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Effect of different binders on Mechanical properties of iron flotation concentrate briquettes☆

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Abstract

The effect of different binders on compressive strength and shatter resistance of flotation iron concentrate briquettes was investigated. Binders used were bentonite, lime, bituminous coal and cellulose. The Haematite concentrate was obtained by reverse flotation of fluorspar tailings. Characterisation of the iron concentrate was done and various operating parameters on the briquetting of the iron concentrate was investigated. The results showed that 80% of the tailings particles were - 150µm in size and major mineral phases are haematite, quartz and calcium tecto-dialuminodisilicate. The iron concentrate briquettes started forming at a concentration of 9% weight for all binders. Bentonite and cellulose briquettes showed compression strength above 650 KN/m^2 at room temperature whilst lime and coal gave compressive strength of 185 and 40 KN/m^2 respectively. Compressive strength of bentonite and cellulose briquettes decreased to 550 and 265 KN/m^2 respectively after heating the briquettes at 1000^{o}C whilst that of lime and coal to 0 KN/m2. Cellulose binder gave briquettes with higher shatter resistance of around 100% at temperatures between 25^{o}C and 200^{o}C. For temperatures above 200^{o}C, bentonite gave better results.

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Keywords: reverse flotation; agglomeration; binders; compressive strength; shatter resistance

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1. Introduction

Due to depletion of high grade iron ores, many companies have resorted to treatment of low grade ores and retreatment of tailings. These are finely disseminated ores and requires a fine grind for liberation. Haematite contained in these ores can be recovered by both reverse and direct flotation processes [1 – 3]. However the concentrate produced from flotation processes are too fine to be charged into the blast furnace. They should be agglomerated. Agglomeration process consist of various methods such as briquetting, pelletizing, sintering, and nodulizing [4 – 8].

Briquetting is one of the oldest agglomeration methods, in which the finely divided material is compressed under pressure, sometimes mixed with the cementing agents called binders to improve the agglomeration of particles. The briquetting technique is now-a-days substituted by sintering and pelletizing. The developed methods of briquetting like hot briquetting yield the same standards of iron ore lumps as the ones produced by pelletizing [4,5]. The briquetting technique has long found the variety of applications like; the briquetting of ilmenite ore, briquetting of self-reducing chromite briquetting and the most abundant application of iron ore lumps.

Pelletizing is the widely used agglomeration method for the production of iron ore pellets. The pelletizing method is believed to produce pellets that possess the chemical, physical and the metallurgical characteristics required for the feedstock of blast furnace [4]. Pellets are made differently from briquettes, in pelletizing the finely divided iron ore is mixed with the cementing agent – binder, and balled using the pelletizing disc. Once the pellets are formed they are dried and heated at elevated temperatures of about 1000ºC to 1300ºC, in order to produce pellets with high physical strength and metallurgical characteristics required for handling and transportation [4].

Sintering involves the mixing of fuel, flux and fine iron bearing in a mixer drum and ignition to form porous iron agglomerates. The sintering method is also widely used for the production of iron agglomerates as the feed stock for blast furnace in iron making. The sintering process is dependent on a number of parameters for the process to be efficient, namely: temperature, time, structure of iron fine, composition of the iron fines. The higher the sintering temperature, the shorter will be the sintering time. The sintering bed is heated to temperature below the melting point of the bed. The fine particles as compared to coarse particle, are fast to sinter, but they don't compact easily as coarse particles, the required particle size for the sintering process is < 150µm [5-7].

Nodulizing – Nodulizing consist of charging the iron fines in the kiln, without any addition of the binders. The kiln is rotated and the fines heated to the point of incipient melting. The formation of the nodules begins as the iron fines cascade on top of each other, and the attachment of the particles starts at the liquefied portion of the partially melted particles [6]. Nodulizing technique is however not practiced anymore, due to its high fuel consumption, operation and control difficulty, non-uniform size, and its low reducibility in the blast furnace.

