Bulk Material Transport and Handling System
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Lecture – 25
Silo Failures and Maintenance

Hello welcome back to our discussions on Bin, Bunker and Silo. We have been talking about the storage system and already we have discussed about how the storage at a smaller scale as in the your different warehouses and also, in the Kirana shops, supermarket to big industry like thermal power station, metallurgical plants, still plant, port everywhere there are different type of storages.

So, out of this storage systems we are discussing on this house silo bunk and bean and bunkers they are being used and the we discussed today about an aspect of silo failures why we need to study then these particular appliances or applications as an engineering students you have learned designing, you have learned engineering mechanics, strength of materials, mechanics of solid.

You have learned about the different type of programming, you have learned this physics mathematics now. Well, we are working on a particular applications which are required in our country there we have talked about this silo, bin, bunker, now this failures there that will tell you exactly where this engineering works are required.

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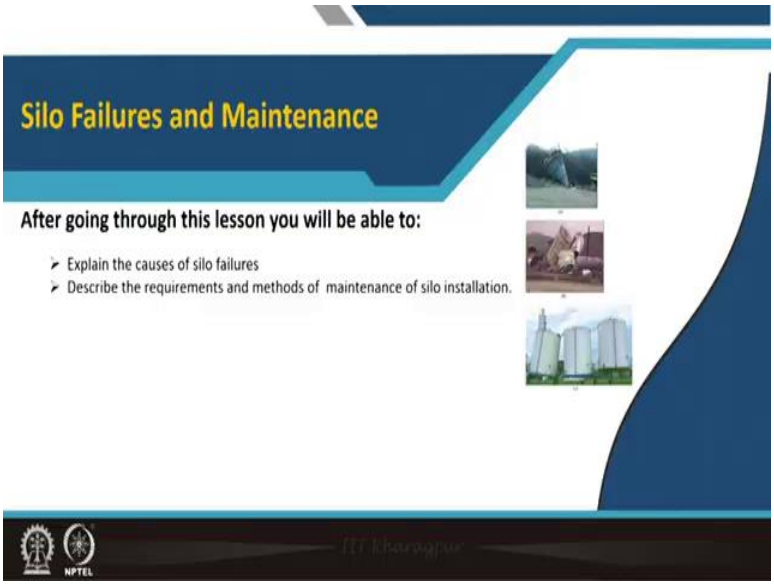

Now, our objective of course here not to design things but explain the causes of silo failures are described the requirements and methods of maintenance of silo installations, we will be giving some idea about how as you can see in this figures that the silo crown is lying somewhere all those silo whole tower collapsed. You can see here a silo is getting bands, in stabilities getting affected that instability has come in.

So, these type of some of the failures you will be understanding today and then maybe one more class I will take where we can give a brief introductions of how you go for designing. The designing is a totally different aspects of it here in this will be just knowing the methodology and some small design part we may be taking in one more class.

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But here today, you need to know how this failure takes place in an installation where you were there. Now, the failure is very important in the sense it can cause not only the loss of your property, loss of money, loss of productivity but it can be fatal also. Loss of life can also, be there. So, every situations wherever you are using in industry, there are some failure potential that means in a silo installations where it may fail and then he will have to take proper maintenance.

And then we will have to observe be vigilant on the system. But these 2 things you cannot do if your design and constructions are not proper. So that is why I tell that to eliminate future failure will have to take care of at the design table itself will have to design considering all the potential cases and then while constructing the construction time will have to take special attention the things become very smooth.

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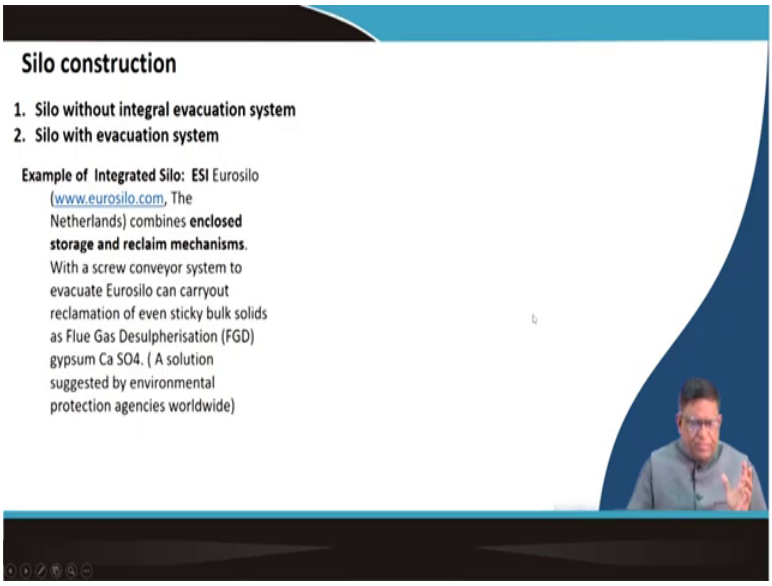

Now this silo construction which is it can be of 2 types, one can be that your evacuation system is inbuilt with the silo itself or it can be else separately or independent. Now, most of the things where you are having a silo are just only we are dropping it over there below a gate and you are taking it over there. This is exactly without much any other integral evacuation system in it. But in some time, you can have that for that as you have said there can be a flow a problem to that is your rat holing or bridging can take place.

