Bulk Material Transport and Handling System

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Lecture - 26
Basics of Bin and Silo Design

Well, we have studied about the stacking and reclaiming and then, we started talking about the closed stories. Now, as in the last class I told that we will be touching upon something of the design aspects of it. We are not going to do the detailed design of bin or silo. But here I will introduce a basic concept that how the whole designing operation is done. Because with the, new our budget as it has planned for that in which way our infrastructure will be revamped.

And there will be a lot of opportunities for improving some of our stock situations. As because all over the country there are number of open cold storage. Like in the thermal power stations, in the port, in the fertilizer plant, in may be in this our railways siding area. Mind these stocks if it is brought into a closed storage system then there could be a lot of environmental benefit out of it. As well as it could be a long-term life cycle cost of operations of different systems also may improve.

So, in our country there are certain houses who are doing the designing job. But as in the last class we told about the euro silo that who are doing mega silos like of 100 thousand meter cube capacity. Those types of business and those types of manufacturing hubs should be coming up in India. But before that two three different type of studies are necessary as exactly having a national level database of our open storage systems.

And then, potential of the business potential for the closed storage system those things will be done. But nevertheless, we should be prepared to design such facilities. So, today I will be just discussing a very brief outline.

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And also, I will be as I have told earlier, we will be doing some so that you can explain the basic concepts of bin and silo design.

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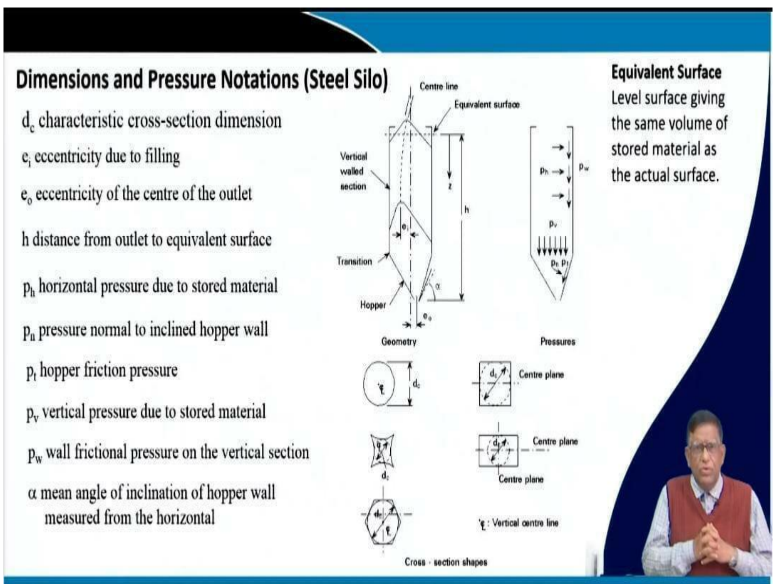

Now, here the first thing we need to know, the different dimensions and different pressure notations when you are going to do. And you should be able to read the design literature and you should be able to follow some of the design related lectures which are available. So, thing is there here we have taken out a figure from this structural silo design lectures I have given at the end the references. I request you please go through that.

Now here you can see that once particular design example has been taken which in the previous lectures, I have not shown you about the eccentric loading Bin. Now, you can see here that what is that eccentricity that means we can have some time designing a silo that your the opening discharge is at a different. The centre line of the discharge point is different from the centre line of your loading point. That silo that material is getting loaded like this and that it is storage.

So, the different geometric parameters that are required while you are designing you will have to that what is the characteristic cross section dimension. That is very important that your opening, how it is going that characteristic dimensions is important then, your how much the eccentricity of the filling. Because, if the storage is getting this is the centre line of that and then whether your loading is having this much of centricity material is being loaded here.

And at the same time that when it is going out here also the centre point of your evacuation point that is having a eccentricity. Now there is also the distance from the outlet to equivalent surface. Say you can see here, you have got this is where your things are going out and then here where it is the, this material we can have an equivalently if this is levelled out it may fill up, up to here. So, this height is called your distance from that is equivalent height.

Then, this material when it will be coming over here it will be giving different pressures. These pressures and then the stress which will have to be withstand by the structure that is very important. So, when you will be designing you will be designing whether if it is a steel silo or steel bin or it is a concrete silo. That will have to be designed for how much pressure with standing capacity that means how much stress it should be there.

Then what will be the if you are having a still that material will have to be how much strength. So, this pressure what is the horizontal pressure because of the material here it will be giving a pressure over here. And then there will be a vertical pressure which is coming down over here. Now there is an inclined surface on that incline surface you have got a that is your upper friction pressure will be coming or the tangentially and normal to it will be a normal pressure to the hopper.

And then, there will be a wall friction because this material when it will be as a mass flow it will be flowing down. Then, this will be giving a friction then how much is this friction that is very important. And then, another important point to design is what is this, your angle at what angle that is called your mean angle of inclination of the hopper. Because, these parameters they will be exactly affecting that your behaviour of flow.

