Utilization of Solid Waste from Steel Melting Shop

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Abstract

In steel Industry, the production of steel is associated with the generation of solid waste materials like slag, dust, sludge, etc. Significant quantities of wastes are generated from steelmaking process which is a focus point now-a-days w.r.t its utilization as well as environmental impact. Steelmaking process broadly includes all operations from primary and secondary steelmaking to ingot and continuous casting of steel. At each of these stages of steelmaking process, substantial amounts of wastes are generated. Thus minimization and utilization of waste through integrated waste management has gained special significance in the present scenario, as these wastes have a wide ranging impact on the environment. The solid waste generation, presently in Indian steel industry is in the range of 450 - 550 kg/t of crude steel and recycling rate varies between 40 - 70 % which lead to higher production costs, lower productivity and further environmental degradation. It is very essential not only for recycling of the valuable metals and mineral resources but also to protect the environment. In advance countries, the solid waste generation has been brought down below 200 kg/tls and the recycling and reuse rates are above 90% approaching almost to 100% level. This paper summarizes and analyzes the generation, composition, characteristics and present status of the utilization of the most of the wastes generated from the steelmaking processes.

The aim of the paper is to explore the various developments for total recycling of solid waste generated from steel industry, so that the vision for making "*clean & green steel with zero waste*" can be achieved for survival and growth of steel business in future.

Introduction

The production of steel in an integrated steel plant involves several operations starting from use of natural raw materials, like iron ore, coal and flux in production of hot metal and further processing of hot metal into steel and subsequently, rolling of steel into finished products in the rolling mills. Quantities of solid wastes generated in steel melt shops are a cause for concern as their nature is quite variable and diversified. The waste materials like slag, dust, sludge, etc. have a wide range of impact on the environment. Earlier these wastes were either dumped or thrown out in the open space but now with rising concern for the environment and lack of space for the dumping of such huge

wastes, new technologies are being explored to tackle these wastes as they contain concealed resources.

Over the years, due to technological improvement in steelmaking and strict environmental regulations, emphasis on raw material quality and new markets coupled with innovative ideas on waste reduction and rescue have resulted in drastic reduction in the quantity of waste generated in steel works from 1,200 kg to less than 200 kg per tonne of crude steel and recycling rates have reached to 95 - 97 % in some parts of the world. Few steel industries have approached to cent percent waste utilization without discharge of any waste to environment.

In India, as per the draft National Steel Policy, 2012 / 2015, the crude steel production is planned to be increased from present 100 Mt/yr to 300 Mt/yr and therefore, the waste management system needs to be further strengthened for making successful and economically viable efforts for 100 % utilization of all wastes.

The progress on technological aspects, process options for enrichment of input materials and solid waste management in Indian steel industry are moving at much slower pace than desired. In order to sustain the present competitive market and for further growth in future, it is essential to use technological innovations and putting R & D efforts in order to reduce waste generation and further for its recycling to steel plants.

Modern trend steel industries are focusing on eco-friendly technologies for making clean & green steel with zero waste to environment to make steel business a sustainable and successful venture.

Types of wastes generation in steel plant complex

In steel industry all three types of waste materials are generated, i.e., solid, liquid & gaseous wastes.

The generation quantity of various types of waste materials differ from one steel plant to other depending upon the steelmaking processes adopted and pollution control equipments installed.

The most common type of wastes generated in steel plant are as follows.

- Solid wastes like, hot metal pretreatment slag, dust, GCP sludge, mill scale, refractories, scrap, muck & debris, etc.
- Liquid wastes like industrial effluent, oil, grease, etc.
- Gaseous wastes like flue gases, fume extraction, etc.

However, waste disposal and dump are very big issue for environment today and therefore, these wastes are being tried for reuse through recycling & utilization.

These wastes are being used and recycled by various means but complete utilization of these waste are still challenges for industries, at present, in steel industry, various efforts and experiments are being carried out in order to make use of 100 % wastes products without disposal of any type of wastes into the environment.

Major advantages of recycling and utilization of wastes are as follows.

- Economic advantages
- Saving of raw materials
- Conservation of resources
- Better & cleaner environment
- Reduced cost of disposal
- Conservation of energy
- Strengthen laws by the Government
- Community relation/Public image etc.

