METALLURGICAL AND ELECTRONIC WASTE RECYCLING

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Week- 6

Lecture-26

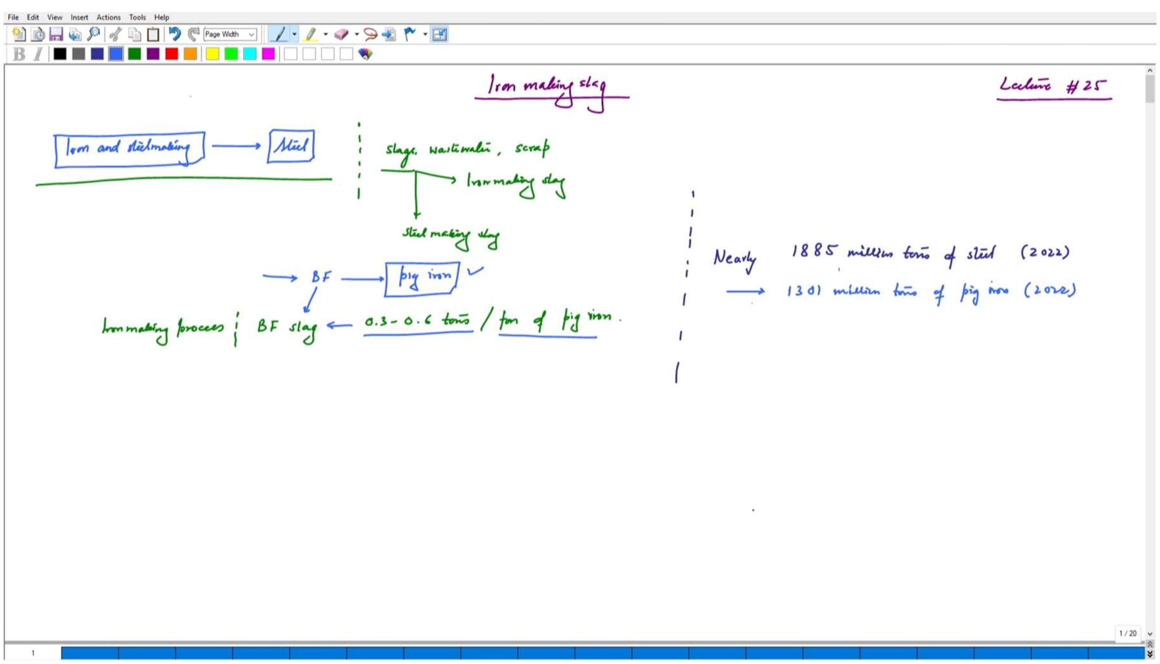
Greetings, I welcome you all to the new lecture of this course and till now we have been discussing various types of metallurgical wastes. And now we will be focusing on the next aspect which is basically the wastes that are generated in iron making and steel making industries, which is probably one of the most important sectors of metallurgical industries and simultaneously the wastes generated in the iron making and steel making industries also become very much prominent. When we think of iron making and steel making wastes, there are couple of important wastes that we should be focusing on.

The iron making and steel making industries are predominantly pyrometallurgy oriented, and so it is fairly relatively easier to guess what type of wastes we are expecting. Slags iron making process slag iron making slag steel making process will give us steel making slags and of course the following processes that are involved after the conventional iron making and steel making processes will also in turn have their own slags and apart from the slags, we will also be discussing about the waste water generation and its recycling.

And similarly, we will also be focusing on the scrap utilization. Just like we have focused on the other metals like aluminium, copper and zinc, we will also try to have the same discussion when while we are discussing iron and steel making industry wastes. We will begin our discussion with iron making slag. Iron making slag will come when we are discussing iron making and steel making. Iron and steel making are the process that generates the finished good of what we call as steel and is one of the most important metals that are available for mankind to use and this whole process has been investigated for lot many years. The process of using raw materials and making iron and then following that will go for steel making and then utilization of steel for various applications.

This has been explored for lot many years. The different categories of wastes are have been mentioned. We will have slags, both iron making and steel making and we will have waste water and we have the scrap utilization. We will be discussing these types of wastes. And when we discuss about slags, it gets partitioned into iron making slag or steel making slag. We can guess that these slags are going to come from different routes. Iron making process is going to give us iron making slag and steel making process is going to give us steel making slag.