And then that how that is if there is a weakness in your structure it may fail. In the last class we told about that, how that your bin failure may take place.

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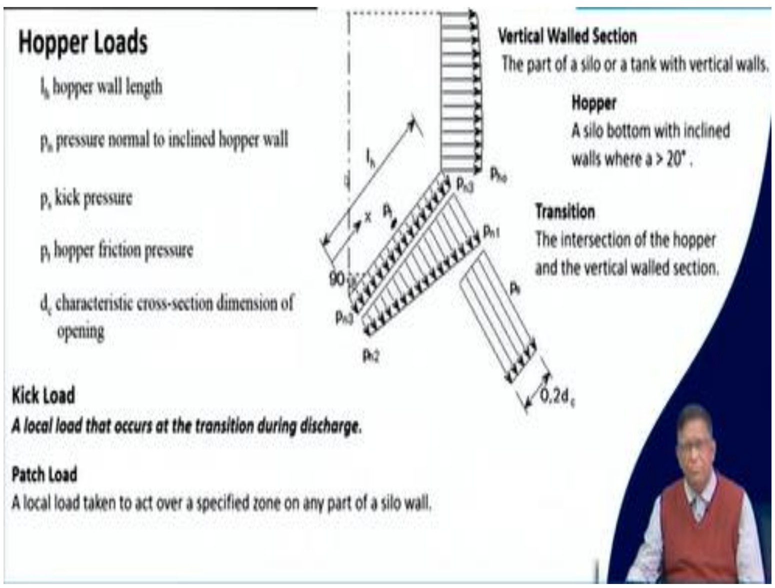

So, then next thing what you need to know in the hopper portion below here, what are those, this hopper load that is here? On the hopper wall we have got a hopper length that this is your the length of the hopper. And there we are having a normal pressure that is which is shown in the previous figure. You can see that these normal pressures this have got different components it may come. Then, the hopper friction pressure that is there.

And then there is two three things to be known that is your kick load that is a local load that occurs at the transition point. This point is a transition point your material was having all this horizontal then there was a vertical and from here we are getting this a tangential in this different this is your a transition point. Here, whatever the load will be coming it is called your kick load.

And patch load is when you are considering a small portion of it then on that whatever load will be coming that will be called as this.

Then, while designing a hopper or a bin or a silo that in particularly bin and silo we have got a vertical wall section and then the hopper section. Now this inclination angle sometimes there could be a silo or bin it is totally flat. Because you are having a good flowing material even if you are flat then you just open the gate and the material will fold up. For example, if you are taking a mustard seed on a bin then, for that mustard seed that the bin if you just keep a flat one.

And then there is a small hole then also the material because it is a highly flowable material, material will get discharge.

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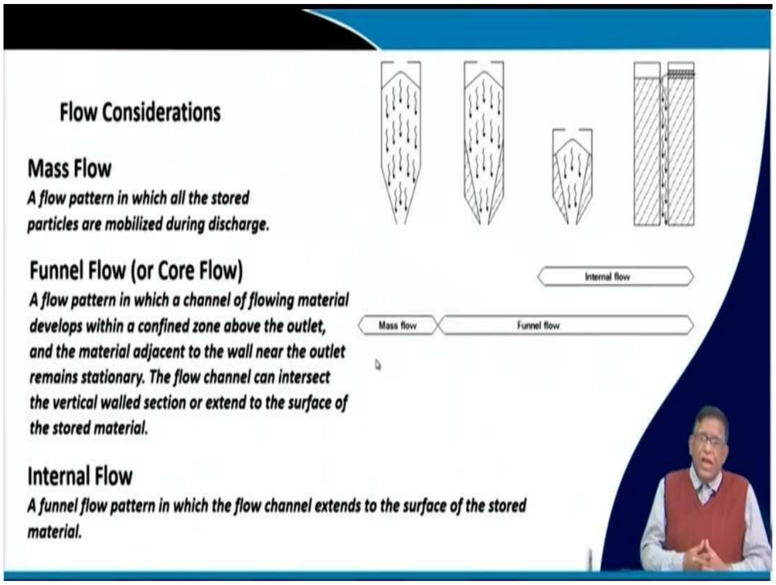

So, then the design should be considering that what type of flow behaviour you want to get. This also we discussed earlier that we may get two types of flow that is your mass flow and the funnel flow. And then, there could be an internal flow that means sometimes you may design it to have a rat hole like this. The rat holing is a problem but, sometimes in some cases you may have even the rat hole formations that is you want to take the discharge on this week.

Because, if it is there you are keep maintaining a static pressure over here and then if it is a highly abrasive material then also your the silo or bin will not be affected because, the friction will not be there with the material and the valve. So, then your, if you are to get these things then what comes the most important things to start with the design. Because, the material is the main your determining factor here.

