Iron Making and Steel Making
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Module – 04
Lecture - 16
Blast furnace and its Raw Material

Welcome, this is the 4th week and the module 4 and in this week, I will cover the Blast furnace, its Raw Material, raw material preparation and testing of raw material.

In this lecture, we will discuss blast furnace and its layout and raw material.

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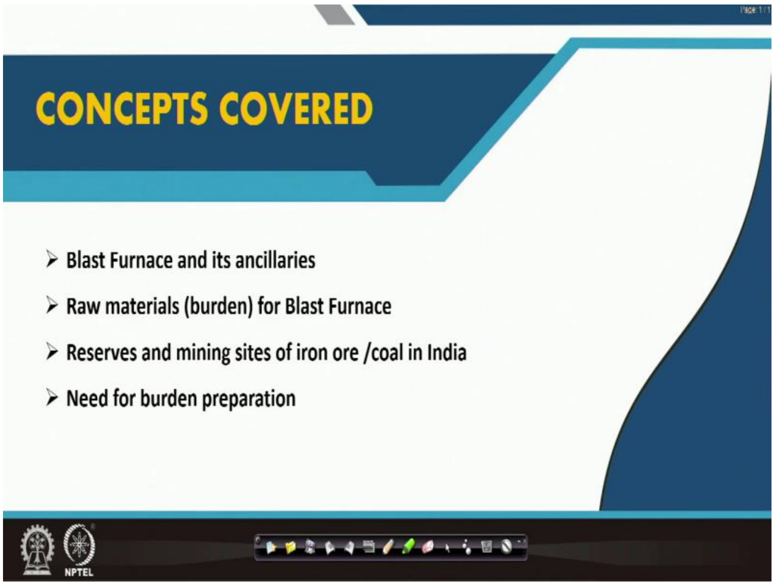

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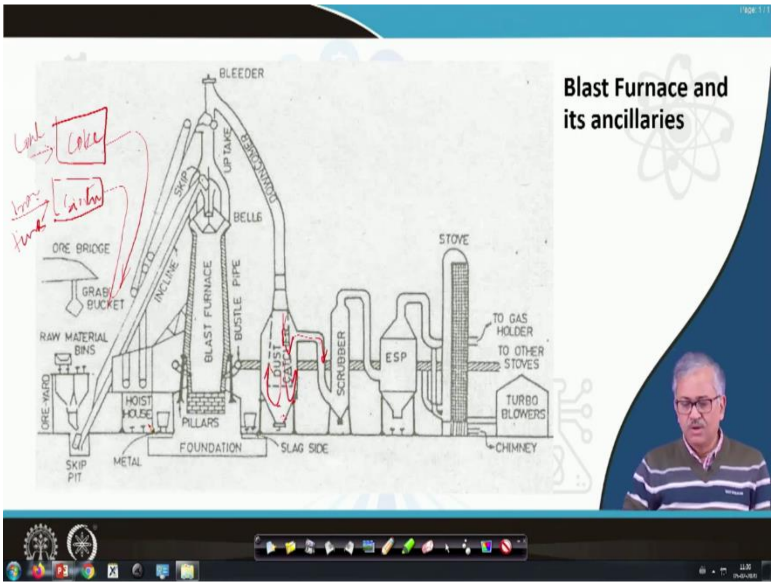

First, let us discuss layout of the blast furnace. Figure 16.1 shows the layout of blast furnace.

