METALLURGICAL AND ELECTRONIC WASTE RECYCLING

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Week-6

Lecture-28

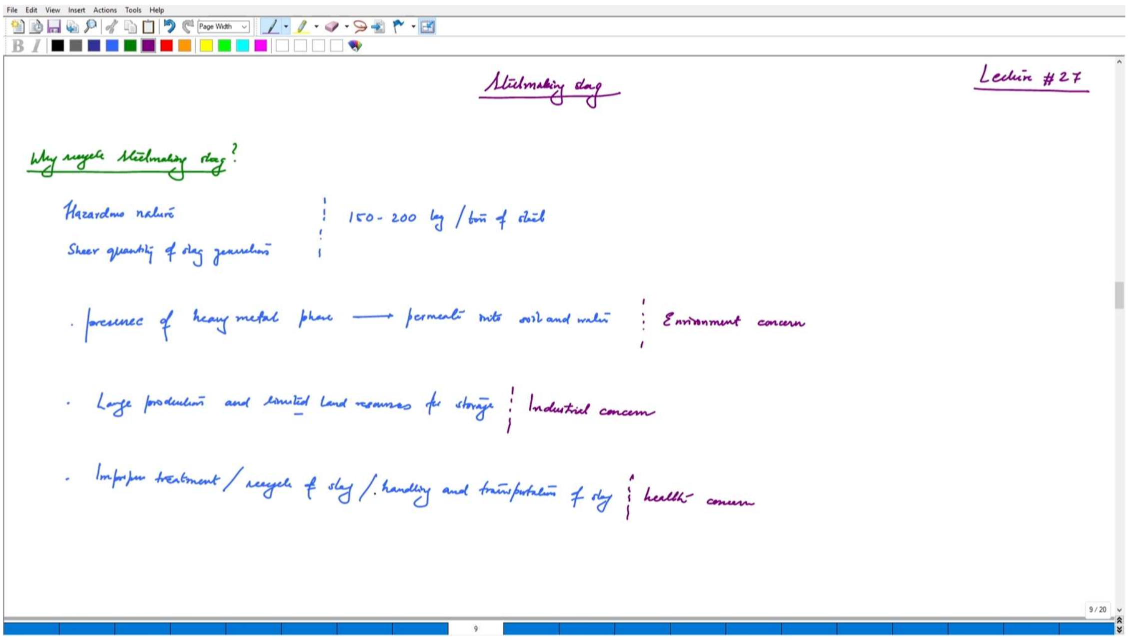
Greetings. We will now discuss where we had left in the previous lecture and we were discussing steel making slag. In the couple of lectures that we had started, we were thinking of the wastes that are present in iron making and steel making industries and we have covered iron making slags and we were discussing the steel making slags. Based on the composition of the steel making slags we had discussed that the three important phases that are very much central to the different steel making slags are CaO, iron oxide Fe_2O_3 and there is the SiO_2. When we have these phases in mind, when we have iron oxide, we have calcium oxide and we have silica, we can think of ways of recovering calcium and iron from this steel making slag such that we are able to use most of the metallic content and if we have the remaining slag left, we can use it for some inert material applications.

Why recycle steel slags? The problem remains the same just as we had discussed for iron making slags and that is the reason why we are trying to have a parallel discussion between iron making slags and steel making slags and we are having applications from both the wastes. The steel making slag also has those phases however the compositions can vary as compared to iron making slags. But the quantity of steel slag generation, we will be discussing that, is also very much enormous. The limited land resources that we had discussed for iron making slags, that limitation still is there. And if we are not extracting the valuable materials from the steel making slags, it is again going to get collected as a waste.

And then there is the possibility of the heavy metal leaching and the disturbance of the environment because of the change in ground water and pH and the accumulation of heavy metal into the land resources. Why do we need to recycle steel making slags? The hazardous nature. We know that the hazardous nature of slag is one of the most important driving forces and it also is important to note what is the sheer quantity of slag generation. Let us just directly look at that. It is nearly about and the figures can vary nearly about 150 to 200 kg per ton of steel.