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Now that, when you will be designing a silo; you can have a bin whether the size of it. You can have sometimes very small bin, intermediate bin, large bin, or eccentrically designed bin depending on your the type of material. Normally your in a bin you may have up to greater than thousand tonne bins are considered as a large bins. Now every country they have got the standard institutes they give the standards.

Because, for the safety the workplaces for this design will have to be, you cannot make any design with that all the permitting and licensing authorities they will not give you the use of such type of things if it is not that is following the required standards. So, that which class what you will be doing that will have to be decided.

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Then, the starting the process will be first you will have to the strength and flow properties of the bulk solid. So, that is why in a any design for transportations for storage and then for other handling your material properties are the most important parameter. And that is why you will have to go for these laboratory studies of the different properties. I think in our first and second lectures we were telling about that what are those state.

And then these tests are also to be done as per the, that is your international standard accepted by everybody. Say all laboratory waiver is being used for doing this testing will have to see that this laboratory is following the standard norm. And if you are in industry, you are not going to take any certified data if that laboratory is not accredited. Now for the getting that accreditation you will have to have those standard equipment that is in the first part.

Now that what are those properties mainly that are exactly, we will be requiring its abrasivity, it is that compressive strength, its shear strength, its flowability, its handleability, it's that moisture content. It is sometimes the responses which much. Then, these are the main properties that you will have to design. Then, the bin geometry, now that you will have to have here all design you say first trial and error.

And we need to do a brainstorming depending on what are your space availability, what are that your location of uses, whether it will be there in planned and that if it is a in between a buffer stock between two processing operations or it is for the final your product to be stored because, if it is your intermediate buffer stock keeping bin you will be loading to the next processing. But if you are taking the bin for the finished products that which will have to be transported either by truck or it will have to be packeted.

Now depending on that the geometry of the bin will have to be different. Because if you are thinking of that your product which is coming after, say maybe in some processing plan after the things you are getting in a wet process, you are doing it by drying after drying, you are getting a powder form or a some particular segregate size those are coming and you are keeping in the bin. From there if it is to be packaged may be a small packet or may be bags.

Depending on that your the geometry in which way it will be going whether, it would be having the bin with a spout for this once whether it say you are going to get it taken out by a vacuum or a force pressure or it is just a free flowing. Depending on that your the bin geometry will be designed. Now that along with that the capacity of course that is your carrying capacity of the hollowing unit that will be defining.

Because your what is the time for your storage, when you are going to design. It will be a simple calculation will have to be made if you are doing to a packeting purposes. Then the packet for each whether, you will have to release the material at what rate or it is continuously flowing and it is going over there. Now then what should be the storage capacity for a but 1 hour 2 hour 3 hour then, you need to decide depending on your processing whether, you want to stock for a 1 day stock 2 day stock or 1 hour or 2 hours stock.

And once the stock that will be determining the capacity. Then your the pattern that is whether, it is a totally your material it is flowing continuously or you are going intermittently. This whole thing will be telling that now you need to see the design, whether you want to get a square type of bin vertical person. And then, you may have a pyramidal type of hopper or you are having a; that is your rectangular big that is your bunker type of storage systems with the bottom number of evacuating that geometry will be different.

Or you want to have a weak circular silo and in that there will be a hopper whether, it will be a single hopper or double hopper. If it is there a hopper then, it will have to be loading onto an ongoing railway wagon or it will be loading on a truck or it will be feeding with a feeder to a conveyor belt. Now once these are specified you do a first conceptualization in the design. And this geometry separately that is your what will be the roof cover will be given in which way.

Depending on the how the material is coming and then what will be the transition from your vertical to this ones at what angle will do. Now if you are bringing a vertical wall and then suddenly when you are bringing it over there at that corner point there will be different type of stress. And there the kick load will be coming. So the type of geometric structures whether, you will be using overlapping and whether, you will be making them to join with a bar joint.

Or you will be welding or will be making with the same sheet metal will be giving or inside you will be giving a liner so that your some stress will be released, those things will be coming in your designing part. Then, the other important thing is you will have to estimate the bin wall loads that is how the wall is getting loaded. In the previous diagram we said that there will be a horizontal processor coming on to the bin and also the vertical pressure.

Now ultimately if you are going for say thinking of a steel structure then it will be a cell type of structure. Some of you in a civil engineering you might have studied about that how the pressure vessels and pressure cell type of structures will be making. It is different not like just on a rod or a Bin how the load is coming. But where you are giving a circular and then a cylindrical shape the stress will be different. We will have to consider how will you consider the hoop stress there.

Now the thing is that, the bin load how much it is coming once you calculate then you will be knowing that what will be the stress, and the stress is determined to find out what should be the thickness of that wall. If you are doing is a concrete then exactly how much reinforcement will have to be placed over there or if you are making sometimes in grains and all we are keeping bulk material even in a wooden silo could be there.

