/P	859.30	839.51	857.71		
K_3/P	851.25	883.74	884.93		
R/P	22.48	44.22	43.29		

Table 11: The quality index of the converter slagging agent

Index	TFe	Alkalinity	Drop intensity	Compressive strength	Water content
Scope	≥50%	≥3	≥2	≥800 N cm^{-2}	≤5%

3.3.2 Chemical composition analysis of the converter slagging agent

The theoretical chemical composition of the slagging agent was calculated from the specific chemical composition of the raw materials in the production formula of the converter slagging agent. At the same time, five groups of slagging agents were randomly selected from the finished converter slagging agent for chemical composition testing. The difference between the actual chemical composition and theoretical value of the converter slagging agent was compared, as shown in Table 12.

In light of the comparison between the actual chemical compositions and the theoretical values of the converter slagging agent, the actual value of each component in the converter slagging agent produced was similar to the theoretical value calculated by the raw material composition. The contents of FeO and Fe$_2$O$_3$ changed greatly. The content of FeO decreased and the content of Fe$_2$O$_3$ increased. This change was because of the oxidation reaction of FeO, which is unstable in structure, in contact with air during the production process to produce Fe$_2$O$_3$ with a stable structure. This change did not have much impact on the performance of the converter slagging agent. Therefore, the slagging agent met the needs of converter smelting in terms of the chemical composition.

3.3.3 Strength analysis of the converter slagging agent

During the production process, 20 shaped green pellets were randomly selected for drop intensity testing, and the average value was calculated as the drop intensity of the samples. The remaining green pellets were dried in a steam dryer along with a conveyor belt. Twenty samples

Table 12: Comparison of theoretical and actual chemical composition of the converter slagging agent

Content	TFe	FeO	CaO	MgO	S	P	Fe$_2$O$_3$
Theoretical value (%)	64.18	40.75	5.23	3.36	0.362	0.021	23.12
Actual value (%)	66.34	35.51	5.95	2.71	0.215	0.022	26.91

Table 13: Strength of the converter slagging agents

No.	Drop intensity (times)	Compressive strength (N/cm^2)
1	3.3	937.51
2	3.1	911.43
3	2.9	897.27
4	3.0	912.36
5	2.8	863.85

were randomly selected from the dried products to test the compressive strength, and the average value was calculated as the compressive strength of the group of dry pellets. The average values of drop intensity and compressive strength are shown in Table 13.

It can be observed from the test results of the slagging agent strength in Table 13 that the drop intensity of the green pellets ranged from 2.8 to 3.3 times, and the compressive strength of the dry pellet ranged from 863.85 to 937.51 N/cm^2, which met the quality requirements.

3.3.4 Moisture content of the converter slagging agent

During converter steelmaking, when adding a slagging agent with high moisture content, because of the low melting point and the high melting speed of the slagging agent, the outer layer first becomes molten, and the internal moisture is unable to evaporate. The moisture content is wrapped inside the slagging agent. When the moisture is heated, the content of H in molten steel increases. When the moisture content is very high, the liquid-to-gas transition of the moisture causes a large volume expansion.

If the steam pressure is very large, it bursts and causes splashing, which causes an important hidden safety hazard during production. Therefore, the moisture content of a converter slagging agent should not be higher than 5%.

Five groups of green pellets were randomly selected from the dried product to test the moisture content. The test results are shown in Table 14.

It can be observed from the results that the moisture contents of the slagging agent ranged from 3.4 to 4.0 wt%, which met the quality standards.

3.3.5 Alkalinity analysis of the converter slagging agent

During converter steelmaking, when the alkalinity of the slag ranges from 2.8 to 3.5, the dephosphorization rate is relatively high. Therefore, the alkalinity of the added

Table 14: Moisture content of the converter slagging agent

No.	1	2	3	4	5
Moisture content (wt%)	3.7	3.4	3.6	3.7	4.0

Table 15: Basicity of the converter slag-making agent products

No.	1	2	3	4	5
Alkalinity	3.1	3.2	3.0	3.2	3.3

converter slagging agent should be approximately 3.0 to avoid affecting the alkalinity of the slag and causing the dephosphorization rate to decrease.

It can be observed from Table 15 that the alkalinity of the converter slagging agent ranged from 3.0 to 3.3, which did not obviously affect the dephosphorization rate.

4 Conclusions

(1) A converter slagging agent was prepared using converter dust ash and oxide scale as raw materials and bentonite, calcium oxide, and sodium silicate as binders. The influence of different binders on the strength of the converter slagging agent was studied. The results show that when bentonite and calcium oxide were used as binders, the drop intensity of the green pellet was higher, but the compressive strength of the dry pellet could not meet the production index. When sodium silicate was used alone as the binder, the compressive strength of the dry pellet was increased, but the drop intensity of the green pellet was decreased. The production requirement can only be met when the addition amount of sodium silicate exceeded 7 wt%.

(2) The optimal ratio of converter slagging agent was determined through orthogonal experiments; that is, the added amounts of bentonite, calcium oxide, and sodium silicate were 4, 7, and 3 wt%, respectively. The converter slagging agent prepared at this time had the best performance herein, the drop intensity of the green pellet was 3.7 times, and the compressive strength of the dry pellet was 988.72 N/cm^2.

(3) According to the established quality indicators, the relevant tests were carried out on the products. The results showed that the chemical composition, strength, moisture content, alkalinity, and other indicators of the converter slagging agent met the needs of converter smelting. Therefore, the sustainable utilization of converter precipitator dust and oxide scale could be realized by the preparation of a converter slagging agent.

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