Construction Methods and Equipment Management
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Lecture-14
Excavating Equipment-Front Shovel, Back Hoe

Hello everyone, I welcome you all to the lecture 14 of this course construction methods and equipment management. So, in this lecture we will be discussing about the fixed position excavating equipments like front shovel and back hoe.

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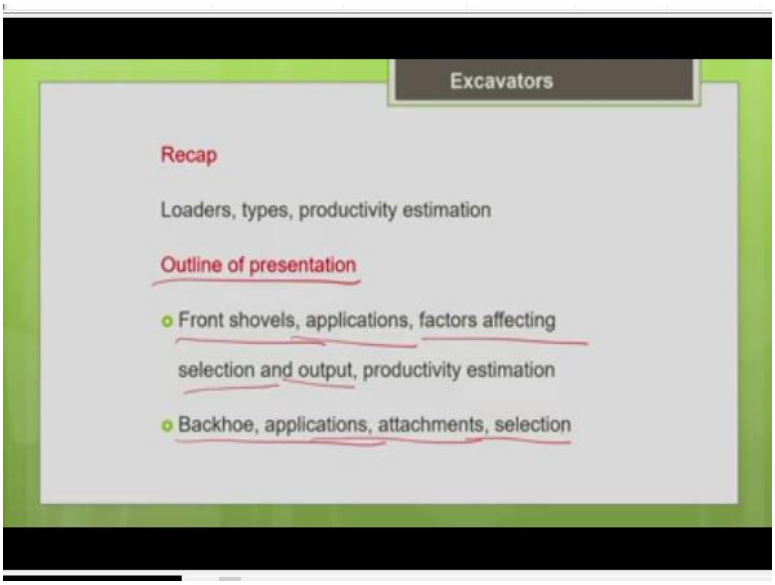

So, in the last lecture we have discussed about the loaders. And we also discuss about the different types of loaders and how to estimate the productivity of loader. So, let us look into the outline of today's presentation. In today's presentation, we will be discussing about the front shovel, its applications and factors affecting the selection of the front shovel and the productivity of front shovel and the productivity of front shove and how to estimate the productivity.

Then, we will be discussing about the backhoe, its applications and what are all the possible attachments which can be used for different applications of backhoe and how to make the selection of the backhoe. So, these are the things which are going to discuss in the upcoming slides.

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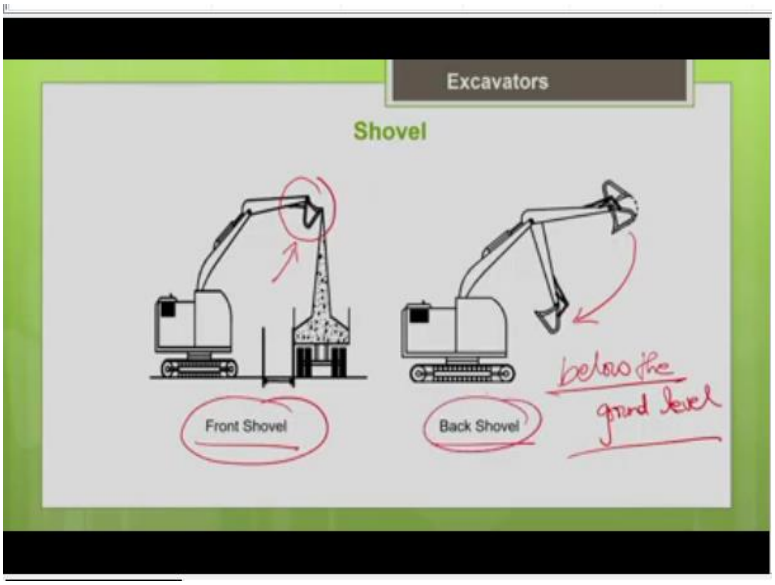

So, basically, shovels can be divided into 2 types based upon the digging motion of the bucket. So, in the first picture, you can see that the digging motion of the bucket is in upward direction. So, it is an upward direction. So, that means the bucket is moving away from the machine. So, that is called as a front shovel, in backhoe or the back shovel, you can see that the digging motion of the bucket is a downward direction.

That is the bucket is moving towards the machine. So, that is called as a back shovel or backhoe. Basically maybe want to go for digging above the ground level at or above the ground level, then we prefer front shovel. So, when you want to go for digging below the ground level, so, for deeper digging below the ground level, you go for the back shovel. So, this is how we have to choose whether will go for a front shovel or a back shovel.

So, wherever you want to do the excavation at or above the ground level go for front shovel. So, for the deeper excavations where we want to do the digging below the ground level, you go for the backhoe or the back shovel.

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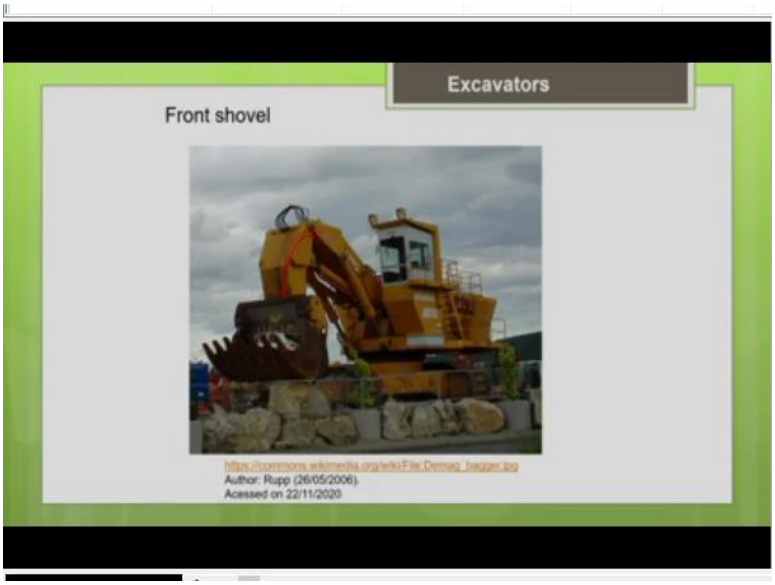

So, let us first discuss about front shovel this picture shows you the front shovel of the very huge capacity. So, basically these shovels are fixed position excavating machines that means they are not designed for much mobility. So, from the loading to dumping position, basically it is not design to move, it will just swing its boom, it will just swing it boom from loading to dumping position. So, that is why we call them as fixed position excavating machine.

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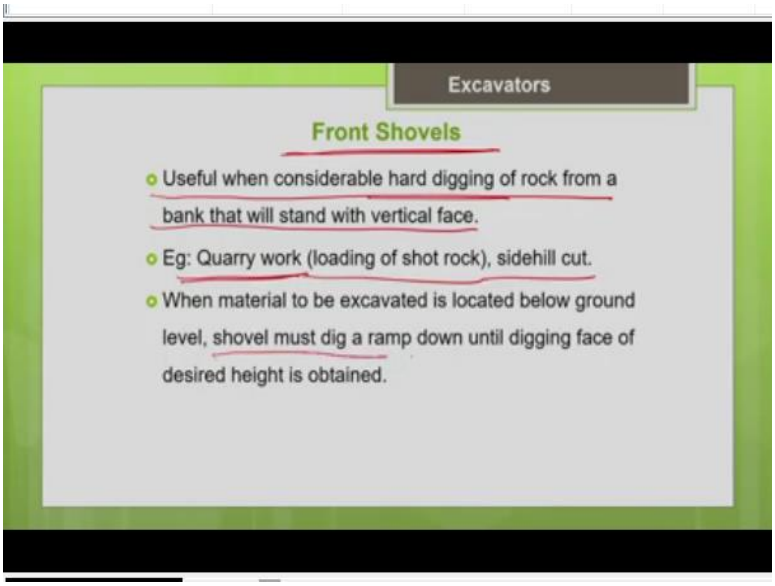

So, as I told you, this front shovel is generally needed when you want hard digging, hard digging a rock say, you can handle the rock easily with this machine, so at or above the ground level. So, this machine is the right choice. So, this is useful when considerable hard digging of rock from a bank that will start with a vertical face. So, that means this machine will give you a very good productivity when it is used for excavating a material which is standing like a vertical wall, perpendicular to the ground.

Say for example, you are going for a hill cutting it stands vertical, perpendicular to the ground. In that case, it will be very convenient to use a front shovel. So, it can be used to excavate any bank of material or in a quarry, very commonly, you can see this machine in the quarry. So, whatever rocks you are blasted using the blasting method. So, those blasted rock pieces as a short rock can be excavated with the help of the front shovel.

So, it is a using quarry work for loading of the short rock, so but it is purely dependent on a truck or any hauling machine for hauling the material. So, basically, this shovel will swing it is boom from loading to dumping position and dumped the material into the truck, it is not designed for high mobility. So, it is used for quarry work or side hill cutting. So, basically if you want to use this material for excavating below the ground level, then what are you supposed to do?

You have to do the ramping down that means the shovel must dig a ramp down into the material until a digging face of desired height is obtained. So, then only it will be easier to use a front shovel. So, if you want to excavate the material below the ground level, basically what they adopt is they will construct the ramp down into the material. There and though till they reach a digging phase, which is the desirable to cut with a front shovel. So, that is how they do for excavation below the ground level, if you want to use a front shovel.

