Guidelines on Management of Pyro-metallurgical Slags

(Iron & Steel Slags)

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Central Pollution Control Board

(Ministry of Environment, Forest and Climate Change)

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Contents

1.0 Introduction

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 notified by Ministry of Environment, Forest and Climate Change, Government of India for the management of hazardous and other wastes define the hazardous waste as below:

"hazardous waste" means any waste which by reason of characteristics such as physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive, causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances, and shall include –

i. *waste specified under column (3) of Schedule I;*

ii. *waste having equal to or more than the concentration limits specified for the constituents in class A and class B of Schedule II or any of the characteristics as specified in class C of Schedule II; and*

iii. *wastes specified in Part A of Schedule III in respect of import or export of such wastes or the wastes not specified in Part A but exhibit hazardous characteristics specified in Part C of Schedule III;*

Pyro-metallurgical slags are defined as "High Volume Low Effect Waste" (herein referred as HVLE wastes) under the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 (HOWM Rules 2016) and were similarly defined earlier under Hazardous Waste (Management, Handling & Transboundary Movement) Rules, 2008. The relevant provision given as note at the end of Schedule-I of the HOWM Rules 2016 is as follow:

"The high volume low effect wastes such as fly ash, Phosphogypsum, Red Mud, jarosite, ***Slags from pyro-metallurgical operations****, mine tailings and ore beneficiation rejects are excluded from the category of hazardous wastes. Separate guidelines on the management of these wastes shall be issued by Central Pollution Control Board."*

NITI Aayog constituted a Committee on Circular Economy which recommended to promote initiatives for Circular Economy in the metal sector (ferrous and non-ferrous) through an action plan. The said action plan includes issuance *of SOP for utilisation of resource material form Iron and steel slag, which is stipulated under Hazardous and Waste Management Rules 2016.*

The increased processing of iron concentrates, and constraints in handling large volume of iron and steel slags would require iron & steel plants to explore the possible options for utilization or disposal including the need for studying the options. The guidelines are prepared to deal with the handling and management of slags generated from pyro-metallurgical operations in Iron & Steel Industries.

2.0 Manufacturing Process - Iron & Steel plants

The manufacturing process in integrated Iron and Steel plants includes iron making followed by steel making. In an Integrated Iron and Steel plant, the iron making is achieved through operation of blast furnace (BF) and the steel making is done

through LD (Linz-Donawitz) steel making shop (SMS) operations. The Integrated steel networks of iron and steel making comprises of various production units such as coke ovens, sinter plant, palletisation plant, blast furnaces and basic oxygen furnace (BOF) for steel making followed by casting house operations.

In an Integrated Iron and Steel Plant the main operational unit is the blast furnace where the iron ores are primarily converted to liquid iron (also term as hot metal). The iron ores for blast furnace are prepared in two agglomeration units – the sinter plant and the pellet plant. Sintering is a process of agglomeration of fines of iron ores into small round products from a pre-designed mixture of fine ores, residues and additives, followed by high temperature sintering of finished products and palletisation is a process of agglomeration of micro fines of iron oxide ores (concentrate) into small round balls. The finished products from sinter plant and pellet plant are taken to blast furnace for feed. In addition to iron ores, coke and pulverised coal are added in blast furnace as reducing agents. The coke used in blast furnace is produced in coke oven through distillation of coal.

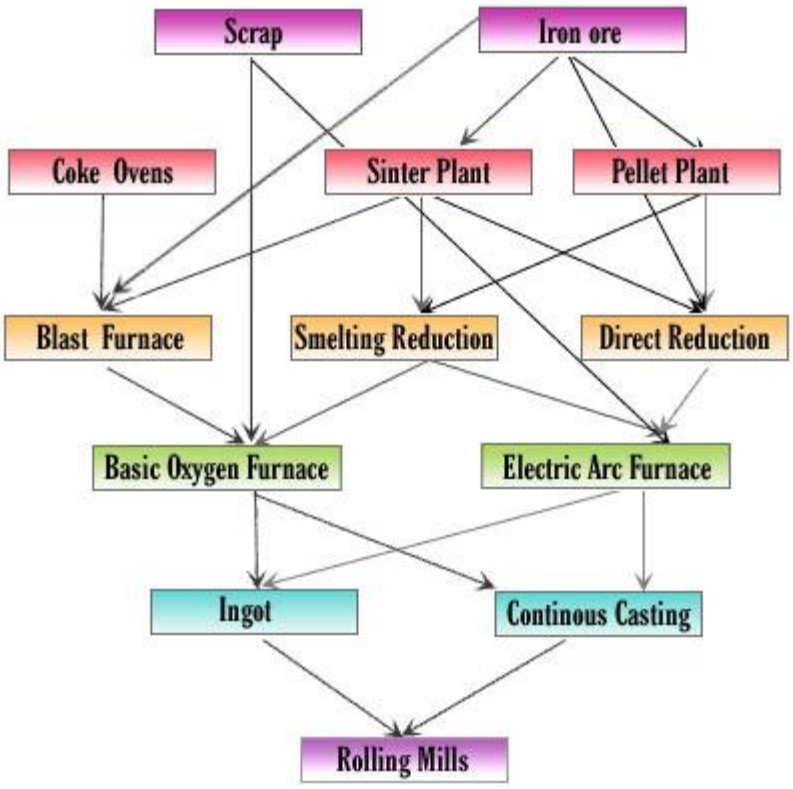

Fig: Technological options for converting iron ore to steel products

(Source: https://sail.co.in/en/learning-center/manufacturing-process)

The raw materials such as coke, mixture of sinter and/or pellets, lump ore, fluxes etc., are charged into blast furnace from the top and hot blast is provided to supply the necessary oxygen required for carbon monoxide (CO) formation. As the feed of blast furnace moves down, the iron ores get reduced and the liquid iron along with

slag is collected from the bottom of the blast furnace. The liquid iron and slag are tapped (collected) separately from the furnace and processed for further requirements.

