Bulk Material Transport and Handling System
Prof. Khanindra Pathak
Department of Mining Engineering
Indian Institute of Technology – Kharagpur

Lecture – 55
Winding Calculations

Welcome students today, we will be taking up some certain discussion on winding calculations because we have now discussed number of different transportation machinery and we now know that what are the problems exist in underground mine transport and handling system? So, we have already discussed about the different type of winding, like case winding and skip winding. But tend to design a system for such operation. What are the things required?

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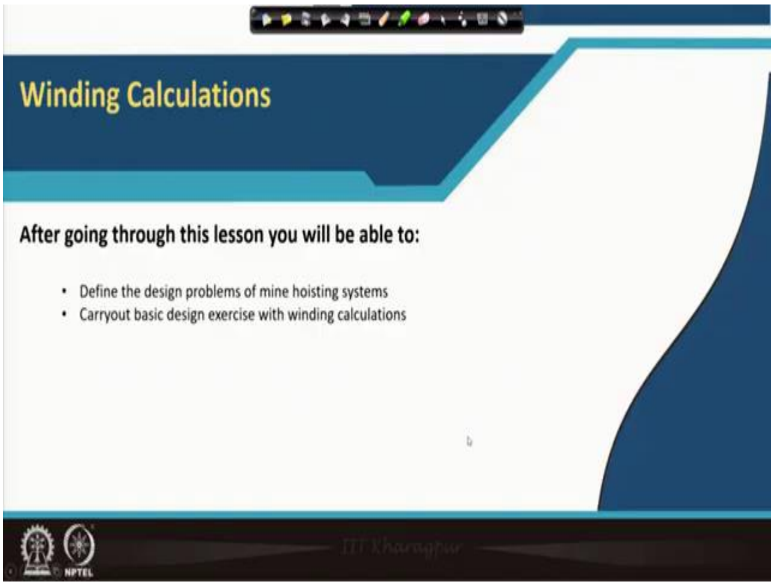

So, we will be discussing today that how to define the design problems of a mine hoisting system. And we will be discussing here that how to carry out the basic design exercise. What are the main things exactly we need to do? Some of the things are very basic, your applications of basic mechanics, some of them are selecting equipment and some of them are putting the things together to a system.

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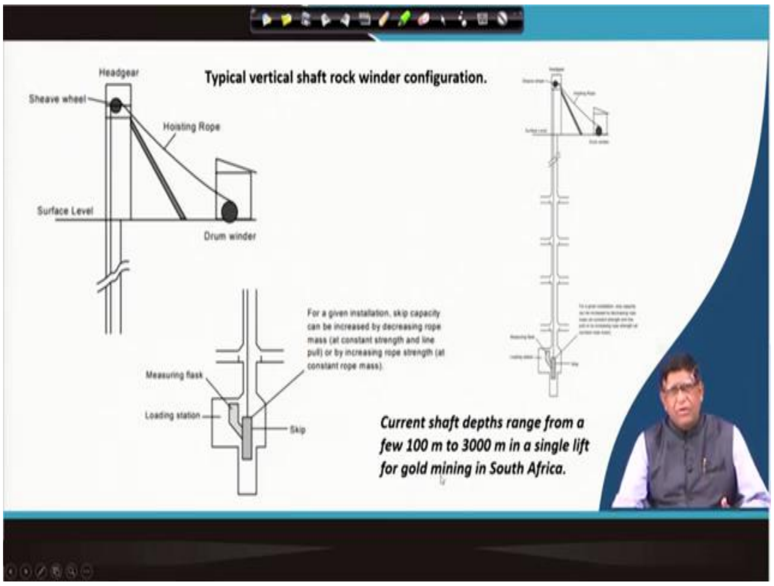

Now, you know that in a typical vertical shaft for the rock winder last class, we discussed about the whole winding system with a skip and particularly when we do it for hard rock mining. It could be quite a deep shaft which could go even up to 3000 in South African gold mine it is 3 kilometre down like this. A vertical shaft is going even we have in our Indian some deep shafts that in cooler gold field, we have got very deep, shaft like this.

And there we keep this skip which has got a loading system and all. So, now, in that what exactly how will you design things? So, you know that a head gear structure. This structure with a backstroke that how strong how this structure will be designed? Some design exercise for this is a civil engineering exercise. Some of you who are interested you can see that how this structure can be given for different type of systems available.

This drum winder, the drum is kept on the ground mounted. Sometimes this drum can be tower mounted and you can keep it over here. So that type of systems will have to design so, there the problem will be how this structure, headgear structure how it will be structurally competent. Because the load which is coming on the sheave and then this both the static load and the dynamic load and also the external wind load and all how it will be coming.

And for that you will have to design the structure, what should be the height of this head gear and what type of shifty arrangements will have to be there in the headgear. These are defined as a your basic design problem, so, you can think of sometimes taking an exercise that how to design what should be the height of the head gear structure. Similarly, if you are having a drum over here that drum will be located at what distance? How much this rope should be there?