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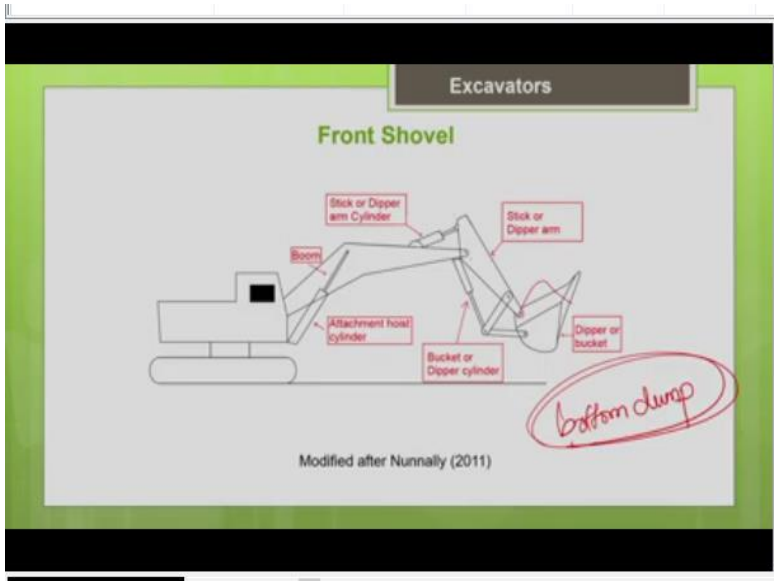

So, this picture shows you the basic operating paths of the front shovel. So, basically the substructure is a mounting mostly you can see crawler mounting and the superstructure is the

operator cab along with the engine. So, you can see the boom, this is a boom you can see the boom and this is a stick or the dipper arm and this one is a bucket or the dipper. So, these are basically hydraulic machines, they were based on hydraulic power.

So, you will be having the IC based diesel engines to operate the hydraulic pump, motor and the hydraulic cylinders which is going to deliver the power for digging operation**.** There are different types of cylinders you can see, the one which is connected to the boom is causing boom cylinder. So, this is the hoist cylinder or boom cylinder. So, other one which is connected to the dipper arm is called a dipper arm cylinder**,** this is a dipper arm cylinder.

And the one which is connected to the bucket is called as a bucket or dipper cylinder. So, there are many hydraulic cylinders you can see, these hydraulic cylinders are only going to deliver the hydraulic power which is needed for digging the material, it will be able to generate the breakout force and dig the material because of the hydraulic power generator.

So, let us see how the front shovel will function. So, basically, when you want to excavate the material, first place the shovel bucket with the bucket facing the material which is to be excavated, so, low it to the base of the material, which is going to be excavated, now curl the bucket through the material to be excavated, the bucket will get loaded, once a bucket gets loaded, now lift it.

Now lift the bucket to the desired height, then swing the bucket to the dumping position. So, basically a truck should come and stand closer to the shovel till you reach the truck, you have to swing the boom. Now as a boom reaches a truck to dump the material into the truck. So, very commonly, you can see bottom dump buckets, which will facilitate the material to be dumped in the downward direction.

So, through a bottom there will be opening which will facilitate you to dump the material. But the main limitation of the bottom dump is these buckets are heavier. So, that will limit the lifting capacity of the bucket. Otherwise, the advantage is you can easily dump the material without much spillage. So, that is a advantage with the bottom dump bucket. Once you dump the material, then what to do is you have to swing it back**,** you have to go for the return swing, swing it back to the original position then lower it.

So, that you can start the cutting again from the base of the material which is to be excavated. So, this is the common production cycle of the front shovel.

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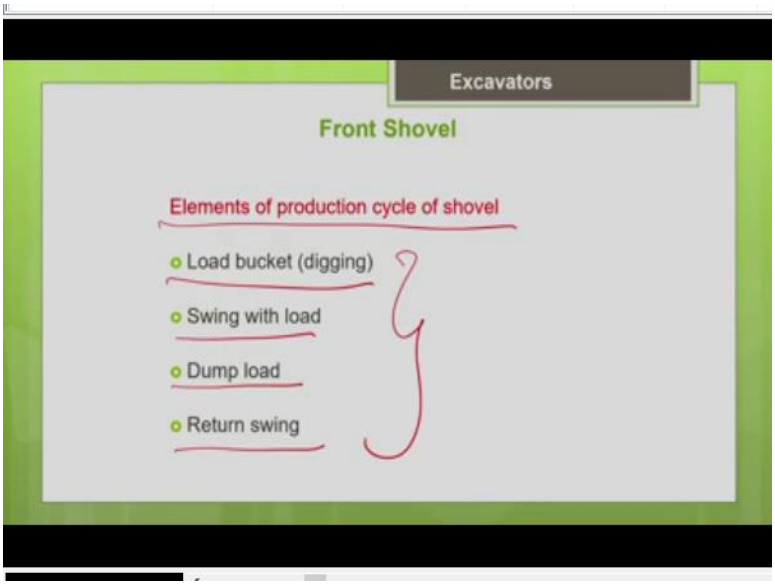

So, what are the elements of production cycle? First is we are going to load the bucket with the material you have to dig it, once the bucket is loaded, you raise your bucket, swing it till it reaches the truck, then dump the load into the bucket, then return swing back to the original position. So, all these things makes up the production cycle of the shovel**.** So, one thing have to noted here is from loading to dumping position, basically this machine is not designed to move, it will just swing its boom. So, that is why it is called as fixed position excavator.

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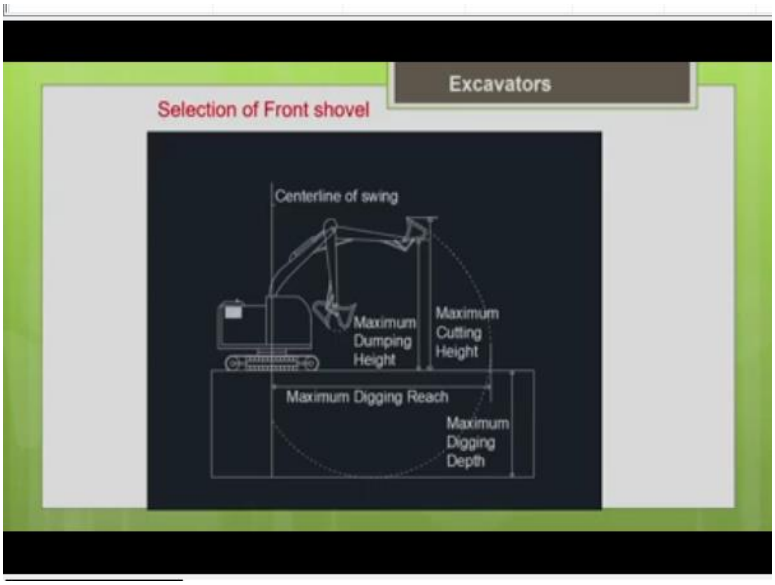

How to select this front shovel for a particular job? So, you know some important parameters related to the machine. So, that you can make the choice of the machine for the particular job.

So, basically for every shovel, the manufacturer will provide you information on what is a maximum cutting height for the shovel, what is the maximum digging depth for the shovel and what is the maximum dumping height for the shovel and what is the maximum digging reach for the shovel.

So, all these informations I can get it from the manufacturer, this depends upon the dimension of you shovel. So, what is digging reach? It is a distance between the centerline of this swing**.** You know that this superstructure have a 360 degree rotation about the slewing ring which is fixed to below it. So, the distance between the centerline of the swing to the end of the bucket. So that is called as a maximum digging reach, a completely stretch your boom or the arm.

You completely stretch the boom, so that you will get what is the maximum digging reach possible**.** So, you completely stretch the boom**,** then you can find what is the maximum digging reach possible with this machine. It depends upon the dimension of the boom , and you can get this data from the manufacturer, it will help you to know what is the maximum working radius possible with this particular machine based upon that you can make the selection.

And another thing is what is the maximum cutting height possible with the machine? So, you can see what is the maximum cutting height and this is the maximum dumping height. So, this information is important because accordingly how to select the truck, because the truck and the shovel they are interdependent machines. So, the dimension of the shovel should be sufficient enough to reach the top of your truck.

So, that it can dump the material that is why we need to know what is the maximum dumping height with this machine. So, based upon our requirements, you have to make the selection of the machine**.** This information I will be getting from the manufacturer. So, for your project, what is the maximum digging reach needed, what is the working radius needed you know, what is the maximum dumping height needed depending upon truck available.

What is the maximum cutting height needed**;** you know it for your project. Accordingly now you can make this the selection of the shovel, match your job requirements with the machine specifications and make the selection**.**

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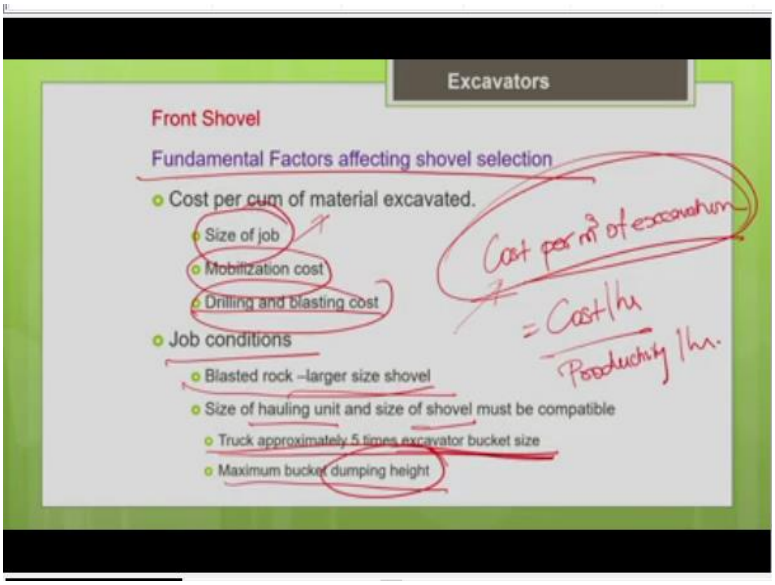

Apart from the above factors there are also the fundamental factors which govern the shovel selection. So, the important factor as everyone knows is the cost per meter cube of excavation, the unit cost of excavation that is very important for any job, what is it unit cost of production is a very important parameter, which we need to estimate. This is because based upon the unit cost only we are going to make the selection of the machine.

So, whenever we have different options of machines for selection, we will generally go with option which will give you the minimum unit cost of production for the minimum unit cost of excavation. So, for that we need to estimate this parameter. So, how to estimate that you need to know the cost associated with the machine and we need to know the productivity of the machine hourly productivity.

If you know these 2 data, I can find a unit cost of excavation associated with the machine, whichever machine is going to give me the minimum unit cost I will select it accordingly. So, basically you have to select the machine based upon the size of your job obviously, you know that. So, for a machine which has to handle a very huge quantity of material, I have to go for a bigger shovel, the size of the jobs will dictate the size of the machine.