The blast furnace slag, iron making process or the blast furnace operation will give us BF slag, blast furnace slag. Blast furnace slags, we will have to discuss something about it. Nearly 0.3 to 0.6 tons of slag is generated per ton. We will write per ton of pig iron. Safe to say that we have let us say a blast furnace and we had our raw materials and we have our output. The output in this case is pig iron. Per ton of pig iron will have 0.3 to 0.6 tons of blast furnace slag, which is basically acting as the waste stream in this case. This is what we want to make. And this is going to go ahead for the steel making process, but blast furnace slag is something that is generated as a waste. What is the overall quantity of steel that is generated? Let us just look at some numbers. The overall quantity nearly million tons of steel has been produced in and this figure is for 2022 and this is the global number. We will have one more statistic that is following that gives us nearly 1301 million metric tons of pig iron. We can just say that this is the quantum of steel and pig iron that has been produced of course, this is a global number and we can say that based on that what is the quantity of glass furnace slag. **(Ref. 7:00)**



By multiplying it we can say that it is an enormous number. The sheer quantity of blast furnace slag that is generated makes it important waste that needs to be handled, that needs to be treated, that needs to be recycled. What really follows is evaluation of the metallurgical waste. The iron making slag or we are calling it as blast furnace slag. This has to be analyzed and then newer methods of recycling have to be developed.

The complete utilization of material is done on a more comfortable basis so that the sheer quantity of blast furnace slag that is generated can be directed for such applications. We will also look at some of the most more important properties of iron making slag. Iron making slag or BFS, blast furnace slag is produced in the iron making industry.

We already have discussed this. But what are the forms? We will discuss forms of BF slag. What are the forms of BF slag? We see that these can be produced as air cooled, we will have pelletized or we can also have granulated. Blast furnace slag can be either air cooled or pelletized or it could be granulated and then of course, we need to see the densities that are present. This is the range of density of the blast furnace slag and we know that when the temperature of the blast furnace is evaluated, we can see what is the temperature of blast furnace slag. When it is getting discharged, so it reaches of a temperature range of 1400 to 1600 °C, plus minus 50 or 100 °C can be seen here.

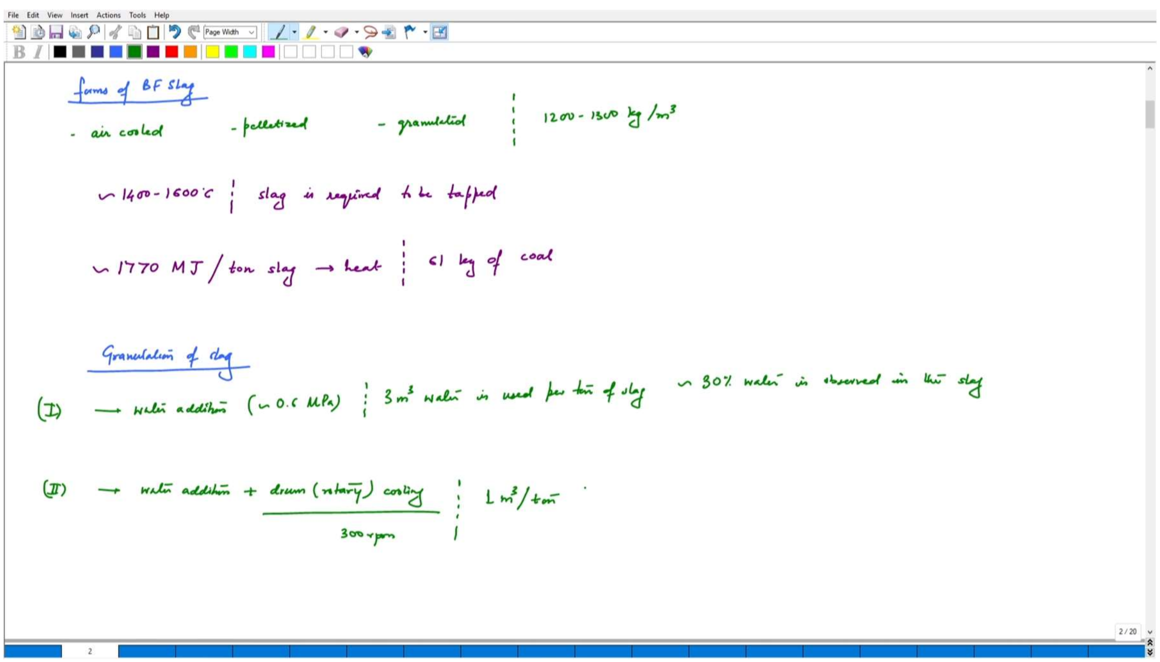
That is the temperature range and at this point of time this slag needs to be tapped. This is a sheer quantity of heat. We will try to put some numbers on that as well. We know that 1770 nearly 1770 MJ per ton slag is the heat. This is the heat present in the blast furnace slag. What it means is if we are able to entrap the heat that is present in the slag that heat could be used for some other applications. Extraction of heat itself because we know that the incoming slag is of the of a very high temperature 1400 to 1600 °C temperature is coming. The slag is of that temperature and one has to extract heat that becomes a bit of a challenge because one has to have devices and infrastructure and facility that is capable enough of extracting heat and then cooling the dross, cooling the slag down and then the blast furnace slag is then used for various other applications. What does it really mean? This quantity of heat can be equivalent to 61 kg of coal, 61 kg of coal so 1770 MJ per ton. If we are just using a significantly large quantity of slag, we would be getting equivalent amount of heat.

