Bulk Material Transport and Handling Systems
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Lecture – 11
Size Selection and Power Calculation

Welcome back to our discussions on bulk material handling and transportation systems, in which, so far we have introduced the bulk material handling operations in different industries and also we have discussed the general applications of different types of conveyor belts. So, today we will be doing little bit of exercise on how the belt conveyors are designed.

Now, for that as I already told you, please refer to the CEMA handbook that conveyor engineering manufacturers association handbook and also some of the theory discussions in books of Spivakovsky conveying machines or by N T Karelin's book on mine transport. These are books where these are discussed but there will be number of classes required for, if you want to go really for the designing of a conveyor belt system.

So, I will be introducing the basics only and then you will have to take up some of the learning activities so that you can really capable of designing a conveyor belt.

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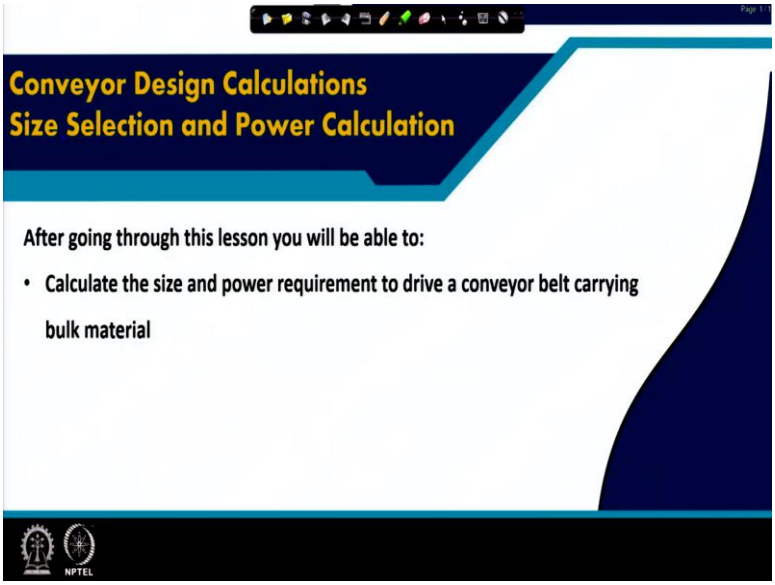

Now that our basic objective today is to calculate the size and power of a conveyor belt.

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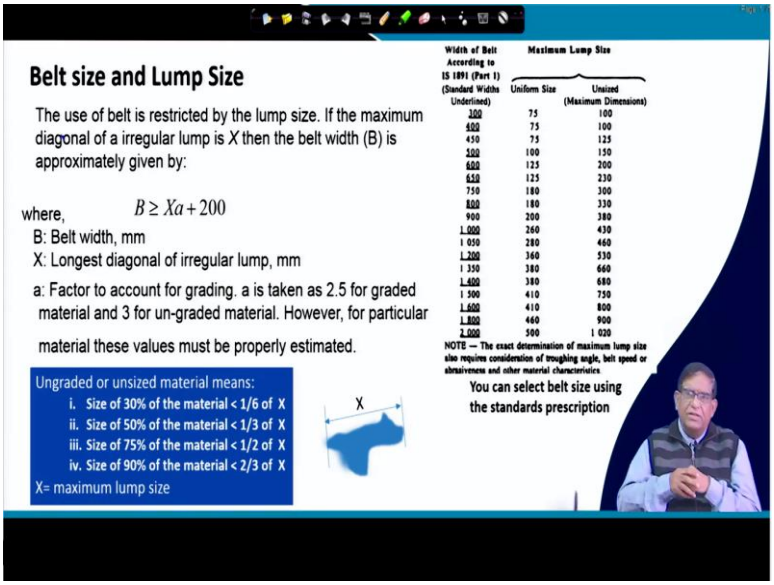

Now, while talking about this size of a belt conveyor, it is the first thing comes what is the width of the belt. Now, the width of the belt will be determined by size of the material being transported. Now, the sizes of material that is also is subjected to whether they are called graded or ungraded. That graded means, whether they are particularly screened and then a particular sample size is there are not.

Now when we are handling lump material lumpy material, the size is again, it is because, it is does not have a uniform shape. It has got a heterogeneous shape and then there will be a different mixture of differences size and shape. So that is why the designing a conveyor belt for a wide width some thumb rule or by experience people have got this rule that belt width should B greater than X a + 200.

Where X is the lump size that lump size is given as the longest diagonal size as you can see in the figure. And then this value of a which is exactly depends on that whether it is a material is graded sized or unsized. Now, when you are having a that bulk of lump materials, how will you know whether it is a sized? if it is size then unsized material means depending on what percentage of mix is there.

So, there are certain rules accepted by the standards that is, if the size of 30% of the material is 1 by 6 of the X. Then it is considered as a that your un-graded material or unsized material. So, similarly, if you are having 50% of the material is one third of the X. Suppose X is your 30 centimeter then one third is 10 centimeter, if the 50 size 50% of it is less than that then we will say it is unsized.

So, the sized then unsized of the material is determined on the basis of that how that it is there in practically it needs to be done. And then from the standards, when your lump size uniform size is a particular value given then you are what belt width you can select from this CEMA has also published understand different standards have published their this lump size chart you can do it from there.

Either you can calculate it from the principal following that empirical relationship or you can give whatever the standards are given. Normally, build sizes you do not buy a belt only by specifying a specific choice which is only for your applications. There are standards so, as you can see here 300 to 2,000 millimeter is shown there. There are also 2200, 2400, 2800 even little wider sizes are also there but they are rare.

But most common is in the mining field is 2400 is this. So, there that your material size that is your it can handle up to 500.