Binders (cementing agents) used in agglomeration of iron ores are bentonite, lime, bituminous coal and cellulose. Bentonite – which is a naturally occurring clay mineral characterised under inorganic binders [6, 7]. Drawback of using this binder is high silica content, which will reduce porosity and reducibility of the briquettes during steel making. This leads to high energy consumption, handling and disposal of increased amount of slags produced. Lime – which has a slight advantage over inorganic binders due to its low silica content and its fluxing ability and fluxed iron briquettes exhibit good strength and reducibility [5]. Its drawback is that it produces weak briquettes which break easily during transportation, handling and charging into the blast furnace. Cellulose – do not occur naturally and are manufactured basically for the purpose of binding. They are effective and can be designed for binding different types of particles and they have reproducible character [6]. Cellulose binders do not leave residues that are detrimental in steel making, do not have silica and their additions do not dilute iron ore content after firing. However they have a disadvantage of being expensive. Bituminous coal- has also been found to be a good binder in that when mixed with iron fines, it increases the reducibility of iron and reduces the high consumption rate of coal charged as fuel. It increases the strength of the briquettes since it partially melts and fill up free space between iron particles when heated, thus increasing the porosity of the briquettes. The ash and Kaolinite content produced by heating increases the bonding of the particles thus increasing the strength of the briquettes [8].

In this study the effects of different binders on the quality of briquettes made from reverse flotation concentrates produced from fluorspar tailings are investigated in terms of compressive strength and shatter resistance.

2. Experimental

2.1 Material and methods

The fluorspar tailings associated with haematite used in this study were obtained from the Vergenoeg Mining

Company in Gauteng province, South Africa. Lime, Coal, Cellulose and Bentonite with purity of 99% was obtained from Merck. Other reagents viz . Dedecylamine (DDA), Dowfroth 200, soluble starch were sourced as AR grade from Merck and Associated Chemical Enterprises respectively. The haematite flotation concentrate was obtained using reverse cationic flotation process and the procedure is described elsewhere [3].

2.2 Experimental procedure

2.2.1 Characterisation

The haematite concentrate sample (sinks) was filtered using pressure filter and oven dried at 100^oC for 24 hrs. It was then characterised using Malvern particle size analyser, X-ray fluorescence (XRF) and X-ray diffraction (XRD).

2.2.1 Mechanical Test Experiments

The flotation concentrate (sinks) was blended for homogeneity and then briquetted. Four different binders were used in briquetting namely: Lime, Coal, Cellulose and Bentonite. A 1kg sample was weighed and perfectly mixed with a binder at different binder concentration. Cylindrical briquettes (50×50mm) were then formed using the Ridsdale compacting equipment by compacting to 57% of original volume. Different concentrations of binders from 3% to 9% mass were used. The wet briquettes were then dried at room temperature, heated to 1000^oC and then they were mechanically tested for compressive and shatter resistance. To test the effect of temperature, a second batch of briquettes containing 9% (Wt) of each binder were heated at different temperatures, cooled at room temperature and then tested for compressive and shatter resistance.

For compressive test, the briquette was placed carefully and properly on the compressive machine figure 1. Once the machine was started, pressure was exerted on the briquette until it fails and the value of the pressure was recorded down from the pressure scale on the machine.

For shatter resistance test, a shatter resistance equipment 2meters high, and equipped with a 13.2mm mesh screen at the bottom was used. The 50×50mm briquettes were dropped at the machine at a height of 2m. On reaching the bottom the briquettes shattered. Some of the shattered particles would remain on the screen and some would pass through the screen. The masses of the screen oversize and undersize were measured and the masses used to calculate the breakage percentage according to the following equation:

% breakage = Mass of screen undersize /Mass of screen oversize x 100 (1)

Figure 1: Compressive strength testing machine

3. Results and discussion

3.1 Characterisation

3.1.1 Chemical analysis

The chemical analysis of the flotation concentrate is shown in table 1. The sample contain 60% Fe and 3.51%Si therefore suitable for iron making [1 – 3].

Table 1. Chemical analysis of flotation concentrate

Element	F	Fe	Si	Ca	O	Al
%	1.09	60.00	3.51	1.87	32.04	0.49

3.2.1 Mineralogy

The X-ray diffraction (XRD) pattern of the flotation concentrate is shown in Fig. 2.