Solid waste generation in steel industry

The technological developments for solid waste management in Indian iron and steel industry is at advanced stage but moving at much slower pace than desired. Generally, for integrated steel plant, each ton of liquid steel needs about 2.8 tonnes of raw materials, 2.5 tonnes of water and 5 tonnes of air. The outcome from iron and steelmaking process is 8 tons of moist dust laden gases, 0.5 ton of effluent water, 0.4 to 0.8 ton of solid waste, besides one ton of liquid steel.

In the first five decades of post independence era, till the year 2000, about 90 million tons of solid waste was estimated to accumulate. There is another addition of about 180 million tons of solid waste till 2010. With the current pace of 30 million tons of solid waste generation per year the present situation of availability of solid waste in the vicinity of integrated iron and steel plants in India will be about 270 million tons by the year 2014-15 considering 30% utilisation. In the similar way, estimated capacity production of crude steel and solid waste generation in Indian steel plants by 2019-20 is depicted in Figure-1.

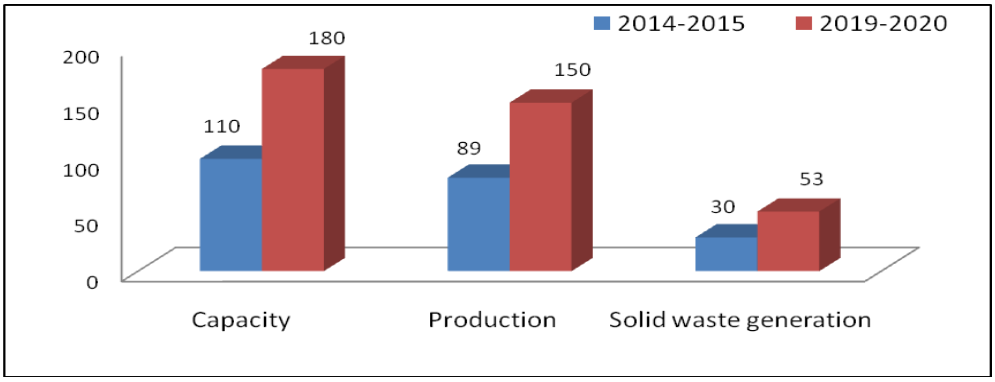

Figure-1 : Estimated capacity production of crude steel and solid waste generation in Indian Steel Plant

India is aiming for a capacity of 300 Mt/yr of crude steel by the year 2025 and the solid wastes generation is likely to increase enormously and gradually by all means, the handling and use of solid wastes are becoming unavoidable for sustenance of steel industries. Generation of different wastes in a steel plant depends on various factors such as characteristic of the raw materials used, technological aspects, pollution control equipments, maintenance and upkeep of plant, etc.

While focusing on the types of solid waste generated from steel melting shop, these can be broadly categorized as follows.

A. Process waste
B. Non-process waste

A. Process waste

The source of generation of these wastes are steelmaking process itself and can be mainly categorized as slag, dust, GCP, sludge, scrap, refractories, scale, muck and debris, etc. Other than GCP sludge all other waste materials are usually generated in mixed condition which means that during generation, one waste material gets contaminated with other waste material. Hence sorting is a very important step for recycling of the waste materials in steelmaking.

B. Non-process waste

Non-process waste are waste materials like rubber, card-board, electric wire, glass, etc.

These waste materials can be segregated at different locations in the plant and can be sold.

Huge solid waste generation from steel plant involves serious focus by all steel makers in order to manage these wastes in effective and environmental friendly manner. The waste generated from steel plant needs to be taken care properly right from the beginning for its successful management.

Waste Management in Steel Industry

Waste management practice involves collection, transportation, processing, recycling or disposal of waste material, in properly defined ways with adequate efforts to reduce their effect on human health or local aesthetics or amenity.

These practices shall be friendly with the natural world and the environment and to recover resources from them.

