AGGLOMERATION OF IRON-BEARING FINES: SELECTION OF THE BINDER FOR OPTIMAL BRIQUETTE STRENGTH UNDER VARIOUS ENVIRONMENTS

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Abstract

In the production of hot briquetted iron some fine by-product is generated. This material consists mainly of metallic iron and iron oxides. Before utilization of these fines in the steel mill and/or direct reduction plant, agglomeration is required. To get briquettes with sufficient strength a binder has to be added to the fines. In this study, the various binders, ranging from bentonite, molasses plus hydrated lime and starch were used in the preparation of the briquetting feed. For evaluation of the different binders, the compressive strength of the briquettes was measured. Before testing, the briquettes were stored under different ambient conditions (temperature, humidity). The results showed large differences in briquette strength depending on the used binder. Additionally, the performance of the binders was strongly dependent on the storage conditions. Thus, before the selection of an optimal binder, the relevant ambient conditions for the briquettes have to be defined.

Keywords: Iron fines, briquetting, binder, compressive strength

1. INTRODUCTION

In the iron and steel industry, recycling of fine material like fines from the production of hot briquetted iron (HBI) or residues from off-gas cleaning is a common method to reduce loss of material especially the loss of Fe [1-3] and minimize landfill. In integratred steel mills, fine granular material can be recycled via the sinter plant [3,4]. However, the recycling of zinc contating fines like blast furnace (BF) and basic oxygen furnace (BOF) dust is very limited because of the zinc limit for the BF charge of 100-150 g/t hot metal [5]. In direct reduction plants or in mini mills, no sinter plant is available for the agglomeration of the fine materials for recycling. In such applications, briquetting is a feasible alternative for the agglomeration of fines [6-9]. However, in order to get briquettes with sufficient strength, a binder has to be added to the fines before briquetting. In contrast, agglomerates produced by pelletizing are usually not strong enough [10].

Various binders, ranging from bentonite, molasses in combination with hydrated lime, lignosulfonate or starch can be used in the preparation of the briquetting feed [11]. The stability of briquettes produced for the recycling fines under the reducing conditions in a furnace has been investigated frequently [12-14]. In contrast, little information is available about the influence of different storage environments on the stability of the briquettes.

Before the utilization of fines generated as by-product in the production of hot briquetted iron (HBI), also an agglomeration step is required. The aim of this study was the evaluation of the influence of different ambient conditions on the compressive strength of briquettes made of HBI fines using various binders.

2. MATERIALS AND METHODS

The briquettes were produced from HBI fines with a moisture content of 6.9 %. The total iron content of the HBI fines was 88 % and the metallic iron content was 73 %. Minor components were SiO_2 (3.8 %), CaO (1.0 %), Al_2O_3 (0.7 %) and MgO (0.3 %). The mass median diameter of the fines was 1.7 mm.

In the briquetting process different types of binders were used: two different types of bentonite (B), molasses and hydrated lime with a mixing ratio of 2:1 (ML), lignosulfonate (LS), three different types of starch (S) as well as an organic polymer (P).

The fines were mixed with the binder in an intensive mixer under the addition of some water. Subsequently, the material was briquetted in a roller press. The produced briquettes had a nominal volume of 10 cm³ and a nominal size of L x B x H = 30 mm x 24 mm x 17 mm. However, the real thickness of the briquettes was influenced by material properties and machine settings as well. Therefore, the thickness varied somewhat around the nominal value. The compressive strength of the different briquettes was tested one hour and twenty-four hours after production. The results are shown in **Table 1**.

Table 1 Binders used and average compressive strength of the briquettes in N

Briquette	Binder	Addition in %	After 1 hour	After 24 hours
B1	Bentonite 1	6	350	840
B2	Bentonite 2	6	390	1250
ML	Molasses + lime	6	220	570
LS	LIgnosulfonate	4	1530	2080
P	Polymer	5.4	350	940
S1	Starch 1	2	270	470
S2	Starch 2	2	520	1510
S3	Starch 3	2	900	2630

Subsequently, 10 to 15 briquettes were exposed to each of the following environmental conditions for a defined storage time before testing their compressive strength:

- Climate chamber: 30 °C and 85 % air humidity for 24 hours (C 24)
- Climate chamber: 30 °C and 85 % air humidity for 48 hours (C 48)
- Freezer: -20 °C for 24 hours (F 24)
- Freezer: -20 °C for 48 hours (F 48)
- Water bath: room temperature for 24 hours (W 24).