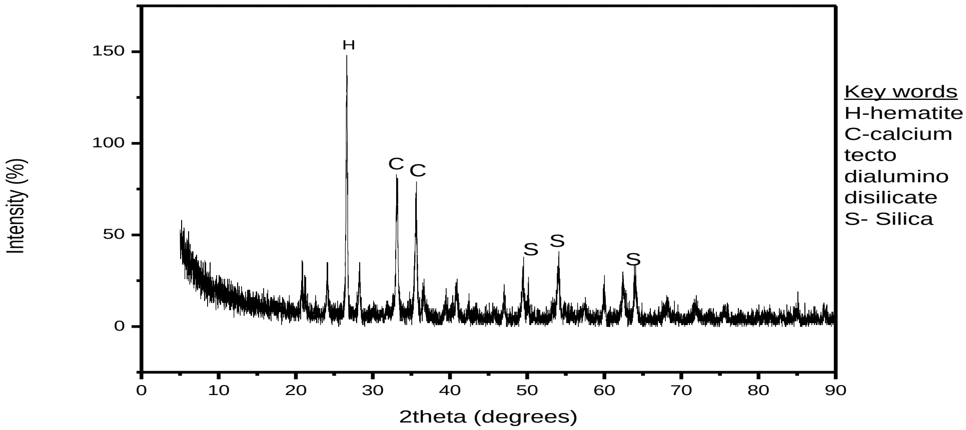

Fig. 2. XRD pattern of the fluorspar tailings

From Fig. 2, it can be seen that major mineralogical phases in the tailings are haematite, calcium tecto dialumino disilicate and silica. There are other minor phases present which are represented by smaller peaks.

3.1.3 Particle size distribution

The particle size distribution of the fluorspar tailings was studied and the results are shown in Fig. 3. Fig. 3 shows that 80% of the material is -150µm. This result proves that the sample is suitable for agglomeration and no milling is required for the subsequent test work.

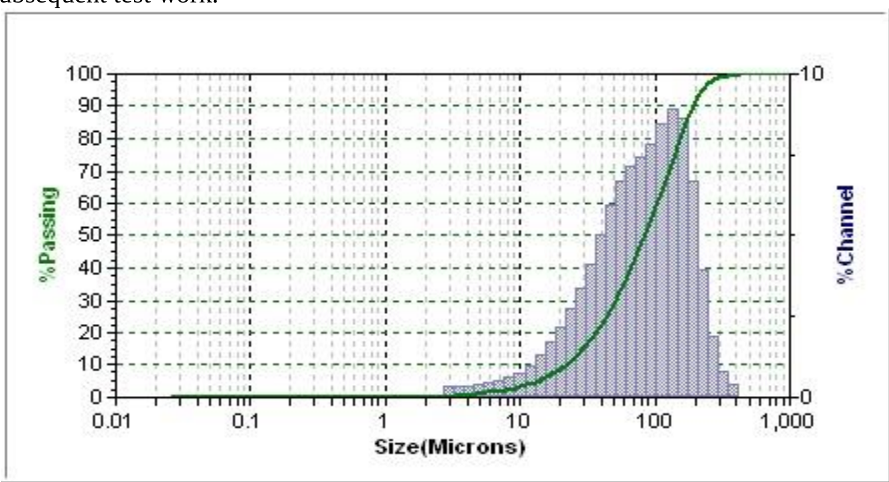

Fig. 3. Cumulative percent passing size distributions of the sample

3.2 Mechanical Test Experiments

3.2.1 Effect of binder concentration on compressive strength

The effect of binder concentration on the compressive strength of briquettes was investigated and the results shown in figure 4. From figure 4 it can be seen that there was no change in compressive strength for all binders from a binder mass % of 3 to 7. Further increase in mass % of binders has an effect on bentonite and cellulose, but no effect on lime and coal. Compressive strength increase with increase in concentration of bentonite and cellulose with bentonite giving better results.

