CHAPTER 1

INTRODUCTION

Steel production is the main driving force of economic progress of a country. World produced 1,868.8 million tonne (Mt) of crude steel in 2019, is increased about 3 pct production with respect to 2018 (1813.6 Mt). On 2018 India become second largest producer of steel in the world which is preceded by China(Table 1.1)[1]. Iron and steel industry's growth in India has been double since last 12 years. India's crude steel production of year 2019 was 111.2 Mt and that was 53.5 Mt in year of 2007. Correspondingly, the per capita steel consumption in India was 43 kg in the year of 2007 which increased to 74.3 kg (72.8pct) in the year of 2019; still which is much lower than the world average 229.3 kg. The industrial development programmed of any country, by and large, is based on its natural resources. For producing 111.2 Mt crude steel required about 190 Mt of processed iron ore and 237 Mt run of mine ore. At present crude steel capacity in India stood at 142.2 Mt in 2018-19 while production of crude steel reached at 110.9 Mt (78pct utilization) [2].

Table 1.1: Five Major Steel Producing Countries in World (Mt) [1]

Ranking in world	2015	2016	2017	2018	2019
1st	China (803.8)	China (807.6)	China (870.9)	China (920.0)	China (996.3)
2nd	Japan (105.1)	Japan (104.8)	Japan (104.7)	India (109.3)	India (111.2)
3rd	India (89.0)	India (95.5)	India (101.5)	Japan (104.3)	Japan (99.3)
4th	USA (78.8)	USA (78.5)	USA (81.6)	USA (86.6)	USA (87.8)
5th	Russia (70.9)	Russia (70.5)	Russia (71.5)	South Korea (72.5)	Russia (71.9)
6th				Russia (72.1)	South Korea (71.4)
World Total	**1,620.0**	**1,627.0**	**1,729.8**	**1,813.6**	**1,868.8**

As per National steel policy 2017 [3], estimated domestic steel production of 300 Mt will be achieved by 2030-31.To reach this visionary aim, Indian steel plants must have to foresee latest technologies, increase their production capacities, uplift the efficiency of operations, implement latest technologies, utilize low-grade raw materials as well as minimize waste generation [4].

For 300 Mt steel production, there will be requirement of 510 Mt of processed iron ore and 636 Mt run of mine ore per year. India is one of the fortunate countries to have reserves of high-grade iron ores. But with time these reserves of high-grade iron ores are bound to be diluted.

Iron and steel are the driving force behind industrial development in any country. The vitality of the Iron and Steel Industry largely influences a country's economic status. The iron ore is an essential raw material for Iron and Steel Industry. With the total resources of over 33,276 Mt of iron ores as on 1.4.2015, India is amongst the leading producers of iron ore in the world[5].Haematite (Fe_2O_3)and magnetite(Fe_3O_4) are the most important iron ores in India.

About 79 pct haematite ore deposits are found in the Eastern Sector (Assam, Bihar, Chhattisgarh, Jharkhand, Odisha and Uttar Pradesh); while about 93 pct magnetite ore deposits occur in Southern Sector (Andhra Pradesh, Goa, Karnataka, Kerala, and Tamil Nadu). Karnataka alone contributes 72 pct of magnetite deposit in India. Of these, haematite is superior because of its higher grade. Indian deposits of haematite ore is within banded iron ore formations occurring as massive, laminated, friable and in powdery form. Another principal iron ore is magnetite that also occurs in the form of oxide. Table 1.2 shows iron ores reserves of India.

Table 1.2: Estimated Iron ores Reserves of India (Mt) (as on 1.4.2015) [5]

Type of Ore	Reserves Category	Remaining Resources Category	Total
Hematite	5,422	17,065	22,487
Magnetite	53	10,736	10,789
Total			**33,276**

India has reasonable coal reserves 319,021Mt. Out of which mineable are only 148,788 Mt (i.e.46.6 pct). The coking coal is 19,082 Mt (only 12.8 pct), which is useful for blast furnace iron making. Out of that prime coking is around 4,649 Mt (3.1 pct), medium coking 13,914 Mt (9.4 pct) and semi coking coal is 519 Mt (0.3 pct).Whereas the non-coking coal is 129,112 Mt (86.8 pct), as shown in Table 1.3 [6]. Enormous amount of coal fines and coke breezes are produced during coal mining and coking of coal respectively. These fine cannot be processed in sponge iron/DRI reactors such as Rotary kiln and Rotary hearth.