So, in that cases or if a sticky material they are not good till flowing in. We can have some integral part of it which will be working as a flow aid and you will get a better if evacuation. Now, in this there are different types of silos are available in the market but one is that very large silo being designed and manufactured in Netherland company like a Eurosilo, ESI Eurosilo.

You can see some of this **(Video Starts: 05:21)** some of the type of silo they have constructed here you can just see that here the material, when it is coming from the your supply system a conveyor belt will be bringing the material from one end and then it will be going and then getting stored in this. Now, this is a very advanced system in which the material you can have that this is a telescopic type of conduit through which the material is brought.

And there have a screw conveyor system is there which is spreading the material the in the silo. So that the layer that material is getting formed within this layer. If you remember that we were

telling one problem particularly in coal silo that is your material if it is dropped from the top, then there could be breakage and more dust can be generated. But in this system, when you are the coal or that whatever quality of different quality of coal may come and they can layer by layer they can be placed over there a blending also, can take place.

So that your required calorific value can be obtained like that you can do it layer by layer, you can store the material and then another thing is there, the for evacuation, you can see that the evacuations will be taking place from the lower if you see the lower diagram here, this funnel flow that is your the material is now the gate is opened it is getting dropped from here. So that means that when you are doing the evacuations or that when the material is coming, you are doing the loading.

But both the cases you are this screw conveyor that which is being used, it is helping you to click the material and bring into the funnel shape, so that the material goes you are in a better way **(Video Ends: 07:27)** you can do it.

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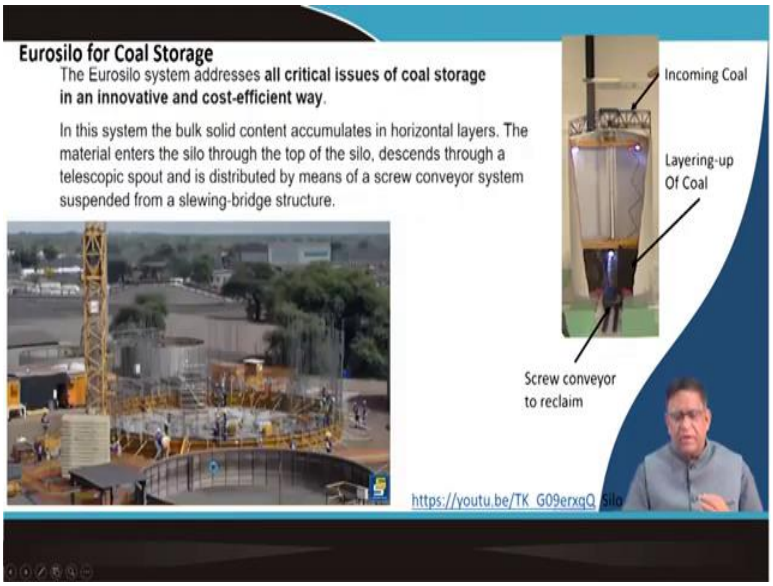

(Video Starts: 07:28) So, you have seen here that this another is when it is a constructed silo, for example, if you that cement concrete silo in a thermal coal, thermal power stations that cold storage, it can get built by step by step that is a huge construction work. That is the civil

engineering is a they have designed such a big that silo and then they construct it in a very systematic manner everything is pre-planned design that where the problem will be coming.

And then after constructing the whole tower, then the that they will have to place this the head tower head on the top of it you can imagine if the tower a head is being that crown is a manufactured that constructed at the bottom then we take crane it will be lifted and then it is placed over here. The type of wind load will be coming, the type of your the stability will have to be maintained.

And then because it will be sustained that with the help of your wear rope and clean and then it will be very precisely wherever the place will be kept over the that you are where you are on the top of the silo tower that will have to be placed. So that is why this whole Storage when did they get constructed, if there is any that is a mistake or if there is a if the precision is not maintained, the placement of the crown on the top of this silo will not take place which we will be creating.