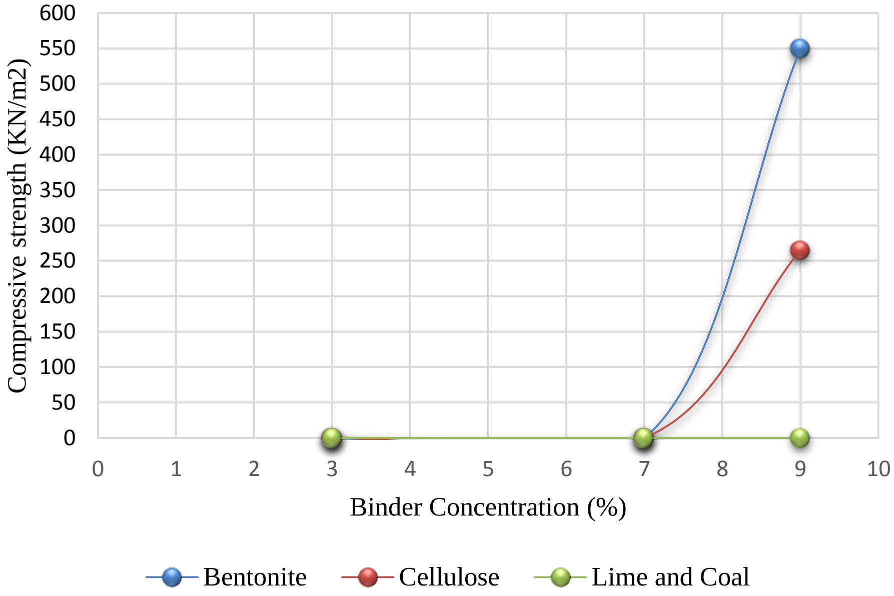

Fig. 4. Effect of binder concentration on compressive strength on iron briquettes

At the binder concentration of 9%, lime and coal briquettes failed during handling, they were not strong. Bentonite and Cellulose briquettes were strong enough to be placed on the compression strength machine and analysed. The binder content for forming iron briquettes is from 0.4% - 3% according to literature, but it was found that at 3% binder content, the briquettes did not form.

3.3.2 Effect of temperature on compressive strength

The effect of temperature on different binders at the same binder concentration was investigated and the results are illustrated in figure 5. The results shows that drying the iron briquettes at ambient temperature (25ºC), the bentonite and cellulose binder have the highest strength of above 650KN/m^2, lime and coal having the lowest strength of about 185KN/m^2 and 40KN/m^2. The compressive strength of briquettes made from bentonite binder decreases as the temperature increases. For those ones made from cellulose it drastically decreases up to temperature of 500 – 600ºC and then increases as temperature is further increased. This can be explained by the fact that cellulose melts at 500ºC. Therefore for temperatures above 500ºC it melts and binds the concentrate particles and increase the compressive strength of the briquettes. For lime briquettes, the general trend is that the compressive strength decreases to 0 at temperature around 100ºC and further increase in temperature has no effect on the compressive strength. The melting point of lime is 2572ºC and thus under these conditions it did not melt and bind the concentrates. There is a slight increase for bituminous coal at temperatures around 500°C because coal melts at temperatures around 407°C. Further increase in temperature has no effect because some of the bituminous coal is lost as vapour.

