DOLOMITE FILLER AS SUPPLEMENTARY CEMENTITIOUS MATERIAL IN COLD-AGGLOMERATED BRIQUETTING

Minna SARKKINEN[1], Sakari TUOMIKOSKI[2], Kauko KUJALA[3], Kimmo KEMPPAINEN[1], Seppo GEHÖR[3]

[1] Department of Mechanical and Mining Engineering, KAMK University of Applied Sciences, 87101 Kajaani, Finland.

[2] SSAB Europe, 92101 Raahe, Finland

[3] Department of Process and Environmental Engineering, University of Oulu, 90014 University of Oulu, Finland

minna.sarkkinen@kamk.fi, sakari.tuomikoski@ssab.com, kauko.kujala@oulu.fi, kimmo.kemppainen@kamk.fi, seppo.gehor@oulu.fi

Introduction

A wide variety of by-products such as dusts, scraps, and mill scale are generated during the production of iron and steel. The by-products need to be processed before being used as burden material in the blast furnace. Briquetting is a commonly used technology to recycle by-products in steel plants[1]. Portland cement (PC) has generally been used as a bonding agent in the cold-bond agglomeration process.

The aim of the study was to examine an alternative binder material for PC in the briquette recipe used at the SSAB steel plant in Raahe. The plant uses the vibration method in briquetting. The size of one hexagonal briquette is *ca.* 60 x 60 mm, and the weight is *ca.* 500 g. The used briquette production mix contains ground granulated blast furnace slag (BFS) and rapid hardening PC as binders. Dolomite filler was chosen for closer investigation due to its ability to partially substitute cement, its low cost, and favourable chemical composition.

Briquette disintegration and compressive strength can be controlled by factors such as binder type and quantity, the composition of raw materials, particle size distribution and curing technique. Briquette compressive strength also depends on processing parameters such as the water to cement ratio, and briquetting force (load force and time). The use of PC as a binder material requires controlled curing conditions to ensure good binding. This depends on curing temperature, relative moisture and strength development time need.

The use of cement in the agglomeration process has some identified disadvantages. The side-effects include higher slag formation, moisture content and increased reduction rate, in addition to costs and environmental aspects.[2,3] Briquette degradation and strength loss at a relatively low temperature (*ca.* 700°C) is one problem caused by the decomposition of CSH.[1,4-9] Cement also requires additional water which evaporates at high temperatures causing a temperature imbalance

impacting blast furnace quality.[2] In addition, cement in briquettes produces additional slag, which requires extra energy.[11] Also, a higher proportion of cement is associated with the decreased reduction rate and swelling in briquettes. It has been stated that swelling could be decreased by substituting cement.[3]

Materials and Methods

The briquetting method, curing conditions and other briquette mix components, excluding binders, were standardised in the trial mixes; only PC and substitute binder dosages in addition to water dosages varied. No admixtures were used in the mixes expect for trial mixes studying the effect of superplasticiser. Rapid hardening cement and the blast furnace slag (BFS) KJ400 (BET 400 m^2/kg) were used. The cement had good initial and final strength: 1 d/20 MPa and 28d/53 MPa. The used superplasticiser (SP) VB-Parmix was based on polycarboxylates containing chlorides ≤ 0.1% and alkalis ≤ 2.0%.

Chemical compositions were analysed by x-ray fluorescence spectrometer (PanAnalytical Minipal 4), diffractograms were identified by x-ray diffractometer (PanAnalytical Xpert Pro). Dolomite was jet milled by Hosokawa Alpine's multiprocessing equipment into finer particle. Particle size distribution was analysed by Alpine's wind sieve. Particle size distribution of the current briquette mix recipe was checked by using the EMMA Mix Analyser based on the optimal packing of particles.

Results and Discussion

The mixes were prepared using a 10 l Hobart mixer and compressed with a briquetting machine, Teksam VU600/6B. The machine pressed 16 briquettes at the same time. The briquette moulds were filled manually. The machine used vibration before pressing at 100 bar for 5 seconds. In total, the test program comprised 2 reference mixes and 5 trial mixes with various dolomite and superplasticiser combinations (Table 1).

Table 1: Test mixes with moisture content (wt%)

Code	PC	BFS	Dol.	Tot.binder	SP	Tot.water	water/binder
R1	60	40	0	11.6	0	9.85	0.849
R2	70	30	0	12.0	0	10.24	0.853
M1	42	40	18	12.0	0	9.76	0.813
M2	42	40	18	12.0	2.9	9.98	0.832
M3	42	40	18	12.0	2.9	9.39	0.783
M4	48	40	12	11.9	2.9	9.02	0.758
M5	25	50	25	12.0	2.9	8.07	0.672

The principal target total moisture content of the mixes was approximately 10.0%. Total moisture content was measured by a moisture analyser. The measured total

moisture content varied between 8.07 and 10.24% in the mixes being highest in the reference mix R2.

The first two mixes (R1 and R2) were without dolomite filler or superplasticiser. The PC % was 60 and 70 in the reference mixes, which were higher than in the first test series (54%). The percent of BFS varied between 30 and 50 in the mixes. R1 was too dry and R2 was slightly too wet, forming some moisture below the briquettes. The trial mixes M1, M2 and M3 included 18 wt% of the total binder weight dolomite filler. M1 was very dry and superplasticiser was added to trial M2 using the same water quantity. The mix became too wet and a lower water quantity was used in trial M3. The consistency improved when using superplasticiser despite lower water content indicating the positive impact of superplasticiser. Two additional trial mixes were prepared with lower (12%) and higher (25%) dolomite filler content with the same water and superplasticiser dosages (M4 and M5). The consistency was satisfactory in both of the briquette test series. M5 indicated that water content can be reduced by approximately 20% when using superplasticiser.