The briquettes were tested for compressive strength immediately after they were taken from the storage. Since the measured strength of briquettes can vary substantially, the cumulative distribution of compressive strength of the tested briquettes is shown in the following diagrams.

3. RESULTS AND DISCUSSION

Generally, there is a significant influence of the binder on the compressive strength of the briquettes produced. The values measured 24 hours after production varied from 470 N to 2630 N (**Table 1**). The most severe storage condition for the briquettes tested was submersion in water. Storage in moist air at 30 °C and freezing of the briquettes showed no strong negative effect on the strength of the briquettes.

Figure 1 shows the results for the briquettes made with bentonite as binder. For both bentonites B1 and B2, similar minimum compressive strength was achieved while the values for the maximum compressive strength were higher for the briquettes produced with bentonite B2. This is because the spread of the distribution of the strength was considerably larger for the B2 briquettes. The average compressive strength after storage in moist air was nearly unchanged in comparison to the average strength after 24 h, while freezing increased somewhat the average compressive strength. The influence of the storage time was relatively small. In contrast, submersion of the briquettes in water had a very negative effect on the compressive strength.

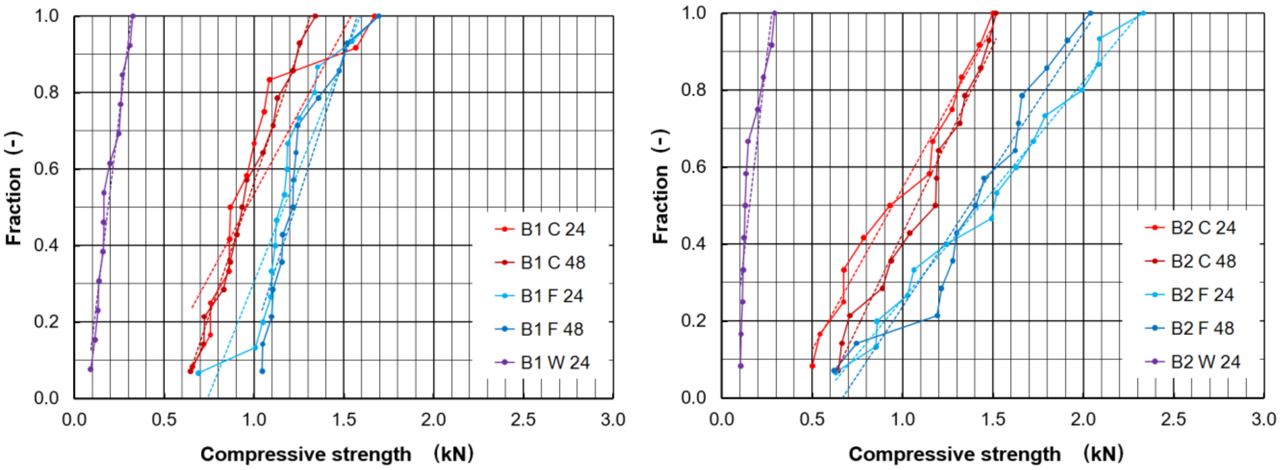

Figure 1 Compressive strength of briquettes made with two different types of bentonite as binder

For the briquettes with molasses and lime as binder, the effects of the storage conditions were similar as found for the briquettes with bentonite (**Figure 2**). The influence of moist air on the average compressive strength was small, while freezing increased the strength and immersion in water reduced the strength. However, the reduction was not as strong as found for the briquettes with bentonite.

The average 24 h compressive strength of the briquettes made with lignosulfonate was very high and the compressive strength after the various storage conditions showed the largest spread (**Figure 2**). The average strength was more than halved by the storage under humid air and it was reduced to one quarter after storage submersed in water. However, the average compressive strength of the lignosulfonate briquettes stored under water was still higher than the strength of the briquettes made with bentonite or molasses and lime. Freezing did not alter the strength of the briquettes made with lignosulfonate.