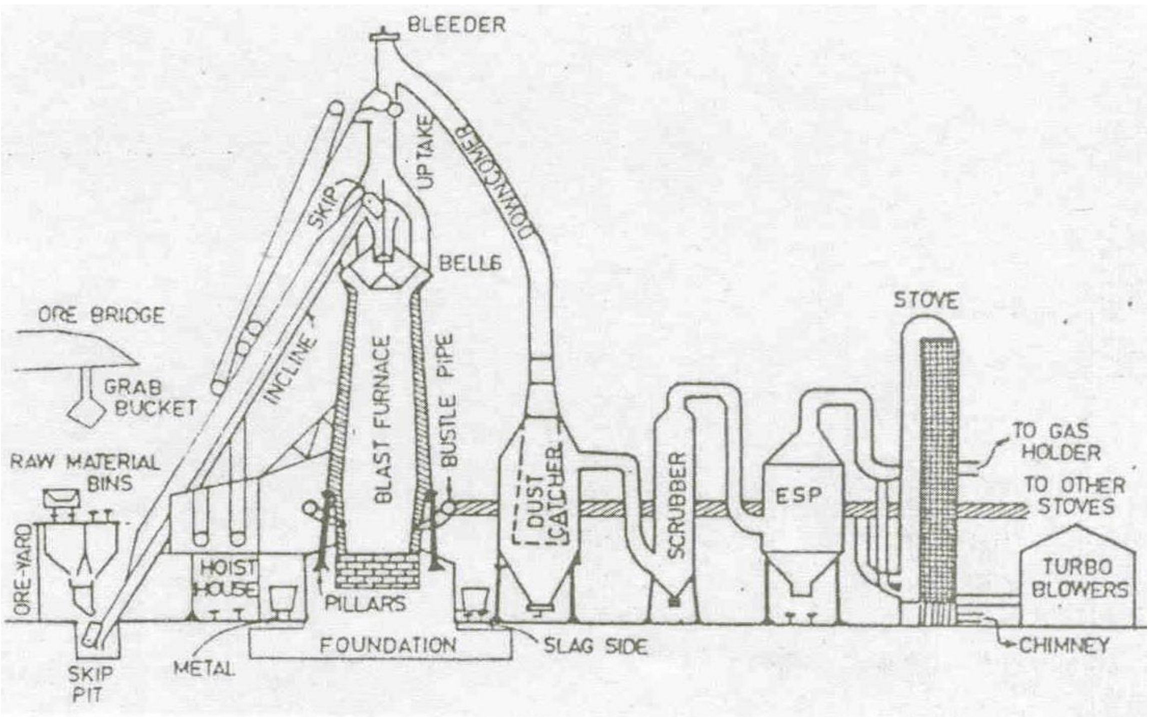

Figure 16.1 Layout of Blast Furnace

Here you can find raw materials bins, charging skip pit, skip car, two bell charging system at the top of blast furnace, main reactor blast furnace, gas cleaning system involving dust catcher, wet scrubber, ESP, and blast furnace stoves.

Raw material yard is a place where the raw material is stored in the bins and then from bins, raw material moves to skip pit, then skip car carries raw material at the top of the furnace for subsequent charging in the blast furnace through bell charging. Now-a-days more advanced bell-less-charging is in place. In the bell charging system there exists two bells; first the skip upload the burden material over the small bell and then small bell is lowered and it is deposited over the top bell; and when the top bell lowered, then material is sent to the stack of the blast furnace right on the stock line; and this is the bell charging.

And you can find that gas cannot escape through this charging path because when material is charging from skip car over the small bell, the small belle is up without any gap between the samll bell and the wall. When small bell is down for downloading the material over the top bell, the top bell is up without leaving any gap between the top bell and the wall. When the top bell is down for charging material on the blast furnace stock line, the small bell is up again without leaving any gap between the small bell and blast furnace inner was. So during charging and discharging of material on the bells either of the bells is up restricting the gas escape through charging path. Gas escape through two vertical pipes called up takes, those are initiated through holes above the stake as shown in the figure. So gas escape from the top can be controlled and gauge pressure at the top can be controlled.

The blast furnace gas are first cleaned for its subsequent use in blast furnace stove and downstream applications. Blast furnace gas has significant amount of sensible heat because per ton of steel produced around 1500 Nm^3 of gas is generated at exit gas temperature of around 150 to 200 degree centigrade. Besides, it contains 15 to 20% CO, where chemical heat is reserved. The energy content of this gas is around 5 GJ/ ton of hot metal, which is approximately 30% of the energy consumed in blast furnace. A part of the cleaned BF gas; around 40 percent of the clean gas is used in the blast furnace stoves to preheat the air blast and the rest 60% of the gas goes out for the downstream applications.

Blast furnace gas contains lot of dust and fines. So, first its course dust is removed in a dust catcher. In dust catcher the gas takes a U-turn and at the point of inflexion with zero velocity, the dust particles separates from the gas and collected in the bag. After that dust catcher, then the gas again goes through a wet scrubber. Here, water spray is used to wet the dust particles and precipitate those. The cleaner gas with very fine dust particle finally passes through electrostatic precipitator where fine dust particles are charged for their subsequent separation from the uninterrupted gas stream.