What it really means is if we try to you know come back to the number of what is the overall steel production on a global scale and we try and see per ton for even each unit of steel making the slag generation may change but generally we can say that 150 to 200 kgs, it could be more or lesser than the this range but if you look at that quantity and multiply it with the total steel production, we see that this quantity of steel slag is enormous, which is why recycling the slag becomes a challenge because of limited land resources and the hazardous nature of the slag. Presence of heavy metal phases or components that can basically permeate into soil and water. This is basically the environmental concern. The other way of looking at is large production and limited land resources. Limited land resources for storage.

Even if we have a route, we must have some sort of storage facility. This is basically the concern of industries. This is the industrial concern. And if we are not having improper route, improper treatment or recycling of slag, and it also involves the handling and transportation; not just recycling it is also handling and transportation/logistics of slag that is also a big challenge and it is basically going to cause health concern. People are involved in the improper treatment. **(Ref. 7:08)**

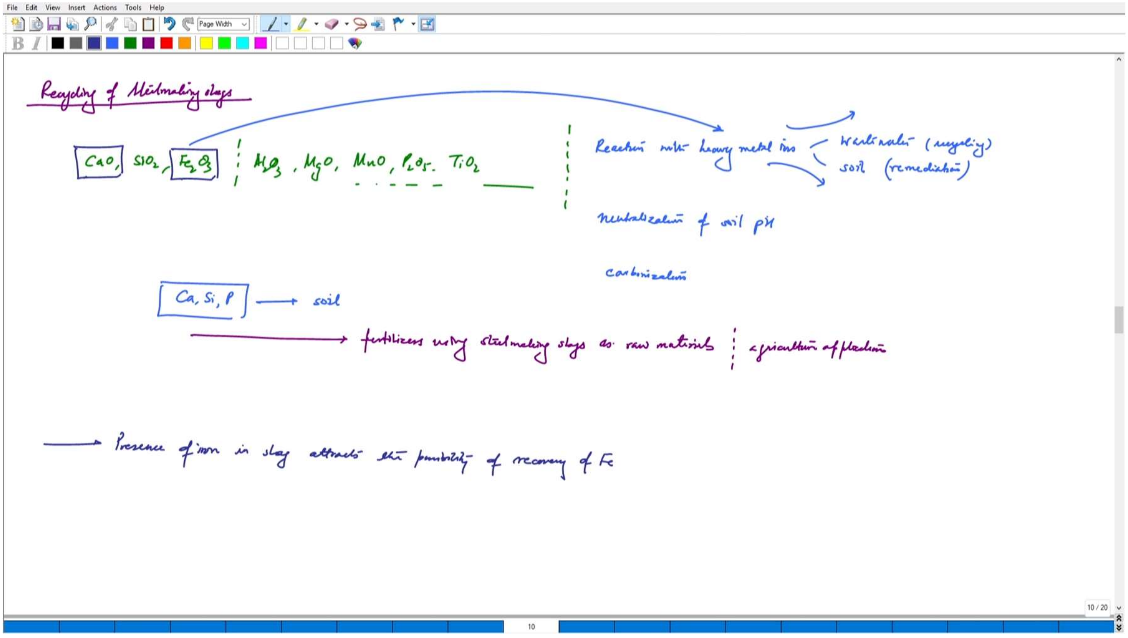


Not conventional and not supervised or unsupervised route of recycling. Under such circumstances, the people involved may get into some sort of accidents or they may contract some other diseases. The handling and transportation is also very much importance. One has to think about all of the aspects when the slags are handled because of just like iron making slags, steel making slags are also having high temperature and these are also used for some sort of heat recovery, but of as we had discussed so iron making slag has better potential for extraction of heat.

At the same time, it is a good raw material for making other valuable other products one of the applications is carbon sequestration. We will now look at the good routes that have been discussed and what are the potential challenges that are available and how people are trying to work up. Recycling of steel making slags. We know that the composition of slag is CaO, SiO_2, Fe_2O_3 and we have Al_2O_3, MgO, MnO and so on and so forth.

We can also have P_2O_5, we also have TiO_2 and these are present in relatively lesser quantities. And these quantities help us in defining what are the alternative applications of a given slag, but the central idea still lies between recovery of the metal and then finding the inert applications. What are the potential applications? Heavy metal ions can be reacted with the CaO and Fe_2O_3. These can counter. Reaction with heavy metal ions; reaction with heavy metal ions in We are actually looking at wastewater or soil. Using this composition, we are actually trying to pit it against heavy metal ions for wastewater or soil.