The liquid iron tapped in container is transported through torpedo ladle-system to Steel manufacturing units consisting of de-sulphurisation unit, LD converter and Ladle furnace unit. The de-sulphurisation process is deployed to ensure removal of sulphur from Hot Metal. This is followed by Basic Oxygen Furnace unit where removal such of undesired elements as C, P, Si, etc. is carried out through charging, blowing and tapping method. The carbon content in the hot metal (liquid iron) is lowered to less than 1% from approx. 4% carbon content in hot metal. The hot metal from basic oxygen furnace is taken to Ladle Furnace Unit for raising the temperature and adjustment of chemical composition of hot metal and refining of steel products as per required quality. The liquid metal is processed to cast house where liquid metal is poured in pre-defined moulds and allowed to cooled and solidify as ingots. The ingots are re-heated and rolled into cold rolling mill and/or hot rolling mill to produce the final desired steel products. In steel making process slag is generated from de-sulphurisation, LD convertor and ladle furnace.

The other steel making processes include the iron making from rotary kiln (DRI) furnace, Gas based vertical shaft (Midrex, HYL) furnace, Corex furnace, etc and steel making from Electric Arc Furnace, Conarc furnace, Induction furnace.

The process of iron making from rotary kiln or gas based vertical shaft furnace (Midrex) is termed as Direct Reduction process where oxygen is removed from iron ores to produce high metallic solid iron product. In the rotary kiln process, the raw materials namely iron ores, dolomite and coal are fed into rotary kiln and heated in range of 700-1200℃ for reduction of iron oxides. In the gas based vertical shaft furnace process, the iron ore pellets and calibrated lump ore are fed into the gas based vertical shaft furnace to produce high metallic solid iron products in the form of Cold DRI or Hot DRI or DRI briquettes and heated in the range of 600-1050℃.

The process of iron making without coke and using two stage reduction process is termed as Smelting Reduction (Corex furnaces) where, in first stage iron ore is heated and reduced by gases generated from the second unit, which is a smelter-gasifier supplied with coal and oxygen. The partially reduced ore is then smelted in the second unit, and liquid hot metal or (in some cases) liquid steel is produced.

For steel making from Electric Arc Furnace (EAF) or Conarc furnace, Induction furnace (IF), the reduced iron along with coal/metallurgical coke, lime, dolime and scraps (if required) are fed into electric arc furnace or Conarc furnace for reduction of oxides for further refining process and formation of alloy/iron products as per required conditions. Slag is generated from electric arc furnace and Conarc furnace which is known as EAF slag or Conarc slag having different physical, chemical and metallurgical properties compared to Converter (LD/BOF) slag.

2.1 Production of Slag in India

About 24 million tonnes of blast furnace slag and 12 million tonnes of steel slag is generated annually in steel industry. It is expected to reach 45-50 million tonnes of BF slag and 15-20 million tonnes of BOF slag by 2030.

EAF and IF slag generation is around 5 million tonnes annually and is expected to increase to more than 10 million tonnes annually by 2030.

(source: Indian Mineral Yearbook 2020)

2.2 Iron and Steel manufacturing in the Country

Total Steel Production Capacity in the Country at Present (2021) is 143.91 Million Tonnes.

The details of production, consumption, export and import of finished steel are as following: -

Year	Total Finished Steel (million tonnes)			
	Production	**Consumption**	**Export**	**Import**
2019-20	102.62	100.17	8.36	6.77
2020-21	96.20	94.89	10.78	4.75
April-June, 2021	26.35	24.85	3.56	1.16

Source: Joint Plant Committee (JPC)

Details of Steel Production Capacity and State-wise No. of Units

(2020-21)

A.		**Public Sector**	
		(thousand tonnes)	(thousand tonnes)
State	**Unit**	**Capacity**	**Production**
Steel Authority of India Limited (SAIL)			
Chhattisgarh	Bhilai Steel Plant	6000	4244
West Bengal	Durgapur Steel Plant	2200	2085
Odisha	Rourkela Steel Plant	3800	3498
Jharkhand	Bokaro Steel Plant	4600	3380
West Bengal	IISCO Steel Plant	2500	1847
West Bengal	Alloy Steels Plant	234	58
Tamil Nadu	Salem Steel Plant	180	100
Karnataka	Visveswaraya Iron and Steel Ltd.	118	0
Total		19632	15213
Rashtriya Ispat Nigam Limited (RINL)			
Andhra Pradesh	Vizag Steel Plant	6300	4302
TOTAL: Public Sector		25932	19515

B. Private Sector			
		(thousand tonnes)	(thousand tonnes)
State	**Units**	**Capacity**	**Production**
Andhra Pradesh	24	2314	1596
Arunachal Pradesh	3	125	0
Assam	6	131	59
Bihar	13	830	465
Chhattisgarh	80	13191	8939
Goa	10	405	400
Gujarat	71	13688	8403
Haryana	14	1037	731
Himachal Pradesh	25	1144	766
Jammu and Kashmir	8	189	118
Jharkhand	30	14888	12169
Karnataka	24	15143	11688
Kerala	29	480	253
Madhya Pradesh	9	457	369
Maharashtra	54	12030	7925
Meghalaya	5	181	37
Odisha	52	21530	17934
Punjab	114	5064	2917
Rajasthan	31	1005	589
Tamil Nadu	90	3542	2059
Telangana	27	1605	1192
Tripura	1	30	7
Uttar Pradesh	46	1617	1005
Uttarakhand	39	1524	950
West Bengal	39	5238	3085
Dadra and Nagar Haveli	10	168	145
Daman and Diu	3	46	40
Delhi	2	16	10
Total: Private Sector	**869**	**117982**	**84030**
Total: Public Sector	**9**	**25932**	**19515**
All Region Total	**878**	**143914**	**103545**

Source: Joint Plant committee

The major wastes produced in integrated steel plants include BF Slag / Iron Slag, Steel Melting Shop (SMS) Slag accounting for nearly more than half a ton for each

ton of steel produced. Generally, BOF/LD route produces 150-180 kg and EAF route produces 200-220 kg slag per ton of steel.