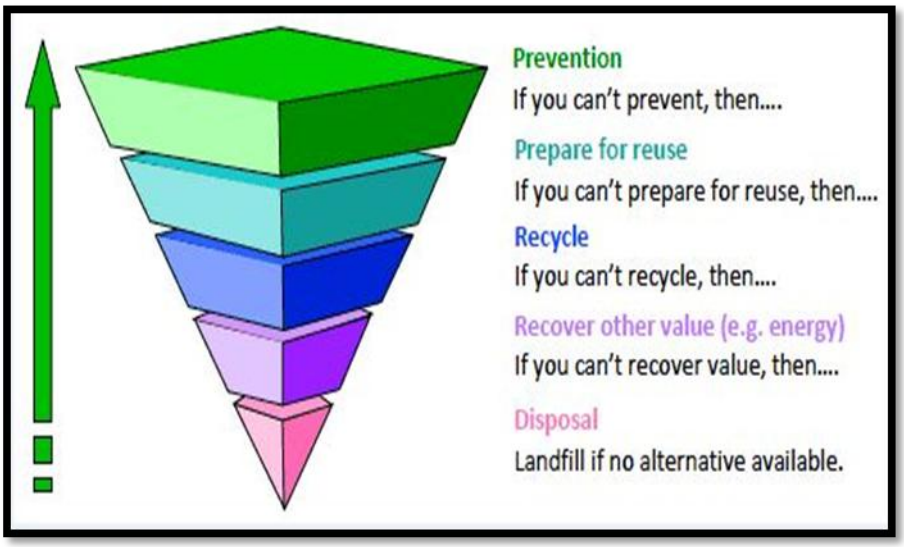

Figure-2 : Waste hierarchy

The policy of waste management is to apply the waste hierarchy principle in steel industry successfully. The waste hierarchy refers to the "4 Rs" reduce, reuse and recycle, restore which classify waste management strategies according to their desirability in terms of waste minimization. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The waste hierarchy as shown in Figure-2 remains the cornerstone of most waste minimization strategies.

In general by reducing or eliminating wastes an industry can:

- Solve the waste disposal problems created by land bans
- Reduce waste disposal costs

- Reduce costs for energy, water and raw materials
- Reduce operating costs
- Protect workers, the public and the environment
- Reduce risk of spills, accidents and emergencies
- Reduce vulnerability to lawsuits and improve its public image
- Generate income from wastes that can be sold.

In the present paper, emphasis has been given mainly on the various types of solid waste generated from “steel melting shop” of steel plant complex. The generation of solid wastes, their use and efforts for making complete use of all solid wastes have been elaborated.

The principle of waste management basically depends on:

- Utilisation & recycling of waste generation
- Minimisation of waste generation

In present scenario, we have to aim for converting the waste management system into a profitable business and to achieve **“zero waste concept”.**

The solid waste generated from steel plant needs various techniques and means with R &D efforts for its proper utilization & recycling in steel industry.

In steel industry for management of solid wastes, following are significant:

- Solid waste generation is controlled by efficient and optimum use of raw material.
- Solid wastes should be disposed properly through a proper disposal system.
- New technologies should be adopted for eco-friendly solid waste disposal.
- Transportation of solid waste from generation point to disposal point should be in a controlled and proper way.
- Displaying the area as solid waste disposal area.
- If possible, selling some of the solid wastes to be further used in some other ways converting waste into wealth.

Solid waste utilisation

Utilization of solid waste has been a difficult aspect but is of great concern in the steel industry. Experts have developed various means by a lot of trials and experiments for using the solid waste. However, R & D efforts are continued in this field to develop the

common methods for use of solid waste of steel plants which can also add profit to steel industry.

a) Steel Slag

The phosphorus content of BOF slag is too high to be used in ironmaking & steelmaking process. In the process of ironmaking, complete phosphorus enters into the metal phase which increases the load of phosphorus in steelmaking process.

R & D efforts are on to develop the ways to recycle the BOF slag in steelmaking & ironmaking process.

However, in order to utilize steel slag, several experiments and developments have been tried and some of the successful means of utilization are described below.

(i) Slag Atomisation: The new technology of atomising molten slag is an innovative process that produces high-specification products with multiple uses. Slag Atomising Technology is a process that converts molten slag (1300-1350ºC) into small spherical balls (Precious slag ball-PS balls) with a diameter range of 0.1 to 4.5mm. The process consists of a high speed air blowing system with catalyst and water exposed to the stream of falling molten slag. The high speed air flow with assistance of water and catalyst employed for this purpose, through a fast heat exchange, converts the slag stream into spherical balls with glassy finish. The PS balls structure is typically a stable spinel structure that induces superior physical characteristics to the balls. PS balls are classified by size through a sieving machine.

Slag atomising technology (SAT) is a new system adopted (invented) to atomise molten slag out of steelmaking furnaces in a most effective way, and is most economical compared to traditional methods of aging and crushing. SAT is a strategic approach to overcome the environmental problems of furnace slag where molten slag is immediately converted to environmental-friendly PS balls as soon as it is dumped into.