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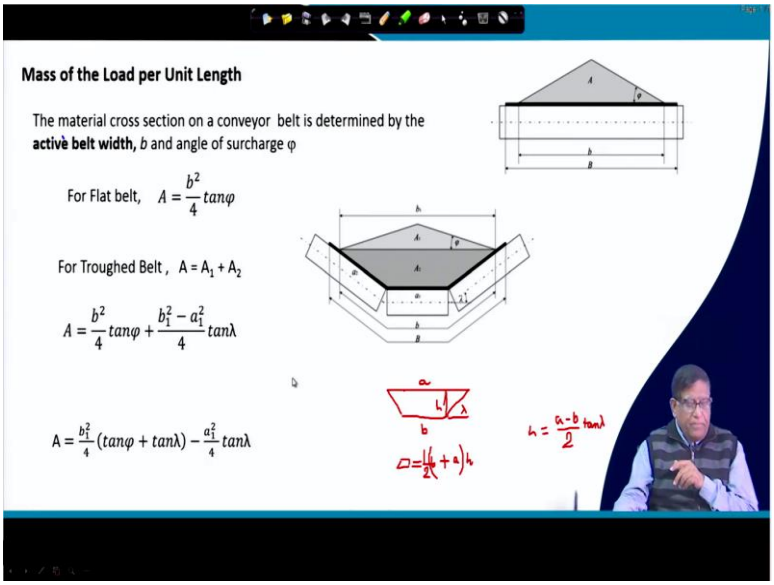

So, next, the sizing is your how much will be the mass of the load per unit length. So that means, your the sized material or un–sized material is there then in your one meter length. How much material will be there? That is another things that in a flat belt, you can see over there that in the belt. You will have to have both and some of this you are free and will have to be there.

So and then the material bulk material, when it is poured, it is based on the angle of repose. But here in case of conveying, we will be considering as an angle of surcharge. That what is the angle of surcharge? That is when you are having a dynamic elated and moving on the idlers, it will be giving some jar kings and all then this angle will be little with flatter and that angle is called Angular surcharge.

Now, from the geometry you can easily find out, if your for flat belt width your that area of cross sections of the material, it is given by 4, 10, 5. Very simple have BH formula for this angle but, if it is a draft one then you can see here there is a trapezoidal part and there is one triangular part. So, your the total area of mass it will be depending on this total area A 1 + A 2.

But you can see here they are depending on this. What is the idler length? Now, these are also standards specified that length idler and then on the basis of dystrophin angle that you can see here lambda dystrophin angle and depending on the type of material again people selected for you can again use the standards but now that here when you leave this. And then there will be a particular dish lent beyond which will be a part of your dish total be length that is your this part now.

This will be depending on what it will be depending on your how much exactly this depth of depth is there. So, it as you can see here for the trapezoidal part, if you take this trapezium part over here, you know the area of a trapezium, you are half b + a. So, you can find out that h will be how much depending on that a, you can calculate out the area of this trapezoidal part which could be that is your; you can derive by simple geometric calculations. Now that is why the total area will be coming sum of these two.

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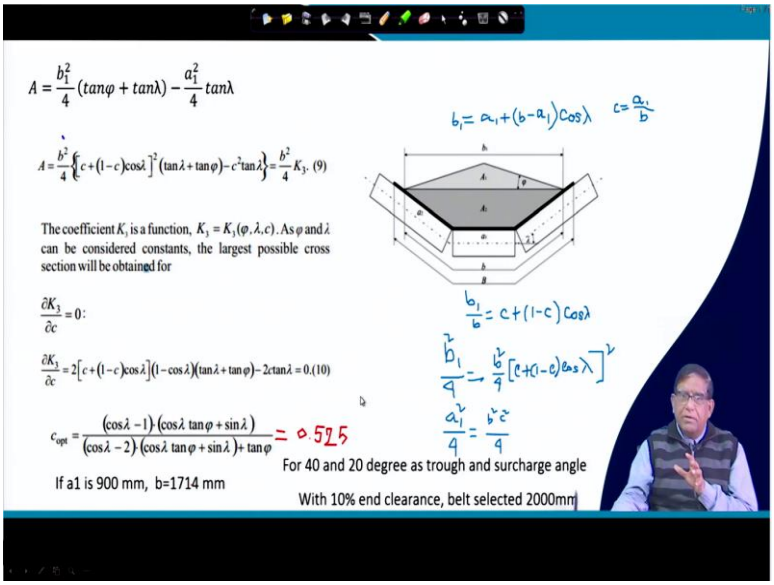

Once you find is that area but often this may not be the triangular here, this may be a curved line at that time, you will have to take it proper care that how will you calculate out the circular part of it. Now, when you find out this your total area you calculate out by this method then you can express the total area in terms of this angle traffic the traffic angle and your angle of searchers.

Here, if you introduce one more parameter as c = a 1 by b which is exactly the ratio of your this smaller length of the idler to the wherever it is the touching this belt. So, this part normally 10% of the belt width you can leave it as and corrections are that is your at the end, you keep 10% of the total length of this the B which is at a 0.1 b is here, 1 b you can keep it here.

And now then this remaining part their ratio is we are giving one parameter c. So then you are these b 1 which is there, this be one can be expressed in terms of this c by putting into these equations. Now from here, if you are using this equations on the this part here from here, you can put this value you come out with an equations A. Now why we go for that? There we are getting this coefficient.

This coefficient which is a function of your search angle, your traffic angle and this parameter c. Then with respect to this parameter, if you take a derivative, you can find a way to the largest cross section of area or that how much maximum material can be carried out under this configurations. So, from there you can exactly find out that what will be the optimal value of this.

So that will lead to you selection from the table. So that means, what I want to introduce you here that by from simple calculations of your geometric area and then by applying the principle of maxima taking the first derivative. You can find out what will be the optimal size. Now, once you know for the optimal size, what should be the ratio of your that Idler length and the belt length can be found out.

And that is where normally you are this 40 degree to 20 degree that you are trapping angle are used. And then we can find out, if you take a small exercise over here taking some value you can calculate it out. So, such type of calculations will be necessary for you to learn.