Because if we are having a very long distance over here, this rope will be forming a catenary type of things. At that time what should be that is your what type of rope should be used over there? You can have a problem for designing what should be the diameter of this wire rope, whether that how will optimize this total energy consumption over here that energy for driving it.

So, there how much torque will be necessary then, how that that rope what type of material that is, what should be the strength of the rope? That breaking strength how much it should be? So, these are the way you find out that how you are defining a design problem. And that will be varying side to side and then at the bottom side, also that what will be having in your, how you will be loading, your skip?

How his will be supported at the bottom? And then how you will be doing the balancing? Those type of questions when you put it over there and that formed a design problem. So that means, while you are talking of your winding calculations. First, you have to know what are the different systems component, as we discussed in our earlier class from that component, you need to find out which part you are going to design.

Or what type of calculations you will be doing. Now, the design problem may vary from side to side. That in some of our Indian coal mines, when we are doing mainly cage winding and in that case winding our depth has gone maximum and 550 metre 600 metre. I think the deepest one is status this Zamaduba Kuliari or in Sudam, the Kuliari of BCCL, where we are going 500 more than 500 metre.

So, now there that you will have to find out that what will be the depending on the rate of production. That is whether what will be the total load coming and what should be the wire rope diametre. Those type of questions also will be coming.

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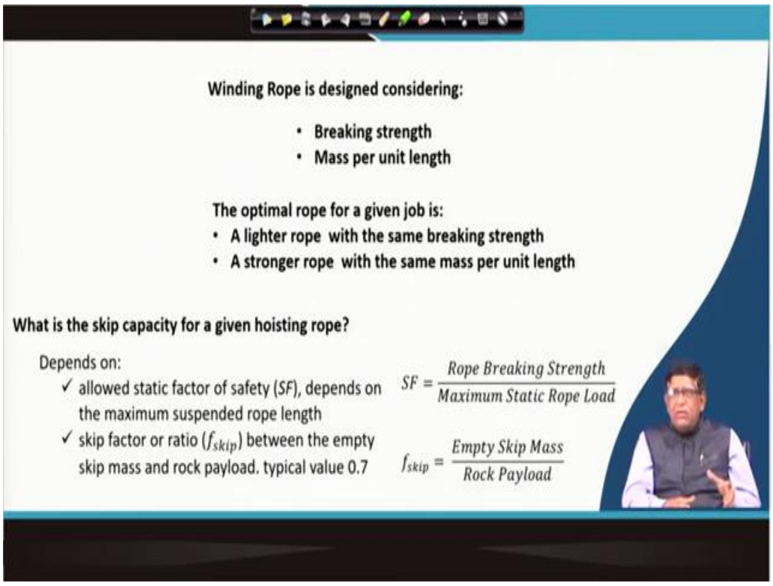

Now, when we are going for this, designing a winding system. The first component is your the wire rope, now in the wire rope you have learned already that the wire rope that they are constructed of this galvanized wire which are wound to form a strength and those strengths around the core they make a rope. Now, this wire rope that is a depending on the that is your the quality of the material we will be having its breaking strength.

That is breaking strength means if it goes beyond that or above that particular strength then the rope will break. That means at some point it will be coming it get that say it will get its diameter will reduce at that a point it will just get it and you can see that say. For example, if you take a small trade and then you put some stone and it and then you have it give more weight and you will find that at particular time that string will break.

That means that string has got certain limit of breaking strength. How much it can break the same thing and this breaking strength is related to the mass per unit length. Because the rope which is made of wires and that wires the material strength that will determine the breaking strength. And if you are making it a very compact, we are giving a thicker of this wire and with that what will happen? That per metre the weight will be increasing.

That means your more mass you have good that is why you are getting more strength. Now, what will happen if mass per unit length is more? Definitely you will be getting some breaking strength will be more but when you are running that system, you will find mass per unit length speed. You are having say, 3000 metre long wire rope if mass per unit length means that if it is a per unit length.

If you are having 5 kg or 15 kg depending on that the whole length when it will be going, it will be having a very big load. Now, with a particular diametre, you will find that you cannot make it up to that length because, after certain length, if you, if you hang a rope like this, this rope weight will be coming over there. Then, after sometime, what will happen due to itself weight? It will be so much that its the ropes breaking strength is increased.

Then that will be breaking. so that means there is a limit for a given diameter or given strength of the material. What could be the maximum length you can have? So that is why, if you want that your mines will be increasing, you will be stepping over there and then your whole thing that same rope will not be applicable when your depth increases at that time if you increase the same dimension, same quality of rope that rope may fail.

So then, if the more weight means again more power, so, there is a what will have to be as a design engineer when you will be looking into your objective will be to have a lighter rope but even if it is lighter, its breaking strength cannot be sacrificed. That is the constraint that will have to have the breaking strength but make the rope lighter. So that is a design that you will have to have what type of rope will be there?

And there they go sometime, this turboplast rope which is having your strengths and all in that they will be blending with plastics and getting it over there. This turboplast ropes are now it is coming by which exactly you can reduce the the mass per unit length. But you can have the same strength then a stronger rope with the same mass per unit length. Now, if you are having a rope, if your materials which you are selecting the type of steel which you are selecting, may be the same weight.