Obviously, when you go for a bigger machine, its mobilization cost is going to be high, though with a bigger machine you can get a high productivity, but the mobilization cost is also going to high, that you have to take into account when you work out the economics, when you decide the selection of the machine. And another important thing you have to know that is when you go for a bigger size shovel.

So, you know that very commonly we use the shovel for quarry work b. So, when I go for a bigger shovel, the bucket will be able to handle bigger pieces of rocks. So, accordingly I can change my drilling and blasting pattern. So, I can have the drilling and blasting pattern economical pattern in such a way that the rock pieces can be bigger, because a bucket is bigger, it can handle bigger pieces of rock.

So, that is advantage of going for the bigger machine, it will reduce your drilling and blasting cost. So, all these things you have to work out the economics and select your machine. . So, apart from this, the other job conditions, which is going to affect a selection is for particularly as I told you earlier, when you are going to handle the blasted rock, you need more effort, you need more breakout force to loosen the material and dig it and load it into the bucket.

So, for that it is preferable to go for larger sized shovel, which can deliver more breakout force. So, that it can easily do the digging operation. So, for blasted rock preferable to go for larger size shovel and another thing you have to always keep in mind is that we have to balance a interdependent machines. Based upon your interdependent machine you have to make the selection.

As you know, your hauling unit truck and a shovel they must be compatible, because they work in team. So, you should not have a very big shovel and a small truck or a bigger truck or a smaller shovel. In both cases, you can see that there will be always some wastage of cycle time. So, that will affect your productivity. So, based upon the studies people have found out, it is always advisable to go for a truck with approximately 5 times the excavator bucket size.

So go for a truck with 5 times the bucket size. So, that is the ideal selection. So, that will help you to give the optimum productivity for both the machines. And you should also to select the machine the shovel dimensions in such a way that it will be able to reach your truck, that is why the maximum bucket dumping height, dumping height is also very important when you select a trucker or the shovel. All these basic guidelines you should keep in mind when you select the shovel for the particular job.

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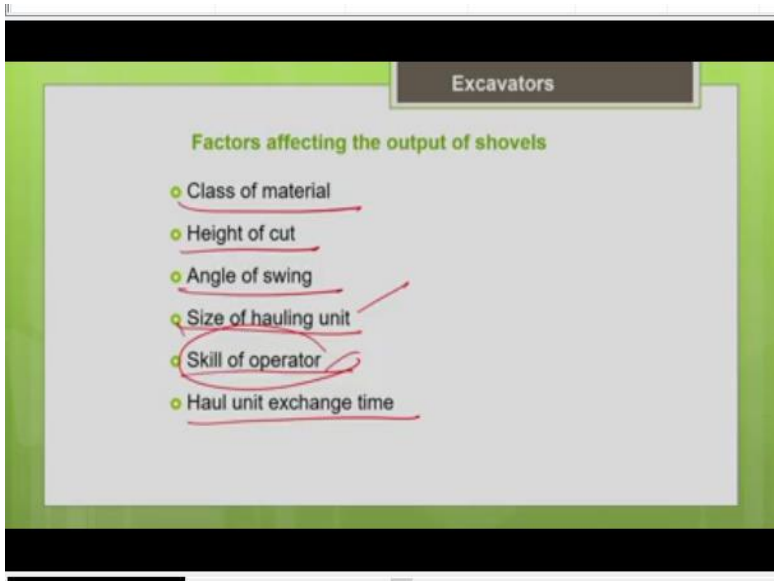

So, what are the other factors which affect the output of the shovel? Let us see class of material, height of cut, angle of swing, size of the hauling unit, skill of the operator**,** haul unit exchange time. So, all these things are going to affect the output of a shovel. Just before we discuss about the size of hauling unit, the hauling unit and your shovel should be compatible with each other.

So, the truck capacity should be 5 times your bucket size that is a right combination to have the maximum productivity and operator skill even that will also affect your cycle time in the productivity of the machine. Now, it is discussed all these factors one by one in the coming slides.

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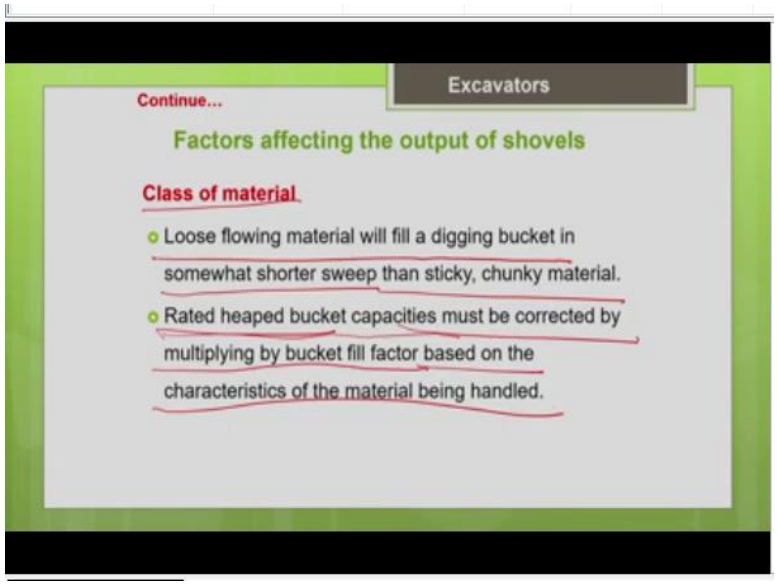

The first thing which we are going to discuss is about the class of material. So, how the material type will affect the productivity of the machine, obviously when you are going to handle some

easy flowing material like loose flowing material like sand. So, you can easily fill the bucket in a very shorter sweep, but if it is going to be a sticky material or raw chunky material. So, in that case, it may take more time to load the bucket.

So, it depends upon the flowing ability of the material. So, that is going to affect the cycle time and the productivity of your machine. Loose flowing material will fill the digging bucket in somewhat shorter sweep than sticky and chunky material. So, an another important thing you already know is just like what we discussed for the loaders, here also we can get the rated heap bucket capacity from the manufacturer.

So, the manufacturer has done the rating of the bucket under standard condition say the particular angle of repose say 1 is to 1. And they have given you the rated heaped bucket capacity, but you have to adjust the bucket capacity according to the filling ability of the material, which you are going to handle a project site, says because some materials can easily fill into the bucket, but some material will have a poor filling ability.

So, rocks may have poor filling ability, sand will have good filling ability, accordingly, the actual load volume in the bucket will vary. So, we are supposed to adjust the rated bucket volume given by the manufacturer according to the material type which we are going to handle at our project site. Rated heaped bucket capacity must be corrected by multiplying by a bucket fill factor based on the characteristics of the material being handled at the project site.

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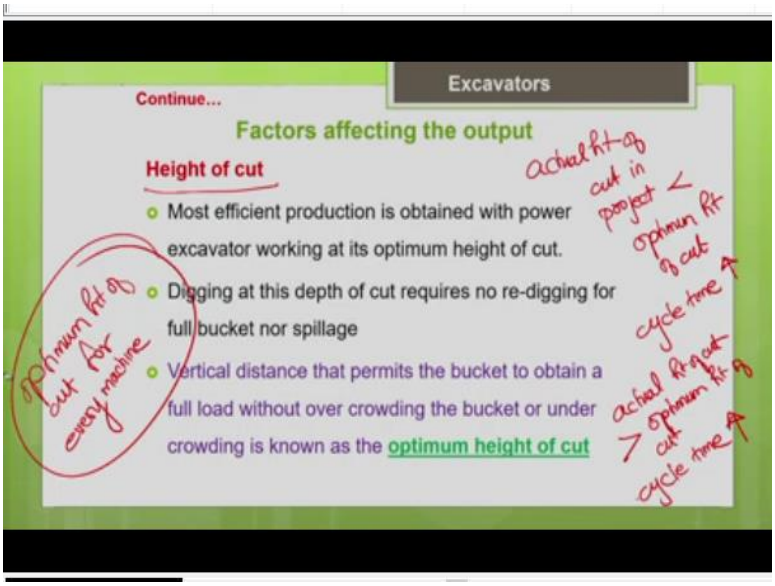

Now the another important factor which we are going to discuss is about the height of cut, how this factor is going to affect the productivity let us see**.** So, every shovel can give its maximum productivity or optimum productivity at a particular height of cut of material. So, the machine will give you optimal productivity only at optimum height of cut. So that optimal height of cut for the particular machine will depend upon that dimension of your machine. **,** it depends upon the dimension of your machine.

Say if I am using a shovel for cutting a very smaller height material. So, buckets optimum height of cut is needed is more, but the actual height of cut of material in my project site is smaller than the optimum height of cut needed for the particular machine. In that case, you can see that you would not be able to fill the bucket in one sweep, you may have to go for another sweep to fill the bucket.

This will increase your cycle time. So, similar note you can see that when the height of cut in your project site there is actual height of cut is greater than the optimum height of cut for the particular dimension of the machine . In that case also your cycle time will be more, this is because your bucket has to maneuver for the entire height of cut, so that it can fill its bucket, **,** and there will be spillage also.

And all these things will result in increasing cycle time. So, what I am trying to say here is there is a optimum height of cut for every machine which depends upon the dimension of the machine. If your actual height of cut in your project is less than the optimum height of cut needed for the particular machine. In the case also you would not be able to fill the bucket in one sweep.

So, your cycle time will be more, cycle time will increase. Similarly, if the actual height of cut in your project site is going to be greater than the optimum height of cut needed for the machine; in the case also cycle time will be more, you have to maneuver the entire height. So, only at optimum height of cut, it will give you the maximum productivity. So, that is what is discussed in this slide.

So, the most efficient production is obtained with power excavator working at its optimal height of cut. Digging at this depth of cut requires no re-digging for full bucket nor spillage. That means when the machine is working at the optimal height of cut when the actual height of cut

of material in a project site is equal to the optimum height of cut needed for the machine you can fill the bucket in shorter sweep.