Even in a other material or your metal alloy plates can be rounded to make a wall. So, you will have to consider that by on the wall loads. And again, that one wall load will be say that the if you are having a keeping say titanium oxides if you keep it or you are keeping sometimes say for example in a tungsten carbide storage small bin you are making in a plant that you want to make this for the manufacturing of the drill bits.

You will have to have the tungsten carbide powders, you are making it over there in between your storing and then going for that then, in that manufacturing process there will have to be in keep some silo. Then depending on the density of the material is different. So, the load will be different and accordingly will have to make it. Then the design and detail the bin structures, once that is there you have got the basic concept but that will be now supported somewhere.

Then, for supporting what type of supporting structures will be there whether, it will be on a platform whether, it will be on a post or a structural post or it is on a reinforced structures those area also will have to be designed. Now one point you can understand from here that, designing is you will have to do a lot of that depending on the situation where you need these points to be taken.

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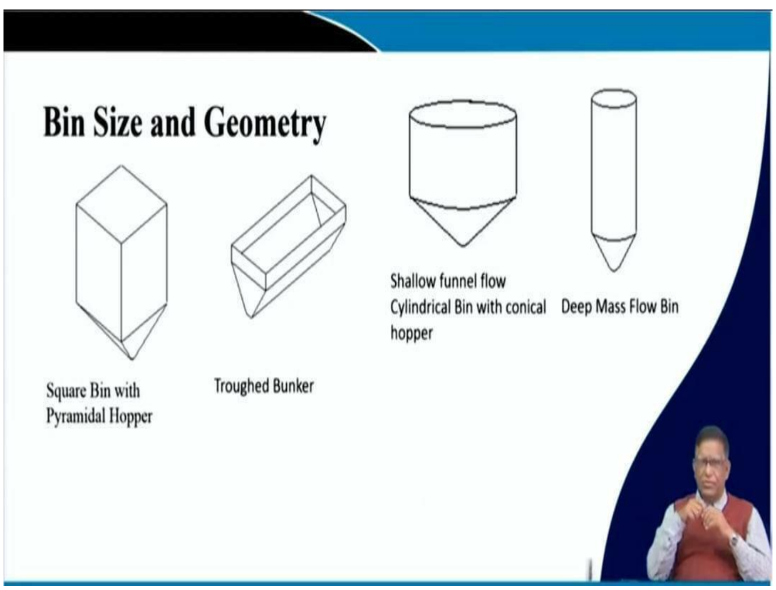

But then you will have to apply your basic engineering knowledge. Now what are those? First thing is that the size and geometry. You conceptualize file that is okay, I will go this type of, these are my alternatives. In the design we will say if we put this type of things then, how my system will be behaving and then if you have to construct it then what will be the total material requirement, what will be the material cost and then what will be my manufacturing difficulty.

In some time, you may find that if a good welder or good derivative type of things in a small bin preparation with a square type of and it will be very easy people can do it very quickly. But then one thing is that somebody will say okay with this how much exactly steel will be required for keeping the same volume. This type of problem you can do every design problem you can formulate and start doing exercise that with the.

To retain the same volume of material, which shape will be requiring more surface area, which shape will be requiring more steel then you can decide that if we are having this different type of shapes then which one will be having more difficulty in manufacturing. Another could be criteria of designing that if we are having these different shapes, which shape will be giving that structure more stress.

That means which type of structure will be more prone to failure because of certain inherent that stress behaviour. So, now is it clear that while designing will have to go one by one and then to find it out.

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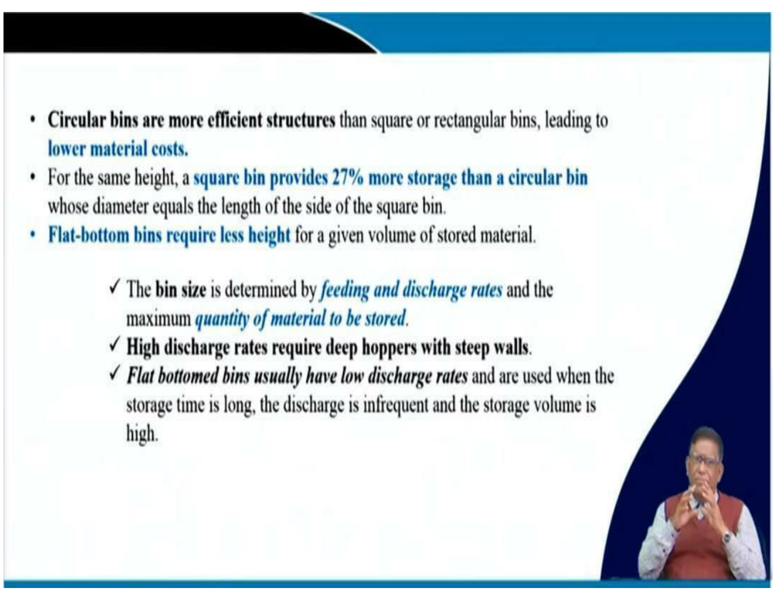

So, for example, each of the type has got its own advantages and disadvantages. You get circular bins for very efficient structure than the square one or rectangular bin. Because, they will be circular bin with the same amount of material it can a same amount of that structural material still you can get more volume. So, as a result, the material cost for a given volume will be less in case of a circular bin.