Remediation: this is soil remediation. Wastewater recycling, soil remediation. What this does is change the chemical composition. It can also be involved in neutralization of soil, soil pH. That is also possible. And carbonization, which is basically the carbon sequestration that we have been discussing so far. And the presence of the minority phases, we already know that there is calcium, silicon, phosphorus. These are important elements for soil. And the trace elements that are present in trace phases, these phases can be used for soil remediation. One can think of devising fertilizers using steel making slags as raw materials. And where are we going to use it? For agriculture applications. What else can we do? We know the major phases are calcium oxide and Fe_2O_3. We will think of iron. Presence of iron makes it a good raw material for iron recovery. Presence of iron in slag attracts the possibility of recovery of iron. How do we normally think of iron recovery? With that People have tried very simple methods, if we can just cool down the slag and if we can just crush and grind and do magnetic separation. **(Ref. 13:27)**



We know that if some iron is present and if that iron can be extracted by just simple physical applications that is also a method of recovering iron. And not only that if we have CaO; suppose that some amount of iron is extracted by physical method and that after that we are having calcium and magnesium in form of CaO or MgO, we can use that as a raw material for sintering applications. Instead of using conventional sintering fluxes we can use steel making slag after iron recovery as a raw material for in-house applications in say let us say sintering unit. This type of recovery has been discussed. We will just look at a route that has been described. We will be using pyrometallurgy and hydrometallurgy combination.

One of the routes involves step 1. Step A, which in this case is using EAF slag. We have the steel making slag in that category, we have the EAF slag and what we have done comminution. This brings down the particle size and we can do the further operations. We know that comminution happens to be one of the most central ways by which we handle the metallurgical wastes. We have a solid waste if at all it can be subjected to crushing, grinding. let us bring down the particle size. The contact area gets increased and then we can let it react with other materials. That is done. And after that we go for mixing with fluxes and let us say cold raw material. We can have the addition of fluxes and then we can have and when we know that when we are adding coal or lignite or any other material, we can just go ahead and sinter it or we can go for smelting or we can go for any other pyrometallurgical route. The step A is that we can focus on the pyrometallurgical route to extract iron from it. One way of doing it is just go for iron recovery directly, but that may not give us good recovery because iron is present as iron oxide and not much iron is available freely for recovery.

The other way could be extract it as much as possible for by smelting process. So, that smelting process can be done by this and we will go for pelletization or any other agglomeration route and we can have the smelting. If we do the smelting operation, we can easily see that there is recovery of iron. When we have recovery of iron, we know that now we have a phase that is relatively free from iron. Low iron slag because some parts of iron is already extracted here. And we can still go for the comminution and the comminution process. We can bring it back here and go for magnetic separation. We are going to apply magnetic separation.

Separation. What is this going to do? It is going to give us iron. Again, recovery of iron. Whatever left, iron is present we can attain it in part 1 and part 2 which is basically the same thing extracting as much as iron from the steel making slag as is possible. Applying various routes smelting again pyrometallurgy if we are still not satisfied, we can go for commution one more time and then extract iron from the remaining slag. Still, some slag is left because the remainder is again a slag.

That slag we can go for hydrometallurgy. If we have slag left, we go for step B which is one can think of applying baking process with acid. And in such cases, people have found that one has to use really high concentration of acids. 98 to 95 percent acid is directly used for baking and we can have a wide range of temperatures. One can go from 100 °C to 500 °C and such temperatures are being used.