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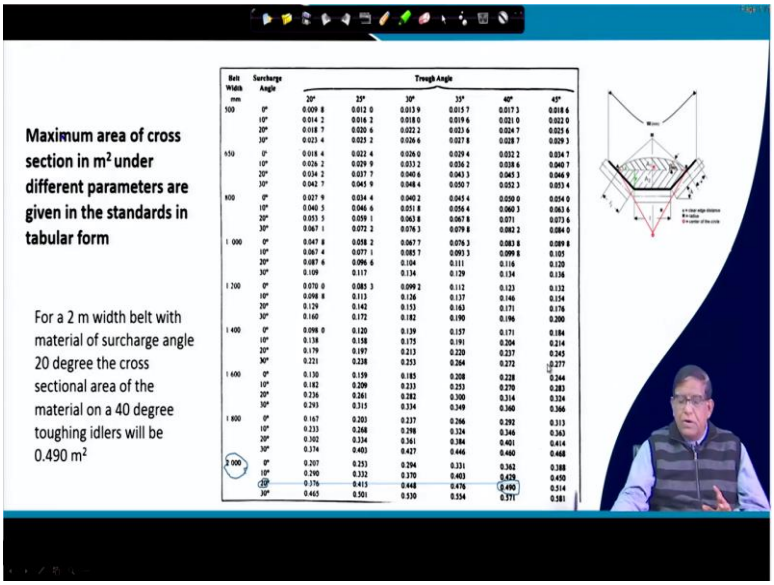

Now, again as we have found there that the maximum cross sectional area we have calculated and these are available also in the design book that CEMA handbook you can find out then you can verify, so, this area in meter square it is given for different belt width and different angles. Now, why I have asked you to verify it, now, you can derive another equation.

Suppose, your material is not in a triangular because it has come in a circular fashion. Now, if it is coming in these 2, you can assume it is almost a that there is a arc so that means, instead of that total is a triangular these mass area will not be coming into will not be getting carried. So, for that reason, you can calculate considering a that center by the geometry you can find it out and then you can derive another equations to find out what will be the optimal capacity.

So that is an exercise you please carry on. So, if we are considering here say from this table, how to use it, if it is a 2000 millimeter belt then, if our surcharge angle is 20 degree, this is the surcharge angle is 20 degree here then you can find out for a trophy angle of 40 degree that is your total material cross sectional area will be 0.490. So, this is where you use the table but I request you kindly verify this table by deriving and equations for this geometrical diagram.

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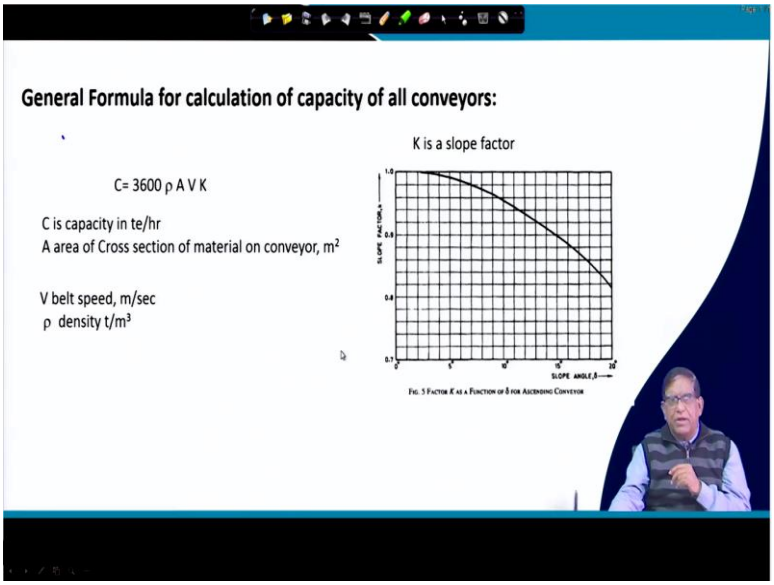

Then, one thing is there you have now learned that how to calculate the area of cross sections of the material, you have seen also how you get the belt width. Now, once we know the belt width and once we know what is the cross sectional area of the material, you can find out the capacity. If it is for all conveying systems your capacity is given by this in ton per hour that is your rho is the density.

When it is given in ton per meter cube is your area of cross sections of the material. And V that is your the velocity at which the speed at which the conveyor is moving and we can find out this as a K is a slope factor. As you can see here, if your slope, if it is increasing, if you are going to in a higher the slope your total that is your capacity that will be decreased, if you are going down the slope your capacity can be increased. That part of thing is there which can be taken.

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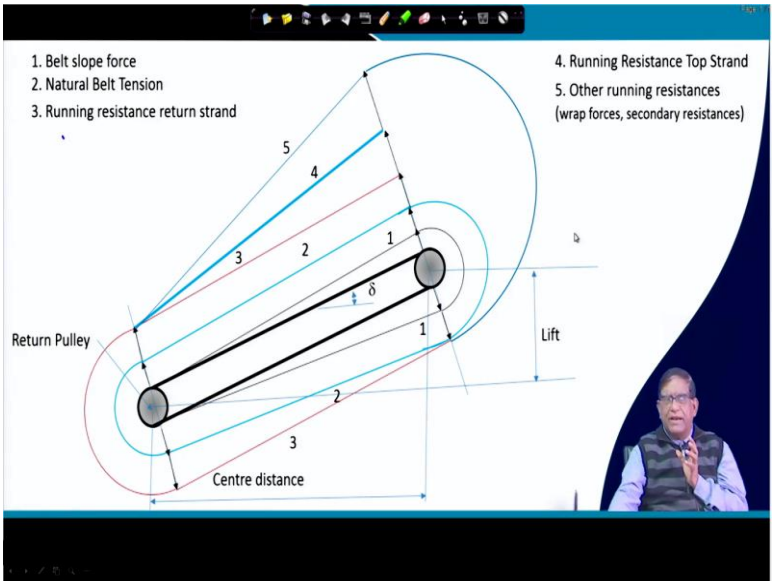

Now, how you calculate that? Suppose this is a conveyor belt. Here, 2 things will be there, this belt when it is running over these 2 pulleys and then carrying the material upward, there will be this belt must be under tension. So, there will be a belt force and natural belt tensions we will be working over there. Then what will be there? There will be another force that is your with the help of the there is a return pulley.

And dismiss lift at an angle is given for that this exactly when does your return build this is moving over here like this. So that there is that is a tension because of this return belt will be coming all along here. Now, overall, these tensions are exactly getting one by one, you can find out the running resistances of the return strand, it comes like this. So, you can get the running resistance of the top strand over here.

That is you can get also some other tensions because of that while we are wrapping it over here, there will be a tensions coming. So, all these resistances when you are to drive this conveyor belt, you will have to take into considerations and also one thing is there that where do you locate the drive wherever the difference of these 2 sites tensions are maximum that will be the best position.