Partially the clean BF gas is used in the blast furnace stoves. It has two chambers; one is called the combustion chamber where BF gas is combusted by supplying air. The other is the checker brick work - a brick pattern with large exposed surface area efficient for heat exchange. The hot gas from combustion chamber is passed through checker brick work for heat exchange and it takes around 2-4 hours to heat up the brick work.

In the next cycle, air is supplied through the hot brick structure such that heat exchange takes place in a reverse direction from the brick to the air; consequently air get preheated and then, preheated air is transferred to the blast furnace by what is called the turbo blowers.

Besides, the ancillaries described above, we have two more units that are not shown here are the sintering machine and coke oven plant. In sintering machine iron ore fines as well as iron bearing solid waste are used for agglomeration for subsequent use in blast furnace. Sinter is considered a better reductant than run off nine calibrated iron ore, because of better strength and reactivity. Besides, through sinter it is possible to utilize the under sized ore and iron bearing solid waste from the plant. Steel plant usually has one or more than one sinter making units.

Another essential unit for blast furnace iron making is coke oven plant. In blast furnace carbon is charged in the form of coke, which is more reactive and stronger form of carbon essential for maintaining the bed permeability and withhold the overburden.

Pellet is another iron ore agglomeration unit where ultrafine iron ore is agglomerated in a strong and reactive product. Pellet is very strong and amenable for long distance transport and therefore, pellet plant is not required to be situated inside the plant. Pellet is a superior product than sinter but costly and can be used to treat ultrafine ore only. Therefore, sinter is used in preference to pellet.

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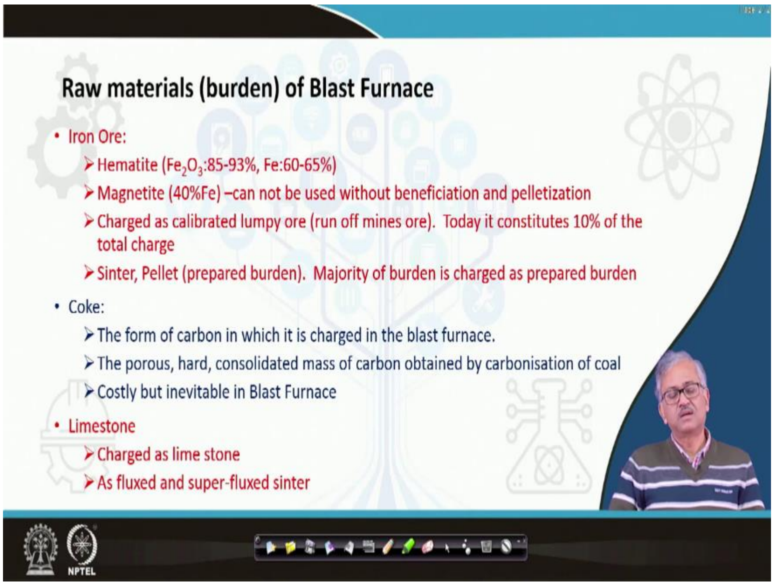

Raw material in blast furnace is also called the burden of blast furnace. Richest iron ore are usually oxide ores. The richest iron ore is the hematite ore, which contain Fe_2O_3 in the range from 85 to 93 percent and total iron content from 60 to 65 percent. But, iron ore containing total iron in the range 62 to 65 percent is called the good grade of ore.

Then another major source of iron ore is the magnetite; but usually it is quite low grade containing around 40 percent of total iron. So, magnetite eventually requires iron ore beneficiation, followed by pelletization.

What are forms of iron ore that are charged in the blast furnace? First form of iron ore charged in the blast furnace is the lumpy iron ore, which are calibrated run off mine ore of required size (20-40 mm) and does not require any pre-processing and can directly be charged into the blast furnace. But lumpy ore is friable, also contains lot of moisture; so, it has some heat demand as well as being friable they are prone to generate fines under impact and abrasion and deteriorates bed permeability. Besides, it has high angle of repose and it forms ridge and does not move much.

So, that is why that lumpy ore is not a very good quality ore compared to the prepared burden like sinter and pellet, the two other forms of iron ore charge in blast furnace. So, that is why its proportion in the iron ore burden is gradually decreasing. Initially, people used more of the lumpy ore, in absence of availability of prepared burden in plenty. Progressively, sinter is replacing lumpy ore and today lumpy ore constitutes only around 10 percent of the iron ore burden in blast furnace.