But it will be having more strength. So, these two options are to be there. Now, what is the skip capacity for a given hoisting rope. So, now, as you know that these two constraints that will have to have a lighter rope with the same breaking strength or a stronger rope with the same mass per unit length. And then we know that this rope, what will be done the optimal rope for a particular skip capacity.

Now they that skip capacity which you will be hanging or you will be lifting with a given rope that will be depending on what is the allowed factor of safety, this safety factor is a very important thing. And that means you, when you are going to put, you will be having, I will be having a factor of safety of that 5 factor of safety, 6 factor of safety 7 or factor of safety, 1.5 that is how much exactly you will be taking a risk that will be there.

And that factor of safety will be depending on what is the maximum suspended rope length that your as if your rope that suspended rope did how much its length will be there that means what is the depth of your shaft? That will determine it. Then skip factor that is the between the empty skip mass and a rock payload. That means that your skip which you have design it, has got its own weight.

And then if you take that how much rock or how much material you have put it over there, their ratio is called as a skip factor which is normally we take it as 0.7. So that means these two things are important here for while discussing on anything on the design of a winding system. That is what is your that static factor of safety? We are not telling about the dynamic one static, just whatever the maximum things it can do.

That is rope breaking strength and the maximum static rope load. This rope load when it will be coming. Does it has got its own self load plus how much you are externally you are adding it over there. So, this factor of safety is very much that is in your mining. There is a regulations that it vary country to country in any country that if you are lifting it for men for that type of hoisting system, you may go even a factor of safety of 10.

But, for while for raising your material you may get up to 6 or 7. So, depending on that this, your the rope will have to be rope will have to be designed to have a particular breaking strength. Because that your maximum static load, how it will be there, it will be, depending on the type of rope selected and what is your production target? And what type of skip you have selected?

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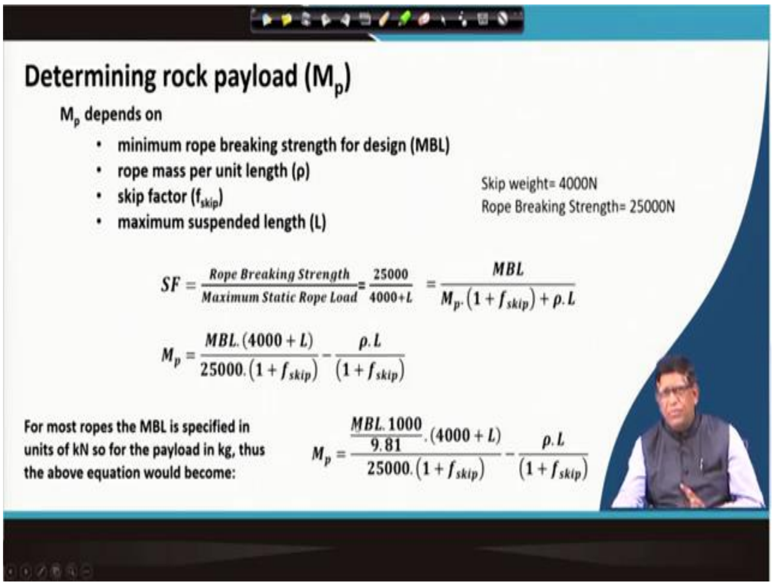

So, I think you now know that where exactly the our domain within which you will have to do the designing. Now that means for a given system when you are going to design. We know that our mines or that particular unit will have to produce, say 1 million tonne per year or say 500.5 million per year. Then we know that to get that production that is in one winding, how much material will have to be skipped at one skip, will have to give.

How much and then how many trips the skip will have to make per hour. So, depending on these two, you will be knowing that what should be the speed of at which you will have to be bringing in. So, if your shaft is very deep at that time, your total travel time will be more. So that means you will be having a longer cycle time. So, if there is longer cycle time then definitely at your particular load.

When it is coming in one trip that will be very, very vital for your productivity. But that amount which will be coming that is the rock payload. That is how much exactly will be the payload to this. Now, this payload or how much material you can put into the skip or that in the winding system onto the rope. It will be depending on what is the minimum rope breaking strength for the design.

That as per that this is denoted by say, MBL that is your minimum the breaking strength of the breaking load or rope mass per unit. That is your you can give a rope that is your per unit length what is the mass of that wire rope. And we know, as we have already said, the skip factor and then the what is the maximum suspended length or that is what is the depth of the shaft?

Once your this factors are defined you know then, certain things as a skip weight that that your rock load will be coming within that skip that skip weight may be your 4000 Newton that is for 4 mass if that is the total weight of it. Then rope breaking strength for a particular type of steel. If you are taking at say, it may be 25000 Newton. That may be the, your general some boundary some value you should have in your mine.

