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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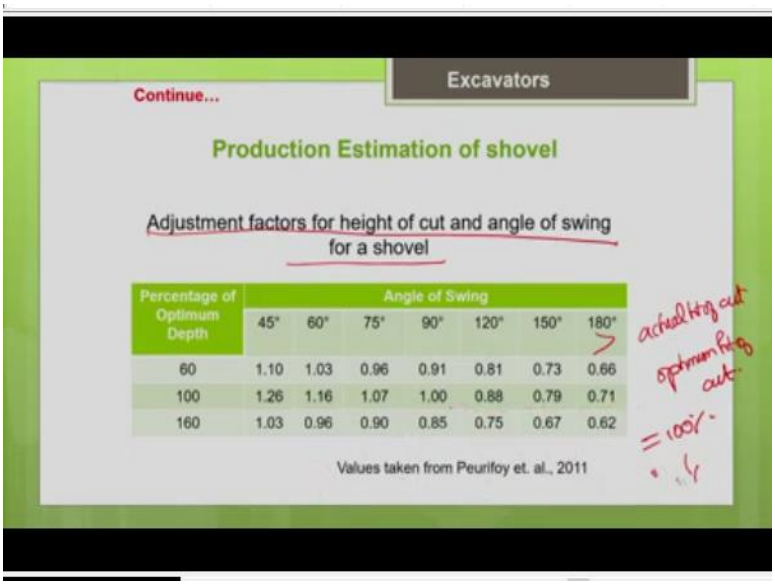

Now, let us see what are all the adjustment factors, we have to apply while doing the productivity estimation based upon the height of the cut of material actual height of cut of material in your project site and based upon the angle of swing that is going to depend upon the position of your truck relative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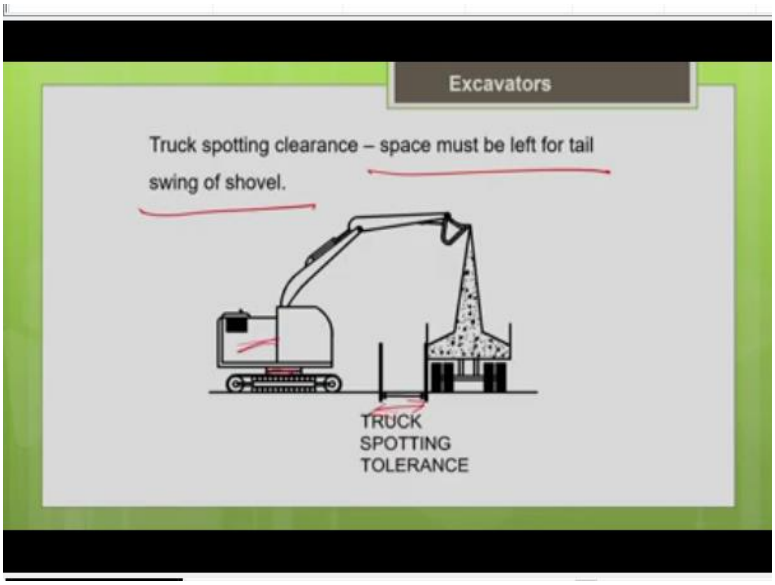

Another thing to be noted is truck spotting clearance. That means, as I told you, it is preferable to place a truck closer to the excavator. But at the same time, note that there should be some space left for the tail swing of the shovel. That means now you can have a complete 360 degree swing, you have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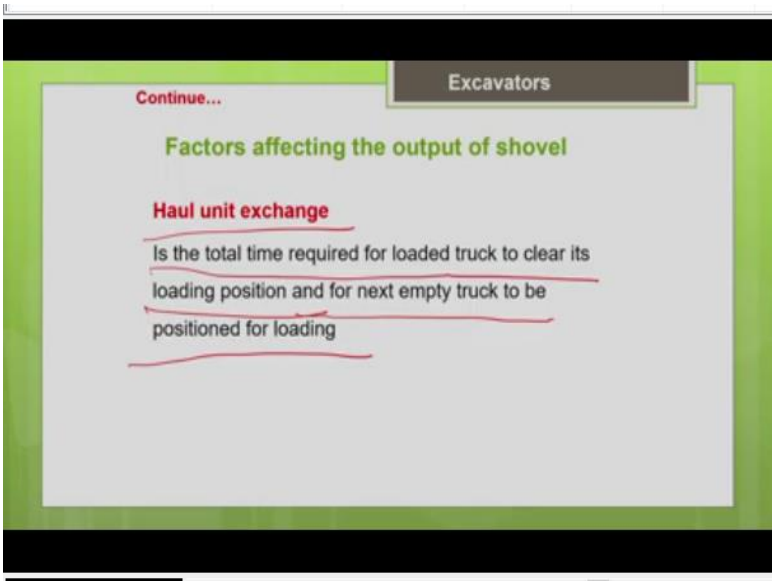