So that is why, if the material is being carried out in these directions, the tensions will be more over here. So, this particular pulley should be considered as a drive pulley.

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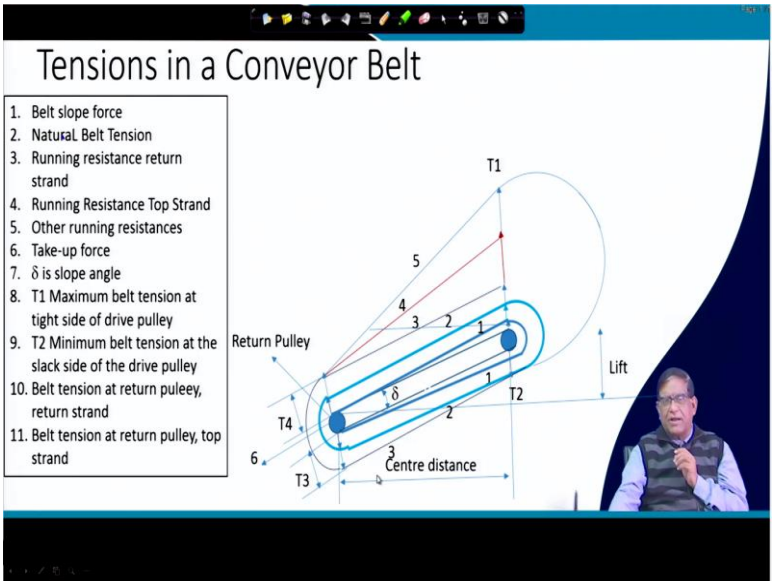

So, once you put it things over here, all these forces, you can see here the total forces what are coming over there. So, this will be depending on all this parameter that center to center distance. Now, basically, you are having attention T1 here, T2 here, T3 here and T4 here. Now, this exactly comprising of number of these different tensions. Now, when we say that how much power will be required to drive the convertible that means.

What effective tension will have to be maintained on this belt and with that effective tension, she will be giving a velocity. So, if you are that tension is Newton velocity is your meter per second that product of that effective tension and the velocity will give you the this your total power required.

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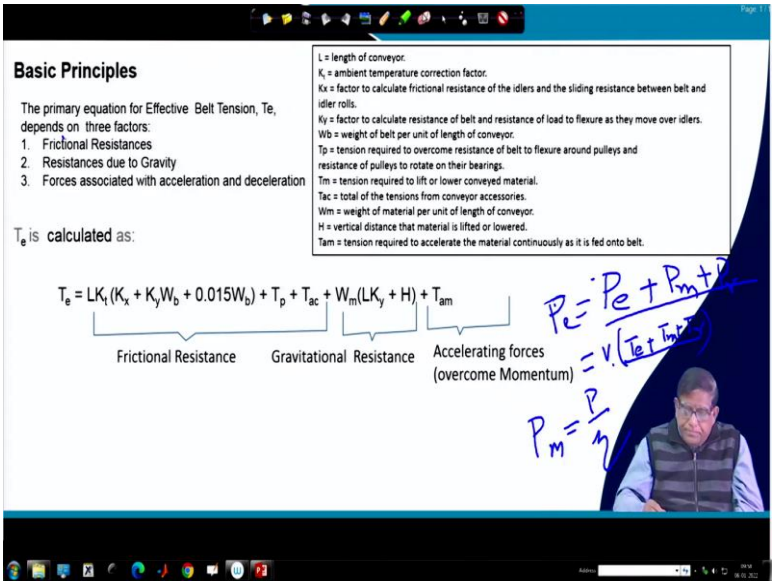

Now, let us see over here that you are having this primary tension the T e it is coming off as I said that the frictional resistances then resistances due to gravity and forces associated with the acceleration and decelerations where the resistance is coming from the belt getting that sort of bending and then over the rulers then there is a frictions all these things coming over here.

And that T e can be calculated that what are these frictional resistance is coming the frictional resistance is factor as you can see here that is your; it will be the L here in this equation is the land, if your that ambient temperature correction factor is applied for that whole thing because the total resistances it is depending on your ambient temperature as well. And then they say K x is their factor to calculate the frictional resistances of the idlers sliding resistances between belt and idler rollers.

Then, K y is a factor to calculate resistance of Bill and resistance load to the flexure as they move over the build. So, there will be certain resistances coming and then weight of the belt that is coming as a main resistance. And then you are having the tension required to overcome the resistance with the belt with the material, when it will be moving those resistances will be coming.

Then your T ac this is your total tensions on the conveyer accessories that will be say you can have the scrapper there, you can have sometimes they see your cleaners, they will be also giving certain resistances over there. So, those factors are also taken. So, like that you can consider that when the material is coming that will be giving another resistances and that will be depending on that how that material giving resistance.

So, overall this tension switch is coming, we can consider a few cases. So, for example, there could be your when belt will be running empty that is your power for empty belt running you will be necessary. When the belt is when you are working with the material that material driving power force will be necessary and then there will be some forces coming because of the that you are how much you will have to rise or lift.

So that is total tensions. The total power required will be sum total of this. Now that what is this empty belt running? If the empty belt whatever the tensions coming for that empty build this impure multiply all these tensions by empty belt tensions due to material and the tensions

due to your rage rising the material for lifting, if this 3 tension separately calculate it and then you know what is the velocity of the build speed of the build then this will be giving you exactly the power.

And the motor power will be the total power required by efficiency of the motor. This is the basic principle for calculating out the to calculate your all the motor power required, we will be following this simple procedure. Now, if you consider the different additional resistances also will have to be taken into considerations, those are your tensions required to overcome this cardboard because when this cardboard will be there.

That is cardboard and then there will have to seal. So that the material do not go out there are also certain tensions will be coming to the conveyor belt. So, those are all the factors in this way when you will be overcoming now, if the bearing of the idlers get jam then they will be again the resistance will be increasing then your total power will query will be more. So that is why, if the bearings are not rolling.

Then you are ultimately there will be more poor conjunctions per ton of material carried. So, these are the things need to be taken care of.