The PS balls have many applications, thanks to their physical and chemical specifications. Most importantly, PS balls are environmentally-benign materials produced by a sophisticated technology, and free of any pollution issues.

Slag Atomising Technology is a multi-function, multi-application system, a great managerial approach to solve environmental and technical problems inherent in waste material.

(ii) Rail Ballast: Steel slag is hard, dense and resistant to both attrition and abrasion making it suitable for use as a railway ballast aggregate. SMS slag has technically been found suitable for use in rail ballast. Steel plants started developing infrastructure for crushing and sizing facilities so that sized material can be supplied to the Railways.

(iii) Road & pavement material: SMS Slag has already been successfully used as road making aggregate in SAIL Steel Plants like BSP, BSL and RSP in place of stone chips. Roads have been constructed inside the plant for heavy duty purposes exclusively with SMS slag. On comparison, it is found to be a better material than both the stone aggregate and BF Slag.

Worldwide steel slags are being used for road making but it needs to be included in all the specification of road materials worldwide so that use of slag for road making can be enhanced to desired level.

Pavements from slag are also developed and these are gaining popularity for use.

(iv) Filling Materials: The finer SMS slag received after crushing and screening of bigger pieces can be used as filler material along with fly ash and fine size BF slag.

(v) Cement Making: SMS slag is used as cement making material for replacement of clinker. BOF slag has high CaO content as compared to Blast furnace slag which acts as an activator and gives better strength. However, the presence of P_2O_5 results in corrosion of reinforced materials in concrete structure. If only 10 % Slag (BOF slag) is used for cement making, the P_2O_5 content will increase to around 0.3% which is not so harmful for Portland slag cement (PSC) because low P_2O_5 in PSC reacts with alkali in slag contributing little towards strength of cement. Some of the foreign countries like China, Japan and Germany already use SMS slag in varying amounts in cement making In India: SAIL has initiated a joint study with the National Council for Cement and Building Materials where SMS slag is proposed to be used as

- Raw materials for production of ordinary Portland cement and
- An admixture in Portland slag cement.

Other steel plants are also putting efforts for using SMS slags for cement making

(vi) Substitute for sinter flux: Due to high content of CaO in BOF slag, it is possible to use as a flux replacement in sinter plant.

(vii) Brick Manufacturing: SMS slag fines can be used in developing bricks. Even, the SMS Slag mixed with fly ash has been successfully tried and being used for brick manufacture.

(viii) Soil conditioners: Crushed SMS slag of size approx 300 mesh sizes can be used for soil conditioning. The soil can be corrected for its pH by suitably adding liming agent including slag. The basicity of the SMS slag makes it a good liming material for acidic soil. Phosphorous in the slag acts as nutrient to the soil. Therefore, SMS slag can be used as soil conditioner. However, SMS slag is required to be ground to very fine size for this purpose. The conventional grinding techniques are energy intensive. It is therefore necessary to develop a commercially viable crushing and grinding facilities for extensive use of this material as soil conditioner. Tea and coffee plantations are potential customers.

(ix) Tiles manufacturing: SMS slags have been successfully used for flooring tiles because of their good abrasive materials properties.

Other uses of SMS Slag which have been tried elsewhere are;

(x) Abrasive blasting material: SMS slag in the formed of precession balls etc. have been successfully used as abrasive blasting materials for various applications.

(xi) Water treatment media: Steel slag contains oxide of aluminum and iron combined with a calcium base which reacts to neutralize the PH of the waste water. This treatment of waste water is being developed as a new and potentially important application of steel slag.

(xii) Briquettes & micro pellets: These are produced by mixing of slag after metal recovery in combination with other solid waste materials like,

- Dust - from fume extraction system
- Sludge - from BOF-GCP system
- Lime- dolo dust – from lime calcination plant etc.

These wastes are agglomerated by mixing them in definite proportion with binders to produce a combination of briquettes and micro-pellets.

The micro-pellets are of size about 5-6 mm approx. with adequate strength and chemical composition suitable for sinter making.The briquttes can be used as a valuable source of

coolant in BOF steelmaking.These are being developed as an important means for internal recycling of solid wastes in the steel plant industries.

Steelmaking slag are also being tried for use as:

- Polymer concrete material
- Hume pipe, tetra-pod, concrete bricks, concrete pipes etc.

In addition to above, there is focus on production of synthetic metallurgical additives for using the steel slag in steelmaking process.