That means there could be a catastrophe even during the constructions. So that is a failure may take place in different way. **(Video Ends: 09:25)**

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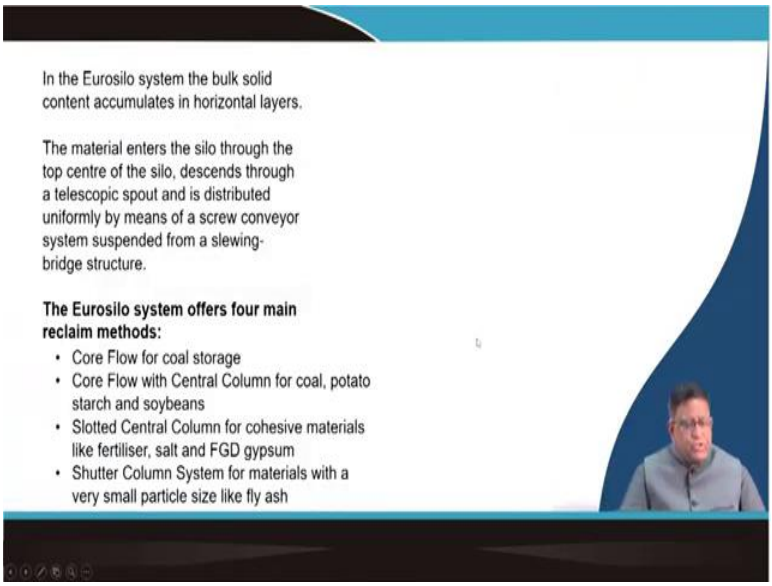

So that our even in a our in a silo system when our the type of reclaiming it can be done depending on that what type of material will be flowing in which way. Because in a coal silo or

in a your iron ore silo or if you are you are having this is your that is your fuel gas desulfurization product as a that is your manufactured gypsum which is a very sticky material. Those things have to be taken over there then how it will be doing. So, for that a different type of design of silo take place.

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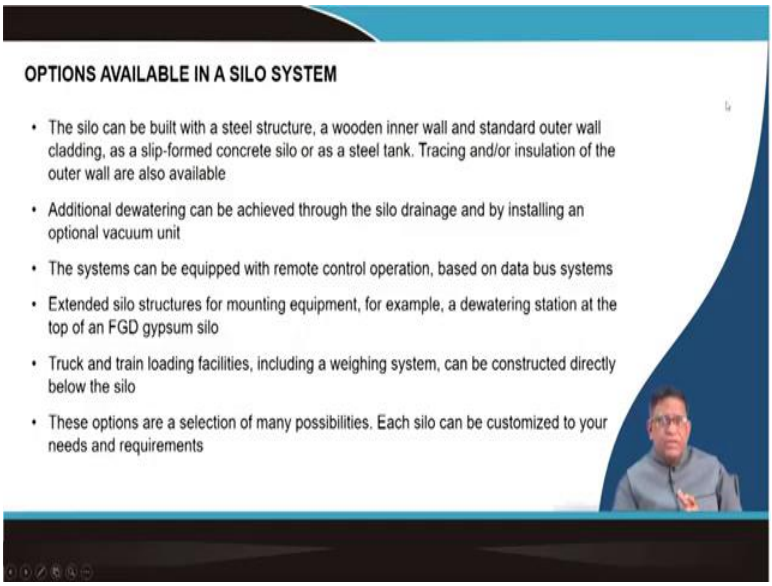

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And those silos, you can see some of the diagram that these there are a lot of informations available.

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You should try to see the placement of that crown this is a area where a big failure may take place. Because this will have to be very precisely placed over the tower.

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(Video Starts: 10:33) So, when we talk of about steel silo that steel silo, they can be constructed by bringing the modular form that means, all the components, they are separately manufactured and then they are all the components are brought to the site and then one by one they are erected. Now, as you can see that the whole components they are assembling operation, it is done over there that each and everything is given in the purchase manual and the construction manual in the site.

The designer and their manufacturer, they come and assemble each and every item and then they erect it. And after erection, they need to install and then commissioned, the commissioning will involve different type of your instrumentations and monitoring whole all the items are put together and then it is given a trial run and they will run it. So, when we talk of a steel silo, these are of different up to 500 ton capacity in agricultural sector, they are very much used for different purposes. **(Video Ends: 11:55)**

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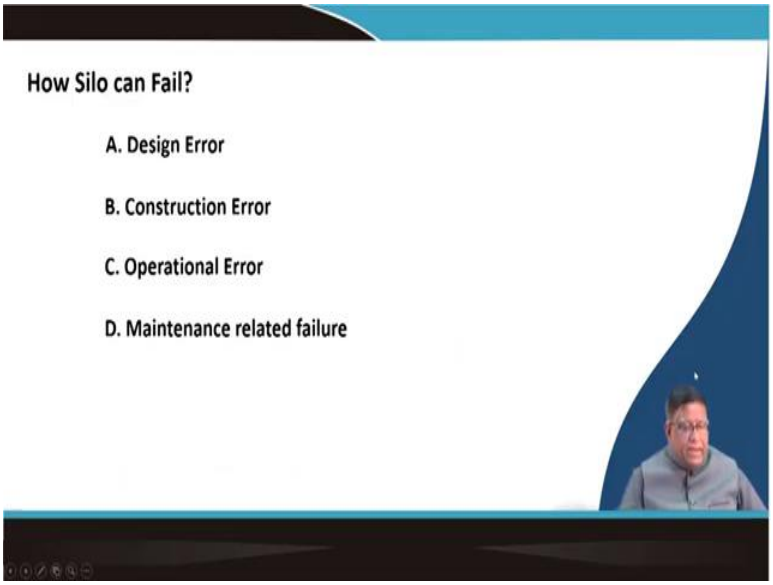