But for same height that your square bin provides more storage space, if the same height of one with that keeping the equivalent diameter. So, this type of geometric and volumetric calculations you can test whether the statements are correct or not by putting a simple mathematical relation you can prove it. It is possible. Then the flat bottom bins require less site because you know that when you are making a hopper thing with a 20 degree or 40 degree or 60 degree as you go more it will become longer.

You might have seen even sometimes even for temporary storage in a cyclone, because of the lower one is such a steep angle and then going to a very low diameter it takes a lot of space. So, your the platform in the plant you will have to keep a lot of height lot of space. But flat bottom if it is there, there is no requirement of that hopper length so, it could be compact. Then, this other than the size is very important that how will be determining that.

What will be the size of your that? What will be the capacity? What is your feeding rate and the discharge rate? Because, in a meal or in a plan your operations will be going continuously at what is your receiving rate and what is your discharging rate and then how much volume your active volume all the time. Then sometimes because of the flow behaviour certain there will be a dead stock.

Now when there is a dead stock at that time that your if it is a rate rolling occurs that flow rate will be reduced at that time the demand will be fulfilled or not. So, these are the things need to be considered while specifying okay. The discharge rate say for example in the thermal power stations we will have to sell the same coal say 5000 ton per hour will have to send it. Now that 5000 ton per hour will be going by a conveyor belt.

Now to feed the conveyor belt we want to have a silo, now that what should be the minimum size of that silo. We can calculate it out by simple mathematical relationship because, this that is the what the question will be coming at what rate the that your feeding conveyor belt is there giving the material to silo. Now the feeding conveyor belt can be having a variable rate because the feeder conveyor belt which is bringing the material to the silo on the thermal power station.

That belt may be loaded at different places by different stick dependent reclaimer. Now at any time that there will be three reclaimers is feeding to the feeder belt. And each of them having say maybe 2000 ton per hour capacity. So, when all are working there will be 6000 ton per hour will be coming and then your material is going at a 5000 ton per hour. So, after some time that will be overflow then your whole conveyor and all that thing will be there.

So, you will have to know that if all these are working at automatically a signal must go that one of the reclaimer will have to be stopped. So, this feeding rate and the discharge rate the whole system operation control need to be part. So, that is why designing will have to look into that in which way our this will be coming. Similarly, that is you will have to determine that, how much quantity to be stored, then high discharge rate required deep hopper and steep wall.

That is if your discharge rate is to be more than your these conditions. So, for that the designing will be there. Then the normally the flat bottoms one will be for the low distance that in the bin we are telling.

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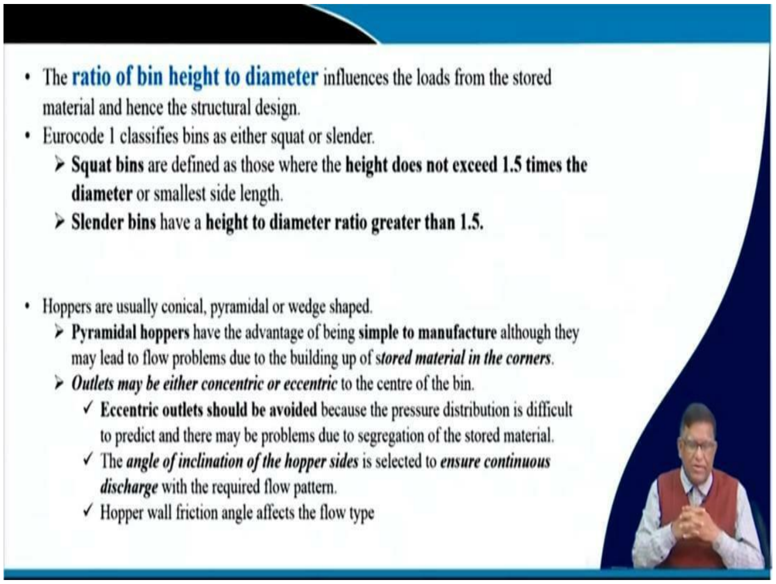

Then this ratio of the bin height to the diameter because this will be having impact on your structural strength. So, that in Europe they have got that Euro code they give the specification and the standard will have to see that how depending on that different bins are given different name in Europe. In Europe there is a squad bin where the height does not exceed 1.5 times the diameter that those are square bin.