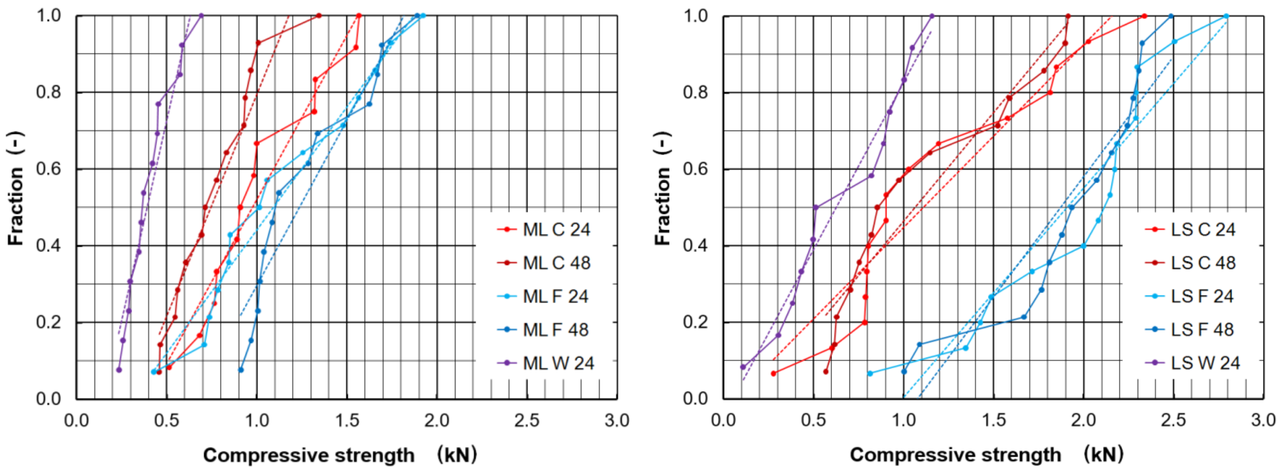

Figure 2 Compressive strength of briquettes with molasses and lime and with lignosulfonates as binder

The results obtained for briquettes produced with starch varied much depending on the type of starch used (**Figure 3**). The 24 h compressive strength was low for briquettes with starch S1, in a medium range for starch S2 and very high for starch S3. After storage in humid air the average strength of the briquettes with S1 was significantly higher, for S2 it was also a little higher while for S3 it was somewhat lower. Freezing resulted in an average compressive strength of approximately 2000 N for all three types of briquettes. Storage under water had a very negative influence on the strength of the briquettes with S3, while the influence was much less negative for S2 and S1.