(xiii) Dry Slag granulation process: Slag is the largest solid waste generated from steel plant industry and quantities of slag are huge for disposal & utilization. In the way of solid waste utilization process, these slags are water granulated. However water granulation process consumes large amount of water and may produce unwanted gas emission. Importantly, the large amount of heat contained (about 1.8 GJ/tls slag) is not being recovered by the existing slag treatment processes. Dry slag granulation could make a fundamental change in slag treatment. In this new approach, molten slag is atomized under centrifugal forces on a spinning disc and the droplets generated are quenched and solidified quickly using air, with simultaneous heat recovery. The process aims to produce solid slag granules suitable for various applications. Compared with water quenching, dry granulation offers a much more sustainable approach through water saving, reducing emissions as well as recovery of waste heat.

This above process initially developed for BF slag may also treat steel making slag. Further demonstration & their evolution of the process are being looked into as this dry slag granulation process is likely to provide considerable savings in both capital & operating costs.

b) SMS Shop Dust : Dust collected from dedusting FES system of the SMS shop contains high % of (Fe>40%) and it is usable for reuse in sinter making plant.

c) Lime Dolomite plant Dust: Due to high content of CaO & MgO, these dust can be used for sinter making.

d) GCP Sludge: Sludge generated from BOF-GCP in rich in iron (> 40% Fe) and it dominantly constitutes Fe_2O_3 and therefore, it can be used for sinter making. The sludge generated from ETP plant is pumped to sludge dewatering plant having filter process. After dewatering dry filter cake is produced.

These dry filter cakes are transported to raw material stock yard for feeding the same to sinter plant for sinter making.BOF sludge are also being tried for use for making of

briquettes as a replacement to sized iron ore in BOF steel making. Industrial trials have been found successful in some steel plants and more trials are being conducted in this area.

e) **Scrap:** Scrap generated can be used as coolant material or re-melting in process of steel melting.

f) **Refractories**

Waste refractories can be broadly used as follows:

- Reusable portion of salvaged refractories are recycled.
- Broken pieces are recycled/sold to outside parties.
- Preparation of mortar etc.

g) **Scale from continuous caster cooling**

Scales are generated during cooling of continuous cast product by direct spray.

The dewatered scale from scale pit shall be transported to raw materials stock yard from where it will be conveyed to mill scale bunker of sinter plant for manufacture of sinter.

Mill scale, caster scale, CRM dust and similar high iron containing waste are mixed and briquetted. Presently these scale briquettes are being used in both the steel making shops as secondary coolant-replacement of iron ore.

h) **Muck & debris:** Scrap removed from SMS slag is recycled back in the converter for cooling purpose. The wastes are being used and recycled in various ways in different industries depending on several local governing factors and provisions etc.

Solid Waste Minimisation

The minimisation of waste generation can be achieved by selection of proper input materials along with adoption of new technologies of steel melting process.

Technologies have been developed in most of the developed nations of the world for utilization of the generated wastes. There are nations which have total utilization of the wastes. In India, utilization of wastes are also improving. Total quantity of wastes can be reduced from the existing levels by way of technological improvements and adopting the measures for minimization of solid waste generation in Indian integrated steel plants. Some of the waste minimization measures are given in Table-1.

Table-1: Measures for minimization of solid wastes generation in integrated steel plants

Shop	Type of waste	Waste minimization measures
BOF shop	BOF dust/BOF sludge	Avoidance of over blown metal, minimization of fines in flux-mix, avoidance of late addition of fluxes, elimination of zinc-coated scrap in the burden, use of optimum top blowing rate, pressure and time in conjunction with bottom blowing rate and time, use of low Si hot metal, use of low SiO_2 lime.
	BOF slag	Use of low SiO_2, high reactivity and low LOI lime, use of low-silicon and low sulphur hot metal, if necessary, through hot metal pre-treatment, computerized charge balance or process control.
EAF shop	EAF dust	Minimization of wastes at source through improvement in process, operation and maintenance such as, continuous charging (Con-steel process, Conti-arc process, Finger shaft furnace; it reportedly reduces the volume of dust discharged by as much as 40%).Lime addition as a part of the bucket charge contrary to addition by pneumatic injection. Adoption of foamy slag practice to the optimum extent. Minimization of carbon blowing by maintaining not so high carbon opening in the bath. Providing adjustable speed drives (ASD) bag house fan to reduce dust emission by 2 to 3% over the whole tap-to-tap cycle .Provision of computerized process control. Use of UHP in all solid charge operation to reduce tap to tap time.
	EAF slag	Improved charge-mix preparation, cost-effective optimization of charge-mix, maintaining minimum basicity by controlling low opening of 'S' & 'P' in the bath through optimized charge-mix, betterment of flux quality.
Continuous	Caster scale	Air mist cooling.