Then what can be done if we, what will be the safety factor breaking strength? We have said if it is a 25000 Newton and then maximum static load on the rope we have given that your that skip load is giving 4000 Newton and that length. What is the rope that rope weight rope weight if it is known because if you know the mass per unit length and the total length of it then from there you can calculate out what is the total load?

So, by this way, you can determine that safety factor. Similarly, what you can find out here? If your mass part that is a payload, can be now calculated out from this relationship of the safety factor you can get this equation that is your if you know the what is the rope breaking length? And for given that skip weight and that rope land and then for the given group breaking strength and that your skip factor, you can calculate out this.

Now, from here one interesting thing you can find out that for most of the ropes this amble is specified in the units kilo Newton. So, for payload if it is given in kg, so, you can that from the kilo Newton you can convert it to over here and by doing his manipulation, you can modify the equation for your calculation.

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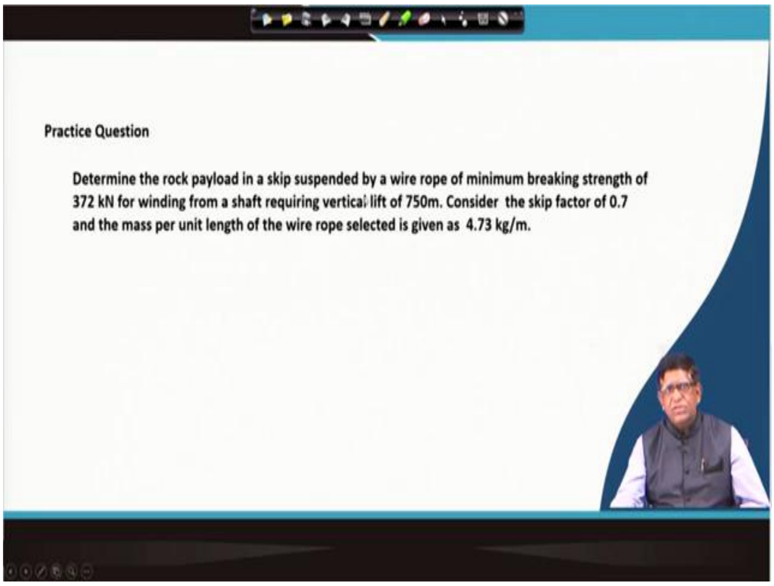

Now, let us see a practice question, determine the rock payload in a skip suspended by a wire rope of minimum breaking strength of 372 kilo Newton for winding from a shaft requiring vertical lift for 750 metre. Consider the skip factor for 0.7 and the mass per unit length of the wire rope is selected 4.73 kg per metre. Now, this one what you can do is? This equations you get it take an excel sheet and in that excel sheet you write down these variables.

And then you can change this values whatever that given over here, you can easily calculate on an excel set and you can find it out.

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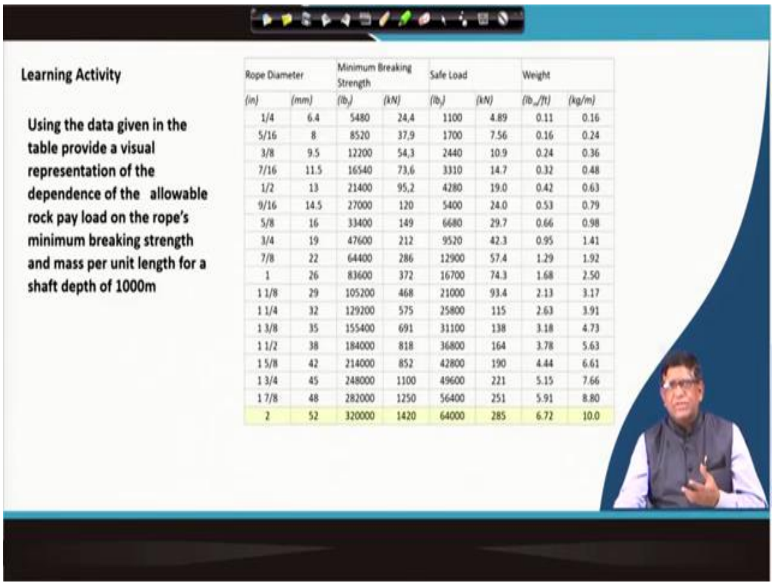

Rope Diameter		Minimum Breaking Strength		Safe Load		Weight	
(in)	(mm)	(lb$_f$)	(kN)	(lb$_f$)	(kN)	(lb$_m$/ft)	(kg/m)
1/4	6.4	5480	24,4	1100	4.89	0.11	0.16
5/16	8	8520	37,9	1700	7.56	0.16	0.24
3/8	9.5	12200	54,3	2440	10.9	0.24	0.36
7/16	11.5	16540	73,6	3310	14.7	0.32	0.48
1/2	13	21400	95,2	4280	19.0	0.42	0.63
9/16	14.5	27000	120	5400	24.0	0.53	0.79
5/8	16	33400	149	6680	29.7	0.66	0.98
3/4	19	47600	212	9520	42.3	0.95	1.41
7/8	22	64400	286	12900	57.4	1.29	1.92
1	26	83600	372	16700	74.3	1.68	2.50
1 1/8	29	105200	468	21000	93.4	2.13	3.17
1 1/4	32	129200	575	25800	115	2.63	3.91
1 3/8	35	155400	691	31100	138	3.18	4.73
1 1/2	38	184000	818	36800	164	3.78	5.63
1 5/8	42	214000	852	42800	190	4.44	6.61
1 3/4	45	248000	1100	49600	221	5.15	7.66
1 7/8	48	282000	1250	56400	251	5.91	8.80
2	52	320000	1420	64000	285	6.72	10.0

