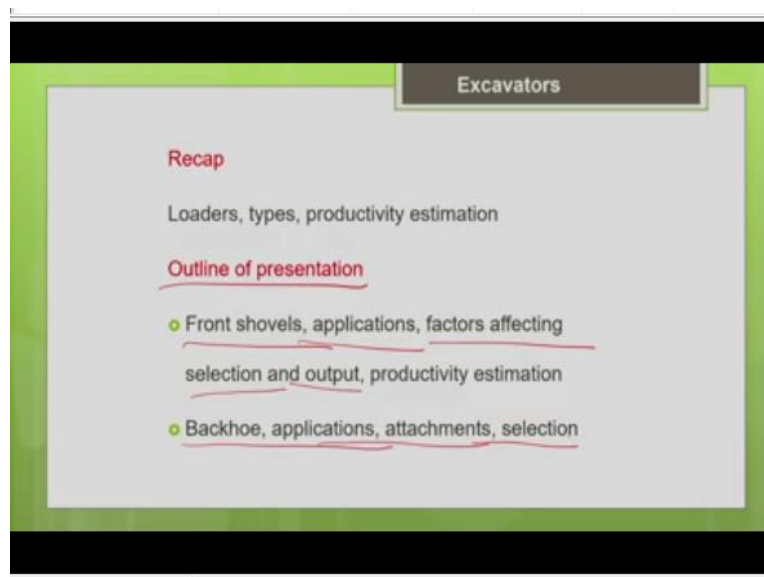


Construction Methods and Equipment Management
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Lecture-14
Excavating Equipment-Front Shovel, Back Hoe

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.

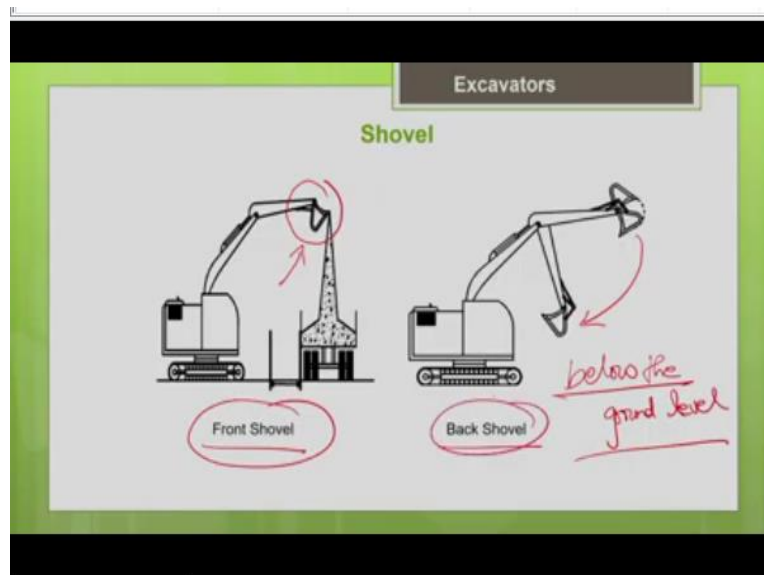
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So, in the last lecture we have discussed about the loaders. And we also discuss about the different types of loaders and how to estimate the productivity of loader. So, let us look into the outline of today's presentation. In today's presentation, 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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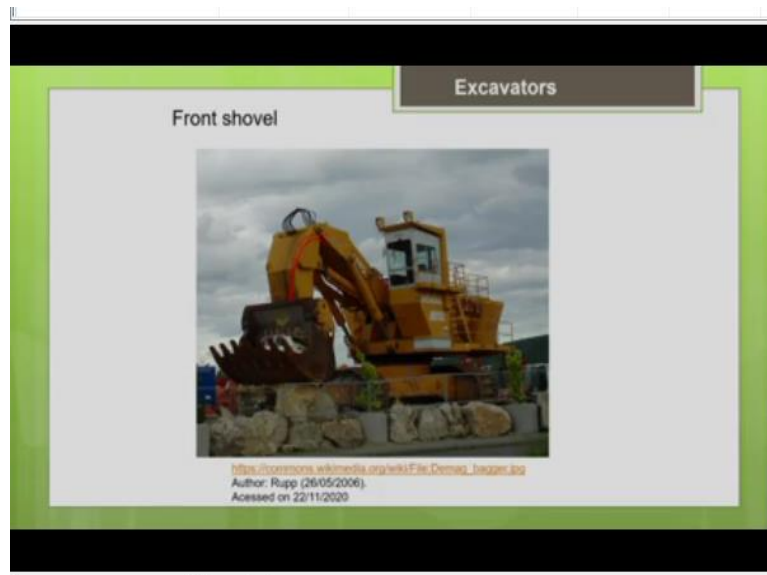