Per ton, we will get 61 kg of coal. We will also look at other characteristics of slag, granulation of slag. Granulation of slag can be done by water addition and one has to do by some sort of applying pressure. You can just say some amount of pressure is also added while adding water onto it so that some sort of granulation is done. What else?

3-meter cube water is used per ton of slag. It does not appear to be a very large quantity, but what happens is water pick up by the slag during this process is observed. Granulated slag when you are adding water with pressure what it does is it picks up water with it. And, then we see the presence of water in the finished product. This is what I am saying nearly 30 percent water is observed in the slag.

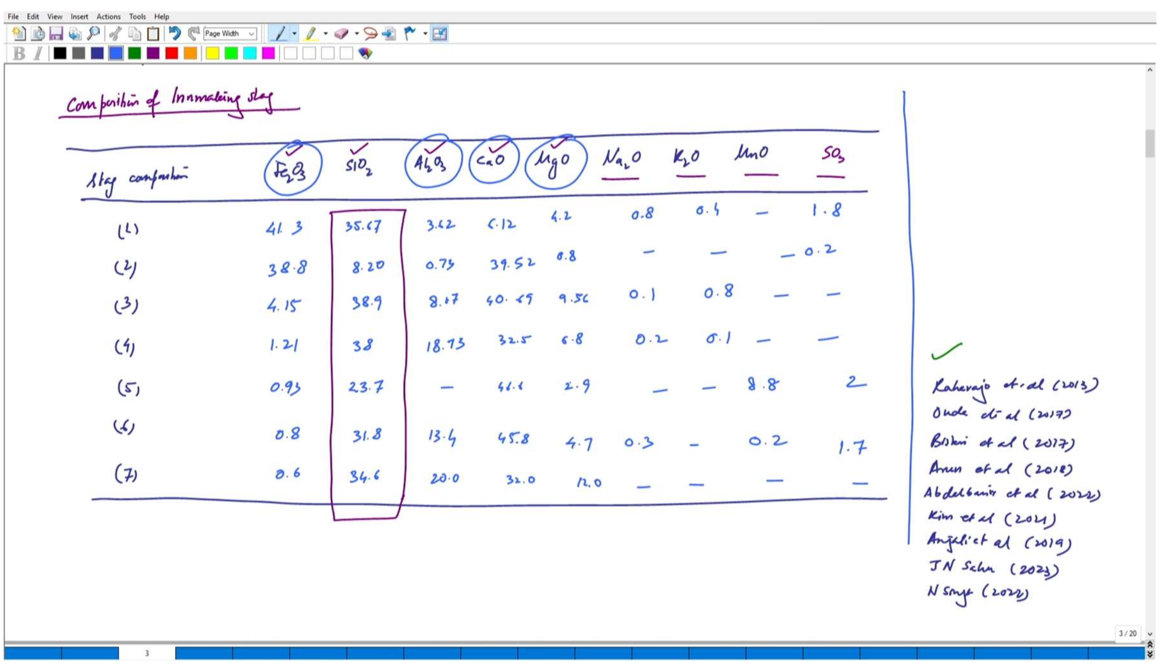
When we are cooling it down by the granulation process and when we are adding water with pressure this is going to happen. The other option could be when it is water cooled and it is charged in a drum. This could be route 1. The other could be water addition plus drum rotary cooling. What this is basically we have a mechanism of cooling we will have a drum which rotates.

