IDENTIFY FACTOR TO ACCELERATE FORCED WEATHERING RATE FOR LD SLAG AT TATA STEEL TO IMPROVE ITS AVAILABILITY

Ajay Kumar GUPTA[1], Subhadra SEN[1], Kumar GAURAV[2]

[1] Process Technology Group, Tata Steel Limited, Jamshedpur-831001, India
[2] IBMD Tata Steel Limited, Jamshedpur-831001, India

ajay.gupta2@tatasteel.com, subhadra.sen@tatasteel.com, kumar.gaurav1@tatasteel.com

Introduction

Slag is a by-product generated during the manufacturing of iron & steel. It is required to mention here that disposal of LD slag is a current major concern for steel industries. Average utilisation of LD slag amongst major steel producing companies across the world ranges from 55% to 75%, whereas average LD slag utilisation in India ranges from 15% to 25%. One of the major usages of this slag is as a replacement of natural aggregate in road construction. LD slag aggregates has tremendous potential in road & rail but the presence of un-hydrated free lime which expands after coming in contact with water limits its usage. The main types of slags that are generated from the iron and steelmaking industries are classified as follows:

- Blast-furnace slag (iron making slag)
- Steel-furnace slag - (HSI slag), (BOF) slag / LD slag, Ladle slag (LF slag)

Chemical Composition of Steel Slags

The main chemical constituents of the basic-oxygen-furnace slag are CaO, FeO, and SiO_2. During the conversion of molten iron into steel, a percentage of the iron (Fe) in the hot metal cannot be recovered into the steel produced. This oxidised iron is observed in the chemical composition of the BOF slag. The silica (SiO_2) content of BOF slag ranges from 7 to 18 by wt%. Large quantities of lime or dolomitic lime are used during the process of conversion from iron to steel and, hence, the CaO content of BOF slag is typically very high (CaO > 35%).

Table 1: Chemical composition of LD slag in wt%

T/Fe	Met Fe	CaO	SiO_2	P	MgO	MnO	Al_2O_3	TiO_2	Cr_2O_3	C	S
19 - 20	0.45 - 0.50	44 - 45	12 - 13	1 - 1.2	5 - 6	0.45 - 0.55	1.8 - 2.0	0.75 - 0.95	0.1 - 0.15	0.5 - 0.7	0.1 - 0.15

Mineralogical Properties of Steel Slag

The common mineral phases present in steel slags include merwinite ($3CaO \cdot MgO \cdot 2SiO_2$), olivine ($2MgO \cdot 2FeO \cdot SiO_2$), β-C2S ($2CaO \cdot SiO_2$), α-C2S, C4AF ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$), C2F ($2CaO \cdot Fe_2O_3$), CaO (free lime), MgO, FeO and C3S ($3CaO \cdot SiO_2$), and the RO phase (a solid solution of CaO-FeO-MnO-MgO). Since BOF have high iron oxide contents, solid solutions of FeO (wustite) are typically observed as one of the main mineral phases. Ladle slag has a lower FeO content, and polymorphs of C2S are therefore frequently observed as the main phase.

Reason for volumetric instability of LD slag

Due to the presence of unstable phases in its mineralogy, steel slags can show volumetric instability, caused mainly by the presence of free CaO. In the presence of water, free lime hydrates and forms portlandite $Ca(OH)_2$. Portlandite has a lower density than CaO and, hence, hydration of free CaO results in volume increase. Ramachandran *et al.* studied the hydration mechanism of CaO and proved that when it is immersed in water, compacted CaO can hydrate almost completely in a few days with a volume increase as high as 100%.

Different Method for Processing of LD slag

1. Wet and Dry Cycle Weathering
2. Hot Slag Modification
3. Open Yard Steam Aging
4. Pressurised Steam Aging

Steel slag should be allowed to stand in stockpiles exposed to the weather for a period of few months for all types of applications. This conditioning period must be applied from the time that the slag is in its final size.

An acceptable method for conditioning steel slag is to thoroughly water the slag one day per week over a four-week period (or longer if appropriate) to create the “dry and wet” cycle.[3] Literature suggests that a protective film provided by a binder such as bitumen would eliminate or limit the amount of hydration of free lime in the slag. It is generally accepted that there is a critical free lime content in steel slag, after which no further hydration occurs.[3]

Design of Experiment

This study has been done with 10 to 20 mm size fraction. LD slag samples were collected from dump yard and 9 piles were made, each of approximately 10 tons. Here, three parameters have been selected to design the experiment: 1) quality of water (pH), 2) quantity of water, 3) shuffling frequency.