Now, this similarly, we have seen now that there are our reinforced concrete silo or steel silo but there is they are having a lot of potential to fail. Fail means they do not deliver the digit service. And this can be due to design error, due to construction error, due to operational error or due to maintenance related failure. The design error means at the time of designing that whatever the load, it is filled that it will be taking up if it cannot take that load means design, design error.

The constructions, if the alignment required if the material which is to be which is prescribed you are not taking the same material, then the operations different vibrations may come and in doing the operation when you are feeding in at that time, whether that you are feeding and evacuating systems, whether the material because of their property get changed you designed for a different moisture level.

Now, you have done with a material coming of a different moisture level at that time what happens bridging may take place while the bridge is breaking at that time suddenly a pressure may come then the pressure will be because it cannot dissipate particularly upward all the materials load is there. So, the your stress will be there on the wall and as a result the wall may collapse, sometimes the wall may fall down.

And then again there is a during the maintenance time you have seen that there is some crack you have gone for doing the welding at the time you did not take the proper that precautions that what type of welding? What is the thickness of the things will be coming and that becomes a weak point and from there the failure starts, lot of things may happen.

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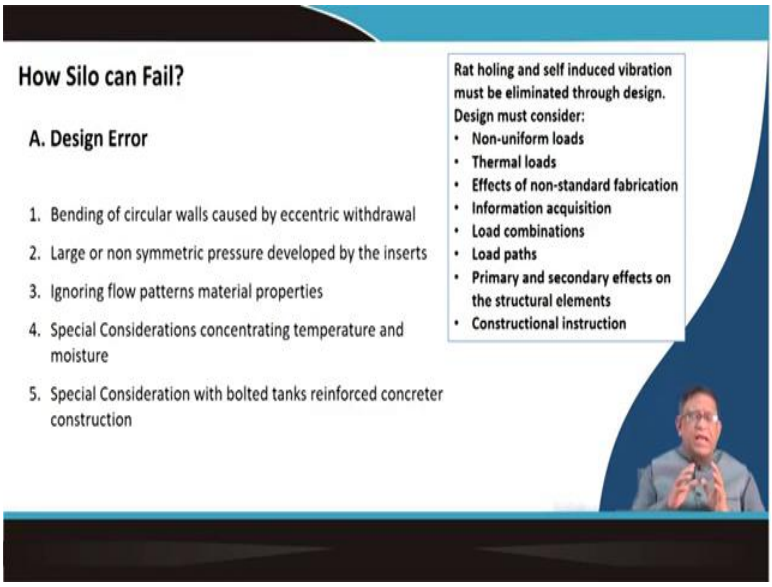

So, when we go for a study of a silo, as they are telling one by one let us discuss that the design error, it can be a bending of the circular walls caused by eccentric withdrawal. That while we are designing the silo, our material should come out that is if it is designed from the center but if you are taking at the that is your eccentrically that means not the center of the of the of your the cylinder.

Where you are storing the material and I work with on that hopper if they are not properly aligned during the design, if it is thought that because of the other evacuation or where it will be loading. You are making the evacuation that is your the withdrawal. Eccentric there may be a

problem. Then large or non symmetric pressures developed by the inserts, sometimes what happen insert means you need to put something, say for example, you can insert a cone so that the material can be taken out by the side of it.

Or sometimes you may give a rod or sometimes you may insert a conveyor over there. So that the material is coming very sticky it is not there, let us put one fluid. Like that inside the that is your for the operational and sometimes for maintenance purposes you can introduce some other material over there during that time the whole load behaviour may change then the flow pattern that we discussed earlier that whether it is a mass flow or a funnel flow that depending on the flow patron.

And the material property if they are not selected then also, there could be some failure, because sudden that is you may give you say there is a not coming you are giving a different vibrations at that time you may induce different stress. Then there are the temperature and moisture there also very important issue, then special considerations with the bolted tanks if you are sometimes you may have the you can say heavy silo for holding your liquid petroleum or sometime water and also, taken in a silo.