So, basically, shovels can be divided into 2 types based upon the digging motion of the bucket. So, in the first picture, you can see that the digging motion of the bucket is in upward direction. So, it is an upward direction. So, that means the bucket is moving away from the machine. So, that is called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

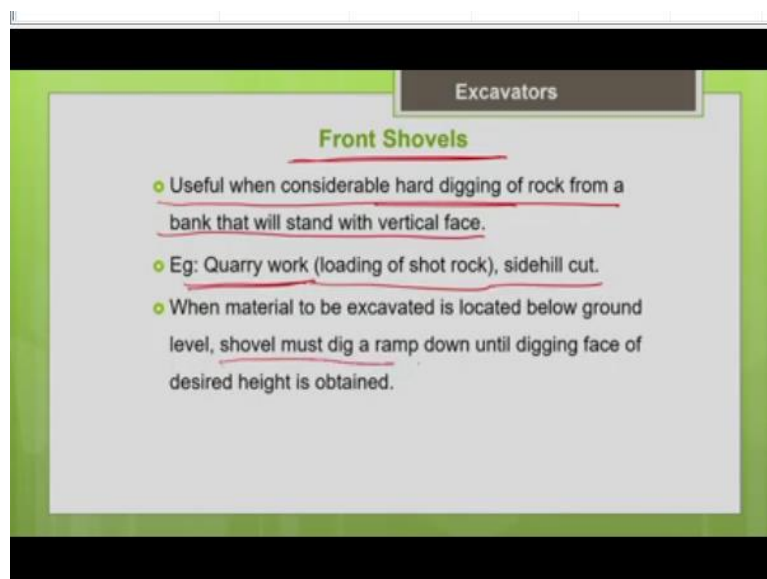
So, wherever you want to do the excavation at or above the ground level go for front shovel. So, for the deeper excavations where we want to do the digging below the ground level, you go for the backhoe or the back shovel.

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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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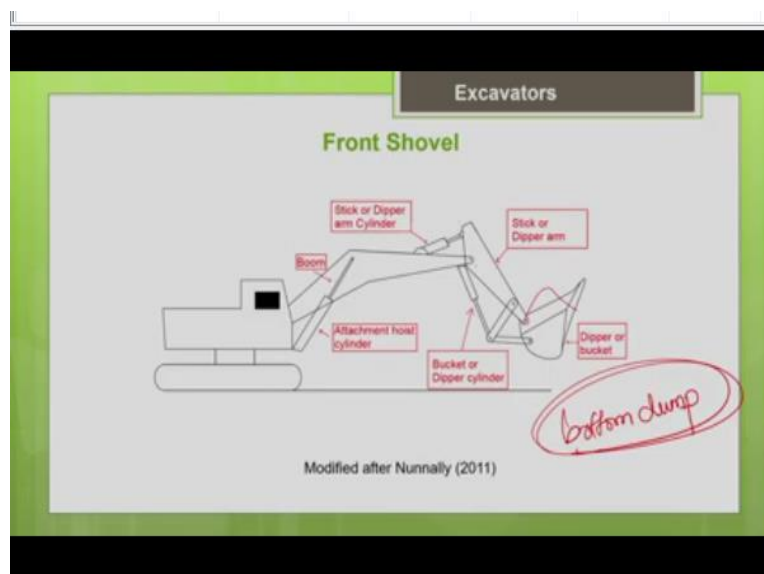
So, as I told you, this front shovel is generally needed when you want hard digging, hard digging a rock say, you can handle the rock easily with this machine, so at or above the ground level. So, this machine is the right choice. So, this is useful when considerable hard digging of rock from a bank 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.