Table 1.3: Estimated Coal Reserves in India (Mt) (as on 1.4.2018) [6]

Type of Coal	Proved/Measured	Indicated	Inferred	Total
(A) Coking				
Prime Coking	4,649	664	0	5,313
Medium Coking	13,914	11,709	1,879	27,502
Semi-Coking	519	995	193	1,707
Sub-Total (A) Coking	19,082	13,368	2,072	34,522

(B) Non-Coking	129,112	125,697	28,102	282,911
(C) Tertiary Coal	594	99	895	1,588
Grand Total (A + B + C)	**148,788**	**139,164**	**31,069**	**319,021**

However, in a steel industry where several processes are employed using of various raw materials. It is natural that many valueless substances are generated which can be termed as waste materials. Average about 500 kg of solid wastes are generated per tonne of crude steel production [7]. World's crude steel production was 1,868.8 Mt (in 2019) which generated huge amount of wastes. Das et al[8] reviewed and briefly reported on utilization of steel plant wastes in the several industries. The various solid wastes in the form of slags and sludges that are emerged from steel plants are blast furnace slag, blast furnace flue dust and sludge, Linz–Donawitz (LD) converter slag, LD sludge, LD dust, mill scale, mill sludge, etc. The solids and liquid wastes generated from a steel plant are shown in Table 1.4.

Table 1.4: Types of Solid/Liquid Waste Generated from Steel Plants [8]

Solid/Liquid wastes	Amount (kg/t)	Source of Generation
Coke breeze	–	Coke oven
Nut coke	–	Coke oven
Coke dust/sludge	–	Coke oven
Blast furnace slag	340 – 421	Blast furnace
Blast furnace dust/sludge	28	Blast furnace
Sintering plant	–	Sintering plant
LD slag	200	Steel melting shop
LD sludge	15 – 16	Steel melting shop
Lime fines	–	Steel melting shop
ACP/GCP sludge	–	Steel melting shop
Carbide sludge	–	Acetylene plant
Mill scale	22	Mills
Mill sludge	12	Rolling mills
Refractory, bricks	11.6	Steel melting shop /mills, etc.
Sludges/scales	–	Water treatment plant
Fly ash	–	Power plant

The solid wastes are from process units and as well as from pollution control units. The process wastes are mostly utilized but the dust and sludge from pollution control unit is the area of attention. The aspect of waste management at various levels from mines to smelters has caught the attention of technocrats, mineral economists, planners and the consumers [9]. The utilization of wastes needs to be dealt with in a judicious and sustainable manner. Solid wastes generated from process units are generally characterized by their uniform size and composition. Low moisture content, high levels of metallic and non-metallic values (e.g. CaO, C etc.) content in wastes, which makes these suitable for recycling within the plant or to be sold out to consuming industries. The production of solid wastes per tonne of production of steel is around 1.2 ton in India compared to around 0.55 tonne of that practicing in abroad due to inferior quality of raw materials used and an absence of proper solid waste management practices. Out of total solid wastes generated in the steel plant in our country around 63% are dumped which needs to be recycled or reused to target a zero-solid waste as being done in many developed countries[10]. Mill scales are also the industrial by-product, which are produced due to hot working processes. The huge quantities of iron ore slimes (containing 55 to 60% iron, size < 0.15 mm) collected in tailing ponds, estimated to be 130 Mt (accumulate to the tune of around 10 Mt per year in India) are not being utilized at present [11]. At present, most of the slimes and, mill scales are thrown away as waste for land filling and create pollution to the environment, which are not desirable.

Efforts are being made to utilize the waste materials by proper characterization, beneficiation and agglomeration techniques. The treatment/utilization of steel plant sludge/dusts is still a problem in many countries of the world. Effective utilization of dust and sludge for iron and steel making can be possible after upgradation of iron percent and discard the valueless materials. There is also shortage of coking coal all over the world in general and particularly in India. Enormous amount of coal fines and coke breezes are generated during coal mining and coking of coal respectively. By incorporating non-coking coal fines or coke breezes with up-gradated dust and sludge are utilized in producing cold bonded iron oxide-coal composite pellets. By using the iron oxide-coal composite pellets, metallurgical coke requirement in the ironmaking furnaces can be reduced.

