Draft

# Guidelines on Management of Pyro-metallurgical Slags

## (Iron & Steel Plants)


**Central Pollution Control Board**

(Ministry of Environment, Forest and Climate Change)

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## 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 ~~is defined~~ 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-metalurgical 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). 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: Scrap Metal (ferrous and non-ferrous) to promote initiatives for Circular Economy in the metal sector (ferrous and non-ferrous) through Action plan which also include and action point about - *Issue of SOP for use of Iron and steel slag under Hazardous and Waste Management Rules 2016.*

The guidelines are prepared to deal with the handling and management of slags generated from pyro-metallurgical operations in Iron & Steel Industries and Copper Smelters.

**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 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 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 and palletisation is a process of agglomeration of micro fines of iron oxide ores (concentrate) into small round balls, followed by high temperature for hardening of finished products. The finished products from sinter plant and pellet plant are taken to blast furnace for feed along with coke and pulverised coal. In addition to iron ores, coke and pulverised coal are added as reducing agents. The added coke and coal partly help in combustion as a fuel in the process. The coke used in blast furnace is produced in coke oven through distillation of coke.

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 at 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 of undesired elements such 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 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 Degree C 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 ~~methane~~ gas based vertical shaft furnace ~~(Midrex)~~ 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 Deg C.

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 or Conarc furnace, Induction furnace, 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.

**Iron and Steel manufacturing scenario in India:**

In India, during 2021 (Jan-Dec) Crude Steel production stood at 118.134 MT.

SAIL, RINL, TSL Group, AM/NS, JSWL & JSPL together produced 73.057 MT with a share of 62% in total production. Pig Iron production was at 5.876 MT.

The major wastes produced in integrated steel plants include BF Slag, Steel Melting Shop (SMS) Slag accounting for nearly more than half a ton for each ton of steel produced in ISPs. Generally, BOF/EOF 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 |
| 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.

### 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 | Formed 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 adopted by iron and steel plants in the country the 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** | **$TiO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Range (%) | Min | 26.4 | 28.72 | 14 | 0.52 | 0.07 | 0.04 | 0.08 | 0.3 | 0.51 |
| | 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)

**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).

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range (%) | Min | 10.13 | 40.95 | 4.16 | 0.58 | 13.54 | 23 | 16 | 0.6 | 0.049 | 0.27 | 2.53 |
| | 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).

**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. Stags produced during production of high alloy steels (>5% alloying elements) may have higher amounts of Chromium, Nickel, Cobalt, Phosphorus, Sulphur etc.

**Slag from Electric Arc Furnace process**

The 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 ton of steel however from Conarc furnace is about 165 kg/F 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.

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

### 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 slag is considered for utilization in land filling.

### 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 separated 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.

### 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 quenched with a wet cooling through sprinkling of water and also air cooling. The air-cooled slag is further processed to crushing & screening and subsequently utilized.

### Steel making slags from LD- Convertors/EAF/Conarc/Induction Furnace

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.

**International Practices**

**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 near by 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.

## 5.0 Specifications of IRC and BIS for 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. Properties of slags in respect of toxic inorganic constituents is not covered in the guidelines.

The Indian Standards IS-383: 2016 of the Bureau of Indian Standards on "Specifications of Coarse and Fine Aggregates for Concretes" permits use of manufactured aggregates, including slags, in concretes to the specified extent. Engineering quality requirements of aggregates are specified in main document. Brief information on other than natural is given in Annexure-A, which include BIS quality standards for slags. However, the quality parameter / permissible concentration are not as per criteria in Schedule II of HoWM Rules 2016. The above mentioned guidelines of IRC also referred to in IS-383: 2016

## 6.0 Guidelines for management of pyro-metallurgical slags

6.1 Use best available options for internal use and recycling of slags.

6.2 Adopt appropriate cooling/treatment techniques to maximise reuse of slag as a resource.

6.3 Use best practices in collection, handling, storage and transport of slag to avoid water and air pollution.

6.4 Implement appropriate measures, such as impermeable base and garland drain, in slag storage area to avoid fluid leakage and prevent soil and water / groundwater contamination.

6.5 Maximize external use or recycling of slag which cannot be used or recycled internally. The slag may be used in following areas as per quality requirement/standard of materials and subject to qualifying the tests for relevant parameters as per HoWM Rules 2016 Schedule II criteria:

i. Cement,
ii. Cement-concrete
iii. Cement-concrete blocks / bricks / tiles
iv. Construction of roads/ railways
v. Construction of embankments like dams / canals

6.6 Adopt environmental policy for continuous improvement by adopting cleaner / new techniques

6.7 Environment management should be supervised by senior management

## 7. Recommended utilization targets

- BF slag utilization for current operation shall be achieved up to 100% within one year, and 100% utilization of legacy BF slag shall be achieved within further one year.

  After two years, the maximum allowable storage at any point of time will not be more than 03 months' generation.

- Steel slag utilization for current operation shall be achieved up to 100% within 2 year and 100% utilization of legacy steel slag shall be achieved within further 2 years.

  After four years, the maximum allowable storage at any point of time will not be more than 06 months' generation

Annexures (Attachments)

- Filled up questionnaires receive from units
- Unit wise compiled slag composition data