So, there is no need for re-digging again to fill the bucket and there would not be spillage also. All these things will improve your productivity of the machine. So, basically what is this optimum height of cut, the vertical distance that permits a bucket to obtain a full load without overcrowding the bucket or under crowding is known as optimum height of cut. So, at this particular height of cut, I can fill the bucket in one sweep without overcrowding the bucket or under crowding the bucket. So, that they can give me optimum productivity or maximum productivity.

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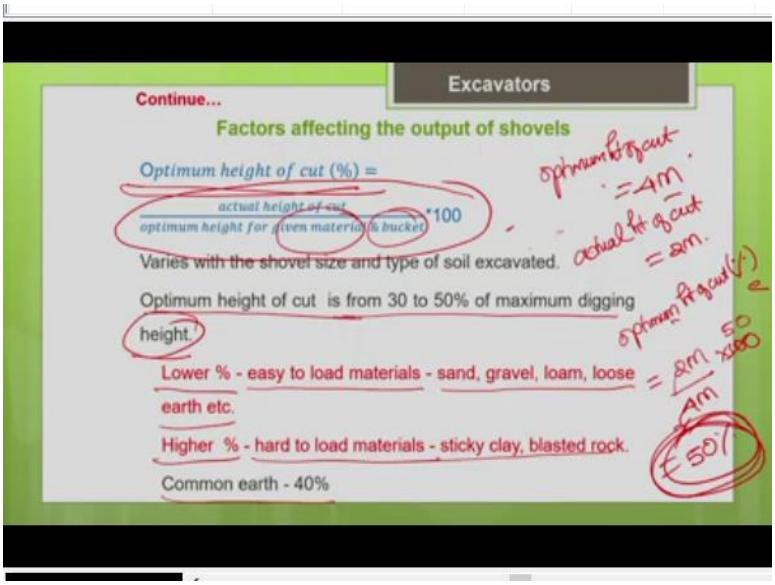

Now, let us see how to know the optimum height of cut for the machine. So, optimum height of cut require for a particular machine depends upon the dimension of the machine as I told you. So, this will be equal to based on studies they found that it is equal to 30 to 50% of maximum cutting height obviously, you know that for every machine for every shovel, I can get the information on what is the maximum cutting height from the manufacturer, what is the maximum cutting height.

What is the dumping height, what is the maximum digging reach, all this information I can get it from the manufacturer and I should know that at its maximum cutting height, definitely it would not give you maximum productivity. So, the optimal height of cut will be 30 to 50% of the maximum cutting height for the particular machine. Now, how to design whether it is 30% or 50% that is going to depend upon the material type.

Material type, say if you are going to handle some easy flowing material, like sand, or loose earth, in that case, a 30% of maximum cutting height, I can easily fill the bucket, but if you are going to have some hard materials like rock or clay, in that case I need 50% of the maximum cutting height to fill my bucket. So, it depends upon the material type, for easy flowing material, I can take the optimal height of cut as 30% of maximum cutting height.

That is what is given here. So, for basically the optimum height of cut is from 30 to 50% of the maximum digging height**.** This information I can get it from the manufacturer depending upon the machine dimension and I should go for lower percentage there is 30% for material which are easy to handle, easy to load like sand, gravel, loam, loose earth, etc. I can go for 30%.

For hard to load material like sticky clay, blasted rock, I should go for higher percentage say 50%, for common earth you can take it as 40%. This is how you have to find your optimal height of cut for the particular machine. So, basically, it depends upon the maximum cutting height possible for the machine as well as depends upon the material type. So based upon that I can find the optimum height of cut.

So, we have determined the optimum height of cut for your machine depending upon the material type and depending upon the maximum cutting height for the particular machine, but in your project, the actual height of cut may be different from the optimum height of cut. So, now if it is going to be as I told you, if the actual height of cut is lesser than the optimum height of cut also it will affect the productivity.

If the actual height of cutting a project site is greater than the optimum height of cut in that case also it will affect your productivity. So, how it is going to affect the productivity we need to assess. So, we need to apply some correction factor to the productivity depending upon the actual height of cut in your project site. So, that is what we are going to do now.

So, the optimum height of cut percentage is nothing but actual height of cut divided by optimum height for the given material and for the given bucket that means for the given dimension of the shovel, so based upon that you can find the optimum height of cut percentage.

$$Optimum\ height\ of\ cut\ (\%) = \frac{Actual\ height\ of\ cut}{Optimum\ height\ for\ given\ material\ \&\ bucket} \times 100$$

Say for example, for a particular front shovel the optimum height of cut needed is 4 meter, optimum height of cut needed for a particular shovel it is 4 meter based upon the material type as well as based upon the maximum cutting height.

We found that it is 4 meter, but the actual height of cut in your project site is a 2 meter. Now, what is the optimal height of cut percentage is equal to 2 meter divided by 4 meter into 100. So, this is going to give me 50%. So, the optimum height of cut is only 50%. So, that means your productivity is going to be affected because the height of cut is less than the optimum height of cut actual height of cut is less than the optimum height of cut.

This correction I have to do for the productivity estimation. So, I will tell you later how to do the productivity estimation in the upcoming slides.

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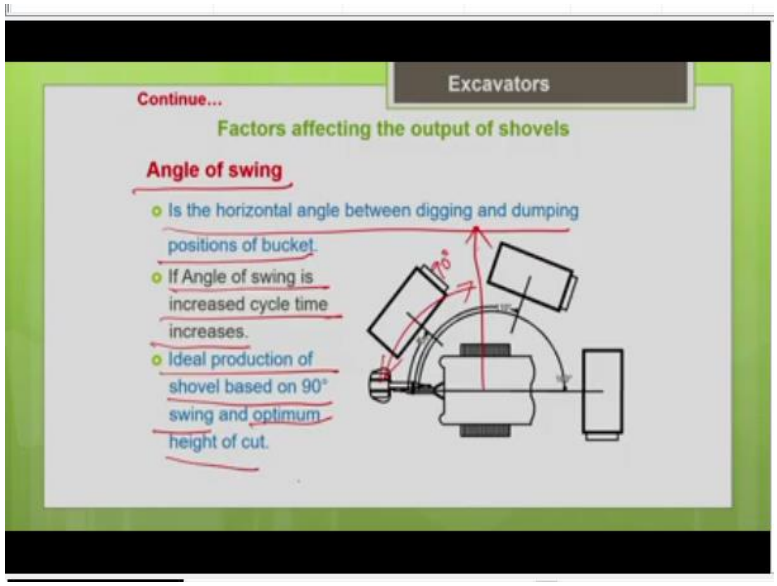

Another important factor you should know that which is going to affect your productivity is the angle of swing. So, basically the angle of swing is nothing but the horizontal angle between the loading and the dumping position, that is your horizontal angle between your bucket and the truck, it will vary depending upon the position of your truck. As I told you for ideal conditions, it is preferable to place a truck close to the excavator, this is because these machines just not good at mobility.

They have poor mobility. So, that is why it is preferable to place a truck very close to the excavator. So, very commonly you can see that the truck is placed at 90 degree. So, the truck is placed at 90 degree, this will be 90 to the bucket position. So, this is a common position. So, basically angle of swing is nothing but the horizontal angle between the digging and the dumping position between the loading and the dumping position.

As the truck moves further away, your angle of swing would increase as the angle of swing increases. As the angle of swing increases, you can see that your cycle time will increase, the productivity will decrease. So, angle of swing is the horizontal angle between the degree and the dumping positions of the bucket, if the angle of spring is increased, the cycle time increases you know it.

So, ideal condition ideal production of shovel is based on 90 degrees swing that is what I told you, the truck will replace it 90 degree is ideal condition and the actual height of cut in your project site should be same as optimum height of cut, that combination that will give you ideal production .

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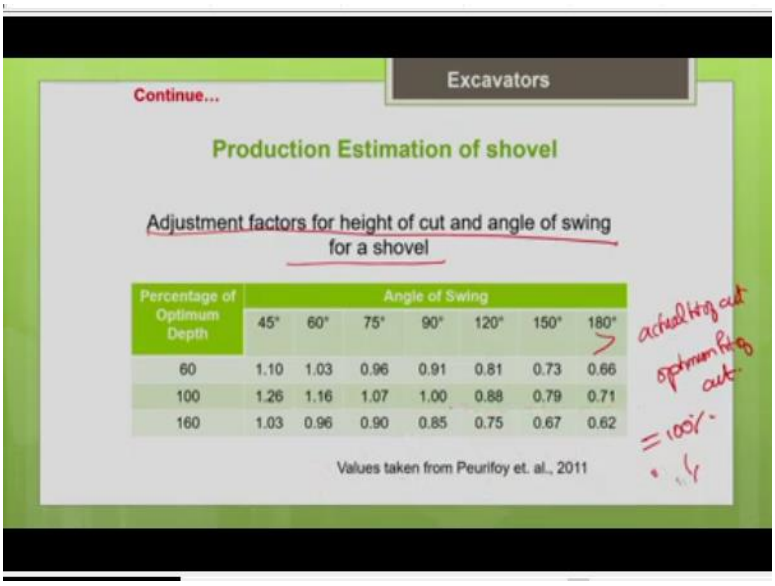

Now, let us see what are all the adjustment factors, we have to apply while doing the productivity estimation based upon the height of the cut of material actual height of cut of material in your project site and based upon the angle of swing that is going to depend upon the position of your truck relative to the position of your excavator. So, adjustment factors for the height of cut and the angle of swing for the shovel.

So, as I told you, if the actual height of cut is same as optimum height of cut, it means the percentage is 100% how do you calculate the percentage actual height of cut divided by optimum height of cut for the particular machine. If this percentage is going to be 100% it means actual height of cut and optimum height of cut are same. So, in that case, you need not apply any correction factor.

Similarly, the ideal condition what we assume is the truck is placed at 90 degree to the excavator**,** So the angle of swing is 90 degree for both these cases the correction factor is 1, that means I need not apply any correction factor based on height of swing because it is an ideal condition, but if your actual project condition is going to differ or vary from the ideal condition, then in that case you have to apply the correction factor.