One batch (16 briquettes) was prepared using each test recipe. The height of the fresh briquettes was measured after removal from the machine. The success of the briquetting process was very sensitive to optimal water content. When the water content was too high, water separated and can be observed as a wet ring at the base of the briquettes. When the water content was too low, the briquettes remained dry, typically showed low density indicating weaker wear resistance. The briquettes were stored at the temperature of 35°C for two days before tumble strength testing.
The usability of dolomite filler to substitute cement depends on strength development and wear resistance achieved within 2 days after casting. Table 2 summarises the tumbler indexes, heights and densities of the test briquettes. Total loss in weight is the sum of weight losses recorded in three tumbler strength tests.

Table 2: Height (mm), density (kg/m^3) and tumbler index (TI) values

	2d			7d			28d			Mass
Code	TI	mm	kg/m^3	TI	mm	kg/m^3	TI	mm	kg/m^3	loss
R1	42.10	67.85	2634	59.71	67.87	2587	66.72	67.77	2533	6.32
R2	81.84	61.08	2906	84.41	60.36	2920	87.78	61.24	2817	5.89
M1	44.16	65.92	2724	54.56	68.99	2574	65.83	69.10	2489	6.13
M2	81.10	59.51	2954	83.36	60.50	2896	87.30	59.78	2869	6.43
M3	78.87	63.11	2839	80.00	64.17	2776	84.12	63.94	2713	5.35
M4	72.36	65.86	2725	76.50	65.89	2693	81.89	66.21	2607	5.82
M5	71.09	63.97	2811	77.99	52.80	2827	82.81	63.86	2702	5.85

The values show that the second reference mix R2 had the highest tumbler index after 2, 7 and 28 days. However, test mix M2 containing 18% of dolomite filler and superplasticiser achieved almost similar results in all age groups.

Conclusions

On the basis of the studies carried out, it could be concluded that comparing to reference R1, all the test mixes already had a higher tumbler index after 2 days, indicating the potential to replace at least 30% of PC with dolomite filler and superplasticiser. Compared to reference R2, mix M2 provided corresponding tumbler indexes by replacing 25% PC with dolomite filler and superplasticiser. Fine dolomite filler did not reduce initial strength development compared to the reference mixes. The use of superplasticiser with dolomite filler enabled water reduction of 20%, increased density and tumbler index values. Superplasticiser did not indicate any negative reducing effects on strength development or wear resistance.

References

1. M. Singh and B. Björkman, "Effect of Processing Parameters on the Swelling Behaviour of Cement-Bonded Briquettes", *Ironmaking and Steelmaking*, **44** (1) 59- 68 (2004).
2. R. Takahashi, T. Akiyama and J. Yagi, "Drying and Reduction of Cement-Bonded Pellets by Using a Moving Bed Reactor", in *Proceeding of The 6th International Iron and Steel Congress*, *ISIJ*, Nagoya, Japan, 1990.
3. M. Singh, "Studies on the Cement-Bonded Briquettes of Iron and Steel Plant By-Products as Burden Material for Blast Furnaces", Ph.D. thesis, Luleå University of Technology, Department of chemical and metallurgical engineering, division of process metallurgy, 2002.
4. C. Castillo and A. J. Durrani, "Effect of Transient High Temperature on High-Strength Concrete", *ACI Mater J*, **87** (1) 47-53 (1990).
5. W. P. S. Dias, G. A. Khoury and P. J. E. Sullivan, "Mechanical Properties of Hardened Cement Paste Exposed to Temperatures up to 700°C (1292°F)", *ACI Mater J*, **87** (2) 160-166 (1990).
6. R. Takahashi, M. Ishii, J. Yagi and A. M. Fudoling, "Lowering of Cement Content in the Production of Cement - Bonded Iron Ore Pellets", in *Proceeding of 6th int. symposium on agglomeration*, Nagoya, Japan, 1993.
7. M. C. Mantovani and C. Takano, "Waste Oxide Recycling by Cold Bonded Roll Briquetting", in *Proceeding of 57th Ironmaking Conf*erence, Warrendale, US, 1998.
8. Z. P. Bazant and M. F. Kaplan, *Concrete at high temperatures*, *material properties and mathematical models*, *Longman Group Limited*, *Essex*, *England*, *1996.*
9. P. A. Jahren, "Fire resistance of high strength/dense concrete with particular reference to the use of condensed silica fume - a review", in *Proceeding of 3rd int. conf. fly ash*, *silica fume*, *slag and natural pozzolans in concrete*, Trondheim, Norway, 1989.
10. M. J. Terro and S. A. Hamoush, "Effect of Confinement on Siliceous Aggregate Concrete Subjected to Elevated-Temperatures and Cyclic Heating", *ACI Mater J*, **94** (2) 83-89 (1997).
11. L. Sundqvist Ökvist, K.-O. Jonsson, H.-O. Lampinen and L.-E. Eriksson, "Recycling of In-Plant Fines as Cold-Bonded Agglomerates in *Seminar Proceeding of Sinter and Pellets*, Brussels, Belgium, 1999.