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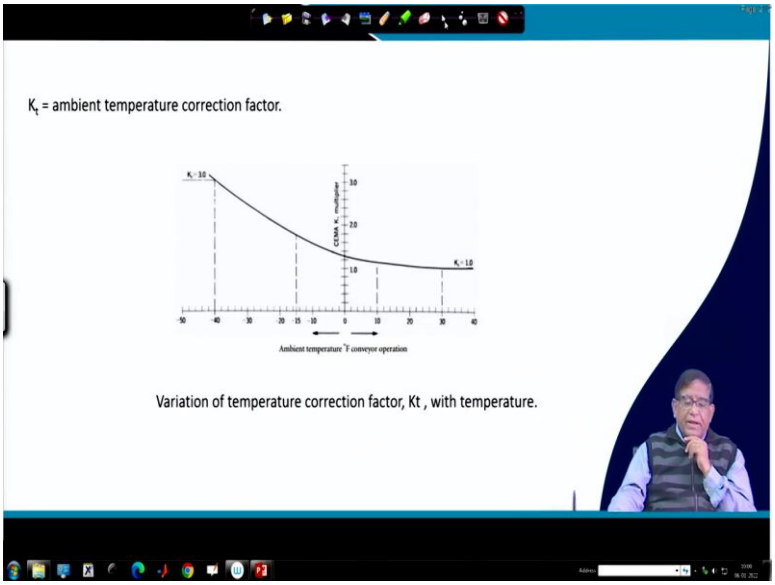

Now, as we see here then there is a another important thing you need to consider is your what happens that with ambient temperature? if particularly in a cold country, when temperature is very less at that time then resistances will be more and that is why that K value is higher.

Normally, for our normal temperatures in our country, our K value is 1 because with normal temperature that effect does not come.

So, in that equation K we have given 3600 A V b K that is important in calculating in the colder countries.

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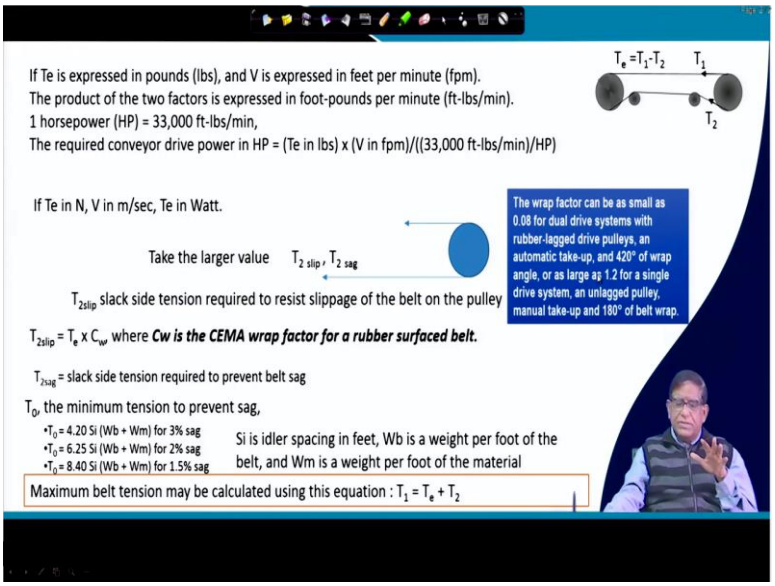

Now, as you can see here that as I was telling you that you need to calculate the tensions that is your what is the T 1in that you have seen depending on the situations the T 1 and T 2 that is your tight side and it is the slack side there are differences is called the effective tension. Now, these again in calculating you should be careful about the units. Sometimes even still we say that.

What is the horsepower of the machine that up the horsepower of the motor those are in your British systems with our foot pounds per minute systems you will have to take that one horsepower is equal to that is 33,000 foot pounds per minute that you do not confuse with that but when we are considering we will be considering mostly in SI units. Now that SI unit is Watt that is our motto.

And all these things will be considered in kilowatt you be careful about that. Now, here are a few points you should know that when this belt is running over here that in the slack side, there could be the belt, if there is a belt in slipping or there is a belt a sagging, it is not properly tight then there will be a different of tensions will be there. Normally that is your that CEMA they give a wrap factor for calculating out the tensions.

So that you should be careful for considering it while solving a real problem. Similarly, your this how much will be the this tensions their relationship is given with your idler spacing that, if the idler spacing on that your how much tension will be coming because of the sag or slip will be depending. Now, if that is your depending on your belt width and then depending on your how much weight is coming on the belt.

That is your per unit feet or per unit meter, whatever is the total weight coming and then what is the weight of the material coming that is WAM is the weight of the material that is your, if your cross sectional area is more the weight per unit length of the belt will be more WAM will be more. If your that is your weight that Wb belt weight it depends on what is the type of belt we have said about the fabric belt or the steel cord build that per unit length.

How much is there depending on that is your how much tension will be required to show that the sagging does not take place that is taken care of. Now, the wrap factor that is your because of wrapping it you will have to give that will depend on what is the angle of wrap whether you are giving a another that is a snap pulley or you are having a 2 more of that is your pulleys are they are really making a loop over there.

So, depending on that the wrap factor will have to be there. So, while going for designing a conveyor belt, the first thing how will you start with? You will start with designing the profile. Now profile means how much chapter you are having a horizontal? How much curve? How is there? Then at every sector, you will have to calculate the resistances. Then the sum total of those resistances that will give you the total tensions and the thing you can calculate out.

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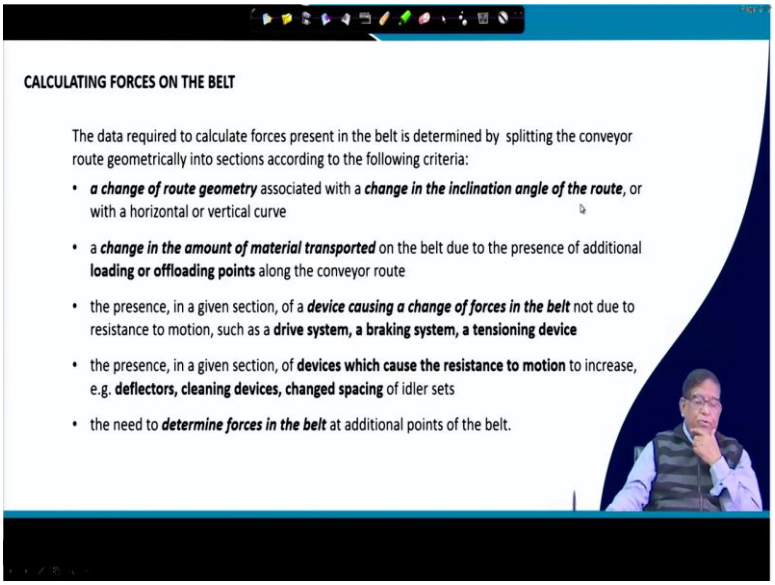

Now, once you find out this tensions then the power calculations will be easy. So, what is a summary for calculating the forces on the belt what you will do? You will have to see the geometry then you will have to see how much material is coming and then what are the devices you are putting what type of idlers and all how you are giving and then how that other resistances might come over here and then you can go ahead with it.