Say if you are going to do the cutting operation and the height of cut is say lesser than the optimum height of cut, say it is only 60% of the optimum height of cut, you can see you have to apply this correction factor. Similarly, when it is 160% also apply this correction factor. So, thing you have to notice is, when the height of cut is less correction factor is also less, that means the productivity is going to be reduced.

When the height of cut is more your correction factor in the case also it is less, the productivity is going to be less. Similarly, when you consider the angle of swing when the angle of swing is more than 90 degree, you can see that the correction factor is reducing, it shows that your productivity will reduce, but if your angle of swing is lesser than 90 degree, you can see that the correction factor is increasing.

That means it shows that your productivity is increasing. So, if possible to keep your truck at an angle of swing lesser than 90 degree, it will be better than the ideal condition. That means because the correction factor is increasing. So, that is going to increase the productivity. So, depending upon the angle of swing in your project site and depending upon the actual height of cut of the material, which you are going to cut, based upon that you have to apply the correction factor while you do the estimation of your productivity.

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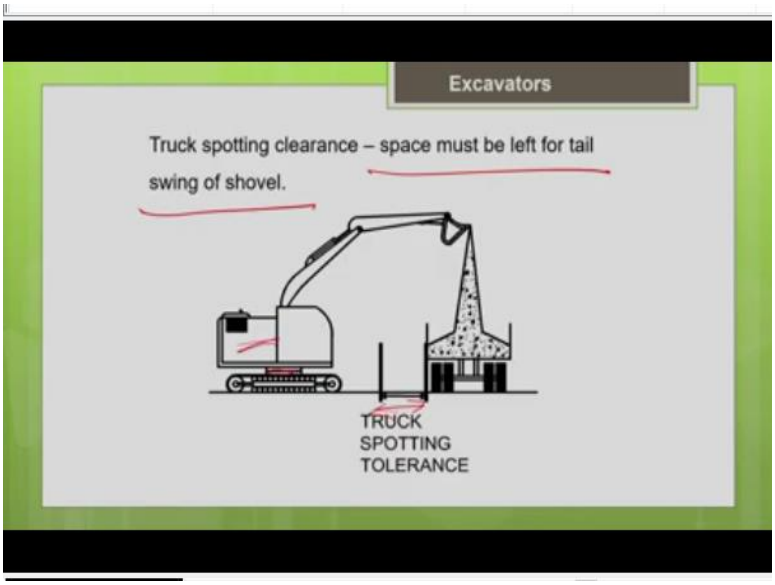

Another thing to be noted is truck spotting clearance. That means, as I told you, it is preferable to place a truck closer to the excavator. But at the same time, note that there should be some space left for the tail swing of the shovel. That means now you can have a complete 360 degree swing, you have a slewing ring here, you can have a complete 360 degree rotation about the mounting.

So when it rotates, you should make sure that the tail of this shovel should not collide with the truck which is placed too close to the truck that is why there should be some space left for the tail swing of the shovel that is called this truck spotting clearance.

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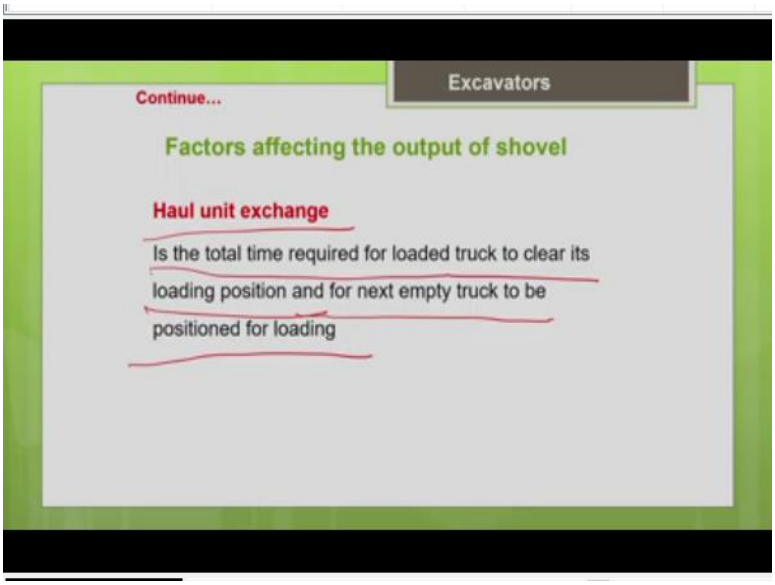

Other important factor is haul unit exchange time. That means the time needed for the loaded truck to leave its position. And for a new truck that is an empty truck to take the position. That

is called as a haul unit exchange time. So, this is also going to affect the productivity. If your truck is not readily available for the loader to load the material or to dump the material into the truck if you do not have a truck readily available, then the loader has to wait for the truck.

So, that will increase the cycle time. So, it is nothing but a total time required for the loaded truck to clear its loading position and for the next empty truck to the position for loading. So, we have to minimize this haul unit exchange time. So, we have to balance the number of machines, balance the number of trucks and the shovels in such a way that the waiting time is minimized.

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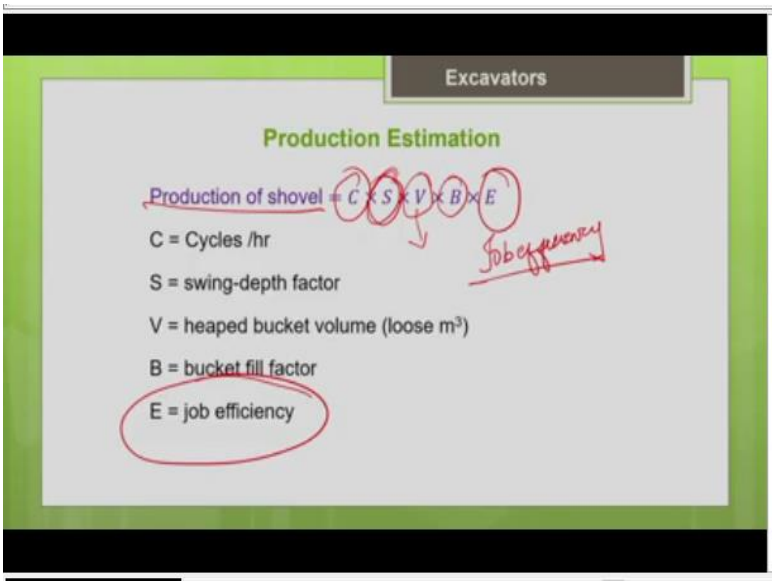

Now let us see how to estimate the productivity of the shovel. So, for all these machines, the principle is going to be the same, you can see the formula everything is going to be similar only. So, the production of shovel, it depends upon the heaped volume of your bucket, heaped the volume of your bucket you can get it from the manufacturer, that you are going to adjust with the bucket fill factor, depending upon your material type, then divide it by the cycle time. Either you can divide it by cycle time, or multiply it by the number of cycles per hour. Either way you can do it.

And another important thing we are supposed to do is we have to adjust the productivity based upon the swing depth factor, swing depth factor nothing but depending upon the actual height of cut of the material in your project site. And depending upon the angle of swing between the truck and the excavator, you have to apply the correction factor. So, hope you remember this table which I showed you.

If the actual height of cut and the angle of swing is going to differ from the ideal condition in your project site, then you have to choose the correction factor accordingly from this table and then apply the correction factor to the productivity, if the actual height of cut is same as optimal rate of cut and if the angle of swing is 90 degree, then you need not apply any correction factor.

If the conditions are going to be different from this ideal condition then you have to adjust a productivity with the swing depth factor. Another important thing that we are going to do is we are going to multiply the production of the shovel with the job efficiency. So, how much time your machine is going to work in a hour , whether it is going to work for 45 minutes in a hour or 50 minutes in a hour or 30 minutes in a hour accordingly have to multiply with the job efficiency factor and get the actual productivity of the shovel.

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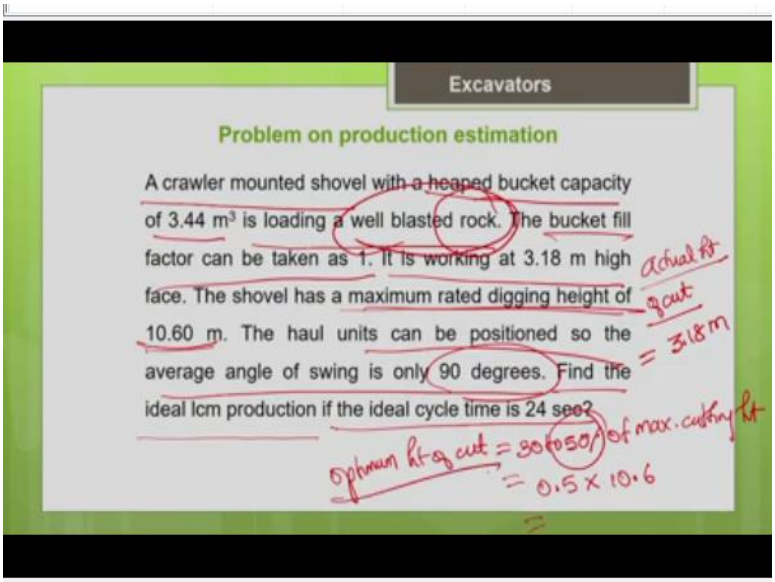

Now let us work out a problem on the production estimation a crawler mounted shovel with a heaped bucket capacity of 3.44 meter cube is loading a well blasted rock. The bucket fill factor can be taken as 1, depending upon the material type, they are supposed to take the bucket fill factor, it is readily given to you in this question as 1. It is working at 3.18 meter high face. So, that means the actual height of cut of material is 3.18 meter, the shovel has a maximum rated digging height of 10.6 meter.

This is provided by the manufacturer; haul unit can be positioned so that the average angle of swing is only 90 degree. Actually 90 degree is ideal condition. So, for the angle of swing, I do not need a correction factor, but for the actual height of cut, we have to see whether the

correction factor is needed or not. For that we need to estimate the optimum height of cut for the machine.