So, there if you are bolting that wherever you are having a nut and bolt you have got a whole those are the weak point. And there could be a stress concentrations which may lead to failure. And then rat holing and self induced vibration must be eliminated through design. Because, whenever there is a rat holing problem at that time the vibration pattern may get changed because of the material is flowing differently it is coming at a speed and at that time they are getting a gap.

It can induce a vibration to the hopper region. Then, if the loading is not coming uniformly that is also, another issue it can give a differential stress that the thermal load is that as I told the last class also that during the daytime it expands during the night time it constructs. So that is called the ratcheting thermal ratcheting in which your the when it is becoming when it is having under recombination at that time that it cannot take the material upward push.

So, it still material or that constant that the wall sidewall they get stressed. Then the fabrication sometimes if you are designing the fabrication but a non standard because of the economic region, sometimes you do not take the standards prescribed material you take a different type of and fabrication, it may give you problems. Sometimes you have not collected the proper information in designing, the material properties and are incomplete at the time also, you find problem.

And the load combinations that means your structural load, your dynamic load, your wind load, all these different load when you are designing, if you are not considering them at the time of designing, it may get a problem. Then the load part in which way the load is distributed to the supporting frame the load is coming from both directly, indirectly, partially those things will also, happen.

Then your primary and secondary effects on the structural element that when you do the structural analysis, at that time you will find that your the there is a after a certain things have happened say extra load has come you have got another column member there will be secondary stress will be developed which can be detrimental for that. Similarly, you are constantly constructional instructions if you are not complete say as I told in a steel structures, your one by one will be coming.

So, if you are that say while tightening them, if you have not tightened and say the diagonally first if you do a tight tightening in from side by side, you may find that other one is not getting properly tightened. So, even that the knob bull tightening sequence is also, should be properly instructed in the manual.

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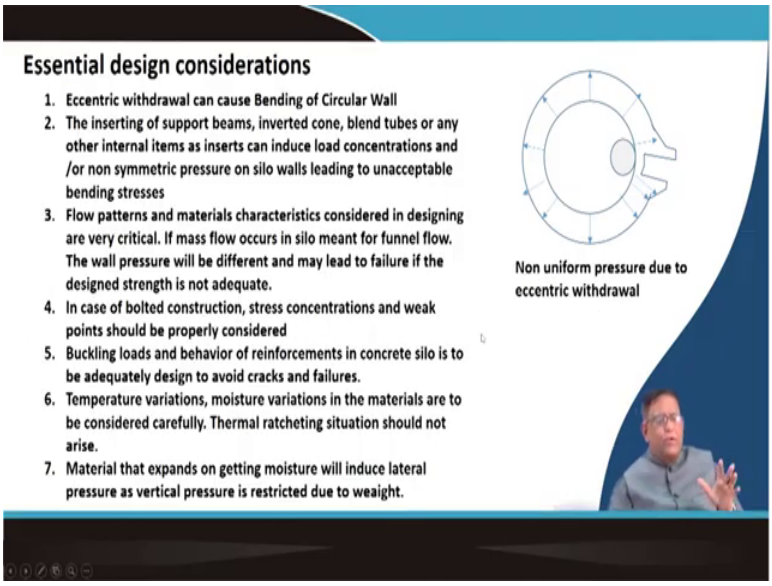

So, then only you can go in a bigger way. So, as we have discussed from there, we were telling that eccentric withdrawal can cause bending of circular wall, why? In the diagram you can see over here in this your this is your evacuation hole this is your from the top we are looking into the wall suppose this is your that concrete walls thickness. Now, when the material is over here, then there is a stresses will be coming all along the radial stresses are going but when you are having this evacuation point, there is a eccentric.

At these places, there will be some more stresses will be coming up. So, the this gives the wall or wall is getting differentially stressed which can lead to sometimes it can induce a bending moment, sometimes it can lead to ultimately a failure also, depending on the situation. So, this is an important that inserting support beams, inverted cone, bent tubes or other internal items as insert can induce load concentrations and or non symmetric pressure on the silo walls leading to an acceptable bending stresses.

This is where you are ultimately the failure may get induced the flow patterns and materials characteristics considering in designing are very critical. If mass flow occurs in silo mean for tunnel flow. Then there will be a problem the tunnel suppose your funnel flow design is for the funnel flow if the material should go like that but if the whole material starts coming over there, the stress which will be induced on the wall will be different and then if you are not designed for that it may fail.

Then in the bolted construction, stress concentration and weak points should be properly considered. Then the buckling load behavior and reinforcements in concrete silo is to be adequately done. Buckling is when you are giving a that is your compressive load at the time it gets bent. Number of failures have taken because of this buckling failure on the structural members then the moisture variations and the temperature variations they also, to be considered very carefully.

That thermal ratcheting I have just told you then materials that expends on getting moisture will induce differently. You know that the material that some of the materials are there. So, for example that is like in a some of the carbon (())(21:46) if your coal is coming along with the coal you cannot have it sometimes shell may be also, coming.