Because once you do this calculation, you can do a lot of say your this problem. You will be solving. You will be solving this problem by these values. You can directly put into this equation and you will be finding. It is very simple, so, you do it over there. You note down that some of the values given over here in this problem and then what you can do. Because if you make the excel sheet that is in the excel sheet, you will be writing down in the vertical column.

This values that what is your mix that is your ambient given your this particle, lift of that is, your L is given and the skip factor is given. Then you can that your rho is given. Then, by putting that equations, you can find it out. Now, from there in that excel set. You do one thing: using the data given in the table provide a visual representation of the dependence of the allowable rock payload on the ropes minimum breaking strength.

And mass per unit length of a shaft depth 1000 metre. Now, you see what you will be doing that excel sheet which you have made there now you can go on varying the things. That is your say for example, you can have different rope diameter for which you can find out what is the minimum breaking strengths are given over here? And then you can find out that what is the static load coming from and what is the rho value?

That is your mass per unit length. Now, if you vary them then you can find out that how exactly this the rope planks and your this payload how much payload can be bearing because if you are having a very deep shaft at that time, you cannot put the same payload as it is with a shallow depth. So that means with the depth wise. How much will be the payload? Their variations graphically you can present and that is what you do in your data analytics?

So, you please try to visualize give a visual representation. Take some data from here or in that same equation this equations, given over here this ones you manipulate with an excel sheets you can make you can give a different bar charts. You can give some graph, you can make a bullet diagram balloons and you can do a different type of visualization over here.

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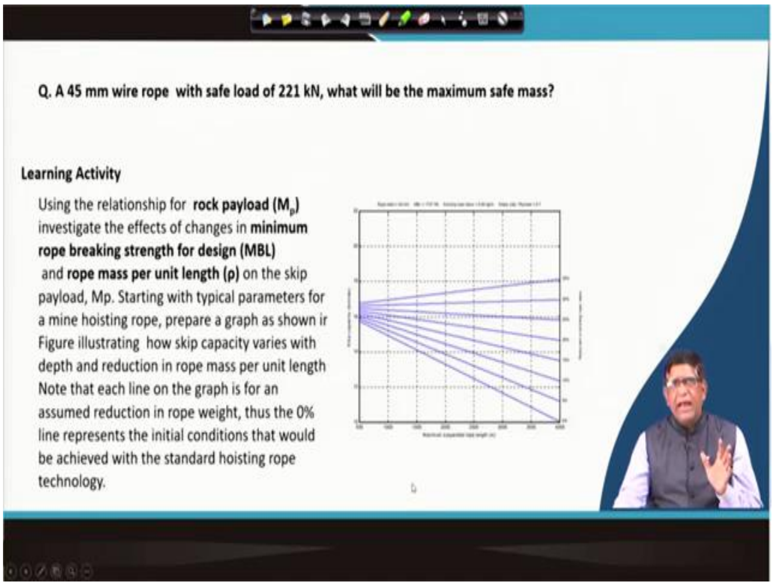

Then the another thing that what you can find out. This could be another question. You can answer very easily from a 45 millimetre wire rope with safe load of 221 kilo Newton. What will be the maximum safe mass? You do this calculations now as a learning activity what you should do is using the relationship for the rock payload investigate the effects of changes in minimum rope breaking strength for design.

Payload that is your at the rope mass per unit length on the skip payload, starting with the typical parametres for a mine hoisting rope prepare a graph, as shown in this figure. Illustrating how skip capacity values vary with depth and reduction in rope mass per unit length. Note that each line on the graph is for an assumed reduction in rope weight does the 0 percent line represents initial condition that would be achieved with the standard hoisting rope technology.

You need to understand that what has been done or what you will be doing with this just this graph you see your for this previous problem. It is very simple your what is to be calculated, you can say your maximum safe load. Safe load will be depending on that is your whatever the acceleration due to gravity you are getting and then what is the total weight is given. That is your F = M g. From that simple Newton's equation, you can find out that what will be that mass which will can be suspended over there is a very simple equation.

