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THE USE OF SHAWINIGAN LIME HYDRATE AS A BINDER IN THE LABORATORY BALLING OF HILTON MINES IRON ORE CONCENTRATES

by

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THE USE OF SHAWINIGAN LIME HYDRATE AS A BINDER IN THE LABORATORY BALLING OF HILTON MINES IRON ORE CONCENTRATES

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G.N. Banks* and G.T. Watts**

SUMMARY

In a series of laboratory balling tests, using Hilton Mines iron ore concentrates, Shawinigan lime hydrate was compared with Wyoming bentonite as a binder. In these tests the lime hydrate, at levels of 1%, 2% or 3%, did not give as strong a green or dry ball as Wyoming bentonite, at a level of 3/4%. It was also found that the maximum balling moisture was about 1% higher with the bentonite binder than with the lime hydrate binder. This fact is probably responsible for the "wet sliding" which occurred at the Hilton Mines pelletizing plant when Shawinigan lime hydrate was substituted for bentonite, with no apparent change in the moisture level of the concentrates being balled.

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BACKGROUND

In the past decade, iron ore pelletizing has become one of the chief methods of preparing iron ore for blast furnace burden. The use of this type of burden has greatly increased the efficiency of the blast furnace. It has been estimated (1) that the world production of iron ore pellets (41 million tons in 1964) (2) will probably increase by 90% in the next four years. In most of the present commercial pelletizing plants, swelling bentonite (obtained from Wyoming) is the only binder used to insure good ball strength. It is estimated that the 1965 Canadian consumption of bentonite, used in pelletizing iron ores, will be 100,000 tons. (3) None of the Canadian bentonites have found commercial acceptance in this field up to the present and hence all of the bentonite used in the Canadian iron ore industry is imported from the United States.

It has recently been demonstrated that self-fluxed sinter will increase blast furnace efficiency over that obtained with acid or regular sinter. It is reasonable to assume that self-fluxed pellets would correspondingly reflect greater furnace efficiencies over acid or regular pellets. A reasonably complete survey of the literature on self-fluxed pellets was given in a paper by Merklin and DeVaney. (4) In this paper it is stated that in 1958 Hilton Mines, P.Q., as a result of the work performed in Pickands Mather's Hibbing Laboratory, made an extended run in their shaft pelletizing furnaces in which 4 1/2% of minus 100 mesh limestone was added to their iron ore concentrate which contained 2% silica. The resulting fully fluxed pellet product was physically stronger than the normal acid pellets produced. The furnace temperatures were 50° to 100° lower, while producing fluxed pellets, than when normal acid pellets were produced. These results appear to be very encouraging, yet it is interesting to note that Hilton Mines still produces an acid pellet, indicating that there must be economic or other undisclosed reasons for not producing a fluxed pellet.

The addition of limestone along with normal bentonite binder appears to increase the final pellet strength. This has been demonstrated in the laboratory by Merklin and DeVaney (7), Ban and Erck (5) and in the pilot plant by Johnson (6). It has also been demonstrated by Ban and Erck (5) and by Merklin and DeVaney (7) that limestone does not possess the necessary characteristics to replace bentonite, since the green and dry ball strengths without the use of bentonite are unsatisfactory. However, two Russian publications (8) (9) indicate that limestone additive will give sufficient strengths for normal pelletizing and the addition of bentonite will increase the strength (8).

Some authors (4) (10) indicate that when bentonite is replaced by burnt or hydrated lime as a binder, the green, dried and fired strengths of the pellets are equivalent to those obtained with bentonite, while other authors (11) (12) indicate that calcium oxide has a deleterious effect on pellet strength.

It is obvious from the above references that several apparently contradictory statements, pertaining to the use of lime or limestone as a binder, may be obtained. It is believed that some if not all of these discrepancies are attributable to differences in the material being balled or to balling techniques. The advantages of substituting lime or limestone for bentonite to approach a self-fluxing pellet composition appear to be sufficiently great to attract industrial interest. Early in 1965, Hilton Mines Ltd. substituted lime hydrate, from Shawinigan Chemicals Ltd., for the normal bentonite binder in one of their balling drum circuits. This trial was unsuccessful. The balling circuit ceased to produce balls and material in the balling drum formed into a mud-like mass. This condition was termed "wet sliding".

Following this trial, Mr. C.L. Huston of Shawinigan Chemicals Ltd. approached the Mines Branch for assistance in determining the cause of this "wet sliding". Letters, dated April 30 and May 13, were received from Mr. Huston and September 13, 1965 was selected as the starting date for an experimental balling programme at the Mines Branch Laboratories. It was also arranged for Mr. Dave Bean, from Shawinigan's technical staff, to participate in this programme.