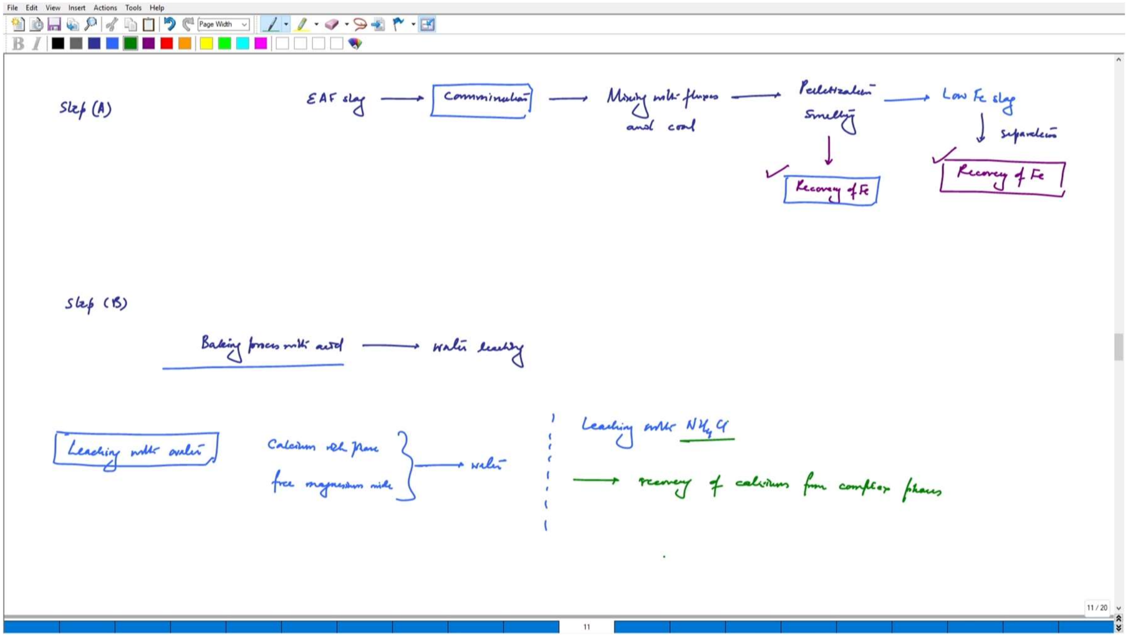
Optimization has to be done. And then one can think of using after baking with acids or alkalis, what we normally do is we go for water leaching. What it does is it helps in fusing the slag with the acid or alkali in this case it is acid and then we bring it into the aqueous medium, we bring water and then based on the leaching parameters that are available. There are so many parameters that come into play, what acid was used at what concentration, what was the acid to slag composition.

That is one set of parameters followed by what was the parameters, what were the parameters used in leaching operation. What was the quantity of water compared to the acid baked slag and what was the time and temperature, what were the other leaching parameters that were present. These parameters have to be optimized to get the recovery and of course, when we think of leaching, we know that there are two important products, the residual solid as well as the leach liquor. Leach liquor will be having some phases and the residual solid can have some phases. In such cases, it is possible that if we are using, let us say, sulfuric acid, we will have sulfates forming. If we are using HCl, we will have chlorides. It depends on what type of acid we are using.

This type of treatment has been performed for steel making slags. And this helps us in recovering iron and calcium from the steel making slag. Alternatively, what we can do is, so if we are not involved in baking with acids, if this process is to be avoided what we can do is we can go for leaching with water. People have tried to just leach steel making slag with water. What it does is if there is calcium rich phase and there is free magnesium oxide. These phases will react with water and then they will be leased out but the efficiency of this process is very less.

When we think of calcium recovery from the steel making slags, one might wonder what should be adding into the system so that calcium in calcium phases, calcium oxide and other phases, how can we recover that? Water leaching just by adding slag in water may not be a good way of recovering calcium and it may also involve some reaction with other phases also, but those may not be very fruitful. The other route could have let us just twist the reagent one more time instead of acids let's go for some other reagents.

In such cases ammonium chloride, NH_4Cl has also been used. Leaching with NH_4Cl. What this can do is it can help in recovery of calcium. In one case we had seen the recovery of iron and in other cases we can have recovery of calcium. When we think of recovery of calcium, we have a good reagent which we can use for, from actually from complex phases. What have we seen right now? We have seen how these steel making slags can be used for various applications. **(Ref. 24:05)**