Now find the ideal cubic meter production, if the ideal cycle time is 24 seconds. So, since it is given ideal, it means the machine is going to work for the job efficiency is very high it is working for 60 minutes in a hour. So, you need not correct it according to the other job efficiency factors, because it is given ideal it means it is working for 60 minutes in a hour. Now, let us see what is the optimal height of cut for this machine**.**

As I told you earlier it is going to be 30 to 50% of maximum cutting height possible for this machine. So, in this case, it is handling well blasted rock, since it is handling rock which is a harder material to deal with it is go for 50%, 0.5 into what is the maximum rated digging height it is given as 10.6 meter. So, we have to find what is 0.5 into 10.6, that will give you the optimum height of cut for this machine.

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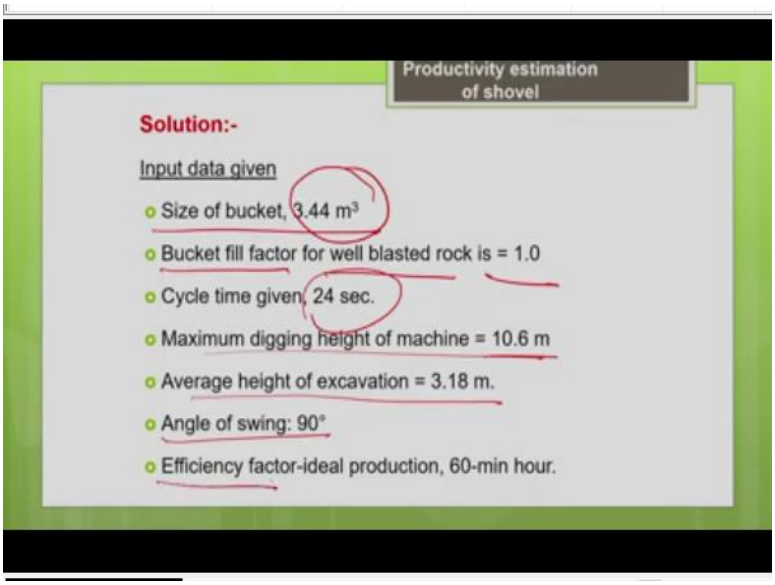

Let us see oh it is now that. So, in this slide, I have just summarized the data whatever the input data given in this problem. So, the size of bucket is 3.44 meter cube, that means it is a heaped bucket capacity given by the manufacturer, bucket fill factor is given us 1 for the well blasted rock, cycle time is given to you as 24 seconds, the maximum digging height for the machine is 10.6 meter.

And average height of excavation is 3.18 meters, which is the average actual height of cut in the project site angle of swing is 90 degree. The efficiency factor, it is going to work for 60 minutes an hour.

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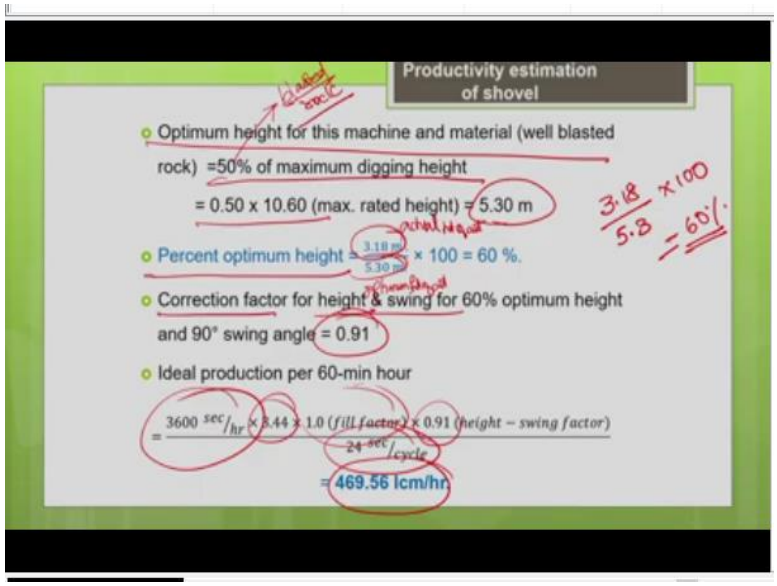

Now, as we discussed earlier, we have to find the optimum height for the machine, it is nothing but 50% of maximum digging height. I hope you know why we do to 50% because it is handling blasted rock, rock is a harder material to handle. So, take 50% of the maximum digging height. So, 0.5 into 10.6 meter it gives you 5.3 meter is the optimum height for the machine, but what is the actual height of cut it is dealing with it is 3.18 meter.

So, in this case, actual height of cut is 3.18 meter. So, it is less than the optimum height of cut. So, what is the optimum height of cut 5.3 meter, since it is less obviously a production is going to be this. So, you have to adjust the productivity based upon the height. So, based upon the height, we have to adjust the productivity, for that I need to estimate the percentage optimum height.

So, how do you calculate the percentage of optimum height 3.8 meter is your actual height of cut? And 5.3 is your optimum height of cut. So, now find the percentage 3.18 divided by 5.3 into 100. So, we will give 60% the optimum height of cut percentage is 60%. So, obviously this will be having an effect on a productivity of the shovel. So, now we have to choose a correction factor based up on the height and the swing.

Swing is 90 degree. So, we discussed about the table earlier, now which is the correction factor these values are taken from Peurifiy text book by Peurifoy et al. So, for 90 degree angle of swing and for 60% of optimum height the correction is 0.91. So, you are going to apply the correction factor is 0.91. Now let us see how the production estimation is done.

$$Ideal\ production\ per\ 60-min\ hour$$

$$= \frac{3600\ {}^{sec}/_{hr} \times 3.44 \times 1.0\ (fill\ factor) \times 0.91\ (height - swing\ factor)}{24\ {}^{sec}/_{cycle}}$$

$$= \mathbf{469.56}\ \boldsymbol{lcm/hr}$$

The volume of bucket is it is given as 3.44 metre cube. The heaped bucket volume 3.44 metre cube, bucket fill factor is 1, your swing and height factor is 0.91 and a cycle time is 24 seconds. So, you need the productivity in loose cubic metre per hour. So, convert it into hour that is the reasons multiplied by 3600 and the job efficiency here is 1. So, now you will get the answer is 469.56 loose cubic metre per hour. So, this is the productivity of your front shovel.

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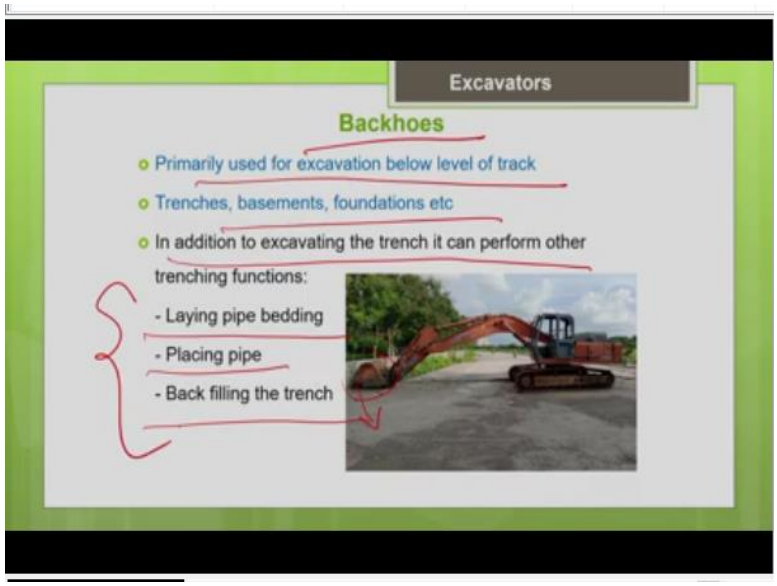

So, now let us discuss about the backhoes. So, you can see that the basic parts and operation are similar for both the machines but only thing to be noted is the digging motion of the bucket is in downward direction. So, it is preferred for the deep digging below the ground level, this machine is used for the digging below the ground level. So, mainly used for excavation below the level of track.

For commonly you can see its application in trenching operation for excavation the basements, foundations, it is very commonly used. So, and one more important thing is this machine is very versatile in the sense for the trenching operation because with the same machine I can complete the entire job. Say for example you need to do the trenching operation laying a pipeline.

So, select width of bucket equal to the width of the trench, so the productivity will be maximum. Now you can do the digging of trench now and you just change the attachment, there will be a coupling device you can just attach the hosting attachment and handle the pipe line which is to be placed. So, place the pipe line with the help of the backhoe, now back fill the trench with the same backhoe. So, the same machine is able to do the complete job, so it can excavate the trench, it can handle the pipe line just by changing the attachment and you can back fill the trench.

So, the complete job is done by the same machine that is why it is very commonly used for trenching and this is the right choice of machine for trenching. In addition to excavating you can say that you can perform all the trenching related functions that is laying the pipe bedding, placing the pipe, back filling the trench, everything can be done with the same machine, that makes it more versatile.

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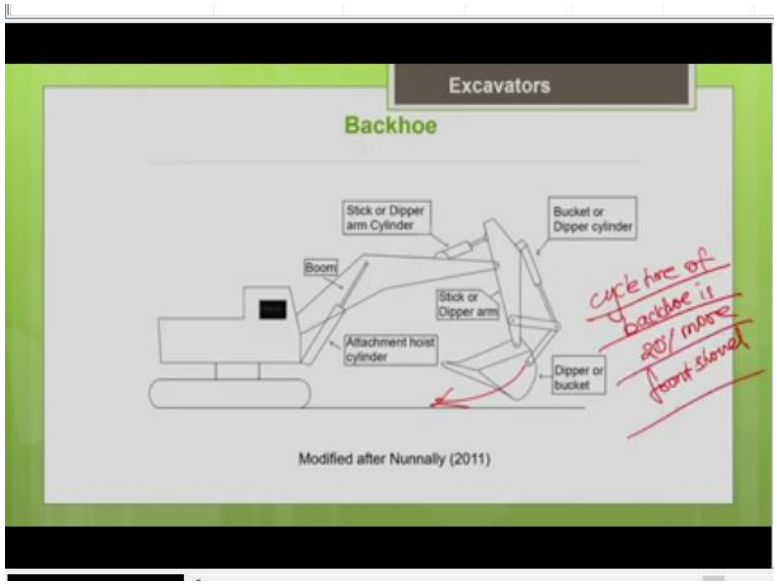

So, these are the basic operating parts of the backhoe it is similar to a front shovel only anything is digging motion of the bucket will be in downward direction. But one thing to note that cycle time of backhoe is 20% more when compared to front shovel. The reason is say whenever the

material when the bucket has to dump the material with the backhoe has dumped the material it has to fully extend the arms and then dump it.