Now, if there is a the incoming material, they are bringing more shell and then it is on a rainy season that maybe your that if the shell come in contact with the water they will be started expanding. Now, this when it expands it cannot give the whole material at the upward it cannot be taken then there will be the literal stresses.

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So, like that your will get stressed and you can see that construction error may be there. So, this type of your wall collapse have taken place because the others are okay, this is not okay, at this

point that means there is a weak member. There could be some defect like this you can see the what is happening on that?

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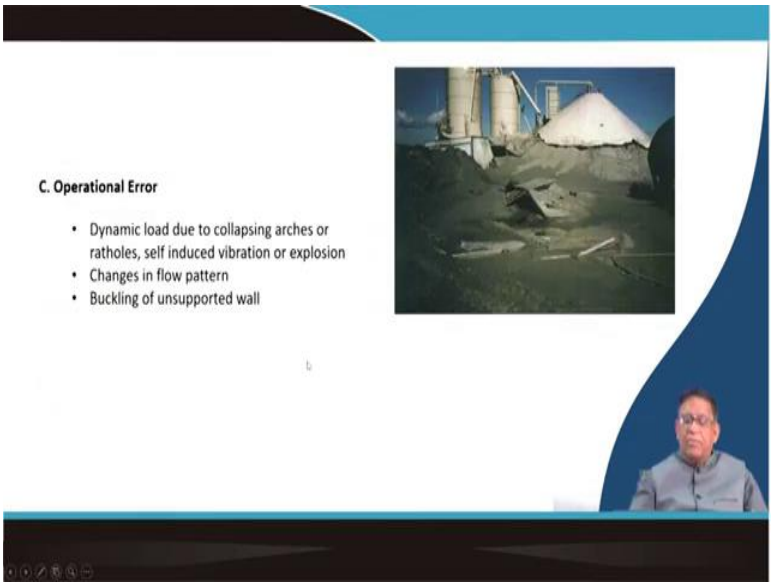

There is a operational error at the time certain things happen that suddenly you have got so much induce the whole collapse of the silo.

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So, this type of things may happen and the maintenance time you need to see that these are the cracks and all are coming. Sometimes the spoiling takes place because during you have not taken a maintenance for a long time or you have that some construction error also.

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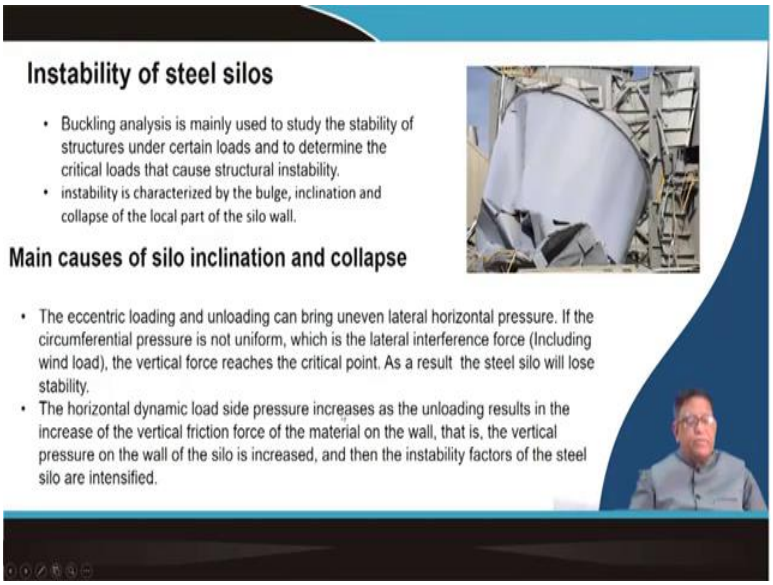

Then this instability is another issue which come particularly in steel silo because it becomes unstable that if you are settling that you are when you are bringing a heavy load on the ground. The ground also, will be having a movement at the time if you have not taken the ground bearing pressure into consideration and then you have constructed it, it may induce instability. Instability that is your may lead to the inclination that is you have seen in the previous picture also, the silo has turned back.

So, now that type of it can be due to that eccentric loading and unloading uneven literal horizontal pressure may come onto the your silo than the horizontal diamond dynamic load and the side pressure can increase as the unloading results in the increase of the vertical friction force of the material on the wall.