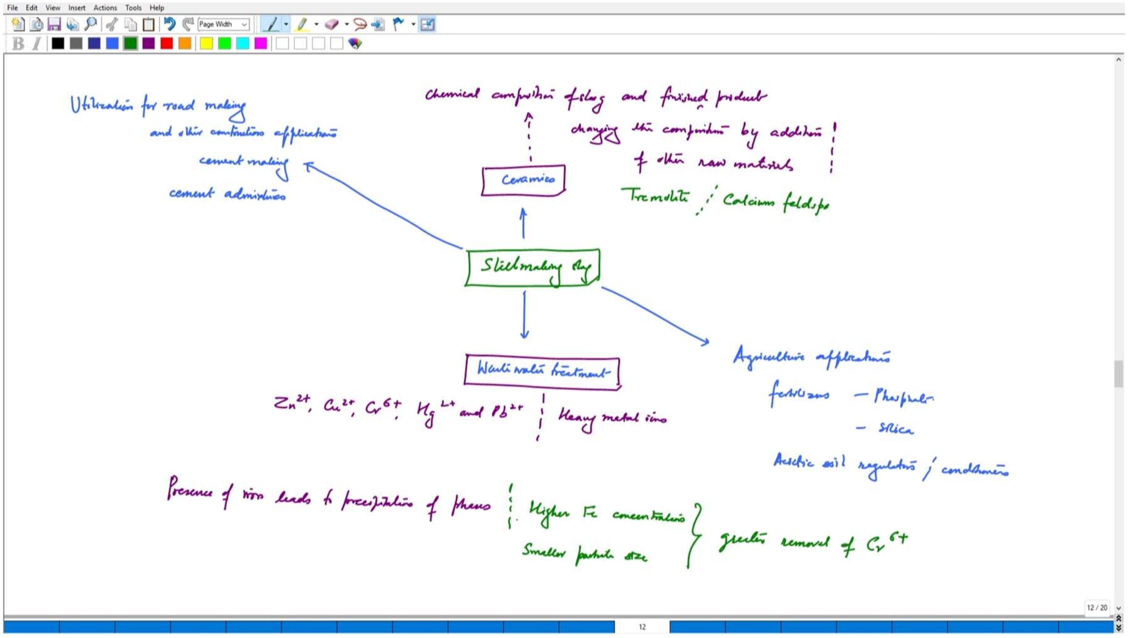


And now, we will be seeing what other applications can be developed. Steel making slags, I will just write. Utilization for construction with specifically road construction, road making applications and other construction applications. And there is a cement making. This is a very important application for steel making slag. And people have tried to use steel making slag for remediation of marine environment also. These are and just by using steel making slag as a raw material for constructions, people are trying to use the mass, the sheer quantity of steel slag in inert applications.

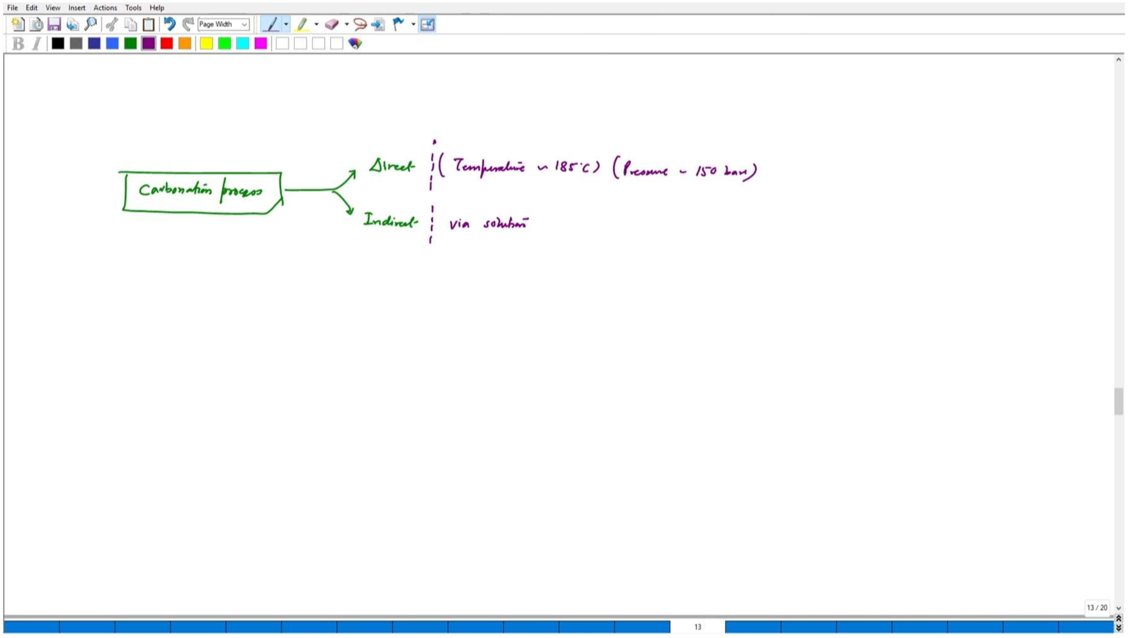
The target is not to make some valuable materials not just that. One has to think of complete utilization of mass of these wastes because these are generated in enormous quantities. If this is not done the application remains a bit incomplete. One of the most important applications is basically using it as a raw material for construction applications. Cement admixtures, so we can have cement admixtures and of course, this is again included in that.