So, that will take some additional time for extending the arms and dumping the material that is why you can say that the cycle time of backhoe is 20% more than the front shovel. So, additional time is needed for dumping because it needs to completely stretch the arms. And one more important thing is say for example, we are using this machine for excavating below the ground level if you are able to place your truck also on the floor pit to construct a ramp and bring your truck or the hauling unit on the floor pit.

You can see that dumping will be easier. You can reduce the dumping time because truck is lying below the bucket because the truck is standing on the floor pit. **,** So, in that case, it will be more beneficial to reduce the cycle time. That is why for deeper excavations what they do is they put a ramp and put the hauling unit and bring the hauling unit on the floor of the pit. So, that the bucket will be above the truck. It will be easy to dump the material into the truck.

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So, this is a crawler mounted backhoe a smaller one. So, let us different models are available. So, when you are working in a narrow space or confined areas you can go for a smaller size backhoe. So, it also has an attachment of the grader you can see for grading.

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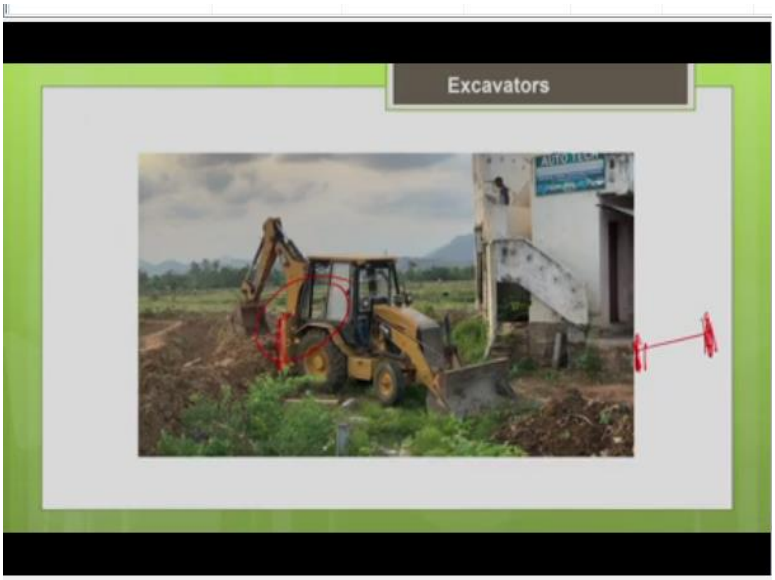

So, this is the combination of front end loader and backhoe. In some places you may need this combination because I may have to use a backhoe for excavating below the ground level, at the same time I may need a help of a front end loader to transport the material to a dumping position, when both are needed together then you have to go for this front end loader backhoe combination.

So, you have a backhoe as well as the front end loader. So, there we need a loader for transporting the materials as well as you need a backhoe for excavating below that ground level in that case you can go for this combination . So, this is a wheel mounted loader. So, you have to carefully note that you have to extend this out trigger you can see this out trigger right, this out trigger you have to completely extend on both the ends and make sure that the load is transferred to the out trigger to the ground.

This is very important from stability point of view, this is because the machine is the wheel mounted. So, when the backhoe is doing the excavation job, you extend the outriggers completely and transfer the load to the ground through the outrigger instead of the wheels. So, this will ensure the stability of the machine when it is doing the excavation. So, now you can see this video how the trenching operation is done with this loader backhoe combination. **(Video Starts: 46:38) (Video Starts: 47:30)** So, this machine as I told you is a very versatile one, you can go for different types of attachments with this machine.

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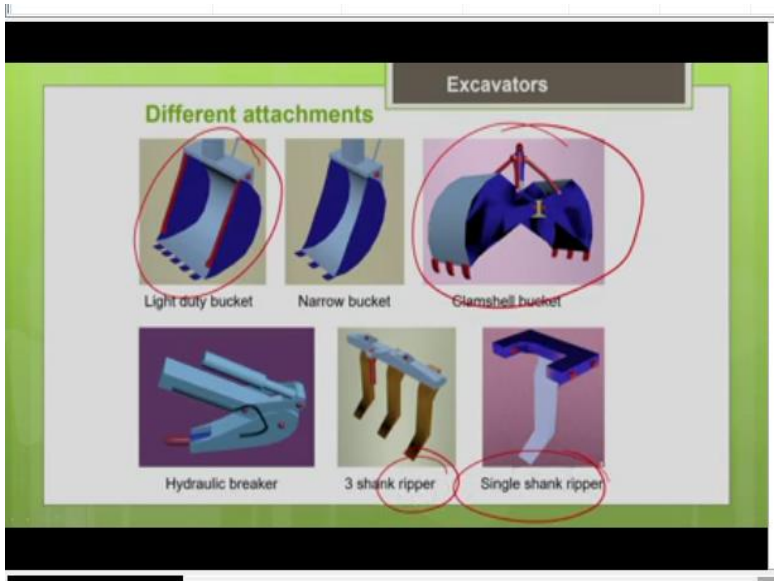

And use it for different applications. So, I can go for a light duty bucket. That means if you are going to handle lighter material, I can go for a wider bucket, but if you are going to handle harder material or denser materials, you go for a narrow bucket with a short tip radius. So, that we facilitate the digging operation. So, another attachment you can see clamshell bucket. So, this is also very commonly the mounted on excavators or it can be even mounted on the cranes**.**

This clamshell bucket is mainly for a deep digging with a vertical digging, you can see 2 scoops, these are the scoops which are hinged. So, with this scooping arrangement, I can easily use it for vertical digging, I can use it for trenching or excavation of material from a manhole sewer or I can use it for excavation from a pier foundation. So, whenever I need some vertical dig, I can use this clamshell arrangement.

So, this is also a very popular attachment. So, as I told you, this can be even mounted on the cranes, have a hydraulic breaker for breaking the rocks, you can go for ripper as we discussed earlier with bulldozer**,** either 3 shank ripper or a single shank ripper for cutting the weaker rocks or cutting the pavements . So, you can use. So, just by changing the attachment. So, as I told you, there will be a coupling device where you can easily change your hoisting attachment and you can use different attachments that go for different applications that makes the machine more versatile.

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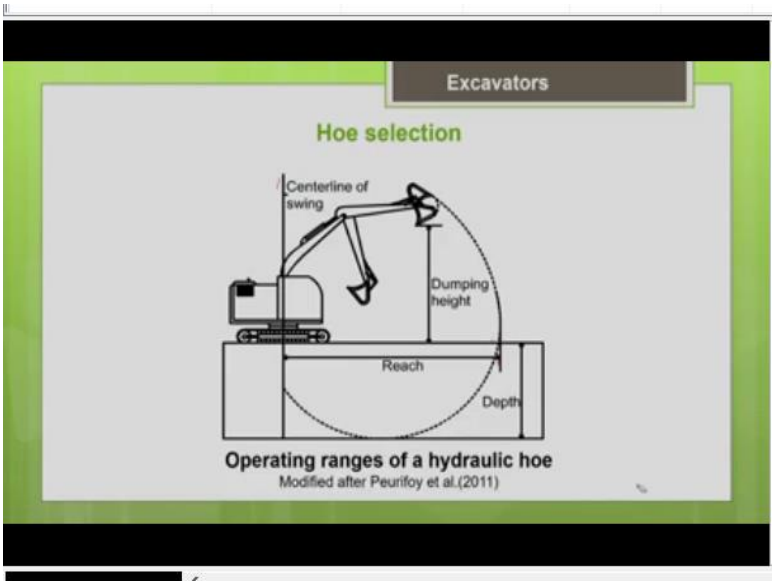

As we discussed earlier for the front shovel here also, these are the important parameters which helps you in the selection, what is the maximum dumping height possibly with the machine? What is the maximum digging reach possible with the machine when you completely extend your arms, when it completely extends it you can get the maximum digging reach possible that will give you the working radius possible.

It is nothing but the distance between the centerline of the swing and the end of the bucket. When you completely**,** stretch the arms, that will give you the reach possible and what is the maximum digging depth possible. So, this information will get it from the manufacture depends upon the backhoe dimensions. So, you know at your project site, what are your requirements?

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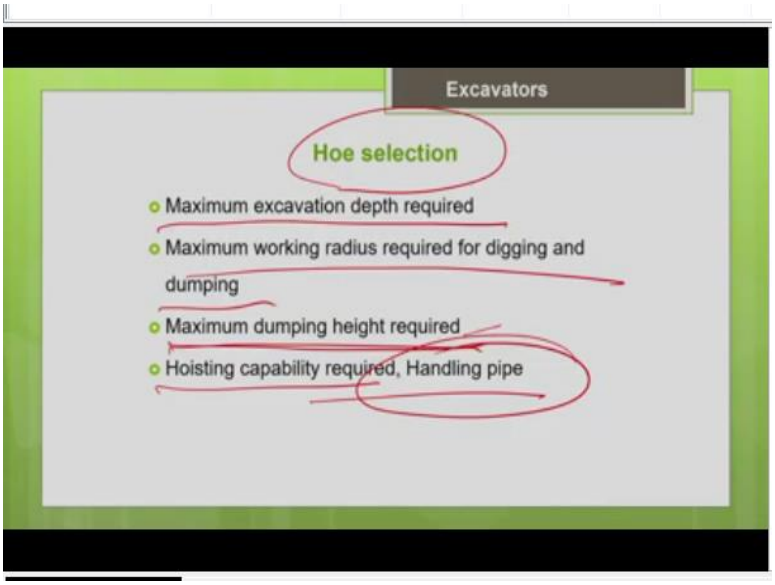

So, maybe what is the maximum excavation depth you need that you know, what is the maximum working radius you need for digging and dumping you know that, accordingly choose a machine with maximum digging reach, then you know what is the truck available for you. So, according to that you should decide whether the shovel dimension or the backhoe dimension is sufficient enough to reach the top of the truck.