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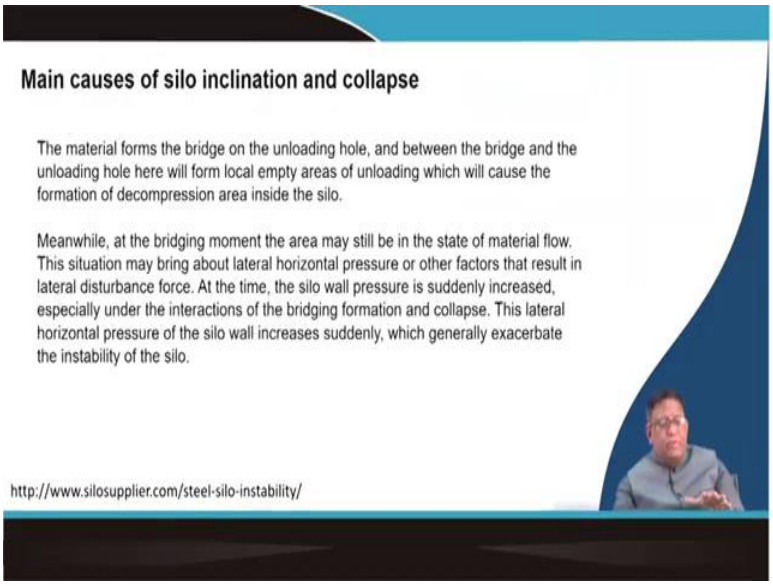

So, how these forces will be coming on to the wall there when you take the each and every component draw the freebody diagram, find the resultant of the forces. You can find whether the balancing situation is coming or not. We will be doing a little bit of exercise on those design aspects of it. The material forms the breach on the unloading hole and between the breach and the unloading hole here will form a local empty areas of unloading.

That is if you are having a local empty in the in this place, when it is coming over there unloading is taking place a void is there. So, at the time there is stress is less and when it is coming in a full at that time stress is more. This stress fluctuations may lead to again a your instability issue. So that they at the bridging moment of that area may still be the state of material flow that material while it is flowing at the time the dynamic load which will be coming over there, if it is not properly designed, it may lead to instability.

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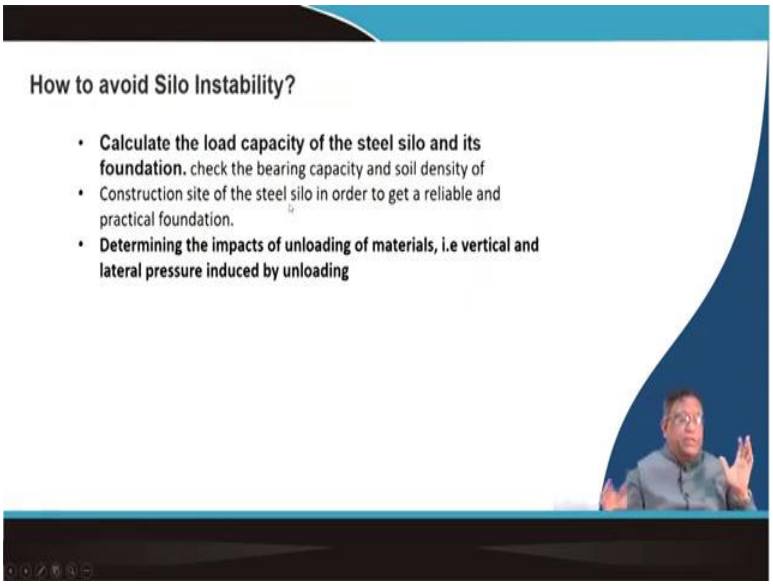

Now that silo instability, you can to avoid it at the time of designing, you must calculate the load capacity of the steel silo and its foundation. That is, if the total load over here and the foundation's harmonisations they should be balanced. If there is a imbalance that could be leading to instability. Then construction site of the steel silo in order to get the reliable and practical foundation is very important determining the impacts of unloading of materials that is your how the vertical and lateral pressure.

There is your there will be on the wall certain load will be coming as a vertical pressure and that your lateral pressures that division. We have discussed that in designing the silo, whether the opening diameter and then you are at which stage you should give what diameters should be taken, this is basically with your the distribution of your shear strength and this your pressure. Now, if the distribution is getting improper due to the material which is coming is different then your silo will be subjected to failure.

So that is why, while designing the silo, you must have an idea that particularly it happens in the mining sector, because there that what will be the material coming in that chim after sometime is many times that a little bit uncertainty is there. Because the whole chim of the ore may be heterogeneous. Now, if there is a very good high fluctuations, particularly in the fluctuation in the density, then there will be a problem.