The other route is basically agriculture. Agriculture applications include basically fertilizers. We have phosphate fertilizers, we have silica, so silica-based fertilizers, we also have acid, acidic soil regulators. These are the additions that are done for acidic soil regulations and which can also be conditioners. We have applications in wastewater, wastewater treatment and we will be discussing about wastewater treatment in some good depth. And we also have the application in ceramics. We know that the application of steel slag should be done in such a way that not only we are making a valuable material, but we are also using the mass of the steel slag directly in that application. That there is no other waste left behind.

For wastewater treatment people have tried to use steel slag by varying some of the compositions and making it more compatible for extraction of, extraction/removal of heavy metals. How is that done? Wastewater treatment. If there are important metal ions that are presents in wastewater let us say zinc, we have copper, chromium 6+, Hg and lead. We have these heavy metals. Heavy metal ions in the wastewater. Extraction of these metals using slag becomes a bit of an advantageous application. Why? Because iron present in the steel making slag is a good material that can help in conversion of these heavy metals into precipitates. What has been observed is presence of iron leads to precipitation of phases. It has been observed that higher ion concentration and smaller particle size can lead to greater removal of Cr^{6+}. This is an observation that has been found we know that if iron and we know that iron is present in iron making and steel making slag. If we have a higher iron concentration and of course, we are using smaller particles because it is assuming that we are doing the comminution, the chances of chromium removal from wastewater also increases and in ceramics. Based on the chemical composition, chemical composition of slag has to be studied and the finished product. Based on the composition of the slag and the finished product, one can think of devising a ceramic process from steel making slag. This actually helps us in changing the composition by addition of other raw materials, changing the composition by addition of other raw materials. This is also possible or changing the composition by addition of other raw materials and what it does is it changes overall properties of slag so that you can make the ceramics. What are the target ceramics that have been prepared using ceramics, using these slags? These are basically tremolite or calcium feldspar. These are the important ceramics that can be targeted using the slag. **(Ref. 32:54)**



In this class we had discussed what are the potential reasons of recycling steel making slags and we had continued our discussions from the point of view of chemical composition and we have seen how recovery of calcium and iron is important, what are the overall routes of recovery of material and what are the applications of steel making slags. One of the most important applications that we need to all discuss that we will be discussing now is basically the carbonation, the carbon sequestration. We will just briefly go into that and then we will be moving on to the next topic. Carbonation process is basically done in two routes. One is direct and the other is indirect. The direct process involves pressure and temperature. We will write, temperature can be nearly 185 °C and pressure of the order of 150 bars. We know that direct carbon sequestration, carbonation process, CO_2 mineralization, it is going to involve the temperature and pressure. The other way is via solutions. Which is why these solutions we have been explored. **(Ref. 35:11)**



One would like to involve the utilization of calcium in the solution which is why now we can understand why we are bringing in calcium from slag into solution because that will be involved in picking up CO_2 and it will be making relatively purer carbonates, relatively purer products. The phases produced after indirect carbonation will be relatively purer. The process involves lots of side steps, side processes and the optimization of such processes is also very difficult and both direct and indirect carbonation processes have been explored for steel making routes and they have been described with varying successes. In the upcoming classes, we will be discussing on the different wastes that are available in steelmaking and ironmaking industries. We have covered ironmaking and steelmaking slags. We will be focusing on wastewater treatment and scrap utilization in the upcoming classes. Thank you.