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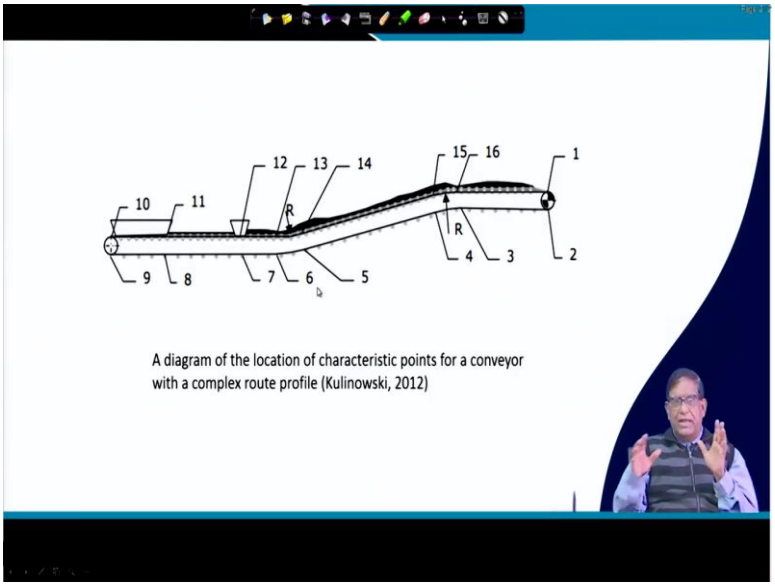

Now, this is your profile of a conveyor belt, you can find out there are so, many things that is your where exactly they you are in that route the resistances will have to be considered at that point. So, this is one horizontal section, there is another horizontal there is another horizontal there is another horizontal sections, you have. Now, these points where the resistances will be coming where it is exactly getting tensed.

Here it is getting slack, here it is negotiating a curve, here is also having a curve then when it is exactly here again having a curve. Here your the cardboard will be affecting, here your loading will be taking place, here a vertical that curvature will be handling. So, like that those points where there will be the more forces will be coming that you need to know then you can calculate it out.

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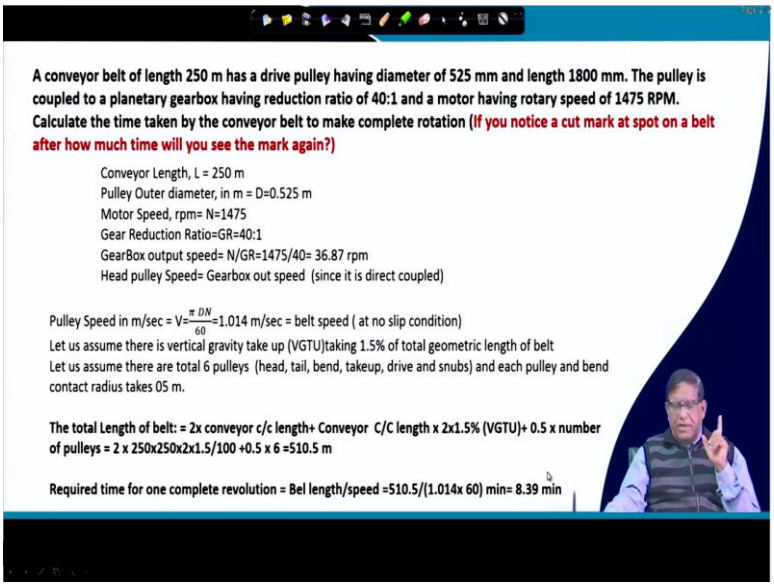

Now, for this let us go for a very simple calculations here. A conveyor belt of length 250 meter has a drive pulley having diameter of 525 millimeter and length 1800 millimeter the pulley is coupled to a planetary gearbox having reduction ratio of 40:1 and the Motor having rotary speed of 1475 rpm. Calculate the time taken by the conveyor belt to make a complete rotation.

Now, why this problem is now able conveyor belt is carrying material, you have seen that you observed at the tail end that there was a small mark or cut mark was there. Now, the belt is done, how much time we will have to wait that again that mark will be coming, how will you calculate it out? Now, you first in this table problem Find out what are the given? You have given the your conveyor length is given your pulley outlet given all this given material.

Then from there, you can find out that pulley speed, how much it is coming. That is you can find out from the diameter that at that pulley speed there at this the at which the conveyor will be running without any slip, you can find it out that is the belt speed. Now, from that, if you think of there is a gravity take up. So, there will be another 1.5% of the total geometric length of the belt will be there in the loop of a gravity loop.

Because what is, if you had 4, you know that total time when it will be coming the total length will have to be there. So, it is not the conveyor length alone but the conveyor is also given the loop sometime in the loop drive sometimes it is given on the gravity take up there will be extra belt loop will be there. So, for this all the length will have to be taken into consideration.

So, from there, you calculate out the total length in this case, the total length is the total conveyor center to central length plus this conveyor center to center length into 2 times plus this year what is the gravity take up percentage and then you have got some length in the diameter of the that is while the wrapping at that time, if that is depending on the number of pulleys, how much extra land it is accommodated.

So, considering all these things for this particular problem that is your 10.5 meter is extra. Though the belt to center to center distance is only 250 + 250 into 250 into 500 meter but all this extra length is coming 10.5 meters. So, these you must calculate out. Once you calculate that then you can find out that is what is the time required because the belt length by speed it gives so, 8.39 minute.