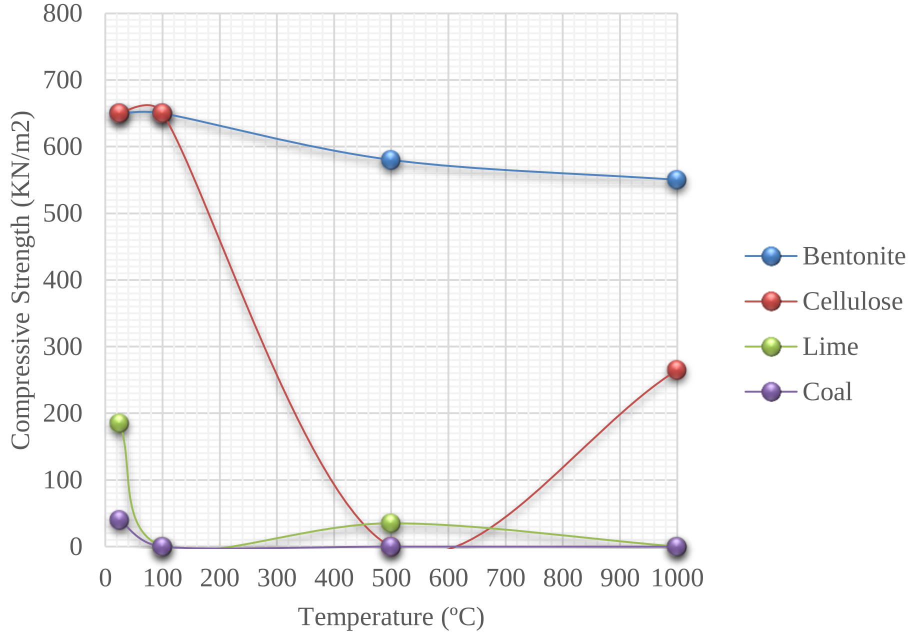

Fig. 5. Effect of temperature on the compressive strength of iron concentrate briquettes

3.3.3The effect of temperature on shatter resistance of the briquettes

The effect of temperature on shatter resistance was investigated and the results are shown in figure 6. From figure 6, it can be seen that briquettes at room temperature gave better shatter resistance than heated ones for all binders. Lime and coal gave the lowest resistance at all temperatures due to the reasons mentioned earlier.

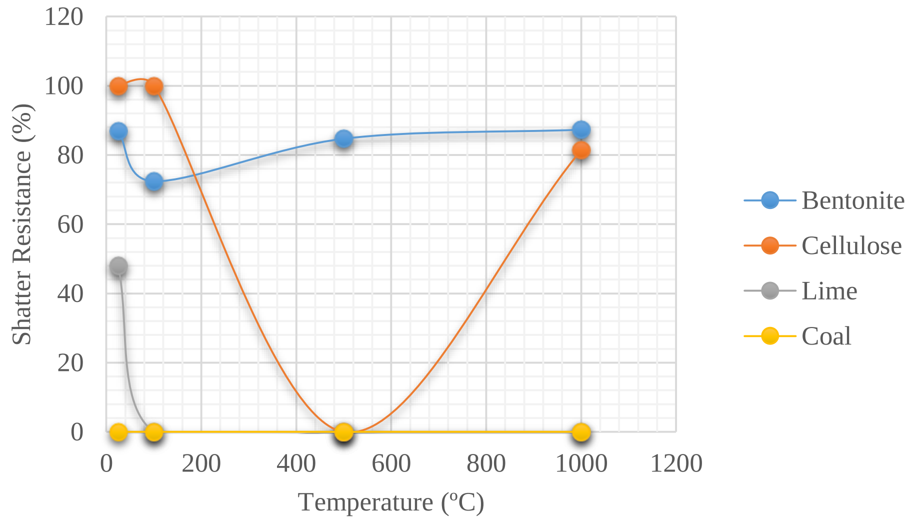

Fig. 6. Effect of temperature on the shatter resistance of iron briquettes

Interestingly cellulose binder gave briquettes with higher shatter resistance than all binders at temperature between room temperature to about 200°C. With further increase in temperature, bentonite binder gave better results. Cellulose binder gave results similar to the results of compressive strength and this may be explained by reasons mentioned above. Lime is sometimes used as a binder to produce briquettes that can be reduced easily, but it produces briquettes that are fragile and break during handling. The maximum compressive strength for briquettes made of lime and coal binders was $180KN/m^2$ and $40KN/m^2$ at room temperature.

4. Conclusion

Compressive strength and shatter resistances have been used to measure the quality of the briquettes produced with different binders and fluorspar reverse flotation concentrate (Haematite). This work has shown that stable concentrate briquettes start to form at 9% binder content by mass for all binders. Both compressive and shatter test results have shown that binder concentration and temperature has a great effect on the quality of the briquettes. Bentonite has proved to give briquettes with better compressive strength than other binders at all temperature. However at temperatures <200^oC, cellulose binder produced briquettes with better shatter resistance. Lime and coal are not good binders for the formation of the concentrate briquettes as they produced briquettes that are fragile, break during handling, and have low strength. For this material, stable briquettes can be formed using bentonite or cellulose at room temperature.

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