Other important factor is haul unit exchange time. That means the time needed for the loaded truck to leave its position. And for a new truck that is an empty truck to take the position. That

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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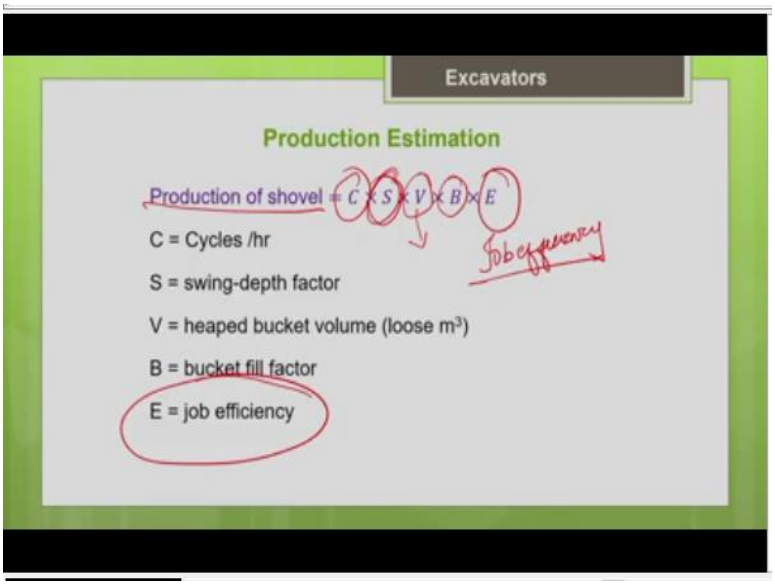

Now let us see how to estimate the productivity of the shovel. So, for all these machines, the principle is going to be the same, you can see the formula everything is going to be similar only. So, the production of shovel, it depends upon the heaped volume of your bucket, heaped the volume of your bucket 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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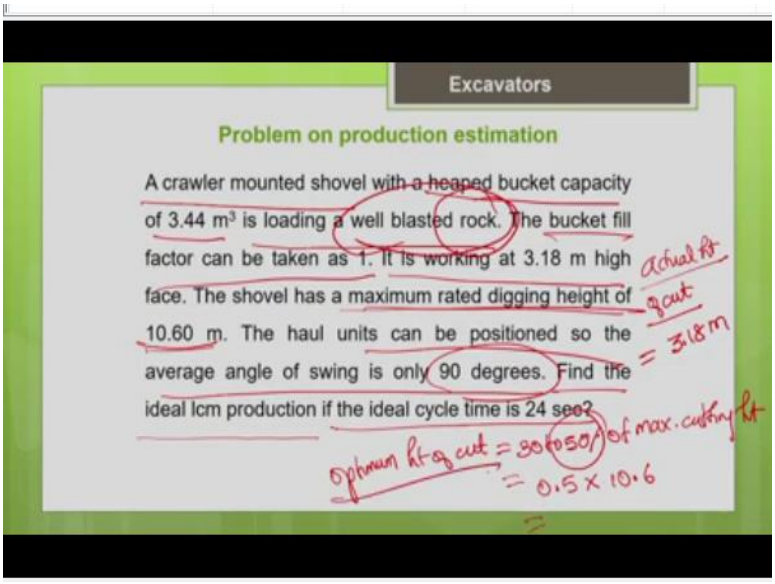