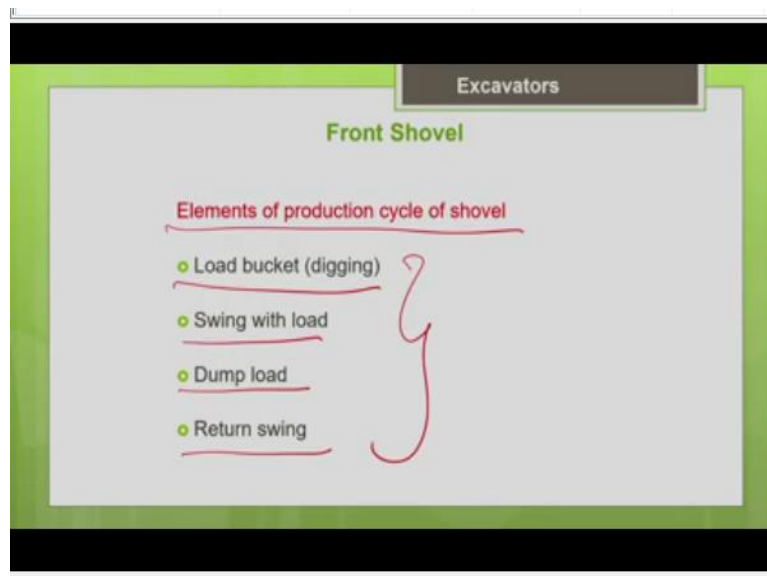
So, let us see how the front shovel will function. So, basically, when you want to excavate the material, first place the shovel bucket with the bucket facing the material which is to be excavated, so, low it to the base of the material, which is going to be excavated, now curl the bucket through the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

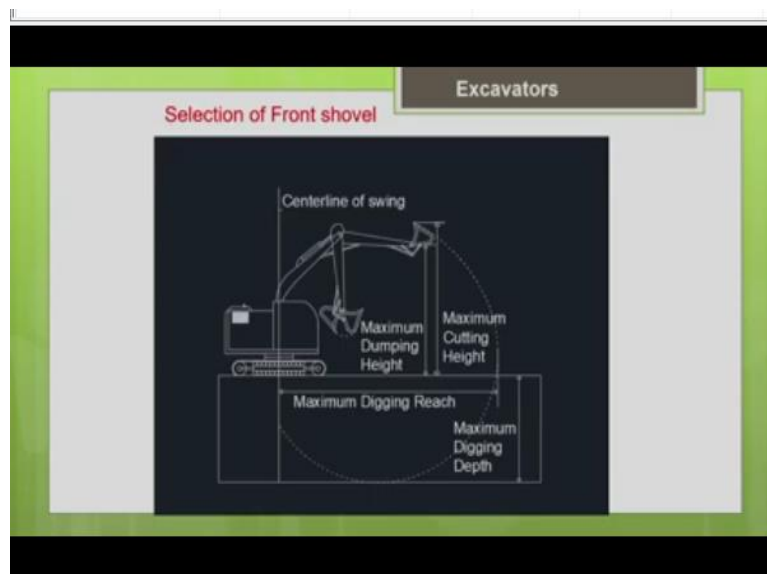
So, that you can start the cutting again from the base of the material which is to be excavated. So, this is the common production cycle of the front shovel.

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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.