We will have a rotary drum and we have the injection of water. What this does is it requires relatively lesser amount of water which means lesser water entrapment in the finished product. We can also think of some sort of rpm, so if this has 300 rpm, we can have a significantly very less quantity of water requirement. This really reduces the water requirement by nearly one-third of course, the values can change. **(Ref. 15:30)**



This tells us that there are various ways in which iron making slags can be handled. We will look at the chemical composition of iron making slag and we will see why exactly this recycling of iron making slag becomes important. We will look at the chemical composition now. We have various samples of iron making slags and these are the references that have been used to collect the data and we see that there are some important observations here. We see that there are some important phases that are present in iron making slag and we know that these materials are usually present in varying composition. Fe_2O_3, SiO_2, Al_2O_3, CaO are important phases and to some extent Mg as well. Na_2O, K_2O, MnO, SO_3 because silica is already mentioned here. We see that these phases are already present here and these are relatively minor phases. These trace elements also play important role in imparting some of the chemical properties, but of course, these are present in really smaller quantities. The major phases are Fe_2O_3, SiO_2, Al_2O_3, CaO and MgO. We will discuss why these phases are so important. We will see the variations. Silica is almost always present in nearly about 30%.

Nearly about 30%. Alumina can range from close to 1% to about 20%. Similarly, CaO can range from around 5% to 40, 45, 46%. MgO is in the ranges of 10s to 20s and Fe_2O_3 can also be varying from relatively being very less to be to about 40. What it really does is CaO, MgO, Al_2O_3 and Fe_2O_3 are important phases that are present in the iron making slag. And one has to think what are the important ways by which we can extract or separate these phases to extract valuable materials out of it. If one aims to extract iron one has to think what is the composition beforehand. If one aims to extract CaO. One has to think what was the composition before we even begin. **(Ref. 18:50)**



Slag composition	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	MnO	SO_3
(1)	41.3	35.67	3.62	6.12	4.2	0.8	0.4	–	1.8
(2)	38.8	8.20	0.73	39.52	0.8	–	–	–	0.2
(3)	4.15	38.9	8.17	40.69	9.56	0.1	0.8	–	–
(4)	1.21	38	18.73	32.5	6.8	0.2	0.1	–	–
(5)	0.93	23.7	–	46.6	2.9	–	–	8.8	2
(6)	0.8	31.8	13.4	45.8	4.7	0.3	–	0.2	1.7
(7)	0.6	34.6	20.0	32.0	12.0	–	–	–	–

Similarly, this analysis has to be done and then we can devise the treatment whether it will be a pyrometallurgical treatment or hydrometallurgical treatment or a pyrohydrometallurgical treatment and then extract these valuable materials from it. One of the most important methods that is explored as we have just been discussing about the energy aspects of the high temperature slag that is getting generated is the heat recovery. One of the most important ways of recycling iron making slag is actually recovering heat first and then recovering the material. We will discuss this.

And, before we go beyond, we should also note what are the key areas of iron and steel applications. This is important because this helps us understand why really iron making slag becomes important. We will just quickly note them. We will have construction and infrastructure; construction also includes infrastructure. We have metal production. We also have mechanical equipment. We also have automobile industries and that also includes some shipment and other industries that are related to automobile consumer goods. This tells us that apart from these iron making slags that we are actually discussing, we will also have some scraps that will be discussed in the upcoming classes.

These will be originating from such wastes. Coming back to our focused topic which is basically why even recycle blast furnace slag. We have seen that one of the most important and attractive aspects of this waste is the sheer quantity and if we are not investing our thoughts on how to recycle it, we will be investing on where to store it. The most important challenge that most of the industrial industries are usually encountering is the lack of land resources associated to the slags.