Now let us work out a problem on the production estimation a crawler mounted shovel with a heaped bucket capacity of 3.44 meter cube is loading a well blasted rock. The bucket fill factor can be taken as 1, depending upon the material type, they are supposed to take the bucket fill factor, it is readily 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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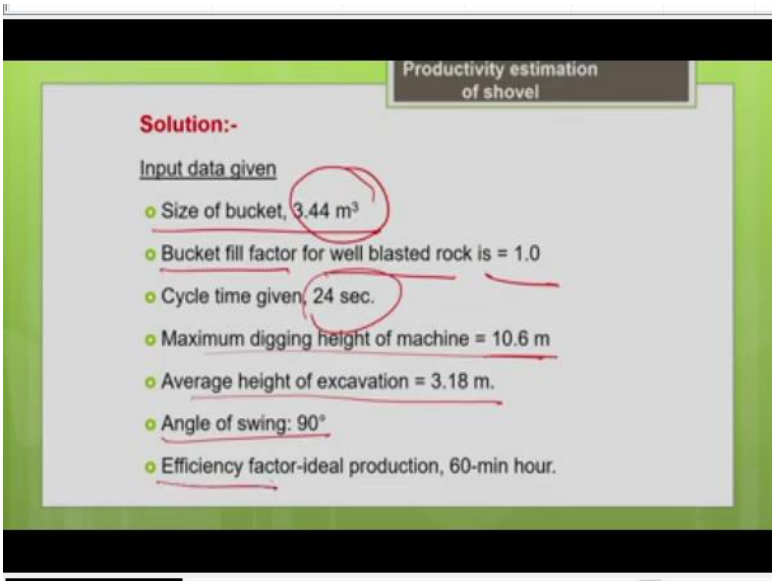

Let us see oh it is now that. So, in this slide, I have just summarized the data whatever the input data given in this problem. So, the size of bucket is 3.44 meter cube, that means it is a heaped bucket capacity given by the manufacturer, bucket fill factor is given us 1 for the well blasted rock, cycle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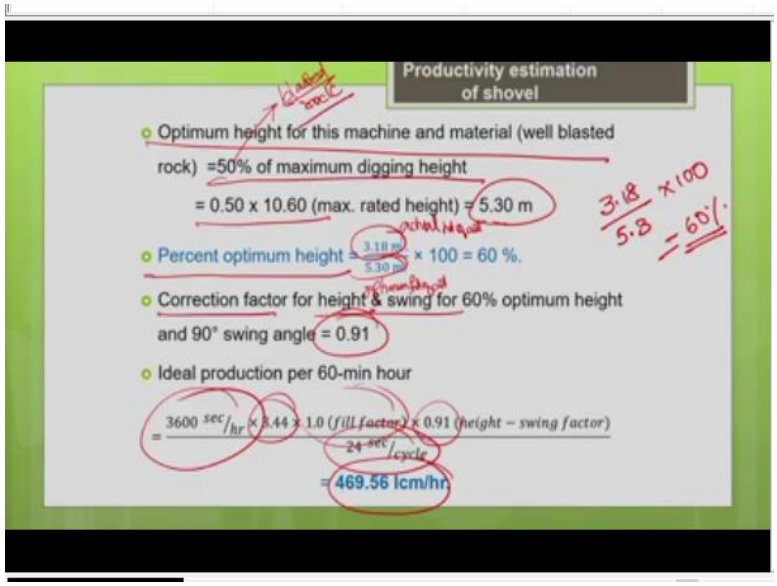

Now, as we discussed earlier, we have to find the optimum height for the machine, it is nothing but 50% of maximum digging height. I hope you know why we do to 50% because it is handling blasted rock, rock is a harder material to handle. So, take 50% of the maximum digging height. So, 0.5 into 10.6 meter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