Although pellets are superior iron ore burden, cost prohibits its use. Besides, some pellets swells, especially in presence of impurities like alkaline metals like Na, K.

Next, coke is charged in the blast furnace as a source of carbon. Coal cannot be directly charged into blast furnace, because coal is friable and it contains lots of volatile, which hampers the blast furnace operation. Therefore, a certain variety of coal (called coking coal) is carbonized (heated in absence of air), which converts the coking coal to coke, a hard, reactive fuel for blast furnace. It is to be mentioned that below the cohesive zone everything except coke is solid and it holds the over burden by forming a deadman's coke zone that can either float or seat over the hearth. Other two function of coke namely heat generation and reduction, may be supplemented by auxiliary injections like PCI, but to the third function of coke to hold the overburden, cannot be supplemented. Coke is costly because coking coal is scarce; it is inhabitable for the blast furnace.

Finally, limestone is also charged in the blast furnace as a fluxing agent to form basic slag to arrest compound impurities. Lime can be charged in the form of a flux sinter or super-flux sinter by mixing lime in the sinter mix. It reduces the thermal load of blast furnace by avoiding decomposition of limestone.

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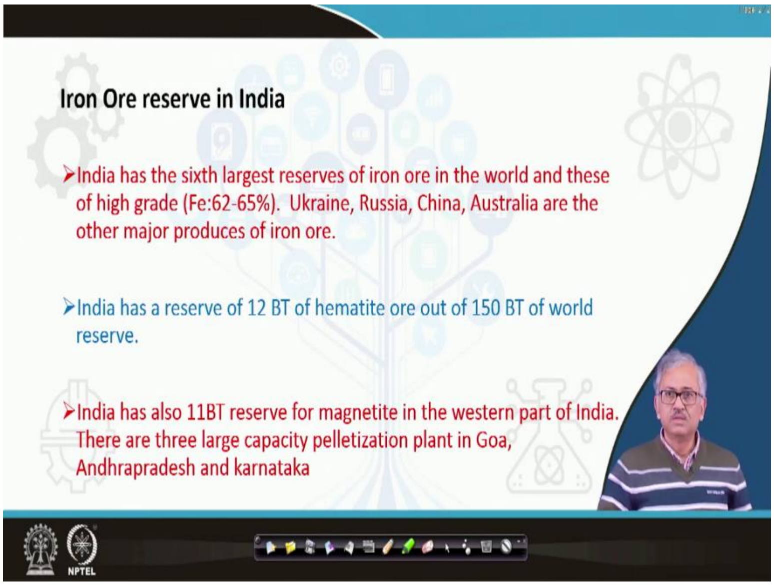

Now, let us have a look of the iron ore reserves in India. India has the sixth largest reserves of iron ore of the world and these are of high grade ore with total ion percentage 62 to 65.

World has 150 billion tons of hematite iron ore reserve; out of which India has a reserve of 12 billion ton. India also has 11 billion tons of magnetite deposit specially in the western part of India Rajasthan, Karnataka, Andhra Pradesh; and there are three large capacity pelletization plants, namely Kudrimukh in Karnataka (1Mtpa), JSL plant in Bhilwara (1.2Mtpa), Rajasthan. 2 Mtpa plant is supposed to setup at Vizag steel under the joint venture of KIOCL and RINL. These pellets are mostly exported.

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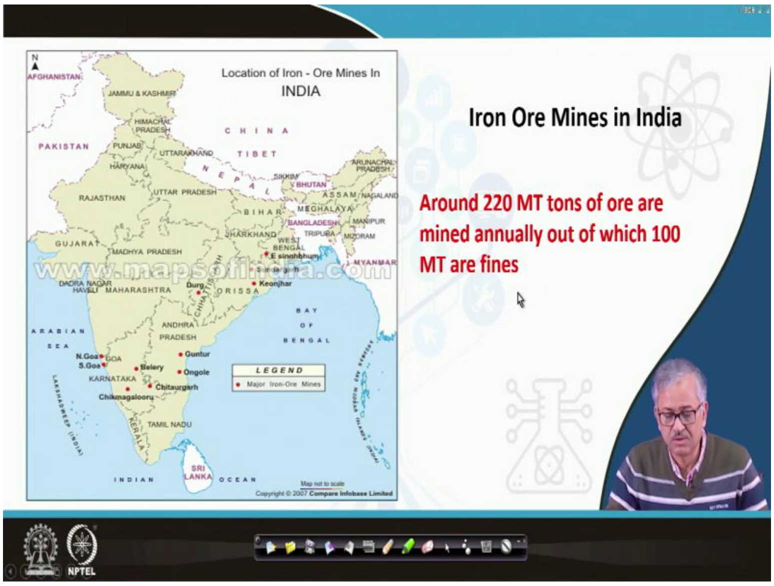

