# Utilisation of Wastes from Integrated Steel Plant with Special Reference To India

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## *ABSTRACT*

*In any integrated steel plant a lot of wastes are generated. By the application of appropriate technology the wastes produced can be recycled and reused. This will help in creating waste into wealth and eco-friendly environment. The recovery and use of steel industry by-products has contributed to a material efficiency rate of 97 % in some of the advanced countries, whereas India is far behind this target. The goal should be 100 % efficiency, or zero-waste. A critical analysis has been presented in this paper with special reference to Indian Steel Industries.*

***Key words:*** *Blast furnace slag, Fly ash, Wasteutilisation, Waste energy*

## 1.0 Introduction

Environmental pollution is the major problem associated with rapid industrialisation, urbanisation and rise in living standards of people. For developing countries, industrialisation ismust and this activity demands to build self reliant and in uplifting nation's economy. However, industrialisation on the other hand has also caused serious problems relating to environmental pollution. Therefore, wastes seem to be a by-product of growth. The country like India can ill affordto lose them as sheer waste. On the other hand, with increasing demand for raw materials for industrial production, the non-renewable resources are dwindling day-by-day. Therefore, efforts are to be made for controlling pollution arising out of the disposal of wastes by conversion of these unwanted wastes into reusable raw materials for various beneficial uses. The problems relating to disposal of industrial solid waste are associated with lack of infrastructural facilities and negligence ofindustries to take proper safeguards. Therefore, the generation, handling and safe utilisation of wastes is a major concern of the world.

A lot of waste is produced from integrated steel plant, while producing pig iron, steel and end products. Generally, 1.0 to 1.5 tonnes of solid waste byproducts are generated while producing one tonne of steel in Indian Steel Plants.[1] If these wastes are not properly utilised, it is bound to cause huge revenue loss, environmental degradation and ecological imbalance. By the application of suitable technology, the generation of waste can be minimized and used effectively elsewhere.

## 2.0Steel production and by-products at a glance

There are two main ways in which steel is produced:

1. Iron ore-based steel production accounts for about 70% of world steel production. Iron ore is reduced to iron andthen converted to steel. The main inputs are iron ore, coal, limestone and recycled steel. The main ore-based production routes are: iron making via the blast furnace (BF) followed by steelmaking in the basic oxygen furnace (BOF), and ironmaking via direct reduction (DRI) followed by steel production in the electric arc furnace (EAF).

2. Scrap-based steel accounts for about 30% of global steel production. It is produced by recycling steel in an EAF. The main inputs are recycled steel and electricity. The main by-products produced during iron and crude steel production are slag (90%), dusts and sludge. An average value is shown for the EAF route, as EAF plants often use a mix of DRI and recycled steel feeds.

## 2.1Slag produced during Iron and steel making

More than 400 million tonne of iron and steel slag is produced each year. Slag is a mixture of silica, calcium oxide, magnesium oxide, and aluminium and iron oxides.During smelting, slag forming agents and fluxes (mainly limestoneor dolomite and silica sand) are added to the blast furnaceor steel producing furnace to removeimpurities from the ironore, steel scrap, and other ferrous feeds. The slag protects the liquid metal from outside oxygen and maintains temperature by forming a cover. As the slag is lighter than the liquid metal,they float and can be easily removed.

There are three main types of marketed iron making or BF slag, categorised by how they are cooled;

- air-cooled,
- granulated,
- pelletised.

Air-cooled slag is hard and dense and is especially suitable foruse as construction aggregate. It is also used in ready-mixedconcrete, concrete products, asphaltic concrete, road bases andsurfaces, fill, clinker raw material, railroad ballast, roofing,mineral wool (for use as insulation) and soil conditioner.[2]

Granulated slag forms sand-sized particles of glass and isprimarily used to make cementitious material. Concretesincorporating granulated slag generally develop strengthmore slowly than concretes that contain only Portland cement– the most common type of cement – but can have betterlong-term strength, release less heat during hydration, havereduced permeability, and generally exhibit better resistance tochemical attack.