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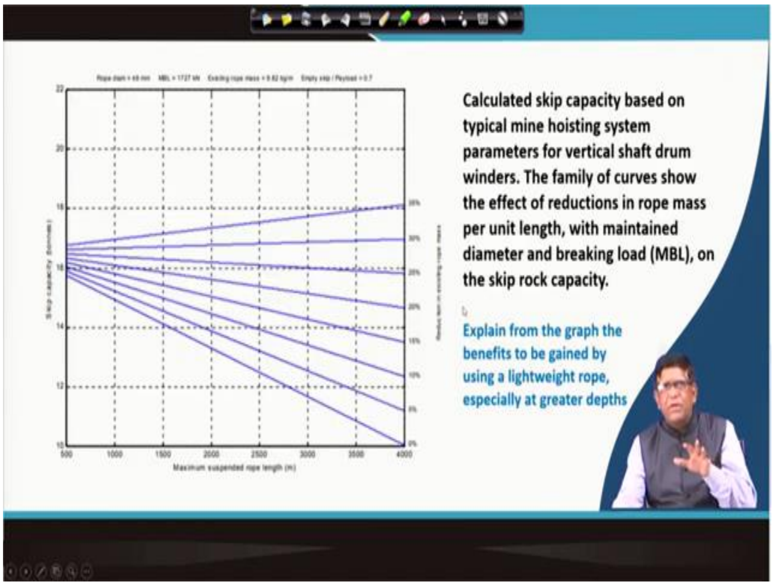

But now, this graph, if you see here what is done you can you can see here this your reduction in your existing rope mass on the particular rope mass, if you can get a better quality material and you reduce the rope mass by 5 percent, 10 percent or 15 percent depending on that reduction, you can see how does keep capacity is increasing. That means it at a 3000 metre depth.

If you are using a rope over here, you can carry only up to your less than 12 tonne. But, if your rope mass per unit length, is reduced by the same rope to say 35 percent by getting a material of a better strength, better quality. If you get that matter that that 3000 metre depth also, this particular winding system will be able to carry about more than 17 tonne of material parts. So, as a result, what will happen your productivity will increase?

So that means what is there when a particular rope diameter is a this particular calculation has been done on the basis of your rope diameter is taken as a 48 millimetre. Your ambient that is your breaking strength, has been taken as 1727 kilo Newton and existing rope must they have taken as a 9.82 kg per metre. And then there your skip factor. They have taken as a 0.7. With that this calculation and they have studied the variation now that is also sometimes you do.

What is called in your sensitivity analysis that how different factor affect the system, how much that also can be done. So that is why, when you will be using this table, this table will be giving some available wire ropes which are available in the market and there the mass per unit length is known. So, from this known figure and using your equations, you can develop this type of comparative additions graph which will be giving you.

So, the calculated skip capacity based on typical mine hoisting system parametres for vertical soft drum winders. When it is placed over here, the family of curves show the effect of reductions of in rope mass per unit length with maintained diameter and breaking load on the skip rock capacity. That what has been shown over here? So, you should do certain exercise like this.

Try to use your knowledge in excel and do these things and later on you can even the whole calculation system can be put into a you can write down code and there is a total formula for that. If you do the total dynamics of the whole winding system, you can do a lot of study on that. So, now, if you get this graph, can you explain from the graph the benefits to be gained by using a light weight rope, especially at a greater depth?

We can see here if your depth has increased from 1500 metre to 2000 metre same rope you see the hoisting capacity. It was 14 tonne. Now, at this, the hoisting capacity has reduced to 13 tonne. So that means, as you go deeper, the productivity or the per skip capacity get decreased. That means you will have to take a skip where payload will be coming less. If you are having the same skip, you cannot make it full.

And that is why, at the first diagram, you have seen that with the bottom, your there will be a system which will be monitoring and depending on the depth. How much material you will be seen if your material which is coming the density is same then your how much material will be filled into the your that skip will have to be determined. Otherwise, if the load becomes more then the system will be stressed, rope life will be reduced and accidents may also take place.

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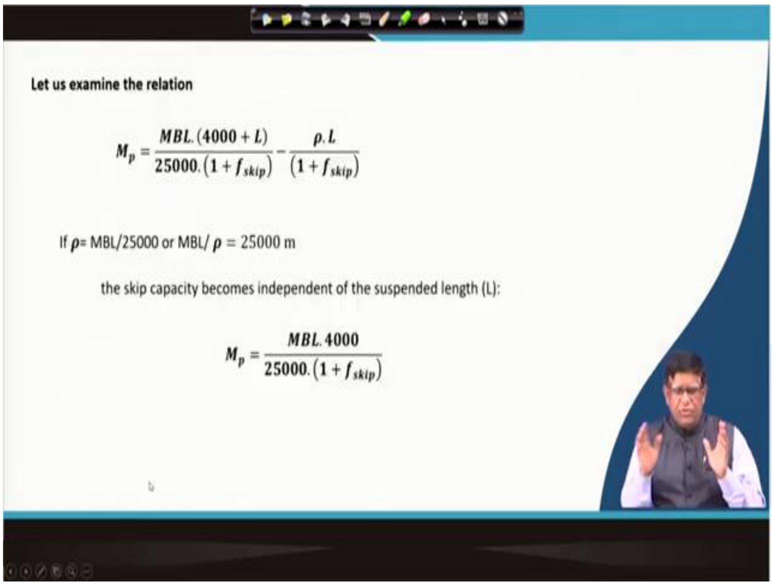

So that is why, while designing this, variations need to be known. Now, let us see the same equation which we are just telling a very simple relationship. There if we take the mass per unit length this one is equal 25000 metre then what will happen? If you put this value over here, you will be finding that see in this function that length L is not coming. So that means the skip capacity is independent of L.