The iron making and steel making slag are different physically and chemically, there are different process technology for iron making like blast furnace, Corex and Sponge iron (DRI - Rotary kiln or Midrex) and steel making like BOF/LD Convertor, EAF, Conarc, IF, etc. Every process generates different kind of slag with different composition range and physical properties. Major Indian iron and steel manufacturing process is summarised in table given below.

Process	Technology	Input	Output
Iron Making	Blast Furnace	Iron ore pellet, Lump Ore, Iron ore Sinter	Hot metal, BF Slag (granulated/ ungranulated)
	Corex	Iron ore pellets	Hot metal, Corex Slag (granulated/ ungranulated)
	Sponge Iron	Gas based sponge iron (iron ore pellets, Calibrated lump ore Coal based sponge iron (iron ore, coal, limestone)	Direct Reduced Iron, Char
Steel Making	BOF (LD Converter)	Hot metal, Lime, Dolime, Oxygen,	Liquid Steel, BOF Slag
	EAF/Conarc	Hot metal/ Cold DRI/ Hot DRI/ Briquettes, Steel Scrap, Pig Iron, Lime, Dolime, Oxygen	Liquid Steel, EAF Slag Conarc Slag
	Induction Furnace	Steel Scrap, Pig Iron, DRI	Liquid Steel, IF Slag
	Ladle Furnace	Liquid Steel from EAF / BOF	Liquid Steel, LF Slag

[Source: ISA]

3.0 Pyro-metallurgical Slags Generation and its Properties - Iron & Steel Plants

As per Indian Minerals Yearbook 2019 (Part-II: Metals and Alloys) Iron, Steel & Scrap and Slag (August 2021), the slag from iron and steel plant is defined as:

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, slag consists of calcium magnesium, manganese and aluminium silicates and oxides in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers.

The chemical composition of slag may remain unchanged but physical properties vary widely with the changing process of cooling.

In an integrated iron and steel plant, the slag is generated from the process namely Blast Furnace, De-sulphurisation Process, Basic Oxygen Furnace Process and Ladle Furnace Process. The composition of iron ore, coal/coke, fluxes, etc. used in iron

making plays an important role in the quantity and quality of slag generation. Certain stand-alone units namely Electric Arc Furnace, Induction Furnace, Secondary Refining units, etc. also generated slag. The quantity of slag generated in Electric Arc Furnace and Induction Furnace processes is less in comparison to quantity of slag generated from other processes.

Most of the steel plants are utilizing 100% of the BF slag produced mostly in cement making and some portion as aggregate, while others are closer to reach the 100% utilization. However, the utilization of SMS (particularly LD) slag is limited due to the following:

- Phosphorous content;
- High Free lime content; and
- Higher specific weight.

To resolve these issues, Ministry of Steel is funding research & development initiatives for finding ways & means for utilization of steel slag.

3.1 Slag from Blast Furnace

The slag generated from blast furnace is tapped in molten form and have a temperature upto 1500 ^{0}C. The blast furnace slag is processed with water or air for formation of desired BF slag product based on end use. There are various methods available for processing of blast furnace slag as below:

Method	Process	End Product
Blowing	Quick cooling by air and steam to produce glass fibre	Slag wool
Granulation	Quick cooling with water to produce vitrified granulates (<5 mm)	Granulated blast furnace slag
Pelletizing	Quick cooling in air to produce glassy/crystalline pellets (< 20mm)	Blast furnace slag pellets
Foaming	Moderate cooling with less water to produce a crystalline/glassy and porous material	Foamed blast furnace slag
Cooling in air	Slow cooling in air in slag pits to produce crystalline material	Crystalline blast furnace slag

#BREF -Best Available Techniques (BAT) Reference Document for Iron and Steel Production

The commonly adopted methods by iron and steel plants in the country for cooling of slag from blast furnace are air cooling and granulation. The Air Cooled BF slag is a crystalline, rock like slag whereas Granulated BF slag is fine granules type slag. The physical properties of slag from blast furnace have similarity with reference to other natural rock materials.

A typical chemical analysis of the slag from blast furnace in the country is tabulated as below:

Composition		SiO_2	CaO	Al_2O_3	MgO	MnO	FeO	Fe	S	TiO_2	Hg
Range (%)	Min	26.4	28.72	14	0.52	0.07	0.04	0.08	0.3	0.51	0.018 mg/ Kg
	Max	37.2	37.22	35.3	10.21	0.47	0.66	0.9	0.85	0.9	
Avg (%)		33.701	35.268	19.588	8.004	0.410	0.483	0.545	0.593	0.707	

[Source: Industry]

BF slag generation rate based on 2017-18 data of 11 major producers varied between 320-426 kg per ton of hot metal (average-358.27 kg per ton of hot metal) and total annual BF slag generation for 2018-19 and 2019-20 in the country was estimated to be 28.3 MT and 27.5 MT.
(Reference: Status Report on Iron and Steel Slag (Generation and Utilization) MoS)

3.2 Slag from Desulphurisation Process

The slag generated in Desulphurisation process is a heterogeneous slag and partially melted. The composition of slag generated from desulphurisation process depends on the desulphurisation agents used for the process. The slag contains relatively high sulphur content. The slag is processed to metal recovery plant for separation of metallic and non-metallic parts.