Slag can also help bring down the cost of cement. For example,in the US it sells for 20-25% less than Portland cement.[3]

While the use of granulated slag in cement is well established,there is still potential in many regions to increase the ratio ofslag used for this purpose.Pelletised or expanded slag has a vesicular texture (likevolcanic rock) and is most commonly used as a lightweightaggregate. If finely ground, it also has cementitious properties.



## 3.0Types Of Waste Generated In An Integrated Steel Plant

- Blast Furnace Slag
- Steel Melting shop Slag
- Desulphurisation Slag
- Coating Slag
- Ammonium sulphate
- Tar product
- Coke
- Benzol products and Heavy Benzol
- Sulphuric acid
- Acid tar
- Polymer
- Sludge
- Scraps
- Blast furnace dust
- Flue dust/ash
- Fly ash
- Waste refractory material
- Waste consumable
- Mill Scale

## 4.0 Reduction In Waste Generation

Better quality of input materials, improved production processes, enhancement in fuel efficiency and conservation of energy result in the reduction of wastes generated. Blast Furnace slag, Steel melting shop slag and fly ash are the major portion of waste generated. Waste generation can be substantially reduced by the following measures:

(i) Generation of slag in blast furnace can be considerably reduced by input of improved quality of raw materials, superior grade of coke, and use of latest technology such as high blast temperature, use of prepared burden, high top pressure, and coal dust injection through tuyeres.

(ii) Modern steel making technology can be instrumental in bringing down the hot metal silicon and sulphur level which will reduce the produced slag rate per tonne of crude steel ore.

(iii) Use of high grade coke with low ash content can bring down the production of fly ash.

(iv) Total energy contained in the waste gas is approximately one giga Joule per tonne of steel. About 70 % of this waste energy can be recovered in the form of un-burnt carbon dioxide with introduction of gas recovery system, modern suppressed combustion system, and gas cleaning equipment. The resultant converted gas is clean and has high calorific value and can be reused effectively.

(v) Application of recent advances in regenerative burner technology for achieving superior fuel and energy efficiency.

(vi) Application of more accurate computer control of reheating parameters to optimise furnace operation and to modify furnace conditions to cope with any planned or unforeseen delays.

## 5.0 Waste Utilisation

### 5.1 Blast Furnace Slag

In some countries, up to 80% of the cement contains granulated BF slag.[4] Using slag prevents it going to landfill as waste, saves energy and natural resources, and significantly reduces $CO^2$ emissions in cement production. According to the Slag Cement Association, replacing Portland cement with slag cement in concrete can save up to 59% of the embodied $CO^2$ emissions and 42% of the embodied energy required to manufacture concrete and its constituent materials.

Steelmaking slag (BOF and EAF) is cooled similarly to air-cooledBF slag and is used for most of the samepurposes. Asthe production process varies at this stage depending on thetype of steel being made, the resulting slag also have diversechemical properties making them more difficult to use thaniron making slag. Some of the recovered slag is used internallyin the steelmaking furnace or sinter plant, while approximately50% of the recovered slag is used externally in constructionapplications, primarily roads.

One of the main barriers to using some steelmaking slag is their high content of free lime, which is not ideal forconstruction applications. Various technologies are currentlyunder development to improve lime separation. Onceseparated, free lime can be used as fertiliser, in cement andconcrete production, for waste water treatment, and in coastalmarine blocks that encourage coral growth.Previously considered as useless by-products and used only as land fill, slag is nowrecognised as marketable products. The worldwide averagerecovery rate for slag varies from over 80% for steelmaking slagto nearly 100% for iron-making slag. The environmental and-economic benefits mean that there is still much potential toincrease the recovery and use of slag in many countries. Blast furnace slag may be used for the following purposes:

- Manufacture of slag cement, super sulphated cement, metallurgical cement.
- Non-Portland cement
- Making expansive cement, oil-well, coloured cement and high early-strength cement.
- In refractory and in ceramic as sital
- As a structural fill ( air-cooled slag)
- As aggregates in concrete.

Crushed and screened blast furnace slag is being used for the sub-grade/sub-base layer of road construction due to its strength, toughness, hardness, soundness and other qualities. However, transportation cost becomes the limiting factor for its use at distant places. These days, slag granulation facility is being installed with most of the blast furnaces which proves quite effective for its reuse in cement industries. For effective utilisation of blast furnace slag, the establishment of cement plant in the vicinity of integrated steel plant is the only option. Approximate chemical composition of granulated slag produced from Tata Iron & Steel Co. and Bokaro Steel Plant is provided in Table- 1 and they are most suitable for the production of slag cement[1].