That, whatever is there, you can do it like this. So that means there is a particular ratio at a for a particular value of your this rope at a at a particular depth, it becomes independent of the length. So, this value that is your a value which is exactly a characteristic rope length. The characteristic rope length when you use at that time, your this, whatever the rock load you can give it over there. This will be independent of that your length.

So, you can, you can put any load and air productivity will remain same. So, this is also that their breaking strength divided by your the mass per unit length of the rope that ratio will be giving a value in this case, it is coming 25000 metre at 25000 metre if a very depth say that is if you can get from there exactly. It will become independent of length.

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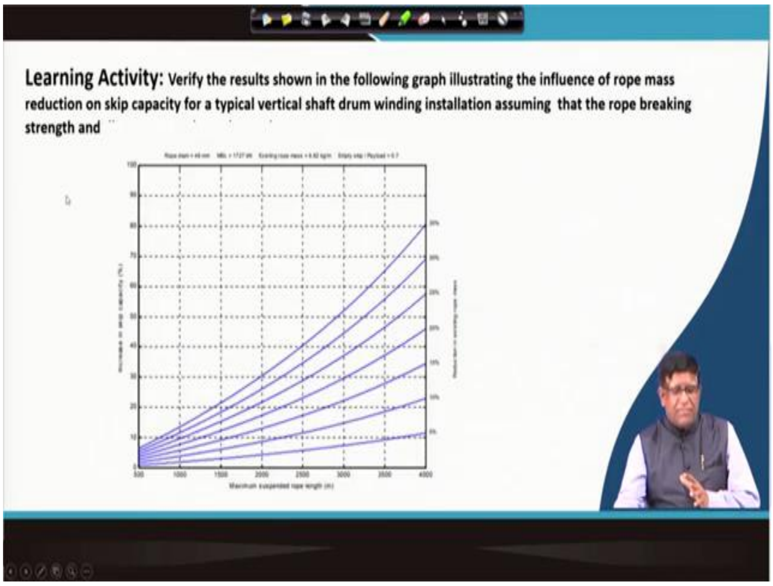

So, this type of some mathematically you can see what is the things over here. So, another learning activity you can do verify the results shown in the following graph, illustrating the influence of rope mass. Rope mass reduction on skip capacity previous one we have said that that how you have reduced that reduction of the existing rope mass when you are using this one and then your with the maximum suspended rope length.

Now, your this rope length will be suspended, rope length is increasing and your increase in the skip capacity. That means with the reduction here again that same value boundary condition. So, this type of graph you can develop by from the basic equations and that will be giving you a good idea.

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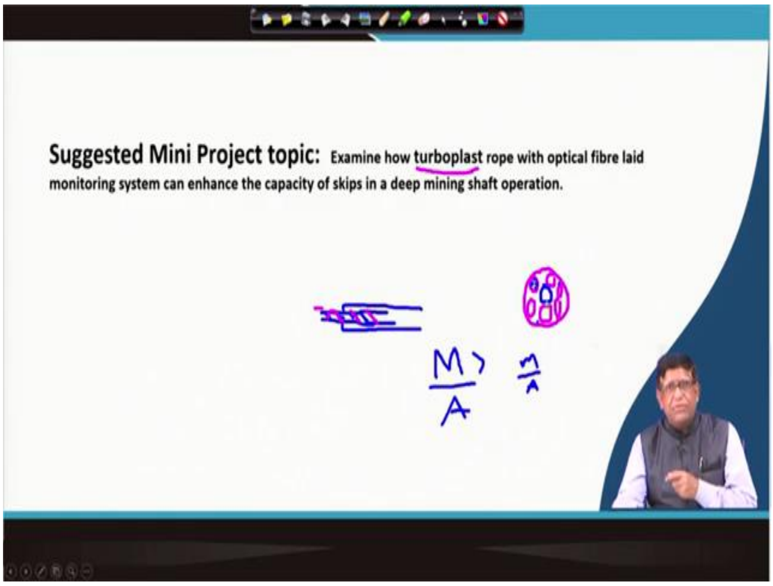

So, what you can do, you can take a mini project to examine, how turboplast rope with optical fibre laid monitoring system can enhance the capacity of skips in deep mining shaft operations? Here I have given a 2 3 things together. What is there exactly optical fibre liad rope? What happens? In sometimes your this wire rope which is you, are having a wire rope will be having a there are different the your strength will be put it over here.

And then we can have a that is over this rope a that means it will be giving a your plastic cover and here we may have that is you can have a fibre optics? Fiber can be kept over here winding now, when this type of wire rope will be used for hoisting. Now, this optical fiber, they can exactly monitor the stress level and all that some instrument if it is there from there, it will send the communication and it could be used for monitoring.