A typical chemical composition of the slag from the desulphurisation process is as below:

Composition	SiO_2	CaO	Al_2O_3	MgO	MnO	Total Fe	P_2O_5	Cr_2O_3	S	Free CaO
Concentration (wt-%)	18	27	8	10	< 0.5	20	< 0.2	0.3-0.85	< 4	< 5

[Source: Industry]

The rate of generation of slag from desulphurisation process is 3-21 kg/ton of Liquid steel (BREF) and 14-16 kg/ ton of hot metal (MoS).

3.3 Slag from Basic Oxygen Furnace

The slag generated from Basic Oxygen Furnace is dependent on the hot metal, flux composition and desired grade steel for end use. The slag is tapped from pot after tapping of liquid steel is completed. The slag is collected in slag pot (ladle) and transferred to cooling yard/pit for air cooling and/or water sprinkling. The effective cooling of the slag is required for achieving the required temperature for further processing. The cooling processes includes the following methods:

Methods	Process
Air Granulation	Use of high pressure air to solidify the molten slag and granulation after cooling.
Instantaneous slag chill (ISC)	Molten slag is collected in steel box for cooling or solidification and further treatment with water sprinkling and immersion cooling.
Water Granulation	Molten slag is collected in container and cooled through rapid water sprinkling.

The chemical composition of the slag from Basic Oxygen Furnace is as below:

Composition		SiO_2	CaO	MgO	MnO	FeO	Fe_2O_3	Total Fe	P_2O_5	S	Al_2O_3	Free CaO	Hg
Range (%)	Min	10.13	40.95	4.16	0.58	13.54	23	16	0.6	0.049	0.27	2.53	0.086 mg/Kg
	Max	19.06	52.35	15.15	3.12	23.5	23.57	20.63	2.68	3.5	5.36	3.96	
Avg. (%)		14.276	46.803	8.454	1.16	19.3	23.285	17.866	2.864	0.954	1.733	3.233	

[Source: Industry]

BOF slag generation rate is 85-165 kg/ton of Liquid steel (BREF) and 150 kg/ton of hot metal (MoS) and total annual BOF slag generation for 2017-18 in the country was estimated to be more than 7.4 MT (Reference: Status Report on Iron and Steel Slag (Generation and Utilization) MoS).

3.4 Slag from Ladle Furnace Process

The slag is generated from Ladle Furnace Process where refining of steel is carried out in ladle after Basic Oxygen Furnace. The slag generated during the ladle furnace process is dependent of the slag composition of primary stage, flux & ferro-alloys added during the process and other technological parameters. The ladle furnace process involved addition of fluxes and ferro-alloys as per desired end product requirements.

Typical chemical composition of the slag generated from Ladle Furnace Process for low alloy steel (< 5% alloys in total) is as below:

Composition		SiO_2	Al_2O_3	CaO	MgO	MnO	FeO	Fe_2O_3	Total Fe	P_2O_5	S	Cr_2O_3
Range (%)	Min	2	8	40.08	4.5	0.2	0.5	4.4	0.37	0.11	0.085	0.14
	Max	20	35	57	10	1.95	15.21	4.4	0.37	0.68	1.83	0.43
Avg. (%)		9.472	22.766	43.772	7.778	0.369	2.885	4.4	0.37	0.224	0.425	0.285

[Source: Industry]

The rate of generation of slag from Ladle Furnace Process is 9-15 kg/ton of Liquid steel (BREF) and 12-27 kg/ton of Steel (MoS). The composition of Ladle furnace slag varies significantly based on the type of steel produced. Slags produced during production of high alloy steels (>5% alloying elements) may have higher amounts of Chromium, Nickel, Cobalt, Phosphorus, Sulphur etc.

3.5 Slag from Electric Arc Furnace process

The quality of slag generated from the electric arc furnace is dependent on the hot metal/Hot DRI/cold DRI/Flux/Scrap composition and desired grade of steel to be produced for end use. A foamy slag practice is followed where slag is removed out from the spout of the furnace first in the form of foam. The slag is collected in a pot stationed at the bottom of the furnace known as slag pot. This process starts a few minutes from the beginning of the process and continues till the end of steel making.

At the end small amount of slag remains in the furnace and liquid steel is tapped by opening the bottom tapping door on the other side where liquid steel is collected in a ladle. The liquid slag is taken in the slag pot to slag processing site where it is cooled either naturally or water spray or air granulation process based on required quality of product for end. The cooling process explained is one of many followed and the cooling process will vary from manufacturing plant wise.

The chemical composition of EAF slag using Sponge Iron/Hot metal/internally recycled scrap as input materials is shown in table below:

Composition		**SiO_2**	**CaO**	**MgO**	**MnO**	**Total Fe**	**P_2O_5**	**T-Cr**	**Al_2O_3**	**Free CaO**
Range (%)	**Min**	17	30	5	0.4	15	0.1	0	5	0
	Max	22	42	8	0.5	23	1	0.1	9	0.2
Avg. (%)		19.5	35.5	6.5	0.45	19	0.5	0.05	7	0.01

[Source**:** ISA]

Generally BF/BOF route produces 150-180 kg and EAF route produces 200-220 kg slag per tonne of steel, however from Conarc furnace is about 165 kg/Tonne of crude steel, however, the quantity of slag generated will be dependent on the quality of input materials especially Iron ore in BF/BOF route.