**TABLE: 1**

| CONTENT | PERCENTAGE | |
|---|---|---|
| | TATA IRON & STEEL PLANT | BOKARO STEEL PLANT |
| $SiO_2$ | 30 t0 33 | 27 t0 38 |
| $Al_2O_3$ | 21 to 25 | 7 to 15 |
| CaO | 30 to 33 | 30 to 38 |
| MgO | 0.06 to 10.0 | 0.2 to 1.6 |
| MnO | 0.2 to 1.0 | 0.2 to 1.1 |
| $TiO_2$ | - | 0.4 to 2.1 |
| S | - | 0.8 to 1.1 |

## 5.2 Slag from Steel Melting Shop

The slag produced from steel melting shop has high iron oxide content and therefore, it is not suitable for use in production of cement. This type of slag can be used as replacement for ballast in railway tracks and in the sub-grade/sub-base of road construction. The finer particles are used as fertiliser for acidic soils because of its high basic values and phosphorous content.



## 5.3 Blast Furnace Dusts Gases and sludge

Gases from iron- and steelmaking, once cleaned, are almostfully reused internally. Coke oven gas contains about 55%hydrogen and may prove an important hydrogen source in thefuture.[5] It is fully reused within the steelmaking plant, and canprovide up to 40% of the plant's power.[6]Dust and sludge are collected in the abatement equipment(filters) attached to the iron- and steelmaking processes.Sludge is produced from dust or fines in various steelmakingand rolling processes and has high moisture content.The dust and sludge removed from the gases consist primarilyof iron and can mostly be used again in steelmaking. Ironoxides that cannot be recycled internally can be sold to otherindustries for various applications, from Portland cement to electric motor cores.

The EAF route may create zinc oxides that can be collectedand sold as a raw material. In the BOF route,cleaningthe coke oven gas creates valuable raw materials for otherindustries including ammonium sulphate (fertiliser), BTX(benzene, toluene and xylene – used to make plastic products),and tar and napthalene (used to make pencil pitch which inturn is used to produce electrodes for the aluminium industry,plastics and paints).[7]

Blast furnace dust is totally recycled through sinter plant. Dust and sludge are produced to recover magnetite and remove alkali. Magnetite can be used in coal washeries. Average composition of flue dust and cleaning plant sludge is shown in Table- 2[1].

**TABLE: 2**

| CONTENT | PERCENTAGE | |
|---|---|---|
| | TATA IRON & STEEL PLANT | BOKARO STEEL PLANT |
| Fe | 32 to 35 | 30 to 50 |
| $SiO_2$ | 7 to 9 | 5 to 8 |
| CaO | 6.5 to 7.5 | 4 to 6 |
| $Al_2O_3$ | 6 to 7 | 2 to 5 |
| Carbon | 21 to 25 | 20 to 25 |
| Alkali | 1.1 to 2.54 | 1 to 2.5 |
| Zinc | Trace | Trace |
| Lead | Trace | Trace |

## 5.4 Fly Ash

Captive Power Plant of integrated steel plants generates huge quantity of fly ash. Fly ash is disposed of in a slurry form in the ash pond. Due to fly ash, water pollution is caused in rainy season and air pollution in the dry season. Large scale damage is caused by fly ash to cultivable land. The fly ash can be effectively used for manufacture of bricks.

In general, a 1,000 MW station using coal of 3,500 kilo calories per kg andash content in the range of 40-50 per cent would need about 500 hectares fordisposal of fly ash for about 30 years'operation. It is, therefore, necessary that flyash should be utilised wherever possible to minimize environmental degradation.