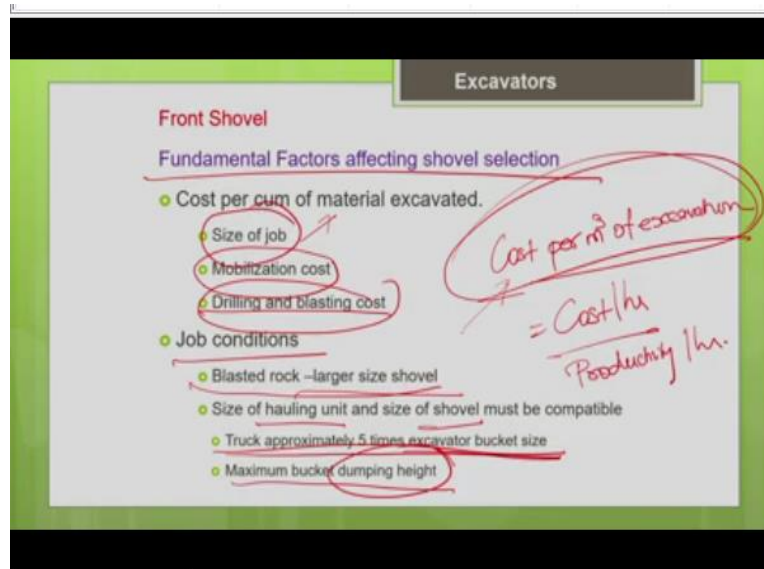
You completely stretch the boom, so that you will get what is the maximum digging reach possible. So, you completely stretch the boom, then you can find what is the maximum digging reach possible with this machine. It depends upon the dimension of the boom , and you can get this data from the manufacturer, 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. 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.

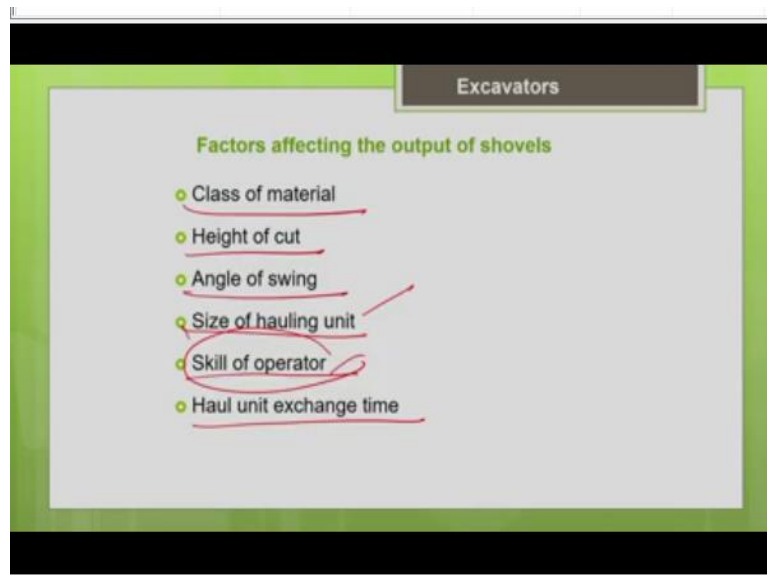
So, that is advantage of going for the bigger machine, it will reduce your drilling and blasting cost. So, all these things you have to work out the economics and select your machine. . So, apart from this, the other job conditions, which is going to affect a selection is for particularly as I told you 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.