Zero waste steelmaking

Globally, steel industry has made tremendous efforts in the past decade to drastically reduce its operating **c**osts and to **c**omply with environmental requirements. In the way of steelmaking as a sustainable technology business, it is must that "Zero Waste" philosophy shall be accepted.

A zero waste approach should mean

1. A structured approach to minimize-waste generation, energy consumption, emissions
2. View wastes & emissions as potential raw materials to be conserved or reused rather than wasted.

3. Clearly identify appropriate manufacturing processes and ensure bottom line cost savings.
4. Implement the identified projects which
   - Reduce process wastes,
   - Convert waste to economically beneficial material
   - Develop new processes that eliminate waste.

For example, the value of EAF steelmaking slag is greatly increased if it is modified for use in cement-making operations.

Redesign or develop a process which produces no unusable by products. For example, the COREX iron making process eliminates the need for coke making, coke oven gas and by-product recovery plants.

Economics for every plant is uniquely determined by its location, age, product mix, equipment, cost structure among other factors. It is neither reasonable nor economical to attempt to make every process within a steel plant into a zero waste process, since the thermodynamics and kinetics of some reactions mitigate against achieving absolute zero waste.

However, with the R&D efforts, technological innovations and better process management, the aim for making the “zero waste philosophy ” successful can be achieved in steel industry .

R&D opportunities in Waste Management in Steel Industry

In the developing market of Indian Steel Industry and present level of utilisation of solid wastes in steel industries, there is a pressing need for R & D in this area.

Government agencies shall take initiatives along with private players of steel sectors for R&D opportunities for making the solid waste management system more effective.

R&D efforts with support of Government and other bodies including private steel players can play significant role for the activities like

- More cost effective management for BOF dust/sludge by adopting the technology of cold briquetting and recycling the briquettes directly into BOF
- Use of SMS slag/dust in BF process for Iron making
- More use of DRI fine injection in EAF/other furnaces
- Interaction with cement, road builders and similar agencies to increase the use of SMS slag

- In-house up gradation and developments of operating practices and technologies

R&D opportunities to improve microstructure control and reduce defects include better sensors for chemistry, cleanliness and defect detection systems. Half of the waste oxide generation in steelmaking furnaces contains iron. A major barrier to reducing this loss is maintaining reliable process control and furnace stability. Potential R&D opportunities to overcome this barrier include sensors for critical chemical and physical parameters in the BOF, and other furnaces; real-time chemistry adjustment technologies; and advanced combustion control systems.

It is emphasized that the entire steel industry is required to be committed to 'sustainable development'. Therefore, steel plants have no option but to plan immediately for a zero waste programme and implement the same. Aim of zero waste programme is to make the total dumped quantity and so the individual waste quantities dumped to zero or near zero, or in other words, to produce 100% or almost 100% products

Conclusion

Steel industry development is focusing on "Clean, green & sustainable technology" for its survival, development and growth. The sustainable technology development means development aims at improving the quality of life for everyone and generation to come.

In order to achieve the above objective for steel industry, the waste management system has a vital role without which development & growth of steel making will be quite difficult.

In this regard, we must adopt the methods and suitable technologies for 100% recycling and use of waste from steel plants.

The enormous supports by way of R & D efforts in this field are required for making "waste management system" not only a successful venture but also as a profitable business.

This concept will strengthen us to make commitment for success in steel industry for making "clean & green steel" for our sustenance and growth in to day's highly competitive global steel market.

References

1. http://eprints.nmlindia.org/2797/1/154-165.PDF

2. http://1999-02725.gobizkorea.com/id=1086349

3. http://www.slagcement.org/news/pdf/no17_concrete_pipe.pdf

4. https://www.google.co.in/search?q=tiles&biw

5. http://www.ajer.org/papers/v3(4)/ZM34309315.pdf

6. Ministry of steel, Govt. Of India – An overview of steel sector. 2015

7. Dry slag granulation with integrated heat recovery- by Sharif Jahanshahi, Dongsheng Xie, Yuhua Pan, Phil Ridgeway and John Mathieson.