Table 2: Experiment parameters

Quality of water (pH)	Pile# P1	Pond water used (9 < pH < 11)
	Pile# P2	Acetic acid processed water (6 < pH < 7)
	Pile# P3	Bore well water (pH~ 7)
Quantity of water	Pile# W1	Watering done for 2 times in a cycle of 7 days
	Pile# W2	Watering done for 3 times in a cycle of 7 days
	Pile# W3	Watering done for 4 times in a cycle of 7 days
Shuffling frequency	Pile# S1	Shuffling done for 3 times in a cycle of 7 days
	Pile# S2	Shuffling done for 2 times in a cycle of 7 days
	Pile# S3	Shuffling done for 1 times in a cycle of 7 days

Results and analysis

In the trial, the average starting free lime percentage was around 6.3%. The percentage reduction in free lime content over a period of three months varied within a range of 45% to 50% for specially treated LD slag samples, whereas the same for the reference pile samples varied within a range of 30 to 35%, which is much lower. Our acceptable limit of volume expansion is below 2% as BIS standard.

Table 3: Experimental pile result -free lime content & volume expansion

		pH control			water control			Schuffling activity		
Free lime content		P1	P2	P3	W1	W2	W3	S1	S2	S3
	Day 0	6.74	6.41	6.13	5.97	5.80	6.23	6.07	5.69	5.97
	Day 15	6.51	7.07	5.83	6.48	5.78	6.56	5.86	5.53	5.95
	Day 45	4.88	3.99	5.01	4.83	4.49	5.06	4.02	4.55	4.26
	Day 60	4.45	4.22	4.88	4.68	4.42	4.81	4.25	4.4	4.22
	Day 75	3.66	3.43	3.98	3.85	3.67	3.95	3.67	3.92	3.79
	Day 90	3.66	3.43	3.98	3.85	3.67	3.95	3.67	3.92	3.79
Volume Expansion (%)										
	Day 30	2.9	2.9	3.2	3.16	2.96	3.1	3.5	3.47	3.6
	Day 60	2.48	2.1	2.6	2.4	2.4	2.8	2.4	2.64	2.48
	Day 90	1.56	1.71	1.6	1.6	1.96	1.92	1.7	1.67	1.84

Conclusion

Experimental investigations were carried out to study the weathering behaviour of LD slag, using special treatments of dry and wet cycles at stock yard. The main objective of this study was to lower down the weathering period to increase the availability of LD slag in order to accelerate the effective evacuation of LD slag to meet the requirements of external customers.

1. Percentage reduction in free lime content over a period of three months varied within a range of 45% to 50% for specially treated LD slag samples, whereas the same for the regular pile samples varied within a range of 30 to 35%, which is much lower.

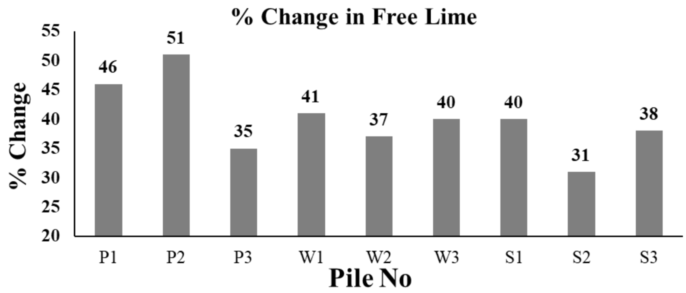

Figure 1: %Change in Free lime content in LD slag in piles after treatment

2. Similarly, percentage reduction in volume expansion over a period of three months varied within a range of 68% to 70% for specially treated LD slag samples, whereas the same for regular pile samples varied within a range of 56% to 58%, which is much lower.
3. Another major observation is that though the frequency of water spraying and reshufflings played a major role in reducing the treatment time for LD slag to stabilise, no such impact was observed with changes in quality of water.

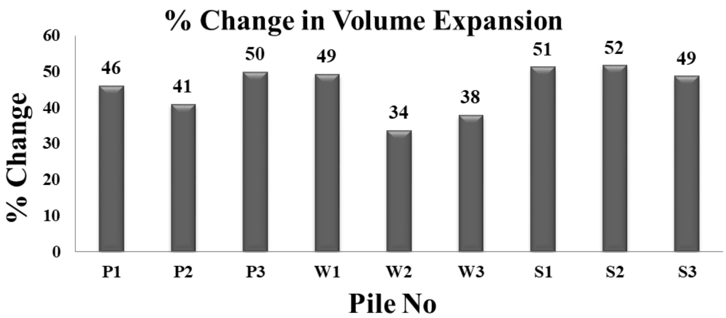

Figure 2: %Change in volume expansion of LD slag samples in piles after treatment

References

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