Globally various options for utilization of iron slag and steel slag are being explored. Status of iron and steel slags generation, utilization and storage in major iron & steel plants in the country is given in **Annexure-I**.

4.0 Current Practices for Handling and Management of Pyro-metallurgical Slag

4.1 Iron making slag from Blast Furnace/ Corex /Midrex

The Slag generated from Blast Furnace is taken to slag handling system where slag is treated through either quenching with water for conversion to granulated slag in Slag Granulation Plant or cooling with air in open dry pit at Blast Furnace. The granulated slag is designated for further use in cement industries for co-processing with raw materials. The air-cooled BF slag is generated while solidification under atmospheric conditions in slag dry pit.

4.2 Slag Granulation

The molten metal in blast furnace along with slag is passed through channel at tapping point in blast furnace bottom. The slag is separated from the molten metal with the use of skimmer method. The separated slag is routed to granulation tank where slag and water get mixed and flows to dewatering drum by action of gravity. Further, it is quenched by water jets in blowing box to produce granulated slag. The de-watering facility in the channel separates the water from granulated slag and the

hot water is collected in water tank below the conveyor belt. The granulated slag is taken to dedicated slag storage area or yard.

4.3 Air Cooling in Dry Pit

The slag dry pit method is used for storage of slag whereby the slag from blast furnace is diverted to dry pits through slag runner and also natural air cooling. The air-cooled slag is further processed to crushing & screening and subsequently utilized use in making insulation material, road sub-surface material, etc.

4.4 Steel making slags from LD- Convertors/EAF/Conarc/Induction Furnaces

The solidified steel slag from different processes is taken to recycling plant for removal of magnetic components and reduction in size. The slag is graded as per further requirement. The Basic Oxygen Furnace slag is stabilized through natural ageing or weathering whereby the steel slag is stocked in open air for adequate exposure to moisture and further hydration of CaO and MgO present in slag. The process is slow in nature, need adequate open space and requires longer time duration for stabilization to occur.

In order to overcome the existing issues of slow weathering, the slag is processed through accelerated ageing process whereby the slag is treated with steam for complete hydration of slag in relatively shorter time duration. The steam passes through the inside pores of slag and hydrates the free CaO and MgO. This results in loss of expansion of slag from 3-5% to < 0.4 %. The steam ageing is carried out in two different methods - atmospheric steam ageing process and pressurised steam ageing process.

EAF/Conarc slag is graded and magnetically separated like LD slag. However these slags do not require any aging treatment as the expansion in slag is inherently low due to absence of free lime content**.** Some of the international practices are given at **Annexure- II.**

5.0 Utilization of slags in road construction and as aggregates in concrete

Indian Road Congress has published “Guidelines for Use of Iron, Steel and Copper Slag in Construction of Rural Roads – 2018”. These guidelines provide detailed information on engineering properties of these slags along with the possible utilisation options.

The Indian Standards IS-383: 2016 of the Bureau of Indian Standards on “Specifications of Coarse and Fine Aggregates for Concretes” permits use of aggregates other than natural sources, including slags as given in Annexure-A of said standards. Engineering quality requirements of aggregates are specified in main document.

Central Road Research Institute, New Delhi (CSIR-CRRI) is bringing out revised Guidelines for Utilization of Steel Slag in Road Construction based on the research findings of CSIR-CRRI emanated out of various steel slag road sections laid across

India using processed steel slag aggregates of BOF, EAF and CONARC Steel Slag of some major steel plants.

6.0 Guidelines for management of pyro-metallurgical slags of iron and steel plants

Iron and steel plants shall follow the principles of resource efficiency for optimal use of primary resources in production of iron and steel. The plants shall take steps to facilitate utilization of various wastes, by-products or process rejects including slags. They shall set-up facilities for internal recovery of material, treating the slags to make it utilizable as alternate material outside the plant. Steel plants shall also take adequate safety measures and standard operating procedures shall be practiced in safe handling of iron and steel slags including the quenching, granulation and recovery operations. It shall be ensured that the slag is tapped in the slag pot or pit only after ensuring that slag pot or pit is dry. The flow of reactive slag into ladle is to be avoided by adopting suitable operational practices. After pouring and filling the Ingot moulds/ Bottom plates, foundry ladle shall be tilted with the help of auxiliary hoist of crane and total residual slag/metal shall be dumped into slag pots slowly. The safety guidelines for handling of hot metals issued by Ministry of Steel shall be followed.

The following guidance is applicable to all types of iron and steel slags as mentioned in this document according to their characteristics;

6.1 Iron and Steel plants shall use best available options for maximising internal use of slags in process and recovery of resource material from slags.

6.2 The plants shall adopt appropriate cooling/quenching/treatment techniques to maximise recovery of resource material from slags. The slag treatment pits if any should have impervious hard surface to avoid contamination of soil and wastewater or surface run-off generated should be either re-cycled or treated prior to discharge. The slag handling in open yards if any should have imperious hard surfaces, and run-off from handling area shall be collected and treated prior to discharge.

6.3 Iron and Steel plants shall adopt environmental friendly practices in collection, handling, storage and transport of slag to avoid water and air pollution.

6.4 Iron and Steel plants shall adopt environmental policy for continuous improvement by adopting cleaner / new techniques. Environment management should be supervised by senior management.

6.5 Un-utilized slag shall be stored in captive storage yard having impermeable base and garland drain to prevent the soil and water / groundwater contamination. The unlined slag handling, storage areas and dumpsites shall be discontinued within 2 years from issuance of these guidelines.