Hematite is primarily is used for producing iron in blast furnace in India. Now, let us see the hematite iron ore mine sites in India? With reference to the map given in the slide above, you can find that major mines of high grade hematite ore are in the Eastern part of India like East Singhbhum in Jharkhand, Keonjhar in Odisha, Durg in Chhattisgarh. Durg has also reserves for limestone. Besides, Guntur and Ongole in Andhra Pradesh, Bellary in Karnataka, Goa has also good reserves for hematite ore.

Indian hematite deposit are of branded hematite-quarzite type and frazile that produces lots of fine during mining. Around 220 million tons of iron ore are mined annually, and it generates around 100 million tons of fines. Goa has several such off grades iron ore fines deposits, which remains unutilized unless those are used by some alternatives routes of ironmaking.

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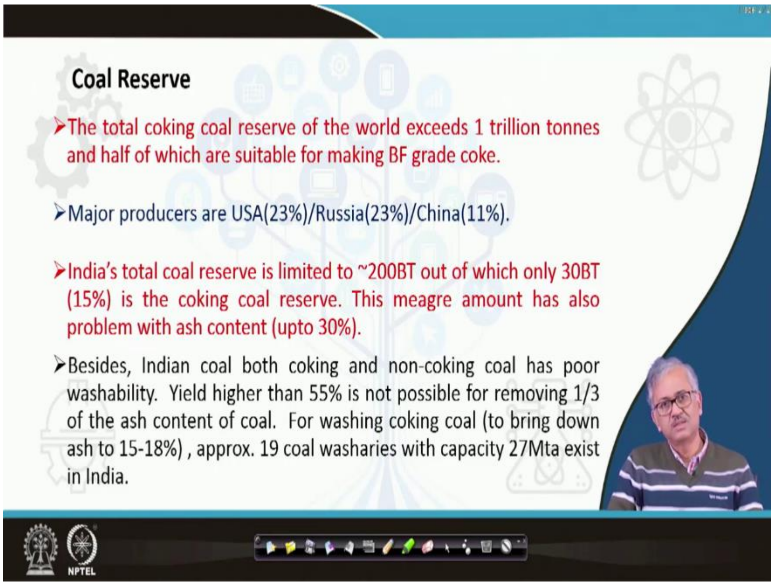

Total coking coal reserve in the world exceeds 1 trillion ton; half of which are suitable for making the blast furnace coke. India's total coal reserves is limited to 200 billion ton out of which only 30 billion ton, i.e., 15 percent of 200 billion ton, is coking coal reserve; too with comparatively higher ash content. So, in India, coking coal reserves is very limited, and it is located mostly into the Jharia, Jharkhand, and Raniganj in west Bengal. Both are near to ISM Dhanbad (presently IIT Dhanbad). Dhanbad has also coal reserves of both non-coking, and coking coals.

Indian coal both coking and non-coking coal has comparatively higher ash content (20-40%) and has to be washed before their use. But washing of coal is also not easy in India because ash are finally disseminated into the matrix. So, physical separation is not very effective; yield higher than 55% is not possible for removing 1/3 of the coal ash. Therefore, after partial removal of ash by washing, Indian coking coal is blended with low ash exported coal such that final ash in coke is maintained between 15-17%. So, for washing coal to bring down ash from 15 to 18 percent approximately 19 coal washer is there in India with the capacity of 27 million tons exist today.