We are generating pig iron, pig iron will be used for making steels, but at the same time slag is also getting generated and it is getting stockpiled. When we have this stacking of slags, it becomes the slag stockpile and it consumes the land resource within the plant premises, within the industries because we cannot discharge the slag into the environment. One has to really think of the land resources that are available in the industries for better utilization. And storing of slags or drosses or scraps is not what land resources should be used. One of the more, why we should be recycling and making slags, we will be pointing it out now. Why recycle blast furnace slag. We know that the phases that are present we have just seen the phases that are present are CaO, MgO, Al_2O_3, Fe_2O_3 and of course SiO_2. These phases are present and they have a significantly large quantity of these phases and Fe_2O_3 recovery is important. The composition can change and it depends upon how the pig iron was made and what was the composition, but still, it some quantity of Fe_2O_3 is still invariably present in the iron making slag. One has to think of recovery of iron. Similarly, one can think of recovery of calcium and other phases also and bringing back to the material cycle. The other reason that we have just discussed, presence of limited resources and which resources are we talking of land resources.

Storage of waste slag is a challenge. First, we do not have resources and the second these materials cannot be stored in conventional open spaces, one has to think of the hazardous leaching tendencies of the phases that are present. It can affect the surrounding land resources and the environment. Conventional route of storage is not an option. The environment, we have already seen what resources are we lacking here and the environment degradation due to leaching, leaching of heavy metals. Leaching of heavy metals can cause the environmental degradation.

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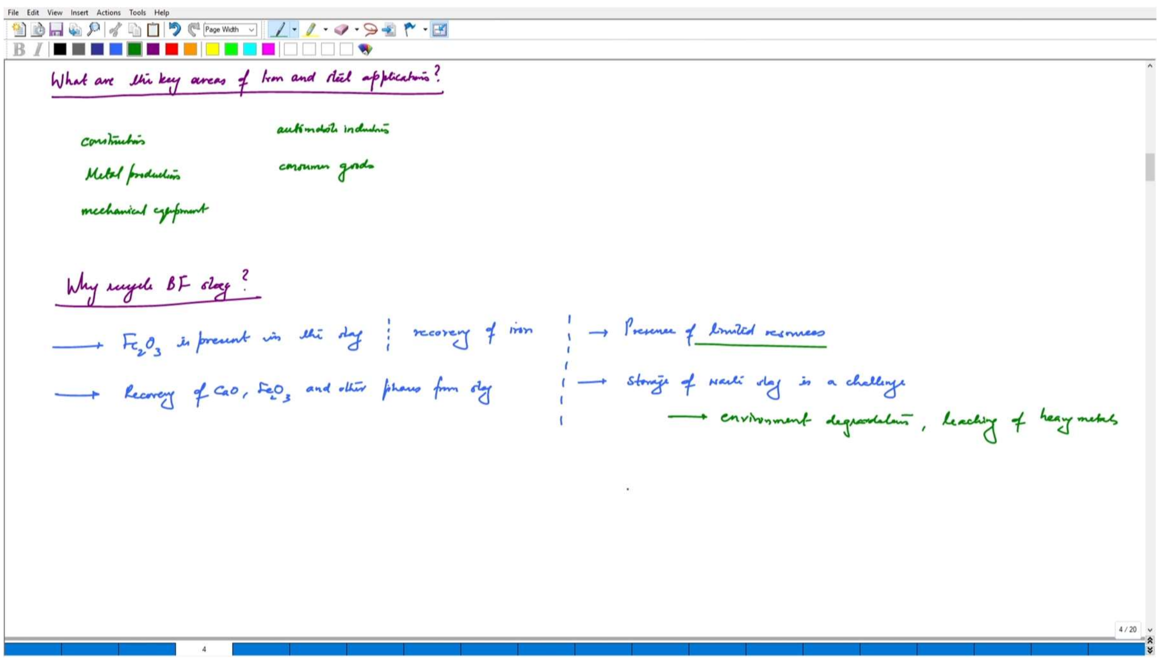

We will be discussing how really; we should be developing the recycling routes. Recycling strategies for blast furnace slag. We already know that of course, the material has to be recovered so whatever slag is there it has to be recovered but the slag that is coming out is already at a very high temperature 1400 to 1600 °C and the heat we have already seen why not tap the heat as much as possible before we even think of material recovery, let us think of heat recovery. And that is how some of the recycling strategies, the modern recycling strategies have been developed. And, there are other methods also. One of the most important strategies include CO_2 mineralization, which is big mineralization, which is basically the carbon sequestration that has been implemented in lot many laboratory experiments and it is being explored in other scales of operations as well.

Steel making slag, of course, we are discussing iron making but still making slag has also some good applications for the carbonation and then, there is the carbonation that is an indirect and indirect route which will be discussing in the upcoming lectures also. People have tried to use iron making slag as well, but it has been seen that this route really does not give as good result as steel making slag.