So, this again, a turboplast, this turboplast rope is a in a rope what will be there? Exactly there will be number of this different strengths and this strengths will be laid over a core. There may be say if there are 6 strengths. These are the strengths which are made of they will be having different your, they will be having the wires here. That is different strengths that wires will be making over there and then they are laid over here and inside there is a core.

Now, in between this space, whatever the space here you are having, they are having a plastic that is plastic, synthetic which give a strength. By that what will happen? The if you take a cross section, total mass per unit area of this air? Your cross section that still is now reduced and then this material in between this void, we are having this plastic with which has got less density than this rod.

So, as a result, the total mass per cross sectional area which suppose, if the whole rope you are having say, for example, in this whole area is made of this your wire and that compact. At that time, this mass will be greater than this small m which is there because of the plast. So that is what is the principle of using this turboplast?, this wire rope and they there is a provision.

You can have this, your fibre optic one fibre optical this your is also laid down. So that it can give the measurement. That is a collecting the data. If you are going to a very deep mine from there this data can be collected through that and that will be bringing you the whole winding system can be modernized. So, such type of systems are not there in our mines yet.

I hope some of you can do as mini project and see that how our winding systems whichever is existing in India, they can be modernized in future to have. But already there are different type of monitoring systems are there. We have not discussed in our course. Those who are interested to you can take a mini project on the whole winding system and you can do it over there.

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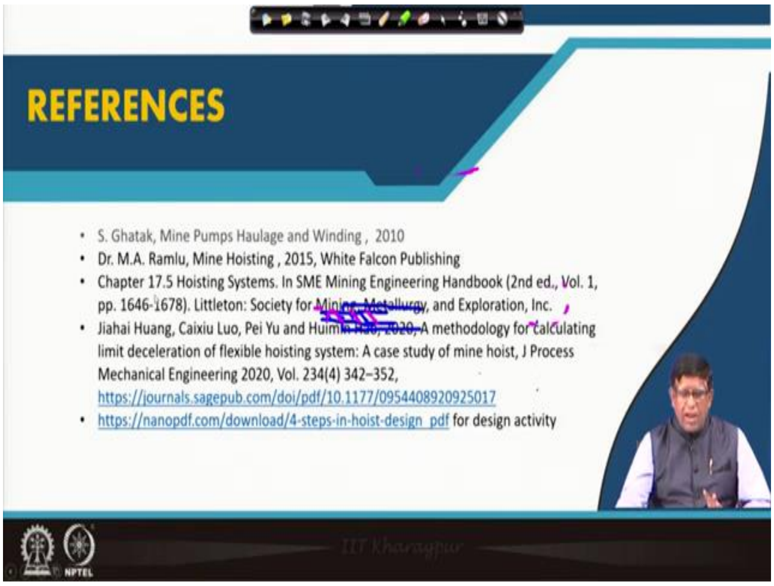

So, coming to this, exactly there are lot of works have been done. I request you to go through that book of Professor Ramlu but there are some very good articles are there in the journal of process mechanical engineering. This can give you how exactly a projects can be taken. Similarly, for the design activity that there is a four steps in hoist design, one very good resource is there in the internet.

You should see this read this and that whole system you can develop for your own project. And that is the learning activity you will have to do. Then only you can learn better.

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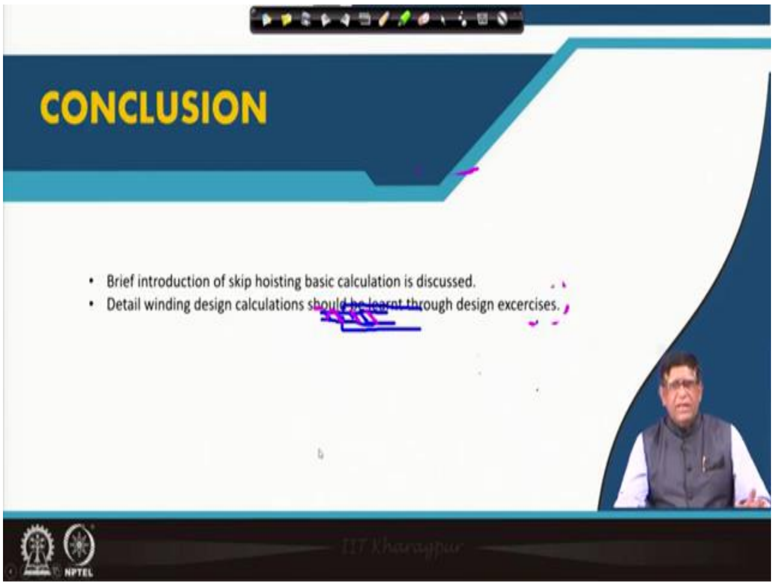

So, for coming to this and that is you should have a brief your introduction of the skip wasting we have just said here. But a design calculations have a lot of things, as I said that by P. K. Chakraborthy book from the CMPDI publications on winder calculation. There you can do and lot of work can be done. So, as an introductory and for initiate your design interest. I hope you will be going to the books and will be studying about this. Thank you very much.