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

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

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

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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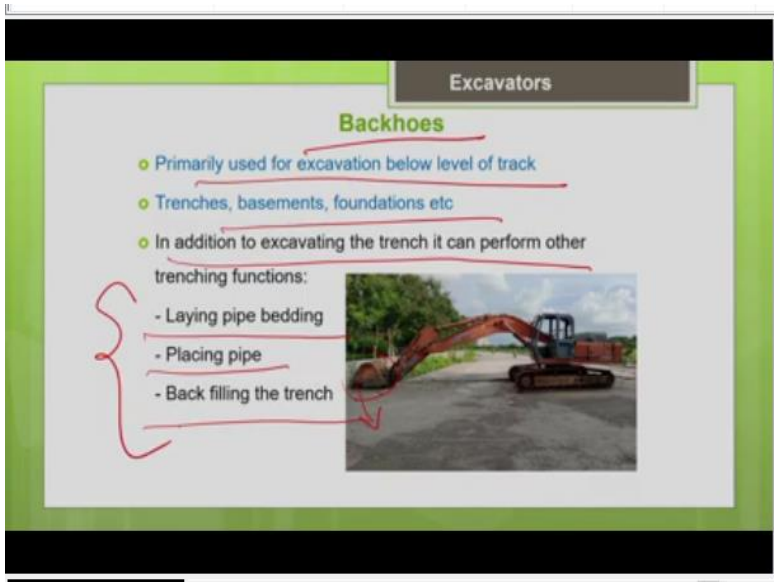

So, now let us discuss about the backhoes. So, you can see that the basic parts and operation are similar for both the machines but only thing to be noted is the digging motion of the bucket is in downward direction. So, it is preferred for the deep digging below the ground level, this machine is used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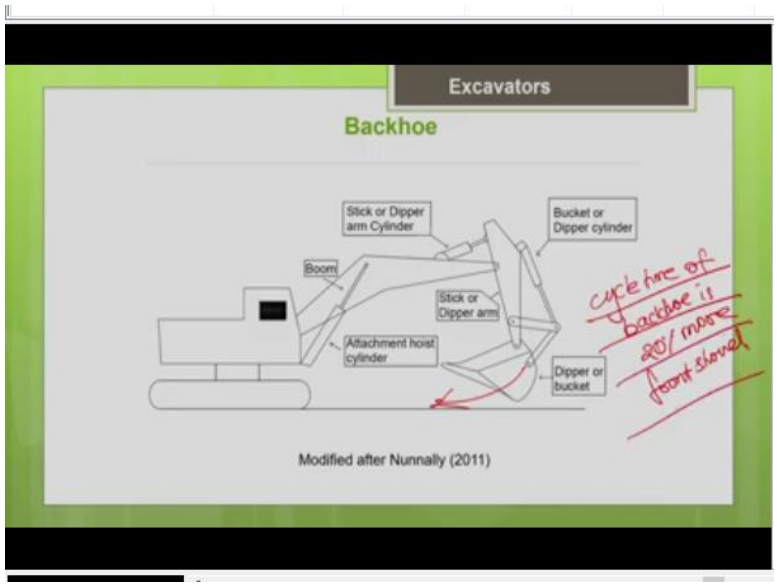

So, these are the basic operating parts of the backhoe it is similar to a front shovel only anything is digging motion of the bucket will be in downward direction. But one thing to note that cycle time of backhoe is 20% more when compared to front shovel. The reason is say whenever the

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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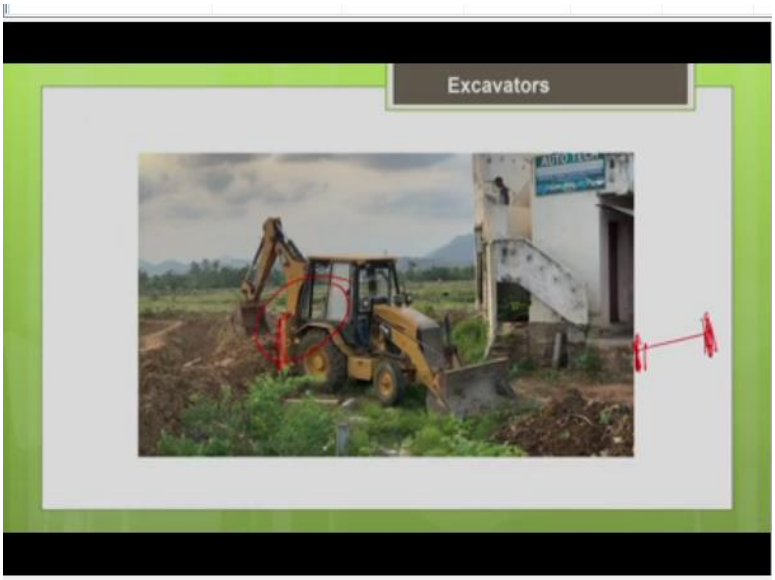