The preferred material would be the stainless-steel slag. In this case, when we think of CO_2 mineralization, steel making slag makes more good raw material for compared to the iron making slag. We will think of waste heat. We know that the temperature is 1450 to 1650 °C. It is and we can use blast furnace slag as thermal energy storage material

because of this high temperature. And comparing just like CO_2 mineralization where steel making slag was a better material, blast furnace slag is actually a better material for this application like for waste heat recovery. People have explored the possibilities and they have said the blast furnace slag should be first used for waste heat recovery and then for material recovery. So, that is the reason why blast furnace slag is first used for this application.

And, what are the other other applications after it the waste heat has been recovered, we can always think of cement making industries, cement making, construction, infrastructure applications. The blast furnace slag will be used as a one of the additive raw materials and then it would be converted to some other applications with the other raw materials and then it would be brought into the construction applications. The evaluation for civil engineering applications is done on the basis of their own tests.

Only after it passes through those tests it will be used as a raw material. What are the key challenges that are associated with the waste heat recovery because of course, we know that CO_2 mineralization seal making slag is a better option. One of the most important challenges we will be noting, low thermal conductivity. The slag itself is a low thermal conducting material. The heat transfer may not be efficient. The slag has corrosive properties, corrosive nature because of so many various phases that are present. It is present at high temperature one has to cool down and the equipment has to sustain heat as well as this corrosive nature. When we think of waste heat generation, during the process itself, the cooling process is done in such a way that the finished product may not be of good applications.

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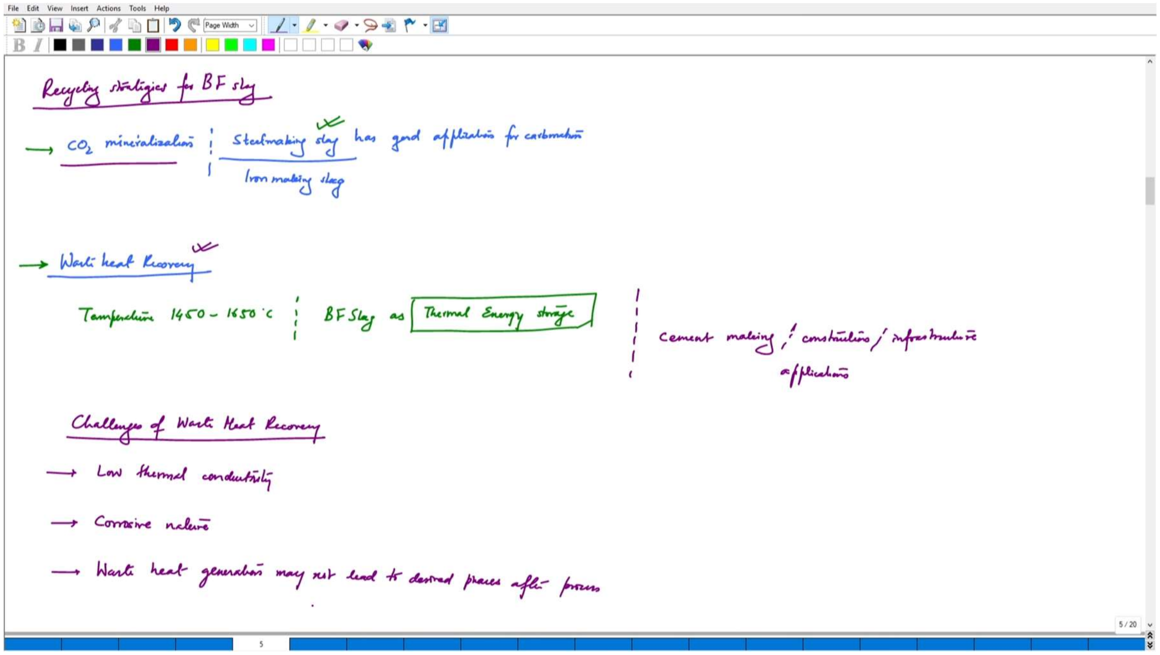

One might think of making it as a raw material for let us say construction applications, but the cooling route would be a bit different. Heat recovery would end up in making phases that may not be applicable for various larger applications of glass furnace slag. These are the typical challenges that one need to address while developing the routes for efficient waste heat recovery. We will be continuing from this point in the upcoming class. Thank you.