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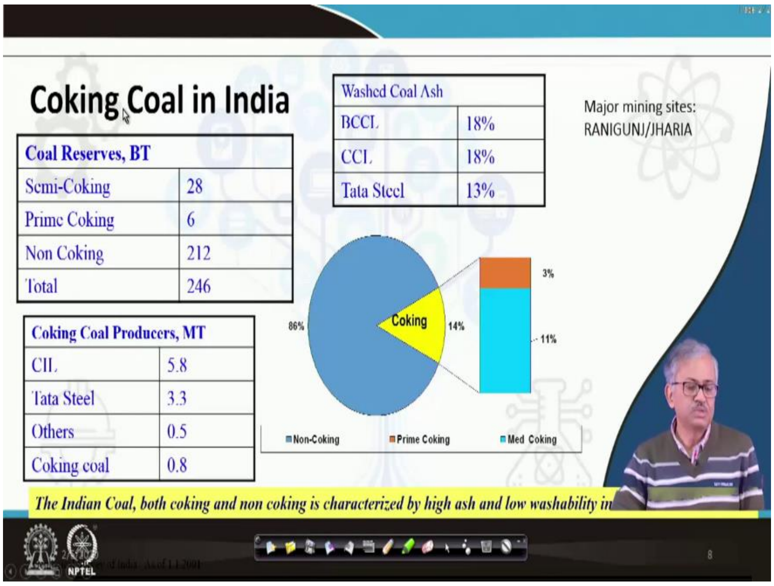

Coal India Limited is the major miners in India and it has subsidiaries like BCCL like Bharat Coking Coal and Central Coal Field Limited, who also mine the coking coal.

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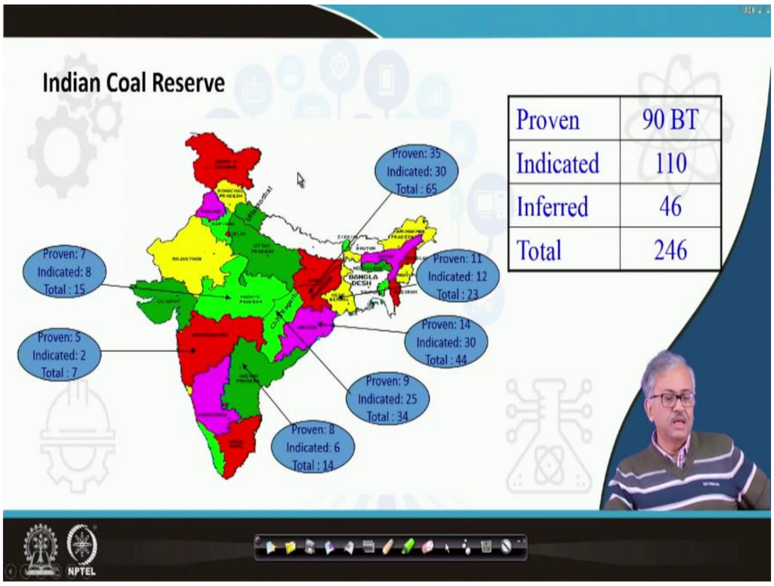

The Indian coal reserves are shown pictorially in the slide and those are located in Jharkhand, west Bengal, orissa, Chhattisgarh, Maharastra and Madhyapradesh. 90 billion ton is proven source out of 246 and total mine mining sites are there in India as indicated.

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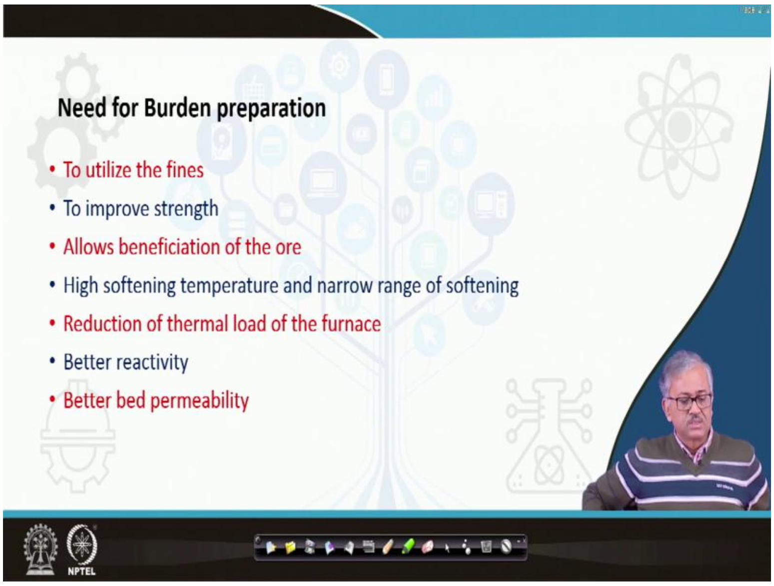

Now, I will talk about the need for the burden preparation. As I said in my previous lectures also, that in the blast furnace, raw material quality is very important; because blast furnace is a countercurrent gas-solid reactor in the upper part and gas-liquid reactor in the lower part of the furnace and therefore maintaining bed permeability is of paramount importance.