So that means, this is a way how some simple calculations of conveyor belt can be done.

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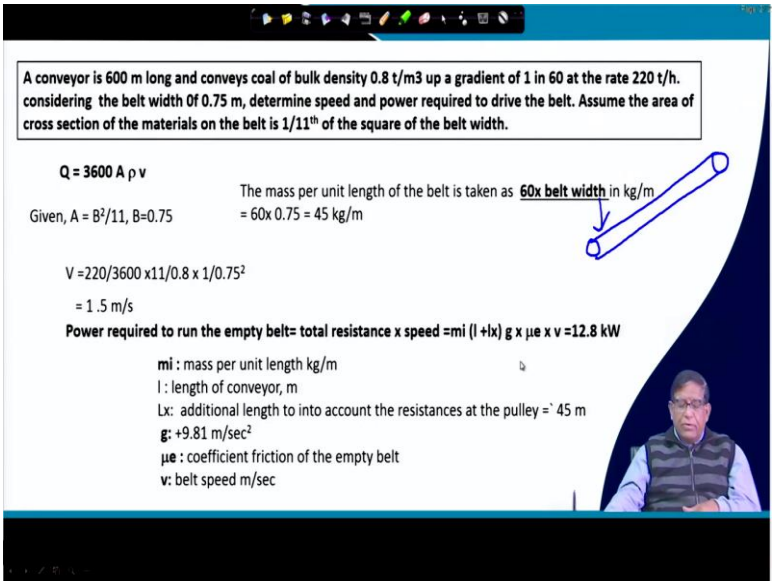

Another problem you can check over here that is a conveyor is 600 meter long and conveys coal of bulk density 0.8 ton per meter cube up a gradient 1 in 60 at the rate of 220 ton per

hour considering the belt width of 0.75 meter determined the speed and power required to drive the belt so that is here you know that is your the first you need to see what will be the configuration of the bill.

So, it is I think simple like this then here you are giving the load you can consider given at the end. So that the whole total length can be considered for the material. Now, once you take these things then you can; you know that what is the capacity given capacity required rate is known to you know that what is your, if your belt width is not there either you can select from the this your chart or one formula empirical formula given by Norman brook.

That was it should be belt cross-sectional area of the material can be considered as a thumb rule between b 2 by 10 to b 2 by 12. That is exactly range they have empirically found so, here we are assuming that belt material it is a b 2 by 11. By that you can calculate it out is coming how much and then the mass per unit length you can calculate that is coming from this, if this is your cross sectional area of the material from there you can find out how much is this.

So, you can calculate the belt speed from here now once you know these things the power required is the total resistance into the speed. Now what is the total resistance for the your material and for your empty belt you can calculate. So, for your there is a empty belt length is your l. We are giving is l x here that is we need to calculate because of the that at the end wrap or that other length you can take x = 40 meter.

For a long conveyor belt up to 40 meter you can give an extra length. So that is your mass per unit length is there and then the length the total mass is known when you know the total mass and then you multiplied by rho as a density and then the your g with the your gravity and then the coefficient of friction and the velocity. So, this with the value given, if you get you will be getting this value of 12.8 you can check these things.

So here once you calculate out like that then what is the, if your that is for power required for taking the material.

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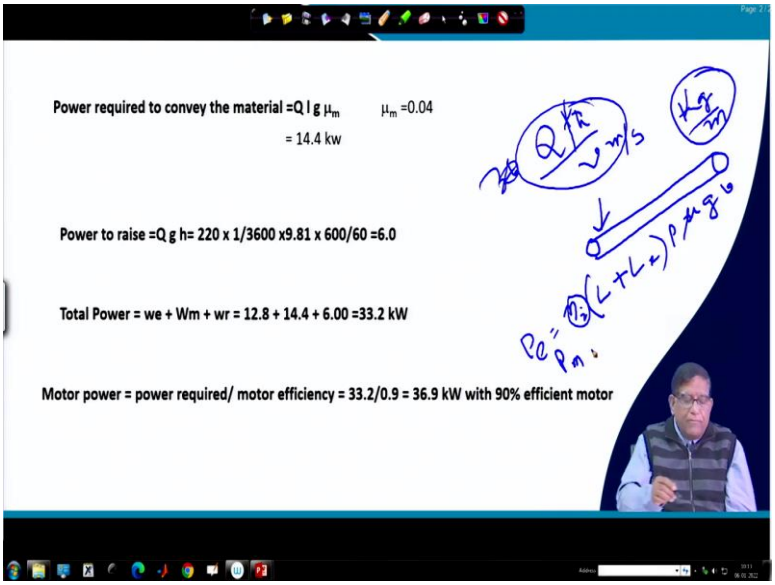

For the material also you calculate in the same formula you put and then per required to raise the material that also you can find out. So, the total that power when you calculate it out you can find out this much kilowatt is required. But the motor power will be, if you take the efficiency of 90% then you can find out the motor power. So, it is a very simple that means what you need to be very careful about that when you first you need to draw the diagram.

Then you find out what is that exactly the resistance coming over here so that is your mass per mass per unit length of the that is empty belt then your length of the belt plus that additional length you are giving for this then it should be multiplied by your that your this mass is. If it is given in kg to convert it you will have to tone that you will have to multiply it by rho then you will have to take what is the your coefficient of friction is coming.

Then, if you multiply by g and then you multiply by v. This will give you power required for empty similarly you can calculate, if your mass for power required for mass all this remaining same. But here instead of mass per unit length of the bell you will have to keep the what is the mass carried per unit length mass carried per unit length, if you know what is the Q ton per hour and then, if you know that is a from that one and, if you know the velocity.

If it is coming ton per hour and then, if you divide it by the velocity then what is it is meter per second? So that is, if you convert this to a your second by multiplying in that is your 3600, if you take the into over here their ratio will be giving what is your ton or that multiplied by thousand to give it kg then you can find out what is kg per meter that kg per

meter is to be determined for finding out the problem of determining how much material will be there in a per unit length.

So this is the way you get the calculations of basic power required and power driven you have got the tensions.