EXPERIMENTAL WORK

Raw Materials

Two samples of lime hydrate were shipped to the Mines Branch from Shawinigan Chemicals for assessment as binders in the balling of Hilton Mines iron ore concentrates. The chemical analyses of these samples are given in Table 1.

TABLE 1

Chemical Analyses of Shawinigan Lime Hydrate

Constituent	Per Cent	
	Sample 1	Sample 2
CaO	69.3	66.7
MgO	0.10	0.11
SiO_2	1.48	1.26
CO_2	13.7	19.7
C	2.31	4.15
H_2O	0.87	1.25

Sample 1 is normal Shawinigan production (containing about 15%+100m and 45%-325m material), while sample 2 has been ground to pass a 100 mesh screen and contains about 97%-325m material. Since results were required rapidly, Shawinigan Chemicals decided to test only that sample which was produced commercially and had been used as a binder at the Hilton Mines plant. Hence, only sample 1 (coarser sample) was used in these experiments.

The density, screen analysis and Blaine specific surface area of the iron ore concentrate used is given in Table 2. A typical chemical analysis of Hilton Mines iron ore concentrate is given in Table 3.

TABLE 2

Density, Specific Surface Area and Screen Analysis of Hilton Mines Iron Ore Concentrate

Density (gm/cm^3	5.01
Specific Surface Area (cm^2/gm)	1479
Screen Analyses (% Cumulative)	
Size (Tyler Mesh)	
+100	1.0
+150	2.8
+200	5.8
+325	23.4
+400	29.9
+500	51.6

TABLE 3

Typical Chemical Analysis of Hilton Mines Iron Ore Concentrate

Constituent	Per Cent
Total Fe	70.82
Fe^{++}	21.34
Fe^{+++}	49.48
SiO_2	0.48
CaO	< 0.03
MgO	0.65
Total S	0.35
P_2O_5	< 0.005
Al	< 0.02

Procedure and Results

The evaluation of Shawinigan lime as a binder was to be achieved by comparing its effect at concentrations of 1%, 2% and 3%, with the effect of 3/4% Wyoming bentonite on the following ball properties:

1. Green and dry ball compression strengths.
2. Optimum moisture of green ball.
3. Maximum moisture of green ball.

The following general procedure was used to produce the green and dry balls for testing:

1. For each series of tests, dry concentrate (15,000g) was mixed with the desired quantity of binder and 5% water in a Hobart mixer for 1/2 hour. Seed pellets, -5+6 mesh size, were made from this mixture in an 8 in. x 20 in. balling tire.
2. Each test of a series consisted of feeding the mixture at a rate of 250 g/min. for 4 minutes onto 50g of seed pellets, contained in the balling tire, which was rotating at 51 rpm.
3. The balls were allowed to roll for 15 minutes after they had formed.
4. The green ball moisture was varied for the different tests of a series by changing the amount of water added with a hand sprayer, while the balls were forming.
5. The rolled balls were removed from the tire after each test and a sample of 10 balls was taken for green compression testing, another sample of 100g was taken for moisture determination, and the remainder were dried in the oven at 110°C for later dry compression testing.

A maximum of eleven tests could be done from a 15000g batch of feed mixture during a single day. The exact diameter and strength of each ball tested was measured by a Pelletester machine and the compression strengths of the balls were then corrected to a 1/2 inch ball on the basis that the compression strength is proportional to the square of the ball diameter (13).

Series One, Two and Three

In the 1st, 2nd and 3rd series of tests, 1%, 2% and 3% lime hydrate was added to the iron ore concentrate sample and the general procedure, as outlined, was followed. The results of these series of tests are recorded in Tables 4, 5 and 6.

TABLE 4

Moisture and Compression Strengths for Balls Containing 1% Lime Hydrate

Test	Moisture (%)	Compression Strength	
		Green	Dry
1	5.4	1.2	3.5
2	5.4	2.0	3.8
3	5.6	2.0	3.9
4	6.3	2.1	3.3
5	6.5	2.4	5.0
6	6.5	2.4	4.4
7	6.8	3.0	4.0
8	6.9	2.2	4.2
9	6.9	2.4	3.4
10	6.9	2.5	5.8
11	6.9	2.9	4.7
12	7.0	2.3	4.4
13	7.1	2.4	3.4
14	7.5	2.0	3.1
15	7.6	2.2	3.2
16	7.7	2.1	2.8
17	7.8	2.1	3.4
18	> 8.0	mixture turned to mud	