So, this is the combination of front end loader and backhoe. In some places you may need this combination because I may have to use a backhoe for excavating below the ground level, at the same time I may need a help of a front end loader to transport the material to a dumping position, when both are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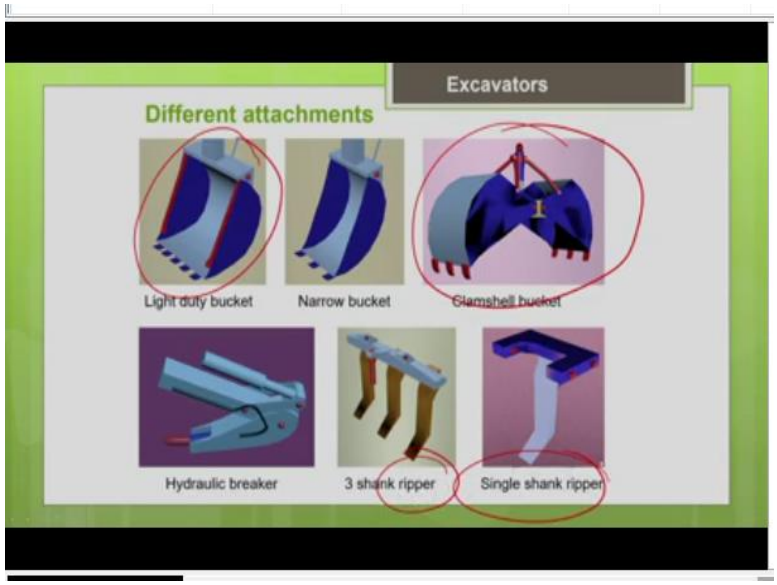

And use it for different applications. So, I can go for a light duty bucket. That means if you are going to handle lighter material, I can go for a wider bucket, but if you are going to handle harder material or denser materials, you go for a narrow bucket with a short tip radius. So, that we facilitate 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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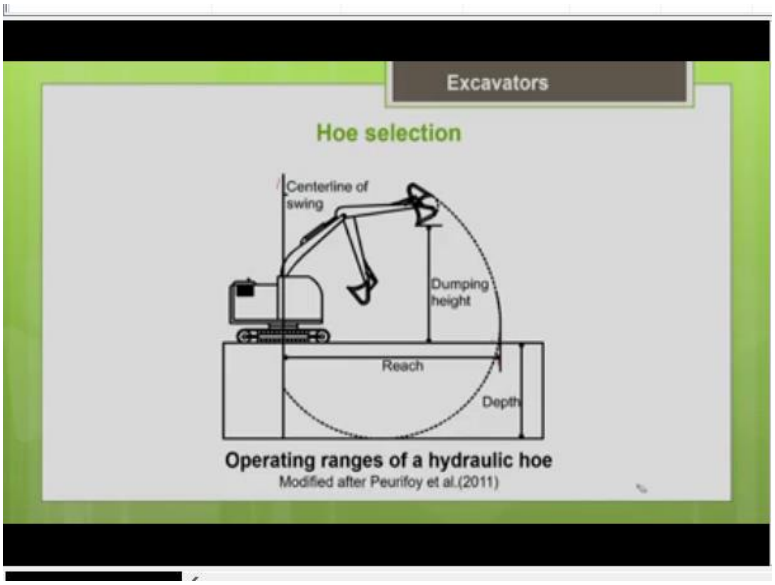