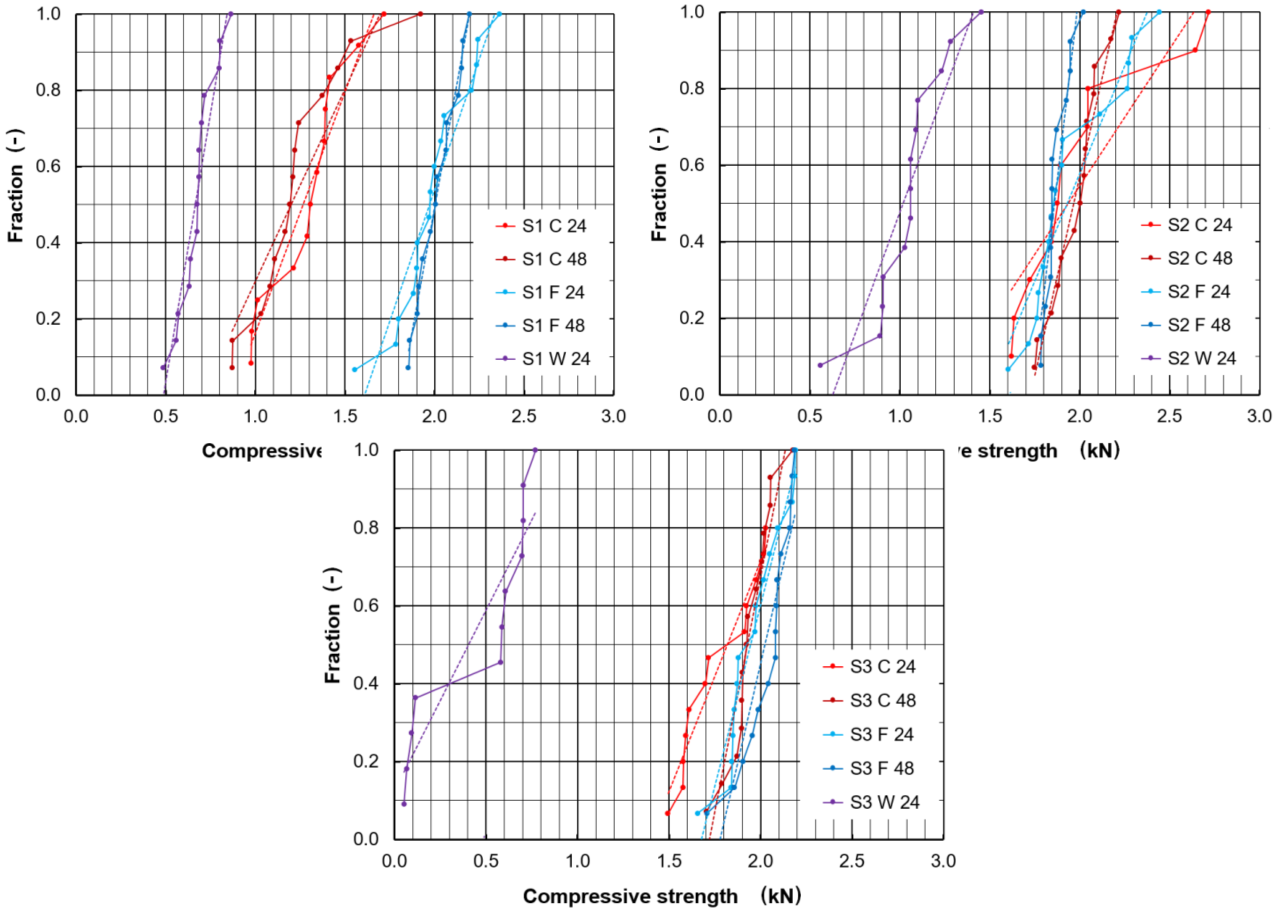

Figure 3 Compressive strength of briquettes with different types of starch as binder

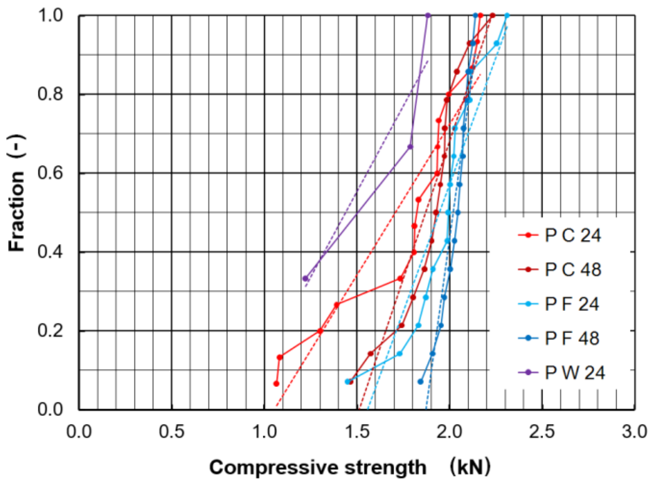

Figure 4 Compressive strength of briquettes with a polymer as binder

Figure 4 shows the results for the briquettes with the organic polymer binder. Since the average compressive strength of the briquettes was higher than after 24 h regardless of the storage conditions it has to be assumed that the hardening of briquettes with this binder takes comparatively more time than for briquettes with the other binders. The average compressive strength was similar for storage in humid air and for freezing. However, the spread of the strength distribution was wider for the briquettes stored in humid air. The strength of the briquettes submerged in water was lower than the strength after the other conditions tested but the average strength was still higher than the average strength after 24 h though these result is less solid because only three briquettes were available for this test.

In the selection of the most appropriate binder with respect to the compressive strength of the briquettes the prevailing storage conditions of the briquettes have to be considered. Thereby, the most important question is if submersion of the briquettes in water can occur. If this can happen, the highest values of the compressive strength can be achieved with the polymer binder and with starch S2. If such conditions are unlikely also starch S3 would be a good choice. The values of the compressive strength achieved in the tests with the other binders were generally lower.

4. CONCLUSION

The selection of the binder is an important topic in the production of briquettes for recycling. One target among others is to get briquette with a high compressive strength under the prevailing ambient conditions. The tests performed showed that there is a strong influence of both the type of binder and the ambient conditions on the compressive strength. Even for one type of binder, especially for starch, the results achieved with different binder qualities can vary in a wide range. Therefore, the selection of the right quality can be even more important than the selection of the binder type.

Freezing and moist air had limited influence on the compressive strength of the briquettes for most binders. In contrast, storage submersed in water reduced the compressive strength substantially, especially for briquettes made with bentonite, with molasses and lime or with some types of starch.

The highest values of the compressive strength under the investigated ambient conditions were measured for briquettes made with starch S2 and with an organic polymer.

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