And slender bin which will look very thin that means their height to the diameter ratio is more than 1.5. Now if there then that exactly when the whole load will be coming you will be knowing those you know structure how the buckling load may come over there. If it is having a too much of slender then over their height that how the load distributions will be there whether this will fail under buckling load or not need to be seen.

Similarly, hoppers are usually conical pyramidal and wedge shaped now, different type of shape has got different type of manufacturing processes difficulties those are to be taken in designing. Then, the outlet which is taking the material as we said in the previous one diagram it can be eccentric also sometime you can design eccentric. But when you are doing an eccentric, you will see that there will be a difference of your pressure distribution that need to be taken into consider.

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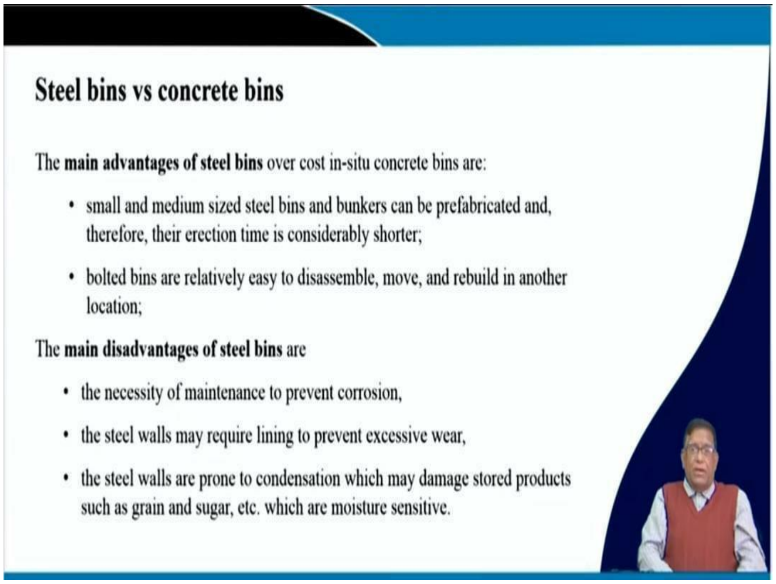

Now, then you will have to also in the design that when you are talking about the material whether you will be going a steel bin or you will be going a concrete bin. That is your when there are different advantages and disadvantages so, you will have to enumerate that. In a steel bin you can find out because it is your sometimes for smaller constructions, they are considerably they are going to be cheaper.

But then the pre-fabricated one and also sometimes they can be bolted and they can be shiftable they can be taken from one to another. But depending on what type of material you are keeping if you are thinking of keeping a rice or a grains then you know in a winter season and then, there is a your that if it is called your some condensation takes place. From the atmosphere the moistures get during because of the coal that the water will get accumulated in chat distance.

Then your if the grains inside that get wet then it may get spoiled. So, depending on the material you will have to see if you are keeping a concrete beam and wall even in the winter season there will not be any this, moisture formations inside that will not be there that can be thought of.

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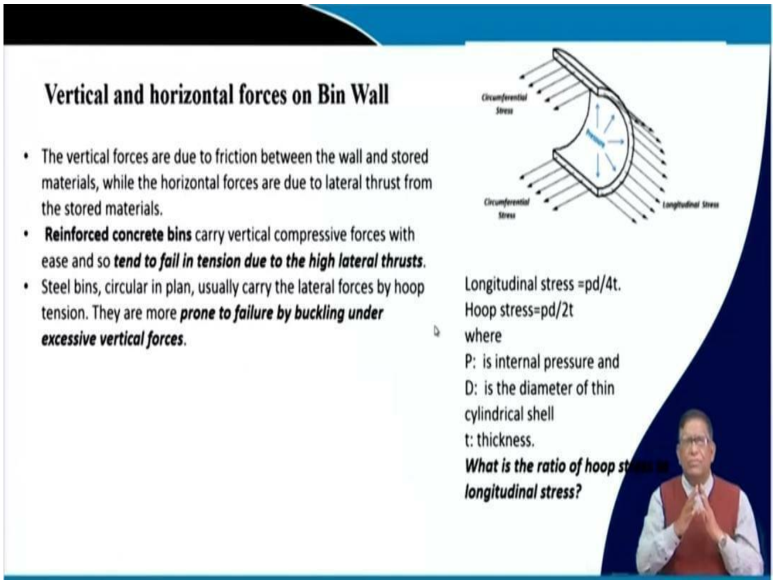

So, these types of issues need to be seen. But as I said earlier also this vertical and horizontal forces on the wall need to be sent. All of you may be knowing that your hoop stress because, when the material will be here there will be pressures will be given to the wall, that wall pressures because of this is a given a shape of a circular shape there will be a circumferential stress which is called also hoop stress and then there will be a longitudinal stress.