First importance of burden preparation is that utilization of the fines. As I have said, India mines around 220 million tons per annum and out of which 100 million tons are fines due to fragile nature of the ore. So, how to utilize those fines? Because you cannot charge iron ore below a particle size because they will reduce bed permeability, or, would be fluidized. So, to utilize the fines, it is very important to have an agglomeration process. By burden preparation you can agglomerate these fines into a stronger and reactive burden.

Since agglomeration process is carried out at high temperature, bonding between particles takes place by fusion as well as diffusion bonding, making the agglomerate stronger.

Thirdly, burden preparation allows the beneficiation of the iron ore. This is true especially for palletization. In palletization ore should be crushed to very fine powder for subsequent green ball formation. Therefore, gangue liberation is very effective in fine powder and allows beneficiation. Specially, Indian iron ore is very nutritious for aluminum. So such beneficiation will be helpful.

Burden should have high softening temperature and narrow range of softening, which can be achieved by burden preparation. Beneficiated burden like pellets become very rich in iron ore with less gangue. When the gang is less, than your softening range will decrease because gangue make the softening range of slag wide; while iron melts in a narrow range. Iron rich burden also melts at higher temperature. High softening temperature and narrow softening range is useful to restrict the wet zone narrower that is helpful because major pressure drop takes place in the lower part of the furnace.

By burden preparation, it is possible to reduce the thermal load of the furnace. If you can partially remove gang from ore; obviously, it reduces the thermal load of the furnace because gang increases slag volume and associated heat of reaction and sensible heat, which is eventually lost. Lesser the gang, lesser will be the slag, lesser will be the heat requirement. Besides, during burden preparation, you can get rid off initial moisture of ore and other impurities that decreases heat requirement of the blast furnace. Also iron burden can be fluxed with lime such that addition of limestone in the blast furnace could be avoided, which increases thermal load of blast furnace through its decomposition.

Reactivity of iron burden is also an important issue. Higher reactivity of iron burden enhances indirect reduction, reduces coke rate and increases productivity. Prepared burden like coke, sinter, pellets has very good reactivity because they have lot of micro/macro porosity that enhances gas-solid reaction.

Bed permeability of blast furnace is an important issue. The burden should be strong enough such that during their descent through blast furnace they do not generate much fines. Usually, prepared burdens are stronger due to strong fusion and diffusion bonding. Pellets also offers excellent bed permeability due to their uniform spherical shape.

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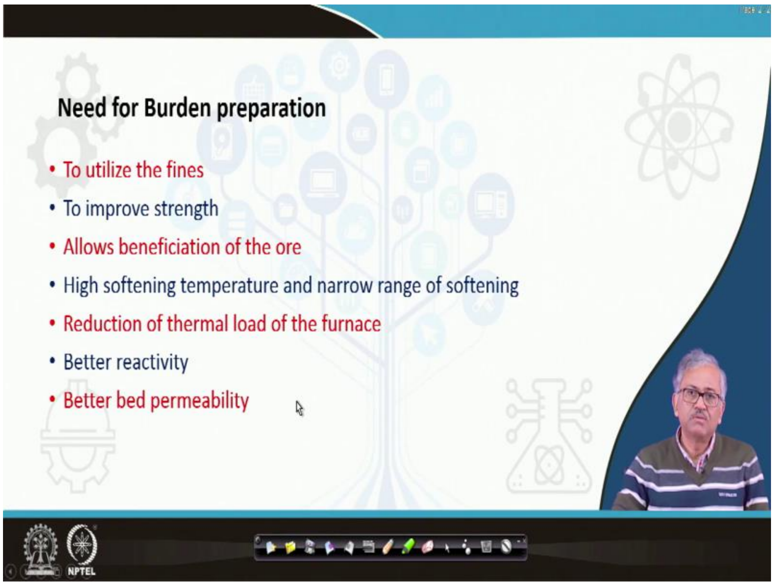