As we discussed earlier for the front shovel here also, these are the important parameters which helps you in the selection, what is the maximum dumping height possibly with the machine? What is the maximum digging reach possible with the machine when you completely extend your arms, when it completely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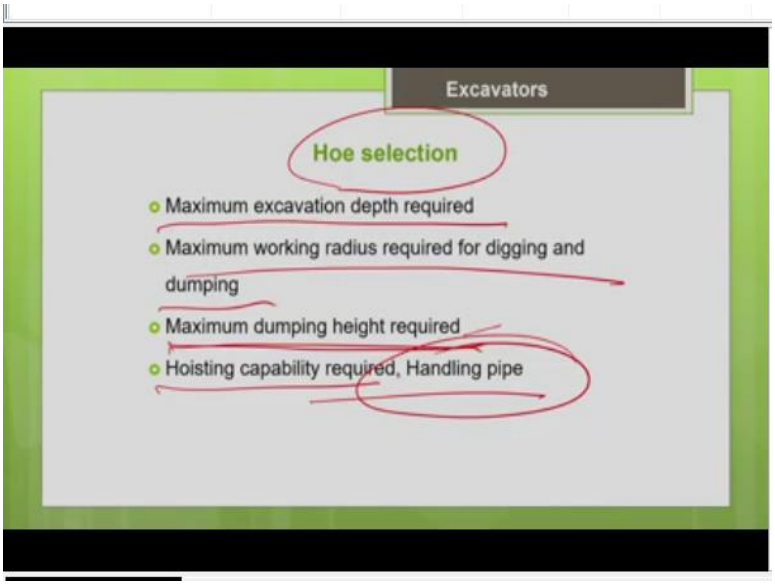

So, maybe what is the maximum excavation depth you need that you know, what is the maximum working radius you need for digging and dumping you know that, accordingly choose a machine with maximum digging reach, then you know what is the truck available for you. So, according to that you should decide 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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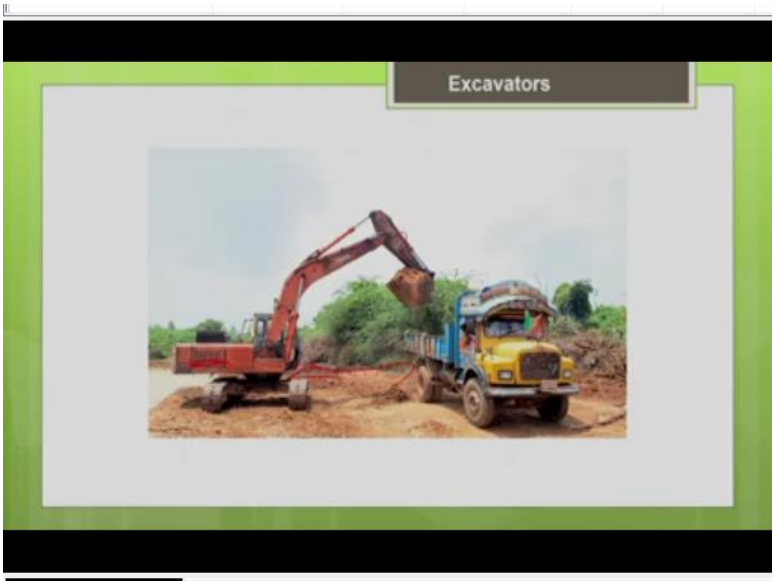

So, this video again shows you how the truck is commonly placed very close to the backhoe. **(Video Starts: 50:58) (Video Ends: 51:39)** As I told you, the angle of swing will be 90 degree, the horizontal angle should be 90 degree between the loading and the dumping position. So, the truck should come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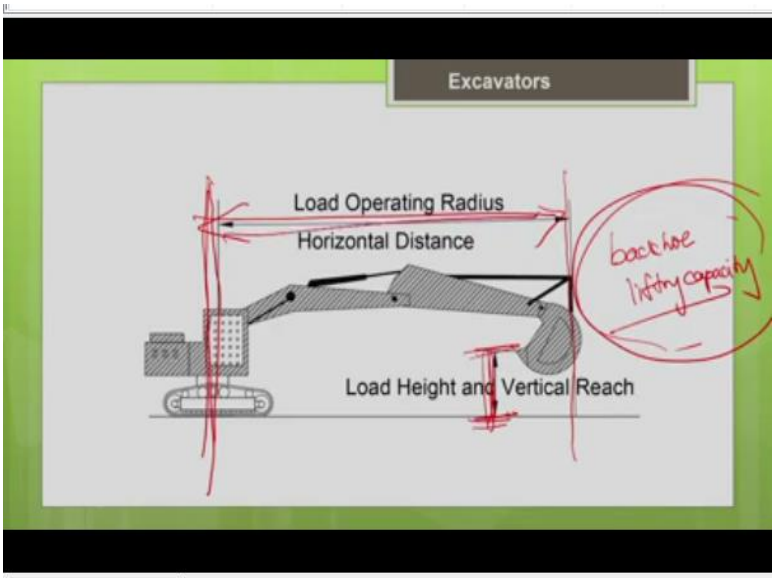