Now this hoop stress which is normally given with your internal pressure and the diameter that divided by your 2t is that thickness so that your this circumference hoop stress it depends on the thickness of this steel wall. We are talking of the steel then, in case of a longitudinal it is given by that is pd by 4t. You can see that the ratio will be just half but, that means which the material how it will behave this the distribution of pressures need to be considered.

Now in case of your RCC bins then what with their, the vertical compressive forces will have a they will tend to fail in the tensions that which type of forces will make them to fail. So, those things are considered in designing the things. Now say in case of steel bin that is a normally the circular one is adopted and there the lateral forces this hoop tensions need to be looked into carefully.

Because, they can be failing (()) (30:20) because it is here as you say that your which stress hoop stress is more that means it is below that is longitudinal stress it is coming less. But thing is that if it is subjected to your vertical pressure then they will be having a more tendency to buckling. That is types of things are to be considered in designing things.

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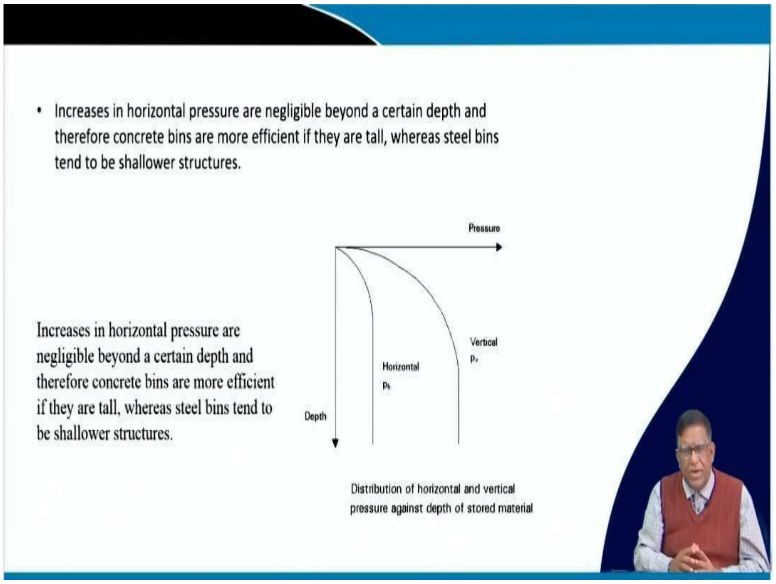

Now on a long tall silo that is your how the pressure vertical pressure and horizontal pressure it varies there are in the (()) (30:49) book all the design books of silo you will find that the day initially very then later after sometime the variation becomes very this almost negligible. Now that is why that increase in the horizontal pressures are negligible beyond certain point.

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But here that while the designer must take a very clear idea and the designing it will have to take a lot of other considerations into point. In a one class we cannot bring out the whole design calculations and things over here. But I wish that you know that how the designing can be affected by lot of factors including that is your temperature variation, consolidation, moisture content, segregation, the degradations of the material.

It may take place if you are not taking in a proper type of storage and taking out if it is having a long-time storage or dead storage. The dead stood material their quality may get changed then how it is a abrasion impact of pressures rapid feeling and (()) (31:54). Then they if they get powders then powders may be having a different behaviour then if it is cool and all their dust which will be getting accumulated with air, they can become an explosive mixture.

So, that those task explosions may take place that there. If the materials are taking different type of settlement if your eccentric loading in one side it is getting consolidated in another side. It may be loose and then there would be a different type of problem then there could be vibrations in the structures. Because of that vibration the material they can get differently segregated then your the discharge equipment on which it will be putting then total how much the load is coming. Because of the roof different type of combination of load so many factors are there.

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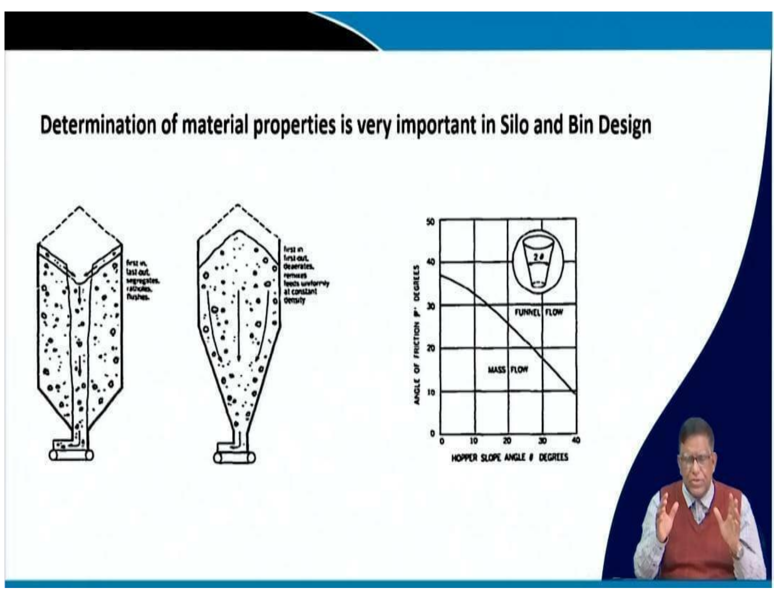

And but what the main in the designing we have discussed earlier also. The angle of friction of the wall and the material that ultimately will be deciding which factor, which type of that flow will occur. So, that is why at that stage of designing your very important is to know the behaviour. And there are experimental data that is design handbook they give this graphs and curve which will be the what flow resin for what type of friction angular friction, what slope angle to be selected this will have to be done carefully.