6.6 A new slag storage yard shall be constructed above the ground with impermeable base such as compacted clay of minimum 600mm thickness over a single layer of 1.5mm thick geo-membrane. Run-off from slag storage area shall be collected and treated prior to discharge.

6.7 All Iron and Steel plants shall monitor grounds water quality around storage area during pre and post monsoon seasons through a recognised laboratory (under the Environment (Protection) Act, 1986 or any NABL Accredited) for assessment of the contamination (if any) and such assessment reports shall be submitted to respective SPCB/PCC annually. The groundwater shall be monitored for parameters namely pH, alkalinity, Calcium, Magnesium, and heavy metals namely Fe, Mn, Al, Cd, Cr, Cu, Ni, Mercury, Pb and any pther parameter that may be prescribed by SPCBs/PCCS/CPCB.

6.8 Iron and steel slags from pyro-metallurgical route may be used in following areas subject to meeting the quality requirement/standard for the material / application:

i. Cement production

ii. Aggregate in cement-concrete

iii. Cement-concrete blocks / bricks /tiles

iv. Aggregate in construction of roads/ railways

6.9 Iron and Steel plants intending to utilise iron or steel slag for any other purpose, not mentioned above may submit the proposal along with relevant details to CPCB through the respective SPCB/PCC.

6.10 Iron and Steel plants shall maximize external use or recycling of slag which cannot be used or recycled internally. Iron and Steel plants shall take steps to achieve 100% regular utilization of iron slag and steel slags for current generation within one year and also fully utilise the legacy iron slag by September 2025 and legacy steel slag by Sep 2027, respectively. Thereafter, the maximum allowable storage of slags at any point of time will not be more than one year's generation for steel slag and 6 months of generation for iron slag

6.11 Industry should submit the annual report on generation, quantity stored, quantity utilized and the concerned usage, and disposal as per format given in **Annexure–II** or on online waste reporting portal as and when developed by CPCB by 30th June of the following year to SPCB/PCC and CPCB.

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Annexure – I

Filled up questionnaires received from units

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
Tata Steel-Jamshedpur	Granulated BF Slag	41000	4081238	-	4041422	80816	Cement Making	Storage facility not required because of continuous utilisation	Sufficient market demand availability and better logistics (rake availability) will improve the utilisation
	Air-cooled BF Slug	10000	270070	14018	263767	2285	1. Road construction 2. Works Project, 3. Mineral Wool Manufacturing	Storage facility not required because of continuous utilisation	Sustaining the current initiatives
	Steelmaking Slug	25300	1614344	339308	1281836	18500	Metallics: -Remelting in Steel Melting Shop Non-Metallics: -Consumption in Sinter making -Works Project -External Project -Fly Ash brick making -Cement Making -Road Making	For slag processing, Storage facility has inbuild Geo-membrane lining.	Sustaining the current initiatives
Tata Steel-Meramandali	Granulated BF Slag	18080	1749020	-	1603104	163996 (In transit for exports)	Cement Making	Storage facility not required because of continuous utilisation	Sufficient market demand availability and better logistics (rake availability) will improve the utilisation

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
Tata Steel-Kalinganagar	Air-cooled BF Slug	505964	24000	-	9964	520000	Road construction	Storage at in-house yard with embankment and garland drains.	Current slag is being 100% utilised. For legacy slag: processing is ongoing and usage is being enhanced in new applications: 1. Usage as aggregate in paver, Concrete 2. Manufacturing Sand
	Steel making Slug	1001495	88264	466507	400174	1017078	Metallics: -Re melting in Steel Melting Shop Non-Metallics: -Consumption in Sinter making -Works Project -External Project/Harstand -Fly Ash brick making -Cement Making -Road Making	for slag processing, Storage facility is with garland drain.	Current slag is being 100% utilised. For legacy slag: processing is ongoing and usage is being enhanced in new applications: 1. Usage as aggregate in paver, Concrete 2. Manufacturing Sand
	Granulated BF Slag	12243	1391610	147925	1251587	4341	Cement Making Ground Granulated BF Slag	Storage facility not required because of continuous utilisation	Sufficient market demand availability and better logistics (rake availability) will improve the utilisation
	Air-cooled BF Slug	11139	58495	34063	35371	200	Road construction Works Project Paver Block Manufacturing	Storage facility not required because of continuous utilisation	Sustaining the current initiatives

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
	Steelmaking Slug	69750	626611	499573	128429	68360	Metallics: -Remelting in Steel Melting Shop Non-Metallics: -Consumption in Sinter making -Works Project -External Project/Harstand -Fly Ash brick making -Cement Making -Road Making	for slag processing, Storage facility is with garland drain.	current slag is being 100% utilised. For legacy slag: following measures will be taken: 1. Higher dispatch to brick customers. 2. Development of new applications/projects.3. Slag dispatches to cement making through rakes.
AMNS HAZIRA SMS-I 4.5 MTPA SMS-II 5 MTPA	Steelmaking slug EAF & Conate	2051288	1520240	664000	2407426	500101	Recycle in sinter/BF/Corex. Sales for road and construction as aggregate	Storage on bare soil in open yard in the form of heap/ dump	Setup advance crushing/ Magnetic separation and screening facility
AMNS Hazira BF 1.8 MTPA Corex 1.7 MTPA	BF/Corex Granulated Slag	1064987	951843	0	1516259	500571	For Cement making Export/ domestic Sale		Huge demand we are already selling more than we are generating
AMNS Hazira BF 1.8 MTPA Corex 1.7 MTPA	BF/Corex Air-cooled Slag	487161	107428	0	460866	133723	Crushing and screening for road making / land filling		Reducing the generation
AMNS Hazira SMS -I 4.5 MTPA SMS-II 5 MTPA	I.F Slag	172958	113852	0	231325	65704	Direct Sales		Magnetic Separation plant
AMNS Hazira	HMDP Slag		11190	0	971		Direct Sales		Magnetic Separation plant