So, what is the maximum dumping height needed? So, that which is need at your project site you should be knowing, see if you are going to use the same machine for handling some pipelines or trench boxes. So, in that case, you have to see what is the hoisting capability needed, what is the hoisting attachment needed, all these things you have to decide before the selection of your backhoe for the particular project.

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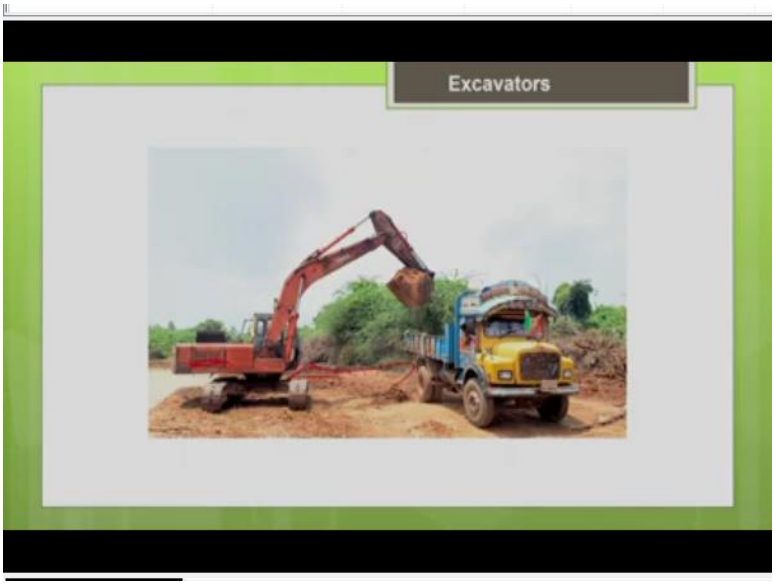

So, this video again shows you how the truck is commonly placed very close to the backhoe. **(Video Starts: 50:58) (Video Ends: 51:39)** As I told you, the angle of swing will be 90 degree, the horizontal angle should be 90 degree between the loading and the dumping position. So, the truck should come very close. So, that backhoe will be able to excavate the material and load it into the truck.

The common ideal condition is 90 degree angle of swing and also you should make sure that when the superstructure when the backhoe rotates about the slewing ring, the tail should not hit against the truck, there should be some sufficient truck spotting distance between the truck and the backhoe that also you have to make sure.

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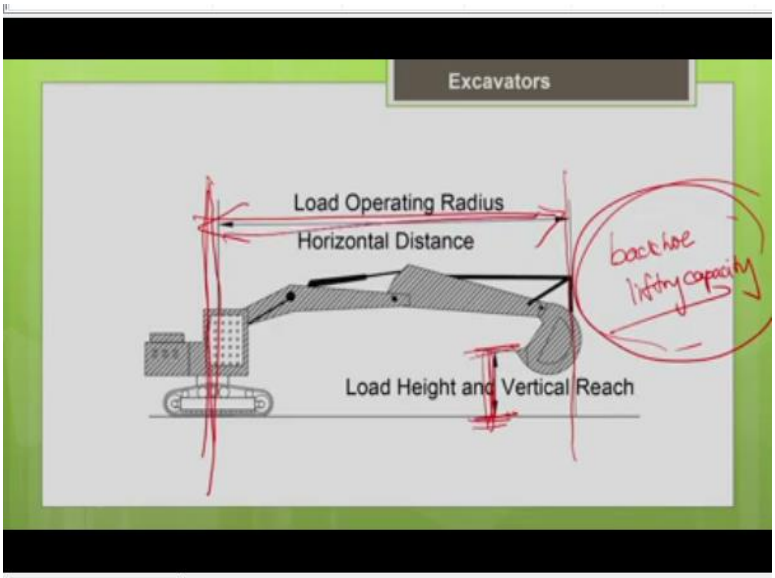

Another important thing you have to note that whenever the manufacturer provided you the lifting capacity for the backhoe. So, when they provide the lifting capacity for the backhoe they will give you a complete chart. So, this is because this also belongs to the cranes family. So, all these operations that are somewhat similar to the crane. So, you can see that based upon the operating radius, the lifting capacity of the machine will vary, what is the operating radius.

It is nothing but the distance between the centerline of the axis of rotation of this machine to the center of gravity of the load in the bucket, this distance will give you the load operating radius. So, this distance gives you the load operating radius. So, then the operating radius is more you can see that the lifting capacity will get reduced obviously. So, when the bucket is completely extended, you can see it is moving away from the center of gravity of the machine.

So, you can see that from stability perspective, the lifting capacity should be reduced, but when the bucket is closer to the machine, when the operating radius is less, you can see that you can have a better lifting capacity. Similarly, the lifting capacity will also vary with the height; it will also vary with the load height above the ground level. So, how the lifting capacity will vary with the operating radius and with the vertical height to the distance you can get it from the manufacturer.

We have to ensure that your loading of the material in the bucket should be within the safe lifting capacity as prescribed by the manufacturer and you should know that it will vary with operating radius. So, we have to monitor it and another important thing you need to note that is just like as we discussed for the loaders, here also the tipping load is taken care , whenever

the manufacturer provide you a lifting capacity, the tipping load is taken care. And then only he will give you the safe lifting capacity and but you should note that it will vary with the operating radius.

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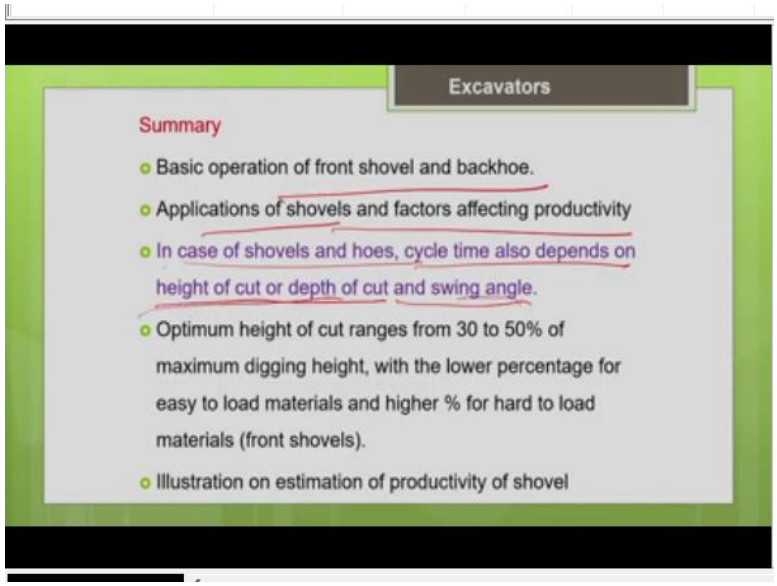

Now we have come to the end of this lecture. Let me now summarize what we have discussed so far. So, in this lecture we have discussed about the basic operation of the front shovel and the backhoe and what are the applications of the front shovel and the backhoe and what are the factor which affects productivity. So, the factors which affects the productivity of the front shovel and backhoe everything is going to be same.

Only thing is the digging operation is different in both the cases digging direction is different. In the case of shovels and backhoes you need to know that cycle time depends upon the height of cut or the depth of cut and the swing angle. So, that is why if the swing angle or actual height of cut is going to differ from ideal condition, you have to apply the correction factor when you estimate the productivity of the machine.

So, the estimation productivity is going to be similar for both the front shovel and the backhoe? So, you can work it out okay for the backhoe. And another important thing you have to keep in mind is the optimum height of cut ranges from 30 to 50% of the maximum digging height for a front shovel we have discussed and you have to choose a lower percentage for the easy materials easy to load material and you have to choose a higher percentage for the hard to load material.

So, that is how you find the optimum height of cut for every machine. So, the optimum height of cut will depend upon the dimension of the shovel. So, because the dimension of the shovel is going to decide what is the maximum digging height possible for the machine and also depends upon the material type, that is what we discussed earlier. So, we have workout a problem on how to estimate the productivity of the front shovel. In a similar manner you can also workout the productivity of the backhoe.

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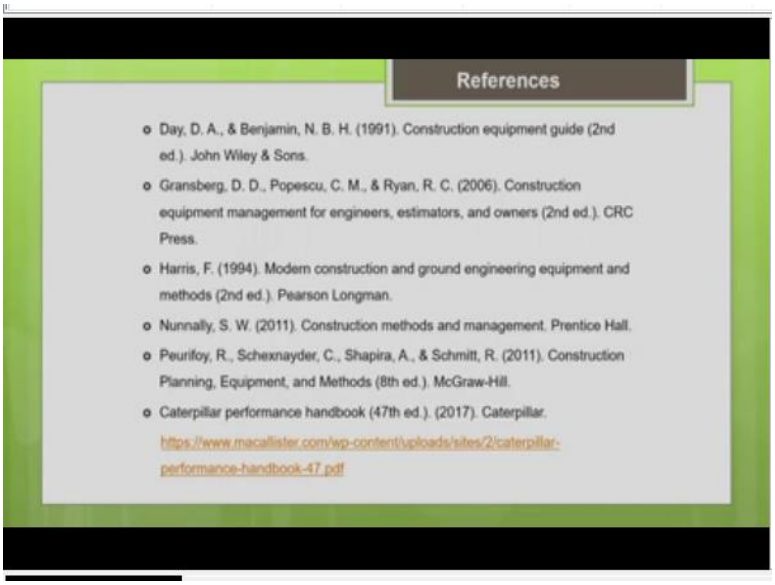

So, these are the references which I have referred for this particular lecture. I advise you to procure some of these books for prepare this topic. In the next lecture, we will be discussing about the trucks, how to estimate the productivity of the trucks and how to balance the number of trucks and the number of shovels because they are interdependent machines. So, we will be also working on some problems based on that. Thank you.