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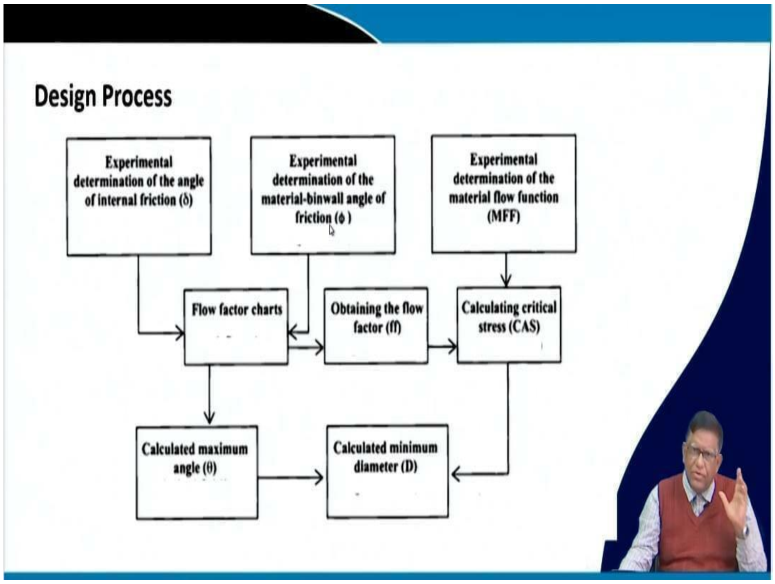

And then once you do the whole design process is I told it in the other class also that experimental determination of the angle of interventional friction, experimental determination of the material bean wall angle of friction, experimental determination of the material flow function then flow factor charts need to be collected. Obtaining the flow factor is very important then calculating critical stress.

This we discussed earlier in the class then, calculated of the maximum angle theta which that your hopper expression will be there. Then the calculated minimum diameter these things will be going on while as a designing process.

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But thing is that there are lot of issues you read this articles that structural design of bins for the steel silo you can get a very good idea.

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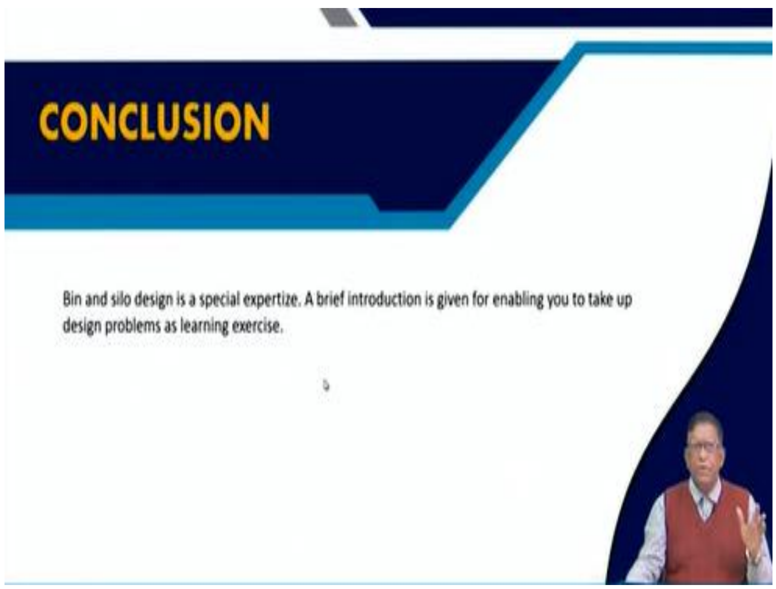

And if you wish you will have to take, if you want to take this is an area of your expertise development. A systematic study of the bulk material properties, how it affect the design and then making a list of the design formula and doing them over there and doing some exercise will be necessary as a learning exercise. But with this will be stopping the discussion on our bin silo and bunker will be going to the next topic.

But I wish please take up some of your design related problem. And go on doing the things while working you will be learning. So, that is the things, now the text books which are there please go through that and this is as I said the design part is a very, very old one that classic designs are there. But today a lot of innovations have come and you will have to take that is why I told you to study about the websites of euro silo.

And then you develop start a writing and finding out what are the new trend has come in designing of this. Thank you very much.