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
JSPL Raigarh	Granulated BF Slag	15605.81	1080815.09	309184.105	442722.13	344514.664	Cement Plant	Storage at designed place	Further dispatch of material to use in cement plant.
JSPL Raigarh	SMS Slag	2888276	931834	41560	286744	3491806	PS Ball making, Cement Making, Metal recovery, Aggregate and Land Filling	Open storage in a designed yard	To utilise maximum quantity in cement production, to replace river sand with slag sand , to use in cement concrete, increase in PS Ball making and increase in aggregate utilisation
JSPL Angul	BF Gr Slag	354106	1316335	8756	811120	850565	Sold to Cement plants	Open Slag yard	Dispatch and consumption in own cement plant
JSPL Angul	BOF Slag	300000	711276	1011276	0	0	land Filling after crushing and metal recovery	No Stock	Installed crusher unit in 2021 and plan to utilization of legacy slag 100% as per generated amount.
JSPL Angul	EAF/NOF Slag	200000	319027	489027	0	30000	land Filling after crushing and metal recovery	storing in big hips and specific locations	Installed crusher unit in 2021 and plan to utilization of current and legacy slag 100% till July 2023.
Bhilai Steel Plant, Bhilai, Chhattisgarh, Production Capacity: Crude Steel = 7.0 MTPA	BF Slag	991981	2430817	0	2237642	1185156	1 Sold to Cement manufacturers and Slag wool manufacturers	Dumped at Slag Yard	100% (Subject to BF-1 being phased-out resulting in no generation of Air cooled BG slag)

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
Durgapur Steel Plant, Durgapur, West Bengal, Production Capacity: Crude Steel = 2.5 MTPA	BF Slag	106289	857619	0	945531	18377	1) Sold to Cement Manufacturers		100% being sold to cement manufactures
Rourkela Ste 81 Plant, Rourkela, Odisha, ProductionCapacity: Crude Steel = 4.85 MTPA	BF Slag	0	1722913	0	1722913	0	1) Sold to Cement Manufacturers		Already achieved
Bokaro Steel Plant, Bokaro Steel City, Jharkhand, Production Capacity: Crude Steel = 5.01 MTPA	BF Slag	250000	1877415	143260	1734255	249900	1) Sold to Cement manufacturers. 2) Used in road making		100% utilisation of granulated BF slag already achieved.
llSCO Steel Plant. Burnpur, West Bengal, Production Capacity: Crude Steel = 2.5 MTPA	BF Slag	240087	902161	0	1066602	75646	1) Sold to Cement manufacturers.		100% utilisation of air cooled BF slag yet to be achieved.
SAIL	BF Slag	1588357	7790925	143260	7706943	1529079			

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
Bhilai Steel Plant, Bhilai, Chhattisgarh, Production Capacity: Crude Steel = 7.O MTPA	BOF Slag	1378742	522168	222294	38441	1640175	1) Processed BOF slag used as input material in Sinter plant , Blast Furnaces and Steel Melting Shop. 2) Unprocessed BOP slug used in road levelling, low lying land filling and sold to external agencies.	Dumped at Slag Yard	Bulk utilization by NHAI/ NRRDA/ State PWD/ in agriculture and enhancement in sale of unprocessed BOF slag
Durgapur Steel Plant,Durgapur, West Bengal,Production Capacity: Crude Steel = 2.5 MTPA	BOF Slag	9078087	344440	236227	2501	9183799		Dumped at Slag Yard	12.4 lakh tonners of BOF Slag (from old stock) was auctioned/ sold on May 2022 for Road Making (National/State Highway). 139812 Ton of material has already been lifted during June 22 Jan2023 achieving BOF Slag utilisation of 110.8% in FY 2022-23 (up to Jan 2023) Auction /Selling of BOF Slag/ LD Slag for Road Making will continue.
Rourkela Steel Plant, Rourkela, Odhisa, Production Capacity: Crude Steel = 4.85 MTPA	BOF Slag	2000000	601317	299709	99067	2202541			Enhancement in sale of unprocessed BOF slag to external agency.

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
Bokaro Steel Plant, Bokaro Steel City, Jharkhand, Production Capacity: Crude Steel = 5.01 MTPA	BOF Slag	50000	421701	404709	36076	30916			Enhancement in sale of unprocessed BOF slag to external agency.
IISCO Steel Plant, Burnpur, West Bengal Production Capacity: Crude Steel = 2.5 MTPA	BOF Slag	614200	294662	155983	11445	741435			Enhancement in sale of unprocessed BOF slag to external agency.
SAIL	BOF Slag	13121029	2184288	1318922	187530	13798866			
RINL (Visakhapatnam Steel Plant)	BF Slag	5598723	2119894	75	2426228	5292314	1. 75T utilised for construction activity within the plant 2. 2426228T sold to cement industries	No specific storage methods present	Sale to cement companies
RINL (Visakhapatnam Steel Plant)	SMS Slag	5453545	879908	294061	11625	6027767	1. 294061 T consumed in process & Land filling with in the Plant 2. 11625 T sold	No specific storage methods present	Maximising in process use, exploring for use in road making