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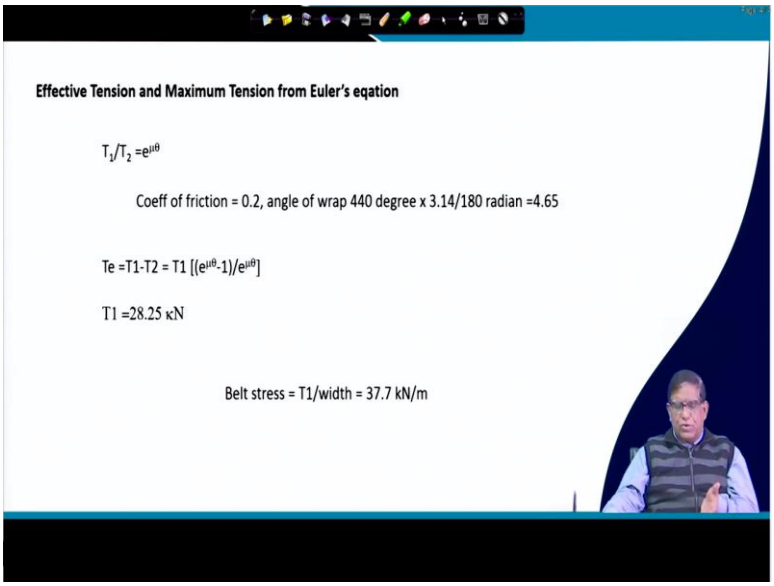

Now what is the effective tension that is you know again Euler's equation gives you T 1 by T 2 = e to the power mu, theta. From there where theta is your wrap angle normally depending on in what way you can give this power to the motor driven it can be given the power to the this can be coupled directly coupled with a gear or you may have sometimes the belt can be going even a you can have a loop like this.

So you are this is your driving at that time this is your take up so, at you are getting this wrap angle is increased for transferring this your material over there. So, this T 1 by T 2 is a very important parameter that mu that can be increased by giving a that is your on the conveyor belt you are using a lagging that is on that conveyor pulley you give a rubber cover over here so that the friction between the conveyor belt and the pulley can be increased.

That means that mu can be increased so that your that effective tensions you can get more so that effective tension is T 1 – T 2. So, from here you put the value of T 2 and then you can find out the T effective tension in terms of T 1and that your parameter. So, from for the equations you can calculate that this what is the maximum tension T 1 is coming on the belt and that when you divide it by the belt width that give the bell stress.

Now, if this bell stress is known then you can find out, if you are taking a fiber fabric belt that how many number of plies divide this, if there is a 7 layers so that means you can select the fabric type based on how much stress it can withstand. So, this is the way how exactly belts are selected.

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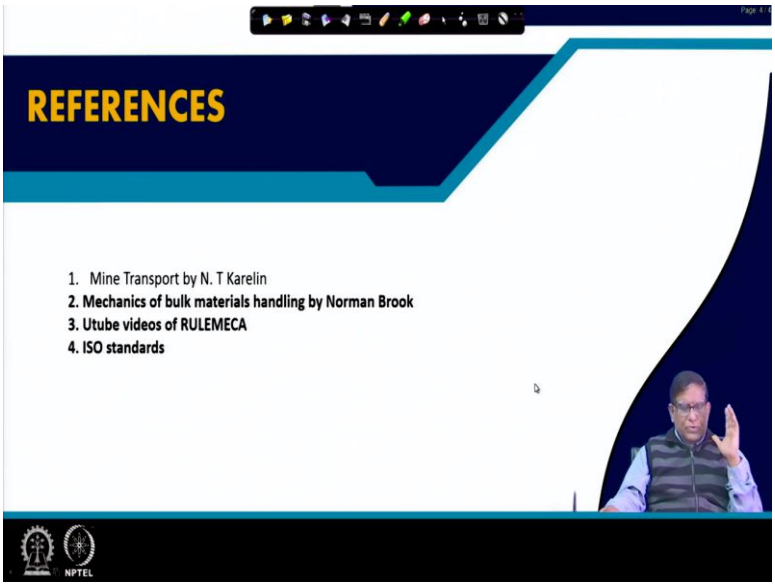

So today we have just given you a basic principle and how general calculations are made.

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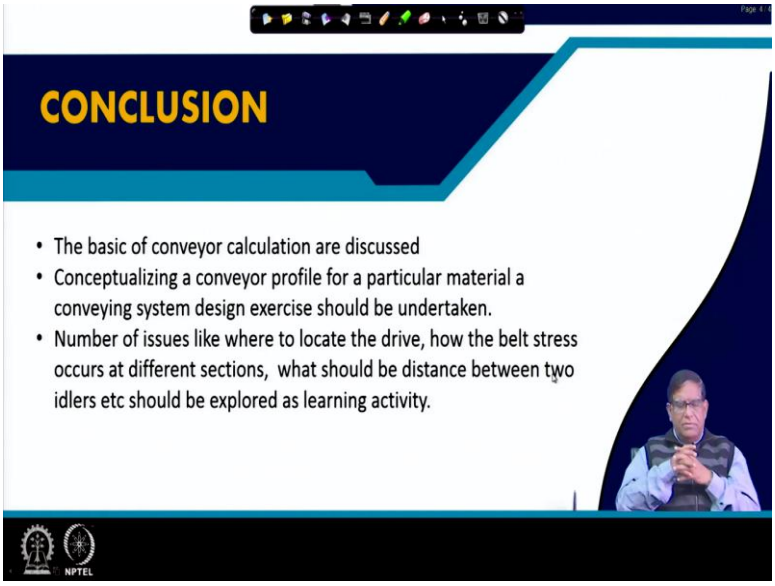

I hope you will be able to take some experiment maybe some of the tutorial and then in the assignments you will get some numerical please resolve that and that the basic conveyor calculations are discussed today. Conceptualizing the conveyor profile of for a particular

material conveying system design exercise should be undertaken and number of issues like where to locate the drive?

How the bill stress occurs at different sections? What should be the distance between 2 idlers? Those things can also be going in a detailed design of conveyor belt classes which can be which is beyond in our this course. But I wish that you will be taking up some exercise on this and you can even develop a small app for calculating the conveyor. There are many the softwares are also available even the freely open service softwares are also there.

But you can start developing a simple excel sheet for designing of belt conveyor and then more cases and more extremes you can add more you will be learning. Thank you very much.