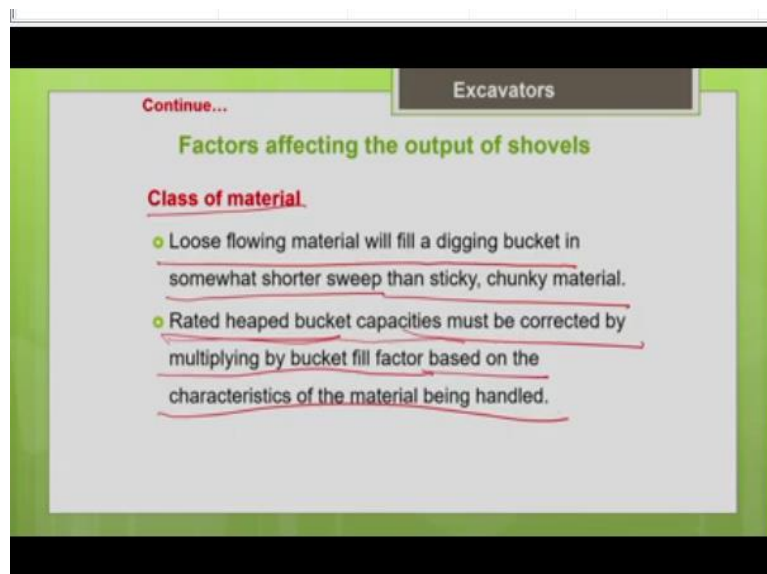
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So, what are the other factors which affect the output of the shovel? Let us see class of material, height of cut, angle of swing, size of the hauling unit, skill of the operator, haul unit exchange time. So, all these things are going to affect the 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, 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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Excavators

Continue...

Factors affecting the output

Height of cut

- Most efficient production is obtained with power excavator working at its optimum height of cut.
- Digging at this depth of cut requires no re-digging for full bucket nor spillage
- Vertical distance that permits the bucket to obtain a full load without over crowding the bucket or under crowding is known as the **optimum height of cut**

Handwritten notes:

- Optimum ht. of cut for easy machine* (circled in red)
- Actual ht. of cut in project < optimum ht. of cut* (green)
- cycle time ↑* (green)
- Actual ht. of cut > optimum ht. of cut* (red)
- cycle time ↑* (red)

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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Excavators

Factors affecting the output of shovels

Optimum height of cut (%) = $\frac{\text{actual height of cut}}{\text{optimum height for given material} \times \text{bucket}} \times 100$

Varies with the shovel size and type of soil excavated.

Optimum height of cut is from 30 to 50% of maximum digging height.

Lower % - easy to load materials - sand, gravel, loam, loose earth etc.

Higher % - hard to load materials - sticky clay, blasted rock.

Common earth - 40%

Handwritten notes:
Optimum height of cut = 4m
actual height of cut = 2m
Optimum height of cut = 50%
Common earth = 40%

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.

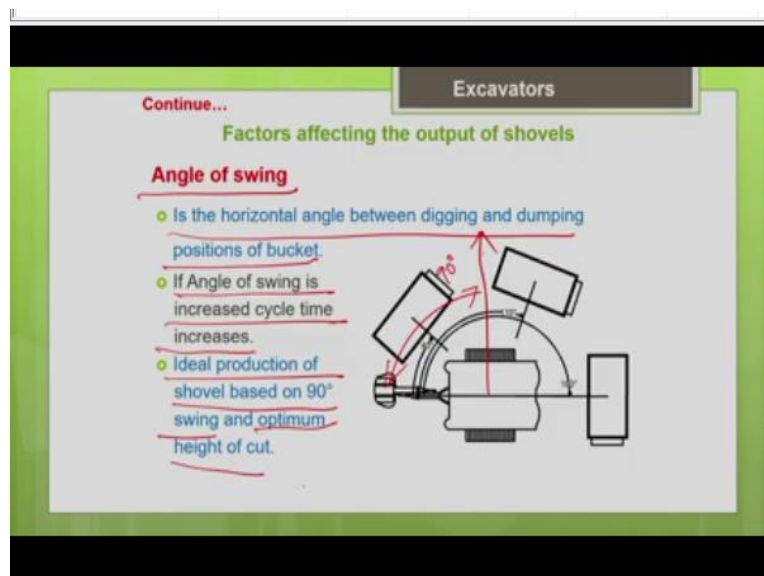
$$\text{Optimum height of cut (\%)} = \frac{\text{Actual height of cut}}{\text{Optimum height for given material \& bucket}} \times 100$$

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.