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
JSW Steel Ltd., Salem Works, Pottaaerl, Mecheri, Mettur, Salemworks. Tamil Nadu.636453.IntegratedSteel Plant with the capacity 1.15 MTPAspecial alloy steelproduction	BF	30237	451752	311	227431	254247	Due to the COVID-19 disposal not happened. From May 2022 onwards slag grinding unit is in operation and slag 100 % generated is sent to slag grinding unit to produce value added product of GGBS. Portion of quantity is sold to cement industries also. The accumulated quantity will be also used in slag grinding unit	BF granulated slag directly sent to slag grinding unit	100 % utilisation
JSW Steel Ltd., Dolvi, Maharashtra	SMS Slag	218975	240657	156394 8	141467	164217	In-house consumption at SP, SMS Paver block mfg and to Cement Industries & open market	SMS Slag sent to crushing unit where iron bearing materials are separated and the crushed material is stored in a yard (dyke) and subsequently sent to Captive consumption and disposal	97 % utilisation. Maximise through paver making facility and sale to cement industries
	BF Slag from BF 1 (Granulated BF Slag		1436782				Used for Cement plant	Stored in a designated place with dyke wall	1
	BF Slag from BF 2 (Granulated BF Slag		574486						1

Slag generation, utilisation and storage data									
Name & Address of plant with Production Capacity	**Type of Slag**	**Qty. of Slag stored on 31.03.2021 (in MT)**	**For F.Y. 2021-22 (April 2021 - Mar. 2022)**			**Qty. of Slag stored on 31.03.2022 (in MT)**	**Method of Utilisation**	**Method of Storage (with details of impervious liner / layers and embankment/dyke)**	**Plan for achieving 100% utilisation of current and legacy slag**
			Qty. of Slag Generated (in MT)	**Qty. of Slag Utilised (in MT)**					
				Within Plant	**Externally**				
	Electric Arc Furnace (EAF) Slag from Steel making Shop-1		1195458	440663	556709	969784	After metal recovery, EAF & BOF slag is utilised for construction purpose, road making in National Highway (Concrete Road and Bituminous Road) land reclamation in low lying area in side premises. Proposed for utilization in marine application like tetra pods and marine structure.	Stored in a designated place with dyke wall	
	Basic Oxygen Furnace slag (BOF) from steel Melting shop 2		143826					Stored in a designated place with dyke wall	

Annexure-II

International Practices in management of Iron and Steel Slags

Slag from Blast Furnace

US Department of Transportation: (User Guidelines for Waste and By-product Materials in Pavement Construction)

Air-Cooled Blast Furnace Slag: Liquid slag is cooled slowly under ambient condition to form a crystalline structure and to produce a hard, lump slag that can be crushed and screened for further use.

Expanded or Foamed Blast Furnace Slag: Liquid slag is cooled and solidified by adding controlled quantities of water, air or steam, in order to accelerate the process of cooling and solidification and to produce a lightweight expanded or foamed product with increased cellular nature.

Pelletized Blast Furnace Slag: Liquid slag is cooled and solidified with air and water in a rotating drum to produce pellets of more crystalline nature as a beneficial for aggregate use.

Granulated Blast Furnace Slag: Liquid slag is cooled and solidified through rapid water quenching to have a low crystallization occurrence and to produce a sand size fragments and clinker like materials

Ground Granulated Blast Furnace Slag: When granulated blast furnace slag is crushed to very fine cement-size particles to produce ground granulated blast furnace slag for use in cement industry as a replacement/additive of Portland cement.

Australasian (iron & steel) slag association: (Blast Furnace Slag Cements & Aggregates: Slag Binders and Aggregates and Australian Standards)

Ground Granulated Iron Blast Furnace Slag: It is defined as the glassy granular material resulting from the rapid chilling of molten, a non-metallic product, consisting essentially of silicates and alumina-silicates of calcium, produced simultaneously with iron in an iron blast furnace slag.

United Kingdom: (Blast Furnace Slag: A technical report on the manufacturing of blast furnace slag and material status in the UK**).**

Air-cooled Blast Furnace Slag (ACBFS): The molten slag is being taken to open air pits located nearby blast furnace and the slag is quenched with water applied through water spray system to provide cooling and its crystallisation. The cooled slag is then crushed and screened to produce aggregates for other applications.

Ground Granulated Blast Furnace Slag (GGBFS): The molten slag is passed through granulation plant where it is quenched rapidly with warm water and results in production of vitrified (glassy) material having sand-like appearance. The cooled granulated slag is grinded in grinding mill for conversion into ground granulated blast furnace slag.

Slag from Steel Industry

BREF – European Union

De-sulphurisation slag: A heterogeneous slag, whose composition is dependent on used desulphurisation agent, contains high sulphur content is generally recycled to sinter mix or partially used for landfill construction.

Basic Oxygen Furnace slag: The slag from basic oxygen furnace is dependent on process employed. It is generally used as an aggregate in road construction as base/sub-base, in asphalt mixtures and in waterway construction. Also, it is selectively used as fertiliser and liming agent in agriculture due to presence of CaO content.

Annexure – III

Format for submission of annual report on slag generation, utilization and storage.

1. Name and Address of the Plant:
2. Contact Person Responsible for Management of Iron & Steel Slag:
   a. Name and Designation:
   b. Mobile Number:
   c. Email ID:

Financial year	Slag Type*	Opening Stock (in MT) as on 31st March	Qty. of Slag Utilised in F/Y (in MT)		Slag stored at the end of the financial year (in MT)	Method of Utilisation	Method of Storage (with details of liner layers and embankment/dyke)
			Within Plant	Externally			
	Iron Making Slags						
	a) Granulated BF Slag						
	b) Air-cooled BF Slug						
	c) Corex Slags						
	Steel making Slags						
	d) BOF/LD Slag						
	e) EAF/Conarc furnace Slag						
	f) Induction furnace Slag						
	g) Other slag (please specify)						

**As applicable*