Recycling and utilization of these fines for extracting metal is of vital concern for resource conservation and pollution control. Industrially fine iron ore concentrate is pelletized into spherical balls of 8-20 mm diameter and then indurated up to 1573 K in an induration furnace to enhance the mechanical strength of pellets. In the induration process, fuel (liquid or gaseous) is consumed to supply the heat, thus CO_2 and other pollutants are emitted. Moreover, the capital cost of the induration furnace is also very high. In order to utilize these fines efficiently and economically, a novel concept of cold bonding technique was developed [12].

The fines of iron bearing oxides and carbonaceous materials are mixed with a suitable binder and optimum quantity of moisture. The mixture is then pelletized into balls of appropriate size. In cold bonding process, the composite pellets are hardened due to physio-chemical changes of the binder in ambient conditions [13] or at slightly elevated temperature(400 to 500K). The challenge in cold bonding is to find a suitable binder that ensures the proper physical and mechanical properties of the composite pellet.

The term composite pellet [13] is employed here to mean pellet containing mixture of fines of iron bearing oxide and carbonaceous material(i.e. coal/char) which has been imparted sufficient green strength for subsequent handling by cold bonding technique. The prepared cold bonded composite pellet should have enough mechanical strength to withstand high temperature and stresses in reduction furnaces.

Interest in composite pellets have grown from the decade of 1980s because of the following advantages [14]:

1. Utilization of cheaper resource and pollution control,
2. Very fast reduction rate due to intimate contact between reductant and oxide particles,
3. Reduction in energy consumption for production because cold bonded composite pellets do not require induration,
4. Promising prospect for iron making at small scale with higher production rate,
5. Because of their uniform size and convenient form, composite pellets can be continuously charged into the furnace leading to higher productivity, and
6. Consistent production quality as the chemical composition of composite pellets does not change.

The concept of Smelting Reduction (SR) process of iron ore, an alternative to blast furnace technology was initiated around 1970. The SR processes involving both reduction and smelting are very similar to blast furnace in which all the reactions takes place in a single reactor. Most of the smelting reduction processes involve by removal of oxygen from the iron ore in the solid state (initially) followed by further removal of remaining oxygen in the liquid phase reduction reaction[15]. Ideally, a smelting reduction process should have 100 pct reduction of iron oxides in the liquid state in a single stage in a single reactor.

There is a shortage of coking coal in India. On the other hand, India has vast reserves of non-coking coal (Table 1.3), which is widely available and cheapest reducing agent for iron oxide reduction. Hence, non-coking coal-based iron making technology has special relevance for country like India. In fact, the need to make non-coking coal-based iron making units economically viable has resulted in the development of SR processes, which do not face sticking problem at high temperature. The SR process exploits faster reduction kinetics at higher temperature due to enlarged specific contact area between reactants in a dispersed phase and increased mass transport rates due to convection and thereby improves productivity[15]. The process makes use of non-coking coal in a broad range of composition and accept a wide range of materials including iron ore fines, plant wastes (after beneficiation)such as dusts and sludge or inferior grade ore directly. Their process control is relatively simple, and they work out economically at small scale operation catering to varying demands of the market. The process is environmentally acceptable keeping the demands of coming years in view. Some of the upcoming SR processes are Corex, Romelt, HIsmelt, Ausmelt, DIOS, Fastmet, Finex, ITmk^{3}etc. Amongst these Corex, Fastmet/ ITmk^3 have already been established at commercial scale.

There have been few studies(16-21) for the utilization of various steel plant wastes in the steel making process. However, the dust and sludge are used in steel making at some places, but the productivity is not good by using directly. There are a very few published literatures(16,19-21) on utilization of steel plant dust and sludge after beneficiation. The composite pellets, produced from steel plant dust or sludge (after beneficiation), can be utilized as the feed material for smelting reduction. Rate of production is expected to be higher with composite pellets due to high degree of pre-reduction to the smelting reactor.

1.1 Objective

Looking into the above aspect, the objective of present study is three-fold:

1. Characterization and beneficiation of dust and sludge by using various methods and establishing proper route for beneficiation with good recovery of iron bearing oxide.
2. To prepare composite pellets using various binders by cold bonding techniques in the laboratory and evaluate their properties; this would be a contribution towards development of suitable binder for cold bonding composite pellets.
3. Utilization of composite pellets in liquid metal bath for steel making in induction melting furnace. As well as auxiliary studies as backup investigation with emphasis on isothermal reduction kinetics.

1.2 Methodology

1. Upgradation of flue dust/sludge by various techniques of beneficiation,
2. Characterization of raw materials,
3. Composite briquette and pellet making,
4. Testing of composite briquette/pellet.