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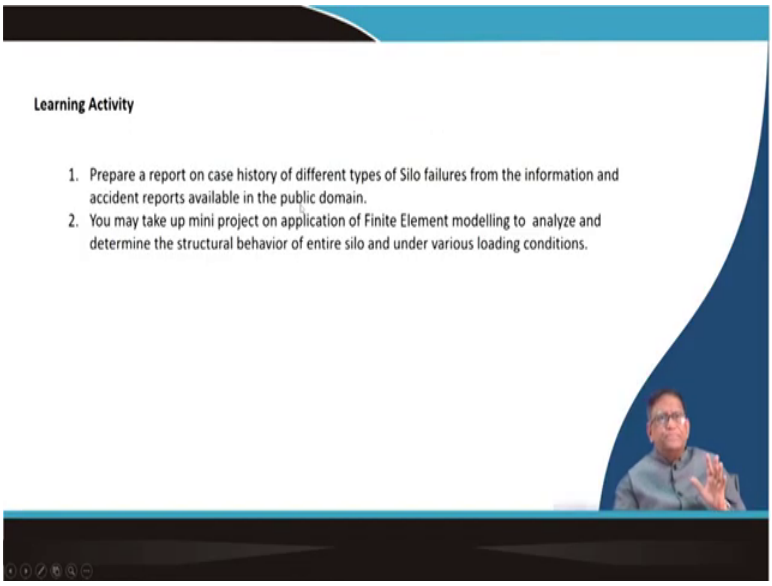

Then, what we have discussed here today, it is just to give you a bird's eye view of the what type of failure problem may come? But thing is that before going to the design aspects of it, you need to do a little bit of exercise, you tried to prepare a report on the case studies of different types of silo failures. From the information and accident reports available in the public domain.

If you look into some of those that will give you an idea that why we when we go for a designing with a particular calculations you will be getting you will be able to appreciate that why those factors are taken into considerations. And also, you may take up a mini project on application of finite element modelling, to analyze and determine the structural behaviour of entire silo under various loading conditions.

So, those are exactly a little bit of elaborate work, we will be discussing only the very basic principle of designing in our next class but what you will have to do, if you were interested in the subject, you can apply higher tools and technique for analyzing and designing and coming into it.

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So, there are a lot of references are available about this because Contemporary Studies, because of number of retrofitting works are going on and this area has got a lot of the though wondering you may be knowing this silo design and this flow patron studies. These are pretty old that chan case studies of 60's 70's still they are using those formula which are developed at that time steel doors are being used.

But recently the their needs and necessity has increased because of the environmental guideline and we need to get go for a close storage system.

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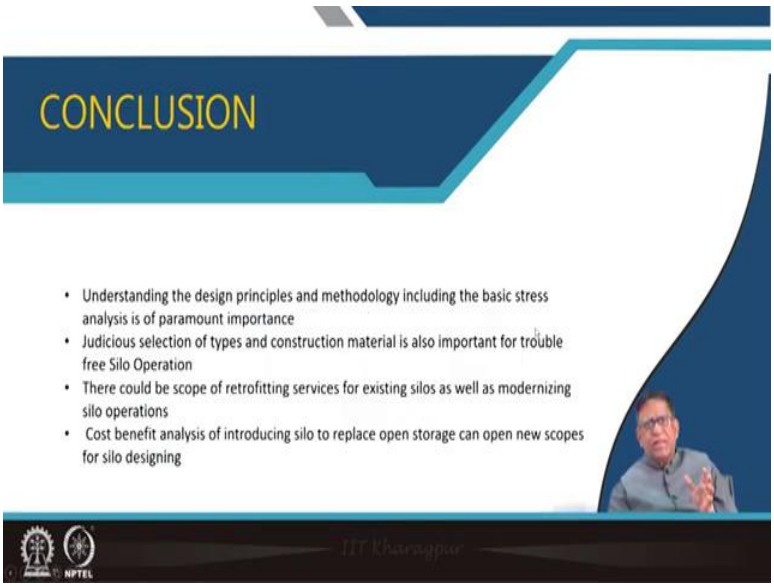

So, I request you to go through these articles and then you will be able to the understanding the design principle and methodology includes basic stress analysis that is of paramount importance. So, we will try to see how the stress analysis of a silo can be done. And then judicious selection of types of construction material also, important for trouble for shallow operations. If you want to avoid failure your right type of silo for the right type of material that is the guiding rule.

That your failure free the construction and failure free design and maintenance is possible when you will be selecting the things properly. So, certain design aspects and the failure aspects must be known. So that you can prescribe properly, what type of silo will have to be selected and how it will have to be constructed. And there could be scope of retrofitting services this is what will be upcoming business in many places.

Because many of our open storages it can be made equals that is your close storage by which your environmental footprint can be reduced. And but as I indicated in our previous discussions that it may be your high capital investment and their return on investment may take longer time. So that is why a cost benefit analysis of introducing silo that can be some of you can study of that in what is the methodology for doing cost benefit analysis.

How the economic terms are taken, because in the next semesters you will be studying about the mineral economics or that you have already studied engineering economics. So, if you combine this together, you can do start working on this how to do the cost benefit analysis for avoiding failure that and that failure cost analysis is another one which you can do while you were studying different case studies for silo failure. Thank you very much.