Another important thing you have to note that whenever the manufacturer provided you the lifting capacity for the backhoe. So, when they provide the lifting capacity for the backhoe they will give you a complete chart. So, this is because this also belongs to the cranes family. So, all these operations 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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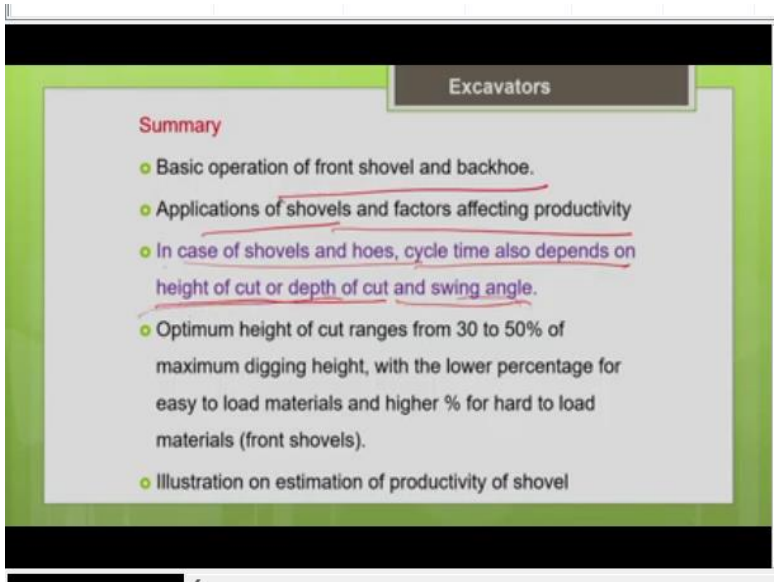

Now we have come to the end of this lecture. Let me now summarize what we have discussed so far. So, in this lecture we have discussed about the basic operation of the front shovel and the backhoe and what are the applications of the front shovel and the backhoe and what are the factor which affects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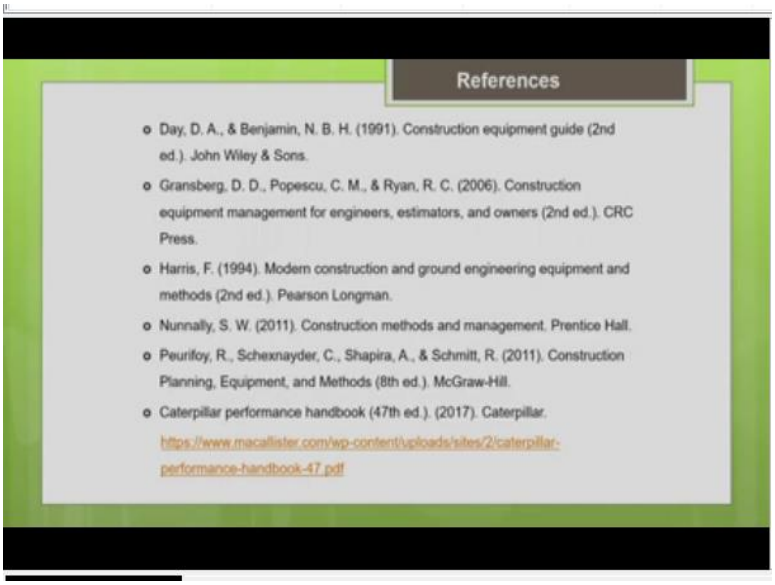

So, these are the references which I have referred for this particular lecture. I advise you to procure some of these books for prepare this topic. In the next lecture, we will be discussing about the trucks, how to estimate the productivity of the trucks and how to balance the number of trucks and the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