The research and development carried out in India for utilisation of fly ash formaking building materials has proved that fly ash can be successfully utilised forproduction of bricks, cement and other building materials. Indigenous technologyfor construction of building materials utilising fly ash is available and are beingpractised in a few industries. However, large scale utilisation is yet to take off.Even if the full potential of fly ash utilisation through manufacture of fly ash bricks74and blocks is explored, the quantity of fly ash produced by the thermal power plantsare so huge that major portion of it will still remain unutilised. Hence, there is aneed to evolve strategies and plans for safe and environmentally sound method ofdisposal. The fly ash may be used for the following purposes:

- Cement
- Raw material in Ordinary Portland Cement(OPC) manufacture
- Manufacture of oil-well cement.
- Making sintered flyash light-weight aggregates.
- Cement/silicate bonded flyash/clay binding bricks and insulating bricks.
- Cellular concrete bricks and blocks, lime and cement fly ash concrete.
- Precast flyash concrete building units.
- Structural fill for roads, construction on sites, Land reclamation, etc.
- As filler in mines, in bituminous concrete
- As plasticizer
- As water reducer in concrete and sulphate resisting concrete
- Amendment and stabilisation of soil.

## 5.5 Efficient utilisation of waste energy

The CDM (Clean Development Technology) methodology comprises technologies and measures to improve the efficiency of electricity or thermal energy generation from recovered waste energy from a single source at an industrial unit.[8,9] The ratio of waste energy to production output is constant for the targeted production process. Examples include replacement of a wet-type dust removal system by a dry-type system prior to a top gas pressure recovery turbine (TRT) in iron and steel industry.

The methodology is applicable under the following conditions:

(a) Production process has homogeneous outputs and it is possible to directly measure and record energy efficiency parameters such as production output, thermal and/or electrical energy produced including the sources used for energy production;

(b) The impact of the measures implemented (improvements in energy efficiency) by the project activity can be clearly distinguished from changes in energy use due to other variables not influenced by the project activity (signal to noise ratio);

(c) Production outputs (e.g., hot metal) in baseline and project scenario remain homogenous and within a range of ±10% with no change in installed capacity. The methodology is not applicable to project activities for retrofit of an existing facility to increase production outputs;

(d) No auxiliary fuel is used and/or co-firing for energy generation in the project activity does not take place.

## 6.0 Ongoing technological development

Technologies to further improve by-product recovery rates and expand their potential benefits include improved material separation technologies and carbon sequestration that could dramatically reduce steel industry $CO^2$ emissions. One technology, in early development, uses slag to sequester carbon during steelmaking and could reduce $CO^2$ emissions by 85% while converting the slag and exhaust gas to potentially marketable products such as carbonates.[10] Together with existing technologies, new developments provide environmentally and economically sustainable solutions to bring the steel industry ever closer to its goal ofzero-waste.

## 7.0 Suggested Action Plan

- All Direct Reduced IronDRI) plants to install Electro Static Precipitators(ESPs), in the kiln, bag filter in dust generating points andpneumatic dust handling system.
- All steel plants and sponge iron plants to develop collection and treatment facility formineral char and coal pile run off during monsoon.
- Installation of online stack monitoring system with real time display system
- Real time ambient air quality monitoring (SOx, NOx, CO, PM10, PM5 )
- Use of SMS slag and Ferro alloys slag for haul road construction in the mine area
- All TPPs to install ESP/BF to meet the emission standard of 50 mg/$m^3$ with one sparefield.
- All lean slurry disposal system to be converted to (High Concentration Slurry Disposal) HDSD.
- Silo to be created for a capacity of at least 7 days ash generation for its dry storage
  and subsequent utilization for cement and after fly ash based products.
- Real time ambient air quality monitoring (SOx, NOx, CO, PM10, PM5 ).
- All the thermal power plants shall adopt zero discharge

## 8.0 Conclusion

(1) Integrated waste management can convert waste produced from Iron and Steel Plants into wealth.

(2) Cost of production will be reduced alongwith the reduction in health hazards and helping in creating eco-friendly environment.

(3) Modern integrated steel plants canreduce the generation of wastes significantly and increase the utilisation of solid, liquid or gaseous wastes by adopting (i) pollution control methods, (ii) latest technologies, (iii) using better grades of input materials, and (iv)enforcing better maintenance of the equipments and controls.

(4) Together with existing technologies, new developments provide environmentally and economically sustainable solutions to bring the steel industry ever closer to its goal of zero waste.

(5) With the earth's resources being rapidly depleted and most of the world chanting go green, it is not surprising that business conglomerates are finally waking up to the need to conserve and recycle.

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