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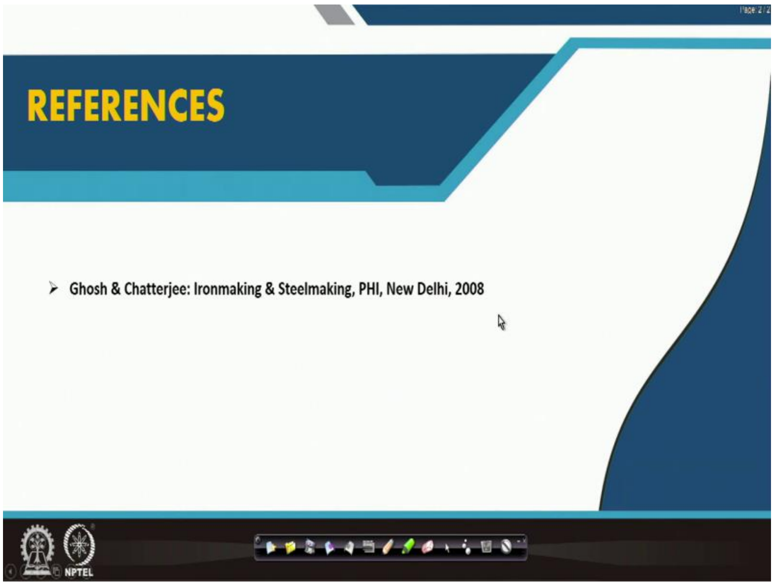

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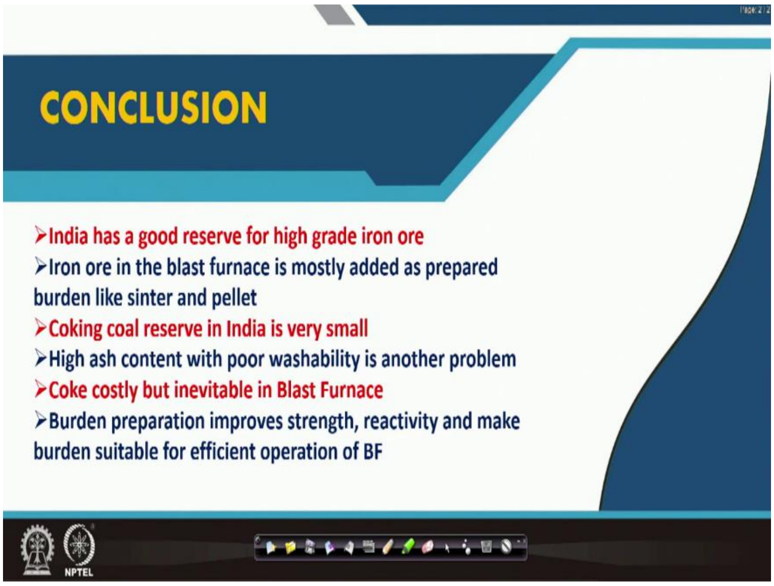

So, we can conclude that India has a good reserves of high grade iron ore (25BT); out of which 12Bt is hematite iron ore with total iron containing 60-65%. Hematite ore is mostly used in India to produce Iron and another 11 BT magnetite ore also available, which is mainly pelletized after beneficiation and exported.

Iron ore in the blast furnace is mostly added as prepared burden like sinter and pellet with a meagre amount of lumpy ore (around 10 percent of the total charge). Coking coal reserve in India is very small a very small (~30 BT out of which 8BT is prime coking coal) and major mines are located in Jharia and Ranigunj. Indian coal including coking coal contains comparatively higher amount of ash. Again Indian coal are not amenable for washing and yield becomes less than 55% only to remove 1/3 of its ash content. Therefore, partially washed coking coal need to be blended with imported low ash coking coal to restrict the ash content in final coke to 15 to 17%. Coke is costly but inevitable in blast furnace to hold the over burden.

Burden preparations involves coke making, pellets and sinters. Burden preparation improves the strength of the burden, promotes fines utilization, reduces thermal load, size of wet zone; and all leads to better performance of blast furnace.

Thank you.