TABLE 5

Moisture and Compression Strengths for Balls Containing 2% Lime Hydrate

Test	Moisture (%)	Compression Strength (lb)	
		Green	Dry
1	5.8	2.0	3.9
2	5.8	3.0	5.1
3	5.9	2.4	4.2
4	6.1	2.2	3.9
5	6.1	2.4	3.8
6	6.5	2.5	5.0
7	6.9	2.0	4.2
8	6.9	2.5	4.2
9	7.1	2.6	4.1
10	7.1	2.8	3.8
11	7.2	2.8	5.2
12	7.2	2.9	5.9
13	7.2	2.6	3.9
14	7.2	2.5	4.3
15	7.3	2.7	5.4
16	7.4	2.2	4.0
17	7.5	2.2	4.6
18	7.7	2.1	3.7
19	> 8.0	mixture turned to mud	

TABLE 6

Moisture and Compression Strengths for Balls Containing 3% Lime Hydrate

Test	Moisture (%)	Compression Strength (lb)	
		Green	Dry
1	6.2	2.2	4.5
2	6.4	2.6	5.4
3	6.5	2.2	4.8
4	6.9	2.4	4.7
5	6.9	2.6	5.5
6	6.9	2.7	5.2
7	7.0	2.4	4.9
8	7.1	2.1	4.0
9	7.1	2.5	4.6
10	7.2	2.5	4.6
11	7.3	2.0	4.5
12	7.3	2.4	4.7
13	7.3	2.5	4.6
14	7.3	2.9	5.4
15	7.4	2.2	6.9
16	7.6	1.9	4.7
17	7.6	1.7	3.8
18	> 8.0	mixture turned to mud	

These series of experiments indicate that when 1, 2 or 3% lime hydrate was used as a binder (see Tables 4, 5 and 6), the maximum balling moisture is in the neighbourhood of 8%. The optimum moisture for the addition of 1% lime hydrate appears to be about 6.8%, increasing to 7.3% with the 2% and 3% lime hydrate addition. The use of lime hydrate as a binder increased the compression strength of the green balls only slightly, but more than doubled the dry ball compression strength in comparison to balls made without the use of binders (see Table 8).

Series four

In the 4th series of tests, 3/4% Wyoming bentonite was added to the iron ore concentrate sample. The general procedure, as outlined, was followed for these tests and the results are recorded in Table 7.

TABLE 7

Moisture and Compression Strengths for

Balls Containing 3/4% Wyoming Bentonite

Test	Moisture (%)	Compression Strength (lb)	
		Green	Dry
1	6.9	3.4	11.7
2	7.1	3.5	11.3
3	7.4	3.1	10.4
4	7.7	3.4	12.5
5	8.9	2.8	11.2
6	> 9.0	mixture turned to mud	

The results tabulated in Table 7 indicate that the optimum moisture, obtained with 3/4% Wyoming bentonite binder, was in the 7 1/2 to 7 3/4% range, with a maximum balling moisture about 9%. The addition of 3/4% Wyoming bentonite to the concentrate gave green and dry ball compression strengths, particularly the latter, that were superior to any of those obtained with the lime hydrate addition.

Series Five

In the 5th series of tests, the iron ore concentrate sample was balled without the use of binders. The general procedure, as outlined, was followed for these tests and the results are recorded in Table 8.

TABLE 8

Moisture and Compression Strengths for

Balls Containing No Binder

Test	Moisture (%)	Compression Strength (lb)	
		Green	Dry
1	5.5	1.1	-
2	6.0	2.0	1.8
3	6.0	2.2	1.8
4	6.3	2.6	2.1
5	6.5	2.0	1.6
6	7.1	2.0	1.3
7	7.1	2.4	1.8
8	7.1	2.2	1.6
9	7.2	1.9	1.5

DISCUSSION

The normal balling moisture at the Hilton Mines pelletizing plant is about 9.3%. Since it is usually uneconomic to remove more water than is necessary, this percent moisture probably represents the maximum percentage that will allow balls to form, when Wyoming bentonite is used as a binder. The balling tests done at the Mines Branch laboratories indicate that replacing bentonite with lime hydrate lowers the maximum balling moisture content about 1%. It is thus suspected that when Shawinigan lime hydrate was substituted for bentonite in the Hilton Mines balling circuit, the moisture content of the circuit was too high and "wet sliding" resulted.

The optimum moisture level for balling Hilton Mines concentrate with a Shawinigan lime hydrate binder appears to increase slightly when the lime hydrate content is increased from 1% to 2%, but remains at about the same level for 3% lime hydrate addition, whereas the maximum balling moisture content appears to remain constant at about 8% for all additions of lime hydrate. Thus there appears to be no advantage in adding more than 2% lime hydrate to the concentrate.

CONCLUSIONS

1. The most probable reason for the "wet sliding", which occurred in the Hilton Mines balling circuit when Shawinigan lime hydrate was substituted for Wyoming bentonite as a binder, was that the moisture level in the feed was above the maximum content for balling with the Shawinigan lime hydrate.

2. The compression strengths of green and dry balls made from concentrate containing 3/4% Wyoming bentonite binder were superior to those of similar balls containing Shawinigan lime hydrate as a binder.

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